# TWENTIETH ANNUAL REPORT

OF THE

# UNITED STATES GEOLOGICAL SURVEY

TO THE

SECRETARY OF THE INTERIOR

1898-99

CHARLES D. WALCOTT
DIRECTOR

IN SEVEN PARTS

PART II.—GENERAL GEOLOGY AND PALEONTOLOGY



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# UNITED STATES GEOLOGICAL SURVEY

PART II.—GENERAL GEOLOGY AND PALEONTOLOGY

# CONTENTS.

# BRIEF MEMORANDUM ON THE GEOLOGY OF THE PHILIPPINE ISLANDS

BY

GEORGE F. BECKER

# BRIEF MEMORANDUM ON THE GEOLOGY OF THE PHILIPPINE ISLANDS.[1]

By George F. Becker.

Much office work must be done on the specimens collected and much literature abstracted before all of the information at my command on the geology of the Philippine Islands can be systematically presented.

So far as my observation or my information goes, the geological history of the whole group is similar. I have seen that the post-Tertiary gradual upheaval, presently to be described, is common to Jolo, Mindanao, Luzon, and the intermediate islands; and descriptions leave little doubt that the Philippines belong, and have long belonged, to a single geological and biological province.

Prior to the Tertiary epoch the Philippines consisted of slates and igneous masses, the age of which is as yet unknown, no fossils having been detected in these ancient rocks. They are now to be found chiefly in the northern and eastern ranges of Luzon, but appear to be represented also by some limited occurrences in Cebu, and seem to form the walls of the gold-bearing quartz veins of the province of Surigao, in the northeastern portion of Mindanao. They are doubtless in reality widely distributed, but in most localities are buried beneath more recent formations.

During the Eocene, or earliest Tertiary, the archipelago must have consisted largely of swamps and shallow seas, perhaps not very different from those now existing in the same region. Limestones were formed at some distance from the coasts, shales and sandstones were laid down near the shores, and accumulations of vegetable matter grew in the swamps. These last were covered by mud, and in the almost total absence of free oxygen they were gradually converted into lignite, probably the most valuable mineral asset of American India.

At the close of the Eocene a great crumpling and upheaval took place, which was felt from Switzerland to the Philippines, and perhaps most of all in the Himalayas, where marine Eocene beds now stand at

[1] Memorandum addressed to the military governor as a preliminary report, and an official copy transmitted by the author to the Director of the United States Geological Survey.

an elevation of 16,000 feet above the sea. In these islands the Eocene strata are frequently thrown into a nearly vertical position and sometimes are actually overturned. In the Visayas the axis of upheaval trended a little east of north, corresponding to the direction of greatest extension of the islands of Cebu and Negros. These disturbances were accompanied by much faulting and it is believed by some metamorphism. Intrusions and extrusions of igneous rocks seem to have accompanied this upheaval, but no satisfactory study has yet been made of the phenomena, good exposures being rare.

During the remainder of the Tertiary the islands appear to have been above water. Miocene and Pliocene strata have not been detected with certainty, though some traces of such beds will probably be discovered in future investigations. Near Jolo I found strata which appeared to be younger than the Eocene and older than the Recent period. In the main the area of the Philippines was probably then continental, and there is zoological evidence of a land connection with the Asiatic continent, probably by way of Borneo, during the middle Tertiary. This connection did not persist to the close of the Tertiary, however, and to its rupture is ascribable the extraordinary peculiarities of animal life in these islands, evolution here having been left to take its own course undisturbed by invasions.

The subsidence which cut off immigration of the lower animals continued, seemingly, till somewhere about the close of the Tertiary and long after *Homo sapiens* had made his appearance in the Malay Archipelago. This group also was very probably already inhabited during the Pliocene, possibly by the ancestors of the Negritos. This is a matter which requires careful investigation, for in the opinion of my late famous colleague, O. C. Marsh, this archipelago is likely to have been one of the earliest haunts of the human species.

When the elevation was at its minimum the archipelago was reduced to a group of small, hilly islets, four of which existed within the area now occupied by the Island of Luzon. Cebu was almost completely submerged.

At or before the period of maximum subsidence, began a series of eruptions which has not yet closed. Mayon Volcano, in southern Luzon, had a violent eruption in 1897. It is probably the most beautifully symmetrical volcanic cone in the world, and the truncation at the top, due to the crater, is scarcely sensible.[1] The work done in fusing lavas and ejecting ash is probably a manifestation of the energy involved in the mighty earth throes which bring about regional upheavals with incidental subsidences. The earlier of the eruptions under discussion were largely submarine, and vast additions were made to the superficial material of the archipelago by these outflows, especially in the

[1] The radius of any horizontal section is the hyperbolic sine of the distance from this section to the summit.

central and southern portions of Luzon. The ejecta include andesites, rhyolites, basalts, and probably other less common rock species.

The period of upheaval, once initiated, does not seem to have been interrupted by any era of subsidence, and the modern coral reefs give evidence that it is still in progress. It is said that uplifts accompanying earthquakes have actually been observed by the Spaniards, and the earthquakes themselves are spasmodic jars in the process of elevation. The elevation has not been, properly speaking, catastrophic, however, for the tremors which may wreck a cathedral are insignificant from a terrestrial standpoint. On the whole, the uplift has been very gradual, so that even the coral polyp has been able to adjust himself to the changing conditions, building outward into deeper water as his old home was raised too high for his welfare. In this way nearly the whole of Cebu, to a height of over 2,000 feet, has been covered with a nearly continuous sheet of coral which can be followed seaward into living reefs. Much of Negros has been clothed with a similar mantle. On a small scale, also, off the coasts of these islands, and particularly about Mactan, reefs can still be studied in every stage of upheaval, all those portions being dead which are exposed to the air even at the lowest tides. In southern Luzon and to the northward of Lingayen Bay similar phenomena can be observed.

Although upheaval does not appear at any time since the close of the Tertiary to have given way to subsidence, there have been repeated pauses in the uplifting process. On exposed coasts these pauses are marked by benches eaten into the land by the action of the waves. Thus the southern ends of Cebu and Bohol are terraced from top to bottom, each terrace being an old beach cut out of the rock mass by stormy seas. Pauses in the uplifting process are also marked by a rude stratification of the corals. Even in the interior of the islands terraces indicative of uplifts are frequently visible. Some of them represent base-levels of erosion; others are ancient coral reefs which have been checked in their upward growth by reaching the surface of the water. In short, terraces constitute one of the most prominent topographical features of the archipelago.

The slowness of the uplift is emphasized by the stupendous accumulation of coral in these islands. Coral is, of course, mainly composed of calcium carbonate, and this is formed by the coral polyp from the lime salts dissolved in the sea. Now, the sea contains a very minute proportion of lime salts (chiefly the sulphate, or gypsum), say a tenth of 1 per cent, and corals are necessarily of slow growth because of the scantiness of the material with which they build. The sheets of coral on uplifted areas seem to have a tendency toward a nearly uniform thickness, approximating to 100 feet. This is explicable from the habits of the coral animal, which does not grow at a greater depth than 15 or 20 fathoms. Unlike merely sedimentary strata, the coral follows the topography of the rising surface, along a contour of which it grew. Where muddy waters or frequent eruptions befoul the sea there are no coral reefs.

When the uplift began, say ten or twelve thousand years ago, the island shores were steep and the sea about them was relatively deep, so that an upheaval of 100 feet added but little to the area of the islands. As the amount of uplift increased to something approaching the mean depth of the circumambient sea, the area of the land increased in a far greater ratio to the increment of upheaval. The last rise of 100 feet has rescued from the seas the most valuable part of the archipelago. Examination of the charts will show that a fresh rise of 100 feet would add a further area, which, though important, would be less important than the actual lowlands of the Philippines. The plateau on which the island stands is now mostly above sea level.

Area has also been added to the land by the formation of deltas at the mouths of the rivers, a process which has been greatly assisted by the mangrove trees and the nipa palms. These grow in the water in all favorable situations, and hold back the solid contents of the streams, adding their own débris to the accumulation. Along the eastern shore of Manila Bay the so-called "estero" or "bayou" country consists of the confluent deltas of the various rivers flowing into the bay.

To the eastward of the estero country the ground passed over by General MacArthur's army from Manila to San Fernando consists of low, base-leveled terraces, all more or less dissected by water courses. These almost always have somewhat high and steep banks. They are in fact engorged, as is characteristically the case in a country undergoing upheaval; for upheaval increases the potential energy of the flowing water and leads to erosion of the stream beds.

In my published memorandum on the mineral resources of the Philippines[1] I have briefly noted the distribution of valuable minerals. The distribution of gold deposits indicates that this metal, when in place, is associated with the older rocks, and it will probably be found that the last great addition to the auriferous deposits was an incident of the post-Eocene upheaval. In some parts of the world gold is found in neo-volcanic rocks, as at Bodie, in California, and elsewhere. I have learned of no such occurrence in these islands. Where streams in the Philippines cut into the older rocks they seem nearly always to carry a little gold, which the natives have been exploiting time out of mind.

There is a very general impression that Mindanao is a rich auriferous region, though little definite information is current on the subject. The absence of information seems to add the attractions of the imagination to the tales of a few prospectors. It is a fact to which attention should be called that each of the two auriferous provinces of Mindanao—

[1] Nineteenth Ann. Rept. U. S. Geol. Survey, Part VI Continued, 1898, pp. 687–693.

viz, Surigao and Misamis—has been reported upon by a competent expert, and that neither expert found anything to excite his enthusiasm. There is gold there beyond a doubt, and the natives have been extracting it on a modest scale, yet with no little skill, for centuries. The information at hand points to very moderate auriferous resources, comparable with those of the Carolinas and Georgia rather than with those of Colorado or California.

Luzon, so far as I can judge from reports, is as rich in gold as Mindanao. It is probable enough that a fair number of spots exist in which capital invested in gold mines will find reasonable remuneration, but I fear that any "rush" to the gold fields will involve great disappointment. The whole archipelago has an area almost the same as that of Arizona. There is nothing known which indicates that the islands contain more gold than this Territory.

The copper deposits of Lepanto seem rich and extensive, but very expensive roads will be needed to render them available. The high quality of some of the iron ores of Luzon is beyond question, but the lignite of the islands is not adapted to iron smelting. A moderate industry could be based on charcoal smelting, while the pig could be converted into steel and manufactured by the use of furnaces burning lignite gas.

The so-called coal is a good lignite.[1] Its heating effect is from two-thirds to three-fourths that of the best steaming coal. There are great quantities of this fuel, and much of it could probably be delivered at a profit on vessels at $2.50 (Mexican) per ton. The lignite is at least as good as the Japanese "coal," which is also lignite. The Japanese fuel often brings $9 or $10 (Mexican) in Manila, and is now much dearer; so that unless the price of such coal were to fall enormously, great profits await the coal miner. The development of a coal industry is of great importance to the industries of the archipelago, and, though our naval vessels would prefer Cardiff or Pocahontas coal, they could use Philippine lignite in case of need.

MANILA, P. I., *September 28, 1899.*

[1] Lignite differs from true coal chiefly in the amount of combined water, which is insignificant in true coal and usually from 8 to 18 per cent in lignite.

# A STUDY OF BIRD MOUNTAIN, VERMONT

BY

T. NELSON DALE

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# ILLUSTRATIONS.

# A STUDY OF BIRD MOUNTAIN, VERMONT.

By T. Nelson Dale.

## PHYSIOGRAPHY AND AREAL GEOLOGY.

Bird Mountain lies in the Taconic Range, 7 miles west-southwest of Rutland, in the townships of Castleton, Ira, and Poultney; its summit (2,200 feet) is in Castleton. Since the writer's brief visit to the mountain in 1891[1] the region has been mapped by the topographers of the

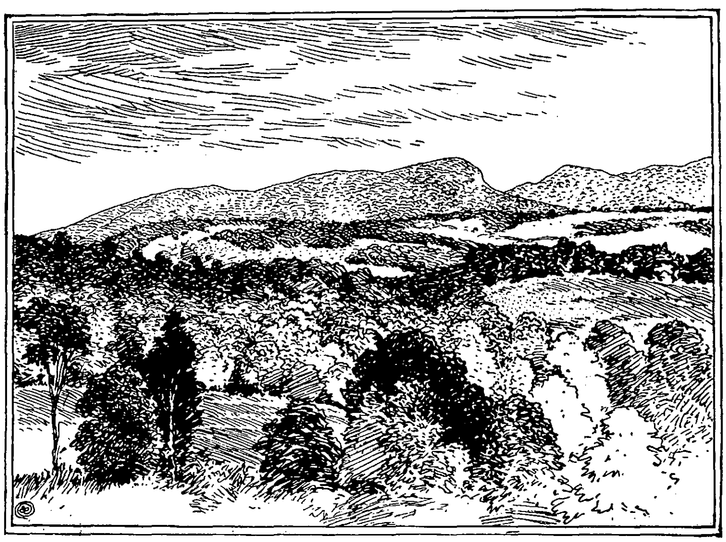


Fig. 1.—Outline of Bird Mountain as seen from the east side of Lake Bomoseen, 5¾ miles northwest of the summit.

Survey (Castleton quadrangle, 1895), and the mountain has been carefully explored by the writer, with the aid of Mr. Fred. H. Moffit (1896), so that the materials are at hand for a more satisfactory description of it. The areal geology is shown on Pl. I.

Although covering less than 4 square miles and lying near to several much larger masses differing not very greatly from it in height,

[1] See Thirteenth Ann. Rept. U. S. Geol. Survey, 1894: The Rensselaer grit plateau in New York; appendix on the continuation of the Rensselaer grit in Vermont, pp. 337-338.

Bird Mountain will always attract the eye of the traveler and the geologist by reason of its outlines, which are unique in the Taconic region. Fig. 1 shows its appearance from the northwest and fig. 2 that from the west; Pl. II, *A* and *B*, shows its form as seen from the south and south-southwest.

The top of Bird Mountain is 1½ miles south of the Castleton River, which flows westward through a valley which cuts the entire Taconic Range transversely down to the 500-foot contour. The mountain is almost entirely isolated from the masses to the south, east, and west by two tributaries of the Castleton River, but on the southeast, at the 1,480-foot contour, a saddle still joins it to the Herrick Mountain mass. While the cliffs which rise to an altitude of about 300 feet above the talus slope on its southern side and the roundish outline of its northern end point to glaciation as one of the principal causes of its form,

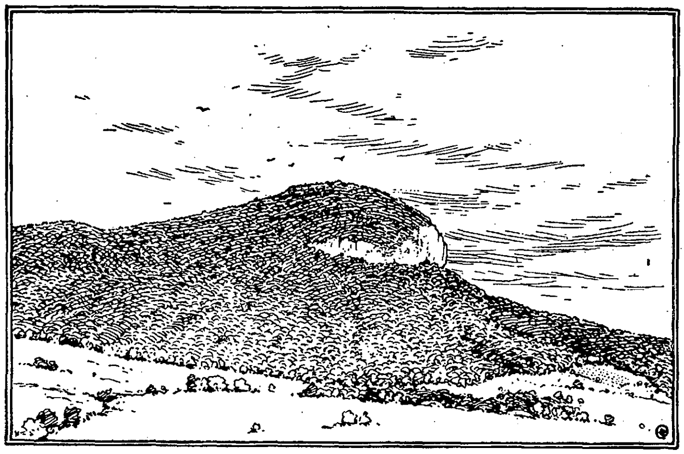
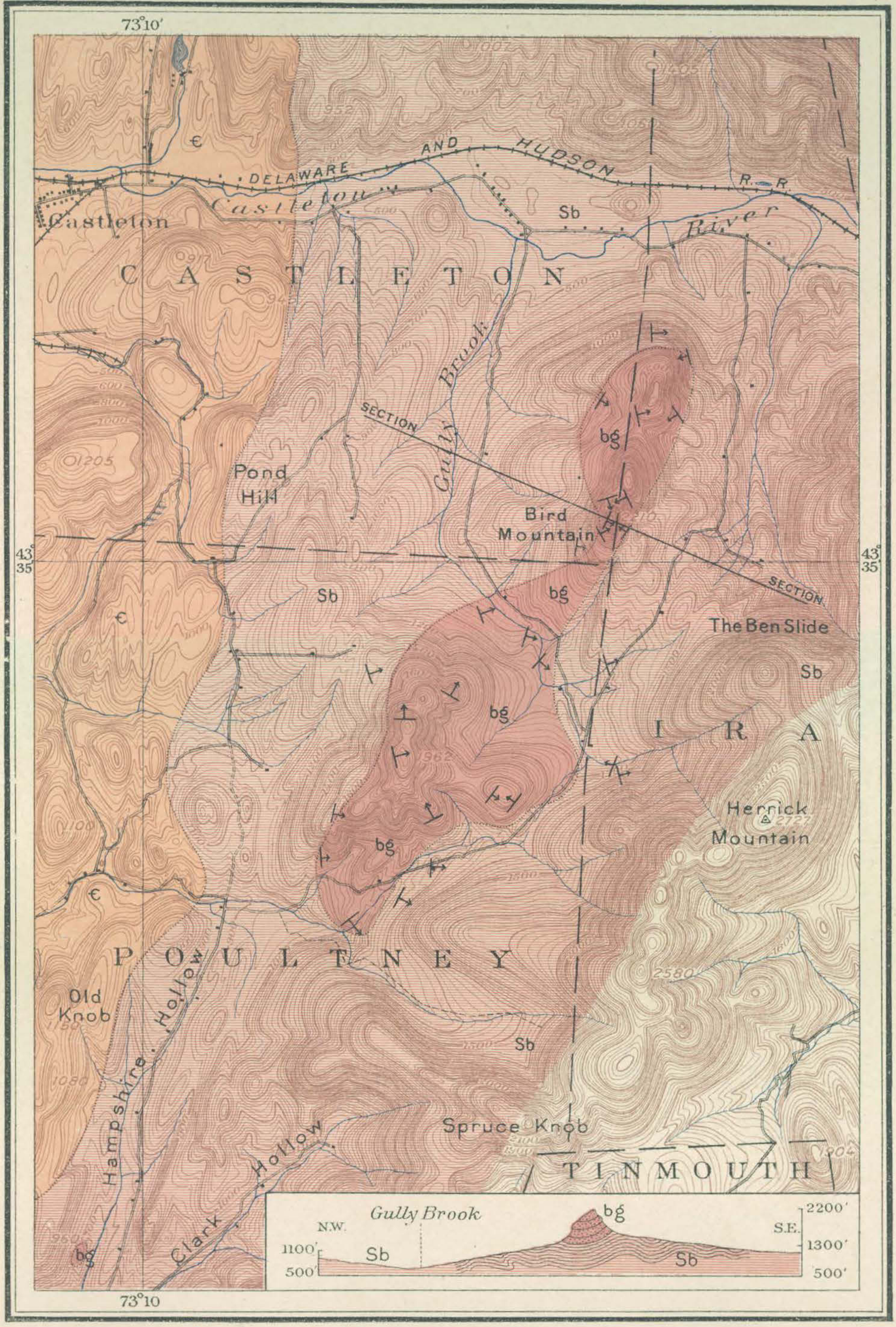


FIG. 2.—Outline of Bird Mountain as seen from Pond Hill, 2 miles west of the summit.

the general relations of the mountain to the adjacent masses throw little light upon its structure or its origin.

After the areal geology was worked out it appeared that the central crest of Bird Mountain forms but part of a larger area of metamorphosed grit and conglomerate, alternating with beds of sericite-schist, measuring altogether about 3¾ miles in length and varying from one-fourth to 1¼ miles in width. This area includes the next mass on the southwest, whose summit (1,962 feet) is 238 feet lower than Bird Mountain, while the incision which separates the two masses reaches down to the 1,000-foot contour. The general trend of this grit and conglomerate area is about north-northeast to south-southwest, which is also the trend of this part of the Taconic Range.

Entirely surrounding as well as underlying the Bird Mountain grit are the muscovite- (sericite-) schists of the Ordovician—the Berkshire schist of the Taconic Range.




# GEOLOGY OF THE BIRD MOUNTAIN REGION, VERMONT

BY T. NELSON DALE AND F. H. MOFFIT, ASSISTANT

1896.

Scale

1 ½ 0 1 2 MILES

Contour interval 20 feet

III bg Bird Mountain Grit

II Sb Berkshire schist *(Lower Silurian)*

I € Cambrian *(Slate, grit etc.)*

JULIUS BIEN & CO. LITH. N.Y.

On the western side of Hampshire Hollow, 2¼ miles southeast of the southern extremity of the Bird Mountain grit area and 1½ miles east of East Poultney, is a lens-shaped area of conglomerate and schist a few hundred feet long, possibly of the same age as the Bird Mountain beds.

## THE GRIT AND CONGLOMERATE.

In the previous survey of Bird Mountain[1] Dr. Wolff, who made the petrographic determinations, found the conglomerate to consist of quartz pebbles (of granite, gneiss, or vein origin) often showing signs of compression, of pebbles of limestone and of quartzite with calcite cement, of pebbles having a dark-brown limonitic matrix inclosing flakes of muscovite and chlorite, and of clastic grains of tourmaline; all in a cement of chlorite, muscovite (sericite), quartz (partly secondary), calcite in grains and in vein-like masses with columnar crystallization, and some grains of pyrite, magnetite, and titanite.

The results of further collecting at the summit and in various parts of the mountain justify the following description: The chloritic green color of the cement, the quartz pebbles, which are milky or bluish or pinkish and sometimes over an inch in diameter, and the abundance of pebbles of a dense, homogeneous, pale-greenish rock, weathering at their circumference and along cracks a light or dark yellowish brown, and eventually completely altered to a limonitic powder, are the most marked features of the rock. The specific gravity of a piece of the conglomerate containing several of the small green pebbles, and a few smaller ones of quartz with the usual amount of cement, proved to be 3.286, or 0.632 higher than that of quartz (taken at 2.654). Pyrite is often found in the cement, and galenite occurs rarely in small particles. Grains of orthoclase and plagioclase feldspar can be detected here and there with the microscope. At the summit of the mountain pebbles of a coarse, calcareous, feldspathic quartzite or grit and of a fine and medium grained brownish-weathering crystalline limestone are not uncommon, some of these measuring as much as 3 by 5 inches. At a point a little south of the ravine on the northwestern side of the mountain, on the 1,200-foot contour, the joint faces in the conglomerate are coated with secondary quartz, forming distorted tabular crystals, sometimes about a quartz pebble. More rarely siderite has crystallized on the joint face, and at the surface passes into hydrous ferric oxide. While the rock is thus in places a metamorphosed grit, in others it is a metamorphosed conglomerate; and in some localities, from the scarcity of cement and the small size and abundance of the quartz grains, it approaches a quartzite. There is a perceptible increase in the size of the pebbles from the lower to the

[1] Loc. cit.

higher strata of Bird Mountain. The interbedding of the grit and conglomerate with sericite-schist occurs throughout, but is probably more or less irregular. At a point a little south of the northern incision in the crest from 50 to 65 feet of schist overlie the grit, and are presumably also overlain by grit farther south. The attempt to use the grit for monuments has been abandoned on account of the weathering out of the calcite from the cement on the polished surface wherever it was exposed.

### THE PEBBLES UNDER THE MICROSCOPE.

The fine, greenish pebbles consist largely of a calcareous mineral without the multiple twinning of calcite and effervescing very slowly with cold dilute hydrochloric acid. Embedded in it are numerous scales of chlorite, fewer of muscovite, and some angular grains of quartz. In weathering, the calcareous mineral passes into limonite, showing the silicates more plainly. As weathering proceeds the limonite itself is carried off, leaving an aggregate of muscovite, chlorite, and quartz. These pebbles thus seem to consist of a mixture of dolomite and siderite, together with detrital quartz, secondary chlorite, and muscovite of uncertain origin; that is, a chloritic and micaceous carbonate of magnesia, iron, and lime, containing quartz grains. The specific gravity of the conglomerate (3.286) is 0.514 lower than that of siderite (taken at 3.80) and 0.109 higher than the average of siderite and quartz. In places the cement itself seems to have the same constitution as these green carbonate pebbles. The amount of limonite present is not sufficient to give the rock economic value.

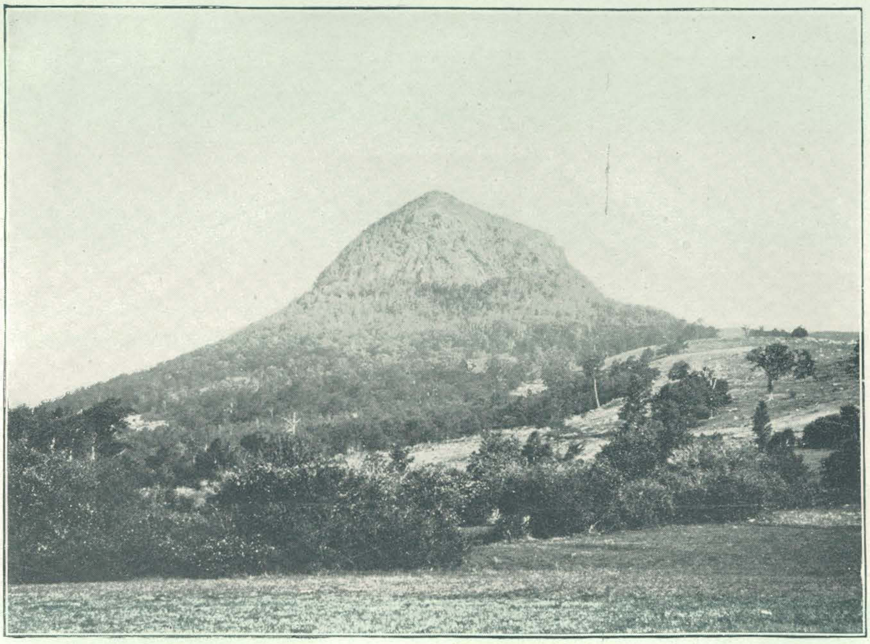
The large, calcareous, granular pebbles consist of large grains of quartz, with fewer of orthoclase and plagioclase feldspar, in a cement of calcite rhombs and plates with multiple twinning and rapid effervescence. The feldspars are partially altered to muscovite; the quartz grains show many inclusions and a wavy extinction; the cement is undergoing partial alteration to limonite. The rock is a calcareous quartz and feldspar grit—a calcareous and feldspathic quartzite.

Other finer-grained pebbles consist mainly of rhombs and plates of calcite, with fine, angular quartz grains and muscovite scales—a quartzose, micaceous crystalline limestone.

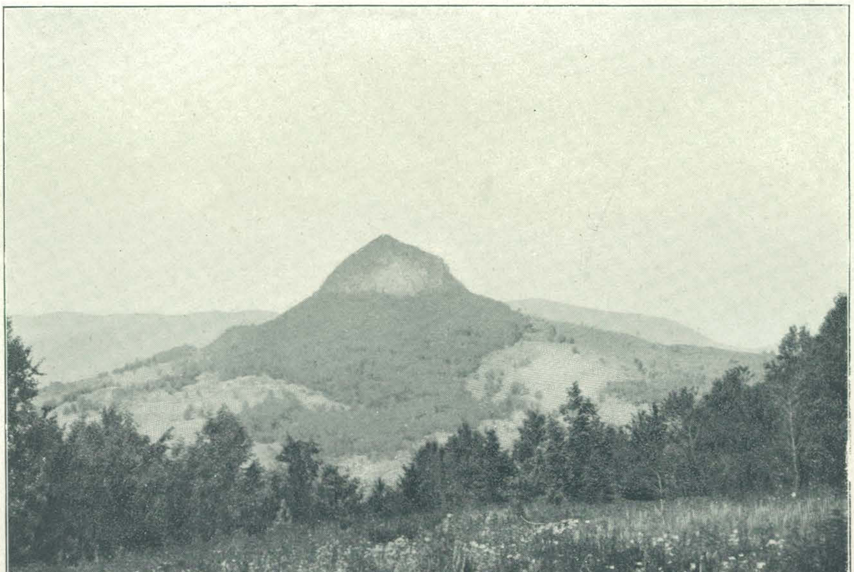
A very fine-grained and noncalcareous pebble consists of partly orientated muscovite and chlorite scales and quartz grains, with thickly disseminated spherules or crystals of pyrite, partly altered to limonite—a fine, micaceous quartzite, or a quartzose mica-schist.

### SOURCES OF THE PEBBLES.

The pre-Cambrian must naturally be regarded as the source of the granitic or gneissic quartz pebbles (frequently bluish or pinkish), and also of the feldspar grains, but either the Cambrian or the Ordovician supplied the crystalline limestone and the calcareous and micaceous



*A*. BIRD MOUNTAIN, SOUTHERN FACE, NEAR VIEW.



*B*. BIRD MOUNTAIN, GENERAL VIEW, FROM A POINT 1¼ MILES SOUTH-SOUTHWEST OF SUMMIT.

quartzite, as well as the carbonate of iron. The writer is not acquainted with any similar deposit of carbonate in the Taconic region.

## THE SCHIST.

A purplish schist from the north foot of the mountain shows the finely plicated sericite, quartz, hematite dots, and many actinolite prisms lying in all directions. A green schist from the ravine on the north-northwest side (1,100-foot contour) is like the purple, but has chlorite and no hematite, and the plications have resulted in the usual slip cleavage. A similar schist occurs also at the foot of the talus on the western side of the summit. In all these specimens the actinolite prisms produce a fine speckling. Such schists recur also on the eastern side of the mountain, but the actinolite is not always present.

In the schists on the western side of the mass southwest of Bird Mountain there is a light-buff, calcareous or dolomitic, brownish-weathering sericitic rock abounding in angular quartz grains. Thin quartzite beds occur in the schist just beyond the southern extremity of the grit area, also a mile northeast on the southeastern side of the mass, again a half mile north on its western side, and also three-fourths of a mile west of the northern part of Bird Mountain.

While the schists which underlie the grit area crop out on all sides of it, their finest exposure is a mile southeast of the top of Bird Mountain, on the northern side of Herrick Mountain in Ira. Here at the 1,600-foot contour is a cliff of schist from 100 to 200 feet high, and about 400 feet wide from east to west, known locally as the Ben Slide. It is traversed by joint planes striking east and west, and dipping about 70° N., from which great blocks have either been pried off by frost or loosened by percolating water, aided by the lubricating action of the muscovite folia of the schist itself; and these blocks have brought down portions of the hemlock forest growing above, so that a large talus of schist blocks and trees has accumulated at the foot of the cliff in chaotic confusion. The northern face of the cliff has also been striated by the descending material.

The schist is here a fine-grained, lustrous, slippery, crumpled, sericite rock, purple and green, in alternating beds. It includes small beds of chloritic quartzite, containing chalcocite ($Cu\ S_2$) and siderite ($Fe\ Co_3$). Both schist and quartzite contain here and there flakes of a bright-green pyrophyllite.[1] The quartzite weathers into a rusty sand with flakes of pyrophyllite. The schist is the Berkshire schist of the Taconic Range, and is of Ordovician age.

While pyrophyllite occurs here and there in these schists, and siderite, usually altered to limonite,[2] is not uncommon in their quartz veins, the occurrence of copper disulphide on the Taconic Range is exceptional.

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[1] For analysis see op. cit., Nineteenth Ann. Rept. U. S. Geol. Survey, Part III, p. 191.
[2] Thirteenth Ann. Rept. U. S. Geol. Survey, p. 303, footnote 1, and Pl. C, fig. 5, a, b.

West of the schist and underlying it are the Cambrian slates, grits, etc., of the slate belt, which are here, however, not considered.

## STRUCTURE OF THE MOUNTAIN.

In looking up at the great cliff on the southern side the most conspicuous structural features are steep easterly dipping joints and low westerly dipping beds, but close inspection shows easterly dipping bedding planes along the western side of the mountain. The structural symbols and the section on Pl. I show the real character of Bird Mountain. It is an open syncline, the axis of which runs along the western half of the mass. This syncline is traversed by several sets of joints, the most conspicuous of which strikes N. 60° to 65° W. and dips 70° N. to 90°; and to this set the southern cliff face is due. Another set which appears on the face strikes N. 20° to 45° E. and dips S. 70° to 75° E. On the west side a third set strikes N. and dips 90°, forming westerly facing cliffs. Still other more obscure sets strike N. 20° W., dip N. 45° E., or strike N. 35° W., dip S. 20° W. The former are slickensided on the southern mass.

While the northern half of the grit mass consists of a single syncline, the southern half appears to consist of at least two, and the main western one of these has a distinct northerly pitch toward Bird Mountain. The symbols in the northern half likewise indicate a southerly pitch. Bird Mountain itself thus forms the structural center of the entire grit area.

The grits commence on Bird Mountain at the 1,780-foot contour—that is, 430 feet below the top—but the section indicates an approximate thickness of from 500 to 550 feet for the grits, conglomerate, and the interbedded schist. The thickness of the underlying Ordovician schist was not determined, but from estimates made at several points on the range it appears to be between 1,000 and 2,000 feet.

## GLACIAL DISTRIBUTION OF BIRD MOUNTAIN GRIT.

As the character of the grit and conglomerate of Bird Mountain is so marked, and as it is not duplicated between Lake Champlain and the Hudson on the west and long. 73° 7′ on the east, and between lat. 43° 35′ and 42° 30′ (with the exception of the small area in Poultney already referred to), there is no difficulty within the area thus bounded in tracing bowlders of it back to their probable source. Such bowlders are very numerous and widely distributed. The following have been precisely located: One (diameter about 1 foot) on Mason Hill, in Pownal, Vermont, or about 58 miles S. 4° W. from the top of Bird Mountain; another (diameter 2 feet 6 inches) 4 miles west of the Hudson and 3 miles south of Schaghticoke village, in the town of that name in Rensselaer County, New York, or about 53 miles S. 12° W. from

Bird Mountain; what is probably still another (size 3 by 2 feet), 2¼ miles southwest of the northeast corner of Pittstown, in the same county, or about 47 miles S. 5° W. from the mountain; another (diameter 4 feet), 1¾ miles southeast of Granville, New York, in the northwestern part of Pawlet, Vermont, 15¼ miles S. 25° W. from the top of the mountain. Such facts have a double significance—they not only indicate the probable direction of some of the glacial currents, but they also show that the Bird Mountain grit mass has been reduced by glaciation. But the slight possibility that these bowlders have come from a like grit deposit farther north should be admitted.

## GEOLOGICAL LITERATURE AND DISCUSSION.

Geological literature does not shed much light on the general relationships of this deposit.

In the writer's former paper[1] the Bird Mountain beds were considered to be of the same age as the grits of the Rensselaer Plateau, and both were regarded as overlying the Hudson formation and thus probably forming the base of the Upper Silurian. Dr. R. W. Ells[2] questions the correctness of this classification, because very similar grits and phyllites near Quebec have been shown by their fossils to be partly of Potsdam (Upper Cambrian) and partly of Calciferous (lowermost Ordovician) age, and he therefore considers the Rensselaer grit as underlying or forming the base of the Ordovician instead of overlying it. He would explain its apparent position by complicated structural relations.[3] As pointed out in the former paper, the Bird Mountain grit is petrographically different from the Rensselaer grit, but they were classed together because of their apparently similar relations to the Hudson beds. To whatever formation the Rensselaer grit may eventually be assigned, the age of the Bird Mountain grit is probably later than Calciferous, for these reasons: The Berkshire schist, which includes the Hudson River formation and which underlies Bird Mountain on all sides, overlies the Stockbridge limestone on the eastern side of the Taconic Range, and the upper part of that limestone is of Calciferous, Chazy, and Trenton age. Again, on the western side of the range, as shown on Pl. I, the schists come close to the Cambrian slates, and may thus along that border possibly be of Calciferous and Chazy age;[4] but the Bird Mountain mass, lying so far toward the axis—i. e., the thicker part of the Taconic synclinorium—could hardly belong to its lower portion.

[1] Thirteenth Ann. Rept., loc. cit.

[2] The Rensselaer grit plateau: The Ottawa Naturalist, April, 1895, Vol. IX, No. 1, pp. 9–11.

[3] Mr. Henry M. Ami, of the Canadian Geological Survey, gives the normal order of the formations as they occur in Canada in this descending series: 7, Hudson River (=Lorraine); 6, Utica; 5, Trenton; 4, Birdseye and Black River; 3, Chazy; 2, Calciferous; 1, Potsdam (=Upper Cambrian). The Utica terrane in Canada: The Canadian Record of Science, Oct., 1892.

[4] See op. cit., Nineteenth Ann. Rept. U. S. Geol. Survey, Part III, 1899, pp. 295–296.

It is not proposed to discuss here at length the age of the Rensselaer grit, upon which it is hoped that further field work southeast of the plateau may throw more light. In a region of such frequent changes of sediment as the Hudson and Champlain Valley it is hardly safe to establish a correlation on the petrographical similarity of beds 300 miles apart, the distance between Troy and Quebec. The structure required by Dr. Ells's interpretation would be that of two transverse, complex anticlines, and the pebbles of quartzite, marble, chert, and phyllite would also require explanation. In Mr. McGee's map, published under Professor Hall's direction in 1894, the plateau and the Taconic Range are colored as "Hudson River and Utica (Oswego Sandstone)."

Beds of fine quartz conglomerate or coarse quartzite occur nere and there in the Berkshire schist of the Taconic Range, but as their thickness is inconsiderable and their pebbles are almost exclusively quartz they are regarded merely as coarser sediments derived from the same sources as those which supplied the material of the schist itself. In the pebbles of clastic rocks in the Bird Mountain grit we have evidence of an unconformity to Cambrian if not to Ordovician beds which these minor beds of quartz pebbles in the lower formation do not afford.

Mr. James P. Kimball's article on "Siderite basins of the Hudson River epoch"[1] shows that during Hudson River time calcareous and ferruginous sediments were formed west of what is now the Taconic synclinorium, and he ascribes the alteration of the original limonite to siderite to buried organic matter, its subsequent change back into limonite being regarded as the result of weathering. As the schists of the Taconic Range are in part, at least, of Hudson River age, the question arises whether the bed which furnished the material for the carbonate pebbles of Bird Mountain may not have been such a small siderite basin; but the apparent conformity of the grits and schists and their interbedding do not favor this view. Another possible source is the Cambrian area west of the Taconic Range, in which, however, no such massive carbonate has thus far been found, although the Cambrian slates do contain not a little carbonate. Still another possibility is that the carbonate pebbles are autoclastic—that is, they resulted from the crushing of beds of carbonate occupying the area of the Bird Mountain grit and were subsequently rounded by solution—but that the limestone, quartz, and quartzite pebbles were detrital; in other words, that the rock is partly a breccia and partly a conglomerate. While the thin sections show cracked pebble-like masses of carbonate, they also show areas of carbonate which are indistinguishable from the cement, and this lends support to such a theory.

[1]Am. Jour. Sci., 3d ser., Vol. XL, 1890, pp. 155–160.

## CONCLUSIONS.

Bird Mountain is an open syncline within the Taconic Range, and consists of about 500 feet of grit and conglomerate interbedded with muscovite- (sericite-) schist, and underlain on all sides by schist of similar character, but frequently containing small beds of quartzite. The presence of pebbles of crystalline limestone, calcareous quartzite, and granitic quartz in the conglomerate shows that at no great distance rocks of these kinds were above sea level at the time of its deposition. The presence of a carbonate of iron, magnesia, and lime, both in the cement and in pebble-like masses in the grit, indicates that these pebbles may be due to brecciation and solution, and that the area of the Bird Mountain grit may have been a basin in which fine ferruginous and calcareous sedimentation took place and in which also coarser detritus was collected. The stratigraphical relation of the schists which underlie Bird Mountain, both to the Cambrian on the west and to the Ordovician on the east, and the synclinal structure and position of Bird Mountain itself, indicate the upper part of the Ordovician as the probable age of the grit. While some of its pebbles must have come from pre-Cambrian rocks, others originated in Cambrian beds,[1] and the carbonate pebbles may also be of that age.

The formation of secondary quartz crystals on the joint faces of the grit shows that important chemical changes went on in the mass after the jointing.

The narrowness of the grit mass at Bird Mountain compared to its width, and its more complex structure at the south, indicate that at least the northern half of the deposit may originally have been much more extensive. The peculiar outline of the mountain as seen from the south (Pl. II), the difference between its material and the underlying schists, its isolation, and the wide distribution of its fragments by the continental glacier, all indicate that it has been greatly reduced by erosion.

The incision which separates Bird Mountain from the rest of the grit mass on the south and the high cliff which forms its southern face are probably due to erosive influences acting along a system of nearly vertical joints, striking N. 60° to 65° W. The steep lateral faces of the mountain are in like manner due to longitudinal joints, while the talus at the foot of the cliffs on all sides is largely the result of more recent weathering by frost and vegetation acting along bedding and joint planes.

The outline of the mass as seen from the northwest and west (figs. 1 and 2), and also that from the Green Mountain range on the northeast, the roundish northern end and the steep southern face are probably the shock and lee sides of a glaciated mountain, although the axis of this one was not parallel to the glacial current, but intersected it at an acute angle.

[1] See on the relation of the Ordovician to the Cambrian in this region, The slate belt of eastern New York, etc.: Nineteenth Ann. Rept. U. S. Geol. Survey, Part III, 1899, pp. 290-297.

# DEVONIAN FOSSILS FROM SOUTHWESTERN COLORADO

## THE FAUNA OF THE OURAY LIMESTONE

BY

GEORGE H. GIRTY

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# DEVONIAN FOSSILS FROM SOUTHWESTERN COLORADO: THE FAUNA OF THE OURAY LIMESTONE.

By GEORGE H. GIRTY.

## INTRODUCTION.

These strata, whose age, on evidence more or less unconvincing, has been variously determined as Devonian and Carboniferous, have long been known to geologic literature. The first mention of Devonian rocks in Colorado concerns a portion of the area furnishing the collections upon which the following descriptions are based. In 1873 F. M. Endlich made a hasty survey of the San Luis division, Colorado, and some of the strata in this area he referred to the Devonian, without, however, presenting any very good evidence for so doing. It is somewhat doubtful whether Devonian strata occur at all in his section *A* of this region,[1] but if any member of the series examined is of that age, it is said to be conformable with the Silurian below and the Carboniferous above.[2] Endlich, however, regarded the presence of Devonian rocks as more probable in section *C*, and he referred 80 feet of yellow and gray shales to that age,[3] though he presents no fossil evidence to support this view, and in his general conclusions on the regions surveyed he states that "the Devonian rocks also seem to be represented, although no strict identification was possible." On page 340 is cited a partially identified fauna from a limestone occurring a little higher in the section than the shales ascribed to the Devonian, the facies of which would suggest to one acquainted with the Ouray fauna that possibly this bed, as well as, or instead of, the other, should be referred to that era. Continuing work in the same general region, Endlich in 1876 reported upon the geology of the San Juan district of Colorado.[4] Here also Devonian strata are recognized, but upon rather insufficient evidence. It is said[5] that "near the head of Cunningham Gulch a light blue to white limestone crops out, which, according to its lithological character, must be referred to the upper Silurian or lower Devonian of that region, no fossils having been

[1] Seventh Ann. Rept. U. S. Geol. and Geog. Surv. Terr., for 1873, map facing p. 305.
[2] Loc. cit., pp. 308, 310, 312.
[3] Loc. cit., p. 340.
[4] Bull. U. S. Geol. and Geog. Surv. Terr., 2d. ser., Vol. I, No. 3, pp. 151-164.
[5] Loc. cit., p. 157.

found that might establish its age beyond a doubt." Mention is also made[1] of Devonian limestone some distance down the Animas.

Making a more detailed report the same year, Endlich identified Devonian strata more authoritatively at several points.[2] One area cited is along Lime Creek down to its junction with Cascade Creek. The series at this locality is said to have a thickness of from 1,200 to 1,500 feet, and is fossiliferous, Rhynchonella, Spirifer, and numerous remains of crinoids having been found at almost every exposure. "A second outcrop belonging to this formation occurs immediately on the southern boundary of the metamorphic area, running in a northwesterly direction from station 48. This station is located on an isolated patch of Devonian limestone, surrounded on all sides by metamorphic granite." At this locality were collected a small Productus resembling *P. subaculeatus*, *Orthoceras*, *Athyris*, *Rhynchonella*, *Bellerophon*, *Euomphalus*, and *Rhynchonella Endlichi*.

On page 114 of the same volume Peale describes his work in the region of the Grand, Gunnison, and Eagle rivers, and he there sets aside a series of beds having a total thickness of over 1,000 feet as possibly belonging to the Devonian. This seems to have been done as much because Endlich and Marvine had discovered rocks of Devonian age in the areas surveyed by them as upon intrinsic evidence. He says, referring to this series (p. 116): "A portion of the upper limestone may have to be referred to the Lower Carboniferous, while the lower layers may be of Silurian age, leaving the center to represent the Devonian. Of course, without fossils to prove their age, all opinions are merely conjectural."

Farther to the north, though still within the confines of Colorado, is found the White River district, which Endlich surveyed in 1876. His report upon this region appeared two years later.[3] The Devonian is said to occur at a number of localities,[4] but is with difficulty discriminated from the Silurian below and the Carboniferous above. It is said to be represented by a very extensive series of limestones, interstratified with shales and sandstones near top and base. On the Animas the most complete development was observed. It is suggested that a large portion of the Colorado Devonian will be found to be parallel to the lower Devonian groups of the East. Attention is called to a prominent feature in Devonian faunas of the West—the intermingling of Devonian with Lower Carboniferous types, a circumstance which, it is said, can be observed in those beds usually assigned to the Carboniferous proper. In the synopsis of geological formations found in Colorado,[5] it is stated that the Devonian strata are 1,200 to 1,500 feet thick on Lime Creek, and 400 feet thick south of Mount Oso. Both expos-

[1] Bull. U. S. Geol. and Geog. Surv. Terr., 2d ser., Vol. I, p. 162.
[2] Eighth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., for 1874, 1876, pp. 211-214.
[3] Tenth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., 1878, pp. 61-131.
[4] Loc. cit., p. 106.
[5] Loc. cit., pp. 123-131.

ures show a massive blue limestone, in the latter case associated with sandstone and shale near the top. *Rhynchonella*, *Spirifer*, and crinoids are cited from Lime Creek, and from Mount Oso *Productus subaculeatus*, *Orthoceras*, *Athyris*, *Bellerophon*, *Euomphalus*, and *Rhynchonella Endlichi*. In Hayden's Atlas of Colorado,[1] which appeared in 1881, three years later, Devonian areas are mapped in the Animas Valley (sheet 15), but nowhere else are rocks of that age recognized. The same year Prof. G. A. Koenig, writing of the occurrence of lustrous coal with native silver in porphyry in Colorado,[2] described the outcropping of Devonian limestone along the Uncompahgre River near Ouray and regarded it as representing the early or middle portion of the era. Nothing of paleontologic interest is added to what was already known. The same is true of three papers by Comstock,[3] which refer more or less briefly to the same subject. The chief point brought out in this connection seems to be the metamorphism of some of the beds.

The latest contribution to the subject of which I have just given a hasty review was made by Mr. A. C. Spencer.[4] In this paper, to which my own is supplemental, a discussion of the Ouray limestone is given as considered from the stratigraphic side. For an account of the geology of the Devonian of Colorado, so far as known, reference should be had to this publication.

As mentioned above, Endlich thought the Devonian of Colorado would be found equivalent to the lower portion of the eastern Devonian. When Meek described *Rhynchonella Endlichi*, which is one of the most persistent and characteristic fossils of the Devonian limestone of southwestern Colorado, he remarked:

> This is a fine species, more nearly resembling some Devonian and Upper Silurian forms than the usual Carboniferous types; [adding that] according to Dr. Endlich's sections, as well as from its affinities, it would seem to be most probably an Upper Devonian species.[5]

In 1883 White redescribed and figured *R. Endlichi* among a number of Carboniferous forms. He states:

> Although Mr. Meek, when he originally described this species, believed it to have been derived from strata of Upper Devonian age, subsequently ascertained facts lead me to believe that those strata really belong to the lower portion of the Carboniferous series. I therefore include it among the Carboniferous fossils of this article.[6]

The nature of the facts subsequently ascertained is unfortunately not stated, but the conclusions thus reached seem to have been not

[1] U. S. Geol. and Geog. Surv. Terr., Geol. and Geog. Atlas of Colorado, etc.
[2] Trans. Am. Inst. Min. Eng., Vol. IX, p. 650.
[3] Trans. Am. Inst. Min. Eng., Vol. XI, 1883, pp. 172-174. Am. Naturalist, Vol. XX, 1886, p. 1007. Proc. Am. Ass. Adv. Sci., Vol. XXXV, 1887, pp. 232-233.
[4] Am. Jour. Sci., 4th ser., Vol. IX, 1900, pp. 125-133.
[5] Bull. U. S. Geol. and Geog. Surv. Terr., 2d ser., No. 1, 1875, p. 47.
[6] Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., for 1878, Pt. I, 1883, p. 133, Pl. XXXIII, figs. 4a, 4b; Pl. XXXVI, figs. 2a, 2b.

without influence, for although the Hayden Atlas[1] shows Devonian areas in the Animas region of southwestern Colorado, rocks of that age are not indicated in either the Pueblo,[2] Pikes Peak,[3] or Anthracite-Crested Butte[4] folios.[5]

While I do not know that the Ouray limestone or its equivalent occurs in the Pueblo or Pikes Peak quadrangles, it is present with its characteristic fauna in the Gunnison region, a portion of which is within the Anthracite-Crested Butte quadrangle. In commenting upon the species *Camarotœchia Endlichi*, in 1897,[6] Mr. Charles Schuchert says:

> This type of Rhynchonella occurs in eastern North America only in the Lower Devonian. It therefore seems probable that Meek's provisional reference to the Devonian is nearer correct than White's to the Lower Carboniferous.

The fossils studied by me consist of such of the collections of the Hayden Survey made by Endlich and others as were to be found in the National Museum, of which they are now the property; of part of rather extensive collections made in the Gunnison and Salida regions by Mr. Eldridge, of the United States Geological Survey, and of several rather complete collections made by Messrs. Cross and Spencer from the Ouray limestone in the Animas region, all in Colorado. These localities, which are twenty in number, show a coincident fauna which is distinctly Devonian in character, and which, as proved by the different points at which it has been recognized, enjoyed a considerable areal dispersion while retaining its integrity and individuality.

## AGE OF THE BEDS.

The evidence against regarding the Ouray limestone as of Carboniferous age is conclusive. Some of the intrinsic evidence can be outlined as follows: The presence in the Ouray fauna of an Orthis related to and perhaps identical with *Schizophoria striatula* is of importance, as no Orthoids of this type are known in this country from Carboniferous rocks. The Productoids, while of Devonian rather than Carboniferous type, might not seem strongly out of place in a basal Mississippian fauna, but at the same time the absence of characteristic Carboniferous species is significant. Species of the genus Athyris, sensu stricto, are not common in the Carboniferous. Perhaps the only form which may be claimed as an exception is *Athyris lamellosa* of the lower Mississippian, but *Athyris lamellosa* is of a very different type from *A. coloradoensis*, which is related to *A. spiriferoides*, of the Hamilton group. Furthermore, we have in the Ouray limestone two Spirifers of a distinctly Devonian habit, a habit which is, at the same

[1] U. S. Geol. and Geog. Surv. Terr., Geol. and Geog. Atlas of Colorado, etc.

[2] Geologic Atlas of the United States, folio No. 36, 1897.

[3] Idem, folio No. 7, 1894.

[4] Idem, folio No. 9, 1894.

[5] I may add that I have not been able to find Devonian colors in this area either on Hitchcock's map (Trans. Am. Inst. Min. Eng., Vol. XV, 1887, pp. 486–487) or on either of the McGee maps (Fifth Ann. Rept. U. S. Geol. Surv., 1885; Fourteenth Ann. Rept., Pt. II, 1894).

[6] Bull. U. S. Geol. Surv. No. 87, p. 166.

time, quite alien to the Carboniferous. One of these seems to be allied to *Sp. disjunctus*, of Chemung age, though it has a high, flat, horizontal area. The other, which also has a high, flat, horizontal area, is similar to *Spirifer asper*, of the Hamilton group. I know of no Carboniferous Spiriferoids, with the possible exception of members of the genus Syringothyris, which at all approach either of these species in the conformation of the valves, while one of them is totally unlike Syringothyris in the character of its surface ornamentation, and both seem to be in point of structure genetically different. *Camarotœchia Endlichi*, as pointed out by Meek and Schuchert, is quite pre-Carboniferous in habit, and, in fact, most nearly resembles certain lower Devonian shells. These constitute the strongest points in evidence of the age of the Ouray limestone, and though much testimony in the same direction might be obtained by a consideration of the Gasteropoda and the Lamellibranchiata and by showing the affinity of the fauna as a whole with other faunas of recognized Devonian age, I think enough has been said to prove conclusively that the Ouray limestone contains a fauna of more primitive character than even the lowest Carboniferous.

It is, perhaps, possible to fix the age of the Ouray limestone somewhat more exactly in the Devonian. The evidence is rather conflicting, but it is my opinion that this fauna represents late middle or early upper Devonian time. It shows many points of approximation to the Athabasca fauna described by Whiteaves,[1] which he justly concludes to be of about the same age as the Tully limestone of the New York section. While the two faunas are far from being identical, they are enough alike to suggest, in view of their wide geographic separation, that the Ouray limestone may represent the same geologic period, namely, the base of the upper Devonian. Much of the evidence of individual species points in the same direction. Prominent among this class of facts may be mentioned *Spirifer disjunctus* var. *animasensis*, which is very closely related to Whiteaves's *Sp. disjunctus* var. *occidentalis*. Both these forms are nearly allied to *Spirifer disjunctus*, a type which, as closely limited, is not, I believe, known in the United States to occur before the Chemung period, though in Europe it was initiated during middle Devonian time. *Schizophoria striatula* also is restricted in its range to middle and upper Devonian rocks, while *Spirifer coniculus* is of a distinctly middle Devonian type. The form which has been identified as *Spirifer bimesialis* also is one which would seem most in place among the later Devonian faunas. I am led to conclude, therefore, that the Ouray limestone was deposited certainly no earlier than middle Devonian time, and that its deposition may have taken place as late as early upper Devonian time.

This fauna not only shows affinities with that of the Mackenzie River basin above mentioned, but is certainly related to that of Nevada and

[1] Geol. Nat. Hist. Surv. Canada; Contributions to Canadian Palæontology, Vol. I, pt. 3, pp. 197-253.

Montana. At the same time the three species, *Spirifer disjunctus* var. *animasensis*, *Athyris coloradoensis*, and *Camarotoechia Endlichi*, which are among its most constant and abundant factors, give it a rather individual character.

## DISTRIBUTION OF THE FAUNA.

The following table shows the fauna of the Ouray limestone and the several localities at which collections have been made:

*Table showing distribution of the fauna of the Ouray limestone.*

| | Gunnison 130. | Gunnison 131. | Gunnison 132. | Gunnison 133. | Gunnison 134. | Gunnison 135. | Gunnison 136. | Gunnison 145. | Gunnison 145*a*. | Salida 26. | Salida 27. | Salida 28. | Salida 29. | Salida 30. | Durango 284. | Durango 286. | Durango 291. | Durango 294. | Engineer Mountain 7. | Ouray. | White River. | Northwestern Colorado. | Cement Creek. | Station 48. | Glenwood 1. | Glenwood 2. | Glenwood 3. | Glenwood 1 and 4. | Glenwood 2 and 3. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Streptelasma sp | | | | | | | | | × | | | | | | | × | | | | | | | | | | | | | |
| Chætetes sp | | | | | | | | × | | | | | | | | | | | | | | | | | | | | | |
| Fenestella sp. 1 | | | | | | | × | | | | | | | | | | | | | | | | | | | | | | |
| Fenestella sp. 2 | | | | | | | | | | | | | | | | | | | × | | | | | | | | | | |
| Monotrypella sp. 1 | | | | | | | | | | | × | | | × | | | | | | | | | | | | | | | |
| Monotrypella sp. 2 | | × | × | | | | | | | | | | | × | | | | | | | | | | | | | | | |
| Monotrypella sp. 3 | | × | × | | | | | | | | | | | × | | | | | | | | | | | | | | | |
| Schizophoria striatula | | | | | | × | × | × | × | | × | | | × | | | × | | | | × | | | | | × | | | |
| Orthis sp | | × | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Orthothetes chemungensis | | | | | | | | | | | | | × | × | | | × | | × | | | | | | | | × | | |
| Orthothetes chemungensis var | | × | | | | | | × | | | × | | × | | | | × | × | × | | | | × | | | | | | |
| Chonetes sp | | | | × | | | | | | | | | | | | | | | | | | | | | | | | | |
| Productella semiglobosa | | | | | | × | | | | × | | | | × | | | × | × | × | | | | | × | | | | × | |
| Productella subalata? | | | | | | | | | | | | | | × | × | | × | | × | | × | | | | | | | × | |
| Productella subalata var | | | | | | | | | | | × | | | × | | | | | | | | | | | | | | | |
| Productella sp | | | | | | | | | | | | | | | | | | × | × | | | | | | | | | | |
| Athyris coloradoensis | × | × | × | | | × | × | × | × | × | × | | × | × | × | | × | × | × | | × | | | × | | × | | | |
| Athyris vittata var | | | | | | | | | | | | | | | | | | | × | | | | | | | | | | |
| Spirifer bimesialis? | | | | | | | | | | | | | | | | | | | | | | | | | | | | | × |
| Spirifer coniculus | | | | | | | | | | | | | | | | | | | × | | | | | | | | | | |
| Spirifer disjunctus var animasensis | × | | × | | × | × | | × | × | × | × | × | | × | × | | × | × | × | × | | × | × | × | | | × | | |
| Camarotœchia Endlichi | × | × | × | × | | | × | | × | × | × | × | × | × | | | × | × | × | | | | | × | × | × | | | |
| Camarotœchia contracta? | | × | | | | | | | × | × | × | | × | × | | | × | × | × | | | | | × | | | | | × |
| Modiomorpha? sp | | | | | | | | | | | | | | | | | × | | | | | | | | | | | | |
| Allorisma sp | | | | | | | | | | | | | | | | | × | | | | | | | | | | | | |
| Paracyclas sp | | | | | | | | | | | | | | | | | × | × | | | | | | | | | | | |
| Mytilarca? sp | | | | | | | | | | | | | | | | | | × | | | | | | | | | | | |
| Naticopsis gigantea | | | | | | | | | | | | | | | | | | × | × | | | | | | | | | | |
| Naticopis? (Isonema) humilis | | × | | | | | | | | | | | | | | | × | × | × | | | | | | | | | | |
| Straparollus clymenioides? | | | | | | | | | | × | | | × | | | | × | × | | | | | | | | | | | |
| Pleuronotus Decewi? | | | | | | | | | | | | | | | | | | | × | | | | | | | | | | |
| Pleurotomaria sp | | | | | | | | | | | | | | | | | × | | | | | | | | | | | | |
| Bellerophon sp | | | | | | | | | | | | | | | | | × | × | | | | | | × | | | | | |
| Orthoceras sp *a* | | | | | | | | | | | | | | × | | | × | × | | | | | | | | | | | |
| Orthoceras sp *b* | | | | | | | | | | | | | | | | | × | | × | | | | | | | | | | |
| Orthoceras sp *c* | | | | | | | | | | | | | | | | | × | | | | | | | × | | | | | |

In the following list will be found a fuller description of the localities which are referred to in an abbreviated form in the table and in the description of species:

Gunnison 130, 131, 132, 133, 134, 135, 136. Crested Butte quadrangle; bluffs on the north side of Cement Creek. Probably from near the base of the Devonian limestone.

Gunnison 145. Maroon formation, Crested Butte quadrangle; about 1 mile NNE. of Cement Peak. From a limestone pebble in a limestone conglomerate in the great series of grits.

Gunnison 145*a*. East of the Crested Butte quadrangle; bluffs on the north side of Dead Mans Gulch, about 1 mile above its mouth.

Salida 26. On East Monarch Mountain, northwest face, Chaffee County, Colorado.

Salida 27. Same as 26, but 100 feet lower topographically.

Salida 28. Same as 26, but 200 feet lower topographically.

Salida 29. Same as 26, but 250 feet lower topographically.

Salida 30. Same as 26, but about 275 feet lower topographically.

Durango 284. Ouray limestone, Durango quadrangle. Limestone below main limestone cliff of the Devonian; Animas River.

Durango 286. Ouray limestone, Durango quadrangle. Top of main limestone; Animas River.

Durango 291. Ouray limestone, Durango quadrangle; north side of Bear Creek, south of moraine camp. Lower part of main limestone.

Durango 294. Ouray limestone, Durango quadrangle; south side of Bear Creek. Granular layer in main limestone.

Engineer Mountain 7. Ouray limestone, Engineer Mountain quadrangle; southern edge of the quadrangle on the Animas River, 2 miles north of Rockwood.

Ouray, Colorado. West side of Canyon Creek, near the falls.

The four collections next described were made a number of years ago by the Hayden Survey and transferred to the National Museum. The descriptions of localities preserved in the museum records are more meager than might be wished. They are given below with such additional information as I have been able to gather:

White River. "The massive limestone of White River, Colorado." This locality seems to be in the Paleozoic area on the head waters of White River, near the White River Plateau, northwest of the central part of the State.

"Northwestern Colorado." This collection, like the preceding, was received from A. R. Marvine, and it seems probable that both were made in the same region, if not at the same locality.

Cement Creek. "Canyon of Cement Creek, Colorado." This collection must have been made very near the point which furnished those designated Gunnison 130, etc.

Station 48. This is the original locality of the Colorado Devonian, the one which furnished the type specimens of *Camarotœchia Endlichi*, and which is described by Endlich in the Eighth Annual Report of the U. S. Geological and Geographical Survey of the Territories [1874], 1876, p. 211. The locality is a point in the Needle Mountains quadrangle, about 4 miles southwest of Mount Eolus. The fauna collected at this point, as cited in the above reference, consists of a Productus like *P. subaculeatus*, *Orthoceras* sp., *Athyris* sp., *Rhynchonella Endlichi*, *Bellerophon* sp., and *Euomphalus* sp. There seem to have been, in addition, a species of Camarotœchia and a poorly preserved Spirifer.

Collections were made at Glenwood Springs, Colorado, in 1889, by Mr. T. W. Stanton, from a blue limestone containing the Ouray fauna. Since these collections were made, and before they were studied by me, a certain amount of mixing had, I am sorry to say, taken place. That is, two lots were found with two different labels in each. This circumstance happens to be, in the present case, a matter of minor importance, as the species are in the main precisely the same as those which characterize the Ouray limestone at its typical localities. However, a species of Chonetes and several specimens of a Seminula were found in the collection, which not only differ specifically from anything yet known in the Ouray fauna, but have a somewhat different matrix and style of preservation from the rest of the collection. As these same species are found in the Hermosa formation, overlying, with which their preservation and matrix more nearly agree, I have concluded that their association with the Ouray fauna is fortuitous, and they have not been considered in the following pages. A species of Spirifer, however, which, though not found elsewhere, is here associated with Ouray species, is a Devonian type of shell, and is in matrix and preservation not to be distinguished from the rest of the material. A description of this species will be found on page 55.

Glenwood 1. Glenwood Springs, Colorado. From loose fragments at the roadside, opposite mouth of tunnel.

Glenwood 2. Glenwood Springs, Colorado. One hundred to 150 feet above base of the blue limestone.

Glenwood 3. Glenwood Springs, Colorado. One hundred and fifty to 200 feet above base of the blue limestone.

Glenwood 4. Glenwood Springs, Colorado. One hundred to 200 feet above base of the blue limestone.

## DESCRIPTIONS OF SPECIES.

### STREPTELASMA sp.

Corallum small, rapidly expanding, and moderately curved toward the ventral side.

Septa, about 64 in number, meeting in the center, where they are somewhat twisted.

Tabulæ and dissepimental tissue entirely wanting.

This species shows the typical arrangement of the septa very prettily. In each of the alar quadrants 16 septa were counted, and in the two counter quadrants combined, 30 to 32. These numbers were not made out with absolute precision, but probably an allowance of one for each quadrant would cover any error in counting. The total number can thus be placed at from 60 to 64.

While having about the same number of septa as *S. rectum* of the Hamilton period, this species seems to differ in being smaller, more rapidly expanding, and more strongly curved.

The length of the best specimen observed was probably 20 mm. from the apex to the center of the distal end. The diameter of the latter is 15 mm.

Another specimen examined is less perfect and shows considerably increased dimensions.

*Formation and locality.*—Ouray limestone: Gunnison 145*a*; Durango 286.

SCHIZOPHORIA STRIATULA (Schlotheim) Schuchert.

Many localities in the Ouray limestone have furnished representatives of the Orthis group, but they are always both few in number and poor in preservation. Several show enough of the internal characters to leave no doubt that they belong to the type of Schizophoria, and the others afford no evidence on account of which they should be removed to another genus. The majority of the specimens are ventral valves, and agree in belonging to a large lenticular species of about the size and conformation of *Rhipidomella Vanuxemi.* One unusually large example, with a transverse diameter of slightly over 50 mm. (the length is somewhat less), shows that the anterior portion is depressed into a narrow, strong sinus. This specimen, at least, seems to belong to the type of *Sch. striatula.* Other smaller specimens show a faint, broad depression, possessing this character in about the degree that the larger example would have had when of the same size. All are but slightly convex.

The dorsal valve has much the same shape as the ventral, but is more gibbous. Larger individuals, the largest being still much smaller than the large ventral mentioned above, show a broad, faint elevation of the anterior portion.

The striæ are subequal and number about 10 in the space of 5 mm.

Making due allowance for difference of age as indicated by size, I have little hesitation in referring all these specimens to the same species, which must be, although this shell is more than usually lenticular, *Sch. striatula* or one closely related.

The synonymy adopted will be found in Schuchert[1] and need not be repeated in this place.

*Formation and locality.*—Ouray limestone: Gunnison 135, 136, 145, 145*a*; Durango 291; Salida 27, 30; White River; Glenwood Springs.

ORTHIS sp.

At Gunnison 131 is found a single specimen of Orthis, which seems to resemble (it is considerably crushed) smaller individuals of the type which I have referred to *Sch. striatula.* It differs, however, in having the striæ unequal, two or three finer radii occurring between two stronger ones. The particular group of Orthis to which this species belongs it has not been possible to ascertain.

*Formation and locality.*—Ouray limestone: Gunnison 131.

[1] Bull. U. S. Geol. Surv. No. 87, 1897, p. 375.

ORTHOTHETES CHEMUNGENSIS (Conrad) Hall and Clarke.

Pl. III, figs. 1–3.

The shells with which I am dealing under this name manifest all the inconstancy in the matter of details which is so characteristic of the genus. The collections from Colorado indicate a certain gregarious tendency often observed, such that, though the genus is known at comparatively few localities, it frequently appears, where it occurs at all, in considerable abundance. Usually specimens from the same locality are fairly constant and resemble one another more than shells from other places.

The form which perhaps more nearly than any in the collection resembles typical *O. Chemungensis*, from New York and Pennsylvania, is found at Salida 29. It is a rather large shell, attaining a width of 43 mm. and a length of 28 mm. It seems to be usually semicircular in outline, with cardinal angles of about 90° and subparallel sides. The amount of convexity of the dorsal valve and elevation of the ventral beak is subject to considerable variation. The growth of both valves is often very irregular. There are 9 or 10 striæ in the distance of 5 mm., between which, and alternating with them, can sometimes be seen much finer striæ, so minute as to be scarcely visible.

For the synonymy of this species here accepted see Schuchert.[1]

*Formation and locality*—Ouray limestone: Engineer Mountain 7; Durango 291; Salida 29, 30; Glenwood Springs.

ORTHOTHETES CHEMUNGENSIS var.

Pl. III, figs. 4–6.

At Engineer Mountain 7 especially, and also at other localities, occurs a form which may be regarded as a variety of the above, chiefly distinguished by being smaller and more finely striated. The shell is small, 25 mm. representing the width of an average-sized individual. The shape is variable, the width greater than the length in varying degrees. Usually the shape is subsemicircular, with the cardinal angles quadrate and the sides for a distance straight and nearly parallel. In some cases the cardinal angles appear to be rounded, so that the greatest width is just below the hinge line, and in others the sides converge anteriorly, so that the hinge line is considerably wider than the shell below. The convexity of the dorsal valve is usually slight, though variable. The convexity of the ventral valve is also slight, but the beak is frequently elevated, so that the altitude of the area is rather great for the genus.

[1] Bull. U. S. Geol. Surv. No. 87, 1897.

Growth in both valves was irregular, more frequently in the way of causing concentric undulations or local elevations or depressions than of twisting to one side or the other, a condition which also obtains.

The radiating striæ are fine, threadlike, subequal, increasing by intercalation, separated by spaces wider than the striæ themselves. The latter number from 13 to 15 in the space of 5 mm.

In a specimen from Gunnison 131, referred to this type, the striæ are unequal. The larger striæ are separated by intervals about 2 mm. in width, and inclose between them smaller ones, 3, 4, or 5 in number.

*Formation and locality.*—Ouray limestone: Engineer Mountain 7; Gunnison 131, 145; Durango 291, 294; Salida 27, 29; Cement Creek.

## CHONETES sp.

A single imperfect ventral valve of Chonetes from Gunnison 133 furnishes the following partial description:

Shell small, tumid. Longitudinally the greatest curvature is posterior. Transversely the slant is rapid from the elevated mesial portion to the depressed sides. Shape of the cardinal angles and number and character of the spines not known.

Radiating striæ rather fine, bifurcating, about 12 in the space of 5 mm. Concentric striæ fine, distinct, but not obscuring the radiating ones.

Width of shell probably about 5 mm.

This species is of the type of Hall's *Chonetes Logani* var. *aurora*, which, as originally defined, seems to include several distinct forms.

Typical examples of that species from the Tully limestone at Tinkers Falls, Truxton, New York, are, as stated by Williams,[1] quite distinct from typical examples of *Ch. Logani* from the oölitic beds of the Kinderhook group of Burlington, Iowa. In *Ch. aurora* the concentric striæ, while not so coarse as the radiating ones, are more strongly expressed, so that they interrupt and obscure them. Comparing the Colorado form with *Ch. aurora*, it is seen that both the radiating and the concentric striæ are much finer, and that, in fact, it is a quite distinct shell. It more nearly resembles *Ch. Logani*, but here again both sets of striæ, especially the concentric ones, are finer. In this regard it can be compared with *Ch. Illinoisensis*, but in that species the radiating striæ are much finer.

This is possibly the same form as that identified by Whiteaves as *Ch. Logani* var. *aurora*. I suspect, however, that Whiteaves's form is distinct from typical *Ch. aurora*, and possibly a new species.

*Formation and locality.*—Ouray limestone: Gunnison 133.

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[1] Bull. Geol. Soc. America, Vol. I, 1890, p. 491.

PRODUCTELLA SEMIGLOBOSA Nettelroth.

Pl. III, figs. 7–10.

*Productella spinulicosta?* Hall, 1867. Pal. New York, Vol. IV, p. 160, pl. 23, figs. 6–8.

*Productus subaculeatus?* Meek, 1876. Simpson's Rept. Expl. Great Basin Terr. Utah, p. 345, Pl. I, figs. 3a–3c.

*Productus subaculeatus?* Meek, 1877. King's U. S. Geol. Expl. Fortieth Parallel, Vol. IV, p. 36, Pl. III, figs. 7–7c.

*Productella semiglobosa* Nettelroth, 1889. Mem. Kentucky Geol. Surv.; Kentucky Fossil Shells, p. 70, Pl. XXVI, fig. 7.

*Productella spinulicosta* Whiteaves, 1891. Cont. Canadian Pal., Vol. I, p. 217, Pl. XXIX, figs. 3–3a; Pl. XXXI, fig. 1.

*Productella subaculeata* Whiteaves, 1892. Cont. Canadian Pal., Vol. I, p. 283.

Shell rather small, narrow, highly convex. Shape subsemicircular, hinge line wide as any portion of the shell below, cardinal angles quadrate, width slightly exceeding the length.

Ventral valve highly inflated. Beak strongly incurved. Longitudinally the greatest curvature occurs posteriorly, the anterior portion being more nearly straight. Sides more or less spreading. Ears small, quadrate, upturned.

The surface of the posterior third of the shell seems to be smooth. Over the remainder of the surface and upon the ears are scattered the bases of a few large, round spines, which tend to arrange themselves in transverse rows. Fine concentric growth lines can also be seen, especially over the more marginal parts of the surface.

A single specimen showing the character of the dorsal valve has come to hand. It is in the usual condition—a convex object, the shell having adhered to the matrix externally, though in this case it is almost completely exfoliated. I will describe the specimen as it is presented to the eye, though the characters of the shell itself would of course be the reverse.

The convexity is rather strong. There is a not very marked geniculation, and the peripheral portions are flattened; but the visceral area in this specimen shows considerable convexity, and the side outline departs but little from a regular curve. A number of fine concentric wrinkles are seen over the visceral area, particularly strong laterally. The anterior or peripheral portions show traces of coarse but faint radiating striæ and a few large pustules.

At Engineer Mountain 7 occur two dorsal valves, much larger than the one just described, though resembling it in shape. They are not of the character which I should expect to go with *Productella subalata*, although they are associated with that species, and I provisionally refer them to *P. semiglobosa*. They may belong to a different species from either. Only the interior of this shell is known, and it can be described as follows: Shell rather large, about 25 mm. in width, transverse, subsemicircular. Visceral portion slightly convex, peripherally geniculate. Ears small, strongly upturned, bounded by grooves. Marked (interiorly of course, as the whole description is based upon this view) by thin discontinuous ridges, having the appearance of minute interrupted striæ. Fine concentric rugosities traverse the visceral portion. The cardinal process appears to be bilobed, and there is present a low, thin, median septum.

This shell is related to several species of Productella from the middle and upper Devonian which are distinguished by their small size, arcuate shape, and comparatively large and rare spines. Some have, like the form in question, been referred to *P. subaculeata* Murch., which, at least as identified in this country, Schuchert believes to be the same as *P. spinulicosta* Hall. This is in many cases doubtless true, but several types so identified can be distinguished from typical *P. spinulicosta* by reason of the fewness of their stout spines, which spring directly from the shell instead of being mounted upon elongate bases.

Without attempting to discuss the synonymy and the specific limitation of these protean forms, I will provisionally identify my shell with Nettelroth's *Productella semiglobosa*, which was found in rocks of supposed Corniferous age at the falls of the Ohio. I have not been able to compare my material with individuals representing *P. semiglobosa*, but as far as can be made out from his descriptions and figures the two forms might well be referred to the same species. There can be little doubt that this is the species which Meek mentions under the name of *P. subaculeatus* in the fauna associated with *C. Endlichi*, and I am inclined to believe that Whiteaves identifies the same form as *P. spinulicosta* from the Hay River, 40 miles above its mouth, where it is associated with *Sp. disjunctus* var. *occidentalis* and an interesting fauna of middle or low upper Devonian age. I am not quite convinced that *P. subaculeata* Meek[1] is the same form which I am describing. Some differences can be detected, but they are slight. Hall[2] figures a form which is very similar to the one in hand. It is said to occur in the Corniferous limestone near Louisville, Kentucky. From the same locality and the same formation was described Nettelroth's *P. semiglobosa* above referred to, and the figures given by the two authors show such marked correspondence that I feel little hesitation in placing them in synonymy.

*Productus subaculeatus* Walcott can hardly be referred to the form under discussion, nor yet to *P. subaculeatus* (=*P. spinulicosta*). It seems more closely allied to *P. subalata* Hall, and with that species I am inclined to place it. When I compare the specimens which I have identified as *P. semiglobosa* with specimens of *P. concentrica* (=*P. Coop-*

[1] King's U. S. Geol. Expl. Fortieth Parallel, Vol. IV, 1877, p. 36, Pl. III, figs. 7–7[b].
[2] Pal. New York, Vol. VI, Pl. XXIII, figs. 6–8.

*erensis* Swallow)[1] of the Kinderhook horizon, I can find no differences which are either constant or important. *P. concentrica* seems to be a trifle more highly arched, and that is all. As the horizon of the Ouray limestone is more nearly that of the strata from which *P. semiglobosa* was described, I have made use of the latter name. It would be interesting if this form should prove to range from the middle Devonian through into the base of the Mississippian. In that case, of course, the name *P. concentrica* would have to be retained.

The synonymy given above should be looked on rather as presenting suggestions than carefully drawn conclusions.

*Formation and locality.*—Ouray limestone: Gunnison 135; Durango 291, 294; Salida 26, 30; Station 48; Glenwood Springs.

### PRODUCTELLA SUBALATA Hall?

*Productus* (*Productella*) *subaculeatus* Walcott, 1884. Mon. U. S. Geol. Surv., Vol. VIII, p. 128, Pl. VII, fig. 2; Pl. XIII, figs. 19, 19[a], 20, 20[a].

There are a few specimens in the collection, only one or two from a single locality and not perfectly preserved, which are related to the species described by Hall under the name of *Productella subalata*. A larger collection of these shells and one better preserved might show that two, or even three, specific or varietal types are here included.

Four ventral valves from as many different localities are probably conspecific. The shell is of medium size (about 25 mm. broad), somewhat transverse, semicircular. Cardinal angles probably quadrate. Convexity slight; beak not much projecting or incurved. The surface is rendered in a measure rugose by reason of numerous though irregular and not very strong concentric inequalities of growth. There are in addition fine microscopic growth lines, and the whole surface is covered, though in varying abundance, with small spines, which arise from slender elongate bases and are arranged in more or less concentric rows. The growth lines and spine bases are for the most part so inconspicuous that but for the irregular concentric rugosities the surface appears nearly smooth.

At Salida 30 occurs a form whose present condition differs somewhat from that of the one just described. The general shape, etc., agree

[1] In a former publication (Mon. U. S. Geol. Survey, Vol. XXXII, Part II, 1899, p. 530) I stated a conviction which I will venture to repeat here—that, in contradiction to what has been sometimes claimed, *P. Shumardiana* Hall (Rept. Geol. Surv. Iowa, Vol. I, pt. 2, Pl. VII, fig. 2) is distinct from *P. Shumardiana* Hall (ibid., Pl. III, fig. 9) and is, moreover, synonymic with *P. Cooperensis* Swallow. That the form from the Kinderhook originally referred to the Devonian species *P. Shumardiana* is distinct, was recognized by Professor Hall himself, for in a footnote, under *P. Shumardiana* (loc. cit., p. 499), occurs the following remark: "At the time these specimens were figured, I regarded certain other forms from near Burlington (Iowa) as identical with them. A further comparison, however, shows the propriety of separating these specimens from those of that locality." *P. Shumardiana* of Pl. VII is undoubtedly only a ventral valve of *P. concentrica* (fig. 3 of same plate), which is based upon a dorsal valve of similar type from the same locality. A careful comparison of *P. concentrica* Hall from Burlington, Iowa, with *P. Cooperensis* Swallow from the Chouteau limestone of Missouri reveals no constant element save size by which they can be distinguished. The Burlington form is regularly about one-third larger than that from Missouri.

sufficiently well, as does the surface ornamentation, where it occurs in a more or less completely exfoliated condition. This is the case over most of the shell, but from what seems to be the anterior margin projects a row of rather stout spines, which are distinctly larger than those of the other specimens and seem to arise directly from the surface without being mounted on elongate bases.

As far as I can judge, this specimen belongs to the same species as *Productella subaculeata* Walcott, which can perhaps be satisfactorily referred to *P. subalata* Hall. *P. subaculeata* of Walcott, however, together with *P. subalata* Hall, approach nearer to *P. subaculeata* Murchison than most of our American forms, and may be identical with it. They are certainly different from *P. subaculeata* of most American authors, part of which I believe to be the same as *P. semiglobosa* Net., and part also Schuchert correctly refers to *P. spinulicosta* Hall.[1] The synonymy of this species, except for the citation suggested above, I adopt from Schuchert[2] without change, and his list need not be here reproduced.

The figure given by Walcott (loc. cit., Pl. XIII, figs. 19, 19[a]) shows a shell with stronger rib-like markings than common, and one which is rather under the usual size.

*Formation and locality.*—Ouray limestone: Engineer Mountain 7; Durango 284,291; Salida 30; White River; Glenwood Springs.

### PRODUCTELLA SUBALATA var.

There is a shell of about the same general character as *P. subalata* and associated with it, which, nevertheless, differs in having the spines much stouter and less numerous. I have but three specimens of this form, and, being crushed and exfoliated, they are unfit for figuring or even detailed description.

*Formation and locality.*—Ouray limestone: Salida 27, 30.

### PRODUCTELLA sp.

Pl. III, fig. 11.

Shell large. Shape somewhat transversely subquadrate.

Ventral valve not highly arched, gradually spreading toward the cardinal angles, which are flattened, and at the sides, but more nearly vertical in the anterior portion. Beak small, incurved. Surface marked over the visceral region by a number of rather fine, discontinuous, concentric wrinkles, and by the elongate bases of a large number of closely distributed spines.

Dorsal valve not known.

Only two specimens of this species have been found, one almost entirely exfoliated, the other a mere fragment.

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[1] Bull. U. S. Geol. Surv. No. 87, p. 318.

[2] Loc. cit.

The characters described seem to indicate that the shell is related to *P. lachrymosa* of the Chemung group, but I think it is not identical with that species.

*Formation and locality.*—Ouray limestone: Engineer Mountain 7; Durango 294.

### ATHYRIS COLORADOENSIS n. sp.

Pl. V, figs. 5-11.

Shell large, thick, subcircular in outline, and often very inequivalve.

Ventral valve usually very convex. Shape subcircular, length and width about equal; if anything the width is slightly the greater. Anterior outline regularly semicircular but broken with a distinct bend where the posterior periphery is retracted toward the beak. The latter is large and incurved but not much produced.

Dorsal valve shield-shaped, always shallower than its fellow and often nearly flat. The anterior margin regularly curved, posterior outline flattened or subrectilinear, broadly rounding into confluence with the anterolateral curvature. Beak small, slightly projecting.

Neither valve has a fold or sinus, and the curvature from side to side is regular and unbroken.

Surface marked by numerous closely arranged, concentric, lamellose growth lines.

This shell is of the type of *Athyris spiriferoides* Eaton, which it resembles more closely than most others of the genus known from this continent. The surface characters and shape are much the same, but *A. coloradoensis* can be readily distinguished by the complete absence, so far as my observations extend, of anything like a fold or sinus on either valve. The beak is larger and the ventral valve more inflated than the dorsal, while in *A. spiriferoides* the reverse holds true. In the absence of fold and sinus *A. coloradoensis* resembes *A. brittsi* Miller and *A. minutissima* Webster. I have not been able to examine specimens of the species mentioned, but *A. coloradoensis* would seem to be distinguished by the unequal convexity of its valves, and doubtless by other characters besides that of size, which is quite marked, that a comparison with descriptions and figures alone does not permit me to point out.

With the possible exception of *Sp. disjunctus* var. *animasensis*, this is the most abundant species of the Ouray limestone as far as its fauna has been explored. It usually occurs in the condition of separated valves, and the shell is almost invariably exfoliated in removing the inclosing matrix. A few weathered specimens show the lamellose surface similar to that of *A. spiriferoides.*

*Formation and locality.*—Ouray limestone: Engineer Mountain 7; Gunnison 130, 131, 132, 135, 136, 145, 145*a*; Durango 284, 291, 294; Salida 26, 27, 29, 30; White River; Station 48; Glenwood Springs.

ATHYRIS VITTATA var.

Pl. V, fig. 12.

Two specimens of a little Athyris observed in the collection may be young shells of *A. coloradoensis*, but they are much smaller and not connected with the large shells by intermediate sizes. They can be almost exactly matched among some diminutive specimens of the same genus from Petosky, Michigan, which, though seemingly distinct from *A. vittata*, nevertheless pass as such, and are said to be linked to it by intermediate forms. The following description is based upon the more perfect of the specimens from Colorado.

Shell minute, length and breadth about the same, 16 mm. Both valves are rather convex, the dorsal slightly more so than the ventral. The outline of the shell is in general sectoral. That of the apical portion would be made by two nearly straight lines at right angles to each other. The rest of the outline, comprising possibly two-thirds the length of the shell, is evenly rounded. The beak of the ventral valve is rather large and projecting. Fold and sinus seemingly entirely undeveloped.

This species approximates *Athyris parvula*[1] Whiteaves, especially the figure seen on Pl. XXXI, fig. 4, but it is without the fold and sinus of that species. It stands in close relationship also with *A. Brittsi* and *A. minutissima*. The species last named has never been figured and a satisfactory comparison is therefore impossible. It resembles the Colorado form, but is very much smaller. *A. Brittsi* is close, indeed, to *A. vittata* var., and may be conspecific. The ventral beak seems to be smaller and slight differences in outline are apparent, but these might not be maintained by a larger suite of specimens.

*Formation and locality.*—Ouray limestone: Engineer Mountain 7.

SPIRIFER CONICULUS n. sp.

Pl. V, figs. 1–4.

Shell somewhat beneath medium size, semiconical. The shape, which is best seen from the dorsal valve, is semicircular, or semielliptical, the length varying from two-thirds to three-fourths the greatest width, which is found at the hinge line or just in front. Sides subparallel, meeting the hinge line at nearly a right angle, front broadly rounded. Sometimes the cardinal angles also are rounded, giving the outline more or less the shape of an ellipse.

Ventral value semiconical, high, with the apical portion frequently twisted to one side or the other, forward, or back. Area usually almost flat, and directed at nearly right angles to the plane of junction of the valves. Often, however, the angle so formed is somewhat less

[1] Geol. Nat. Hist. Surv. Canada; Contributions to Canadian Palæontology, Vol. I, pt. 2, 1891, p. 228, Pl. XXXII, figs. 4, 5, 5a.

than this. The area, though varying in altitude, is always high, and sometimes the height is as much as three-fourths the greatest width. Foramen high and narrow, usually more than twice as high as it is broad. The slope from the apex to the front and sides is usually direct, and except for distortion due to twisting of the apical portion there is seldom any longitudinal curvature of moment.

The dorsal valve is nearly flat, being highest along the middle and sloping off regularly to the sides.

The fold and sinus are distinct, but broad and shallow, and not sharply defined from the rest of the shell. They are themselves unplicated, but on either side are found 8 to 10 coarse and indistinct ribs. These are so poorly marked that sometimes the shell looks smooth and altogether destitute of plications. Although at present all the specimens are exfoliated, even in this condition it is possible to discern that the entire surface was covered with fine, closely set pustules.

This species is related to *Spirifer asper* and others of the same type, but is evidently distinct. In fact, the small size of *Sp. coniculus*, its elevated ventral valve, nearly obsolete plications, and pustulose surface ornamentation, combined, give it great individuality. I know of no species with which a close comparison is necessary. It resembles *Sp. altus* in the character of its obsolescent plications, but has not a plicated fold and sinus and shows other important differences.

*Spirifer coniculus* is of interest in its bearing upon the determination of the age of the Ouray limestone. This type of Spirifer, with high, flat, and horizontally directed area and unplicated fold and sinus, especially when, as in this case, the surface ornamentation is papillose instead of lamellose, may be regarded as very characteristic of middle Devonian time. Although the type was initiated in the lower Devonian and persisted into the upper portion of the same, it is most prolific of individuals and of species in the middle Devonian. I know of but four species of this type in the lower Devonian. These are *Spirifer arctisegmentum*, *Spirifer segmentum*, *Spirifer Manni*, and *Spirifer varicosus*. In the upper Devonian I know of but one, *Spirifer McBridei*, while in the middle Devonian over a dozen can easily be mentioned. The testimony of *Spirifer coniculus* would therefore seem to be in favor of assigning the Ouray limestone to about the age of the Hamilton group.

*Formation and locality.*—Ouray limestone: Engineer Mountain 7.

### SPIRIFER DISJUNCTUS var. ANIMASENSIS n. var.

Pl. IV, figs. 1–10.

Shell of medium size, transverse, pyramidal, marked by numerous rather fine radiating ribs.

Ventral valve subpyramidal in shape. Beak elevated, frequently twisted to one side or the other, and only slightly, often not at all, incurved. Area large, usually flat, and nearly or quite perpendicular to the plane of junction of the two valves. Its width is from 2½ to 3 times the height. The large delthyrium is a little higher (about 1¼) than it is broad. It is usually entirely open, showing only the thickened edges of the dental plates, but in one specimen the upper portion of the delthyrium is plainly seen to be covered, as in Spirifer, by a concave deltidium, deeply emarginated in its inferior outline. The front of the valve is marked with numerous rather fine radiating ribs, which cover the sinus equally with the wings. Those upon the latter appear to be simple, but those in the sinus often bifurcate, especially in older individuals. There are from 20 to 25 striæ upon the sides, and from 5 to 10 in the sinus, the usual number being about 24 on the sides and 7 or 8 in the sinus. The latter is broad and shallow, though clearly defined, and extends quite to the apex.

Dorsal valve shallow, fold rounded, low, and broad, though clearly defined from the rest of the shell. There are from 20 to 25 simple striæ on the sides, and from 9 to 16 bifurcated ones on the fold. The higher numbers are not at all uncommon, owing to frequent bifurcation.

The striæ are rounded and separated by angular grooves. Any finer ornamentation which may have covered them has in every case been lost through exfoliation, and neither its presence nor its character has been determined.

*Spirifer disjunctus* var. *animasensis* is a variable type, and the description above detailed applies to the average individual. In rather young specimens the shell is usually transverse, the width being greatest at the hinge line, where it is not infrequently more than twice the length. From that point it contracts rapidly toward the front, so that the outline is, in the main, that of an inverted isosceles triangle of broad base and low altitude, truncated at the apex. The area has usually a horizonal direction, the shell being viewed dorsally.

In older examples, growth of the shell seems often to proceed more rapidly in front than laterally, so that the length sometimes nearly equals that of the hinge length. Another effect of this process is to tilt the area backward until it tends to assume more of an erect or vertical position when viewed dorsally. The area varies considerably in height as seen in different specimens of the same size. In some examples it is almost perfectly flat, but in others decidedly concave, especially at the beak.

The delthyrium, while it is usually somewhat higher than it is wide, has been observed in one specimen to be a trifle wider than high, with the width almost half that of the entire area.

Variation within moderate limits is also to be seen in the radiating ribs in both size and number.

There can be little doubt that *Sp. disjunctus* var. *animasensis* belongs to the *disjunctus* type of the aperturati, in which Hall and Clarke[1] include *Sp. arenosus*, *Sp. unicus*, *Sp. Whitneyi*, *Sp. disjunctus*, *Sp. disjunctus* var. *sulcifer*, and *Sp. Billingsanus*, all from the Devonian rocks of North America. Schuchert regards *Sp. unicus* as a synonym for *Sp. arenosus*, and in any case its affinities are certainly with this type. I feel some doubt about the propriety of assigning *Sp. Billingsanus*, to the same group. It presents many points of similarity to *Sp. divaricatus*, and perhaps belongs with the *divaricatus* type rather than this, but if retained here it must be regarded as a somewhat aberrant form. To the list just quoted can, I think, be added *Sp. disjunctus* var. *occidentalis*, *Sp. Kennicotti*, *Sp. utahensis*, *Sp. altus*, *Sp. cyrtiniformis*, and the form under discussion. It will be seen that among the species mentioned are found some which have been referred by authors to the genus or subgenus Cyrtia. There Hall and Clark place the Devonian species *Sp. cyrtiniformis* and *Sp. altus*, and Schuchert[2] refers *Sp. utahensis* to the same assemblage on the strength of marked resemblance in external form. I think, however, that these Devonian forms are unwisely withdrawn from Spirifer and associated with the Silurian species which exhibit the typical condition of Cyrtia. Hall and Clarke state that "the general habit of these shells is the coexistence of the vertical cardinal area with a convex deltidium perforated by a circular, oblique foramen." These authors have certainly failed to demonstrate the existence of the distinctive structural characters of Cyrtia in either *Sp. cyrtiniformis* or *Sp. altus*. The best material they obtained to illustrate these features in *Sp. cyrtiniformis* preserves no deltidial covering of any sort, while *Sp. altus*[3] is shown to have a concave deltidium neither perforated by a

[1] Pal. New York, Vol. VIII, pt. 2, p. 37.

[2] Bull. U. S. Geol. Surv. No. 87, 1897, p. 197 (as *Cyrtia Norwoodi*).

[3] The deltidium of this species seems to have been sometimes convex, as in Cyrtia, but usually concave. The description of *Sp. altus* in Pal. New York, Vol. IV, 1867, p. 248, states that the fissure "is closed by a concave, transverse septum for two-thirds of its length from the apex," and the figures, which were drawn from impressions of natural molds of the exterior, show that the deltidium must have had a concave flexure in those specimens. Schuchert, writing in 1890, says (Ninth Annual Report New York State Geologist, p. 35) that "the deltidial opening was closed by a lamellose convex covering," etc. Hall and Clarke (Pal. New York, Vol. VIII, pt. 2, p. 42), by referring this species to Cyrtia, which they define as having a convex deltidium, imply that this condition existed in *Sp. altus*, and they figure a specimen in which this seems to have been the case. At the same time they reproduce, without comment or correction, Hall's earlier figure in which a concave deltidium is shown (pl. 26, fig. 3). I have been able to examine three or four undoubted examples of this species which show the structures in question. One of these is especially convincing in the manner in which its characters are manifested. Casts of the exterior and of the interior are presented to view, separated by a space representing the original thickness of the shell. The external cast shows a decidedly concave, incomplete, imperforate, deltidial covering, impressions of which correspond in detail to Hall's figures already mentioned. The internal cast shows the spaces left by the powerful dental plates, while on the blunt edge of the wedge-shaped mass between them is preserved the groove representing the internal median thickening noted by Hall and Clarke as below. This specimen is quite conclusive as to the points involved, and the facts which it demonstrates are corroborated by

foramen nor showing traces of having had this condition. In *Sp. utahensis* also I have not found the deltidium preserved, but only an open delthyrium is seen, bounded by the thickened edges of the dental plates. Under the circumstances, therefore, the separation of these Devonian forms, based almost together on a peculiar external expression, from Spirifer, and their union with Cyrtia, seems scarcely justified by the facts.

Nor, does it seem to me, do these cyrtiniform Spirifers, when joined to the *disjunctus* group, form an incongruous assemblage. Hall and Clarke define the *disjunctus* type in the following terms: "Forms with well-developed fold and sinus, elongate hinge and elevated cardinal area, lateral plications simple, median plications dichotomous or intercalary."[1]

All of the species just mentioned answer to this diagnosis in every particular except, perhaps, that which pertains to the area, and experience has demonstrated that such characters as height, inclination, and flatness or concavity of the area are often very variable, even in the same species, and can be held at little or no value even in such inferior coordination as the group in question. There is, in fact, some reason, a priori, for expecting that the Spiriferoid type, with plicated fold and sinus, should develop a varietal group with high, flat, horizontal areas, since the type with unplicated fold and sinus has done so. The amount of variation of these characters in the same species and their intergradation in the group is illustrated by an examination of *Sp. disjunctus* and its allies. The British form of *Sp. disjunctus*[2] seems to have the area nearly erect, i. e. parallel to the plane of the valves, but it may be flat or concave, low or elevated. In specimens from New York the area is usually low and concave, either erect or not much reclining,[3] and presumably the same condition obtains in the var. *sulcifer*. *Spirifer Whitneyi*, which represents *Sp. disjunctus* in the Mississippi Valley, has the area always low, but it is sometimes

several other good examples. In no specimen that I have seen or read of is there any evidence that the deltidium was perforate, and the only cases in which that structure is shown to be convex that have come to my knowledge are the specimen figured by Hall and Clarke and the statement of Schuchert quoted above. I am led to believe, therefore, that the deltidium was imperforate and incomplete so that the pedicle issued below it instead of through a perforation in its upper or apical portion, and that it was usually but not invariably concave. The range of variation thus suggested is not altogether unprecedented, since in a representative of Syringothyris (*S. hannibalensis*, from Pike County, Mo.), a genus of which *Sp. altus* was probably the immediate progenitor, I have observed nearly an equal latitude, for the detidium in that species, though pretty constantly convex, is sometimes depressed below the plane of the area, sometimes on a level with it, and sometimes elevated above it. Hall and Clarke explain the absence of a deltidial perforation in the following manner (loc. cit.): "In the Devonian Cyrtias the foramen in the deltidium is frequently obscured or absent at maturity. It may have existed at earlier stages of development and have become obliterated by subsequent overgrowth, but this assumption has yet to be verified. That maturity induces a modification of the deltidium is evinced by the internal median thickening of this plate in *C. alta*." No such explanation for the admitted absence of the perforation in the deltidium of *Sp. altus* is, I think, needed.

[1] Pal. New York, Vol. VIII, pt. 2, p. 24.

[2] See Davidson's Mon. Brit. Foss. Brach., plates.

[3] Pal. New York, Vol. IV, Pls. XLI, XLII.

only slightly, often strongly incurved, and in position it seems to vary from nearly vertical to nearly horizontal. *Sp. disjunctus* as identified in the Rocky Mountain region has usually a rather high area, which in mature shells is seen to be at first nearly flat and horizontal in direction, with the beak sometimes only slightly, more often strongly, concave. In *Sp. cyrtiniformis*[1] the area seems to be regularly flat, high, and horizontal, and the same is true of *Sp. altus*, where, in fact, the area is a little inclined from the plane of the horizon. *Spirifer utahensis* has a high area, usually nearly horizontal in direction, flat for the greater part of its height, but apically more or less concave. In *Sp. Kennicotti* the area, which is only slightly overhung by the small beak, is flat, indeed, but low and almost vertical in direction. *Sp. disjunctus* var. *occidentalis* has the area high, horizontal, and nearly flat, with usually only the apex slightly concave, while the range of variation in the variety *animasensis* has already been described. It is evident that among the species just mentioned there is a more or less continuous series from one extreme, best represented by certain forms of *Sp. disjunctus*, where the area is low, vertical, and strongly arched, to the other extreme seen in *Sp. cyrtiniformis* (or almost as well in *Sp. disjunctus* var. *occidentalis*[2]), whose area is high, flat, and horizontal. One or two of the species grouped here may have to be eliminated when the characters, especially the minuter surface ornamentation, of all are known more in detail, but for the present they seem to form a fairly homogeneous assemblage. *Sp. altus* and *Sp. cyrtiniformis* are, perhaps, the most likely to be withdrawn, and in the latter the slightly developed and differentiated fold and sinus, and the infrequent bifurcation of ribs in the median region, give it a distinct individuality of expression when compared with the true *disjunctus* type.

It will be apparent from the above discussion that several of this *disjunctus* type of Spirifers are very closely related to the form here described. I refer to *Spirifer disjunctus* itself, *Sp. disjuntus* var. *occidentalis*, *Sp. disjunctus* var. *sulcifer*, *Sp. Kennicotti*, *Sp. Whitneyi*, *Sp. utahensis*, *Sp. cyrtiniformis*, and *Sp. altus*.[3] These resolve themselves naturally into two groups—one with high, horizontal, and flat areas, the other with low, erect, and incurved areas.

[1] Whiteaves (Cont. Can. Pal., Vol. I, pt. 3, 1891, pp. 222-223) identifies *Spirifer cyrtiniformis* at the Hay River locality. The form found there is said to be of much larger size, with fewer plications, and is probably a distinct species.

[2] If *Sp. altus* is admitted to close relationship with *Sp. disjunctus*, it certainly forms one of the extremes in the series described, for the area is high and flat and is inclined to the plane of the valves at a more or less acute angle, so that the apex of the ventral valve is projected in front of that of the dorsal.

[3] *Spirifer arenosus*, *Sp. unicus*, and also *Sp. Billingsanus* if it really belongs to the *disjunctus* group, are Oriskany species, and less closely related to *Sp. disjunctus* and its allies which appear in middle and upper Devonian time (in New York only in the latter). They have the area low, erect, and concave, as in *Sp. disjunctus*.

Walcott[1] places *Sp. utahensis* and *Sp. Kennicotti*, both of Meek, in the synonymy of *Sp. disjunctus*. In this he is followed by Whiteaves,[2] who places *Sp. Whitneyi* also in the same category on the strength of a suggestion contained in the Twenty-third Regents' Rept. New York State Cab. Nat. Hist., p. 213 (under *Spirifer Orestes*). This is no place to discuss the synonymy of *Sp. disjunctus*, but *Sp. Whitneyi* has an individuality of expression which seems to justify the granting it varietal distinction, and *Sp. Kennicotti*, with its low but nearly flat area and unusually contracted visceral space,[3] can also claim to be considered distinct. These three cognate species, however, together with *Sp. disjunctus* var. *sulcifer* and the Oriskany forms, constitute a group to which *Sp. disjunctus* var. *occidentalis*, *Sp. disjunctus* var. *animasensis*, *Sp. utahensis*, *Sp. altus*, and *Sp. cyrtiniformis*, are less closely related. Concerning relations of these species to one another I am less confident. In form and size and ornamentation the different specimens of *Sp. utahensis* can be almost exactly matched among small and probably immature specimens of *Sp. disjunctus* var. *animasensis*. And, furthermore, in some localities, as at Durango 235, smaller individuals of the latter alone occur, just as at the others (e. g., Durango 291) the larger ones predominate. Thus at Durango 235 the largest individual seen measures 35 mm., this being one of the very transverse forms in which the width far exceeds the length. At Durango 291 a width of 45 mm. is not uncommon, while one individual is 50 mm. across, and all are large shells, nearly as long as broad. On the other hand, while every specimen of *Sp. utahensis* examined has the area more or less incurved, the prevailing type in *Sp. disjunctus* var. *animasensis* has a flat area, and the delthyrium, which is long and narrow in *Sp. utahensis*, almost always proportionately broader. I think, therefore, that *Sp. disjunctus* var. *animasensis* is distinct from *Sp. utahensis* by reason of being usually much larger, with a flatter area and proportionately broader delthyrium. Turning now to *Spirifer disjunctus* var. *occidentalis*, of which Professor Whiteaves has kindly loaned me specimens for comparison, a still closer affinity is found. The area in the Canadian form is high, flat, and horizontal, sometimes more or less twisted to one side. The beak is but slightly incurved, being more constant in this character than *Sp. disjunctus* var. *animasensis*. The delthyrium also resembles the latter species rather than *Sp. utahensis*, in being rather broad. The chief distinction between these two varieties accredited to *Sp. disjunctus* consists in the fact that the lateral plications in the var. *animasensis*

[1] Mon. U. S. Geol. Surv. Vol. VIII, 1884, p. 34.

[2] Cont. Can. Pal., Vol. I, pt. 3, pp. 221–222.

[3] Schuchert calls attention to this character in Bull. U. S. Geol. Surv. No. 87, 1897, p. 394. The circumstance that *Sp. Kennicotti* is a middle Devonian species, while *Sp. disjunctus*, or the form accepted as such in New York, occurs at a considerably higher horizon, gives additional weight to this distinction.

are usually appreciably finer and more numerous. This form has more nearly the expression of true *disjunctus*, while the var. *occidentalis* rather suggests *Spirifer mucronatus*, with, however, a plicated fold and sinus.

Two small and two larger specimens of *Sp. disjunctus* var. *occidentalis* have come under my observation. The smaller examples, with a common length of about 17 mm. and a width of 24 mm. and 35 mm., respectively, have 17 or 18 lateral plications. The larger individuals, both being about 42 mm. across and 21 mm. long, measured on the dorsal valve, have also 16 or 17 plications. They are thus more coarsely plicate than one of the smaller specimens, which in turn is somewhat coarser than the other. When of the same size, the larger individuals would have had only 13 or 14 plications. *Sp. disjunctus* var. *animasensis* of the same size as the smaller individuals of the var. *occidentalis* have 19 or 20 ribs on a side, while mature specimens have 25 or more. At the same time more coarsely plicated forms do occur in Colorado, and one large longitudinally produced form, in especial, has not more than 18 to 20 ribs on a side. These are 2½ mm. wide, much flattened, and separated by narrow, shallow grooves. The shell from which these measurements were made, a dorsal valve, must have been originally about 45 mm. long and 54 mm. wide. It is now considerably broken. Another point in which our Colorado form differs from Whiteaves' species is the shape of these larger shells, all of which are subquadrate, not much wider than long, and with slightly converging lateral and broadly rounded anterior outlines. The largest specimens of *Sp. disjunctus* var. *occidentalis* seen were transverse, submucronate, a distinctly alate form. However, as in most Spirifers the growth of the shell at and after maturity is chiefly anterior, these alate forms might readily have grown into the more quadrate ones. Comparisons with *Sp. cyrtiniformis* and *Sp. altus* seem scarcely necessary, and *Sp. disjunctus* var. *animasensis* finds its closest allies in *Sp. utahensis* and *Sp. disjunctus* var. *occidentalis*.

*Spirifer disjunctus* var. *animasensis* has been found at almost every point at which collections from the Ouray limestone have been made, and it is usually a common fossil. It seems strange, therefore, that it should not have been present in the collections accompanying the original specimens of *Camarotœchia Endlichi*, but such appears to have been the case, for no member of the genus is mentioned in the list of forms which Meek cites as associated with that species.

The bearing of this species in determining the age of the Ouray limestone deserves a few words of consideration. I feel no doubt of the affinity of *Sp. disjunctus* var. *animasensis* with *Sp. disjunctus* itself as representing the general stock from which it is a variant. Although in the New York section *Sp. disjunctus* is restricted in its range to the upper Devonian (Chemung), the type is known in England to range through both middle and upper Devonian rocks. Turning now to *Sp. utahensis* and *Sp. disjunctus* var. *occidentalis*, with which it is especially allied, I find *Sp. disjunctus* is a member of a fauna which Whiteaves,[1] for satisfactory reasons, correlates with the Cuboides zone of Europe or with the Tully limestone of New York, while Meek,[2] speaking of the fauna in which *Sp. utahensis* is found, makes the statement: "Hence we can not doubt that these beds belong to the Devonian, and probably to about the horizon of the Hamilton group of the New York series."

*Formation and locality.*—Ouray limestone: Ouray, Colorado; Engineer Mountain 7; Gunnison 130, 132, 134, 135, 145, 145 *a*; Durango 284, 291, 294; Salida 26, 27, 28, 30; northwestern Colorado; Cement Creek; Station 48; Glenwood Springs.

### Spirifer bimesialis Hall?

Among some material from Glenwood Springs, Colorado, which has come to hand since the rest of the collection was worked up, and after the manuscript of this report had been completed and submitted for publication, occur two not very perfect specimens of an interesting species of Spirifer. The form in question seems to be associated with the characteristic Ouray fauna, but does not occur in any of the other local collections. The shell is very alate and mucronate, the width being about 26 mm. and the length only 8 mm. There are 8 to 10 simple plications on either side of the fold, which is well defined, thin, and high. The sinus is deep and the ribs bounding it are heavy. In the bottom of the sinus is a well-developed plication, and presumably the fold had a median furrow to correspond. The surface is crossed by concentric ornamentation of coarse, heavy, lamellose striae.

So far as the two specimens examined furnish a correct expression of the specific characters of this form, we have here a species intimately related to *Sp. bimesialis* Hall. The most important difference that I have been able to discover is that the concentric lamellæ are more distant and heavier than in the latter species, but collections in which this form is more plentifully represented may furnish other differentiating characters or obliterate this. *Sp. mesicostalis* Hall is another allied species, and some varieties of *Sp. mucronatus* approach it closely. The evidence of this species seems to be favorable to assigning the age of the Ouray limestone to late middle or to upper Devonian age.

*Formation and locality.*—Ouray limestone, Glenwood Springs, Colorado.

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[1] Cont. Can. Pal., Vol. I, pt. 3, 1891, p. 252.
[2] U. S. Geol. Expl. Fortieth Parallel, Vol. IV, 1877, p. 6.

CAMAROTŒCHIA ENDLICHI (Meek) Schuchert.

Pl. VI, figs. 1–4; Pl. VII, fig. 1.

To Meek's very complete description of this species I have little to add, and subsequent collections from the same region have failed to furnish anything quite equal in size[1] and perfection to the material upon which the original description was based. *C. Endlichi* is a variable species, especially in the character of its plications, and presents an almost endless diversity in shape and ornamentation. The specimens selected for illustration by White are characteristic, and have been reproduced here, together with drawings made from more recently gathered material, to show some of the various forms presented. Large specimens like those figured by White occur in both the earlier and the later collections in association with much smaller individuals, which appear to belong to the same species and at the same time bear evidence, in their gibbosity and strong development of fold and sinus, of having nearly or quite attained a mature condition. (See Pl. VI, figs. 1, 2; Pl. VII, fig. 1.)

Meek says[2] of *C. Endlichi:*

> This is a fine species, more nearly resembling some Devonian and Upper Silurian forms than the usual Carboniferous types. Its most marked features are the large size of its mesial sinus, the flattening of its posterior lateral slopes, and the angularity of the posterior lateral margins of its ventral valve on each side of the sinus, formed by the abrupt flexure of those margins to meet those of the other valve, this peculiar truncated, rectangular appearance contrasting strongly with the very acute angles formed by the connection of the antero-lateral margins of the valves.

The forms with which Meek would compare *C. Endlichi* are doubtless the group of Oriskany Rhynchonelloids for which Hall and Clarke have proposed the subgeneric or group name *Plethorhyncha*,[3] including *Camarotœchia* (*Plethorhyncha*) *Barrandii*, *C.* (*P.*) *speciosa*, and *C.* (*P.*) *pleiopleura*, together with such species of *Uncinulus* as *U. Stricklandi* of the Niagara group and *U. Campbellanus* of the Lower Helderberg, etc. The only internal character which I have succeeded in determining in *C. Endlichi* is the presence of a long and well-developed median septum which is divided posteriorly so that it is Y shaped in cross section, the two branches extending to the hinge plate, where they support the crural processes. In this structural character, as well as in the superficial peculiarities pointed out by Meek, *C. Endlichi* agrees with the species of Plethorhyncha and Uncinulus mentioned. Plications of the character of those of *C. Endlichi*, which are bifurcate and very variable in number and size, are not common in the genus Camarotœchia, and if possessed at all by the species mentioned above seem to be found in

[1] Since the above was written there has come to hand some material from Glenwood Springs, Colorado, among which I find several large specimens of *C. Endlichi*. One of them shows the unusual length of 75 mm.

[2] Bull. U. S. Geol. and Geog. Surv. Terr., 2d ser., Vol. I, 1875, p. 47.

[3] Pal. New York, Vol. VIII, pt. 2, 1893, p. 191. Schuchert places *Rhynchonella Endlichi* in this group.

*C. pleiopleura* only. They are, however, quite common in the genus Leiorhynchus, and, conjoined with the obsolescence of the lateral plications, especially upon the dorsal valve—a fact of common occurrence not mentioned by Meek—it gives the shell of *C. Endlichi* considerable of the expression of that genus, with which the internal structure, so far as ascertained, also agrees. The peculiar angulation of the posterior lateral margins which has been described by Meek is not found, I believe, in Leiorhynchus, though it occurs also in Eatonia, which has, however, different structural peculiarities. On the whole, it seems that *Rhynchonella Endlichi*, though of a rather peculiar type, must be left in the genus Camarotœchia, with a probability of its belonging to the group Plethorhyncha. If the latter have any stratigraphic value, the evidence of this form would tend to throw the horizon of *C. Endlichi* into the lowest Devonian, but Meek, presumably because of its occurrence "with a small Productus of the type of *P. subaculeatus*," refers *C. Endlichi* to the latter portion of the same era. He says: "According to Dr. Endlich's sections, as well as from its affinities [?], it would seem to be most probably an Upper Devonian species."[1] This conclusion is corroborated by Schuchert, who observes:[2]

> This type of Rhynchonella occurs in eastern North America only in the Lower Devonian. It therefore seems probable that Meek's provisional reference to the Devonian is nearer correct than White's to the Lower Carboniferous.

In 1883 White concludes, from facts ascertained subsequent to Meek's description, that the strata from which this species was derived really belong to the lower portion of the Carboniferous series. In this he is followed by Weller.

The synonymy of this species which I adopt will be found in Schuchert.[2]

*Formation and locality.*—Ouray limestone: Engineer Mountain 7; Gunnison 130, 131, 132, 133, 136, 145*a*; Durango 291, 294; Salida 26, 27, 28, 29, 30; Station 48; Glenwood Springs.

### Camarotœchia contracta (Hall) Hall and Clarke?

Pl. VII, figs. 2–4.

The figures annexed will afford a better idea of this shell, which is common-place in every particular, than I am able to give by verbal description. In shape it is one of the transverse, spreading types of Rhynchonella, of which examples could be cited from Silurian, Devonian, and Carboniferous rocks. Its internal characters, which, so far as observed, consist of diverging dental plates in the ventral valve and a thin, strong septum in the dorsal, taken in connection with its stratigraphic occurrence, leave little doubt that it belongs in the group of Camarotœchia. There are, pretty uniformly, 4 plica-

[1] Loc. cit.

[2] Bull. U. S. Geol. Surv. No. 87, 1897.

tions on the fold and 3 in the sinus, with 6 lateral ones. The plications are thin and angular; the fold and sinus well developed.

This shell is, as a rule, considerably smaller than the average specimen of *C. contracta*, which it otherwise much resembles both in shape and in the number and disposition of its plications. Some individuals, however, are as large as the normal shell of *C. contracta*, one dorsal valve being 13 mm. long and 16 mm. wide.

I would not assert that the form in question is genetically so closely related to *C. contracta* as to be really identical with it, but with the material in hand a separation would scarcely be justified, the two being in so close external agreement.

The synonymy of this species found in Schuchert[1] is adopted here and need not be repeated.

*Formation and locality.*—Ouray limestone: Engineer Mountain 7; Gunnison 131, 145*a*; Durango 291, 294; Salida 26, 27, 29, 30; Station 48; Glenwood Springs.

### MODIOMORPHA (?) sp.

PL. VII, fig. 6.

The following description is based upon a single specimen, which is the only representative of the species yet found.

Shell very small, transverse, pyriform. The superior border is subrectilinear, but by degrees enters upon the curvature of the anterior and posterior margins. Posterior outline broadly rounded, the greatest curvature occurring below the median line. Inferior outline slightly sinuous though nearly straight, with a gentle emargination a little in front of the middle. Anterior end narrower than the posterior, and strongly rounded. Beak large, projecting beyond the hinge line, and subcentral, being located slightly anterior to the center of the shell.

Convexity considerable, somewhat flattened toward the posterior superior angle, falling away rapidly in front of the beak to the anterior end, which is nasute and reflexed.

Surface marked by fine concentric striæ and stronger constrictions of growth.

The generic position of this form is purely conjectural, and it is not certain that it is properly referred to Modiomorpha, with which I have provisionally placed it on account of a certain similarity of contour.

When both valves were in contact the shell must have been gaping in front by reason of the reflexed anterior portion, and also below on account of the emargination at that point.

The possibility that this may be an immature example of *Allorisma* sp., with which it is associated, is worthy of consideration, but it scarcely

[1] Bull. U. S. Geol. Surv. No. 87, 1899.

seems probable because of the great difference in important particulars which exists between the two.

*Formation and locality.*—Ouray limestone: Durango 291.

### ALLORISMA sp.

There is nothing distinctive about this form, of which only a single specimen has come to hand. The width is 43 mm. and the length 28 mm. The beak is about one-fourth the entire length of the shell back from the anterior end. There is a faint sulcus a little anterior to the median line. The surface is concentrically rugose.

The form may properly belong to the genus Grammysia, but it has more the proportions of an Allorisma, and might very well pass as a young example of such a characteristic species as *A. subcuneatum.* It is more elongate than *Grammysia hannibalensis*, and has its sinus less strongly marked than *G. communis.*

*Formation and locality.*—Ouray limestone: Durango 291.

### PARACYCLAS sp.

Neither the quality nor the condition of the material representing this species wholly justifies separate notice, but as it is found at several localities I mention it here for the sake of completeness. The shell is moderately convex, subcircular, with a diameter of about 25 mm., marked by regularly disposed concentric striæ. The preservation is extremely poor, and the generic reference suggested by its shape is not altogether trustworthy.

*Formation and locality.*—Ouray limestone: Durango 291, 294.

### MYTILARCA? sp.

Pl. VII, fig. 5.

Shell rather small, subquadrate; length a trifle greater than the width. Hinge line straight and equal to about half the width of the shell. Beak slender, prominent, terminal with regard to the hinge line. Anterior outline retracted under the beak; then becoming convex, the curvature is regularly maintained around the inferior and part of the posterior outline. The upper portion of the posterior outline is rectilinear, meeting the hinge line at an obtuse angle.

Convexity slight, the most elevated point of the shell being on the line of the beak just below the hinge line.

Surface apparently marked only by concentric lines of growth.

The shape of this shell, none of the generic characters being retained, is so peculiar that it is referred to Mytilarca with some doubt, though to that genus it appears to be more nearly related than to any other which I recall. In some respects it is suggestive of Myalina.

A single specimen, a left valve, is all that represents this species, which I have little doubt is new. The outline of the figure on Pl. VII has been restored in places.

*Formation and locality.*—Ouray limestone: Durango 294.

NATICOPSIS GIGANTEA Hall and Whitfield.

*Naticopsis gigantea* Hall and Whitfield, 1873. Twenty-third Ann. Rept. New York State Cab. Nat. Hist., p. 238, Pl. XII, figs. 8 to 10.

Associated with the preceding is a shell which I at first placed with *N.* ? *humilis*, but now refer with doubt to *N. gigantea* H. and Wh. One specimen from Durango 294 is much larger than those referred to the former species. The spire is missing, but as it stands it is closely similar to specimens from Iowa which have been referred to *N. gigantea.* Another individual which was collected at Engineer Mountain 7 is young, or represents only the apical portion of a larger shell. The spire is higher than in the form referred to *N.* ? *humilis*, and seems to have more the form of that of *N. gigantea.* This specimen is probably distinct from *N.* ? *humilis*, at least to the degree of being a variety, but the other may be merely an example of *N.* ? *humilis* in which a final volution has been added to the shell, large and produced diagonally downward.

*Formation and locality.*—Ouray limestone: Engineer Mountain 7; Durango 294.

NATICOPSIS ? (ISONEMA) HUMILIS Meek.

Pl. VII, figs. 9–11.

*Isonema humilis* Meek, 1871. Proc. Acad. Nat. Sci. Phila., p. 79.

? *Naticopsis lævis* Hall and Whitfield, 1872. Desc. New Species Fossils, Pl. XII, figs. 3–5 (not *N. lævis* Meek, 1871).

? *Naticopsis lævis* Hall and Whitfield, 1873. Twenty-third Ann. Rept. New York State Cab. Nat. Hist., Pl. XII, figs. 3–5 (not *N. lævis* Meek, 1871).

*Naticopsis* ? (*Isonema*) *humilis* Meek, 1873. Geol. Surv. Ohio, Palæontology, Vol. I, p. 214, Pl. XIX, figs. 1a–1c.

Meek calls attention to the fact that the form figured by Hall and Whitfield as *N. lævis* Meek is not that species at all, but *N.* ? *humilis* Meek or a species very similar. *N.* ? *humilis* was described from the Corniferous limestone of Columbus, Ohio. Hall and Whitfield give neither description, horizon, nor locality for their shell, but from the comments of Meek it would seem to have been found in strata of Corniferous or Hamilton age at Louisville, Ohio.

The Colorado specimens, which are not very perfect, present a type which is close indeed to the one described by Meek, though future comparisons with better material may show them to be different species. Where the shell is broken away the shape of the volution is the same as represented by Meek's figure, which is also that of an exfoliated specimen. In examples not reduced to this conditon the shell seems to be distinctly thickened on the upper and lower portions, so that the true outline of the peritreme is more flattened peripherally than seen in the figure. Associated with *N. gigantea* at Rockford and at Hackberry, Iowa, is a form probably identical with that under discussion; at least with the material in hand I doubt if they can be distinguished.

*Formation and locality.*—Ouray limestone: Engineer Mountain 7; Gunnison 131; Durango 291, 294.

### STRAPAROLLUS CLYMENIOIDES Hall?

Pl. VII, figs. 7–8.

*Euomphalus clymenioides* Hall, 1861. Desc. New Species Fossils, etc., p. 26.
*Euomphalus clymenioides* Hall, 1862. Fifteenth Ann. Rept. New York State Cab. Nat. Hist., p. 54.
*Euomphalus (Straparollus) clymenioides* Hall, 1862. Ibidem, p. 166, Pl. VI, figs. 1, 2.
*Euomphalus clymenioides* Hall, 1876. Illustrations of Devonian Fossils; Cephalopoda, Pl. LXX, figs. 1–5.
*Euomphalus clymenioides* Hall, 1876. Illustrations of Devonian Fossils; Gasteropoda, Pl. XVI, fig. 15.
*Euomphalus (Straparollus) clymenioides* Hall, 1877. Geol. Surv. New York; Palæontology, Vol. V, pt. 2, p. 62, Pl. XVI, fig. 15; Pl. XVII, figs. 1–5.

Shell attaining a rather large size, discoidal, section across the peritreme nearly circular. Volutions gradually expanding, rather numerous, tangent. The spire is depressed below the plane of the outer volutions, so that the upper side of the shell is slightly concave, while the lower side is still more so.

The largest specimen observed has a diameter of about 35 mm.

The form upon which the description just given is based is not common in the Ouray limestone, and not well preserved. I think the characters cited are warranted by the material examined, and they indicate a species closely related to Hall's *Straparollus clymenioides.*

*Formation and locality.*—Ouray limestone: Durango 291, 294; Salida 26, 29.

### PLEURONOTOS DECEWI (Billings) Hall?

*Euomphalus Decewi* Billings, July, 1861. Canadian Journal, p. 358.
*Euomphalus Conradi* Hall, 1861. Fourteenth Ann. Rept. New York State Cab. Nat. Hist., p. 107.
*Euomphalus Decewi* Meek, 1873. Geol. Surv. Ohio; Palæontology, Vol. I, p. 220, Pl. XIX, figs. 3a–3b; Pl. XX, fig. 1.
*Euomphalus Decewi* Hall, 1876. Illustrations of Devonian Fossils; Gasteropoda, Pl. XV.
*Euomphalus Decewi* Hall, 1879. Geol. Surv. New York; Palæontology, Vol. V, pt. 2, p. 55, Pl. XV, figs. 1–8.
*Pleuronotus Decewi* Hall, 1879. Ibidem, pp. 137–138.

There is also in the collection a Euomphaloid shell in a fragmentary condition which is characterized by having the peritreme flattened above and subangular upon its superior peripheral line. A further description is impossible because of the imperfect condition of the material. So far as its characters are known it seems to belong to *Pleuronotus Decewi* or some nearly related species.

*Formation and locality.*—Ouray limestone: Engineer Mountain 7.

BELLEROPHON sp.

Shell large, very gradually expanding, not flaring at the aperture. Umbilicus open. Volutions somewhat flattened above, so that a transverse section at any point would be elliptical. Slit band in the form of a narrow ridge, not much elevated, traversing the median dorsal line. The surface is marked by transverse, lamellose ridges, about 1 mm. broad, which appear to be but little deflected as they cross the dorsal ridge.

One large specimen measures about 60 mm. on its longest diameter. The others are somewhat smaller.

This species evidently belongs to the genus Bellerophon as restricted by Waagen, and seems to be related to *B. Pelops* of the Corniferous limestone. Of further comparison than this, the poor preservation of the material hardly admits.

*Formation and locality.*—Ouray limestone: Durango 291, 294; Station 48.

ORTHOCERAS sp. *a*.

Several species of Orthoceras are represented by fragments in the collections from the Ouray limestone.

One form is distinguished somewhat by its size. One large fragment has a diameter of 35 mm., the measurement being taken still within the chambered portion. The taper of this species is so gradual that the convergence in outline is only just discernible.

The most perfect specimen is about 50 mm. long. The larger end measures 27 mm. on one diameter and 21 mm. on the other. It is seen from this that the transverse section would be elliptical in outline. The flattened shape may be the result of compression. The measurements of the other end would be slightly less.

The chambers at this stage measure about 4 mm. in height. The siphuncle is eccentric and situated near one of the less convex sides. It is very large, measuring 9 mm. in diameter.

*Formation and locality.*—Ouray limestone: Durango 291, 294; Salida 30.

ORTHOCERAS sp. *b*.

This species is much smaller than the preceding, but may be founded upon the smaller ends of individuals whose distal portions would have had the characters of sp. *a*. As the two forms are not connected in the collection by intermediate examples, and as new names are not being proposed, it seems advisable to take cognizance of the existing differences.

Like the preceding, shells of this species taper very gradually. The largest diameter observed is about 11 mm., and the transverse section is circular. The chambers are 2½ mm. high. The position of the siphuncle is not known.

*Formation and locality.*—Ouray limestone: Engineer Mountain 7; Durango 291.

ORTHOCERAS sp. *c*.

The third species of Orthoceras recognized in the Ouray limestone is one of the annulated types. From the single specimen observed, it appears to be a shell of small diameter (about 8 mm.) and but slightly tapering. The chambers are low, the diaphragms being only about 2½ mm. apart. The annulations are strongly marked, not quite horizontal, and disposed at intervals of about 5 mm. The siphuncle is small and nearly central. This species resembles *Orthoceras crotalum* Hall, of the Hamilton group of New York. It is this form which was mentioned by Meek in the list of species found at the time *Camarotœchia Endlichi* was discovered.

*Formation and locality.*—Ouray limestone: Durango 291; Station 48.

PLATE III.

# PLATE III.

| | Page. |
|---|---|
| ORTHOTHETES CHEMUNGENSIS | 40 |

1. A characteristic dorsal valve of the type referred to this species.
1*a*. Specimen seen from above, showing the rather coarse striæ, and the irregularities of curvature, many of which are due to growth.
Ouray limestone; Salida 29.
2. A characteristic ventral valve of the same type.
2*a*. Specimen seen from above.
2*b*. Side view of the same in outline.
2*c*. Posterior view of the same.
Ouray limestone; Salida 29.

ORTHOTHETES CHEMUNGENSIS? .......... 40

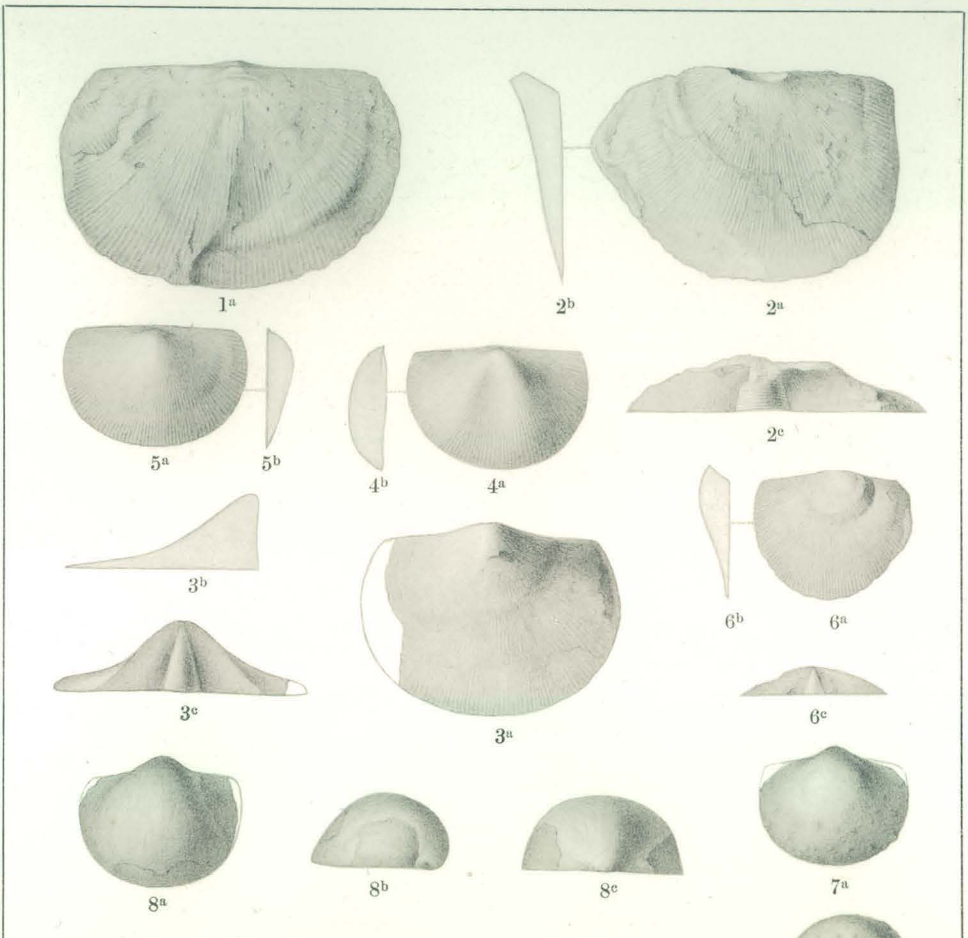
3. A type of which several specimens have been found. It has fine striæ more like *Orthothetes chemungensis* var., with the proportions of the form referred to *O. chemungensis* itself.
3*a*. A ventral valve seen from above.
3*b*. Side view of the same in outline, showing vertical direction of the area.
3*c*. Posterior view of the same.
Ouray limestone: Durango 294.

ORTHOTHETES CHEMUNGENSIS var .......... 40

4. A dorsal valve of a type considered to be varietally distinct from *Orthothetes chemungensis* as above identified. It is smaller in size and more finely striate.
4*a*. Specimen seen from above.
4*b*. Same; outline of side view.
Ouray limestone: Durango 294.
5. Another dorsal valve of the same species.
5*a*. Specimen seen from above.
5*b*. Side view of same in outline.
Ouray limestone: Engineer Mountain 7.
6. A small, finely striated, ventral valve of the same type as the one last figured and associated with it.
6*a*. Specimen seen from above.
6*b*. Same; side view in outline.
6*c*. Posterior view of the same.
Ouray limestone: Engineer Mountain 7.

PRODUCTELLA SEMIGLOBOSA .......... 42

7. A specimen of the usual size and shape found in the Ouray limestone and referred to *Productella semiglobosa*. This specimen shows a considerable number of large spine bases arranged in concentric rows, chiefly in the anterior region of the shell.
7*a*. Ventral valve as seen from above.
7*b*. Anterior view of same.
7*c*. Posterior view of same, showing almost complete absence of spines in this region, either through erosion or nondevelopment.
7*d*. Side view of the same.
Ouray limestone; Gunnison 135.




FOSSILS FROM THE OURAY LIMESTONE

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PRODUCTELLA SEMIGLOBOSA—Continued. Page.

8. Another ventral valve belonging to the same species where the surface, probably owing to imperfect preservation, appears almost smooth.

8*a*. Specimen seen from above.

8*b*. Same; side view.

8*c*. Same; posterior view.

Ouray limestone; Durango 291.

9. The only dorsal valve observed, which, it is believed, with certainty belongs to this species. The interior of the shell here seems to be presented to view. This specimen is a part of the old Museum collections, and is probably the one upon which Meek based his determination of *Productus subaculeatus* as associated with *Rhynchonella Endlichi* in the Ouray fauna.

9*a*. Specimen seen from above.

9*b*. Side view of same in outline.

Ouray limestone; east of the Animas River.

PRODUCTELLA SEMIGLOBOSA? .................................................. 42

10. A dorsal valve of somewhat larger size than and different character from the preceding, though provisionally referred to the same species. This valve, of which only the interior is known, seems to belong to an arcuate species like *Productella semiglobosa*, but presents points of dissimilarity to the dorsal valve shown by figs. 9*a*, 9*b* of the same plate.

10*a*. Shell seen from above.

10*b*. Side view of same in outline.

Ouray limestone; Engineer Mountain 7.

PRODUCTELLA sp .................................................. 45

11. The only specimen found of a large Productella of uncertain affinities. The shell of this specimen is almost completely exfoliated.

11*a*. Specimen seen from above.

11*b*. Side view of same in outline.

11*c*. Same; posterior view.

Ouray limestone; Durango 294.

# PLATE IV.

# PLATE IV.

Page.

SPIRIFER DISJUNCTUS var. ANIMASENSIS .......................................... 48

1. A small vental valve of a common type. The shell is transverse; the area high, flat, and normal to the plane of junction of the two valves.

1*a*. Shell seen from above.

1*b*. Side view in outline.

1*c*. Posterior view showing rather broad delthyrium.

Ouray limestone; Engineer Mountain 7.

2. A somewhat larger specimen, with less elevated area. The beak is slightly incurved and twisted to one side.

2*a*. Specimen as seen from above, showing somewhat distorted mode of growth. The sinus is covered with numerous plications, finer than those on the wings.

2*b*. Same; side view in outline.

2*c*. Posterior view of same.

Ouray limestone; Durango 294.

3. A medium-sized specimen with high area, beak somewhat twisted and incurved, and a large number of fine striæ in the sinus. Too few of these are shown by the figures.

3*a*. Ventral valve seen from above.

3*b*. Side view of same in outline.

3*c*. Anterior view of same.

3*d*. Same; posterior view.

Ouray limestone; Engineer Mountain 7.

4. A specimen similar to the last, but very much distorted in growth.

4*a*. Ventral valve seen from above.

4*b*. Outline side view of same.

4*c*. Posterior view of same.

Ouray limestone; Engineer Mountain 7.

5. Ventral valve of medium size with a high, flat area, directed at right angles to the plane of junction of the valves. The sinus is marked by numerous bifurcated striæ, not well shown by the figure.

5*a*. Specimen seen from above.

5*b*. Same; side view in outline.

5*c*. Posterior view of same, showing wide foramen.

Ouray limestone; Durango 294.

6. A large ventral valve, with its high area nearly flat and inclined backward toward the plane of junction of the valves. The sinus is traversed by coarse bifurcated striæ.

6*a*. Specimen seen from above.

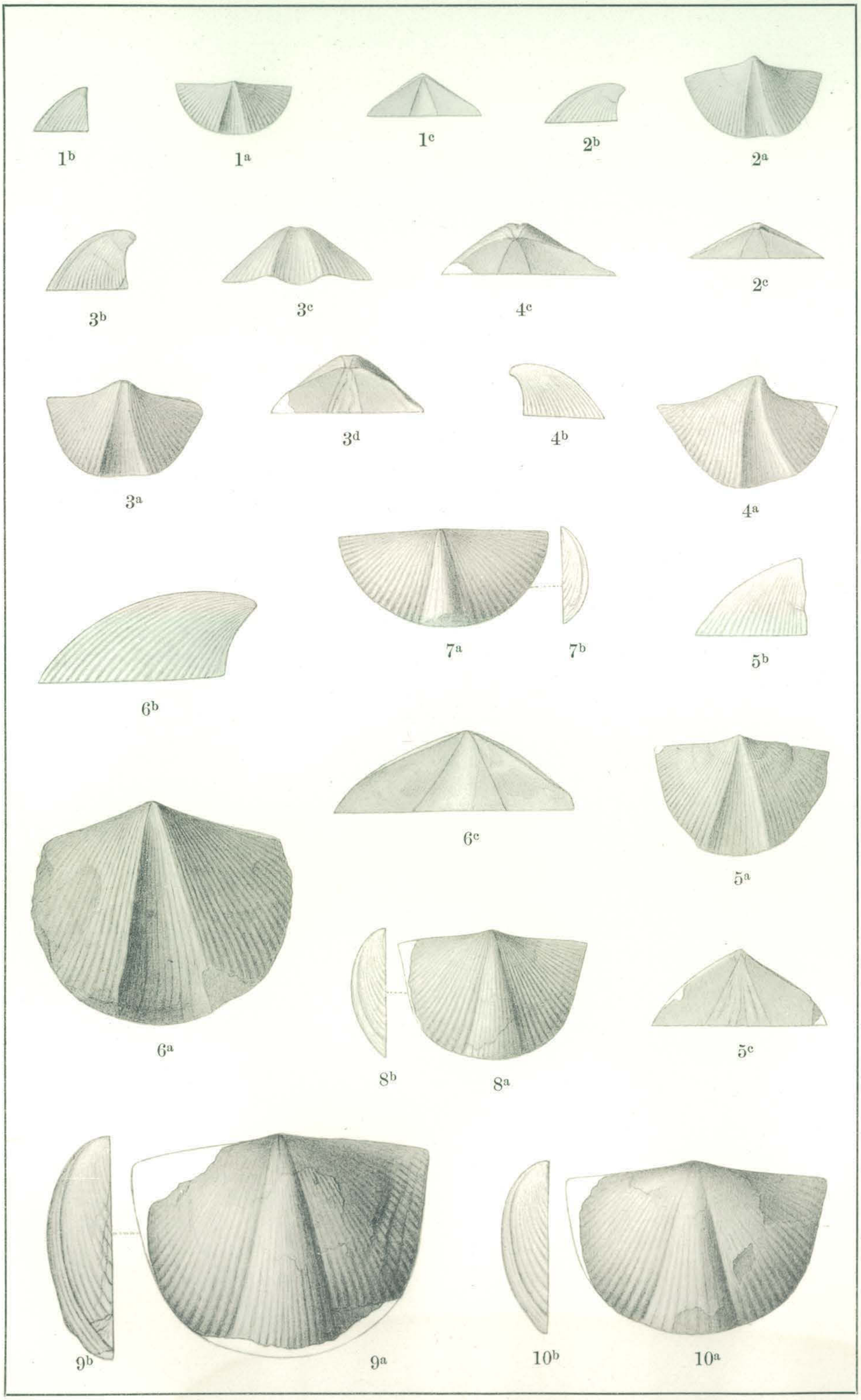
6*b*. Side view of same in outline, showing inclination of the area and its slight concavity.

6*c*. Posterior view of same, showing the broad delthyrium.

Ouray limestone; Durango 291.

7. Dorsal valve of a transverse type.

7*a*. Shell seen from above.

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SPIRIFER DISJUNCTUS var. ANIMASENSIS—Continued.

7*b*. Same; side view in outline.
Ouray limestone; Durango 294.

8. A dorsal valve of the subquadrate type, and of medium size. The fold is covered by a large number of bifurcated striæ, finer than those at the sides.

8*a*. Specimen seen from above.

8*b*. Side view of same in outline.
Ouray limestone; Durango 294.

9. A large dorsal valve of subquadrate shape. The fold is traversed by numerous striæ, large and fine, simple and bifurcate.

9*a*. Shell seen from above.

9*b*. Same; side view in outline.
Ouray limestone; Durango 291.

10. A subquadrate dorsal valve of large size, in which the plications upon the fold are coarse and simple.

10*a*. Specimen seen from above.

10*b*. Side view of same in outline.
Ouray limestone; Durango 291.

# PLATE V.

# PLATE V.

| | Page. |
|---|---|
| SPIRIFER CONICULUS | 47 |

1. A rather large but distorted and not very perfect ventral valve belonging to this species.

1*a*. Anterior view.

1*b*. Side view in outline. The peculiar conformation of this specimen renders visible portions of the further side, when viewed as in the drawing.

1*c*. Posterior view, showing high area and narrow foramen.

1*d*. Another view of the same, showing the bilateral asymmetry of this specimen.

Ouray limestone; Engineer Mountain 7.

2. A slightly undersized but nearly perfect specimen, preserving both valves in conjunction.

2*a*. Ventral view, in which part of the area is brought to view by its slightly resupinate character and the faint distortion of the beak. The plications are seen to be low and indistinct, and the sinus not strongly demarked.

2*b*. Dorsal view of same specimen in which the obsolescent plications and indistinct fold are well shown.

2*c*. Anterior view of the same specimen.

2*d*. Posterior view of same, showing high area and narrow delthyrium.

2*e*. Side view of same, showing slightly retrorse area.

Ouray limestone; Engineer Mountain 7.

3. A well-preserved specimen of about the average size and character.

3*a*. Ventral view, showing slightly twisted and overarching apex. The striæ and the sinus are both seen to be faintly defined.

3*b*. Posterior view of same. The rounded character of junction of the areal plane with the sides of the shell is well shown. This is constant and characteristic.

3*c*. Anterior view of the same.

3*d*. Side view, in which the height of the ventral valve and the slight concavity of the area are well shown.

Ouray limestone; Engineer Mountain 7.

4. A small and imperfect ventral valve, which is peculiar by reason of its incurved beak, and its apparently smooth surface without either plications or sinus.

4*a*. Specimen seen from above.

4*b*. Posterior view of same.

4*c*. Anterior view.

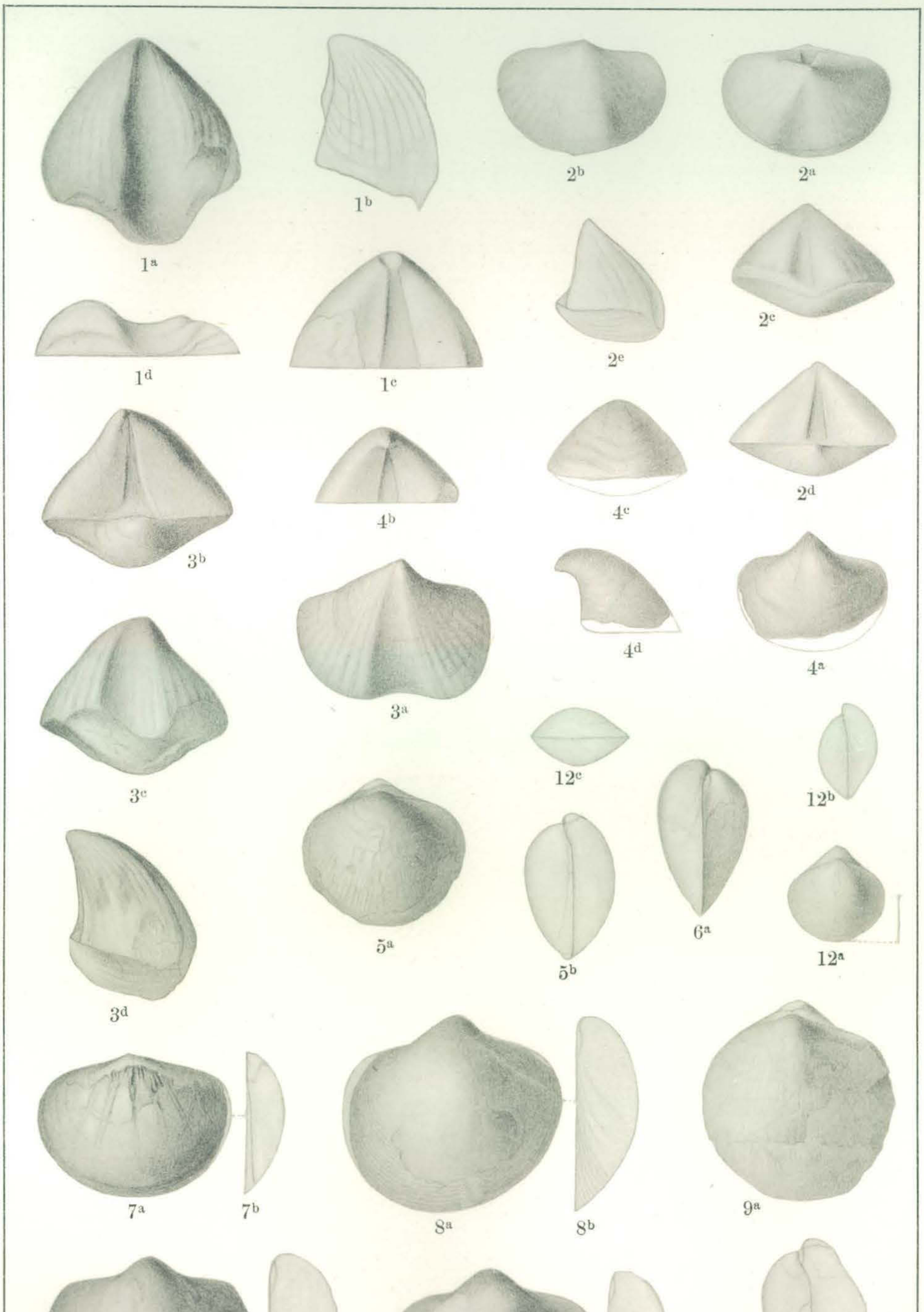
4*d*. Side view.

Ouray limestone; Engineer Mountain 7.

| | |
|---|---|
| ATHYRIS COLORADOENSIS | 46 |

5. A rather small example of nearly circular shape, in which the two valves have retained their normal position.

5*a*. Dorsal view.

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ATHYRIS COLORADOENSIS—Continued. Page.

5*b*. Side view in outline. The convexity of the two valves, as represented in this figure and the one following, seems to show this character as existing in nearly equal degree in each. Such is far from being universally the case, especially in full-grown shells. The ventrals often become highly inflated, and many dorsal valves are but slightly arched.

Ouray limestone; Salida 29.

6. Another undersized shell, better preserved in this regard than the last, in which both valves are retained in their natural position and convexity. This specimen was probably the Athyris mentioned by Meek as occurring associated with *Rhynchonella Endlichi*.

6*a*. Side view, showing the relative convexity of the two valves.

Ouray limestone; Station 48.

7. A dorsal valve of transverse type, in which the shell is almost completely gone and some of the internal markings preserved on the cast.

7*a*. Specimen seen from above.

7*b*. Side view in outline.

Ouray limestone; Salida 30.

8. A ventral valve, somewhat distorted by pressure but weathered so as to retain the shell and preserve in part the surface ornamentation, which is seen to consist, peripherally at least, of closely set, lamellose-growth lines, as in *Athyris spiriferoides* and other members of the genus.

8*a*. Specimen seen from above.

8*b*. Side view in outline.

Ouray limestone; Gunnison 145.

9. A specimen of an elongate type; somewhat crushed. This example, together with 10*a* and 11*a*, shows in some measure the massive character of the shell, which breaks off usually in thick, angular exfoliations.

9*a*. Dorsal view of specimen.

9*b*. Side view of same in outline.

Ouray limestone; Durango 294.

10. A semiorbicular specimen of considerable convexity.

10*a*. Seen from above.

10*b*. Same; outline of side view.

Ouray limestone; Durango 294.

11. Another convex specimen; transverse and shield-shaped.

11*a*. Shell seen from above.

11*b*. Side view of same in outline.

Ouray limestone; Durango 294.

ATHYRIS VITTATA var .......................................................... 47

12. A small, subcircular shell of doubtful affinities; perhaps a young specimen of *Athyris coloradoensis*.

12*a*. Dorsal view of a specimen, showing both valves in conjunction. x2.

12*b*. Same; side view in outline. x2.

12*c*. Same; front view in outline. x2.

Ouray limestone; Engineer Mountain 7.

# PLATE VI.

# PLATE VI.



1. A small specimen of a type common in the later collections from the Ouray limestone, and present also in the material described by Meek.

1*a*. Dorsal view of an entire specimen.

1*b*. Ventral view of same, showing broad and deep, though ill-defined, sinus.

1*c*. Side view of same, in which the laterally angulated and flattened character of the ventral valve is shown.

1*d*. Anterior view, in which the nature of the fold and sinus is well exhibited.

1*e*. Posterior view of same, showing angulation and flattening at the sides of the ventral valve.

Ouray limestone; Durango 294.

2. A specimen of about the same size as the last, and, though much smaller than those figured by White, probably mature or even senile, as shown by its gibbosity. The plications are finer and more numerous than those of 1.

2*a*. Ventral view of specimen.

2*b*. Side view of same, showing gibbosity of dorsal valve and angulated lateral margin of the ventral valve.

2*c*. Front view of same, showing high fold and sinus, and strong lateral angulation of the ventral valve.

2*d*. Posterior view of the same, showing broad, undefined sinus, and lateral angulation of the ventral valve.

Ouray limestone; Durango 291.

3. A large, nearly perfect specimen, figured by White, the original of his figures 2*a*, 2*b*, pl. 36 (Twelfth Ann. Rept. U. S. Geol. and Geog. Surv. Terr., 1883, p. 133). This specimen is of the type of 1 of this plate, though much larger.

3*a*. Dorsal view, after White.

3*b*. Side view of same, after White. This drawing shows the lateral angulation mentioned by Meek. (See also 1*c*, 1*e*, 2*b*, 2*c*, 2*d*, etc.)

3*c*. Posterior view of same, showing the broad, undefined ventral sinus, and the lateral angulation of the same valve.

3*d*. Anterior view of same, showing high fold and sinus.

Ouray limestone; Station 48.

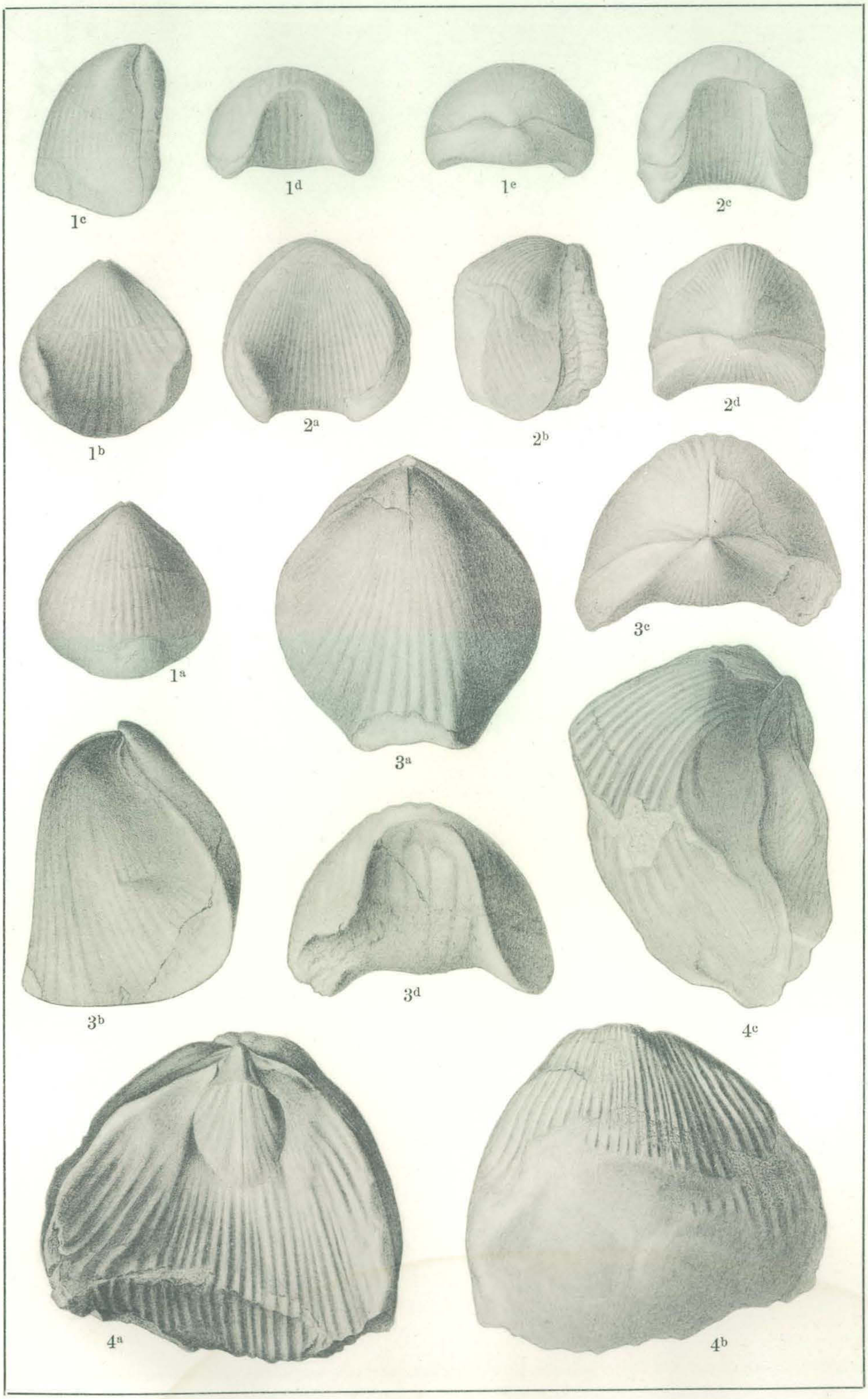
4. A very large though imperfect specimen; one of the types figured by White (l. c., pl. 33, figs. 4*a*, 4*b*). This gibbous specimen is of the same type as that shown by fig. 1 of this plate, though much larger.

4*a*. Ventral view, after White.

4*b*. Dorsal view of same.

4*c*. Side view of same.

Ouray limestone; Station 48.

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# PLATE VII.

## PLATE VII.

Page.

CAMAROTŒCHIA ENDLICHI .......... 56

1. A small example of the type of fig. 1, Pl. VI.

1*a*. Dorsal view, showing undefined fold.

1*b*. Ventral view, showing broad, undefined sinus.

1*c*. Side view, in which the lateral angulation of the ventral valve is well exhibited.

1*d*. Posterior view, showing the broad, though ill-defined, fold and sinus and the lateral angulation of the ventral valve.

1*e*. Anterior view showing the character of the fold and sinus. These are seen to be marked by a few strong ribs, the more lateral plications in this, and also in other individuals, manifesting a marked tendency toward obsolescence.

Ouray limestone; Durango 294.

CAMAROTŒCHIA CONTRACTA? .......... 57

2. A small but characteristic specimen, and the best preserved which has come under my observation. Much larger shells of the same species occur in the collection, but their poor preservation renders them unfit for illustration.

2*a*. Dorsal view.

2*b*. Ventral view.

2*c*. Anterior view.

2*d*. Side view.

Ouray limestone; Salida 27.

3. A small but imperfect specimen in which but two ribs occur in the sinus.

3*a*. Specimen seen from above.

Ouray limestone; Engineer Mountain 7.

4. A nearly perfect dorsal valve in which the fold is surmounted by four plications, the middle two being more prominent than those at the at the side.

4*a*. Shell seen from above.

4*b*. Same; side view.

Ouray limestone; Engineer Mountain 7.

MYTILARCA? sp .......... 59

5. A left valve of a peculiar lamellibranch shell of uncertain affinities. The shape suggests a Mytilarca or a Myalina.

5*a*. Specimen seen from above. The outline has been restored in places.

5*b*. Side view of same in outline.

Ouray limestone; Durango 294.

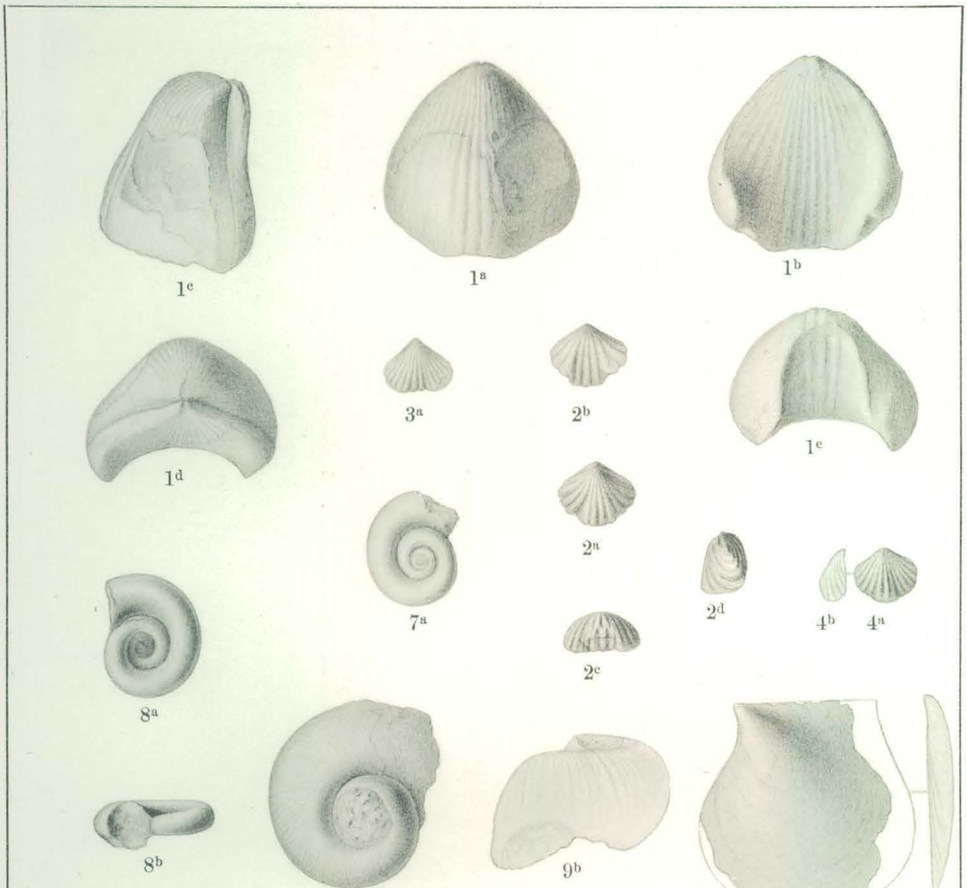
MODIOMORPHA? sp .......... 58

6. The left valve of a small lamellibranch shell, which may be a representative of the genus Modiomorpha, but is possibly only a very young example of *Allorisma* sp.

6*a*. Specimen viewed from above; enlarged.

6*b*. Side view of same; enlarged.

Ouray limestone; Durango 291.




FOSSILS FROM THE OURAY LIMESTONE

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| | Page. |
|---|---|
| STRAPAROLLUS CLYMENIOIDES ? | 61 |

7. A small specimen referred to this species. Much larger specimens occur in the collections, but they are unfortunately too poor for illustration.
7*a*. Superior view.
Ouray limestone; Durango 294.
8. Another small example similar to the last.
8*a*. Inferior view.
8*b*. Side view of the same.
Ouray limestone; Durango 294.

| | |
|---|---|
| NATICOPSIS? (ISONEMA) HUMILIS | 60 |

9. An imperfect specimen referred to this species in which the shell is retained, showing the shape of the peritreme and the nature of the surface ornamentation.
9*a*. Superior view.
9*b*. Same; side view, showing the shape of the peritreme. This is seen to be slightly different from the exfoliated examples figured beyond.
Ouray limestone; Engineer Mountain 7.
10. Another specimen of the same species.
10*a*. Side view.
10*b*. Superior view.
Ouray limestone; Engineer Mountain 7.
11. A specimen in which the shell is largely removed.
11*a*. Superior view.
11*b*. Same; side view.
11*c*. Same; inferior view.
Ouray limestone; Durango 294.

# A PRELIMINARY PAPER

ON THE

# GEOLOGY OF THE CASCADE MOUNTAINS IN NORTHERN WASHINGTON

BY

ISRAEL C. RUSSELL

# CONTENTS.

# ILLUSTRATIONS.

# A PRELIMINARY PAPER ON THE GEOLOGY OF THE CASCADE MOUNTAINS IN NORTHERN WASHINGTON.

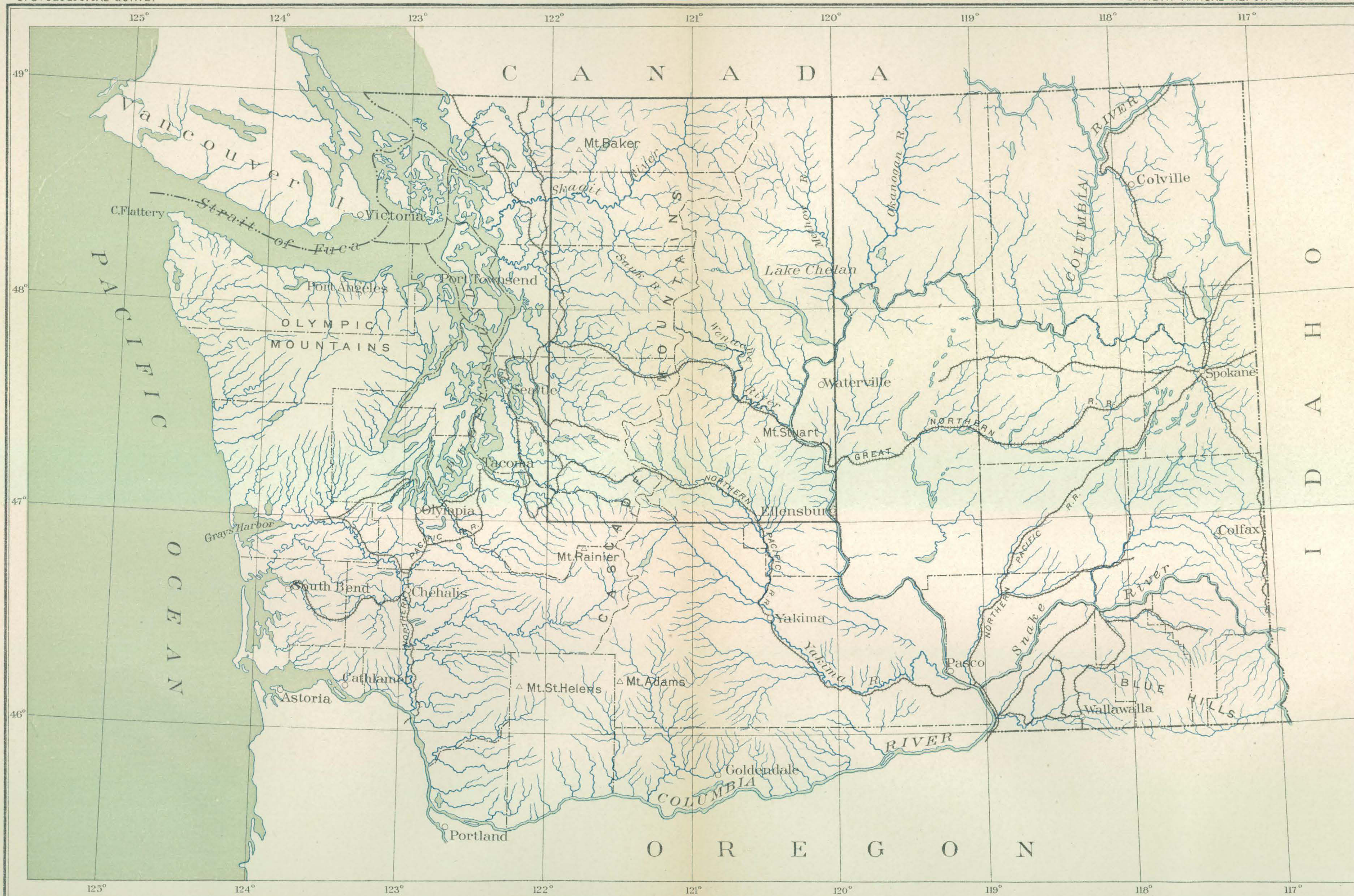
By Israel C. Russell.

## INTRODUCTION.

The region referred to in the above title embraces a tract of country about 60 miles wide, extending from the Northern Pacific Railway, where it crosses the Cascade Mountains, northward to the United States–Canadian boundary, a distance of approximately 100 miles. A large portion of this area is included in what is known as the Washington Forest Reserve, established in 1891. Only reconnaissance geological work has been done in this region, and the present paper is intended as a preliminary report, to be followed by more detailed studies.

The field work which forms the basis of the present paper was done principally during the summer or field seasons of 1897 and 1898, but some of the country under consideration was visited during a reconnaissance in 1892, a report of which forms Bulletin No. 108 of the United States Geological Survey. The work done during the last two years was under the direction of Mr. Bailey Willis, assistant to the Director, and to him I am indebted for every facility that could be afforded in aid of my work and also for many suggestions based on his own observations in the same general field, more especially while he was connected with the Northern Transcontinental Survey. In 1897 my work began July 5 at Clealum, a station on the Northern Pacific Railway, and terminated at the same place September 22. During this interval a preliminary geological examination was made of an area including about 750 square miles, in what is known in the reports of the Geological Survey as the Mount Stuart quadrangle, a rectangular area embracing one-quarter of a square degree (latitude 47° to 47° 30′ and longitude 120° 30′ to 121°), with Mount Stuart in the northwestern portion. The boundaries of this quadrangle are shown on the sketch map, Pl. IX. Detailed geological work has since been done in this area by Mr. George Otis Smith,[1]

Messrs. Willis and Smith have kindly read the manuscript of this paper and given me the benefit of their searching criticisms, but are in no way responsible for the observations and conclusions presented. I am also greatly indebted to Mr. Smith for the determination of numerous rock specimens, and to Mr. F. H. Knowlton for the study of the fossil plants collected.




OUTLINE MAP OF THE STATE OF WASHINGTON
Showing area occupied by Geological Sketch Map Plate IX.
Scale
50 40 30 20 10 0 50 MILES

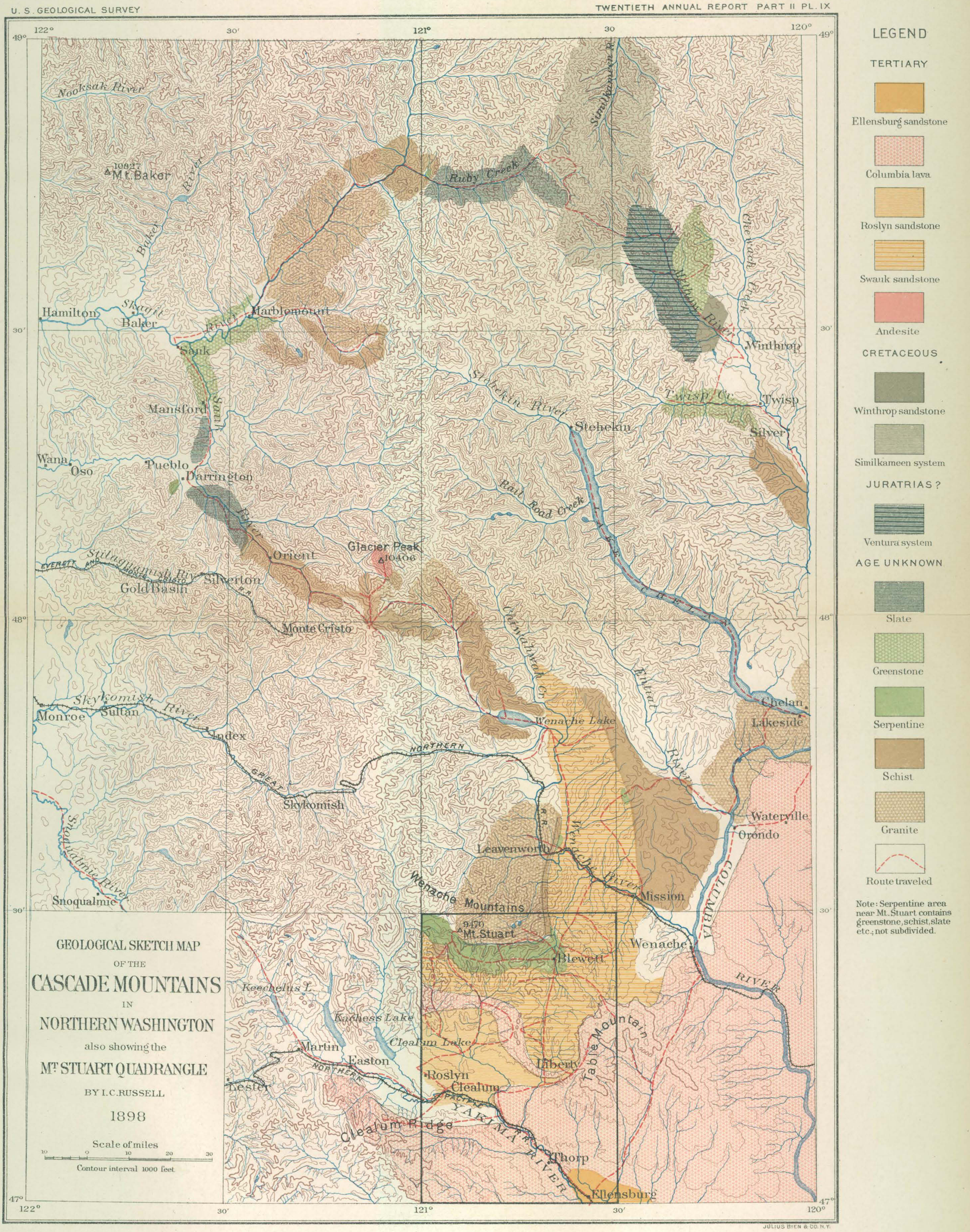
and to him I am indebted for much assistance, in reference especially to the geology of the southern portion of the region treated in the present report. Early in July, 1898, I resumed work at Clealum, reviewing, in company with Mr. Smith and Mr. G. C. Curtis, the conclusions previously reached in reference to the geology of the Mount Stuart quadrangle, and on July 22 began a rapid reconnaissance through the Cascade Mountains to the north of Mount Stuart, which extended nearly to the international boundary. This journey led me, in a general way, up the Wenache River to the head of Lake Wenache, thence westward, following the West Fork of White Creek to Indian Pass, and down the Sauk River to its junction with the Skagit. Proceeding northward, I ascended the valley of the Skagit to the mouth of Ruby Creek, and then traveled eastward up the canyon of that stream to the main Cascade divide. Crossing Crater Pass, I followed the Methow River to its junction with the Columbia, and thence continued my explorations southward to Mission, a station on the Great Northern Railway, in the Wenache Valley, where my party was disbanded on September 20. The routes followed during these several journeys are indicated on the sketch map, Pl. IX.

The region embraced in the Mount Stuart quadrangle has been mapped by Messrs. R. U. Goode, S. S. Gannett, and G. E. Hyde, of the topographic branch of the United States Geological Survey, on a scale of 1:125,000, or about 2 miles to 1 inch, with 100-foot contour intervals. Of the region to the north of Mount Stuart a map, known as the Washington Forest Reserve map, has been made from surveys by Messrs. R. U. Goode and D. C. Harrison, on a scale of 6 miles to 1 inch, with contour intervals of approximately 500 feet. Photographic copies of each of these maps were used by me in the field, and form the basis of the sketch map, Pl. IX. The portion of the State of Washington embraced in this map is indicated on the outline map of the State, Pl. VIII.

Concerning previous explorations in the region covered by this report little need be said, since, for the most part, it has received but slight attention from geologists. The eastern border of the area was visited by Prof. George Gibbs during the surveys for the Pacific Railroad in 1853, and is briefly described in Vol. I of what are commonly designated the "Reports of the Pacific Railroad Survey." Gibbs also published a paper on the "Physical geography of the northwestern boundary of the United States,"[1] in which attention was directed to the geography, climate, forests, etc., of the northern portion of the Cascade Mountains.

The preliminary railroad surveys made under the direction of Governor Stevens, in connection with the explorations just referred to, traversed the Yakima Valley at the southern margin of the area under

[1] Jour. Am. Geog. Soc., 1870–71, pp. 134–157.


GEOLOGICAL SKETCH MAP
OF THE
CASCADE MOUNTAINS
IN
NORTHERN WASHINGTON
also showing the
MT STUART QUADRANGLE
BY I. C. RUSSELL
1898
Scale of miles
Contour interval 1000 feet
LEGEND
TERTIARY
Ellensburg sandstone
Columbia lava
Roslyn sandstone
Swauk sandstone
Andesite
CRETACEOUS
Winthrop sandstone
Similkameen system
JURATRIAS ?
Ventura system
AGE UNKNOWN
Slate
Greenstone
Serpentine
Schist
Granite
Route traveled
Note: Serpentine area near Mt. Stuart contains greenstone, schist, slate etc.; not subdivided.
Mt. Baker
Glacier Peak
Mt. Stuart
Chelan
Wenache
Ellensburg
Leavenworth
Winthrop
Stehekin
Skykomish
Roslyn
Clealum
COLUMBIA RIVER
JULIUS BIEN & CO. N.Y.

consideration, and much information concerning the geography of this portion of the field may be found in various portions of the Pacific Railroad reports. This region was also examined by several parties connected with the Northern Transcontinental Survey in 1880, but no reports on the general geology have appeared. The results of this survey relating to economic geology were in part included in the Reports of the Tenth Census. The foregoing list of reports, etc., relating to the geology of the northern part of the Cascades is probably not complete, but, so far as I am aware, it includes about all the sources of information concerning the geology of the region under consideration. Reference to a few minor papers will be made later. Practically the northern portion of the Cascade Mountains was geologically unknown previous to the explorations described in the present paper, and it is for this reason mainly that a report on a preliminary geological examination of it was thought desirable.

## CLIMATE, VEGETATION, AND DRAINAGE.

### CLIMATE.

To the geographer the climate of a region is of primary interest, not in itself alone, but for the reason that the relief of the land and many of the changes recorded by the topography are brought about largely by atmospheric influences. To the geologist, also, the general climatic conditions now prevailing are suggestive, inasmuch as the causes on which they depend are far-reaching and long-lived, and may have been essentially the same—or in one region may have held a similar relation to the climate of adjacent regions—during the later geological ages. It is not intended to imply by this statement that the climate of Pleistocene time in any part of the United States, for example, was closely similar to what we now find, but it seems to be true that in some instances the relation of the climate of one region to that of an adjacent region, or the ratio of the two, we may say, has been similar for long periods of time. Exceptions will, no doubt, be taken to even this cautious statement, but as applied to the State of Washington, at least, I judge it will be found true.

There is a strongly marked contrast at the present time between the climate of the west and east sides of the Cascades. The west side, exposed to the prevailing westerly winds, which are warm and humid, is characterized by a mild winter climate, heavy rainfall, and long-continued cloudy or foggy weather. The snowfall is slight near sea level, but heavy in the mountains. The total annual precipitation about the shores of Puget Sound varies from 70 to over 100 inches. Observations to show the increase in precipitation with increase in elevation are wanting, but it is safe to assume that at altitudes of from 4,000 to 8,000 feet on the west side of the Cascades the mean annual precipitation is much in excess of what it is at Port Townsend, Seattle, Tacoma, etc. The western slope of the Cascades may be characterized as the rainy side, in distinction from the eastern slope, which with equal truthfulness may be termed the sunny side. The western slope is humid; the eastern slope, semiarid. The former is clothed with forests; the latter, while in part forested, is largely without trees, especially in the region adjacent to the Columbia. To the west of the crest line of the Cascades grass is scarce, while to the east of that line great areas furnish rich natural pastures.

### FORESTS.

The mild, equable temperature and the abundant moisture of the Puget Sound region favor the growth of vegetation, and the entire land area from tide water to an elevation of about 7,000 feet, except where the slopes are too precipitous, is clothed with a splendid forest of giant trees. This belt of forest adjacent to the Pacific begins at the south, in California, and extends to southern Alaska. It is the most magnificent forest in North America, and one that demands far more space from both a geological and a geographical point of view than can be given to it at this time. "The great forest" extends up to the western slope of the Cascades, through the lower passes, and far down the larger valleys on the eastern or sunny side. Its grandeur in an artistic sense is beyond description, and can be fully appreciated only by one who abides for weeks or months in its perpetual twilight. Great fir trees, rising from 150 to 250, and even 300, feet above the ground, stand in closed ranks, their rugged trunks from 6 to 8 or 10 feet, and even more, in diameter, shaggy with mosses and lichens of many subdued tints of brown, green, and yellow. Mingled with the giant firs are equally massive cedars, although of lower stature. The cedars are frequently 25 or 30 feet in circumference near the ground, but taper rapidly from a deeply fluted base to a sharp, spine-like top. These great trees do not form groves or detached clumps, as in the forested regions of less humid lands, but stand thickly together for mile after mile, and as one threads his way along the deeply shaded roads and trails he soon gets the impression that the forest is of interminable extent. Beneath the deep shade of the boughs, which, to one looking upward from beneath them, seem to mingle with the clouds—and during much of the prevailing misty weather this is literally true—there is a rank undergrowth, especially in the valleys and along the smaller streams, of vine-like maples, alders, frequently of the size of what may be termed forest trees, elders, the devil's club (*Echinopanax horridum*), with its broad tropical-looking leaves, and young firs, cedars, hemlocks, yews, etc. Of still more lowly habits are the ferns, equiseta, mosses, and lichens, which form the luxuriant and ever-varied carpet of the forest.

The ground throughout the great forest is encumbered with fallen trunks, sometimes piled one on another, which, owing to the continued moisture, remain undecayed for centuries. Not infrequently a massive cedar or fir, in size and shape not unlike a prostrate column, supports three or more trees, each large enough to be cut for lumber, whose gnarled and twisted roots clasp the sides of their host and descend to the earth beneath. The beauty of these fallen giants of the forest when overgrown with shaggy mosses and decorated with hundreds of small hemlocks and a multitude of gracefully bending ferns, always fresh in color and usually beaded with moisture, is beyond the power of the most skillful artist to portray. The fascination of the great forest is such that the explorer, weary with forcing a passage through dense undergrowths and climbing over prostrate trunks, is lured by its charms into more and more inaccessible retreats, probably never before invaded by man, or is tempted to rest content on the inviting couches of lichens and study the varied charms and endless details of the dream-like picture. While ever a source of interest and a delight, the forest clothes the ground and even the rocky precipices with so impenetrable a mask that the geologist has but little hope of being able to read the secrets of the strata that are buried beneath it. Where the great trees cast their shadows, grasses and all forage plants are absent, thereby rendering traveling with horses difficult, and thus again impeding the work of the explorer. Owing to the many and serious obstructions in the way of geological work on the west side of the Cascades, it must be many years before the nature, structure, etc., of the rocks, even of the surface, can be determined.

To the east of the Cascade Mountains in Washington lies a generally plain area of vast extent, with topographic and climatic conditions characteristic of the Great Basin region farther south, of which in reality it is an extension. Instead of being an area of interior drainage, however, it is crossed by the Columbia, which sends a great and never-failing flood to the ocean. The mean annual precipitation in what is known as the Big Bend country of east-central Washington, is in general from 16 to 20 inches. The minimum, so far as known, is near Pasco, where the total precipitation for a year is not over 8 inches. In no other portion of North America is a region of excessive humidity like that on the western slope of the Cascades in so close proximity to a land of almost desert-like aridity, such as borders the Columbia in central Washington.

To the east of the Cascade Mountains the rainfall is not only small, but the days of cloud and fog are rare. The summers are long and hot and the winters cold, but without much snow, except in the mountains. While the traveler on the west side of the Cascades is exposed to frequent rains, on their east side he has clear weather continuously. On account of the heat and dryness of the air in the region of the Upper Columbia, there are broad, prairie-like areas where grass grows thriftily and furnishes the richest of pasture. The subhumid conditions characterizing the Great Plains of the Columbia extend westward to the foothills of the Cascade Mountains, and there, because of greater elevation and close proximity to the humid lands farther west, a gradual change is manifest both in the character of the vegetation and in the humidity and cloudiness of the air. The east or sunny side of the Cascades is clothed with open, park-like forests of pine and fir, beneath which luxuriant grasses furnish a rich carpet of shining green in spring and russet brown in late summer and autumn. In earlier times, and even to this day throughout certain broad regions, this favored land furnished a congenial home for herds of deer and elk. Mountain goats and the bighorn are still found in considerable numbers about the most elevated peaks. The streams are nearly all clear, cold, and of wonderful transparency, and abound in trout. In this intermediate region, between the hot, dusty valleys near the Columbia and the damp forests of the Puget Sound country, persons who delight in camp life may find a paradise. The three main requisites of comfortable out-of-door life—water, wood, and grass—are everywhere abundant, as are also the spruce boughs with which the experienced mountaineer makes his bed. The stream sides furnish most delightful camping places, while the neighboring peaks and towering cliffs tempt one to climb to their summits and scan the pages of the earth's history as they lie spread before him, illuminated by an ever-brilliant sky.

The striking contrast between the climate of the two sides of the Cascades is again manifest in the distribution of the scores of small glaciers that cluster about the higher peaks. By far the larger portion of the existing glaciers are on the west side of the main divide, which parts the waters of the eastward from those of the westward-flowing rivers. The streams on the west side of the divide are mostly turbid with glacial silt, while of the larger streams that discharge their waters to the Columbia, from Yakima River northward to the Similkameen, only those having their sources near Glacier Peak reveal the characteristic milky color of glacial waters.

The suggestion offered on a previous page, to the effect that the main differences in climatic conditions between the wet and dry sides of the Cascades are of great antiquity, is sustained, I think, by the records of past glaciation. The ancient glaciers which flowed down the western slope of the mountains were far more extensive and of greater thickness than those that descended the deeply cut valleys on the east side. As the growth of glaciers is favored by heavy precipitation when in the form of snow, we are justified in concluding that the west side of the Cascade Mountains during the Glacial epoch received a heavier snowfall than the east side, the mean temperature of the entire region, in common with that of the rest of the continent, being lower than now. If we go still farther back, and study the great valleys that have been excavated in the Cascade Plateau—for a plateau it really is, in spite of its rugged aspect—we shall find that the valleys on the west side are deeper and show a more advanced stage of development than those on the east side. These valleys had about their present depths previous to the birth of the old glaciers, and, as I hope to show later, owe their main differences to contrasts in the climatic conditions to which they were subjected previous to the Glacial epoch.

The dense forest of giant trees, which gives to the country on the west side of the Cascades its most distinctive feature, extends through the passes in the central portion of the mountainous region, losing some of its characteristics, however, on account of changes in climate and elevation, and reaches far down the narrow, trench-like valleys to the east. In the narrow defiles or passes which cross the main water-parting the firs characteristic of the forests on the lowlands are replaced by other species belonging to the same genera, and mingled with them are hemlocks and tamaracks; but in the bottoms of the valleys leading eastward huge firs and cedars reappear, together with many of the lowly shrubs, ferns, and mosses that seem indigenous to their shade. On the eastern slope of the Cascade Mountains, particularly in the deep, canyon-like valleys drained by White Creek, the Chiwahwah, Stehekin, etc., traveling is nearly as difficult, on account of the dense thickets of alder, young fir trees, yews, hemlocks, etc., and the prostrate trunks of trees killed in large part by forest fires, as it is in the heart of the great forest on the borders of Puget Sound. In fact, throughout the entire Cascade region of northern Washington traveling is arduous, not only on account of the steep declivities, the sharpness of the mountain crests, and the marked degree to which the ancient plateau has been dissected, but also for the reason that the valleys with their cold streams are clothed with a dense tangle of vegetation through which, unfortunately, but few roads or trails have been opened.

## DRAINAGE.

In the northern half of the Cascade Mountains, as is shown on the sketch map, Pl. IX, the streams flowing eastward are separated from those flowing westward by a divide or watershed, which follows a generally north-south direction. These opposite-flowing streams head against each other, and have extended their head waters until the divide between them has become an irregular sharp-crested ridge. Every main stream has numerous branches, and all portions of the uplift are well drained, except where lakes exist, and these, as will be shown later, are due principally to the obstructions left by glaciers in previously stream-eroded valleys.

An examination of the accompanying map, Pl. IX, will show that the streams have reached a stage in their development that may be designated maturity. The smaller creeks and the multitude of brooks and rills tributary to the larger streams are not shown, but even in their absence it is manifest that all portions of the region are well drained. When the topography of the land is considered, later, it will be shown that this conclusion in reference to the stage of development reached by the streams is sustained by many other facts.

In the region under consideration the principal streams flowing eastward from the main Cascade divide are, in their order from south to north, the Yakima, Wenache, Stehekin, Chelan, Methow, and Similkameen. Each of these rivers has its source close to the main divide and is tributary to the Columbia.

The streams on the west side of the Cascades furnish even stronger evidence of maturity than those on the east side. The waters of hundreds of brooks and creeks there unite to form rapid but not impetuous rivers which discharge into Puget Sound. The principal westward-flowing river to be considered at this time is the Skagit. This especially typical river has its source to the north of the United States–Canadian boundary, and flows at first southward through an exceedingly rugged country for some 50 miles, and throughout this distance is a narrow and for much of the way a swift stream; then bending westward, it becomes a broad, navigable river for about 70 miles, to the point where it discharges into Puget Sound. Its main tributary from the south is Sauk River, which has its source in the neighborhood of Glacier Peak. To the south of the region drained by the Skagit there are other rivers which conduct the waters from the mountains to Puget Sound by somewhat direct courses, but of these little need be said in the present paper.

One of the most instructive features in connection with the rivers of the northern Cascades is that their valley tracts[1] extend far into the mountains. Many of the larger river valleys have what may be termed railroad grades to within a few miles of their ultimate sources. Near the main divide the gradients of the streams are high, and in these short mountain tracts their waters are swift, and cataracts and foaming rapids are of frequent occurrence. The features just referred to will be recognized at once by geographers as evidences of well-developed drainage. The main streams have reached maturity, except near their sources, and have comparatively low gradients throughout

[1] Geographers recognize three divisions in a normal river, in the direction of its length; these are the mountain tract, the valley tract, and the plains tract. In the first, the stream is impetuous, for the most part flows over bed rock, and is without flood plains; in the second, it is less rapid and is bordered by narrow flood plains, commonly of coarse material; in the third, it is still less rapid and perhaps sluggish, and usually meanders in sweeping curves through broad flood plains. The divisions between these three several tracts are indefinite, and the extent of each depends on the stage in development that any individual stream has reached. In the old age of streams the plains and valley tracts are greatly extended at the expense of the mountain tract.

their greatly extended valley tracts; only the westward-flowing rivers are bordered by plains, and these are near their mouths. The rivers flowing to Puget Sound have reached a more advanced stage in development than their rivals on the east side of the Cascades, and certain well-characterized differences in the topography of the two sides of the range have resulted from this cause.

Reasons for the differences in the amount of work performed by these opposite-flowing streams are not difficult to find. The streams flowing westward discharge directly into an arm of the sea, while those flowing eastward join the Columbia, the master stream of all of the eastern portion of Washington, at a considerable elevation above sea level, or, to use more technical language, above base-level of erosion. The elevations in feet above the sea of the mouths of the eastward-flowing streams, as determined by the topographic branch of the United States Geological Survey, are as follows: Yakima, 317 (at Pasco); Wenache, 610; Chelan, 670; Methow, 690 (?); Okanogan, 718 (?). In general, the distances that the westward-flowing rivers have to traverse in order to reach tide water is somewhat less than the average lengths of the streams which join the Columbia. The amount of rock that the westward-flowing streams had to remove in order to deepen their channels to base-level was therefore less than in the case of the similar streams on the east side of the Cascades. The westward-flowing streams made the descent from the crest of the mountains to sea level in a shorter distance than their rivals on the east made it, and consequently during at least the earlier stages in the deepening of their valleys must have flowed more rapidly. Other conditions being the same, the westward-flowing streams would evidently have been able to deepen their channels to base-level more quickly. But other conditions were not the same; the rainfall on the west, as we have seen, was greater than on the east side of the mountains, and this, again, favored the work of the westward-flowing streams. At the present time the dense vegetation on the western slope of the mountains retards mechanical erosion, although favoring rock decay and solution, while on the east side the slopes are in general much more freely exposed to the infrequent rains and more readily eroded. It does not seem probable, however, that the differences in the forests were so marked in late Tertiary times. While the rocks on each side of the Cascade divide are in general about the same so far as their resistance to erosion is concerned, the conditions on the west side have been much more favorable for stream work than those on the east side, and consequently the western slope has been more deeply dissected and the valleys have been given great widths.

Another contrast between the westward- and eastward-flowing trunk streams is that the former are all, or nearly all, turbid with glacial mud, while the latter are generally clear, the most notable exceptions being White Creek, which receives some of the waters supplied by the melting of glaciers about Glacier Peak and discharges into Lake Wenache.

The characteristics of the present streams of northwestern Washington, to which attention has just been directed, have an intimate bearing on the study of the origin and history of the leading features in the topography of the Cascade Mountains, and will be more fully discussed later.

## GENERAL TOPOGRAPHIC FEATURES.

The impression among geologists and geographers in reference to the general character of the Cascade Mountains is, I think, that they form a narrow, sharp-crested range, composed largely of basaltic rocks. Each of these ideas, so far at least as the mountains in northern Washington are concerned, is erroneous. On crossing the mountains one beholds what at first seems a puzzling complex of ridges and peaks, occupying a tract of country in general from 100 to 125 miles wide and exceedingly rugged throughout. A multitude of peaks and ridges in the central portion of the range and throughout a belt of country from 50 to 70 miles broad rise to a general elevation of about 7,500 feet, while many peaks near the flanks of the range have approximately the same height. Here and there among the mountains there are peaks or groups of peaks which have still greater heights, but these isolated elevations will be considered later. An observer standing on the summit of any one of the several hundred peaks referred to, sees at once that he is surrounded by a deeply dissected table-land. The more extensively one travels through the Cascade Mountains the more he is impressed with the plateau-like character of their generalized form. Instead of being a sharp-crested uplift, they consist in reality of a broad, deeply stream-cut plateau. The sharp divide which parts the eastward- from the westward-flowing rivers—the Cascade divide, as I find it convenient to designate it—owes its present characteristics to the backward or head-water extension of the opposite-flowing streams. In the northern portion of Washington especially this divide is less elevated than many of the peaks and ridges situated several miles nearer the borders of the dissected plateau of which they form a part.

The great block of the earth's crust, 100 to perhaps 150 miles broad, and with a much greater but as yet unknown length, with an elevation of from 7,500 to 8,000 feet, from which the Cascade Mountains, as we now know them, have been sculptured, was a nearly flat-topped, elongated dome. Further studies to the north and south of the region under discussion may modify this conclusion, but so far as the reader's understanding of the present report is concerned, he can not do better than to hold in mind as the generalized form that the Cascade Moun-

*A*. GLACIER PEAK, FROM THE SOUTH.

*B*. SNOW FIELD ON SOUTH SIDE OF GLACIER PEAK.

tains would present had there been no erosion, the picture of a great, much elongated, nearly flat-topped dome, all the central part having the characteristic features of a plateau. The dissection of such a dome, composed of rocks of various degrees of resistance and folded and faulted so as to have a complex structure, by streams furnishes an explanation of by far the greater part of the vast array of diversified topographic forms that attract one's attention while traveling through the Cascade Mountains.

The picture of a high plateau or flat-topped dome, that I have asked the reader to frame in his mind as the generalized form of the Cascade region, needs, however, to be modified in certain particulars. In portions of the uplifted region there are secondary elevations, which are of the nature of secondary domes or protuberances on its surface and flanks. One of these secondary elevations, greatly modified by erosion, forms an offshoot or spur of the Cascades on the east, between the Yakima and Wenache rivers, and is known as the Wenache Mountains. The highest summit in this group of peaks is Mount Stuart, which rises 9,470 feet above the sea. The mountainous region to the west and northwest of the Wenache Mountains is geologically unexplored.

The instance just cited of a secondary elevation on the eastern slope of the great Cascade uplift is the only one of its kind that is now definitely known, but the elevated region of granitic rocks and schists about Lake Chelan seems, from such evidence as is in hand, to be of the same general nature. Other irregularities in the main Cascade dome are thought to occur also on the western slope of the mountains, as about Monte Cristo and in the region drained by the Skagit, but sufficient evidence to clearly demonstrate the geological structure about these granitic areas is not in hand.

In addition to the leading topographic features in the Cascade region due to differential upheavals, there are prominent volcanic mountains. If we include the entire Cascade region in the State of Washington, there are five of these ancient volcanoes now known; these are, in their order from south to north, Mount Adams, Mount St. Helens, Mount Rainier, Glacier Peak, and Mount Baker. Only one of these, however, Glacier Peak, is situated in the portion of the Cascade Mountains which forms the basis of this report. Some of the volcanic mountains just named are of more recent origin than the elevation of the Cascade Plateau, and either stand upon it or, as in the cases of Mount St. Helens and Mount Baker, are adjacent to its immediate borders. They came into existence before it was deeply dissected by streams.

Glacier Peak, a view of which from the south is presented in Pl. X, *A*, is an andesitic cone now much defaced by weathering, which stands in the central portion of the Cascade Mountains and forms a part of the Cascade divide, between the westward-flowing tributaries of the Sauk and the eastward-flowing streams which join the Wenache. Its elevation is 10,436 feet, and it overtops the general level of the adjacent portions of the Cascade Plateau by about 3,000 feet. A more detailed account of this prominent glacier-crowned summit, so exceptional in nearly all of its features to the multitude of lesser peaks about it, will be given later.

The outline sketch of the main features in the topography of the region under consideration presented in the last few pages includes as its leading elements the much elongated, flat-topped Cascade dome, or plateau, with gently sloping sides merging indefinitely with the lower regions both on the east and on the west. The regularity of this great dome in general form is modified by secondary elevations, consisting principally of granite, and by at least one ancient volcano. The topographic elevations produced by these three methods of mountain building have been sculptured so as to produce an infinite variety of details, and give to the Cascade Mountains some of the most rugged and beautiful scenery our continent affords.

The task of the geologist in deciphering the history of the region under consideration embraces a study of the nature and origin of the rocks composing it and the manner in which they have been upraised, and in this connection much attention needs to be given to secondary movements which have produced numerous folds and faults. The presence of at least one volcanic mountain, and of many dikes, brings forward various questions relating to the connection between orogenic disturbances and extrusions and injections of molten magmas. The manner in which the elevations produced in various ways have been modified by erosion, and the evidences of climatic changes furnished by the fossils contained in the rocks and the records made by streams and glaciers, also claim attention. Many of these questions can be studied to advantage from both a geological and a geographic point of view. So much of this combined history as I have been able to interpret with such a degree of confidence as seems to warrant its publication is presented in the following pages.

## GEOLOGICAL FORMATIONS.

The rocks composing the Cascade Mountains furnish examples of all of the larger divisions of lithology, namely, those commonly classed as metamorphic, igneous, and sedimentary. The metamorphic terranes include rocks which were originally sedimentary, and others which are of igneous origin but in most cases are now so changed and recrystallized as to destroy or greatly modify the characteristics pertaining to their previous condition. The main representatives of this important and widely distributed group are several varieties of schist, characterized by the predominance of mica and hornblende, and also possibly some of the granite-like rocks.

The igneous rocks are represented by both plutonic and volcanic varieties. Of the former there are two divisions: first, those that were forced upward from deep within the earth's crust, so as to form boss-like intrusions of large size, which raised into domes the rocks beneath which they were injected; and second, the cooled and hardened magmas that were injected into fissures and formed dikes. Of these dikes there are two main groups, namely, acid and basic. The volcanic rocks of Tertiary or later date, so far as my observations indicate—with the exception of certain superficial deposits of basaltic lapilli of small extent and sheets of basalt (Columbia lava) which occupy the southern border of our field—were extruded from a single vent at Glacier Peak and formed lava streams and various fragmental deposits.

The sedimentary beds include great thicknesses of sandstone, shale, and conglomerate, with minor quantities of limestone. These rocks occupy large areas, are practically unaltered, and in places are abundantly charged with fossil leaves, or, as in the case of some of the limestones, contain marine shells.

What is probably the most striking feature of the northern Cascades is the absence of basaltic lavas, except in the extreme southern portion of the region under consideration. The Columbia lava, as is well known, is widely spread over southeastern Washington, and, as is thought at present, occurs also throughout the Cascade Mountains from the Northern Pacific Railway southward through southern Washington and Oregon; but this vast series of lava flow barely enters the region shown on the accompanying map, where it forms the surface sheet of Lookout and Table mountains and certain neighboring ridges. These lavas, however, do not extend westward or northward so as to form any part of the main Cascade uplift to the north of the Northern Pacific Railway.

## METAMORPHIC ROCKS.

Metamorphic rocks, as stated above, are such portions of the material of the earth as have undergone marked lithologic changes from what is usually termed their original condition. This is a loose statement, however, as the rocks composing the earth are constantly undergoing changes, and in many instances have passed, perhaps repeatedly, from one great lithologic division to another. The same material, as is well known, may at one stage in its history be molten and extruded at the earth's surface as a volcanic rock, and later be worn into pebbles, sand, etc., and spread out by water currents and waves as sedimentary strata; and still later, when deeply buried beneath subsequently deposited layers and depressed far below the surface, be subjected to heat, heated solutions, and movements producing crushing or shearing, so that its structure and mineral composition become greatly altered, in which condition it is known as a metamorphic rock. Following such a series of changes might come a second fusion, followed by another extrusion at the surface as lava. In discussing the history of the transformations of a given magma, each of the three stages just referred to might, for convenience, be termed a geologic cycle. A metamorphic rock in the present cycle might have been an igneous or a sedimentary rock during the cycle preceding. This is the idea that was intended to be conveyed by the statement made above, that metamorphic rocks originally belonged in either the igneous or the sedimentary series.

The changes or conditions which produce metamorphism and those resulting in actual fusion and recrystallization on cooling, merge one with the other, and to a great extent form parts of a single series. One important distinction between these two processes, however, is that mechanical change, more especially motion under great pressure, which in itself, unaided by a high degree of heat, may bring about decided mineralogic changes and the production of a schistose structure, does not of necessity enter as an essential condition in the history of igneous rocks. The gradations between metamorphic and igneous rocks make it difficult to apply even the broader principles of lithologic classification in a strictly logical manner during field studies. For this reason, in this preliminary discussion of the geology of the Cascade Mountains, it is deemed best to place all the granites in the broad division of the igneous rocks. With the granites also are included certain diorites and allied rocks which at present it is not practicable to describe and map separately. As may be inferred from these statements, the following classification is intended to be tentative, and subject to revision when further study is possible.

## SCHISTS.

Rocks with a schistose structure, in which mica, chlorite, hornblende, etc., occur in thin, nearly parallel but frequently greatly contorted laminæ, occupy large areas in the northern Cascades and are believed to be among the oldest, and in part at least the most ancient, rocks as yet recognized in that region. The geological age of these schists is unknown, and they probably belong to several distinct periods of the earth's history. Lithologically these terranes are similar to Archean schists of the eastern portion of North America. But metamorphic rocks on the Pacific coast with as great a similarity to those commonly occurring in the Archean are known to be of Mesozoic age. The schists of the northern Cascades are presumably Paleozoic or post-Paleozoic, but much more information is needed before this hypothesis can be positively affirmed or denied. Typical schists occur in a great escarpment on the south side of Yakima Valley, 2 miles southwest of Clealum, to the west of Clealum Point. This exposure is at first of small vertical extent, and is overlain by sandstone and basalt, but may be traced westward for at least 10 or 12 miles with an increasing thickness exposed. The full extent of this outcrop westward is as yet unknown, but from various indications is thought to extend far into the Cascade Mountains, along the general course of the Northern Pacific Railway.

Schistose rocks similar to those just mentioned come to the surface about the base of the Wenache Mountains, at various localities at the head of the Teanaway River and on Nigger Creek, and thence northward to beyond Leavenworth on the Great Northern Railway. In the outcrops about the Wenache Mountains the schists are much disturbed, and associated with them are small lens-shaped masses of white or dove-colored limestone.

The next exposure of schist met with in traveling northward occurs in a bold escarpment on the north side of Wenache Valley, known as the Entiat Range, which touches the Columbia a few miles north of the town of Wenache and extends for about 50 miles to the northwest, where it merges with the elevated region along the main divide of the Cascades. This lateral spur of the Cascades has an approximately level sky line, as seen from the southwest, and presents a bold and remarkably even escarpment toward the lower sandstone region bordering Wenache River. The Entiat Range is similar in its general features to the great escarpment on the south side of Yakima Valley.

During the reconnaissance of 1898 the Entiat Range was examined at a locality on Mad River about 10 miles northeast of Lake Wenache, and later in the season I ascended the valley of the Entiat from its mouth to a locality 12 miles up its course, and then crossed the range, there about 6 miles broad, traveling southwest on a trail leading to Leavenworth. During each of these examinations I found the range to be composed of mica- and hornblende-schist. On the Entiat-Leavenworth trail large dikes of basalt, trending about northwest and southeast, were observed breaking through the schist. On Mad River, at the locality mentioned above, both basic (basalt) and acid dikes cut the schist, the former having an approximately northwest-southeast trend, while the latter bear nearly north and south. In this region quartz veins in the schist carry gold. While the entire length of the Entiat Range was not traversed, its topography, as seen from a distance, shows that it is composed of essentially the same kind of rock throughout. What is probably a portion of this same area of schist occurs in the bold mountains between Chiwahwah Creek and White Creek, to the north of Lake Wenache. Schists occur at Dirty Run Peak, near the west end of Lake Wenache, and also on the excessively rugged mountain crest which extends from it some 10 miles to the northwest. In this instance the rock is a hornblende-schist, and appears to have resulted from a shearing of diorite. This area of schist forms the northeast border of the valley of White Creek to the junction of its two main forks, where it meets rugged mountains of nearly white granitic rock. The south wall of the valley through which flows the West Fork of White Creek is also composed of schist, while the north wall is of white granite. The schist continues along the south side of the West Fork of White Creek to the main divide in the vicinity of Glacier Peak. The valley of Indian Creek is almost entirely surrounded by similar rocks. On crossing Indian Pass and descending the deep canyon-like valley of the Sauk, one finds schist to be the prevailing country rock all the way to the mouth of the Whitechuck Creek.

The occurrence of schistose rocks, as just described, from the Columbia, near the town of Wenache, westward across the central axis of the Cascades and down the Sauk to the mouth of Whitechuck Creek, a distance of about 70 miles in a direct line, the topography of the country for several miles to the north and south of the route traversed, and the character of the débris brought down by the tributaries of the main streams, all serve to show that metamorphic rocks, mainly mica- and hornblende-schists, have a great development in this portion of the Cascades. A marked feature of the schist throughout this region is the presence in it of numerous small garnets, which give much of the rock a knotty appearance, and also the occurrence of a great number of small fissure veins of quartz.

Schistose rocks similar in all of their general features to those briefly described above occur on Cascade Pass and on the southwest side of Cascade Creek from its source to near its mouth.

Another large area of schist was traversed in the valley of the Skagit, from the mouth of Skaadle Creek, which joins the main stream from the west, northward to beyond the mouth of Beaver Creek. On the east side of Skagit Valley this schistose area begins on the north side of Thunder Creek and extends northward to beyond the mouth of Ruby Creek. The nature of the topography of the steep-sided valley of the Skagit above the mouth of Ruby Creek indicates that these schistose rocks extend northward to beyond the United States–Canadian boundary. This conclusion is sustained by the reports of the Canadian Geological Survey,[1] which state that the adjacent region in Canada is composed of "metamorphosed Paleozoic rocks (Cascade crystallines)." These schists extend up the valley of Ruby Creek for about 5 miles, and are succeeded to the eastward by black slates.

There is also an extensive area of schistose rocks on the Methow, below the mouth of the Twisp, and extending to the Columbia. The extent of this area to the east and west is unknown, but much of the rugged country between the portion of the Methow just mentioned

[1] George M. Dawson, Preliminary report on the physical and geological features of the southern portion of the interior of British Columbia: Geol. Nat. Hist. Surv. Canada, Report of Progress for 1877-78, pp. 63 B-64 B. The distribution of the crystalline rocks referred to is shown on the geolog ical map accompanying this report.

and Lake Chelan, judging from the character of its relief and the débris in the stream channels leading from it, is composed of similar schistose rocks. Schists are known to occur on the borders of Lake Chelan, and may be expected to occupy an extensive area in that region, but up to the present time this portion of our field has not been studied.

From this description of the distribution of schistose rocks and the similar data presented on the sketch map, Pl. IX, it may be seen that schists—varying greatly in appearance, but having mica, chlorite, and hornblende as their characteristic constituents—form a large portion of the northern Cascades.

With the metamorphic rocks should be included also certain slates or argillites, but as these are closely associated with similar rocks which show only moderate alteration and carry fossil leaves, it is thought best to include them all, in this provisional classification, in the division devoted to the sedimentary beds. Large areas of serpentine were also seen, and are described later, together with the peridotite from which they have been derived.

## IGNEOUS ROCKS.

### GRANITE.

In this group there are included certain rocks which are probably of metamorphic origin, but our studies have not been carried far enough to admit of a more detailed classification.

As already stated, the central part of the Wenache Mountains is composed of granite, which forms all of the higher peaks of the group, including Mount Stuart, and hence may be conveniently designated the Mount Stuart granite. The extent of this area westward is as yet unknown. Its southern border is sharply defined, and in general follows the course of Ingall Creek from near its source to within about 4 miles of its junction with the Peshastin; the boundary then turns abruptly northward, and, crossing the mountains at an elevation of from 2,000 to 3,000 feet above the Peshastin, descends to the Wenache at Leavenworth; north of that town it continues northward for 7 or 8 miles and then bends abruptly westward. The diameter of the area occupied by the Mount Stuart granite is 15 or 16 miles from north to south in the widest part, and its known east-west extent is about 13 miles. As previously stated, however, it may have a broad extension to the northwest. The rock in question is a light-colored and remarkably homogeneous biotite-granite, carrying hornblende, which in some cases is nearly or quite equal in quantity to the mica. In places nearly black segregations, usually spheroidal, occur, which are much finer grained than the inclosing rock, but are composed of the same minerals, with a far higher percentage of biotite and hornblende. These nodular masses sometimes have the appearance of included fragments, but, as just stated, are in reality of the nature of segregations.

The group of rugged peaks composed of Mount Stuart granite are precipitous on all sides, but especially so on their southern border. This southern slope rises from Ingall Creek like a mountain wall to a height of from 5,000 to 6,000 feet, and in no place can the summit be reached without true mountaineering.

Mount Stuart and almost the entire mountain mass which it surmounts is generally bare of vegetation and but slightly encumbered with débris. The light color of the naked granite gives the precipices and crags a seemingly white color when seen from a distance, and produces a striking contrast with the dark and more varied shades of the encircling mountains of gneiss, serpentine, greenstone, etc. The summit of the granite mass, except where it has been smoothed by glaciers, is rugged and serrate, the many joints traversing the rock having influenced the manner in which it has yielded to the weather and produced numerous tapering pinnacles and spires.

The junction of the Mount Stuart granite with the rocks surrounding it presents three different aspects. It is intrusive into the older schists, as is shown by the fact, observed by Messrs. Smith and Curtis about the head of Ingall Creek, that it sends out offshoots or dikes into the neighboring terrane. No local metamorphism or alteration of the rocks in contact with the granite has, however, been observed. The junction of the granite with the older rocks has elsewhere become a plane of fracture or faulting, along which differential movement of the rocks on opposite sides of the breaks has taken place since the granite magma cooled and crystallized. This faulting was observed by the author about the head of Ingall and Icicle creeks and near Leavenworth. Again, the granite underlies Tertiary sandstones, to which it yielded clastic material of which a basal conglomerate is formed.

The granite would make a good building stone, and is free from iron pyrites or other minerals which might be expected to decompose readily and cause stains. It is not traversed by mineral veins and holds out no inducements to the prospector. In a few places, as near Leavenworth, it is cut by narrow basic dikes, similar and probably belonging to a series of basaltic dikes which traverses a neighboring area of Tertiary sandstone. The granitic core of the Wenache Mountains now stands in bold relief on account of the removal to a great extent of the softer rocks with which it was formerly surrounded, and is one of the most striking and picturesque groups of sharp peaks to be found in the entire Cascade region. A notable fact in connection with the erosion of the mountain mass is the manner in which it is trenched by the canyon of Icicle Creek, a tributary of Wenache River. This creek has its source to the west of Mount Stuart and

MOUNT STUART, FROM SOUTH SIDE OF INGALL CANYON.

flows eastward directly through the granite area, in a canyon that is from 2,000 to 3,500 feet deep. This behavior of Icicle Creek indicates that its course was established before the Wenache Mountains had their present prominence. In this same connection I may note that the Wenache River leaves a region of comparatively low relief composed of soft sandstone and makes an excursion into the granitic area 5 or 6 miles in length, flowing in this portion of its course through a canyon fully 3,000 feet deep, and then returns to the sandstone once more. These interesting facts have a bearing on the origin of the present topography and will be discussed later.

The next area of granite met with by the writer along the route of exploration followed in 1898 has its southern border about 12 miles northwest of Lake Wenache, where the two forks of White Creek unite. The drainage basin of the North Fork of White Creek, with the exception of an area of a few square miles surrounding two moraine-dammed lakes situated some 2 miles to the eastward of the junction of the forks of White Creek, is entirely in granite. This same nearly white rock in places approaches a diorite in appearance, and forms the rugged region between the two forks just mentioned, and reaches westward to the Cascade divide. Its full extent westward is unknown, but it is thought to extend several miles northward of the head of the North Fork of White Creek and possibly to connect with a similar granite which is exposed near Cascade Pass. Similar granite occurs also on Indian Creek and on the main divide in the vicinity of Glacier Peak. Between Indian Pass and Glacier Peak there are irregular dikes of granite which branch off from the south side of the main body and traverse the adjacent schist.

Exposures of granite were noted along Sauk River where schist is the prevailing country rock, but, the time available did not permit of an examination of its extent or its relations to the associated terranes. Light-colored granite, similar to that exposed on White Creek, was met with on Cascade Creek, and on each side of the Skagit from near Marblemount upstream to the mouth of Thunder Creek, a distance of about 20 miles. The breadth of this area east and west is unknown, but is at least several miles, as the débris brought down by the streams tributary to the Skagit in the portion of its course referred to is mainly granitic. Small bosses of granite rising into much distorted quartzite occur on the Cascade divide at the head of the Similkameen. Like all of the other exposures of granite seen in the Cascades, these outcrops are light colored and appear to be intrusive.

A small area of granite has been reported by Bailey Willis as occurring south of Monte Cristo, some 7 or 8 miles to the southwest of the route followed by me in descending the Sauk. A large granitic area is also known to exist about Lake Chelan, but at present it is impracticable to state its extent. A portion of this area, however, was traversed by me near the east end of Lake Chelan, and is indicated on the map, Pl. IX.

Our present knowledge of the geology of the northern Cascades, although incomplete, is sufficient to show that granite enters largely into their composition. This rock, in all of the exposures that were examined, is light colored, but presents several varieties, each separate area seemingly having minor characteristics of its own. The Mount Stuart granite and that occurring about Glacier Peak are plainly intrusive, and the most plausible hypothesis is that several other areas have a similar origin. However, the rock on the north side of Cascade Creek, which forms a bold peak 3 or 4 miles east of Marblemount, although here classed as granite, contains what appear to be rounded pebbles of quartzite and is probably of sedimentary origin.

### GREENSTONE.

Large areas of dark, basic eruptives, similar to the diabase of the Newark system of the Atlantic coast, occur in several places in the region under consideration and constitute a considerable portion of the surface outcrops. These rocks are massive, frequently brecciated, and may be in part old lava streams, but provisionally it is convenient to consider them as being intrusive. The question as to their true nature, whether plutonic or volcanic, is left for more detailed study. They are hard and extremely resistant to the attacks of erosive agencies, and hence, for the most part, stand in bold relief and form prominent mountains and serrate peaks and ridges.

Rugged peaks of greenstone occur about the southern border of the Wenache Mountains, in intimate association with serpentine; some of these masses are 2 miles or more in diameter, while others are isolated peaks and crests but a few rods in circumference. The structure is here highly complex, and it is evident that the greenstones have been greatly broken and displaced, and also invaded by dikes of peridotite, since changed to serpentine, and by other intrusions. A detailed study of this area has been made by George Otis Smith, and the conclusions reached will, I understand, be discussed in a separate publication. The greenstone areas just referred to are of small extent in comparison with other areas of similar rock farther north, and are indicated only in part on the accompanying map, for the reason that the scale adopted is too small.

To the west of the Cascade divide, greenstone occurs on both sides of the valley of the Sauk for about 20 miles above its mouth, and extends up the Skagit from the town of Sauk to beyond Marblemount. This region is rugged, having been deeply dissected by streams, and is heavily forested. The full extent of the area occupied by greenstone is unknown, but it evidently measures 100 square miles or more. Greenstone, nearly identical, so far as can be judged from field observations, with the rocks of the areas just referred to, occurs on the Methow in the vicinity of Ventura, and for a distance of at least 5 miles on each side of the Twisp, one of the tributaries of the Methow from the west. The exceedingly bold cliff bordering Methow Valley on the east for a distance of some 8 miles south of Ventura, and known in part as Goat Wall, is composed of hard, massive greenstone, and is the finest exposure of this rock now known in the northern Cascades. This same greenstone area extends several miles up Goat Creek, a tributary of the Methow from the north, but in this region there are many basic dikes seemingly of later date than the greenstone but resembling it in appearance, which, in a reconnaissance, makes the determination of the actual nature of the country rock somewhat uncertain. The greenstone forming Goat Wall is not known to be connected with the similar area of wide extent on the Twisp, but evidently has a wide distribution northward. Similar rocks occur near Winthrop, and, judging from the topography, the reports of miners, etc., occupy a broad area in the mountains on the east side of Methow Valley. The age of the greenstone has not been accurately determined, but it is known that those on the south side of the Wenache Mountains are pre-Tertiary. The lithologically similar rock on the Methow bears such relations to certain sandstones, charged with fossil leaves, as to indicate that it is older than the Cretaceous. A more precise determination of age is at present not practicable.

### SERPENTINE.

Several areas of serpentine occur in the portion of the Cascade Mountains under consideration. The largest of these now known is situated in the Wenache Mountains and, in a general way, encircles the central core of Mount Stuart granite. With the serpentine are schist, slate, greenstone, etc., as previously stated. Together, these metamorphic and igneous rocks form a belt of varying width, which in places is fully 4 miles broad, and has an exceedingly complex geological structure. As is so frequently the case, the serpentines and associated rocks, not only in the Wenache Mountains but in each of the similar areas noted below, contain mineral deposits, notably gold and copper, which promise to be of much economic importance. As will be briefly described later, in connection with other notes on economic geology, several mines and many hundreds of mineral claims are located in this serpentine-bearing belt.

The serpentine in the Wenache Mountains has its greatest surface exposure to the southwest of Mount Stuart, on the head waters of the South Fork of Icicle Creek and of Fortune Creek, near the sources of the Middle and North forks of Teanaway River, along the south side of Ingall Creek, and throughout the area drained by Nigger Creek. Serpentine, with its accompanying igneous rocks, occurs also along the Peshastin in the neighborhood of Blewett, and extends about the eastern border of the Mount Stuart granite. To the north of the granite it has been traced, but not continuously, as far as Leavenworth. Whether the circle is completed on the west so as to inclose the granite has not been determined.

Throughout the belt of rugged country partially and perhaps wholly encircling the Mount Stuart granite, the serpentine forms very irregular and frequently isolated areas which separate and many times completely surround masses of schist and old eruptive rocks. In many localities these associated rocks, and especially the old eruptives, stand as bold mountains, while at other times the serpentine forms the greater part of prominent elevations. The serpentine predominates over the associated rocks in the rugged region to the southwest of Mount Stuart, where Ingall, Icicle, and Fortune creeks have their sources. The breadth of the outcrop is there about 3 miles, with but few isolated masses of other rock. Owing to the deep dissection of the formation by the streams mentioned, and the general absence of soil and vegetation, it is unusually well exposed and not only gives character to the landscape on account of its influence on the topographic form but also imparts its characteristic color to the scenery.

The serpentine in the Wenache Mountains presents two well-marked phases, the differences between them being due, in the main, to dynamical changes, which in many portions of the area have led to the crushing of the rock and extensive movements among the fragments produced. One variety of the serpentine is mostly dark green in color, but shows many variations, from nearly black through various shades of green, brown, and yellow to dark red. This variety is always greatly crushed and the sides of the fragments are rounded, smoothed, and frequently highly polished; that is, they have been ground against one another under great pressure, owing to the extensive movements that have occurred, and their surfaces slickensided. The second variety of serpentine is massive, not shattered, and usually dull green or yellowish green. The passage from one to the other of these varieties, although frequently abrupt, is in many instances gradual. The most conspicuous difference between the two varieties is that one has been crushed and otherwise altered by the movements that have occurred, while the other variety has not been affected in this manner. The massive variety is in large part peridotite and reveals the character of the rock from which the serpentine was formed. The fact that the crushed and slickensided serpentine differs in so marked a way from the massive "mother rock" suggests that the metamorphism it has experienced is largely due to the shearing and crushing.

The serpentine and associated schists and eruptive rocks in the outer border of the Wenache Mountains are older than the Mount Stuart granite, which was forced upward through them, and caused, in part at least, the strongly pronounced disturbances that characterize them. Fragments of serpentine and intimately associated rocks, as well as of the Mount Stuart granite, occur in the Swauk system, described later, thus showing that the Wenache Mountains were upraised before the deposition of the encircling sedimentary formation. In some instances, however, where the Swauk system comes in contact with the serpentine, there is a fault, and detached masses of sandstone occur several rods from the boundary, and completely inclosed in crushed and slickensided serpentine. The crushed serpentine also surrounds masses of greenstone, etc., varying in size from a few yards in diameter to much larger dimensions. In some of these instances the crushed serpentine is known to pass under the masses of rock referred to so as completely to inclose them. Larger masses of greenstone, etc., some of them making mountain peaks, are separated one from another by areas and dike-like bodies of crushed serpentine. At the contact the massive rocks are smoothed and striated. Again, in the Swauk system there are a vast number of basaltic dikes which have a remarkably uniform trend of N. 15° E. These will be described later. This system of dikes traverses the serpentine and the inclosed masses of old eruptive rocks, but where the dikes in the sandstone or in the older eruptive meet the serpentine they are usually broken off and the sheared surface of the basalt is smoothed and striated. The dikes in the crushed serpentine are frequently displaced from their normal position, and in some instances are turned so as to be approximately parallel with the border of the serpentine belt. The fragments of basaltic dikes in the serpentine lack the uniformity in trend that characterizes them where they cut the Swauk formation and some of the included masses of greenstone, etc., and have evidently been much disturbed. In the high ridge between the North Fork of the Teanaway and Stafford Creek the disturbances that have affected the basaltic dikes are well displayed, as is also the abrupt broken junction of the sandstone with the serpentine. Examination was made of several basaltic dikes which thus cut the sandstone and have their normal trend about N. 15° E. and can be followed into the serpentine area, where they turn fully 60° from their usual course and trend nearly east and west, parallel with the line of faulting which determines the junction of the Swauk formation with the serpentine and associated rocks at the locality referred to.

These observations, and many others of similar significance, show that intense movements have occurred since the deposition of the Swauk, and that during these disturbances the serpentine was to a great extent crushed and caused to flow. The evidence is such as to suggest that the Wenache Mountains have experienced at least two peiods of upheaval, during each of which marked disturbances occurred in the serpentine belts.

## SEDIMENTARY ROCKS.

One of the most interesting results of the explorations thus far made in the Cascade Mountains in Washington is the great extent and remarkable thickness of unmetamorphosed or but slightly altered sedimentary beds. Large portions of these strata, as shown by the fossils they contain, are of Cretaceous and Tertiary age, while other portions are of older date, perhaps of Juratrias, or possibly in part of Carboniferous, age. For the present we will consider these terranes as forming four divisions, under the titles—slate, pre-Cretaceous, Cretaceous, and Tertiary.

### SLATE.

What are thought to be in part the oldest stratified rocks, which are but moderately metamorphosed, met with up to the present time in the northern Cascades are certain fine-grained black slates. These slates occur in at least four distinct areas, but the absence of fossils in all except one of them and lack of other evidence make it impossible at present to state whether or not they are all of the same geological age. Black slates similar to those described below were found by Messrs. Willis and Smith near Snoqualmie Pass in 1895. These contained fossil leaves indicating Tertiary age. This find furnishes a suggestion as to the possible age of the similar slates farther north, but can not be accepted as definite evidence, except so far as the outcrops near Snoqualmie Pass are concerned.

Detached outcrops of black slate of limited extent occur in intimate association with serpentine, greenstone, gneiss, etc., on the south side of the Wenache Mountains, in the region drained by Nigger Creek and the head waters of the North and Middle forks of the Teanaway. The general trend of the slaty cleavage in these small areas is about east and west, or parallel with the southern border of the Mount Stuart granite.

Similar black slates, but with numerous quartz veins, usually a small fraction of an inch in thickness and running parallel with the cleavage, occur on each side of Sauk River for a distance of about 10 miles below the mouth of Whitechuck Creek. On the south side of the Sauk this terrane extends upstream for a distance of at least 2 miles above where Whitechuck enters the Sauk Valley from the northeast. The breadth of this area is unknown, but is certainly several miles. Rocks of the same description outcrop on the west bank of the Sauk for a distance of about 4 miles, beginning some 3 miles north of Darrington post-office. It is more than likely that these two areas are united. The valley bottom in the immediate vicinity of Darrington is occupied by alluvium, which conceals the underlying terrane. In each of the areas just referred to the strike of the predominant cleavage is about east-west.

Another area of black slate, probably of greater extent than either of those just mentioned, occurs on Ruby Creek and several of its branches, including Slate Creek. This area begins on the west, in the valley of Ruby Creek, approximately 5 miles above its mouth, and extends eastward to beyond the mouth of Slate Creek; its full extent eastward, as well as north and south from Ruby Creek, remains to be determined. Its known breadth from east to west is 14 miles. The major cleavage in this area is about north and south, or parallel with the strike of the heavily bedded stratified sandstones, shales, and limestones bordering the slate area on the east. These same slates extend far up Slate Creek, and form the excessively rugged Slate Creek Range, which is probably the most picturesque mountain ridge in the northern Cascades.

### PRE-CRETACEOUS.

#### VENTURA FORMATION.

In the mountains bordering Methow Valley, near the abandoned mining camp known as Ventura, there are thick-bedded sandstone, shales, and coarse conglomerates which have a characteristic reddish-brown color and are both lithologically and structurally distinct from the Cretaceous terranes bordering them on the east and west. This formation is here termed provisionally the Ventura formation.

The characteristic red sandstones and conglomerates of this system occur on each side of the valley of the Methow, from Robinson Creek eastward. On the north side of the valley they reach to the great bluff of greenstone known as Goat Wall, about 1 mile east of Ventura, but in the bold mountains forming the south side of the valley they have a much greater development and extend to within about 5 miles of Winthrop. The outcrops on the south side of the Methow have an extent, measured along the valley side, of about 15 miles. Throughout this distance the strata are highly inclined, and in places vertical. The rocks of this formation are well exposed at Ventura, but the outcrops are there obscured by landslides, and although not highly inclined, have diverse dips. On the north side of Lost Creek the dip is west at angles of from 25° to 30°, the strike being about north and south. At the mouth of Early Winter Creek, a tributary of the Methow from the west, and for several miles up that stream, the red Ventura rocks are conspicuously displayed. The strike is there north and south and the dip 45° to 50° E. Other dips and strikes show a diverse structure, due principally to folding along generally north-south axes, but the strata have also been faulted, sometimes in a conspicuous manner.

The exposures of the Ventura formation are abundant, and its history, as recorded both in the character of the rocks and in their structure, is easily read, but the multitude of details, the roughness of the country, and the very limited time available for study render it inexpedient to attempt to give an extended description of the formation at this time. The most that I can do at present is to point out the fact that an extremely interesting formation here awaits detailed examination.

No fossils have thus far been found in the Ventura formation, but its characteristic color, "Triassic red," and its association with the Similkameen formation on the west and with the Winthrop sandstone on the east, both of which are of Cretaceous age, suggest the hypothesis that it belongs to the Triassic. The formation has a wide extent both to the north and to the south of the Methow, as may be seen from commanding summits on account of its strong color. While it seems probable that the disturbances that have affected the Ventura, and given the strata their prevailingly steep dips, are the same in general that caused the close folding of the Similkameen formation, the structure is in marked variance with that of the adjacent Winthrop sandstone, thus showing the presence of a time interval between the two.

## CRETACEOUS.

### SIMILKAMEEN FORMATION.

To the east of the black slate so extensively exposed on Ruby Creek there is an area, at least 15 miles broad from east to west and extending far to the north and south of Crater Pass, which is composed mainly of sandstones, shales, and limestones, with quartzite and minor quantities of conglomerates and breccias near the bottom. These rocks have a thickness of at least 4,000 or 5,000 feet, and appear to constitute a well-defined formation, which I propose to term, provisionally, the Similkameen formation, since it is exposed throughout a large portion of the elevated region drained by the head waters of the river of that name.

The strata in this formation, so far as they have been seen, are frequently highly inclined and in many places stand nearly or quite vertical. The general interpretation of the structure is that it consists of a series of closely compressed folds having a north-south trend. In several instances, as on Gold Ridge, to the north of Crater Pass, the rocks dip eastward in such a manner as to indicate that the folds have been overturned to the west. In Gold Ridge, which is considered the eastern member of an overturned fold, the strata dip eastward at an angle of 8°, but when followed southward the dip increases and soon becomes vertical. The basal portion of the Similkameen formation consists of hard, nearly white quartzite, changing locally to conglomerate and breccia, as at the Eureka mine. The quartzite is some 800 or 1,000 feet thick and is succeeded by slates, sandstones, shales, and limestones. Beneath the quartzite, and in places extending upward into it in such a manner as to suggest that it has been intruded, are bosses of white granite. The granite and quartzite form a portion of the Cascade divide between the head waters of the Similkameen and

Ruby Creek. This divide is lower than the ridges to the east and west, and on every side there is evidence of deep dissection by stream erosion. The general absence of vegetation and the abundant outcrops, especially on Gold Ridge, make this an excellent locality for detailed studies of the lithology and structure of the system.

A thick bed of bluish sandstone at the base of Gold Ridge, penetrated by the tunnels of the St. Paul and Minneapolis mines, contains fossil ferns and nearly upright tree trunks. One sample of fern collected has been determined by F. H. Knowlton as approaching closely *Aspidium œrstedi*, from the Cretaceous rock of Greenland. A siliceous limestone in the same ridge, but several hundred feet higher in the series and extending southward to the border of Crater Pass, is abundantly charged with bivalve shells,[1] which, as determined by T. W. Stanton,[2] are of a species of *Actæonella*. The evidence furnished by the fossils just mentioned indicates a Cretaceous age.

This same formation extends far to the north, and, judging by distant views of the country obtained from commanding stations on the main divide, reaches to the north of the United States–Canadian boundary. Similar terranes are reported by George M. Dawson[3] to occur in the adjacent portions of Canada, and are termed "Paleozoic and Triassic of interior plateau (Cache Creek group, Nicola series, etc.)." The Cache Creek group, referred to in the legend just quoted, is stated in the report which the map accompanies (page 63 B) to be in part of Carboniferous age, while the Nicola series (page 81 B) is placed provisionally in the Triassic.

A more definite determination of the age of the rocks in question will have to be deferred until additional information concerning it is in hand.

The Similkameen formation occurs on each side of Crater Pass, and on its south border the beds stand vertical, forming a bold crest, which trends nearly east and west, at right angles to the strike of the strata. The same system extends eastward along Rattlesnake Creek to its junction with the Methow and eastward along the Methow to the mouth of Robinson Creek, where a nearly north-south fault occurs. On the west side of this break are black shales and gray sandstones of the Similkameen formation, and on the east are dark-red sandstones and conglomerates of the Ventura formation.

In many places the Similkameen formation is cut by dikes which

[1] Samples of these fossils were collected for me by Mr. Alac McClean, who also presented the fossil fern referred to above.

[2] In reference to these fossils Mr. Stanton says: "The most abundant species is a rather large form of *Actæonella*, which is probably undescribed—at least it differs from all the described American species. The genus is stated by Zittel to be thoroughly characteristic of Middle and Upper Cretaceous beds in Europe, and the oldest species known to me occur in the Lower Cretaceous, Comanche series of Texas. The Similkameen species may therefore be confidently referred to the Cretaceous system. The only other fossils observed on these fragments are some impressions of a *Cerithium* and an obscure bivalve shell which I am unable to identify."

[3] Geological map accompanying the annual report of the Geological Survey of Canada for 1877–78.

have a general north-south trend parallel with the longer axis of the folds into which the stratified beds have been crumpled. These dikes form two series, one composed of dark basic rocks corresponding closely to the basaltic dikes which cut the Mount Stuart granite and the Tertiary sandstones and shales to the south of the Wenache Mountains, and the other, by far the most abundant in the region about the head waters of the Similkameen and Methow, consisting of light-colored granite-porphyry. The basic dikes are represented by a well-defined example at the west base of Gold Ridge, which is exposed at the entrance of the St. Paul and Minneapolis mines. This diabase dike is from 3 to 4 feet thick, nearly or quite vertical, trends north and south, and cuts sandstones which dip eastward at an angle of 8°. The acid dikes are numerous, especially along Rattlesnake Creek, and many of them are of large size. One occurs in the bold crest to the south of Crater Pass, mentioned above, and forms its topmost pinnacle. It stands vertical, is parallel with the inclosing strata, and is, locally at least, an intruded sheet from 50 to 60 feet thick. Another similar, light-colored porphyritic dike occurs about one mile to the east of Crater Pass. This example, visible at a distance of several miles, is practically vertical, and, although somewhat irregular, has a width of from 45 to 60 feet and strikes N. 15° E. The inclosing strata dip eastward at an angle of about 30°. Other similar and nearly parallel dikes occur at intervals along Rattlesnake Creek, but are largest and most numerous near its mouth. Several of these dikes are from 40 to 60 feet wide. At what is known as Deadhorse Point, a bold promontory on the north side of the mouth of Rattlesnake Creek, there are several dikes, all probably branches of a single great intrusion of granite-porphyry. These dikes cut sandstone and associated rocks, which have a general strike of N. 10° W., but are much disturbed between the usually vertical dike sheets. Other dikes occur still farther east and may be seen cutting the sandstones and shales on each side of the valley of the Methow. The facts just stated will serve to show how greatly the Similkameen system has been broken and injected with molten magmas. In fact, the acid dikes, and perhaps interbedded sheets of igneous rock, compose no inconsiderable portion of the area occupied by the formation in question, and occur abundantly along the route followed from the head waters of Ruby Creek to near Ventura on the Methow. Their most constant characteristics are their nearly north-south trends, approximately vertical position, light color, and porphyritic structure.

At the head of the East Fork of Slate Creek and on the extreme head waters of the Similkameen the rocks are broken by numerous nearly east-west fissures, at right angles to the longer axes of the folds, which have been filled with quartz containing free gold. These fissure veins are now being explored and numerous mining locations have been made on them. The Eureka, Mammoth, St. Paul, and

Minneapolis mines, and numerous other prospects, are on veins of this nature, and in several instances hold out promises of rich returns when developed. Although my reconnaissance did not furnish an opportunity to study the numerous veins referred to, there seems no doubt that the Slate Creek mining district has a promising future.

Among the numerous interesting features of the Similkameen formation, none impress themselves on the attention of the geologist more forcibly than the fact that the rocks were intensely folded previous to the period of erosion which planed off the summits of the folds. It is in this region that the plateau character of the Cascade uplift, and the fact that it is an upraised peneplain, find the clearest proof. Since the old peneplain was upraised it has been deeply dissected by streams and also modified in a marked way by glaciation.

### WINTHROP SANDSTONE.

On the northern border of the valley of the Methow, about 5 miles northwest of Winthrop, there is a fine exposure of nearly white, massive arkose sandstone and light-gray, sandy shales which strike N. 20° E., and dip eastward about 80°. The relation of these beds to the red rocks of the Ventura system is shown on the south side of the Methow, opposite the locality just referred to, where the latter are well exposed with a strike N. 10° W. and a dip of about 80° eastward. The full extent of the Winthrop sandstone is unknown, but the portion seen has a thickness of some 2,000 feet, and extends far both to the north and to the south of the Methow Valley. Several of the more shaly layers are abundantly charged with fossil leaves, a small collection of which was submitted to Dr. F. H. Knowlton for examination. A preliminary report on these fossils is presented below, in which it is stated that they indicate a Cretaceous age.

#### PRELIMINARY REPORT ON A COLLECTION OF FOSSIL PLANTS FROM THE VICINITY OF WINTHROP, METHOW VALLEY, NORTHERN CASCADE MOUNTAINS, WASHINGTON, MADE BY PROF. I. C. RUSSELL, SEPTEMBER 4, 1898.

By F. H. Knowlton.

The material consists of about thirty pieces of matrix of a light-gray sandstone, upon which the plants are preserved with great fidelity. The flora consists of a mixture of ferns, conifers, palms, and dicotyledons, the latter not always satisfactory, as few of them are entirely preserved. The portions present are well enough preserved, but, as stated, they are somewhat fragmentary. The material embraces about three species of ferns, one conifer, one rather doubtful palm, and five or six species of dicotyledons. They may be distributed in part as follows:

*Gleichenia* sp. cf. *G. Zippei* Heer., *G. Rinkiana* Heer.
*Gleichenia* sp. cf. *G. Giesekiana* Heer.
*Cyathea* sp. cf. *C. angusta* Heer.
*Glyptostrobus?* sp.
Palm—genus uncertain.
*Rhus* sp. cf. *R. bella* Heer.
*Ficus?* sp.

This flora is in all probability altogether new, as I have not been able to correlate any of the species with previously described forms. They are not to be compared with any North American flora with which I am familiar, but find their closest affinities with the upper Cretaceous of Greenland. All of the forms I have mentioned in the above list as having more or less close relationship with the plants under consideration are found in the upper Cretaceous of Greenland.

When the additional material is at hand I hope to be able to make a more definite statement of the age of these plants, but at present I do not feel justified in making more than the following general statements:

(1) Not a single species in this collection has thus far been found in either the Ellensburg, the Swauk, or the Roslyn formations.

(2) Not a single species is to be found among those reported by Dawson in his paper on the "Fossil plants from the Similkameen Valley and other places in the southern interior of British Columbia." (Trans. Roy. Soc. Canada, Vol. VIII, pp. 75–91.)

(3) The plants appear to find their closest affinities with the upper Cretaceous of Greenland.

At the locality mentioned above, the Winthrop sandstone is cut by a dike of white diorite-porphyry from 25 to 30 feet thick, which trends nearly north and south and stands about vertical.

On the west and to the north of the Methow, the Winthrop sandstone comes in contact with greenstones, and south of the river joins the red sandstones of the Ventura formation, both formations, as just stated, standing nearly vertical but with strikes that diverge at an angle of 30°. On the east the boundary of the Winthrop sandstone is indefinite, so far as known, but seems to pass into a series of basic eruptives associated with shale and conglomerate, the age and relations of which are unknown.

The Winthrop sandstone agrees lithologically with portions of the Swauk and Roslyn sandstones described below, but, as shown by its fossils, is not of the same age.

## TERTIARY.

Within the area represented on the sketch map, Pl. IX, and on the east side of the Cascades, there are three areas, not including the black slate at Snoqualmie Pass, which are occupied by Tertiary rocks. These are, in their order from north to south, the Swauk sandstone, the Roslyn sandstone,[1] and the Ellensburg sandstone.

### SWAUK SANDSTONE.

The rocks included in this formation present two quite distinct phases, which led me during field work to divide them into two systems, one termed the Camas sandstone and the other the Wenache sandstone; subsequently, however, these terranes were studied, in part with considerable detail, by Messrs. Willis and Smith and were

[1] In Bulleton No. 108, U. S. Geological Survey, page 20, the author proposed the term "Kittitas system" for the formations here named the Roslyn and Swauk sandstones. It has been thought best to abandon the provisional name first used.

found by them to be the deposits of a single Tertiary lake or estuary; therefore the name Swauk sandstone was given to the entire formation, after the Swauk mining district, where it occurs.

About Camas Land, to the east of the Wenache Mountains, and in the valley of the Wenache, in the vicinity of Mission, Leavenworth, etc., the Swauk formation consists largely of thick-bedded, nearly white but still impure sandstone, with minor quantities of sandy shale. These rocks correspond closely with the characteristic white sandstone of the Roslyn formation. To the south of the Wenache Mountains, in the region drained by the North and Middle forks of the Teanaway and by Swauk Creek, the Swauk formation consists largely of thin-bedded, yellowish, arkose sandstone and yellowish, sandy shale, with a thick-bedded, coarse conglomerate of granite and serpentine at the base.

The Swauk formation occupies about 250 square miles in Wenache Valley, where it is bordered on the northeast by schists of the Entiat Range, and on the southwest by the granite and schists of the Wenache Mountains. In this portion of the area the rocks have been folded, the longer axes of the folds running northwest and southeast, or parallel with the bordering mountain ridges. In general, along the base of the Entiat Range the sandstone dips westward, or away from the range, at high angles, and in its basal portion consists largely of conglomerate. The evidence shows that the Entiat Range has, in great part at least, been upraised apparently in a monoclinal flexure, and has carried up the sandstone so as to give a steep dip to the layers in the now eroded fold. The junction of the sandstone with the schist, serpentine, and granite forming the mountains bordering it on the southwest is abrupt; the sandstone dips away from the crystalline rocks at high angles. Between the two inward-dipping borders of the Swauk, more especially in the region to the northeast of Leavenworth, the beds are arched upward into what seems to be a single great anticline, the upper portion of which has been eroded away.

Throughout nearly the entire area occupied by the Swauk sandstone, in the drainage area of Wenache River, the rocks are highly inclined, and have in part been greatly folded, but in an irregular manner. To the southeast of Camas Land, where the sandstone passes under the basalt capping Table Mountain, the folds have their longer axes in a general northwest-southeast direction and involve the basalt as well as the sandstone. The structure here indicated can not be represented on the accompanying map, owing to its small scale, but in part has been mapped by Willis and Smith, in connection with other details of the Mount Stuart quadrangle, which will be published as a folio of the Geologic Atlas.

As stated above, the Swauk sandstone passes under the sheet of basalt forming the surface of Table Mountain, and is thought to have a wide extension beneath that layer, but thus far evidence to sustain this hypothesis has not been obtained. The folds that have affected the two terranes, namely, the sandstone and the overlying basalt, have permitted erosion to cut away the superior member so as to form valleys in the plateau, of which the one occupied by Naneum Creek is an example, and to expose the shales and sandstones beneath, but these exposures are not sufficiently extended to enable one to trace the sandstone southward to where other similar beds are exposed. The western border of Table Mountain is a bold and in several places a vertical escarpment, from 400 to 500 feet high, surmounting a steep slope, which descends about 2,000 feet, vertically, to the adjacent valleys. The slope below the escarpment is encumbered with landslides and talus in such a manner as to conceal, to a great extent, the outcrops of the rock which occur below the basalt.

The Swauk formation extends southward of Camas Land and occupies nearly the whole of the drainage basin of Swauk Creek. This system also occupies a belt of country from 4 to 10 miles broad, from north to south, and encircles the southern border of the Wenache Mountains. The rocks consist of a thick, coarse conglomerate at the base, succeeded by thin-bedded, gray sandstones and sandy shales. The general thickness of the formation is, by estimate, 6,000 to 8,000 feet.

The basal conglomerate referred to, in places fully 200 feet thick, is composed of imperfectly rounded and frequently angular pebbles of granite, schist, old eruptive rocks (mostly greenstone), and serpentine. The terranes represented by these pebbles outcrop in the Wenache Mountains, and hence that uplift must have been in existence at the time the Swauk sandstone was deposited. Although this conclusion seems well sustained by the evidence just mentioned, there are certain features in the structure of the system which do not clearly harmonize with it. For example, the Swauk sandstone dips away from the Wenache Mountains at certain localities, and has clearly been upraised, together with the schists, greenstones, serpentine, and granite composing that elevation. The basal conglomerate of the Swauk is not only tilted but in places highly inclined, and the pebbles of which it is composed, as is shown in a number of exposures, have been crushed and faulted. Some of the bowlder-like masses of serpentine in the conglomerate are smoothed and slickensided, owing to movements in their matrix. These facts lead to the provisional conclusion that there have been at least two periods during which the Wenache Mountains have experienced an upward movement. This discussion, however, belongs more properly to the detailed report on the Mount Stuart quadrangle, and will therefore be postponed. The rocks of this formation rest unconformably on the schists, greenstones, serpentine, etc., forming the foothills of the Wenache Mountains, and are conformably overlain by

DIKES IN SWAUK SANDSTONE, HEAD OF STAFFORD CREEK.

volcanic tuffs and lava flows, designated in this paper the earlier sheet of the Columbia lava.

The most marked feature of the region occupied by the Swauk sandstone to the south of the Wenache Mountains is the manner in which it is traversed by dikes. These are all or almost all of dark, basic rocks, corresponding lithologically with the basalt known as Columbia lava, and occupy, in part at least, the fissures through which that extensive series of lava sheets came to the surface. The Columbia lava has been eroded from the area now occupied by the outcrops of the Swauk where the dikes occur, so as to furnish much information in reference to the manner in which the material forming the vast series of lava sheets was forced out. The dikes referred to occur in hundreds and probably in thousands. Practically they are countless. In one section near the head of Stafford Creek, about 5 miles southeast of Mount Stuart, fifty dikes, ranging in thickness from 15 to 60 feet, were observed in an area 3,500 feet broad, measured at right angles to their trend. Several other areas that were examined show fully as great a proportion of basaltic to sedimentary rocks. Individual dikes can frequently be traced with ease for a mile or two. On account of their numbers and the roughness of the country, it is not practicable, without extreme care, to follow an individual dike across ridges and valleys for a greater distance than that just stated, but there is every reason to believe that some of the larger ones are at least several miles in length.

The characteristics in reference to the dikes recorded above may be seen throughout the extent of the Swauk formation from the west base of Table Mountain westward across the Mount Stuart quadrangle. They have not been studied to the west of the area mentioned, but are known to occur there.

The dikes range in breadth from a few inches to 160 feet or more, large numbers of them being from 15 to 60 feet across. They trend with remarkable uniformity N. 15° E., and seldom vary from this direction, except locally, more than a very few degrees. Their hade is nearly vertical, but in the majority of instances has a westward inclination of 5° to 15° from a vertical plane. The dikes are frequently columnar, especially in their central portions, the columns being at right angles to their walls. In some instances the adjacent sandstones and shales are altered for a distance of 10 or 15 feet from the basaltic rocks, but more commonly no change in the country rock is noticeable. One marked feature in this connection is the slight degree to which the rocks bordering the dikes have been disturbed. In several instances where four or five dikes occur in close proximity the strata between them have the same strikes and dips, and are cut squarely off where they come in contact with the nearly vertical sheets of intruded material.

In connection with what has just been said in reference to the dikes of the Swauk sandstone, it is of interest to note that, with one exception, there is an absence of intrusive sheets. The instance referred to occurs at Camas Land, in the northeast corner of the Mount Stuart quadrangle, which owes its peculiar topography to an intruded sheet of gabbro. This sheet of resistant rock has maintained its position while the adjacent regions on all sides, except the southwest, have been lowered by weathering and deeply dissected by stream erosion. Camas Land is an elevated basin or shallow saucer-shaped depression, about 1 mile in diameter, floored with fine swampy soil, and in part by a remnant of the sandstone which was formerly widely spread above the sheet of gabbro. The intruded sheet referred to is from 50 to 70 or 80 feet thick and is upturned about its margin.

The system of basaltic dikes just described traverses the slates, schists, greenstones, serpentine, etc., which occur stratigraphically below the Swauk and come to the surface in the secondary peaks of the Wenache Mountains. In the serpentine, especially, the dikes are much disturbed, and their normal strike, as already stated, is changed in some instances to an approximately east-west direction. The dikes, in greatly diminished numbers and usually of small thickness, also traverse the Mount Stuart granite.

The Swauk sandstone to the south of the Wenache Mountains has not been crumpled into folds, as in the case of the portion of the same formation to the northeast, but upraised in at least two regions so as to have more or less quaquaversal dips. One of these regions has its center in the Wenache Mountains, and the rocks dip southward from the region about Mount Stuart as far as they have been traced. In my opinion, field observations favor the view that the Wenache Mountains experienced an upward movement after the deposition of the Swauk sandstone. Erosion has since removed a large portion of the stratified beds, and rivers have carved deep valleys in the part that remains.

The dip of the Swauk sandstone in the region adjacent to the southern border of the Wenache Mountains is southward at angles varying, in general, from 30° to 40°, but the prevailing dip decreases somewhat when followed southward, and becomes on an average 15° to 20° where the sandstone passes under the earlier sheet of Columbia lava. Although the fact that there is a general southward dip, and that the strike of the outcrops curve about the Wenache Mountains as a center, impresses one while on the ground, yet the multitude of dikes, some of them accompanied by local disturbances of the adjacent strata, renders a determination of the more detailed features of the structure uncertain.

A second uplift, but of much smaller size, which involves the Swauk sandstone, occurs in the area drained by Swauk Creek, adjacent to the west base of Table Mountain, but affects also a large portion of the rocks of which that mountain is composed. This elevation, if uneroded, would have an east-west diameter of some 6 or 8 miles, and a north-south diameter of 10 or 12 miles; its height above the present level of Swauk Creek at Liberty, for example, can not be accurately stated, but would be in the neighborhood of 5,000 feet. All the upper portion of this elevation has been eroded away, leaving the harder beds in the truncated base in relief, so that the central part of the uplifted region is now topographically a basin. In this basin, which is diversified by ridges and valleys, lies the Swauk Creek mining district. This district is traversed by many basaltic dikes, on the sides of which there are frequently fissure veins, filled with quartz and calcite and carrying gold.

The disturbances that have affected the Swauk sandstone and other systems which overlie it will be described more fully later, in connection with a discussion of the general structure of the Cascade region. At many localities the Swauk formation was found to be abundantly charged with fossil leaves, which, as determined by F. H. Knowlton, are of Eocene age.

The Swauk sandstone is succeeded above, at least in part, by probably conformable beds of lapilli and lava sheets, which will be described later, in connection with other sheets of Columbia lava. Resting on this sheet of igneous rocks there occurs an important Tertiary formation termed the Roslyn sandstone.

#### ROSLYN SANDSTONE.

The coal mined at Roslyn, with its associated shales, occurs beneath thick-bedded, light-colored sandstone, and is underlain by rocks of the same general character. For this entire system of sedimentary beds, passing below into the tuff accompanying the lowest sheet of Columbia lava and overlain by a second sheet of lava, the name Roslyn sandstone is here proposed.

The boundaries of the Roslyn sandstone within the Mount Stuart quadrangle are shown on the accompanying map, but, for several reasons, are less definite than could be desired. In the first place, I have nowhere found its junction with the tuffs associated with the lowest sheet of Columbia lava to be abrupt and well marked.[1] One terrane passes into the other by insensible gradations, and it is probable that no two observers would draw the boundary in precisely the same place; yet it is believed that the line on the map representing the lower limit of the Roslyn sandstone is not far from the

[1] Mr. Willis, from observations made since this was written, states that the base of the Roslyn on the Teanaway is precisely determined by a conglomerate containing pebbles of basalt.

average position that would be assigned it by several observers. Again, the upper limit of the Roslyn, especially in Yakima Valley, is indefinite, owing to the fact that the junction with the next higher formation is obscured by gravel deposits and landslides. It is known from coal mines and deep borings, however, that the sandstone passes under the valley gravels near Clealum and extends as far south as Yakima River. Near Teanaway Station, on the Northern Pacific Railway, the sandstone forms a conspicuous outcrop on the north side of the flood plain of the river.

At the west base of Lookout Mountain the Roslyn sandstone passes beneath white volcanic tuffs occurring just beneath the lava sheet (the next later sheet of the Columbia lava) which forms the summit of that sloping table-land. The junction of the Roslyn with the rocks next above is here again greatly obscured by landslides. To the north of Lookout Mountain the Roslyn sandstone underlies the valley which extends eastward past McCallum and up the course of First Creek. Immediately east of McCallum the area occupied by these rocks rapidly contracts to less than a mile in width, but their position is quite definitely defined by the topography. On the north side of the valley of First Creek there rise steep hills composed of volcanic tuff and lava belonging to the earlier sheet of the Columbia system, and on its south side are cliffs formed of the broken edge of the second sheet of Columbia lava or the one forming the surface of Lookout and Table mountains at their western margins. These so-called mountains, it is to be noted, are in reality plateaus sloping gently southward and eastward. Between the two prominent elevations formed by the first and second sheets of Columbia lava lies the deep wooded valley through which First Creek flows westward to join Swauk Creek.

On ascending First Creek to what is known as Green Canyon one finds a wind gap in the ridge of lava joining Lookout Mountain with Table Mountain. This gap leads southward, and is plainly a stream-cut channel from which the creek that excavated it has been diverted. A stream of considerable volume once flowed through this gap, coming from the central part of the Swauk Creek dome, but was diverted by First Creek, which extended its head waters along the outcrop of Roslyn sandstone and captured its waters above the entrance to Green Canyon. This capture was somewhat recent, and at the locality where it occurred a large body of Roslyn sandstone is exposed in just the position where one studying the origin of the topographic features of the region would be led to expect it. At this locality light-colored sandstone, having all the characteristics of the similar rocks near Roslyn, is exposed over an area of about 1 square mile. At the north end of Green Canyon there is an abandoned shaft in which coal is said to have been reached.

Eastward from Green Canyon the outcrops of Roslyn sandstone are concealed beneath landslides, but the topography indicates the course it must follow. Near Reeser Point, the west escarpment of Table Mountain turns abruptly northward, and the outcrop of the Roslyn system must make a similar bend, and should be looked for beneath the talus slopes that stream down from the palisade of basalt forming the western margin of the plateau.

This prediction is abundantly confirmed by the occurrence of a good outcrop of fine, black, thinly laminated shale, already referred to, at the west base of the highest portion of the escarpment of Table Mountain. A thickness of 35 feet of shale with thin layers of impure coal is there exposed. As nearly as one can judge, the entire thickness is not far from 100 or 150 feet. Beneath the shale there is a layer of columnar basalt 80 feet thick, which rests on evenly bedded tuff from 100 to 150 feet thick. The basalt just mentioned belongs to the Columbia system, and is intermediate between what I have termed the earlier and later sheets. At present no other exposures of this sheet are known, and it is believed to be local. It is important to note that here the Roslyn sandstone decreases in thickness to probably less than 200 feet, and consists of thinly laminated, fine-grained, highly carbonaceous shale. Evidently the mud forming these beds was deposited in the central part of the basin, far enough from its shores to escape being mingled with sands washed in by tributary streams. The significance of the marked contrast that these rocks present, both in composition and in thickness, with the western portion of the same system in the vicinity of Roslyn will be considered later.

It is of interest to note here that along Naneum Creek, which heads near the western verge of the Table Mountain Plateau and flows eastward in a deep canyon, thin, black shales, with coal, are reported to occur and to have been examined for coal. Naneum Creek has evidently cut through the later sheet of Columbia lava and into the rocks beneath it. These and other observations indicate that the Roslyn system extends northward along the base of the escarpment of Table Mountain, but it has not been traced continuously in the field. The topographic conditions indicate its presence, although the outcrops are deeply covered by talus slopes and landslides.

The Roslyn system consists of massive, light-yellowish, and in places nearly white, arkose sandstone, composed of quartz and feldspar, and black shales with coal seams. The sandstone predominates and makes up by far the larger portion of the formation. The shales belong in the central portion of the system and are underlain by massive sandstone and covered by equally massive rocks of the same character. Conglomerates are notably absent, although thin bands of well-worn pebbles of light-colored igneous rock occur at times. These pebbles are different from any rocks yet discovered in place within the neighboring mountains.

The character of the rocks in the central portion of the Roslyn system is shown by the following section, obtained from the records of the main shaft at the Roslyn coal mines, in the town of Roslyn, and kindly supplied by the superintendent of the mines:

*Section exposed in main shaft at Roslyn coal mines*

[Strike N. 60° W.; dip S. 12°-14°.]

| | Ft. | in. |
|---|---|---|
| Surface material; loose talus slopes | 50 | 6 |
| Sandstone and shale | 18 | 0 |
| Coal | 2 | 8 |
| Sandstone and shale | 16 | 0 |
| Sandstone and shale | 31 | 0 |
| Shale | 5 | 0 |
| Coal and black shale | 3 | 8 |
| Shale and sandstone | 40 | 0 |
| Shale | 24 | 0 |
| Sandstone | 56 | 0 |
| Shale | 4 | 0 |
| Sandstone | 22 | 0 |
| Shale and sandstone | 74 | 0 |
| Sandstone | 16 | 0 |
| Black shale | 3 | 0 |
| Dark shale | 30 | 0 |
| Coal No. 1, "Big Dirty seam" | 19 | 0 |
| Sandstone | 60 | 0 |
| Coal No. 2, with some sandstone | 3 | 2 |
| Shale | 9 | 0 |
| Sandstone and shale | 9 | 0 |
| Coal No. 3, mixed with shale | 2 | 2 |
| Shale | 34 | 0 |
| Shale, sandy | 3 | 0 |
| Coal No. 4, with black shale, sandy | 4 | 2 |
| Shale with sandstone | 42 | 0 |
| Shale | 9 | 0 |
| Shale | 5 | 0 |
| Coal No. 5, Roslyn seam | 5 | 4 |
| Total | 600 | 8 |

The shale mentioned in this section is mostly fine grained and dark colored, but at times becomes sandy, although still of a dark color on account of the organic matter present.

The outcrops of the Roslyn system, so far as the area embraced in the Mount Stuart quadrangle is concerned, curve about the southern slope of the Wenache Mountains. In the Yakima Valley the outcrops of the strata run northwestward and southeastward and dip to the southwest. More accurately the general strike, as, for example, in the bold ridge north of Roslyn, Clealum, and Teanaway, is N. 60° W., and the dip southwest from 12° to 18°. When the terrane is traced eastward the strike becomes east and west, and the dip increases. At a good exposure on First Creek near Green Canyon the dip is S. 32°.

Northward from this locality, and at the head of Williams Creek—that is, at the base of the west escarpment of Table Mountain—the strike is nearly north and south and the dip east at angles of 4° or 5°.

In a section running northeast and southwest through Roslyn we find a breadth of 12 miles of Roslyn sandstone and shale, in which the dip varies from 5° to 20°. Throughout this section, as determined by Willis, there are numerous small faults and landslides which make measurements uncertain, but as nearly as can be ascertained the system is not less than 3,500 feet thick.

Extensive collections of fossil plants made at the Roslyn coal mine, and at other mines near Clealum, have been studied by F. H. Knowlton and show the rocks to be of Eocene age.

### ELLENSBURG SANDSTONE.[1]

Along the immediate banks of the Yakima between Dudley and Ellensburg there are good exposures, in some instances embracing about 200 feet. These contain much volcanic dust and two beds of sandstone from 6 to 8 feet in thickness. In this section also there are loose, incoherent conglomerates, containing well-worn pebbles 5 to 8 inches in diameter. With these beds, composed of the water-laid débris derived from older terranes, there are sheets of volcanic lapilli and white volcanic dust.

This series of beds rests on a sheet of lava, and, as shown by a well drilled 2 miles northeast of Ellensburg, on the farm of Charles A. Sanders (sec. 30, T. 18 N., R. 19 E.), is about 700 feet thick. The entire thickness of the sedimentary material flooring Kittitas Valley, in which Ellensburg is situated, is at least 800 or possibly 1,000 feet. At the south end of the valley, and about 1 mile from where the Yakima River leaves it and enters a narrow gorge in basalt, there is a small quarry, where light-colored, friable sandstone, composed largely of volcanic dust, has been taken out and used for building purposes in Ellensburg. Associated with the sandstone are thin layers of well-rounded pebbles, imperfectly cemented, and thick layers of fine, white clay. Some of the layers of sandstone and clay bear the impressions of leaves in a good state of preservation. A small collection of these fossils, obtained by me in 1892, has been studied by F. H. Knowlton, who found them to consist of ten species, mostly of willows, poplar, elm, platanus, and magnolia. This shows that the lakes in which the rocks containing these fossils were deposited were surrounded by a luxuriant flora, of a character indicating a much milder climate than central Washington now enjoys. The age of the beds, as shown by the fossil plants, is upper Miocene.[2]

[1] The relation of the Ellensburg sandstone to the John Day beds (Oregon) and the Auriferous gravels of California is discussed in Bulletin No. 108 of the United States Geological Survey.

[2] F. H. Knowlton, Bull. U. S. Geol. Survey No. 108, pp. 103-104.

As has been stated, the outlet of Kittitas Valley is through a narrow canyon, cut in basalt. This basalt sweeps about the southern border of the valley in a precipitous line of escarpments and bold bluffs, but whether these indicate a fault or the weathered border of a sheet of basalt which occurs geologically above the stratified beds about Ellensburg has not been determined.

## SUMMARY.

The sedimentary rocks of the northern Cascades may be divided into two great classes, namely, those of pre-Tertiary and those of Tertiary age. The former again fall in two classes, in respect to the changes they have suffered, some of them being metamorphosed and others practically unchanged. The metamorphosed rocks are now schists, gneisses, granites, etc., and their age is unknown. The unmetamorphosed pre-Tertiary sediments, represented by conglomerates, sandstones, shales, limestones, etc., embraced principally in the Similkameen, Ventura, and Winthrop formations, exposed over extensive areas near the Canadian boundary, are believed to be in part Carboniferous, but mainly of Mesozoic age. This conclusion, however, is based on a small number of fossils, and is tentative.

The Tertiary, probably including some and perhaps all of the black slate of Snoqualmie Pass, Sauk River, Slate Creek, etc., and the Swauk, Roslyn, and Ellensburg sandstones, are of fresh-water origin; at least, no evidences of marine life have been found in them, and they are considered as the sediments of large Tertiary lakes. Fossil leaves are abundant at many localities in these deposits, and on this evidence a judgment of their geological position has been based. The relative age of the Swauk, Roslyn, and Ellensburg sandstones is known from their stratigraphic arrangement. The Swauk is the oldest of the three, and is separated from the Roslyn by the earlier sheet of Columbia lava and its associated tuffs; and the Roslyn is separated from the Ellensburg, which occurs stratigraphically above it, by the several later sheets of Columbia lava and their associated tuffs.

As the Columbia lava, to be described later, in the region under consideration is interbedded with Tertiary sediments, its age is evidently middle Tertiary, The great disturbances affected the region embraced in the northern Cascades after the Tertiary sediments and associated Columbia lavas were spread out, and hence the range, as we now know it, may be considered as having been elevated in late Tertiary or post-Tertiary time. The best provisional determination of the date of the upheaval of the great block of the earth's crust from which the present peaks and ridges of the Cascades have been carved seems to be that it occurred during the Pliocene.

## VOLCANIC ROCKS.

The volcanic rocks in the portion of the Cascade Mountains under consideration, but not including the greenstones and other old eruptives, of which but little definite information is at present available, belong in two well-defined groups, namely, the Columbia lava and the andesite composing Glacier Peak. The numerous basaltic dikes that occur in various localities, and which, in many instances, probably lead to surface flows now eroded away, have already been considered in connection with other features of the rocks they traversed.

### COLUMBIA LAVA.

The vast region occupied by sheets of basalt termed the Columbia lava lies principally to the southeast of the portion of the State of Washington embraced in this report, and has been described in part by various writers,[1] but never systematically studied. Its area is estimated at between 200,000 and 250,000 square miles, and its thickness, as exposed in the canyon of Snake River, is in excess of 4,000 feet. This great series of lava sheets barely enters the southeastern portion of the field under consideration, but is of special interest, as its border is there well exposed, as is also a large area of sandstone traversed by numerous dikes, from which the lava has been eroded. The Columbia lava, in common with the Swauk and Roslyn sandstones, has been upraised, and the removal of the upper portions of these elevations has left exposed the edges of four distinct sheets of lava. The lowest of these sheets formerly extended to near the base of Mount Stuart, and covered a region many miles square to the southwest of that peak, as is shown by the vast number of truncated dikes exposed in the Swauk sandstone. The second, third, and fourth sheets of lava, portions of which now form the surface of the Table Mountain Plateau, also had a broad expansion over the region between the west face of Table Mountain and Mount Stuart, but the full extent of country from which these sheets have been eroded has not been satisfactorily determined. The lowest sheet of Columbia lava in the region to the south of Mount Stuart, and embraced in the Mount Stuart quadrangle, is separated from the second sheet by the Roslyn sandstone,

[1] The following is a partial list of the publications in which the Columbia lava is described:

George Gibbs, Report on the geology of the central portion of Washington Territory: "Pacific Railroad Reports," Vol. I, 1854, pp. 473–486.

F. Baron Richthofen, The natural system of volcanic rocks: Memoirs California Academy of Sciences, Vol. I, Part II, 1868.

Joseph Le Conte: Am. Jour. Sci., Vol. VII, 3d series, 1874, p. 168.

T. W. Symons, Report of an examination of the Upper Columbia River: Senate Executive Document No. 186, Forty-seventh Congress, first session, 1882.

I. C. Russell, A geological reconnaissance in central Washington: Bull. U. S. Geol. Survey No. 108, 1893. A reconnaissance in southeastern Washington: Water-Supply and Irrigation Paper U. S. Geol. Survey No. 4, 1897. Volcanoes of North America, The Macmillan Co., New York, 1897.

which, as previously stated, has a thickness of from about 200 to 3,500 feet or more. The higher sheets of lava in the Columbia series are, in places, separated one from another by layers of volcanic lapilli and volcanic dust, as well as by lacustral clays, but in the area under consideration these partings do not claim special attention.

The lowest sheet of Columbia lava consists of lava flows, of which there are several, and associated volcanic tuffs. In intimate association with these, in the region embraced between the North and Middle forks of Teanaway River, there are peaks composed of nearly white rhyolite. The relation of the rhyolite to the Columbia basalt is not well known, but it seems to be a dike exposed by erosion and much shattered and altered in color by weathering.

The massive layers of basalt in the lowest general sheet of Columbia lava consist of fine-grained rock with a glossy-black color, which breaks with a conchoidal fracture and is crossed in all directions by a network of thin seams, which are almost imperceptible to the unassisted eye, except on weathered surfaces. Where the rock has been long exposed it frequently exhibits a well-characterized perlitic structure in the spaces bounded by the small seams and joints. Although commonly compact and massive, it sometimes becomes scoriaceous, and contains cavities of all sizes up to 4 or 5 inches or more in diameter, which are usually filled with compact, yellowish, chert-like material or lined with quartz and zeolite crystals. These characteristics seem, at least locally, to distinguish the first sheet of lava from others higher in the series. The rocks just described are frequently jointed, but the columns thus formed are seldom conspicuous or noticeable for their regularity. At a few localities, especially along the Middle Fork of the Teanaway, the sides of the joints which divide the basalt present glossy-black or brownish-black surfaces, divided by a series of rectilinear lines, so as to give them an appearance resembling the leather made from alligator skin. The lines which cover the surfaces of the major joint planes are due to secondary joints, which die out at a depth of about one-fourth of an inch. One side of each secondary joint is usually raised slightly above the other, so as to produce a little step or offset on the surface of the plane produced by the master joint. At first glance the glossy surfaces of the columns appear to be due to slickensiding, but the little offsets referred to preclude this explanation. In reality their brilliancy is due to a thin film of glass-like material, possibly the mineral hisingerite, which has been deposited on them.

The volcanic tuffs, associated so abundantly with the massive lava flows of the earlier sheet of Columbia lava, are usually fine grained, and of a dark-purple color when unweathered, but present a great variety of reds, yellows, browns, etc., on exposed surfaces.

Both the lava flows and the sheets of tuff described above are of variable thickness, and no satisfactory measure of their vertical extent has been made. In places, as on the Middle Fork of the Teanaway, the tuffs are certainly 3,000 or 4,000 feet thick, and in the same region the massive, glossy-black basalt is fully as thick, but thins away rapidly when followed eastward, and is wanting on the North Fork of the Teanaway, where tuffs alone represent the series. The sharply upturned border of the earlier sheet of Columbia lava is cut across by Swauk Creek between Liberty and McCailum.

The outcrops of the division of the Columbia under consideration cross the area embraced in the Mount Stuart quadrangle, in its central portion, from west to east, but not in a linear belt. To the west of the center of the quadrangle the lava sheet forms an irregular arc of a circle, while in the eastern portion of the quadrangle it sweeps about the western and southern border of the Swauk Basin. In the first-mentioned instance the dip is at an angle, in general, of about 15°, and in the second instance is much more highly inclined, especially in the southwestern and southern portions of the curve, where the inclination is usually 30° to 40°. On the east of the Swauk district the lava flows under consideration thin out, and the tuffs become indefinitely defined, but pass beneath the second sheet of Columbia lava, which forms the surface of Table Mountain. The westward extension of these rocks in the region embraced in the Snoqualmie quadrangle has not been traced.

The earlier sheet of the Columbia lava rests comformably on the Swauk sandstone, and is overlain conformably, so far as can be judged, by the Roslyn sandstone. Each of these junctions is obscure, however, and where the tuffs come in contact with either of the inclosing terranes the passage from one to the other is indefinite, the tuffs being in part interbedded with the sandstone and vice versa. In part the lava flows and tuff sheets seem to have been formed in the same Tertiary lake basins in which the Swauk and Roslyn sandstones were deposited.

The second or Table Mountain sheet of Columbia lava is much more uniform in thickness than the earlier sheet, and more widely spread. It consists of dark-gray or black, massive basalt, which breaks with a granular fracture, and is for the most part free from scoria and steam holes. This rock, as determined by George Otis Smith, has a crystalline texture, plainly visible without the aid of a microscope, and when examined in thin sections is easily recognizable as being basalt and distinct in its microcrystalline structure from other associated sheets in the Columbia series. It is porphyritic, with a glassy base, and carries feldspar as its most important constituent, while the augite present exceeds the olivine. In distinction from the first sheet, described above, the rock is without the fine, glassy texture and glossy-black color, previously mentioned, and also lacks the perlitic structure, geodes, etc., found so commonly in the lower sheet.

There are large quantities of volcanic tuffs associated with the second sheet, especially beneath the principal lava flows, which are usually light colored and of much more acid character than the lava. On the western slopes of both Table and Lookout mountains these tuff beds have a thickness of at least several hundred feet, but are nearly everywhere concealed by landslides and talus slopes.

The geographic distribution of the outcrops of the several sheets of Columbia lava within the area embraced in the accompanying map is, in general, much the same as in the case of the lower sheet of the same series; that is, the outcrops in a general way circle about the Wenache Mountains and Swauk Basin, but being farther removed from the center of elevation the dip of the exposed edges of the layer is less than in the case of the first sheet. The lava forming the surfaces of Table and Lookout mountains is inclined away from the center of the Swauk dome at angles in general of 4° or 5°, and presents a nearly vertical inward-facing escarpment. West of Lookout Mountain and forming the south side of Yakima Valley there is a continuation of this general line of escarpments, the summit portion of which is formed by the same lava sheet, which there dips southward at an angle of from 3° to 5°. This escarpment runs nearly east and west and is in general about 2,000 feet high, the precipitous upper portion, approximately 400 feet high, being formed of the broken edge of the second sheet of Columbia lava. This sheet, as just stated, is inclined gently south ward, the dip decreasing in that direction, and constitutes the surface of a table-land, termed, for convenience, the Clealum Ridge, which corresponds with Table Mountain in its essential features, but is much narrower and more deeply dissected.

The Clealum Ridge is topographically one of the most pronounced of the secondary features in the relief of the area embraced in the Mount Stuart quadrangle, and has a great extension westward, its entire length being in the neighborhood of 40 miles. From where the Yakima River breaks through this escarpment, just south of Lookout Mountain, westward to the vicinity of Clealum Point, it is a continuation of the similar escarpment forming the western border of Table and Lookout mountains, and is therefore a cliff of recession, but its western extension exhibits other features, due, it is believed, to faulting.

The second sheet of Columbia lava is of so wide extent that it has been affected not only by local uplifts, as just stated, but by the elevation of the far greater Cascade Range. This becomes apparent in views of the Clealum Ridge obtained from peaks to the north of it. In clear weather an observer standing on Redtop or other prominent points along the outcrop of the first sheet of Columbia lava may see to the south of his station not only the bold northward-facing escarpment of Clealum Ridge, but the country to both the east and the west, and can trace the second sheet of Columbia lava from the desert region adjacent to Columbia River, where the elevation is only a few hundred feet above the sea, to the crest of the Cascades, where the same sheet of lava has an elevation of about 6,000 feet. This ascent is made in a distance of 50 or 60 miles. The same sheet of lava can be seen to cross the highest portion of the Cascades in the region referred to, and to extend at least several miles westward. Evidently the Cascade Plateau has been upraised since the second sheet of Columbia lava was spread out. Its present position, while influenced in a broad way by the great Cascade uplift, has been given sharper local dips by the smaller elevations referred to on the eastern flank of the main uplift.

The border of the second sheet of Columbia lava exposed in the escarpment forming the western margin of Table Mountain has been traced northward to where it crosses the Columbia a few miles downstream from Wenache, and from there along the eastern border of the valley of the Columbia to beyond the mouth of Okanogan River. This portion of the sheet and its wide extension in the Great Plains of the Columbia have been briefly described in a previous report.[1]

On Table Mountain in the vicinity of Reeser Point and about a half mile eastward from the westward-facing cliffs formed by the second sheet of Columbia lava, there is a line of precipices, in general about 200 feet high, which is due to the outcrop of a third lava sheet. This sheet is approximately from 300 to 350 feet thick and composed of cellular basalt, gray in color, and readily distinguishable, at least locally, from the older flows in the same general series. The abundant steam cavities in the third lava sheet are not lined or filled with quartz or other minerals of secondary origin, and in this respect differ from the amygdaloids found so frequently in the lowest sheet and its associated tuffs.

The third lava sheet at its outcrop has a more gentle dip than the sheet below it. The two sheets are essentially comformable, however, and the lower inclination of the upper sheet is due to its greater distance from the center of the uplift. Owing to the absence of thick beds of tuff or other soft rocks beneath this scoriaceous lava, its outcrop does not stand up so prominently as the escarpment formed by lava number two. The presence of volcanic tuff between these two sheets is suspected mainly from the topography of the region between their palisade edges, but has not been seen.

To the eastward of the outcrop of the third sheet of lava in the vicinity of Reeser Point there is another line of low cliffs, due apparently to the outcrop of the edges of a fourth lava sheet, with a gentle eastward dip. The character and extent of this fourth sheet remain to be determined.

The third and fourth sheets of lava, just considered, do not occur

[1] Bull. U. S. Geol. Survey No. 108, 1893.

on Lookout Mountain, and have not been detected to the south of Yakima Valley. As is known from previous studies in central and southeastern Washington, the several sheets of lava exposed in the region just described are succeeded by other similar flows, many of them of wide extent and probably as important as the great Table Mountain sheet just considered. The number of separate overflows in the entire Columbia system is not known, but is certainly a score or more. These may be recognized by their scoriaceous surfaces, and also by the fact that they are sometimes separated by beds of sedimentary origin which in several instances contain fossil stumps and tree trunks. As previously stated, the best exposures of the Columbia lava occur in Snake River Canyon, where the original horizontal position of the sheets is maintained and a vertical thickness of 4,000 feet may be seen in a single great escarpment.[1]

### ROCKS OF GLACIER PEAK.

Glacier Peak, as previously stated, rises from the summit portion of the Cascade Mountains, between the head waters of Wenache River, which flows eastward, and Sauk River, which flows westward. The peaks have an elevation of 10,436 feet and rise about 2,500 or 3,000 feet above the general level of the Cascade Plateau. This prominent peak is the remnant, considerably modified by erosion, of a volcanic mountain which was formed on the Cascade Plateau previous to its being deeply dissected by the stream erosion. The volcano referred to was in action after the period of extensive base-leveling which produced the broad peneplain afterwards upraised; but there is but little direct evidence whether the volcano came into existence previous to the upheaval of the old peneplain or subsequent to that event. As the old volcano still retains the form of the original cinder cone, although rising well above the snow line, and therefore exposed to the full rigors of an alpine climate, it seems evident that it has not been in existence during all of the time that has witnessed the deep dissection of the plateau on which it stands. Judging from the amount of erosion that the peak has suffered, as compared with similar work on the plateau, it seems as if the peak is relatively young, and must have been formed since the plateau on which it stands acquired about its present position.

Glacier Peak is a cinder cone, composed in large part of lapilli, from which a stream of lava 3 or 4 miles in length flowed southward. The effusion of lava was rather small, however, unless streams not yet seen exist on the north side of the peak. The rock is andesite, usually of a dark-purple color, with prominent crystals of feldspar, and takes on various forms, from a compact, glassy, porphyritic structure, as exhib-

[1] Some account of the Columbia lava in southeastern Washington has been published by me in Water-Supply and Irrigation Paper U. S. Geol. Survey No. 4, 1897.

ited in the lava flow, to scoriaceous and even nearly white pumice in the cinder cone.

About Glacier Peak, especially on the divide between the head waters of the Sauk and White Creek, there are many dikes, some of them 50 to 60 feet wide, which in a general way radiate from the volcano and are composed of similar rock. Widely scattered over the Cascade Mountains from Lake Wenache westward there are fragments of light-yellow pumice, sometimes in sufficient abundance to form a large portion of the soil. These accumulations occur especially on the summits of ridges, and seem to have a connection with the old volcano, the cold and ice-sheathed remnant of which forms Glacier Peak.

The prominent mountain just described is the only recognizable remnant of a volcano known at the present time in that portion of the Cascade Mountains under consideration. It is believed to belong to the same category as Mount Baker, Mount Rainier, etc., which constitute a group of now extinct andesitic cones. While some evidence of residual volcanic heat still lingers about the summit of Mount Rainier,[1] steam fissures or heated rocks were not observed on Glacier Peak, which is almost completely snow covered above an elevation of about 6,000 feet, and gives origin to several glaciers.

On Indian Pass there is an accumulation of dark-brown and reddish lapilli, which has a thickness of upward of 80 feet, and which consists of basaltic material and contains numerous basaltic bombs. This is the only accumulation of this nature met with during the explorations here described, and its source is unknown. Although only about 5 miles from Glacier Peak, it was evidently not thrown out by that volcano, as it differs widely in character from the rocks composing that mountain. The basaltic lapilli referred to occur on the Cascade divide, on the north side of Indian Pass, in just the topographic situation where it would be longest spared by erosion. On account of its position and, so far as known, the absence of other similar deposits, it may be assumed to be of very considerable age.

### SUMMARY.

The igneous rocks of the northern Cascades include great masses of intruded granite which is in all cases light colored, and frequently nearly white, each separate area of which usually shows minor variations peculiar to itself. Associated with the granite and closely related to it are light-colored diorites and similar rocks which on weathering produce topographic forms similar to those characteristic of the true granitic areas. The granites and allied rocks are usually jointed in a conspicuous manner. The influences of these joints on

[1] An account of the present condition of Mount Rainier, by myself, may be found in the Eighteenth Ann. Rept. U. S. Geol. Survey, Part II, 1898.

the rugged spires and cathedral-like forms resulting from weathering are among the most characteristic details in the magnificent scenery of the Cascade Mountains. The granites and related rocks are in general of the nature of massive boss-like intrusions on a grand scale, which have raised into domes the stratified and other terranes beneath which they were injected. The dome, in distinction from anticlinal folds, I consider one of the important elements in the structure of the region under discussion. Diverging from the granitic cores of these domes there are in some instances true granite dikes.

Plutonic rocks are also represented by a great number of dikes, which form two classes, namely, acid and basic. In each of these two classes, but especially in the first, there are several well-marked types. The acid dikes are all or nearly all composed of light-colored porphyritic rocks, and include andesites, rhyolites, diorites, etc. The basic dikes are mostly of basaltic rocks and occur in greatest numbers in the Swauk (Eocene Tertiary) sandstone, but also cut the Mount Stuart granite in a few instances. At least one basaltic dike occurs in the Cretaceous rocks of the Similkameen formation.

A common feature of all the dikes, whether acid or basic, is the fact that in general they have a nearly north-south trend. Perhaps, more accurately, their general direction is in the neighborhood of N. 15° E., but there are many departures from so strict a generalization. This general trend, it will be observed, is in the direction of the longer axis of the Cascade Plateau, and corresponds also with the trend of the longer axis of the folds into which the rocks have been pressed, more especially in the great area of sedimentary beds adjacent to the Canadian boundary, but nearly at right angles to the folds in the Swauk sandstone to the east of the Wenache Mountains. The prevalence of a nearly north-south trend to the dikes is rendered conspicuous by the absence of wide departures to the rule. No east-west dikes have been observed except in the much-disturbed region at the south base of the Wenache Mountains, where marked deformations have occurred in late Tertiary time, which have displaced the dikes previously formed; and in the immediate vicinity of Glacier Peak, where dikes of andesite radiate from the base of that old volcano.

Many of the dikes about the south base of the Wenache Mountains, which originally consisted of a peridotite, have been changed to serpentine. This change seems to be due largely to the crushing, and movement among the crushed fragments, of the original rock. Similar conditions on a smaller scale occur near Darrington, and again on Ruby Creek about 5 miles from its mouth.

The overflows of volcanic rock, as in the case of the dikes, fall in two great groups, namely, acid and basic. The former are represented by the andesite about Glacier Peak, and the latter by the old eruptives, mostly greenstone, which outcrop over large areas about the south base of the Wenache Mountains, on Sauk and Skagit rivers, and on the Methow, and by the Columbia lava. No craters have been discovered in connection with any of these overflows, except those of andesite about Glacier Peak; the others, especially the Columbia lava, are believed to represent great fissure eruptions. The Columbia lava, however, is accompanied by vast quantities of lapilli, which show that volcanic explosions on a grand scale occurred, particularly during the earlier stage of the extrusion of the basalt. A marked feature in this connection is the acid character of the lapilli, in comparison with the basic composition of the associated lava.

## GEOLOGICAL STRUCTURE.

From the general statements made in the preceding section in reference to the presence of extensive areas of granite, schist, etc., and the strikes and dips of the stratified terranes of the northern Cascades, it will be seen that the structure of the range is highly complex and is by no means a single great north-south anticline or a simple monoclinal block sculptured by erosion. The region as a whole, however, has been raised since the origin of its more pronounced structural features. The rocks may be conveniently divided into two major groups (using the term group in its general sense): First, the granite and other eruptives, together with sedimentary beds now extensively metamorphosed, large areas of both of these having been changed to schists and allied rocks; second, a younger group, consisting of sedimentary beds and lava sheets, which, although frequently greatly disturbed from their originally horizontal position, are not known to have suffered metamorphism. In a general way the dividing line between the areas occupied by these two groups in the central portion of the Cascades, so far as the region represented on the sketch map, Pl. IX, is concerned, passes northwest and southeast through a locality some 5 or 6 miles to the southward of Ventura. The younger group of formations, it will be observed, however, has an extensive development in the southeastern portion of the area under consideration.

The structure throughout the region occupied by the older group of terranes referred to resembles that of the Sierra Nevada, and demands detailed study before its history can be even outlined with confidence. It seems safe to assume, however, on account of the intrusive nature of the granitic masses, that they must be held accountable for a large part of the disturbances that have occurred, and that they once raised the rocks beneath which they were injected into dome-like forms. Erosion has greatly altered the topographic features due to elevation, and deeply trenched the portions of the terranes now standing above sea level.

The sedimentary beds to the eastward of this area are believed (in part, for the reason that no marine fossils have been found in them) to have been laid down in lakes and to have been at first essentially horizontal. These beds have since been greatly disturbed, folded, and faulted, and are usually steeply inclined and in places nearly or quite vertical. Evidently complex movements have occurred since these Tertiary sediments were deposited. In addition to well-defined folds and the disturbances produced by faults and dikes, there is evidence that the layers of sediment, together with the interbedded sheets of basalt, have been deformed in a broader way, so as to produce what I find it convenient to term domes. It will also be found, I think, that corresponding downward movements, especially in the region of the Columbia lava, have occurred, so as to form broad basins.

In the extreme northern portion of the Cascade Mountains in Washington, where the younger group of terranes referred to above is extensively developed, the general structure is very like that of the Appalachian Mountains, and consists of compressed or closed folds, with nearly north-south major axes. Many of the folds have been truncated by erosion, and in the portions remaining the strata frequently stand vertical. In some instances the anticlines seem to have been overturned toward the west, so that the strata, entirely across the bases of their truncated remnants, dip eastward.

In addition to the north-south folds just referred to, which have their longer axes parallel with the general trend of the Cascade Mountains, there are a number of folds and faults which diverge at a high angle to the direction of the main structure lines. The nature of this diagonal structure is indicated by the folds and faults in the Swauk sandstone and along its borders. In the vicinity of Leavenworth, Mission, and Camas Land there are strongly pronounced anticlines which trend about southeast. This is also the trend of the Entiat Range. On the south side of Yakima Valley the great escarpment, termed in this paper the Clealum Ridge, the western extension of which, judging largely from the topography, is thought to be determined by a fault, branches off from the main Cascade uplift nearly at right angles. Again, to the east of the portion of the Yakima Valley just referred to, as described in a previous report,[1] there are several mountain ridges, such as the two bordering Moxee Valley on the north and south—known, respectively, as Selah Ridge and Yakima Ridge—and Satas Ridge, which forms the northern border of the tilted plateau termed Horse Heaven. Each of these ridges is due mainly to the tilting of a block of the earth's crust, capped with basalt, along lines of fracture. This series of faults, and perhaps in part of monoclinal folds, trends nearly east and west, and some of them cross the Columbia, as, for instance, the break on the north border of Saddle Mountain. Thus,

[1] I. C. Russell, A geological reconnaissance in central Washington. Bull. U. S. Geol. Survey No. 108, 1893, map forming Pl. II and pp. 28-31.

throughout the central portion of the Cascade region in Washington, especially on its eastern side, there are strongly pronounced structural lines indicated principally by faults which branch off at high angles from the main north-south axis of the mountains. The general trend of these lateral fractures is, in fact, nearly at right angles to the longer axis of the Cascades and of the principal folds of which that range is composed. It will, perhaps, be of interest in the future, when the structure of the Cascade Mountains is more critically studied, to note that the fissure veins in the Slate Creek district, traversing the Similkameen formation, also trend nearly east and west, or at right angles to the folds in the rocks where they occur.

Whether there are lateral folds or faults in the west side of the Cascades, corresponding to those just cited, has, so far as I am aware, not been determined, but their presence should be looked for during future explorations.

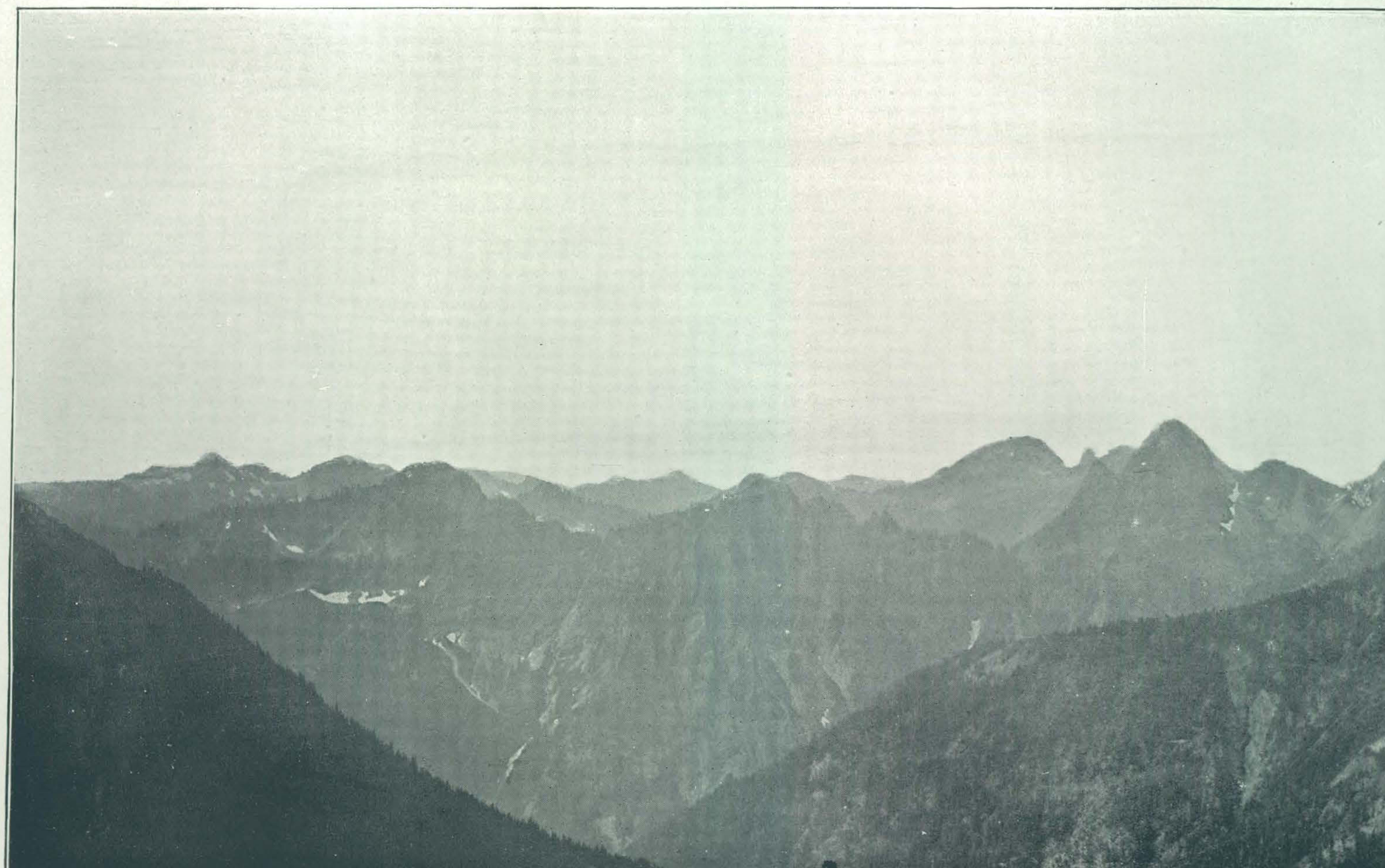
The age of the secondary disturbances just described is indicated by the fact that they involve Tertiary sediments and the associated Columbia lava, and hence occurred in late Tertiary or post-Tertiary time, and contemporaneously, as nearly as can be judged, with the latest great upward movement in the Cascade Mountain mass. In some instances the secondary folds and faults referred to originated after the initiation of the present system of drainage. The Columbia crosses Saddle Mountain by means of a sharply cut water gap, and the Yakima flows through narrow gaps of the same character at several localities. Evidently the right of way, so to speak, of the Columbia, and of its several larger branches from the west, was determined before the rocks over which these streams flow were broken and the blocks thus formed variously tilted. More than this, the tilting of the blocks or the growth of the faults bordering them must have gone on so slowly that the larger streams were able to maintain their previously established courses and were not turned aside. This is a significant fact in reference to the date of the elevation of the old peneplain which gave the Cascade Plateau its generally uniform surface level.

At one time during the field studies which form the basis of this paper the hypothesis was entertained that the granitic masses of the Wenache type were elevated at a later date than the base-leveling of the Cascade Plateau. One series of facts which seemed to sustain this conclusion was the generally radiate arrangement of the stream-cut valleys on the south side of the Wenache Mountains. Subsequently it was found, however, that Icicle Creek, formed by the union of numerous head-water streams to the west of the central granitic core of the mountains, flows eastward directly across the granite and has excavated a canyon some 3,000 feet deep. The Mount Stuart granite evidently did not form a topographic elevation at the time the general course of Icicle Creek was established. Again, the Wenache River, as already explained, leaves a region of soft sandstone, now of comparatively low relief, and makes a detour some 6 miles in length through a steep-walled canyon in Mount Stuart granite and then returns to the sandstone at Leavenworth. When the course of the river was established it seemed evident that the sandstone and granite must have had the same general surface level. Other similar relations of stream courses to granitic intrusions are known in the region about Lake Chelan, and again on the west side of the Cascades. These facts show that the main structural features of the Cascade Plateau came into existence previous to the period of erosion that truncated the domes and before the secondary fold and fault-scarps of the region originated, and the hypothesis of a more recent origin of the granitic mountains has to be abandoned.

As described in an early portion of this paper, many peaks and ridges in the central portion of the Cascade Mountains rise to a generally uniform height of about 7,500 feet. If the present valleys could be filled to the level of the crests of the intervening ridges, the now excessively rugged mountain range would be transformed into a broad plateau. The structure of the rocks composing this plateau would find little, if any, expression in the surface topography. Many of the stratified beds would expose their edges and reveal the fact that they are the truncated bases of folds, and in many instances would stand vertical. In other words, if we accept the "peneplain idea," as elaborated by Davis and others, the surface of the plateau would be a plain such as is produced by base-level erosion. Briefly stated, the Cascade Mountains as we now know them seem to have been carved from an upraised peneplain. This plain we term the Cascade peneplain, and the plateau may be conveniently designated the Cascade Plateau.

Rising above the general level of the Cascade Plateau there are two classes of peaks. First, volcanic mountains, of which Glacier Peak is the only known representative in the region considered in this paper; and, second, granitic mountains, such as the Wenache Mountains and the lofty peaks about Lake Chelan. The volcanic mountains stand on the Cascade Plateau and were formed after the period of base-leveling referred to above, and need not claim further attention at this time. Some of the granite peaks have an elevation of over 9,000 feet, and hence rise some 2,000 feet above the general level of the Cascade Plateau. These are the mountains which, in my opinion, could not have been in existence as topographic elevations at the time the main drainage lines were established.

Possibly the granitic mountains referred to are of the nature of monadnocks, or remnants left standing on the Cascade peneplain. If this is true, the river courses which cross them may be explained as



THE CASCADE MOUNTAINS NEAR MONTE CRISTO.

an inheritance from an earlier time of erosion which preceded the general base-leveling.

It may also be suggested in this same connection that the Cascade peneplain was developed above the present general summit elevation of the large majority of peaks and ridges now remaining, and has been lowered by erosion, leaving the more resistant rocks in the boldest relief. Under this supposition the Cascade Plateau would now have a general surface level of about 10,000 feet, having been raised from near sea level. In favor of this hypothesis it is to be noted that the peaks and ridges of the Cascade Mountains are nearly all sharp. No recognizable flat-topped remnants of the original plateau remain in the more elevated portion of the region under review. As soon as a region has been so deeply dissected by streams that the ridges are sharp crested, any further erosion will tend to a general lowering of their summits, and for a time they will continue to maintain this knife-edge characteristic. For this reason the Cascade Plateau, since being sculptured into a plexus of sharp-crested ridges, may have suffered a general diminution in height, owing to the wasting away of the ridges in soft rock, while the hard rocks, presumably in this case the granites, retained more nearly their original elevation. It may be said in this connection that field observations do indicate that the granitic rocks of the Cascades are in general more resistant than the associated schists, serpentines, slates, etc. Again, the general level of the Cascade Plateau as it exists at present corresponds, approximately, with the timber line as determined by existing climatic conditions. As weathering is more active above timber line than below it, we have, perhaps, additional reason to assume that the Cascade peneplain, raised, as we have assumed, to a position about 10,000 feet above the sea, has in general been lowered to the horizon of the timber line, leaving the more resistant granitic rocks in relief. There are thus several arguments which it may be claimed tend to show that the surface of the Cascade Plateau was formerly higher than it is now and that it has been lowered by erosion, but to me the evidence seems far from conclusive.

Another tentative explanation of the greater prominence of the granitic mountains over their neighbors of schist, etc., calls for local upheavals since the Cascade peneplain was raised into a plateau and subsequent to the initiation of the present master drainage lines. That is, if we assume that the granitic cores of the mountains have been pushed upward since the plateau was raised to its present general elevation of about 7,500 feet, all of the observed facts bearing on the question under discussion fall in line and find a mutual explanation. The cores of granite of the Wenache type may reasonably be supposed to be somewhat conical masses, with broad, but probably indefinitely defined, bases. While lateral pressure would probably tend to depress such masses, a pressure vertically upward would cause them to rise above the surrounding terranes. Although at present convincing evidence can not be advanced that the secondary elevation in the Cascade region continued after the Cascade peneplain had been formed, yet I am strongly inclined to favor this hypothesis to account for the general prominence of the granitic peaks above the otherwise approximately uniform level of the multitude of peaks and ridges in the dissected Cascade Plateau. In this connection I may note that earthquake shocks are common in northwestern Washington, especially in the Wenache Valley, and probably indicate that orographic movements are still in progress in the faulted and folded region adjacent to the Wenache Mountains on the northeast. Possibly these disturbances, observed in part during the present year (1898), indicate that the upward movement of the Wenache Mountains is still in progress.

Briefly stated, my conception of the origin of the larger topographic features of the northern Cascades is that the region, having a complex structure, was reduced by erosion to a condition of low relief, and at a later date than the folding of the Tertiary sediment and the outspreading of the Columbia lava was broadly upraised about 7,500 feet in the axial region. The courses of the larger streams were then established and the plateau was deeply dissected. During this later cycle there have been movements in the rocks which, as a part of their results, have raised certain of the granitic areas above the general level of the plateau.

The immense development of igneous rocks, and especially basalt, in Oregon and southern Washington has been accepted as evidence that the Cascades should be considered as distinct from the Sierra Nevada, but when the northern portion of the Cascades is more thoroughly studied it will probably be found that the differences between the two are much less than is now generally supposed. Not only are the main structural features of these two great ranges strikingly similar, with the exception that the Cascades are not bounded by a faulted belt on the east, as is the case with the Sierra Nevada, but the formations of which they are composed are much the same. In each range there is a highly complex older group of terranes, consisting of slates, gneisses, schists, lenses of limestone, eruptive rocks largely greenstone, serpentine, granite intrusives, etc., which is separated by a great unconformity from a younger group of formations consisting principally of Cretaceous and Tertiary sediments. The main differences seem to be a greater development of intrusive granite at the south, in the older group, and far more widely spread plutonic intrusions and volcanic overflows in the younger group, at the north.

The similarity between the geology of the northern Cascades and the Gold Belt of California is such that the generalized section of the rocks of the Sierra Nevada, presented by Turner and Lindgren in folios 37 and 39 of the United States Geological Survey, might, with changes in the formation names, be made to represent the conditions that exist in the northern Cascades with a remarkable degree of accuracy. While it would be premature to make a close comparison between the geology of the Cascades and that of the Sierra Nevada, such information as is in hand certainly suggests that the two ranges as they are now considered have much in common, and perhaps really form a single range, a large portion of which, extending from Lassen Peak, in northern California, to the Northern Pacific Railway, in Washington, consists of Tertiary lavas. In southern Washington, at least, these lavas were spread out in approximately horizontal sheets, and were subsequently elevated, folded, and faulted, in common with the associated Tertiary beds, during the uprising of the Cascade Mountains.

## CASCADE PENEPLAIN.

A peneplain, as defined by modern geography, is a nearly plane surface produced by stream erosion. The rivers draining a region—no matter what its elevation above the sea, and without reference to the structure of the rocks, whether horizontal, inclined, or folded, etc.—first cut down their channels nearly to sea level and then broaden them by lateral wear, or corrasion. As this lateral corrasion progresses the uplands between the master streams are more and more reduced in breadth as well as in height, and finally disappear. The plains produced by the lateral corrasion of several streams thus become united, and broad areas are planed down nearly to sea level. The later stages in this process are long delayed, and, in fact, so far as known, the plain produced never reaches the ultimate stage of a perfect plain at sea level. An approximation to such a condition seems frequently to have been reached, however, and the plain in this penultimate stage, with a moderately uniform surface and a gentle seaward slope, is termed a peneplain.

Should the rocks beneath a peneplain consist of horizontal sheets it might be difficult to show that great thickness of strata had been carved away in order to produce the approximately level surface. When, however, the rocks previous to the long period of erosion necessary to produce such results were folded and faulted or upheaved into great domes, we find the basement portions of such structural forms in the rocks that remain, and from the inclined positions of the strata can reconstruct the original shapes of the truncated folds, etc., and thus show how much rock has been removed.

In traversing the Cascade Mountains we find the rocks in many places steeply inclined, and in numerous instances standing vertical.

When stratified beds, such as sandstone, shale, limestone, etc., occur, we can readily see from the portions remaining that the folds have been carved away, as with a horizontal saw, to a generally uniform level. The manner in which such results are brought about has been indicated above in describing the manner in which peneplains are produced. As no other way is known in which similar ends could be brought about, we are justified in concluding that the Cascade region was at one time reduced by stream erosion to a plain, or an approximately plain, condition nearly at sea level.[1] Of what the topography of the land was previous to the production of a peneplain we have but little definite knowledge. Judging from the remnants of the folds and domes we now find, it was a mountainous region, bordered on the east, throughout a portion of its history, by broad lakes, in which much of the débris removed was deposited. During the later portion of the time of base-leveling the widely spread sheets of Columbia lava were poured out. The date of the period of planation is shown approximately by the fact that folded beds of Eocene age were truncated. The broad peneplain must, therefore, have reached its greatest degree of perfection in late Tertiary time, probably extending into the Pleistocene.

### CASCADE PLATEAU.

After the time of long-continued erosion referred to above, when the Cascade region in northern Washington was reduced to a peneplain, there came a time of elevation, when the peneplain, or a very large portion of it, was bodily raised some 7,500 feet at least, and thus became a plateau. In a broad view of the region this Cascade Plateau may be considered as of the nature of a broad, flat-topped anticline, or, as Dana would probably have called it, a geanticline. The rocks composing this uplifted region had previously been folded, but we are justified in assuming, on what may be said to be general principles, that renewed movements occurred along these old structural lines. The main change was a general rise of a region of some 10,000 or 15,000 square miles. The total area affected was much greater than this, as the Cascade Plateau extends both north and south of the field under discussion.

One of the most remarkable features in the relief of the Cascade

[1] It may, perhaps, be claimed that the waves and currents of the ocean might produce such a plain as is described above by eating into the land; but this question has been discussed by physiographers, and it has been shown that the power which the sea has of eating into the land is limited by conditions inherent in the process itself. While broad sea shelves or ocean terranes may be formed by the attack of the waters on the land, the power of the waves diminishes in probably more than a simple ratio as the shelf becomes broader and broader. With a gradual subsidence of the land a plain of marine denudation might result, but the submerged portions of such a plain would be covered by marine deposits, which would preserve a record of the process and influence the character of the subsequent changes brought about by stream erosion, should the plain be elevated above the sea. Without pressing this discussion, I may say that in the Cascade region no evidences of a plain of marine denudation have been discovered. The facts in hand point clearly to the conclusion that the plateaulike surface of the Cascade Mountains is an old peneplain.

Plateau is the seemingly nearly level character of its original surface. The uprising was effected without pronounced tilting. Perhaps when our knowledge is more extended it will be found that this conclusion is too hasty, but at present, from a study of the distribution of the rivers, as well as of the heights of the peaks left by erosion, it does not seem that the plateau had a decided, if any, inclination toward either the east or the west. This is the most marked difference between the Cascade Plateau in northern Washington and the Sierra Nevada. The Sierra Nevada as we now find it is the result of the erosion of a tilted plateau, bordered on the east, from Owens Lake to Mono Lake at least, by a great belt of branching fractures and faults. No such belt of fractures and displacements parallel with either border of the Cascade Plateau is known. The evidence is that the rise from each side of the plateau to its nearly flat summit portion is gradual. This is shown especially in the region immediately south of the Northern Pacific Railway, where, as previously stated, the Columbia lava ascends from the valley of the Columbia to the highest portion of the range with a generally uniform eastward dip of about 4°.

## DISSECTION OF THE CASCADE PLATEAU.

Since the Cascade Plateau was upraised the streams flowing from it have deeply intrenched themselves and developed a multitude of branches, each of which has eroded a steep-sided, canyon-like valley in the upraised rocks. This process of dissecting the plateau has gone on until the once approximately even surface has become a complex of sharp-edged ridges and tapering, spire-like peaks. The master streams flowing east or west from the central portion of the plateau have deepened their channels nearly to base-level. More accurately, the streams flowing westward, such as the Skagit, lowered their channels near their mouths practically to sea level, and, owing to a subsequent depression of the land, have upgraded their channels; while the eastward-flowing rivers, such as the Yakima, Wenache, Methow, etc., have cut down their beds in their lower courses nearly to the level of the Columbia, the master steam with which they unite. This lowering of the stream channels has been extended upstream from where the rivers discharge, maintaining, however, sufficient fall to insure a strong current far into the central portion of the plateau. As remarked on an early page of this report, one of the most striking features in the present drainage of the Cascades is the low grade of all the larger streams far toward their ultimate sources. In several instances a low grade—that is, a slope of perhaps 10 feet to a mile—is found from the mouths of the rivers to within 4 or 5 miles, and in some cases a considerably less distance, of the main divide. Throughout these low-grade tracts the streams are mostly free from cascades, and flow over gravel deposits which deeply fill the true rock-cut valleys. Since the period of deepest cutting the valleys have been filled with gravel to a depth in some instances of 600 feet or more, and then in part or wholly reexcavated. Records of the depth of this filling are to be seen in the gravel terranes on the sides of the valley, as will be more fully described later. The streams in the majority of instances have not completed the task of reexcavating the valleys, the depth of waterworn gravel beneath their channels in some localities, as shown by mining shafts on the border of Ruby Creek, for example, being 70 feet. In other cases, as in the valleys of the Methow, Chelan, Wenache, Yakima, etc., the depth of the substream gravels is, by estimate, at least 200 or 300 feet, and may be much greater. The few rapids that occur are due to the fact that the streams have failed in some instances to follow their previous courses in reexcavating their valleys, but have cut across salient angles in the borders of their rock-cut valleys, or else have been partially dammed by glacial moraines.

These rivers flowing through deep, low-grade, but narrow valleys are examples of what geographers term consequent streams. Their courses were determined, in the main at least, by the surface slopes of the upraised Cascade peneplain. Their branches usually have steep gradients, and many of them are torrents from source to mouth. The larger branches, however, have deepened their channels at the same rate as the master streams, and extended their low-grade trunks far into the interstream uplands. The completeness of the drainage system of the Cascades, the depth to which the streams have sunk their channels, the absence of remnants of the original plateau surface in the higher portion of the range, are all features of mature stream development. The Cascade Plateau has, in fact, been about as deeply dissected as it is possible for streams to carry on that work. It is for this reason that the region now sculptured into a rugged mountain range is so difficult to traverse. It is one of the best illustrations of a deeply dissected mountain mass that the United States affords, and possesses some of the most magnificent scenery to be found in North America exclusive of Alaska.

Future changes will be in the direction of broadening the valleys, thus narrowing and lowering the interstream ridges, and finally leading to the reduction of the land approximately to sea level; that is, at the close of the present geographic cycle the Cascade region will be again worn down to a peneplain.

While the general features in the drainage of the Cascades are such as just described, there are certain exceptions to the impression that these statements may convey. The streams about the southern side of the Wenache Mountains, and some of the features in the associated topography, indicate that this mountain mass, in part, at least, had a drainage system of its own, independent of the influence of the greater

Cascade uplift. This is shown especially at the head waters of the North Fork of Teanaway River and along the south side of Ingall Creek Canyon. The first-mentioned streams flow southward in deep, narrow valleys which cross the outcrops of the stratified rocks encircling the Wenache Mountains nearly at right angles; but below where the three forks of the Teanaway unite, the trunk streams run eastward in a monoclinal valley eroded along the strike of soft shales and sandstones. Ingall Creek flows east, in part along the contact of the Mount Stuart granite with the terranes to the south, in a canyon-like valley some 3,000 feet deep.

The several branches of the North Fork of the Teanaway start on the ridge now forming the south side of Ingall Creek Canyon, but at the head of each considerable creek there is a notch or wind gap in the crest line of the ridge. The hypothesis which presents itself in explanation of this and associated typographic conditions is that the branches of the Teanaway had their positions established on the Wenache uplift subsequent to its reelevation after the deposition of the Swauk sandstone, and before it was deeply dissected, and flowed southward from the higher central mass of Mount Stewart granite. These were consequent streams and flowed across the strike of the stratified bed encircling the granite. As these streams deepened their channels they maintained their position, but developed many lateral branches, which, choosing the softer rocks, caused the harder beds to be left in relief. The main streams cross these outcrops of hard rock in narrow water gaps. In addition a branch of Peshastin River, which passes the east base of the Wenache Mountains and is a northward-flowing, consequent stream of the Swauk dome, previously described, developed a branch which joined the main stream from the west, and as it grew by headway corrasion, robbed and diverted the head waters of several of the branches of the North Fork of the Teanaway. The reversed or "obsequent" portions of these streams are now known, in their order from east to west, as Cascade, Hardscrabble, Fourth, and Turnpike creeks. These are all branches of Ingall Creek, and now join it from the south, and are indicated as fully as the scale will permit on the accompanying map, Pl. IX, but still better on the topographic map of the Mount Stuart quadrangle. Ingall Creek Canyon is bordered on the north for about 10 miles from its source by a steeply sloping wall of granite from 4,000 to 5,000 feet high. Evidently, as the creek deepened its channel it migrated southward, and gave an exceedingly precipitous character to its southern wall, which, however, is scored transversely by the deep, high-grade channels of the several tributaries named above. Similar evidences of rivalry and of river piracy, as it has been termed, may be had at the head of the several branches of the main trunk of the North Fork of the Teanaway, and at the head waters of Fortune Creek, which flows westward and joins Clealum River, and again between the branches of the Middle Fork of the Teanaway and Clealum River.

The smaller Swauk dome, like the Wenache elevation, gave origin to consequent streams, which were variously modified as erosion progressed; the summit of the dome was removed and the rocks beneath were eaten away so as to form a basin. The surface waters now escape from the Swauk Basin by means of two streams—the Peshastin, which flows northward, and Swauk Creek, a tributary of the Yakima. Of these, the Swauk is the more instructive, as the southern side of the dome on which it started is more regular than the opposite side, drained by the Peshastin, where folds in the rocks approached and perhaps merged with the original structural dome.

Swauk Creek began as a southward-flowing consequent stream, which held its position as it lowered its channel, and the summit of the uplift on which it originated was eroded away. The dome was composed in part of the earlier sheet of Columbia lava, and as it was truncated and its central portion of soft sandstone and shale slowly removed, the hard lava was left as a bold ridge, surrounding the central basin on the west, south, and southeast. Swauk Creek flowed directly across this ridge and has cut a notch or water gap through it, which is now about 1,000 feet deep.

There are suggestions that Swauk Creek originally had its source on the great Wenache uplift and flowed across the Swauk dome, but at a later stage was beheaded. Swauk Creek now drains a basin composed entirely of sandstone, shale, basaltic dikes and sheets, and volcanic lapilli. There are no outcrops of acid igneous rocks or of serpentine, gneiss, granite, etc., within the rim of the present hydrographic basin; yet in the coarse gravel and bowlders along the sides and forming the bed of the present stream there are waterworn stones, some of them between 1 and 2 feet in diameter, that have been derived from the crystalline areas about Mount Stuart. At one locality an estimate based on an examination of the cleanly washed bowlders at a hydraulic placer mine gave from 10 to 12 per cent of large stones that are foreign to the Swauk Creek Basin, but agree lithologically with the crystalline terranes in the central portion of the Wenache Mountains. These are considered as representing ancient stream transportation, as no such bowlders occur in the sedimentary beds within the present reach of Swauk Creek, and there is no evidence of glaciers ever having entered that basin.

There was at least one other consequent stream which originated on the Swauk dome and flowed southward, the course of which is now marked in part by abandoned water gaps. This stream flowed about southeast and crossed the edge not only of the earlier but of the later sheet of Columbia lava. I may say, also, that both Swauk Creek and the nameless stream just referred to probably began on the second or perhaps some still higher sheet of Columbia lava, but we have no measure of the original extension of these basaltic layers to the west of the westward-facing escarpments of Table and Lookout mountains. Swauk Creek now crosses the second sheet of lava in a canyon to the east of Lookout Mountain, there finding a break, radial to the Swauk dome, which assisted its work.

To return to the nameless stream referred to above, we find one of its abandoned gaps, although faintly defined, in the semicircular ridge formed by the first sheet of Columbia lava, and another in the upturned edge of the second sheet. This second gap is known as Green Canyon. To understand this somewhat detailed description the reader should consult the topographic map of the Mount Stuart quadrangle, published by the Geological Survey.

The stream which flowed southeast down the Swauk dome and carved Green Canyon was beheaded to the north of the bold outcrop of the first sheet of Columbia lava by a branch of Swauk Creek, and was again robbed, as previously stated, by First Creek, a branch of the Swauk from the east, developed in the soft Roslyn sandstone which intervenes between the first and second sheets of Columbia lava. This last event is of recent date and is one of the most instructive examples of stream capture and stream diversion yet found in the Cascade region. For a long time after Swauk Creek had captured the head waters of the stream flowing through Green Canyon, its beheaded portion continued to flow and received from the east, in the sandstone valley between the first and second lava sheets, a tributary of larger volume than itself.

At a later date First Creek extended its head waters so as to tap the stream and draw off all of its waters above Green Canyon, leaving that gorge as a wind gap, from which the beheaded and much weakened lower portion of the stream continues to flow southward. First Creek was enabled to make this capture by reason of its high grade, and also because it flows over soft sandstone and shale, while the stream flowing through Green Canyon had a sheet of hard basalt to corrade, some 400 feet thick. At the entrance to Green Canyon on the north there is at present a large exposure of nearly white sandstone, through which First Creek has cut a narrow, steep-sided trench which bears the signs of youth. So little change has been made at this locality that the upper portion of First Creek has been turned from its course and conducted into Green Canyon in order that its waters may be utilized for irrigation near Ellensburg. This recent change is why a stream is represented on the topographic map of the Mount Stuart quadrangle as flowing southward through this gorge.

Many other details might be instanced to illustrate the intimate connection between the larger features in the structure of the region under consideration and its present topography and drainage, but a report of a reconnaissance does not seem to be the proper place for such discussions. I will venture to indicate one other instance, however, closely associated with those just cited. Yakima River leaves that portion of its valley in which the town of Clealum is situated through a narrow gateway or water gap cut through the upturned edges of the second sheet of Columbia lava. This water gap admits of the escape of all the surplus waters from the south side of the Wenache Mountains, and of other streams which join the Yakima farther west and drain the Cascade Mountains proper. The conditions are thus somewhat complex, but the relation of the gap occupied by the Yakima, just south of Lookout Mountain, to the Wenache Mountains is about the same as the relation of the gap cut by Swauk Creek, between Liberty and McCallum, to the Swauk dome. Each one is a gap cut by a consequent stream in the outcropping edge of a hard layer in the truncated rim of a deeply eroded uplift. In closing this discussion it is only just to state that the interpretations of stream development and of the origin of certain topographic forms, presented in the last few pages, are but an application of physiographic principles first clearly enunciated by W. M. Davis.

One of the most interesting features in the geography of the Cascade Mountains is the independence of the stream courses of the smaller features in the structure of the upraised region which is being slowly removed. The larger streams flow across granite, schist, sandstone, shale, etc., with but little change in passing from one terrane to another. The courses of the streams are in a marked way independent of the geological structure. They have shaped the topography and have not been controlled by it. This fact is illustrated on many sharp-crested divides where hard and soft strata stand nearly vertical and cross the ridges at right angles to their longer axes. Nearly all of the larger streams and hundreds of smaller ones have their sources in glacial cirques or amphitheaters at the head of deep, narrow valleys. This serves to introduce to the reader another important agency which has assisted the streams in dissecting and sculpturing the Cascade Plateau and in transforming it into a wonderful complex of tapering mountain peaks and sharp-crested ridges separated one from another by deep, narrow valleys. By far the larger part of this herculean task has been performed by running water, but glaciers of large size have modified the contours of the valleys so formed, and have impressed upon them the characteristics of their work.

## EVIDENCES OF PREVIOUS INTENSE GLACIATION.

In the more elevated portions of the Cascade Mountains, near the main divide, there are hundreds of amphitheaters nearly surrounded by precipitous walls, frequently several hundred feet high, which owe their characteristic shapes mainly to the influence of the névés of glaciers. These bowl-shaped recesses, with one side of the rim absent—the break leading by steep and usually transversely terraced slopes to the draining canyons—are clearly the heads of old stream-cut channels which have been enlarged and given their present forms by glaciers.

Glacial ice, in distinction from streams of water, may be said to be artisans who fashion their work into broad, curved surfaces. These surfaces are either broadly concave or convex; the former are basins or troughlike valleys with rounded bottoms, as seen in cross section; while the latter are hills and bosses with flowing outlines. In these two series of forms the surfaces are remarkable for the bold, even sweep of their curves and the smooth finish of the work. The perfection of the burnish, however, is marred by multitudes of fine incised lines, and less frequently by elevated ridges which taper to a point in the direction in which the ice flowed. The streams, on the other hand, while working toward strong effects, as is shown by the breadth of mature river-cut valleys and by the massive mountain forms left by the deep dissection of an elevated region, and still more markedly by the broad expanse of a base-level plain, reach these results through a multitude of ever-changing, sharply cut trenches of infinite variety of detail. The creek-, brook-, and rill-cut channels bifurcate and expand one from another like the branches and twigs of a well-grown tree. On account of the strongly marked differences, both in the general forms and in the minute details, between these two methods of earth sculpture, the results produced by them in a landscape may be as readily distinguished as is the work of the potter who shapes a vase and of the artist who decorates it.

I shall not attempt to present in full the evidence furnished by the glacial records of the Cascades, but give simply an outline of the history so far as it has been deciphered.[1]

One fact of primary importance in studying the glacial records referred to is that the Cascade Plateau was almost as deeply dissected by stream erosion before the birth of the glaciers as it is at present. In fact, the valleys were probably deeper then than they are now, for the reason, as already stated, that the larger ones more particularly are at present filled to a very considerable depth with gravel. While the Cascade Mountains had during the presence of the old glaciers essentially the same broad topographic features that characterize them at present, the general elevation of the region was probably about 1,000 feet higher than it is now. This is indicated by the gravel deposits in the valleys, but more especially by the depth of the basin of Lake Chelan. This long, narrow lake occupies a pre-Glacial stream valley, the bottom of which, not including the clays and gravels which presumably

[1] The various ways in which glaciers and streams modify the earth's surface have been discussed by me in the following books: Glaciers of North America, Ginn & Co., Boston, 1897; Rivers of North America, Putnam's Sons, New York, 1898.

partially fill the rock channel, is 300 feet below sea level. The lake, as shown by soundings made by Henry Gannett in 1897, is 1,400 feet deep, while its surface is but 408 feet above the Columbia at the mouth of Chelan River, the lake surface being 1,078 feet, and the Columbia at the mouth of the Chelan River 670 feet, above the sea. This greater elevation was maintained during a long period previous to the coming of the glaciers, but we have no positive evidence that it continued during the Glacial epoch, although I am inclined to the opinion that such was the case.

There is abundant evidence that broad névé fields and true glaciers once occupied all of the central portion of the Cascades, and that great trunk glaciers flowed both eastward and westward from this central region. These outward-flowing ice streams descended previously excavated valleys, and although of large size, were true alpine glaciers.[1] This statement applies more accurately, perhaps, to the eastward- than to the westward-flowing glaciers, as the latter during their greatest expansion became to a considerable extent, and possibly throughout the entire length of the northern Cascades, a confluent ice sheet, which descended into the Puget Sound region and became a typical piedmont glacier.

These glaciers, more especially those flowing eastward, were well-defined ice streams, which modified the cross profiles of the valleys they occupied and deposited large lateral and terminal moraines. On retreating they left abundant deposits, which in some instances dammed the valleys and gave origin to lakes. The streams flowing from the ice and from adjacent snow fields were heavily charged with débris, and the valleys downstream from the extremities of the glaciers at the time of their maximum extension, as well as many neighboring valleys not occupied by glaciers, and, in part, the valley left as the ice withdrew, became deeply filled with gravel. There is thus an intimate and for the most part a genetic relationship between the old glaciers and the valley gravels found so generally throughout the State of Washington and adjacent areas.

While the statement made above, to the effect that the glaciers of the Cascades were consequent to the slopes of the main uplift, is in general true, it is perhaps too sweeping, as there were local centers of ice dispersion in the same region. The Wenache uplift, which, as we have seen, gave origin to consequent streams, was also an independent center from which glaciers flowed in several directions. It will, perhaps, be found by future explorers that the névé on the Wenache Mountains was but an eastward extension of the far larger snow fields of the main Cascade Range, but, essentially, it was an independent center of glacial dispersion. The region about Mount Baker and

[1] The characteristics of alpine, piedmont, and continental glaciers are described in the book on Glaciers of North America, referred to in the preceding footnote.

Mount Shuksan, to the west of the main Cascade uplift and near the Canadian boundary, will, I predict, be found to be another practically independent névé region which gave origin to a radial system of alpine glaciers similar to that now existing on Mount Rainier. As exploration progresses other divisions in the broader features of the ancient glaciers of northwestern Washington will no doubt be discovered.

As my acquaintance with the eastern slope of the Cascade Mountains is much more extended than with the western, I shall confine this discussion principally to the records of the eastward-flowing glaciers. Beginning at the south, in the region shown on the sketch map, Pl. IX, there is abundant evidence to show that a glacier formerly flowed eastward from the central portion of the Cascade Mountains down the Yakima Valley. Other glaciers radiated from the Wenache Mountains; a large trunk glacier followed the course of the Wenache, another occupied the valley of Lake Chelan, and similar conditions existed in the Methow, Similkameen, and Okanogan valleys. The distribution of these glaciers and some of their leading geographic features are shown on the sketch map, Pl. XVIII.

## ANCIENT GLACIERS AT THE HEAD OF YAKIMA VALLEY.

My examination of the region on the east of Snoqualmie Pass, drained by the head waters of the Yakima, was made hurriedly during stormy weather, and I have but little to report in connection with the records of ancient glaciers which occur there except the bare fact that a large alpine glacier occupied that region and extended at least a few miles below the outlet of Kachess Lake, which is retained by a series of moraine ridges. Another glacier occupied the basin now holding Keechelus Lake, and apparently left a terminal moraine similar to that just referred to. Views of the valley of Clealum River, a branch of the Yakima from the north and near its source, as well as the accounts of prospectors, etc., indicate that a large glacier once existed in Clealum Valley, which extended below the site of Clealum Lake. This lake is evidently retained either by a morainal dam or by the deep filling of gravel which occupies the valley below it. It does not appear that the three glaciers just referred to—which may be designated, in their order from south to north, the Keechelus, Kachess, and Clealum glaciers, after the names of the lakes in the basins they left—were united. From a study of the maps of the region it seems that Clealum Glacier was the longest of the three, but did not reach Yakima Valley. Its length was between 20 and 25 miles. Kachess Glacier was about 15 miles, and the Keechelus not over 10 or 12 miles, in length. The comparatively small size of these ice streams is significant, in connection with the great length of the similar glaciers farther north.

## ANCIENT GLACIERS ABOUT THE WENACHE MOUNTAINS.

As will be recorded later, four small glaciers still exist on the Wenache Mountains; these may be considered as remnants of great alpine glaciers which flowed away from the same elevated region during the Glacial epoch. All of the summit portion of the Wenache Mountains above an elevation of about 7,000 feet, with the exception of the numerous rugged pinnacles which rose into and possibly projected above the former blanket of ice and snow, furnishes abundant evidence of ice abrasion. This elevated gathering ground for snow was 9 or 10 miles in diameter from east to west and from 3 to 5 miles broad. Its boundaries, however, are indefinite, and the former névé which covered it was probably confluent with the snow fields on the surrounding mountains, which have elevations of 7,000 feet or more. The valleys, basins, and amphitheaters in the summit portion of the range are intensely glaciated and mostly free of débris. The bare white granite is fresh or but slightly weathered, and in many places preserves the glacial polish and striations given to it by flowing ice. There are several depressions in the granite, which formerly contained glaciers, and in the eastern portion of the range a magnificent amphitheater has been hollowed out, which discharges its waters northward into Icicle Creek. In the more elevated portions of this amphitheater there is still a small glacier, below which, and at the bottom of a steep, bare slope of polished granite, there are two rock-basin lakes, known as the Twin Lakes. To the north of these, and beyond a great cathedral-like mass of clustering granite spires rising within the amphitheater, or rather prolonged from the central and highest portion of its encircling rim, so as to divide the vast depression into two cirques—for the present amphitheater has been formed by the partial removal of the dividing wall between these two alcoves—there is a third and smaller rock-basin lake. The walls of granite about these lakes are bare of vegetation and almost entirely without débris, but about the lower margin of the basin holding the Twin Lakes a few trees are growing. This Twin Lakes amphitheater was the source of a large glacier at a former period, which flowed northward down a high-grade canyon and joined a much larger glacier that came from the west, down the canyon of Icicle Creek. The Twin Lakes Glacier, as it may be termed, was from 5 to 6 miles long and, in its well-defined stream-like portion, about 3,000 feet wide, but in the névé region it expanded to fully a mile. It was the most easterly tributary to the glacier which descended Icicle Canyon.

On the south side of the precipitous granitic core of the Wenache Mountains there were three or four well-defined ice streams, which occupied exceedingly steep gorges; but in general the granitic escarpment bordering Ingall Creek on the north is so precipitous and

ROCK-BASIN LAKE AT HEAD OF INGALL CREEK.

so slightly trenched by gorges that the heavy snows of the Glacial period, like those of modern winters, must have fallen in large part as avalanches.

To the north of the lofty mountain mass intervening between the Twin Lakes and Mount Stuart the descent to Icicle Creek is less steep than the opposite slope leading down to Ingall Creek, and is more diversified by gulches and intervening buttresses. In several of the gulches there are evidences of glaciation. Some of these small glaciers descended to the great river of ice in Icicle Canyon, but others seem to have terminated on steep slopes, and probably broke away so as to form avalanches. On the west side of Mount Stuart the cliffs are high and precipitous, and during the Glacial epoch must have contributed their snow directly to the névés in the valley below, from which flowed the great Icicle Glacier, first northward and then eastward about the Mount Stuart group of peaks, and the equally characteristic Ingall Glacier, which flowed eastward and then northward about the same mountain mass of granite.

## INGALL GLACIER.

From its source at the present head of Ingall Creek, and at the west base of Mount Stuart, the Ingall Glacier flowed almost due east for about 12 miles. Throughout this extent it was gently concave to the north; that is, for the greater part of this distance it skirted the base of the granite forming the central mass of the Wenache Mountains. On entering the valley of the Peshastin, 3 miles north of the site of Blewett, it curved sharply northward and followed a northerly course for about 4 miles to where it terminated in the Peshastin Valley, but did not leave a conspicuous moraine to record its maximum extension. Near the head of the broad U-shaped canyon once occupied by Ingall Glacier there is a fine rock-basin lake, a photograph of which is reproduced on Pl. XIV.

Ingall Glacier was supplied in large part by avalanches which descended the exceedingly precipitous southern slope of Mount Stuart, but 4 or 5 miles east of the highest pinnacle on that mountain. The border of the central core of granite is less precipitous, and the rounded and striated condition of the rocks, as well as the existence of broad-bottomed troughs descending from aloft, shows that well-defined glaciers formerly flowed from the summit portion of the range, adjacent to the névé fields of Twin Lakes Glacier. A view of some of these high-grade glaciated troughs is shown on Pl. XV. On the south side of Ingall Creek Valley there are four deep ampitheater-like depressions, now occupied by Turnpike, Fourth, Hardscrabble, and Cascade creeks, respectively. There was formerly a glacier in each of these depressions, which flowed northward and became tributary to Ingall Glacier. The heads of these secondary glaciers were at an elevation of between 5,500 and 6,000 feet. The largest of them, the one in Hardscrabble Canyon, was about 2 miles long, with a depth of ice of 1,000 to 1,100 feet near its junction with the main glacier. The others were somewhat smaller, but owing to the depth of ice in Ingall Creek Canyon, which acted as a dam, the thickness of the ice in the tributaries from the south was about the same in each instance.

Ingall Glacier, where it passed the mouth of Hardscrabble Creek, was between 1,200 and 1,500 feet deep, and maintained about this thickness all the way to Peshastin Valley. This fine ice stream was, in general, about a mile broad, but became narrower through a distance approximating 2 miles just before entering the valley of the Peshastin. In this constricted portion it was not over a half mile across, but on turning northward on the course now followed by the Peshastin soon widened to fully a mile.

Throughout Ingall Creek Valley there is an absence of well-characterized moraines, except at the outlets of the depressions drained by Hardscrabble and neighboring creeks. In each of these instances a morainal train starts from the west side of the entrances of the lateral valleys and is prolonged, with decreasing elevation, nearly across them. Near the head of Ingall Creek there are well-marked, terrace-like steps in solid rock, which cross the valley in the manner well known to characterize high-grade valleys which were formerly occupied by glacial ice.

After expanding on entering Peshastin Valley, the Ingall Glacier deposited heavy lateral moraines on each side of its course, at an elevation of about 1,100 feet above the river. The moraine on the east side of the valley is especially conspicuous, as it starts from a massive, outstanding butte of coarse conglomerate, and extends north as a free ridge for over a mile, its height decreasing from the rocky pinnacle at which it starts to its distal end. There are also many large bowlders in Peshastin Valley, about 2 miles below the mouth of Ingall Creek, which are remnants of a terminal moraine. In this same region the conglomerate flooring the valley is smoothed and striated. The Ingall Glacier entered the valley of the Peshastin nearly at right angles, and, as stated above, made an abrupt bend and flowed down that valley, at the same time expanding to two or three times its former width. The Peshastin above the mouth of Ingall Creek is a steep canyon-like valley, with fragments of terraces on its sides, and for about a mile above where the old glacier entered there are occasional bowlders of Mount Stuart granite. These were brought by the Ingall Glacier, which extended up the Peshastin Valley and formed a lobe of stagnant ice.

MOUNT STUART GRANITE ON NORTH SIDE OF INGALL CREEK.

## ICICLE GLACIER.

Only some 5 or 6 miles of the lower portion of the valley and canyon of Icicle Creek, to the west of Leavenworth, and 2 or 3 miles of the extreme upper portion of the south fork, at the west base of Mount Stuart, have been explored by the writer, although the greater portion of the intermediate tract has been seen from commanding summits.

The ancient glacier which flowed down this previously deeply eroded canyon, with precipitous walls, mostly of white granite, was formed by the union of at least three strong ice streams, two of which had their névés on the main Cascade divide, while the most southern one derived much of its snow from the steep western escarpment of the mountain mass formed of Mount Stuart granite. Tributary glaciers descended the northern slope of Mount Stuart and neighboring peaks to the east, the largest of these having its source in the Twin Lakes amphitheater.

The length of Icicle Glacier, from its most westerly névé field on the east side of the Cascade divide to where it terminated in the Wenache Valley, about 1 mile downstream from Leavenworth, was approximately 24 miles. The gathering ground of this glacier was some 50 or 60 square miles in area, but extremely rugged, and contained a score or more secondary or tributary glaciers, which descended lateral gorges and joined the resultant trunk glacier or some one of its main branches. In Icicle Canyon, to the northeast of Mount Stuart, the main or trunk portion of the old glacier was less than a mile broad; but about 3 miles up the present Icicle Creek, above where it joins the Wenache at Leavenworth, the glacier emerged from the canyon cut in hard granite, and entered a valley that had been excavated in softer schists and sandstone, and there expanded to a width of between 2 and 3 miles, and on melting left well-characterized lateral moraines on each side of its course and at an elevation by aneroid of 900 feet above the valley's bottom. Many angular blocks of granite occur in the highest moraine on each side of the valley, some of them measuring 20 by 30 by 15 feet.

On leaving the narrow canyon in granite, referred to above, and entering the broader valley to the southwest of Leavenworth, the old glacier turned abruptly northward, and on reaching Wenache Valley made another bend and took an easterly course down the last-named valley, but halted about a mile below the site of Leavenworth and built a conspicuous and typical terminal moraine completely across its extremity, which occupied the entire width of the valley. The glacier then receded without leaving any other distinct terminal moraines. The sides of the trough, however, particularly on the east, are strewn with vast numbers of granitic blocks up to the mouth of the granite canyon. These bowlders are piled in confused heaps, which extend many hundreds of feet into the valley, forming spur-like ridges, of the nature of incomplete terminal moraines.

The large moraine below Leavenworth is from 80 to 100 feet above the river, which has cut through it, and presents a steep descent on its downstream face and a much more gentle slope on its upstream border. It is composed of concentric ridges, consisting largely of granitic blocks, frequently 10 feet or more in diameter, and has a breadth of 1,000 to 1,500 feet. As the ice withdrew this terminal moraine formed a dam which held the water in check for a time and caused a lake to form, which extended at least to the mouth of the granite canyon through which Icicle Creek now flows. In this canyon the stream is swift and is broken by small cataracts and rapids, but in crossing the old lake bed it becomes a placid stream, which meanders in sharp curves and at times divides so as to inclose islands. The plain left by the draining of the old lake is composed of granitic sand and gravel, overlain in part by rich alluvial soil, which forms fine farming lands. A low delta composed of micaceous sand and granitic gravel, formed in the southern portion of the former lake, is now finely terraced.

Icicle Glacier crossed the mouth of the narrow granite canyon, some 3,000 feet deep, ending at Leavenworth, through which Wenache River now flows for a distance of about 6 miles, where it emerges from a V-shaped gateway barely wide enough at the bottom for the waters to escape.[1] This canyon must have been dammed by Icicle Glacier at its mouth, but no evidence of its having been occupied by a lake can now be recognized on its precipitous walls. The Wenache Glacier reaches the upper end of this canyon, but, judging from such facts as have been gathered, did not extend into it, and was not united at any time with Icicle Glacier.

In this connection I may add that there is no evidence of the former presence of glacial ice in Wenache Valley below the terminal moraine left by Icicle Glacier, but this portion of the valley is deeply gravel filled.

### OTHER GLACIERS NEAR MOUNT STUART.

To the south of Ingall Creek Canyon, at the head of Stafford Creek, there is a broad amphitheater, the bottom and sides of which are glaciated. The upper limit of glaciation is about 6,500 feet, and the former glacier flowed southeastward, but was probably less than 2 miles in length. A similar glacier, but somewhat larger and at about the same elevation, occupied the extreme upper portion of the valley drained by the North Fork of the Teanaway. These small glaciers are interesting, for the reason that they occurred at a distance of 4 or 5 miles

[1] Some account of this remarkable canyon has already been given in connection with the discussion of the structure of the region, and it has also been referred to in describing Wenache River.

from the central and most elevated portion of the Wenache Mountains and were supplied by local snow fields adjacent to secondary peaks having a general elevation of about 7,000 feet, and also because they were of the type of glacier now common in the Cascade Mountains. In this same general region also there is evidence of the former presence of a large ice stream which headed against Ingall Glacier and flowed westward down the valley of Fortune Creek and became tributary to Clealum Glacier. Between the amphitheater at the head of Ingall Creek and the similar basin-shaped depression at the head of Fortune Creek there is a rugged mountain of peridotite and serpentine, which has been cut into also on the north by the ice which excavated a less characteristic amphitheater at the head of Icicle Creek. This mountain mass formed a center from which these glaciers flowed in their several directions, and illustrates one stage in the removal of a central core by the headward extension or the general enlargement of glacial amphitheaters. A more advanced stage in this process would have produced a steep three-sided mountain with concave faces, each of the angles being prolonged into a buttress-like ridge.

### WENACHE AND CHIWAHWAH GLACIERS.

These two ancient glaciers, named after the rivers now occupying the valleys down which they flowed, united in the vicinity of Fish Lake, just east of Lake Wenache, but the ice body formed by their union extended only some 5 or 6 miles down Wenache Valley. The precise locality at which it terminated has not been determined. This same expanded ice body may have been joined also by another glacier which came from the west, down the valley of Nason Creek, as is indicated on P. X, but the glacial records in this region have not been studied, except during a single day's reconnaissance, and will have to be passed by for the present.

But little can be said, also, in reference to the Chiwahwah Glacier. Its source was on the east side of the Cascade divide, 8 miles northeast of Glacier Peak. It flowed southeast, through a generally straight valley, to the site of Fish Lake, a distance of approximately 30 miles, where, as just stated, it became tributary to the still larger Wenache Glacier. It received six or eight well-defined but short feeding glaciers from the rugged southwest side of its course, and had other branches, particularly near its source, on the northeast side. The main ice stream was approximately a mile and a half wide, but expanded on joining the Wenache Glacier. The combined ice body left moraines on the hillsides 1,180 feet above the level of Lake Wenache, but this is probably not a record of its maximum thickness. The Chiwahwah Glacier throughout at least 10 miles of its lower course was probably about 2,000 feet thick, but a thoroughly reliable measure in this connection has not been made.

Wenache Glacier had two main branches which united at the west end of the site of Lake Wenache, one branch coming from the west, down the Upper Wenache Valley, and the other from the northwest, down the valley of White Creek. Each of these branches had its source in an amphitheater on the east side of the Cascade divide and was fed by numerous lateral tributaries. The main White Creek branch has two important feeding ice streams, one in each of the deep canyon-like valleys now occupied by the North and West forks, respectively, of White Creek. After the union of these two main branches Wenache Glacier flowed eastward through that portion of its valley now occupied by Lake Wenache, and left moraines on its side between 1,700 and 1,800 feet above the present level of the lake. The glacier was here about 3 miles broad, but became still broader after uniting with Chiwahwah Glacier. As the ice melted it left heavy moraines in the region now occupied by Fish Lake. This lake is shallow and is retained mainly by a lateral moraine of the Wenache Glacier and by irregular heaps of débris, which in part have the characteristics of kames. Lake Wenache is retained by conspicuous terminal moraines which extend westward along its sides, particularly on its northern margin, and become well-developed lateral morainic ridges. The valley below the lake is deeply filled with gravel.

The waters of each of the main branches of White Creek are now intensely muddy, and those of the Chiwahwah opalescent, on account of the glacial silt they hold in suspension, thus bearing testimony, confirmed in part by direct observation, that small glaciers still exist near their sources. The Upper Wenache and White Creek enter Lake Wenache by separate mouths, and each is building a delta. Rounded glaciated rocks form a conspicuous feature at the entrance of the Upper Wenache Valley, from 1 to 2 miles west of Lake Wenache, but similar ice-burnished surfaces are elsewhere absent except far up the courses of the main valleys and in the cirques from which flowed the numerous lateral tributaries.

One feature characteristic of the glaciated valleys of the Cascades, previously noted in other similar regions, and especially in the Sierra Nevada,[1] is the fact that many lateral valleys with low gradients open from the main valleys high above their bottoms. The streams from the side valleys frequently plunge in picturesque cascades in order to reach the bottom of the large valley which formerly held trunk glaciers. This is well shown by Indian Creek, which starts at the east end of Indian Pass and flows northeast for about 6 miles through a flat-bottomed valley which bears all the usual evidences of having once been occupied by a glacier. The slope or gradient of the trough is so exceedingly gentle that the waters are ponded by fallen timber and vegetable

[1] I. C. Russell, Quaternary history of Mono Valley, California: Eighth Ann. Rept. U. S. Geol. Survey, 1886–87, pp. 332–333.

growths and form lakelets and marshes. Where Indian Creek Valley opens into the much larger valley of the West Fork of White Creek there is a precipitous descent of from 800 to 1,000 feet. The waters of Indian Creek plunge down this slope, forming cascades and foaming rapids, to join White Creek, which, although rapid, flows over gravel deposits. Such steep descents at the mouths of low-grade and nearly flat-bottomed lateral valleys to the bottoms of the much larger valleys to which they discharge are a common feature in the Cascade Mountains. An example similar to the one just cited occurs on Cascade Creek, which flows westward from Cascade Pass, and after a sluggish course of 4 or 5 miles descends rapidly, in part by falls about 40 to 50 feet high, to the larger valley, which conducts its waters to the Skagit. Other examples of like character have been noted by Henry Gannett[1] on the border of Stehekin Valley, to the west of Lake Chelan. Mr. Gannett renews the suggestion that the differences in the elevation between the bottoms of the lateral and of the main valleys to which they are tributary are due to the deeper corrasion performed by the larger ice streams as compared with the similar work done by their tributaries. At present there seems to be no alternative explanation, but this interpretation of the records implies a far greater amount of ice corrasion than most students of glacial phenomena are inclined to accept.

## CHELAN GLACIER AND LAKE CHELAN.

From the accounts already given of the ancient glaciers on the east side of the Cascade Mountains it may be noted that in general they increased in size and extent from south to north. This is, no doubt, due in part to difference in latitude, but to a far greater extent to an increase in the breadth of the elevated country and the greater numbers of lofty peaks and ridges northward through the Cascade Mountains. This is illustrated by the glacier which formerly occupied the valley of Lake Chelan and reached the Columbia River. From the Cascade divide to the mouth of the Chelan River, a distance of 65 miles in a straight line, the country is exceedingly mountainous, many of the peaks rising from 3,000 to 5,000 feet above the surface of the lake. In this region of granite and schist, as in the case of the Wenache Mountains, there is an eastward-reaching spur, or, what will more likely prove to be the case, an independent or partially independent uplift. The influence of this region of bold mountains on the old glaciers is indicated by the fact that Chelan Glacier was prolonged some 40 miles farther toward the southeast than either of its nearest neighbors—the Wenache Glacier to the southwest or the Methow Glacier to the northeast. The part played by the high mountains bordering the course of the Chelan Glacier in the history

[1] Nat. Geog. Mag., Vol. IX, 1898, pp. 419-441.

of the valley after the glacier melted, and in the origin of the magnificent lake which now occupies it, will be referred to later.

Chelan Glacier, like its neighboring ice streams, had its source at the Cascade divide and flowed in a southeasterly direction. Its length was about 75 miles and its width from 1 to 2 miles. It received several tributaries in the rugged regions west of the head of Lake Chelan, and an important branch through what is termed Railroad Canyon, a low-grade valley which opens into Chelan Valley from the west, about 11 miles south of the head of the lake.

Along the borders of Lake Chelan the mountains are precipitous and generally without glacial records, although polished and striated surfaces may be seen at several localities. About 10 miles west of the lower end of the lake the valley expands and the old glacier became 3 or 4 miles broad and left somewhat conspicuous moraines. The highest of these is near the foot of the lake and within some 4 or 5 miles of where the glacier terminated, and is about 800 feet above the surface of the lake. The surface gradient of the glacier, as is well known, must have increased from its foot toward its source; and as Lake Chelan is 1,400 feet deep at a distance of 35 or 40 miles from its outlet, it is safe to assume that the old glacier had a thickness of from 2,500 to 3,000 feet for a distance of many miles in the central part of its course.

Owing to the steepness of the walls of Chelan Valley throughout nearly its entire length, the glacier which once occupied it must have been abundantly charged with débris. But little of this material, however, was stranded on the valley sides, except at the end of the retreating glacier, where, for a distance of 4 or 5 miles back from its terminus, its abandoned trough was deeply filled. This material in part formed characteristic terminal moraines, which now dam the entrance to Chelan Valley and in large part at least hold the waters of the lake in check. That the lake owes its existence only in part to the morainic dam at its foot is shown by the fact, mentioned on a preceding page, that its bottom is below sea level, and, therefore, probably a rock basin. Subsequent to the deposition of these moraines Columbia Valley became deeply filled with gravel, which rose above the terminal moraine at the outlet of Lake Chelan. Chelan Valley, like many other similar valleys that have been excavated in the Cascade Plateau, owes its existence mainly to stream corrasion. It does not differ essentially from neighboring valleys, such as the one through which the Methow flows, for example, except in the fact that it holds a large lake. The lake is about 50 miles long, and in general less than a mile wide.[1] Why should this fine lake be present in Chelan Valley when neighboring valleys of the same general character are deeply filled with gravel, deposited since the glaciers which once occupied them melted away?

[1]Henry Gannett, Lake Chelan: Nat. Geog. Mag., Vol. IX, 1898, p. 426.

To be sure, Wenache Valley holds a comparatively small lake, which, as in several other similar instances, is retained by a terminal moraine. There are certain ways, however, in which the conditions in Chelan Valley differ from those in neighboring valleys.

The surface of Lake Chelan, as shown by accurate surveys made by the topographic branch of the United States Geological Survey, is 408 feet above the adjacent portion of Columbia River. Chelan River, starting from the lake, makes this descent in about 4 miles, and is a rushing torrent of clear water, which would soon cut a channel through any ordinary moraine. It happened, however, that when the extremity of Chelan Glacier receded, and the valley of the Columbia became deeply gravel filled, a lake was formed in Chelan Valley, which overflowed through a break in the solid rocks on the south side of the old valley, and only in part across the terminal moraine. If the stream had not met solid rock it would long since have cut down its channel, so as to lower the lake about 400 feet. The lake has been lowered, as shown by terraces, about 275 feet. One reason for the existence of Lake Chelan, as we now find it, is, therefore, the resistance met with by the draining stream in corrading its channel.

Methow Valley and many other similar valleys are occupied, to the depth of at least several hundred feet, by gravel deposits laid down since the retreat of the former glaciers. Why was not Chelan Valley also gravel filled? The explanation seems to be that the ice body which occupied it was thicker than in any other eastward-flowing glacier in the same region, and, besides, was sheltered by precipitous mountain walls, which delayed its melting. The Chelan Glacier lingered longer than its neighbors, and although the process of filling its abandoned basin with gravel, which produced such auspicious results in adjacent valleys, made itself felt there also, the task was greater and the time available less than in other similar instances. The fact that the process of gravel filling is still in progress in the Chelan Basin is shown by the deep gravel deposits at the west end of the valley, above the head of the lake. In the portion of the valley referred to gravel has been deposited so as to give it a generally flat bottom, higher than the surface of the lake. This deposit is of the nature of a delta, which is being prolonged into the lake. This gravel-floored portion of Chelan Valley has the same characteristics (so far as its post-Glacial history is concerned) as are found throughout Methow Valley and many other similar stream-cut trenches on the east side of the Cascades. Chelan Valley is of special interest in this connection, as it illustrates a process of gravel filling still under way. This process has been completed in a great majority of neighboring valleys, in some of which the reverse process, that of cutting channels through the gravels and removing them, is far advanced.

Space will not permit of such a description of the magnificent scenery about Lake Chelan as its importance demands, or an account of the clearness of its waters, the abundance of fish it contains, the vegetation of its shores, the snow-capped mountain, with small glaciers about its western portion, and other characteristic features. For these and other related attractions of the most charming lake on the Pacific coast of the United States, except, perhaps, Lake Tahoe, I must refer the reader to the publications named in the footnote.[1]

In addition to the features of geographic interest already mentioned in connection with Lake Chelan, there is a chapter in its history not yet fully interpreted, which may be mentioned in order to invite the attention of future visitors.

The moraines blocking the east end of the valley and forming the dam which retains the lake, at least in part, do not have the ordinary topographic features of glacial deposits, but are rounded and in general covered by waterworn gravels. On each side of the valley also there are gravel terraces, the most conspicuous of which, and I believe the highest of a similar character, being 250 feet above the surface of the lake.[2] This broad terrace is, measured by aneroid, about on a level with a similar gravel terrace in the adjacent portion of the valley of the Columbia, which is known as the Great Terrace of the Columbia, and which rises in one unbroken slope to a broad shelf between 600 and 700 feet above the river. This Great Terrace is present at various places, as will be described later, on each side of Columbia River, and shows that the valley where it occurs was formerly filled with gravel up to the level of its surface.[3] This gravel deposit filled the Columbia Valley to a level of from 225 to 250 feet above the present surface of Lake Chelan, and must have raised the morainic dam which retains that lake by the amount named. Previous to the deposition of the thick gravel deposit in the valley of the Columbia, Lake Chelan very likely discharged through a channel which crossed the old terminal moraine at a lower level than that at which Chelan River now flows, but this former channel was filled with gravel brought by the Columbia. When the Columbia began the reexcavation of the thick gravel deposit it had previously laid down, and left portions of it as the Great Terrace, the

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[1] I. C. Russell, A reconnaissance in central Washington: Bull. U. S. Geol. Survey No. 108, 1893, pp. 77–83. Lakes of North America, Ginn & Co., Boston, 1895, pp. 65-69.

Henry Gannett, Lake Chelan: Nat. Geog. Mag., Vol. IX, 1898, pp. 417–428.

[2] This terrace and other features in the relief of the region referred to are shown on a contour topographic sketch, by W. L. Dawson, in Am. Geologist, Vol. XXII, 1898, p. 216.

[3] Some of the facts concerning this Great Terrace and the interpretations of its history that have been proposed may be found in the following publications:

I. C. Russell, A geological reconnaissance in central Washington: Bull. U. S. Geol. Survey No. 108, p. 80.

W. L. Dawson, Glacial phenomena in Okanogan County, Washington: Am. Geologist, Vol. XXII, 1898, pp. 203–217.

I. C. Russell, The Great Terrace of the Columbia and other topographic features in the neighborhood of Lake Chelan, Washington: Am. Geologist, Vol. XXII, 1898, pp. 362–369.

present course of Chelan River was chosen. The river was forced to the extreme southern border of its valley by the current and gravel deposits of the Columbia, and had its present course established in part over solid rock.

This interpretation of the complex records at the outlet of Lake Chelan, as stated above, is tentative, and will no doubt have to be modified in details when opportunities for further study are available. Other considerations bearing on the history of the Chelan outlet will be presented later, in connection with a description of additional features of the Great Terrace of the Columbia, and especially its relation to Saunders Lake, near the mouth of the Methow.

It is but just that I should here refer to another hypothesis to account for the 225-foot terrace on the north side of Chelan Valley at Chelan, advanced by W. L. Dawson in the paper already referred to. In this paper it is assumed that Okanogan Glacier, which crossed the Columbia some 25 miles upstream from the mouth of Chelan River, sent a branch down the canyon of the Columbia, past the entrance to Chelan Valley, and was there sufficiently thick to form a dam and cause a rise of the waters in the valley to the west to the height of the 225-foot terrace. This measure of 225 feet for the terrace above the present surface of Lake Chelan refers to its outer edge, but the true water level is higher. I know of no evidence that the branch of the Okanogan Glacier had such an extent as claimed by Dawson, but am not prepared to deny it. In support of this hypothesis Dawson mentions the presence of a bowlder of basalt "weighing hundreds of tons * * * half buried in the hillside about 50 feet above the water on the north shore of the lake and also 5 miles from the Columbia."[1] The parent ledge of this block of basalt is stated to have been on the eastern border of the Columbia or in the region east of the Okanogan River, where the Columbia lava now occurs. If this source for the bowlder in question can be proved, we must evidently accept the hypothesis that the branch of the Okanogan Glacier in the canyon of the Columbia expanded after the recession of the Chelan Glacier, and reached at least 5 miles into Chelan Valley, as Dawson claims. I doubt, however, if this explanation is called for, as there are other possible sources for the basaltic bowlder referred to, as well as for others of similar character in the valley of the Methow, 5 miles from its mouth, also referred to by Dawson. One possible source for these bowlders is in dikes of basalt to the west of the Columbia, but more likely they came from remnants of the Columbia lava on the west side of the same river. The Columbia lava was spread out, as we have already seen, during late Tertiary time, and before the deep dissection of the region about Lake Chelan. The eroded border of the lava now forms a bold escarpment some 500 or

[1] Am. Geologist, Vol. XXII, 1898, p. 214.

600 feet high, crowning the bluffs on the east side of the Columbia opposite the mouths of Chelan and Methow rivers, and evidently had a wider extension westward when first extruded. Remnants of it are to be expected to occur in the foothills, at an elevation of 1,000 or 1,500 feet above the present valley bottoms, on the west side of the Columbia Canyon.

## METHOW GLACIER.

The next large glacier to the northward of Chelan Glacier flowed from the Cascade divide down the valley of the Methow. Its course, as may be seen on the accompanying map, Pl. XVIII, was first a little north of east for about 15 miles, to the mouth of Lost Creek, near the site of Ventura; it then bent southward and followed a southeast course for nearly 20 miles, to beyond the site of Winthrop. Several tributary ice streams came down the deep canyon on both the north and the south of its upper course above Ventura, and a large glacier descended the canyon of Early Winter Creek, which joins Methow Valley, from the west, 3 miles below Ventura.

Like the ancient glaciers already described, the one in the valley of the Methow was a comparatively narrow, well-defined ice stream in the bottom of a deep valley, with bold mountains on either side. Its width in general was about 1 mile, but on reaching the wider valley in which Winthrop is situated it expanded and became 2 or 3 miles broad. Its depth in the main trunk portion of its course is not known, but about 5 miles from its terminus it left lateral moraines 1,050 feet above the present level of the adjacent valley, which, however, is deeply filled with post-Glacial gravel.

Whether the valley of Chewach Creek, which joins the Methow from the north at Winthrop, was occupied by a glacier or not has not been ascertained. Perched bowlders occur, however, on the hills at the junction of these two valleys, 1,800 feet above their bottoms. The lateral moraines of Methow Glacier near Winthrop dammed the mouths of tributary valleys and gave origin to several small lakes; and in the area occupied by its expanded terminus there is an unusually fine series of gravel hills, with undrained basins between. This group of kames occupies an area of some 4 or 5 square miles, and contains a score or more of small lakelets, or swampy flats which were formerly lakelets. The hills are without any regular arrangement, and rise in general 30 to 50 feet above the lakelets, while a few are 70 feet or more in height, and some of them are connected by gravel ridges. They may be divided into two series: First, those which rise above the level of a widely extended gravel terrace; and second, those which occur below that level. The larger ones rise above the terrace and are surrounded by it; others are situated below the level of the terrace and have basins about them. Many of the smaller hills rise to the level of the terrace and seem to be portions of it, the adjacent basins having been formed since the terrace gravels were deposited. The hills in the first series are typical kames, deposited by the old glacier through the agency of the waters formed by its melting, while the second series appears to owe its origin to the melting of ice which was covered by the terrace gravels. Whether this last suggestion is the true explanation or not I desire to leave undecided until a better opportunity is afforded for the study of the region in question.

## SIMILKAMEEN GLACIER.

Only the source of this glacier near the Cascade divide, at the head of the river from which it takes its name, has been examined by me. From these studies, and from distant views of the upper portion of the Similkameen Valley, it is evident that a large glacier—larger, in fact, than any of those previously described in this paper—once flowed northward down this broad channel, and, after crossing the Canadian boundary, probably became a tributary of the Okanogan Glacier, briefly described below.

The valley of the Similkameen is fully 2 miles wide at the bottom, and now heavily forested, but has the characteristic U-shaped cross profile that glacial ice imparts to a previously water-cut trough. The old glacier for a distance of 10 miles from its source must have been upward of 3 miles broad. Several of its head branches start from deep amphitheaters near the Cascade divide.

## OKANOGAN GLACIER.

The river after which this ancient ice stream is named has its source to the north of the United States-Canadian boundary, and flows nearly due south, to its junction with the Columbia, in a broad valley bordered on both the east and the west by bold mountains. A detailed account of the glacial records in the northern portion of Okanogan Valley has been given by G. M. Dawson.[1] These show that a large ice stream formerly flowed down the valley and crossed the line of the present boundary into the territory of the United States. In this report the conclusion is presented that the region in question bears evidence of a general glaciation, as if it was formerly covered by an extended ice sheet flowing southward, and that after the melting of this earlier ice body a smaller but yet extensive valley glacier flowed down Okanogan Valley.

Evidence of the glaciation of Okanogan Valley south of the international boundary is presented by Bailey Willis in Bulletin No. 40 of the United States Geological Survey.

The southern end of Okanogan Valley was visited by me in 1892,

[1] Preliminary report on the physical and geological features of the southern portion of the interior of British Columbia, Geol. Nat. Hist. Survey Canada, Report of progress from 1877-78, Montreal, 1879, pp. 52 B, 137 B-153 B.

and evidence obtained of the remarkable changes made by the great great glacier which formerly flowed down it and crossed the canyon of the Columbia. These observations are recorded in Bulletin No. 108 of the United States Geological Survey, pages 86–87. In order to bring together, so far as practicable, the records of the glacial history of the general region described in the present paper, those just referred to in Bulletin 108 are, with slight changes, here transcribed.

In traveling northeast from the plateau overlooking Lake Chelan (across the northwest portion of the Great Plains of the Columbia) we gradually left behind us the farms that cluster about Waterville and crossed a still more prairie-like region in which the carpet of bunch grass was unbroken. Just when our ride was becoming monotonous our attention was attracted by a new feature in the topography of the plain. In front of us rose an irregular undulating ridge, which started at the brink of the canyon on our left and ran for many miles to the southeast, until lost to view in the distance. On the ridge, and rendering it conspicuous from a distance of several miles, were hundreds of bowlders, some of them larger than the cabins of the settlers, to be seen here and there among them. Actual measurements show that many of the blocks are between 50 and 60 feet in their various diameters. Beyond the first line of bowlders others could be seen, and on gaining the top of the ridge we found that the country to the east as far as the eye could reach was strewn with them. Sometimes the bowlders are piled in heaps, but usually they are separated by a few rods of grassy meadow. The greater part of the bowlders and all of the larger ones are black basalt, which in many cases show a well-defined columnar structure. A strange appearance is given to the scene by the various directions in which the joints dividing the volcanic blocks are inclined. With the angular masses of basalt there are also occasional bowlders of granite-gneiss, etc., of smaller size, but frequently measuring 8 or 10 feet in diameter.

The reason for the change in the character of the surface of the plateau was easily detected. The evidence of ice action was not only recorded by the bowlders, but also in the surfaces of outcropping layers of basalt, which were planed down and scored by lines running southeast, conforming with the trend of the long lines of bowlders and showing the direction in which the ice invasion moved.

The great glacier which carried bowlders in thousands over the northern border of Douglas County came from the north, down the broad valley now drained by Okanogan River, and crossed the canyon of the Columbia without being deflected from its general course. The passage of the Columbia Canyon is remarkable, as the great glacier, on reaching its southern wall, formed by basalt resting on granite, met an escarpment running directly across its course and 2,500 feet high. The granite on the face of this bluff is much disintegrated, but in places from top to bottom the scoring of the ice can be recognized. Where the earth has been recently removed the surface of the rock is highly polished and covered by fine striæ.

On reaching the Columbia the glacier from Okanogan Valley divided; one arm flowed down the river valley, but the greater part of the ice continued southeastward and reached to about the present site of Coulée City, where it ended in a lake. The eastern border of the glacier, after reaching the basaltic plateau of Douglas County, was determined by the Grand Coulée, which was cut before the ice invasion. The huge bowlders and piles of débris left by the glacier may be traced to the western verge of the Grand Coulée all the way from Coulée City northward to where the great gorge in the plateau joins the canyon of the Columbia. Bowlders and all other evidences of an ice invasion are absent to the east of the Grand Coulée.

From the above account, in connection with the descriptions of other glaciers given in the present paper, it will be seen that Okanogan Glacier was by far the largest on the east side of the Cascade Mountains in northern Washington. Although the records it left have not been systematically studied, they seem to suggest that the ice body in question was rather of the type of piedmont than of alpine glaciers.

The Okanogan Glacier crossed the Columbia, as just described, and dammed its waters. A lake was thus formed, which extended up the canyon and found an outlet across the Great Plains of the Columbia through what is known as the Grand Coulée. Some account of this old outlet is given in Bulletin No. 108 of the United States Geological Survey. At the time the Okanogan Glacier entered the canyon of the Columbia and during its maximum southward extension we have reason to conclude, from the general behavior of glaciers, that a branch of the ice stream flowed westward down the canyon. Direct evidence that this was the case has not been obtained, as the portion of the canyon referred to has not been traversed, so far as I am aware, by anyone especially interested in the glacial history of the region. In the canyon of the Columbia, however, at the mouth of the Methow, and for 2 or 3 miles downstream from that locality, there are immense quantities of bowlders, ranging from a few feet to 30 or 40 feet in diameter. These are composed mostly of granitoid rocks, but contain also huge angular masses of Columbia lava, like those scattered over the plateau surface to the northwest of Coulée City and described above. These thousands of bowlders belong to a moraine from which the finer material has been washed by the Columbia in cutting its modern channel through a gravel deposit which formerly completely covered the moraine and filled the valley to a level of about 460 feet above the present stream. The bowlders extend from the water's edge 235 feet up the escarpment, forming the broken border of a broad terrace (the Great Terrace of the Columbia) which formerly covered them.

I take it that these bowlders were brought down the Columbia Canyon by an offshoot or distributary of the Okanogan Glacier, but how much farther the same ice tongue may have extended down the canyon is not known.[1]

## ANCIENT GLACIERS ON THE WESTERN SLOPE OF THE CASCADES.

It is known from various sources, and especially from a paper by Bailey Willis on The Drift Phenomena of Puget Sound,[2] that the great plain or depression between the Cascade Mountains on the east and the Olympic Mountains on the west was formerly occupied by a large piedmont glacier similar in many ways to the existing Malaspina Glacier of Alaska; also that two stages of marked ice extension, separated by an interglacial stage of mild climatic conditions, are there recorded. The glacial records in this same general region, but to the north of the United States–Canadian boundary, have been described and discussed by G. M. Dawson.[3] It is evident, from the accounts referred to, as well as from the observations of the writer, that great alpine glaciers flowed westward from the Cascade Mountains and joined a still larger ice movement which came from the north into the Puget Sound region and discharged seaward through the Strait of Juan de Fuca, to the north of the Olympic Mountains and toward Grays Harbor to the south of that range.

The observations made during the explorations recorded in this paper cover so small a part of the great glaciated region just referred to that it does not seem desirable to devote much space to them, as their full significance and proper interpretation can not be conceived until a wider region shall have been examined.

I may say in brief, however, that hundreds and probably thousands of cirques exist on the western slope of the Cascade divide and on the sides of hundreds of lateral ridges between deeply eroded valleys which were formerly filled to their brims with névé snow and ice. Each of these cirques was drained by an alpine glacier, many of them of large size and joined by many tributaries. The main westward-flowing glaciers in northern Washington descended the valleys of the Snoqualmie, Skykomish, Sauk, and Skagit rivers. The Sauk Glacier joined the Skagit, however, about 40 miles from the eastern shore of Puget Sound. Each of these large alpine glaciers was a tributary of the Puget Sound ice sheet, and probably had two stages of maximum extension, separated by an intermediate stage, when they retreated far toward the Cascade divide. No direct evidence of such an interglacial episode, however, has as yet been discovered in the valleys occupied by

[1] The first published account of the remarkable accumulation of bowlders near the mouth of the Methow was, I believe, by W. L. Dawson in the American Geologist, Vol. XXII, 1898, p. 215.

[2] Bull. Geol. Soc. America, Vol. IX, 1898, pp. 111-162.

[3] Quart. Jour. Geol. Soc. London, Vol. XXXIV, p. 89. Geol. Nat. Hist. Survey Canada, Report of Progress for 1877-78, Montreal, 1879, pp. 136B-139B.

these glaciers, but it is inferred from the condition that obtained in the Puget Sound Basin.

The glacial records thus far referred to on the western slope of the Cascades are essentially the same as on the east side, but the westward-flowing glaciers were larger than their neighbors east of the Cascade divide and the country was much more completely ice covered. In fact, during the height of the Glacial epoch, or more accurately, perhaps, during its two maxima, the west side of the Cascade Mountains, down to a general altitude of something like 3,500 feet, seems to have been completely buried beneath the confluent névés of many glaciers. In the higher portions of the mountains near the head of Ruby Creek the crests of sharp divides are glaciated and covered in part with transported bowlders, apparently of local origin. These facts seem to show that the westward-flowing glaciers in reality formed a confluent ice sheet, which moved westward over an exceedingly rugged country. How generally the local divides on the west side of the Cascades are glaciated remains to be determined, but enough has been seen to sustain the conclusion just stated in regard to the region adjacent to the Canadian boundary.

During the Glacial epoch a great glacier in the valley of the Skagit crossed the international boundary and flowed southward to the mouth of Thunder Creek, then followed a southwest course to the site of Marblemount, where it curved once more and took a more westerly direction to Puget Sound. Above Marblemount tributary glaciers, some of them of large size, came in from lateral canyons, on both the east and the west. A large glacier flowed down the valley of Cascade Creek, and a much larger one, as already stated, descended the valley of the Sauk. The thickness of the ice in the middle and lower portions of Skagit Valley has not been determined, but, judging from glaciated surfaces and stranded bowlders on Sauk Mountain, it was not less than 1,000 feet, although this is probably not the maximum.

All of the larger valleys on the west side of the Cascades in northern Washington, except in their extreme upper courses, are deeply gravel filled and have high gravel terraces along their borders. For this reason but slight evidence of the former presence of glacial ice can be had in their immediate bottoms. Near their sources, however, where their valley tracts end, and throughout their short mountain tracts, the conditions for gleaning information are more favorable. In the valley of the Skagit, above the mouth of Thunder Creek, the bottom is of hard granite, rising in huge, bare bosses which show intensely glaciated surfaces. In this portion of the valley bottom, also, there are numerous rock basins, some of them holding swamps. These conditions prevail all the way from the mouth of Thunder Creek to above the mouth of Ruby Creek. Throughout this distance the modern river has worn a narrow, steep-sided canyon in the bottom of the much broader U-shaped valley. Near the town of Ruby, where this inner canyon is crossed by a rude bridge, it is about 80 feet wide and 70 to 80 feet deep. The broad-bottomed Skagit Valley extends for at least 8 or 10 miles north of Ruby Creek, and, judging from distant views, has all the characteristics of a river valley that has been widened and given a U-shaped cross profile by a great glacier which formerly flowed down it.

Ruby Creek also had its trunk glacier, which, like all the similar ice streams heading at the Cascade divide, received many branches, each of which started from an amphitheater; at least, such were the conditions except during the stages of maximum ice occupation, when, as already stated, the entire region, including the high ridges near the main divide, were buried beneath confluent ice sheets. Ruby Glacier was one of the larger tributaries of Skagit Glacier from the east.

## SUMMARY.

During the Glacial epoch the Cascade Mountains in northern Washington were heavily snow covered and gave origin to large glaciers of the alpine type. These flowed both east and west from the main divide, down previously deeply eroded stream valleys. The snow fields from which large trunk glaciers descended on the higher portions of the eastern slope of the mountains were confluent. On the west side of the main divide the snow fields were broader and thicker than on the east side—so thick, in fact, that when glacial conditions were at their maximum a general ice sheet was formed which buried some of the most prominent ridges, especially in the northern portion of the region under consideration. It seems possible that along the northern portion of the Cascade divide in northern Washington the snow was piled so high on the west side of the main divide that the snow divide was some distance west of the present rock divide.

The main eastward-flowing glaciers occupied the valleys of the Yakima, Icicle, Wenache, Stehekin-Chelan, Methow, and Similkameen rivers. Each of these main trunk glaciers had many branches and ended independently at various distances from the main divide. The longest of these ice streams, excepting, perhaps, the Similkameen-Okanogan, was the Chelan Glacier, which flowed southeastward (like all of its neighboring ice streams, except the Similkameen in its upper course) for about 75 miles and reached the canyon of the Columbia. These eastward-flowing glaciers did not unite so as to form a piedmont glacier, and no evidence of a general ice sheet in the low country to the east of the Cascade Mountains and south of the Canadian boundary has been discovered, unless the Okanogan Glacier, having within the United States the characteristics of a large alpine glacier, was in reality the southern end of a lowland ice sheet.

The westward-flowing glaciers drained a vast series of confluent snow fields, which, during times of maximum glaciation, formed a continuous ice sheet on all the higher portions of the western slope of the mountains. The trunk glaciers flowing from this ice sheet were, in general, broader and thicker than the similar glaciers on the east side of the range, and became true alpine glaciers of the character of the Seward Glacier, Alaska, but expanded and united at their lower extremities and assisted in forming a large piedmont glacier which occupied the Puget Sound Basin. This piedmont glacier had two stages of broad expansion, separated by an interglacial stage, during which thick gravel deposits, together with layers of peat, were spread out on top of a basement layer of till.

The correlation of the former great glaciers of the Cascade Mountains with the Glacial epoch is made principally on general considerations well understood by geologists and need not be discussed at this time. The climate of Washington, in common with that of the whole of North America, was colder than it is now, but conditions analogous to the present differences in respect to precipitation on the two sides of the Cascades are shown to have existed by the greater extent of the glaciers on the western slope in comparison with those in the valleys draining to the Columbia. During the time of stream erosion which preceded the appearance of the glaciers the land was more elevated than it is now, as is indicated by the depth to which the valleys were corraded, but evidence is lacking to show that this greater altitude persisted until the glaciers were formed.

## POST-GLACIAL GRAVELS AND STREAM TERRACES.

Among the most interesting phases of the surface geology of Washington are the stream-deposited gravels which occur in practically all the valleys and the terraces that the streams have made in these deposits as they reexcavated their channels. Not only are the bottoms of the present valleys in a large number of instances floored to a considerable depth by waterworn gravel, over which the present streams flow, but on their sides, often to a height of 400 or 500 feet or more, there are well-defined gravel terraces which show that the valleys were formerly filled from side to side with similar material up to the level of the highest of these benches.

These gravel deposits occur both below the extremities of the old glaciers, more especially on the east side of the Cascades, and in the troughs that the ice formerly occupied. It is thus evident that they are largely post-Glacial, but, in fact, as will be shown more definitely below, they were laid down in part while the glaciers occupied the upper portions of previously stream-cut valleys. The evidence is such as to show that the streams were overloaded for a considerable length of time and upgraded their channels, and after this stage were able to excavate channels in the material they had previously deposited. It is well to keep in mind these two well-marked episodes in the lives of the streams, the first including the time of the advance and retreat of the glaciers, and the second succeeding their disappearance and continuing to the present day. During interglacial stages the gravel deposits made during the preceding ice advance were probably in part, or perhaps wholly, removed, but as to this we have no direct evidence. The valleys that did not contain glaciers have similar records of a time of abundant deposition followed by a time of erosion.

The detailed observations on which these conclusions are based are too numerous to record at this time, and only the more striking examples need to be described. It is not claiming too much to say that every valley in the Cascade Mountains in Washington contains evidence in this connection. This same statement is known to be true, also, of the valley in the mountainous portions of the northeastern and eastern borders of the State and adjacent portions of Idaho and Canada. The measurements of the height of terraces given in the following notes were made with aneroid barometers and can be considered merely as approximations to their true altitudes.

GRAVEL DEPOSITS ALONG THE YAKIMA AND ITS TRIBUTARIES.

Thick gravel deposits occur in Yakima Valley from Clealum to Lakes Clealum and Kachess, as already stated in describing the Yakima Glacier. Near Clealum these deposits have had a channel about a half mile wide and 130 feet deep cut through them by the river. The surface of the gravel deposit spared by this channel cutting forms broad terraces, and on the sides of the cut there are smaller and lower terraces at certain favorable localities. Below Clealum the erosion of the gravels has been so great that only scanty remnants can be clearly distinguished on the north side of the valley, but the highest terrace there present soon broadens and in the vicinity of Teanaway Station becomes about a half mile wide, with a steep escarpment facing the Yakima River. On the south side of the Yakima, from Clealum to near the gateway in basalt through which the river flows on the south side of Lookout Mountain, the terraces are much obscured by landslides from the steep escarpment that rises above where they should occur. The hypothesis of the former presence of a lake in the portion of the valley of the Yakima just referred to has been entertained, but not enough facts have been discovered to justify it. It seems that the valley was formerly filled with stream-deposited gravel from side to side up to the level of the highest terrace on its borders, and then reexcavated.

Along the Teanaway, a tributary of the Yakima from the north, valley gravels again occur, and a conspicuous gravel terrace was

PLEISTOCENE GRAVEL NEAR LIBERTY.

observed between 90 and 100 feet above the present stream. The gravel deposits just referred to extend far up each of the three main forks of the Teanaway, and in many localities have been cut into well-defined terraces. On the North Fork, just above Ryepatch, especially characteristic terraces occur at 75, 80, and 113 feet above the adjacent river.

On Swauk Creek, also, typical gravel terraces occur, which have extensions up each of its tributaries. An interesting feature in this region is that the basin of the Swauk was never occupied by glacial ice. Another instructive fact is that in some of the smaller tributary valleys the level flooring of gravel, from 70 to 80 feet deep, as shown by mining shafts, has not been trenched by modern stream erosion. It is these valley gravels that yield placer gold near Liberty. The broadest and highest terrace near Liberty is from 80 to 90 feet above the present drainage. A section of this terrace and of the rough bed rock of Swauk sandstone and shale on which the gravel rests is shown on Pl. XVI.

### GRAVEL DEPOSITS AND TERRACES ALONG THE WENACHE.

The bottom of the valley through which the Wenache flows is deeply gravel filled from its mouth to a locality about 1 mile west of Wenache Lake, with the exception of the portion of its channel sunk in granite just above Leavenworth. At the mouth of the Peshastin the valley of the Wenache is some 3 miles broad. On the south side of the river there is an abandoned flood plain about 3,000 feet wide and from 60 to 70 feet above the river. On the steep border of this terrace, overlooking the river, there are lower terraces.

In the neighborhood of Lake Wenache, especially about its east end, there are lake terraces which merge with stream terraces along the border of the outflowing river. The valley of the Chiwahwah is bordered in places by two conspicuous terraces, one 40 feet and another and broader one 70 to 80 feet above the creek. Similar conditions prevail also far up White Creek, but all of the valleys in the region about Lake Wenache are densely forested, and but little information concerning their recent history was obtained during the limited time at my command.

### GRAVEL DEPOSITS AND TERRACES ALONG THE METHOW AND ITS TRIBUTARIES.

The gravel deposits in Methow Valley are a conspicuous feature all the way from the mouth of Rattlesnake Creek, and even a mile or two above that locality, to the Columbia, a distance of from 65 to 75 miles. About 10 miles up the Methow, above Winthrop, broad, well-defined gravel terraces occur here and there on the border of the valley at an elevation of about 500 feet above the present stream. The valley between these fragments of terraces is more than a mile broad, and is floored from side to side by coarse gravels, which evidently form a sheet of very considerable thickness. At Winthrop these gravels have been penetrated to the depth of 70 feet without finding bed rock. From the breadth of the Methow Valley in the vicinity of Goat Wall, Ventura, etc., and the character of its precipitous borders, which go down in places almost vertically below the gravels flooring the valley, one can not avoid the conclusion that these deposits are at least 200 or 300 feet thick.

Along Early Winter Creek, a branch of the Methow from the west, near Ventura, there are broad terraces of coarse gravel, the broken escarpments of which rise 350 feet above the stream. This creek is swift and has a comparatively high grade. The terraces have about the same slope as the present stream.

Terraces are also conspicuous along the sides of Methow Valley below Winthrop to the mouth of the river, where they merge with similar but still more characteristic examples along the Columbia. About 24 miles below Winthrop are two well-defined gravel terraces on the sides of the valley, one 200 and the other 400 feet above the adjacent portion of the river. On the Methow, 4 miles from its mouth, there is a well-defined terrace at 225, another at 440, and another at 600 feet above the river. The last terrace referred to merges with the great terrace of the Columbia, briefly described below.

### GRAVEL DEPOSITS ALONG THE COLUMBIA.

Occurring at intervals on each side of the Columbia, from an indefinite locality 8 or 10 miles downstream from the mouth of Chelan River and extending upstream to above the mouth of the Okanogan (and no doubt very much farther, but this upper portion of the river's course has not been explored), there are well-defined gravel terraces, the highest in the series being sometimes a mile to a mile and a half broad. The height of the surface of this broad terrace, which may be termed the Great Terrace of the Columbia, as shown by aneroid measurements, is between 600 and 700 feet.[1] Where the terrace is broad, as in the vicinity of the mouth of the Methow, its slope forms the uplands to the escarpment overlooking the river, and is sometimes about 100 feet high. This slope of the surface causes variations in the height of the fragments that have been left, according as they are broad or narrow.

The Columbia, for a score or more of miles in the region just referred

[1] An aneroid measurement of the height of this terrace in 1892, at a locality on the east side of the river, about 3 miles below the mouth of Chelan River, gave 700 feet as its approximate elevation above the river at its base (Bull. U. S. Geol. Survey No. 108, p. 78). The accuracy of this observation has been called in question by W. L. Dawson, who states its height to be 300 feet (Am. Geologist, Vol. XXII, 1898, p. 213). A reply to this criticism, with additional data in reference to the height of the Great Terrace, may be found in the American Geologist, Vol. XXII, 1898, pp. 362-365.

to, flows with a swift current, but is unbroken by cascades, and evidently has not yet cut through the gravels deposited in its old rock channel. The entire depth of the original gravel filling must have been in excess of 700 feet.

At the time the gravel deposits, remnants of which occur in the Great Terrace, were laid down, the Columbia was a broad, swift stream, which, in the vicinity of the mouth of the Methow, meandered over a flood plain some 3 or 4 miles wide. Certain peculiar results were produced by the deep filling of the old valley.

Opposite the mouth of the Methow the Columbia makes a sharp bend, concave to the southeast, and a bold, rocky shoulder or promontory, runs out into the valley. The end of this promontory is composed of a number of rocky crags, which rise some 50 feet or more above the level of the gravel filling now surrounding them. The general surface of the end of this promontory is on a level with the Great Terrace and is a part of it. A portion, or perhaps the whole, of the river once flowed between the crags referred to and the eastern border of the valley, as is shown by a coulée or gorge, some 150 feet deep, which cuts across the promontory and leaves its western portion as a table-land or mesa. This transverse channel is in solid rock, and is of older date than the gravel deposit represented by the Great Terrace, although modified to some extent by the waters which subsequently flowed down it. The present conditions at the locality referred to are shown in the above topographic sketch (fig. 3) by W. L. Dawson, borrowed from the article in the American Geologist, already referred to.

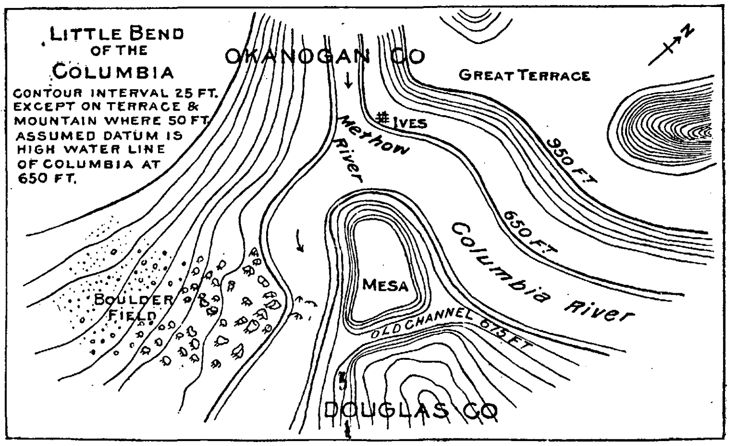


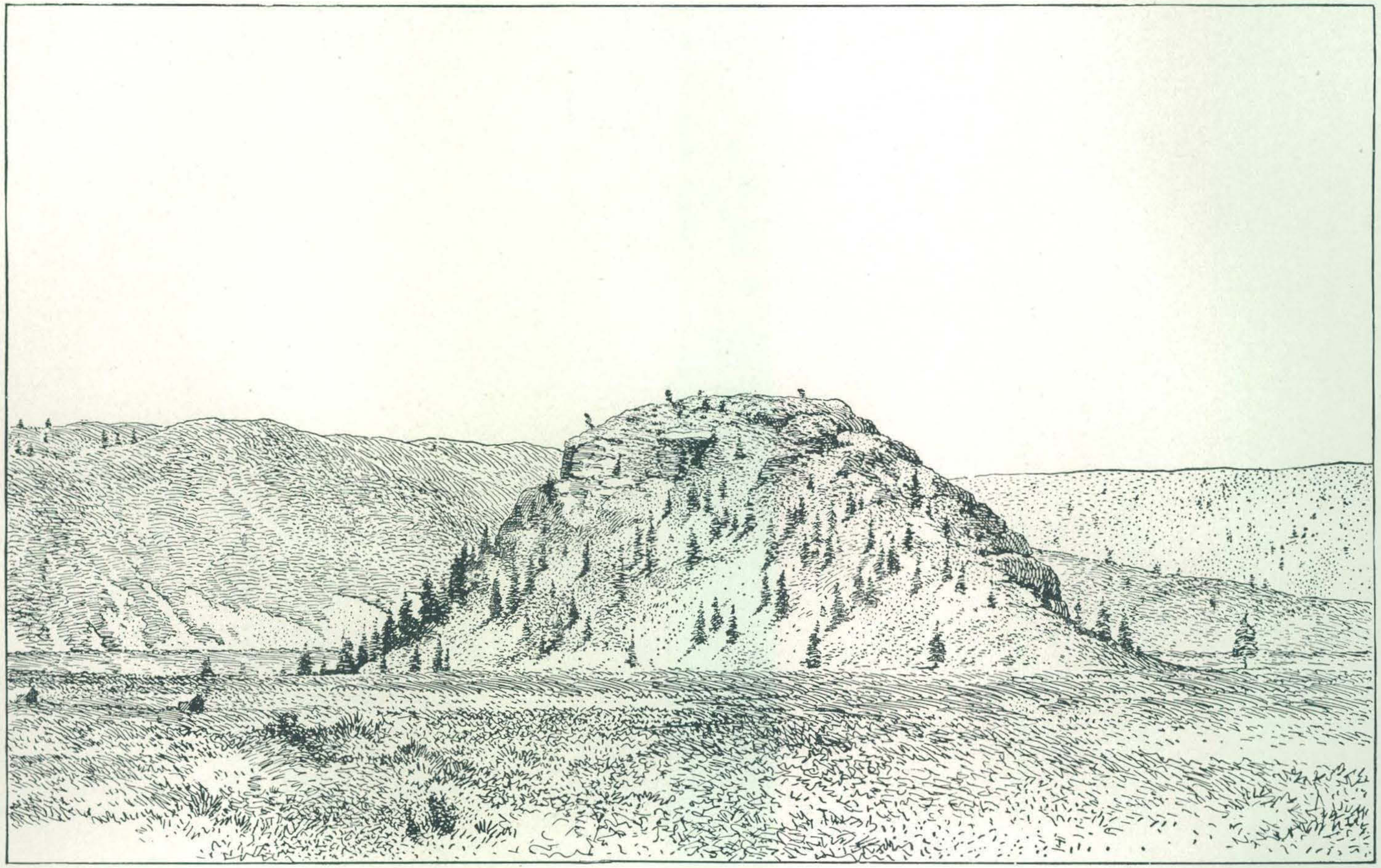

FIG. 3.—Sketch map showing junction of Methow River with the Columbia.

The history of this peculiar topographic feature seems to be that, when the Columbia Valley was filled from side to side with gravel, up to the level of the surface of the Great Terrace, a branch of the river flowed over the site of this channel, leaving the crags on the present mesa as islands. When the river began to excavate its present inner canyon the mouth of the old transverse channel was reached first, as the river downstream from it deepened its bed, and all of the waters of the river flowed through the side channel, forming a rapid or series of cascades. Subsequently the waters of the Methow and those from the broad plateau extending northward from the present small mesa excavated a channel, since widened by the Columbia, and drew off the waters of the main river, so as to cause them to abandon the transverse channel in solid rock and take an easier course through the gravels in the former valley. A different explanation of the origin of the conditions represented in the figure has been advanced by Dawson in the article referred to, but I think it need not be again discussed.[1]

There are several other peculiar topographic features on the border of the Columbia Valley, which are an inheritance from the time its valley was deeply filled with gravel.

On the west side of the valley to the south of the Methow, there is another coulée—as canyons not now occupied by streams or but imperfectly drained are termed in the Northwest—known as Antwines Coulée, which is far larger than the one referred to above. This is a deep, narrow defile in granite, and connects the valley of the Methow, at a locality about 4 miles from its mouth, with the valley of the Columbia some 10 miles downstream. The entrance to this coulée is about 100 feet lower than the surface of the Great Terrace of the Columbia, but a mile or two southward, its bottom, owing to talus slopes and alluvial fans deposited in it, is higher than the terrace. When the Columbia flowed over the surface of the gravel deposits in its valley its waters entered Antwines Coulée, but could not flow through it. A lake-like embayment was formed on the side of the river, cut off from it in part by rocky crags, which the currents of the river could not enter. The gravels deposited in the valley of the Columbia and in the lower portion of Methow Valley extended to the mouth of the coulée, but did not fill it. When the Columbia reexcavated its channel this basin was left as a lake, and has remained in this condition ever since. The lake's surface was lowered by percolation, but it did not cut an outlet channel, and its present representative, Saunders Lake, does not overflow. This lake is about 1 mile long from north to south, and a half mile wide. The surface of the lake is about 100 feet below the level of the Great Terrace, the slope of which forms the north wall of its basin, and is subject to a fluctuation of about 5 feet. Its waters are fresh, but have deposited a thin coating of calcareous tufa on its rocky shores. Southward from the lake the coulée is obstructed by alluvial fans and talus slopes, as already stated, which divide it into a number of small basins. Three of these basins hold

[1] My reasons for rejecting this hypothesis have been presented in the American Geologist, Vol. XXII, 1898, pp. 362-369.



ROCK RISING THROUGH THE GREAT TERRACE OF THE COLUMBIA.

lakelets, while others are swampy. It is evident that waters have not flowed through this old channel for a long time, and there is no evidence that it was ever occupied by glacial ice. Its origin will be discussed in connection with other similar topographic features on a subsequent page.

The surface of the Great Terrace in the valley of the Columbia adjacent to the mouth of the Methow is markedly irregular. Kettle-like depressions occur in it, which are frequently 20 to 40 and sometimes fully 60 feet deep, and 200 or 300 feet or more broad. These are without notches in their rims, and plainly are not due to erosion. Sometimes one basin is separated from its neighbor by a narrow ridge of gravel with a curved summit line, lowest in the center. The reason for these numerous irregular depressions below the generally plane surface of the terrace is apparently to be found in the irregular settling of the deposit; or, as they resemble the undrained basins so frequently associated with kames, they may possibly be due to the melting of ice which was buried beneath or inclosed in the deposit.

The Great Terrace of the Columbia forms what I understand is known as Howard Flat, or "Poverty Flat," on the west side of the river, and about 4 miles above the mouth of Chelan River. In the central part of this flat a bold, rocky mass rises like an island to a height, by estimate, of about 400 feet, and at the level of the terrace, above which it projects, it is 1,000 or 1,500 feet in diameter. A view of this rock is presented in Pl. XVII. The most striking feature in connection with this island-like rock rising through the level plain of gravel is a great crescent-shaped pit on its northern side, between 80 and 100 feet deep, with a flat bottom, on which pine trees about 2 feet in diameter are growing. The surface of the terrace is free of trees and shrubs, except such as are under cultivation. The straight, or but moderately curved, border of the pit, as seen in a ground plan, is formed by the northern slope of the rock mass which rises above the gravel; while the rim of its north wall, which curves away from the island and presents a slope of 35° toward it, is on a level with the gravel plain. The length of the pit from east to west—that is, from one horn of the crescent in a straight line to the extremity of the other horn—is, by estimate, about 800 feet, and its width in the central portion, approximately, 300 or 400 feet.

This unique feature in the gravel terrace is analogous to the curved depressions to be seen on the upstream side of bowlders in the bed of a swift stream which is sweeping along sand and gravel. In such instances, as is well known, the eddies in the current, produced as the waters strike a stone which obstructs their flow, keep open a crescent-shaped pit, as seen in ground plan, while a sheet of sand and gravel is deposited about the obstruction. From this analogy and other considerations, it may be suggested, as a tentative hypothesis, that the

Columbia, at the time it filled its valley with gravel to the level of the present Great Terrace, was flowing with a strong current and carrying along gravel and sand; on coming in contact with the great crag rising in Howard Flat an eddy was produced, which prevented the gravel and sand from being deposited on the upstream side of the obstruction. On all other sides of the island-like rock the surface of the gravel terrace comes in immediate contact with its sides. On the southern border of the former island there are sandy deposits, which suggest a low triangular platform pointing southward; but this feature is not well shown and has been observed only from one side. The flood plain of the Columbia where Howard Flat was formed was from 4 to 5 miles broad. Some account has already been given of the great gravel terrace of the Columbia in the neighborhood of the outlet of Lake Chelan.

As the surface of the Great Terrace, as shown by aneroid measurement, is about 250 feet above the present surface of Lake Chelan, it seems as if the valley in which the lake is situated had essentially the same relation to the Columbia as has been described in the case of Antwines Coulée. The strong current of the Columbia did not enter Chelan Valley, as it was occupied by a lake and had a discharge of its own, but the gravels, brought in part by the Columbia, were carried into the entrance of the lateral valley on its north side and there deposited in a broad terrace, which still remains, with but slight modification, at an elevation on its outer border of 225 feet above the present lake. A terrace at the same level is faintly represented on the south side of the valley.

When the Columbia reexcavated its valley the water of the lake in Chelan Valley fell rapidly, the outflowing waters being forced to the south side of the basin, where it opens out into the Columbia Valley, and finding a final avenue of discharge through a break much like Antwines Coulée. The deepening of this channel has caused the level of Lake Chelan to be lowered about 40 feet, as is shown by a terrace at Chelan City.

### GRAVEL DEPOSITS AT PETERS CANYON.

Near the southern end of Antwines Coulée that deep, narrow trench joins a narrow valley, down which flows a small stream, known, I believe, as Peters Creek. The canyon of this stream opens out into the valley of the Columbia about midway between Chelan and Methow rivers. Remarkably fine gravel terraces occur, especially on the south side of Peters Canyon and overlooking the Great Terrace of the Columbia. These terraces are composed mostly of coarse, well-rounded gravel, but on their surfaces there are a few angular blocks of rock 8 to 10, and in at least one instance 15, feet in diameter. There are two conspicuous terraces at the locality referred to. The escarpment of the lowest one rises in one unbroken slope, as steep as the gravel will lie, 400 feet high above Peters Creek, which flows along its base. The second terrace is 110 feet above the first. The border of the higher terrace is also a steep gravel slope, somewhat less precipitous than the one below. The opposite margin of the higher terrace, adjacent to the former border of the stream that formed it, is a steep gravel escarpment ascending to a sloping gravel plain, or great "wash," as such deeply gravel-filled valleys are sometimes termed, the surface of which ascends with a well-marked gradient for at least 4 or 5 miles into the mountains to the west. On the surface of this gravel deposit there are angular masses of crystalline rock some 12 or 15 feet in diameter. The base of the escarpment which descends from the lower of the two terraces just described is above the level of the Great Terrace of the Columbia, and from each of the great steps on the side of the valley one has an unobstructed view into the valley of that river, but from the head, as it were, of a reentrant alcove on its side.

The topographic conditions I have just attempted to describe are most striking and difficult of explanation, but on the whole can not be considered as unique in the general region where they occur.

The great gravel deposit, which has been terraced, and which is certainly over 600 feet thick, is a portion of the material which filled Peters Canyon and another canyon to the south, which joined it just before the two opened out into the far larger valley of the Columbia. Peters Canyon has been very nearly cleared of its gravels down to the level of the stream flowing through it, and has extended its modern canyon diagonally across the gravel deposit in the tributary canyon and left that material strongly terraced. The small stream which flows down the companion of Peters Canyon has done but little in the way of clearing out its old valley, perhaps because it has been shifted to hard rock. That this is truly the case, however, has not been observed. Both Peters Canyon and its companion have comparatively high gradients, and the gravel deposit now deeply filling the one that has not been reexcavated has a similar surface gradient. As the locality where the terraces occur is, by estimate, about 4 miles from the Columbia, it would seem as if the gradient of the stream which deposited the gravels was sufficient to account for their elevation above that river. Under this hypothesis the blocks of stone on the terraces and on the alluvial slope above them must be considered as having been brought to their present resting places by the stream which deposited the gravel, and not by glacial ice.

In speaking of these remarkable terraces Mr. W. L. Dawson[1] says:

Moreover, the lower or southern extension of this (Antwines) coulée is bordered by walls of terrace material, which were evidently accumulated at a time when the occupation of the Columbia Gorge by the still moving Okanogan Glacier prevented the free escape of drainage waters.

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[1] Am. Geologist, Vol. XXII, 1898, p. 212.

The difference in elevation between the highest of the terraces referred to and the surface of the Columbia in the neighboring portion of its course is about 1,250 feet. A glacier in the valley of the Columbia would necessarily have had greater thickness than this in order to pond the waters in Peters Canyon at the level of the highest terrace, but thus far no evidence of such a thickness of ice in that valley has been obtained. Moreover, such a ponding of the waters in Peters Canyon and in its companion would not account for the surface slope of the gravel deposit above the highest of the terraces.

It should be understood in this connection that the high terrace described above is not to be referred to the Columbia itself, but pertains to the streams which flow down Peters Canyon and its companion and later join the Columbia. Moreover, similar terraces in high-grade valleys are a common feature of the eastern slope of the Cascades, and the great majority of these can not be accounted for by assuming the presence of ice dams in the larger valleys to which they are tributary.

### GRAVEL DEPOSITS ON THE WESTERN SLOPE OF THE CASCADES.

Gravel deposits now forming terraces like those of the Methow, Columbia, etc., occur also on the western slope of the Cascades. These show that the valleys of the westward-flowing streams were also deeply filled with gravel and sand after the retreat of the old glaciers, and have subsequently been deeply reexcavated. Our knowledge of the terraces on the western slope of the Cascades is less extensive than of those on the eastern slope, in part on account of the dense forests that clothe them, and also because of less extended explorations.

On the western border of the valley of the Sauk, from 6 to 10 miles above its mouth, there is a well-defined terrace of coarse gravel and sand at an elevation of 160 feet above the river. Near the mouth of Mill Creek, on the southern border of the narrow, canyon-like valley of Ruby Creek, there is a gravel terrace some 400 or 500 feet above the adjacent portion of Ruby Creek, but this may belong in part to Mill Creek, which has a high gradient. It is evident, however, that Ruby Creek Valley or Canyon was formerly deeply gravel filled. As shown by a mining shaft, the stream now flows over gravel throughout much of its course at a level of 70 feet above bed rock.

### GRAVEL DEPOSITS IN EASTERN WASHINGTON.

As briefly described in a previous report,[1] there are gravel terraces in the canyon of Snake River near where it crosses the Idaho-Washington boundary. The highest of these now clearly recognizable is 360 feet above the present stream. This now flows over solid

[1] I. C. Russell, A reconnaissance in southeastern Washington: Water-supply and Irrigation Paper U. S. Geol. Survey No. 4, 1897, pp. 20-21.

rock and has resumed the task of deepening its rock-cut channel, having to a great extent removed the gravel deposits previously laid down in it.

A similar but much more interesting record occurs along the border of Spokane River in the neighborhood of the city of the same name. As described in part in the report just referred to, Spokane River flows in a narrow canyon cut in gravel, and probably less than 100 feet deep, for many miles before reaching the basalt over which it plunges at the city of Spokane. Below that city the stream is in the bottom of a deep canyon, on the sides of which there are several gravel terraces. The Spokane Valley above the city is a gravel plain 2 to 3 miles or more broad, sloping downstream with a moderately steep gradient. This sloping plain or "wash" is formed of gravel brought from the mountains to the east, and illustrates by a most remarkable example the characteristics of a deeply gravel-filled valley. The gravel has not been dissected, for the reason that the river in flowing over the deposits in its valley meandered from side to side, as may still be seen by the shallow channels bordered by low terraces in the surface of the old flood plain. This plain at one time, it is safe to assume, although its occurrence has not been traced for more than 2 or 3 miles west of the city of Spokane, extended to the Columbia, but when the river ceased upgrading and began to reexcavate its valley, it chanced in its meanderings to flow over the site of a buried ledge of basalt at Spokane Falls, and the rate of its down cutting above the sill of hard rock thus encountered was greatly retarded. Below the falls it reexcavated its valley, leaving gravel terraces on either side and bringing about conditions almost precisely similar to those we find in the valley of the Methow, Columbia, etc. Above the falls, however, the stream has cut only a shallow channel in its old deposit. This still deeply filled portion of the valley, which attracts the attention of the observant traveler on the Northern Pacific Railway for a distance of several miles to the eastward of Spokane, is a well-preserved example of the condition of very many of the larger valleys of Washington after the Glacial epoch and before the rivers had made much headway in the removal of the gravels previously laid aside in this flood plain.

## TERRACES IN THE ADJACENT PORTIONS OF CANADA.

In describing the surface deposits and terraces of British Columbia adjacent to the northern boundary of Washington, G. M. Dawson[1] recognizes two main classes of terraces; one series made about the shores of extensive lakes, or during a depression of the land when

[1] Preliminary report on the physical and geological features of the southern portion of the interior of British Columbia: Geol. Nat. Hist. Survey Canada, Report of Progress for 1877-78, Montreal, 1879, pp. 139B-153B.

the surface with essentially all its present features was submerged so as to allow the waters of the ocean to build terraces which are now over 5,000 feet above the present sea level; the other series such as have been made by streams. In connection with the first series of terraces referred to, according to Dawson there occur certain fine, evenly stratified white silts varying from a few feet to fully 100 feet in thickness.

In the report just cited numerous descriptions of terraces on the borders of valleys are given, together with measurements of their elevation above the sea, which show that in part the terraces in the region adjacent to Washington on the north are of the same character as those along the Methow, Columbia, etc.; but as two distinct classes of terraces are described by Dawson, it is not practicable for one not familiar with the facts in the field to clearly separate them.

It is safe to conclude, from Dawson's observations, that the valleys of southern British Columbia have been deeply filled, as is the case of the valleys of Washington, and thus wholly or in part reexcavated.

The most conspicuous terraces along the Frazer, judging from personal observation while traveling over the Canadian Pacific Railway, are true stream terraces, the highest being about 600 feet above the river.

As will be stated more definitely in the summary which follows, no evidence of a post-Glacial submergence of the portion of Washington considered in the present report has been recognized. For this reason a close comparison of the surface deposits and terraces of southern British Columbia and of northern Washington is not now practicable.

## SUMMARY.

The evidence presented in part on the last few pages shows that the valleys of the northern and eastern portion of Washington were filled with gravel and sand in Glacial and post-Glacial times to a depth in general of several hundred feet. Subsequently the streams excavated channels through these deposits, and in many instances removed them almost completely, down to the level of the present streams. Some of the streams, as, for example, Snake River, have cut entirely through the gravels, and have renewed the corrasion of the hard-rock floors of their valleys and canyons. In the majority of instances, however, the beds of the streams are formed of gravel, generally of considerable thickness. The gravel beneath Ruby Creek, as we have seen, is 70 feet deep, and in the Methow Valley it exceeds this depth. The remaining portions of the gravel deposits form terraces along the sides of the streams, some of which are a mile or more broad and have a downstream gradient. As the streams reexcavated their valleys other terraces, also fragments of flood plains, were left at lower levels. These steps on the sides of the valleys are thus plainly stream terraces.

A noticeable feature in connection with the terraces is that not only do they border the larger and comparatively low-grade rivers, but they occur in mountain gorges and along torrential streams, and in such instances have a conspicuous downstream slope, which is less steep than the gradients of the present streams in the same valleys.

That these terraces are not due to a tilting of the land so as to slacken the flow of the streams is shown by the fact that they occur along the borders of streams which flow in various directions. They occur in association with streams flowing westward from the Cascades, as well as along those flowing eastward from the same divide, and also in the valleys of the rivers flowing westward from the mountains of Idaho, and border the streams flowing southward, as in the case of the Okanogan. More than this, the terraces are well developed not only along the main trunk streams but up their various branches, no matter what their gradients may be, unless, perhaps, their beds are excessively steep and their waters fall in cascades. These conditions show that a tilting of the land has not played an important part in the history of the gravel deposits or in the manner in which they have been reexcavated and the sides of the modern channels terraced.

Thus far in the study of the surface geology of Washington no evidence has been obtained of a modern depression of the land of such a nature as would admit of the flooding of the valleys by the waters of the ocean, unless possibly such an event is indicated by certain faint terraces in the basin of the Columbia in south-central Washington, which have been referred to the wave action of a lake named Lake Lewis.

Again, no evidence is known of the presence of silt deposits in Washington corresponding with the "white silt" found so abundantly in the valley of the basin-like region in the adjacent portion of Canada, to the east of the Cascades.

Practically all of the terraces in the portions of Washington referred to in this paper are stream terraces. The exceptions are mainly, if not entirely, certain lake terraces of local occurrence, such as those about Lakes Wenache and Chelan and on the borders of a few valleys which formerly held small lakes.

As the terraces have been produced through the agency of streams, and can not be accounted for as a result of such movements of the land as would have reduced their gradients and allowed them to deposit material for a long period of time, and then, by a reverse movement, renewed their power to corrade, some other change must be looked for to account for the facts observed.

The valleys throughout at least three-fourths of the State of Washington, as already shown, have a similar history so far as their gravel deposits and terraces are concerned, and it is evident that the cause which produced the changes must have been wide reaching. If not due to changes in the land, their origin may perhaps be correlated with changes in the atmosphere, or, more properly, with changes in climatic conditions. That a great climatic change did occur during Pleistocene time is well known, and was so widely extended that it affected the whole of North America, and, in fact, the entire atmospheric envelope of the earth.

The origin and vast extension of glaciers which occurred at this period in the northern part of North America, including Washington, together with their several great fluctuations and final retreat or disappearance, are evidence that the climate of the region under consideration was formerly much colder than it is now. About the southern margin of the former continental ice sheets and in the valleys between the snow- and ice-covered Pacific Mountains [1] we are justified in assuming that the mean annual precipitation, taking the form of both rain and snow, was greater than at present. Abundant facts to sustain this conclusion are furnished by the records of the Pleistocene lakes of the Great Basin. The melting of the snow on the mountains, together with the rainfall, must have swollen not only the streams flowing from the glaciers, but others as well, so that all the streams had their volumes increased to a marked extent during the Glacial epoch.

Now, as is well known, an increase in the volume of a stream means greater energy available for transportation, and, other conditions remaining unchanged, an increase in its power to corrade. On this ground alone we might justly assume that the streams of Washington and adjacent regions should have greatly deepened their channels during the Glacial epoch instead of deeply filling them. Streams fed by glaciers, however, as is also well known from the study of many existing examples, are usually supplied with more débris than they can transport, or are overloaded, and consequently aggrade their channels. For this reason we seem justified in assuming that the streams flowing fro the glaciers of the Cascades and neighboring mountains were overloaded during the Glacial epoch, in spite of their increased volumes, and consequently made deposits in their previously eroded valleys and canyons.

Assisting in the process just referred to, as I think we may assume, was the deeply decayed condition of the surface rocks, as a result of the long-continued mild and humid climate of the preceding Tertiary period, during which they were exposed to the chemical action of warm waters charged with organic acids. When the climatic change which culminated in the Glacial epoch, having probably three or more maxima, made itself felt, the streams, although enlarged, had their loads increased also, and, as it would seem, in a greater ratio. Both

[1] The name Pacific Mountains is here applied collectively to all of the great chains of mountains on the west side of the continental basin of North America. See Bull. Geog. Soc. Phila., Vol. II, 1899, pp. 55–89.

the glaciers and the streams found an abundance of material ready for transportation. In this same connection attention may be directed to what seems a fair deduction, namely, that the sheet of decayed rock débris on the uplands was sheltered and preserved during the Tertiary by a luxuriant and largely arboreal vegetation, which, to a great extent, must have been destroyed by the climatic change that permitted of the development of glaciers on a grand scale where palms had previously flourished. The decayed rock surface, denuded of vegetation and subjected to marked changes of temperature, the freezing of absorbed water, and the wash of an increased rainfall, insured the loading of both glaciers and streams flowing from them with an abundant supply of débris. Streams not fed by glaciers must also have received an increased supply of the same class of material. The process of upgrading must have begun before any considerable extension of the glaciers occurred, and continued during their retreat. In fact, the process in some instances has been continued to the present day, as is illustrated by the still broadening flood plains of the streams flowing from the larger glaciers about Mount Rainier.

As the climatic conditions favorable for the growth of glaciers passed their maximum, and conditions similar to those which prevailed before the Glacial epoch were more and more nearly approached, in reference especially to mean annual temperature and precipitation; the streams were no longer overloaded, for the reason, in part, that the supply of rock fragments was not equal to the demand, and they began to reexcavate their deeply filled channels. The portions of these former flood plains not removed remained as terraces.

The process of cutting channels through the flood-plain gravels was subject to fluctuation, owing to changes in local conditions, which led to the formation of terraces on the sides of the newer channels. Each of these terraces, or each pair when portions of the same flood plains were left on the opposite sides of a stream, is a record of a halt in the process of channel making. The causes of all these halts are not known, but some of them were certainly due to the presence of lakes in the courses of the streams, which for a time delayed the deepening of the channels of tributary streams by forming a local base-level. The streams, when their work of vertical corrasion was checked by a lake, broadened their channels by lateral corrasion at the expense of the gravel deposits through which they flowed, and when the lake was filled or its outlet channel lowered the stream again intrenched itself, leaving portions of its second flood plain as a terrace. Similar results would follow also if the streams in deepening their channels encountered ledges of resistant rocks which had to be trenched before the process of reexcavating the gravel deposits above the obstruction could be completed. The remnants of the first-formed and highest flood plains, especially in the larger valleys, are frequently broad terraces like the

Great Terrace of the Columbia, while the remaining portions of the lower flood plains are commonly narrow shelves on the sides of the canyons sunk in the older flood plains.

In the foregoing discussion of the mode in which the valleys referred to have been deeply gravel filled and subsequently terraced, but little reference has been made to the influence of lakes on these processes. In some instances lakes retained by morainal dams were formed after the retreat of the glaciers, and were filled by their tributary streams. Some of these bodies of water still exist, as is illustrated by Lakes Wenache and Chelan, in which the inflowing streams are now building deltas. A lowering of the level of these lakes by the cutting down of their outlets is recorded by terraces about their shores. The terraces in some of the valleys, not in association with existing lakes, are probably also of lacustral origin, but owing to the low gradient of the larger valleys it is difficult to distinguish lake terraces from stream terraces. The occurrence of true lacustral terraces, perhaps, formed in part of light-colored silt, is to be expected both at higher and at lower levels than the Great Terrace so frequently mentioned on the last few pages.

Links, as it were, in the chain of events recorded by the gravel deposits and terraces just considered may be selected, which will serve to illustrate the history outlined above. The streams flowing from the existing glaciers about Mount Rainier, as Carbon River, for example, owing to the superabundance of bowlders, gravel, and sand supplied to them by the glaciers, are still upgrading their previously deeply corraded valleys. Certain of the larger channels now particularly free of ice, as Wenache and Chelan valleys, still retain lakes, and another variation in the process by which valleys became filled with gravel is now in progress. Other valleys in which the upgrading stage has been passed, but which, for some cause, as the encountering of a ledge of hard rock by Spokane River, have not been deeply trenched, illustrate the conditions of many valleys when the streams flowing through them have just begun the task of removing their previously deposited débris. Later stages in the reexcavation of the valleys are illustrated by a great number of examples, ending with such streams as have completed their long-deferred tasks.

Another phase in this interesting history is furnished by a large number of well-defined stream-cut valleys, especially on the eastern slope of the Cascades and among the mountains of Idaho, which are no longer avenues of drainage. The rainfall is now too small to form even ephemeral streams in these deeply gravel-filled troughs, and their nearly flat bottoms, having, however, in numerous instances a well-defined gradient, are without stream channels. In many instances transient streams flow down gulches in the precipitous borders of these practically dry valleys and have formed typical alluvial fans or cones, which expand on their bottoms and not infrequently cross them from side to side so as to form obstructions, between which the water collects. In this way small lakes without outlets are formed, while in other cases these basins are occupied by swamp or grassy meadows. The water which reaches these streamless valleys, where there are no basins with bottoms rendered impervious by fine silt, is absorbed and allowed to percolate away. The sides of these valleys also, where their borders rise in cliffs, are frequently encumbered with talus slopes or screes, and in many instances large angular blocks of rock that have fallen from the cliffs are scattered over their surfaces. A typical example of the class of valleys just described is furnished by Elbow Canyon, which is traversed by a trail leading from Winthrop southwestward to the canyon of the Twisp, at a locality about 10 miles from its junction with Methow. Hundreds of other equally characteristic instances may be found, especially on the lower slopes of the eastern border of the Cascades, and even more abundantly amid the mountains of Idaho. Several of these streamless valleys bear evidence that decided changes in the drainage have taken place in recent times, owing to the deflection of streams by glaciers, by the moraines they left as well as by the deep gravel accumulations described above.

## EXISTING GLACIERS.

While the numerous small glaciers on the Cascade Mountains are not of special interest in themselves, they form a portion of a great series of ice bodies on the Pacific Mountains, which are among the most remarkable in the world. This glacier belt, as has been described elsewhere,[1] begins at the south, with the score or more of small alpine glaciers about the higher peaks of the Sierra Nevada in south-central California. As one follows the great Cordilleran glacial belt northward from its first appearance in the High Sierra, the lower limit of perennial snow, or the "snow line," at first about 12,000 feet above the sea, descends lower and lower, until finally in the vicinity of Mount St. Elias it has an elevation of only 2,000 or 2,500 feet. Farther west, along the curve made by the mountains about the northern shore of the Pacific, the snow line again rises, and on the Aleutian Islands has an elevation of perhaps 8,000 or 10,000 feet. The glacial ice everywhere extends below the limit of perennial snow, but is most thoroughly exposed in late summer or early autumn, when the true position of the snow line is sharply defined. In the High Sierra the extension of glacial ice below the névés is but slight, and during seasons of unusual snowfall, or when the summers are exceptionally cool, may not be recognizable. Proceeding northward, the ice extension is more and more pronounced until the region of maximum glaciation is reached.

[1] I. C. Russell, Glaciers of North America, Ginn & Co., Boston, 1897.

Thence westward the length of the tongues of ice below the snow fields decreases.

In the High Sierra, as already stated, the glaciers do not descend below about 12,000 feet; farther north they reach lower and lower limits, until in the vicinity of Stikine River, in about latitude 57°, they gain the sea level. Thence northward and westward to beyond Mount St. Elias, a distance along the coast of between 700 and 800 miles, there are hundreds and possibly thousands of glaciers that descend practically to sea level, and scores which enter the sea and, breaking off, form bergs. Beyond the Mount St. Elias region their lower limit gradually rises.

At the south end of the crescent-shaped belt of glaciers under consideration the ice bodies are small and detached and are separated from one another by intervening ridges and mountain peaks. Proceeding northward, they increase in area and in frequency, and unite one with another in the névé region. The snow belt broadens and finally becomes a confluent sheet 80 or 100 miles broad in southern Alaska, but narrows again westward and is there broken into individual névés of limited extent, similar to those of the High Sierra. The most thoroughly snow- and ice-covered portion is in the region between Lynn Canal and Cook Inlet, Alaska, where not less than 15,000 square miles of mountainous country is almost completely buried beneath a single vast névé field from which ice streams of the alpine type flow both north and south through rugged defiles in the flanks of the mountains. The southward-flowing glaciers are larger, more numerous, and much longer than those that find their way northward, and, in gaining the lowlands adjacent to the ocean, expand and unite one with another, so as to form broad plateaus of ice, known as piedmont glaciers.

Could the observer obtain a bird's-eye view of the western portion of North America, he would find that the Cordilleran glaciers form an irregular curve, broadest and reaching sea level in the Mount St. Elias region, and narrowing and becoming more and more elevated at its southern and western extremities. The attenuated arms of this shining crescent are broken, for the reason that only the more elevated mountains near its extremities reach the horizon at which perennial snow exists. As in the crescent of light reflected from the surface of the moon, the mountains occupied by this ice crescent where the belt is broadcast are white to their bases, while only the peaks of the most lofty elevations at the extremities of the broken circle are brilliant. The length of this crescent of snow and ice is about 3,000 miles. Its form is less regular, however, than the comparison made above might lead one to suppose, as its southern prolongation is broader and more broken than its central and western portions.

The largest and finest glaciers in Washington are on Mount Rainier, and have been described by me in the Eighteenth Annual Report of the United States Geological Survey, Part II. Other similar ice streams occur on Mount Adams and Mount Baker, but these have not yet been studied. In the portion of Washington under consideration there are several hundred glaciers, all of the alpine type and of small size. Such notes as have been obtained concerning them are here presented.

## GLACIERS ON THE WENACHE MOUNTAINS.

In describing the records of the old glaciers it was found that the Wenache Mountains formed an independent center of ice dispersion, from which flowed several large glaciers. One is not surprised, therefore, to find small glaciers still lingering on the higher portions of this rugged and exceedingly picturesque group of granite peaks.

On the summit portion of the Wenache Mountains, about 4 miles due east of the culminating pinnacle of Mount Stuart, there is a glacier measuring, by estimate, one mile from north to south and, including both névé and true glacial ice, of somewhat less width. This glacier lies like a blanket on the broad surface of the mountain top at an elevation of between 8,000 and 8,500 feet, but slopes eastward and is fully exposed to the sky, there being no sheltering peaks. The waters formed by its melting descend a steep, glaciated slope of bare granite and supply the Twin Lakes. The stream flowing from these lakes is the most easterly branch of Icicle Creek, and joins it about 5 miles south of Leavenworth. The glacier just described is on the highest portion of the western rim of a magnificent amphitheater excavated in compact granite. A view into this desolate but wonderfully attractive basin from the narrow crest forming its east wall is the finest and most instructive picture of its kind to be found in the entire Cascade regions.

On the north side of Mount Stuart, and 1,000 feet below its summit, or at an elevation of about 8,500 feet above the sea, there are three small glaciers, situated in steep gorges or clefts in the granite and sheltered by outstanding cliffs. The gathering grounds for these glaciers are small, and the three combined would probably make an ice body less in mass than the one above Twin Lakes. The glaciers here referred to are narrow, and extend down the gorges where they occur for some 2,000 feet. When seen from a distance, a well-defined contrast between the névé portions and the true glacial ice below is apparent. Below each glacier there is a small and fresh-looking moraine.

The glaciers just described derive their main interest from the fact that they are isolated, being some 25 or 30 miles to the east of the main divide of the Cascade Mountains.

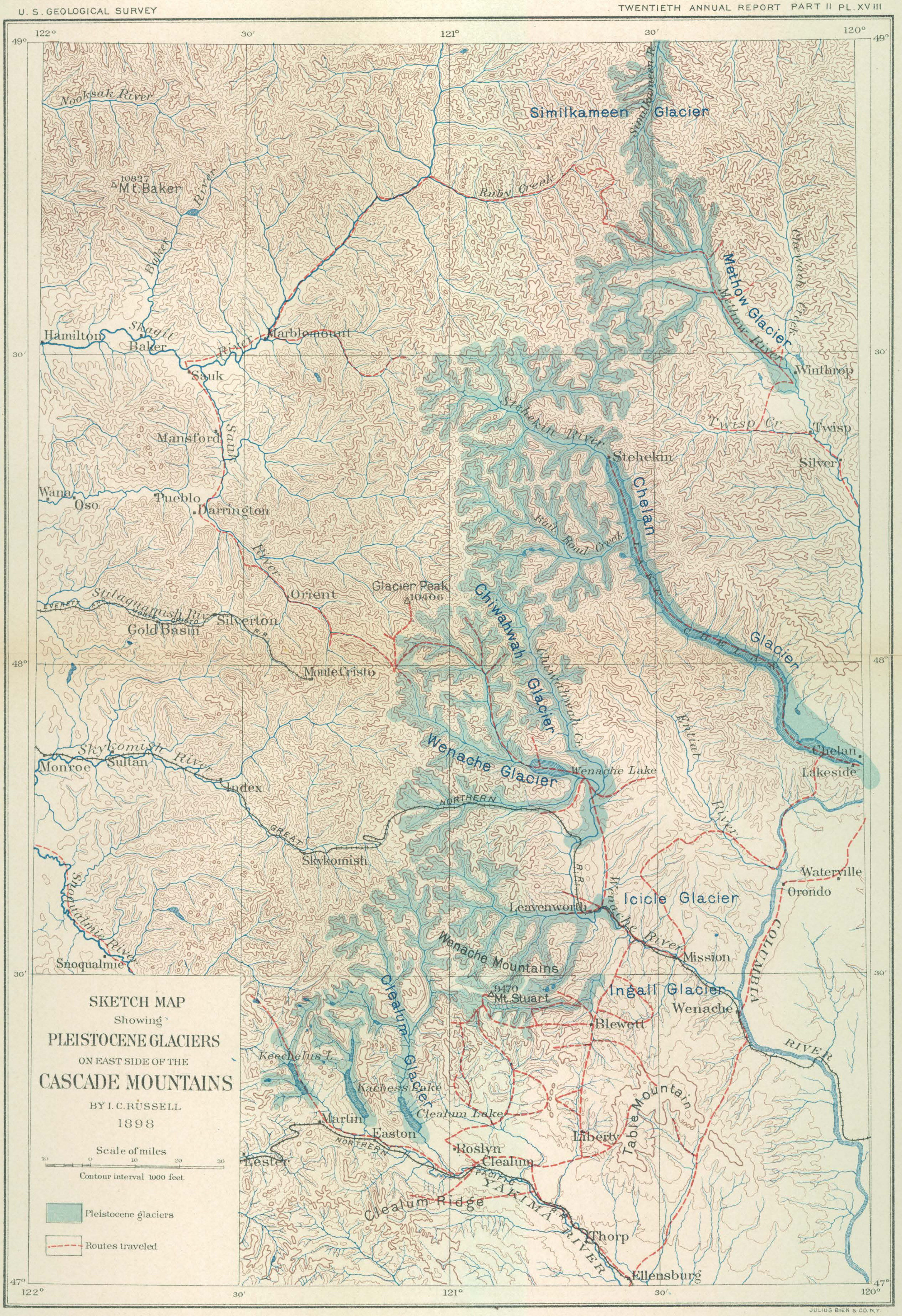
## GLACIERS ON THE CASCADE MOUNTAINS.

The glaciers of the Cascade Mountains south of the United States-Canadian boundary probably number several hundred. About 100 or 150 have been seen by me, but of these only a few in the immediate vicinity of Glacier Peak have actually been traversed. From the small amount of detailed observations available, it is now obviously impracticable to give an adequate account of the existing glaciers in the region here discussed.

As previously stated, all of the glaciers in the Cascades are small; of those seen, probably the largest single individual is not over 2 miles long, and a large majority are considerably below this in length. They are nearly all in amphitheaters or cirques, which were formed principally during a previous time of more intense glaciation, and have broad névés in comparison with the areas of the ice tongues which protrude from beneath them. While exhibiting most of the features that characterize typical streamlike alpine glaciers, there seems to be but little that is novel concerning them. Their principal interest centers in their distribution, their relation to present climatic conditions, and the fact that all of those seen are accompanied by evidences of recent recession.

There is one small glacier, however, that is worthy of special study, particularly in reference to the manner in which an ice stream expands when not confined by walls of rock and not heavily loaded with débris, and, in expanding, forms longitudinal or perhaps more properly radial crevasses in its fan-shaped terminus. The glacier referred to is at the head of Whitechuck Creek, at the immediate south base of Glacier Peak, but on the south side of the deep canyon in which flows the branch of the creek nearest to its base. This glacier flows northward, and is in full view from Glacier Peak. The periphery of its broadly expanded extremity is by estimate not over 1,000 or 1,500 feet, and is broken by some four or five radial crevasses, which are widest on the outer margin of the fan-shaped expansion and contract to mere clefts which become narrow and disappear when traced toward the feeding névé. This is a typical miniature example of glaciers like the Rhone Glacier, Switzerland, and the Davidson Glacier, Alaska.

Most of the glaciers on the Cascades have a lower limit of about 6,000 feet, and the majority of them are west of the Cascade divide. Those to the east of the dividing line between the east and the west-flowing streams are mostly in close proximity to it, as at the head of White Creek, which flows eastward and joins Wenache River, or on the high granitic peaks overlooking the western portion of Lake Chelan. To the north of the group of peaks just referred to there are no glaciers on the east side of the Cascade divide, as far at least as the northern boundary of Washington.

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The glaciers to the west of the Cascade divide are mostly in the vicinity of Glacier Peak or on the sides of lateral ridges branching from it; a few, however, occur in somewhat detached peaks, some of them 10 to 20 miles west of the crest of the range. Of these outlying groups of glaciers, the most numerous, as has been observed by Willis, are at the heads of high-grade valleys in the granitic peaks about Monte Cristo and on similar granitic peaks bordering the upper course of Skagit River. There is also an outlying group of glaciers on Mount Baker and neighboring mountains.

The broadest névé fields and most numerous glaciers occur on Glacier Peak and the rugged mountains surrounding it. The snow fields in this region cover a rugged area some 10 square miles in extent, and are confluent, and from this gathering ground there flow several short ice streams, or, rather, ice tongues, as none of them have a characteristic streamlike form. These glaciers, on melting, supply the West Fork of White Creek, which flows east, and both the south and north forks of Whitechuck Creek, which flows west and becomes tributary to Sauk River. The character of the névé fields just mentioned is shown on the accompanying photographs, Pl. X. Their surfaces are undulating and show the broader inequalities in the rocks, which they cover as with a blanket. The névé snows extend up the sides of the culminating cone of Glacier Peak and occupy the remnant of a crater still recognizable at its summit. From the top of Glacier Peak fully fifty glaciers are in view within a radius of about 30 miles. But little, if any, difference in the distribution of these glaciers can be recognized on looking northward or southward, thus indicating that their existence depends on general climatic conditions rather than on topographic environment.

## LANDSLIDES.

It is well known that masses of rock sometimes break away on steep slopes and descend into adjacent depressions as landslides and avalanches. There seems to be no commonly recognized distinction between landslides and avalanches, but in this paper I shall consider that the term avalanche applies to the rapid descent of snow and ice on slopes more or less steep, accompanied at times by large quantities of rock débris; while the term landslide will be understood to mean the displacement either of large rock masses or of quantities of loose rock fragments. The distinctions just made are admitted to be lacking in accuracy, since there is no sharp boundary between snow and ice avalanches charged with débris and landslides of loose material, or rock avalanches, as they are aptly termed. Again, there is no sharp distinction that can be recognized between a landslide and the flow of saturated clay, or even the slow creep of débris down steep slopes. The best that we can do is to recognize typical examples of each of these several ways in which material finds its way down declivities, as the basis for such genetic terms as landslide, avalanche, mud flow, the creep of talus slopes, etc., and make more specific designations when combinations of two or more of these several processes occur. Again, there is a gradation from what are commonly recognized as landslides, through rock masses a quarter of a cubic mile or more in volume, which break off from mountain sides and subside a few feet in such a manner as to leave open fissures, to great blocks of the earth's crust bounded on one or more sides by faults. Examples of each of these methods of surface displacement of rock material are furnished in the Cascade region.

Landslide, as the term is here used, refers to the rapid descent of a rock mass either as a single block or as a quantity of loose débris moving more or less as a single mass. It would be convenient to have a term by which to designate the fallen mass after coming to rest, but none such has been proposed.

The topography of a region where landslides occur is changed in two ways—by the removal and by the accumulation of material.

The contours of a mountain, plateau, or other land form that stands in relief are altered by the removal of material; for example, when a portion of the border of a plateau falls away, a reentering angle or curve is produced; or, when a rock avalanche occurs on a mountain side, a gorge or depression with a high gradient may result. The material composing a landslide comes to rest in ridges and piles which have certain characteristic shapes. The most noticeable feature in such instances is the backward slope of the surface of the displaced material after it comes to rest. The surface of the landslide, whether composed mainly of a single block or of a heterogeneous mass of loose material, slopes toward the cliff from which it came. This backward slope tends to the formation of basins, in which water accumulates, and lakes and swamps result. The backward slope referred to appears to be due to friction between the moving mass and the rocks beneath, which retards the progress of the material at the bottom and in front, so as to allow the material which comes later and at a higher level to slide over it. In heterogeneous masses of fallen rocks there frequently appear to be several planes of shear along which differential motion has taken place.

The geological conditions most favorable to the occurrence of landslides are furnished when massive rocks overlie soft and more incoherent material, such as clay, soft sandstone, lapilli, etc., and when such a series forms a bold escarpment. The occurrence of landslides is also favored by a vertical jointing of the superior, massive bed, by the undercutting of an escarpment by stream corrasion, and by the saturation of the rocks with water.

The conditions favorable for landslides are fulfilled in nearly all particulars in places where the Columbia lava, in sheets 400 or 500 feet or more thick, rests on clays and sand, or on deposits of volcanic lapilli, and the series has been eroded so as to form steep escarpments. In such instances the rocks may be horizontal or variously inclined. Many examples of these conditions are furnished along the great northward-facing escarpment of Clealum Ridge, and on the westward margins of the sloping table-lands known as Lookout and Table mountains. Numerous other localities, along the western border of the Columbia lava, from Table Mountain northward to beyond the mouth of Okanogan River, mainly on the east side of the Columbia, furnish as favorable conditions for landslides as those just referred to. Throughout this irregular line of great escarpments, more than 100 miles in length, the landslides that have occurred are to be numbered, not by scores or hundreds, but by thousands. The great escarpments themselves are cliffs of recession, their slow retreat having been accomplished in large part by the breaking away of large masses of the lava sheets which form the summits of the cliffs and the descent of these masses into the adjacent valleys. As will be shown below, the displaced blocks and the more or less comminuted débris produced by their fall are slowly removed by rock decay and stream erosion.

The fact that the escarpments referred to are formed of the edges of nearly horizontal or but slightly inclined layers of hard basalt, which are traversed by joints at right angles to the planes of bedding, and also the occurrence of layers of soft rocks beneath the hard, cliff-forming layers, furnish conditions unusually favorable for landslides. In fact, landslide topography, as it may be termed, is nearly as characteristic of the Columbia lava region as are its magnificent cliffs. The topographic features, due directly to the fallen masses themselves, are probably seldom recognized, while the long lines of frowning escarpments obtrude themselves on the attention of even the least observant. The fact is, however, that the cliffs in many instances have resulted from the breaking away of large rock masses, and will in time be destroyed by the same process.

The alternation of lava sheets and lacustral sediments, lapilli, etc., is not a marked feature of the entire country occupied by the Columbia lava, and for this reason great variations occur in the extent to which the escarpment of that region has been affected by landslides. In southeastern Washington, in the region of the Blue Hills, for instance, sedimentary or other soft layers between the lava sheets are relatively unimportant, and throughout scores and even hundreds of miles of canyon, walls appear to be absent. In this portion of the field the evidences of former landslides on a large scale have not been noted.

A striking contrast with the region just referred to is furnished by the region of tilted sandstone and lava sheets to the northeast of the Wenache Mountains. In these instances the truncated edges of the hard layers form prominent escarpments which sweep about the centers of elevation in vast, irregular curves. As erosion progressed it caused a slow recession of inward-facing cliffs, due principally to their having fallen from time to time in landslides and the gradual decay and removal of the fallen blocks by streams and percolating waters. This process is still in progress, and a series of topographic changes from fresh landslides to rolling, prairie-like lands, with deep, rich soils and features characteristic of oldland surfaces, can be easily traced. The reader must not infer, however, that the entire area from which the successive sheets of Columbia lava have been removed has a low relief. The streams have cut deeply into the rocks from which the lowest lava sheet has been removed, and produced a markedly different series of land forms, in which sharp ridges and deep, narrow valleys are conspicuous elements. A belt of country marked by landslide topography which was gradually smoothed out, owing to the decay and erosion of the fallen blocks of basalt, receded with the slow retreat of the encircling cliffs, and was replaced by exceedingly rugged topography.

The nature of the changes produced by landslides and the subsequent decay of the fallen masses and their melting down, as it were, into an undulating plain with undrained basins is graphically displayed at many places adjacent to the still receding escarpments. Favorable localities for this study are furnished by Table and Lookout mountains. Standing on Lookout Mountain, for instance, one beholds toward the southeast a gently sloping table-land which rises toward his station. The surface of this inclined table is formed of a sheet of Columbia lava which dips southeast at an angle of 4° or 5°. On its northwestern margin this table-land breaks off so as to form a precipice 400 or 500 feet high. In many places this escarpment is vertical, but its lower slopes are masked by talus. Below the main palisade-like escarpment are many others of a similar character, but of less height and seldom over a half mile in length. The lower escarpments are formed of the edges of blocks of lava which have broken away from the higher cliffs from time to time and plowed their way down into the valley. The fallen blocks are inclined at angles of 10° to 15° toward the cliffs from which they fell. At the base of the main escarpment there is a series of irregular depressions or basins, which connect with one another more or less perfectly and are bounded on their northwestern margins by the backward-sloping blocks. At the present time there are small lakes without visible outlets in three of these basins. Each lake is several acres in area, and, except where the basin has become partially filled with talus from the overshadowing cliffs to the eastward, is deepest on that side. The western edges of the fallen blocks rise some 200 or 300 feet above the surface

*A*. LAKE IN LANDSLIDE BASIN, LOOKOUT MOUNTAIN.

*B*. LANDSLIDE TOPOGRAPHY NEAR LOOKOUT MOUNTAIN.

of the lakes situated on their depressed borders. A view of one of these interesting lakes is given on Pl. XIX, *A*.

To the northward of the basins holding lakes, just referred to, there is a series of ridges and hills inclosing undrained basins, which extends about 2 miles from the base of the main escarpment; the ridges in this series gradually decrease in height at the same time that the minor features in their relief become more and more subdued. This belt of ridges and basins finally merges by insensible gradations into a tract of undulating, prairie-like land, 2 to 3 miles broad. The edges of the more recent of the fallen blocks stand out as sharp-crested ridges, with gentle slopes toward the great cliffs from which they fell, but present precipitous slopes of bare rock toward the valley. Descending the series of ridges and hills, one finds the cliffs becoming less and less sharply defined, and soon giving place to rounded swells. At the same time the old lake basins change to swampy areas, and at a still greater distance they become grassy dells.

As already stated, to the northward of Lookout Mountain there is a gradual transition from a still hilly region, where the remains of former landsides are yet recognizable, to an undulating plain, where the relief has been smoothed out and only gentle, flowing outlines attract the eye. At the margin of the plain, adjacent to the lower hills, are obscure ridges, on which there are many rounded and much-weathered bowlders of basalt, but a mile farther west the soil is exceedingly fine and homogeneous and scarcely a stone can be found. Such pebbles as do occur are mainly of basalt, rounded by decay. A characteristic feature of the plain, now cleared of the scattered groves of pine that formerly covered it, and sown with wheat, is the presence of shallow basins, with low, gently swelling hills between them. This tract of country lies between Teanaway River and Swauk Creek, but is entirely without stream channels. The scanty rain is absorbed by the deep, porous soil.

The undulating prairie-like land just described has resulted from the slow disintegration and decay of basalt, which fell as landslides during the slow recession of the thick lava sheet, and the soft volcanic tuff beneath, which once covered the region. The undulating surface of the wheat lands, with undrained basins, illustrates the old age of landslide topography. A view of this undulating plain is reproduced on Pl. XIX, *B*. The hills seen in the distance owe their origin to another sheet of Columbia lava, the lowest of the series, which slopes toward the observer and breaks off in steep slopes to the northward.

An ideal section through the margin of Lookout Mountain is shown on the next page. The section crosses one of the lake basins at the base of the mountain and is continued northwestward through the belt of hills and basins to the plain into which they merge. In this diagram an attempt has been made to indicate the breaking down and the rounding of the fallen blocks and their gradual change to an undulating plain.

In some instances a landside plows its way into a valley for a mile or more from the base of the cliffs from which it came, and forms about its margin a series of ridges and mounds composed of valley débris. These ridges have a striking resemblance to terminal moraines left by the recession of glaciers, but the scars on the adjacent escarpment or mountain sides and the associated hills and basins plainly show their origin. Examples of landslides of this nature occur near Topenish, in Yakima Valley, and are described and illustrated in Bulletin No. 108 of the United States Geological Survey.

The sequence of topographic changes described above, so well illustrated at Lookout Mountain, is typically and characteristically displayed at hundreds of other localities in the same general region, and is not confined to the basin of the Columbia. With minor modifications due to local conditions, it may be recognized in many lands where bold escarpments occur. Where a humid climate prevails and

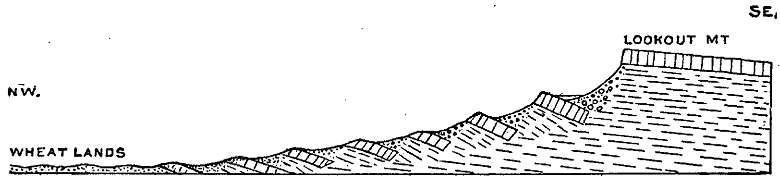



FIG. 4.--Ideal profile of landslides on north side of Lookout Mountain.

streams occupy the valleys, however, the old age of landslide topography is seldom reached.

The Columbia lava, it will be remembered, was spread out during a series of inundations of molten rock, and has an area of approximately 250,000 square miles. Previous to the opening of the fissures through which the lava reached the surface the country had a rugged topography, due to erosion. The lava covered the plains and entered the valleys in the mountains, so as to give them level floors. Hills, ridges, and mountains were in some instances partially or wholly surrounded by the fiery flood and became capes and islands. Isolated eminences of the oldland in some instances rise through the sheets of lava which cooled and hardened about them, in much the same manner that nunataks break the monotony of the borders of the Greenland ice fields. When these islands in the sea of lava are of resistant rocks, like quartzite, which withstand the attacks of the destructive agencies of the air better than the encircling basalt, they still remain in bold relief, as is illustrated by Steptoe and Kamiack buttes, in eastern Washington, described elsewhere.[1]

[1] A reconnaissance in southeastern Washington, by Israel C. Russell: Water Supply and Irrigation Paper U. S. Geol. Survey No. 4, 1897, pp. 37-40.

When, however, the projecting portions of the nearly submerged peaks and ridges were of granite, volcanic tuff, limestone, etc., which weather more rapidly than the surrounding lava, they have frequently been wasted away so as to give origin to basins, valleys, and canyons, with encircling walls of basalt. In some instances the sheets of basalt in these escarpments rest on less resistant rocks, and a recession of the cliffs, due to the breaking away and falling of large masses of their capping layers, takes place. The fallen blocks disintegrate and waste away in the manner described above, and the canyons and valleys increase in size. The ground plans of the depressions originating and enlarging in this manner vary according to the shapes of the island-like rock masses which have been removed. Some of the depressions are nearly circular, others are greatly elongated, and now form flat-bottomed canyons with vertical walls.

The remarkable circular valley surrounded by an almost continuous palisade in eastern Oregon, known as Grande Ronde Valley, from which a river of the same name flows northward to join the Snake, is an illustration of the class of topographic forms produced in the manner described above. I can not testify from personal observation as to the nature of the soft rocks beneath the lava in the walls of Grande Ronde Valley, but other similar and neighboring valleys, less regular in outline, have resulted from the removal of island-like masses of soft volcanic tuff.

Another unique feature in the topography of the region drained by the Columbia is the Grand Coulée, in what is known as the Great Plains of the Columbia, or, more familiarly, the "Big Bend Country," in central Washington. The Grand Coulée is a flat-bottomed canyon some 30 miles long and varying in width from 2 to 4 miles. In its vertical walls, usually about 350 feet high, the edges of several sheets of Columbia lava are exposed. This great trench through the but little disturbed plain of lava was in existence previous to the Glacial epoch and furnished an avenue of escape for Columbia River when dammed by Okanogan Glacier. At the southern end of the Grand Coulée, as can be seen from Coulée City, the lava sheets on its east side dip gently eastward, while the beds comprising its west wall are apparently horizontal. This fact led me to infer that the Grand Coulée, like several other similar but smaller canyons in the lava, is due to stream erosion along a line of fracture,[1] but I now wish to suggest another possible explanation. At the north end of the canyon granitic rocks form a portion of its walls, and stand as isolated tower-like masses within it. Some of these towers are capped with horizontal lava sheets. When the lava was poured out, it surrounded a granite ridge having the position of the Grand Coulée, but probably not

[1] A geological reconnaissance in central Washington, by Israel C. Russell: Bull. U. S. Geol. Survey No. 108, 1893, pp. 90-92.

extending as far south as the depression since formed. The weathering and removal of the granite gave origin to a trench-like depression with vertical walls, composed of basalt above and granite below. The more rapid crumbling of the granite led to the breaking away of the jointed basalt resting on it and the widening of the depression in the manner already noticed.

From the brief and inadequate description just given of certain of the more striking features of Washington and Oregon, it will be seen that landslides have modified in several ways the topography of the region occupied by the Columbia lava. There are yet other changes in the geography of that most interesting and instructive land due to the same causes. Chief among them are the obstructions to the streams formed by landslides and the production of lakes and rapids. At several localities in the Upper Columbia, masses of rock which have fallen from the cliffs bordering the stream obstruct its course. There are now along the course of the river no lakes due to this cause, but terraces above rocky rapids show where such water bodies previously existed.

Perhaps the most interesting fact brought out by the study of landslide topography is that certain broad, nearly level areas, now covered with deep, rich soil, and in the autumn golden with the sheen of ripened grain, owe the minor features in their relief to ancient landslides. In such regions the hills, with broadly rounded summits, and the shallow undrained basins between, are an inheritance from a time when long, precipitous escarpments, by their slow recession, left the land covered with a rugged, confused mass of fallen blocks. A review of the facts concerning the minor features in the relief of the broad wheat lands of southeastern Washington,[1] in the light of the conclusions here presented, leads to the suggestion that some of the ridges and basins of that region may be due to the recession of cliffs produced by stream erosion. Many portions of the deeply decayed surface of the basaltic plateau in the region referred to closely resemble the old landslide topography in the valley to the northwest of Lookout Mountain.

## DISPLACED BLOCKS AND OPEN FISSURES.

In some instances the blocks of rock displaced at the summit of an escarpment suffer but comparatively little movement, and are tilted toward the adjacent valley, so as to leave an open fissure on the border adjacent to the main portion of the plateau or mountain mass. These blocks, in many instances no doubt, have taken the initial step which will result in a landslide, but when they are large a sufficient adjustment to slowly changing conditions is attained to insure their

[1] A reconnaissance in southeastern Washington, by Israel C. Russell: Water Supply and Irrigation Paper U. S. Geol. Survey No. 4, 1887, pp. 58-69.

remaining for centuries, perhaps, in an inclined position. From such instances, in which the changes that have occurred are apparent, there is a gradation up to rock masses containing a cubic mile or more of material that have been tilted away from the mountain of which they form a part, so as to leave an open fissure, which is wide at the top and narrows downward. These fissures sometimes become waterways, and are variously modified by erosion, so that the recognition of the process by which they were initiated becomes difficult. This is especially the case in a region like central Washington, which has experienced climatic changes of such a nature that many stream-cut valleys are now abandoned as lines of drainage. It is with hesitation that I cite the following examples of what seem, from the facts now in hand, to be fissures due to the displacement of large portions of mountain sides.

On the western border of the canyon-like valley of the Columbia, between the mouths of Entiat and Methow rivers, there is a series of narrow, steep-sided defiles, termed coulées, which are practically without drainage and which cut across the ends of mountain spurs so as to be parallel, in a general way, with the Columbia. The mountain spurs referred to are between deep valleys and canyons which join the valley of the Columbia nearly at right angles. These coulées have already been mentioned in connection with the account given of the gravel deposits of the Columbia. Antwines Coulée and another to the south of it, without definite name, are thought to be the best illustrations of the features to which attention is here directed. Knapps Coulée may belong to a system of abandoned stream-cut valleys.

Antwines and the other similar trench south of it have precipitous and rugged walls from 500 to perhaps 1,000 feet high, from which alluvial cones and talus slopes have descended and more or less completely blocked the trenches into which they extend. The width of these trenches at the level of the débris now occupying them is seldom over 500 feet. As previously stated, they give no evidence of ever having been occupied by glacial ice, but are partially filled with alluvial fans, talus slopes, and talus blocks, so as to form irregular surfaces and inclosed basins. Antwines Coulée is about 10 miles long, and its near neighbor is not over 3 miles in length. Each one, it will be remembered, crosses the end of a mountain spur between deep, canyon-like valleys, and is, in a general way, parallel to the west wall of Columbia Valley or Canyon.

The hypothesis here proposed is that these gulfs have been produced by the displacement of the mountain masses bordering them on the east and intervening between the coulées and the valley of the Columbia. It is difficult to present the facts on which this explanation rests, and in part it is entertained for the reason that no phase of stream erosion can be made to account for the facts observed. The valley of the Columbia, it will be remembered, is deeper than the present bed of the river. Judging by the depth of the Chelan Basin, a tributary of the Columbia, the bed rock in the latter is at least 400 or 500 feet below the present river. Previous to the deposition of the valley gravels, the walls of the canyon of the Columbia were therefore 400 or 500 feet higher than they are now. At the time referred to, the mountain spurs now cut across by the coulées were exceedingly precipitous on the side overlooking the Columbia Valley, and it is presumed great masses of rock became displaced at their extremities and were tilted toward the valley, leaving open fissures on the western border. On the south side of Chelan Basin, where it opens into the valley of the Columbia, there is, again, a bold mountain spur, across which there are three breaks, running approximately northwest and southeast, each about one mile in length. The blocks between these breaks have been variously displaced, and through one of the fissures thus formed Chelan River now flows, as previously described. These breaks are of the same character as the much larger fracture that gave origin to Antwines Coulée.

The displacement of mountain masses, with the formation of fissures, now broadened by the falling of material from their walls to 2,000 feet or more at the top and narrowing rapidly downward, would have produced great shocks similar to the earthquakes that accompany movements along fault lines. In fact, every considerable landslide must cause an earthquake. On the other hand, landslides themselves may be precipitated by an earthquake shock originating from other causes.

In this connection it is of interest to note the fall of a large mass of rock a few years since at what is known as Kockshit Point, on the west side of the Columbia, about 3 miles above the mouth of Entiat River, which caused a marked change in the appearance of the cliff and produced a shock that was felt for many miles around.

## AVALANCHES.

Judging from the accounts given by miners and others who remain in the Cascade Mountains during the winter months, avalanches are then of common occurrence. This testimony is abundantly sustained by the records that the avalanches themselves have left.

On the precipitous sides of the valleys, in the more rugged portions of the Cascade Mountains especially, there are numerous localities where the trees have been swept off by the snow avalanches, and, together with large quantities of rocks and soil, piled in confused heaps in the bottoms of the valleys. Where the valleys are narrow it not infrequently happens that an avalanche in rushing down one side gains such momentum as to carry it 200 or 300 feet up the opposite slope. Where these slides have occurred during the last few years their paths are denuded of timber, many of the trees having been cut squarely off. Similar slides in past years are recorded by changes in the character of the vegetation that has grown up on them. These avalanches tend to dam the valleys into which they descend and produce lakelets and swamps where the gradients of the streams are low. Good illustrations of the process referred to occur in Indian Creek Valley on the east side of Indian Pass, which, as previously stated, has a remarkably low grade and is bordered by precipitous walls; moreover, the elevation is 5,000 feet or more, which insures a heavy winter snowfall.

Besides the avalanches consisting principally of snow, there are others composed largely of mud and stones. These are even more destructive than the snow avalanches, and leave more enduring records. These mud avalanches, as they have not inaptly been termed, usually occur when a sudden thaw follows a heavy snowfall, or when a fohn or chinook wind occurs in midwinter and the snow on the mountains is rapidly melted.

The most notable of the mud avalanches the records of which were seen during my journeys through the Cascades occurred on the right or northern border of Sauk Canyon about 8 miles west of Indian Pass. In this instance a stream of mud mixed with stones and resembling glacial till flowed down a steep mountain side for fully a mile and dammed the Sauk so as to form a temporary lake, which has since been emptied by the cutting of a channel across the obstruction. Where this avalanche reached the bottom of the canyon it was about 1,000 feet broad, and surrounded the larger trees to a depth of from 15 to 30 feet. For a height of 10 to 12 feet above the present irregular surface of the hardened clay the trees left standing are battered and denuded of their bark, thus indicating that the flow at the time of its occurrence was composed largely of snow, which has since melted and allowed the clay to settle. This interpretation agrees, too, with the accounts of trappers and others who have witnessed these peculiar avalanches. They describe them as being composed of water, snow, and mud. The one just referred to carried vast numbers of stones, some of which were left on the surface of the hardened mud or were partially embedded in it. The exposed portion of one of these blocks, composed of granite, which had been moved at least a mile, measured 27 by 12 by 15 feet, the basal portion being buried. This avalanche started above timber line and passed down through a dense forest, cutting away all but the largest trees. The trunks and branches of the trees and bushes swept away were left, in part mingled with the stony clay and in part heaped in a confused mass in the bottom of the valley.

Another variety of landslide occurs at several localities farther down the Sauk, where the river is bordered by high terraces composed of blue clay at the base with cross-bedded sand and gravel above. One of these slides, on the right bank of the river between Orient (now abandoned) and the mouth of Clear Creek, covers an area of between 30 and 40 acres. The cliff-like banks from which the material came expose from 40 to 50 feet of cross-bedded sand and clay. The material which descended seems to have flowed almost as a liquid, but left an excessively rugged surface, and on parting with its water became hard. In the low places, however, the clay when I traversed it was so soft that one was in danger of miring, and much care had to be exercised to get a horse across it. Several other similar mudflows were seen along the Sauk, but the dates at which they occurred were unknown. The two just described, however, judging from the manner in which the trail was cut away and the development of the buds on the dead shrubs, must have occurred early in the spring of 1898. These mudflows came from terraces and were caused by the breaking away of large masses of material, owing in part to the undercutting of the banks of streams, thus leaving bold escarpments frequently from 70 to 100 feet high, but in addition, as the evidence shows, the clays were saturated with water to such an extent that they behaved like a viscous fluid. Evidently the flows occur during or after heavy rainfalls or when a thick sheet of snow was melting.

These comparatively great flows, involving many thousands of cubic feet of material, are distinct and different from the smaller slides caused simply by a stream undercutting its banks.

There are thus many ways in which material on steep slopes becomes displaced, ranging from the slow creep of the débris in talus slopes, due largely to changes in temperature and the flow of saturated clay and partially melted snow which rushes down steep declivities, to true snow avalanches and to well-defined landslides, which involve or consist of huge masses of solid rock. A part of this general process is the formation of fissures adjacent to the border of table-lands and steep escarpments. These "avalanche fissures" are in some instances, as along the Columbia, of such size that they become conspicuous in the general topography, and on weathering increase in breadth, and may have a decided influence on the courses of streams.

## ECONOMIC GEOLOGY.

While it is understood that a report on a reconnaissance is not the place to discuss the mineral resources of a region, yet a few facts in reference to the mines of the portion of Washington under consideration may be of interest to the general reader.

## COAL.

The most valuable of the mineral deposits here claiming attention are the coal seams in the Roslyn sandstone. At the town of Roslyn a shaft 628 feet in depth has been sunk and from its bottom an extensive series of galleries excavated in the main coal seam, which, as stated in the section given on a previous page, is 5 feet 4 inches thick. The coal is bituminous and highly valuable for steam generating purposes. At the Clealum mine, in the eastern outskirts of the village of Clealum, a shaft 250 feet deep, begun in 1894, reached a seam of coal 4.5 to 5.5 feet thick. In July, 1897, a drift had been carried eastward from the bottom of this shaft for 60 feet; another westward about 600 feet, and another northward about 300 feet. The dip of the strata exposed in these workings is south at an angle of 14°. The output of the mine at the date just stated was 125 tons per day. This coal seam is not the same as that worked at Roslyn, but occurs at a higher level in the geological series. At a locality in the hills about 2 miles north of Clealum the Ellensburg Coal Mining Company has worked another coal seam in a small way by means of a drift starting at the outcrop of the coal and running eastward about 600 feet. The coal is there 4 feet thick, and the bed dips S. 10° E. at an angle of 16°.

The total output of these mines, but derived mainly from the workings at Roslyn, was 281,534 tons, with a value of $485,520, in 1895, and 481,710 tons, with a value of $1,027,209, in 1896.

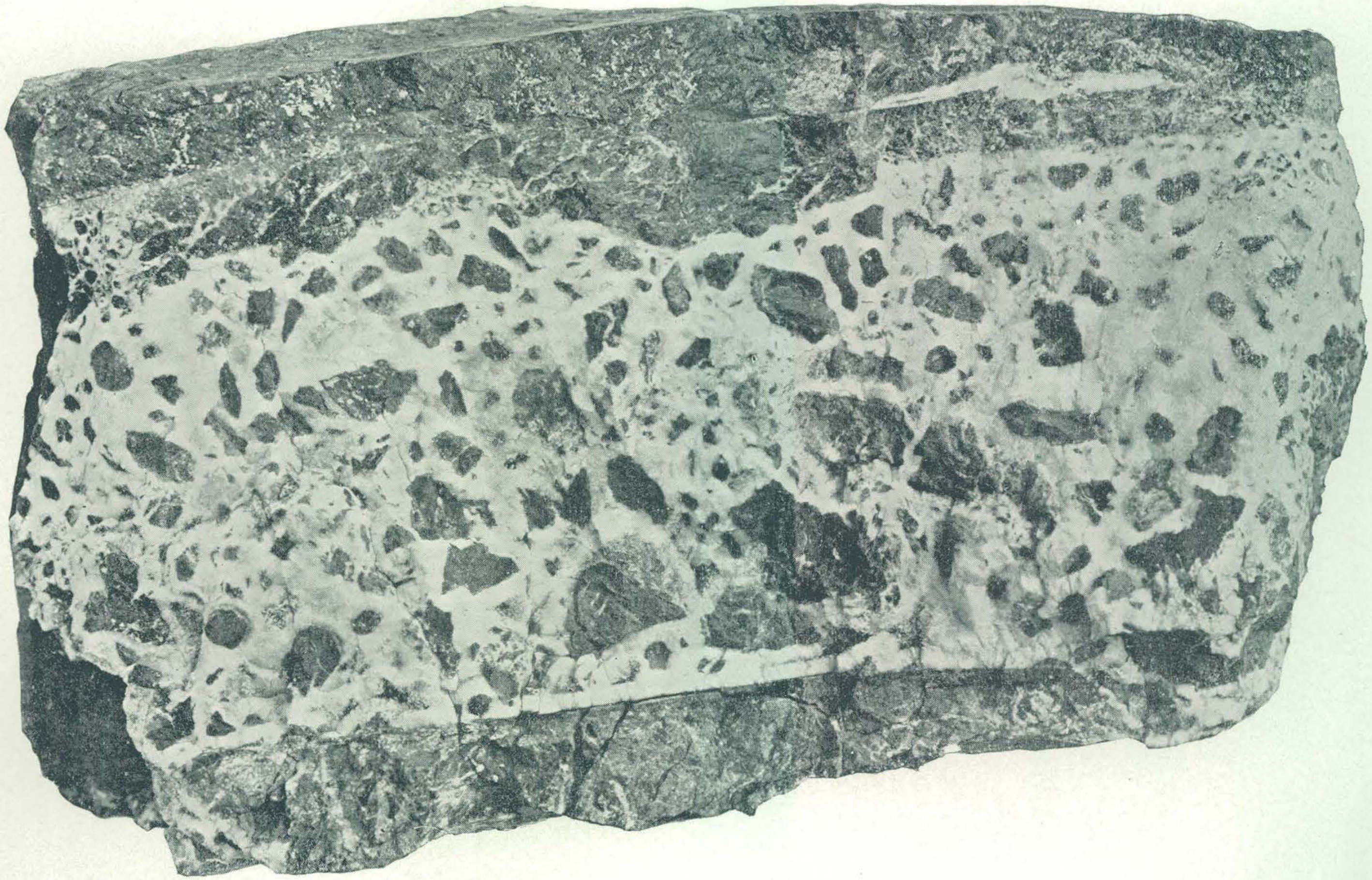
Tests made by means of the diamond drill, conducted by the company operating the Roslyn mines, as I have been informed by the superintendent, Mr. B. F. Bush, show that coal of workable thickness and good quality underlies an area, measuring a square mile or more, in the valley of the Yakima, to the southeast of Clealum. This area extends to the Yakima River, but whether it occurs to the south of the river, as might reasonably be expected, has not been ascertained. Coal outcrops in the valley of the main trunk of Teanaway River to the north of Roslyn and Clealum, but no mines have been opened in that region. Examinations for coal have been made on First Creek, near the north end of Green Canyon, at the head of Williams Creek, on the west side of Table Mountain, and on Naneum Creek, a southward-flowing stream which has excavated a canyon-like valley in the more elevated portions of the Table Mountain Plateau. Coal seems to have been found at each of these localities, but not in commercial quantities. Whether these examinations have been sufficient to demonstate the absence of valuable coal seams is not known to the public. Several openings have been made in search of coal near Camas Land, along the Peshastin below the mouth of Camas Creek, and in the valley of the Wenache, but thus far without success. It does not seem, however, that any of these tests were sufficiently extended to demonstrate the absence of workable seams. All of the coal mines and coal prospects thus far mentioned are in Tertiary rocks. Up to the present time the Cretaceous rocks to the north of Lake Chelan have failed to yield favorable indications of coal, although an outcrop of carbonaceous shale on the Twisp has been reported to be coal. This locality, however, does not merit further attention. But little is known in detail of the Cretaceous rocks referred to, or of the associated formation termed in this paper the Ventura formation, and no opinion can be ventured at this time as to the possibility of workable coal seams occurring there.

The Roslyn sandstone, which contains all of the coal now worked in Washington to the east of the Cascade divide, extends eastward and southward from where it comes to the surface and passes beneath the second sheet of Columbia lava. This formation may have a wide distribution in the directions indicated, and should be looked for wherever the overlying formation has been deeply eroded or where disturbances have brought the base of the lava sheet to the surface. The relation of the "anthracite" reported to occur near Natchees Pass to the Roslyn or other formations is unknown.

## GOLD.

At a large number of localities throughout the northern Cascades in Washington gold has been found, both in veins and in stream gravels, and at a few places quite extensive mining operations have been carried on. The formations known to carry gold range from the crystalline rocks, such as granite, schist, serpentine, greenstone, etc., which are of unknown age, to Cretaceous and Tertiary terranes. Several mining districts have been established. The best known of these are the Swauk and Peshastin districts, to the west of Table Mountain; those at Monte Cristo and Darrington, on the west side of the Cascades, and on Ruby Creek and Slate Creek, near the Canadian boundary. There are still other regions where promising prospects have been opened, as on the Methow and near Lake Chelan. Actual mining operations have been carried on in the Swauk, Peshastin, and Monte Cristo districts, but the others have not yet passed the prospecting stage.

The mines in the Swauk district, near Liberty, include both placers and veins. The country rocks are sandstones and shales of Tertiary age and the basalt of the numerous dikes. The veins occur on each side of the vertical dikes of basalt, and are peculiar, if not unique, in character. They consist of quartz and calcite, usually crowded with angular fragments of shale and sandstones, which are entirely separated one from another. A portion of one of these veins is shown on Pl. XX. The walls of basalt forming one border of each of the veins are usually slickensided, showing that much movement has taken



PORTION OF A BRECCIATED VEIN, SWAUK MINING DISTRICT.

place since they were formed. The fracturing of the adjacent stratified rocks is due to these movements, but the separation of the fragments produced seems to be due in part, at least, to the crystallizing of the quartz and calcite. I venture the suggestion that these minerals, in crystallizing, have exerted a force analagous to the expansion of water on freezing, which has crowded the rock fragments asunder. These "brecciated veins" are usually 2 or 3 feet, and in some instances 5 or 6 feet, thick. The wall adjacent to the basalt in each pair is well defined, but the opposite wall is usually indefinite. Free gold occurs both in the quartz and in the included fragments of country rock, at least above the surface streams; below water level it is to be expected that sulphurets will appear, and that the rock will cease to be free-milling. Previous to 1898 the ore from the quartz veins was worked by arastres, in several instances with highly favorable results. At the date mentioned a small stamp mill was erected at the Kugar mine, about 2 miles north of Liberty.

The placer gold along Swauk Creek and its tributaries occurs in the stream gravels and in talus slopes. The gold is mostly coarse, and in the talus slopes adjacent to the veins from which it was derived is frequently angular and branching; crystalline specimens, termed "leaf gold," are not infrequent. It should be remembered that the gravel deposits carrying gold occupy the bottoms of the present valleys and gulches, and are a part of the great series of Pleistocene gravels described on a former page. In many instances the streams have reexcavated their channels in part, leaving portions of the previously deposited gravel as terraces along their borders. Not infrequently the present streams flow at a lower level than the beds of hard rock on which the gravel rests. In no instance are the Pleistocene gravels known to be covered with lava flows or other hard rock, and they do not extend under the rocks forming the sides of valleys, as many prospectors suppose. At many widely separated localities in the Cascade region there are gravel deposits similar to those at Liberty, which are known to contain gold. In the narrow valley of Peshastin River near Blewett, and along Ruby Creek, these deposits have been worked for gold with favorable results. In all similar instances gold may be expected to occur on bed rock, although on the sides of valleys and near the heads of drainage lines the stream-deposited gravel, consisting of waterworn material, frequently merges with talus slopes in which gold may occur at any horizon from top to bottom. The rock fragments forming the talus slopes are angular, unless derived from the disintegration of conglomerate, and are unassorted, and the gold when present does not have the characteristic worn and rounded appearance usually found in placers.

At Liberty and Blewett placer mining is being carried on both by sluices, into which the gravel is shoveled, and by hydraulic methods.

The bed rock at Liberty is Tertiary sandstones and shales, which are highly inclined and, where they have been planed off by stream action, present an uneven surface, admirably suited to act as natural "riffles" in retaining the gold or other heavy minerals. A photograph of the stream gravels, resting on an uneven surface of Tertiary sandstone and shale, exposed by hydraulic mining near Liberty, is presented on Pl. XVI. The large number of valleys that are partially filled with Pleistocene stream-deposited gravel in the Cascade region favors the hope that much more extensive placer mines than have yet been worked will, in time, be discovered. The great thickness of these deposits in many instances, particularly along the larger rivers, and the depth of bed rock below the present streams are highly unfavorable for ordinary hydraulic mining, but if sufficiently rich gravel can be found it can be brought to the surface by actual mining operations and subsequently washed. There are many high-grade gorges, however, in the vicinity of gold-bearing veins, where bed rock is well above the main streams, and the conditions are favorable for hydraulic mining on a large scale.

The country rock in the Peshastin district is mainly schist, serpentine, greenstone, etc., which has been much disturbed since the mineral-bearing veins were formed. On account of the disturbances that have affected the rocks and the small extent of the veins, most of which are rather "gash veins" than true fissure veins, extensive and continuous bodies of gold-bearing quartz are scarcely to be expected. Rich quartz has been discovered, however, and at least one of the mines has paid well. The belt of rocks in which the mines at Blewett occur extends for some 18 or 20 miles to the westward, about the southern base of the central granitic core of the Wenache Mountains, and northward to beyond Leavenworth, and has been found to carry gold at numerous localities. This same complex belt of rocks has been found also to contain copper, nickel, cobalt, and mercury (cinnabar) in many places. It is safe to say that several thousand mineral locations have been made in this region, more especially along Nigger and Ingall creeks, on the head waters of Icicle and Fortune creeks, and in the mountains from which flow the several branches of the north and middle forks of Teanaway River. Only a few of these "prospects" have been opened so as to show what the conditions really are, and with the exception of a few locations on Nigger Creek, no actual mining operations have been undertaken. The fact that so few "prospects" have been developed, and the total absence of paying mines (in 1898), lead to the inference that this region is not promising from the miner's point of view. Although rich ores seem to have been discovered in many instances, no large bodies of such ores have as yet been revealed. To the geologist the main difficulty seems to be the many disturbances that have affected the region since the deposition of the ores. The numerous faults and the large areas where the rocks have been crushed and displaced make it evident that only the most careful explorations, guided by a critical knowledge of the geological conditions, can hope to lead to success.

Formations similar to those just referred to, and including serpentine, occur in the Entiat Range, and have there been found to carry gold. This same metal has been found, also, at many localities in the Lake Chelan region, and thence northward to the Canadian boundary. A great number of "prospects" have been discovered in this region, and a few promising localities are being developed.

The well-known Monte Cristo district was not visited by the writer, but many favorable reports were heard concerning it. The region about Darrington has produced some good ore, but how extensive the veins may be is unknown to the public. The occurrence of large bodies of serpentine in this field suggests, as do other facts, that it is much like the Peshastin district. Along Ruby Creek there are rather extensive gravel deposits, which have yielded gold, and evidently demand careful attention, as the natural conditions for the concentration of heavy minerals are there unusually favorable. Plans for hydraulic mining at the mouth of Ruby Creek were about to be put in operation in 1898, but the results attained are unknown to me.

A hasty visit was paid to the Slate Creek district, where many fissure veins, some of them of large size and carrying free gold, have been discovered. Prospecting is being actively carried on in this region by men well qualified to determine the nature of the deposits, and the conditions certainly favor the hope that valuable results will be reached. I can not presume to speak with authority in this connection, but feel it my duty to suggest that capitalists would do well to give this field careful attention, and to assist in its development.

The impression gained from my hurried visits to the various mineral-bearing districts referred to above is that the entire Cascade region, not only where crystalline rocks occur, but—as is shown by the peculiar quartz veins in the sandstone of the Swauk district—the areas occupied by Cretaceous and Tertiary sedimentary deposits as well, needs to be carefully investigated. What is required is not confidence in the widely current saying, "If one goes deep enough gold will be found," for there is no real foundation for such a faith, but a careful and painstaking study of the conditions as they exist, and the working out of plans for the most economical methods of developing the ore bodies actually present. The State of Washington holds out many promises to the miner, but much more scientific methods than are now employed must be applied before the State can take even a modest position in the ranks of those now noted for their gold, silver, copper, and other similar mineral industries. In addition to a careful search for coal and gold, attention should be given to the development of the less attractive industries based on the excellent building stones and clays, and attempts should be made to utilize the deposits of diatomaceous earth, volcanic dust, and serpentine, and to make use of the alkaline lakes which are known to exist.

# STATUS OF THE MESOZOIC FLORAS OF THE UNITED STATES

## First Paper: THE OLDER MESOZOIC

BY

LESTER F. WARD

WITH THE COLLABORATION OF

WM. M. FONTAINE, ATREUS WANNER, AND F. H. KNOWLTON

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## FIRST PAPER: THE OLDER MESOZOIC.

By Lester F. Ward.

### INTRODUCTORY REMARKS.

It is proposed in this paper to give a succinct account of the progress thus far made in the direction of developing the Mesozoic floras of the United States. The treatment will be primarily in the ascending geological order, secondarily in such geographical order as seems most natural, and finally in the chronological order of discovery. The aim will be to enumerate for the several formations, geographical areas, and special localities the fossil plants that have been found, collected, and reported upon, and to give a somewhat complete bibliography of the work accomplished in strictly paleobotanical lines, with special reference to correlation, but without any attempt to treat the subject from the stratigraphical or general geological standpoint, since this latter task would be much too large, and has, moreover, to considerable extent, been done already by numerous writers. The stratigraphical results thus arrived at will be simply accepted, and the horizons will be arranged with reference to them. There will be no attempt to republish what has already appeared, and the new matter will consist altogether of additional results here published for the first time.

A special feature will be the enumeration of discoveries made and of materials collected and in hand, either now in process of elaboration or to be taken up as early as possible for future publication.

It is believed that such a paper will be useful not only as showing the work that has been done, the results of which are now scattered through a great number of volumes of the most diverse character, and are difficult to find, but also as indicating the direction and prospects of future work along the same lines.

The paper naturally falls under three general heads, based on the general geological nomenclature of the Mesozoic—Triassic, Jurassic, and Cretaceous—which, notwithstanding the difficulty in making the

American beds conform in all respects with the older classification, still proves a convenient and more or less satisfactory basis of subdivision. These general heads may be made to designate the three parts, I, II, and III, of the paper, and each of the parts may then be conveniently further subdivided into lesser heads dealing with the smaller geological groups or formations, designated for the most part by special names derived from localities where each is best exposed.

In view of the considerable magnitude which such a memoir is found to assume, and especially of the impossibility of having all the illustrations prepared in time to be embodied in the Twentieth Annual Report of the Survey, it has been necessary to make a more general subdivision of it into two papers, one on the Older Mesozoic (Parts I and II), and the other on the Younger Mesozoic, or Cretaceous, and to confine the present paper to the former of these subdivisions, the matter for which is ready, leaving the other subdivision to form the subject of a second paper to be published in a subsequent report.

## PART I.

### THE TRIASSIC FLORA.

There are certain beds which are generally admitted to belong to the great series called Triassic in all parts of the world, and the fossil plants only help to confirm the conclusions on this point which have been drawn from stratigraphical considerations and from other forms of life. It so happens, however, that the paleobotanical record is here very incomplete, and there is no adequate evidence that any plant remains have thus far been found in any but the uppermost portion of the Triassic series. It is true that Mr. Benjamin Smith Lyman, of the Pennsylvania Geological Survey, argues for a great thickness of the Triassic beds in Bucks and Montgomery counties, Pennsylvania,[1] claiming that they extend into the Permian and contain the remains of Calamites and Lepidodendron, but no one else finds the same conditions, and Mr. Henry B. Kümmel, after an exhaustive study of these beds in the adjacent State of New Jersey, with Mr. Smith's results before him, finds reasons for doubting his conclusions, and reduces the thickness from 27,000 to 12,000 or 15,000 feet by the discovery of faults.[2]

With regard to the fossil plants, Mr. Lyman admits that the supposed Calamites was never submitted to a competent specialist, and it is altogether probable that it represents the stem of a large Equisetum, as, for example, *E. Rogersii* (Bunb.) Schimp. It must be remem-

[1] Proc. Am. Philos. Soc., Vol. XXXIII, pp. 5-10; 192-215; Pennsylvania State Geological Survey Summary, Final Report, Vql III, Pt. II, pp. 2589-2638.

[2] Annual Report of the State Geologist of New Jersey for 1897, p. 138.

bered that Bunbury[1] in 1851, when he named that species, and all before that date, back to Brongniart in 1828, who first figured it,[2] regarded it as a Calamites. For the existence of Lepidodendron there would seem to be good authority; not, however, for its occurrence in the thick deposits of Pennsylvania, but in the New Jersey beds, in quarries of Newark and Belleville, a photograph of a specimen from which was sent to Professor Lesquereux by Professor Cook, State geologist of New Jersey. In his report Professor Lesquereux says:

The photographs are sufficient, if not for specific determination at least for positive reference of the specimens to Lepidodendron. Even I should say that the specimens represent *L. Veltheimianum* Presl, as distinctly as a specific representation can be made upon a decorticated trunk of Lepidodendron. *L. Veltheimianum* is a leading species of the Old Red Sandstone found here, as in Europe, from the Subcarboniferous Measures down to the Devonian, while until now we do not have any remains of Lepidodendron of any kind from the Upper Coal Measures (Permo-Carboniferous), or from higher up than the Pittsburg coal.

*L. Veltheimianum* is recorded only once from the true Coal Measures; this by Eichwald, from the Carboniferous sandstone of Russia. But European authors, among others Goeppert, doubt the identity of the Russian species with *L. Veltheimianum*, which is, moreover, extremely variable, and has been described already under about thirty different names.[3]

While the authority in this case is not to be questioned, there is certainly room for doubt as to whether so important a conclusion drawn from a photograph of a decorticated specimen can be regarded as final.

After reading Mr. Lyman's articles I wrote to Professor Fontaine under date of May 4, 1894, as follows:

Have you seen Mr. Lyman's articles in the Proceedings of the American Philosophical Society (Vol. XXXIII, January, 1894, No. 144, pp. 5–10)? I wish you could see the specimen of so-called Lepidodendron from the Newark brownstone, to see whether you agree with Lesquereux. It is just possible that there may be points at which the change from the brown sandstone to the underlying Carboniferous is not easily distinguished, and they may have got down into the Carboniferous. The whole matter ought surely to be looked into.

To this Professor Fontaine replied under date of May 12, 1894, as follows:

I had seen a notice of Lyman's remarks on the Newark beds, but not the articles. Since you called my attention to them I have carefully read them. I think that he makes out a case strong enough to call for a careful revision of all that is known of the flora of these strata. It is possible, but I do not think probable, that the Devonian may be reached in some of the Newark strata. I think that the supposed Lepidodendron is the plant that I have figured in Monograph VI, pl. xlviii, fig. 5, which I supposed to be the stem of a cycad (see p. 91 of monograph) like Williamson's stem of *Zamia gigas*. This may be really a coniferous stem and belong to the conifer that bore the cones depicted on pls. xlvii and xlviii. These are possibly kin to Abies and the ancestral forms of the Abietites of the Potomac. This is strikingly

[1] Quart. Jour. Geol. Soc. London, Vol. VII, 1851, p. 190.

[2] Histoire des Végétaux Fossiles, Vol. I, p. 125, Pl. XVI, fig. 1.

[3] Geological Survey of New Jersey, Annual Report of the State Geologist for the year 1879, Trenton, 1879, pp. 26–27.

like Lepidodendron, but even if it be such the absence of all other Paleozoic plants and the fact that the accompanying flora is wholly Mesozoic would simply indicate that Lepidodendron survives into the Mesozoic. It is noteworthy, with reference to what Lesquereux says, that this Richmond coal-field plant is more like *L. Veltheimianum* than any other of that genus. I do not know what Mr. Lyman's authority is for the statement that the Newark beds are 9,000 feet below the Milford strata, or for the great thickness he gives for the Pennsylvania Trias, 27,000 feet. I have not seen any publication indicating that thickness. Do you know of such? Mr. Lyman questions my rejection of Lepidodendron from the Mesozoic flora. I do not see that that, if correct, helps his contention, which is that the fossils may be Lepidodendron, and therefore the beds may be Paleozoic. If we grant that these plants are Lepidodendron, all that can be deduced is that this genus lived in the Mesozoic, for the supposed Lepidodendron of North Carolina and Virginia is accompanied by an abundance of well-marked Mesozoic plants; otherwise we must conclude that the North Carolina and Virginia beds are Paleozoic. Surely he would not maintain that.[1]

In all this the question has not been whether we have in these few doubtful remains representatives of the flora of the lowest Triassic beds corresponding to the Variegated Sandstone or Vosgian and the Muschelkalk, but whether they are Mesozoic or Paleozoic. Professor Fontaine seems to have sufficiently answered this question, and all agree to the absence thus far of the characteristic Lower Triassic forms, such as Æthophyllum, Voltzia, Albertia, and Yuccites.

With regard to the alleged Trias of Prince Edward Island,[2] it presents a question singularly similar to the one just considered, since none of the fossil plants at least are claimed to represent the Lower Trias, while two of them are decidedly Paleozoic in their affinities. I therefore fully indorse all that Dr. Knowlton has said[3] with regard to them. I had myself raised the question whether the *Cycadeoidea abequidensis* may not represent a cone of some coniferous tree. It is very small for a cycadean trunk, though this alone would not negative such a reference. Sir William Dawson's fig. 29, which is about natural size, does not bring out cycadean characters, and the supposed scars of leaves and buds represented enlarged in figs. 29*a* and 29*b* do not help support his view. He does not explain why he places the small end down and describes it as "obovate" instead of reversing it and treating it as originally conical, but if the side of the scars toward the small end are, as represented, more pronounced than that toward the large end, this would seem to justify that position. A photograph, slightly enlarged, which Sir William was so good as to send me, and which bears enlargement with a lens much better than the engraving, still fails to answer the question of orientation, but it must be admitted

[1] At the time this letter was written the negotiations described below (pp. 274-276) relative to the then recently discovered Emmons's collection were going on, and it will be observed that Professor Fontaine, after examining the specimens themselves, refers the supposed Lepidodendron to *Zamiostrobus virginiensis*, virtually confirming his previous conclusion derived from an examination of the figures alone.

[2] Report on the Geological Structure and Mineral Resources of Prince Edward Island, by J. W. Dawson, assisted by B. J. Harrington; Montreal, 1871; 51 pp., 3 plates. See pp. 13-22, 45, 46, pl. iii.

[3] In the Newark system, by I. C. Russell: Bull. U. S. Geol. Survey No. 85, 1892, p. 29.

that some of the supposed buds when thus enlarged simulate very closely the reproductive organs of certain Cretaceous cycadean trunks. This treatment further shows that the scars or scales point toward the large end, which would be singular for a cone, whatever the conditions of compression to which it might have been subjected. It would seem, therefore, that the whole question must be left for the present in abeyance, but there is at least no evidence of these beds representing the early Trias.[1]

It will therefore be necessary to treat the American Trias as a geological unit, and to confine the classification to the several geographical areas in which its flora has been developed.

There is no fact more commonly remarked by paleontologists than that of the defectiveness of the geological record in Mesozoic time, especially as regards fossil plants. Of the three divisions or systems of the Mesozoic, the defectiveness of this record is most apparent in the earliest or lowest, viz, the Trias. In Europe the lower member of the Trias, viz, the Buntersandstein, contains fossil plants at some points, notably in Alsatia, on the slopes of the Vosges, and in the vicinity of Strasburg. The second or middle member, viz, the Muschelkalk, is also represented by a few plant remains at Recoaro, in Italy, and perhaps at a few other points. The last member, viz, the Keuper, is very well represented at many different localities on the Continent. The Triassic fossil plants are most numerous of all in the extreme upper member or transition beds, viz, the Rhetic, especially in the Kingdom of Bavaria, province of Franconia, near Baireuth, and in South Sweden (Scania).

The attempt to correlate the Trias of America with any other of these three series of the European Trias has thus far been more or less unsuccessful, but it is remarkable that all the fossil plants that have ever been discovered in American strata within the proper limits of the Trias not only appear to belong to nearly the same horizon, but also have their nearest affinities with those found in the very uppermost of the four different members which have been enumerated. It is quite immaterial whether we denominate this member the upper Keuper or call it the Rhetic.

The principal plant-bearing deposits which have been assigned to the Trias in America occur in the Connecticut Valley, in the vicinity of Richmond, Virginia, and in North Carolina. In the West there are large tracts of country which have been assigned to the Trias and which probably belong to that system, and many eminent geologists, including Dr. J. S. Newberry, have been disposed to identify this Western formation with that of the eastern part of the country. These deposits are most extensive in New Mexico and Arizona, but are perhaps to be found in Indian Territory and adjacent parts of Texas. They also

[1] See Dana, Manual of Geology, 4th ed., 1895, p. 741.

extend into Utah, Nevada, and Colorado. The beds near Taylorsville, California, will receive separate treatment.

Of these several deposits the one that has attracted the largest share of attention is the so-called Richmond coal field in Virginia, which has been the subject of a valuable contribution by Prof. William M. Fontaine, published in 1883 as Monograph VI of the United States Geological Survey.

Next in importance is the region in the State of North Carolina which was early investigated by Dr. Ebenezer Emmons, who published the results primarily in his report on the Geology of North Carolina as State geologist, and finally embodied them in his American Geology, Part VI.

A few fossil plants were long ago described and figured by Dr. Edward Hitchcock in his report on the geology of Massachusetts, and in several papers in the American Journal of Science. Later, Dr. J. S. Newberry elaborated certain material in his hands at the School of Mines, Columbia College, New York, and published the same in connection with the fossil fishes of the Connecticut Valley in a monograph of the Geological Survey.[1] This work is of special value to us in the consideration of the question of correlation of the various Triassic beds, since Dr. Newberry took much interest in this question and made careful comparisons with all the other plant remains as well as the animal remains of the Trias. His conclusions, therefore, upon this question are of the highest importance and are quite freely expressed.

The material from the Western beds has consisted chiefly of fossil wood, of which vast quantities exist, strewn over the plains of Arizona and New Mexico, and which has been repeatedly reported upon and graphically described by many writers. But until recently very little else has been known from that region. The work upon which we must rely for most of our information with regard to that region, aside from the fossil wood, is that known as the report of the Macomb Exploring Expedition, in which Dr. J. S. Newberry, as naturalist of that expedition, describes and figures a considerable number of Triassic fossil plants; but most of the plants dealt with in this report come from Mexico and not from any part of the United States.

Better to understand the history of the work done on the fossil plants of the American Trias, we will now undertake a brief review of the subject.

### THE CONNECTICUT VALLEY AREA.

Beginning with the most northern of the Eastern deposits, viz, that of the Connecticut Valley, we find that the earliest mention made of fossil plants was that by Dr. Edward Hitchcock, in the American

[1] Fossil fishes and fossil plants of the Triassic rocks of New Jersey and the Connecticut Valley, by John S. Newberry: Mon. U. S. Geol. Survey, Vol. XIV, Washington, 1888.

Journal of Science for 1823, in an extended article read before the American Geological Society on September 11, 1822.[1] Neither of the two objects found is specifically determinable, the first being some sort of cane or grass, the other a coniferous branch, possibly Palissya or Voltzia. The first was found one-half mile south of Newgate Prison, and the second at Sunderland, in Massachusetts.

The first mention made of the petrified tree found in the Southbury area of the Connecticut Trias, about which so much has been said, was a paragraph devoted to it by Dr. Hitchcock in his Miscellaneous Notices of Mineral Localities, with Geological Remarks, in 1828,[2] describing a fragment from it obtained by Dr. Smith of Southbury, broken off by a man who had mistaken it for a recent stump and ruined his ax upon it.

In his first Geological Report of Massachusetts, published in 1833,[3] and accompanied by an atlas of 18 plates, Dr. Hitchcock made passing mention on pages 232–234 of vegetable remains in the Trias and figured a few obscure objects on pl. xiii of the atlas. He supposed that he had found a species of Calamites agreeing closely with *C. arenaceus* of Brongniart, and refers to the mention by De la Beche, in his Manual of Geology, of the discovery of *Lycopodites Sillimanni* at "Hadley, Connecticut," which he believes to have meant South Hadley, Massachusetts. Speaking of the coniferous plant figured in the American Journal, already referred to, he concludes that it is probably a Voltzia related to *V. brevifolia*. The fucoid there found he was disposed to regard as *Fucoides Brongniartii;* but, as we shall see later, he afterwards gave this plant another name. It was found in Deerfield and Greenfield, and was referred to Dr. Morton for determination. Dr. Hitchcock also here again calls attention to the fossil trunk of a tree discovered at Southbury, Connecticut.

The Report on the Geological Survey of Connecticut, by Charles Upham Shepard,[4] 1837, refers to the occurrence of vegetable remains in the red sandstone at Middletown and in the cupriferous sandstone-slate at Enfield Falls, in Suffield, and at Southington and Durham.

In his second Geological Report of Massachusetts[5] Hitchcock devotes nine pages (pp. 450–458) to the subject of fossil plants in the Trias or New Red Sandstone, as he calls it. Some of these are of doubtful vegetable nature; others that he figures are probably fucoids, which can scarcely be determined from his description. The one men-

[1] A sketch of the geology, mineralogy, and scenery of the regions contiguous to the River Connecticut, with a geological map and drawings of organic remains, and occasional botanical notices, Part I, by Edward Hitchcock: Am. Jour. Sci., 1st series, Vol. VI, 1823, pp. 1–86. For reference to fossil plants see p. 80, pl. ix, figs. 4, 5.

[2] Am. Jour. Sci., 1st series, Vol. XIV, 1828, p. 228.

[3] Report on the Geology, Mineralogy, Botany, and Zoology of Massachusetts, by Edward Hitchcock, Amherst, 1833.

[4] New Haven, 1837, pp. 1–188, 8°. See pp. 62, 166.

[5] Final Report on the Geology of Massachusetts, Vol. II, Northampton, 1841.

tioned in the previous report he now calls *Fucoides Shepardi*, and he distinguishes another as *F. connecticutensis*. These plant impressions are for the most part figured in the text; but in addition he gives one plate (which in the text he refers to as pl. 29, but which bears the number 28) on which occur four figures of various small objects, none of which are generically determinable, and only one can be with certainty referred to the vegetable kingdom. viz, fig. 2, which probably represents a Palissya.

The same author read a paper before the Association of Geologists and Naturalists in 1842, in which he described a number of additional plant forms from this same region.[1]

In this paper Dr. Hitchcock gives an account of the fossil tree already mentioned, which was found at Southbury, the specimens of which he had sent to Professor Bailey at West Point, whose language he quotes in this paper and whose figures he also gives on the plate. Professor Bailey had made three sections, one of which was longitudinal and sufficiently radial to show conclusively that the wood of this tree was coniferous, and he so pronounced it. Dr. Hitchcock also here figures a specimen found in the dark-gray sandstone of Mount Holyoke, Massachusetts, which he says belongs to the genus Tæniopteris, and which he compares with *T. vittata* Brongn., as figured in Bronn's Lethæa Geognostica. The figure (fig. 2) of this specimen is so very poor that no one would suspect it of being a fern, but inasmuch as he states that the specimen closely resembles *Tæniopteris vittata* we can interpret the figure with some satisfaction, and there would scarcely seem to be any doubt that this specimen actually represented a Tæniopteris or Macrotæniopteris. This is interesting in view of the fact that Dr. Newberry, in his work already quoted,[2] speaking of *Tæniopteris magnifolia* of Rogers, says that "this has not yet been found anywhere in the North, nor has any other similar fern been met with there," showing that Dr. Newberry had probably overlooked this paper by Dr. Hitchcock. The other three figures represent a conifer allied to Voltzia or perhaps belonging to Palissya, but too poorly preserved and too badly figured to be determinable.

In 1847 Dr. Benjamin Silliman gave an account[3] of two fossil trees, one of them with branches, found in place in the red sandstone in the town of Bristol, Connecticut. A clear picture of the quarry with the trees exposed is given on page 117, and his description is rather full and satisfactory. As in the case of the Southbury specimens, a report was secured from Prof. J. W. Bailey on the internal structure, with the same result, that it indicated the coniferous character of these remains.

[1] Description of several species of fossil plants from the New Red Sandstone Formation of Connecticut and Massachusetts, by Edward Hitchcock: Report of the first, second, and third meetings of the Phil. Assoc. of Am. Geologists and Naturalists, 1840-1842, Boston, 1843, pp. 294-296, pl. xiii.

[2] Mon. U. S. Geol. Survey, Vol. XIV, 1888, p. 12.

[3] Am. Jour. Sci., 2d series, Vol. IV, 1847, pp. 116-118 (fig. on p. 117).

At the close of the paper Dr. Silliman mentions the fact that "large stems of reedlike plants are found in the beds which furnish the fish, at Middlefield, in the same State."

In the same volume[1] Dr. Hitchcock noted the occurrence in bowlders of porphyritic trap at Amherst of "a vegetable stem from 1 to 3 inches in diameter, scarcely flattened."

Several years later (1855), in an article contributed to the American Journal of Science,[2] Dr. E. Hitchcock, jr., describes another fern, which he calls *Clathropteris rectiusculus*, found in the sandstone of Mount Tom, in Easthampton, Massachusetts. From the figures on page 24 Professor Fontaine, in his Older Mesozoic Flora,[3] identifies this with *Clathropteris platyphylla* (Göpp.) Brongn. There is some further mention of this plant by the elder Hitchcock in 1861.[4] In his paper Dr. Hitchcock, jr., speaks of other specimens of what he supposed to be Clathropteris in the cabinet of Amherst College, taken from the quarry of Roswell Field, in Gill, Massachusetts. These specimens are not figured, but from the description Dr. Hitchcock gives of them Professor Fontaine concludes that they can hardly represent a Clathropteris, and are probably Dictyophyllum or Camptopteris.

In a paper by Dr. James Deane on the Sandstone Fossils of Connecticut River (Turners Falls, Massachusetts), published in the Journal of the American Academy of Natural Sciences of Philadelphia for November, 1856,[5] he figured one specimen (pl. xix, fig. *a*) which was thought by Professor Gray to be the "leaf scars of some plant like a tree fern," and which Professor Dana could refer "to nothing but a plant, the prominences being the traces of leaves, probably coniferous;" but he admitted it was "not like any known coniferous plant, ancient or modern" (see p. 177). Dr. Deane, however, did not share these opinions, and says of this specimen:

I think in the present state of science it is impossible to explain the origin of this elegant fossil. If the accumulated bodies that constitute the various lines of impressions be not due to the deciduous fronds of plants, they must be taken for the dermoid protuberances of some animal. There is not the slightest evidence of a compressed stem of a coniferous or other plant, which should certainly be the case in so perfect a specimen; and, moreover, upon the superior or superincumbent stratum the imprint is reversed; it is a cast, and this, it appears to me, is conclusive evidence against a vegetable origin.

In his Ichnology of New England[6] Dr. Edward Hitchcock speaks, on page 6, of the fern (*Clathropteris rectiusculus*) described by Dr.

[1] Loc., cit., p. 202.

[2] Description of a new species of Clathropteris, discovered in the Connecticut Valley sandstone, by Dr. E. Hitchcock, jr.: Am. Jour. Sci., 2d series, Vol. XX, 1855, pp. 22-25.

[3] Mon. U. S. Geol. Survey, Vol. VI, 1883, p. 57.

[4] Proc. Am. Assoc. Adv. Sci., Vol. XIV, pp. 158-159.

[5] 2d series, Vol. III, pp. 173-178, pl. xviii-xx.

[6] Ichnology of New England: A Report on the Sandstone of the Connecticut Valley, made to the Government of the Commonwealth of Massachusetts, by Edward Hitchcock; Boston, 1858, 4°. See pp. 6, 8, pl. v, fig. 1; pl. vii, figs. 1 and 2.

Edward Hitchcock, jr., mentioned above, and gives a figure of the whole frond (pl. v, fig. 1), showing the radiating structure, and another (pl. vii, fig. 1) of a small segment more enlarged than that previously published.

In the same work (p. 8) he mentions a cone found in the quarries of Mr. Roswell Field at Turners Falls, which he thought similar to some described in Europe from the Wealden. A sketch of this cone and of some coniferous twigs from the same locality, made by Mr. F. A. Lydston, is introduced on pl. vii (fig. 2). Professor Fontaine, in a letter dated February 7, 1891, expresses the opinion that the twigs here figured belong to *Cheirolepis Muensteri*, and that the cone may have been that of a species of Palissya of the type of *P. aptera* Schenk.

From the date of the Ichnology of New England there seem to have been nearly thirty years during which no additional paleobotanical discoveries were made in the Connecticut Valley. In 1885 Mr. H. H. Hendrick, a member of the Meriden Scientific Association, found in the Durham shales the fruit of a cycadean plant, a brief notice of which was published by the Rev. J. H. Chapin, of Meriden, president of the association, in the proceedings for that year.[1] The specimen was sent to Dr. J. S. Newberry, who described and figured it in his Fossil Fishes and Fossil Plants (p. 92, pl. xxiv, fig. 4) under the name of *Cycadinocarpus Chapini*. Mr. Chapin recorded this fact in a later volume[2] of the same series in which the original announcement was made.

On March 28, 1887, Dr. Newberry presented to the New York Academy of Sciences a very brief account of the results at which he had arrived in his study of the paleontology of the Triassic beds. An abstract of this paper appeared the same year.[3] It contains a list of the plants that had been obtained from both the New Jersey and the New England beds, all of which were fully treated in the work on which he was then engaged.

The above enumeration brings the record of paleobotanical discovery in the Trias of the Connecticut Valley and New England areas down to the date of Dr. Newberry's Monograph of the Fossil Fishes and Fossil Plants, to which reference has already been made (supra, p. 222). In this he gives a sketch of the Triassic, and includes 17 species of fossil plants. They were collected at Sunderland, Massachusetts, at Durham and Middletown, Connecticut, and at Newark and Milford, New Jersey, and are treated in a thorough and systematic way, being illustrated in six plates with very excellent figures. Through this work we are therefore at length placed in possession of a considerable body

[1] Proceedings and Transactions of the Scientific Association, Meriden, Connecticut, 1885-86, Vol. II, Meriden, 1887, p. 29.

[2] Vol. IV, Meriden, 1891, p. 62.

[3] The fauna and flora of the Trias of New Jersey and the Connecticut Valley: Trans. N. Y. Acad. Sci., Vol. VI, 1886-87, pp. 124-128.

of facts relating to the fossil flora of the northern extension of the American Trias.

My own investigations in this area began in the year 1890. During the month of August of that year Professor Fontaine and myself visited the beds in the vicinity of New Haven and most of the localities above mentioned in Connecticut and Massachusetts, especially those in the Connecticut Valley as far as Turners Falls and Gill, Massachusetts. Our object was, first, to see the collections at Yale University, at the Wesleyan University in Middletown, Connecticut, and at Amherst and Turners Falls, Massachusetts, and to examine the older material that had been collected as above stated and all the fossil plants from the Trias deposited in these collections; secondly, to examine, so far as possible, the beds themselves from which fossil plants have been taken, and to note their mode of occurrence in the rocks.

Of recent collectors in this section by far the most successful has been Mr. S. Ward Loper, of Middletown. Mr. Loper was in the field at the time of our visit, and we met him at Tariffville, Connecticut, at which place he had discovered a plant-bearing locality. There being no true coal mines in the Connecticut Valley Trias, the mode of occurrence of the fossil plants is, of course, somewhat different from that in Virginia. It is equally true here, as in Virginia, that fossil plants are not found in the red sandstone, but are confined to the dark shales, and those in the Connecticut Valley occur for the most part in close connection with the trap ridges of that region. They are usually found at the margin of the shales near their contact with the trap. The locality at Tariffville was in close contact with one of the secondary trap ridges located on the eastern side of the main ridge, which, in the general trend of these ridges, places it higher in the Trias, geologically speaking, or, as Professor Davis expresses it, "posterior." From what Mr. Loper told us, and from numerous observations upon localities from which fossil plants have been previously reported, it would seem that they usually occur in this position. A fairly good specimen of *Ctenophyllum Braunianum angustum* was found during our visit to this locality, and Mr. Loper had already sent considerable material of this character to Professor Davis, which subsequently found its way into the general collection at Washington.

Besides examining the Portland quarries and those of Turners Falls and Gill, Massachusetts, where no vegetable remains other than those presently to be named occur, we visited several places in Connecticut where Mr. Loper had obtained fossil plants, especially at Westfield and Highlands. In the Portland quarries there occur large logs clearly representing Triassic trees embedded in the red sandstone and now thoroughly silicified; but besides these and the fine specimens of Dendrophycus which occur there, nothing of a vegetable nature seems to have been found. At Turners Falls careful investigation was made in the red shales bearing the tracks so celebrated in that locality, and under the guidance of Mr. T. M. Stoughton we visited all the important places from which specimens of interest had been taken. We saw in these beds nothing that could be called vegetable, and it seems very doubtful whether any plants either grew or were ever transported by any agency into the riparian clays in which the Brontotheria and other saurians left their footprints in such profusion.

Special attention was paid on this excursion to the form called *Dendrophycus triassicus* Newb. The original of one of the specimens figured by Dr. Newberry[1] was seen at the museum of Yale University, the other[2] was examined at the museum of the Wesleyan University. Two other good specimens were afterwards secured at the Portland quarries by Mr. John H. Sage, of Portland, and generously donated by him to the National Museum. The finest specimens, however, are those at the Wesleyan University, also from the Portland quarry. Through the courtesy of Prof. W. N. Rice, of that institution, permission was obtained to have these specimens photographed, and Mr. De Lancey W. Gill, then chief of the division of illustrations of the United States Geological Survey, kindly undertook to visit Middletown in November and attend to the photographing of these specimens. Pl. XXXV, Fig. 1, represents one of these views. Although this differs considerably from the specimens figured by Dr. Newberry, coming as they do from the same quarry, it is to be supposed that they represent one species, and it may be assumed that the specimens figured by Dr. Newberry show the lower portion of the frond and did not contain those higher and finer lines so beautifully shown in the specimen at the Wesleyan University. These, therefore, will also be treated as belonging to *D. triassicus*.

I may add that at Amherst several specimens of Dendrophycus from the Portland quarry, and, perhaps, from other points, were seen by us. They were labeled, apparently in the handwriting of Dr. Edward Hitchcock, "Aroid plants." This is of special interest as showing that Dr. Hitchcock supposed them to be of vegetable origin.

At the Washington meeting of the Geological Society of America in December, 1890, Prof. W. M. Davis and Mr. S. Ward Loper read a joint paper giving the results of their work in the Connecticut Valley.[3] The first part of this paper, by Professor Davis, is devoted to the discussion of his theory of the formation of the "trap" and the general stratigraphy of the Triassic formation in the Connecticut Valley. The second part, by Mr. Loper, treats of the fossils. It gives an enumeration of the fossil fishes and fossil plants found by him and their stratigraphical position, showing those that are confined to the anterior and

[1] Op. cit., pl. xxi, fig. 2.

[2] Loc. cit., fig. 1.

[3] Two belts of fossiliferous black shale in the Triassic formation of Connecticut, by W. M. Davis and S. Ward Loper: Bull. Geol. Soc. America, Vol. II, Rochester, 1891, pp. 415-430.

to the posterior shales, and those that are common to both. This enumeration includes 13 plant forms, 11 of which are specifically named. Six of these forms are confined to the anterior and 2 to the posterior shales, while the remaining 5 are common to both situations.

## THE HUDSON-POTOMAC AREA.

By this name may be designated the continuous belt of Triassic deposits that begins with the palisades of the Hudson and ends with the Seneca quarries on the Maryland side of the Potomac. Its position is too well known to require description. The several States may be treated in their order. No fossil plants have been reported from any locality in the Trias of New York.

### TRIASSIC PLANTS FROM NEW JERSEY.

Prof. Henry D. Rogers, in his description of the Geology of the State of New Jersey, published in 1840, devotes a chapter (Chapter III, p. 114) to "the Middle Secondary Rocks," which is the designation preferred by him for this series, and of these rocks he says (pp. 115–116):

> The organic remains hitherto discovered are extremely few, and the evidence they afford is not sufficient to establish within near limits the era to which these strata should be referred. They consist merely of a few rather imperfect relics of one or two species of fishes, some indistinct impressions of Fucoides, or other aquatic vegetation, and occasional thin bands of ligniform coal, in which the fibrous structure, apparently that of the wood, is traceable.

On May 6, 1869, Mr. T. A. Conrad presented a paper to the Conchological Section of the Philadelphia Academy of Natural Sciences[1] in which he described two species of fossil mollusks from South River, New Jersey, found in ash-colored clay near Washington, Middlesex County, which he says "contains abundant stems and leaves of *Cyclopteris*." He further remarks that, although Rogers had referred this clay to the Cretaceous, he (Conrad) had "ascertained it to be Triassic."

No one, to my knowledge, has since seen these "Cyclopteris" leaves. Whitfield[2] refers to this and remarks:

> It will be seen by reference to Professor Lesquereux's list published in the "Report on Clays" (Geol. Rept. New Jersey, 1878, p. 28, 29) that Professor L. does not include this genus among those examined and reported upon. We may, therefore, consider that Mr. Conrad may have been mistaken.

As the list in the Report on Clays contains only species found in the Plastic Clays, which are Cretaceous, this seems curious reasoning. There are clay pits near Washington from which I have myself collected beautiful impressions of fossil plants belonging to the flora of

[1] Am. Jour. of Conchology, Vol. IV, 1869, pp. 278-279.
[2] Mon. U. S. Geol. Survey, Vol. IX, 1885, p. 22.

the Amboy Clays, but they were chiefly dicotyledonous leaves, and this clay does not seem to be the source of the specimens mentioned by Conrad. The Triassic runs under the Cretaceous a short distance west of Washington and Middletown, and it is quite possible that the clays in question may be Triassic.

Mr. I. C. Russell, in 1878, found "a considerable abundance of obscure vegetable remains" at an abandoned copper mine on the western slope of the First Newark Mountain, near Plainfield.[1]

The discovery of fossil plants in the Newark and Belleville quarries, as recorded in the Report of the State Geologist for 1879, has already been referred to (supra, p. 219). Besides the specimen of a supposed Lepidodendron, of which a photograph was sent to Professor Lesquereux, it is added that—

Another fragment has since been obtained from the same quarries by Dr. Skinner, of Belleville, and is now in our possession. It is 7 inches long, 5½ inches wide, and 1½ inches thick, and is as plainly marked as the first. Other and smaller specimens somewhat like the above have also been found in the quarries in Newark. If these fossils are sufficient to determine the geological age of these beds, they put it in the Upper Carboniferous, at least, which is lower than has been heretofore claimed for it. A larger and more complete collection of such fossils must be made if possible.

Vegetable impressions are found in large numbers at the quarries of Mr. Smith Clark, of Milford, but most of them are fragmentary and indistinct. Those which can be seen plainly enough for identification resemble the Equisetum and some coniferous plants. They are evidently much newer than the fossils at Newark and Belleville.[2]

Reference may be made to a paper by Mr. Henry Carvill Lewis, published in the Proceedings of the Philadelphia Academy of Sciences for November 24, 1879, On a New Fucoidal Plant from the Trias. This plant was found at Milford and is figured in this paper. The generic determination was made by Professor Lesquereux, who considered it a new species of Palæophycus, and Mr. Lewis called it *P. limaciformis*.

In the Report of the State Geologist of New Jersey for 1885, page 95, it is stated that Prof. T. C. Porter had obtained specimens of a conifer and an Equisetum in some Triassic sandstone quarries in Hunterdon County, and also that the *Clathropteris rectiusculus* Hitchcock had been found at a quarry near Pluckemin, in Somerset County.

Plant remains were also seen by Mr. F. Braun in a layer from 3 to 4 inches in thickness near the base of a bed of slate under the trap rock along the western bank of the Hudson River at Weehawken, Guttenburg, and neighboring localities in New Jersey, as noted by Mr. Gratacap in 1886.[3]

[1] On the occurrence of a solid hydrocarbon in the eruptive rocks of New Jersey, by I. C. Russell: Am. Jour. Sci., 3d series, Vol. XVI, August, 1878, pp. 112-114.

[2] Geological Survey of New Jersey, Annual Report of the State Geologist for the year 1879, Trenton, 1879, p. 27.

[3] Fish remains and tracks in the Triassic rocks at Weehawken, New Jersey, by L. P. Gratacap: Am. Naturalist, Vol. XX, March, 1886, pp. 243-246

The Annual Report of the State Geologist of New Jersey for the year 1888 is largely devoted to the Triassic or red sandstone rocks, and mentions the occurrence of vegetable remains at a number of points, especially at Belleville, Little Falls, Pleasant Dale, Martinsville, Pluckemin, Wilburtha, and Milford.

The above embraces the greater part of the record of paleobotanical discovery in the Trias of New Jersey beyond what is noted in Dr. Newberry's monograph.

### TRIASSIC PLANTS FROM PENNSYLVANIA.

In Pennsylvania there are several localities at which vegetable remains have been noted.

In 1856 Mr. Isaac Lea gave an account[1] of some observations of his made the previous year in this vicinity, where he found in dark shales, and associated with Posidonia, saurian teeth and footprints, "impressions of plants, some of which belong to the *Conifera* [sic]." He continues:

> One of the cones was nearly 6 inches long and a full inch wide. These were accompanied by other plants of very obscure character, covering large portions of the surface of some of the layers.
>
> Mr. Lea also mentioned that he had observed the same red, black, and gray shales at Gwynedd, on the North Pennsylvania Railroad, where he found the same Posidonia and some of the same obscure plants, impressions of which covered the surfaces of many of the rocks. A single specimen was obtained of a plant with long leaves somewhat resembling *Noeggerathia cuneifolia* Brongniart, which is from the Permian.[2]

More or less successful attempts must have been made to determine these plants collected by Lea, as Mr. Wheatley, in a paper read before the Connecticut Academy of Arts and Sciences on February 20, 1861,[3] identified a number of them with forms described by Rogers and Emmons from Virginia and North Carolina.

In his Older Mesozoic Flora, p. 116, Professor Fontaine says that, according to Professor Lesquereux, *Ctenophyllum robustum* (Emm.) Font. (*Pterophyllum robustum* Emm.) occurs at Phœnixville, Pennsylvania, but he does not state where Professor Lesquereux has made this statement, and I have been unable to find any reference to it from that locality.

Mr. Persifor Frazer, in his Geology of Chester County,[4] says that "plants are numerous at one or two horizons in the Mesozoic formation; referable to Equisetes (horsetails); Zamites therefore Triassic; with lignitic fragments of conifers;" but he does not state the exact locality and only leaves it to be inferred that this refers to Pennsylvania, as he has been describing fossils of other kinds from Phœnixville.

[1] Proc. Acad. Sci. Phil., Vol. VIII, April 15, 1856, pp. 77-78.

[2] See also Am. Jour. Sci., 2d series, Vol. XXII, 1856, pp, 123, 422.

[3] Remarks on the Mezozoic red sandstone of the Atlantic slope, and notice of the discovery of a bone bed therein, at Phœnixville, Pennsylvania, by Charles M. Wheatley, M. A.: Am. Jour. Sci., 2d series, Vol. XXXII, July, 1861, pp. 41-48. (See p. 43.)

[4] Second Geological Survey of Pennsylvania, 1883, $C^4$, p. 213.

In the Report of the State Geologist of New Jersey for 1885, page 96, the following paragraph occurs:

The recent discovery of a stratum full of impressions of the plant *Schizoneura* (*Calamites*) *planicostata* (Fontaine), in the red shales near Doylestown, Pennsylvania, by Mr. E. C. Pond, and of bivalve mollusks in those near Phœnixville, Pennsylvania, where also a deposit containing cycads is reported, taken with the finds above noted, suggests that the flora and fauna of the Triassic may be richer than hitherto supposed, and encourages further search.

In the Annual Report of the Geological Survey of Pennsylvania for 1887 Mr. A. Wanner[1] describes supposed vegetable remains from the red sandstones of York County, in the vicinity of Goldsboro, and figures three specimens on pl. xiii. He regards them as representing algæ of a very ancient type, and proposes for this form the name *Ramulus rugosus*. As we shall presently see, Mr. Wanner followed up his investigations with great success.

Mr. Benjamin Smith Lyman, in the several papers already cited (supra, p. 218), does not seem to have made any fresh contributions to the Triassic flora of Pennsylvania, and is content to enumerate the plants that had already been reported, and to use some of them as proofs of the Paleozoic age of certain beds previously regarded as Triassic.

Mr. Frederick Ehrenfeld, of Philadelphia, a student at the University of Pennsylvania, presented to the faculty, in 1898, a thesis[2] which was the result of a somewhat careful study of the Triassic beds in the vicinity of York, and virtually the same as those in which Mr. Wanner had been working, as it seems independently and without knowledge of the work of Mr. Ehrenfeld.

In this paper (pp. 10–15) Mr. Ehrenfeld enumerates half a dozen fossil plants that he had found in the Trias of that section, and had himself identified. They are: *Macrotæniopteris magnifolia* (Rogers) Schimp., *Cheirolepis Muensteri* (Schenk) Schimp., *Baiera Muensteriana* (Presl) Heer, *Loperia simplex* Newb., *Mertensides bullatus* (Bunb.) Font., and *Equisetum Rogersii* (Bunb.) Schimp.

As above remarked, Mr. Wanner continued his researches, and reached the results which are here published for the first time. Before completing his work he made two visits, in April and May, 1899, to Washington, bringing with him a part of his material, and carefully comparing it with the type specimens at the National Museum. He finally concluded to turn over his manuscript and drawings to the Director of the United States Geological Survey for publication, and they were referred to me to edit and see through the press. After correspondence with Mr. Wanner it was decided to send them, as also

[1] The discovery of fossil tracks, algæ, etc , in the Triassic of York County, Pennsylvania, by Atreus Wanner: Ann. Rept. Geol. Survey of Pennsylvania for 1887, Harrisburg, 1889, pp. 21-35.

[2] A Study of the Igneous Rocks at York Haven and Stony Brook, Pennsylvania, and their Accompanying Formations, by Frederick Ehrenfeld; Philadelphia, 1898; pp. 1-24, 1 plate.

his entire collection of fossil plants, to Professor Fontaine for thorough revision, and for a report upon them, including such notes and suggestions as he should deem of interest. This was done, and the work was completed about the middle of June. The collection proved of special interest, coming as it does from this wholly new region of the Trias, and, as might have been expected, it contained a number of new species and hitherto unknown plants, besides several not heretofore found in American deposits.

In editing the manuscripts of the two authors I have aimed to give the fullest possible expression to the views of both. Professor Fontaine's long experience and extensive researches in this group render him the recognized authority, and Mr. Wanner fully acknowledges this. His determinations are therefore accepted as final by all concerned, and will be embodied in the following systematic treatment of the plants. Mr. Wanner's notes, however, as the collector and original investigator of the material, are of the utmost value and are also embodied as nearly in his own language as accords with Professor Fontaine's determinations. His figures are used as finished up by himself, but to them Professor Fontaine has added a number, and in a few cases has redrawn the same specimens to emphasize his own interpretation of their characters. The joint result may be put into the following form:

## TRIASSIC FLORA OF YORK COUNTY, PENNSYLVANIA.

By ATREUS WANNER and WILLIAM M. FONTAINE.

### INTRODUCTORY REMARKS BY MR. WANNER.

For a number of years the writer, as opportunity permitted, has been exploring the Trias of York County. Encouraged by discoveries made elsewhere, and impelled by an inherent love of geological study and investigation, he has collected enough material to warrant its presentation. It is a report of progress.

So far as the writer knows, no one else[1] has discovered or reported

[1] Since the preparation of this report, but prior to its publication, and at the time of its presentation to Hon. Charles D. Walcott, I received a thesis on A Study of the Igneous Rocks of York Haven and Stony Brook, Pennsylvania, and their accompanying formations, by Frederick Ehrenfeld.

On pages 10 and 11 the author names the following fossils which he found near York Haven:

Macrotæniopteris magnifolia.

Cheirolepis Muensteri.

Baiera Muensteriana.

Loperia simplex = Bambusium Font.

Mertensides bullatus?

Equisetum——?

Mr. Ehrenfeld had no knowledge of the fact that I had previously found fossils at the York Haven locality and had in preparation the report now submitted, for which reason to him also must be given the credit of having discovered fossil plants at that locality, and the further credit of having first published his report.

Mr. Ehrenfeld's thesis was received by me on April 10, 1899, and my report was presented to Hon. Charles D. Walcott on April 15, 1899.

As I understand the facts, the work of each has been unknown to and independent of that of the other.

any fossils from the Trias in this region, with a single exception. That exception relates to Lecrone's copper mine. About twenty years ago fossil teeth and bones were found at the bottom of a shaft sunk for the purpose of developing a supposed vein of copper. These were sent to the late Prof. E. D. Cope, of Philadelphia.

The drawings were all carefully made by the writer and are intended to be exact illustrations of the specimens. No details have been supplied, though the possession of a number of other specimens in different instances clearly furnished the material from which to fill out missing parts.

In the description of fossil plants the publications of William M. Fontaine have been referred to almost exclusively. Such has been the case not simply because the York County fossil plants are almost wholly included in Fontaine's Mesozoic Flora, but because of the completeness and clearness of his descriptions and illustrations.

The writer is indebted to Mr. J. Heckert for valuable assistance. In this connection it is but just to acknowledge the potent influence exerted by the indefatigable energy and comprehensive and exhaustive methods of research of the Director of the United States Geological Survey, Hon. Charles D. Walcott, whom it was the author's privilege to accompany in a hurried inspection of the Cambrian rocks of this section. That association served as an inspiration and stimulated the writer to still more zealously continue his researches.

The author is further indebted to the Director of the United States Geological Survey and to Prof. Lester F. Ward and his associates in the National Museum for the opportunity of examining the collection of Mesozoic and related floras at Washington.

*Flora.*—A brief description of the geological and lithological features of the Trias in this section will be found in the reports of the Geological Survey of Pennsylvania.

In York County the bedded Triassic series is largely made up of the characteristic red shales, quartz conglomerate, and sandstones, matrices not favorable to the preservation of recognizable fossil forms. Moreover, intrusive trap, in dikes and great sheets, has contributed greatly to modify and disturb the original deposits. Because of these conditions the search after impressions that can be identified is generally disappointing and unproductive. A few localities yield illegible impressions of plants. Occasionally there is but a dark, earthy, carbonaceous band, in a sand bank, or a thin, short seam of coal, a mere trace of irregular width, unmistakably to locate a vegetable deposit.

More frequently rough casts of limbs or trunks of trees, in blocks of quartz conglomerate or sandstone of varying composition, mark the final resting place of vegetation now decomposed.

A shale at the York Haven locality, yielding most of the plants described, and the Little Conewago Creek shales, encouraged the hope that like deposits might be found elsewhere and still further enrich the contributions to the flora of York County.

It was mainly due to that expectation, a vain one, thus far, that the writer did not publish the results of his geological explorations years ago, when he first discovered the York Haven locality.

## DESCRIPTIONS OF THE SPECIES.

### Subkingdom PTERIDOPHYTA (Ferns and Fern Allies).

### Class FILICALES.

### Family FILICES (Ferns).

### Genus THINNFELDIA Ettingshausen.

THINNFELDIA ? RETICULATA Fontaine n. sp.

Pl. XXII, Figs. 1, 2.

Professor Fontaine says of this plant:

This is a fragment of what seems to be a new species of fern. It is a portion of the terminal part of an ultimate pinna. The plant does not show enough for one to make out its true character. The nerves anastomose in an irregular manner. It has the general aspect of a Thinnfeldia, and but for the anastomosis of the nerves might without hesitation be placed in that genus.

As the portion is from the upper part of the frond, the pinnules probably differ from the normal ones lower down on the plant, and hence the true character may not be disclosed. There is a midnerve at the base of the pinnules, but it splits up into branches. Lateral nerves go off on each side of it from the main rachis very obliquely. All the nerves are strong and distinct. They anastomose irregularly at long intervals and form elongate meshes.

It is without doubt a new species and may be a new genus. Provisionally it may be called *Thinnfeldia reticulata.*

Mr. Wanner makes this statement:

The lobes are decurrent and the rachis winged. Fig. 2, Pl. XXII, shows the anastomosing nervation. More specimens are needed better to define it.

*Locality.*—N. C. R. R. cut, south of York Haven.

### Genus CLADOPHLEBIS Brongniart.

CLADOPHLEBIS RETICULATA Fontaine n. sp.

Pl. XXI.

Professor Fontaine's description of this species is as follows:

This is a fine specimen of a new and interesting fern. Mr. Wanner's Fig. 1 gives a good idea of the appearance of the largest specimen as seen with all accidental imperfections. I have attempted in Fig. 3 to indicate its character as seen under the lens and omitting accidental imperfections. Figs. 4, 5 give the basal and terminal portions of a pinnule magnified three diameters, in order to show the nervation, which is uncommon. I have very carefully studied it and failed to see some of the points given in Mr. Wanner's Fig. 2. The nerves are more slender than is indicated in that figure and more closely placed. There is some indication of a toothing on the margins of the pinnules, but, as I see it, it is not so constant and regular as that indicated by Mr. Wanner. It appears to be a laceration of the margin at the termination of some of the lateral nerves, that is due to accident in the splitting of the slate on which the impressions are found. The description is as follows:

The midrib is strong and rigid. The pinnules are opposite or subopposite, and extremely long and slender. They are a little over 5 cm. long and only 4 mm. wide near their base. They are falcate, with the basal portion of the lamina on the upper side of the midnerve a good deal wider than that on the lower side, tending to form an ear. This upper basal portion overlaps the lower basal portion of the pinnules following next above, and all the pinnules are so closely placed as to overlap or touch at their margins. The pinnules narrow gradually to a subacute tip. In the lower portion of the pinnules there is a distinct midnerve, which is inserted on the rachis below the middle of the base of the pinnules. The midnerve disappears in the upper part of the pinnule, being split up into very long branches that fork at long intervals. These branches and the lateral branches sent off above the base are remarkable for their length and closeness of position, and for the fact that they diverge so slightly that they are almost parallel. The nerves at base on the upper side of the midnerve diverge more strongly to fill the ear. Some of the lateral basal nerves, especially on the upper side of the midnerve, go off from the rachis. Lateral nerves go off from the midnerve on each side so obliquely that they almost follow the course of that nerve. They fork at long intervals, and, as stated before, diverge so slightly that they and their branches are approximately parallel. The branches occasionally anastomose in a straggling, irregular manner, so as to form no regular and definite meshes.

This plant may form the type of a new genus. It reminds one in its habit of Otozamites, especially of some of the forms of *O. Bucklandii*, as given by Schenk in Foss. Flor. der Grenzschichten, more especially of figs. 2, 3, pl. xxxiii, but the nervation and other points are different. The nervation, apart from the reticulation, resembles the peculiar nervation of some of the forms of Zamiopsis of the Potomac formation. It may be compared with that of *Z. insignis*, Mon. U. S. Geol. Survey, Vol. XV, pl. lxv, fig. 4. It is, however, a plant quite different from any species hitherto described. But for the anastomosis it agrees well with the genus Cladophlebis, and may be provisionally placed in that genus, with the name *C. reticulata*.

The following is Mr. Wanner's account of it:

No other specimen found here so completely presents the original in its entirety. The exceptionally well-preserved group of leaves, Fig. 1, Pl. XXI, showing the shape of the frond, angle of departure of the pinnæ and their shape, stands alone. Even the rootstalk, showing the points where the leaves were attached, as well as numerous slender rootlets, has left its plain impress upon the shale.

A slightly mutilated basal end of a leaflet, Fig. 2, Pl. XXI, shows the auricle as well as the forking and anastomosing nerves.

*Locality.*—N. C. R. R. cut, south of York Haven.

## Genus ASTEROCARPUS Göppert.

### ASTEROCARPUS FALCATUS (Emmons) Fontaine.

Pl. XXII, Fig. 3.

1856. *Pecopteris falcatus* Emm.: Geological Report of the Midland Counties of North Carolina, p. 327, pl. iv, fig. 9.
1856. *Pecopteris carolinensis* Emm.: Op. cit., p. 327, pl. iv, figs 1, 2.
1857. *Pecopteris falcatus* Emm.: American Geology, Pt. VI, p. 100, pl. iv, fig. 9.
1857. *Pecopteris falcatus variabilis* Emm.: Op. cit., pl. iv, fig. 5.
1857. *Pecopteris carolinensis* Emm.: Op. cit., p. 100, text fig. 68, pl. iv, figs. 1, 2.
1883. *Asterocarpus virginiensis* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 41, pl. xix, figs. 2, 2a, 3–5; pl. xx; pl. xxi, figs. 1, 1a, 1b, 2; pl. xxii; pl. xxiii; pl. xxiv, figs. 1, 2, 2a.
1883. *Laccopteris Emmonsi* Font.: Op. cit., p. 102, pl. xlviii, figs. 6, 7.
1883. *Laccopteris carolinensis* (Emm.) Font.: Op. cit., p. 102, pl. xlix, figs. 11, 12, 12a.

Only one important pinna of this plant seems to have been found. Mr. Wanner figured it and says that the figure shows part of a frond not referred to any genus because of insufficient data. The nervation can not be discerned, nor were any other specimens of its kind found. Professor Fontaine seems to have found the specimen, and remarks:

This seems to be a fragment, with small pinnules, of *Asterocarpus virginiensis*. At least such a fragment of that fossil occurs among Mr. Wanner's plants.

*Locality.*—N. C. R. R. cut, south of York Haven.

## Genus TÆNIOPTERIS Brongniart.

### TÆNIOPTERIS? YORKENSIS Fontaine n. sp.

Pl. XXII, Figs. 4–6.

Professor Fontaine's treatment of this species is as follows:

In Fig. 4 of Pl. XXII Mr. Wanner depicts a long, narrow leaf as a form of *Macrotæniopteris magnifolia*. A careful inspection of this specimen convinces me that it is not *M. magnifolia*. It is, I think, a Tæniopteris, but as the leaf is imperfect and there is only one specimen of it, I do not positively identify it as such. If it be one, it is the first of the genus found in the Older Mesozoic of the Atlantic States. The following points indicate that it is a Tæniopteris: The length is great for a leaf of its small width, and the width changes little throughout. The midrib is strongly defined and prominent, unlike the vaguely defined, flat midrib of *M. magnifolia*. No form of *M. magnifolia* as narrow as this ever attained such a length. It reminds one strongly of some of the Tæniopterids of the Oroville Jurassic flora. It may also be compared with *T. tenuinervis* Brauns. The nerves, however, seem to be finer and closer than those of the latter plant.

Fig. 5 of Pl. XXII represents a plant that certainly is not *M. magnifolia*. It probably is the same with the plant represented by Fig. 4.

Fig. 6 of Pl. XXII may represent a smaller form of the same plant, or it may be *Pseudodanæopsis reticulata* Font. [*P. plana* (Emm.) Font.] Provisionally the plant given in Fig. 4 may be called *Tæniopteris ? yorkensis*. It comes from York Haven, N. C. R. R. cut, as do the forms depicted in Figs. 5 and 6.

As Professor Fontaine has said, Mr. Wanner regarded these specimens as small forms of *Macrotæniopteris magnifolia*, and in discussing the larger leaves he almost entirely neglected to comment on them after having drawn them. The following is his only allusion to them:

Parts of leaves from the Conewago locality are shown in Figs. 4–6, Pl. XXII. The only tip found and illustrated, Fig. 6, Pl. XXII, is somewhat obscure, whilst no basal ends have been obtained from here.

## Genus MACROTÆNIOPTERIS Schimper.

### MACROTÆNIOPTERIS MAGNIFOLIA (Rogers) Schimper.

### Pl. XXII, Figs. 7–9; Pl. XXIII; Pl. XXIV.

1843. *Tæniopteris magnifolia* Rogers: Philadelphia Association of American Geologists and Naturalists, 1843, p. 306, pl. xiv, unnumbered fig. on the right, ½ nat. size.

On this species Professor Fontaine remarks:

Mr. Wanner has in his collection several good specimens of this plant. On Pl. XXIV he gives a good representation of a portion of a leaf of the largest size. Fig. 7 of Pl. XXII gives a form that is probably *M. magnifolia*. It may, however, well be some larger Tæniopteris, like *T. superba*.

Mr. Wanner took a special interest in this species and gives the following descriptive account:

No impressions of whole leaves were found. Pl. XXIV shows part of a large leaf with a truncate termination. Figs. 2 and 3, Pl. XXIII, are ends of other leaves, in all cases truncate. Whilst impressions of different parts of leaves are very common at the York Haven locality, strange to say, no tips similar to those which one would expect to find were observed. All ends, as shown, were truncate.

Figs. 8 and 9, Pl. XXII, are illustrations of typical bases. The side of one is entire, that of the other nearly so.

Fig. 1, Pl. XXIII, shows the venation. The nerves are fine, parallel, and about one-third of a millimeter apart. In nearly all of the specimens the forking of the nerves is not evident; on the contrary, they seem to be single and parallel to the point of insertion; but in a few specimens, by closer inspection, nerves are seen that fork very close to the point of attachment, and apparently within the rachis.

Fontaine calls attention to the difference in shape of the specimens which he examined, a peculiarity which is strikingly presented in the specimens from these two localities.

*Localities.*—N. C. R. R. cut, south of York Haven; Little Conewago Creek, exploitation pit.

## Genus PSEUDODANÆOPSIS Fontaine.

### PSEUDODANÆOPSIS PLANA (Emmons) Fontaine.

### Pl. XXV, Figs. 1, 2.

1857. *Strangerites planus* Emm.: American Geology, Pt. VI, p. 122, fig. 90.

1883. *Pseudodanæopsis reticulata* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, pp. 59, 116, pl. xxx, figs. 1, 2, 2a, 3, 4, 4a; pl. liv, fig. 3.

Professor Fontaine says of this specimen:

This plant, left in doubt by Mr. Wanner, is almost certainly *Pseudodanæopsis reticulata*. It has the copious anastomosis, with the thick and smooth leaf substance of that plant.

Mr. Wanner's statement with regard to it is as follows:

The specimen Fig. 1, Pl. XXV, contains neither base nor tip, and reveals the nervation shown in Fig. 2 on but a small part of the surface. The nerves are not easily distinguished, evidently because of the thickness of the leaf substance, as indicated by the impression. The midrib is prominent and stout. This is the only specimen of its kind found, though several other impressions somewhat similar, in which no venation can be traced, may belong to the same species.

*Locality.*—N. C. R. R. cut, south of York Haven.

## Genus LONCHOPTERIS Brongniart.

### LONCHOPTERIS OBLONGA (Emmons) Fontaine.

Pl. XXV, Figs. 3-5.

1856. *Acrostichites oblongus* Emm.: Geological Report of the Midland Counties of North Carolina, p. 326, pl. iv, figs. 6, 8.

1857. *Acrostichites oblongus* Emm.: American Geology, Part VI, p. 101, pl. iv, figs. 6, 8.

1883. *Lonchopteris oblongus* (Emm.) Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 103, pl. xlix, figs. 1, 1a.

Mr. Wanner correctly classed this in the genus Lonchopteris. Professor Fontaine says:

This is much like *Lonchopteris oblongus* of the North Carolina Mesozoic, and most probably is that plant. The pinnules are not smaller than many of those of the North Carolina fossil; the nervation is also similar. The only difference is that the York fossil has a distinct granulation, strikingly like the fructification of Acrostichites. As, however, the fructification of *L. oblongus* is not known, this feature does not preclude the identification of the York fossil with that of North Carolina.

The following are Mr. Wanner's notes:

Assuming that the specimens, Figs. 3-5, Pl. XXV, are pinnæ of a compound fern, the shape of the pinnules, together with the elliptical meshes formed by the anastomosing nerves, Fig. 5, refer this impression to Lonchopteris. The pinnules, however, are very much smaller in proportion to the length of the pinnæ than in *L. virginiensis*, nor are they so closely crowded together, moreover they show a very pronounced variation in size and shape near the base of the pinnæ.

*Locality.*—N. C. R. R. cut, south of York Haven.

## Genus SAGENOPTERIS Presl.

### SAGENOPTERIS sp. Fontaine.

Pl. XXV, Fig. 6.

The very defective character of this specimen makes it doubtful whether it is best to admit it at all, but in view of the special interest attaching to the York florula it may stand as a stimulus to further discovery. As Professor Fontaine says, "It is too poorly preserved to give any distinct character, but the nervation indicates that it is a fragment of some Sagenopteris."

Mr. Wanner speaks of it as an undetermined frond, and says that the figure shows an impression sufficiently legible to be referred to a fern, but so fragmentary as to prevent any further conjecture as to genus or species. It suggests Thyrsopteris.

*Locality.*—N. C. R. R. cut, south of York Haven.

### Genus ACROSTICHITES Göppert.

#### ACROSTICHITES LINNÆÆFOLIUS (Bunbury) Fontaine.

Pl. XXV, Figs. 7, 8.

1847. *Neuropteris linnææfolius* Bunb.: Quart. Jour. Geol. Soc., Vol. III, Pt. I, pp. 281, 288, pl. x.

1857. *Cyclopteris linnææfolia* (Bunb.) Heer: Am. Jour. Sci., 2d Ser., Vol. XXIV, p. 428.

1883. *Acrostichites linnææfolius* (Bunb.) Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 25, pl. vi, figs. 3, 3a; pl. vii, figs. 1–4; pl. viii, figs. 1, 1a; pl. ix.

Mr. Wanner had doubtfully identified this plant with *Mertensides bullatus* Font. Professor Fontaine says:

This identification is probably not correct. I noted several sterile pinnules of *Acrostichites linnææfolius* and none of *Mertensides bullatus*. The specimen is probably the former plant.

Mr. Wanner had made the following very brief statement with regard to it:

A fragmentary part of the original, Pl. XXV, Figs. 7, 8, seems to belong here. However, other and better specimens are needed satisfactorily to locate it. Fig. 8 shows the venation.

*Locality.*—N. C. R. R. cut, south of York Haven.

#### ACROSTICHITES MICROPHYLLUS Fontaine?

Pl. XXV, Figs. 9, 10.

1883. *Acrostichites microphyllus* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 33, pl. vii, fig. 5; pl. x, fig, 2; pl. xi, fig. 4; pl. xii, figs. 3, 3a.

Mr. Wanner doubtfully identified this plant with *Mertensides distans* Font. Professor Fontaine thinks it can not be that species, and remarks:

This small fragment, marked doubtfully as *Mertensides distans*, did not show, so far as I could see, the nervation given by Mr. Wanner. The pinnules have a granulation that suggests that the plant may be an Acrostichites. If so, it is probably *A. microphyllus*. Another specimen, not figured by Mr. Wanner, shows some rather obscure pinnules of *A. microphyllus*. At the same time the pinnules of Mr. Wanner's *Mertensides distans* look much like his Lonchopteris?

The following is Mr. Wanner's note:

Whilst the exact shape of the pinnules of the frond, Pl. XXV, Fig. 9, can not be determined easily, the opposite is true of the nervation. The lower pair of lateral nerves forks twice (Fig. 10), all the rest but once. The pinnæ are broken off at each end. Only one other specimen was found.

*Locality.*—N. C. R. R. cut, south of York Haven.

## Class EQUISETALES.

## Family EQUISETACEÆ.

### Genus EQUISETUM Linnæus.

#### EQUISETUM ROGERSII (Bunbury) Schimper.

Pl. XXV, Figs. 11, 12.

1851. *Calamites Rogersii* Bunb.:[1] Quart. Jour. Geol. Soc. London, 1851, Proceedings, p. 190.
1869. *Equisetum Rogersii* (Bunb.) Schimp.: Traité de Paléontologie Végétale, Vol. I, p. 276.

Professor Fontaine says of this:

Mr. Wanner indicates by question his doubt regarding the species. He has, without doubt, in his collection a large fragment of a crushed stem of *E. Rogersii*, showing several nodes and the imprint of a portion of the outer surface of the plant. There are also several small imprints of Equisetum, which suggest the presence of *E. Muensteri*, but they are too vague to justify this identification.

The following is Mr. Wanner's description:

The compressed and distorted specimen, Fig. 11, unmistakably reveals the fact in its nodes and appearance that it belongs to the Equiseteæ. No other specimens were found to shed additional light on its individuality, though a still more fragmentary impression made by another member of the same family is illustrated in Fig. 12.

*Locality.*—The pumping station, N. C. R. R. cut, 600 feet above the plant-bearing shales.

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[1] Specimens of this species had been several times described and figured by other authors, who confounded it with the Carboniferous species *Calamites Suckowii* Brongn. Brongniart distinguished it as var. δ (Hist. Vég. Foss., p. 125, pl. xvi, fig. 1).

## Subkingdom SPERMATOPHYTA (Phanerogams).

## Subdivision GYMNOSPERMAE.

## Class CYCADALES.

### Family CYCADACEÆ.

### Genus PTEROPHYLLUM Brongniart.

#### PTEROPHYLLUM INÆQUALE Fontaine.

Pl. XXVI, Figs. 2, 3.

1883. *Pterophyllum inæquale* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 64, pl. xxxvi.

Mr. Wanner identified this doubtfully with *Ctenophyllum Emmonsi* Font. Professor Fontaine simply says:

This is almost certainly a fragment of *Pterophyllum inæquale* Font. of the Virginia Older Mesozoic.

Mr. Wanner's description is as follows:

The leaf, evidently a Ctenophyllum, has its upper portion pushed out of place, but in such a manner as to be restored easily to its true position. The leaflets are of uniform width, with a slight expansion along the rachis. They are striated by closely placed parallel nerves, about one-third of a millimeter apart, some of which fork shortly after leaving the rachis. Fig. 3 shows the nervation. Several of the leaflets terminate in broadly rounded or truncate tips, which, taken in connection with the absence of any great length, suggests *Ctenophyllum Emmonsi*. More specimens are needed better to define its properties.

*Locality.*—Little Conewago Creek, west of Manchester, exploitation pit.

### Genus ANOMOZAMITES Schimper.

#### ANOMOZAMITES PRINCEPS (Oldham and Morris) Schimper?

Pl. XXVI, Fig. 1.

1862. *Pterophyllum princeps* Oldh. and Morr.: Mem. Geol. Surv. India, Palæontologia Indica, Ser. II, Foss. Fl. Gondw. Syst., Vol. I, Foss. Fl. Rajmahal, p. 23, pl. x; pl. xi, fig. 1; pl. xii, fig. 1; pl. xiii, figs. 1, 2.

1870. *Anomozamites princeps* (Oldh. and Morr.) Schimp.: Traité de Paléontologie Végétale, Vol. II, p. 142.

Professor Fontaine's description, which follows, explains the circumstances under which this species was brought to light. For some reason he prefers to retain the original name of Oldham and Morris and call it *Pterophyllum princeps*, although not only did Schimper place it in his genus Anomozamites, but Feistmantel accepted this change and it has been so known since 1870. The figure is Professor Fontaine's.

Among the specimens collected by Mr. Wanner is a fragment of a large leaf that has not been figured and described by him. The name given on the label is *Macro-*

tæniopteris magnifolia. This form, in the segmentation of the leaf, is strikingly suggestive of a large Pterophyllum, and it most resembles *P. princeps* Oldh. and Morr., of the Rajmahal flora of India, showing the same variation in the width of the segments and the same dimensions. As, however, there is only one specimen, it is possible that it is a leaf of *Macrotæniopteris magnifolia* that has by accident been segmented in this manner. I have collected many hundred specimens of *M. magnifolia* from the Older Mesozoic of Virginia and have never seen a case of a leaf lacerated by accident that was so suggestive as this. It should be stated also that Emmons mentions seeing in the flora of the Older Mesozoic of North Carolina supposed leaves of *M. magnifolia* that were so regularly segmented that they attracted his attention as being possibly not that plant. They may well have been some forms similar to this from York.

## Genus CTENOPHYLLUM Schimper.

### CTENOPHYLLUM GRANDIFOLIUM Fontaine.

### Pl. XXVII.

1883. *Ctenophyllum grandifolium* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 73, pl. xxxix, figs. 1, 1a, 2, 3, 3a; pl. xl; pl. xli; pl. xlii, fig. 1.

This specimen was accurately determined and figured by Mr. Wanner. After looking over the collection Professor Fontaine says:

Mr. Wanner has several very good specimens of this plant, and gives some good figures of it.

Mr. Wanner's notes are as follows:

The leaf, three separated parts of which are shown in Figs. 1, 2, 3, Pl. XXVII, is very fragmentary. One and two closely associated with three in the matrix, the impressions being in the same piece of shale, probably belong to the same leaf and are so considered. Only parts of the leaflets remain extending to varying distances from the rachis, in all cases without tips. After a slight expansion they are attached throughout their entire width to the rachis. Immediately beyond the midrib some of the leaflets are narrowest, from whence they gradually expand. Two of the longest segments at length attain a uniform width, for which reason the same peculiarity is assumed to be a characteristic of the leaf.

In this specimen it is difficult to determine whether only some or all of the nerves fork shortly after leaving the rachis, as shown in Fig. 5, a magnified portion of a leaflet. The nerves are close, about one-third of a millimeter apart, and parallel; in this specimen they can not be resolved into two nerve strands, a property to which Fontaine calls attention.

*Locality.*—N. C. R. R. cut, south of York Haven.

### CTENOPHYLLUM WANNERIANUM Fontaine n. sp.

### Pl. XXVIII, Fig. 1.

This was supposed by Mr. Wanner to represent *Ctenophyllum Braunianum* var. *α* of Göppert, but Professor Fontaine says:

This is a new species of Ctenophyllum, allied to *C. Braunianum*. The specimen figured by Mr. Wanner is a fine one. There is in his collection a smaller fragment of the same species, showing leaflets narrower and more delicate than those of the form he depicts. It, however, evidently belongs to the same species. The form given by Mr. Wanner may be taken as the type. It has narrower leaflets that are uniformly narrow, not more than 1 mm. wide. None of them are entire. The greatest length seen is 4 cm. They go off from the midrib at an angle of 45° and are inserted on its side after the position of *C. Braunianum.*

Mr. Wanner has made the following note:

The lower part of the leaf, its apex, and the tips of the leaflets are wanting. Enough, however, remains to present very clearly the characteristics of *Ctenophyllum Braunianum.* The long, narrow leaflets, slightly expanded at the base, are attached throughout their entire width to the rachis. The closely placed nerves, about six in number, are parallel.

The few other specimens found strikingly duplicate the one illustrated in its essential features. In one the leaflets are not more than one-half as wide.

*Locality.*—N. C. R. R. cut, south of York Haven.

## Genus DIOONITES Miquel.

### DIOONITES CARNALLIANUS (Göppert) Bornemann.

### Pl. XXVIII, Fig. 2.

1843. *Pterophyllum Carnallianum* Göpp.: Uebersicht schles. Ges., 1843, p. 130, pl. i, fig. 4.

1856. *Dioonites Carnallianus* (Göpp.) Born.: Ueber organische Reste der Lettenkohlengruppe Thüringens, p. 56.

This plant was regarded by Mr. Wanner as *Ctenophyllum Braunianum* and classed with the one represented by Fig. 1 of Pl. XXIX. Professor Fontaine regards them as different. Of this one he says:

Schenk, in Foss. Flor. der Grenzchichten, pl. xxxix, fig. 4, gives a representation of a plant which he calls *Pterophyllum Carnallianum,* but which Schimper regarded as a Dioonites. This fossil seems to be identical with one of the specimens considered by Mr. Wanner as *Ctenophyllum Braunianum.* The Pennsylvania fossil has broader leaflets and stronger nerves than any form of *C. Braunianum.* The specimen is the terminal portion of a leaf, not, however, retaining the tip. The length of the fragment is 14 cm. The midrib of the leaf is stout and rigid, showing a maximum width of 3 mm. It has narrower leaflets, none of which are entire. The largest fragment has a length of 6 cm. The leaflets toward the summit are narrower and seemingly shorter. They are set on the midrib at a very large angle (75°–80°). The texture of the leaflets seems to have been thin, and they have the same width from base to end. Their width is about 3 mm. The nerves could not be made out satisfactorily. This specimen is a finer one than that figured by Schenk.

Mr. Wanner says of it:

Fig. 2 is marked by a somewhat abrupt shortening of the leaflets near the apex, after which their length remains about the same. The leaflets are terminated by rounded tips and striated by closely-placed parallel nerves, about one-third of a millimeter apart. It is difficult to trace the nerves to the point of insertion in the rachis, but they seem to be parallel throughout their extent.

Fragmentary specimens from the Little Conewago Creek, evidently belonging to the Ctenophylla, may or may not be of the species *Braunianum*, for which reason attention is called to that locality in this connection.

*Localities.*—N. C. R. R. cut, south of York Haven; Little Conewago, exploitation pit, west of Manchester(?).

## Genus ZAMITES Brongniart.

### ZAMITES PENNSYLVANICUS Fontaine n. sp.

Pl. XXVIII, Figs. 3, 4.

Mr. Wanner referred this plant very doubtfully to *Ctenophyllum truncatum* Font. Professor Fontaine regards it as a new species of Zamites and has refigured it (Fig. 4). The following is his description of it:

Schenk, in Foss. Flor. der Grenzschichten, pl. xxxv, fig. 8, gives a figure of a plant that he calls *Zamites angustifolius*. Schimper named it *Podozamites angustifolius*. The plant Mr. Wanner calls *Ctenophyllum truncatum* is very much like this. It is a true Zamites, as is shown by the insertion of one entire leaflet seen on it. This shows that the leaflets are 3 cm. long, 2 mm. wide, and that they are widest near their base, where they are abuptly rounded off. They are attached by a callosity to the upper surface of the midrib. At their tips they are narrowed to a sharp lancet-shaped termination. The nerves are several in number and fine, but were not clearly visible.

The following is Mr. Wanner's account:

Fig. 3, Pl. XXVIII, shows part, a very fragmentary part, of a leaf containing the bases of several leaflets. Two other specimens from the same locality, one of which contains leaflets only one-half as wide, exhibit certain characteristics easily recognized in this one. No entire leaflets and no tips of leaflets were found. The opposite and rather remote leaflets contract near the line of attachment to the rachis, and are neither procurrent nor decurrent. Shortly after emerging from the midrib many of the nerves fork, after which they continue close together and parallel. Were it not for the evident absence of decurrent leaflets the author would refer the specimen to *Dioonites Buchianus* with greater confidence than he feels now in associating it with the partially defined *Ctenophyllum truncatum*. More specimens are needed better to define its characteristics.

*Locality.*—Little Conewago Creek, west of Manchester, exploitation pit.

### ZAMITES YORKENSIS Fontaine n. sp.

Pl. XXIX, Figs. 1–4.

Mr. Wanner regarded this as probably representing *Ctenophyllum Braunianum* Göpp., and says:

In Fig. 1 the leaflets are very close together, overlapping and pushed over the rachis in such a manner as largely to conceal the midrib and make it difficult to determine the exact manner in which the veins depart from the line of contact. Fig. 2 represents a magnified portion of a leaflet and shows the venation.

Professor Fontaine sees in it another new species of Zamites, and has refigured the same specimen (Figs. 3, 4) to give his interpretation of it. He describes it as follows:

On the fragment of slate that shows the imprint of *Tæniopteris? yorkensis*, there is an imprint of what seems certainly to be a true Zamites of the type of *Z. Feneonis*, which type characterizes the Jurassic. This plant may be the form depicted by Mr. Wanner in Fig. 1, Pl. XXIX. If so, the figure does not correctly represent the insertion of the leaves. It should also be stated that then the identification of the plant given in that figure with *Ctenophyllum Braunianum* var. $\alpha$ is erroneous. The description of the plant now in question is as follows:

The specimen is a portion of a leaf showing a number of leaflets, some of them entire. The leaves are closely placed, about 25 mm. long, 4 mm. wide, and widest at base. They taper to a subacute tip. At base they are slightly auriculate and are inserted on the upper surface of the midrib. The nerves are fine and closely placed. They are not distinct enough to show the details. Fig. 3 represents the specimen of natural size, and 4 gives a leaflet enlarged 2 diameters, and partly restored. This and the preceding constitute the first species of Zamites found in the older Mesozoic flora of the Eastern States.

## Genus PODOZAMITES Friedrich Braun.

### PODOZAMITES DISTANS (Presl) Friedrich Braun?

### Pl. XXIX, Figs. 5–7.

1833. *Zamites distans* Presl in Sternberg: Flora der Vorwelt, Vol. II, p. 196, pl. xli, fig. 1.

1843. *Podozamites distans* (Presl) Friedrich Braun in Münster: Beiträge zur Petrefactenkunde, Vol. II, Pt. VI, p. 28.

Mr. Wanner identified this doubtfully with *Zamites tenuinervis* Font. Professor Fontaine says:

These are not *Zamites tenuinervis*, but fragments of some other Zamites or Podozamites. The fragments are too obscure to determine fully. The smaller fragment is like Schenk's *Zamites distans* (*Podozamites distans*), as given in Foss. Flor. der Grenzschichten, pl. xxxvi, figs 1–9, 9a, 9b. The larger resembles the variety given in fig. 10 of the same plate.

Mr. Wanner has the following note:

Figs. 5 and 7 of Pl. XXIX show parts of detached leaflets containing the remains of basal ends exhibiting properties which agree with those described by Fontaine. No whole leaves and no tips were found.

Fig. 6 shows the venation. The veins are parallel, very fine and close, being about one-tenth of a millimeter apart. The surface of some leaflets presents a regularly banded appearance, owing to the prominence of stronger nerves, about one in five.

*Locality.*—Little Conewago Creek, lowest horizon.

## Genus SPHENOZAMITES Brongniart.

### SPHENOZAMITES ROGERSIANUS Fontaine.

Pl. XXIX, Figs. 8, 9.

1883. *Sphenozamites Rogersianus* Font.:[1] Older Mesozoic Flora, of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 80, pl. xliii, figs. 1, 1a; pl. xliv, figs. 1, 2, 2a, 2b; pl. xlv, figs. 1, 2.

Professor Fontaine simply remarks that this is correctly determined. Mr. Wanner's notes are very meager:

Figs 8 and 9, Pl. XXIX, present part of a turned-over leaf. The specimen is poor but shows the dichotomous forking of the nerves and the transverse bars, characteristics of Fontaine's type specimen.

But two specimens were found; the other, being equally fragmentary, while it agrees with the one illustrated, reveals nothing additional.

*Locality.*—N. C. R. R. cut, south of York Haven.

## Genus CYCADEOSPERMUM Saporta.

### CYCADEOSPERMUM WANNERI Fontaine n. sp.

Pl. XXIX, Fig. 10.

Mr. Wanner called this a "seed of Leptostrobus." Professor Fontaine says:

This is not a seed of Leptostrobus but is probably one of some cycad. It is almost circular in form and looks somewhat as if it were winged, as represented by Mr. Wanner. This appearance is probably due to the accentuation, from pressure, of the thicker central portion of the nut. It has the dimensions 8 by 11 mm. It may be called *Cycadeospermum Wanneri.*

Mr. Wanner says of it:

This seed, by reason of association with Leptostrobus, has been referred to it. Seeds of this kind were not found at York Haven. They are plentiful at the other locality, on the Little Conewago, suggestively associated with Brachyphyllum but not with Leptostrobus, the latter being unknown in this locality and represented by only one specimen at York Haven.

*Locality.*—Little Conewago Creek, 1½ miles west of Manchester, exploitation pit, green shale.

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[1] In view of the fact that Professor Fontaine did not find at Williams College the specimen figured by Emmons in his American Geology, Part VI, pl. vi, fig. 5, and described on p. 35 under the name *Calamites punctatus*, considered to belong to this species (see Mon. U. S. Geol. Survey, Vol. VI, p. 98, and infra, p. 288) it is not thought best to enter that form in the synonymy, especially as its earlier date would involve a change of nomenclature.

## Class BENNETTITALES.

### Family BENNETTITACEÆ.

### Genus CYCADEOMYELON Saporta.

#### CYCADEOMYELON YORKENSE Fontaine n. sp.

#### Pl. XXX.

1888. *Palissya?* sp. Newb.: Fossil Fishes and Fossil Plants of the Triassic Rocks of New Jersey and the Connecticut Valley, Mon. U. S. Geol. Survey, Vol. XIV, p. 94, pl xxvi, figs. 1, 2.

Mr. Wanner designated this as the "trunk of a conifer?" resting the case on the figures of Dr. Newberry. Professor Fontaine, however, regards it as a Cycadeomyelon not hitherto described, and remarks:

This is an imprint of the same kind as those Saporta has described, with the generic name Cycadeomyelon, in Paléont. française, Plantes Jurassiques, Tome II, pp. 331–332. He considers them as casts of partly decayed cycad trunks. The cigar-shaped prominences on this fossil are decidedly larger than those of Saporta's *C. hettangensis*. If it is worth while giving a name to it, it might be called *Cycadeomyelon yorkense*.

Mr. Wanner gives the following account of it:

Dr. J. S. Newberry, in Mon. U. S. Geol. Survey, Vol. XIV, p. 94, pl. xxvi, figs. 1, 2, illustrates and describes what he supposed to be the decorticated trunk of some conifer from Newark, New Jersey. A similar impression from here, Fig. 1, Pl. XXX, comes from a locality which yielded nothing else. For that reason as well as because of the decorticated and compressed condition of the specimen, no additional light is shed upon the character of the trunk which produced it. Thin seams of carbonized vegetable matter are irregularly included in the overlapping folds that mark the specimen. The section, Fig. 2, is drawn at the point of greatest width.

*Locality*.—Fox Run, one-eighth of a mile from its junction with the Little Conewago Creek.

There seems scarcely any doubt that whatever the stems from Newark may be, this one from York represents the same plant. Dr. Newberry's fig. 2 is almost exactly the same as Mr. Wanner's Fig. 1. Dr. Newberry refers to the specimen called *Voltzia coburgensis* Schaur., figured by Schenck in Palæontographica, Vol. XI, pl. xlvi, fig. 2, and there certainly is a close resemblance between this figure and those of the American specimens.

It may not be out of place to draw attention to the somewhat similar class of objects which I have described under the name Feistmantelia.[1] The specimen from the Lettenkohl, near Würzburg, forms a sort of transition between some of the forms to which I there call attention and those now under consideration.

[1] Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1899, pp. 693–696, pl. clxix, fig. 19.

## Class GINKGOALES.

### Family GINKGOACEÆ.

### Genus BAIERA Friedrich Braun.

#### BAIERA MUENSTERIANA (Presl) Heer?

Pl. XXXI, Figs. 1, 2.

1838. *Sphærococcites Muensterianus* Presl in Sternberg: Flora der Vorwelt, Vol. II, p. 105, pl. xxviii, fig. 3.
1841. *Baiera dichotoma* Fr. Braun: Flora, Neue Reihe, Jahrg. XXIV, p. 33.
1843. *Baiera dichotoma* Fr. Braun in Münster: Beiträge zur Petrefactenkunde, Vol. II, Pt. VI, p. 20, pl. xii, figs. 1–8.
1857. *Baiera* ? sp. Emm.: Am. Geol., Pt. VI, p. 133, fig. 102.
1863. *Jeanpaulia Schlagintweitiana* Popp: Neues Jahrb f. Mineralogie, 1863, p. 412.
1866. *Jeanpaulia Muensteriana* (Presl) Schenk: Foss. Flor. der Grenzschichten des Keuper und Lias Frankens, p. 39, pl. ix.
1878. *Baiera Muensteriana* (Presl) Heer in Saporta: Plantes Jurassiques. Paléontologie Française, 2e Sér., Vol. III, p. 272, pl. clv [xxvii], figs. 10–12; pl. clvi [xxviii], figs. 1–6; pl. clvii [xxix ], figs. 1–3.

Mr. Wanner thought this might be a Baieropsis. Professor Fontaine admits its doubtful character, and says:

This is an obscure and very fragmentary specimen. It is too imperfect to show anything definite, but may be a small form of *Baiera Münsteriana*. It is a small form, resembling that plant.

Mr. Wanner's note is equally brief:

The few specimens found are so fragmentary as to present but little more than outlines; yet in general appearance they sufficiently resemble Baieropsis to justify their being referred to some species of that genus.

*Localities.*—N. C. R. R. cut, south of York Haven; Little Conewago, lowest horizon.

## Class CONIFERÆ.

### Family PINACEÆ.

### Genus PALISSYA Endlicher.

#### PALISSYA SPHENOLEPIS (Friedrich Braun) Brongniart.

Pl. XXXII.

1843. *Cunninghamites sphenolepis* Fr. Braun: Beitr. z. Urgeschichte d. Pflanzen, Programm z. Jahresber. d. Kön. Kreis-Landw. u. Gewerbsschule z. Bayreuth, pp. 17, 18, pl. ii, figs. 16–20; also in Münster: Beiträge zur Petrefactenkunde, Vol. II, Pt. VI, p. 24, pl. xiii, figs. 16–20.
1847. *Palissya Braunii* Endl.: Synopsis Coniferarum, p. 306.
1849. *Palissya sphenolepis* (Fr. Braun) Brongn.: Tableau, p. 68.
1856. *Walchia longifolius* Emm.: Geological Report of the Midland Counties of North Carolina, p. 333.
1857. *Walchia longifolius* Emm.: American Geology, Pt. VI, p. 105, pl. iva.

Mr. Wanner determined this plant correctly, following Professor Fontaine in the use of the synonymy *P. Braunii* of Endlicher. As Endlicher founded the genus Palissya on the plants that Braun called *Cunninghamites sphenolepis* and carefully described and figured in two prominent places, he had, of course, no right whatever to change Braun's specific name.

Professor Fontaine says:

There are numerous fine specimens of *P. Braunii* in Mr. Wanner's collection. Some of them are better and larger than any previously known to me. One of these large specimens shows a feature not seen by me on any previously known fossils. The young, undeveloped branches are seen in the axils of the leaves. Fig. 2, Pl. XXXII, represents one of these forms, and Fig. 1, of the same plate, gives a good representation of one of the large fragments.

The following is Mr. Wanner's account:

Part of a large limb, Fig. 1, Pl. XXXII, containing broken branches and leaves in a fairly good state of preservation, exhibits the characteristics of the plant as presented in this and other specimens. Fig. 4 represents a leaf magnified to show the venation. The midrib is prominent. The leaves are decidedly decurrent and, when not pushed out of place or macerated, as is frequently the case, are uniformly and strongly falcate. Another specimen, Fig. 2, only part of the impression in the shale, presents a different phase and well illustrates the changed appearance caused by the presence of young shoots. Fig. 5 illustrates part of another limb containing fewer young branches of greater length than those shown in Fig. 2. Another specimen, Fig. 3, natural size, shows the leaf scars.

The descriptions of *Palissya Braunii*, to which the author has had access, are very meager and unsatisfactory, hence, notwithstanding the fact that his specimens are well defined, he is unable to assert, with any degree of certainty, that the plant belongs here. It strongly suggests *Sequoia Reichenbachi.*

*Localities.*—York Haven, N. C. R. R. cut; Little Conewago Creek, exploitation pit and lowest horizon.

### PALISSYA DIFFUSA (Emmons) Fontaine.

### Pl. XXXI, Figs. 3–5.

1856. *Walchia diffusus* Emm.: Geological Report of the Midland Counties of North Carolina, p. 333, pl. iii, fig. 2.
1857. *Walchia* (*Lycopodites*) *diffusus* Emm.: American Geology, Pt. VI, p. 105, pl. iii, fig. 2.
1857. *Walchia gracile* Emm.: American Geology, Pt. VI, p. 108, fig. 75.
1883. *Palissya diffusa* (Emm.) Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI., p. 107, pl. li, fig. 4.
1883. *Cheirolepis Muensteri* (Schenk) Schimp. in Fontaine: Op. cit., p. 108, pl. liii, fig. 3.

Of this Professor Fontaine says:

Mr. Wanner has correctly determined this plant, of which he has a number of very fine specimens. Some of them are much finer than any obtained by even Emmons from the North Carolina beds. There is some difference between the Pennsylvania and the North Carolina fossils. The Pennsylvania specimens do not show such a marked recurving of the leaves as those from North Carolina, and the midnerve of the leaves is not so distinct. These features may be due to the accidents of preservation, and do not call for the separation of the Pennsylvania plant as a variety. The leaves of this form are strikingly like those of *Cheirolepis gracilis* Feistm. of the Rajmahal flora.

The following is Mr. Wanner's record:

Fig. 3, Pl. XXXI, represents a very symmetrical branch in an excellent state of preservation. Both twigs and leaves are crowded closely together. Fig. 4 presents another specimen, containing near the extremity of one of its lateral branches the impression made by some kind of a fruit. Beyond the general outline and the unmistakable imprint made by the stem, by which it is attached to the twig, the fruit contains no definite markings to give it character. In another specimen not illustrated the leaves are somewhat larger. Fig. 5 shows the venation in a magnified leaf.

*Palissya diffusa* is common at the York Haven locality and may be represented at the Little Conewago Creek, but the few fragmentary specimens from the latter place cannot be positively identified.

*Locality.*—N. C. R. R. cut, south of York Haven.

## Genus BRACHYPHYLLUM Brongniart.

### BRACHYPHYLLUM YORKENSE Fontaine n. sp.

Pl. XXXI, Figs. 6–9.

Mr. Wanner identified this with *Brachyphyllum crassicaule* Font., of the Potomac flora. Professor Fontaine does not accept this, and says:

This is not *Brachyphyllum crassicaule*, but a new and smaller species, which may appropriately bear the name *B. yorkense*.

There are in Mr. Wanner's collection several imprints of a small Brachyphyllum which resembles Saporta's *B. Papareli*, a plant of the Rhetic and Infralias of France. It is, however, I think, a new species. Mr. Wanner's figure shows the most complete specimen. The ultimate twigs on this are very slender. The full length of none of them is shown. They are only 2 mm. wide. The leaves seem to be thinner in texture than those of the Jurassic Brachyphylla. They are rotundate-rhombic in form, with the longer diameter transverse to the axis of the twig. Fig. 8 shows the shape of the best-preserved forms, the enlargement being 3 diameters. They are subspirally arranged, somewhat after the fashion of those of Palæocyparis (Echinostrobus) of the Oolite.

Mr. Wanner says of it:

Fig. 6, Pl. XXXI, presents a branch containing closely placed lateral twigs. Other specimens from the same locality vary considerably in the number of branches, usually having fewer than are contained in the illustration. No terminal branches were identified to a certainty, though several blunt ends may represent extremities, and if such is the case the width of the branch remains the same throughout its extent. The leaves are thick and closely appressed, with beaks and a scarcely perceptible keel, as illustrated in Fig. 7, a magnified leaf.

*Locality.*—Little Conewago Creek, exploitation pit.

With regard to the small specimen, Fig. 9, Professor Fontaine remarks:

I did not see this small fragment. It is probably a portion of a twig of *Brachyphyllum yorkense*, above described.

Mr. Wanner's note upon it was as follows:

This specimen, Fig. 9, Pl. XXXI, is suggestive of Frenelopsis, and that is about all that can be said of it. It is a fragment of a stem of some sort, the only one of that kind found. No traces of leaves and no marks of any sort are visible.

*Locality.*—N. C. R. R. cut, south of York Haven.

## Genus CHEIROLEPIS Schimper.

### CHEIROLEPIS MUENSTERI (Schenk) Schimper.

Pl. XXXIII, Figs. 1, 2.

1867. *Brachyphyllum Muensteri* Schenk: Fl. der Grenzschichten des Keupers und Lias Frankens, p. 187, pl. xliii, figs. 1–3, 3a, 3b, 4–12, 12a.

1870. *Cheirolepis Muensteri* (Schenk) Schimp: Traité de Paléontologie Végétale, Vol. II, p. 248.

This fine plant was correctly determined and well figured by Mr. Wanner. Professor Fontaine remarks:

Mr. Wanner's collection has a number of specimens of this plant which he has correctly determined and figured well. Some of them are splendid fragments, much finer even than those figured by Schenk. It should be stated that the specimens of this plant hitherto found in the United States are small and imperfect. The finding of such fine imprints of this and a number of other older Mesozoic plants makes these Pennsylvania localities very important.

The following is Mr. Wanner's note:

A limb, Fig. 1, Pl. XXXIII, bearing branches and twigs, with short decurrent leaves, falcate in arrangement, admirably illustrates the characterictics of the species. The other illustration, Fig. 2, presents a remarkably well preserved and symmetrical branch, a property, however, not peculiar to a few specimens, but belonging to most of those found.

*Localities*:—N. C. R. R. cut, south of York Haven; Little Conewago Creek, exploitation pit and lowest horizon.

## Genus SCHIZOLEPIS Friedrich Braun.

### SCHIZOLEPIS LIASO-KEUPERINA Friedrich Braun.

Pl. XXXIII, Figs. 3–5.

1847. *Lepidodendron liaso-keuperinum* Fr. Braun: Flora, Neue Reihe, Jahrg. V [XXX], p. 84.

1847. *Lepidodendron laricifolium* Fr. Braun: Loc. cit.

1847. *Isoetites pumilus* Fr. Braun: Loc. cit.

1847. *Schizolepis liaso-keuperinus* Fr. Braun: Ibid., p. 86.

1852. *Halochloris baruthina* Ett.: Abh. d. k. k. Geol. Reichsanst., Vol. I, Pt. III, No. 3, p. 6, pl. ii, fig. 4.

1867. *Schizolepis Braunii* Schenk: Foss. Fl. der Grenzschichten des Keupers und Lias, p. 179, pl. xliv, figs. 1–4, 4a, 5.

Mr. Wanner believed that the specimen, Fig. 5, represented a different plant from that of Figs. 3 and 4. The latter he regarded as

*Sequoia Reichenbachi longifolia* of the Potomac formation, while the other he identified with *Leptostrobus foliosus*, also of the Potomac.

Professor Fontaine finds them the same, and refers this form to the *Schizolepis Braunii* of Schenk. Schenk worked over all of Braun's material, from the Rhetic of Veitlahm, near Culmbach, in the vicinity of Baireuth, in Bavaria, and found that he had given several names to this form. As it is a Schizolepis, Braun's name, *S. liaso-keuperina* must be retained, and can not be changed to *S. Braunii*, as Schenk proposed to do.

The following is Professor Fontaine's comment on this plant:

This is what appears to be a specimen of *Schizolepis Braunii*, differing from the type only in the somewhat narrower leaves. This is given in Pl. XXXIII, Fig. 3. Fig. 5 of this same plate gives a plant which Mr. Wanner calls *Leptostrobus foliosus*. It is the same Schizolepis. This latter specimen is a fragment of a large twig, with several ultimate branches carrying leaves.

Mr. Wanner's notes follow. Relative to the first of these specimens he says:

Two specimens were found, only the better of which, Fig. 3, Pl. XXXIII, is illustrated. They probably belong to a new species. The author is unable to locate the specimen, and names it as he does simply because the leaves in width and falcate arrangement, particularly in the specimen not drawn, suggest *Sequoia Reichenbachi longifolia* Font. Fig 4 shows a leaf magnified two diameters.

On the other specimen he remarks:

In the only specimen collected, Fig. 5, Pl. XXXIII, the parallel nerves are faintly visible in several leaves, but the number is not definitely revealed. Three nerves are recognized beyond question, but doubt exists as to whether or not there is another. As yet no entire leaf has been found. Closely crowded pit marks on the macerated stems indicate a dense foliage, without betraying the order in which the leaves were attached.

*Locality.*—N. C. R. R. cut, south of York Haven.

## Genus ARAUCARITES Presl.

### ARAUCARITES ? PENNSYLVANICUS Fontaine n. sp.

Pl. XXXIV, Figs. 1, 2.

Mr. Wanner made scarcely any attempt to identify this specimen, and contents himself with saying:

The author is unable to locate Fig. 1, Pl. XXXIV. The venation is shown in Fig. 2. Another specimen, not drawn, has leaves of about the same length, but of greater width. In it the nerves still more plainly converge at the tip.

Professor Fontaine is in doubt with regard to the generic affinities, and describes it as a new species, probably of Araucarites. He says:

The specimen figured by Mr. Wanner is a portion of a twig with a number of small leaves. These in size resemble somewhat Saporta's *Araucaria microphylla*. On the label accompanying this plant Mr. Wanner has given the name *Nageiopsis heterophylla* ?

I have carefully examined this specimen. The nerves are too obscure to be made out with positiveness, and I am not sure that they are not single in each leaf. If so the plant is a Palissya. Mr. Wanner speaks of a second specimen which I have not seen. If the nerves be really numerous, as he gives them, the plant is probably an Araucarites, and possibly the same with the cone in his collection.

*Locality.*—N. C. R. R. cut, south of York Haven.

ARAUCARITES YORKENSIS Fontaine n. sp.

Pl. XXXIV, Fig. 3.

Mr. Wanner merely says of this that it shows the impression made by part of a large cone. The specimen is too fragmentary to be identified or described. Professor Fontaine makes it a new species of Araucarites, which he describes as follows:

This is an imprint of a portion of what must have been a fine, large cone. It is not complete enough to show certainly the original shape, but a globular form is indicated, with a diameter of about 6 cm. The impressions of the terminations of a number of scales are quite distinct, and they have the character of Araucarites. It might be called *Araucarites yorkensis*. This may be the cone of *Araucarites ? pennsylvanicus*, determined from a leafy branch.

*Locality.*—N. C. R. R. cut, south of York Haven.

## Subdivision ANGIOSPERMAE.

### Class MONOCOTYLEDONEÆ.

### Family GRAMINEÆ.

Genus YORKIA Wanner nov. gen.

YORKIA GRAMINEOIDES Ward n. sp.

Pl. XXXIV, Figs. 4–6.

Mr. Wanner has here drawn some very clear figures of this form. Professor Fontaine says of it:

Mr. Wanner regards this plant as a new species of grass. The specimen he uses as a type shows no distinct features. The supposed leaves appear to me to be long succulent stems of some kind. I am not prepared to say that the plant is not some form of grass.

Mr. Wanner's description is as follows:

GRAMINEÆ. *Yorkia* nov. gen.: leaves long, narrow, smooth, thick, and deeply channeled, with no perceptible variation in width. In the specimen illustrated, Fig. 4, Pl. XIV, there are no whole leaves, nor were any found, but the impressions indicate that none were less than 15 cm. in length, ranging from 1 to 2 mm. in width. An indistinct impression at the base can be traced clearly, but can not be resolved into more than a faint vegetable imprint. Markings made by slender roots extend a short distance below the base. No tips of leaves were observed, but Fig. 6 represents the nearest approach to an entire end. Fig. 5 shows the base of another cluster of leaves, about which is a delicate obscure mantle produced by some organic substance.

*Locality.*—N. C. R. R. cut, south of York Haven.

The Marquis Saporta described and figured,[1] under the name of Poacites, a considerable number of grass-like forms from the Mesozoic of Portugal; some of them from the Infralias, others from the uppermost Jura, and still others from the Lower Cretaceous. They were all supposed to represent portions of leaves and not culms. The plant discovered by Mr. Wanner closely resembles some of these, but the leaves are much longer than any obtained by M. Choffat from the Portuguese beds. If these leaves grew directly from a cæspitose base, as Mr. Wanner's figures would imply, it is difficult to refer them to the grass family, but if Fig. 5 represents a short collection of culms giving off leaves from their upper nodes, this would not wholly negative the idea of their belonging to the Gramineæ, as Mr. Wanner supposes. At any rate, the form is quite definite and extremely interesting. I therefore retain the generic name suggested by Mr. Wanner, which carries with it no systematic implications, and express the likeness of the plant to a grass by the specific name chosen. The systematic position given to the plant is, of course, merely conjectural.

The following general remark by Professor Fontaine on Mr. Wanner's collection and work may fittingly conclude this part of our subject:

Mr. Wanner has succeeded in making a surprisingly good and varied collection of fossils. A number of them had not yet been found in the Trias of America. Some of them are apparently new. A number of splendid impressions of fossils previously described are found in his material. These are better specimens than those by which these fossils have been hitherto known. Mr. Wanner deserves great credit for his intelligent use of the opportunity afforded him for collecting from a region heretofore not known as yielding good plants.

The plants in this collection seem to indicate a somewhat higher Mesozoic horizon than that of the Virginia, and even of the North Carolina beds, being more decidedly Rhetic in character.

## TRIASSIC PLANTS FROM MARYLAND.

In 1883[2] Mr. P. Frazer, in treating the New Red Sandstone Region, makes passing mention "of a plant bed in Frederick County, Md." At the meeting of the Geological Society of America on December 30, 1890, in the course of the discussion of Dr. Williams's paper on the Petrography and Structure of the Piedmont Plateau in Maryland, Mr. Charles S. Prosser called attention to the remark quoted above and asked Dr. Williams for further information.[3]

In reply, Dr. Williams said:

Fossils have recently been found in two localities in the Triassic of Frederick County, Maryland: first, by Professor Philip R. Uhler, about 2 miles west of Fred-

[1] Flore Fossile du Portugal, Direction des Travaux Géologiques du Portugal; Lisbonne, 1894.
[2] Second Geological Survey of Pennsylvania, C[4], 1883, p. 29.
[3] Bull. Geol. Soc. America, Vol. II, March, 1891, p. 318.

erick; and, secondly, by Mr. S. L. Powell, not far from Utica Mills. Those collected by Mr. Powell are from the red shales, and are very abundant. Some of the forms resemble nuts; others may be interlacing roots.[1]

I am not aware that anything has been published relative to the discoveries of either Professor Uhler or Mr. Powell here recorded.

In the spring of 1890 there were discovered in the red sandstone quarries at Seneca, on the Potomac, at the mouth of Seneca Creek, Maryland, some very fine specimens of Dendrophycus. The first of these, and the finest that has been found, was brought to the National Museum on May 7 by Mr. D. L. Shoemaker, proprietor of the quarry. I recognized it at once and took so deep an interest in it that I visited the place a few days later, in company with Mr. Charles S. Prosser, and we collected a number of additional specimens. They are well marked and typical of this form; but, like all others thus far known, are destitute of organic matter or coaly pellicle. They closely resemble *D. Desorii* Lx., of the Devonian of Iowa, a fine specimen of which is in the collection of the National Museum, but they have the red color of the building stone in which they occur. They differ perhaps more from the form found in the Trias at Portland, Connecticut, and named by Dr. Newberry *D. triassicus*, of which mention has already been made. It is, however, interesting to know that this genus occurs at two widely separated localities of this formation.

Important differences exist between these and the Maryland specimens, differences sufficient to constitute the latter a distinct species. I shall therefore call this species *Dendrophycus Shoemakeri*, thereby acknowledging Mr. Shoemaker's kindness in bringing the above-mentioned specimen to the Museum, without which act the existence of this form in the Maryland deposit might never have been discovered.

The fine specimen brought by Mr. Shoemaker was carefully photographed, under the immediate supervision of Mr. De Lancey W. Gill, and the accompanying half-tone illustration shows with great minuteness all the details of structure; and I also had photographs taken of the best specimen collected by Mr. Prosser and myself. This last is represented on Pl. XXXV, Fig. 2, and by the side of it, Fig. 1, is the view of *D. triassicus* Newb., of Portland, Connecticut, already mentioned (supra, p. 228). Pl. XXXVI is the view of the original specimen brought by Mr. Shoemaker, the most complete thus far found.

The description of the species is as follows:

### Dendrophycus Shoemakeri Ward n. sp.

Pl. XXXV, Fig. 2; Pl. XXXVI.

Upper portions of the so-called rhizomes alone present, forming the rachis of the frond. Fronds very numerous, covering large areas, 8 to

[1] Loc. cit.

10 cm. long, 5 cm. broad at the summit, consisting of 3 to 5 secondary divisions proceeding alternately from each side of the rachis at a uniform angle of about 30°, these again throwing off tertiary branches chiefly from the other side, some of which still further fork or ramify, forming a spreading fan-shaped mat of overlapping fibers covering the rock. The surface of the rock is very uneven, the fronds forming reliefs, and each branch, strand, or subdivision constituting a smooth raised ridge or line. The counterparts of the fronds of course present the opposite features, the reliefs becoming intaglios.

This is not the place to enter into a discussion of the question whether Dendrophycus really represents a plant. I will only say that Professor Fontaine, who has not only seen all the Seneca and Portland specimens but has visited the locality and examined their mode of occurrence, does not, any more than did Dr. Newberry, hesitate to pronounce them as of vegetable nature. I reserve my own opinion, if I can be said to have one, until more and stronger evidence shall be produced.

## THE VIRGINIA AREA.

Fossil plants were early discovered in the rich beds of the Richmond coal field, and mention of them was from time to time made by geologists and other writers near the beginning of the century.

Among the earliest of these mentions was that of Mr. William Maclure, in 1817.[1] After having discussed the primitive formations of the more northern sections, he proceeds to speak of—

"A range of secondary, extending with some intervals, from the Connecticut to the Rappahannock rivers, in width generally from 15 to 25 miles; bounded on the northeast, at New Haven, by the sea, where it ends to recommence on the south side of Hudson River. * * * This secondary formation is interrupted after it passes Frederickstown, but begins again between Monocacy and Seneca creeks, the northeastern boundaries crossing the Potomac by the west of Cartersville, touches the primitive near the Rappahannock, where it finishes. * * * About 10 or 12 miles west of Richmond, Virginia, there is an independent coal formation, 20 to 25 miles long, and about 10 miles wide; it would not be far distant from the range of the red sandstone formation had it continued so far south; it is situated in an oblong basin, having the whitish freestone, slaty clay, etc., with vegetable impressions, as well as most of the other attendants of that formation."

This last hint is of special interest in view of the fact that all the more northern deposits are of the red or brown sandstone, while that of the Virginia basin, in the vicinity of Richmond, is a true coal formation, and Mr. Maclure must therefore have derived this information largely from paleontological data.

In 1821 we find Mr. Thomas Nuttall[2] discoursing learnedly with

[1] Observations on the Geology of the United States of America, by William Maclure, Philadelphia, 1817. (See pp. 39–49.)

[2] Jour. Acad. Nat. Sci., Phila., Vol. II, Pt. I, pp. 35–38.

regard to this same formation. Speaking of what he calls "the second calcareous formation," he says:

In its geographical limits it occupies a position universally to the east of the primitive and transition formations. * * * It appears, however, to be destitute of the concomitant minerals, excepting, indeed, it were possible to conceive it in connection with the coal basins of Richmond, which I have found on examination to be actually underlaid with a calcareous rock of peculiar appearance. Mr. Heath's coal mines, and in fact nearly all of them, except those which were in a state of combustion, are overlaid by a massive micaceous conglomerate, or grit rock, containing crystals of feldspar like porphyry, in which, besides gigantic *culmarii*, occur veins of the argentine calcareous spar of Kirwan. * * * In the bituminous slate clay, which, as usual, accompanies this coal, besides impressions of ferns and the supposed Equiseta, there are vestiges of some enormous flaccid-leaved gramineous plant, leaves of one of the Scitamineæ similar to those of the ginger, and fine casts of a palm resembling the pennate fronds of some species of Zamia or cycad. * * * Although there can remain but little doubt of the continuity of the Floëtz limestone we are endeavoring to trace toward the south, still, in consequence of the more recent alluvial deposits, it is not again discernible until we arrive in North Carolina.

Relative to his "gigantic Culmarii," he appends a footnote explaining that it "is an assumed generic name for an assemblage of extinct Zoophytes, one species of which is the *Phytolithus striaticulmis* of Martin's Petrificata Derbiensia." This *Phytolithus striaticulmis* is a Calamites, and the Culmarii described by Nuttall are undoubtedly the *Equisetum Rogersii* (Bunb.) Schimp.

Mr. Richard C. Taylor, in 1834,[1] was somewhat unfortunate in combating the views of Nuttall and Maclure relative to the secondary age of the Richmond coal field, and in claiming for it a Carboniferous age. But he was supported by the opinion of Adolphe Brongniart upon a specimen which had been sent to him, which he had identified as *Calamites Suckowii* Brongn., but of which species he made it a new variety, and in describing it he remarked:

La var. δ, dont la surface externe est assez mal conservée, se rapporte cependant à cette espèce par sa forme générale et par la ténuité de l'écorce. Les côtes sont seulement plus convexes, ce qui peut tenir à une moindre compression; car ces tiges, qui étaient probablement verticales, paraissent avoir été comprimées dans le sens de leur longueur, et presentent des replis nombreux qui semblent indiquer combien leurs parois étaient minces et flexibles. Cet échantillon est même fort remarquable sous ce rapport, et prouve que ces tiges étaient fistuleuses comme celles des Equisetum vivans.[2]

In an article by Mr. A. W. Wooldridge,[3] president of the Midlothian Mining Company, mention is made of the occurrence of "vegetable remains, such as ferns, bark, and knobs of wood found in the slate overlying the coal" in the basin which is now more generally understood by the name of the Richmond coal field.

[1] Memoir of a section passing through the bituminous coal field near Richmond, in Virginia, by Richard C. Taylor: Trans. Geol. Soc. Pennsylvania, Vol. I, p. 275.

[2] Histoire des Végétaux Fossiles, Vol. I, 1828, p. 126.

[3] Geological and statistical notice of the coal mines in the vicinity of Richmond: Am. Jour. Sci., Vol. XLIII, 1842, pp. 1-14 (see pp. 9 and 11).

At the Third Annual Meeting of the American Association of Geologists and Naturalists, held at Boston in 1842, Prof. W. B. Rogers read a very important paper On the Age of the Coal Rocks of Eastern Virginia. The second and much larger part of this paper is devoted to the description of the vegetable remains known to him at that date, and of which he enumerates some dozen species. This paper was published in the Transactions of the Association for that year (pp. 298–316), and is accompanied by a plate (pl. xiv), on which three of these species are figured. It is reproduced in the Geology of the Virginias, New York, 1884, pp. 645–658, with the plate.

When Sir Charles Lyell was making his journey through the United States, so fruitful in geological results, he visited this coal field in the vicinity of Richmond and made a careful study of the strata and of the remains of animal and vegetable life. He took back with him to England a quantity of the material which he had collected and handed the vegetable remains over to Sir Charles J. F. Bunbury for determination. Bunbury's report upon this collection was contributed to the Geological Society of London, and published in 1847.[1] Bunbury describes in this paper about fifteen different forms, a few of which were not the same as those described by Rogers, with whose paper he was acquainted. He shared with Lyell and Rogers the belief that Calamites occurred in this formation, and several of the coniferous forms were provisionally referred by him to Sigillaria, Lepidodendron, and Knorria.

On June 18, 1849, Mr. Jules Marcou made a communication to the Geological Society of France on the coal of Chesterfield County, Virginia, near Richmond.[2] Mr. Marcou had recently visited the Chesterfield bed and had observed the abundant plant remains. He collected many of them and discusses their affinities, relying apparently upon Bunbury's determinations. Nevertheless, he refers these beds to the Keuper, which was at least a shrewd guess.

The paper which Professor Rogers read before the Boston Society of Natural History on January 4, 1854,[3] makes mention of the fossil plants of the Richmond coal field, but adds nothing to what he had previously said on this subject. His statement, however, that "in the belt in Virginia, toward the Potomac River * * * he had met, in the more sandy rocks, vegetable impressions which, although obscure, are strongly suggestive of the leaves of Zamites," furnishes a datum point for future investigations. It is to be regretted that he did not definitely locate these discoveries. One additional line describing the exact spot at which these remains were observed might have saved weeks of patient search to the student of the present generation.

[1] Description of fossil plants from the coal field near Richmond, Virginia, by C. J. F. Bunbury: Quart. Jour. Geol. Soc. London, Vol. III, Pt. I, pp. 281–288, pls. x, xi.

[2] Note sur la houille du comté de Chesterfield, près de Richmond (État de Virginie), par J. Marcou: Bull. Soc. géol. de France, 2d series, Vol. VI, 1848–1849, pp. 572–575.

[3] Proceedings, Vol. V, July, 1854, pp. 14–18.

Mr. Jules Marcou, as we have seen, had visited this region and made a small collection of fossil plants. Some of these he took with him on a visit to Europe and showed them to the eminent paleobotanist, Prof. Oswald Heer, of Zurich. In his Geology of North America[1] he introduces a translation of Professor Heer's report upon this collection. It contains nothing additional to the forms described by Rogers and Bunbury.

At the Philadelphia meeting of the American Institute of Mining Engineers, in February, 1878, Mr. Oswald J. Heinrich read an elaborate paper on the Mesozoic Formation in Virginia, which was published in the Transactions.[2] He gives numerous sections in the principal mines of the Richmond coal field, mentioning the occurrence of plants, and on page 264 he attempts an enumeration of the species, basing it on determinations made for him by Prof. C. E. Hall, of the University of Pennsylvania, to whom the material collected was referred. The list is short, and the names the old erroneous ones of Brongniart, Bunbury, and Rogers.

Prof. William M. Fontaine commenced his important researches in this field early in the seventies and contributed a preliminary paper[3] in 1879. This paper is chiefly geological and covers a wide field, discussing the relations of the older to the younger Mesozoic, but it is based largely on the evidence furnished by the flora, and that of the Richmond coal field receives special treatment (pp. 37-39).

This paper was the natural forerunner of his Older Mesozoic Flora of Virginia,[4] with which we have already had much to do, and which is unquestionably the most important contribution that has yet been made to the flora of the American Trias. It forms one of the smaller monographs of the United States Geological Survey, containing 144 pages of text and 54 plates. As stated by the author, "it is based upon the study of a number of plants obtained after several years of diligent search in the older Mesozoic strata of Virginia." The number of species, or rather of distinct plants, that are here described and figured amounts to 45, which will be seen to be a large increase over those hitherto known. Eight of these species were already known from other localities under established names; 4 more of this class are referred to different genera or species, making 12 not confined to Virginia. Of the remaining 33, which are so confined, 9 have close affinities with species already described. It thus appears that considerably over half of the entire number are peculiar to the locality and have no weight in determining its horizon.

[1] Geology of North America, with Two Reports on the Prairies of Arkansas and Texas, the Rocky Mountains of New Mexico, and the Sierra Nevada of California, originally made for the United States Government: by Jules Marcou; Zurich, 1858; p. 16.

[2] Vol. VI, pp. 227-274.

[3] Notes on the Mesozoic of Virginia: Am. Jour. Sci., 3d series, Vol. XVII, January, 1879, pp. 25-55.

[4] Mon. U. S. Geol. Survey, Vol. VI, Washington, 1883, 4°.

One of the most important purposes subserved by this work is that of correcting the determination of the forms that had previously been described. Professor Fontaine undertook, in the preparation of this work, to make careful comparisons of all the forms in his collection with the figures that had already been published, and he went to great pains to indicate those species occurring in beds of similar age in Europe and other parts of the world which were capable of being compared with those of Virginia. This was possible in a considerable number of cases, and we are, therefore, placed in a position to consider the age of this formation from the point of view of vegetable paleontology in its relation to older and better-established deposits. In view of its importance, Professor Fontaine's work must, therefore, serve as the basis, or general starting point, from which not only this discussion but the general discussion of the Triassic plants of North America will proceed.

Professor Fontaine did not restrict his investigations and comparisons to the Oolite of Yorkshire, as Rogers and Bunbury had done, but availed himself of all the extant literature upon the subject relating to the fossil plants of all the formations of Europe and other parts of the world whose geological position is not far removed from that to which the American beds had already been referred. The important researches of August Schenk upon the fossil flora of the Mesozoic of Bavaria, especially of Franconia, in the vicinity of Baireuth, previously known to him only imperfectly through Count von Münster's Beiträge and two papers by D. Brauns, had opened up a new and important field and furnished a very much broader basis for the study of the analogous floras the world over. Nathorst had also contributed in an important way to the study of the Rhetic flora of southern Sweden. Heer had investigated the Oolitic floras of the Arctic regions and Siberia, and Feistmantel had published his exhaustive works on the Gondwana system of India. All these, and other important works, were consulted by Professor Fontaine, so that he was in position to revise and correct the works of Rogers, Bunbury, Emmons, and Hitchcock upon the fossil flora of the American Mesozoic.

It was thus found that the Virginia Mesozoic flora did not correspond with anything like the same completeness as had been supposed to the Oolite of Yorkshire. Many of the most important species which had been depended upon to establish its Oolitic age were discovered to have been wrongly named and to belong to different genera from those to which they had been assigned.

This revision operated in two directions, viz: primarily, in showing that those who had regarded the Richmond coal field as Carboniferous or Permian, or had supported their views upon the supposed discoveries in these fields of such Carboniferous plants as Calamites, Sigillaria, and Lepidodendron, were mistaken in these determinations, and that no such ancient forms exist in the Mesozoic formation; and, secondly, in showing that many of the species referred to the Yorkshire flora are not identical with those forms and are either new species belonging to the same orders or genera or are species nearly or quite identical with those of the Rhetic beds of Europe. So that while upon the whole the revised flora indicates that these deposits are more ancient than the Oolite of England, at the same time it does not indicate an age having anything like the antiquity of the true coal floras of this country and of Europe.

Forms supposed to belong to Calamites were shown to belong to Equisetum, having the broad trunks and great size of those Equisetums which occur in the Trias. The supposed Sigillarias and Lepidodendra were shown to belong to the Cycadaceæ or Coniferæ, probably to the genus Palissya, which is strictly Mesozoic. On the other hand, the important *Pecopteris whitbiensis* and *Neuropteris linnææfolia*, supposed to be common to the Oolitic flora and that of Virginia, are both shown to belong to the genus Acrostichites, which is Rhetic, and the equally important *Pecopteris bullatus*, from which so much had been argued, is referred by Professor Fontaine to an entirely new genus of his own, viz, Mertensides, by which it loses altogether its diagnostic value. These are merely examples of the searching character of Professor Fontaine's investigations and of the important alterations in the data for forming a conclusion with regard to the age of these deposits.

After describing the species of the Virginia flora, Professor Fontaine sets forth in a table of distribution the general elements of this flora as compared with those of other countries. Forty-two species had been enumerated, of which 21, or just half, prove to be new to science, or at least peculiar to Virginia. In the table appended to this paper it will be shown that several of these have affinities with other plants whose geological age is known, therefore are not without diagnostic value from a geological standpoint. Professor Fontaine could find no forms identical with any that had hitherto been described from any part of the Trias, but 4 of his species were allied to species of the Trias. Only 2 of them were shown to be identical with any plants of the Jurassic, and neither of these belong to the Oolite of Yorkshire, but there are 5 species related to Jurassic forms. With the Rhetic flora the affinities seem closer, 4 species having been identified with Rhetic plants of Europe, and 8 others are shown to be closely related to such. Professor Fontaine's table is carefully discussed by him, each species being taken up and its geological bearings considered. Without following him through this discussion, we will content ourselves by quoting a few of his concluding remarks:

It is clear then from these facts that we must consider this flora as not older than the Rhætic. The only question is whether or not its strong Jurassic features ought to cause us to regard it as at least Lower Liassic in age. I think that it is fully as much entitled to be regarded as of Liassic age as is the flora of the Rajamahal group of India. Feistmantel and Zigno think that the age of this group is that of the Lias. Taking everything into consideration, the flora of the older Mesozoic of Virginia is, of the European floras, nearest to that of Theta, near Baireuth, in Franconia (p. 96).

Some authors hold that the Rhætic beds form the uppermost of the Triassic strata. Others think that they are transition beds, having more affinity with the Lower Lias. The latter view will, I think, be justified by a study of the flora, and I have, in this memoir, assumed its correctness (p. 128).

This important work of Professor Fontaine's especially attracted the attention of the late distinguished director of the Austrian Geological Survey, D. Stur, who had found at a place called Lunz, in Austria, a deposit yielding fossil plants having a very remarkable resemblance to those of the Virginia flora. Unable to satisfy himself with sufficient certainty by the study of the figures and descriptions of Professor Fontaine, Director Stur made application to Professor Fontaine and received, through the intervention of the United States Geological Survey, a good series of specimens of the Virginia fossils. In the Proceedings of the Geological Survey of Austria, published in 1888, Director Stur gave a brief account[1] of the results of his comparisons of the Virginia plants with those of Lunz. The general conclusion is that they are identical in age, many of the species being the same. But Stur regards the Lunz flora as Keuper and not Rhetic, and as nearly equivalent to that of Raibl and Stuttgart. He had arrived at this conclusion by a preliminary study already given to the flora of Lunz.[2]

This paper, as he admits, was only a Prodromus, and contains simply a list of the genera and species in systematic order, but no descriptions or figures. It bears date 1885, or two years later than Professor Fontaine's monograph. Therefore it is obvious that all Stur could do under the recognized laws of nomenclature would be to accept Professor Fontaine's species and genera in so far as they were new and identical with those of Lunz; although, of course, he would be authorized to point out any error in determination tending to show that Professor Fontaine had erroneously identified any of his plants with those of other deposits in Europe or elsewhere, or to show that any of his new species were not such, but were identical with species already described. We are therefore surprised to find that in a number of cases, as for example Speirocarpus, Heeria, etc., Stur created new genera of his own, and undertook at a later date to substitute them for the genera of Professor Fontaine. This, it is clear, can not be allowed by the laws of nomenclature. Pseudodanæopsis and Mertensides must stand and the Lunz plants be placed in them.

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[1] Die Lunzer- (Lettenkohlen-) Flora in den "Older Mésozoic Beds of the Coal Field of Eastern Virginia," von D. Stur: Verhandl. k.- k. geol. Reichsanstalt, Wien, Jahrg. 1888, pp. 203–217.

[2] Die obertriadische Flora der Lunzer-Schichten und des bituminösen Schiefers von Raibl, von D. Stur: Sitzungsber. K. Akad. Wiss. Wien, math.-nat. Cl., Vol. CXI, 1885, pp. 93–103.

As confirming, so far as it goes, the views of Stur regarding the somewhat lower position of the Richmond coal field and that of North Carolina, may be fitly noted the discovery in the Lower Trias of the Vosges ("Grès bigarré de Saint-Germain près Luxeuil"), by M. Despierres, of a specimen identified by Zeiller[1] with Professor Fontaine's *Acrostichites rhombifolius rarinervis.* From this and other indications Zeiller is inclined to regard the American deposits as Triassic rather than Rhetic. This opinion, after noting the views of Professor Heer contained in the letter to Mr. Marcou, already mentioned, he expresses in the following words:

Je serais, en résumé, très disposé à accepter l'assimilation de Heer de préférence à celle de M. Fontaine, c'est à dire que je placerais les couches en question dans le trias supérieur plutôt que dans le rhétien.

This whole subject was discussed quite at length by Mr. Jules Marcou in 1890,[2] and he takes occasion to go over the history of his own investigations along with those of others. Very little is added to our knowledge of the subject, but a letter from Zeiller, which he inserts on page 172, contains his determinations of Mr. Marcou's collection, sent in 1849 to the Jardin des Plantes, and which had lain there during this long period without attention. It contained eight or ten species, none of which were new.

Some specimens of fossil wood were collected by Mr. W J McGee, near Taylorsville on the South Anna River in Hanover County, who supposed them to belong to the Potomac formation, and they were included in Dr. Knowlton's paper on the Fossil Wood and Lignite of the Potomac Formation.[3]

As all the other specimens from that formation had proved to be of Sequoian type and been referred to the genus Cupressinoxylon, there was a suspicion that these might represent an older formation. I therefore decided to visit the locality at the first opportunity, which presented itself on the occasion of the return of our expedition, presently to be recounted, over the Triassic beds of Virginia in 1890. On June 18 of that year, accompanied by Professor Fontaine and Mr. Charles S. Prosser, I examined the bed on the South Anna River and made further collections of the wood. The Trias appeared at several points in that vicinity, sometimes in the form of red shales, and the wood in question occurred in a superficial deposit, probably Lafayette, immediately overlying the Trias. It could not have come from the Potomac farther to the east, and had undoubtedly weathered out of the Trias.

During the month of June, 1890, an excursion was made by Pro-

[1] Sur la présence dans le grès bigarré des Vosges de l'*Acrostichides rhombifolius* Fontaine, par R. Zeiller: Bull. Soc. géol. de France, 3d series, Vol. XVI, 1888, pp. 693-699.

[2] The Triassic flora of Richmond, Virginia: Am. Geologist, Vol. V, March, 1890, pp. 160-174.

[3] Bull. U. S. Geol. Survey No. 56, 1889, p. 50, pl. vii, figs. 2-5.

fessor Fontaine, Mr. Charles S. Prosser, and myself over the Triassic formation in Virginia. After visiting the Seneca sandstones, and tracing the approach of the Trias along the Monocacy River to the Potomac, we crossed the river at Point of Rocks and proceeded to Leesburg, skirting the western margin of the belt which consists entirely of conglomerates early called "Potomac marble," but known locally only as "calico rock." At Leesburg the trap appears not in the form of ridges as in New England and on the Hudson, but rather as a bowlder formation covering the surface; nevertheless, along Goose Creek it is heavily bedded and extensively quarried, there called "granite." Near points of contact of the trap with the red shales these latter become lighter colored and in a few places somewhat dark and carbonaceous. The nature of our expedition did not allow us time to search in these darker shales for fossil plants, but it is possible that such may occur and that future researches may reveal them. Several such localities were noted for this purpose. At Brentsville heavy beds of sandstone of excellent quality for building purposes occur and promising quarries have been opened. Several of these were visited by us in company with Mr. J. L. Sprogle, the general manager, who offered us special facilities for examining them. In some respects this stone seems to excel that of the quarries in Maryland, but in all the Potomac beds the color is a more lively red than in the Connecticut Valley. A short distance east of Brentsville we found in lighter shale a fossil plant, *Cheirolepis Muensteri* (Schenk) Schimp. We also found near Weaversville specimens of an Estheria and scales of fishes. Near the Rappahannock and Rapidan rivers and southward as far as Orange, notably at Culpeper, a marked difference occurs in the conglomerate from what we find at Point of Rocks and Leesburg, the material cemented in the sandstone consisting of bowlders of considerable size. We named this the Culpeper conglomerate. It is very similar to what may be seen in the Connecticut Valley and also in the vicinity of New Haven, being the same noted by Professor Dana on the east side of Pond Ridge. Professor Fontaine and myself found this conglomerate at a number of points in the Connecticut Valley.

On this excursion we traced the Trias to Barboursville, where Professor Rogers supposed it to end, and where, in fact, it does disappear; but proceeding thence to Charlottesville we were surprised to find it in the valley of the Rivanna, only a short distance from that place, and a few miles north of Monticello. From Charlottesville we proceeded to the coal field, striking it at Manakin or Dover Mines. We visited Carbon Hill and all the mines on the left bank of the James; crossed at Boscabell's ferry and proceeded to Midlothian and Clover Hill, examining with minuteness the material thrown out at all the shafts in this region. The most promising places for fossil plants in that part of the field were the Gowrie shaft and the new Stonehenge shaft, near Midlothian, and the Bright Hope and Raccoon shafts at Clover Hill. Nevertheless, many other interesting places were noted, and in the following September these were all visited by Professor Fontaine and collections made.

In the course of the more recent extended investigations that have been made in the Richmond coal field by Prof. N. S. Shaler and his field parties,[1] Mr. J. B. Woodworth, in 1896, made a small collection of fossil wood in Chesterfield County, at three localities given as near Skinquarter Station, near Otterdale, and south of Moseley Junction, at somewhat different horizons. This material was submitted to Dr. F. H. Knowlton for determination, and his results were published as an appendix to Professor Shaler's paper.[2] Dr. Knowlton distinguished two species of Araucarioxylon, *A. virginianum* and a new species which he names *A. Woodworthi*, both of which are fully described and illustrated. It will be noted that the first of these species is the same as that from Taylorsville in Hanover County (see supra, p. 264). The other species is closely allied to *A. arizonicum* of the West (see infra, pp. 273, 319).

## THE NORTH CAROLINA AREA.

Our knowledge of the existence of a coal basin in North Carolina dates back to a very remote period, and the occurrence of vegetable remains in this region was known almost as early as in any of the others considered.

Dr. Ebenezer Emmons, in his first report upon the geology of North Carolina,[3] in speaking of the coal fields of that State, mentioned (page 142) the occurrence of vegetable remains. He says:

> The vegetables are few in number, and differ from those of the coal rocks of Pennsylvania or the flora of the Carboniferous system. An Equisetites differing from *E. communis* is the only one of this genus I have seen. A Lycopodites, and other allied forms, are all I have yet found, except a naked and rather spinous vegetable, which is unknown in the Carboniferous rocks. It is a cellular cryptogamous plant. This is very common and abundant at Madison, and one or two layers of slate are covered with it at Evans Mills. The roots of vegetables, in the fire clay, are thin, narrow, ribbon-like tissues, and have lost their vegetable structure. Their thinness and compressibility show, however, that the roots were spongy, of a loose texture, and were "quatic."

Later on in the same report, speaking of the Dan River coal measures (p. 147), he says:

> Immediately above this bed of brecciated conglomerate there is one of the finest exhibitions of an ancient forest in this country. It consists partly of roots of trees

[1] Geology of the Richmond Basin, Virginia, by N. S. Shaler and J. B. Woodworth: Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1899, pp. 385-519.

[2] Report on some fossil wood from the Richmond Basin, Virginia, by F. H. Knowlton: Op. cit., pp. 516-519, pl. lii.

[3] Executive Document No. 13, Report of Professor Emmons on his Geological Survey of North Carolina, Raleigh, 1852.

changed into lignite, and partly of perfectly silicified trunks of trees, exceeding two feet in diameter. The soil in which the majority of these trees grew is still concealed. Segments of their trunks stand out of the soft rock, inclining at an angle to the horizon, but lean in a direction contrary to the dip of the rock. A road cuts through the strata in which the forest grew. All that remains of it are the trunks; it was impossible to find a leaf or stem of herbage or fruit. The softer and more perishable parts and organs are destroyed by unknown agencies. Perhaps some fortunate blow of the hammer may bring to light the leaves and fruit. The structure of these trunks prove them to belong to the natural family of Coniferæ, or the family to which the pines, spruces, and hemlocks belong.

The trees extend for half a mile or more, and no one, on seeing the number, can doubt that here grew a forest when the rocks were forming. Similar trunks have been found at Madison, and pieces of trunks occur upon Deep River, near Evans's bridge, and another forest of the same character upon Drowning Creek, in Richmond County. They occupy the same position in the series.

We next find a casual mention by Professor Rogers in the Proceedings of the Boston Society of Natural History for January 4, 1854,[1] that he had found in the summer of 1850 in the coal rocks of Deep River, North Carolina, several of the same plants which he was describing from Virginia. Among the plants mentioned as having been seen there by him were *Equisetum columnare*, a Zamites, and a plumose plant referred to Lycopodites, strongly resembling *L. Williamsonis* of the Yorkshire coast.

At the Albany meeting of the American Association for the Advancement of Science in 1856, Dr. Ebenezer Emmons read a paper entitled: Permian and Triassic Systems of North Carolina. This paper was published only by title in the Proceedings of the Association, but a brief abstract of it occurs in the Edinburgh New Philosophical Journal for 1857,[2] in which, in addition to animal remains, he mentions the occurrence in the North Carolina deposits, regarded by him as Keuper, of a variety of plants, among which he enumerates some belonging to the Cycadaceæ, a Voltzia, and also a supposed Walchia.

The same year (1856) appeared Dr. Emmons's Geological Report of the Midland Counties of North Carolina, which contains the first important mention of the fossil plants of the North Carolina basin. In this report Dr. Emmons, besides giving the most exhaustive geological account of the North Carolina deposits that had thus far been made, paid special attention to both the vegetable and animal remains. The former he supposed to occur in two somewhat distinct formations, viz, the so-called Permian and the Trias. His Permian deposits holding vegetable remains occur along the Deep River at Haywood in Chatham County, near Wadesboro in Anson, and also some 15 miles southwest of Troy in Montgomery. He mentions the remains of petrified and silicified wood, and seems to regard these as the "most important vegetable remains" that are found at all the above-mentioned localities; also at Jones Falls, and in the Miocene of Wayne County, where they

[1] Vol. V, p. 15. [2] Vol. V, p. 370.

appear to have been washed out of the so-called Permian and stranded on the surface. This silicified wood may be the same as that which had several times previously been referred to,[1] but these previously mentioned fragments occurred along the Neuse River, and the lignites described in the second paper mentioned agree quite well with those found in the Potomac formation of Virginia. The vegetable impressions occur chiefly in the deep coal shaft at Egypt, on Deep River; also at Evans Bridge, and on the Dan River at Madison, Stokes County. Among them he enumerates several fucoids, referred to Chondrites, besides vascular cryptogams, such as Equisetum, ferns, and some forms referred to the Lycopodiaceæ. The treatment of these plants occurs in Chapter XXXIX, pp. 283–293, pl. i–iii.

A much larger number of plant forms are described by Dr. Emmons from the overlying Trias, which he identifies with the Keuper of Europe, and regards as equivalent to the coal shale of the Thüringerwald. These also occur, for the most part, on Deep River, principally at Jones Falls, which is also called Lockville; also in the blue slate at Ellingtons, and in the soft reddish marls near Haywood. These plants include a number of ferns, Cycadaceæ, Lycopodiaceæ, Coniferæ, and Equisetaceæ.

It is proper to remark that recent determinations of these various forms have changed the views expressed by Dr. Emmons in regard to their nature and systematic position, and also that Professor Fontaine does not see any reason for considering the so-called Permian forms as indicating a distinct age from those of the Trias.

To these vegetable remains are devoted four double plates of very well-drawn and well-printed figures.

A notice of Professor Emmons's North Carolina Report, relating to the Trias, which appeared in the American Journal of Science for November, 1857,[2] signed by the initials C. D., which are understood to have been those of Professor C. Dewey, is chiefly important in containing what purports to be a translation of a letter from Prof. Oswald Heer, who had made a somewhat careful study of Dr. Emmons's figures, and, as it would seem, of specimens which had been shown him by Mr. Jules Marcou, and the latter gentleman states[3] that the letter itself was originally addressed to him and was subsequently submitted to Dr. Emmons, who placed it in the hands of Professor Dewey. It is the same letter to which reference has already been made, a translation of which appeared in Mr. Marcou's Geology of North America, at page 16; but the two translations differ in some rather important respects.

In Part VI of his American Geology, Chapters VII and XV, Dr. Emmons has reproduced, almost without change, this discussion of

[1] See mention by Olmsted in Am. Jour. Sci., Vol. V, 1822, p. 261, and Vol. XIV, 1828, p. 250.
[2] 2d series, Vol. XXIV, pp. 427–429.
[3] Am. Geologist, Vol. V, March, 1890, p. 165.

the fossil flora of the Carolina Trias, making, however, a few additions and corrections. The illustrations are somewhat superior to those of the former work, and a considerable number were added. This volume bears date 1857.

Nothing further was done with this North Carolina flora until Professor Fontaine undertook, in his Older Mesozoic Flora, 1883, a careful revision of Dr. Emmons's work as published in his American Geology. This forms Part III of that important monograph, and is, as may well be judged, a very welcome contribution to this general subject, bringing the determinations down carefully to date and eliminating the greater part of Dr. Emmons's mistakes. It proved conclusively that the North Carolina basin is very closely related to that of Virginia, since of the 40 species enumerated in the North Carolina flora, 9 only are peculiar to that State, while 16 occur in Virginia. Six of his plates are devoted to reproductions of Dr. Emmons's figures, without, it must be confessed, any artistic improvement in them; but this seemed necessary in order to place the discussion in a compact form and in a clear light.

As indicative of the probable age of the coal plants, he says, at the outset:

Most of Emmons's plants come from above the horizon of the Mesozoic coal beds of North Carolina; hence, if this coal be on the same horizon as the Virginia Mesozoic coal, as it probably is, most of the North Carolina plants must come somewhat higher up in the series of older Mesozoic strata than those from Virginia. Nearly all of the latter come from the beds immediately associated with the Mesozoic coal of Virginia (p. 97).

Referring to the bituminous shale groups, which Dr. Emmons regarded as Permian, he says:

This bituminous shale group comes some distance above the base of the North Carolina Mesozoic series of strata, and, as stated, most probably stands on the horizon of the strata yielding most of the Virginia plants (p. 98).

On page 121 he further remarks:

It is not necessary to dwell upon the character of the strata of the two North Carolina areas. It is evident that they have a close resemblance to each other and to the Mesozoic beds of Virginia. The physical and stratigraphical resemblances are sufficient, without the evidence of the plants, to indicate that the North Carolina and the Virginia Mesozoic strata are of the same age, and that they were formed under similar conditions.

On pages 122 and 123 he gives a table of distribution similar to that given for the Virginia flora. This table certainly shows a remarkable similarity between the two floras. For example, only 9 species of the North Carolina plants are peculiar to that State, while 15 occur also in the Virginia flora, and one other, *Lonchopteris oblonga*, is closely allied to *L. virginiensis*. None of these forms occur in the Trias of any other country, nor are any allied to any Triassic plants. Two species occur in the Jurassic of other parts of the world, and 6 are allied to Jurassic species, but when we come to the Rhetic we find 7 identical with, and 8 others closely related to, typical Rhetic forms. The evidence of Rhetic age is therefore very strong. The results of this table are then analyzed and thoroughly discussed, and from the data here presented and from other sources he arrives at the following general conclusion :

European authors, and especially Schimper, often call attention to the strong resemblance between the Rhætic and Lower Jurassic floras, the likeness to the flora of the Lower Oolite of England being especially striking. In accordance with this fact, the presence of a marked Jurassic element in the flora of these Mesozoic beds, both in North Carolina and Virginia, is of itself an evidence that they can not be older than Rhætic. We are, then, I think, entitled to consider that the older Mesozoic flora of North Carolina and Virginia is most probably Rhætic in age, and certainly not older (p. 128).

The letter of M. R. Zeiller to Mr. Jules Marcou, published in the paper to which reference was made (supra, p. 264), contains a remark which it is appropriate to quote here in connection with Dr. Emmons's determinations and Professor Fontaine's conclusions drawn from the original figures. M. Zeiller says:

In studying the excellent figures of Emmons, very roughly reproduced by Fontaine, I have been led to contest several of the attributions and determinations of the latter, more especially about the Albertia, which Fontaine wants to make an Otozamites. The *Albertia latifolia* of Emmons is certainly an Albertia related to both *Alb. latifolia* and *Alb. Brauni;* and until now all the Albertiæ have been found in Europe in the Buntersandstein or Lower Trias.[1]

It is interesting to know that the original specimen was found in the collection at Williamstown, redescribed and refigured by Professor Fontaine, who adheres to his formerly expressed opinion that the plant "is certainly not an Albertia," comparing it with *Otozamites Beanii* (L. and H.) Brongn. (see infra, pp. 298, 299, Pl. XLII, Figs. 5, 6).

Professor Fontaine stated in the beginning of this revision[2] that on inquiry he had learned "that Dr. Emmons's collections of plants were destroyed during the late war," and it was supposed that none of his specimens were in existence, but in the spring of 1890 a collection, long ago received by the Smithsonian Institution from Mr. Isaac Lea, of Philadelphia, consisting chiefly of shells, was examined by Prof. William H. Dall and found to contain a few fossil plants, which were turned over by him to the department of fossil plants of the National Museum, and thus came into my hands. Among these plants, most of which were from the Newcastle coal fields of England, were several specimens that Dr. Emmons had sent to Mr. Lea from North Carolina, and with them was a letter from the former to the latter, dated July 12, 1856, mentioning these plants, and setting forth some of the conclusions to which a study of the coal fields of the State had led him. The plants bore provisional names, but it was thought best that they be

[1] Am. Geologist, Vol. V, 1890, p. 172.
[2] Mon. U. S. Geol. Survey, Vol. VI, 1883, p. 97.

sent to Professor Fontaine for his inspection. This was done, and I introduce here his report upon them, as some of the results are important, and no better opportunity may present itself for their publication:

NOEL, VIRGINIA, *July 8, 1890.*

Prof. LESTER F. WARD.

SIR: I have examined the fossil plants of the Older Mesozoic (Trias) of North Carolina, which were formerly sent by Dr. Emmons to Dr. Isaac Lea, and which are now in possession of the United States National Museum.

I find among them the following forms:

Nos. 1 and 2. Asterocarpus virginiensis obtusiloba (in fruit).

No. 3. Fucoid, not capable of identification.

Nos. 4 and 5. Ctenophyllum Braunianum var. β Göpp.

No. 6. Apparently a root.

No. 7. Specimen not capable of identification.

No. 8. Equisetum, too vague to identify.

Nos. 9, 10, and 11. Specimens not capable of specific identification.

No. 12. Cheirolepis diffusa.

Nos. 1 and 2 are fruiting forms of *Asterocarpus virginiensis obtusilobus*. This species, before the discovery of this specimen, had been known only from the locality Clover Hill in the Richmond coal field. Emmons does not appear to have either figured or described it among the forms given in his American Geology. Possibly he may have identified it with his *Pecopteris falcatus*=*Laccopteris Emmonsi.*

No. 3. This is a cast of a fucoid which is too imperfect to be determined. There are in the collection several other specimens showing vague imprints of fucoids. They are too imperfect to call for further notice.

Nos. 4 and 5. These specimens are *Ctenophyllum Braunianum* var. β Göpp., or the form with shorter leaflets. This plant is figured and described in Emmons's American Geology as *Pterozamites obtusifolius.* From an inspection of the figures, I came some time ago to the conclusion that no good reason existed for separating this plant from Göppert's variety β of *Ctenophyllum Braunianum.* An examination of the plant itself confirms the conclusion. Emmons seems at first to have identified this species with Rogers's *Zamites obtusifolius,* and the labels accompanying these specimens bear this name. Later he regarded it as Pterozamites.

No. 6. This is marked by Emmons as coming from the coal shale, in which the fossil plants do not seem to be so abundant and in such variety as in the shales much higher up. The label with this specimen gives the name *Gymnocaulus alternatus,* but the impression does not show any significant character. It looks more like a root than anything else.

No. 7. As indicated by the label accompanying this specimen, Emmons regarded it as a Lepacyclotes, but it is too imperfect to show anything definite.

No. 8. This is an Equisetum, an imprint of the outer portion, but it is too indefinite to permit identification. It is most probably *E. Rogersii.*

Nos. 9, 10, and 11. These specimens are all too imperfect to permit their identification with certainty.

No. 12. This is a fine specimen, called by Emmons *Walchia diffusus.* With this name he gives a figure of the plant in his American Geology, pl. iii, fig. 2. From an examination of this figure, no specimens of the plant being accessible to me, I came with doubt to the conclusion (see Older Mesozoic Flora of Virginia, p. 106) that the plant is a Palissya. An examination, however, of a specimen of this form shows that it is not a Palissya, and also that it is not a Walchia. It requires a study of more than one specimen of the plant satisfactorily to make out its character, for although a fine specimen, it does not show distinctly some features. All that can now be said of it is that it is probably a new genus; in foliage at east, intermediate between Cheirolepis and Pachyphyllum, standing nearer the former. As this single specimen does not suffice to establish a new genus, it is perhaps best provisionally to regard the plant as a Cheirolepis. In that case it might be called *Cheirolepis diffusa*.

In this connection it is proper to state that although Emmons says that he made a rich collection of the North Carolina Older Mesozoic fossil plants, I know of the existence of no collection of these plants available for study.

Accompanying these plants of Dr. Lea there are several fine specimens of ganoid fishes obtained by Emmons from the shales associated with the coal of North Carolina. They are worthy of careful study.

Respectfully, WM. M. FONTAINE.

Dr. F. H. Knowlton received from Prof. I. C. Russell some pieces of fossil wood from the Trias of North Carolina, from which he made six slides. These have not thus far been figured, but after an examination of the slides Dr. Knowlton was able to make to Professor Russell the following statement, which the latter published in his Correlation Paper on the Newark System.[1] At my request Dr. Knowlton has kindly drawn the figures and furnished the following descriptive notes:

## DESCRIPTION OF A SMALL COLLECTION OF FOSSIL WOOD FROM THE TRIASSIC AREA OF NORTH CAROLINA.

By F. H. KNOWLTON.

In 1885 Prof. I. C. Russell, then of the United States Geological Survey, submitted to me a small collection of fossil wood made by himself in the Triassic area of North Carolina. He requested a brief report on this material, which I made, and which he published in his Newark System[1] in 1892. Recently Professor Ward, who is engaged on a systematic review of the fossil plants of the Triassic of this country, has asked for a more detailed description of this wood for use in his report. The following notes are the result of this study.

This collection consists of about a dozen specimens, representing the following localities: Triassic strata between Walnut Cove and Germantown; 1 mile west of Polkton; and Lockville, all in North Carolina. None of the material is well preserved, the structure having suffered greatly in the process of fossilization. Six of the best-preserved pieces were selected and thin sections cut from them. Of these, three proved to have been so poorly preserved as to be worthless for purposes of study, and the results obtained are therefore based on the three remaining pieces.

I stated in my brief report to Professor Russell[1] that, with the possible exception of one piece, I was able to identify them with *Araucarioxylon arizonicum* Knowlton,[2] a species described from the Shinarump group of Arizona and New Mexico, and since detected, or at most

[1] Correlation papers—The Newark system: Bull. U. S. Geol. Survey No. 85, 1892, p. 29.

[2] Proc. U. S. Nat. Mus., Vol. XI, 1888, p. 3, pl. i, figs. 1-5.

only a slightly divergent variety of it, from the copper mines near Abiquiu, New Mexico.[1] Since preparing this report for Professor Russell I again looked over the slides in connection with the study of a number of pieces of wood from the Richmond Basin, Virginia, a report of which is given in the Nineteenth Annual.[2] Among the Richmond Basin specimens I found one having the same structure as those from North Carolina, which had previously been referred to *Araucarioxylon virginianum*. Although very close to the species from New Mexico and Arizona, there seem to be slight, but thus far constant, differences, and I gave the name *Araucarioxylon Woodworthi* to the specimen from the Richmond Basin. A more complete study of the material from North Carolina confirms this view, and it is so referred here.

In 1889 I described, under the name of *Araucarioxylon virginianum*,[3] a piece of fossil wood that was supposed to have come from the Potomac formation at Taylorsville, Virginia. Subsequent investigation has shown that this specimen came from Triassic strata, the locality where it was found being almost the only known place where the Potomac formation rests on the Triassic. The specimen from North Carolina mentioned in my report to Professor Russell as doubtful appears to belong to this species, although not agreeing in every particular. The following is a brief discussion of the two species based on the North Carolina material:

### ARAUCARIOXYLON WOODWORTHI Knowlton.

Pl. XXXVII, Figs. 7–9.

1899. *Araucarioxylon Woodworthi* Knowlton: Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. II, p. 517, pl. lii, figs. 1–6.

As may be seen in comparing the figures here given with those accompanying the original description of *A. arizonicum*,[4] the agreement between the woods from North Carolina and those from New Mexico and Arizona is very close indeed. The annual ring is very faint and is detected with difficulty. It consists of only two or three rows of smaller, thicker-walled cells. The wood cells are seen to be equally thick-walled from both localities. The wood cells in the Richmond Basin specimen are also identical.

The medullary rays in *A. arizonicum* are composed of 1 to 22 superimposed cells, whereas in this species, both from the Richmond Basin and from North Carolina, the number ranges from 1 to 12, the usual number being perhaps 4 to 6. The rays are short-celled in all.

The bordered pits as seen on the radial walls of the wood cells are

[1] Proc. U. S. Nat. Mus., Vol. XIII, 1890, p. 285.

[2] Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. II, 1899, pp. 516–519, pl. lii.

[3] Bull. U. S. Geol. Survey No. 56, p. 50, pl. vii, figs. 2–5.

[4] Proc. U. S. Nat. Mus., Vol. XI, 1888, p. 3, pl. i, figs. 1–5.

in a single series, or rarely in two series. In the Richmond Basin specimen there is one, rarely two, and very rarely three series. When in a single row they are approximately circular; when in two or three rows they are very slightly compressed and hexagonal.

In tangential section the ends of the medullary rays are of course shown. They are seen to be composed of from 1 to about 12 superimposed cells. The wood cells as seen in this section are without the bordered pits that form so important a character in *A. arizonicum.*

As I took occasion to say in my report on the Richmond Basin material, this species is very closely allied to, if not indeed identical with, *Araucarioxylon arizonicum*, differing in having a less number of cells in each medullary ray, and particularly in the absence of bordered pits in the tangential walls of the wood cells. These are, however, not important differences, and a larger series of specimens might show the breaking down of this character, but for the present, at least, it may be regarded as distinct.

*Locality.*—Road between Walnut Cove and Germantown, North Carolina; collected by I. C. Russell, August 21, 1885. Near Lockville, North Carolina, collected by I. C. Russell, July 25, 1885.

### ARAUCARIOXYLON VIRGINIANUM Knowlton.

Pl. XXXVII, Figs. 1–6.

1889. *Araucarioxylon virginianum* Kn.: Bull U. S. Geol. Survey, No. 56, p. 50, pl. vii, figs. 2–5.

1899. *Araucarioxylon virginianum* Kn.: Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. II, p. 516, pl. lii, figs. 7–10.

As stated above, this species was described from what was thought at the time to be Potomac strata, but which later investigation has shown to be undoubted Triassic. It was also detected in the Richmond Basin, as mentioned in my report on that material. Its presence is now demonstrated in the Triassic area of North Carolina.

On comparing the drawings here given with the original figures, it will be seen that the agreement is very close indeed. The medullary rays have about the same number of cells and the same characters. The pits on the radial walls of the wood cells are identical. When the pits are in a single row they are less evidently hexagonal, but when in two rows they are distinctly so. I therefore do not hesitate to refer the specimen to this species.

*Locality.*—Lockville, North Carolina; collected by I. C. Russell, July 25, 1885.

## THE EMMONS COLLECTION.

On the evening of March 28, 1894, at the close of a meeting of the Geological Society of Washington, before which I had read a paper on

The Potomac Formation, Dr. T. Nelson Dale, of Williams College, Williamstown, Massachusetts, approached me and asked if I was also interested in the flora of the Trias. When I informed him that I had been studying it for the last five years and had prepared an extended paper on it which I hoped sometime to publish, he volunteered the startling information that all of Dr. Ebenezer Emmons's types from the North Carolina coal fields were deposited at Williams College and were under his charge.

As it had been so frequently and confidently stated that these types were lost or destroyed during the war, this piece of news came as a revelation. I asked him if it would be possible to obtain access to them in order to have them reexamined by Professor Fontaine and a final report published upon them, and he said that so far as his authority went he would be glad to cooperate in securing this result. He said he had compared a number of them with the published figures and was certain that a portion at least of the type specimens were in the collection, and he presumed all. Indeed, he thought there was considerable material that had not been published.

I immediately wrote to Professor Fontaine and asked him if he would like to undertake to overhaul the collection and prepare a report. His interest was of course great and he consented to do so. He corresponded directly with Dr. Dale, and after some delay the desired result was brought about. In a letter to Professor Fontaine, dated May 10, 1894, Dr. Dale says:

DEAR SIR: I have at last found time to look over Emmons's fossil plants. The specimens from which the figures reproduced by you in your monograph on the Older Mesozoic were drawn are mostly here. I have identified the following:

Your pl. 48, figs. 6 and 8 (the latter slightly damaged, the former, 2 specimens).
Pl. 49, fig. 6.
Pl. 51, fig 1 (marked *Voltzia acutifolia*) and figs. 2, 3.
Pl. 52, fig. 6.
Pl. 53, figs. 4, 5 (of the latter a better specimen).
Pl. 54, figs. 4, 7.

There is one marked "impression of trunk of cycad" somewhat like your pl. 52, fig. 5.

Also the following: *Cycadites longifolius*, Calamites, Lepacyclotes with *Walchia diffusus*, *Walchia variabilis*. A *Sphenopteris egyptiaca* better than pl. 48, fig. 8.

Besides these there is a drawer 30 by 16 by 2½ inches, full of smaller specimens, many of them with his labels still attached.

Should you chance to be in New England sometime I would be pleased to give you every facility for studying the specimens, but I ought to be advised beforehand lest I should chance to be out of town.

Yours, respectfully, T. NELSON DALE.

The pressure of other work, however, delayed attention to this important matter for a period of over three years. I had become specially interested in the subject of cycads, and as several supposed cycads had been reported from the North Carolina coal fields by Dr. Emmons, I decided to visit Williams College and endeavor to find the types of his figures of these. I accordingly arranged with Dr. Dale to meet him there on July 17, 1897, and look at the collection and try to hunt up certain specimens. Every facility for this was placed at my disposal. I found two of the supposed cycadean trunks and took detailed notes upon them. One of those figured could not be found. Another proved to be merely an impression, but evidently that of a cycadean trunk. It is tolerably clear and is described and figured below with the specific name given to it by Professor Fontaine. Dr. Emmons practically recognized it as a Cycadeoidea (see infra, p. 302, Pl. XLIII, Fig. 3). Another specimen was found which was never figured. It is a disk of a small trunk, faintly showing scars around the edge. As Professor Fontaine has not in the report to follow dealt with this specimen, the following note written with the specimen before me may as well be recorded:

This is a thin segment of a small trunk. It consists of a gray coarse sandstone and is mainly a mere cast, but around the edge is a thin layer of a finer material on which there are faint indications of scars. The cross section is elliptical, 9 by 11 cm. The thickness (length of the trunk) is from 2 to 3 cm. On one side is a label with the words "Zamites, Stem of Cycad," probably in Dr. Emmons's handwriting.

Some time afterwards, at my request, Dr. Dale brought this specimen to Washington, and, through the kindness of Professor Diller, the most promising portions were ground slightly in the hope that something of the internal structure might be revealed, but it proved to be only a sandstone cast, all within being wholly structureless. Professor Fontaine, while engaged in working up this collection, as presently to be mentioned, examined this specimen, and in a letter to me dated August 5, 1898, he says:

> The disk of sandstone which you examined to see if it might be a cycad trunk, seems to be a cross section of a cylindrical cast of an Equisetum.

I am quite prepared to accept this conclusion.

A year later arrangements were made for working up the collection, and on August 3, 1898, Professor Fontaine went to Williams College and made an exhaustive study of the material, occupying over two weeks. He described all the species, but did not then figure them, making an arrangement with Dr. Dale to have the types that he selected to be figured sent to the University of Virginia and to the United States Geological Survey, Division of Illustrations, where the drawings could be made with all necessary care. Professor Fontaine elaborated his notes and completed his report in January, 1899, and the types not figured by him were drawn in the Division of Illustrations during the winter and spring. They were returned to Williams College in June.

This careful recension by Professor Fontaine of the classic collection of Dr. Emmons, so happily preserved to science, proves to be of course a most important consummation and sheds a flood of new light on the whole subject of the Older Mesozoic flora of America. Among other results, it has the effect of rescuing from an oblivious synonymy and uncertainty a number of Dr. Emmons's names, some of them dating back to his North Carolina report of 1856. In the synonymy of the species in Professor Fontaine's descriptive paper that follows, and for which I am alone responsible, I have endeavored to do full justice to Dr. Emmons's names by preserving them as having priority over all others. In a few cases these old species of Dr. Emmons also occur in the York deposits as made known by Mr. Wanner and embodied in an earlier part of this paper. In such cases, to avoid unnecessary repetition, the synonymy is given there and only a reference to it made here.

Prof. J. A. Holmes, State geologist of North Carolina, has recently found a few more of Dr. Emmons's Triassic plants, which he sent to Professor Fontaine. The latter informs me that there is nothing new among them, and has offered to send them to Washington.

The following is Professor Fontaine's report on the Emmons collection:

NOTES ON FOSSIL PLANTS COLLECTED BY DR. EBENEZER EMMONS FROM THE OLDER MESOZOIC ROCKS OF NORTH CAROLINA.

By WM. M. FONTAINE.

Dr. Ebenezer Emmons, when State geologist of North Carolina, collected a number of fossil plants in the Older Mesozoic beds of that State. In Pt. VI of his American Geology, published in 1857, he gave descriptions and figures of them. At a subsequent time the writer made collections of fossil plants from beds of apparently the same age in Virginia. Descriptions and figures of these were published as a Monograph of the United States Geological Survey, Vol. VI.

As it was apparent from a comparison of the Virginia fossils with the figures and descriptions given by Emmons of his plants that there was much resemblance in a number of cases, it was necessary for a satisfactory determination to examine Emmons's specimens. Emmons identified some of his forms with Virginia plants. It was quite possible that the number of plants known to him from the Virginia beds was much smaller than that collected by the writer. Had he been able to compare this larger collection with his own he would possibly have made additional identifications. Besides, the more complete series of specimens collected from the Virginia beds might throw light on plants that he, from more imperfect specimens, had erroneously determined. A careful inspection of his material would be required to settle these points. Accordingly efforts were made to locate the type specimens of the forms described in Pt. VI of the American Geology, but without success. Neither the types nor any of the fossil-plant material collected by Emmons could be found. That being the case, the figures given by Emmons were the sole dependence for comparison, and under the circumstances they could not be very satisfactory. It was thought best, then, to reproduce these figures in Monograph United States Geological Survey, Vol. VI, giving Emmons's descriptions, and to accompany them with such criticisms as would be suggested by the Virginia specimens. Even from the figures it could be seen that there was a larger number of plants common to the two States than Emmons had noticed. This review was embodied in the Monograph.

Recently, Prof. T. Nelson Dale, in examining the unsorted and unclassified fossils in the collections of Williams College, Massachusetts, found fossil plants which he recognized as having been collected by Emmons. This led him to think that probably the long-lost collection might be found to have been placed in Williams College, and he so stated to Professor Ward. Professor Ward, knowing its importance, visited Williams College, and after an examination of the specimens was convinced that they formed all that remained of Emmons's collection.

Dr. Dale only recently took charge of the collections of fossils in Williams College. He found a large mass of heterogeneous and unsorted material, and going over this for the purpose of labeling the specimens and placing them in cases for preservation, he found the fossils above alluded to. They were scattered among animal fossils and other specimens. No attempt had been made to keep them together and credit them to Dr. Emmons. A considerable number of the specimens were evidently as Emmons had packed them in collecting, and they were accompanied by his field labels, bearing the names of the plants and the localities yielding them. There is no record as to how these fossils came into the possession of Williams College, and no one prior to Dr. Dale's discovery knew of their existence. It is probable that they were presented to the college by Dr. Emmons after the publication of the descriptions, or by Mrs. Emmons after his death.

The collection made by Dr. Emmons will in all probability stand as the most complete one of the plant fossils of the Older Mesozoic of North Carolina. He made it under exceptionally favorable circumstances, which will most probably never be met with again. The rocks closely associated with the coal of North Carolina are the only ones that in future will probably be opened up and afford opportunity for the collection of plant fossils. If we may judge from Emmons's experience, they, unlike those similarly placed in Virginia, are very poor in plant fossils. Emmons found nearly all his specimens, and all his best-preserved and most interesting plants, in measures that have been proved to be without workable coal, and which occur, according to him, many hundred feet above the workable coal. It is not probable that in future these strata will be extensively explored. The case, however, was quite different when Emmons was State geologist. There was at one time great activity in the search for coal. The upper portion of the Older Mesozoic had not then been shown to be without workable coal. In a number of places these beds contain thin seams of coal, enough to have caused trial pits to be sunk. A great many of these pits were opened, and in a number of cases they afforded well-preserved plants. Emmons's position as State geologist gave him unusual opportunities both for hearing of the plants and for collecting them. Fortunately he appreciated the importance of taking advantage of them.

With the passing away of the inducement to search for coal in the upper measures all opportunity for collecting in them ceased. The shallow pits soon filled up and all trace of them disappeared, so that in time no one even remembered them. I had occasion to note these pits. When it proved impossible to find in North Carolina any trace of Emmons's collection it was thought advisable to visit the localities mentioned by him as giving him his most abundant and best fossils. This was done, and the outcome was complete failure to find Emmons's localities or any others. No one remembered them. The exposures of rocks are few and poor and showed no recognizable plants. It was evident that Emmons owed his success in collecting plants to the exceptional conditions mentioned above, under which he operated.

The Emmons plants found in the Williams College collections being the best representatives of the Older Mesozoic flora of North Carolina, Professor Ward requested me to study them. I visited Williams College in the summer of 1898 and made a careful examination of the North Carolina material. It is the object of this paper to give the results obtained.

In this material most of the plants figured and described by Dr. Emmons were found. There are, besides the type specimens, many duplicates of some of the forms and some that were not given in the published figures and descriptions.

# DESCRIPTIONS OF THE SPECIES.

## Subkingdom PTERIDOPHYTA (Ferns and Fern Allies).

## Class FILICALES.

## Family FILICES (Ferns).

## Genus SPHENOPTERIS Brongniart.

### SPHENOPTERIS EGYPTIACA Emmons.

Pl. XXXVIII, Fig. 1.

1857. *Sphenopteris egyptiaca* Emm.: American Geology, Pt. VI, p. 36, figs. 8 and 9 on p. 37.

1885. *Acrostichites egyptiacus* (Emm.) Font.: Older Mes. Fl. Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 99, pl. xlviii, figs. 8, 8a.

Emmons, in American Geology, Pt. VI, pp. 36–37, figs. 8 and 9, gives a description of a fine fern, which he names *Sphenopteris egyptiaca.* He says it is found only in the coal-bearing portions of the North Carolina Mesozoic. It is the finest of the few plants that this portion of the measures has yielded. Emmons's fig. 8, so far as it goes, gives the character of the plant very well, but it gives only a portion of the imprint visible on the specimen in the collection, which is evidently the original of the figure. Fig. 8 of Emmons gives only parts of two ultimate pinnæ attached to a primary rachis on the right-hand side. The specimen shows much more of the plant. The facies of the ultimate pinnæ and of the pinnules is given very well in this figure, and fig. 9, which represents an enlarged pinnule, shows quite faithfully the details, so far as they can be made out. The impression of the plant on the stone is not very distinct.

The original specimen shows a considerable portion of two primary pinnæ, both of which contain more of the plant than Emmons depicts. The primary pinna, a portion of which he figures, had its rachis originally much larger than represented. There is shown on the right-hand side another ultimate pinna similar to those figured, going off as if it had been attached to the rachis prolonged above. Below the pinnules figured, and on the same side, there are portions of three other ultimate pinnæ, which evidently were originally attached to the rachis prolonged below. Emmons's figure shows, on the left-hand side, only the basal portions of two ultimate pinnæ that are without pinnules. But the specimen shows here two ultimate pinnæ with pinnules nearly as numerous and well preserved as those on the right-hand side. In addition there is found on the slab of stone, to the right of the primary pinna above described, a second pinna of the same character, but with a considerably smaller rachis. This has its lower termination, about 14 cm., distinct from the lower termination of the first-mentioned primary pinna, and it is so placed that if the two were prolonged downward they would meet under an angle of 45°. This smaller pinna looks as if it were sent off lower down from the larger rachis, or probably from near the summit of a common trunk.

This smaller rachis on the right is, like the first named, only a fragment. It has attached to it, on both sides, a number of ultimate pinnæ, carrying pinnules similar to those figured by Emmons, but somewhat smaller. There are also several ultimate pinnæ so placed as to indicate that they were attached to it lower down. It will be seen from this description that the fern must have had a wide spread and that it was much larger than is indicated by Emmons's figure. Emmons's figure of the principal rachis makes it too straight and rigid. It is really rather flexuous and shows ridges. The epidermis of the plant seems to be very durable, for it is now retained on the stone as a black, shining film. The pinnules are more obtuse than Emmons's figure indicates. I have represented one of these enlarged in Pl. XXXVIII, Fig. 1. This plant is much like *Acrostichites princeps* (Presl) Schenk,[1] but as it shows no fructification it can not be stated that it is an Acrostichites. The habit of the pinnules is much like that of the pinnules of *A. princeps*, which fact is not well shown in Emmons's figure. This makes the plant too rigid in aspect. The pinnules, however, are on an average larger than those of Schenk's plant, and if it is an Acrostichites it is almost a modified form or representative of *A. princeps*. But most probably it is a new species. The attitude of the two principal pinnæ indicates that they radiate from a common trunk, as Schenk represents in *A. princeps*.

## Genus LACCOPTERIS Presl.

### LACCOPTERIS LANCEOLATA (Göpp.) Presl n. comb. ?[2]

Pl. XXXVIII, Figs. 2–4.

1836. *Asterocarpus lanceolatus* Göpp.: Syst. Fil. Foss., p. 382.
1838. *Laccopteris elegans* Presl in Sternberg: Flora der Vorwelt, Vol. II, p. 115, pl. xxxii, figs. 8a (1, 2, 3), 8b, 8c.
1857. *Pecopteris* sp.? Emm.: American Geology, Pt. VI, p. 104, pl. vi, fig. 2.
1883. Undetermined fern (cf. *Laccopteris elegans* Presl) Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, p. 105, pl. li, fig. 6.

Emmons[3] notes a small fern which he leaves undescribed, but he says of it that it is probably a Pecopteris. Judging from the aspect of the

[1] Foss. Fl. der Grenzschichten des Keupers und Lias Frankens, pp. 46–49, pl. vii, figs. 3, 3a, 4, 4a, 5; pl. viii, figs. 1, 1a.

[2] Göppert's name *Asterocarpus lanceolatus* has priority over Presl's by two years. He bases his description on the same plate and figures, which Sternberg seems to have sent him, so that there is no question of identity. The specific name given by Göppert must therefore stand. Although he credits it to Sternberg, there is no proof that Sternberg suggested it. It was probably a mere compliment, and it must be credited to Göppert, who first published it. L. F. W.

[3] American Geology, Pt. VI, p. 104, pl. vi, fig. 2.

plant as shown in this figure, and especially from the apparent digitate arrangement of the foliage, I was led to think it a Laccopteris, probably identical with *L. elegans* of Presl, and so stated in Mon. U. S. Geol. Survey, Vol. VI, p. 105. The original of the figure is in the Williams College collection of Emmons. This is the only specimen of the plant that I saw.

Emmons's figure does not give an exact representation of the plant. This figure indicates only two pinnules going off, diverging from a common point, whereas, in the specimen, there are three if not more. Two of them are as Emmons has indicated, and the third, standing on the left of the other two, is denoted by a very short portion of its base, where it was attached to the others. Hence it may be easily overlooked. The character of the plant is given in Fig. 2, Pl. XXXVIII. The basal pinnules differ from those higher up on the rachis. They are wider than long, with a rotundate-subquadrate shape. The nervation of these is like that of Odontopteris, while that of the higher ones is like that of Pecopteris. The form of the higher pinnules is not so Pecopteris-like as Emmons's figure makes them. Their bases are much the widest portions and they are decurrent. They are obliquely placed on the rachis. Fig. 3 gives an enlargement of the lower pinnules, and Fig. 4 of the upper ones.

The features seen make it still more probable that the plant is a Laccopteris like *L. elegans*, but as no fructification is shown, and the amount of material insufficient, it will be best to leave the determination doubtful.

### Genus ASTEROCARPUS Göppert.

#### ASTEROCARPUS FALCATUS (Emmons) Fontaine.[1]

Pl. XXXVIII, Figs. 5, 6.

Many specimens of a large fern are in Emmons's collection which prove to be identical with *Asterocarpus virginiensis*, a common form in the Virginia Older Mesozoic. It is the most abundant plant collected by Emmons, *Lonchopteris oblonga*, standing next to it. The large number of specimens collected most probably indicates that the plant is in fact common in the Older Mesozoic of North Carolina. This agrees well with its occurrence in the Virginia beds, where it is one of the most widely distributed ferns, affording many good specimens.

In the North Carolina strata, as indicated by Emmons's specimens, both sterile and fertile forms occur, the former being much the more common. Most of the sterile forms contain long, narrow pinnules, the proportion of slender pinnules being greater than is shown in the Virginia specimens. On one specimen of shale from Ellingtons, three

[1] For synonymy, see supra, p. 237.

ultimate pinnæ are shown, one of them 10 cm long. They are numerous, long, slender pinnæ, and are so placed as to indicate that they were all attached to a principal rachis. This denotes a plant of large size, comparable with the large Virginia forms. While the long, slender pinnules are most common on Emmons's specimens, some of them show the short, very obtuse pinnules that are more common in the Virginia forms. Fig. 5 represents the more common form of Emmons's fossils. Fig. 4 gives a fragment of a penultimate rachis and a portion of an ultimate pinna that was probably attached to it. The ultimate pinna carries some pinnules of the shorter and proportionally broader form, which are less common.

Emmons, in Pt. VI of his American Geology, p. 100, pl. iv, fig. 9, describes a fern that he calls *Pecopteris falcatus*, and in fig. 5 of the same plate he gives an allied fern, which he says may be called *P. falcatus variabilis.* On pages 100–101, fig. 68, pl. iv, figs. 1, 2, he describes sterile and fruiting forms of what he regards as a different fern, and names it *P. carolinensis.* All of these are forms of the polymorphous *Asterocarpus virginiensis.* The different appearance of the sori in the forms regarded by Emmons as different species is due to the fact that the sori of the supposed *P. falcatus* are seen with the upper surface of the frond presented uppermost, while in the forms given as *P. carolinensis* they are presented with the lower surface of the frond uppermost and show their true character, which is that of *Asterocarpus virginiensis.* Emmons's figures of these plants are not good.

In reviewing these plants in Mon. U. S. Geol. Survey, Vol. VI, p. 102, I had to depend on Emmons's figures. I supposed that they represented plants that were constant in the different forms depicted, with no specimens forming a passage from one form to the other. Hence I accepted the conclusion of Emmons that two species are involved, and, from the fructification, I supposed them to be Laccopteris. I suggested that *Pecopteris falcatus* be called *Laccopteris Emmonsi* and *Pecopteris carolinensis* be named *L. carolinensis.*

## Genus MACROTÆNIOPTERIS Schimper.

### MACROTÆNIOPTERIS MAGNIFOLIA Schimper.[1]

Emmons makes mention of this fern, which is so common in the Virginia Older Mesozoic, in American Geology, Pt. VI, p. 102, but does not say where it occurs. He gives a figure (fig. 70, on p. 103) of a fern of this general character, with the lamina in segments, saying that this form occurs often, if not always, in this shape. Possibly this may really be an Anomozamites or Nilsonia.

I saw a fragment of a leaf 13 cm. long that is certainly *M. magni-*

[1] For synonymy, see supra, p. 238.

*folia.* The lamina on one side of the midrib is all missing and on the other side there is at most only a width of half an inch. This leaf does not seem to have been large, as the midrib is only 2 mm. wide.

### Genus DANÆOPSIS Heer.

#### DANÆOPSIS ? sp. Fontaine.

Pl. XXXVIII, Fig. 7.

Emmons's collection contains a small fragment of shale, with the locality not given, similar to that from Ellington's, that yields the best-preserved fossil plants, and on this there is shown a fragment of what must have been a very large pinnule, clearly of the Danæopsis type. In his published descriptions he makes no allusion to it. A label, however, evidently attached by him, is marked "Strangerites, in fruit."

The fragment is quite imperfect. It shows a portion of a stout rachis, which retains on both sides a small portion of the lamina, more on the left side than on the right. On each side there are parallel rows of small sori, which appear to have stood, originally, one on each side of the lateral nerves, as in *Danæopsis marantacea* (Presl) Heer. Of course, only the basal portions of the rows next to the rachis are preserved. The rows are arranged as they would be to follow the course of the nerves. They make at the rachis an acute angle with it, but farther off curve away, so as to make a right angle with it. Fig. 7 shows what is now to be seen on the specimen. The fragment is too imperfect to disclose fully the nature of the plant. It may be a fructified form of *Pseudodanæopsis nervosa*, or of *P. reticulata* Font. [*P. plana* (Emm.) Font.], both of which, in sterile form, appear to occur in the North Carolina Older Mesozoic. If we take the course of the sori as indicating the nature of the lateral nerves, they not being preserved, the plant is nearer to *Danæopsis marantacea* than either of these. The lateral nerves are in that case closer than in either of the species of Pseudodanæopsis and much resemble those of *D. marantacea.*

### Genus PSEUDODANÆOPSIS Fontaine.

#### PSEUDODANÆOPSIS PLANA (Emmons) Fontaine.[1]

Emmons gives, on p. 122, fig. 90, of the same work, a description of a plant nearly allied to the above, and this he calls *Strangerites planus*, thinking that both forms are cycads. This plant I identified, in Mon. U. S. Geol. Survey, Vol. VI, p. 116, from Emmons's figure, with *Pseudodanæopsis reticulata* of the Virginia Older Mesozoic. In Emmons's collection I saw a well-preserved fragment of a pinnule of this plant

[1]For synonymy, see supra, p. 238.

that shows about 6 cm. of its length, with margins well preserved, but not possessing the basal and terminal portions. This is probably Emmons's type specimen. It is without doubt *Pseudodanæopsis reticulata*. It shows all the characteristic features of the Virginia plant,[1] both in nervation and in the general character of the pinnules. These features are strongly marked and not common.

### Pseudodanæopsis obliqua (Emmons) Fontaine.

1856. *Strangerites obliquus* Emm.: Geological Report of the Midland Counties of North Carolina, p. 325.
1857. *Strangerites obliquus* Emm.: American Geology, Pt. VI, p. 121, fig. 89 on p. 122.
1883. *Pseudodanæopsis nervosa* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, pp. 61, 116, pl. xxxi, figs. 1, 2; pl. liv, fig. 3.

Emmons, in American Geology, Pt. VI, pp. 121, 122, fig 89, gives a description of the pinnule of a large fern which, from its resemblance to *Pseudodanæopsis nervosa*, I was led to regard as identical with it, and so stated in Mon. U. S. Geol. Survey, Vol. VI, p. 116. The original of Emmons's figure was not seen in his collection, but a fragment of a large pinnule of a similar plant was found. This shows a portion of its margin with the characteristic marginal anastomosis of the nerves seen in the Virginia form. This, with the character of the pinnule and its strong, rarely branching, remote nerves, shows that without doubt the plant does occur in the North Carolina beds, and that probably the form described by Emmons is identical with it. It seems to have been rare, as only the fragment mentioned was seen. The nerves in Emmons's figured specimen owe their straggling character to distortion from maceration and pressure.

## Genus LONCHOPTERIS Brongniart.

### Lonchopteris oblonga (Emmons) Fontaine.[2]

Pl. XXXVIII, Figs. 8–10.

Emmons gives[3] a representation of a fern with reticulate nervation, which he names *Acrostichites oblongus*. Fig. 8 is a good representation of one of the specimens in the collection, which, however, is now at least more fragmentary than the figure represents it to be. It is one of the smaller forms of this plant. In preparing Mon. U. S. Geol. Survey, Vol. VI, I was led, from an inspection of this figure, to think that this species is not an Acrostichites, but a Lonchopteris, as it resembles *L. virginiensis* of the Older Mesozoic of Virginia. I was confirmed in this view after examining the considerable number of specimens of this plant that occur in the collection of Williams College.

[1] Mon. U. S. Geol. Survey, Vol. VI, pp. 59, 60, pl. xxx, figs. 1–4.
[2] For synonymy, see supra, p. 239.
[3] American Geology, Pt. VI, pl. iv, figs. 6, 8.

To judge from the number of specimens that Emmons obtained, which is quite large, this fern must have been one of the most common plants in the North Carolina beds. None of the pinnules seen equal in size those of the largest size in *L. virginiensis*. The plant, however, must have attained considerable size, for one of the penultimate rachises seen is 1 cm. wide. This specimen, which is represented in Fig. 8, Pl. XXXVIII, shows pretty well the general character of the larger forms of the fossil. The ultimate rachises are always strong in the forms with largest pinnules, as is shown in Fig. 9, which represents an ultimate rachis that carries pinnules of the largest size seen. The pinnules are never large, as is shown by the figure. Like the Virginia Lonchopteris, the leaf substance is thick and leathery, so that it masks the details of the nervation. This is the type of the genus, and it appears to be rather more closely reticulate than Emmons has represented it to be. The pinnules are generally oblong in shape and very obtuse at their tips. The smaller pinnules, however, such as are represented in Fig. 10, tend to be more acute. They are closely crowded together, but not imbricated as Emmons has represented them in his fig. 8. In the lower portion of the frond they are separate, but higher up become more and more united.

### Genus SAGENOPTERIS Presl.

#### SAGENOPTERIS EMMONSI Fontaine n. sp.[1]

Pl. XXXIX, Figs. 1–3.

Emmons, in his American Geology, Pt. VI, p. 104, pl. iv, fig. 10, describes a plant which he names *Cyclopteris obscurus*. In Mon. U. S. Geol. Survey, Vol. VI, p. 104, I identified this with *Sagenopteris rhoifolia*. An inspection of specimens of the plant makes it most probable that it is a different species. I did not see in the collection any specimen that appears to be the original of Emmons's figure, but there are several that plainly belong to the same plant. All the specimens are very imperfectly preserved. The most complete one is that represented in Pl. XXXIX, Fig. 1. The others are fragments of single leaves. One of the largest and the most perfect of them is represented in Fig. 3. The leaves are too poorly preserved to indicate with certainty what their size and exact shape were. They seem to have been of very thin texture and to have been grouped, after the fashion of Sagenopteris, at the summit of a common stem. Basal portions of two are shown in Fig. 7, which seem to be thus arranged. In shape they seem to have been oblong, widening toward their summits and narrowing to their

[1] In view of the doubts that Professor Fontaine expresses as to whether this is really the same as Emmons's *Cyclopteris obscurus*, and especially of the fact that the type specimen was not found at Williams College, I shall not treat it as the same plant by retaining Emmons's name for it, but as a new species, leaving the question of identity as it stood before. L. F. W.

bases. They appear to have been quite small—much smaller than the normal leaves of *S. rhoifolia.* The texture appears to have been much more delicate than that of the latter plant, but the most important difference is in the nervation. There is no trace of midrib or even of a parent nerve at the base of the leaves. Schimper makes the existence of a midnerve a feature in the character of Sagenopteris. If it is an essential one, then this plant is not a Sagenopteris. In the ultimate nervation the anastomosis occurs at long intervals, the nerves forking, and occasionally a branch uniting with an adjoining nerve. The method of anastomosing resembles that of Nathorst's genus Arthrophyopsis. Nathorst[1] describes, from the Rhetic flora of Bjuf, a plant with the name *Sagenopteris dentata* that is much like the one now in question. It has the same thin texture, absence of midrib, and sparse anastomosis, but the North Carolina plant, perhaps owing to its imperfect preservation, does not show any dentation.

### Genus ACROSTICHITES Göppert.

#### ACROSTICHITES LINNÆÆFOLIUS (Bunbury) Fontaine.[2]

*Acrostichites linnææfolius*, a fern that is very characteristic of the Older Mesozoic of Virginia, is not given by Emmons as occurring in North Carolina. His mention of it on page 104 of Pt. VI indicates that he had not seen it in the North Carolina beds.[3] In his collection at Williams College I saw an imprint of a fragment of an ultimate pinna, containing a number of pinnules, which show the form of the sterile pinnules of this plant, and also the characteristic sori. The specimen had no label giving the locality, hence it is possible, but not probable, that it comes from the Virginia beds.

#### ACROSTICHITES TENUIFOLIUS (Emmons) Fontaine.

Pl. XXXIX, Fig. 4.

1856. Undetermined plant. Emm.: Geological Report of the Midland Counties of North Carolina, p. 349, pl. iii, fig. 5.
1857. *Odontopteris tenuifolius*[4] Emm.: American Geology, Pt. VI, p. 105, pl. iii, fig. 5.
1883. *Acrostichides rhombifolius* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI., pp. 29, 105, pl. viii, figs. 2, 2a, 3, 3a, 3b; pl. xi, figs. 1, 1a, 2, 3; pl. xii, figs. 1, 1a, 2; pl. xiii, figs. 1, 1a, 2; pl. xiv; pl. xlix, fig. 7.

One of the type specimens of the plant described by Emmons[5] as *Odontopteris tenifolius*, was seen by me in his collection. It is the

[1] Floran vid Bjuf, Vol. I, p. 27, pl. ii, figs. 5-7.
[2] For synonymy, see supra, p. 240.
[3] His figure (North Carolina Report, pl. ii, fig. 6; American Geology, Pt. VI, pl. vi, fig. 6) is a copy of the upper part of Bunbury's, in Quart. Jour. Geol. Soc. London, Vol. III, 1847, pl. x. L. F. W.
[4] Misprinted "Odontopteris tenifolius."
[5] American Geology, Pt. VI, p. 105.

original of Emmons's fig. 5 on pl. iii. In my review of Emmons's plants, published in Mon. U. S. Geol. Survey, Vol. VI, pp. 105–106, I was led, judging from Emmons's fig. 5, to regard this plant as identical with *Acrostichites rhombifolius*, a fern that is characteristic of the Older Mesozoic of Virginia. An inspection of the specimen confirms me in that belief. Emmons's fig. 5, pl. iii, gives pretty well the general aspect of this, the only specimen seen. It does not, however, represent the pinnules of the lower pinnæ quite as wide and as much separated as they are in the original. The nerves of this latter are not very distinct, but they show the character of those of *A. rhombifolius*. I give in Pl. XXXIX, Fig. 4, a representation of a few of the lower pinnules on a pinna, to indicate their character on the specimen. I did not see the original of pl. vi, fig. 1. Possibly that is a different species.

## Class EQUISETALES.

### Family EQUISETACEÆ.

#### Genus EQUISETUM Linnæus.

EQUISETUM ROGERSII (Bunbury) Schimper.[1]

In the collection there are several fossils which are much flattened casts of the stems of an Equisetum and several imprints, which were made by the exterior surface of apparently the same species of plant. Both are exactly like the markings left by similar parts of *Equisetum Rogersii*, as found in the Older Mesozoic of Virginia. Hence there can be little doubt that this plant is found in North Carolina. Emmons, in American Geology, Pt. VI, p. 35, describes a form which he calls *Calamites punctatus* and refers to pl. ii, fig. 5, for a figure of it. Plate ii is absent, but pl. vi, fig. 5, gives a plant that agrees with his description.[2] In my review published in Mon. U. S. Geol. Survey, Vol. VI, p. 98, I concluded that this is not an Equisetum, but a fragment of a leaf of *Sphenozamites Rogersianus*. I saw nothing like it in the collection and have no reason to change my opinion. The original, also, of Emmons's *Equisetum columnaroides*, described in American Geology, Pt. VI, p. 35, and figured in pl. vi, fig. 3 (given by Emmons as pl. ii, fig. 3), was not seen. The casts above mentioned are quite different from each of these fossils as described by Emmons, and they show the finely striate surface so characteristic of the casts of the Virginia plant, which has been called *Calamites arenaceus*.

Emmons gives in pl. vi, fig. 9 (p. 109), the figure of a form which

[1] For synonymy, see supra, p. 241.

[2] It is pl. ii, fig. 5, of the earlier Geological Report of the Midland Counties of North Carolina, which Professor Fontaine did not use. The plates are the same in the two volumes, but pl. ii of the earlier is plate vi of the later one. On p. 349 (description of the plates) of the former, Dr. Emmons says of this figure: "Leaflet of an undescribed plant." He does not mention it in the text. L. F. W.

he named *Equisetum columnare*. This in its markings is more like the imprints made by the exterior of the stems of *E. Rogersii* above mentioned, but these last do not show the teeth on the sheath as Emmons's figure does in its upper part. The original of Emmons's figure was not seen. His *Calamites disjunctus* is an imprint of the same nature as *Calamites arenaceus*.

### Genus SCHIZONEURA Schimper.

#### SCHIZONEURA PLANICOSTATA (Rogers) Fountaine?

1843. *Calamites planicostatus* Rogers: Trans. Assoc. Am. Geol. and Nat., Philadelphia, 1843, p. 305.
1883. *Schizoneura planicostata* (Rogers) Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 14, pl. i, fig. 1.

One imprint of the interior of a stem was seen that has features presented by fossils found in the Older Mesozoic of Virginia, which I regarded as probably a new species of Schizoneura, and named it *S. planicostata*. The Williams College specimen has the same kind of raised lines or ribs on the imprint. They are decidedly wider and stronger than the lines formed by the interior of the stems of *Equisetum Rogersii* and appear to belong to a quite different plant. I do not positively identify it with *S. planicostata*, on account of the small amount of material. Emmons makes no mention of such a plant.

## Subkingdom SPERMATOPHYTA.

## Subdivision GYMNOSPERMAE.

### Class CYCADALES.

### Family CYCADACEÆ.

The cycads of Emmons's collection are the most important type of plants both in number of species and in abundance of individuals. It is important to note that they are, as Emmons states, found only in his upper series, 1,500 to 2,000 feet above the beds that contain coal.

## Genus PTEROPHYLLUM Brongniart.

### PTEROPHYLLUM DALEANUM Ward nom. nov.[1]

1857. *Pterozamites pectinatus* Emm.: American Geology, Pt. VI, p. 117, fig. 84.
1883. *Pterophyllum pectinatum* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 112, pl. liii, fig. 4.

In American Geology, Pt. VI, p. 117, fig. 84, Emmons gives a description of a cycad which he calls *Pterozamites pectinatus.* The type specimen is in his collection, and fig. 84 gives a very accurate delineation of it. In Mon. U. S. Geol. Survey, Vol. VI, p. 112, I expressed the opinion that it is a new Pterophyllum, near to *P. Lyellianum* of Dunker. An examination of the fossil shows that it is a true Pterophyllum, and a new species. It is a beautiful specimen, and remarkably well preserved for so delicate a plant. As Emmons says, the leaflets are narrow, many nerved, and stand at right angles to the strong midrib. It may be added that they are obtuse at their tips, and are thin in texture. They are a little over 1 mm. wide and 2 cm. long, and stand close together.

## Genus ANOMOZAMITES Schimper.

### ANOMOZAMITES ? EGYPTIACUS Fontaine n. sp.

Pl. XXXIX, Fig. 5.

One of the few plants that Emmons obtained from the coal-bearing portion of the Older Mesozoic of North Carolina is the fine specimen of what he calls *Sphenopteris egyptiaca.* On the slab which bears this specimen is a rather obscure imprint of a fragment of what seems to have been a large leaf. It shows only a portion of the lamina or leaflets on one side of the midrib. None of the latter are certainly preserved, for the leaflets, in part, seem to have been torn off close to it. In one or two of the supposed leaflets there is an indication that a thin strip of the midrib is still preserved. The segments look in some respects much like *Pterophyllum affine* Nath., which occurs in the Virginia beds.[2] It resembles this plant in its fine, parallel, single nerves, which go off at right angles with the midrib, but is unlike it in the great inequality of its leaflets. These stand at right angles with the midrib, and have their margins parallel. They do not show

[1] Both the earlier names are anticipated. Brongniart (Tableau, 1849, p. 62) says that his *Zamites pectinatus* (*Zamia pectinata*, Prodrome, 1828, p. 94) is a Pterozamites, and a number of authors have referred this same plant from the Oolite of Stonesfield, in England, to the genus Pterophyllum. The earliest such reference that I have been able to find is in the Précis élémentaire de Géologie, par J. J. d'Omalius d'Halloy, Paris, 1843, p. 481. It is true that these are all synonymys of Sternberg's *Polypodiolites pectiniformis* (Flora der Vorwelt, Vol. I, fasc. iii, 1823 p. 39, pl. xxxiii, fig. 1), but for that reason as well as for others the specific name must be dropped.

In naming this elegant species for Dr. T. Nelson Dale, I wish to express a small part of the gratitude that all who are interested in the subject feel toward him for bringing to light, in the manner described, this long-lost scientific treasure—the Emmons collection. L. F. W.

[2] Mon. U. S. Geol. Survey, Vol. VI, p. 66, pl. xxxii, figs. 2–4.

their tips, as they are torn off. The width of the leaflets varies from 11 mm. to 25 mm. or more, for the widest one, as shown in Fig. 5, is not wholly preserved. Possibly the plant is a Nilsonia, as the mode of attachment of the leaflets is not certainly shown. They seem, however, to have been attached to the side of the midrib. The general facies and nervation are unlike those of *Macrotæniopteris magnifolia*, even if we admit the segmentation to be identical. This plant resembles slightly the form mentioned above as figured by Emmons for *Tæniopteris magnifolia* of Rogers. Emmons says, as quoted before, that it is often, if not always, divided into segments down to the midrib.

It is, of course, not possible to determine from this amount of fragmentary material the true position of this plant. It should be noted that the expression quoted from Emmons implies that the plant is rather common, but he says nothing explicit regarding its occurrence, and does not mention the locality yielding it. It is significant that the constancy of its segmentation attracted Emmons's attention, and suggested the idea that it might not be accidental. In the hundreds of specimens from the Virginia Older Mesozoic that I saw many were variously lacerated, but it was always evident that the segmentation was accidental.

## Genus CTENOPHYLLUM Schimper.

### CTENOPHYLLUM BRAUNIANUM ANGUSTUM (Friedrich Braun) Schimper.

Pl. XXXIX, Figs. 6, 7.

1843. *Pterozamites angustus* Fr. Braun in Münster: Beiträge zur Petrefactenkunde, Vol. II, Pt. VI, p. 30.
1856. *Pterozamites decussatus* Emm.: Geological Report of the Midland Counties of North Carolina, p. 330, pl. iii, fig. 1.
1856. *Zamites graminioides* Emm.: Op. cit., p. 330 (*Dionites graminoides*, p. 349), pl. iv, fig. 11.
1856. *Pterozamites* sp. Emm.: Op. cit., p. 349, pl. iii, fig. 8.
1857. *Pterozamites spatulatus* Emm.: American Geology, Pt. VI, p. 120, fig. 88.
1857. *Dionites linearis* (*Zamites graminoides*) Emm.: Op. cit., p. 121, pl. iv, fig. 11.
1867. *Pterophyllum Braunianum* var. $\alpha$ Schenk: Foss. Fl. der Grenzschichten des Keupers und Lias Frankens, p. 164, pl. xxxviii, fig. 6.[1]
1870. *Ctenophyllum Braunianum* var. $\alpha$ (Schenk) Schimp.: Traité de Paléontologie Végétale, Vol. II, p. 144.
1883. *Pterophyllum decussatum* (Emm.) Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 111, pl. li, fig. 2.
1883. *Pterophyllum spatulatum* (Emm.) Font.: Op. cit., p. 114, pl. liii, fig. 6.

There are in Emmons's collection several fine impressions of *Ctenophyllum Braunianum* var. $\alpha$. They differ in no respect from the typ-

[1] Schenk leaves no doubt that his var. $\alpha$ here is the *Pterozamites angustus* of Braun in Münster's Beiträge. It is therefore much better to restore Braun's name with varietal rank than to perpetuate the awkward designation by a Greek letter. L. F. W.

ical form of this plant that is so common in the Older Mesozoic of Virginia. None of them, however, are as large specimens as some obtained from the Virginia beds. The number of specimens in the collection is proportionally large, and this fact seems to indicate that in the strata of North Carolina, as in those of Virginia, the fossil is a common one. Fig. 6 of Pl. XXXIX gives a portion of the midrib and parts of several leaflets taken from a specimen 9 cm. long, with numerous leaflets on each side of the midrib.

Emmons gives, in American Geology, Pt. VI, p. 121, pl. iv, fig. 11, a description of a form that he calls *Dionites linearis*. The original of this was found in his collection. The specimen shows leaflets slightly wider than those drawn by Emmons. He represents the bases of some of the leaflets as inserted on the upper face of the midrib. This appearance is caused by distortion due to pressure. The bases have slipped over slightly, owing to the creeping of the shale. The plant is, no doubt, a form of *Ctenophyllum Braunianum* var. $\alpha$ that is somewhat narrower in its leaflets than the average. Perhaps this narrowing is also due to pressure. The type specimen of *Pterophyllum decussatum* was also seen.

Emmons's fig. 1 on pl. iii gives an exact representation of this fossil. It is clearly *Ctenophyllum Braunianum* var. $\alpha$. The specimen belongs to a lower portion of the leaf, but the leaflets probably did not originally stand so exactly at right angles with the midrib. They probably were brought into this position by pressure. The shale on which these fossils are preserved seems sometimes to have crept, under the action of pressure, producing more or less displacement of the parts of the fossils.

Emmons gives, on p. 120 of his work, a description of a form which he calls *Pterozamites spatulatus*, representing it by fig. 88. The original of this was found in his collection, and it is given in Fig. 7 of this paper. Emmons's figure is erroneous and would completely mislead one. He represents all the leaflets on the right side of the midrib as showing their original terminations. None of them do this, and they were originally longer than the parts they now show. The narrowing of the leaflets toward their bases, as represented by Emmons, is much more decided than that shown in the specimen. What is present appears to be due mainly to pressure, which has in the basal parts pushed the margins down in the shale to a slight extent. The basal portions are not so far apart as Emmons represents them to be. The specimen now in question is the only one seen that has any tendency to a spatulate shape. There can hardly be a doubt that this is a distorted specimen of *Ctenophyllum Braunianum* var. $\alpha$.

### CTENOPHYLLUM BRAUNIANUM ABBREVIATUM (Friedrich Braun) Schimper.

Pl. XXXIX, Figs. 8, 9.

1843. *Pterozamites abbreviatus* Fr. Braun in Münster: Beiträge zur Petrefactenkunde, Vol. II, Pt. VI, p. 30.
1843. *Zamites obtusifolius* Rogers: Trans. Assoc. Am. Geol. and Nat., Philadelphia, p. 312, pl. xiv, lower left-hand figure.
1857. *Pterozamites obtusifolius* (Rogers) Emm.: American Geology, Pt. VI, p. 118, fig. 85.
1857. *Pterozamites gracilis* Emm.: Op. cit., p. 118, fig. 86 on p. 119.
1867. *Pterophyllum Braunianum* var. β Schenk: Foss. Fl. der Grenzschichten des Keupers und Lias Frankens, p. 164, pl. xxxviii, fig. 2.[1]
1870. *Ctenophyllum Braunianum* var. β (Schenk) Schimp.: Traité de Paléontologie Végétale, Vol. II, p. 144.

Emmons, in American Geology, Pt. VI, gives on pp. 118–119 a description, with figs. 85, 86, of two cycadaceous forms, which are the var. β, with shorter leaflets, of Göppert's *Ctenophyllum Braunianum*. Numerous specimens were seen in his collection of cycad leaves that range in character from the smaller leaf, which he calls *Pterozamites gracilis*, to the larger form, which he names *P. obtusifolius*. Leaves with still larger leaflets, belonging, however, to this species, occur in the collection. Figs. 8 and 9 of Pl. XXXIX show common forms of the leaves seen. To judge from the number of specimens collected by Emmons, this plant must have been one of the most common ones in the Older Mesozoic of North Carolina. It was not seen in the Virginia strata. The leaflets are not quite so obtuse as Emmons has represented them in both his *P. obtusifolius* and *P. gracilis*.

### CTENOPHYLLUM LINEARE (Emmons) Fontaine.

1857. *Pterozamites linearis* Emm.: American Geology, Pt. VI, p. 120, fig. 87.
1883. *Ctenophyllum lineare* (Emm.) Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 114, pl. liv, fig. 2.

Emmons gives a description of a small cycad which he calls *Pterozamites linearis*. His fig. 87 is a very good representation of the plant, as is shown by the type specimen, which occurs in his collection. It is the only specimen seen of this cycad. It seems to be a Ctenophyllum of the same type as *C. Braunianum* var. β, and possibly may be a narrow abnormal form of it. It is, however, probably a distinct species, as the leaflets are much narrower and more crowded than those of *C. Braunianum* var. β.

[1] Schenk here leaves no doubt that his var. β is the *Pterozamites abbreviatus* of Braun in Münster's Beiträge. It is therefore much better to restore Braun's name with varietal rank than to perpetuate the awkward designation by a Greek letter.

L. F. W.

CTENOPHYLLUM ROBUSTUM (Emmons) Fontaine.

Pl. XXXIX, Fig. 10.

1857. *Pterophyllum robustum* Emm.: American Geology, Pt. VI, p. 122, fig. 91 on p. 123.
1857. *Pterophyllum robustum* var.? Emm.: Op. cit., p. 123, fig. 92.
1857. *Pterozamites obtusus* Emm.: Op. cit., p. 119, fig. 86a.
1883. *Ctenophyllum robustum* (Emm.) Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 116, pl. liv, figs. 6, 7.
1883. *Ctenophyllum Emmonsi* Font.: Op. cit., p. 113, pl. liv, fig. 1.

Emmons gives, in American Geology, Pt. VI, pp. 122, 123, figs. 91, 92, a description of a cycad which he calls *Pterophyllum robustum*. I did not find in his collection any form corresponding to his fig. 92, which represents the terminal portion of a leaf. Only one imprint with its reverse was seen. This is evidently the original of Emmons's fig. 91. This figure represents the ends of the leaflets as entire, whereas the specimen shows, on careful inspection, that the original tips are wanting. The plant may be a Pterophyllum, but the oblique position of the leaflets seems to be the natural one. It is more likely to be a Ctenophyllum.

I did not see the original of Emmons's fig. 86a, given to represent what he calls *Pterozamites obtusus*. The plant represented by it does not seem to be different from *Ctenophyllum robustum*. Pl. XXXIX, Fig. 10, gives a representation of some of the leaflets of *C. robustum*, to show how the ends of the fragments of leaflets were left in such shape that casual inspection might determine them to be true tips. Emmons's fig. 91 gives correctly the dimensions of the leaflets, their closely crowded, oblique position, and the number (8 or 9) of the strong nerves. But the leaflets narrow slightly toward their tips and are somewhat decurrent.

## Genus PODOZAMITES Friedrich Braun.

PODOZAMITES LONGIFOLIUS Emmons.

Pl. XL; Pl. XLI.

1856. *Cycadites longifolius* Emm.: Geological Report of the Midland Counties of North Carolina, p. 330.
1856. *Podozamites longifolius* Emm.: Op. cit., p. 331.
1857. *Cycadites longifolius* Emm.: American Geology, Pt. VI, p. 115, fig. 82.
1857. *Podozamites longifolius* Emm.: Op. cit., p. 116, fig. 83.
1883. *Dioonites longifolius* (Emm.) Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, pp. 111, 122, pl. liii, fig. 5.
1883. *Podozamites Emmonsi* Font. non Newb.: Op. cit., p. 77, pl. xxxiii, fig. 2.

Emmons gives, in American Geology, Pt. VI, p. 116, fig. 83, a representation of a fine cycad which he calls *Podozamites longifolius*. The figure unfortunately represents a distorted specimen, and hence the true facies of the plant is not given. I found among Emmons's specimens a number of well-preserved impressions of a fine plant that had not been described in his account of the North Carolina fossils. A careful examination of them, and of the cycads described by him, convinced me that these apparently new plants are the undistorted forms of the plant given in his fig. 83. Notwithstanding the fact that Emmons's description and figure give an incorrect impression, I shall retain his name for the plant, as there is no convincing evidence that it is not a Podozamites, while the specific name *longifolius* is justified by the length of the fragments of leaves. These indicate that the entire leaves must have had great length. In the same work (p. 115, fig. 82) Emmons gives a description of a form which he calls *Cycadites longifolius*. His figure does not indicate the presence of a midrib, a fact mentioned by Emmons. He states that the midrib is indicated only by a longitudinal channel, because "the frond adheres to the rock by the back." From this he does not seem to have distinctly seen a midrib. I have seen in the collection no cycad with a midrib like this figure, but some of the forms of *Podozamites longifolius* strongly resemble it. Moreover, in *P. longifolius*, which has thick leaflets, there is often a deceptive appearance, which at first sight gives the impression of a midrib. Careful inspection, however, shows that it is due either to a wrinkle in the middle of the leaflets or to a film of carbonaceous matter that remains there. In both these species of Emmons the leaflets are represented as not narrowing much at their insertion on the midrib. That is due to the fact that both of the specimens figured present their lower surface uppermost, and the actual insertions are covered by the broad midrib. Specimens of *Podozamites longifolius* that present their lower face uppermost have the insertions of their leaflets disguised in this way.

The following may be given as the description of *Podozamites longifolius*:

The texture was thick and apparently leather-like. The leaves probably attained the length of half a meter or more. The general facies of the leaf is much like that of *Dioonites Buchianus*, having the leaflets of the lower part of the midrib so set on the midrib as to make an angle with it of 45° or more. Toward the summit of the leaf the leaflets are inserted under more and more acute angles, while at the summit there is a terminal leaflet that is found in the direction of the prolongation of the midrib. Pl. XL gives a form that belongs to perhaps the middle of the leaf. It shows the true attitude of the leaflets only in the lower ones on the right-hand side, the others going off under too large an angle, owing to distortion from pressure. The midrib is strong and ridged. Portions were seen 6 to 7 mm. wide, but these were not the largest parts, as the petioles and basal portions are represented in none of the fossils. The texture of the leaflets was thick and leathery, so as to hide the nerves. These could not be seen distinctly, but they appear to have the character of those of Podozamites. The leaflets are widest not far above their bases, and grow narrower very slowly toward their tips. They end in a lancet-shaped tip. At their bases they are abruptly narrowed and rounded into a very short petiole, by which they are inserted on the midrib. They are then in general shape linear. Pl. XL gives the specimen with the largest ones seen, and these have probably the maximum size attained. In this specimen the tips of none of the leaflets are preserved, but enough is shown to indicate that they were a little more than 7 cm. long. Their maximum width is 6 mm. The insertion of the leaflets on the midrib is mostly on the side. In some the insertion seems tc be on the upper face of the midrib and slightly within its margins. Possibly this appearance may be due to pressure, which has caused the bases to slip over on the upper face of the midrib. The insertion is made by what does not seem to be a true petiole, but rather a much narrowed and thickened portion of the base. Pl. XLI shows a form that is the terminal portion of a leaf, and it is apparently the terminal part of the leaf the lower portion of which is represented on Pl. XL. Here the leaflets grow smaller and shorter and are set on more and more obliquely. This part of the leaf seems to end with a leaflet lying in the direction of the prolongation of the midrib.

As shown by the specimens collected by Emmons, there are in the Older Mesozoic strata of North Carolina at least two species of this type of plant. Emmons detected this fact. He described the form with larger leaflets in American Geology, Pt. VI, p. 116, pl. iii, fig. 7, calling it *Podozamites lanceolatus*. As it is not the *P. lanceolatus* of the Jurassic, Dr. Newberry suggested that it be named *P. Emmonsii*. Emmons's figure of it is not very good. It is clearly a different species from *P. longifolius*. I found a plant in the Older Mesozoic of Virginia of the same type with Emmons's species, and with some hesitation identified it with the latter,[1] from oversight, not crediting Dr. Newberry with suggesting the specific name *Emmonsii*. Since I have had the opportunity to examine Emmons's specimens I am satisfied that the Virginia fossil is not the same as the larger form, which must retain the name *Emmonsii*, but is *P. longifolius*. There is a marked resemblance between this type of plant and the genus Nageiopsis of the Younger Mesozoic of the Potomac formation. I am inclined to the opinion that such plants as *Podozamites Emmonsii*, *P. longifolius*, and *P. tenuistriatus* are not cycads, but conifers allied to the Nageia section of Podocarpus, and perhaps ancestral forms of Nageiopsis. Of course, until they show branching forms, or some other feature not belonging to the cycads, they must be left in the old group of Podozamites.

[1] Mon. U. S. Geol. Survey, Vol. VI, pp. 77, 78, pl. xxxiii, fig. 2.

### PODOZAMITES EMMONSII Newberry.

Pl. XLII, Figs. 1, 2.

1856. *Podozamites lanceolatus* Emm. non (L. and H.) Fr. Braun: Geological Report of the Midland Counties of North Carolina, p. 331, pl. iii, fig. 7.
1857. *Podozamites lanceolatus* Emm.: American Geology, Pt. VI, p. 116, pl. iii, fig. 7.
1866. *Podozamites Emmonsii* Newb. in Pumpelly: Geological Researches in China, Mongolia, and Japan; Smithsonian Contributions to Knowledge, No. 202, p. 121, pl. ix, fig. 2.

The figure given by Emmons of this plant, as before stated, is, I think, misleading. I did not find the specimen that he illustrated, but saw others that appear to belong to this species. They are not *P. longifolius*, and agree pretty well with Emmons's figure. If we may judge from these, the figure mentioned makes the leaflets too rigid in aspect, with a petiole too long and strong. The basal portions, also, are made to appear too thick. Emmons makes all the insertions of the leaflets well within the margins and on the upper face of the midrib. They appear to be arranged in a long spiral, like those of *P. longifolius*. Some of the insertions are on the upper face and some on the side. The leaflets contrast strongly with those of *P. longifolius*. They are thin in texture and show the nerves very distinctly. The latter are as given by Emmons. The leaves are wider, in proportion to their length, than those of *P. longifolius*, but the width, in proportion to length, is not quite so great as is given by Emmons. Fig. 1 of Pl. XLII gives the most complete specimen seen by me. It is much more fragmentary than the specimen figured by Emmons. The leaflets appear to be more deciduous than those of *P. longifolius*. Emmons mentioned that some of the detached leaflets are half an inch wide. I saw none so large. Fig. 2 shows the largest seen. Possibly this is a different species from both of those described.

### PODOZAMITES TENUISTRIATUS (Rogers) Fontaine.

Pl. XLII, Fig. 3.

1843. *Zamites tenuistriatus* Rogers: Trans. Assoc. Am. Nat. and Geol., Philadelphia, p. 314.
1883. *Podozamites tenuistriatus* (Rogers) Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 78, pl. xlii, figs. 2, 3, 3a, 3b, 4, 5; pl. xliv, fig. 3.

Emmons does not seem to have seen in the North Carolina beds *Podozamites tenuistriatus*, which, perhaps, is the most common cycad of the Older Mesozoic of Virginia. His collection at Williams College, however, shows several well-characterized specimens of this species. They agree best with the larger forms as shown in the Virginia beds, but some of the leaflets are rather larger than any seen in the Virginia strata. Pl. XLII, Fig. 3, represents one of the specimens with small leaflets.

PODOZAMITES ? CAROLINENSIS Fontaine n. sp.

Pl. XLII, Fig. 4.

One of the specimens in Emmons's collection seems to be a Podozamites of a species different from any hitherto described. It is nearest to *P. tenuistriatus*, but has leaflets that are decidedly larger than any shown by that plant, besides differing in other respects. I hesitate to regard it as a new species, on account of the small amount of material, only one specimen being seen. This specimen is the terminal portion of a leaf. It is well preserved. The lowest leaflets seen go off at an angle of about 40°. Higher up they are more obliquely placed. The terminal ones lie in the prolongation of the midrib. The leaflets are long in proportion to their width. None of them are entire. The longest fragment seen is 5 cm. long, indicating an original length of about 7 cm. At their bases they narrow gradually, so that the basal part is elliptical in shape. They are attached to the side of the midrib by a very short, thickened, much narrowed portion of the leaflet. In the leaflets lower down on the midrib this thickened portion may appear as a petiole, and the leaflets may be in part attached to the upper face of the midrib and be alternate. In this terminal portion of the leaf they are opposite. They are linear in form, varying little in width from the average, which is 3 cm. The nerves are distinct, as the texture of the leaflets was thin. They resemble those of *P. tenuistriatus*, being fine and closely placed. Possibly this is a large variety of *P. tenuistriatus*, but the dimensions of the leaflets at the end of the leaf, as seen here, indicate a much larger plant. The general aspect of the specimen, and especially of the terminal leaflets, reminds one strongly of *Dioonites Buchianus* of the Lower Cretaceous, but the basal portions and mode of attachment of the leaflets are different.

Genus OTOZAMITES Friedrich Braun.

OTOZAMITES CAROLINENSIS Fontaine.

Pl. XLII, Figs. 5, 6.

1857. *Albertia latifolia* Emm. non Schimp.:[1] American Geology, Pt. VI, p. 126, fig. 95.
1883. *Otozamites carolinenesis* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, pp. 117, 118, pl. lii, fig. 6.

Emmons has given, in Pt. VI, pp. 126, 127, fig. 95, a description of a fossil which he names *Albertia latifolia*. The original of this is in his collection at Williams College, and besides that, some detached leaflets and a second imprint showing several attached leaflets. The original of Emmons's fig. 95 is preserved on an argillaceous sandstone, which is not fitted to retain the finer details, and, in addition, the

[1] See letter of M. René Zeiller to Jules Marcou, cited above (p. 270).

specimen is much distorted by pressure, so that it does not appear so distinct as Emmons has represented. The stem to which the leaflets were attached is not so continuous or well defined as it is given in the figure. It is broken up, and, in places, pressed down into the sandy material. None of the leaflets are so distinctly outlined and entire as he makes some of them to be. The striation that he gives on them is not shown in the original, for the rock is too coarse in texture to show any such feature. The leaflets are, in fact, so distorted from the doubling down of their margins into the rock that the true character of the plant could hardly be made out from this specimen. Fortunately the imprint given in Pl. XLII, Fig. 5, has one leaflet, the lower right-hand one, that possesses still enough of its original character to give a good idea of it. All the others on this specimen are imperfect. Even this best-preserved leaflet has the lower portion of its base doubled under and hidden in the rock, and the outer or lower margin is also slightly bent down into the rock. Still, from this and other leaflets seen, a good deal of the true nature of the fossil can be made out. The character seems to be as follows:

The stem is rather stout. The leaflets had a rather thick, leathery texture, as they leave a black, shining film. On this specimen they are nearly opposite in position. The exact mode of attachment, owing to distortion, can not certainly be made out, but they appear to be inserted on the upper face of the stem, slightly within its margin. The attachment is made by the lower portion of the base of the leaflet, which is prolonged down the stem, making the leaflet decurrent. The upper portion of the base is larger and in the form of a rounded ear, which is free and curves more or less freely to the stem. The leaflets are subrhombic and slightly falcate in form, with obtuse tips. They were about 2 cm. long from the attachment to their tips, and 1 cm., or a little more, wide. The nerves are rather strong. They radiate from the point of attachment and fork repeatedly. The branches curve strongly away from the central line of the leaflets, so that they meet its margins under a large angle. There is no true midrib, but the central nerve is stronger than the others and splits up into branches, which, in turn, fork several times.

This plant may be a fern. It is certainly not Albertia. It is much like *Otozamites Beanii* (*Cyclopteris Beanii* of Lindley and Hutton), being near the smaller form given in Foss. Flor. of Great Britain, Vol. I, pl. xliv.

Pl. XLII, Fig. 5, gives the form with attached leaflets, one of which is better preserved than any in Emmons's figure, and Fig. 6 is a partial restoration of this, enlarged two diameters to show the nervation and probable original character of the leaflets.

## Genus CYCADITES Sternberg.

### CYCADITES ACUTUS Emmons.

1856. *Cycadites acutus* Emm.: Geological Report of the Midland Counties of North Carolina, p. 330.
1857. *Cycadites acutus* Emm.: American Geology, Pt. VI, p. 114, fig. 81.

In American Geology, Pt. VI, p. 114, fig. 81, Emmons describes a plant which he calls *Cycadites acutus*. There is in the collection a specimen which is clearly the original of fig. 81. The figure gives the general aspect of the plant fairly well, but it is erroneous in some points. The leaflets are not quite so stiff looking and thick as the figure shows them. None of them have their tips preserved, whereas the figure represents several retaining their entire original length. The leaflets were probably wider originally than they appear to be now, as their margins are slightly doubled under in the shale by pressure. The specimen shows that the general form, mode of insertion, and falcate curvature of the leaflets are well represented in Emmons's figure. The point in which the figure is most misleading is the midnerve of the leaflets. It is wider than is given in the figure. The midrib might, as now seen, be exaggerated by pressure. It seems to separate the leaflets from base to tip into two narrow parts, which look like two very narrow leaflets, so that they appear to be placed in closely approximate pairs.

### CYCADITES TENUINERVIS Fontaine.

Pl. XLIII, Fig. 1.

1883. *Cycadites tenuinervis* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 84, pl. xliv, figs. 4–6.

Three specimens of a cycad were found in Emmons's collections that are exactly like *Cycadites tenuinervis*, a plant found in the Older Mesozoic of Virginia, and not hitherto noted in the North Carolina beds. They show the falcate curvature of the leaflets and the slender, rather vaguely defined midrib that are characteristic features of the Virginia fossil.

The specimens are portions of leaves, showing a number of closely placed leaflets, that, in the different imprints, show considerable variation in size. The smallest are about 1 cm long; the longest are 2 cm. in length. They are widest near their bases and taper gradually to their ends, which are lancet-shaped and rather obtuse. Emmons does not give their locality. The general aspect of the leaflets is much like that of *Ctenophyllum Braunianum* var. β, and, but for the midrib, they might be taken as belonging to this plant. They have a thick texture and are about 2 mm. wide in their widest part.

## Genus ZAMIOSTROBUS Endlicher.

### ZAMIOSTROBUS VIRGINIENSIS Fontaine.

Pl. XLIII, Fig. 2.

1857. *Lepidodendron* sp. Emm.: American Geology, Pt. VI, p. 124, figs. 93, 94 on p. 125.

1883. *Zamiostrobus virginiensis* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 85, pl. xlvii, figs. 4, 4a, 5, 5a.

1883. *Zamiostrobus* sp. Font.: Op. cit., p. 117, pl. liv, fig. 10.

In the collection of Emmons there is an imprint of a cycadaceous form that seems to be identical with fossils found in the Older Mesozoic of Virginia and named by me *Zamiostrobus virginiensis*. The specimen has Emmons's field label, marked Lepidodendron. From this he probably regarded this plant as of the same general nature as those fossils which he mentions on pages 124 and 125 of his work, as having the external marks similar to those of Lepidodendron. He gives figures of two of these (figs. 93, 94) and speaks of them as branching. If they branch they are probably some conifer. The fragment seen by me is a portion of an imprint of a stem or cone. Not enough is shown to enable one certainly to make out the size and shape of the original. It seems to have been of small size. Its original shape seems to have been oblong with at least one end truncately rounded off. To the unaided eye the scars, which are of small size, appear as crescent-shaped depressions, transverse to the axis of the cone. Examined closely with the help of a lens, they are seen to be leaf scars of the same character as those shown by *Cycadeoidea Emmonsi*, but decidedly smaller. They have their present form from having been distorted by pressure, which has caused a creeping of the rock matter in the direction of the axis of the fossil, so as nearly to close up the scars in that direction. It is quite possible that this is an imprint of a cycad trunk of the same kind as *Cycadeoidea Emmonsi*. If so, this specimen must have been a still smaller trunk. It is noteworthy that both this fossil and the Cycadeoidea are simply impressions, apparently made by the surface of the organism. Most cycad trunks are petrifactions.

## Class BENNETTITALES.

## FAMILY BENNETTITACEÆ.

### Genus CYCADEOIDEA Buckland.

### CYCADEOIDEA EMMONSI (Fontaine) Ward.

Pl. XLIII, Fig. 3.

1857. Impression or cast of a part of a trunk of a cycad Emmons: American Geology, Pt. VI, p. 123, fig. 92a on p. 124.
1883. *Zamiostrobus Emmonsi* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 117, pl. lii, fig. 5.
1894. *Cycadeoidea Emmonsi* (Font.) Ward: Proc. Biol. Soc. Washington, Vol. IX, p. 86.[1]

Emmons, in Pt. VI, pp. 123, 124, fig. 92a, gives a description of an imprint of a trunk of a small cycad which he does not name and for which he gives no locality. The original of this is probably the form given in Fig. 3 of Pl. XLIII. If so, Emmons's figure does not give a good representation of it, either for the shape of the trunk or for the character of the leaf scars. Nearly the whole of the trunk is

[1] On the occasion of my visit to Williams College, mentioned above (p. 276), I found the original of Emmons's fig. 92a, and after a somewhat careful examination of it, I took the following notes:

"This is nothing but a thin slab of light-colored shale bearing on its reverse side an impression of a very broad cycadean leaf. The slab is only 15 mm. thick. It is fissile and other plant impressions occur at other planes of cleavage within it, as seen by their projecting ends. On the side of the cycad a label is glued, on which are written, probably in Dr. Emmons's hand, these words: 'Impression of a trunk of a cycad.'

The right half of the impression is dark or nearly black, due to a thin deposit of carbon. This is partly worn off by handling, but remains at the bottom of the depressions. On the left it gradually fades out and probably never existed near the left margin. It is probable that the rounded conical form at the top and on the right side correctly represents that of the trunk, but on the left below the slab is so broken as to carry away a part of the impression. The general concavity is slight, and if it indicated the curvature of the surface the trunk would have been rather large, but from the small size of the scars and their spiral arrangement it seems to have been small, or not more than twice the diameter of the impression.

With the exception of the abrupt break on the left the cleavage all round is in the nature of a diagonal cross fracture from one natural plane to the next below it, and although not shining seems to be a slickenside. This condition gives the impression a sort of relief. It is evident that the top of the impression does not reach the top of the trunk, and the whole represents a small area of the side of a trunk near the top. It is difficult to determine the exact position of the axis, but the impression is probably nearly vertical. The impression is 7 cm. high and 6 cm. wide, maximum measurements.

The leaf scars are arranged in two spiral rows, those arising from left to right being nearly horizontal, but curving so as to have an angle near the summit of about 45°. The other set of rows are vertical at the lower end, but curve slightly to the left, reaching the summit at an angle of 10° or 15°. The scars are very small and almost exactly rhombic, with a large difference between the long and short sides. The long diagonal, which is usually nearly vertical, is about 7 mm. and the short, nearly horizontal one 4 mm. The long side is nearly 5 mm. and the short side scarcely more than 3 mm.

The ramentum walls are over 1 mm. thick, with a distinct central raised ridge, which probably represents a commissure. As the scars are depressions surrounded by these walls, it is evident that the bases of the petioles were present and rose above the ramentum walls, also that their outer ends were convex, so as to produce these concave depressions.

There is nothing on the impression from which the existence of fruiting axes or buds can be preserved so as to show its original dimensions and form. It was evidently unusually small, the height being only 6 cm. and the maximum width probably 8 cm. A portion of the right-hand side is missing, so that the entire original width is not shown. The shape was approximately broadly elliptical or bulbous. At the top is what seems to have been the growing bud. This appears to have been pressed down upon the sandy shale, which has preserved the imprint. It is merely an imprint, and not, as is commonly the case, the petrifaction of the trunk itself. The leaf scars are remarkably distinct, and they are rather small, as might be expected from the size of the trunk. They are approximately rhombic in form, about 6 mm. long and 4 mm. in height, the longer dimension being transverse to the axis of the trunk. They have a raised margin surrounding a depressed rhombic space. The upper and lower angles of the scar are more or less rounded and the lateral ones drawn out. The form clearly belongs to a new species of the group Cycadeoidea.

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inferred. The irregularity in the lower right-hand corner seems to be the result of defective preservation."

The specimen was sent to the University of Virginia, along with the other types requiring to be drawn, and came back to Washington with the rest. It was very carefully drawn by Mr. F. von Dachenhausen of the Division of Illustrations of the United States Geological Survey, under my immediate supervision and with the aid of all the descriptions and figures that had been made of it, including Professor Fontaine's fresh notes and my own, as quoted above. We fully discussed the question of orientation, especially in view of the fact that Professor Fontaine, in copying Dr. Emmons's figures, had reversed it, believing that Dr. Emmons had misinterpreted its nature. I have recently had occasion to examine and minutely describe several hundred specimens of cycadean trunks from the Mesozoic deposits of the United States, especially from the Potomac formation of Maryland, the Lower Cretaceous of the Black Hills, and the Jurassic of Wyoming (see infra., pp. 382–417). I also visited in 1894 the principal museums of Europe where collections of such trunks exist, notably the British Museum at South Kensington and the Geological Museum at Bologna, and I have thus made myself somewhat familiar with the nature of these objects. I was satisfied at a glance at Emmons's figure that he was right in regarding the impression as that of a trunk, and so stated early in 1894 (Proc. Biol. Soc. Washington, April 9, 1894, Vol. IX, p. 86).

It is true, as Professor Fontaine remarks, that such trunks are usually petrifications, having somewhat their original form and three dimensions, whereas this is only a flat impression similar to that which most other kinds of fossil vegetable remains present. Still, there is nothing in this fact that precludes the possibility of this representing a trunk. It is possible that the Triassic cycads may have been more succulent and less decidedly woody than those of the later ages. Again, the well-known petrified trunks have all been preserved under entirely different conditions. None of them occur in coal beds, but all in a more or less sandy matrix. Such is the case in the Black Hills, and the fine collection of fossil plants made by Professor Jenney in the Hay Creek coal field, at the same horizon as that of the cycads, yielded no fossilized trunks (see Nineteenth Annual Report, Part II, pp. 521-946). Any such trunks that may be found in coal beds will, in all probability, have the general character of the one now under consideration.

Special attention was paid to the true direction of the axis. The scars represent the leaf bases, and in all cases these have something like a keel on the lower side. One of the angles of the scar is therefore certain to be on the lower side, and this is one of the safest guides in finding the axis of the trunk. The position in which Dr. Emmons placed the specimen is an almost impossible one. It makes one series of rows of scars vertical and the other horizontal, or nearly so, and none of the angles are downward. By turning the bottom of his figure about 30° to the left the conditions of normal growth are fairly well satisfied. This is done in the new figure (Pl. XLIII, Fig. 3). The true apex was also found, and the spiral rows of scars encircle the trunk in a normal way and cross one another as in most other well-preserved forms.

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## Class GINKGOALES.

### Family GINKGOACEÆ.

#### Genus BAIERA Friedrich Braun.

BAIERA MULTIFIDA Fontaine?[1]

Pl. XLIII, Fig. 4.

(?) 1857. *Noeggerathia striata* Emm.: American Geology, Pt. VI, p. 127, fig. 96.
1883. *Baiera multifida* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, pp. 87, 118, pl. xlv, fig. 3; pl. xlvi; pl. xlvii, figs. 1, 2; pl. liii, fig. 1.

Emmons gives a description in American Geology, Pt. VI, p. 127, fig. 96, of a fragment, which he calls *Noeggerathia striata*. In Mon. U. S. Geol. Survey, Vol. VI, p. 118, I expressed the opinion that this is a portion of *Baiera multifida*, a plant found in the Older Mesozoic of Virginia. I did not find in the collection the original of Emmons's figure, but did see a fragment with Emmons's field label marked Baiera. This specimen, given in Fig. 4, is too poorly preserved to permit a positive determination of it. It is a carbonaceous film that shows no nerves, but only striation. It may be a Baiera, but it is most likely a stem of some kind.

## Class CONIFERÆ.

### Family TAXACEÆ.

#### Genus CEPHALOTAXOPSIS Fontaine.

CEPHALOTAXOPSIS CAROLINENSIS Fontaine n. sp.

Pl. XLIII, Fig. 5.

There is in Emmons's collection a fragment of slate carrying an impression of a conifer. It is without label, and there is nothing to show the locality yielding it. It is, however, apparently from Lockville, to judge from the character of the rock. This plant impression does not seem to have been described by Emmons, as it is distinctly different from any of those given in American Geology, Pt. VI. It is nearest to Emmons's Pachypteris, but is not this plant. The fossil in question is apparently a new species of Cephalotaxopsis, much like *C. magnifolia* of the lower Potomac formation, and it may be the ancestral form of that plant. The following description of it may be given, based on the fragment of an ultimate twig 1 cm. long, which is the only portion of it that was found:

Stem rather slender, but rigid. Leaves apparently all in one plane,

[1] As the type of Emmons's *Noeggerathia striata* was not found at Williams College, it can only be admitted with doubt into the synonymy, and the names left as they were.
L. F. W.

linear in form, with apparently subacute tips. The texture was thick and leathery. The maximum length of the leaves is 4 cm. and the maximum width, which occurs near their bases, 4 mm. They narrow gradually toward their tips and more suddenly at their bases, which are elliptical in form. They are apparently attached by a very short, twisted petiole. The midnerve is rather slender but distinct, and it is continued to the top of the leaf.

## Family PINACEÆ.

### Genus PALISSYA Endlicher.

#### PALISSYA SPHENOLEPIS (Friedrich Braun) Brongniart.[1]

Pl. XLIV; Pl. XLV, Fig. 1.

Emmons gives, in American Geology, Pt. VI, pp. 105, 106, pl. iv*a*., figs. 72, 73, a description of a plant which he calls *Walchia longifolius*, saying that it is common at Lockville. There are in his collection a number of specimens, including apparently the original of pl. iv*a*, but not those of figs. 72 and 73. If, however, that is the original of pl. iv*a*, it does not show so much of the plant as is given in this plate. Possibly it may have been broken since it was drawn. In Mon. U. S. Geol. Survey, Vol. VI, p. 107, I stated that I thought that this plant is *Palissya Braunii*. A study of the specimen confirms me in that opinion. The plant was evidently, as Emmons states, common. The largest impression of it is that given in Fig. 1 of Pl. XLIV, which is the supposed original of Emmons's pl. iv*a*. It shows a principal stem to which a penultimate twig is attached on the right-hand side. There are several large penultimate twigs, so placed on this side that they would unite with the principal stem if it were prolonged lower down. On the left-hand side there is a stout twig of penultimate order that apparently once joined the main stem lower down. The smaller stems are more or less thickly clothed with leaves. Most of the leaves, however, which were present when the fragment was entombed have disappeared. The appearance of the fossil indicates that the main stem and its branches were all thickly clothed with leaves of the same character. The larger stems are represented mainly by their imprints, but in some places a portion of the woody matter remains, which sometimes carries leaves on its sides. The leaves are distichous in the plane of cleavage of the rock. They vary slightly in dimensions and shape. The longest are 15 mm. long and 1 mm. wide in their widest portion, which is at the base. Some, however, are 5 mm. shorter, and some are rather wider and tend to an elliptical form. Perhaps some of these variations are due to distortion. The normal leaves are thin

[1] For synonymy, see supra, p. 249.

in texture, slightly falcate, linear-lanceolate, narrowing to a subacute tip, and widening to their bases. They are slightly decurrent, with their bases overlapping one another. There is a slender but distinct midnerve. These leaves are strikingly like those of *P. Braunii*, given by Saporta in his Flore Jurassique, Pal. Française, Vol. III, pl. lxviii, figs. 2, 3. There is little doubt that the plant is that species. Pl. XLIV, Fig. 2, represents an ultimate leafy twig, with leaves of the largest size, and Pl. XLV, Fig. 1, shows a portion of a stem of largest size, which still retains remains of leaves. These are pressed close to the stem and their shape is disguised. On his field labels, on some specimens, Emmons has written *Voltzia acutifolia* Brongn. No plant of this name is mentioned in American Geology, Pt. VI, and he probably changed it. The specimens so marked are *Palissya Braunii* (*P. sphenolepis*), with leaves somewhat shorter and smaller than the normal ones.

### Palissya diffusa (Emmons) Fontaine.[1]

Pl. XLV, Figs. 2, 3.

To judge from the large number of specimens in Emmons's collection, the most abundant conifer in the North Carolina beds is one with minute leaves that he in American Geology, Pt. VI, p. 105, pl. iii, fig. 2, describes as *Walchia diffusus*. It is the same as the plant that he describes as *Walchia gracile* in the same work, p. 108, fig. 75. In Mon. U. S. Geol. Survey, Vol. VI, pp. 106, 107, discussing *Walchia diffusus*, and aided only by Emmons's figure, I regarded this plant as probably a Palissya, suggesting that it be called *P. diffusa*. In the same monograph, p. 108, I gave the opinion that Emmons's *Walchia gracile* is a small form of *Cheirolepis Muensteri*, as I then thought that *Palissya brevifolia* was that plant. A careful inspection of the fossils leads me to think that the *Walchia gracile* is a small form of the rather variable *Palissya diffusa*. This latter plant is of the same general type as *P. Braunii* and *P. brevifolia*, although it differs decidedly from them in some points. It is probable that the abundance of this plant in the fossils collected is, in part, due to the nature of the tissue. The leaves are thick and leather-like, so that they remain in the form of a dense shining film that may be peeled off like paper from the stone. They seem to have been very durable. Only fragments of penultimate twigs, carrying numerous ultimate twigs, were seen. I did not see the original of Emmons's pl. iii, fig. 2, but one of the specimens seen, that given on Pl. XLV, Fig. 2, of this paper, is as large as that. Emmons's fig. 2 gives the facies of the plant very well, and shows accurately the appearance of the leaves on the ultimate twigs, with their characteristic curvature away from the stems, but he does not

[1] For synonymy, see supra, p. 250.

give the midrib of the leaves, which is distinct, although slender. He gives on the main stem leaves that are longer and straighter than those on the ultimate twigs. I did not see such leaves. They are not well preserved on the main stems of the specimens seen, but appear to be of the same nature as those on the smaller twigs, although somewhat larger. For a plant having such small leaves and slender ultimate branches the penultimate ones had remarkably large stems. One was seen 7 mm. wide. The plant may be described as follows:

Stems of the penultimate branches very stout and rigid. Ultimate branches numerous, closely placed in one plane, alternating with one another on opposite sides of the penultimate stem. They are slender and rather short, about 55 mm. long, with tips not preserved, and very uniform in length. They are thickly clothed with leaves on very slender stems. These ultimate branches have sometimes short lateral branches, with rather smaller leaves. These leaves, and those toward the tips of the ultimate branches, are smaller than the normal ones on the latter, and are often shorter, more distinct, and broadly elliptical, sometimes almost circular in form. The normal leaves on the ultimate branches are about 1 mm. wide and 3 mm. long. They are oblong-elliptical in form, with very obtuse tips. They curve strongly away from the stem, so as to stand almost at right angles with it. The midrib is distinct. As in the Palissya, above described, the leaves are decurrent at base, so as to overlap one another and cover the stem. All the leaves are remarkably firm and leathery in texture. Pl. XLV, Fig. 3, gives a penultimate twig smaller than that shown in Fig. 2.

### PALISSYA BREVIFOLIA (Emmons) Fontaine.

### Pl. XLV, Fig. 4.

1857. *Walchia brevifolia* Emm.: American Geology, Pt. VI, p. 107, fig. 74.
1883. *Cheirolepis Muensteri* Font. non (Schenk) Schimp.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 108, pl. liii, fig. 3.

The original of Emmons's *Walchia brevifolia*, as described in American Geology, Pt. VI, p. 107, fig. 74, was not seen in his collection at Williams College, but there are in it specimens of a plant that agrees so closely with it that there is little doubt that it is the same species. This fossil has no label showing its locality, but it occurs on rock exactly like that from Lockville which contains *Palissya Braunii* (*P. sphenolepis*). Only one specimen of it was seen. The specimen is a fragment of a penultimate twig, with a portion of several ultimate branches. All the branches contain leaves. The ultimate twigs are fully clothed with well-preserved ones. This plant clearly belongs to the same genus with the fossil above described as *Palissya sphenolepis*, and the leaves have the same arrangement and mode of attachment as those of that form. In other respects they are different. They are much smaller. The largest are 5 mm. long and a little over 1 mm. in width. In form they are linear-oblong, with obtuse tips. They are in two rows, with slightly decurrent bases that overlap one another. The leaves are slightly falcate and their texture is thick and leathery. They have a distinct but slender midnerve running to their tips.

To judge from the portions of ultimate twigs that are preserved, they must have been long and slender. It is possible that this may be a small form of *Palissya Braunii*, but the differences in the leaves are too many and great for one to regard it as a species. It seems best to regard it as a species of Palissya, retaining Emmons's specific name *brevifolia*, which is applicable. In Mon. U. S. Geol. Survey, Vol. VI, pp. 107, 108, I stated that I regarded it as *Cheirolepis Muensteri* Schimp. This opinion was based on Emmons's figure of the plant, which makes the leaves too acute at their tips and misses their shape.

There are two previously described plants which are sufficiently like this fossil to suggest an affinity, but not specific identity. One is *Cyparissidium septentrionale* (Agardh) Nath.[1] The form shown in Nathorst's fig. 10 is most like our plant. The other is *Palissya conferta* Feistm.[2] Feistmantel's fig. 6, pl. xlv, gives the form of *P. conferta* that is nearest to the North Carolina fossil.

### Genus PAGIOPHYLLUM Heer.

#### PAGIOPHYLLUM PEREGRINUM (Lindley and Hutton) Schenk.

Pl. XLVI.

1833. *Araucaria peregrina* L. and H.: Foss. Fl. of Great Britain, Vol. II, p. 19, pl. lxxxviii.
1849. *Brachyphyllum peregrinum* (L. and H.) Brongn.: Tableau, p. 69.
1857. *Walchia variabilis* Emm.: American Geology, Pt. VI, p. 108, fig. 76.
1870. *Pachyphyllum peregrinum* (L. and H.) Schimp.: Traité de Paléontologie Végétale, Vol. II, p. 250.
1884. *Pagiophyllum peregrinum* (L. and H.) Schenk in Zittel: Handbuch der Palæontologie, Abth. II, p. 276, fig. 192a.

Emmons gives, on page 108, fig. 76, of his work, a description of a plant which he calls *Walchia variabilis*. The specimen figured by him, and another containing a number of ultimate twigs of this conifer, are in the Williams College collection. The imprint figured is 4 cm. longer than his figure represents it to be. In Mon. U. S. Geol. Survey, Vol. VI, p. 108, I stated my conclusion, judging from this figure, that the plant is *Pagiophyllum peregrinum*, the *Araucaria peregrina* of Lindley and Hutton. An inspection of the original and of the other specimen confirms me in that conclusion. Emmons's figure does not give very well the facies of the specimen drawn. The facial leaves show

[1] Floran vid Höganäs, p. 29, pl. iv, figs. 4–15.

[2] Foss. Fl. Gondw. Syst., Vol. I, Pt. II, Pal. Indica, 2d series, pp. 85–86, pl. xxxii, figs. 9, 10; pl. xlv, figs. 4–8, 8a; pl. xlviii, fig. 4.

on the upper surface of the twig, but they are not so close together or so conspicuous as is indicated in fig. 76. They are broadly elliptical in form, and are pressed close to the stem. No doubt the elliptical form is due to the pressure. They are really of the same character as the lateral ones or those that lie in the cleavage plane of the rock. These latter are very thick and leathery in texture, with more or less of a triangular form. They are very wide toward the base and decurrent, while toward their ends they narrow rapidly and are incurved at their tips. They are markedly uniform in shape. They have a strong midnerve, which becomes very much stronger at the base. The second specimen now in the Williams College collection is a large fragment of a very fissile, argillaceous sandstone, of fine grain, that contains a number of fragments of ultimate twigs, with numerous leaves, mostly lateral or in the plane of cleavage. These twigs show very well the character given for the lateral leaves. They seem to have been quite long, and when covered with their thick, leather-like leaves, must have been rope-like. Some of the twigs on this fragment are represented on Pl. XLVI of this paper.

### Genus ABIETITES Hisinger.

#### ABIETITES CAROLINENSIS Fontaine.

Pl. XLVII, Fig. 1.

1857. *Pachypteris* sp.? Emm.: American Geology, Pt. VI, p. 112, fig. 80.

1883. *Palissya carolinensis* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 109, pl. li, fig. 5.

In American Geology, Pt. VI, p. 112, fig. 80, Emmons described a fragment of a conifer which he regarded doubtfully as a Pachypteris. In Mon. U. S. Geol. Survey, Vol. VI, p. 109, I suggested that this plant is a Palissya, and that it might be called *P. carolinensis*. The original of Emmons's figure is in the Williams College collection, and is the only specimen of the plant there. It is very imperfect, showing only a fragment of a stout ultimate twig, from which most of the leaves have been removed, those remaining being fragmentary. Emmons's figure does not give very accurately the character of the plant. Pl. XLVII, Fig. 1, is given to represent it. As Emmons states, the stem is strong. It is even stronger than is represented in his figure. The leaves are short, very thick, and coriaceous in texture. They are of the same width from base to tip, and at each end are abruptly and obtusely rounded off. They are attached by a short petiole and the midnerve is very strong and continuous to the end of the leaf. The leaves seem to be arranged in two rows, which lie in the same plane. Only the lowest right-hand leaf is entire enough to give an idea of its character. This, however, has its base defective, as it has been crushed down on the stem, and it is broken across about midway of its length. The leaves, however, were probably originally not much longer than this, and had pretty much the same shape. The plant is apparently an Abietites not hitherto described, and it may be called *Abietites carolinensis*.

## PLANTS OF DOUBTFUL AFFINITY.

### Genus ACTINOPTERIS Schenk.

#### ACTINOPTERIS QUADRIFOLIA (Emmons) Fontaine.

Pl. XLVII, Fig. 2.

1856. *Sphenoglossum quadrifolium* Emm.: Geological Report of the Midland Counties of North Carolina, p. 335, pl. i, fig. 2.

1857. *Sphenoglossum quadrifolium* Emm.: American Geology, Pt. VI, p. 134, pl. v, fig. 2.

1883. *Actinopteris quadrifoliata* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol VI, pp. 120, 121, pl. lii, fig. 3.

Emmons gives, in American Geology, Pt. VI, p. 134, a description of a plant which he calls *Sphenoglossum quadrifolium*. He gives a figure of the plant in pl. v, fig. 2. Of this plant he says: "The layer upon which the plant is preserved is soft, and hence has suffered from abrasions; but many specimens were found in the upper marly sandstone (Keuper), some single, some in two, and others with three leaves, and the base of the fourth. One is therefore restored in the figure."

In Mon. U. S. Geol. Survey, Vol. VI, pp. 120, 121, I expressed the opinion that the plant is probably an Actinopteris and suggested that it be called *Actinopteris quadrifoliata*.

In the Emmons collection at Williams College there is a specimen of this plant, the only one seen. It shows one nearly complete leaf and fragments of two others. They are wedge-shaped and grouped around a central point, which seems to be the top of a stem. There is a vacant space which seems to have been occupied by a fourth leaf, for it is placed like the leaves that are present, and the size of it suggests a missing leaf. If there had been originally a fourth leaf present they would have stood opposite one another and the four would have nearly filled a circular space, with their edges almost touching. The specimen contains now no trace of carbonaceous matter of the leaves; only an impression of them is shown. This may be the original of Emmons's figure. I could, however, see no trace of the fourth leaf mentioned by Emmons as showing its base. I am not sure that the original termination is now shown on the most complete leaf. If so, then it would be rounded in the form depicted in Emmons's figure. The leaves show distinctly only striations. There are obscure indications of nerves. If these really are nerves, then they radiate in fan shape from the base of the leaf, repeatedly forking like those of the living Gingko. Pl. XLVII, Fig. 2, represents the specimen seen.

## Genus COMEPHYLLUM Emmons.

### COMEPHYLLUM CRISTATUM Emmons.

Pl. XLVII, Fig. 3.

1857. *Comephyllum cristatum* Emm.: American Geology, Pt. VI, p. 128, fig. 97.

A single specimen of an imprint of Emmons's plant *Comephyllum cristatum* was seen in his collection. It bears his field label with that name. It may be the original of his fig. 97 of the plant described in American Geology, Pt. VI, p. 128. If so, it does not agree in some points with the figure given. This may be due to the splitting off of some portions of the shale after the drawing was made. The specimen as it now exists does not show any stem, and the narrow basal portion of the supposed leaf and the imprints Emmons supposed to be nerves, that curve to the leaf, are wanting. The imprint is too vague to show, with the small amount of material, the character of the plant. Hence I leave it with Emmons's name. The fossil seems to be a bundle of narrow pine-like leaves, each with a single nerve, that diverge from a common point and curve around to the right. The group gives the appearance of a cock's tail. There is no trace of a membrane or lamina between the leaves. The linear imprints are not nerves, but appear to be acicular leaves. It is most like *Schizolepis Braunii* and may be that plant. Pl. XLVII, Fig. 3, represents the specimen.

## Genus LEPACYCLOTES Emmons.

### LEPACYCLOTES CIRCULARIS Emmons.[1]

Pl. XLVII, Fig. 4.

1856. *Lepacyclotes circularis* Emm.: Geological Report of the Midland Counties of North Carolina, p. 332, pl. iii, fig. 4.

1857. *Lepacyclotes circularis* Emm.: American Geology, Pt. VI, p. 130, pl. iii, fig. 4.

1883. *Araucarites carolinensis* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, p. 119, pl. xlix, fig. 8.

### LEPACYCLOTES ELLIPTICUS Emmons.

Pl. XLVII, Fig. 5; Pl. XLVIII.

1856. *Lepacyclotes ellipticus* Emm.: Geological Report of the Midland Counties of North Carolina, p. 332, pl. iii, fig. 6.

1857. *Lepacyclotes ellipticus* Emm.: American Geology, Pt. VI, p. 129, fig. 98; pl. iii, fig. 6.

1883. *Araucarites carolinensis* Font.: Older Mesozoic Flora of Virginia, Mon. U. S. Geol. Survey, Vol. VI, pp. 118, 119, pl. iii, figs. 4, 4a.

Emmons describes certain singular plant fossils in American Geology, Pt. VI, p. 129, as a new genus, which he calls Lepacyclotes. He gives

[1] Described in connection with *L. ellipticus*, below.

two species, *L. ellipticus* and *L. circularis*. These he describes on p. 130. In fig. 98, on p. 129, he gives a representation of a complete form of *L. ellipticus*, and in pl. iii, fig. 6, he depicts two scales of it. In pl. iii, fig. 4, he represents a complete specimen of *L. circularis*. The genus he describes as—

A disk or discoidal plane, formed of distinct and separate wedge-form grooved scales, arranged in a circle or ellipse, and the scales terminating outwardly in triangular laminæ, and forming around the main disk a collar of pointed scallops.

His description of *L. ellipticus* is as follows:

Disk elliptical, scales attached to an elliptical nucleus. Disk supported by or attached to a stem, which passes through the middle in the direction of its long axis. The number of scales of the disk is from twenty to twenty-four. The stem is not always visible.

His description of *L. circularis* is:

Disk or circle, formed of scales, as in the preceding, but they appear to radiate from its center. In this specimen a dark-colored, flattish, or circular body is connected to the central termination of the scales, which may have been the fruit or seed.

In addition he says:

There are certain facts connected with this plant, which are not rationally explained, on the natural supposition that they are analogous to the cones of pines or fruit-bearing bodies; for the same species of disks with their scales occur, which are less than half an inch in diameter, and in another instance the disk is formed of three concentric tiers of scales, the center one similar to the figure given, but the outer one bordering it, formed of shorter scales. It is 7 inches in diameter, and another, formed of a single row of scales, is 5 inches in the longest diameter.

Still farther on he says the detached scales are very numerous.

In Mon. U. S. Geol. Survey, Vol. VI, pp. 118, 119, I stated my opinion that these fossils are cones of some conifer near to Araucaria, the cones being mashed flat in the direction of their longer axis. I also stated my belief that the two supposed species are the same. This opinion of the fossil was based upon the assumption that Emmons found the imprints, commonly, in the complete state figured, with the features given in the descriptions.

There are in Emmons's collection numerous specimens of these fossils, some of them still bearing his field label, with the name Lepacyclotes. I examined them carefully and could find no specimen anything like his fig. 98. One specimen, that given in Pl. XLVII, Fig. 4, of this paper, is evidently the original of pl. iii, fig. 4, which represents Emmons's *L. circularis*. The other specimens are either the so-called scales detached, or attached to a circular or elliptical ring. Only a few of the latter kind were seen, and in no case was the ring complete. It is evident that the exact shape, whether it be circular or elliptical, is not significant. They both were originally circular, and the elliptic form comes from distortion. The detached parts, the so-called scales, are by far the most common forms of the plant, and Emmons has collected a large number of them. In order to give some idea of the fossil, it will be best to begin with the detached, single object, which, for convenience of description and for lack of a name, we may call a scale. There is no evidence, however, that it is a scale like that of the cone of a conifer. The epidermal tissue of the scales, which is in many cases preserved, is exactly like that of *Equisetum Rogersii*, which is seen when the exterior surface of the sheaths of this plant is shown. One of the scales is represented in Pl. XLVII, Fig. 5, which gives a complete form, as made out from a number of imperfect ones. The scale is long and narrow, gradually diminishing from one end to the other, so as to have a wedge shape. The broader end has a curving cord-like termination, which may or may not have attached to it a patch of epidermal tissue, which is approximately triangular in form. From the broad end it narrows gradually, as stated, to greater or less lengths, and in the case of detached single scales terminates with no particular shape. The detached scales have very varying. lengths, which seem to depend upon the accidental mode of preservation, rather than upon any definite original length. When the scales are grouped and attached they, with the single exception of the disk depicted in Pl. XLVII, Fig. 4, have their narrower ends radiating from a poorly defined depressed ring, which is apparently the imprint of a hollow cylinder, which stood at right angles to the plane of cleavage of the shale. This ring may be approximately circular or elliptical. It is of various sizes, and there is no indication that the space within it ever contained any carbonaceous matter. Figs. 1 and 2 of Pl. XLVIII give portions of such rings, with scales radiating from them. These are the most complete specimens seen, and the nearest approach to Emmons's *L. ellipticus* that were seen. In each scale there is a keel that starts in the cord-like rim of its broad end. Where it springs from the rim it is very broad, but narrows suddenly, and then continues narrowing very gradually until it disappears toward the narrow end of the scale. These keels look much like casts in relief of the depressed lines of the sheath of *Equisetum Rogersii* that run down between each tooth. From an examination of all the specimens I got the impression that Emmons's *L. ellipticus*, when most complete, is composed of more or less closely placed scales, radiating from the central rim, and having their cord-like terminations at the free ends connected more or less fully to form an outer ring. It is, of course, difficult to judge of the correctness of Emmons's description and figure of *L. ellipticus* unless one knows what he actually saw. It also makes a great difference in judging the character of a plant if one collects the specimens himself. Much may be seen in the rock that is ruined in collecting, and much that is significant may be neglected. Hence I feel a hesitation in coming to a conclusion in this case. If, however, I must judge from the specimens, I think his fig. 98 is ideal in large part and is a restoration that is erroneous.

The specimen of *L. circularis*, given in Fig. 4 of Pl. XLVII, and which, as stated, is probably the basis of Emmons's description quoted above, differs from the forms he calls *L. ellipticus*. The imprint is on a piece of rather soft shale, which, in the vicinity of the fossil, has a tendency to split off. It apparently has split away to some extent, carrying off a portion of the disk-like fossil, so that at present only a portion of the imprint is shown. Evidently it was originally a complete circle, 4 cm. in diameter. This circle has at its circumference a depressed cord-like groove, which corresponds to the cord-like elevated line seen at the tips of the scales of *L. ellipticus*. On the exterior of this depression there is a faint indication of a ragged fringe of epidermal tissue, but there is nothing definite like the circle of triangular teeth given by Emmons. Within the marginal circle there are narrow wedge-shaped imprints of the same general character as those of the scales of *L. ellipticus*, but much smaller and less distinct. These imprints converge to the center of the circle, touching one another, so that they completely fill the circular space which forms the disk composing the fossil. The imprints of the scales seem to have keels like those of *L. ellipticus*, but they are much less distinct and more slender. These imprints of scales disappear under an irregularly shaped patch of coal, in the form of a structureless layer, which is located around the center of the disk. This layer once evidently extended over the whole disk, but it has suffered much from handling, so that only a patch of it remains toward the central part of the disk. It is thickest on its outer edges, and thins away to nothing in the center of the disk, where the scale shows through it. There is on these imprints of scales no epidermal tissue like that on the scales of *L. ellipticus*. The dark-colored, flattish, or circular body, mentioned by Emmons as connected with the central termination of the scales, is apparently this patch of coal. It presents no appearance of being a fruit or seed, but is without structure, and has no significant shape.

The great variation in the diameter of the disks mentioned by Emmons, varying from half an inch to 7 inches, and the fact that three concentric tiers of scales were found on one disk, indicate that the plant is not a cone or inflorescence. Heer gives, in Flor. Foss. Helvetiæ, Die Pflanzen der Trias, some figures of Equisetum that may throw some light on these North Carolina plants. In pl. xxvi, fig. 2, he gives a diaphragm of Equisetum with its disk striated by lines narrowing from the circumference, converging toward the center. The outer margin of the disk has three concentric rows of triangular teeth. Pl. xxvii, fig. 2, gives a diaphragm in the form of a disk composed of ribs, which radiate from a central area, bare of carbonaceous matter, and which has attached to its circumference a row of triangular teeth.

Taking everything into consideration, I think that the detached scales, and those that radiate from a central ring, called *L. ellipticus*, are dissected stems of *Equisetum Rogersii*. They seem, while standing erect, with their lower portions buried in mud and partly filled with the same, to have had the part above the mud crushed down by pressure in the direction of the axis of the stem. This split up the free end into strips. The forms such as are depicted in Fig. 4 of Pl. XLVII are detached diaphragms of the same Equisetum.

## THE SOUTHWESTERN AREA.

We will next consider the extensive beds chiefly in New Mexico and Arizona, but probably reaching into Texas on the east, and certainly found in the State of Sonora, in Mexico.[1] They are doubtless also the equivalents of beds much farther south, near the City of Mexico and in Honduras, from which fossil plants have been reported.[2]

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[1] The following correspondence shows that the localities in Sonora are by no means exhausted, and it is much to be hoped that the plant-bearing beds may yet be traced across the Rio Grande into Texas:

NOEL, VIRGINIA, *July 24, 1899.*

Prof. LESTER F. WARD.

DEAR SIR: Some time ago Prof. I. C. White sent me a small box of fossil plants, obtained by Mr. Dumble, from Mexico. There were some six or eight species, mostly new. To judge from a slight study of them, I was struck with the perfection of their preservation and the adaptation of the slate to give good specimens. I sent a letter, through Professor White, saying that I thought the nearest plants to them were Newberry's New Mexican copper mine fossils. As the material was so promising and seemed to yield so many good plants, I asked Mr. Dumble if he could get more specimens. I send you his reply. Please return it after reading. The slate splits almost like roofing slate, and seems full of plants. A good collection of it would, I think, help immensely to our knowledge of the Triassic flora of America, giving splendid material.

Yours truly, WM. M. FONTAINE.

HOUSTON, TEXAS, *July 18, 1899.*

Prof. WM. M. FONTAINE,
*Noel, Virginia.*

DEAR SIR: Dr. I. C. White has inclosed me your letter of July 3. The plants are from the Triassic coal beds of Sonora, Mexico, the most of them being from La Barranca, where I am now working, and only a few miles from the locality at which the plants described by Dr. Newberry were collected. I have been unable to secure a copy of his paper, but a list of his determinations is given by Aguilera in his Geological Sketch of Mexico, and I have copied it in my Notes on the Geology of Sonora, New York meeting of the A. I. M. E., of which I will send you a copy as soon as my separates arrive. The field is a very interesting one, as it contains large bodies of anthracite coal and of natural coke. I have found no less than 31 distinct beds of coal, the most of which are more than 4 feet thick. The igneous rock has been forced in along the bedding planes and produces quantities of excellent coke, one bed of which I have opened to a depth of 130 feet and find it has an average thickness of over 8 feet. The slates are filled with well-preserved plant impressions and there are many large silicified tree trunks in the sands.

I will probably spend the next winter in the field, and if you would like to study the plants we can probably arrange to get you as large a collection as you can possibly wish.

Yours very truly, E. T. DUMBLE.

[2] See a letter from Professor Fontaine in the Eighth Ann. Rept. U. S. Geol. Survey, for 1886-87, Washington, 1889, p. 825, relative to a collection made in the vicinity of the City of Mexico and brought to Washington by Señor Mariano Barcena in 1884. In 1890 Señor Castillo brought another collection, which I examined, and Castillo and Aguilera, in their Bosquejo Geológico de Mexico (Boletin del Instituto Geológico de México, Nos. 4, 5, and 6, Mexico, 1897), p. 203, give a list of the species which they were able to identify from these beds. See also Dr. Newberry's article in the Am. Jour. Sci., November, 1888, 3d series, Vol. XXXVI, pp. 342-351, pl. viii.

Mr. Jules Marcou in 1853[1] describes these beds as Lias or Jurassic, and says:

According to the collection of fossil plants made by the officers of the United States Army, the beds of coal which are found at Raton Mountain, on the route from Missouri to Santa Fe, and at Muddy River, on the route to Oregon, have been recognized as also belonging to the Jurassic epoch (p. 43).

On his map he colors a small area, on the one hundred and fourth meridian and on and below the thirty-eighth parallel of latitude, which falls chiefly in the State of Colorado, but probably extends into New Mexico.

His extended paper in the Bulletin of the Geological Society of France[2] is not a translation of the work already mentioned. It was communicated to the society on May 21, 1855, and contains the general results of three expeditions made by him to the West between the years 1848 and 1854. In treating of what he calls the "terrain du nouveau Grès Rouge," he mentions the occurrence on one of the little affluents of the False Washita River, near Antelope Hills, of a silicified tree which had preserved the branches adhering to the trunk, and which, when polished, presents sections having the greatest resemblance to those of *Pinites Fleurotii* (p. 869). As near as can be judged from his description, this locality is in the western part of Indian Territory, or possibly in the Panhandle of Texas, and simply shows the extension of these deposits to the eastward.

On page 871 of the same volume he says:

One often meets in the sandstones of this stage abundant débris of silicified wood, frequently whole trees; thus on the western slope of the Sierra Madre, between Zuñi and the Little Colorado River, I encountered a veritable silicified forest, with trees 30 to 40 feet long, divided into sections 6 to 10 feet in length, and having a diameter of 3 to 4 feet. The cellular tissue has almost entirely disappeared and the wood has been replaced by a very compact silex, extremely brilliant in color, presenting magnificent specimens for jewelry work. The Indians of this region make use of them for stone ornaments and also chip arrow heads from them. These trees, some of which are seen erect embedded in the sandstone, almost all belong to the family of conifers, some to that of ferns with arborescent trunks, and to Calamodendron.

In his Geology of North America,[3] published the same year, he speaks, on page 57, of finding at his camp No. 28, at Alamo, near the Rio Puerco, "numerous fragments of fossil silicified trees," in a gray marl which he refers to the Upper Cretaceous, but says that the camp No. 28 "is again on the New Red Sandstone rocks."

Möllhausen, in his journal of a voyage[4] across the continent in 1853,

[1] A Geological Map of the United States and the British Provinces of North America, with an Explanatory Text, etc., Boston, 1853, pp. 42–44.

[2] Résumé explicatif d'une carte géologique des États-Unis et des provinces anglaises de l'Amérique du Nord, avec un profil géologique allant de la vallée du Mississippi aux côtes du Pacifique et une planche de fossiles; par M. Jules Marcou: Bull. Soc. géol. de France, 2d series, Vol. XII, 1854-55, pp. 813-936.

[3] Geology of North America, by Jules Marcou, Zurich, 1858.

[4] Tagebuch einer Reise vom Mississippi nach den Küsten der Südsee, von Balduin Möllhausen, Leipzig, 1858, p. 300.

gives a somewhat glowing account of what he saw in the valley of the Rio Secco (which is probably the Rio Puerco), accompanied by a colored plate, representing a prostrate trunk broken into sections and a stump or short projecting upright portion. Such sights are now known to be common throughout that region. Specimens of this petrified wood procured by him were conveyed to Europe and placed in the hands of Dr. Göppert, who subjected them to microscopic examination, and furnished a short report as to their internal structure and probable nature, which was published as a note at the end of this volume, on page 492.[1] Only one species was distinguished from this material, which was identified as belonging to the genus Araucarites, and which in a footnote he named, after the explorer, *Araucarites Mœllhausianus*. He did not, however, furnish the character, and it remains a *nomen nudum*.

In the geological report made by Dr. J. S. Newberry in what is known as the Macomb Report,[2] impressions of leaves or plants other than fossil wood are first mentioned (p. 69). Of the 14 species of fossil plants described in this report,[3] only 2 were found within the territory of the United States, the rest having all come from Sonora, in Mexico, collected at a point called Yaki. The American species were found in and about the copper mines in the vicinity of Abiquin, New Mexico, and there is little doubt that the Sonora specimens represent a western extension of the same great formation (see supra, p. 315, for later development of these beds).

Dr. Newberry's geological report of the Macomb expedition forms a volume by itself. It was prepared soon after the close of the expedition, but owing to the breaking out of the civil war it was not published until 1876. It consists chiefly of an itinerary. On page 69 he refers to the fossil plants from the copper mines near Abiquiu, and makes the following remarks:

> The most interesting incident of our visit to this copper mine was the discovery in the shale roof stone of thousands of impressions of plants, of which abundant specimens were procured. They are mostly cycadaceous—Otozamites and Pterozamites—with a few conifers (Brachyphyllum and Voltzia?). The species are probably new, and will not afford the means of determining with precision the age of the stratum containing them, but the discovery is of great geological interest, as showing the wide distribution of the cycadaceous flora of the Triassic and Jurassic epochs, and gives additional confirmation of the generalization of Brongniart, who characterized this epoch in the botanical history of the world as the reign of Gymnosperms.

In a footnote to this remark he says:

> Descriptions of these plants will be found in another chapter, where it is shown that the most conspicuous species (*Otozamites Macombii*) is the same with one found

[1] Ueber die von Möllhausen mitgebrachten Fragmente des Holzes aus dem versteinerten Walde, von H. R. Göppert.

[2] Report of the Exploring Expedition from Santa Fe, New Mexico, to the Junction of the Grand and Green Rivers of the Great Colorado of the West, in 1859, under the Command of Capt. J. N. Macomb; Geological Report by Prof. J. S. Newberry, Geologist of the Expedition, Washington, 1876.

[3] Pp. 141–148, pls. iv–viii.

in the Triassic strata of Los Bronces, Sonora, where it occurs in company with *Pecopteris Stuttgardiensis*, *Tæniopteris magnifolia*, and other well-known Triassic plants of Virginia, North Carolina, and Europe. We have, therefore, in these plants evidence of the Triassic age of all the variegated gypsiferous rocks of Northern New Mexico; for the Lower Cretaceous sandstones immediately overlie the plant bed of the Cobre.

In this report Dr. Newberry mentions (p. 69) and figures (pl. v, figs. 4, 5; pl. vi, fig. 9) some twigs and cones of a plant that he doubtfully refers to the genus Pachyphyllum, without assigning any specific name. For more convenient reference I will supply a specific name here, and as the genus Pachyphyllum is preoccupied and all the species are being referred to Heer's substitute, Pagiophyllum, I will call the plant *Pagiophyllum Newberryi*, assuming that the specimens all belonged to one species, although they may have represented more than one.

Major Powell, in the Geology of the Uinta Mountains, 1876,[1] was the first to give a local name to these extensive deposits. He calls them the Shinarump formation, and thus describes them:

The summit of the Shinarump group is a series of gypsiferous sandstones exceedingly friable. They have often been called marls, and the separation between them and the massive vermilion sandstone is never very distinct. The difficulty is much greater where the gypsum disappears from the lower beds, as it does in places, where they are also found to be more indurated and more or less massive sandstones. The conglomerate which is found in the middle of the group is persistent over a very large area, and the whole group is characterized throughout the entire province by the occurrence of silicified wood in large quantities. Sometimes trunks of trees from 50 to 100 feet in length are found. The Shinarump conglomerate is usually very hard, and weathers in such a manner as to form hog backs or cliffs, and the softer gypsiferous beds above, when carried away by rains, leave behind fragments of this silicified wood, so that the Shinarump conglomerate is often covered with great quantities of this material. Shinarump means literally "Shin-au-av's rocks." Shin-au-av is one of the gods of the Indians of this country, and they believe these tree trunks to have been his arrows (pp. 68–69).

As already remarked, the silicified wood, which is found in Arizona and New Mexico, has long been the subject of popular admiration, and has been mentioned in many periodicals ever since emigration commenced to cross the plains. Some of this petrified wood is very beautiful, admits of a high polish, and is capable of being worked into a variety of useful objects. Two large trunks of this material were shipped in 1879 by the War Department to the Smithsonian Institution, an account of which will be found in Vol. V (1882) of the Proceedings of the United States National Museum, by Lieuts. J. T. C. Hegewald and P. T. Swain.[2]

With regard to these silicified and agatized trunks, the economic point of view has been particularly dwelt upon by Mr. George F.

[1] Report on the Geology of the Eastern Portion of the Uinta Mountains and a Region of Country Adjacent thereto, by J. W. Powell. U. S. Geog. and Geol. Surv. Rocky Mountain Region. Washington, 1876, 4.°

[2] Information concerning some fossil trees in the United States National Museum, by Lieut. Col. P. T. Swain, U. S. A., and Lieut. J. T. C. Hegewald, U. S. A.: Proc. U. S. Nat. Mus., 1882, pp. 1–3.

Kunz in a series of notes and papers[1] on jasperized and agatized woods of Arizona, and in his work on Gems and Precious Stones of North America, New York, 1890, pp. 135ff; more especially in the second edition, 1889, pp. 135, 137, and Appendix, pp. 352–355.

Portions of these trunks, which were long on exhibition at the National Museum, were examined by Dr. F. H. Knowlton and found to exhibit internal structure with sufficient clearness to be capable of microscopic study. Slides were prepared and the results of his investigation were published in the Proceedings of the Museum.[2] Both trunks appear to have the same structure and belong to the same species, and the generic determination was practically the same as that of Möllhausen, viz, Araucarioxylon, formerly called Araucarites. But as Göppert failed to describe or figure Möllhausen's specimens, it was impossible for Dr. Knowlton to tell whether he had the identical species or not; he was therefore obliged to give it a specific name, and called it *Araucarioxylon arizonicum*.

A collection of fossil plants was made by Major Powell in the fall of 1886 in the vicinity of Abiquiu, New Mexico, among the copper mines. It consists largely of vegetable impressions belonging to the Cycadaceæ, etc. A second collection was made in 1889 by Dr. F. H. Knowlton, both in the same region last mentioned and also among the petrified forests of Arizona and New Mexico. This latter collection is quite large and very important, especially that of the silicified wood, as he visited nearly all of the best localities, and with his practiced eye selected only such material as was capable of successful scientific investigation. The plant impressions of both these collections have been examined by Professor Fontaine, and Dr. Knowlton has found the wood of the copper mines to be the same as that thus far identified from the plains.[3]

There is no part of the American Trias that possesses greater interest for the geologist and paleontologist than this great southwestern area, and yet we have, as the above record shows, exceedingly meager scientific data respecting it. The petrified forests of Arizona are now celebrated, and a movement has been set on foot to have the most important tract in that Territory set apart as a national park. Before I had heard of this movement I had planned to make at least a reconnaissance into the region on my return from the Pacific coast in the fall of 1899, but before I left Washington in August the matter had been brought forcibly to my attention by a letter from the honorable Commissioner of the General Land Office to the Secretary of the

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[1] Trans. New York Acad. Sci., Vol. V, 1885, pp. 9–11; Pop. Sci. Monthly, January, 1886, Vol. XXVIII, pp. 362–367 (copied in Scientific American Supplement, Vol. XXI, February 6, 1886, p. 8418); Exchangers' Monthly, Vol. I, Nos. 6–8, 1886.

[2] New species of fossil wood (Araucarioxylon arizonicum) from Arizona and New Mexico, by F. H. Knowlton: Proc. U. S. Nat. Mus., Vol. XI, 1888, pp. 1–4, pl. i.

[3] Notes on Triassic plants from New Mexico, by Wm. M. Fontaine and F. H. Knowlton: Proc. U. S. Nat. Mus., No. 821, Vol. XIII, 1890, pp. 281–285, pls. xxii–xxvi.

Smithsonian Institution, which the latter had referred to me. On stating my intention to visit the region, I was requested, and subsequently instructed, to collect data and make a report covering both the scientific and the practical aspects. This I did, and my report was submitted to the Director of the United States Geological Survey on December 12, 1899.[1]

An account of the results of my operations in this field will have a considerably broader scope than that of the report just mentioned, as they covered a large amount of territory more or less remote from the region popularly known as the petrified forests, extending as far west as Supai, and north to the Grand and Marble canyons, including an expedition down the Litttle Colorado on its right bank to the crossing of the Lee's Ferry road, 70 miles below Winslow.

Owing to the almost entirely volcanic character of the great region occupied by the Bill Williams Mountain, San Francisco Mountain, Kendricks Peak, and the Elden Mesa, it was impossible for me in so short a time to work out the stratigraphy of that region, but that there are Triassic remnants in it seems certain. Petrified wood was found at the most westerly point examined, viz, a mile northwest of Supai. I was informed from a reliable source that large silicified logs occur 3 miles west of Williams.

The Colorado Plateau to the north, as is well known, is occupied by Carboniferous limestone, and this extends eastward to near the Little Colorado. Dr. Newberry observed that this limestone—

> descending from the San Francisco Mountain, * * * showed a dip to the northeast of at least 100 feet to the mile; and before reaching the [Little Colorado] river it passed under beds of red shale and sandstone, which are conformable with it. This sandstone is deep blood red in color, is soft, and eroded into fantastic blocks and masses, of which the surfaces are most curiously etched and carved by weathering. Above these heavier beds are soft, red, argillaceous shales, with layers of red and green, foliated, ripple-marked, fine-grained, micaceous sandstones, all without fossils. Such is the geology of the south bank of the river. On the north bank the red shales appear at intervals, but are usually concealed by alluvial soil, sand, and gravel. About 7 miles from the river the valley is bounded by a mesa wall nearly 1,000 feet in height, of which the base is formed by the red shales and sandstones before described.[2]

The party were then on the northeast side of San Francisco Mountain, and the Permian beds are reached some distance southwest of the Little Colorado. On the south side of the volcanic area, the principal vents of which formed the San Francisco and Kendricks peaks, Mount Sitgreaves, the Elden Mesa, and Bill Williams Mountain, no one seems to have reported any sedimentary strata higher than the Upper Carbon-

[1] Report on the Petrified Forests of Arizona, by Lester F. Ward, Paleontologist, U. S. Geological Survey; Department of the Interior, Washington, 1900; 23 pages, 8°.

[2] Report upon the Colorado River of the West, explored in 1857 and 1858 by Lieut. Joseph C. Ives, Washington, 1861, 4°. Part III, Geological Report, by J. S. Newberry, p. 75.

iferous limestones which overspread the Colorado and Kaibab plateaus and stretch away for many miles to the south and southeast, but the presence of Permian and Mesozoic remnants in many parts of this great Paleozoic terrane is one of the best-attested facts in the geology of this region,[1] and its importance as constituting the principal evidence of the former integrity of the sedimentation over this entire country has not been overlooked.

East of the volcanic area on its south side the descent to the Little Colorado is on an average about 40 feet to the mile, but the dip of the strata is still greater, and the Carboniferous passes under the red shales of the next overlying formation before the bed of that stream is reached. This holds true for the lower portions of the river at least as far northwest as the crossing of the Lee's Ferry road, 30 miles above its mouth.

I examined these red sandstones and shales on the left bank of the river from Winslow to a point 40 miles below, which practically corresponds to the space between Camp 89 and Camp 85 of the Ives Expedition, and I found scattered blocks and small pieces of fossil wood at many points. They were usually weathered out and lay on the surface, and may have all been below the horizon in which they were actually embedded, but the evidence that they belonged to the formation in which they were found is strong. The fact that this wood is not found on the Carboniferous terrane to the west, but is met with only in the sandstones, confirms this view and makes the assumption that it belongs to a higher formation which formerly overlay them improbable, to say the least. No such assumption could arise but for the fact that almost all the geologists who have treated the region have referred these saliferous red sandstones to the Permian. If they are such the wood also is probably Permian.

Below this point for many miles the east side of the valley is covered with a sheet of lava and black basaltic rock, and the surface on both sides is strewn with black bowlders of all sizes, which at Black Falls form the bed of the river. On the right bank, however, there arise terraces several hundred feet high, presenting bold escarpments of brownish-red sandstones, with occasional white limestone and gypsum beds and variegated marls. One of the gypsum beds is 10 feet in thickness. Petrified wood occurs at nearly all points, and I observed many logs in place. Still farther down on the same side, and for more than 10 miles above and below the crossing of the Lee's Ferry road, there is an exceedingly interesting series of buttes, consisting of remnants of the mesa on the northeast, which rises in successive terraces some thousand feet above the river bed, the nearest bluff being 150 feet high. Scattered over the plain at its base, with a width of more than

[1] Tertiary history of the Grand Cañon district, by Clarence E. Dutton: Mon. U. S. Geol. Survey, Vol. II, Washington, 1882. 4°, pp. 46, 68, 117ff.

a mile, stand these symmetrical cones, buttes, and knolls of variegated marls, often almost wholly of blue clay. This blue-clay stratum, 20 feet in thickness, can be seen along the base of the general escarpment overlain by red marls, and these in turn by brown or reddish sandstones, the topmost stratum being a massive sandstone. The taller buttes have the blue clay at the base and the red marls above.

Immense quantities of fossil wood occur on and around these eroded buttes, and in many cases large, much disintegrated logs occupy their immediate summits, and have been the occasion of their preservation.

At the foot of one of these buttes I found a specimen that I consider to be a petrified cone, but only the upper portion is represented for a length of 3 cm. It is somewhat compressed laterally, and the longer diameter is 3 cm., while the shorter is only a trifle over 2 cm. The transverse fracture is uneven, consisting of two unequal planes, rising at different angles toward the apex and forming an obtuse reentrant angle on one side of the center, which passes across the cone in the direction of the minor axis. On the larger face of the fracture the radiate structure is clearly shown. The surface is occupied by the thick, irregularly rhombic scales, arranged in quincunx order, varying somewhat in size, but averaging 12 mm. wide by 8 mm. high, and often showing the polygonal scars of the deciduous tips.

So far as the cone itself is concerned, it might, except for its small size, be referred to the living genus Araucaria, and the form and general appearance of the scales approach very close to those of *A. cretacea* Brongn., as figured by Saporta in Schimper's Traité de Paléontologïe Végétale, Atlas, pl. lxxvi, fig. 2 (see text, Vol. II, p. 255), which comes from the Greensand (Neocomian) of Nogent-le-Rotrou (Eure-et-Loir), in France. Considering the age of these beds, however, it is more probable that it represents the ancestral form of the present genus, and it is safer to refer it to the extinct genus Araucarites. I will give it the name *Araucarites Chiquito*, which refers to the Colorado Chiquito, or Little Colorado, on whose banks it was found, and also emphasizes its relatively small size.

That this cone was actually borne on some one of the many trees among the petrified remains of which it lay when I picked it up can not, of course, be doubted, but it is equally obvious that no means are at hand for connecting it with specimens of wood collected at the same time and place.

I also found in these denuded hillocks petrified bones. They come from the red marls over the blue clay, and were seen in place. No attempt was made to excavate the beds, but an expert collector of vertebrate remains could in all probability do this with success. The specimens collected were weathered out of the sides of the buttes and lay at their base. They were mere fragments, but included one complete vertebra.

I submitted the material to Mr. F. A. Lucas, curator of the Department of Comparative Anatomy in the United States National Museum, who kindly examined them and reported as follows:

The majority of the fragments are from a species of Belodon, apparently related to, possibly identical with, a peculiar genus and species (*Heterodontosuchus ganei* Lucas) described by me from the Trias of Utah. The Belodonta are Triassic.

There is also the vertebra of a small Dinosaur and two dermal spines of some Dinosaur, undescribed, but suggestive of a genus having some affinities with the Stegosaurs.

None of the specimens indicate genera older than the Trias.

The geological position of these beds is one of special importance, because, according to all the determinations hitherto made and all the maps that have appeared, this locality would fall on the extreme western border of the Permian, next to the Carboniferous and many miles from the nearest Mesozoic deposits. As already remarked, the red sandstones cross the river at this point and extend some distance still farther to the southwest, but I did not attempt to follow them to their contact with the Carboniferous, because at the time I was there I was not aware that the area had been mapped as Permian, and assumed that the occurrence of Mesozoic strata there was what was to be expected.

It was easy to follow the quite persistent bands of white, blue, red, and brown along the bluffs to the southeast. They dip very slightly in the opposite direction, but the dip is less than the fall in the river, and as a consequence the lower strata successively disappear in ascending the stream.[1] Twenty miles above the crossing the blue clay was no longer seen and the red marls became the basal member of the cliffs. This would give about 1 foot to the mile as the rate at which one rises in a southeasterly direction, which would make the lowest beds at Winslow some 70 feet higher than those at the crossing of the Lee's Ferry road.

The course of the Little Colorado above Winslow is more westerly, so that Holbrook, 35 miles above, is only 8 miles farther south, and the formation spreads out some distance on the left or south side of the river. Still its most important exposures are on the right bank, and they occupy a broad area to the northeast, finally passing under the higher Jurassic and Cretaceous beds of the Rabbit Ear Mesa region. The red saliferous sandstones are overlain by alternating marls and sandstones, but there is strict conformity, and if the former are Permian we must have in this series the entire Triassic system, because there is, according to all accounts, complete conformity, also, of the overlying beds.[2]

[1] This fact was observed by Dr. Newberry, who says: "The fall of the river * * * is somewhat more rapid than the dip of the strata, so that, following it toward its sources, we were constantly ascending in the geological series." Ives Report, p. 74.

[2] See Newberry's sections in the Ives Report, pp. 77-85, and compare Dutton, op. cit., Chap. XII.

PETRIFIED FORESTS OF ARIZONA.

As already remarked, fossil wood is almost universal. I examined a fine forest less than a mile from Holbrook on the first terrace above the valley below that place. The valley is here half a mile wide on the north side. Most of this is occupied by an alkaline flat covered with greasewoods and saltweeds. The bluff is 50 feet high and precipitous. Many chips and blocks of petrified wood lie about its base weathered out, also detained in their fall at all elevations on the sides of the escarpment. The beds are brownish-red sandstones with thin seams of white or blue clay shales. On top lie immense petrified logs in great profusion, usually much split and broken, sometimes reduced to heaps of splinters. I collected a number of specimens that seemed to show structure perfectly. In a few cases the wood is red and jasperized. The hill back of the first terrace rises by a gradual slope for another 50 feet, and is chiefly covered by blown sand, but as far as I went I found fossil wood wherever the surface was exposed. None of this material seems to be in place, and its true source is probably still higher.

The junction of the Rio Puerco with the Little Colorado is 2 miles above and nearly due east of Holbrook. There is running water in the latter at this point all the year round, but it all comes from a spring a few miles above, and from there on the Little Colorado is a dry run except in the rainy season. The Rio Puerco is dry at its mouth and for most of its length, but in most such streams water can be reached by digging a few feet in the gravelly bed, and it is said that horses have the instinct to paw out the gravel until they make a trough in which water will stand in sufficient quantities for them to drink.

The Whipple expedition of 1853, in coming from Zuñi on the south, crossed the Rio Puerco at Navajo Springs and followed it down on its right or north bank. It was some 20 or 30 miles above its mouth that the party passed through the remarkable petrified forests described in the reports of Lieutenant Whipple and Mr. Marcou,[1] and also by Möllhausen, who accompanied the expedition. Here was the Lithodendron Creek, named by Lieutenant Whipple (op. cit., Pt. I, p. 73.), and so frequently mentioned in connection with the petrified forests of Arizona, but which in reality is not located in the heart of what is now called the petrified forest, but is on the other side of the Rio Puerco and some distance farther west.[2]

It is now well known that petrified wood is exceedingly abundant

[1] Reports of Explorations and Surveys to ascertain the Most Practicable and Economical Route for a Railroad from the Mississippi River to the Pacific Ocean, Vol. III, 1856, Pt. I, pp. 73-75; Pt. II, p. 28; Pt. IV, pp. 43, 150, 151, 167.

[2] It is difficult to identify on modern maps, but a careful study of the map accompanying the Whipple report and of Lieutenant Whipple's description given in the itinerary (p. 73) seems to require the assumption that his "Carriso Creek" is what is now called Dead Creek on the Land Office map, and that Lithodendron Creek was what is now called Carrizo Creek or Carrizo Wash.

throughout the entire region and will be met with whatever route one may take, but there are differences in the degrees of abundance and of perfection or intensity of coloration of the wood at different points or centers of accumulation. The climax in all these respects, so far as has yet been discovered, is reached in an area lying between the Rio Puerco and the Little Colorado, but nearer to the former. It is bounded on the east by the meridian of 109° 45′ west from Greenwich, is nearly square, and its center falls in about latitude 34° 52′, longitude 109° 49′. Its western border is about 15 miles east of the junction of the two rivers and 17 miles east of Holbrook. Its northern boundary is 6 miles due south of the Rio Puerco at Adamana Station on the Santa Fe Pacific Railroad. The area is about 8 miles square and falls chiefly within township 17 N., range 24 E., but extends a short distance on the south into township 16 N., and on the west into range 23 E.

This region consists of the ruins of a former plain having an altitude above sea level of 5,700 to 5,750 feet. This plain has undergone extensive erosion, being worn down to a maximum depth of nearly 700 feet, and is cut into innumerable ridges, buttes, and small mesas, with valleys, gorges, and gulches between. The strata consist of alternating beds of variegated marls, sandstone shales, and massive sandstones. The marls are purple, white, and blue, the reddish tints predominating, the white and blue forming bands of different thickness between the others, which give to the cliffs a lively and pleasing effect. The sandstones are chiefly of a reddish-brown color and closely resemble the brownstone of the Portland and Newark quarries, or the red sandstone of the Seneca quarries on the Potomac River and at Brentsville in Virginia, but some are light brown, gray, or whitish in color. The mesas are formed by the resistance to erosive agencies of the massive sandstone layers, of which there are several at different horizons, and which vary in size from mere capstones of small buttes to tables several miles in extent, stretching to the east and to the northwest.

The drainage of the area is to the south, and in the middle of it, having a nearly due southern course, but winding much among buttes, is the arroyo which has been mistaken for the famous Lithodendron Creek named by Lieutenant Whipple in 1853, as already explained. This arroyo or creek is dry most of the year, but has a gravelly bed often 20 feet in width, and, as with many other streams in this region, if holes are dug in this gravel to a depth of 4 or 5 feet water will accumulate and stand in them.

The valley of this creek is narrow in the northern and central parts of the area and there are several short branches or affluents, but at the southern end it broadens out and its rugged, spurred, and canyoned slopes are highly picturesque. Here is located the principal petrified forest, and this is the region that has been characterized by some as

Chalcedony Park. The petrified logs are countless at all horizons and lie in the greatest profusion on the knolls, buttes, and spurs and in the ravines and gulches, while the ground seems to be everywhere studded with gems consisting of broken fragments of all shapes and sizes and exhibiting all the colors of the rainbow. When we remember that this special area is several square miles in extent some idea can be formed of the enormous quantity of this material that it contains.

Although much fossil wood occurs throughout the whole region as above delimited, still for several miles to the north of this Chalcedony Park it is less abundant, and it is not until the northern end of the area is reached that another center of accumulation occurs. This lies between two mesas, in a valley that opens out upon the general plain which stretches north to the Rio Puerco. It is much smaller in extent than the southern park, but substantially the same general features are presented.

There is still a third center of accumulation, called the "middle forest," which lies some 2 miles southeast of this last and extends to the eastern margin of the general region. It occupies the western slope of the table-land on the east, and is very extensive, stretching a mile or more in a north-south direction and having a width of half a mile in places. It presents many interesting novelties.

All the petrified forests thus far described are, geologically speaking, entirely out of place, and the trunks bear every evidence of having dropped down to their present position from a higher horizon in which they were originally entombed and from which they have been subsequently washed out. Nor is their original position to be discovered by ascending the several mesas included in the area, although some of these rise 400 feet above the lowest ground. It is not until the still higher plateau is reached which bounds the whole region and lies more than 700 feet above the valley that the stratum is at last found which actually holds the fossil wood. A geologist might therefore traverse the entire area from north to south, visit all three of the principal forests, and go out with the impression that everything was out of place, and with no correct idea of the true source of the fossil wood. Even on the east it would be difficult to settle this question, on account of the paucity of the trunks in that direction, but it could doubtless be done by prolonged and careful search. On the west side, however, and directly west of the southernmost area, the plateau is only about 2 miles wide and has a western escarpment, with another valley extending both south and west of it. This plateau or elongated mesa is highest on its western side, rising to the 5,750-foot contour line immediately above the escarpment, and here is exposed a fine series of petrified trunks fringing the mesa, with many weathered out on the slope or rolled down into the valley below. A few feet below the actual summit is a bed, some 20 feet thick, of coarse, gray, conglomeratic, cross-bedded sandstone, at many places in which were found, firmly embedded, logs and branches of the petrified wood, often projecting from it in the cliffs, and clearly in place. This, then, is the true source of the fossil wood, and after several days' study on all sides of the area I became convinced that no other layer holds any of it, at least in this region.

This bed was found at nearly all points where the requisite elevation can be attained, but the petrified logs do not occur in the same abundance throughout. They are massed or collected together in groups or heaps at certain points and may be altogether absent at others. From their great abundance in the three areas above described, which may be called the upper, lower, and middle forest, respectively, but in all of which they are out of place and lie several hundred feet below their proper position, it must be inferred that the stratum which held them was especially rich and that the trunks must have lain in heaps upon one another. This bed may have been considerably thicker in these areas than it is farther out on the margins where it is now found in place.

At only two points within the general petrified forest area did I find remnants of this bed which had not been broken down and disintegrated. One of these is at the extreme northern end, half a mile northeast of the upper forest. Here there is a small mesa, which lies at an elevation of nearly 5,700 feet, or about 400 feet above the valley that contains the upper forest. It is isolated, and its nearly flat top, which is approximately circular, is about half a mile in diameter. The coarse conglomeratic sandstone stratum, 20 to 30 feet in thickness, occupies the summit of this mesa and is often hardened into rock, but in all essential respects it is identical with that of the elongated mesa on the southwest side of the area above described. The petrified wood is less abundant here, but sufficiently common, and is embedded in and often projects from the sandstone ledges.

Besides the fact that this bed lies wholly within the petrified forest area, there is another important circumstance which serves to give it special prominence. One of the most celebrated objects in this entire region is the well-known "Natural Bridge," mentioned by so many travelers, consisting of a great petrified trunk lying across a canyon and forming a natural footbridge, on which men may easily cross. This occurs on the northeast side of the above-mentioned mesa, near its rim, and the bed in which it lies is the coarse sandstone which holds all the petrified wood. The Natural Bridge therefore possesses the added interest of being in place, which can be said of very few of the other petrified logs of this region.

It was observed in the southwestern exposure and at other points that all the petrified logs and blocks lying in the sandstone or only recently washed out of it are surrounded by a coating of the sandstone firmly cemented to the exterior. The absence of this coating from most of those in the principal forests is due to their long exposure to climatic influences, which ultimately disintegrate and detach the sand-rock adhering to them and strip them clean to the body of the trunks themselves. That this process requires ages of time is proved by the fact that the Natural Bridge is still coated over a large part of its surface by the remains of the cemented sand rock in which it was once completely embedded. This is true chiefly of the lower portion, and farther up the trunk it has nearly all disappeared. The trunk is in an excellent state of preservation and is complete to the base, where it is abruptly enlarged and shows the manner in which the roots were attached. This portion still lies partially buried in the sandstone, which is the same in character as that which still adheres to the lower 20 feet. The canyon or gulch has a due north direction and is very precipitous, beginning only 200 yards above the bridge and rapidly broadening in its descent. At the point where the bridge crosses it is about 30 feet wide, but the trunk lies diagonally across and measures 44 feet between the points at which it rests on the sides of the canyon. The angle is nearly 45°, and the tree lies with its roots to the southeast and its top to the northwest. The canyon is here about 20 feet deep, and from its bottom and slopes several small trees are growing, some of which rise considerably above the bridge. The trees are mostly cedars, but there is one cottonwood (*Populus angustifolia*). The root is quite near the brink of the canyon, but rests on a solid ledge for a distance of 4 feet, so that there is no probability that in this dry region it will be endangered by further erosion. The total length exposed is 111 feet, so that more than 60 feet of the upper part lie out on the left bank of the canyon. At about the middle of the canyon, and above where the coating of sandstone still adheres, it measures 10 feet in circumference, giving a diameter of over 3 feet. At the base it is now 4 feet in diameter, but the thickness of the incrustation is not exactly known. At the extreme summit the diameter is reduced to 18 inches. As in the case of practically all the petrified logs of the region, there are no indications of limbs or branches at the top. The significance of this fact will be noted later.

A conspicuous characteristic of all the petrified trunks, not only of this area and of the general Triassic terrane of Arizona and New Mexico, but of all petrified forests, is their tendency to break across into sections or blocks of greater or less length. All travelers have remarked this, and the sketches given by Möllhausen and in the Pacific Railroad reports show them thus divided. Some observers have noted the fact that the Natural Bridge has several of these transverse cracks, and all the good photographic views of it show them. I counted four, but most of them seem to be as yet only partial and probably do not extend entirely through the trunk. There is one, however, near the left bank of the canyon which has the appearance of doing so, and the trunk is probably only kept from parting at this point by the mechanical adjustment which causes the adjacent faces to perform the office of a keystone to an arch. Any considerable shrinkage due to climatic or other causes would overcome this influence and the entire bridge would crash to the bottom of the canyon and roll down the escarpment in a number of huge segments.

An examination of the relations of the Natural Bridge to the gulch which it spans shows clearly that the trunk was primarily entombed in the sandstone bed covering this entire region, and that, with the progress of erosion, which ultimately carried away the entire plain to the north as well as in other directions, leaving this small mesa, it was at last exposed and lay for a great period near the rim of the escarpment. At first it was only partially buried and later came to lie on the surface of the ground. As the land rises somewhat to the south of it rills were formed above, and in times of floods or heavy rain it obstructed the flow of the water, forming a sort of dam. The water lying against the trunk long after it had ceased to overflow it, tended to disintegrate the rock upon which the trunk lay, until eventually it found its way through beneath the trunk at some one point. The smallest opening of this nature would soon become a free passage for the water, and a simple continuation of this process of local erosion would ultimately result in the formation of the entire gorge as it exists to-day.

The other case which I observed of the presence of the conglomeratic sandstone within the general petrified forest area occurs near its center, about midway between the upper and lower forests, along the narrow portion of the valley of the creek above described, on both sides of the canyon and near the level of its bed, at an altitude of about 5,300 feet. The exposure is typical in all respects, and logs were seen projecting from the canyon walls, from one of which specimens were collected. As this exposure is 400 feet below that in which the Natural Bridge occurs and 450 feet below that on the southwestern mesa, its presence there can be accounted for only on one of two hypotheses—either that of the existence of another exactly similar stratum at this horizon, or that of a fault, or what would amount to the same thing, a slide or slipping down of a large block of the uppermost beds in such a manner as not to disturb their stratigraphical arrangement.

The first of these hypotheses is rendered improbable by the fact that a careful study of the beds at the same horizon in other places revealed no such stratum, and it could scarcely be so local as not to be found elsewhere. The second hypothesis seems in every way probable, as in such a much-disturbed region it would be easy for the erosive agencies to undermine a small outlier or mesa and cause it to sink down intact to a lower level. The question, however, requires more detailed investigation than I was able to give it.

Leaving this phenomenon out of the account, therefore, and considering the two exposures in which there is no question as to their natural position, we may use them as a means of determining whether the strata have any dip and to some extent in ascertaining the amount and direction of the dip. The topographic map has a 250-foot contour interval, which is too large to be employed with any very great accuracy, and an aneroid can hardly be depended upon for measurements made six hours apart, as had to be done in this case, but, as nearly as I could judge from all sources of information, the Natural Bridge mesa seems to be between 50 and 100 feet lower than the southwestern mesa. As the distance is about 5 miles, the dip to the northeast is somewhere between 5 and 10 feet to the mile. As, however, the strike was not accurately determined, there is no certainty that this is the true dip of the strata, and more precise observations on a much larger scale will be necessary to settle this question.

Although there is no longer any question as to the true stratigraphical position of these profuse vegetable remains, there are many facts which stand in the way of the supposition that the trees actually grew where we now find them. Several accounts[1] profess that stumps occur erect, with their roots in the ground, showing that they grew and were buried and petrified on the spot, but I was unable to confirm any such observations, and on careful inquiry of residents of the country who had minutely examined every part of the area I was unable to learn of a single indisputable instance of such an occurrence. The only trunk that I saw standing on end was one that was inverted and had its roots high in air. In fact, from the nature of the case, as I have just shown, there would be no use looking for any such phenomenon in any of the principal fossil forests, since they all lie from 100 to 400 feet below where they were originally deposited. It is only in the beds of coarse sandstone that hold them, therefore, that the evidence need be sought. This I did with the utmost care, but even here I found no example of an upright trunk.

In this, as I was glad to learn after my return on looking the matter up, I was only confirming the observations and conclusions of Dr. J. S. Newberry, made in 1858 and published in 1861.[2]

Dr. Newberry's statement is as follows:

> I examined these specimens with some care to determine, if possible, whether they had grown on the spot, as those of Lithodendron Creek are supposed to have done by the members of Captain Whipple's party, or whether they had been transported

[1] Möllhausen, loc. cit. Marcou, Bull. Soc. géol. France, 2d séries, Vol. XII, 1855, p. 871. Repeated in Geology of North America, etc., Zurich, 1858, p. 13.

[2] Newberry, in the Ives Report, p. 80.

to their positions. In all that came under my observation I failed to find any evidence that they had grown in the vicinity. All the trunks are stripped of their branches and exhibit precisely the appearance of those transported to some distance by the agency of water. In confirmation of this view I should also say I found in the marls, with the entire trunks, rounded and water-worn fragments of wood, in some instances silicified and in others converted into lignite.

I gathered the same impression from all the collections of silicified wood which I observed in this formation in western New Mexico, viz, that all had been transported, but not far removed from their place of growth.

Although it is easy to find petrified limbs and small twigs among the other objects, still these occur sporadically and accidentally at any and all points. They are no more likely to be found beyond the termination of the tall trunks than anywhere else, as would be the case if the trees lay near where they grew. In fact, it happened that I never found small twigs in this position, although I searched in hundreds of cases. I found no petrified cones, but I heard vague reports of their having been found. It would be strange if none were preserved in such a vast mass of trunks of cone-bearing trees.

Finally, the great abundance of the material would seem to negative the idea that it could have all grown on the same area. Even if every tree had been preserved, there are places where it would have been impossible for them to stand as thickly as they lie on the surface, not to speak of the space that trees in a forest require in order to thrive, as these trees evidently did thrive. And while there is now no place where they lie so thickly in the original bed of sandstone, still, even here they are not only all prostrate, but lie in little collections and huddles, quite differently from what should be expected if they were precisely where they grew.

The preservation of a forest in situ with the trunks erect could scarcely take place except by some sudden, commonly eruptive agency. Such agencies have undoubtedly operated in the preservation of the petrified forests of the Yellowstone Park, and of others that I have visited in Wyoming and elsewhere, in which the stumps and sometimes tall trunks do stand in position with their roots in the ground, but in the region under consideration there are only faint indications of eruptive agencies, certainly not sufficient to account for the phenomena.

The indications, therefore, all point to some degree of transportation of this material by water antecedent to petrifaction, and the great amount of it at this particular place argues for the existence there of such a condition as would arrest the process and cause the floating logs to accumulate in masses, as often happens in great eddies or the deltas of rivers. The character of the bed in which they occur further supports this view. The coarse sand and gravel, highly favorable to the process of silicification, denotes the proximity of the land, and the cross bedding bears witness to the existence of rapid and changing currents. As this stratum occupies the highest elevations in this region, the nature of the overlying beds is not revealed, and the question whether the period was followed by one of general subsidence can be settled only by a study of the higher plains lying some distance to the east and north, but it is probable that the bed sank and that finer deposits ultimately buried it at the bottom of the Mesozoic sea, there to remain until the Tertiary epeirogenic movement raised the entire country from 5,000 to 6,000 feet above sea level.

### THE TAYLORSVILLE,[1] CALIFORNIA, AREA.

The Mesozoic beds, believed to be of Triassic age, in the vicinity of Taylorsville, Plumas County, California, and now generally known by the name of that town, are the only ones of that age as yet known to me in California from which fossil plants have been collected. Lying near the fortieth parallel, the region was naturally entered by the geologists of the Fortieth Parallel Survey at an early date, and those of the California State surveys also passed over it and made important discoveries, including, approximately, that of the age of the rocks and some collections of animal fossils.

Dr. George F. Becker, in 1885,[2] mentions Triassic fossils from the Genesee Valley, Plumas County; and Prof. J. S. Diller, who made his first excursion through this region in 1885, gave some account of it the following year.[3] Shortly after this the region was visited by Prof. I. C. Russell, Prof. Alpheus Hyatt, Mr. H. W. Turner, and Dr. Cooper Curtice, and large collections of animal remains were made.

Dr. Curtice, in 1890, and again in 1891, was successful in securing a few fossil plants, but all proved to be in an imperfect state of preservation. The localities from which Dr. Curtice obtained his plants, as recorded on his labels, are as follows: "Hillside north of a hut near Mr. Forman's house, near Taylorville," 1890. "On trail opposite Bostwicks Bar, near Reynolds Ferry, Stanislaus River," 1891. "Six miles from Copperopolis, on route to Sonora, and on grade to Angels Creek," 1891. "Stanislaus River, near canyon opposite mouth of Bear Creek," 1891.

In 1891 Messrs. E. G. Paul and James Storrs made still another collection of fossil plants from the same general region, their labels giving the locality as "Formans, North Arm of Indian Valley, near Taylorville."

All these collections came ultimately into my hands, and every effort was made to determine them and ascertain their bearing on the age of

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[1] In all collections from this place and in Professor Diller's published papers the name is written Taylorville, but it is called Taylorsville in the U. S. Postal Guide.

[2] Notes on the stratigraphy of California: Bull. U. S. Geol. Survey No. 19, 1885, p. 21.

[3] Notes on the geology of northern California: Bull. U. S. Geol. Survey No. 33, 1886, pp. 9-21.

the beds. The first installment received was sent to Professor Fontaine for determination, and he reported upon it, under date of December 8, 1891, as follows:

I have carefully examined the small collection of fossil plants made by Mr. J. S. Diller in northern California, which you sent to me for determination.

The plants are very fragmentary, and most of them are poorly preserved. The most distinct are a small Equisetum and several ferns with small pinnules. The ferns are the most numerous, but unfortunately they present mostly such portions as the tips of pinnæ and detached fragments of pinnæ. The amount of material is not sufficient to enable one to determine with positiveness their relations to previously described forms, for ferns are so notoriously variable in foliage that a considerable amount of material is needed to make reliable determinations. Still, taking the collection as a whole, and looking to the nearest relationships with previously known fossil plants, we may arrive at some results with a considerable degree of certainty.

The plants are certainly younger than Paleozoic, and as the elements of the flora are ferns, equiseta, cycads, and conifers, with no trace of dicotyledons, they are Mesozoic, most probably older than Cretaceous, with the possible exception of its very base.

Owing to the imperfection of the material and the absence of the type forms, I can not come to a positive conclusion as to the exact position in the Mesozoic of these plants, but I think the weight of evidence is strongly in favor of the flora being Rhetic or uppermost Trias.

The following enumeration of determinable forms will give the reasons for this conclusion:

1. *Equisetum Muensteri* (Sternb.) Brongn.? This Equisetum is one of the most common and best-preserved fossils in the Forman slates. It has a small stem, the largest imprints indicating a diameter not greater than one inch. The character of the teeth and the small size cause it to differ decidedly from the large equiseta of the Older Trias. There are no good characters separating it from *E. Muensteri*, as figured by Schenk in his Grenzschichten, while some of the imprints remind one of *E. Lyellii*.

2. Podozamites or Pterophyllum. This is a strap-shaped fragment showing no base and no tips. Hence its true place can not be determined. The nerves are parallel, and appear to fork at one end of the leaf, which is probably the basal end. The imprint is most probably that of a Podozamites, but it may be a Pterophyllum. It seems to be very rare.[1]

3. A small fern. This has very small pinnules shown on small detached fragments of pinnæ, which have the general aspect of those of a Pecopteris. They show no nerves, and are granulated with what seem to be sori covering the surface of the pinnules. This is probably the fructification of Acrostichites, to which genus we may perhaps regard the fern as belonging. It is, however, smaller in pinnules than any previously described Acrostichites. It is rare.[2]

4. A small fern. This, in the form of its pinnules, resembles a Sphenopteris, but the fructified forms show the pinnules apparently covered with sori, producing a granulation, which makes this, too, probably an Acrostichites. The sterile pinnules of this fern remind one of Schenk's *Coniopteris Braunii*.[3]

5. A small fern. This has small pinnules, or segments of pinnæ, which are in shape similar to *Acrostichites microphyllus* of the Virginia Rhetic formation, as described in in Mon. U. S. Geol. Survey, Vol. VI, but the species is a new one, with ultimate pinnæ shorter than those of any previously described Acrostichites. It seems to be clearly an Acrostichites, for the fructified pinnules show the characteristic granulation. In

[1] We will call this *Podozamites ? taylorsvillensis* Ward, n. sp.

[2] This may be called *Acrostichites ? fructifer* Ward, n. sp.

[3] Let this bear the name *Acrostichites ? coniopteroides* Ward, n. sp.

the form of its sterile pinnules it is a good deal like Schenk's *Sphenopteris Rœssertiana*, described in his Foss. Fl. d. Grenzschichten. This is quite rare.[1]

6. *Acrostichites princeps* (Presl) Schenk? This fern is one of the most common and best preserved. In both the shape of the pinnules and the granulation that covers the fructified pinnules it agrees pretty closely with Schenk's *Acrostichites princeps*, from the Rhetic of Europe. The pinnules, like those of the latter, are small, with margins more or less undulating, and when fructified, as they mostly are, they are covered with sori. The amount of material does not suffice, I think, to make the identification positive.

7. Sagenopteris or Cheiropteris. This is a fragrant of what seems to have been a rather large leaf with very thin texture. It shows a border which may be a portion of the extremity of the leaf or of a lateral margin. The nerves are approximately parallel, thin, and not distinct. They anastomose at considerable intervals, so as to give long meshes. The nervation seems nearer that of Sagenopteris than any other fern. If it is a Sagenopteris the leaflets are larger than those of any described species of that genus. Only one specimen was seen.[2]

According to this list, the plants now in question would seem to find their nearest affinities in the Rhetic flora of Franconia, as described by Dr. Schenk.

Professor Diller, in a paper published the following year,[3] gives (p. 374) a condensed statement of Professor Fontaine's report, but it has never before been published entire. Another collection was made in 1893, but the material was even poorer than the rest, and it has been impossible to determine it. The record will, therefore, have to close with Professor Fontaine's report above, but it is greatly to be hoped that some better locality may yet be found and further light shed on the flora of these beds.

# PART II.

## THE JURASSIC FLORA.

### PLANT-BEARING DEPOSITS SUPPOSED TO BE JURASSIC.

It is not, of course, proposed here to go over the ground so long under discussion relative to the Triassic deposits considered in the last chapter, although the Richmond coal field was first regarded by Rogers as Oolite, and Mr. Marcou first referred those of the Southwest to the Jurassic. This question we will consider as settled, and whether, with Professor Fontaine, we place the highest of them in the Rhetic or regard them all as more probably representing the Keuper, we may at least include them all in the American Trias.

The deposits now to be considered are recognized by all as lying above these last, and the ones that have been under discussion are so much higher that the question has always been whether to regard them as Jurassic or as Cretaceous. Neither do I now propose to open up the questions relative to the alleged Jurassic age of the Potomac formation

[1] This can bear the name *Acrostichites brevipennis* Ward, n. sp.

[2] From the large leaflets this may be called *Sagenopteris? magnifoliola* Ward, n. sp..

[3] Geology of the Taylorville region of California: Bull. Geol. Soc. America, Vol. III, 1892, pp. 369-394.

and of the cycad-bearing beds of the Black Hills (Lakota formation of Darton). The former of these questions has been much discussed and it will suffice to refer to its recent literature.[1]

Mr. Jules Marcou, in a somewhat acrimonious article on the Triassic flora of Richmond, Virginia, published in 1890,[2] alludes (p. 161) to a "Jurassic florula" found by Dr. Newberry in 1858 at the Moqui Pueblo in New Mexico. Although I presumed he referred to Dr. Newberry's report in the Report of the Colorado River of the West by Lieutenant Ives, 1861, still there was some uncertainty, and I therefore called Dr. Newberry's attention to the matter and asked him whether he recognized any true Jurassic floras in America. There was some further correspondence, and some extracts from his letters are well worth publishing in the present connection. He says:

The fossil plants to which you refer are described in the geological part of the Ives Colorado report, page 129, pl. iii. The deposit from which this handful of plants was taken is quite near to the Moqui villages, a few miles south of the table-land on which are situated the towns known as "Mooshanove" and "Shungopave," and at a point where the Moquis obtained clay for their pottery. The Dakota sandstone, with its dicotyledonous leaves, rests on these clays and they contain much lignite; below them are the highly colored marls which form the top of the Trias.

The Jurassic ("Atlantosaurus") beds—sandstones and shales with Saurian bones—occur just beneath the Dakota and upon the Triassic marls 150 miles north from this locality, but they are fresh-water deposits and local. No Jurassic rocks have been detected in that part of Arizona where these plants occur, and the Jurassic rocks seem to thin out toward the south and not to cross the north line of Arizona or New Mexico. At Abiquiu, 60 miles north and west of Santa Fe, the Dakota sandstone rests upon strata which contain unmistakable Triassic plants, but all are different from those at the Moqui villages. As that group of plants and the clay and lignite in which they occur have not been recognized anywhere else we are absolutely without proof of their age. Because these plants are different from those known to be Upper Triassic in New Mexico I have been inclined to regard them as Jurassic, but have never asserted that they were such, nor indeed that they were Triassic or anything else.

I have always been doubtful about the geological position of the lignites and the clay beds at the Moqui villages. This doubt is due to the facts that the lignite and clay beds have not been identified elsewhere, and that the small number of plants obtained from them are different specifically from any found elsewhere in the world. It will be impossible, therefore, for any man, however learned and wise, to assign an age to the Moqui florula without more facts to base a conclusion on.

I never really regarded the Moqui plants as Cretaceous, because the beds which contain them are overlain by the Dakota sandstone, which, when my report was written,

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[1] See papers by Prof. O. C. Marsh in the Sixteenth Ann. Rept. U. S. Geol. Survey for 1894–95, Pt. I, 1896, pp. 133–414; Am. Jour. Sci., 4th Ser., Vol. II, October, 1896, pp. 295–298; November, 1896, pp. 375–377; December, 1896, pp. 433–447; Vol. VI, August, 1898, pp. 105–115, 197; Science, N. S., Vol. VIII, August 5, 1898, pp. 145–154—by G. K. Gilbert in Science, N. S., Vol. IV, December 11, 1896, pp. 875–877—by Jules Marcou in Am. Jour. Sci., 4th Ser., Vol. IV, September, 1897, pp. 197–212—by Robert T. Hill in Science, N. S., Vol. IV, December 18, 1896, pp. 918–920; Am. Jour. Sci., 4th Ser., Vol. IV, December, 1897, pp. 449–469—by Lester F. Ward in Science, N. S., Vol. V, March 12, 1897, pp. 411–423; Nineteenth Ann. Rept. U. S. Geol. Survey for 1897–98, Pt. II, 1899, pp. 521–946—by William B. Clark in The Physical Features of Maryland, Maryland Geological Survey, April, 1897, 4°—by Clark and Bibbins in Journal of Geology, Vol. V, July–August, 1897, pp. 479–506—by Arthur Hollick in Proc. Am. Assn. Adv. Sci., Vol. XLVII, 1898, pp. 292–293.

[2] Am. Geologist, Vol. V, March, 1890, pp. 160–174.

was supposed to be the oldest member of the Cretaceous system on this continent. The question in my mind has been: Are they Jurassic or Triassic? No Jurassic plants, unless these are such, have been found in America, and the Triassic flora of Abiquiu and Sonora is Keuper, so there is a possibility, not to say probability, that we here get our first glimpse of the flora which covered the land while the Jurassic limestones of the Black Hills and the Wasatch were accumulating in the sea, and the Atlantosaurus beds were filling up fresh-water lakes around which was land that supported a luxuriant vegetation. This was so because the Jurassic fresh-water beds contain the remains of the largest herbivores known. Atlantosaurus was 100 feet or more in length, stood 30 feet in height, and must have consumed several tons of vegetable tissue per day. This shows how much we have to learn in regard to the vegetation of our continent in geological times. Knowing the herbivorous character of the great Jurassic Dinosaurs, I have been on the lookout to find traces of their food, but the Atlantosaurus beds, where I have examined them, contain no plants. Somewhere they will be found, however, and I envy the man who first gets a view of them.[1]

The localities where I have seen the fresh-water Jurassic strata are near Canyon City in Canyon Pintado, north of the Sierra Abajo and in South Canyon, near Glenwood Springs. In none of the localities did I find any remains of plants, but I had very little time to look, and I beg you will make a note of these places, as well as that of the Moqui plants, as deserving of further search.

The so-called Jurassic florula lies in No. 15 of the section on pages 84 and 85; all above that is unquestionably Cretaceous. No. 14 is Dakota, as is proven by its numerous dicotyledonous leaves and by its relation to the overlying shales, which represent the Colorado group and contain its characteristic fossils. No. 12 of the section on page 85 contains numerous plant remains, some of which are represented on pl. iii, but they have nothing to do with the flora found in the clays and lignites (No. 15) which lie below all the strata of the Moqui table-lands. Only the plants of which the figures are numbered 1, 2, 3, 4, 4a on pl. iii are from this horizon. None of the plants taken from this stratum have been found elsewhere, so I can not say to-day any more than when my Colorado report was written whether this florula is Jurassic or Triassic. I have never asserted that it was one or the other, and no one else is warranted in taking any other ground than I took in that report, viz, that further collections must be made from this deposit before the question can be decided. I hope you will keep the locality in mind and some time be able to send one of the employees of the Geological Survey there and gather more material. I shall be delighted if the flora of this deposit shall prove to be Jurassic, for as yet we have not obtained a glimpse of the great flora that must have prevailed on this continent during the Jurassic age and which afforded subsistence to the great herbivores, Atlantosaurus, Stegosaurus, etc.

Soon after this I had some correspondence with Professor Fontaine relative to the probable affinities of the plants figured in the Ives report. He made a careful examination of the figures and the text, and wrote me as follows:

I have examined carefully the figures of the fossil plants described by Dr. Newberry in the Ives report on the Colorado River of the West, which are given on pl. iii, figs. 1–4, and have read all that Newberry says about them. I should say decidedly that they are neither true Triassic nor Rhetic in age, but beyond this I can not speak with conviction. There is not enough material figured to fix the character of the flora, and the plants figured are not identical with any described species known

[1] This prediction has now been fulfilled by the discovery of the cycads and fossil wood described in this paper. L. F. W.

to me. Besides this, the notice by Dr. Newberry of the fossils found by him with these, but not figured, adds to the doubt in my mind.

The plant figured in figs. 1 and 2 is certainly not a Cyclopteris. It is probably a fern and, if so, has quite a modern look, resembling more than others some of the living Adiantums. For shape it may be compared with the living *A. asarifolium* Willd., and for the possession of a basal midrib, with the living *A. Wilsoni* Hook. It may, however, be some old Proteaceous type, for it has something of the habit of a dicotyledonous leaf.

Figs. 3 and 4 probably represent a Gleichenia, and they look something like some of Heer's forms from Kome, with, however, decided differences. If I were compelled to determine the age from the figured plants alone, I should say it is lowest Cretaceous or Neocomian.

Newberry says that the dicotyledonous leaf given in fig. 6 comes from the lignite beds that furnished the other plants of the flora now in question (see p. 131, under *Phyllites venosissimus.*)

The nervation and shape of this reminds me of some of the forms of Sapindopsis of the Potomac. If this leaf was really found in the lignite bed, and not higher up in the Dakota group, its evidence would point to a Cretaceous age.

In connection with this I may refer to what Newberry says at the top of page 131, in closing his remarks on his *Pecopteris cycloloba*, the possible Gleichenia. He says of this plant that it is associated with Clathropteris of Jurassic affinities, and the first-appearing species of the dicotyledonous plants of the Cretaceous epoch, etc. He does not put the lignite bed and underlying strata in the same group with the beds of the uppermost mesa, which yielded him dicotyledons, so that I infer that he means to say that he found dicotyledons with *P. cycloloba*, but I can not understand why he does not lay stress on that fact. Again, on page 132, he mentions finding Clathropteris in the lignite bed, yielding the above-mentioned plants, but he says that the fragments were too imperfect for description. If this is in fact a Clathropteris, then it would indicate strongly that the age of the bed is Jurassic. I would suggest, however, that under some conditions a Clathropteris might, if imperfectly preserved, be similar to some imperfectly preserved dicotyledons, and these fragments may be really no more Clathropteris than the dicotyledonous leaf given in pl. iii, fig. 5 is a Neuropteris.

Dr. Newberry, in his letter to you, in which he says that the plants were obtained in No. 15 of the section on pages 84, 85, seems to have forgotten the section obtained at camp 92, before reaching the Moqui villages, given on page 81, where he found the same plants as in No. 15, and he overlooked the statement made at the bottom of page 131, which attributes *Phyllites venosissimus* to the same lignite bed. He says in his letter that only the plants figured in Nos. 1 to 4 come from this horizon. Are we to take his present recollections or his statement made then? Of course the presence of this dicotyledon may be accounted for by supposing that it came really from the Cretaceous strata above, but got mixed up with the lignite plants.

Have you noted the fact that Newberry, on page 131, says that his *Phyllites venosissimus*, pl. iii, fig. 6, comes from the beds with the supposed Jurassic plants? This Phyllites is apparently a dicotyledon like the Potomac Sapindopsis. Is what he says of the Clathropteris, page 132, all that is known of it? I wish I could feel sure that it is really a Clathropteris. It may be no more that plant than *Neuropteris angulata*, pl. iii, fig. 5, is a Neuropteris, for this is a small dicotyledonous leaf.

Now, if the supposed Clathropteris is really one, it would be worth more than his Cyclopteris and Pecopteris in deciding age. All the supposed Jurassic plants seem to come from No. 2 of the section at camp No. 92 (see p. 81).

I am afraid that *Cyclopteris moquensis* (which is of course no Cyclopteris) and *Pecopteris cycloloba* will be of no help in making out age. Has it occurred to you that the plants may be Potomac?

I have been struck with the general resemblance that Newberry's *Cheiropteris Williamsii* bears to his *Cyclopteris moquensis* from the Moqui villages. I refer especially to the specimen given in fig. 11, pl. xiv, of his recent paper on the Flora of the Great Falls coal field, published in the Am. Jour. Sci. (3d series, Vol. XLI, March, 1891). The anastomosis of the veins of *Cheiropteris Williamsii* occurs at such long intervals that it might easily have been overlooked in *Cyclopteris moquensis*.

From all this I think it may be safely concluded that the claims of any of these plant-bearing beds to a Jurassic age are very slender, and it is probable that they are not Jurassic, whatever their real age may be.

The following correspondence will give the history of the only other case within my knowledge of fossil plants occurring at a horizon which is near the boundary line between the Jurassic and the Cretaceous, and the true position of which is not yet settled:

BERKELEY, CALIFORNIA, *January 21, 1896.*

Prof. LESTER F. WARD,
*Washington, D. C.*

DEAR SIR: I have forwarded to your address to-day four specimens of fossil plants collected by Mr. H. W. Fairbanks in rocks underlying the Knoxville in California. We are very anxious to know what they are and what their probable age is. The fauna associated with them is, peculiarly enough, rather of Cretaceous than Jurassic aspect.

Would you kindly look at them and send me your opinion as soon as possible? Full credit will be given to you in a note to be published.

Very sincerely yours, JOHN C. MERRIAM.

WASHINGTON, D. C., *February 10, 1896.*

Prof. JOHN C. MERRIAM,
*University of California, Berkeley, California.*

MY DEAR SIR: I am much interested in the specimens you send. I can hardly trust myself to determine them for you, and will take the liberty of sending them to Professor Fontaine, who is working up all my collections from California. I obtained several specimens in the Shasta group that somewhat resemble them, but I also found a very few imperfect impressions in the Mariposa slates that look like them. I presume it will turn out with the plants as Dr. Stanton says it has with the shells, that they are not wholly diagnostic of the age of the beds. It seems to be a conifer, perhaps the descendant of the old Voltzia and the somewhat later Palissya, foreshadowing the Lower Cretaceous Geinitzia and the more modern Sequoias. But what Professor Fontaine will call it I do not know. It is a highly transitional form, and all your specimens are the same, I think. As soon as I hear from Professor Fontaine on the subject I will let you know.

Very sincerely yours, LESTER F. WARD.

WASHINGTON, D. C., *February 11, 1896.*

Prof. WM. M. FONTAINE,
*University of Virginia, Virginia.*

MY DEAR PROFESSOR FONTAINE: I send you a little package containing four specimens of fossil plants from beds underlying the Knoxville of California. They were sent to me by Prof. John C. Merriam, of the University of California, with a letter, of which the inclosed is a copy, which you need not return. I am as anxious as he to know what the plants signify. I got some things a little like them in my collection from the Knoxville beds, which are all boxed up and ready to go to you. I also got a very few minute fragments of the tips of branches that resemble these from the true Mariposa beds (Jurassic). I hardly know what genus to refer them to. Will you please look at them and see whether you recognize them readily, and say what they seem to be most like?

Very sincerely yours,

LESTER F. WARD.

CHARLOTTESVILLE, VIRGINIA, *February 12, 1896.*

DEAR MR. WARD: I return the specimens of Mr. Merriam by this day's mail.

The only Jurassic genus known to me that may contain these fossils is Elatides of Heer, provided we grant that he correctly places in it the leafy twigs, which he describes in Vol. IV, Pt. II, Flor. Foss. Arct., page 79, and figures on pl. xiv, figs. 6, 6b, 6d. Heer founded the genus on cones, but there is nothing except his experience to call for the association of these branches with the cones.

The leaves are most strikingly like those of *Sequoia Reichenbachi*, especially those of the Potomac form, which I made the variety *longifolia* (see pl. cxvii, fig. 8, of Mon. U. S. Geol. Survey, Vol. XV). I see no difference. The leaves of Merriam's fossils are probably not shown in their full width, owing to imperfect preservation. They appear fully as long as the longest of the Potomac form. They are too long and narrow for the typical *S. Reichenbachi*. Clearly the plant is a Sequoia of the *Reichenbachi* type, and if it were a true *S. Reichenbachi* I do not think that would forbid the conclusion that the strata are uppermost Jurassic, as this Sequoia persists so long. Still, under the circumstances, I would not identify it with *S. Reichenbachi*, even as a variety, but would consider it provisionally a new species of the well-marked *Reichenbachi* type. It may be an ancestral form of that species. I do not think that these fossils can throw any light of value on the question of the age of the beds. So far as they show any indication, they rather incline to lowest Cretaceous.

Yours truly,

WM. M. FONTAINE.

WASHINGTON, D. C., *February 15, 1896.*

Prof. JOHN C. MERRIAM, *Berkeley, California.*

MY DEAR PROFESSOR MERRIAM: I return herewith, by mail, the fossils from beds below the Knoxville, and inclose Professor Fontaine's report thereon. You will see how nearly it agrees with what I said, and while it may not be very comforting, you can rest assured that it is the best that can be done in the present state of science.

I have talked with Dr. Stanton, who has seen the shells from the same beds, and he makes almost exactly the same statement with regard to them. He says they rather point to lowest Cretaceous, and I think, perhaps, it may be safe to say that these beds form a transition from the Jurassic to the Cretaceous. However, I do not feel confident, from the small amount of evidence which has thus far been produced.

Very sincerely yours,

LESTER F. WARD.

As in the former case, so in this, while there is some doubt, the weight of evidence thus far appears to be against the Jurassic age of this plant-bearing deposit.

## PLANT-BEARING DEPOSITS OF UNDOUBTED JURASSIC AGE.

One of Mr. H. W. Turner's assistants, A. I. Oliver, collected in 1894 in the Mariposa beds of California in Yaqui Gulch, Mariposa County, 5 miles south of Princeton (Bullion Mountain), a small fragment of a fern, which came in due time into my hands. In his letter, dated January 31, 1895, to the Director of the Survey, transmitting it, Mr. Turner says: "The age of the slates from which the specimen came is Jurassic (Mariposa formation)."

In the early part of October, 1895, I joined Mr. Turner's party for a time while operating in this same general region, having with me Mr. James Storrs, who was with Mr. Turner at the time the fern was collected, although neither of them were with Mr. Oliver when he found it. Still, the exact gulch in which it was found was known to Mr. Storrs and we made a prolonged search for additional material. The shales are so transformed that scarcely any impressions are retained and we were mainly unsuccessful, but did find a few faint impressions of a vegetable nature, one of which was a fern nearly as well preserved as the original specimen. All this material, including the original specimen, was sent to Professor Fontaine, who reports upon it as follows:

I have examined the specimens of fossil plants collected from the Mariposa slates, near Princeton, California. They are very few in number and very fragmentary and poorly preserved. The plant fragments before entombment had evidently drifted some distance. It is therefore not possible to make positive determinations.

The specimen collected by Mr. Oliver, of Mr. Turner's party, in 1894, from Yaqui Gulch, Mariposa County, shows the end of an ultimate pinna of a fern. Several pinnules on each side of the rachis and the terminal one are preserved. No fructification is shown. The pinnules indicate that the plant is a Dicksonia. It agrees very well, so far as the character is shown, with *D. Saportana* Heer,[1] from the Jurassic of the upper Amur of eastern Siberia, and may be provisionally identified with that species.

One of the specimens collected by Messrs. Ward and Storrs in 1895, at nearly the same place as the last, shows the terminal portion, in a small fragment, of an ultimate twig of some conifer. It has several leaves of thick texture placed in two ranks on each side of the stem. They are widest at base, and decurrent, while they narrow to an acute tip. The terminal portion of the leaves is strongly incurved after the fashion of Pagiophyllum, to which genus it seems to belong. It resembles the specimen of *P. peregrinum,* given by Saporta in Paléontologie Française, Végétaux, Plantes Jurassiques, Tome III, Atlas, pl. clxxvi, fig. 3, and may be doubtfully identified with that species.

There is one other very problematic plant in that collection. It is a small bit of a twig, carrying on one side three small round bodies, which may be the cones of some conifer. They may be those of Leptostrobus. The mode of attachment and form indicate this, and the plant, for the sake of a name, may be called *Leptostrobus? mariposensis* Font. n. sp.

The above form all the identifiable plant impressions in the material sent.

### THE OROVILLE FLORA.

On the 9th of October, 1894, Dr. T. W. Stanton, assisted by Messrs. Storrs and Oliver, made two small collections of fossil plants from the blue gold-bearing shales on the Feather River, in Butte County, California, 4 miles above the town of Oroville, the true age of which was

[1] Heer, Flora Fossilis Arctica, Vol. IV, Pt. II, pp. 89, 90, pl. xvii, figs. 1, 2; pl. xviii, figs. 1-3.

wholly unsettled. One of these collections was made at the stamp mill of the Banner mine, and the other half a mile south of the Banner mine, on the right or north bank of Feather River. These collections came to Washington, and were transmitted to me through the Geological Survey, by Mr. Turner, at the end of January, 1895, along with the Mariposa fern above mentioned. They were sent to Professor Fontaine for determination on April 9, and his report upon them bears date April 22, 1895.

In an article on the Age and Succession of the Igneous Rocks of the Sierra Nevada,[1] Mr. Turner, to whom I sent a copy of the report, published it in full (pp. 395, 396). Professor Fontaine's conclusion, as expressed in the last paragraph of this report, is as follows:

> Taking all the evidence, I think it can be positively said that this flora is not older than the uppermost Trias, and not younger than the Oolite. I feel pretty sure that it is true Rhetic, somewhat younger than the Los Bronces flora of Newberry, and the Virginia Mesozoic coal strata. It is much like the Rhetic flora of France, made known by Saporta. At any rate, this is a new grouping of plants that certainly deserves to be carefully collected. I do not think the fossils now in hand suffice to fix narrowly the age, which may be lower Jurassic.

While operating in the Sacramento Valley in the autumn of that same year, having Mr. James Storrs as my assistant, I thought best, in view of the meagerness of the previous collections and of the importance of this, the only paleontological evidence that these beds furnish, to visit the localities and endeavor to obtain more and better material. We reached Oroville on September 25, and proceeded on the 26th to the Banner mine. We spent three days in the work, first collecting from the dumps around the deep shafts, then on the bank of the river, with some measure of success. At last we entered a deep ravine that leads from the mine to the river, and here we found the rocks far better exposed and made a very fine collection, containing large slabs with impressions of great spreading pinnæ of Ctenis, Ctenophyllum, Tæniopteris, Macrotæniopteris, etc. Six large boxes were thus quickly filled and were shipped to Washington, arriving in good condition in November.

I worked this material over with much care during the winter, and not wishing to reship it on account of its fragile nature, I arranged with Professor Fontaine to come to Washington during his summer vacation of 1896 and elaborate it in the United States National Museum. This he did in July. As it would necessarily be some time before the drawings could be made and the first report published, Professor Fontaine consented to prepare a preliminary paper embodying the principal results, which appeared in October of that year.[2] It unfortunately seemed necessary to publish the list of species, including the new ones,

[1] Jour. Geol., Vol. III, May-June, 1895, pp. 385–414.

[2] Notes on some Mesozoic plants from near Oroville, California, by Wm. M. Fontaine: Am. Jour. Sci., October, 1896, 4th series, Vol. II, pp. 273–275.

in this article without descriptions, and as such they are mere *nomina nuda*, but the types are at the National Museum duly labeled and accessible to all, so that there could be no question as to identification. The closing paragraph of this article shows that in the course of his examination of this thoroughly representative collection, with the original small collection in his hands at the same time, Professor Fontaine was induced to regard the deposit as somewhat higher than he formerly supposed:

> From this it will be seen that the evidence that the age is Jurassic is stronger than for any other, and as the Oolitic plants predominate, we may assume with considerable probability that it is rather late Jurassic, being about that of the lower Oolite (p. 275).

All this, taken in connection with the close lithological resemblances, seems to point to the practical identity of these auriferous slates with the typical Mariposa slates farther south.

There are many causes that have delayed progress in bringing out the final report on the Oroville collections. Professor Fontaine's manuscript containing the full descriptions and directions for illustration was submitted August 11, 1896, but the Division of Illustrations was unable to take them up until the fall of 1897, and owing to prolonged interruptions they were not completed until the spring of 1899. The drawings were submitted to Professor Fontaine for revision and all steps taken to render them as perfect as possible. Having worked out the synonymy with special care I introduce the report into this paper in the following form:

### NOTES ON MESOZOIC PLANTS FROM OROVILLE, CALIFORNIA.

By WM. M. FONTAINE.

The plants described in this paper were collected in September, 1895, by Mr. Lester F. Ward, assisted by Mr. James Storrs. They were obtained near Oroville, California, from a formation which for convenience of reference I will call the Oroville beds. They were collected from four localities, which are all near together. The following are the localities:

1. The old dump at the Banner mine, near Feather River, 5 miles east of Oroville, California.
2. The new dump, 300 yards farther north than the old dump.
3. Bank of Feather River, one-half mile south of the Banner mine.
4. In the bed of a ravine that leads from the Banner mine to the Feather River, from one-fourth to one-half mile south of that mine.

All the fossils occur on the same horizon. Mr. Ward says in a note that these Oroville beds closely resemble the Jurassic Mariposa slates, but the identity is not made out. According to oral statements made by him, the formation where the plants were collected is in the form of a narrow belt, perhaps 500 yards wide, with a dip of from 70° to 80°.

The beds contain no fossils besides the plants. They are not connected stratigraphically with any known formation, and their age, so far as yet known, must be determined from the plant fossils.

Mr. H. W. Turner, in a paper on The Age and Succession of the Igneous Rocks of the Sierra Nevada, published in the Journal of Geology, Vol. III, No. 4, May–June, 1895, p. 394, speaking of the eruptive rocks of the Smartsville area, says:

> These rocks, largely augite-porphyrites and their tuffs, are presumed to have covered, as with a mantle, the underlying Paleozoic formation. There are some streaks of slates among the eruptive masses, but these have not in the Smartsville area afforded any fossils. However, during the past season, in the north extension of the same area, in a belt of clay-slate interbedded with augite-breccia and tuff, fossil plants were collected by T. W. Stanton. The exact locality is by the stage road south of the Oroville Table Mountain, near the Banner gold quartz mine.

The locality referred to by Mr. Turner is that from which Mr. Ward collected. The plants collected by Dr. Stanton were submitted by Mr. Ward to me for determination. They will be noticed further on.

The rock material carrying the plants described in this paper shows some chemical disturbance, so that the fossils, especially in the coarser matrix, are sometimes poorly preserved in their more delicate parts. They are a good deal rubbed, crushed, and distorted. The rocks show considerable induration, the finer argillaceous material being in the condition of a fine slate. The tuffs have the aspect of a hard sandstone. The slate varies in color from lead-gray to black, the latter having much carbon in a diffused state. It looks much like the roof slates of a coal bed.

To judge from the specimens collected by Messrs. Ward and Storrs, most of the rock of the Oroville beds that carries plants consists of alternations of sandy-looking beds with layers of slate. The former are probably the tuffs noticed by Mr. Turner. I will refer to this material as tuffs in describing the plants.

## DESCRIPTIONS OF THE SPECIES.

### Subkingdom PTERIDOPHYTA (Ferns and Fern Allies).

### Class FILICALES.

### Family FILICES (Ferns).

### Genus THYRSOPTERIS Kuntze.

#### THYRSOPTERIS MAAKIANA Heer?

Pl. XLIX, Fig. 1.

1876. *Thyrsopteris Maakiana* Heer: Jura-Flora Ostsibiriens, Fl. Foss. Arct., Vol. IV, Pt. II, pp. 23, 31, 118, pl. i, figs. 1a, 1b; pl. ii, figs. 5, 5b, 6.

This plant was found in one specimen at the locality "In the bed of a ravine that leads from the Banner mine," etc., and in three specimens from the locality "Bank of Feather River," etc. It is too fragmentary and too poorly preserved to permit its character to be made out fully. It most resembles the *Thyrsopteris Maakiana* of Heer, from the Jurassic of Siberia,[1] but the pinnules are more entire, probably because they are higher up on the frond.

The most complete specimen is the one figured. This occurs on a fragment of indurated tuff that has the physical character of sandstone, hence the imprint is not distinct and is somewhat distorted. This imprint shows a portion of a penultimate pinna, with several ultimate pinnæ on each side of the rachis. These are lanceolate in form and alternate in position, with lobes and teeth cut obliquely into an oblong or ovate shape. The basal upper pinnules are decidedly larger than any of the rest. Toward the ends of the ultimate pinnæ the pinnules become entire, or nearly so. The incision of the lamina is made to varying depths, according to position, so that the lobes pass to teeth higher up.

## Genus ADIANTITES Göppert.

### ADIANTITES OROVILLENSIS Fontaine.

Pl. XLIX, Figs. 2, 3.

1896. *Adiantites orovillensis* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

Frond tripinnate, primary and secondary rachises strong and rigid. The principal rachis was seen with a thickness up to 5 mm. The primary pinnæ are long and lanceolate in form. Their mode of insertion was not seen. The ultimate pinnæ are subopposite and oblong in form, with 4 to 5 pinnules on a side that do not diminish much in size from the base to the summit of the pinnæ. They are terminated by a spatulate pinnule that is nearly as large as the rest, an unusual feature in ferns. The pinnules are round to reniform in shape and subopposite. They are rather remote and decurrent to form a narrow wing. They are small, about 6 mm. wide and 4 mm. in height. Their nervation was not clearly made out, but seems to be composed of a bundle that spreads in the lamina of the pinnule, in a flabellate manner, forking once in each branch.

This elegant little fern was found in only one specimen at the locality "Bank of Feather River, one-half mile south of the Banner mine." Pl. XLIX, Fig. 2, gives this specimen, and Fig. 3 represents one of the pinnules magnified to show details.

This plant seems to be new and not very near any described form.

[1] Flora Foss. Arct., Vol. IV, Beiträge zur Jura-Flora Ostsib. und des Amurlandes, p. 31, pl. i, fig. 1a; pl. ii, fig. 6.

## Genus CLADOPHLEBIS Brongniart.

### CLADOPHLEBIS SPECTABILIS (Heer) Fontaine.

Pl. XLIX, Figs. 4, 5.

1876. *Asplenium* (*Diplazium*) *spectabile* Heer: Jura-Flora Ostsibiriens, Fl. Foss. Arct., Vol. IV, Pt. II, pp. 96, 120, pl. xxi, figs. 1, 2a, 2c, 2d.
1896. *Cladophlebis spectabilis* (Heer) Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

This beautiful and well-characterized fern was found in two pretty well-preserved specimens at the locality "Bank of Feather River, one-half mile south of the Banner mine." The specimens show only detached portions of ultimate pinnæ. The specimen given in Pl. XLIX, Fig. 4, shows portions of three ultimate pinnæ in a position that they would have if they had been attached to a principal rachis. This specimen shows that the fern was at least bipinnate. The plant was clearly a large one, and it was probably subarborescent. The rachises are strong and rigid. The pinnules are large and closely placed, but separate to their bases. Their ends are very obtuse and their texture seems to have been thin. The midnerve of the pinnules is sharply defined, but not very thick. The lateral nerves are very distinct, but not strong; they fork twice, the forking taking place near the midnerve. The branches diverge suddenly, and then go nearly parallel until they reach the margins of the pinnules.

The general aspect of this plant is not common among ferns, and hence it can be easily recognized, and there is not much danger of confounding it with other species. This fact gives to even small fragments a value not possessed by less well-defined forms.

Fig. 4 gives the most complete specimen, and Fig. 5 a pinnule of the same, magnified to show details.

This plant is no doubt identical with that described by Heer as *Asplenium spectabile* from the Jurassic formation on the upper Amur, in Siberia.[1] Heer regards the species as an Asplenium on the strength of supposed sori that he saw on his specimens. Nothing resembling sori was seen on the Oroville plants. The species clearly belongs to the Cladophlebis type of fern. I prefer to call all ferns of this type Cladophlebis and not to identify them with living species in the absence of satisfactory proof.

### CLADOPHLEBIS ARGUTULA (Heer) Fontaine.

Pl. L, Figs. 1–6.

1876. *Asplenium argutulum* Heer: Jura-Flora Ostsibiriens, Fl. Foss. Arct., Vol. IV, Pt. II, pp. 24, 41, 96, 118, 120, pl. iii, figs. 7, 7b, 7c, 7d; pl. xix, figs. 1, 1b, 2, 3, 3b, 3c, 4.
1896. *Cladophlebis argutulus* (Heer) Fontaine: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

[1] Flora Foss. Arct., Vol. IV, Pt. II, Beiträge zur Jura-Flora Ostsib. und des Amurlandes, pp. 96, 97, pl. xxi, figs. 1, 2a.

A considerable number of specimens of a small fern were obtained that agree so well with Heer's *Asplenium argutulum* that it may without much hesitation be identified with it. Heer's plant was obtained from the Jurassic formation on the upper Amur River, the same that yielded *C. spectabilis*.[1] Most of the Oroville specimens are fragmentary and distorted by pressure. This is the case with the form represented in Fig. 1, and in consequence of this the pinnules appear more united and wider than in Heer's normal forms.

This is the most common small-leaved fern at the Oroville localities. It occurs at most of them, but is most abundant at the locality "In the bed of a ravine that leads from the Banner mine to the Feather River," etc.

Fig. 1 gives the upper part of a compound pinna. Fig. 3 represents several detached ultimate pinnæ from the lower part of the frond, and Fig. 4 gives a pinnule of the same enlarged to show details.[2]

### CLADOPHLEBIS WHITBIENSIS TENUIS var. a Heer?[3]

Pl. L, Fig. 7.

1876. *Asplenium (Diplazium) whitbiense tenue* var. a Heer: Jura-Flora Ostsibiriens, Fl. Foss. Arct., Vol. IV, Pt. II, pp. 24, 39, 95, 118, 120, pl. iii, figs. 3, 3b; pl. xx, figs. 2, 3a; pl. xxi, figs. 3a, 3b, 4, 4b.

1896. *Cladophlebis whitbiensis tenuis* var. a (Heer) Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

Two small fragments of a fern that is without doubt of the *whitbiensis* type were found at "The old dump at the Banner mine." Both are the terminations of ultimate pinnæ, parts of ferns that have little value in fixing character, and hence, as the amount of material is so small, the identity of this fern must remain in doubt. It is, however, clearly different from the other ferns found at Oroville, and is so much like the form described by Heer[4] from the Jurassic of Siberia that it may be provisionally identified with it. The Oroville plant may be compared with fig. 2 of Heer's pl. xx. The plant has a sharply defined character marked by the possession of pinnules that are very broad at

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[1] Flora Foss. Arct., Vol. IV, Pt. II, Beiträge zur Jura-Flora Ostsib. und des Amurlandes, p. 96, pl. xix, figs 1-4.

[2] After Professor Fontaine had studied the specimens it was observed that there was a counterpart of the upper part of the specimen, Fig. 1, which shows the details somewhat better, and this is shown in Fig 2. A small piece on the left of the portion of the large slab, designated Fig. 3 by Professor Fontaine, split off, revealing the pinna included in that figure, which lies in the opposite direction and is not in the same plane as the others on the rock. The reverse of this on the small piece thus split off shows more than the side adhering to the large slab, and is represented in Fig. 5. The perfect pinnule near the top of this on the left is given in Fig. 6, enlarged two diameters.
L. F. W.

[3] It is not worth while to attempt to work out the synonymy of this form, as it is clearly different from the original *Pecopteris tenuis* Schouw, Mss., based on a specimen in Prince Christian's Museum and figured by Brongniart in his Hist. Vég. Foss., Vol. I, pl. cx, fig. 4, and the whole group needs revision. L. F. W.

[4] Flora Foss. Arct., Vol. IV, Pt. II, Beiträge zur Jura-Flora Ostib. und des Amurlandes, p. 95, pl. xx, figs. 2, 3a.

base with acute tips. At the same time they are inclined forward in a peculiar manner. They can not be united with *Cladophlebis spectabilis*, the plant nearest to it that occurs at Oroville.

This fern belongs evidently to that well-marked Jurassic type brought under the comprehensive name *Cladophlebis whitbiensis*, and resembles Brongniart's form more than that of Lindley and Hutton.

### CLADOPHLEBIS DENSIFOLIA Fontaine.

Pl. LI.

1896. *Cladophlebis densifolia* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

Frond tripinnate at least. The largest primary rachis seen, given in Pl. LI, Fig. 1, has a width of 6 mm. The primary pinnæ are alternate and very long. The largest portions found were 14 cm. in length, with the basal and terminal portions not preserved. This portion does not change in width much throughout its length, and hence must belong to a pinna that was much larger than the part seen. The primary pinnæ were probably linear-lanceolate in form, and tapered very gradually from base to tip. They are closely placed, so that they overlap. The rachises are strong and rigid, going off from the principal rachis at an angle of 45° and curving away from it. The secondary pinnæ are alternate to subopposite and very closely placed so as to overlap. They gradually diminish in length and size from their insertions on the primary pinnæ to their ends. The longest basal ones are about 2 cm. in length and the width of these is about 2 mm. In shape they are oblong with subacute ends. They are inserted at about an angle of 45°, and are falcately curved toward the ends of the primary pinnæ. The lowest, basal, ultimate pinnæ are cut in their lower portions down to the midrib into ovate subfalcate and subacute pinnules that are closely placed, but the portions higher up have the lamina of the leaf more and more entire, the incisions passing, at the tips of the ultimate pinnæ, into teeth. Higher up on the frond and more toward the ends of the primary pinnæ the ultimate ones become more and more entire and pass into lobed and dentate pinnules. The tip of the primary pinna has pinnules and lobes like those of the ultimate pinnæ lower down. The nervation could not be made out.

Fig. 1 represents a portion of a primary pinna. Fig. 2 gives several secondary pinnæ, placed as if they had been attached to a principal rachis. Fig. 3 gives the terminal portion of a frond, or of one of the lower primary pinnæ. Fig. 4 gives a portion of a lower ultimate pinna magnified to show details.

This is one of the most abundant small-leaved ferns in the formation, and it shows larger portions better preserved than any of the small ferns.

The plant previously known that is perhaps nearest to this is the sterile form of *Pecopteris lobata* Oldh., of the Rajmahal flora.[1] The enlarged pinnules on pl. xxx, of Oldham and Morris, allowing for their evident distortion, are much like those of the Oroville fossils. At the same time the density of the lobes and pinnules in the ultimate pinnæ, the shape of the ultimate pinnæ, their close position, and mode of insertion, are much like features shown in the plant from Oroville. The Indian plant is mostly fructified, but this feature is wanting in the fossil now being described. While these points show that the two are probably near together, it seems the better usage, in the case of plants growing in regions as far apart, and in the absence of stronger proof of identity, to regard them as distinct species. *Cladophlebis densifolia* is found at the locality "Bank of Feather River, one-half mile south of the Banner mine."

CLADOPHLEBIS INDICA (Oldham and Morris) Fontaine?

Pl. LII, Fig. 1.

1862. *Pecopteris* (*Alethopteris*) *indica* Oldh. and Morr.: Palæontologia Indica, Ser. II. Foss. Fl. Gondw. Syst., Vol. I, Pt. I, Foss. Fl. Rajmahal Series, p. 47, pl. xxvii.

1869. *Alethopteris indica* (Oldh. and Morr.) Schimp.: Traité de Pal. Vég., Vol. I, p. 568.

1896. *Cladophlebis indica* (Oldh. and Morr.) Font.?: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

A single specimen was obtained from the locality: "In the bed of a ravine that leads from the Banner mine," etc., of a fern that seems identical with the typical *Pecopteris indica*[2] of Oldham and Morris, from the Rajmahal series of India. It is especially like fig. 1 of pl. xxvii of the Fossil Flora of the Rajmahal Series. The specimen is an imprint of the middle portion of an ultimate pinna that shows several pinnules. These are united at the base. They are pretty large, and show little diminution in width from their bases to their tips. They are strongly falcate, but show no nerves, except a pretty strong midrib. There is not enough material to permit a positive identification of this species to be made.

Genus TÆNIOPTERIS Brongniart.

TÆNIOPTERIS OROVILLENSIS Fontaine.

Pl. LII, Figs. 2–4.

1896. *Tæniopteris orovillensis* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

The fronds vary in length from 1 to 4 cm. The maximum length seen is 13 cm. on fragments of fronds. The largest were probably at

[1] Fossil Flora of the Rajmahal Series, p. 52, pl. xxviii, fig. 1; pl. xxix; pl. xxx.
[2] Op. cit., p. 47, pl. xxvii.

least 26 cm. long. The fronds taper gradually from near the middle toward their base and tip, so that they are narrowly elliptical in shape. The midrib is strong, prominent, and rounded. The lateral nerves go off nearly at right angles, curve slightly away from the midrib, and then, near the margin, curve slightly toward the ends of the fronds. They are parallel throughout their course, very fine but distinct, and very closely placed, being about three in the space of 1 mm. The leaf substance is thick and durable, giving the pinnule a rigid aspect. No entire specimen was seen.

This plant is by far the most common fossil at Oroville. It occurs abundantly at the localities "Bank of Feather River," etc., and "In the bed of a ravine that leads from the Banner mine," etc. It is very near the plant figured and described by Saporta[1] as *Tæniopteris tenuinervis* Brauns, from the Infralias of France. From an inspection of the material afforded by Stanton's collection it was regarded as identical with Saporta's plant. This species varies a good deal in dimensions, and from the imperfect material in the above-mentioned collection the writer supposed that another species figured by Saporta from the same formation, viz, *T. stenoneura* Schenk, was also present. The very abundant and well-preserved material collected by Messrs. Ward and Storrs establishes a complete gradation between all the forms of Tæniopteris found at Oroville, and shows that only one species exists there. In addition, it makes it pretty clear that this is a new species. The larger specimens much surpass in size any of Saporta's, and, what is of more importance, the nerves are finer, more closely placed, and they do not fork at any point.

Fig. 2 gives a portion of one of the small fronds, not the smallest, and Fig. 3 represents the average of the largest forms. It shows well the mode of tapering toward the base of the frond, while it gives as much of the stipe as is seen on any of the specimens. Fig. 4 gives an enlarged fragment, to show the nervation.

### Genus MACROTÆNIOPTERIS Schimper.

#### MACROTÆNIOPTERIS CALIFORNICA Fontaine.

Pl. LIII, Fig. 1; Pl. LIV, Figs. 1, 2.

1896. *Macrotæniopteris californica* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

Fronds variable in width, mostly large. The largest seen had a midrib 1 cm. in width and a leaf at least 15 cm. wide. Only fragments were seen. The smallest form had a width toward its base of only 4 cm. The widest leaves were not entire, so that their maximum width

[1] Paléontologie Française, 2e Série, Végétaux, Vol. I, p. 441, pl. lxiii, figs. 1-5.

probably surpassed the greatest dimensions seen. The nerves are about three-fourths of a millimeter apart. They are slender but sharply defined. They go off nearly at right angles with the midrib and then arch slightly forward toward the end of the frond. They are parallel in their course and are nearly all unbranched. Very few branch and nearly all that fork do so before reaching the middle of the lamina of the frond.

Several specimens of this plant were found at the locality "In the bed of a ravine that leads from the Banner mine," etc., but all were quite fragmentary and poorly preserved. The varying size of the fronds is no doubt due to the varying age of the same.

This fossil, although probably a new species, seems to be quite near to *Tæniopteris lata* Oldh. and Morr.,[1] of India, but the midrib is wider and not so rigid as that of the plant from the Rajmahal flora.

Pl. LIV, Fig. 1, gives the basal portion of a small form, and Pl. LIII, Fig. 1, a fragment of one of the largest leaves.

### MACROTÆNIOPTERIS NERVOSA Fontaine.

Pl. LIV, Fig. 3; Pl. LV, Fig. 1.

1896. *Macrotæniopteris nervosa* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

Leaf very large, dimensions not made out. Midrib very large. The largest imprint of it seen had a width of 15 mm. Not enough of the frond was seen to show the entire course of the lateral nerves. As seen, they go off from the midrib at a large angle, then arch slightly away from it and are parallel for all their course seen. They sometimes have a common point of insertion for two adjacent lateral nerves, which are then single. Sometimes each nerve has an independent point of insertion, and then these may fork near the midrib. The lateral nerves are very thick and cord-like and very remote.

No known Macrotæniopteris has nerves anything like those of this plant. The fragments found were evidently but small portions of the original fronds. They indicate for it a gigantic size.

Two fragments were found, one at the locality "Bank of Feather River," etc., and one at the locality "In the bed of a ravine that leads from the Banner mine," etc., that must have belonged to gigantic fronds. Pl. LIV, Fig. 3, and Pl. LV, Fig. 1, give the two most perfect specimens, which have a midrib 8 mm. wide.

[1] Fossil Flora of the Rajmahal Series, pl. ii, fig. 1.

## Genus ANGIOPTERIDIUM Schimper.

### ANGIOPTERIDIUM CALIFORNICUM Fontaine.

Pl. LV, Figs. 2–5.

1896. *Angiopteridium californicum* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

Two fragments of a fern that seems to be an Angiopteridium were found at the locality "In the bed of a ravine that leads from the Banner mine," etc. One of these is the fragment of the middle portion of a sterile pinnule. This is 25 mm. wide. It has very distinct, but slender, lax, and rather remote lateral nerves that go off at a large angle from the midrib, curve away from it, and then, near the margin of the lamina, bend slightly toward the tip of the pinnule. In general aspect the fragment looks much like *Tæniopteris orovillensis*, but the nerves are quite different. The lateral nerves leave from a common point on the midrib, and then are either single or fork at varying distances from the midrib, but only once, and mostly halfway between the midrib and margin. The branches are, approximately, parallel. This sterile form resembles somewhat *Angiopteridium nervosum* Font., of the Potomac formation of Virginia.

The other fragment seems to be the fertile form of the same species as the sterile portion just described. It has the same nervation as the sterile fragment, and is the imprint of a portion of a frond, about 2 cm. wide in its widest portion. The imprint shows a length of 85 mm., with the basal and terminal portions not preserved. It bears, at the margins of the pinnule, elliptical sori of large size. They are carried on the ends of the lateral nerves.

This fertile form resembles *Angiopteridium McClellandi* (Oldh. and Morr.) Schimp. It should be stated that the sterile form is a good deal like that depicted by Feistmantel on pl. xlvi, fig. 5, of the Jurassic Flora of the Rajmahal Group, which he supposes is a form of *A. McClellandi*.

Pl. LV, Fig. 2, gives the sterile form, and Fig. 3 an enlarged fragment to show the nerves. Fig. 4 represents the fertile form, and Fig. 5 an enlarged portion to show the sori.

## Genus SAGENOPTERIS Presl.

### SAGENOPTERIS NILSONIANA (Brongniart) Ward n. comb.[1]

### Pl. LVI, Fig. 1; Pl. LXVII, Fig. 2.

1820. *Bladaftryck* (*folium ovatum*, etc.) Nilsson: K. Vet.-Acad. Handlingar, Stockholm, Vol. I, p. 115, pl. v, figs. 2, 3.
1825. *Filicites Nilsoniana* Brongn.: Ann. Sci. Nat. de Paris, Vol. IV, p. 218, pl. xii, fig. 1.
1828. *Glossopteris Nilsoniana* Brongn.: Prodrome, pp. 54, 194; Hist. Vég. Foss., Vol. I, p. 225, pl. lxiii, figs. 3, 3A.
1834. *Glossopteris latifolia* Münst.: N. Jahrb. f. Min., 1834, p. 43.
1836. *Glossopteris elongata* Münst.: Op. cit., 1836, p. 510.
1836. *Acrostichites inæquilaterus* Sternb. in Göppert: Syst. Fil. Foss., p. 287.
1836. *Aspidites Nilsonianus* Göpp.: Op. cit., p. 354.
1838. *Sagenopteris rhoifolia* Presl in Sternberg: Flora der Vorwelt, Vol. II, pp. 165, 210, pl. xxxv, fig. 1.
1838. *Sagenopteris diphylla* Presl: Op. cit., p. 165, pl. xxxv, fig. 4.
1838. *Sagenopteris semicordata* Presl: Op. cit., p. 165, pl. xxxv, fig. 2.
1838. *Sagenopteris acuminata* Presl: Op. cit., p. 165, pl. xxxv, fig. 3.
1843. *Sagenopteris elongata* Münst.: Beitr. z. Petrefactenkunde, Vol. II. Pt. VI, p. 28.
1845. *Acrostichites ? (Sagenopteris) diphylla* (Presl) Ung.: Synops. Pl. Foss., p. 77.
1845. *Acrostichites ? (Sagenopteris) semicordata* (Presl) Ung.: Loc. cit.
1845. *Acrostichites ? (Sagenopteris) acuminata* (Presl) Ung.: Loc. cit.
1849. *Phyllopteris Nilsoniana* Brongn.: Tableau, pp. 22, 103.

Several poorly preserved specimens of a Sagenopteris are found at the locality "In the bed of a ravine that leads from the Banner mine," etc. They occur in the form of detached pinnules on indurated tuff, and the nervation is poorly shown, but is very dense. Pl. LVI, Fig. 1, gives one of the most perfect pinnules, and Pl. LXVII, Fig. 2, a large pinnule in which the anastomosis is not visible. This plant seems to be quite near *Sagenopteris rhoifolia elongata* Münst.[2] The midrib in the Oroville plant is less strong, the nervation denser, and the pinnules are on an average smaller. It may be a new species, but there is not enough material to fix positively the character of the plant.

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[1] Schimper (Traité de Pal. Vég., Vol. I, p. 642) says:

"Le *Glossopteris* (*Phyllopteris*) *Nilssoniana* Brongn. appartient sans aucun doute à cette espèce. J'en ai pu examiner dans la collection de M. Nilsson à Lund de très-bons échantillons, qui m'ont convaincu que la plante de la Suède ne diffère en rien de celle de l'Allemagne."

As the *Filicites Nilsoniana* of Brongniart (1825) was the earliest name given to the plant, and as all are now agreed that it belongs to Presl's genus Sagenopteris (1838), there is no way of escaping this combination for the plant that has so long gone by the name *Sagenopteris rhoifolia*, which Professor Fontaine continues to apply to it. The synonymy here given rests entirely on the authority of Presl and Schenk. Presl himself admitted that his plant was the same as Sternberg's *Acrostichites inæquilaterus* (1836), which he had shown to Göppert and allowed him to describe. This alone condemns Presl's specific name. Schimper confirms all that Schenk says as to the other names, and the former worked over the original material. In the synonymy here given I have not taken account of the three varieties that Schenk distinguishes. It is sufficiently doubtful whether the American forms really belong to this widespread polymorphous species or not. L. F. W.

[2] See Schenk, Fossil Flora der Grenzschichten, pl. xii, fig. 1.

## Genus DIDYMOSORUS Debey and Ettingshausen.

### DIDYMOSORUS ? BINDRABUNENSIS ACUTIFOLIUS Fontaine.

Pl. LVI, Figs. 2, 3.

1860. *Pecopteris* (*Gleichenites*) *linearis* Oldh.: Mem. Geol. Survey of India, Vol. II, Pt. II, p. 324.

1863. *Pecopteris* (*Gleichenites*) *gleichenoides* Oldh. and Morr.: Op. cit., Pal. Ind., Ser. II, Foss. Fl. Gondw. Syst., Vol. I, Pt. I, Foss. Fl. Rajmahal Series, p. 45, pl. xxv; pl. xxvi, figs. 1, 3.

1869. *Gleichenia bindrabunensis* Schimp.: Traité de Pal. Vég., Vol. I, p. 670.

1875. *Gleichenites bindrabunensis* (Schimp.) Feistm.: Verh. d. k.-k. Geol. Reichsanst., Wien, Jahrg. 1875, p. 190.

1877. *Gleichenites* (*Gleichenia*) *bindrabunensis* (Schimp.) Feistm.: Mem. Geol. Survey of India, Pal. Ind., Ser. II, Foss. Fl. Gondw. Syst., Vol. I, Pt. II, p. 93 (Jur. Fl. Rajm. Group, p. 41).

1888. *Didymosorus ? gleichenoides* (Oldh. and Morr.) Etheridge, var.: Proc. Linn. Soc. N. S. W., 2d Ser., Vol. III, Pt. III, p. 1308, pl. xxxviii, fig. 3.

1892. *Didymosorus ? gleichenioides* (Oldh. and Morr.) Jack and Etheridge, var.: Geology and Palæontology of Queensland and New Guinea, p. 557.[1]

Only a small fragment of this plant was found at the locality "In the bed of a ravine that leads from the Banner mine," etc. The specimen is an imprint of a small fragment of the terminal portion of a penultimate pinna that contains several ultimate pinnæ. The latter are very small and narrowly linear. The largest are about 2 cm. long and not more than 4 mm. wide. They are not very distinctly preserved, as they occur on indurated tuff. They are also somewhat distorted by pressure. The nervation was not made out. The plant resembles *Pecopteris gleichenoides* Oldh. and Morr.[2] It is probably an acute form of the Indian fern. This latter has pinnules with obtuse tips. It is most like the plant from the Rajmahal series figured on pl. xxvi, fig. 3, but is smaller than that. The narrow pinnæ are cut into narrow ovate-acute lobes or pinnules. Should it prove to be a form of the Indian fern it might be called variety *acutifolius*.

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[1] Jack and Etheridge here change the spelling of the specific name so that the combination becomes identical with *Didymosorus gleichenioides* Debey and Ettinghausen in their memoir, Die Urweltlichen Acrobryen des Kreidebirges von Aachen und Maestricht, p. 10 (Denkschr. Wien. Akad., Vol. XVII, p. 190, pl. i, figs. 1-5), with which no one has compared it, and which is a different plant. Neither Oldham and Morris nor Etheridge seemed to have observed that Debey and Ettinghausen gave this name to one of the original forms on which they based the genus, although these authors refer to this memoir and call attention to other species. As the specific name *linearis* is also preoccupied, the only remaining name is that of Schimper, and this therefore must be retained. L. F. W.

[2] Fossil Flora of the Rajmahal Series, p. 45, pl. xxv; pl. xxvi, figs. 1, 3.

## Subkingdom SPERMATOPHYTA.

## Subdivision GYMNOSPERMAE.

## Class CYCADALES.

## Family CYCADACEÆ.

### Genus PTEROPHYLLUM Brongniart.

#### PTEROPHYLLUM RAJMAHALENSE Morris?

Pl. LVI, Figs. 4, 5.

1863. *Pterophyllum rajmahalense* Morr.: Mem. Geol. Survey of India, Pal. Ind., Ser. II, Foss. Fl. Gondw. Syst., Vol. I, Pt. I, Foss. Fl. Rajm. Series, p. 25, pl. xiii, figs. 3-5; pl. xiv.

Several specimens of a Pterophyllum, which can hardly be separated from *P. rajmahalense* Morr.[1] of the Rajmahal flora, were found at the locality "Bank of Feather River," etc. They are imprints of small portions of leaves, showing several leaflets on each side of a rather slender midrib. They agree especially well with the small form given on pl. xiii, fig. 4, of the work of Oldham and Morris. The Oroville plant has its leaflets opposite to one another and going off at right angles with the stem. They are about 15 mm. long and 5 mm. wide. The nerves are about 12 in number. They make right angles with the midrib and are slender but distinct. They are parallel throughout their entire course and single. The points of difference between the Oroville and Indian plants are the smaller size of the midrib in the former and the somewhat fewer nerves. The amount of material, however, is not sufficient to permit the full character of the plant to be made out and its identification must remain in doubt for the present.

### Genus CTENIS Lindley and Hutton.

#### CTENIS GRANDIFOLIA Fontaine.

Pl. LIII, Fig. 2; Pl. LVI, Figs. 6, 7; Pl. LVII.

1896. *Ctenis grandifolia* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

Only fragments of leaves were seen, hence the character of the entire leaf can not be determined. The segments, or leaflets, are large and ribbon shaped. Their terminations were not seen. They are attached by their entire base to the sides of a moderately strong midrib. The strongest midrib seen had a width of 4 mm. They go off nearly at right angles and then curve slightly toward the summit of the compound leaf, so as to have a falcate form. They are slightly

[1] Fossil Flora of the Rajmahal Series, p. 25, pl. xiii, figs. 3, 4, 5.

expanded at base, closely placed, and in some cases touch one another. The leaflets vary in width. The largest obtained has a width of 4 cm. and a length of 20 cm., being only a fragment with the terminal part not preserved. This is represented in Pl. LVI, Fig. 6. The nerves are very strong and single. They go off at a large angle and are approximately parallel in their course. They anastomose at long intervals, so as to form very much elongated meshes. The mode of anastomosis was not fully made out. It is apparently as follows: A nerve forks dichotomously, one branch continues the course of the original nerve, the other coalesces with an adjacent one. This union takes place rarely near the bases of the leaves, and more freely at a distance of 3 or 4 cm. above the base of the leaflet. This more frequent anastomosis appears to occur also at the same interval, toward the middle and terminal portions of the leaflets. This, however, could not be clearly made out, owing to the fragmentary condition and imperfect preservation of the leaflets.

A number of fragments of this fine cycadaceous plant were found at the locality "In the bed of a ravine that leads from the Banner mine," etc., that indicate that it obtained a gigantic size. Pl. LVII shows a leaf with several leaflets in fragments, only the basal portions being represented. The leaflets here are of the smallest size. Pl. LVI, Fig. 6, gives a portion of a leaflet of the largest size. Fig. 7 represents the restoration of a portion of a leaflet, to show the nervation and mode of insertion. Pl. LIII, Fig. 2, shows the general habit of the plant.

This plant and the two to be next described belong to a type that is not common, and which seems to be complex in character. The general aspect reminds one of the large Pterophylla of the Rajmahal series, especially of *Pterophyllum princeps* Oldh. and Morr.,[1] but this does not have similar nerves. Perhaps they should be placed in a new genus, but they are near enough to the *Ctenis falcata* of Lindley and Hutton[2] to be placed in the same genus with it. The chief difference is the much greater size of the Oroville plant. Nathorst's *Ctenis fallax* and *Ctenis imbricata* Font. of the Potomac of Virginia belong to the same type, but are specifically different. A noteworthy feature of this plant is the unequal width of the leaflets, and in this respect it resembles Nilsonia.

[1] Fossil Flora of the Rajmahal Series, pl. x, fig. 3.
[2] Fossil Flora of Great Britain, Vol. III, pl. ciii.

CTENIS AURICULATA Fontaine.

Pl. LVIII, Figs. 1-3.

1896. *Ctenis auriculata* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

Only portions of leaflets were seen. The most complete specimen, given in Pl. LVIII, Fig. 2, shows a portion of the compound leaf, with the basal parts and attachment of two leaflets. The plant must have reached a large size, but the true dimensions can not be made out. Only the basal portions of the leaflets were seen, and in these portions they show some variation. The form represented in Fig. 1 has the least narrowing at base and the least auriculate form, having somewhat the shape of the bases of the leaflets of *C. grandifolia.* The bases of the leaflets in the form represented in Fig. 2 are considerably rounded off and narrowed at their insertion, so that they have a pronounced auriculate form. The nerves are quite different from those of *C. grandifolia*, but the general plan of anastomosis is similar, although more abundant. The nerves, near their attachment, are rather remote and straggling. They go off at a large angle and are, near their bases, mostly single, but above branch more or less copiously. Those in the middle and upper sides of the lamina of the leaflet are less copiously branched, but those in the lower portion branch repeatedly in a flabellate manner, curving outward and downward in the more auriculate leaves to fill the expanded base. This description applies only to the basal portions of the leaflets, for only these were seen. The nerves are very strong and cord-like, being considerably stronger than those of *C. grandifolia.* They anastomose by one of the branches of a forking nerve coalescing with an adjacent nerve to form elongate meshes, after the general fashion seen in *C. grandifolia*, but there is no regularity in the intervals at which this takes place, and the union of nerves is more common.

A considerable number of specimens of this plant are found at the locality "In the bed of a ravine that leads from the Banner mine," etc. The specimens are not complete enough to show the full character of the plant, but they are enough so to indicate that it is quite different from *C. grandifolia*, and, indeed, from any hitherto-known species. The auriculate form of the bases of the leaflets reminds one of *C. imbricata* Font. of the Potomac formation, but there is hardly any other feature of resemblance except the existence of a reticulation of the Ctenis type.

Fig. 3 gives a portion of a leaflet above the base and shows well the copious reticulation of that portion.

### CTENIS OROVILLENSIS Fontaine.

Pl. LVIII, Fig. 4.

1896. *Ctenis orovillensis* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

The most complete specimen, given in Fig. 4, shows the basal portions of several leaflets, placed on each side of the midrib of the compound leaf. They are subopposite, closely placed, at right angles with the midrib, and have expanded bases, so that they are separated by a V-shaped sinus, while at their bases they are apparently united to form a narrow wing. The leaflets vary somewhat in width, but not so much as those of *C. grandifolia.* The nerves are strong and distinct, but not so much so as those of the two previously described species. Those in the middle portion of the lamina go off at right angles, while those near the upper and lower margins of the same go off at obtuse angles and arch away from the midrib to enter the leaflet. The nerves anastomose rather rarely at and near the midrib and more freely at the distance of about 25 mm. above the midrib. They anastomose again more freely at about 5 cm. above the midrib. Hence the free anastomosis occurs at intervals of about 25 mm., forming elongate meshes, with a similar length.

Several specimens of this plant are found at the locality "In the bed of a ravine that leads from the Banner mine," etc. Like *C. grandifolia*, this plant reminds one of the large Pterophylla of the Rajmahal series. It may be a form of *C. grandifolia*, but has not the facies of that plant. The leaflets also are smaller, with a thinner texture, and they are of more uniform width. The leaflets in shape, size, and texture resemble those of *Ctenophyllum Wardii*, which will be next described, but this latter has no reticulation in the nerves.

## Genus CTENOPHYLLUM Schimper.

### CTENOPHYLLUM WARDII Fontaine.

Pl. LIX; Pl. LX; Pl. LXVII, Fig. 5.

1896. *Ctenophyllum Wardii* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

Entire leaves not seen. Probably they were nearly a meter long. The largest fragment seen showed only the middle portion of a leaf, with no sensible diminution in the leaflets from one end to the other. It is 26 cm. long, with a slender midrib, not more than 2 mm. wide. A number of leaflets go off on each side of this, none of which are entire. The leaflets are quite far apart, having a distance of about 15 mm. They are subopposite and ribbon-shaped. They are separate to their bases, which are decurrent on their lower sides and slightly rounded off on the upper ones. They do not alter in width throughout their length. The maximum length seen was 13 cm. The leaflets go off at an angle of about 60°, and then turn slightly away from the midrib. Their width is somewhat variable. The average width is 2 cm. and the maximum 3 cm. The nerves are fine, but distinct and very numerous. They go off at an angle of 45°, and immediately after leaving the midrib turn strongly away from it, and then are parallel throughout their course. They fork once near their bases. No additional forking was certainly made out. If it takes place it must occur at long intervals and irregularly.

Several specimens of this splendid plant were found at the locality "In the bed of a ravine that leads from the Banner mine," etc. Pl. LIX gives the most complete form and Pl. LX that with the widest leaflets. A few fragments of leaflets of this species are also seen on Pl. LXVII, Fig. 5.

This fine plant is one of several species found at the Oroville locality which are evidently allied and probably belong to the same genus. The genus Ctenophyllum, as defined by Schimper, seems to be the one in which they must be placed; that is, provided we may translate his description, "foliolis lateri rachis superiori, oblique adfixis," by: leaflets attached obliquely to the upper side (not face) of the rachis. The leaflets are attached obliquely to the sides of the rachis in the plane of the upper face of the same. It must be admitted that these plants are of a very different type from *Ctenophyllum Braunianum*, so far as their general aspect is concerned.

The plant now in question is nearer *C. latifolium* Font.[1] of the Potomac of Virginia than any other hitherto known, but the leaflets do not vary so much in width and the nerves are more slender and closely placed.

The plant is named for Mr. Lester F. Ward, by whose efforts the fine collection from Oroville was obtained.

### CTENOPHYLLUM DENSIFOLIUM Fontaine.

Pl. LXI.

1896. *Ctenophyllum densifolium* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

The size of the leaf is unknown, as all the specimens were fragments. The most complete portion found is a fragment of a compound leaf, 29 cm. long, from the middle part. This indicates that the plant must have been very large. It is apparently the largest Ctenophyllum occurring at Oroville. It shows a number of leaflets on a side, the largest of which, with the upper portion of it not preserved, is 13 cm. long. Notwithstanding the considerable size of this specimen, it shows no diminution from base to summit in the size of the midrib and of

[1] Mon. U. S. Geol. Survey, Vol. XV p. 175, pl. lxviii, figs. 2, 3.

the leaflets. The leaflets go off nearly at right angles with the midrib, have the same width throughout their length, and are closely placed, being only 1 mm. apart. They are 1 cm. wide, and are very uniform in width. The nerves go off nearly at right angles. They are slender, but strongly defined, unbranched, and parallel throughout their course, being about 10 in number. This fine plant is rather abundant at the locality "In the bed of a ravine that leads from the Banner mine," etc. It occurs in large specimens, the finest of which is given on Pl. LXI. It is nearly allied to *C. grandifolium*, but is clearly a different species.

CTENOPHYLLUM GRANDIFOLIUM STORRSII Fontaine.

Pl. LIII, Fig. 3; Pl. LXII; Pl. LXIII, Fig. 1; Pl. LXVI, Fig. 3.

1896. *Ctenophyllum grandifolium Storrsii* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

This plant can not be distinguished specifically from *C. grandifolium* Font., of the Older Mesozoic of Virginia,[1] but although it evidently attained a very large size, it was inferior to the Virginia plant, and had uniformly narrower leaflets, with fewer nerves. The midrib was wide and flat, with apparently no great amount of wood tissue. The leaflets go off nearly at right angles with the midrib. They are placed far apart and are separate, being mostly 5 mm. from one to another. Throughout most of their length they are strap-shaped and narrow, near their bases they grow narrower, and at their base, where they unite with the midrib, they are slightly widened. The narrowed portion appears to have been thick and fleshy. The leaflets must have been very long, equaling the Virginia plant in that respect. The width of the leaflets, even on the same midrib, was not constant, but varied irregularly, although slightly, resembling in this point the Virginia fossil. The nerves are very strong, 5 or 6 in number, and either single or forking once, at various distances from the midrib. Near the midrib they are almost always single, and go off nearly at right angles with the midrib, being then parallel. This nervation differs from that of the Virginia plant, in which the nerves fork once at their bases and are then single.

This fine plant was found with several specimens at the locality "In the bed of a ravine that leads from the Banner mine," etc. Pl. LXII represents the most complete fragment found, and Pl. LXIII, Fig. 1, a portion of a leaflet enlarged to show the nervation. Other less perfect fragments are represented by Pl. LIII, Fig. 3, and Pl. LXVI, Fig 3.

The variety is named for Mr. James Storrs, the intelligent assistant of Mr. Ward in collecting the Oroville fossils.

[1]Mon. U. S. Geol. Survey, Vol. VI, pp. 73-76, pl. xxxix, figs. 1-3; pl. xl; pl. xli; pl. xlii, fig. 1.

CTENOPHYLLUM ANGUSTIFOLIUM Fontaine.

Pl. LXIII, Figs. 2, 3.

1896. *Ctenophyllum angustifolium* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

This plant was found in two small imprints, occurring on the same fragment of rock at the locality "Bank of Feather River," etc. Although the amount of material is so small, it is enough to show certainly that the plant is quite different from any other cycad occurring in the Oroville region. The most complete specimen, shown in Pl. LXIII, Fig. 2, has a midrib 4 cm. long and 1 mm. wide, with several leaflets going off on each side. Only the basal portions of these are preserved, the largest being only 35 mm. long. The leaflets make right angles with the midrib, are only 1 mm. wide, and are slightly expanded at base. The nerves are only three or four in number and strong, but they are not very distinctly shown.

This plant is plainly one of the narrow-leaved Ctenophylla of the type of *Ctenophyllum Braunianum*. It is especially like the form depicted in Mon. U. S. Geol. Survey, Vol. VI, pl. xxxiv, fig. 4, but the leaflets are closer in the Oroville plant.

Genus PODOZAMITES Friedrich Braun.

PODOZAMITES LANCEOLATUS (Lindley and Hutton) Friedrich Braun.

Pl. LXIII, Fig. 4; Pl. LXIV, Fig. 1; Pl. LXVI, Fig. 4; Pl. LXVII, Figs. 3, 4.

1836. *Zamia lanceolata* L. and H.: Foss. Fl. Gt. Brit., Vol. III, p. 121, pl. cxciv.
1840. *Zamites lanceolatus* (L. and H.) Fr. Braun: Verzeichniss Kreis-Nat.-Samml. Bayreuth Petrefact., p. 100.
1843. *Podozamites lanceolatus* (L. and H.) Fr. Braun in Münster: Beitr. z. Petrefactenkunde, Vol. II, Pt. VI, p. 33.

A large number of imprints of this plant are found at the locality "In the bed of a ravine that leads from the Banner mine," etc., and at least one was obtained from the locality "Bank of Feather River," etc. The most common are detached leaflets, but some imprints are found with the leaflets attached. The leaves are rather variable in size, but the average, or normal forms, can not be distinguished from those that Heer describes from Cape Boheman.[1] The larger leaflets are exactly like the larger ones from Cape Boheman and surpass in size any of the species of *P. Emmonsii* or of the type form of Lindley and Hutton.

This plant is of special importance in fixing the age of the strata containing it, as, next to *Tæniopteris orovillensis*, it is the most abun-

[1] Flora Foss. Arct., Vol. IV, Pt. I, Beiträge zur Foss. Flor. Spitzbergens, p. 35, pl. vii, figs. 1–7.

dant fossil. Heer regards the Cape Boheman Jurassic as Middle Brown Jura (Bathonian) in age.

Pl. LXIII, Fig. 4, gives one of the most complete forms, and Pl. LXIV, Fig. 1, represents a form with somewhat narrower leaflets. An imperfect specimen is seen at Fig. 4 of Pl. LXVI, and it seems probable that the parts of leaves represented by Figs. 3 and 4 of Pl. LXVII belong to this plant.

### PODOZAMITES LANCEOLATUS LATIFOLIUS (Brongniart) Heer.

Pl. LXIV, Fig. 2.

1828. *Tæniopteris latifolia* Brongn.: Prodrome, pp. 62, 199; Hist. Vég. Foss., Vol. I, p. 266, pl. lxxxii, fig. 6.
1833. *Odontopteris latifolia* (Brongn.) Sternb.: Flora der Vorwelt, Vol. II, p. 79.
1838. *Zamites latifolius* (Brongn.) Presl: Op. cit., Vol. II, p. 199.
1867. *Podozamites distans latifolia* (Brongn.) Schenk: Foss. Fl. der Grenzschichten des Keupers und Lias, p. 162, pl. xxxvi, fig. 10.
1876. *Podozamites lanceolatus latifolius* (Brongn.) Heer: Jura-Flora Ostsibiriens, Fl. Foss. Arct., Vol. IV, Pt. II, pp. 109, 120, pl. xxvi, figs. 5, 6, 8b, 8c.

Two or three detached leaflets of a Podozamites of the type of *P. lanceolatus* were found at the locality "In the bed of a ravine that leads from the Banner mine," etc., which seem to differ at least varietally from the narrow *P. lanceolatus*, being broader and shorter. They agree well with the leaflets described by Heer[1] from the Jura formation on the Upper Amur as a variety *latifolius* of *P. lanceolatus.*

## Class GINKGOALES.

## Family GINKGOACEÆ.

### Genus BAIERA Friedrich Braun.

### BAIERA MULTIFIDA Fontaine?

Pl. LXV, Figs. 1, 2.

1883. *Baiera multifida* Font.: Mon. U. S. Geol. Survey, Vol. VI, p. 87, pl. xlv, fig. 3; pl. xlvi; pl. xlvii, figs. 1, 2.

Portions of a plant that appears to be a Baiera, near *B. multifida* Font., of the Older Mesozoic of Virginia, were found in two specimens; one, showing the basal part, given in Pl. LXV, Fig. 1, was obtained at the locality "In the bed of a ravine that leads from the Banner mine," etc., and the other, showing laciniæ, represented in Fig. 2, at the locality "Bank of Feather River," etc. The amount of material is too small to permit a positive determination of the plant. It is, however, a coarse, large form, that reminds one strongly of *Baiera multifida* Font.

[1] Flora Foss. Arct., Vol. IV, Pt. II, Beiträge zur Jura-Flora Ostsib. und des Amurlandes, p. 109, pl. xxvi, figs. 5, 6, 8b, 8c.

## Class CONIFERÆ.

### Family PINACEÆ.

### Genus PAGIOPHYLLUM Heer.

#### PAGIOPHYLLUM WILLIAMSONIS (Brongniart) Fontaine.

Pl. LXVI, Figs. 1, 2.

1828. *Lycopodites Williamsonis* Brongn.: Prodrome, pp. 83, 199.
1829. *Lycopodites uncifolius* Phillips: Geology of Yorkshire, pp. 147, 167, pl. viii, figs. 3, 3a.
1833. *Lycopodites Williamsonis* Brongn. in Lindley and Hutton: Foss. Fl. Gt. Brit., Vol. II, p. 33, pl. xciii.
1849. *Palissya? Williamsonis* Brongn.: Tableau, pp. 68, 106.
1870. *Pachyphyllum Williamsoni* Schimp.: Traité de Paléontologie Végétale, Vol. II, p. 251.
1896. *Pagiophyllum Williamsoni* (Schimp.) Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

Several impressions of a conifer strongly resembling *Pagiophyllum Williamsonis* were found at the locality "In the bed of a ravine that leads from the Banner mine," etc. The largest imprint is that of a stem 8 cm. long. This has portions of several branches and one entire branch. The latter is 15 mm. long and bears at its summit an elliptical, scaly cone, of the same shape and dimensions as that depicted by Lindley and Hutton on a branch of their *Lycopodites Williamsonis* on pl. xciii of the second volume of the Fossil Flora of Great Britain. This, as Schimper showed, is not a Lycopodites, but a conifer, of the type he named Pachyphyllum, and for which, owing to the preoccupation of the name Pachyphyllum, the appellation Pagiophyllum of Heer is now chosen.

The stems carry one-ribbed, curved, and stiff leaves, in the Oroville specimens. There is no doubt that they belong to the genus Pagiophyllum, and are very near to the English plant.

### Genus PINUS Linnæus.

#### PINUS NORDENSKIÖLDI Heer ?

Pl. LXV, Fig. 3.

1876. *Pinus Nordenskiöldi* Heer: Beitr. zur Foss. Fl. Spitzbergens, Fl. Foss. Arct., Vol. IV, Pt. I, pp. 45, 135, pl. ix, figs. 1, 1b, 2, 2b, 3, 3b, 4, 5, 5b, 6.

Several detached fragments of a broad-leaved Pinus were found at the localities "In the bed of a ravine that leads from the Banner mine," etc., and "The old dump at the Banner mine," etc. They show neither their bases nor their tips. They belong to broad, stiff, one-nerved Pinus leaves that agree well with Heer's plant.[1] Of course no positive determination can be made from such imperfect material.

[1] Flor. Foss. Arct., Vol. IV, Pt. I, Beiträge zur Foss. Flor. Spitzbergens, p. 45, pl. ix, figs. 1–6.

## Genus LEPTOSTROBUS Heer.

### LEPTOSTROBUS ? sp. Fontaine.

### Pl. LXVII, Fig. 1.

1896. Undetermined cone Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

A rather vague imprint occurs at the locality "In the bed of a ravine that leads from the Banner mine," etc., which, although it shows no structure, in shape and the arrangement of its parts, looks something like a cone of Leptostrobus. It may be compared with the cone of *Leptostrobus crassipes* Heer, as given in Flor. Foss. Arct., Vol. IV, Pt. II, Beiträge zur Jura-Flora Ostsibiriens, pl. xiii, fig. 14.

# PLANTS OF UNCERTAIN AFFINITY.

## Genus CARPOLITHUS Stokes and Webb.[1]

### CARPOLITHUS STORRSII Fontaine.

### Pl. LXV, Figs. 4-6.

1896. *Carpolithus Storrsii* Font.: Am. Jour. Sci., 4th Ser., Vol. II, p. 274.

A considerable number of imprints of an aggregation of nut-like fruits was found at the locality "In the bed of a ravine that leads from the Banner mine," etc. The nut-like seeds appear to have been borne in pairs at the summit of short pedicels, arranged at considerable intervals and spirally, around a flexuous axis. The thickest axis seen has a diameter of 3 mm. The pedicels are stout and about 5 mm.

[1] In the Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. II, p. 691, this genus was credited to Artis, whose use of this orthography in his Antediluvian Phytology, 1825, pp. XV and 22, was then thought to be the earliest. I have since observed that it was so spelled by Stokes and Webb in their Description of some Fossil Vegetables of the Tilgate Forest in Sussex (Trans. Geol. Soc. London, 2d series, Vol. I, 1824, p. 423) one year earlier. Schimper (Traité de Pal. Vég., Vol. II, p. 225) credits it to Sternberg, but he wrote the name *Carpolites* (Flora der Vorwelt, Vol. I, Tentamen, p. XL, 1825). Schlotheim, in 1820, wrote *Carpolithes* (Petrefactenkunde, p. 418), and this seems to be the earliest date at which fossil fruits were systematically treated. Parkinson, in his Organic Remains, Vol. I, 1804, figured a considerable number on pl. vi, but an examination of the letterpress fails to indicate that he attempted to give them even a generic name. In Bronn's Index Palaeontologicus (Nomenclator, pp. 238-241) most of these are named under Carpolithes and credited to Parkinson, with reference to pl. vi of the Organic Remains, but without reference to the text, and it seems probable that Göppert named them from the figures and is to be credited with the names.

The form *Carpolithus* seems preferable to *Carpolithes* or *Carpolites*, but if it is to be treated as a genus it should conform to the law of priority in use. It is retained here only on the assumption that it may ultimately be found to have priority when the investigation is complete. In fact, there is some justification for this, since Walch, in 1771 (Die Naturgeschichte der Versteinerungen zur Erläuterung der Knorrischen Sammlung von Merkwürdigkeiten der Natur, herausgegeben von Johann Ernst Immanuel Walch, Dritter Theil, Nürnberg, 1771, p. 51), uses this term in the plural, "Carpolithi," for fossil fruits in general, taking pains on page 91 to give the Greek derivation from καρπος and λιθος, but he does not seem to have used the singular, which would of course be Carpolithus. As, however, his treatment was not systematic (binomial) it may be questioned whether this constitutes the earliest use of the genus. L. F. W.

long. The fruits are elliptical or fusiform, about 8 mm. long and 4 mm. thick in their thickest portions. They are mostly much distorted by pressure, but some show their former and true shape.

There are several known fossils with which this may be compared, but from which it is almost certainly, at least specifically, different. It resembles an aggregation of nut-like fruits that Heer[1] ascribes to *Czekanowskia rigida*, for no reason except that it is found on the same rock specimen with leaves of that plant. Heer's plant, however, has smaller nut-like seeds and the pairs are placed much farther apart than they are in the plant from the California locality. Heer's fossil has also the axis on which the pedicels are placed much straighter than that of the plant now in question. This latter may also be compared with *Stachyopitys Preslii* Schenk, as figured by Schenk in Fossil Flora der Grenzschichten, pl. xliv, fig. 12, but the two plants are clearly different species, for that of Schenk has smaller ribbed seeds of ovate shape.

Fig. 4 gives a form showing the double nuts, and Fig. 6 represents a more complete form of larger size.

## GENERAL REMARKS AND CONCLUSIONS.

The collection referred to in the preceding pages, that was made by Mr. Stanton and referred by Mr. Ward to me for determination, was a small and imperfect one. A study of it left me in doubt as to its precise age. The conclusion to which I came was expressed in the following words, quoted from a report made to Mr. Ward:

> This flora is not older than the uppermost Trias and not younger than the Oolite. I feel pretty sure that it is true Rhetic, somewhat younger than the Los Bronces flora of Newberry and the Virginia Mesozoic coal flora. It is much like the Rhetic flora of France made known by Saporta. It is a new grouping of plants. I do not think the fossils now in hand suffice to fix narrowly the age, which may be lower Jurassic.

The much more complete collection and better-preserved fossils obtained by Mr. Ward from the same beds give more satisfactory data, although the evidence is not sufficient to fix conclusively within narrow limits the age of the formation. The collection made by Mr. Ward, although much larger than that made by Mr. Stanton, and containing better-preserved plants, is still not large enough to be exhaustive. Correcting the results obtained from the examination of Mr. Stanton's collection by the facts made known by the study of that of Mr. Ward, we find 28 distinct forms in the Oroville beds (see table below, p. 367).

[1] Flora Foss. Arct., Vol. IV, Pt. II, Beiträge zur Jura-Flora Ostsibir. und des Amurlandes, p. 116, pl. xxi, fig. 8a.

Of these 28 different plants—for they are different, whatever may be their true place and affinities—14 are new and of no value for fixing age by identity. Counting out the undetermined cone, we have only 12 forms that may be compared with previously known ones. Seven of these, viz, *Cladophlebis spectabilis*, *C. argutula*, *C. whitbiensis tenuis* var. a?, *Thyrsopteris Maakiana*, *Podozamites lanceolatus*, *Podozamites lanceolatus latifolius*, *Pinus Nordenskiöldi?*, were found by Heer in the Jurassic formation, which he regarded as middle Brown Jura, which is about the equivalent of the lower Oolite of Scarborough. Of these, *Cladophlebis spectabilis* and *Podozamites lanceolatus* are especially valuable for fixing age by determination of identity. *Cladophlebis spectabilis*, as stated in the notice of the species, is a type not common among ferns, and it has a character that enables its identity to be fixed by a small amount of material. The Podozamites also is a form readily distinguished, while it is, at Oroville, very abundant and well preserved. Three of the plants whose identity with previously known ones is more or less fully made out are: *Didymosorus? bindrabunensis?*, *Cladophlebis indica?*, and *Pterophyllum rajmahalense?* They were all originally made known from the Rajmahal beds of India. These Feistmantel regards as of Liassic age. None of the forms from Oroville are well enough preserved to enable us to make a very close comparison with the India fossils. Although the establishment of identity is not certain, yet the existence of a close resemblance in type has considerable value in determining age. This fact will be again noticed farther on. The Pagiophyllum type of conifer is highly characteristic of the Jurassic, and it is significant that the Oolitic form *P. Williamsonis* is the only conifer of importance in the Oroville flora. It will be noticed that the proportion of conifers in this flora is remarkably small, the ferns and cycads making up most of the plants. This is a feature that is more characteristic of the Older Mesozoic than of any other flora. The only remaining plant possibly identical with a known one is the doubtful *Sagenopteris Nilsoniana*. This Sagenopteris is most characteristic of the Rhetic. The Oroville specimen, standing alone and being doubtful, can not have much weight.

Turning now to the plants which must be regarded as new, we find that, although we can not derive any evidence from their identity with known forms, they are not without indications that may be taken as evidence of age. As was stated before, the prevalence of a particular type is of value as indicating age. We find that certain types abound in the floras of particular ages, and are absent or rare in others. For example, the Alethopteris, Neuropteris, and Pecopteris types of ferns are most characteristic of the Carboniferous. The Thyrsopteris and Cladophlebis type is conspicuous in the Mesozoic and most characteristic of the Jurassic.

Macrotæniopteris is a type of fern that, in typical forms, can not be mistaken for any other. Its range in time seems to have been from uppermost Trias to Oolite, reaching its maximum development, if Feistmantel is right as to the age of the Rajmahal series, in the Lias. Now, although the amount of material obtained showing it in the Oroville flora was not large, it was evidently a conspicuous plant in that flora. The most common species, *M. californica*, is nearer *Macrotæniopteris* (*Tæniopteris*) *lata* of the Rajmahal flora than any other plant. *M. nervosa* is unique. Even if neither of these species bore any resemblance to known forms, the very fact that Macrotæniopteris is an important type in a flora is evidence favorable for the age being Jurassic.

The common Tæniopteris in the Oroville flora is so near *T. tenuinervis*, the characteristic one of the Infralias (Rhetic) of France, that it may be considered its representative, modified by differences in its surroundings. As this is a common type as late as the Oolite, its presence need not indicate an age greater than the Lias. *Cladophlebis densifolia*, if it has any relationship to known species, is best compared with *Pecopteris lobata* Oldh., of the Rajmahal series.

*Adiantites orovillensis* seems to be unique and not very near any known species. The Angiopteridium has *A. McClellandi* of the Rajmahal series as its nearest plant.

The three new species of Ctenis belong to a type that begins in the Rhetic with the peculiar *C. fallax* of Nathorst and exists in the basal Cretaceous in at least one species, *C. imbricata* Font., of the Potomac of Virginia. Except in its inferior size, the Oolitic plant of Lindley and Hutton, *Ctenis falcata*, seems to be the form nearest to the Oroville type.

It should be noted, however, that in their general facies these plants are close to the large Pterophylla of the Rajmahal series, the anastomosis of the nerves, which may be a special development, being the principal difference.

The large Ctenophylla were evidently common and very important plants in the flora. *Ctenophyllum densifolium* and *C. grandifolium Storrsii* were related to the *C. grandifolium* of the Virginia older Mesozoic, the variety *Storrsii* being near enough to be regarded as a variety of the latter.

The small *Ctenophyllum angustifolium* has probably a near relationship to another Older Mesozoic plant, viz, *C. Braunianum*.

*Carpolithus Storrsii* appears to be unique. So far as any relationship can be made out for it it is with a Jurassic plant.

Putting the Oroville plants in the form of a table that shows the age of the plants nearest to them or identical with them, we may denote identity by the letter i and related forms by r, getting the following results:

*Age of plants nearest to or identical with Oroville plants.*

| Species. | Uppermost Trias and Rhetic. | Potomac. | Lias. | Oolite. | Age not identified by relationship. |
|---|---|---|---|---|---|
| 1. Thyrsopteris Maakiana Heer | | | | i? | |
| 2. Adiantites orovillensis Font | | | | | × |
| 3. Cladophlebis spectabilis (Heer) Font | | | | i | |
| 4. Cladophlebis argutula (Heer) Font | | | | i | |
| 5. Cladophlebis whitbiensis tenuis var. a Heer | | | | i? | |
| 6. Cladophlebis densifolia Font | | | r | | |
| 7. Cladophlebis indica (Oldh. and Morr.) Font | | | | i? | |
| 8. Tæniopteris orovillensis Font | r | | | | |
| 9. Macrotæniopteris californica Font | | | r | | |
| 10. Macrotæniopteris nervosa Font | | | | | × |
| 11. Angiopteridium californicum Font | | | r | | |
| 12. Sagenopteris Nilsoniana (Brongn.) Ward | i? | | | | |
| 13. Didymosorus? bindrabunensis acutifolius Font | | | i? | | |
| 14. Pterophyllum rajmahalense Morr | | | i? | | |
| 15. Ctenis grandifolia Font | | | | | × |
| 16. Ctenis auriculata Font | | | | | × |
| 17. Ctenis orovillensis Font | | | | | × |
| 18. Ctenophyllum Wardii Font | | r | | | |
| 19. Ctenophyllum densifolium | r | | | | |
| 20. Ctenophyllum grandifolium Storrsii Font | r | | | | |
| 21. Ctenophyllum angustifolium Font | r | | | | |
| 22. Podozamites lanceolatus (L. and H.) Fr. Braun | | | | i | |
| 23. Podozamites lanceolatus latifolius (Brongn.) Heer | | | | i | |
| 24. Baiera multifida Font | | i? | | | |
| 25. Pagiophyllum Williamsonis (Brongn.) Font | | | | i | |
| 26. Pinus Nordenskiöldi Heer | | | | i? | |
| 27. Leptostrobus? sp. Font. Undetermined cone | | | | | × |
| 28. Carpolithus Storrsii Font | | | | | × |

The comparison of the Oroville plants with known floras shows that most of the forms for which any relationship with known plants can be made out find their like in the Lias and Oolite, or, without distinguishing these, in the Jurassic. As the Oolitic forms are predominant, we may conclude that the age of the flora is not only Jurassic but rather late Jurassic, probably about the age of lower Oolite. If this be correct, we may regard the fossils showing Rhetic affinities as survivors.[1]

## THE JURASSIC FLORA OF OREGON.

As far back as 1872 and in subsequent years, Mr. Aurelius Todd, a mining engineer, then living in Oregon, now a resident of Florida, while prospecting among the mountains of Douglas County, Oregon, made collections of fossils from numerous points, and among these were many fossil plants. Some of the latter were collected on Buck Mountain, which forms part of the watershed between Cow Creek and Lookingglass Creek, two principal tributaries of the South Fork of the Umpqua River. Buck Mountain is about 8 miles nearly due west of the town of Riddles. It has an altitude of about 3,500 feet above the level of the sea, and rises 2,000 feet above the beds of the streams that flow along its base. On the west side, flowing north, is Olalla Creek, a tributary of Lookingglass Creek. A branch of this, locally called Thomson Creek, but named Hunter Creek on the Land Office

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[1] The careful reader of this paper who may be acquainted with Professor Fontaine's brief report on the first collection from Oroville made by Dr. Stanton's party as above set forth (see Journal of Geology, Vol. III, pp. 395-396) may observe that Professor Fontaine does not explain specifically the changes made in his determinations, but only states that the new and more abundant collections required the conclusions drawn from the early small collection to be modified and extended. It is, therefore, perhaps worth while to attempt to clear the matter up at this time lest some one might ascribe to the Oroville florula species mentioned in the first report that have not as yet really been found there. The only such species as to which Professor Fontaine spoke with any degree of confidence are the following:

Tæniopteris tenuinervis Brauns.
Tæniopteris stenoneura Schenk.
Danæopsis marantacea Presl.
Ctenophyllum grandifolium Font.
Podozamites Emmonsii Newb.
Podozamites tenuistriatus Font.

It happened that at the time Professor Fontaine was in Washington working up the large collection made by Mr. Storrs and myself, the small collection was still at the University of Virginia, a fact which I had overlooked until he arrived. I therefore requested him on his return to reexamine the original collection at once, while the results of his study of the new one were fresh in his mind and with his own sketches before him. This he did and reported that he found nothing additional in the first collection. To make this all the more certain, he then and there attached labels to all the specimens of Dr. Stanton's collection and subsequently returned the whole and I embodied it in the general collection.

I have been to the pains to go through, while preparing this paper, and note all the species, as thus labeled by him, that he found to occur in the original collection. They are the following:

Thyrsopteris Maakiana Heer. ?
Cladophlebis argutula (Heer) Font.
Cladophlebis densifolia Font.
Cladophlebis indica (Oldh. and Morr.) Font.
Tæniopteris orovillensis Font.
Angiopteridium californicum Font.
Ctenis grandifolia Font.
Ctenis auriculata Font.
Ctenophyllum densifolium Font.
Podozamites lanceolatus (L. and H.) Fr. Braun.
Baiera multifida Font.?
Carpolithus Storrsii Font.

A comparison of the two lists given will doubtless be sufficient to enable anyone at all acquainted with these forms to decide to which ones of those on the second list those on the first list most probably correspond. L. F. W.

map, flows westward along its base on the north side. On the south side two streams called Buck Creek and Doe Creek rise near its base, flow south, and join Cow Creek below Nichols station on the Southern Pacific Railroad. The mountain lies in latitude 43° 57′ N., longitude 123° 30′ W., from Greenwich, and in township 30 S., range 7 W., of Willamette meridian.

The locality at which Mr. Todd collected his specimens of fossil plants on Buck Mountain is about 300 feet below the summit on the east side, in a gulch which it has been agreed to call Todd Gulch. It lies north of Seven Spring Ridge, over which a trail runs from the east, making the ascent of the mountain easy. Mr. Todd revisited the locality in 1886 and made additional collections.

A single specimen from among Mr. Todd's collections from this locality came into my hands in 1885 through Prof. W. H. Dall, who turned it over with some shells to Dr. T. W. Stanton, and the latter passed it on to me. It was a pretty little fern, and Professor Fontaine subsequently identified it with *Dryopteris monocarpa* (*Aspidium monocarpum* Font., Proc. U. S. Nat. Mus., Vol. XV, 1892, p. 490, pl. lxxxiii, figs. 4–6, 6a), from the Kootanie of Great Falls, Montana. The specimen is recorded as No. 972 in the locality or lot catalogue of the Division of Paleobotany of the United States Geological Survey.

There are two other specimens now in my hands which I believe to have been collected at the same locality. They were received from Prof. J. S. Diller through Dr. T. W. Stanton, and were turned over to me by the former in 1893. They bear the locality number 568, and were recorded from data accompanying them as "from about sec. 16, T. 30 S., R. 7 W., Oregon Nickel mines, Riddles, Douglas County, Oregon, elevation about 2,000 feet." This accords sufficiently closely with the Todd locality to admit of no serious doubt. The specimens are covered by the same fern and the rock is of precisely the same character, but unfortunately the original label did not state when or by whom they were collected. It is certain that they did not come from the Oregon Nickel mines, which lie in range 6, 5 miles east of Buck Mountain, and no fossil plants have ever been found in that vicinity. Professor Fontaine, while studying this material, observed the similarity in these specimens, and in a letter to me dated January 26, 1898, he says:

In studying the Oregon plants for description, I had regarded the fern visible on the two specimens credited to the Nickel mine, and numbered 568, as the same with that on the specimen numbered 972, and credited to Todd's locality, i. e., Bucks Peak, 300 feet below its summit. On comparing these specimens again, after washing them, to see if they were really the same ferns, I found on the Nickel mine specimens inconspicuous imprints of a conifer, *Sphenolepidium Kurrianum*, that I had not observed before. This led me to examine the supposed Todd specimen carefully, to see if any conifers were shown on that. I had begun to suspect that the specimens all came from the same place, as the ferns are identical and the shale carrying them is exactly similar. I found on Todd's specimen the same conifer, obviously the counterpart of the impression on the Nickel mine specimens, but not exactly corresponding to them in dimension. On trying to fit the specimens together I found they nearly fitted. The conifer impressions occur on all the specimens on the side opposite to that which carries the much more distinct fern impressions. On this side there is a thin layer of soft, flaky shale, in which the conifer impressions occur. Rubbing in transportation had almost hidden the imprints previously obscure. Hence they were overlooked in the former examination. Either in the original splitting of the rock to obtain the specimens, or in subsequent transport, flakes of the soft shale layer carrying the coniferous imprints had been removed from the rock specimens, hence they do not exactly fit together, and the conifer imprints do not exactly correspond.

I have fully confirmed this description by a careful comparison of the specimens since they were returned, and I no longer doubt that they are all parts of the same piece of shale. They were, of course, probably all collected by Todd at the same time, but it might have happened that a subsequent collector picked up the two additional pieces left by Mr. Todd.

A large number of other small collections had been made from time to time in Douglas County, but they were either from the marine shell-bearing Knoxville and Horsetown beds or from the Eocene rocks of that region and therefore do not concern us here, but those from the Cretaceous will be treated in the second paper (Part II) of this series. There was considerable confusion in the labels of all these plants and for a long time all the Mesozoic forms were believed to represent the Shasta group (Knoxville and Horsetown beds), but the Buck Mountain region presented some serious stratigraphical difficulties. These Professor Diller was very anxious to clear up before mapping the region. In 1896 he visited the Buck Mountain district and made a somewhat hurried reconnaissance. A fossil-plant bed was discovered by Mr. James Storrs, of his party, and a small collection made and shipped to Washington. In transmitting this collection to me through the Director of the Survey he says, in his letter to the Director dated November 18, 1896, that the specimens "were obtained from rocks which appear to underlie the Lower Cretaceous," and adds:

These fossils come from a locality which promises to yield a rich harvest to the collector. They were found too late in the day to make a more extensive collection, but it is hoped that enough were obtained to indicate the geological age. No other fossils whatever were found in the same or immediately associated strata.

This locality is at the base of Buck Mountain on the northwest side, in section 3 of the same township and range, on the tributary of Olalla[1] Creek above referred to as Thompson or Hunter Creek. These plants came into my hands in the autumn of that year and I made a

[1] The beds at this point will for convenience be referred to as the Olalla Creek beds. Olalla is the Indian word for *berries*, the black raspberry and other berries being abundant in this region, and it is said that the term originally applied to the country all about the head of Olalla Creek and that all the streams went by that name.

somewhat careful preliminary study of them before sending them to Professor Fontaine for final determination. In my letter to him dated January 8, 1897, transmitting them, I said:

There is a Tæniopteris that seems to be *T. orovillensis* or something very near that, and it is the commonest plant in the collection. The other things are different in the main from the Oroville plants, but I believe they are as old.

I wish you could look over this collection pretty soon and let me know whether you think it is Jurassic and whether you think it important, because Mr. Storrs made it all in one day in a great hurry, and I understand there is plenty more.

Professor Fontaine made the following prompt preliminary report on this collection:

I have examined the Douglas County fossils and have no doubt that this is essentially the same flora as that of Oroville. The material is coarse and does not preserve the plants very well, but so far as I can judge from the impressions, there is a remarkably large number of identical forms here and at Oroville. Of course I would not like to give a final decision on forms from such imperfect material, but it seems to me that *Tæniopteris orovillensis* occurs here and perhaps a larger form. *Ctenophyllum angustifolium* seems to be common. Several of the small ferns seem identical with Oroville forms. The Oroville Sagenopteris almost certainly occurs here, also an Angiopteridium like that of Oroville. Some fragments look much like the Ctenophylla of Oroville with coarse nerves. *Pterophyllum rajmahalense* is probably found here.

The Oroville plants ought to be figured for comparison before these are worked up. I certainly think that a larger collection ought to be made before a final determination can be formed. I should think that the strata would yield some shale bands which would preserve the fossils better. However, for a "haphazard" collection in one day, this is a remarkable yield.

Professor Diller was informed of these results and the importance of increasing the amount of material and of making a more careful study of the stratigraphical position of these beds and their relation to the bed near the summit of Buck Mountain yielding the specimens collected by Mr. Todd. On June 30, 1897, Mr. Storrs returned to the locality and made a much larger collection, which was at once transmitted to me, through the Director of the Survey. In his letter to the Director, dated July 4, 1897, Professor Diller says:

By this mail I have the honor to transmit seven packages of specimens of fossil plants from the locality on Olalla Creek, at which a number of similar specimens were collected last year by Mr. Storrs. I respectfully request that they be referred to Professor Ward for study and report. For his information I desire to say that the plant beds appear to belong to the series of strata containing Aucella. Specimens of the Aucella were collected in shales which appear to underlie the leaf beds and will be sent also by this mail for examination. The Aucellæ are from Buck Peak, at the base of which the leaves occur, and do not appear to have the characteristics of the Jurassic Aucellæ, but rather those of the Knoxville beds.

As a consequence of all this a lively correspondence took place during the summer of 1897, participated in by Professors Diller and Fontaine, Mr. Storrs, and myself, as to the probable age of the plant-bearing beds, and in the course of which Professer Diller succeeded in locating Mr. Aurelius Todd at Dunedin, Florida, and obtaining from him, through a letter dated September 12, a full statement of his early operations in this field. In this letter Mr. Todd says:

Yours of August 18 at hand. Inclosed I send you a drawing as I remember the place and which I think you will find very nearly correct. I revisited the place in 1896, and got all I could find in half an hour, but as they are in a solid bluff I think you will have little trouble if persevering in getting all you want. However, if you fail I have a lot in Eugene, Oregon, which you are quite welcome to if you can find them, but they will have to be sent me here for identification, I fear, as they are not all labeled. If you have occasion to visit Eugene go to Professor Condon and make your wants known. Then go to Horn & Pain's gun store (Sporting Emporium) and look through the specimens I left there. Then go to the house on the corner of Fourteenth and Hilyard streets. I left some boxes there containing my duplicates packed up in their barn in boxes. Go through them and take what there is you want. All the Aucella in conglomerate came from Big Buck Mountain; those in lime from near Riddles or Big Pine; the ferns in shale from Big Buck Mountain. I gave Dr. Snapp, of Cottage Grove, Oregon, an order for these things, but I think he has never moved them nor does he care for the specimens. I know you can get them if they have not been destroyed. I have forgotten the man's name who owns the house now. I am very sorry I did not get to accompany you in your work in that section. I have found it one of much interest.

Let me hear of your success in visiting the old Buck Mountain fossils. I spent many an interesting day and night roaming those hills, prospecting, hunting, and mining, during the early seventies, and my older brother was killed in Lookingglass the day I discovered this same fossil bed and about the time of day—thrown from a horse and dragged—in August, 1872.

It will be seen that this last statement in Mr. Todd's letter fixes the date of his collections. The drawing that accompanied the letter is remarkably accurate, considering that it was made twenty-four years after the collections were made, and eleven years since he had seen the place. It also contained directions how to go to find the place without danger of mistake. Professor Diller received this letter while in the field at Myrtle Point.

Armed with this document, Mr. Storrs, very soon after its arrival, revisited the Buck Mountain region. He had no difficulty in finding and identifying Mr. Todd's locality, and he collected quite a number of plants, chiefly ferns, from it. He also revisited his other localities on Olalla Creek and made further collections there, extending the range considerably. These specimens were subjected to a critical preliminary examination by both Professor Fontaine and myself. The occurrence of a number of ferns associated with the cycadean forms in the Olalla Creek beds and having much the same *facies* as those from Todd Gulch on the mountain began to shake the hitherto somewhat settled opinion that the two beds must be of different age, the latter never having been suspected of being Jurassic. After further study of the collections from both localities, Professor Fontaine, in a letter dated January 7, 1898, says:

I have been including Todd's specimen and the other Oregon plants in the description of the Shasta flora, because they were sent as occurring in that group. There is, however, nothing in the nature of these plants to compel one to regard them as Lower Cretaceous. They may very well be of the age of the Oroville plants. They are pretty old looking. Why may not Todd's plant bed be the same as that on Olalla Creek (Diller's No. 2 bed), with the plants like those of Oroville, and both Jurassic?

At a little later date (January 26) he reported more fully as follows:

I have examined all the collections from the horizon (Olalla Creek), apparently above the Aucella beds of Buck Peak, and find that they indicate a flora of essentially the same age, and that it is apparently Jurassic, of the same age with that of Oroville. Mr. Storrs has made a pretty good collection from Todd's old locality. Unfortunately, nearly all of the fossils from this place are ferns, and ferns are not the best kind of fossils to determine geological age. The plants from this locality seem to belong to a flora of essentially the same age as that from the Olalla Creek, and to be Jurassic and not Cretaceous. Many of them, it is true, are different from those of Olalla Creek, but a number are the same, and my impression, from this preliminary examination, decidedly is that the floras of the Todd locality and Olalla Creek are not essentially different in age from that of Oroville. Mr. Storrs has got some fine plants from Olalla Creek. Among them are fine Ginkgos, probably of more than one species, with broad lobes, of the type of the Jurassic Ginkgos, *G. digitata* and *G. Huttoni.*"

During the season of 1898 additional collections from the Olalla Creek beds were made by Mr. Will Q. Brown, of Riddles, Oregon, and Mr. Claude Rice, which they offered to send to Washington for determination, but, in view of the amount of material already in hand and the still existing confusion as to the stratigraphy, no effort was made to secure them. Mr. Brown, however, collected and turned over to Professor Diller a few plant remains from a railroad cut half a mile north of Nichols station, just south of the whistling post for that station. The railroad here follows the left bank of Cow Creek, and the locality is close to that stream. Nichols station is 7 miles exactly due south of the plant beds on Olalla Creek, and also due south of the locality on Bucks Peak. The plants from this locality closely resemble those obtained at the more northern points, and hence had an especial interest. They were sent to Professor Fontaine, and, in a letter by him to Professor Diller, dated April 12, 1899, he says:

The locality, "Railroad cut near whistling post, one-half mile north of Nichols, Douglas County, Oregon," is a very promising one and seems to contain a great variety of plants. The specimens sent are quite fragmentary, but they indicate over 20 different species, which, I think, show that the strata are of Horsetown age. This locality should have additional collections made from it.

Commenting on this report, Professor Diller wrote me, on April 14, as follows:

These fossils Mr. Brown expected to be Jurassic. It seems much more probable that they are Cretaceous. If the ones from the Olalla region are the same as those at Oroville, this locality assumes very great importance in furnishing an opportunity to study the flora which will connect the Upper Jurassic and the Cretaceous. Were it not for the fossil plants I should not hesitate to put all of the rocks in the Cretaceous. If they are not Cretaceous, however, it is important that the line should be drawn between them and their relation determined, for it is between the upper

Jurassic and the Cretaceous that some of the most important movements of the Pacific coast have occurred. I have just dictated a letter to the Director requesting that, if possible, arrangements be made to have that field studied this summer by some paleobotanist.

On April 19 Professor Fontaine again writes:

I wish you would go out and collect from Mr. Brown's localities. I was especially struck with his locality, "Railroad cut near whistling post, one-half mile north of Nichols," etc. He got about 24 specimens from that place and nearly all of them were different species. Some of them seem to be new species and genera. The material seems to preserve the plants well. I am sure fine and interesting plants can be gotten there.

Such was the condition of things at the beginning of the field season of 1899, and acting upon the suggestions of Professor Diller and Professor Fontaine I presented the matter to the Director on May 1, in the following form:

There is a small region in the vicinity of Riddles, including Buck Mountain, Olalla Creek, Cow Creek, etc., in which the strata are much disturbed, but which seems to be the key to the geology of that whole country. The geologists have not been able to work it out. There are few animal fossils, but an abundance of vegetable fossils; these latter are clear and fairly diagnostic, and seem to indicate two or three horizons extending down to the Jurassic. A large number of small collections have been made from this region at various times by different collectors, some of them amateurs, others geologists making hasty reconnoissances, and in only a few cases by collectors who have any skill in selecting material. What is needed is, as I stated in my previous letter, for someone to go there who can recognize the species and carefully work out the stratigraphical relations of the different classes of material. If this could be done, even though no collections at all were made, the object which Professor Diller wishes to secure would be accomplished. Still, it would be better to make additional collections at critical points, especially as Professor Fontaine, in working up the material, has carefully indicated the localities from which further collections need to be made.

I received instructions to visit this region, and arranged with Mr. Will Q. Brown, mining engineer, at Riddles, Oregon, to provide an outfit and accompany me as guide and scientific assistant. I also wrote to Professor Diller at his camp at Myrtle Point, on the coast due west of there, urging him, if possible, to join us, in the hope that all of us working together might succeed in tracing out the complicated stratigraphy. Owing to work in hand that must be finished before I could go, and to the necessity of stopping for a week in Wyoming to examine the Jurassic cycad locality in the Freezeout Hills, I was unable to reach Riddles until September 10. Mr. Brown had the outfit in readiness and Professor Diller and Mr. Storrs were on the ground. The party left Riddles on the 11th and proceeded at once with pack and riding animals to the Buck Mountain region, distant only 9 miles by a mountain trail, and camped at the foot of the mountain on the north side, on the branch of Olalla Creek called Thompson or Hunter Creek, in the bed of which, some distance below, Mr. Storrs had first obtained the plants denoting a Jurassic age. Five days were spent here, and all the localities were visited, several new ones found, and the whole district searchingly explored. Buck Mountain was several times climbed, the original locality of Mr. Todd carefully worked, and other plant-bearing beds discovered in the Todd Gulch below, and at other points both north and south of this. The collections from this region were no longer confined to ferns, but included several of the other distinctively Jurassic types of vegetation found below.

The most extensive collections were made in beds of slate overlying heavy conglomerates on the above-mentioned stream nearly due north of Buck Peak. The Day Hydraulic Gold Mining Company has dammed the stream at this point and built a conduit to the mines some distance below. The plant-bearing slates commence immediately below the dam, and it was in this first or stratigraphically lowest bed that Mr. Storrs made his principal previous collections. The beds have a dip toward the coast of from 35° to 40° and the strike is from 15° to 20° east of north, but in tracing them up the mountain side the strike was found to vary considerably. This plant-bearing stratum is only a few feet thick, and is overlain by a bed of conglomerate 50 feet or more in thickness. Following the bed of the stream down, this is crossed and another bed of slate is encountered, similar in general appearance to the first. This is also plant-bearing, and yielded by far the larger part of the specimens collected. It also preserved them better, and the most complete impressions were found here. Although the principal plant-yielding strata of the two beds of slate are separated by about 75 feet of vertical thickness, no very marked difference in the flora was apparent. Certain ferns in the lower bed were less common in the upper, and the latter yielded a larger proportion of broad-leaved cycadean genera, such as Ctenis, Ctenophyllum, and perhaps Pterophyllum. The species of Ginkgo, mentioned by Professor Fontaine (supra, p. 373) as occurring in Mr. Storrs's collection, is one of the most abundant fossils of this upper horizon, and very fine specimens were obtained. It is possible, as he suggests, that more than one species are represented, as some specimens have shorter, blunt lobes and others long and pointed ones.

This form, although not found in the Oroville flora, really constitutes one of the strongest proofs that we have of the Jurassic age of the beds. The digitate-leaved Ginkgos are an ancient type and mark a special stage in the progress from the Baiera of the Rhetic to the only slightly lobed Ginkgo of the late Cretaceous, the Tertiary, and the present. It is characteristic of the Brown Jura (Lias or early Oolite) of Siberia. Associated with this form were found fruits which may have been borne by them.

It may be added that these Ginkgo forms were also found on Buck Mountain. Professor Diller and Mr. Brown brought in a specimen on the 13th, which they collected in a gulch some distance north of

Todd Gulch, and on the 15th Mr. Storrs and I found them not only in the original Todd locality, but lower in the same gulch at two horizons, one 20 feet and the other 30 feet lower in the beds.

Professor Diller and Mr. Brown devoted the greater part of the time to carefully working out the stratigraphy. They followed the plant-bearing slates all the way from Olalla Creek to the Todd Gulch and proved their complete continuity. On Olalla Creek these slates are immediately overlain by the Eocene, only a short distance below the uppermost plant bed. On Buck Mountain, on the contrary, they are overlain by a bed of conglomerate, doubtless of the same age, which underlies the Aucella-bearing Knoxville beds on which the Eocene here rests. Everywhere to the east is a very thick bed of conglomerate, through which is intruded a great thickness of eruptive rock, principally serpentine. Still farther east, on the Nickel Mountain, are other Aucella beds, as if occupying the eastern slope of a great Mesozoic anticline, and when the bed of Cow Creek is reached at Riddles the higher Horsetown beds appear in force.

Such seems to be a general view of the much-discussed stratigraphy of the Buck Mountain region, and thus far the fossil plants furnish the only evidence of the existence of a great Jurassic deposit running through the State of Oregon; but this evidence is not only conclusive from a paleontological point of view, but when correlated with all the remaining facts and worked out, as was done by our party, it proves to be perfectly harmonious and consistent.

There remained the problem presented by Mr. Brown's collection from near Nichols station, on Cow Creek, 14 miles above and nearly southwest from Riddles. A glance at the map shows that Nichols station is exactly due south of Buck Peak, and all the plant localities in the Buck Mountain region are arranged along a nearly north-south line. The strike of the slates, as was shown, varies considerably even in short distances, but probably averages nearly north and south. The distance in a straight line from the Olalla bed to the Nichols bed is nearly 7 miles due south. We were unable to follow the strike with our pack train, but were obliged to go down one of the tributaries of Doe Creek from the eastern slope of Buck Mountain and then to follow Doe Creek to its junction with Cow Creek, 3 miles below Nichols station, thus avoiding the great Table Mountain on the west.

Very little additional to Mr. Brown's collection was found in the railroad cutting, but it was seen that we had here the same slates as those of the Buck Mountain district and that they came in in a regular way from the north. At this point Cow Creek has a course slightly west of north and the slates cross its channel very obliquely and even follow the bed of the stream for some distance. At the point where they emerge on the right bank to the north they expose their upturned edges for a long distance over that portion of the stream bed which is not overflowed in the dry season. Here was a fine opportunity to examine them, and although it is usually difficult to obtain large slabs lying in such a position, yet, from the easy cleavage and generally workable character of these slates, we were able to work out fine pieces and secure good specimens. The slates here are nearly vertical; in fact, there seems to be an easterly dip, as if they were tilted more than 90°. They have a thickness of about 200 feet, with no conglomerate bands. They are full of plants of typical Jurassic types. Most of the Olalla Creek forms occur, including the Ginkgo and the leading cycadaceous genera, Ctenis, Ctenophyllum, Pterozamites, Pterophyllum, etc. Some of the same ferns, notably a narrow Angiopteridium, were found present at nearly all the Buck Mountain localities. Besides these, a number of forms not seen farther north were collected, including many long, narrow coniferous leaves resembling those of Cephalotaxus or Taxodium, but showing fine transverse striæ on both sides of the midrib. A large collection was made.

Professor Diller and Mr. Brown worked out the stratigraphy in the same manner as in the Buck Mountain district. It is more complicated, and the Knoxville beds occur on Iron Mountain Creek not more than a mile east of the Jurassic outcrop. Eocene plant-bearing beds lie on the hills on both sides of Cow Creek, and it is evident that much still remains to be done before all will be made clear, but the general fact seems established that a Jurassic deposit of unknown extent and of considerable thickness trends through these mountains from north to south, which can no longer be overlooked in treating the geology of Oregon.

## CYCADEAN TRUNKS FROM THE JURASSIC.

A considerable number of cycadean trunks have been found in beds that are referred with more or less certainty to the Jurassic. There are as yet, however, only two sources of such material, and one of these is of doubtful age and is only represented by a single specimen. This locality is in Colorado. The other locality is in Wyoming, and there is no doubt as to its Jurassic age. I will treat the Colorado trunk first.

### THE BOULDER CYCAD.

Early in the summer of 1896 Dr. F. H. Knowlton and Dr. T. W. Stanton, in passing through the museum of the State School of Mines at Golden, Colorado, observed a cycadean trunk on exhibition there, and made inquiries relative to its source. In a letter which I received from Dr. Knowlton soon after this, dated June 18, 1896, he says:

Dr. Stanton and I visited Golden yesterday, and as a preliminary went through the collections belonging to the State Mining School. One of the first things that I saw was a beautiful silicified cycad trunk. It was about 2 feet in height, regularly oval in cross section, the long diameter being about 12 inches and the short diameter about 8 inches. It came from the vicinity of Boulder, Colorado, and it is said to have been two or three times as long as now when first discovered. It was found in excavating for a railroad, and was smashed and buried—all but this piece—before its value was recognized. It is the same size throughout, and is hardly at all worn. It looks very much like one of the Black Hills specimens.

Knowing that Professor Jenney, who had shown so much interest in the cycads of the Black Hills, was at the time in Denver, and presuming that he was familiar with matters at the Colorado State School of Mines, I immediately wrote to him and asked him to assist me in securing, if possible, the loan of this specimen to the Geological Survey or National Museum long enough to describe it and report upon it. He communicated with President Regis Chauvenet, of the State School of Mines, and prepared the way for a correspondence on the subject. I wrote to President Chauvenet in September, and received a reply from Prof. Horace B. Patton, dated September 30, 1896, in which he says:

Your letter of recent date, asking for the loan of the cycad in the possession of the Colorado State School of Mines, has been received, also the photographs of cycads, for which please accept our thanks. We take pleasure in sending the cycad as you suggest. It was accordingly shipped several days ago by freight to the National Museum. I am sorry that I can not tell much as to the locality where it was found. It was secured by a certain J. Alden Smith in a railroad excavation near Boulder, Colorado. Mr. Smith was able to secure only one piece, although he was told by workmen that others belonging to the same piece had been found, but they were covered up somewhere in the dump. This was probably not less than ten or twelve years ago. Mr. Smith has been dead for some years. The above information I secured from President Chauvenet of this school, who bought the cycad with the rest of a large collection from Mr. Smith.

The specimen arrived in due time and is still in my hands, awaiting an appropriate occasion to publish a description of it. The description here given was written in 1897, and the photographs used in illustrating it were taken by Mr. T. W. Smillie, in the gallery of the U. S. National Museum, soon after the specimen was received.

### Genus CYCADEOIDEA Buckland.[1]

#### Cycadeoidea nigra Ward n. sp.

#### Pl. LXVIII; Pl. LXIX.

Trunk large and rather tall, simple, much compressed laterally, thoroughly silicified, of a uniform black color externally and internally, very hard and heavy, 1 meter or more in height, 40 to 50 cm. in greater diameter, 25 to 30 cm. in lesser, with a girth of about 1 meter; organs of the armor descending below the middle; leaf scars arranged in two regular and distinct spiral rows around the

[1] For the systematic position of Cycadeoidea see supra, p. 302.

trunk, those passing from left to right forming an angle of about 30° and those from right to left of about 45° with the vertical axis; scars of the usual size, nearly triangular in shape, rarely somewhat arched above, but sometimes concave, so as to appear inversely heart-shaped, the upper side of the triangle nearly horizontal, the other two sides in line with the rows of scars, thus making different angles with the axis, the three angles all sharp, averaging 20 mm. wide by 15 mm. high, while the right and left sides of the triangle are respectively 16 mm. and 18 mm.; leaf bases always present 1 to 3 cm. below the surface, their summits level or slightly concave indicating a natural plane of disarticulation, presenting a roughened or spongy surface without pits or visible bundle scars, usually traversed by thin longitudinal dikes crossing one another at varying angles; ramentaceous walls very thick, 5 to 8 mm., with thickenings in the angles of the scars often as large as the scars themselves, rough and wrinkled on the outer edges, homogeneous but having a very thin (0.5 mm.) layer lining the inside of the scars, which may be the periderm of the petioles; reproductive organs very abundant and well developed, one in the axil of each leaf standing over the upper side of the scar and sometimes depressing it so as to cause the inversely heart-shaped appearance of the scars, making the walls on that side very thin or removing them altogether and exposing the bud on the upper side of the scar, elliptical in cross-section, 25 mm. in horizontal and 15 mm. in vertical thickness, their summits flush with the upper edges of the walls or rising slightly above them, rarely projecting, always filled with the remains of the organs composing them and showing a concentric structure with a heterogeneous center, the crescent-shaped involucral bract scars mostly at the ends of the ellipses and extending far out along the walls, sometimes aggregated at other points denoting abortive buds; armor very thick, 5 to 6 cm., separated from the axis by a definite but irregular or jagged line; woody zone 2 to 7 cm. thick, consisting of a homogeneous, black, cherty or partially chalcedonized substance showing concoidal fracture without division into rings or traces of bundles or medullary rays; medulla faintly distinguishable from the wood, compressed into a slab 3 cm. thick and 20 to 25 cm. wide in the only specimen known.

A large specimen of a trunk that was much compressed laterally, containing more than half the basal portion. It is broken by a somewhat even vertical fracture in the plane of the minor diameter a little to one side of the center, and also broken across obliquely above, so that the vertical fracture constitutes the shorter side. The amount that is wanting above is unknown, but Dr. Knowlton's statement that "it is said to have been two or three times as long," was probably an exaggeration on the part of his informant. Still, it might well have been considerably longer. It is scarcely at all worn, and is in an excellent state of preservation. It is of a nearly uniform black color, thoroughly silicified, with a cherty aspect in places, and high specific gravity. The total weight is 34.93 kilograms.

Its maximum height is 40 cm., but the base is 5 cm. lower in the middle than elsewhere, and the upper fracture is oblique both ways, so that the length of the minor face is only 28 cm., and that of the side opposite 32 cm. The partial major axis, which is nearly the same at all points, is about 26 cm., and the minor axis varies from 20 to 24 cm., being greatest near the base. The partial girth (exclusive of the broken inner face) is from 58 to 60 cm.

The organs of the armor are slightly declined throughout the entire length, the angle diminishing upward. They were probably horizontal on the lost upper portion of the trunk. The leaf scars are arranged in two regular and distinct spiral rows around the trunk, those ascending from left to right forming an angle of about 30°, those from right to left of about 45° with the vertical axis. One of the former would make a revolution in about 1 meter, one of the latter in about 65 cm.

The scars are of about the normal size and nearly triangular, rarely somewhat arched above, but sometimes concave, so as to appear inversely heart-shaped. The upper side of the triangle is nearly horizontal and the other two sides are in the line of the two rows of scars respectively, what may be called the right side being steeper than the left, and the lower angle a little to the right of the center of the upper side. The sides are thus of slightly different lengths, the upper longer than either of the others and the left longer than the right. Where the upper side is 20 mm., which is about the average, the left side will be 18 mm. and the right side 16 mm. The distance from the lower angle to the center of the upper side averages about 15 mm.

The leaf bases are always present at a certain depth, usually 1 cm. but sometimes 3 cm. or more. Their summits are nearly level or slightly concave, and there seems to be a joint at which they are usually disarticulated. They present a roughened or spongy appearance without pits or bundle scars, but in some cases they seem to be traversed by thin longitudinal dikes crossing one another at varying angles.

The walls are very thick, 5 to 8 mm., with large thickenings in the angles of the scars, often as large as the scars themselves. The scars are lined with a layer 0.5 mm. thick, the union of which with the walls can generally be seen; otherwise the walls are nearly homogeneous and rough on the outer edges.

Reproductive organs are very abundant and well developed. There is practically one in the axil of every leaf. They stand for the most part directly over the upper side of the scar, and sometimes depress that side, but usually the effect is confined to a considerable thinning of the wall on that side, and in a few cases the wall has disappeared here, leaving the bud exposed on the upper side of the leaf scar. The buds are elliptical in form and average about 25 mm. in horizontal and 15 mm. in vertical thickness (major and minor axes of cross section). They are flush with the upper edges of the walls and sometimes rise a little above them, but rarely project; still they serve to give the trunk a rough, uneven surface. They are never wanting so as to leave a cavity, and they all clearly show a concentric structure with a heterogeneous center, due to the form of the essential organs. Crescent-shaped bract scars occur, especially at the ends of the ellipse, but are not generally arranged all round the organ. The bases of the bracts are often preserved flush with the surface. The bract scars sometimes straggle away to some distance and appear in the walls remote from the buds, and there are a few abortive buds represented only by such scars.

The armor is very thick and nearly the same on the flattened sides as on the rounded edge of the trunk. It is everywhere between 5 cm. and 6 cm., and some of the leaf bases exceed 6 cm. in length. It is beautifully shown all round the broken portions, where the leaf basis, the walls, and the reproductive organs are exposed. The last named are usually much decayed, at least in their outer portions, but the central parts may be preserved. Some of them resemble the *Bennetties Morierei* fruit studied by Lignier.

The axis is well exposed over the whole surface of the vertical and oblique fracture, a length of 46 cm., and the somewhat regular line separating the armor from it is fairly distinct, but the internal tissue is an apparently homogeneous black, cherty, or partially chalcedonized rock, showing conchoidal fracture and revealing to macroscopic inspection no differentiation into layers or rings and no traces of bundles. There is a faint indication of the distinction between wood and pith. As seen along this broken surface, whether on the vertical fracture showing the longitudinal section or near the summit where the fracture makes an angle of about 45° to the axis, the thickness is nearly uniform throughout and does not exceed 7 cm. Of this the medulla probably occupies about 3 cm., leaving the wood on an average 2 cm. thick. The axis, therefore, has the form of a flat slab, which may have been 20 or 25 cm. wide. The width to the vertical fracture is over 15 cm.

In February of the present year (1900) Mr. George R. Wieland, who is engaged in working out the internal structure of the cycadean trunks at the Yale Museum, visited Washington for the purpose of examining the material in the United States National Museum, and when shown this trunk he expressed the belief that it would probably show structure, especially in some of the numerous fruits, and offered to examine it from this point of view if supplied with such parts as he should select from near the fractured surface that could be easily detached without injury to the specimen. I had taken the precaution to obtain permission from the State School of Mines of Colorado to have sections cut in case this seemed advisable, and Mr. Wieland took to New Haven several detached fruits, which he has carefully examined. While the proofs of this paper were passing through my hands I received a letter from him, dated March 17, 1900, giving the results of his investigations, which I am glad to introduce here as a fitting supplement to the above description, and as a welcome addition to our knowledge of this interesting specimen. Mr. Wieland says:

I am unable to find even basal portions of fruits in the Boulder cycad, only the peduncles surrounded by very large bracts. The sections made, even when quite thin, show the dense blackness and require very careful polishing to reach the thinness requisite to bring out structure. Each of those axes which seemed so much like fruits in a rather early stage is then seen to consist of a rather slender peduncle, surrounded by five or more bracts, whose transverse section is almost as large as that of the peduncle itself. The whole is deeply embedded in ramentum resembling that of the Wyoming cycads in the large number of cells seen in transverse section. The bract ramental hairs are apparently thinner than those belonging to the leaf bases. The peduncles are subequilateral-triangular in transverse section, the bracts the same, or in part of crescentic transverse section, with the horns of the crescent gracefully rounded. There are slight differences in the arrangement of the xylem and phloem of the peduncle, as compared with the Black Hills cycads, *Cycadeoidea Paynei* and *C. Wielandi*, which I presume compare most nearly with this form in general outline of the trunk and appearance of the fruiting axes. There is a strong suggestion that the fruits when mature must have hung well out from the trunk, very much as a *Zamia angustifolia* cone.

*Cycadeoidea nigra* is certainly well named. The sections as thin as paper are still black. It is, moreover, a very distinct species—a very interesting cycad. I am sorry that I could not catch so much as a parenchymatous cushion.

Pl. LXVIII shows the best side of the trunk and brings out the leaf scars with their arrangements and the reproductive organs very clearly. Pl. LXIX represents the vertical fracture and shows all that can be seen of the internal structure. The indistinctness at the summit is due to the oblique direction of the fracture at that point, sloping back from the camera so as to become out of focus.

### JURASSIC CYCADS FROM WYOMING.

A considerable number of fossil cycadean trunks have been obtained from the Jurassic of Wyoming. The locality is in what are called the

Freezeout Hills of Carbon County, 25 miles nearly due north of Medicine Bow.

The history of the discovery of these fossil trunks dates back only to 1898. The first intimation that I had of it was contained in a telegram from Prof. O. C. Marsh, dated July 15, 1898, as follows: "Have two small cycads, apparently new, from the new Wyoming locality; will send them by express if you can use them in your report." The "report" alluded to is the description of the Black Hills cycads in the Nineteenth Annual Report of the U. S. Geological Survey (Pt. II, pp. 594–641, pls. lxi–clvii), which had gone to the printer before the telegram was received. As the new locality is not in the Black Hills, it would not have been appropriate to include the Wyoming cycads in that paper, and I so informed Professor Marsh.

Professor Marsh promptly made public all the information he had on this subject in the "Postscript" to his paper on "The Jurassic Formation on the Atlantic Coast—Supplement," which he had read before the National Academy of Sciences on November 18, 1897. This "Supplement" with the "Postscript" appeared in the American Journal of Science for August, 1898 (4th ser., Vol. VI, pp. 105–115), and also in Science of August 5, 1898 (N. S., Vol. VIII, pp. 145–154).

The next reminder I had of the existence of these vegetable fossils was through Dr. F. H. Knowlton, who had received a letter from Prof. Wilbur C. Knight, State geologist of Wyoming, dated September 3, 1898, in which he said: "Recently my assistant made a very rich find of Jurassic cycads. Would you care to describe the species, or possibly several species? I have some fine ones. One on my desk is 8 by 6 by 12 inches or larger."

Dr. Knowlton showed me this letter, and, knowing that it referred to the same locality as that from which Professor Marsh had obtained his specimens, I immediately wrote to Professor Knight and offered to describe the specimens if he could find a way of placing them in my hands. As a result a negotiation was entered into with the authorities of the United States National Museum as to conditions on which the material would be received, and it was not until the 16th of March, 1899, that the collection finally arrived.

In a letter from Professor Knight, dated October 18, 1898, in answer to questions I had asked him relative to the age of the beds, he says:

There is no question as to the horizon of the find; it is in the Jurassic fresh-water beds, and near the bottom. In the locality where this bed has been opened there is a typical Jurassic exposure, and the fresh-water and marine beds can be sectioned to a foot. I have not visited the cycad beds yet, but I am well acquainted with the locality and have made rough sections many times. In my opinion it is a very excellent find and is well worth a careful study. I am at the present time making a special study of the Jurassic of Wyoming, contemplating a monograph on the subject as soon as it is possible to complete the work. If you wish, I can go to the field and give you an absolute section of the bed.

In another letter dated November 1, 1898, he makes the following more specific statement:

A section through the locality will be about as follows:

| | Feet. |
|---|---|
| Triassic red sandstone | 1,000 |
| Lower Jurassic (marine) | 200 |
| Upper Jurassic (fresh water) | 225 |
| Dakota conglomerate | 50 to 200 |

Your Black Hills section reminds me of the Big Horn Basin country where I found beds that I could not place in the Dakota. In no instance in the section given have I detected any nonconformability, although I anticipate that such exists between the Jurassic and Dakota.

I spent the latter part of November of that year at the Yale Museum describing the new material that Professor Marsh had acquired since my visit in June. This included the two specimens received from Mr. Reed from the Jurassic of Wyoming, and I took as full notes on them as possible. It was apparent at a glance that they had nothing to do with the Black Hills cycads, and that they were very different from anything that I had seen either in this country or in Europe. In some respects they resembled the specimens from the Purbeck beds of the Isle of Portland, especially the small ones that I saw there in 1894, and of which I obtained 20 specimens for the United States National Museum. This, however, had less to do with their botanical than with their mineralogical character, their light color, soft, ashy constitution, and especially their obviously partially calcareous nature. In writing to Professor Knight after my return, in a letter dated December 5, 1898, I said:

I was in New Haven all last week working up a collection of cycads that Professor Marsh has obtained since I was there in June. Among them were the two from Wyoming that Mr. Reed sent him. I took full notes on them. One is immature and the other a fragment, and neither ought to form the basis for a species, although they seem to be specifically different from each other and also from any other cycads known to me. If there is any prospect of my handling your full collection, or any considerable part of it, I shall delay describing these until I have seen more material.

While I was in New Haven in November, 1898, Professor Marsh requested me to name one of the Wyoming species, should there prove to be a new one, for Mr. Reed, the original collector. I have complied with this request in the present paper. I should have naturally done so, in conformity with the general practice of naming species after the collector, but in the present case, since Professor Marsh so strongly requested it, it becomes an obligation, as it certainly is a pleasure.

Although from Professor Knight's representation, and from all accounts, there was little doubt as to the Jurassic age of the cycad bed in the Freezeout Hills of Wyoming, still my desire to visit the spot and obtain a clear first-hand idea of it and of its relations to other deposits was very great, and I gladly availed myself of Professor Knight's generous offer to go with me to the locality. An arrangement was made to meet him at Laramie September 1, 1899, for this purpose. I was there at the appointed time, and a small party started on the 2d and reached the Freezeout Hills on the 3d.

The Freezeout Hills occupy an area some 10 miles square in about latitude 42° 7′ N., longitude 106° 15′ W. from Greenwich, and lie principally in T. 25 N., R. 79 W. Its topographic position is between the Big and Little Medicine rivers, which unite to form Rock Creek 10 miles due south of its central portion; but Muddy Creek, a branch of the Little Medicine, bounds the area on the north and east sides, while tributaries of the Big Medicine have their origin in its western portion. The highest of the hills is called Freezeout Mountain, the name being derived from a somewhat vague tradition that in early times an entire party of men were frozen to death in its immediate vicinity. The general uplift, which nowhere exceeds 8,000 feet, extends in a southeasterly direction to Medicine Bow and beyond. It is in one of the spurs of it, 7 miles east of the last-named place, and opposite the station called Aurora, on the Union Pacific Railroad, in the valley of Rock Creek, that the famous Como Bluff is located, in which dinosaurian remains were early found, and which furnished the well-known section so often published by Professor Marsh.

In traveling north from Medicine Bow, areas of Fort Benton and Dakota are passed over before reaching the Little Medicine, 5 miles from that place, in the valley of which the Jurassic is exposed, underlain by the Red Beds, both of which look very familiar to one acquainted with the Black Hills. The beds dip rapidly to the south, and there is an anticline to the north of the Little Medicine, the summit of which consists of a curious white sandy limestone, probably Permian in age, and comparable to some of the Permian beds of Kansas. Beyond this there is a wide plain, over which, at favorable places, the Jurassic and the Red Beds again successively make their appearance. Crossing this plain, a distance of some 12 miles, the southeastern border of the Freezeout Hills is reached. They are somewhat isolated and slope gradually to the east, while the west end of the spurs presents a ragged escarpment. The wagon road passes around them on the east, while at their western bases there is a somewhat narrow valley. As the geology can be much better studied on the west side, several members of the party, including Professor Knight and myself, took through this valley on foot from Trabing Brothers' ranch to the cabin which had been erected by the University of Wyoming on the north side of the hills, a distance of 6 miles. We thus passed along the foot of Freezeout Mountain, which rises 600 feet above the plain. The strata were seen dipping to the southeast, exposing at the base of the cliffs heavy beds of massive light-colored limestone, which weathers red and is supposed to belong to the Trias. The marine Jurassic rests upon this, and over it is the fresh-water Jurassic, which everywhere throughout this region holds saurian bones. The whole is capped by a formation which is called Dakota, but which in all essential respects resembles the Lower Cretaceous of the Black Hills. In some places, however, it has a different appearance and can be compared with phases of the Kansas deposits underlying the Dakota, especially as exposed at the head of the Medicine Lodge River.[1]

The cycad locality is in the northern portion of the hills and only half a mile from the cabin, and is located on section 13 of the township and range above mentioned. It occupies a rectangular area some 300 yards long east and west and 50 yards wide north and south, a little below and on the north side of the summit of a low rounded ridge in a sort of gap near the west end of the most northerly spur of the Freezeout Hills. This spur is much higher to the east of this gap, with a western scarp like the rest, and is capped by Cretaceous rocks, as shown in the section opposite. It lies near the middle of the fresh-water Jurassic. The cycadean trunks are buried in a loose and soft reddish-gray calcareous sand, easy of excavation, and a considerable number were dug out with a mattock. There are doubtless many more beneath the surface, and Professor Knight proposed to have the entire area turned over with a subsoil plow in the hope of bringing them to light.

This loose calcareous sand is so different from the material on the ridge above and below the cycad bed as to make it apparent that it consisted of a disintegrated stratum which was unlike those of the underlying and overlying beds, and I set about tracing it to the east, where the northern slope of the spur is much steeper and the strata are better exposed. I had no difficulty in doing this, and soon found the bed well exposed and continuing uniformly through the hill on its northern flank. It forms a ledge much of the way, and consists of a coarse, reddish-brown, cross-bedded sandstone with streaks of small, white, calcareous flecks, or small pellets. In some places these pellets are larger and give the rock somewhat the appearance of a conglomerate. There are also black carbonaceous streaks, containing compressed bits of lignitized wood. Silicified wood is very abundant in the cycad bed proper and is occasionally seen in the ledges.

After familiarizing myself with this important stratum I crossed over to the low hills north of the valley in which the cabin is located, and found it occupying the summit of some of them. It is much thicker there and forms crags. No cycads were found there, but large trunks of silicified wood lie embedded in the rock, and the gulches below are strewn with them and with blocks of the wood that have weathered out.

[1]See Science, new series, Vol. VI, Nov. 26, 1897, p. 815, and the paper of Mr. C. N. Gould On a series of transition beds from the Comanche to the Dakota Cretaceous in southwest Kansas: Am. Jour. Sci., March, 1898, 4th series, Vol. V, pp. 169–175.

A somewhat careful section was made east of the cycad locality at the point where the spur attains it greatest elevation, which is where it suddenly breaks away and exposes its western end down to the level of the low ridge holding the cycadean trunks. The following is the section:

*Section of the Freezeout Hills, Wyoming.*

| | Feet. |
|---|---|
| Cretaceous capping the hill | 50 |
| Fresh-water Jurassic (190 feet): | |
| Top of cycad stratum to base of Cretaceous | 100 |
| Cycad stratum | 10 |
| Top of marine Jurassic to bottom of cycad stratum | 80 |
| Marine Jurassic from Red Beds exposed in bottom of valley to base of fresh-water Jurassic | 115 |
| Total exposure | 355 |

The fresh-water Jurassic consists of fine soft sandstones, white, reddish, or yellowish, and olive-gray calcareous shales, at nearly all parts of which occur lenses or extensive beds of dark marls holding saurian bones and other vertebrate remains in great numbers. Some of these occupy a position above and others below that of the cycad-bearing stratum, and a number of bones were found in the cycad bed itself at its eastern end. These, however, may not have been in place, as no marls occur at this point.

I may add that there was no part of the section that is not practically paralleled in the Black Hills, and it does not differ more in general geological character or in the thickness of the several members from those I made in several parts of the Black Hills than those sections differ from one another.[1] The conclusion seems inevitable that practically the same general geological conditions obtain over a vast region of the Rocky Mountain uplift. Not less important to the paleontologist is the other general inference which so naturally flows from all the facts observed, that the life, both animal and vegetable, of this enormous period, extending, apparently unbroken, from the Permian to the Tertiary, has left its record, and will ultimately be known with a high degree of certainty. The marked difference that we shall presently see to exist between the cycadean forms of the Jurassic and those of the Lower Cretaceous fully attests the rapid change that took place during the comparatively short interval that separates them.

The material collected on this expedition was shipped to the National Museum by Mr. Charles Schuchert, who was a member of the party. Several other trunks were collected by Mr. Charles Gilmore before my arrival, and are at the University of Wyoming awaiting shipment. These I have not seen, nor have I had time since my return to study

[1] See Nineteenth Ann. Rept. U. S. Geol. Survey, Part II, pp. 554-565.

the others. The following account will therefore be confined to the original collections of Mr. W. H. Reed, sent me by Professor Knight, and the two specimens which Mr. Reed sent to Professor Marsh. The former of these collections consists of 83 specimens of cycads and 3 specimens of silicified wood. The specimens of cycads bear the numbers 500.1 to 500.83, and those of the wood the numbers 500.85 to 500.87, of the Museum of the School of Mines of the University of Wyoming, at Laramie, Wyoming. They are for the most part fragments, but there are a few entire trunks. The three largest, Nos. 500.1, 500.2, and 500.65, though all present, are each broken in two pieces which fit together perfectly. In a number of cases complementary parts had been detected and, unfortunately for their convenient study, glued together. In others such complements had been recognized and given the same number. It was obvious, however, that many fragments that belong together had not been identified, and much time was spent in finding and joining these counterparts. This study ultimately resulted in finding about 25 such cases. In addition to these there are a number which, although they do not actually fit together, nevertheless evidently belong to the same trunk, the structure being continuous and explicable on the assumption of the loss of intermediate portions. Putting these two classes together, the number of independent trunks and fragments is reduced to 61. In several cases more than 2 fragments belong together; for example, in three cases there are 3 and in two cases there are 5 separately numbered pieces of the same trunk.

A large proportion of the specimens were covered on the side on which they lay in the field by an incrustation of lime. This completely obscured the structure, and it was necessary to remove it. This was the case with many of the Black Hills cycads, but it presented no serious difficulty beyond the labor and expense of placing the trunks in a vat of hydrochloric acid and leaving them there until the lime was removed, the pure silica of those trunks being wholly unaffected by the process. But, as already remarked, the Jurassic trunks, although mainly silicified, contain calcareous matter, and the acid unavoidably etches the surface somewhat. If this had been all it would have been a comparatively small matter. The worst difficulty arises from the fact that the oxidation of the specimens turns the parts affected by the acid black or dull brown, and thereby more or less obscures the markings of the surface, on which the different organs normally have a different shade of color, which brings them out distinctly. After the acid bath, although the lime is removed and the surface little eaten or injured, all the organs have this uniform black or brown color. It is, however, fortunate that, while this interferes seriously with an ordinary macroscopic examination, the application of a lens removes the obscurity to a considerable degree, and in photographing the specimens it is observed that the dark surfaces come out almost as clearly as the light or variegated ones.

Besides the lime incrustations on the under surface, there was usually a coating of lichens on the surface which lay uppermost, and this, where it existed, was quite as fatal to an examination of the parts thus concealed as the coating of lime. This, though somewhat more difficult to remove, yields to a strong alkali, which has no effect upon the underlying structures.

The cleaning of the specimens by both the processes employed was undertaken as soon as possible after the collection had been unpacked, and I commenced the systematic study of the trunks almost at once, thoroughly noting and recording the characters and peculiarities of every specimen and of all parts of each, and by the end of May, 1899, I had completed this part of the work. I have compiled tables of the characters, and the subdivision into specific groups has been based mainly upon such characters. Notwithstanding considerable sameness among these characters, it is possible to classify them, and there seems no doubt that, could their foliage and reproductive organs be known, the cycadean flora of the Jurassic of Wyoming would be represented by a considerable number of species if not of genera, although it would be rash to assert that the lines would be drawn in all cases where we must draw them here.

The most marked feature that struck me on first casual inspection of these trunks, aside from their relatively small size, light color, and soft calcareous structure, was the frequency of a sort of smooth, to the naked eye structureless, dull, uniform covering that invests their outer surfaces and cuts off the view of the normal organs of the armor. A closer examination revealed the fact that this was not an occasional condition, but the normal state of these cycads, and that the cases in which this outer coating is wanting represent the abnormal state. It further became clear that there really are no cases in which it is naturally absent, and that its absence is always due to some external influence acting upon the surface which has removed it. There is an abundance of proof of this, and most of the specimens show parts over which the external coating still adheres and other parts where it is absent. The latter usually reveal the nature of the agency that has removed the coating—whether a sudden and violent concussion, gradual erosion, or a process of weathering. The contact of the outer layer with the surface of the armor proper is always marked by a clear plane of separation, and usually by an open structure or even a partially void space. This becomes a natural plane of cleavage, and almost any influence will cause the outer coating to scale off like the outer bark of a tree.

In the specimens of the Yale Museum this outer coating had almost entirely disappeared, though not absolutely, so that the phenomenon did not specially strike me, and I noted only that the surfaces were obscure in places. Through the kindness of Dr. C. E. Beecher these specimens were sent to me for further examination and comparison with those of the large collection from Professor Knight. Some of the important results of this comparison will be noted later on, but it is sufficient to state here that they form no exception or anomaly, but are simply part and parcel of the general lot.

Generic characters, with the exception of Bennettites, which is identical with Cycadeoidea except in the accident that seeds have been discovered in the spadices, have generally been based on the shape of the trunk and on the character of the armor, i. e., of the remains of the foliar organs still adhering to the trunk in the fossil state. The former of these characters has proved of less constancy, and, in cases where the latter class of characters is distinctive, authors have not hesitated to ignore variations in the former, as, e. g., *Cycadeoidea gigantea* of Seward, a tall, cylindrical trunk, wholly different in form from other species of that genus. I was obliged to do the same with *C. excelsa* and *C. Jenneyana*.

The second class of characters is relatively constant and diagnostic, and to show the differences in the different genera[1] I will reproduce the descriptions of different authors of these generic characters, translating where necessary:

Bucklandia: scarred-areolate by the scars of the spadices, scales, and petioles (Carruthers).

Yatesia: covered by the scales and persistent bases of the petioles (Carruthers).

Williamsonia: scarred-areolate by the markings of the deciduous petioles (Carruthers).

Bennettites: covered with the persistent bases of the petioles (Carruthers).

Mantellia: same as Bennettites (Carruthers. This was Brongniart's name of Cycadeoidea, which Carruthers adopted).

Raumeria: densely covered or scarred by the persistent bases of the petioles and stipule-shaped, connate scales (Carruthers).

Fittonia: covered by the scales and persistent, large, geniculate bases of the petioles (Carruthers).

Crossozamia: covered by the short, subimbricate bases of the petioles (Carruthers).

Clathraria: marked by transverse rhombic or irregularly pentagonal and hexagonal scars of leaves truncated above the base (Schimper).

Cycadeoidea: enveloped by the basilar remains of the leaves, rhomboidal in cross section (Schimper).[2]

Bolbopodium: completely enveloped by the disjointed rhombic leaf bases of different lengths (Saporta).

Cylindropodium: leaf bases short, densely crowded, with rhombic, convex scars (Saporta).

Clathropodium: leaf bases long-rhombic or elliptical in cross section (Saporta).

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[1] Many of the generic names mentioned here are of course synonyms, but have been described as genera.

[2] Buckland's description was not compact.

The peculiar outer coating or second armor of the Jurassic cycads of Wyoming obviously constitutes a good generic character. At the same time, as is seen by the above descriptions, it is wholly different from that of any other genus of cycadean trunks, and it is therefore necessary to regard it as a new genus, altogether different in its most essential generic characters from any other. From the generally small size of these trunks, especially when compared with the giant forms of the Black Hills, I have concluded to call this new genus *Cycadella*.

Although a macroscopic examination is sufficient to show this generic distinction, still it does not immediately indicate the true nature of this supplementary envelop. I was at first disposed to think that it consisted of matted leaves. I observed that the leaf bases were always present, filling the scars, and sometimes projecting somewhat above the general surface, and I did not know but that expanded portions of them might have also persisted and been rolled and packed against the trunks in the process of entombment in a manner to produce the observed effect. But a strong glass failed to bring out the difference on the surface that would be expected if such had been the case: striations, folds, leaf margins, etc. Moreover, the fractured margins often showed the darker leaf bases coming out to the surface of the true armor but never continuing across the line of separation and mingling with the tissue of the outer layer, which is sometimes more than a centimeter in thickness.

Since, aside from the reproductive organs, less abundant than in the Cretaceous cycads, the armor consists of nothing else than the leaf bases and the ramentum that is attached to them and constitutes the walls, this last must have furnished the covering which forms the outer coat. It has been observed that these fine scales or hairs are always the most certain to be preserved, and whatever the degree of imperfection in the state of preservation in other respects, the walls are usually intact. This accounts for the large number of trunks that consist of these walls penetrated to a great depth by the rhombic or triangular cavities, looking like petrified honeycomb or sponges. This is a most fortunate circumstance, since otherwise we should in such cases have nothing but the woody cylinder of the trunk, and would be entirely incapable of determining the true nature of the objects.

This special susceptibility to petrification on the part of the ramentum explains the presence of the external covering of the Wyoming Jurassic cycads, since it seems actually to consist of a matted mass of these ramentaceous hairs, which in some way developed so luxuriantly upon the sides of the petioles as to push out beyond the surface and roll over the spaces formerly occupied by the leaves and fruits. It seems necessary to assume that this occurred long after the fall of the leaves, and, indeed, this latter doubtless took place much as it does in living cycads, the leaves always forming a crown to the trunks and falling away as the trunk elongates, leaving only their persistent bases to form a false bark. These are not wholly dead, but manifest vegetative activity, and doubtless have some physiological function. The development of copious ramentaceous hairs would form a protection to the trunk both from cold and from violence.

Something analogous to this may be seen in living cycads and in tree ferns; also in some palms, and a similar function is sometimes performed in other ways, as by the coat of wax on the wax palms. At any rate, we are confronted with the fact that Cycadella developed an exuberant growth of fine scales or hairs from the bases of its old petioles below the apex, which formed a woolly or mossy covering of considerable thickness, sufficient when tightly appressed to the trunk and petrified there to form a layer 5 to 15 mm. thick all over the fossil trunks.

As already remarked, there is usually a clean line of separation between the armor proper and this outer covering, but if the latter consists of ramentum there must be points at which it crossed this boundary and reappeared in the superficial layer. Such points are not easy to find in the collection, but the fractured surfaces of a few specimens reveal the process of transition in a more or less imperfect way. Such specimens were carefully searched out and the most promising cases were sectioned and the surfaces polished. Slides were also made, and the whole process is as fully illustrated as the nature of the material will permit.

The following is the description of the new genus Cycadella and the species distinguished in the collections examined:

## Genus CYCADELLA Ward.[1]

### Pl. LXX.

1900. *Cycadella* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 263, pl. xiv.

Trunks relatively small, bulbous, subspheroidal, or subconical, variously compressed, incased in a layer 5 to 15 mm. thick of dense tissue, consisting of the chaffy ramentum exuberantly developed from the leaf bases and extruded from the armor, massed and matted in the fossil state so as to form a thick outer covering to the trunk; leaf bases always filling the scars, occasionally caught in the meshes of the outer coating, but normally truncated below, and constituting, with the ramentum walls, a dense armor 1 to 5 cm. thick; otherwise as in Cycadeoidea.

Pl. LXX merely illustrates the nature of the ramentaceous chaff and the great length that it attains, but it would be obviously impossible

[1] The systematic position of Cycadella is the same as that of Cycadeoidea (see supra, p. 302).

to show the full length with a power of 90 diameters. The manner in which the chaffy hairs protrude from the armor and pour over the surface of the trunk, upon which they lie in mats of wavy lines, is shown on Pls. XCIV and XCV, illustrating *C. Knowltoniana*. The phenomena will be more fully described under that species.

I am indebted to Dr. F. H. Knowlton, for the drawing of Pl. LXX, made from slides of the two species, *C. Knowltoniana* (Figs. 1–3) and *C. ramentosa* (Figs. 4, 5), under the compound microscope. For further details see description of that plate.

### CYCADELLA REEDII Ward.

### Pl. LXXI–LXXVI.

1900. *Cycadella Reedii* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 264, pl. xv.

Trunks small (8 to 12 cm. high, 6 to 16 cm. in diameter), subspheroidal or subconical, unbranched, usually more or less laterally compressed, the axis oblique; rock substance rather soft, light colored, of low specific gravity; organs of the armor ascending; leaf scars arranged in rows around the trunk nearly at right angles to the axis, subrhombic, 15 to 20 mm. wide, 6 to 10 mm. high; leaf bases porous; walls 1 to 3 mm. thick, hard and fine-grained, often flinty, usually white and somewhat striate; reproductive organs very obscure; armor 1 to 3 cm. thick, separated from the axis by a definite line; wood 2 to 3 cm. thick; cortical parenchyma 1 to 2 cm. thick; fibrous zone divided into two or three rings of fine, more or less distinctly radiate structure; medulla 2 to 4 cm. in diameter, nearly circular, consisting of fine-grained homogeneous tissue.

To this species are referred five of the specimens. One of these, which is taken as the type, is the more complete of two originally sent to Professor Marsh by Mr. W. H. Reed, for whom the species is named. It is No. 127 of the Yale collection. The other specimens are Nos. 500.6, 500.10, 500.19, and 500.29 of the Museum of the State University of Wyoming. The Yale specimen is larger than any of the others, weighing 2.04 kilograms, while No. 500.10 is the smallest trunk in either collection and weighs only 0.37 kilogram. No. 500.6 weighs 1.48, No. 500.19, 1.56, and No. 500.29, 1.67 kilograms.

Pl. LXXI represents the best side of the Yale specimen, with the eccentric medulla projecting. Pl. LXXII shows the side opposite this, which is considerably obscured by remains of the outer coat. Pl. LXXIII, Fig. 1, shows a side view of No. 500.29, of the Museum of the University of Wyoming, and Fig. 2 is a view of the base. Pl. LXXIV gives two views of opposite sides of No. 500.6, the base being faintly visible in both. Pl. LXXV, Fig. 1, represents the best-preserved side of No. 500.19, and Fig. 2 the base. Pl. LXXVI shows the two opposite broadest sides of the small No. 500.10.

### Cycadella Beecheriana Ward.

Pl. LXXVII; Pl. LXXVIII.

1900. *Cycadella Beecheriana* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 265, pl. xvi.

Trunk cylindrical, contracted at base and summit, somewhat laterally compressed, unbranched, 35 cm. high, 18 by 22 cm. in diameter; rock substance soft, generally light colored with darker stripes and spots strongly contrasting, of low specific gravity; organs of the armor horizontal; phyllotaxy concealed by the outer coating of ramentum; leaf scars subrhombic or somewhat elliptical, 15 to 20 mm. wide, 5 to 10 mm. high; leaf bases dark colored, punctate; walls about 5 mm. thick, firm, white, sometimes with a median line; reproductive organs well developed, somewhat raised above the general surface, elliptical in cross section, 2 by 3 cm. in diameter, surrounded by subrhombic bract scars in several rows, the central portion heterogeneous and more or less crystallized; armor 3 to 4 cm. thick, joining the axis by an irregular line; wood 3 to 4 cm. thick; cortical parenchyma 1 to 2 cm. thick; fibrous zone 2 cm. thick, not differentiated into rings, firm and dark colored; medulla mostly wanting in the only specimen known, the preserved remains flinty and white.

Of this species there has thus far been found less than half of one trunk. The upper two-thirds of this consists of the fragment No. 128 of the Yale collection. When I studied this fragment in November, 1898, it was all in one piece, but subsequently broke into two nearly equal pieces by an oblique transverse fracture, and a small lump came out of the lower one of these pieces. While studying the larger collection at Washington in June, 1899, I felt the need of again seeing the two Yale specimens in order to correlate them with the rest, and at my request Dr. C. E. Beecher kindly sent them to me for the purpose. As soon as I saw this fragment I at once recognized its resemblance to a smaller fragment of the Knight collection, No. 500.54, which I had been unable to class with any of the rest. On confronting them it was found that No. 500.54 of the Wyoming collection fitted perfectly on the lower end of No. 128 of the Yale collection, thus nearly completing it in that direction, but still leaving a small part of the base unrepresented. Thus restored the specimen represents nearly half of the original trunk, which was split down quite evenly from summit to base on a longitudinal plane a trifle on one side of the center. On the fractured surface thus presented the internal characters are exposed with great clearness.

As a partial recognition of the interest taken by Dr. Beecher in the subject of cycads in general and in the Wyoming specimens in particular, I dedicate this species to him.

The Yale specimen weighs 3.18 and the Knight specimen 1.45 kilograms.

Pl. LXXVII represents the inner fractured surface of the specimen as restored, the lines separating all four of the pieces being distinctly visible. Pl. LXXVIII shows the outer surface of the same.

### Cycadella wyomingensis Ward.

### Pls. LXXIX–XC.

1900. *Cycadella wyomingensis* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 266, pl. xvii.

Trunks relatively large (25 to 30 cm. high, 15 to 25 cm. in diameter), short-conical or slightly contracted at the base, more or less laterally compressed, unbranched or with a few projecting secondary axes; rock substance hard and fine-grained, generally light colored but with varying shades, of medium specific gravity; organs of the armor slightly ascending; rows of scars from left to right making an angle with the axis of 70° to 80°, those from right to left of 45°; leaf scars subrhombic, 15 to 20 mm. wide, 8 to 12 mm. high; leaf bases relatively dark, affected with black or sometimes white tubular punctations; walls 2 to 4 mm. thick, light colored and striate but without any proper commissure; reproductive organs few but often well developed, sometimes projecting or passing through the outer coating, elliptical in cross-section, 2 by 3 cm. in diameter, surrounded by mostly obscure, rather large involucral bract scars of variable shape, the central portion solid but heterogeneous in structure; armor 3 to 6 cm. thick, joined to the axis by a definite but usually irregular, sometimes scalloped, line; wood 3 to 4 cm. thick; cortical parenchyma 10 to 15 mm. thick; fibrous zone 1 to 2 cm. thick, usually consisting of two rings, one or both radiate in structure, the medullary rays often distinct; medulla 5 to 10 cm. in diameter, the cross-section elliptical in the compressed specimens, of a nearly homogeneous fine-grained structure.

This species includes some of the handsomest specimens in the collection, having about a medium size, and therefore being fairly representative of the Jurassic cycads. Nos. 500.3, 500.14, and 500.15 are nearly perfect trunks. The rest are fragments. Nos. 500.7 and 500.20 are somewhat thin segments bounded by transverse fractures, and almost certainly belong to the same trunk at different elevations. No. 500.26 may be a lower segment of the same trunk, but if so it must have been contracted at the base, as is the case with No. 500.3. Nos. 500.8 and 500.67 fit each other, and the former, which was shattered when received, has come in three pieces. It represents a section between two oblique but chiefly vertical fractures. No. 500.52, a thick, somewhat cubical piece, almost certainly belongs to No. 500.8, as shown by the identical structure of its principal fracture.

The weights of the specimens are as follows:

| | Kilograms. |
|---|---|
| No. 500.3 | 11.03 |
| No. 500.7 | 2.41 |
| No. 500.8 | 1.28 |
| No. 500.14 | 12.00 |
| No. 500.15 | 8.89 |
| No. 500.20 | 3.57 |
| No. 500.26 | 4.00 |
| No. 500.52 | 1.13 |
| No. 500.67 | 0.40 |

Pls. LXXIX and LXXX illustrate two of the sides and the base of No. 500.3. Pls. LXXXI to LXXXIII do the same for No. 500.14. In Pl. LXXXI, which is a side view of No. 500.14, the distinction between the parts covered with the ramentaceous cortex on the right and those from which this has peeled off on the left, with the exposed edge of this layer, is clearly brought out. In Pl. LXXXII the compressed leafy summit of the trunk, broken down on one side, is made clear, and the circular area near the top represents the probable eccentric terminal bud or end of the main axis with small scars. Pls. LXXXIV and LXXXV show the broadest side and the base of No. 500.15. Pls. LXXXVI to XC illustrate the segmentary fragments Nos. 500.7, 500.8, 500.20, 500.26, and 500.52, several of which probably represent the same trunk.

## CYCADELLA KNOWLTONIANA Ward.

Pl. LXX, Figs. 1-3; Pls. XCI–XCV.

1900. *Cycadella Knowltoniana* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 267, pls. xviii–xx.

Trunks medium size (25 cm. in diameter), cylindrical, bearing a few small secondary axes; rock soft, light colored without, dark and variegated within; organs of the armor horizontal; leaf scars subrhombic, 8 to 12 mm. wide, 4 to 6 mm. high; leaf bases relatively dark, punctate with minute white-walled tubes; walls thick, sometimes 5 mm., soft, white on their outer edges, brown within as shown on the fractures, contrasting strongly with the nearly black leaf bases, the ramentaceous hairs very distinct, showing their mode of origin in the petioles and their passage from the armor into the outer coating which they form, to a thickness in places of nearly 2 cm.; reproductive organs few but distinct, usually raised, 16 by 25 mm. in diameter, surrounded by two or more rows of narrow involucral bract scars, the bracts distinctly traceable in longitudinal section to their origin in the receptacle, from which also proceed the essential organs in an advanced stage of decay and mineralization; armor 3 to 4 cm. thick, joined to the axis by a very irregular but somewhat definite line, the petioles emerging from different depths as projections of the wood substance;

wood 2 to 3 cm. thick, very imperfectly differentiated into two zones, the inner wall, exposed in one specimen, showing large scars of the medullary rays, consisting of elongated alternating depressions, 10 to 15 mm. long, 5 to 8 mm. wide, each with a raised point or cushion above the middle; medulla 4 cm. in diameter, hard, fine-grained, and homogeneous.

This species consists of Nos. 500.62 and 500.76, which seem to belong to the same trunk, but are not exactly contiguous. They probably belong end to end, No. 500.62 being the upper segment and reaching nearly to the apex of the trunk, while No. 500.76 falls considerably short of reaching the base. The trunk probably had a height of about 20 cm. No. 500.62 has lost the medulla, thus exposing the inner wall of the woody axis as described. Both specimens are nearly covered without by the coating of ramentum, and the transverse fractures reveal its nature better than in any other specimens in the collection. One of these surfaces (the upper fracture of No. 500.76) has been cut across and polished, and microscopic slides prepared from the region which most clearly shows the transition of the ramentum to the outer investiture (see Pl. LXX, Figs. 1–3). This polished surface was photographed natural size and also enlarged four times linear, and the most instructive portions of the large view have been selected to illustrate the behavior of the ramentaceous chaff in forming the external layer.

On account of the great interest taken by Dr. F. H. Knowlton in the question of the true nature of this peculiar generic character, the material assistance he has rendered me in preparing and examining microscopic slides illustrating it, and the fact that the most successful of these investigations have been made on specimens of this species, I have thought it a proper recognition of his services that the species should bear his name.

The weight of No. 500.62 is 1.22 kilograms, and that of No. 500.76 (before cutting) 1.39 kilograms.

Pl. XCI shows the outer surface of No. 500.62, which is completely encased in the ramentaceous layer, so that none of the scars are visible. Fig. 2 represents the inner wall of the woody zone with the scars of the medullary rays. Pl. XCII, Fig. 1, presents the lower transverse fracture of the same specimen, which shows very clearly the leaf bases and walls in longitudinal section overlain by the investing case of matted ramentum.

Pl. XCII, Fig. 2, and Pls. XCIII to XCV, illustrate the instructive specimen No. 500.76, which probably belongs lower in the same trunk as the last. The polished surface of the upper transverse fracture, from which the microscopic slides were taken, is represented by Pl. XCII, Fig. 2. The figure is somewhat enlarged, and even here the origin of the ramentum from the sides of the leaf bases is distinctly visible without a lens. The line dividing the armor from the outer layer is clear, and a good general idea of the nature of the latter can be gained from this view. The irregular attachment of the armor to the axis is also well shown. Pl. XCIII, Fig 1, shows this same surface as it appeared before it was polished. Fig. 2 gives the outer surface invested by the ramentum layer, but a few organs are visible, having forced their way through it or been disarticulated near its outer surface.

Pls. XCIV and XCV represent two areas of the polished upper transverse plane enlarged 4 diameters. An inspection of Pl. XCII, Fig. 2, shows that there is a short interval near the center of the specimen over which, for some reason, there is no outer layer, to the left of which it extends entirely to the margin, and on the right of which it fills a deep depression in the surface. Pl. XCIV includes the greater part of the portion on the left where this layer is present, and Pl. XCV covers the area on the right. All the characters, generic and specific, are admirably brought out in these two enlarged areas, especially the nature of the ramentum outside of the armor, and its wavy, crinkled character as determined by the irregularities of the surface and the unknown agencies that compressed it from without and packed it down against the trunk. In several places portions of leaf bases and perhaps of reproductive organs, detached from the armor and caught, as it were, in the meshes of chaff, can be seen lodged in the outer coat. These show their normal vascular structure under the compound microscope. Owing to inequalities of pressure and unexplained conditions, the long strands of matted chaff are differentiated into bands of different color and density that lie parallel to one another and zigzag across the exposed cross sections of the investing layer. Near the left margin of Pl. XCV there is a region where one of the petioles is clearly seen to cross the boundary line between the armor and the ramentaceous covering, and the chaff that developed from its left side can also be traced across this boundary and out into the outer layer. This is particularly instructive from the point of view of the origin of the latter. Upon the whole, these several illustrations afford a tolerably clear idea of the character of this remarkable group of extinct plants.

### CYCADELLA COMPRESSA Ward.

### Pl. XCVI; Pl. XCVII.

1900. *Cycadella compressa* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 269.

Trunks small (10 to 20 cm. high, with major diameter 12 to 15 cm.), originally conical, all much compressed laterally or sometimes vertically or obliquely, unbranched; rock soft, light colored, of low specific gravity; organs of the armor tightly appressed to the trunk for the most part upwardly, obscuring their arrangement; leaf scars subrhombic, where normal 15 to 20 mm. wide and 8 to 12 mm. high; leaf bases soft, rough or porous; walls 1 to 2 mm. thick, soft-sandy or decayed and depressed, light colored or yellowish; reproductive organs few and obscure, sometimes slightly elevated, elliptical in cross section, 12 by 20 mm. in diameter, with or without visible bract scars, the central portion obscure; armor very variable in thickness (5 to 25 mm.), joined to the axis by a definite but more or less irregular line; wood 2 cm. thick; cortical parenchyma 1 cm. thick; fibrous zone 1 cm. thick, not differentiated; medulla in laterally compressed specimens a thin slab 5 mm. thick and 7 cm. long, in vertically compressed specimens circular, 2 cm. in diameter.

This species embraces 6 much-flattened specimens, viz, Nos. 500.4, 500.18, 500.22, 500.35, 500.68, and 500.69. Of these Nos. 500.4, 500.18, and 500.35 are nearly complete trunks, No. 500.18 being vertically or somewhat obliquely compressed. All the rest are laterally compressed. Nos. 500.22, 500.68, and 500.69 may all belong to the same trunk, the last two especially resembling each other, but none of them are contiguous. They all bear a general resemblance to one or other of the species already described, but aside from their great compression and small size, not specific characters in themselves, there are numerous features which forbid their union with any of these.

The weights are as follows:

| | Kilograms. |
|---|---|
| No. 500.4 | 1.11 |
| No. 500.18 | 1.14 |
| No. 500.22 | 0.79 |
| No. 500.35 | 0.88 |
| No. 500.68 | 0.59 |
| No. 500.69 | 0.56 |

The only specimens that it was thought worth while to illustrate are Nos. 500.4 and 500.18. The former is shown on Pl. XCVI. The figure gives an exaggerated idea of the specimen, which is flat and thin, and only the broad side was taken. Pl. XCVII illustrates No. 500.18, Fig. 1 showing the upper side which below is a side view, but near the top the apex is turned toward the observer and the terminal bud may be seen a little on the left. The lack of perspective causes its true form to be obscured.

### CYCADELLA JURASSICA Ward.

### Pls. XCVIII-CXII.

1900. *Cycadella jurassica* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 270.

Trunks rather small (10 to 15 cm. high, 10 to 20 cm. in diameter), very irregular in shape, more or less compressed in various directions and distorted, often much branched with several primary axes, sometimes with secondary axes only, the branches usually terminating in regular buds; rock substance soft except where excessively mineralized, light ash colored with dark, sharply contrasting stripes and spots, usually of low specific gravity; organs of the armor mostly ascending and adjusted to the axes of the branches; phyllotaxy not generally traceable except in secondary arrangement around certain branches; leaf scars subrhombic or somewhat elliptical, 15 to 20 mm. wide, 8 to 12 mm. high; leaf bases dark and affected with white fistular punctations; walls 2 to 4 mm. thick, soft-sandy, white or yellowish, striate, often with a median groove, depression, or crack; reproductive organs somewhat rare, often well-developed, either flush with the surface or raised above it, elliptical in cross section, variable in size, 15 to 30 mm. in diameter, surrounded by large triangular bract scars, the central portion solid and marked by the scars of the essential organs; armor 4 to 6 cm. thick, joined to the axis by an uneven, more or less definite line; wood 2 to 3 cm. thick; cortical parenchyma 1 to 2 cm. thick; fibrous zone 1 to 2 cm. thick, sometimes in two rings with radiate structure; medulla 3 to 6 cm. in diameter, fine-grained and homogeneous.

This species is one of the most common in the Jurassic of Wyoming, and is typical of the smaller branching forms. It embraces Nos. 500.5, 500.23, 500.30, 500.36, 500.38, 500.41, 500.49, 500.70, 500.77, 500.78, 500.80, and 500.82. Nos. 500.49 and 500.77 fit together, and No. 500.41 evidently belongs to the same trunk. A small piece has become detached from No. 500.49. Nos. 500.78 and 500.82 also fit together, and No. 500.70 seems to form a cap to this small trunk, but a portion is lost between them. The rest are all single. Nos. 500.5 and 500.23 are practically complete trunks. Nos. 500.36 and 500.38 are parts of two of the largest trunks of the species, and No. 500.30 is over half of another nearly as large. They are all very handsome specimens, presenting the regular mottled striped or spotted appearance due to contrast between the dark leaf bases and the light-colored walls. No. 500.23 is nearly unbranched and is anomalous in several respects. It may represent a different species, but can not be identified with any other specific group.

The weights of the specimens are as follows:

| | Kilograms. |
|---|---|
| No. 500.5 | 2.41 |
| No. 500.23 | 1.05 |
| No. 500.30 | 2.30 |
| No. 500.36 | 3.43 |
| No. 500.38 | 3.32 |
| No. 500.41 | 0.37 |
| No. 500.49 | 1.84 |
| No. 500.70 | 0.56 |
| No. 500.77 | 1.14 |
| No. 500.78 | 0.79 |
| No. 500.80 | 0.79 |
| No. 500.82 | 0.62 |

Pls. XCVIII and XCIX represent the two opposite broadest sides of the specimen No. 500.5; Pls. C and CI afford side views of the fine branching trunk No. 500.38, and Pl. CII shows the interior from the fractured side; Pl. CIII shows the outer surface and Pl. CIV the inner fractured surface of No. 500.30; Pl. CV presents the best-preserved side of the trunk No. 500.36 with its broken summit, and Pl. CVI includes the broken base and a portion of the other side. Views of the two sides of the combined Nos. 500.49 and 500.77 are given in Pls. CVII and CVIII, and the internal structure of No. 500.49, as revealed by the transverse fracture, is shown in Pl. CIX. The nearly complete small trunk made up of Nos. 500.78 and 500.82 is well shown on Pl. CX, in which *a* is the former and *b* the latter of these specimens. Pl. CXI represents the specimen No. 500.70, which is believed to be the apex of that trunk extending over portions that are lost in the lower pieces. Fig. 1 is a view from the top showing the rounded summit, and Fig. 2 a view from below showing the concave, partially decayed fracture, corresponding very closely with the upper portion of No. 500.82 as seen in Pl. CX at *b*. The anomalous specimen, No. 500.23, is shown on Pl. CXII, Fig. 1 being a view of the left top and Fig. 2 a view of one side.

### CYCADELLA NODOSA Ward.

### Pls. CXIII–CXXII.

1900. *Cycadella nodosa* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 271.

Trunks small, 8 to 14 cm. high, 10 to 20 cm. in diameter, ellipsoidal or conical, somewhat laterally compressed or otherwise distorted, covered with small secondary axes forming prominences or protuberances and giving the specimens a knotty or gnarly appearance; rock hard, light ash colored or brown on weathered surfaces, black within, of medium specific gravity; organs of the armor generally horizontal; leaf scars subrhombic, 15 to 20 mm. wide, 5 to 10 mm. high; leaf bases punctate with small white tubes; walls 1 to 3 mm. thick, firm, light colored, striate, sometimes with a median groove or line; reproductive organs few, obscure, simulating the secondary axes, surrounded by large subrhombic involucral bract scars in several rows passing into leaf scars, central portion solid, heterogeneous; armor 2 to 4 cm. thick, joined to the axis by a definite line; wood 2 to 4 cm. thick; cortical parenchyma 1 cm. thick; fibrous zone 1 to 3 cm. thick, consisting of two or three rings, the outer one showing radiate structure; medulla either circular and 4 cm. in diameter or elliptical in cross section, the lesser diameter 2 to 4 cm. and the greater 3 to 8 cm.

After considerable hesitation I have decided to group together seven of the specimens under this name, although from different states of preservation and degrees of compression they present a somewhat varied aspect. They all agree, however, in the one leading character of being more or less densely covered with small protruding secondary axes which greatly obscure and distort all other characters. I name the species from the character, using the word *nodosa* in its primary and more correct sense of *knotty* or *full of knots*, and not in the secondary and less correct sense which most naturalists give it of *jointed*, which should properly be expressed by the Latin word *articulatus*.

The specimens referred to this species, with their weights, are as follows:

| | Kilograms. |
|---|---|
| No. 500.9 | 2.41 |
| No. 500.11 | 1.14 |
| No. 500.12 | 0.87 |
| No. 500.17 | 2.55 |
| No. 500.21 | 2.12 |
| No. 500.47 | 2.35 |
| No. 500.48 | 1.25 |

With the exception of No. 500.21 these are all nearly perfect trunks. That one seems to be only the upper part of a trunk larger than the rest, but it is impossible to decide how much more there was below this, and in fact the base may not have been far away. In that case it would have had a low, vertically flattened form, which is different from the rest. No. 500.9 is considerably larger than the others and has fewer branches, but it can not be referred to any other group. Nos. 500.11, 500.12, and 500.48 are all smaller and have about the same general facies. I would make Nos. 500.17 and 500.47 the types of this species. They are very similar in all respects and display the specific characters to good advantage. They are much less distorted by pressure than the other specimens.

Pls. CXIII and CXIV give side views of the two broad sides of No. 500.9; Pls. CXV and CXVI illustrate No. 500.47, the first showing the normal shape with contracted base, and the second the numerous knotty branches; Pl. CXVII is the only view taken of the specimen No. 500.17, very similar to the last; Pl. CXVIII, Fig. 1, shows the low rounded apex of No. 500.21, and Fig. 2 the transverse fracture. The former is covered with little knots, but they do not come out well in the photograph. Pls. CXIX and CXX illustrate the small specimen No. 500.11, Pl. CXIX giving the broadest side, Pl. CXX, Fig. 1, one of the other side views, and Pl. CXX, Fig. 2, a view of the base. Pl. CXXI, Figs. 1 and 2, show, respectively, the side and base of No. 500.48, and Pl. CXXII, Figs. 1 and 2, do the same for No. 500.12, the last figure showing the concave and perhaps somewhat decayed base, the axis and lower leaf bases being clearly exposed.

CYCADELLA CIRRATA Ward.

Pls. CXXIII–CXXIX.

1900. *Cycadella cirrata* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 272.

Trunks of medium size, short-cylindrical, rounded at the summit, somewhat laterally compressed, unbranched; rock rather hard, drab on the weathered surfaces, dark within with white stripes, of medium specific gravity; organs of the armor ascending, especially above the middle toward the summit, as seen on the fractured surfaces, curving first upward and then gracefully outward in continuation of the clearly marked strands from the interior of the axis; leaf scars subelliptical or subrhombic, 12 to 15 mm. wide, 5 to 6 mm. high; leaf bases hard, dark, and porous; walls 3 to 5 mm. thick, hard and smooth, light colored or nearly white; reproductive organs few and obscure; armor 3 to 5 cm. thick, irregularly joined to the axis; woody zone 2 cm. thick, undifferentiated; medulla 2 to 3 cm. in diameter, black, striped and blotched with white flinty patches.

This species includes the specimens numbered 500.42, 500.46, 500.59, 500.71, and 500.75, but they all probably belong to the same trunk. No. 500.46 matches No. 500.42 and No. 500.75 matches No. 500.46 by a narrow facet with the loss of intervening chips. No. 500.71 has exactly the same markings as No. 500.42 on the side opposite No. 500.46. These markings are too definite and peculiar to recur, and amount to a proof of identity, although a thin plate between has disappeared. No. 500.59 is evidently the downward continuation of No. 500.42. On one side there is almost complete continuity, but a large triangular piece is wanting on the other side.

The specific name, from Latin *cirrus*, curl, refers to the beautiful curving lines and different-colored stripes formed by the various strands and organs of the armor as seen on the fractured surfaces.

The weights of the pieces are as follows:

| | Kilograms. |
|---|---|
| No. 500.42 | 1.53 |
| No. 500.46 | 0.57 |
| No. 500.59 | 1.11 |
| No. 500.71 | 0.28 |
| No. 500.75 | 0.70 |

After all are put together we still probably have less than half the original trunk.

In Pl. CXXIII (*a* to *d*) the four fragments Nos. 500.42, 500.46, 500.59, and 500.75, which all join by fractured surfaces or areas of contact of greater or less extent, are shown in their natural relations. No. 500.59 forms the lowest part. No. 500.42 joins it above, reaching nearly to the apex. No. 500.46 joins No. 500.42 by a longitudinal fracture and reaches to about the center of the trunk. No. 500.75 lies by the side of this, carrying the summit some distance past the center. The figure lies in the position in which the specimens were placed for photographing. There was no other position in which they could be made to lie for that purpose. It is therefore necessary to remember that the base is on the right and the summit on the left, so that in order to see the trunk in the position in which it grew it is necessary to turn the plate.

Pl. CXXIV shows the innermost and approximately central longitudinal fracture of No. 500.42, and Pl. CXXV the outer somewhat tangential longitudinal fracture of the same specimen. Pl. CXXVI shows the two broken sides of No. 500.46, Fig. 1 being the face that matches No. 500.42 and Fig. 2 that which joins No. 500.75. Pl. CXXVII shows the two sides of No. 500.75 in the same way, Fig. 1 being the fracture joining No. 500.42 and Fig. 2 the outer fracture. Pl. CXXVIII presents the two sides of No. 500.71, which very nearly joins No. 500.42 on the opposite side from No. 500.46. Fig. 1 is the broader and Fig. 2 the narrower face. Pl. CXXIX represents the basal specimen, No. 500.59, which is of the same thickness as No. 500.42, and, with some loss, a downward extension of it. Fig. 1 shows the face which constitutes a continuation of the inner fracture of No. 500.42 represented on Pl. CXXIV, and Fig. 2 that of the tangential fracture, which is in like manner a continuation of the side represented in Pl. CXXV.

### CYCADELLA EXOGENA Ward.

### Pls. CXXX–CXXXVII.

1900. *Cycadella exogena* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 273.

Trunks small or of medium size (12 to 20 cm. high, 8 to 20 cm. in diameter), ellipsoidal, somewhat compressed latterly or (in one specimen) vertically, unbranched; rock hard and fine-grained, light colored on the weathered surfaces, dark within, variegated with brown or white stripes or spots, of medium specific gravity; organs of the armor horizontal; rows of scars making an angle of 50° with the axis in both directions (traceable only in one specimen); leaf scars subrhombic, 12 to 20 mm. wide, 6 to 9 mm. high; leaf bases hard, fine in structure, punctate or porous; walls 1 to 3 mm. thick, soft-sandy, and more or less decayed, light colored, sunken between the leaf bases, striate or wrinkled, sometimes with a median line or commissure; reproductive organs mostly concealed, well developed, generally projecting, 15 by 25 mm. in diameter, surrounded by narrow bract scars, the central portion solid and showing the scars of floral organs; armor 3 to 5 cm. thick, definitely but irregularly joined to the axis, the leaf bases penetrating to different depths; wood 2 to 3 cm. thick, clearly exposed on longitudinal and transverse sections; cortical parenchyma 1 cm. thick, irregular on its outer, even on its inner face; fibrous zone consisting of three very definite exogenous rings of wood, the outer 5 mm. thick, the middle one 2 mm. thick, and the inner one 1 cm. thick, all with radiate structure, the medullary rays visible across the entire zone, the inner wall of which is scalloped by the rounded inner edges of definite woody wedges, 8 mm. wide, and the sharp reentrant angles between them; medulla when circular 4 cm. in diameter, when elliptical 3 by 5 cm., in one specimen 5 by 7 cm. in diameter.

This species is represented by seven different numbers in the collection, but Nos. 500.13 and 500.72, Nos. 500.44 and 500.73, and Nos. 500.53 and 500.61 each match and complement each other. No. 500.37 is larger than the rest and represents most of the lower part of a trunk. With the exception of Nos. 500.53 and 500.61 all the specimens so closely resemble one another that the suspicion arises that they may all belong to the upper part of No. 500.37. But a careful examination negatives this view, and it seems necessary to suppose that they represent at least two different trunks. The combination Nos. 500.44 and 500.73 may be a part of the same trunk as No. 500.37, but the combination Nos. 500.13 and 500.72 must be distinct, as it forms nearly half of a trunk of different shape, with the large mammillary terminal bud and a small portion of the base, which show that this trunk was low and vertically compressed, if at all.

The combination Nos. 500.53 and 500.61 constitute more than two-thirds of a handsome little trunk, broken longitudinally through the center of the axis and one of the halves tranversely above the middle, the fractures being as clear and perfect as if sawn. This specimen shows the internal structure more perfectly than any other in the collection, especially the three exogenous rings of wood, as described.

The weights of the specimens are as follows:

| | Kilograms. |
|---|---|
| No. 500.13 | 1.08 |
| No. 500.37 | 2.41 |
| No. 500.44 | 1.25 |
| No. 500.53 | 1.64 |
| No. 500.61 | 1.16 |
| No. 500.72 | 0.59 |
| No. 500.73 | 0.65 |

Pl. CXXX shows the back or outer surface of No. 500.53 and Pl. CXXXI the base of the nearly complete trunk resulting from the complementary Nos. 500.53 (*a*) and 500.61 (*b*). Pl. CXXXII illustrates the internal structure of the same trunk, Fig. 1 being the longitudinal section offered by No. 500.53 and Fig. 2 the transverse section of No. 500.61, which has already been described. Pl. CXXXIII illustrates in a similar manner the combination Nos. 500.13 (*a*) and 500.72 (*b*). Fig. 1 is a somewhat oblique view, showing the terminal bud and outer surface generally, and Fig. 2 the tranverse fracture. Pl. CXXXIV gives a side view of No. 500.37, Pl. CXXXV, Fig 1, a view of its base, and Fig. 2 the transverse fracture. Pl. CXXXVI, Fig. 1, shows the almost wholly concealed outer surface of the combination Nos. 500.44 (*b*) and 500.73 (*a*), and Fig. 2 the transverse section at top of No. 500.44. Pl. CXXXVII gives the longitudinal fractures of the same two fragments.

### CYCADELLA RAMENTOSA Ward.

### Pl. LXX, Figs. 4, 5; Pls. CXXXVIII–CXLIV.

1900. *Cycadella ramentosa* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 275.

Trunks rather large (15 to 25 cm. high, 2 to 25 cm. in diameter), cylindrical or subellipsoidal, somewhat compressed laterally or vertically, mostly unbranched; rock hard and much mineralized within, dark brown on the surface, the fractured surfaces variegated with black and white, more or less flinty or chalcedonized; specific gravity above the mean; organs of the armor horizontal or radiating from an equatorial zone; leaf scars subelliptical, 10 to 15 mm. wide, 6 to 9 mm. high, hard, dark, rough, punctate with white, tubular pores; walls 1 to 3 mm. thick, firm and smooth, light colored or yellowish, sunk below the leaf bases, with a median line or groove; reproductive organs few, mostly concealed by the ramentum coating, where exposed well developed, raised above the leaf bases, mostly elliptical and 15 by 20 mm. in diameter, inclosed in an involucre of narrowly rhombic bracts visible in transverse and longitudinal section, central portions well shown on fractured surfaces, the interior mostly decayed and somewhat crystallized; armor 4 to 6 cm. thick, attached to the axis by an irregular, somewhat scalloped surface; wood 3 cm. thick, undifferentiated; medulla elliptical in cross section, 3 by 5 cm. in diameter.

This species includes ten numbers of Mr. Knight's collection, but probably only represents three trunks, since five of these fragments (Nos. 500.40, 500.43, 500.45, 500.66, and 500.81) all fit together and may be built up into a single specimen representing nearly half of one trunk, and Nos. 500.50 and 500.60 also match, forming about one-third of another. Nos. 500.39 and 500.55 do not exactly match, but so closely resemble each other that the amount and character of the part lost can be determined with considerable certainty. They can not well belong to either of the other combinations. No. 500.39 is the next most important specimen in the collection in furnishing the generic characters, and slides illustrating them have been prepared from it. From these were obtained the cross sections of the chaff shown by Figs. 4 and 5 of Pl. LXX.

No 500.34 is a small apical portion of a trunk of the same type and may well have formed the top of No. 500.39 and the lost piece that belonged with it, but there was a short interval between them, as they do not exactly match.

The weights of the several fragments in the order of the numbers are as follows:

| | Kilograms. |
|---|---|
| No. 500.34 | 1.02 |
| No. 500.39 | 2.41 |
| No. 500.40 | 2.04 |
| No. 500.43 | 1.50 |
| No. 500.45 | 1.64 |
| No. 500.50 | 2.55 |
| No. 500.55 | 1.70 |
| No. 500.60 | 1.53 |
| No. 500.66 | 2.33 |
| No. 500.81 | 0.68 |

The large combination, therefore, has a total weight of 8.19 kilograms, and Nos. 500.50 and 500.60 together weigh 4.08 kilograms.

The specific name is not meant to imply that there is anything exceptional in the ramentum of this species, although most of the specimens have a well-developed outer coating of it; but some of the fractures afford fine examples, and the detailed study of the generic characters has chiefly been made on this species and *C. Knowltoniana*.

Pl. CXXXVIII illustrates the cylindrical form of the trunk, of which Nos. 500.34, 500.39, and 500.55 are believed to be detached portions. Although none of them fit naturally, their size and general appearance justified this assumption, and it is not probable that the interval is very great between them. No. 500.55, represented by Fig. 3, is considerably thicker than No. 500.39, represented by Fig. 2, i. e., the longitudinal fracture of the latter is nearer the surface exposed, while in the former it falls on the other side of the center. No. 500.34 extends entirely across the trunk, and forms its apex complete. No. 500.55 shows that the trunk was somewhat contracted at the base, but the rapid narrowing of No. 500.39 (Fig. 2) is due to the longitudinal fracture being considerably oblique to the axis, so that the upper end is much thinner, and therefore narrower, than the lower. Only occasionally can any of the organs of the armor be detected. Pl. CXXXIX, Fig. 1, is a view of the upper transverse fracture of No. 500.55, and Fig. 2 of the lower transverse fracture of No. 500.39. It is from this latter that microscopic slides were made after the views had been taken. Reproductive organs may be seen in longitudinal section on both these faces. Pls. CXL and CXLI show the restoration of the portion of a trunk represented by the complementary fragments Nos. 500.45 (*a*), 500.40 (*b*), 500.66 (*c*), 500.43 (*d*), and 500.81 (*e*), forming a good part of another very interesting trunk belonging to this species, the first being a view of the external surface, almost wholly covered with the ramentum layer, and the second a view of the longitudinal fractures. Pl. CXLII, Fig. 1, is a view of the transverse fracture of the lower side of No. 500.66, which fits the upper fracture of No. 500.45, and Fig. 2 shows the longitudinal fracture of No. 500.40, the lower portion of which fits the longitudinal fracture of No. 500.45, but between the upper portion and the longitudinal fracture of No. 500.66 there is an interval of about 1 cm. Pls. CXLIII and CXLIV represent, respectively, the outer and inner surfaces presented by the united complementary fragments Nos. 500.50 (*a*) and 500.60 (*b*).

CYCADELLA FURRUGINEA Ward.

Pls. CXLV–CXLVII.

1900. *Cycadella furruginea* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 276.

Trunk small (18 cm. high, 9 by 22 cm. in diameter), ovoid, laterally compressed, unbranched; rock hard, rust-colored without, striped and spotted with the same in the interior, of medium specific gravity; organs of the armor horizontal at the middle, descending below, and erect at the summit; leaf scars subelliptical, 10 mm. wide, 5 mm. high; leaf bases fine-grained, not porous nor punctate; walls 2 to 3 mm. thick, soft, rust-colored, with a median groove; reproductive organs much obscured, sometimes raised, elliptical, 15 by 20 mm. in diameter, surrounded by thin, obscure, involucral bract scars, the central portion clearly shown only on the fractured surfaces, heterogeneous and much altered by mineralization; armor 2 to 3 cm. thick, irregularly joined to the axis; wood 1 cm. thick; cortical parenchyma 5 mm. thick; fibrous zone 5 mm. thick, not clearly differentiated into rings, but longitudinally striate, parallel to the axis of the trunk; medulla a thin slab visible only on the narrow edge, where it is 1 cm. thick, apparently 4 to 5 cm. wide.

This species includes the two fragments Nos. 500.51 and 500.74, exactly alike in all their characters and certainly belonging to the same trunk. The fracture in both cases is longitudinal in the direction of the minor axis, starting in obliquely near the top and becoming vertical near the middle. In No. 500.51 this vertical direction continues to near the base, and then runs out on the same side it went in. In No. 500.74 it describes a sort of curve, cutting in to near the center and out again at a still sharper angle long before it reaches the base. The true base and summit are therefore lost in both specimens. There is one point at which the two pieces probably are actually contiguous, though the surface of contact is not large enough to demonstrate this.

No. 500.51 weighs 1.36, and No. 500.74, 0.81 kilograms; total, 2.17 kilograms.

Named from the ferruginous or rusty color peculiar to these specimens.

Pl. CXLV represents the two specimens side by side as they are supposed to have been related in the perfect trunk, and shows the broad side view. Pl. CXLVI is a view of the longitudinal fracture of No. 500.51. Pl. CXLVII, Fig. 1, shows the back or thin edge of No. 500.74, and Fig. 2 the fracture as has been described above.

### CYCADELLA CONTRACTA Ward.

### Pls. CXLVIII–CLIII.

1900. *Cycadella contracta* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 277.

Trunks of small or medium size (height not known, 15 to 25 cm. in diameter), probably conical above, strongly contracted at the base, laterally compressed, more or less branched; rock hard and fine-grained, of a nearly uniform drab color or dull reddish on the outer surface, of medium specific gravity; organs of the armor ascending at their origin, curving outward and becoming horizontal or declined, rows of scars (traceable in one specimen) from left to right forming an angle of 40° with the axis, those from right to left 55°; leaf scars subrhombic, 12 to 20 mm. wide, 6 to 12 mm. high; leaf bases of uniform color, punctate with white tubular pores; walls 1 to 3 mm. thick, rather soft, depressed, striate, with a median line or crack; reproductive organs imperfectly developed, somewhat raised, 15 by 22 mm. in piameter, surrounded by large bract scars passing into leaf scars, central portion solid, roughened, warty; armor about 3 cm. thick; wood 1 to 3 cm. thick, differentiated in one specimen, the outer zone 5 mm. thick, the inner 1 cm., longitudinally striate; medulla 15 to 30 mm. in diameter, hard, fine-grained, and homogeneous.

The specimens constituting this species are Nos. 500.56, 500.57, 500.58, and 500.79. With the exception of the last their general resemblance is obvious, which probably accounts for the contiguity in the numbers. No. 500.79 is probably a thin segment from much higher on the same trunk as No. 500.56, where the size and shape had considerably changed, but the same structure persists. Nos. 500.57 and 500.58 are portions of the lower end of two different trunks.

The weights of the several fragments, in the order of the numbers, are as follows:

| | Kilograms. |
|---|---|
| No. 500.56 | 1.13 |
| No. 500.57 | 1.25 |
| No. 500.58 | 1.92 |
| No. 500.79 | 0.76 |

The specific name refers to the contracted base.

Pl. CXLVIII, Figs. 1 and 2, show respectively the outer surface and the longitudinal fracture of No. 500.57. Pl. CXLIX is a side view, and Pl. CL a view of the longitudinal fracture of No. 500.58. Pl. CLI is designed to show the relations between Nos. 500.56 and 500.79 as above mentioned, and Figs. 1 and 2 show what seem to be the same side of the two specimens. The interval between them was of course larger than it was possible to place between the two figures. Pl. CLII shows the other broad side of No. 500.56, and Pl. CLIII gives the upper transverse fracture of No. 500.79.

CYCADELLA GRAVIS Ward.

Pl. CLIV.

1900. *Cycadella gravis* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 277.

Trunk small (12 cm. high, 8 by 13 cm. in diameter), conical-flattened, rounded at the summit, laterally compressed, unbranched; rock very hard, coarse-grained, of a gray color and very high specific gravity; organs of the armor upwardly appressed, especially on one side; rows of scars from left to right making an angle of 35°, those from right to left of 50°, with the axis; scars subrhombic, 18 to 22 mm. wide, 8 to 10 mm. high; leaf bases on the side of the specimen appressed to the trunk but exposed at their summits and on their lower sides, the keel distinct, rough or honeycombed on the exposed ends, but on fresh fractures fine in structure and white-punctate with small, narrowly elliptical, white pores appearing as short white lines; vascular bundles faintly visible, forming a row part way round the petiole on the side next the trunk; walls 1 to 2 mm. thick, striate with alternating light and dark lines; reproductive organs few, poorly developed, sometimes raised, 2 by 3 cm. in diameter, the interior porous or heterogeneous; armor 2 cm. thick, joined to the axis by a definite line of appreciable thickness (libro-cambium layer), wood 2 cm. thick; cortical parnechyma 1 cm. thick, of coarse structure; fibrous zone 1 cm. thick, consisting of two rings of equal thickness separated by a light-colored band, the structure radially disposed; medulla 2 by 6 cm. in diameter, hard and coarse with white punctations or variously shaped markings.

This small specimen, No. 500.63 of the collection, is so totally different from all the rest that it was necessary to regard it as constituting a species by itself. It weighs 1.5 kilograms and has the highest specific gravity observed, feeling almost like heavy spar, whence the specific name.

Pl. CLIV, Fig. 1, shows the best side, and Fig. 2 the base.

CYCADELLA VERRUCOSA Ward.

Pls. CLV–CLVII.

1900. *Cycadella verrucosa* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 278.

Trunks large (30 to 40 cm. high, 20 to 30 cm. in larger diameter), obovate, contracted at the base, much laterally compressed, unbranched or with a few small secondary axes; rock hard and fine at least in the interior, light colored or brown on weathered surfaces, dark or black on freshly exposed ones, of medium specific gravity; organs of the armor horizontal; leaf scars subrhombic, 15 to 20 mm. wide, 7 to 10 mm. high; leaf bases hard, rough or porous, with a raised ridge near the margin indicating the position of the vascular bundles, which are themselves sometimes visible in the form of pits; walls 2 to 5 mm. thick, hard and somewhat porous, light colored with darker striæ; reproductive organs numerous, well developed, prominently projecting in the form of large warty protuberances distorting the arrangement of the leaves, elliptical in cross section, 20 by 30 mm. in diameter, surrounded by large, narrowly subrhombic bract scars in several rows passing into leaf scars, central portions heterogeneous, marked by the scars of the essential organs; armor 2 to 5 cm. thick, clearly but irregularly joined to the axis; woody zone 15 mm. thick, not differentiated; medulla a thin slab 3 to 6 cm. thick, 15 cm. wide, of a fine uniform structure resembling the white iron ore of the Potomac beds of Maryland.

Nos. 500.27, 500.32, and 500.64 are referred to this species. The last is anomalous and shows relatively few of the characters, but it has the same shape. The fruits are little elevated, but otherwise this leading character holds for it. No. 500.27 is probably the top of the same trunk as No. 500.32, but there is an interval between them, and they have been subjected to different conditions since they became fossilized. On a casual view, therefore, they do not seem so closely to resemble each other as they do when carefully inspected. They are then found to have almost exactly the same width, thickness, and general form, so that it is easy to see which sides correspond. All the characters also agree except that the fruiting axes are more prominent on No. 500.32, representing the lower portion. This is partly due to the fact that this specimen has suffered more from erosion, and owing to the greater hardness of these organs they are made to stand out more conspicuously. It was the appearance thus produced that suggested the specific name.

No. 500.27 weighs 5.19, No. 500.32, 8.31, and No. 500.64, 4.68 kilograms.

In Pls. CLV and CLVI the two specimens, Nos. 500.32 and 500.27, are represented from opposite broad sides in the position in which they are supposed to have existed as a trunk, but for want of space on the plate they had to be brought practically together, whereas, as already stated, the theory of their identity requires the assumption of a certain amount of loss between these parts. Pl. CLV, Fig. 1, shows the warty projections better than any other. Pl. CLVII is the only view taken of No. 500.64 and represents its best side.

### Cycadella jejuna Ward.

Pls. CLVIII–CLXI.

1900. *Cycadella jejuna* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 279.

Trunks of medium size (18 cm. high, 7 to 12 cm. in lesser, and 16 to 20 cm. in greater diameter), ovoid or subconical, laterally compressed, unbranched; rock hard, gray on weathered surfaces, drab in the interior, black on fresh exposures, with rather high specific gravity; organs of the armor horizontal; rows of scars forming an angle in either direction of 45° to 50°; leaf scars subrhombic, 15 to 20 mm. wide, 7 to 9 mm. high; leaf bases hard and firm, rough on the exposed ends; walls 2 to 4 mm. thick, light colored and contrasting with the leaf bases, sometimes with a median ridge; reproductive organs few and poorly preserved; armor 2 to 4 cm. thick, joined to the axis by a clear line; wood 15 to 20 mm. thick; outer zone 5 mm. thick, traversed by rays or vessels; inner zone consisting of two rings, the outer 5 mm. thick with fine radiate structure showing medullary rays and woody wedges, the inner 5 to 10 mm. thick of a less definite structure; medulla elliptical in cross section, lesser diameter 2 to 3 cm., greater 8 cm., homogeneous.

The two specimens, Nos. 500.28 and 500.31, which I have brought together here, have at first view very little to mark them or interest the student, but while they differ essentially from all others in the collection, they resemble each other in all the main points. No. 500.28 is smaller and more compressed, and is mostly black on the outer surface, but the outer coating has pretty much entirely disappeared and the leaf scars are clearly exposed. The fracture at the base also reveals some very definite internal structure. No. 500.31 shows much less, but so far as visible the characters are the same. The former weighs 2.33 and the latter 3.97 kilograms. The specific name refers to the somewhat negative and meager character of the specimens.

Pls. CLVIII and CLIX show opposite sides of No. 500.28, and Pls. CLX and CLXI those of No. 500.31. In the former of these specimens scarcely any ramentum remains on the surface and the leaf scars are quite clearly shown. The same is true for one side of No. 500.31, but the other side, represented on Pl. CLXI, shows the area over which it has been scaled off along a definite line, and the edge of it is distinctly visible.

### Cycadella concinna Ward.

Pl. CLXII.

1900. *Cycadella concinna* Ward: Proc. Wash. Acad. Sci., Vol I, p. 280.

Trunk small (12 cm. high, 14 by 15 cm. in diameter), irregularly and obliquely short-conical, somewhat vertically compressed, unbranched, broad at the concave base, terminating in an imperfect bud; rock soft on the surface, harder within, dark colored or bluish except a light weathered area, the specific gravity above the normal; organs of the armor at right angles to the oblique axis; rows of scars from left to right making an angle with the axis of 75° to 80°, those from right to left of 30° to 40°; leaf scars narrowly subrhombic, very small, 12 to 13 mm. wide, 3 to 5 mm. high; leaf bases dark, firm but porous; walls 3 to 5 mm. thick, of denser structure than the leaves, lighter colored, sometimes with darker stripes; reproductive organs doubtful and practically wanting; armor 2 cm. thick, joined to the axis by a definite line; wood 2 cm. thick, undifferentiated; medulla elliptical, 3 by 6 cm. thick, smooth and homogeneous.

It has been necessary to regard the nearly perfect, compact, and rather handsome little trunk, No. 500.16, as constituting a species by itself, and it is much to be hoped that other specimens of the same may be found. It weighs 2.18 kilograms.

Pl. CLXII, Fig. 1, gives a good idea of it as seen from one side, and Fig. 2 shows the somewhat concave base.

CYCADELLA CREPIDARIA Ward.

Pl. CLXIII; Pl. CLXIV.

1900. *Cycadella crepidaria* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 280.

Trunk small, elliptical in cross section, much vertically compressed, having the form, when inverted, of a shoe or moccasin, having a height (thickness) of 7 cm., a width (lesser diameter) of 12 cm., and a length (greater diameter) of 19 cm., with two lateral axes nearly at right angles to the primary axis, the terminal bud forming a large raised area, the base projecting downward in a rounded protuberance; rock soft and coarse-grained, dark brown or nearly black, bluish within, of low specific gravity; organs of the armor mostly appressed or concealed; leaf scars where visible distorted and abnormal in shape, subelliptical, 12 to 15 mm. wide, 4 to 5 mm. high; leaf bases coarse and homogeneous in texture; walls 1 to 3 mm. thick, relatively hard and light colored; reproductive organs few, abortive or immature; thickness of armor unknown; wood 3 cm. thick; outer zone 1 cm. thick, coarse; inner zone 2 cm. thick, finer, and longitudinally striate; medulla elliptical, 3 by 5 cm. in diameter, coarse and homogeneous.

No. 500.83 of Professor Knight's collection, which constitutes the species, is in all respects a unique specimen, and notwithstanding its apparent deformity there is evidence that this is by no means wholly due to external agencies. The position in which the trunk grew no doubt had much to do with this, but it probably represents a dwarf, flat, branching species, all the members of which would present most of these peculiarities. When inverted and laid on its back, the terminal bud down and the base uppermost, it has much the shape of a broad, low, wooden shoe or sandal, the thicker end representing the heel and the thin, flattened end, which is a sort of terminal bud of one of the lateral branches, representing the toe — a comparison which suggested the specific name.

It weighs 1.45 kilograms.

Pl. CLXIII is a view from the top downward, and Pl. CLXIV from the bottom upward.

### Cycadella gelida Ward.

Pls. CLXV–CLXIX.

1900. *Cycadella gelida* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 281.

Trunks rather large and relatively tall (the largest of the specimens 39 cm. high, 12 by 20 cm. in diameter), subcylindrical, slightly diminishing from base to summit, laterally compressed, having a few secondary axes, terminating in a large conical bud, the base projecting; rock of medium hardness and specific gravity, light brown on weathered surfaces, nearly black within and on freshly exposed portions; organs of the armor slightly ascending; rows of scars from left to right making an angle with the axis of 45°, those from right to left of 50°; leaf scars subrhombic, 20 to 25 mm. wide, 8 to 12 mm. high; leaf bases rough and punctate; walls 1 to 2 mm. thick, friable, white, with a median line or crack; reproductive organs well developed, usually raised or projecting, elliptical in cross section, 2 by 3 cm. in diameter or larger, the involucral bracts not visible, the central portions solid and amorphous; armor 1 to 3 cm. thick, joined to the axis by a more or less definite line, all within it a black undifferentiated mass of cherty and apparently structureless matter which tends to crack into cubes or flake off.

The large fine specimen, No. 500.1, scarcely injured by being broken in two by an obliquely transverse fracture near the base, was at first supposed to be altogether unique, but in my efforts to correlate the fragment, No. 500.24, of a considerably smaller trunk, I found that it had scarcely any affinities except with this, and upon a thorough comparison of all the characters I am convinced that it belongs to the same species. That specimen was broken into three unequal pieces, but mended with glue before sending. A small flake or cap, numbered 500.25, from the light weathered surface of some trunk, having a coarse black structure on the fractured side, resembles No. 500.24 more than any other specimen, but does not exactly fit its broken summit. Rather than leave it wholly unassigned I assume that it belongs here.

No. 500.1 weighs 12.56, No. 500.24, 2.52, and No. 500.25, 0.11 kilograms.

The specific name has a vague reference to the Freezeout Hills, in which the beds occur.

Pls. CLXV and CLXVI are side views of the opposite side of No. 500.1, and Pl. CLXVII is a view of its base. Pls. CLXVIII and CLXIX show the opposite sides of No. 500.24.

### CYCADELLA CARBONENSIS Ward.

Pl. CLXX; Pl. CLXXI.

1900. *Cycadella carbonensis* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 282.

Trunk of maximum size (39 cm. high, 21 by 39 cm. in diameter), subglobular, both laterally and vertically compressed, the principal axis oblique to the plane of compression, having numerous secondary axes forming large short branches or rounded elevations interspersed with smaller ones, the primary axis terminating in a well-developed bud, the base occupied by a circular concavity; rock of medium hardness and specific gravity, nearly black, considerably mineralized in the interior; organs of the armor radiating from an equatorial zone; phyllotaxy not traceable; leaf scars subrhombic, rhombic, or irregular in shape, 30 mm. wide, 15 mm. high; leaf bases rough and porous; walls 2 to 3 mm. thick, firm, and definitely bounded, longitudinally striate with raised white lines, median line higher than the rest; reproductive organs numerous but not well developed, of two kinds, large and small, the former difficult to distinguish from secondary axes, all usually more or less elevated, but occasionally depressed or decayed so as to leave a shallow concavity, elliptical in cross section, the larger ones 3 by 5 cm. in diameter, the smaller about half as large, the former class surrounded by faintly visible large subrhombic involucral bract scars simulating and passing into leaf scars, the central portions solid and heterogeneous; armor 4 to 5 cm. thick, its junction with the axis obscure; woody zone 4 to 5 cm. thick, undifferentiated; medulla nearly circular, 5 to 6 cm. in diameter, smooth and homogeneous in structure.

The largest specimen in the collection, No. 500.2, weighing 37.69 kilograms, is unique also in its form and a considerable number of other characters, and has to form a species by itself. I name it for Carbon County, in which the locality for all the specimens is located. It constitutes an almost complete trunk, but came in two nearly equal pieces, the fracture passing through the narrowest dimension, through the center of the apex, down the back and lower side, and emerging at the center of the basal concavity along a nearly even plane. Unfortunately, the interior thus exposed shows scarcely any structure.

Pl. CLXX shows the broad rounded back of the specimen, and Pl. CLXXI the base and lower portion.

### CYCADELLA KNIGHTII Ward.

Pls. CLXXII–CLXXVII.

1900. *Cycadella Knightii* Ward: Proc. Wash. Acad. Sci., Vol. I, p. 283, pl. xxi.

Trunks very large (30 to 40 cm. high, 19 by 28 cm. in diameter), subellipsoidal, somewhat laterally compressed, unbranched, depressed at the summit; axis eccentric; rock hard, somewhat mineralized, dark colored or nearly black, of high specific gravity; organs of the armor horizontal; rows of scars from left to right forming an angle of 45° with the axis, those from right to left of 70°; leaf scars subrhombic or subelliptical, 18 to 20 mm. wide, 8 to 12 mm. high; leaf bases hard, punctate; walls 3 to 5 mm. thick, hard, striate, with or without a median groove; reproductive organs few, poorly developed, flush with the surface or slightly raised, elliptical in cross section, 2 by 3 cm. in diameter, surrounded by large subrhombic involucral bract scars passing into leaf scars, the central portion solid and showing the scars of the floral organs; armor 4 to 6 cm. thick, obscurely attached to the axis; woody zone 3 to 4 cm. thick, undifferentiated; medulla 6 by 10 cm. in diameter, difficult to distinguish from the woody zone, hard and black, with flinty or crystalline areas.

The next largest specimen in the collection, and probably the finest, from the standpoint of symmetry and general appearance, is No. 500.65. It came in two pieces of unequal size, caused by a transverse fracture below the middle. The larger piece weighs 15.48 and the smaller 9.8 kilograms, making the total weight 25.28 kilograms. There was one other specimen, viz, No. 500.33, which so closely resembles this that it is impossible to separate it. It consists of considerably over half of the lower portion of a somewhat smaller trunk, having the base perfect and a nearly horizontal transverse fracture across the trunk above This weighs 8.87 kilograms.

I take great pleasure in dedicating this fine species of Cycadella to Prof. Wilbur C. Knight, State geologist of Wyoming, through whose enterprise the collection was made, and who has so generously placed it in my hands for elaboration.

Pl. CLXXII represents the best-preserved side of No. 500.65, Pl. CLXXIII its base, and Pl. CLXXIV the upper transverse fracture of the lower piece. Pl. CLXXV is the best side view of No. 500.35, Pl. CLXXVI its base, while in Pl. CLXXVII we have a representation of the upper transverse fracture.

The following is a list of the twenty species of Cycadella in the order in which they have been described:

1. Cycadella Reedii.
2. Cycadella Beecheriana.
3. Cycadella wyomingensis.
4. Cycadella Knowltoniana.
5. Cycadella compressa.
6. Cycadella jurassica.

7. Cycadella nodosa.
8. Cycadella cirrata.
9. Cycadella exogena.
10. Cycadella ramentosa.
11. Cycadella ferruginea.
12. Cycadella contracta.
13. Cycadella gravis.
14. Cycadella verrucosa.
15. Cycadella jejuna.
16. Cycadella concinna.
17. Cycadella crepidaria.
18. Cycadella gelida.
19. Cycadella carbonensis.
20. Cycadella Knightii.

The order can scarcely be called a classification. There is, however, something in common in the first twelve, viz, their general light color and calcareous structure, while the last seven are darker, coarser grained, and less calcareous. *C. gravis* and *C. verrucosa* are intermediate in these respects, but the former differs in its high specific gravity. These distinctions all relate rather to the mineral than to the vegetable character, and although there is always some connection between them arising out of differences of structure, still it can scarcely be called a systematic grouping. The strictly botanical characters traverse these more conspicuous ones in such a manner that it is impossible to arrange the species according to both, and it was considered more satisfactory, upon the whole, not to attempt any finer classification until the internal structure can be studied, which should be done, and promises most interesting results.

## FOSSIL WOOD FROM THE JURASSIC.

Fossil wood has been reported from the Jurassic in a number of cases, but I am able to illustrate it at the present time from only two localities.

### FOSSIL WOOD FROM THE CYCAD BEDS OF WYOMING.

Accompanying the cycad collection of Professor Knight were three pieces of fossil wood, numbered 500.85, 500.86, and 500.87 of the Museum of the University of Wyoming. Two of these, Nos. 500.86 and 500.87, were placed in the hands of Dr. F. H. Knowlton, who offered to work out the internal structure and report the result. One of the specimens, No. 500.86, was a small limb somewhat split up and splintered, and it proved difficult to obtain from it slides of the proper character. The other, No. 500.87, is a thick block of wood and has furnished good slides, although the structure is somewhat obscure. Enough was learned from the other specimen to indicate that it belongs to the same species, and the piece which was not treated, No. 500.85, is clearly a part of the same stem as No. 500.86. All the wood, therefore, probably belongs to the same species. No explanation has been made of the source of this wood further than that it accompanied the cycads and is supposed to have been found with them. In fact, it was at first thought possible that they might be found to belong to the interior of cycadean trunks. They are, therefore, of course, of the same age as the cycads.

Dr. Knowlton finds the wood probably to belong to the genus Araucarioxylon, but to be specifically distinct from any hitherto described. His note upon it is as follows:

DESCRIPTION OF A NEW SPECIES OF ARAUCARIOXYLON FROM THE CYCAD BED OF THE FREEZEOUT HILLS, CARBON COUNTY, WYOMING.

By F. H. KNOWLTON.

ARAUCARIOXYLON? OBSCURUM Knowlton n. sp.

Pl. CLXXVIII.

Annual ring not apparent to the naked eye, the line of demarcation between the rings consisting of only four or five slightly modified layers of cells; wood cells very small, approximately square in cross-section, thick walled, provided on the radial walls with a single row of small contiguous or weathered bordered pits; medullary rays in a single series of 1 to 8 superimposed cells; resin cells and resin passages wholly wanting.

Transverse section: The appearance of the wood in this section is well shown in the figure (Pl. CLXXVIII, Fig. 1). The wood cells are seen to be of very uniform size and shape and are quite thick walled. The growth rings can not be made out by the naked eye, but under the microscope they are found to be quite broad (2 to 3 mm.) and to be separated by only four or five layers of slightly thicker cells. The absence of longitudinal resin cells or passages is also well shown in this section. The medullary rays appear as long remotely broken cells.

Radial section: The wood cells as seen in this section are provided with a single row of small bordered pits. Usually they are somewhat remote, as shown in Figs. 1 and 2 of Pl. CLXXVIII, but occasionally they are contiguous and slightly modified in shape by contact with each other. The inner pit is often minute, but the preservation is not good enough to permit measurements. The medullary rays are seen to be made up of relatively long slender-walled cells and probably without markings, although there is some evidence to show that there may have been narrow slits or oblong pores in their cell walls. This evidence, however, is not conclusive.

Tangential section: The wood cells are without pits or markings on this wall, at least so far as can be made out. The medullary rays are very numerous and composed of from one to not more than twelve superimposed cells, and usually the number is from three to perhaps five or six. They are very small and have relatively thick walls.

Discussion: The placing of this wood in the genus Araucarioxylon is open to more or less question, yet as it approaches more closely to this genus, I have tentatively so referred it. It has the obscure growth rings usually to be observed in this genus, but is without certain other characters. The medullary rays are similar to those of numerous species of Araucarioxylon, but the pits with radial walls of the wood cells are not the same as in what may be called typical wood of the genus; that is, they are not in the least hexagonal. The latter feature, however, is somewhat variable, and for the present it seems best to place this wood in Araucarioxylon.

This species resembles in some particulars several of the described species of the genus in this country. Thus it has the same type of tracheids and medullary rays as *A. virginianum* Kn., but has the bordered pits quite unlike that species. On the other hand, the pits are quite similar to those found in *A. Woodworthi* Kn., of the Triassic of Virginia and North Carolina, but the medullary rays are entirely different. From *A. arizonicum* Kn. the species under consideration, which agrees somewhat in the character of the bordered pits, differs in having the ray cells very long instead of short, and further in the absence of pits on the tangential walls of the tracheids. The character of the rays as shown in transverse section is quite similar in all of these species.

*Locality.*—Cycad bed, Freezeout Hills, Carbon County, Wyoming. Collected by W. H. Reed.

FOSSIL WOOD FROM THE JURASSIC OF THE BLACK HILLS.

Prof. W. P. Jenney sent a few very imperfectly preserved specimens of fossil wood from his bed No. 5 of the Hay Creek region of Crook County, Wyoming, in the Black Hills, and noted its occurrence in that bed in the ample notes that accompanied his collection.[1] When I was in the Black Hills in October, 1898, Mr. H. F. Wells informed me that he found it frequently in the pink and white sands that overlie the Atlantosaurus beds, and he took me to one locality near his house, three or four miles northwest of Sturgis, South Dakota, where beds of carbonaceous shales containing lignite are overlain by sands in which silicified wood occurs in great quantities and in a perfect state of preservation. I brought away one specimen which shows the annual rings more distinctly than any other fossil wood I have ever seen. This Dr. Knowlton also consented to treat microscopically for this paper. When I obtained it I had no doubt of the Jurassic age of the bed in which it occurred, but Dr. Knowlton finds the internal structure very modern in character, scarcely distinguishable from that of Pinus except in the absence of fusiform rays. I hesitate, therefore, to assert that the age is certainly Jurassic, and reserve my final decision on this point until a more thorough investigation can be made than was possible at the time I was there. Still, I think there was no mistake, and that this specimen simply represents a Jurassic ancestor of Pinus which has persisted to the present day with little modification. Dr. Knowlton proposes for it the name *Pinoxylon*, as a new genus, this name not having been used, so far as we can learn.

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[1] See Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. II, pp. 573, 589, fig. 122 facing p. 593.

The following is his description of the genus and the species:

DESCRIPTION OF A NEW GENUS AND SPECIES OF FOSSIL WOOD FROM THE JURASSIC OF THE BLACK HILLS.
By F. H. Knowlton.

### Genus PINOXYLON Knowlton nov. gen.

Internal structure of the wood same as in Pinus, except in the absence of fusiform rays.

### Pinoxylon dacotense Knowlton n. sp.

Pl. CLXXIX.

Trunks of medium size; annual rings broad, very distinct; tracheids of spring and summer wood very large, thin walled, more or less hexagonal in shape; tracheids of fall wood thick walled, elliptical in outline; bordered pits on radial walls of tracheids, mainly in spring wood, of large size, mostly in two rows, rarely in a single row; medullary rays in a single series; resin cells wanting; resin passages present, scattered, mainly in the fall wood.

Transverse section: In this section the annual rings show very plainly, even to the naked eye, being from 2 to 4.5 mm. in width. The distinction between the spring and fall wood can also be seen with the naked eye, the former appearing as broad white bands and the latter as dense black bands of varying width. Under the microscope the line of demarcation between its fall and spring wood is observed to be very sharp, indeed. The fall wood consists of thick-walled cells of an elliptical or oblong outline and rather loosely placed, as may be seen from the figure (Pl. CLXXIX, Fig. 1). The succeeding spring wood is composed of very large cells with relatively thin walls.

The medullary rays as shown in this section (Fig. 1) are long and quite thick walled. As far as could be ascertained from the sections made there are no resin cells in this wood. The resin passages, however, are present and quite numerous. They do not seem to be confined to any particular portion of the ring, but are scattered, being, perhaps, most abundant in the fall wood. They are of relatively large size and lined with thin-walled epithelium cells (Fig. 2).

Radial section: There is much to be seen in this section. The walls of the cells of spring and summer wood are preserved in most cases with two rather irregular rows of large bordered pits. In rare cases these pits are in a single row, as shown in Fig. 3. The average size of the outer circle is .025±, that of the inner circle about .015±. The rays are seen to advantage in this section. The cells are rather long, covering the width of usually some four or more cells of the spring wood. They are rather thick walled, the walls being strongly dentate or somewhat irregularly thickened. This irregular thickening is well shown in the figures. The ray cells are provided with a few scattered bordered pits, usually only one to the width of a spring cell of the wood, although not rarely there are two in a similar width. They are always in only one row on the ray cells. They are also shown in the figures.

Tangential section: The medullary rays are naturally the most prominent feature in this section. They are always in a single superimposed series. They number from 1 to rarely 30 cells, an average number being from 5 to 12 cells high. None of the rays in sections examined are of the fusiform type, or that in which resin passages are included. The wood cells, as far as can be made out, are without pits or markings of any kind on their walls.

I am not a little in doubt as to the proper disposition that should be made of this interesting wood. It is so beautifully preserved, and the histological elements are so plainly discernible, that it seemed at first an easy matter satisfactorily to place it, but a somewhat prolonged examination has failed to settle it. Before it could be examined microscopically, and basing the conclusion upon its supposed geological position, it was presumed to belong to Araucarioxylon, but a glance at the structure serves to show that this can not be so. This genus is without resin passages, and, moreover, is well characterized by having the bordered pits more or less distinctly hexagonal. This hexagonal form of the pits, of which the living Araucaria may be taken as the type, appears to have had its origin in the Lower Paleozoic in the forms known as Cordaites and Dadoxylon. It is sufficient to say in the present connection that all of these distinctive features are absent from the wood under consideration.

From a number of other types of living wood this is separated by characters of importance. Thus from Sequoia it differs in having very broad instead of narrow growth rings and distinct resin passages, these being either entirely absent or very imperfectly found in both the living Sequoias, and finally the absence of resin cells.

In an exhaustive paper on the Generic Characters of the North American Taxaceæ and Coniferæ,[1] Prof. D. P. Penhallow presents the distinguishing characters of the living genera. They are readily divisible into two groups, as follows: Resin passages and fusiform rays present, including Pseudotsuga, Larix, Picea, Pinus, *Sequoia sempervirens*, and several species of Abies, and those in which these features are wholly wanting, including Taxodium, Sequoia, Libocedrus, Juniperus, Thuja, Cupressus, Tsuga, and most of Abies. The fossil wood under consideration is excluded from the last of these two groups, for it has very pronounced resin passages, and it must therefore be included in the first division in spite of the fact that there are seeming contradictions. This first division is again divisible into three subgroups on characters taken from the presence or absence of the fusi-

[1] Trans. Roy. Soc. Canada, 2d series, Vol. II, Section IV, 1896, pp. 33-57, pls. i-vi.

form rays. Our fossil seems to combine certain of the characters here given as distinct for the living woods; that is, our wood has distinct resin passages, but is without the fusiform rays. But after careful examination it appears to be most closely related to the genus Pinus. It agrees perfectly in having broad growth rings, dentate or irregularly thickened walls to the medullary rays, and prominent resin passages. It differs in the absence of the fusiform rays. From its undoubted resemblance to Pinus I have ventured to regard it as an ancestral form of this genus and to give it the name of Pinoxylon. It may be possible that the absence of this character of the fusiform rays is of such importance that it can not be regarded as the ancestor of our modern pines, but on account of its unquestioned resemblance in other perhaps equally important characters I have so regarded it.

*Locality.*—Three miles northwest of Sturgis, South Dakota. Probably Upper Jurassic. Collected by Lester F. Ward, October 3, 1898.

## DISTRIBUTION OF THE OLDER MESOZOIC FLORAS OF THE UNITED STATES.

To complete this presentation of the status of the Older Mesozoic floras of the United States I introduce a table giving all the species thus far known, with the general region or area in each formation at which they occur.

*Table of distribution of the fossil plants of the Older Mesozoic of the United States.*

| No. | Name. | Triassic. | | | | | | | | | | Jurassic. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Connecticut Valley area. | | Hudson-Potomac area. | | | | | Southwestern area. | | | | | | | |
| | | Massachusetts. | Connecticut. | New Jersey. | Pennsylvania. | Maryland. | Virginia area. | North Carolina area. | New Mexico. | Arizona. | Taylorsville, California, area. | Mariposa beds, California. | Oroville, California. | Colorado. | Wyoming. | South Dakota. |
| 1 | Abietites carolinensis Font. | | | | | | | × | | | | | | | | |
| 2 | Acrostichites brevipennis Ward n. sp. | | | | | | | | | | × | | | | | |
| 3 | Acrostichites? coniopteroides Ward n. sp. | | | | | | | | | | × | | | | | |
| 4 | Acrostichites densifolius Font. | | | | | | × | | | | | | | | | |
| 5 | Acrostichites? fructifer Ward n. sp. | | | | | | | | | | × | | | | | |
| 6 | Acrostichites linnææfolius (Bunb.) Font. | | | | × | | × | × | | | | | | | | |
| 7 | Acrostichites microphyllus Font. | | | | ? | | × | | | | | | | | | |
| 8 | Acrostichites princeps (Presl.) Schenk. | | | | | | | | | | ? | | | | | |
| 9 | Acrostichites tenuifolius (Emm.) Font. | | | | | | × | × | | | | | | | | |

*Table of distribution of fossil plants of Older Mesozoic of the United States*—Continued.

| No. | Name. | Triassic. | | | | | | | | | | Jurassic. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Connecticut Valley area. | | Hudson-Potomac area. | | | | | South-western area. | | | | | | | |
| | | Massachusetts. | Connecticut. | New Jersey. | Pennsylvania. | Maryland. | Virginia area. | North Carolina area. | New Mexico. | Arizona. | Taylorsville, California, area. | Mariposa beds, California. | Oroville, California. | Colorado. | Wyoming. | South Dakota. |
| 10 | Acrostichites tenuifolius rarinervis (Font.) Ward n. comb. | | | | | | × | | | | | | | | | |
| 11 | Actinopteris quadrifolia (Emm.) Font. | | | | | | | × | | | | | | | | |
| 12 | Adiantites orovillensis Font. | | | | | | | | | | | | × | | | |
| 13 | Anabacaulus duplicatus Emm | | | | | | | × | | | | | | | | |
| 14 | Anabacaulus sulcatus Emm. | | | | | | | × | | | | | | | | |
| 15 | Angiopteridium californicum Font. | | | | | | | | | | | | × | | | |
| 16 | Anomozamites? egyptiacus Font. n. sp. | | | | | | | × | | | | | | | | |
| 17 | Anomozamites princeps (Oldh. & Morr.) Schimp. | | | | ? | | | | | | | | | | | |
| 18 | Araucarioxylon arizonicum Kn | | | | | | | | × | × | | | | | | |
| 19 | Araucarioxylon? obscurum Kn. n. sp. | | | | | | | | | | | | | | × | |
| 20 | Araucarioxylon virginianum Kn | | | | | | × | × | | | | | | | | |
| 21 | Araucarioxylon Woodworthi Kn. | | | | | | × | × | | | | | | | | |
| 22 | Araucarites Chiquito Ward n. sp. | | | | | | | | | × | | | | | | |
| 23 | Araucarites? pennsylvanicus Font. n. sp. | | | | × | | | | | | | | | | | |
| 24 | Araucarites yorkensis Font. n. sp. | | | | × | | | | | | | | | | | |
| 25 | Asplenites Rœsserti (Presl.) Schenk var. Schenk | | | | | | | × | | | | | | | | |
| 26 | Asterocarpus falcatus (Emm.) Font. | | | | × | | × | × | | | | | | | | |
| 27 | Asterocarpus falcatus obtusifolius (Font.) Ward n. comb | | | | | | × | | | | | | | | | |
| 28 | Asterocarpus penticarpus Font. | | | | | | × | | | | | | | | | |
| 29 | Asterocarpus platyrachis Font. | | | | | | × | × | | | | | | | | |
| 30 | Baiera Muensteriana (Presl.) Heer | | × | | ? | | | × | | | | | | | | |
| 31 | Baiera multifida Font. | | | | | | × | ? | | | | | ? | | | |
| 32 | Bambusium? sp. Font | | | | | | × | | | | | | | | | |
| 33 | Brachyphyllum yorkense Font. n. sp | | | | × | | | | | | | | | | | |
| 34 | Brachyphyllum? sp. Newb. | | | | | | | | × | | | | | | | |
| 35 | Carpolithus Storrsii Font. n. sp. | | | | | | | | | | | | × | | | |
| 36 | Cephalotaxopsis carolinensis Font. n. sp | | | | | | | × | | | | | | | | |

*Table of distribution of fossil plants of Older Mesozoic of the United States*—Continued.

| No. | Name. | Triassic. | | | | | | | | | | Jurassic. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Connecticut Valley area. | | Hudson-Potomac area. | | | | | South-western area. | | | | | | | |
| | | Massachusetts. | Connecticut. | New Jersey. | Pennsylvania. | Maryland. | Virginia area. | North Carolina area. | New Mexico. | Arizona. | Taylorsville, California, area. | Mariposa beds, California. | Oroville, California. | Colorado. | Wyoming. | South Dakota. |
| 37 | Cheirolepis Muensteri (Schenk) Schimp | ? | ? | × | × | | × | × | × | | | | | | | |
| 38 | Chondrites gracilis Emm | | | | | | | × | | | | | | | | |
| 39 | Chondrites interruptus Emm | | | | | | | × | | | | | | | | |
| 40 | Chondrites ramosus Emm | | | | | | | × | | | | | | | | |
| 41 | Cladophlebis argutula (Heer) Font | | | | | | | | | | | | × | | | |
| 42 | Cladophlebis auriculata Font | | | | | | × | | | | | | | | | |
| 43 | Cladophlebis densifolia Font | | | | | | | | | | | | × | | | |
| 44 | Cladophlebis indica (Oldh. & Morr.) Font | | | | | | | | | | | | ? | | | |
| 45 | Cladophlebis microphylla Font | | | | | | × | | | | | | | | | |
| 46 | Cladophlebis obtusifolia (Andrä) Schimp | | | | | | | × | | | | | | | | |
| 47 | Cladophlebis ovata Font | | | | | | × | | | | | | | | | |
| 48 | Cladophlebis pseudowhitbiensis Font | | | | | | × | | | | | | | | | |
| 49 | Cladophlebis rarinervis Font | | | | | | × | | | | | | | | | |
| 50 | Cladophlebis reticulata Font | | | | × | | | | | | | | | | | |
| 51 | Cladophlebis rotundiloba Font | | | | | | × | | | | | | | | | |
| 52 | Cladophlebis spectabilis (Heer) Font | | | | | | | | | | | | × | | | |
| 53 | Cladolphlebis subfalcata Font | | | | | | × | | | | | | | | | |
| 54 | Cladophlebis whitbiensis tenuis var. a Heer | | | | | | | | | | | | ? | | | |
| 55 | Clathropteris platyphylla (Göpp) Brongn | × | × | × | | | | | | | | | | | | |
| 56 | Clathropteris platyphylla expansa Sap | | | | | | × | | | | | | | | | |
| 57 | Comephyllum cristatum Emm | | | | | | | × | | | | | | | | |
| 58 | Coniferous plants, undetermined | × | | | × | | × | | | | | | | | | |
| 59 | Ctenis auriculata Font | | | | | | | | | | | | × | | | |
| 60 | Ctenis grandifolia Font | | | | | | | | | | | | × | | | |
| 61 | Ctenis orovillensis Font | | | | | | | | | | | | × | | | |
| 62 | Ctenophyllum angustifolium Font | | | | | | | | | | | | × | | | |
| 63 | Ctenophyllum Braunianum abbreviatum (Fr. Braun) Schimp | | | | | | × | × | | | | | | | | |
| 64 | Ctenophyllum Braunianum angustum (Fr. Braun) Schimp | | | | | | × | × | | | | | | | | |

*Table of distribution of fossil plants of Older Mesozoic of the United States*—Continued.

| No. | Name. | Triassic. | | | | | | | | | | Jurassic. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Connecticut Valley area. | | Hudson-Potomac area. | | | | | South-western area. | | | | | | | |
| | | Massachusetts. | Connecticut. | New Jersey. | Pennsylvania. | Maryland. | Virginia area. | North Carolina area. | New Mexico. | Arizona. | Taylorsville, California, area. | Mariposa beds, California. | Oroville, California. | Colorado. | Wyoming. | South Dakota. |
| 65 | Ctenophyllum densifolium Font | | | | | | | | | | | | × | | | |
| 66 | Ctenophyllum giganteum Font | | | | | | × | | | | | | | | | |
| 67 | Ctenophyllum grandifolium Font | | | | × | | × | | ? | | | | | | | |
| 68 | Ctenophyllum grandifolium Storrsii Font | | | | | | | | | | | | × | | | |
| 69 | Ctenophyllum lineare (Emm.) Font | | | | | | | × | | | | | | | | |
| 70 | Ctenophyllum robustum (Emm.) Font | | | | ? | | | × | | | | | | | | |
| 71 | Ctenophyllum taxinum (L. & H.) Font | | | | | | × | | | | | | | | | |
| 72 | Ctenophyllum truncatum Font | | | | | | × | | | | | | | | | |
| 73 | Ctenophyllum Wannerianum Font. n. sp | | | | × | | | | | | | | | | | |
| 74 | Ctenophyllum Wardii Font | | | | | | | | | | | | × | | | |
| 75 | Ctenophyllum ? sp. Font | | | | | | | | × | | | | | | | |
| 76 | Cycadella Beccheriana Ward | | | | | | | | | | | | | | × | |
| 77 | Cycadella carbonensis Ward | | | | | | | | | | | | | | × | |
| 78 | Cycadella cirrata Ward | | | | | | | | | | | | | | × | |
| 79 | Cycadella compressa Ward | | | | | | | | | | | | | | × | |
| 80 | Cycadella concinna Ward | | | | | | | | | | | | | | × | |
| 81 | Cycadella contracta Ward | | | | | | | | | | | | | | × | |
| 82 | Cycadella crepidaria Ward | | | | | | | | | | | | | | × | |
| 83 | Cycadella exogena Ward | | | | | | | | | | | | | | × | |
| 84 | Cycadella ferruginea Ward | | | | | | | | | | | | | | × | |
| 85 | Cycadella gelida Ward | | | | | | | | | | | | | | × | |
| 86 | Cycadella gravis Ward | | | | | | | | | | | | | | × | |
| 87 | Cycadella jejuna Ward | | | | | | | | | | | | | | × | |
| 88 | Cycadella jurassica Ward | | | | | | | | | | | | | | × | |
| 89 | Cycadella Knightii Ward | | | | | | | | | | | | | | × | |
| 90 | Cycadella Knowltoniana Ward | | | | | | | | | | | | | | × | |
| 91 | Cycadella nodosa Ward | | | | | | | | | | | | | | × | |
| 92 | Cycadella ramentosa Ward | | | | | | | | | | | | | | × | |
| 93 | Cycadella Reedii Ward | | | | | | | | | | | | | | × | |
| 94 | Cycadella verrucosa Ward | | | | | | | | | | | | | | × | |
| 95 | Cycadella wyomingensis Ward | | | | | | | | | | | | | | × | |
| 96 | Cycadeoidea Emmonsi (Font.) Ward | | | | | | | × | | | | | | | | |
| 97 | Cycadeoidea nigra Ward n. sp | | | | | | | | | | | | | × | | |
| 98 | Cycadeomyelon yorkense Font. n. sp | | | × | × | | | | | | | | | | | |

*Table of distribution of fossil plants of Older Mesozoic of the United States*—Continued.

| No. | Name. | Triassic. | | | | | | | | | | Jurassic. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Connecticut Valley area. | | Hudson-Potomac area. | | | | | South-western area. | | | | | | | |
| | | Massachusetts. | Connecticut. | New Jersey. | Pennsylvania. | Maryland. | Virginia area. | North Carolina area. | New Mexico. | Arizona. | Taylorsville, California, area. | Mariposa beds, California. | Oroville, California. | Colorado. | Wyoming. | South Dakota. |
| 99 | Cycadeospermum Wanneri Font. n. sp. | | | | × | | | | | | | | | | | |
| 100 | Cycadinocarpus Chapini Newb. | | × | | | | | | | | | | | | | |
| 101 | Cycadites acutus Emm | | | | | | | × | | | | | | | | |
| 102 | Cycadites tenuinervis Font. | | | | | | × | × | | | | | | | | |
| 103 | Cycadites ? sp. Font. | | | | | | | | × | | | | | | | |
| 104 | Cyclopteris sp. Conrad | | | × | | | | | | | | | | | | |
| 105 | Danæopsis ? sp. Font. | | | | | | | × | | | | | | | | |
| 106 | Dendrophycus Shoemakeri Ward n. sp. | | | | | × | | | | | | | | | | |
| 107 | Dendrophycus triassicus Newb. | | × | | | | | | | | | | | | | |
| 108 | Dicksonia Saportana Heer. | | | | | | | | | | | ? | | | | |
| 109 | Dicranopteris ? sp. Font. | | | | | | × | | | | | | | | | |
| 110 | Dictyophyllum ? sp. Font. | × | | | | | | | | | | | | | | |
| 111 | Didymosorus ? bindrabunensis acutifolius Font. | | | | | | | | | | | | × | | | |
| 112 | Dioonites Carnallianus (Göpp.) Born | | | | × | | | | | | | | | | | |
| 113 | Dyctuocaulus striatus Emm. | | | | ? | | | × | | | | | | | | |
| 114 | Echinocarpus sp. Emm | | | | | | | × | | | | | | | | |
| 115 | Equisetum abiquiense Font. | | | | | | | | × | | | | | | | |
| 116 | Esquisetum Knowltoni Font. | | | | | | | | × | | | | | | | |
| 117 | Equisetum Muensteri (Sternb.) Brongn. | | | | | | | | | | ? | | | | | |
| 118 | Equisetum Rogersii (Bunb.) Schimp. | | | × | × | | × | × | | | | | | | | |
| 119 | Fucoides connecticutensis Hitchc. | | × | | | | | | | | | | | | | |
| 120 | Fucoides Shepardi Hitchc. | × | | | | | | | | | | | | | | |
| 121 | Gymnocaulus alternatus Emm | | | | ? | | | × | | | | | | | | |
| 122 | Laccopteris lanceolata (Göpp.) Presl. n. comb. | | | | | | | ? | | | | | | | | |
| 123 | Lepacyclotes circularis Emm | | | | | | | × | | | | | | | | |
| 124 | Lepacyclotes ellipticus Emm | | | | | | | × | | | | | | | | |
| 125 | Leptostrobus ? mariposensis Font. n. sp. | | | | | | | | | | | × | | | | |
| 126 | Leptostrobus ? sp. Font. (Undetermined cone) | | | | | | | | | | | | × | | | |
| 127 | Lonchopteris oblonga (Emm.) Font. | | | | × | | | × | | | | | | | | |
| 128 | Lonchopteris virginiensis (Font.) | | | | | | × | | | | | | | | | |

*Table of distribution of fossil plants of Older Mesozoic of the United States*—Continued.

| No. | Name. | Triassic. | | | | | | | | | | Jurassic. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Connecticut Valley area. | | Hudson-Potomac area. | | | | | Southwestern area. | | | | | | | |
| | | Massachusetts. | Connecticut. | New Jersey. | Pennsylvania. | Maryland. | Virginia area. | North Carolina. | New Mexico. | Arizona. | Taylorsville, California, area. | Mariposa beds, California. | Oroville, California. | Colorado. | Wyoming. | South Dakota. |
| 129 | Loperia carolinensis (Font.) Ward n. comb | | × | | ? | | | × | | | | | | | | |
| 130 | Lycopodites Sillimanni Brongn | × | | | | | | | | | | | | | | |
| 131 | Macrotæniopteris californica Font | | | | | | | | | | | | × | | | |
| 132 | Macrotæniopteris crassinervis Feistm | | | | | | × | | | | | | | | | |
| 133 | Macrotæniopteris magnifolia (Rogers) Schimp | | | | × | | × | × | | | | | | | | |
| 134 | Macrotæniopteris nervosa Font | | | | | | | | | | | | × | | | |
| 135 | Mertensides bullatus (Bunb.) Font | | | | ? | | × | ? | | | | | | | | |
| 136 | Mertensides distans Font | | | | | | × | | | | | | | | | |
| 137 | Otozamites brevifolius Fr. Braun | | × | | | | | | | | | | | | | |
| 138 | Otozamites carolinensis Font | | | | | | | × | | | | | | | | |
| 139 | Otozamites latior Sap | | × | | | | | | | | | | | | | |
| 140 | Otozamites Macombii Newb | | | | | | | | × | | | | | | | |
| 141 | Pagiophyllum brevifolium (Newb.) Ward n. comb | × | × | | | | | | | | | | | | | |
| 142 | Pagiophyllum ? Newberryi Ward n. sp | | | | | | | | × | | | | | | | |
| 143 | Pagiophyllum peregrinum (L. & H.) Schenk | | | | | | | × | | | | ? | | | | |
| 144 | Pagiophyllum simile (Newb.) Ward n. comb | × | × | | | | | | | | | | | | | |
| 145 | Pagiophyllum Williamsonis (Brongn.) Font | | | | | | ? | ? | | | | | × | | | |
| 146 | Palæophycus limaciformis Lewis | | | × | | | | | | | | | | | | |
| 147 | Palissya brevifolia (Emm.) Font | | | | | | | × | | | | | | | | |
| 148 | Palissya diffusa (Emm.) Font | ? | ? | ? | × | | | × | | | | | | | | |
| 149 | Palissya sphenolepis (Fr. Braun) Brongn | | | × | × | | | × | | | | | | | | |
| 150 | Palissya sp. Font. (cone) | | | | | | | | × | | | | | | | |
| 151 | Pinoxylon dacotense Kn. n. sp | | | | | | | | | | | | | | | × |
| 152 | Pinus Nordenskiöldi Heer | | | | | | | | | | | | ? | | | |
| 153 | Podozamites ? carolinensis Font. n. sp | | | | | | | × | | | | | | | | |
| 154 | Podozamites distans (Presl) Fr. Braun | | | | ? | | | | | | | | | | | |
| 155 | Podozamites Emmonsii Newb | | | | | | | × | | | | | | | | |
| 156 | Podozamites lanceolatus (L. & H.) Fr. Braun | | | | | | | | | | | | × | | | |

*Table of distribution of fossil plants of Older Mesozoic of the United States*—Continued.

| No. | Name. | Triassic. | | | | | | | | | | Jurassic. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Connecticut Valley area. | | Hudson-Potomac area. | | | | | South-western area. | | | | | | | |
| | | Massachusetts. | Connecticut. | New Jersey. | Pennsylvania. | Maryland. | Virginia area. | North Carolina area. | New Mexico. | Arizona. | Taylorsville, California area. | Mariposa beds, California. | Oroville, California. | Colorado. | Wyoming. | South Dakota. |
| 157 | Podozamites lanceolatus latifolius (Brongn.) Heer. | | | | | | | | | | | | × | | | |
| 158 | Podozamites longifolius Emm | | | × | | | × | × | | | | | | | | |
| 159 | Podozamites taylorsvillensis Ward n. sp | | | | | | | | | | × | | | | | |
| 160 | Podozamites tenuistriatus (Rogers) Font | | | | | | × | × | | | | | | | | |
| 161 | Pseudodanæopsis obliqua (Emm.) Font | | | | | | × | × | | | | | | | | |
| 162 | Pseudodanæopsis plana (Emm.) Font | | | | × | | × | × | | | | | | | | |
| 163 | Pterophyllum affine Nath. | | | | | | × | | | | | | | | | |
| 164 | Pterophyllum Daleanum Ward n. sp. | | | | | | | × | | | | | | | | |
| 165 | Pterophyllum inæquale Font | | | | × | | × | | | | | | | | | |
| 166 | Pterophyllum rajmahalense Morr | | | | | | | | | | | | ? | | | |
| 167 | Ramulus rugosus Wanner. | | | | × | | | | | | | | | | | |
| 168 | Sagenopteris Emmonsi Font. n. sp | | | | | | | × | | | | | | | | |
| 169 | Sagenopteris ? magnifoliola Ward n. sp | | | | | | | | | | × | | | | | |
| 170 | Sagenopteris Nilsoniana (Brongn.) Ward n. comb | | | | | | × | × | | | | | × | | | |
| 171 | Sagenopteris sp. Font | | | | × | | | | | | | | | | | |
| 172 | Schizolepis liaso-keuperina Fr. Braun | | | | × | | | | | | | | | | | |
| 173 | Schizoneura planicostata (Rogers) Font | × | × | × | × | | × | ? | | | | | | | | |
| 174 | Schizoneura virginiensis Font | | | | | | × | | | | | | | | | |
| 175 | Schizoneura ? sp. Font | | | | | | × | | | | | | | | | |
| 176 | Sphenopteris egyptiaca Emm | | | | | | | × | | | | | | | | |
| 177 | Sphenozamites Rogersianus Font | | | | × | | × | × | | | | | | | | |
| 178 | Tæniopteris orovillensis Font | | | | | | | | | | | | × | | | |
| 179 | Tæniopteris vittata Brongn | ? | | | | | | | | | | | | | | |
| 180 | Tæniopteris ? yorkensis Font. n. sp | | | | × | | | | | | | | | | | |
| 181 | Thinnfeldia ? reticulata Font. n. sp | | | | × | | | | | | | | | | | |
| 182 | Thyrsopteris Maakiana, Heer | | | | | | | | | | | | ? | | | |
| 183 | Undetermined stem (cycad ?) Font | | | | | | × | | | | | | | | | |

*Table of distribution of fossil plants of Older Mesozoic of the United States*—Continued.

| No. | Name. | Triassic. | | | | | | | | | | Jurassic. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Connecticut Valley area. | | Hudson-Potomac area. | | | | | Southwestern area. | | | | | | | |
| | | Massachusetts. | Connecticut. | New Jersey. | Pennsylvania. | Maryland. | Virginia area. | North Carolina area. | New Mexico. | Arizona. | Taylorsville, California, area. | Mariposa beds, California. | Oroville, California. | Colorado. | Wyoming. | South Dakota. |
| 184 | Yorkia gramineoides Ward n. sp | | | | × | | | | | | | | | | | |
| 185 | Zamiostrobus virginiensis Font | | | | | | × | × | | | | | | | | |
| 186 | Zamites occidentalis Newb | | | | | | | | × | | | | | | | |
| 187 | Zamites pennsylvanicus, Font. n. sp | | | | × | | | | | | | | | | | |
| 188 | Zamites Powelli Font | | | | | | | | × | | | | | | | |
| 189 | Zamites yorkensis Font. n. sp | | | | × | | | | | | | | | | | |

## DISCUSSION OF THE TABLE.

In this table there are 189 separate entries. It would be too much to say that it represents that many distinct species, and yet each entry stands for a different form, so far as the nature of the material enables us to judge. Quite a number are early determinations that have not been recently examined, some of them, perhaps, no longer represented by types that can now be found, and therefore they have little real value, but having gone unchallenged into the literature, it seems best to keep them in view, in the hope that they may some time receive attention.

It will be observed that very few species are common to the Triassic and Jurassic as here recorded. *Baiera multifida* Font., of the Richmond coal field, is identified with doubts in the Oroville flora, and *Pagiophyllum Williamsonis* (Brongn.) Font., of the Yorkshire Oolite, found at Oroville, also occurs in doubtful forms in the Trias of both Virginia and North Carolina. *Sagenopteris Nilsoniana*, a polymorphous species, which will doubtless be subdivided into several species, was found in the Richmond and North Carolina coal fields and reappears in the Oroville florula.

Next in interest come the species common to the eastern and western Triassic beds. *Cheirolepis Muensteri* (Schenk) Schimp., found throughout the Newark system, occurs also in the Trias of New Mexico. The same is true of *Ctenophyllum grandifolium* Font., common in the Virginia area, and found by Mr. Wanner in the Trias of York County, Pennsylvania. The splendid variety, *C. grandifolium Storrsii*, from Oroville, shows that this form only underwent certain modifications in passing from the Trias to the Jura, and its exclusively American character gives it great value as an index to plant evolution on this continent in Older Mesozoic time.

As all the other columns of the table represent the Newark system, which is believed to constitute a geological unit from Massachusetts to North Carolina, little interest attaches to the discovery of forms common to the several areas. A large number are found in both the Richmond and the North Carolina coal fields, which was, of course, to be expected, and the rediscovery of the Emmons types has done much to demonstrate the stratigraphical identity of these coal fields. Mr. Wanner's excellent work in Pennsylvania has tended to bring the deposits of York County, Pennsylvania, into substantial harmony with those farther south. The material from the Connecticut Valley and from New Jersey is as yet too meager to make a full comparison possible, and it seems altogether probable that, even on the assumption of identity of age and aside from differences due to geographical distribution, the element of climate may have had some effect in causing the northern and southern areas to differ in their flora in Mesozoic time.

# PLATE XXI.

## PLATE XXI.

Page

Cladophlebis reticulata Font. n. sp ........................................ 235

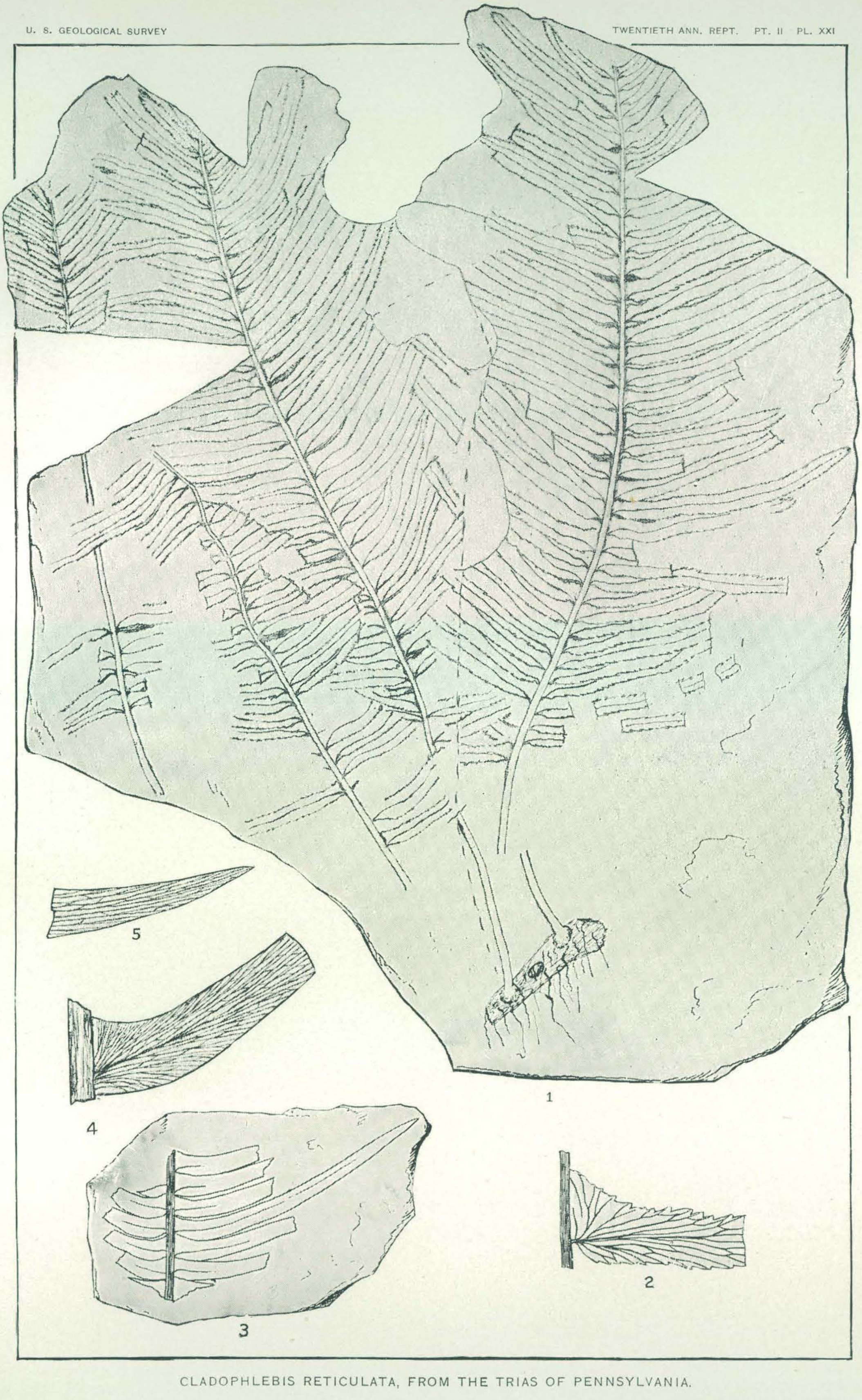
Fig. 1. Fronds and rootstock, natural size.

Fig. 2. Base of a leaflet showing auricle, enlarged.

Fig. 3. Portion of a frond, natural size.

Fig. 4. Basal portion of a pinna, enlarged 3 diameters.

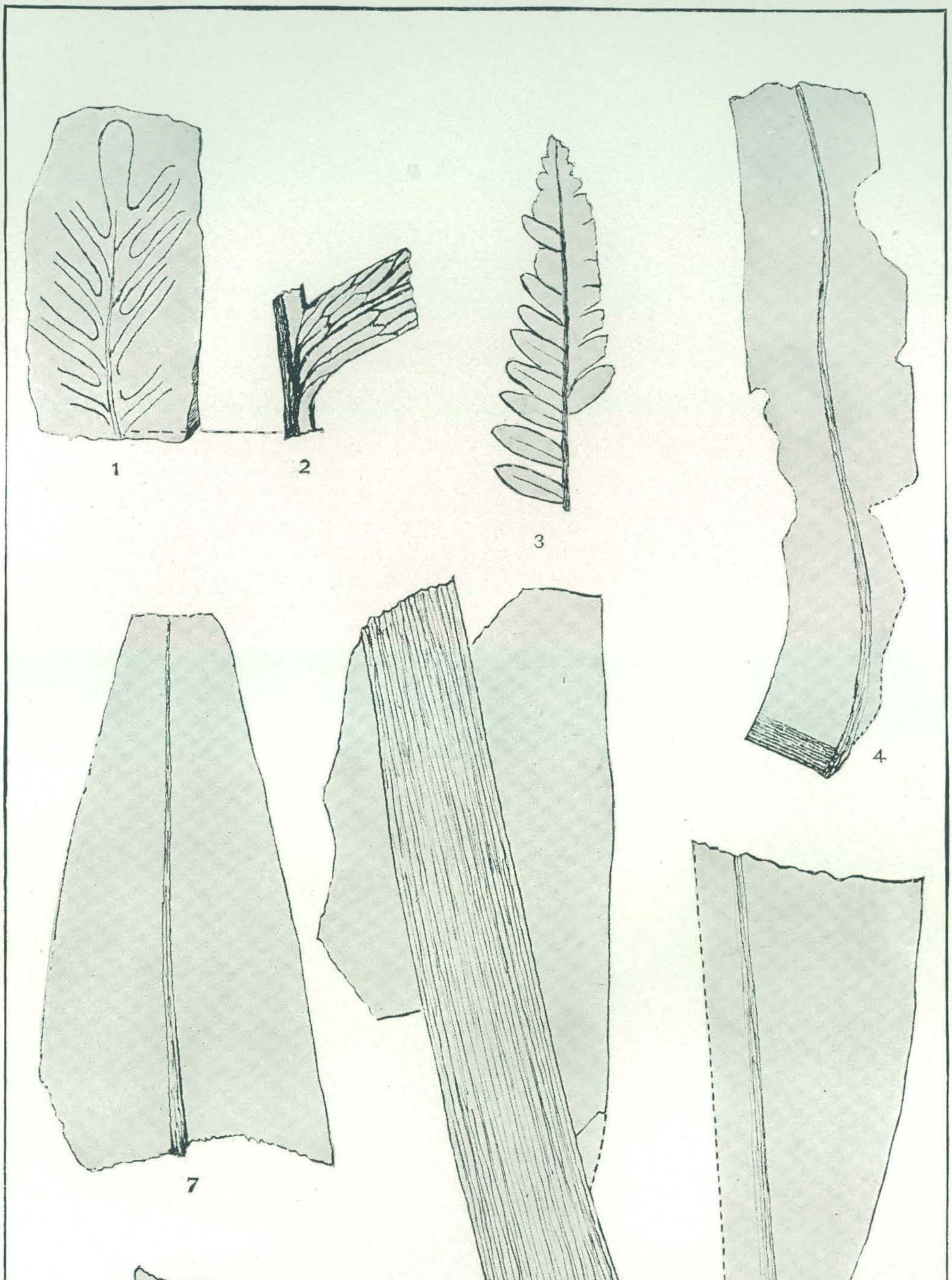
Fig. 5. Terminal portion of a pinna, enlarged 3 diameters.




CLADOPHLEBIS RETICULATA, FROM THE TRIAS OF PENNSYLVANIA.

# PLATE XXII.

## PLATE XXII.




FERNS FROM THE TRIAS OF PENNSYLVANIA.

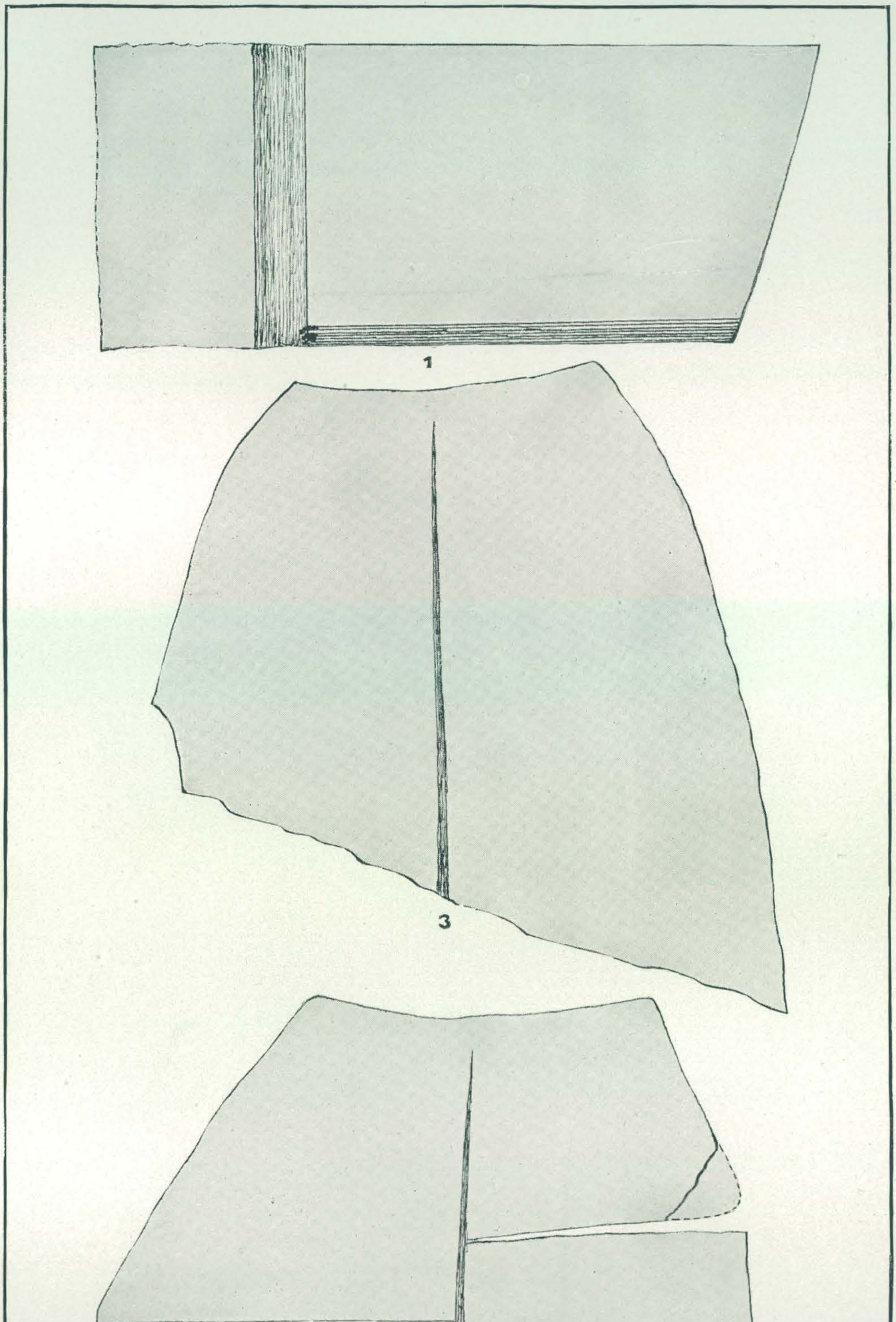
# PLATE XXIII.

# PLATE XXIII.

| | Page. |
|---|---|
| MACROTÆNIOPTERIS MAGNIFOLIA (Rogers) Schimp. | 238 |

Fig. 1. Portion of specimen figured on Pl. XXII, Fig. 9, enlarged to show the nerves.

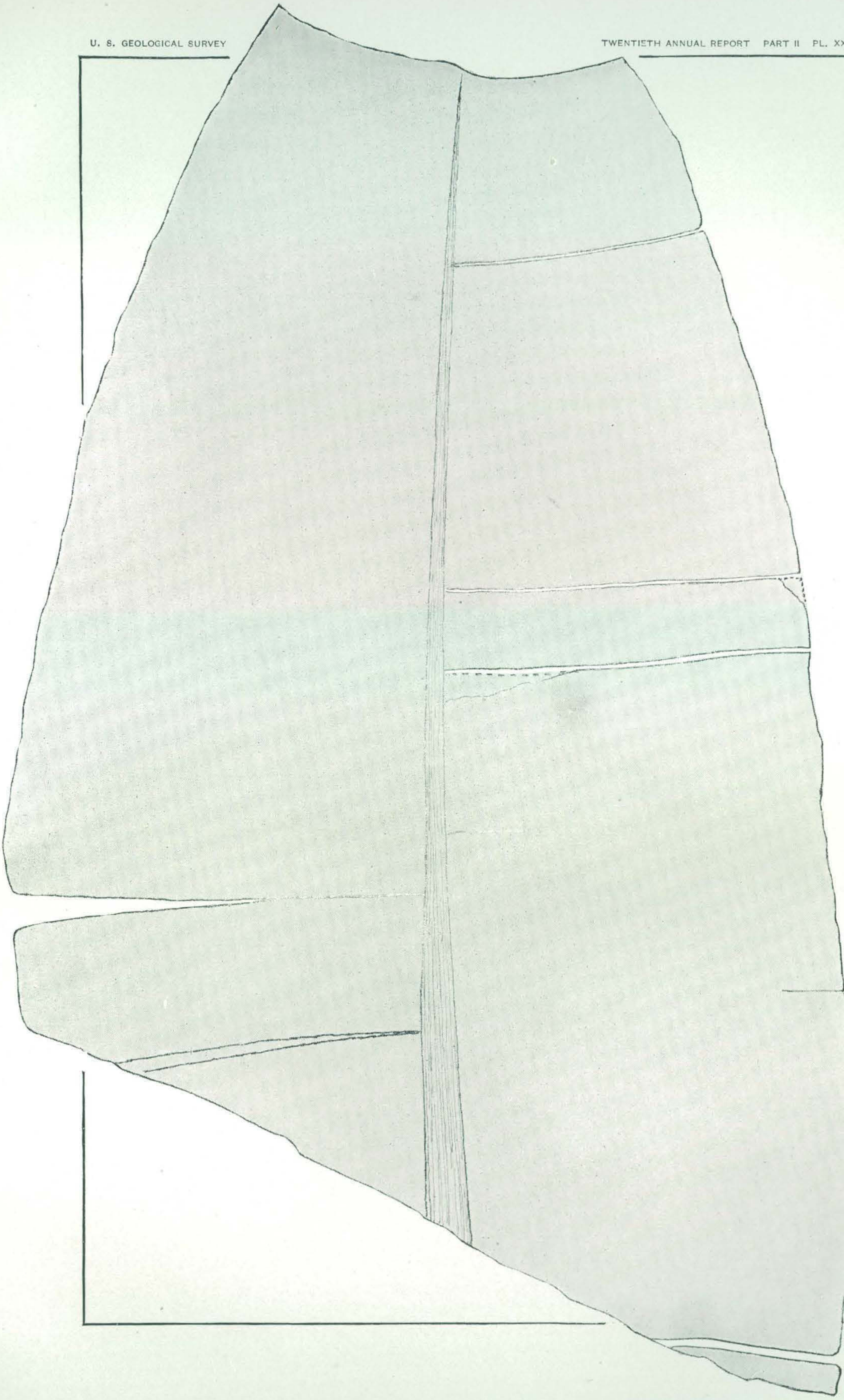
Figs. 2, 3. Summits of two large leaves.




MACROTÆNIOPTERIS MAGNIFOLIA, FROM THE TRIAS OF PENNSYLVANIA.

# PLATE XXIV.

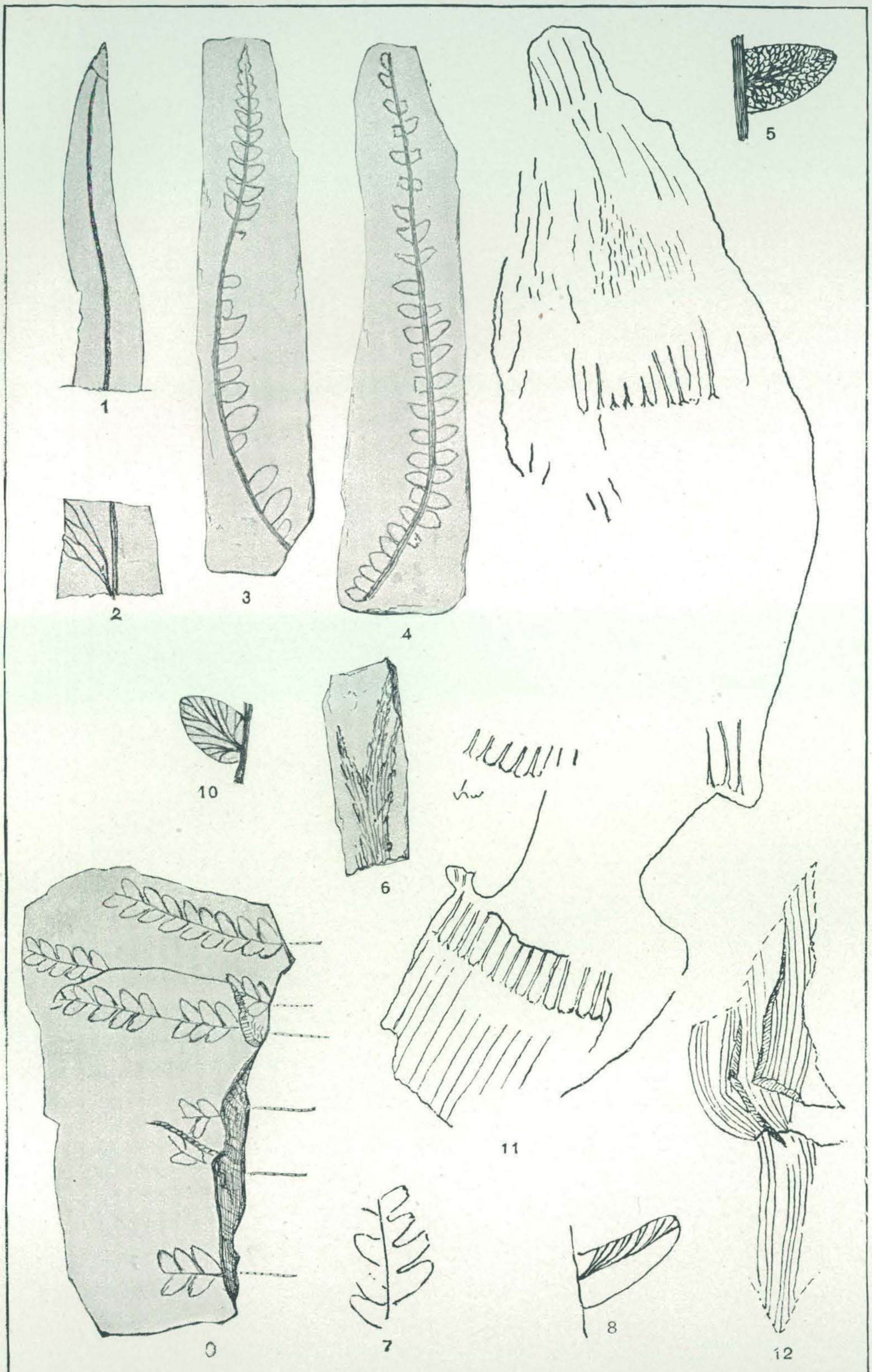
## PLATE XXIV.



MACROTÆNIOPTERIS MAGNIFOLIA, FROM THE TRIAS OF PENNSYLVANIA.

# PLATE XXV.

## PLATE XXV.




FERNS AND FERN ALLIES FROM THE TRIAS OF PENNSYLVANIA.

# PLATE XXVI.

# PLATE XXVI.

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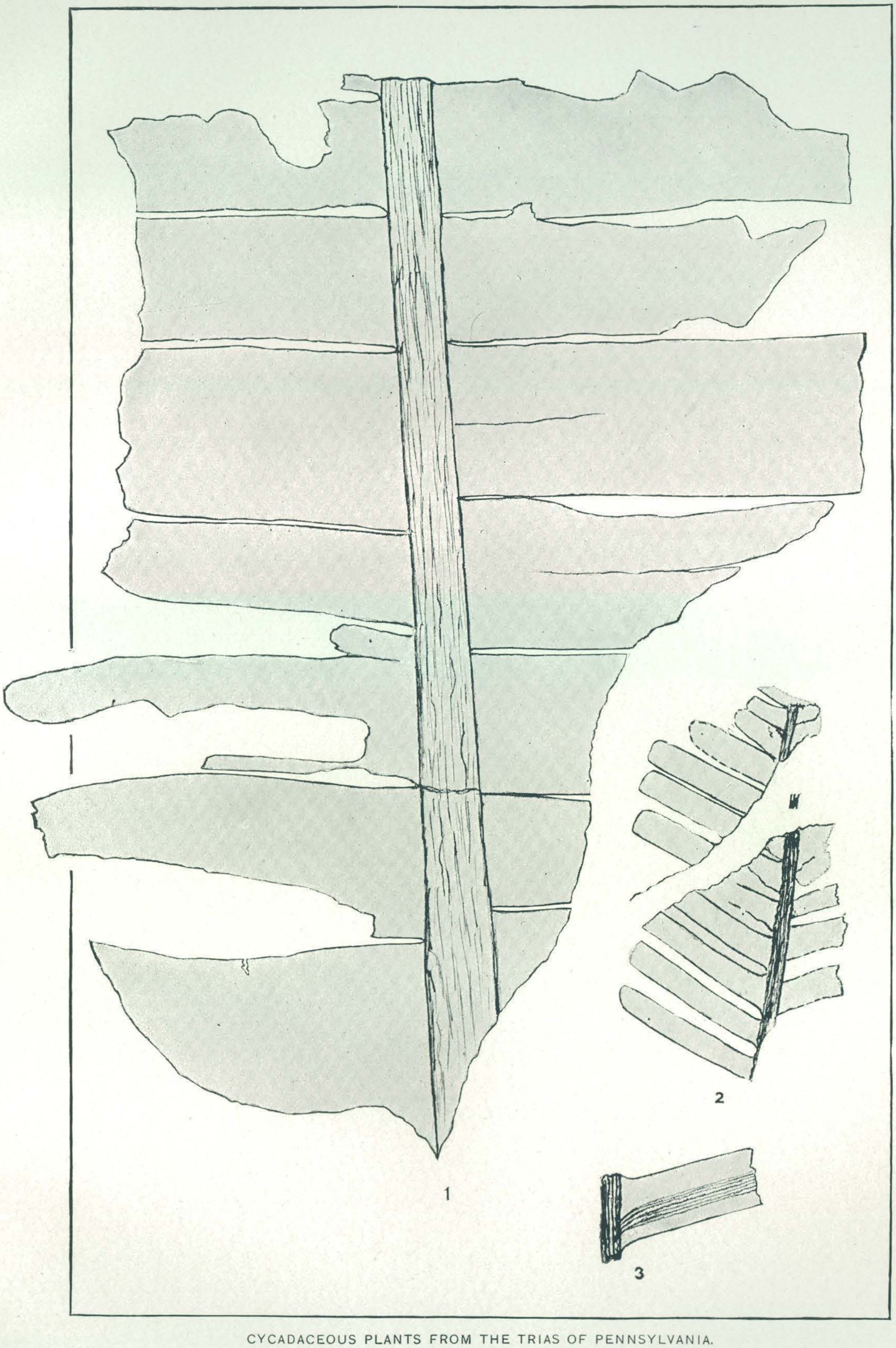
| Fig. 1. | ANOMOZAMITES PRINCEPS (Oldh. and Morr.) Schimp? | 242 |
| Figs. 2, 3. | PTEROPHYLLUM INÆQUALE Font | 242 |

Fig. 3. Pinnule of Fig. 2, enlarged.

442




CYCADACEOUS PLANTS FROM THE TRIAS OF PENNSYLVANIA.

# PLATE XXVII.

# PLATE XXVII.

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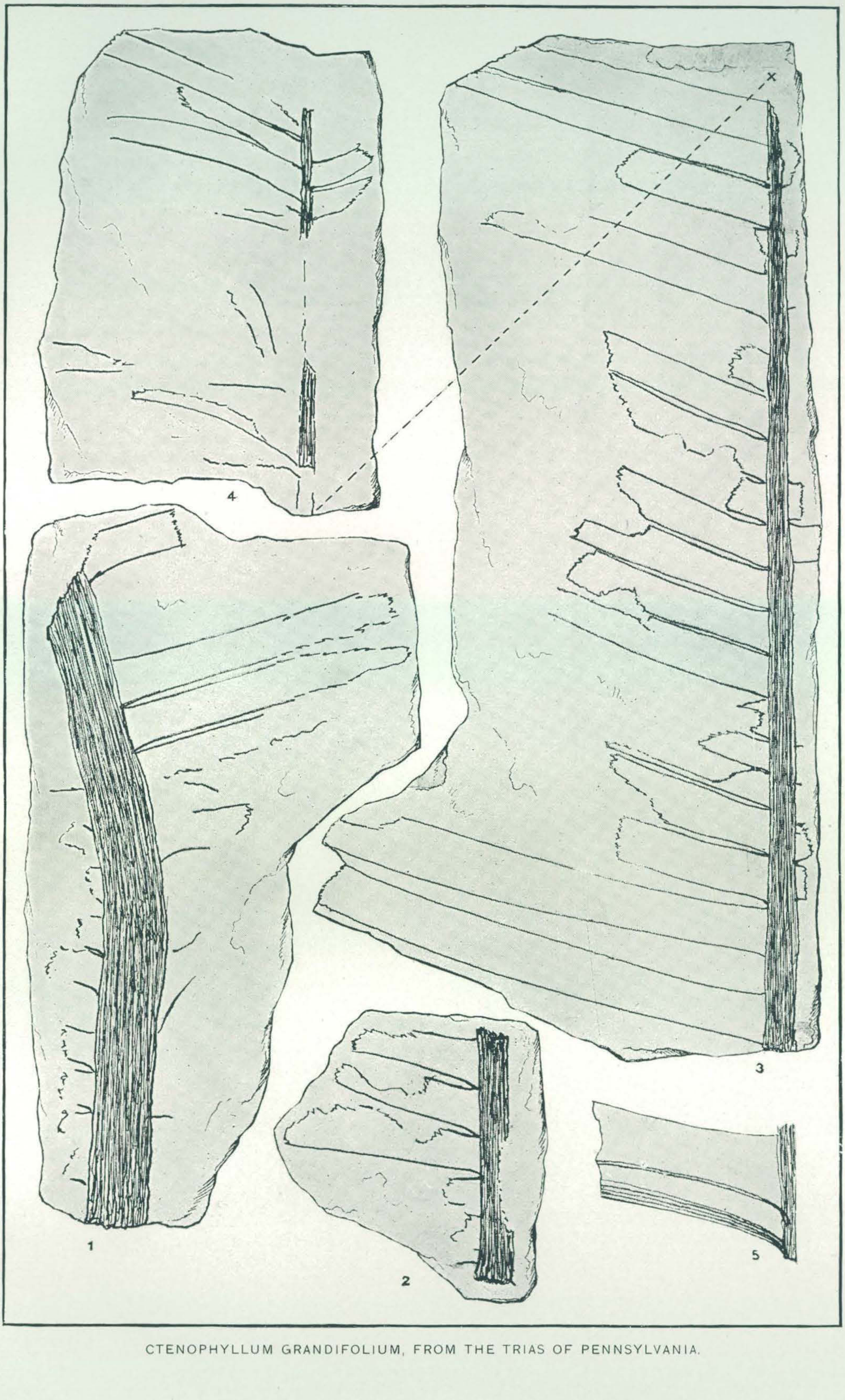
Ctenophyllum grandifolium Font. ........................................ 243

Figs. 1–5. Separated parts of the same leaf.

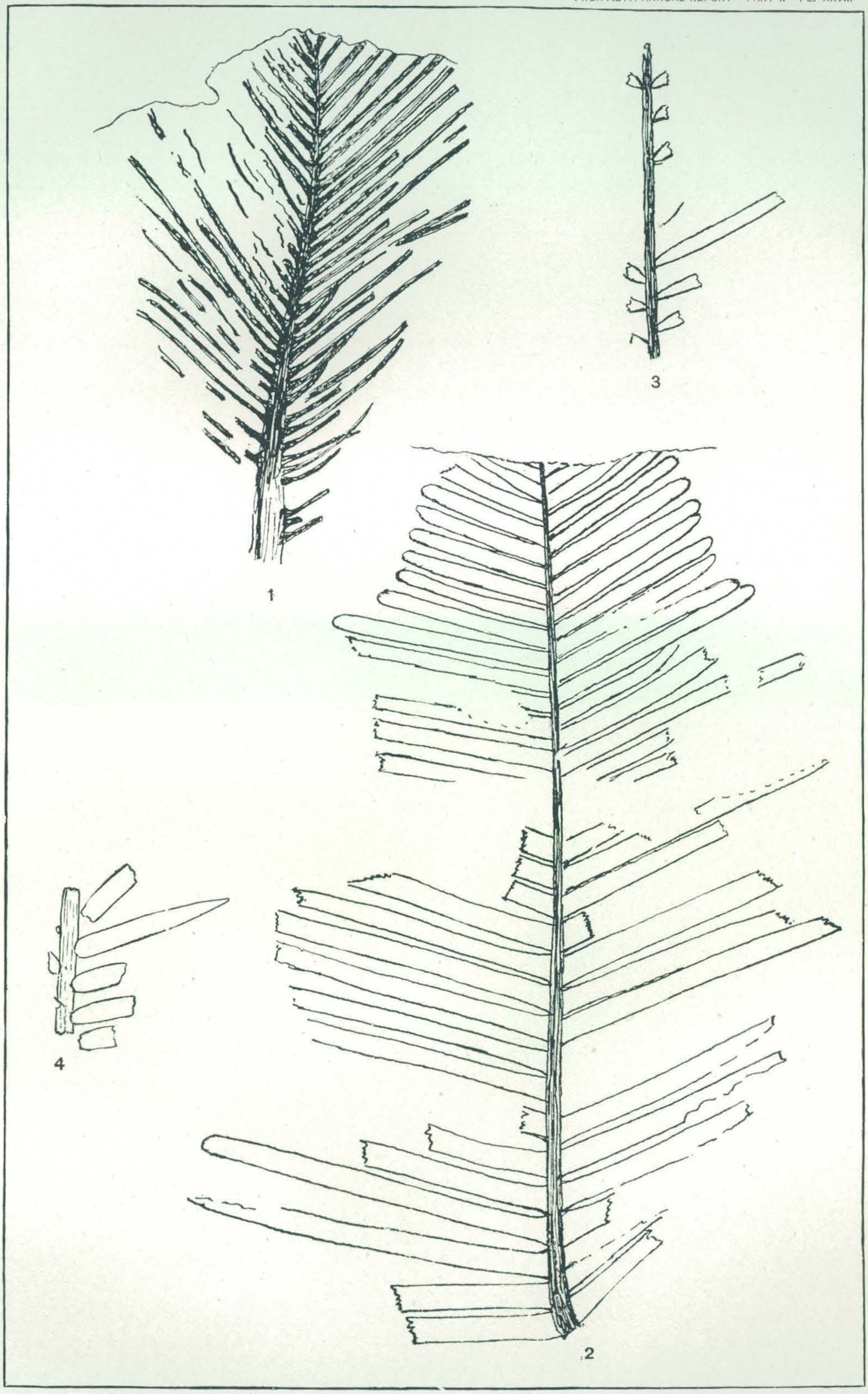
Fig. 4. Portion of pinnule, enlarged to show forking nerves.




CTENOPHYLLUM GRANDIFOLIUM, FROM THE TRIAS OF PENNSYLVANIA.

# PLATE XXVIII.

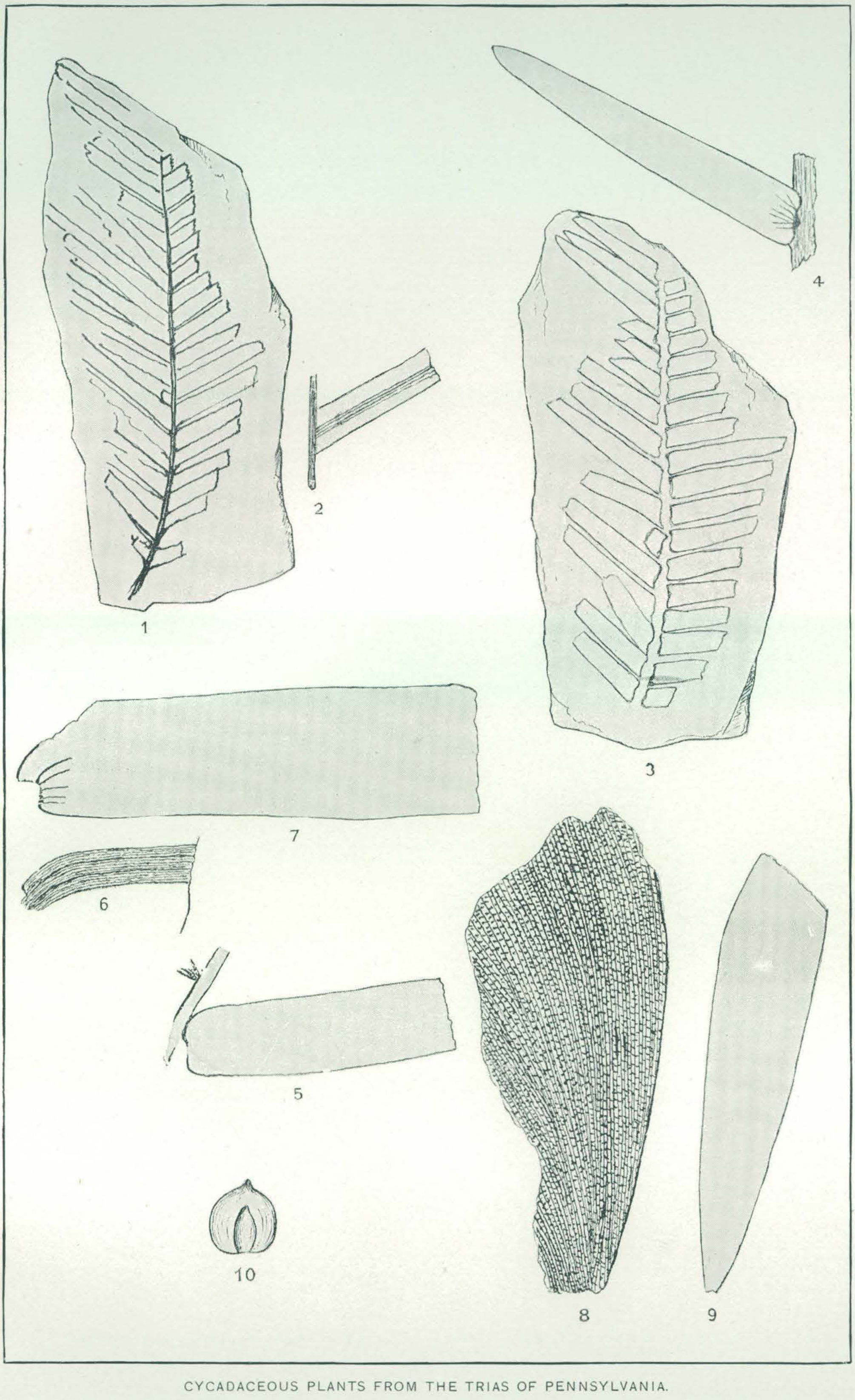
# PLATE XXVIII.




CYCADACEOUS PLANTS FROM THE TRIAS OF PENNSYLVANIA.

# PLATE XXIX.

## PLATE XXIX.




CYCADACEOUS PLANTS FROM THE TRIAS OF PENNSYLVANIA.

# PLATE XXX.

# PLATE XXX.

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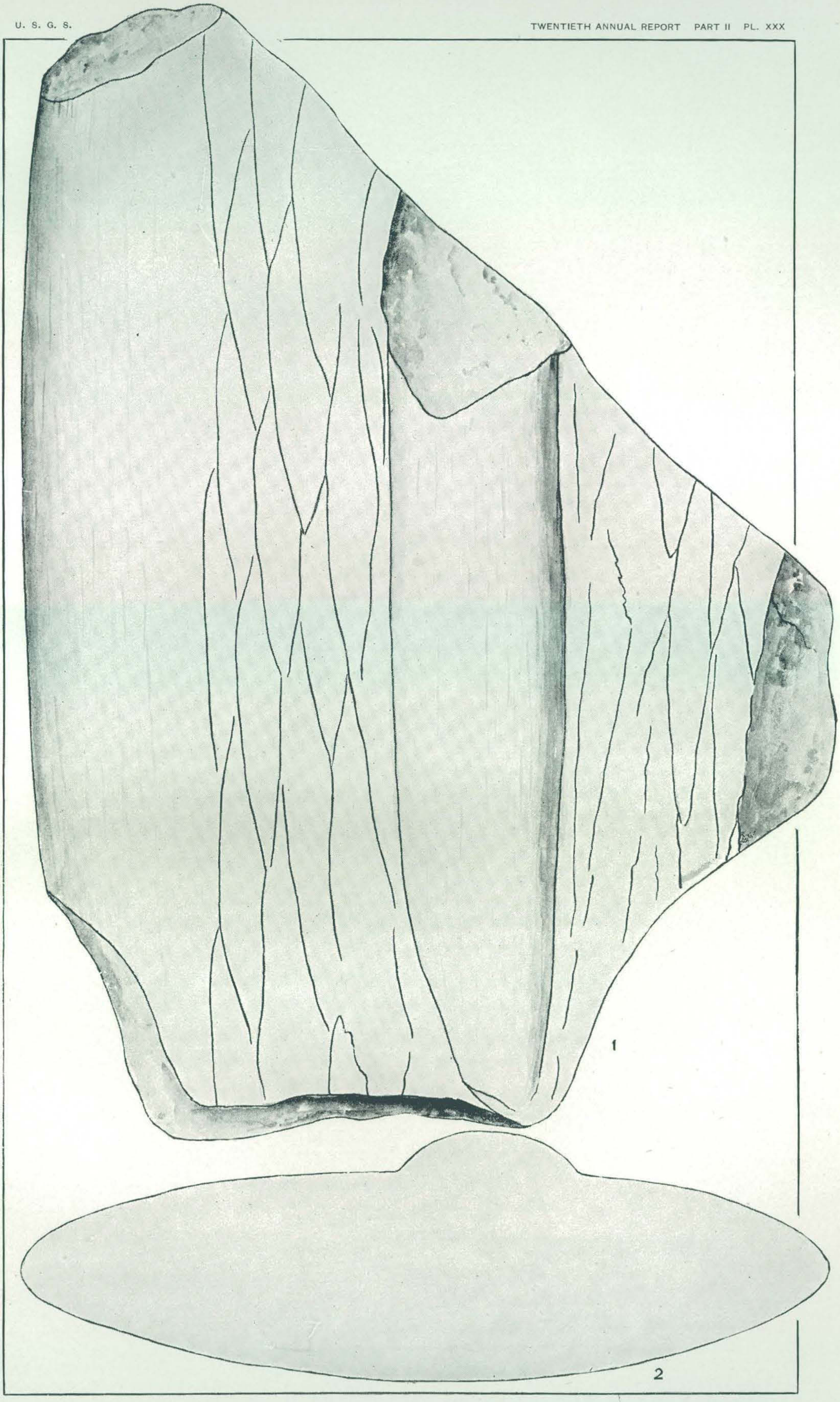
Figs. 1, 2. CYCADEOMYELON YORKENSE Font. n. sp. .......... 248

Fig. 2. Transverse section of the trunk showing the markings of Fig. 1.




CYCADEOMYELON YORKENSE, FROM THE TRIAS OF PENNSYLVANIA.

# PLATE XXXI.

# PLATE XXXI.

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Figs. 1, 2. BAIERA MUENSTERIANA (Presl) Heer? ........ 249

Figs. 3–5. PALISSYA DIFFUSA (Emm.) Font. ........ 250

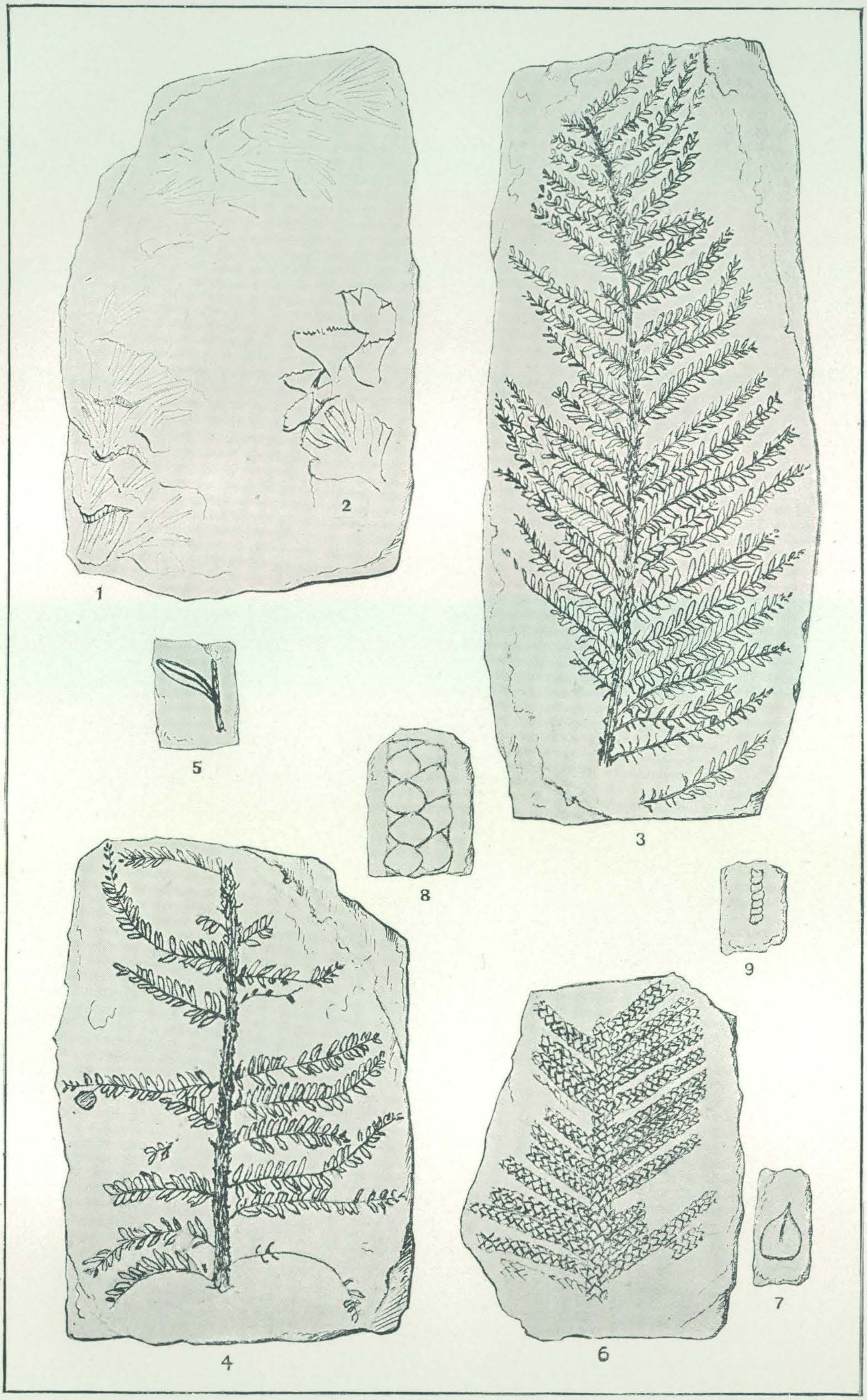
Fig. 5. Pinnule of Fig. 4, enlarged.

Figs. 6–8. BRACHYPHYLLUM YORKENSE Font. n. sp. ........ 251

Fig. 7. Scale-like leaf of Fig. 6, enlarged to show the keel.

Fig. 8. Portion of the stem of Fig. 6, enlarged to show the arrangement of the scales.

Fig. 9. BRACHYPHYLLUM YORKENSE Font. n. sp. ? Small, doubtful fragment... 251




GINKGOACEOUS AND PINACEOUS PLANTS FROM THE TRIAS OF PENNSYLVANIA.

# PLATE XXXII.

## PLATE XXXII.

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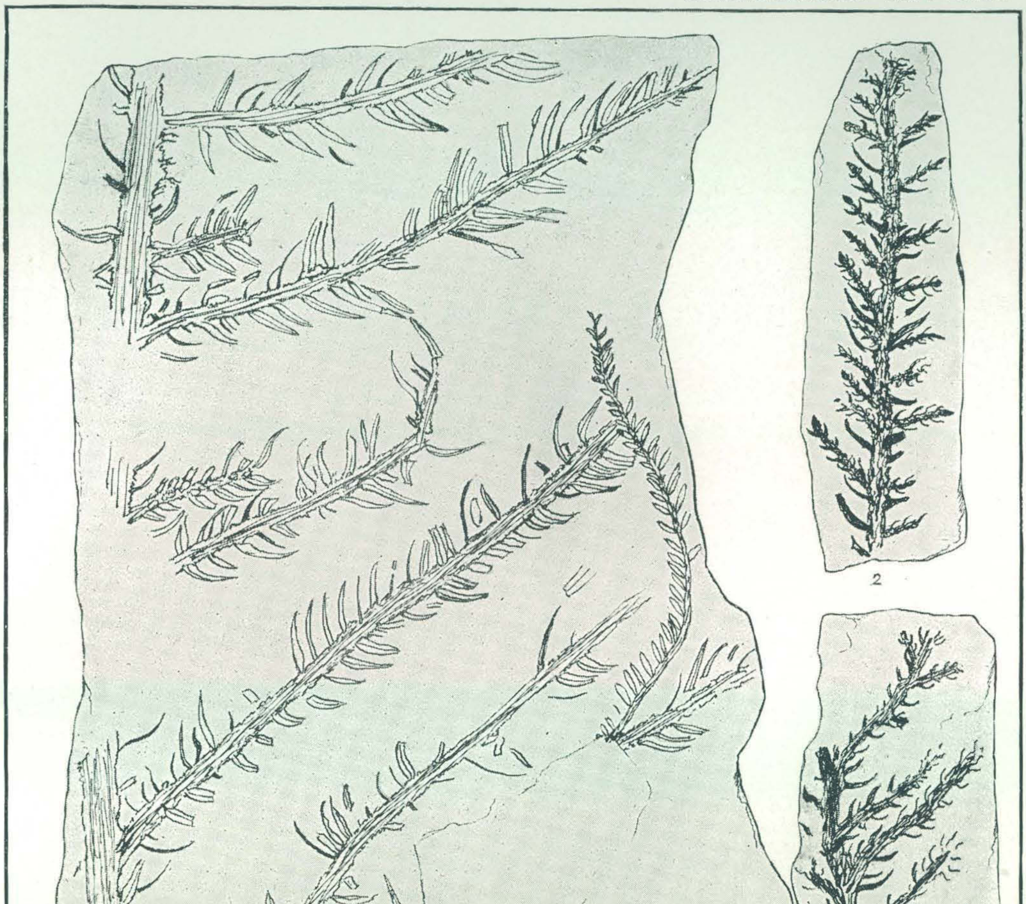
| Figs. 1–5. Palissya sphenolepis (Fr. Braun) Brongn ........................ | 249 |

Fig. 4. Leaf of Fig. 1, enlarged 2 diameters.




PALISSYA SPHENOLEPIS, FROM THE TRIAS OF PENNSYLVANIA.

# PLATE XXXIII.

## PLATE XXXIII.

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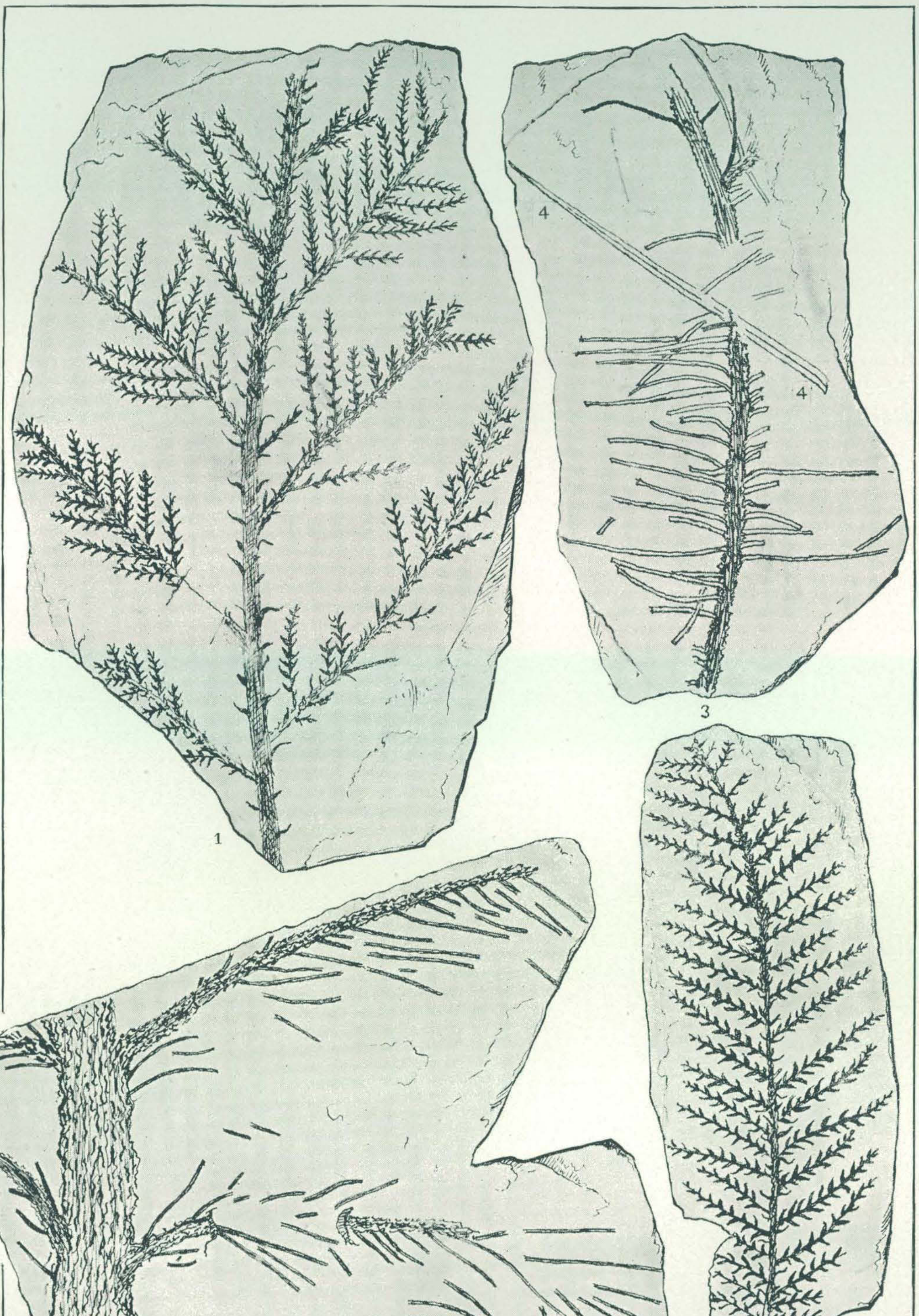
| Figs. 1, 2. | CHEIROLEPIS MUENSTERI (Schenk) Schimp | 252 |
| Figs. 3–5. | SCHIZOLEPIS LIASO-KEUPERINUS Fr. Braun | 252 |

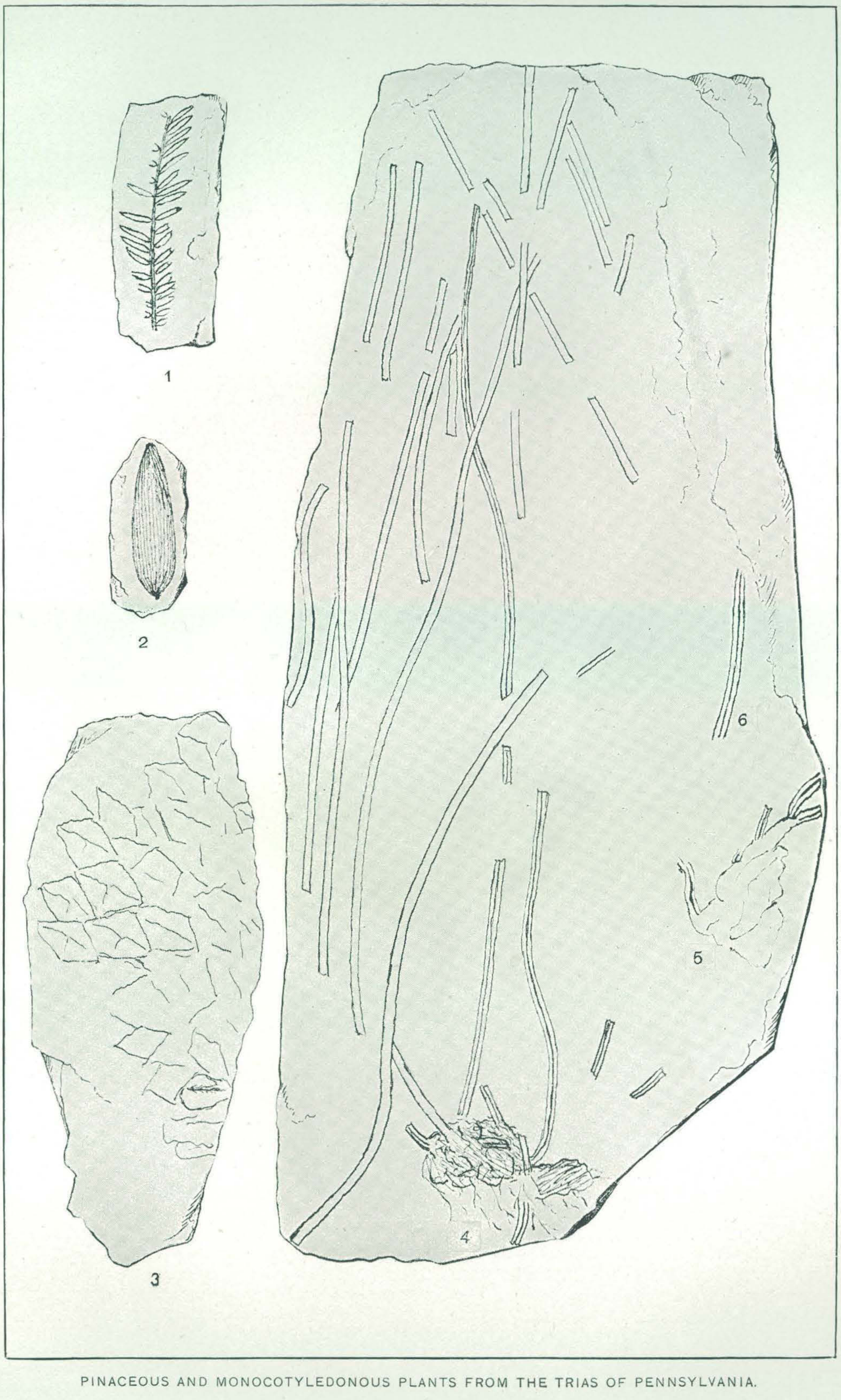
Fig. 4. Leaf of Fig. 3, enlarged 2 diameters.




PINACEOUS PLANTS FROM THE TRIAS OF PENNSYLVANIA.

# PLATE XXXIV.

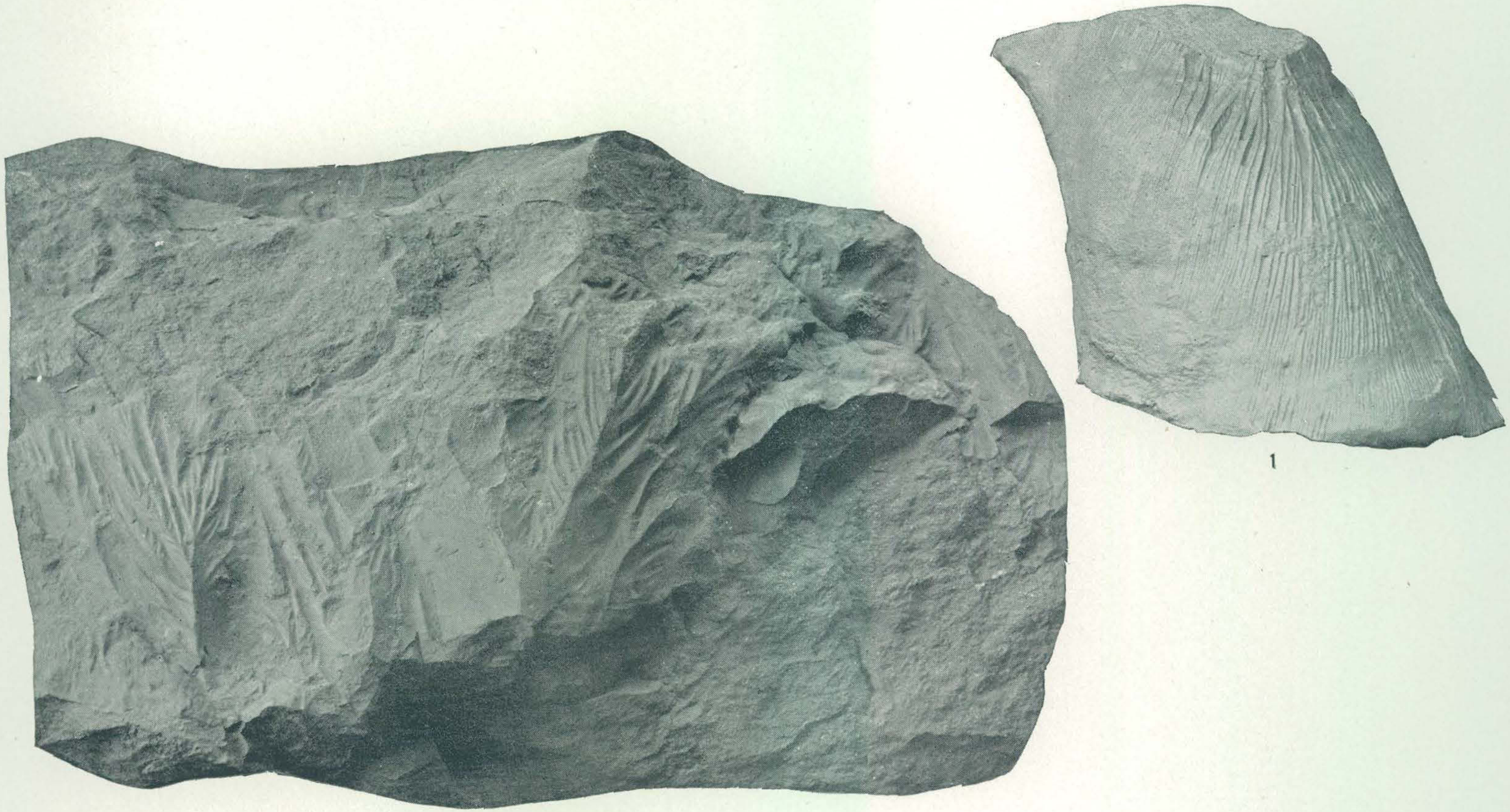
# PLATE XXXIV.




PINACEOUS AND MONOCOTYLEDONOUS PLANTS FROM THE TRIAS OF PENNSYLVANIA.

# PLATE XXXV.

## PLATE XXXV.



1

2

CENTIMETERS

DENDROPHYCUS, FROM THE TRIAS OF CONNECTICUT AND MARYLAND.

# PLATE XXXVI.

## PLATE XXXVI.

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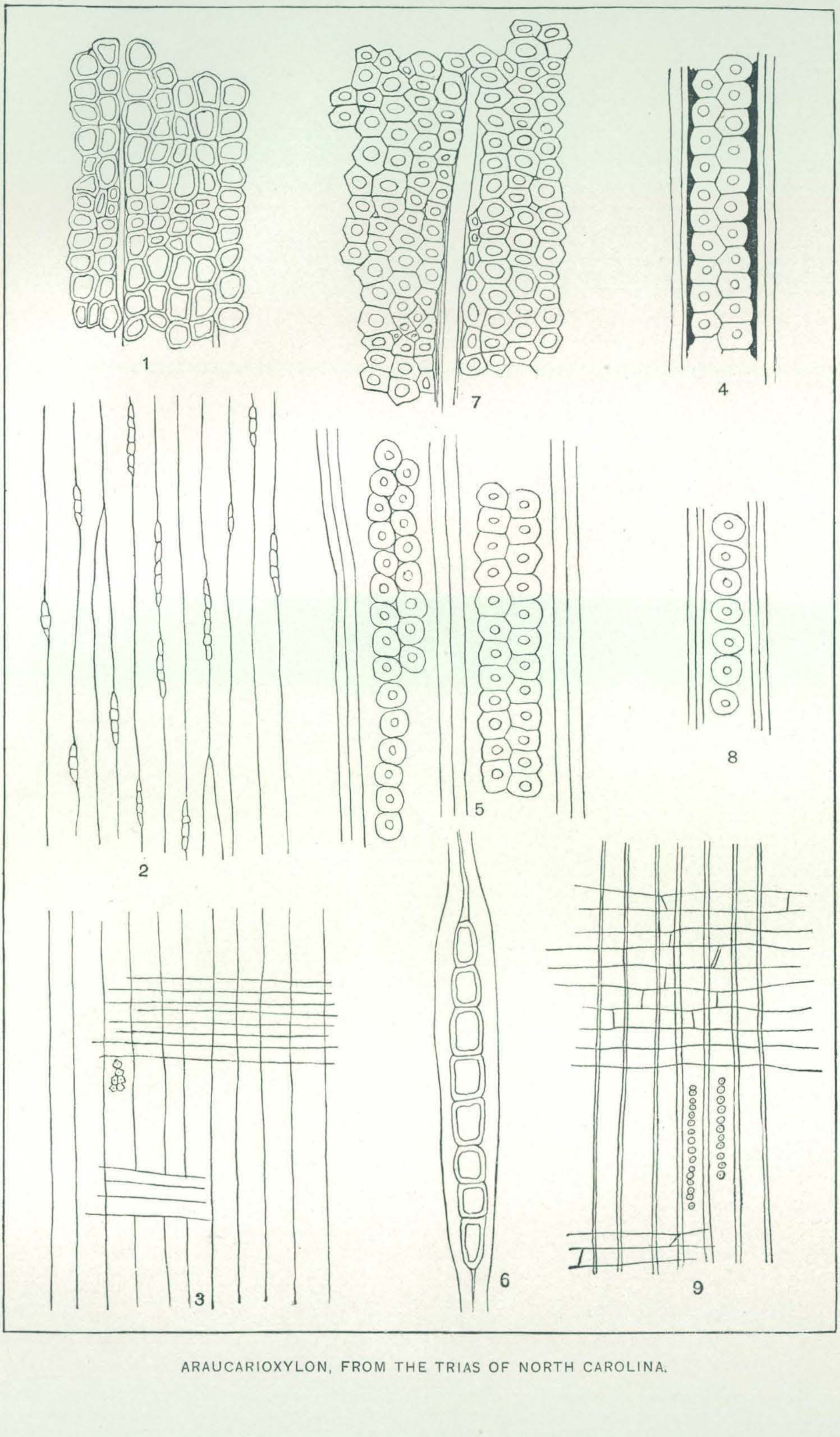
| Dendrophycus Shoemakeri Ward n. sp. | 256 |


DENDROPHYCUS SHOEMAKERI. FROM THE TRIAS OF MARYLAND.

# PLATE XXXVII.




ARAUCARIOXYLON, FROM THE TRIAS OF NORTH CAROLINA.

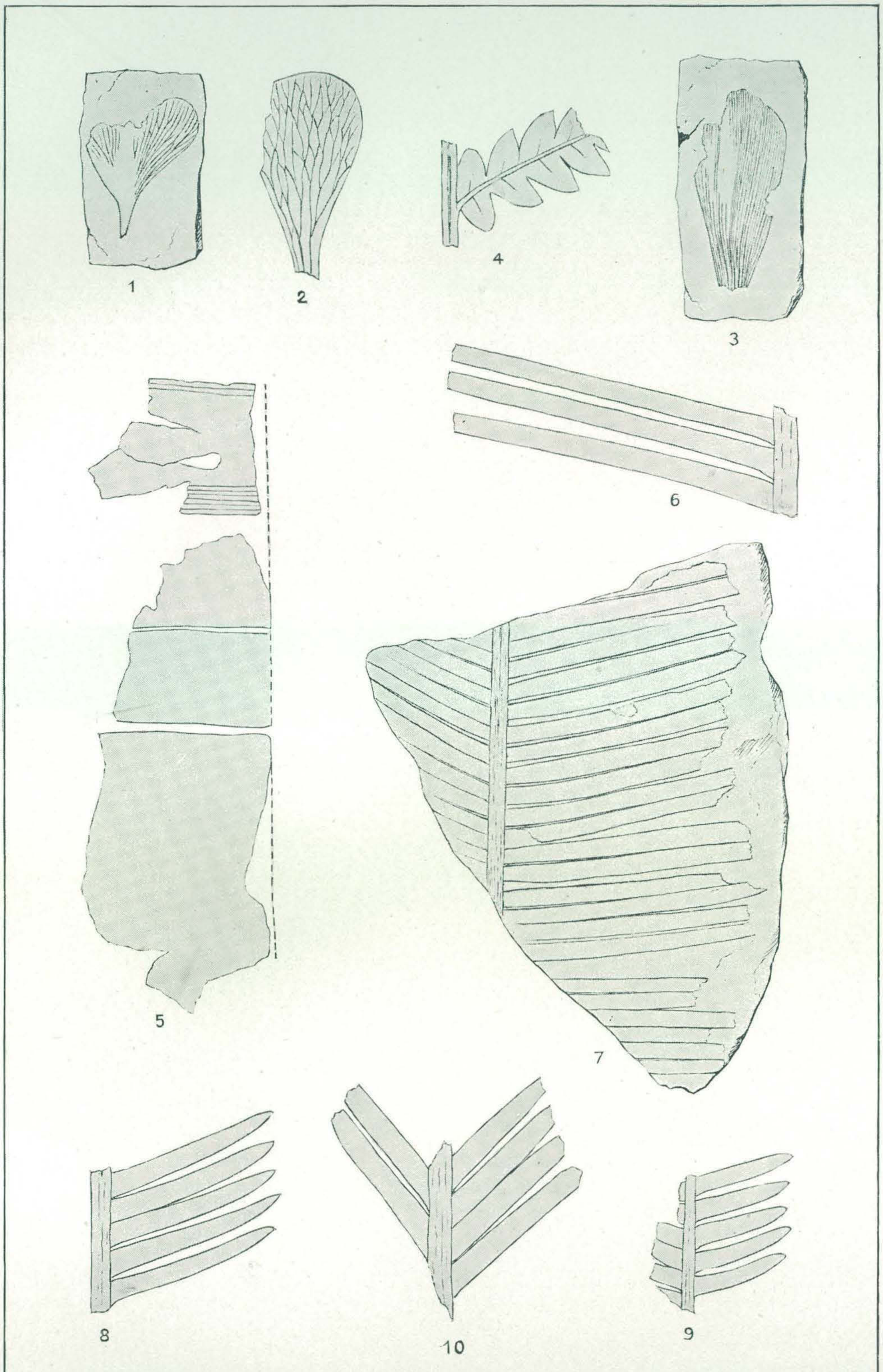
# PLATE XXXVIII.

## PLATE XXXVIII.


FERNS FROM THE TRIAS OF NORTH CAROLINA.

# PLATE XXXIX.

## PLATE XXXIX.




FERNS AND CYCADACEOUS PLANTS FROM THE TRIAS OF NORTH CAROLINA.

# PLATE XL.

PLATE XL.

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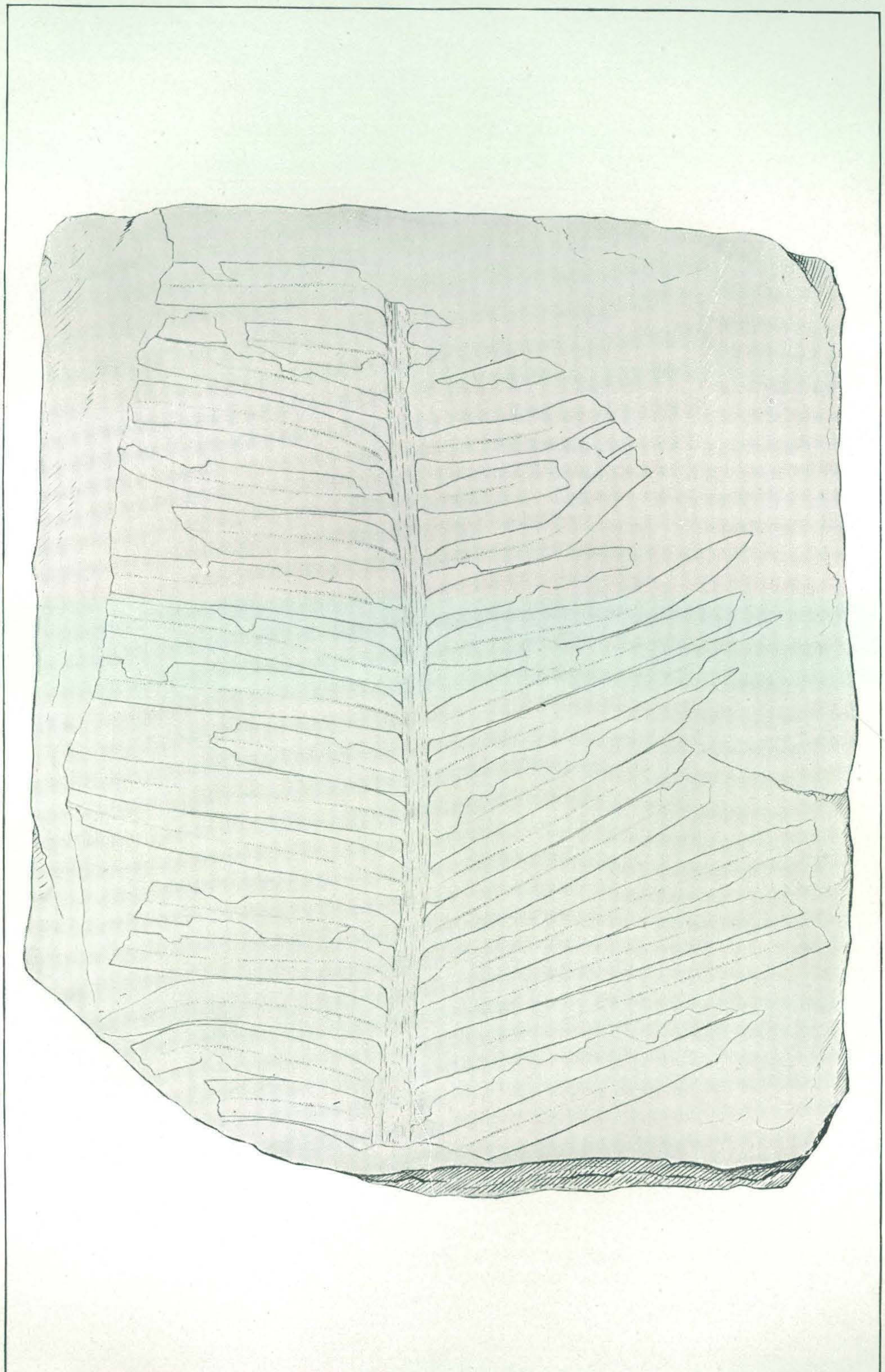
| PODOZAMITES LONGIFOLIUS Emm | 294 |



PODOZAMITES LONGIFOLIUS, FROM THE TRIAS OF NORTH CAROLINA.

# PLATE XLI.

## PLATE XLI.

PODOZAMITES LONGIFOLIUS, FROM THE TRIAS OF NORTH CAROLINA.

# PLATE XLII.

## PLATE XLII.

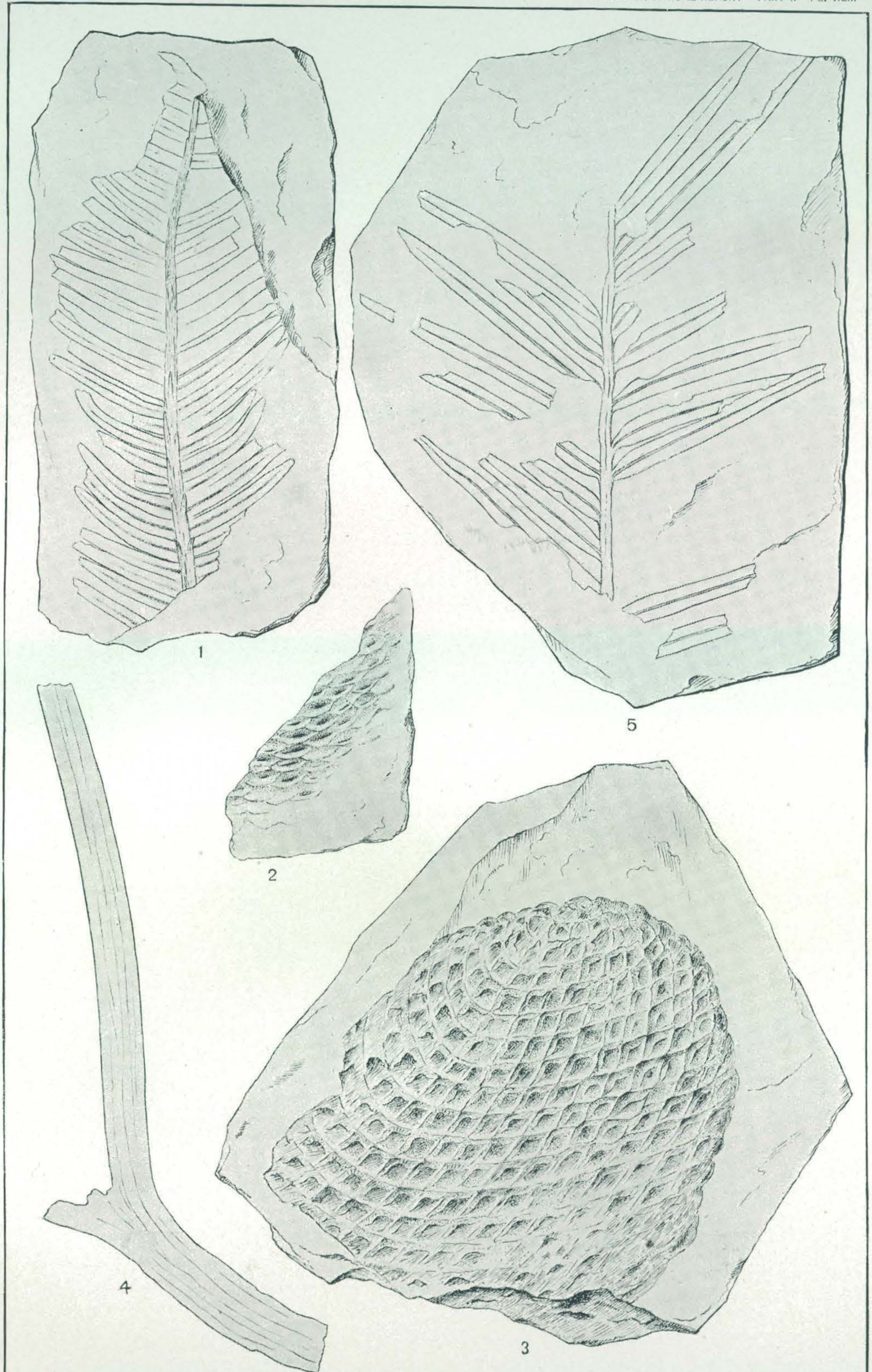


Fig. 6. Enlargement of portion of Fig. 5.


CYCADACEOUS PLANTS FROM THE TRIAS OF NORTH CAROLINA.

# PLATE XLIII.

# PLATE XLIII.




MISCELLANEOUS PLANTS FROM THE TRIAS OF NORTH CAROLINA.

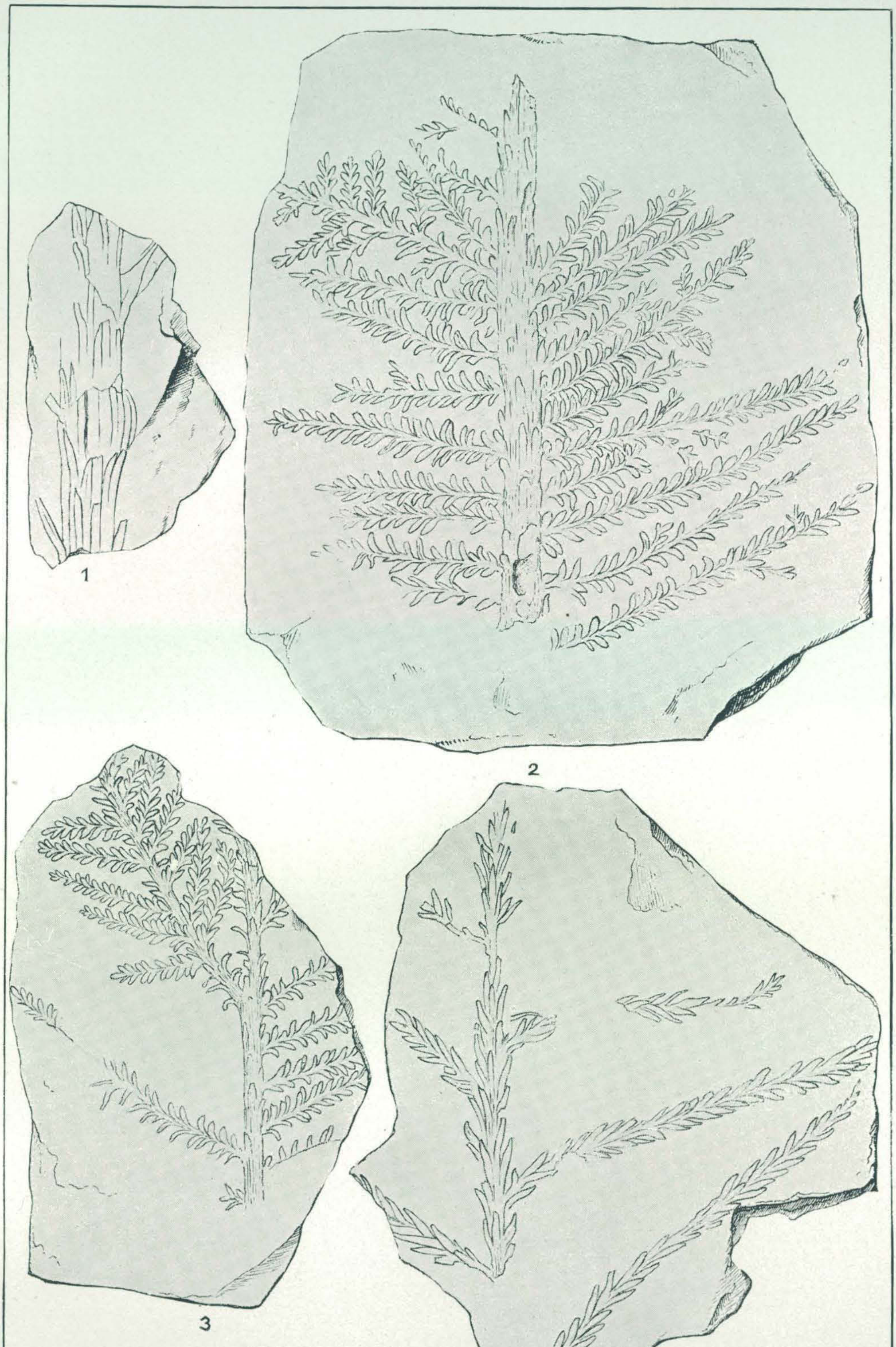
# PLATE XLIV.

## PLATE XLIV.


PALISSYA SPHENOLEPIS, FROM THE TRIAS OF NORTH CAROLINA.

# PLATE XLV.

## PLATE XLV.




PALISSYA, FROM THE TRIAS OF NORTH CAROLINA.

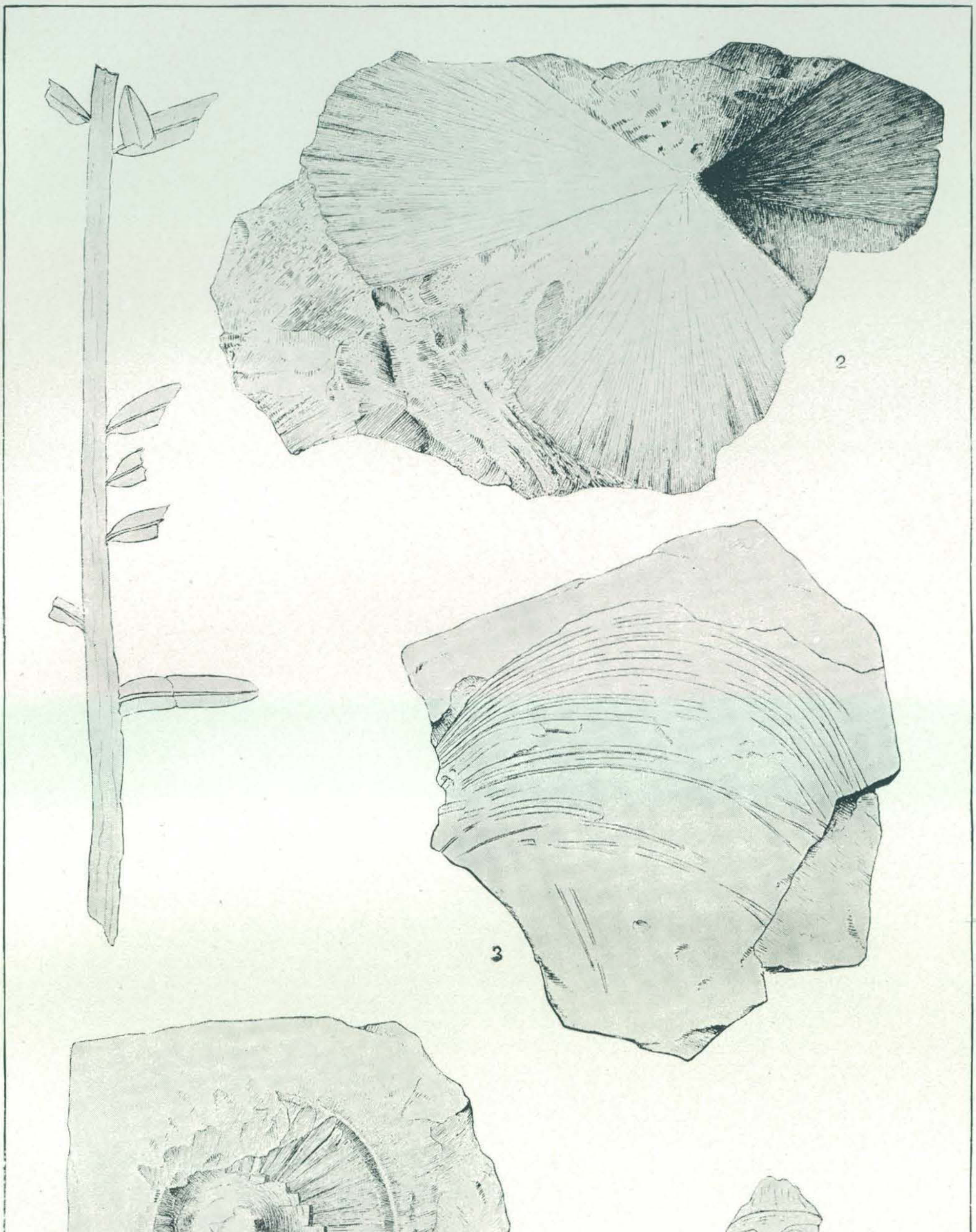
# PLATE XLVI.

## PLATE XLVI.

PAGIOPHYLLUM PEREGRINUM, FROM THE TRIAS OF NORTH CAROLINA.

# PLATE XLVII.

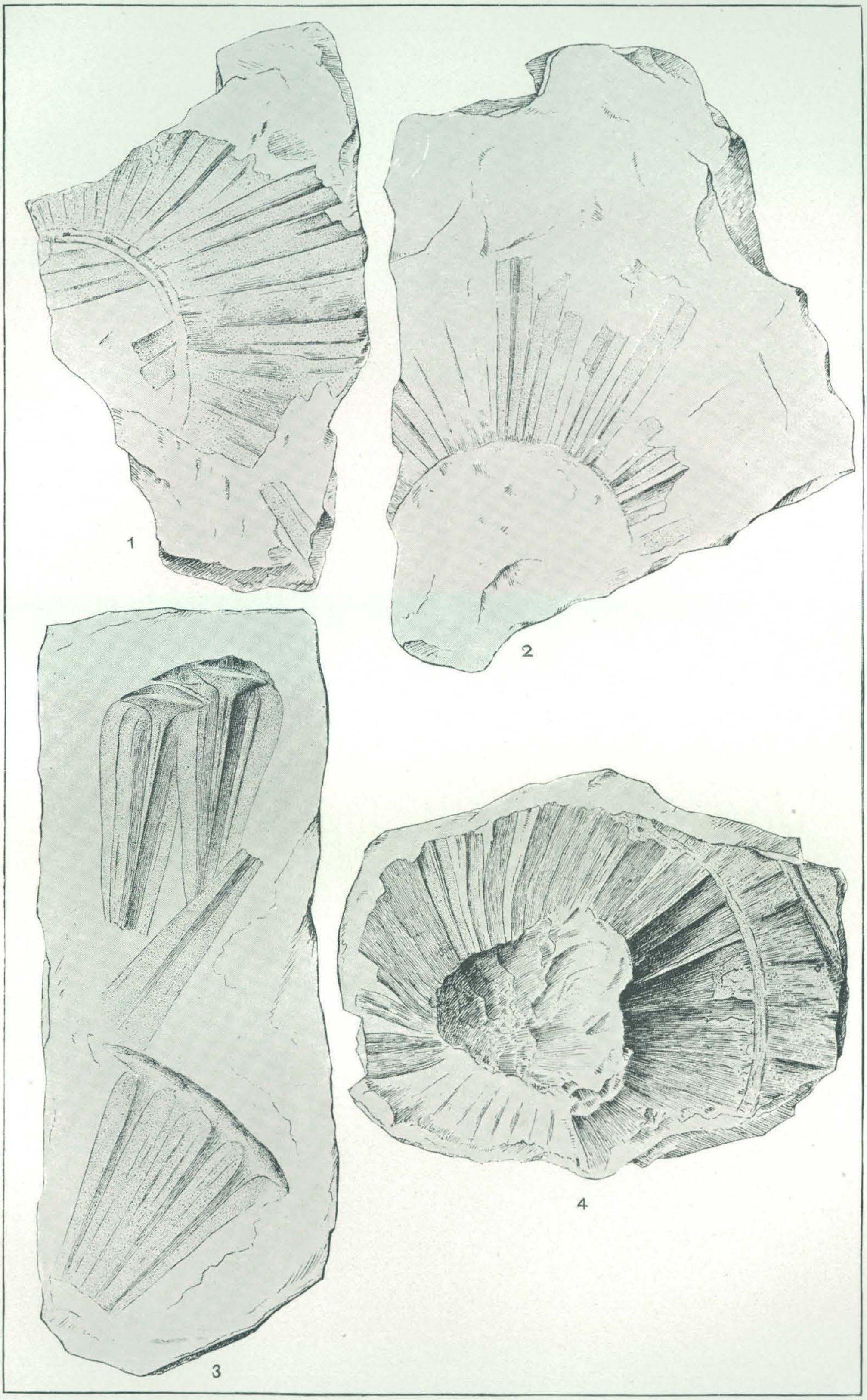
## PLATE XLVII.




PINACEOUS PLANTS AND PLANTS OF UNCERTAIN AFFINITY, FROM THE TRIAS OF NORTH CAROLINA.

# PLATE XLVIII.

## PLATE XLVIII.




LEPACYCLOTES ELLIPTICUS, FROM THE TRIAS OF NORTH CAROLINA.

# PLATE XLIX.

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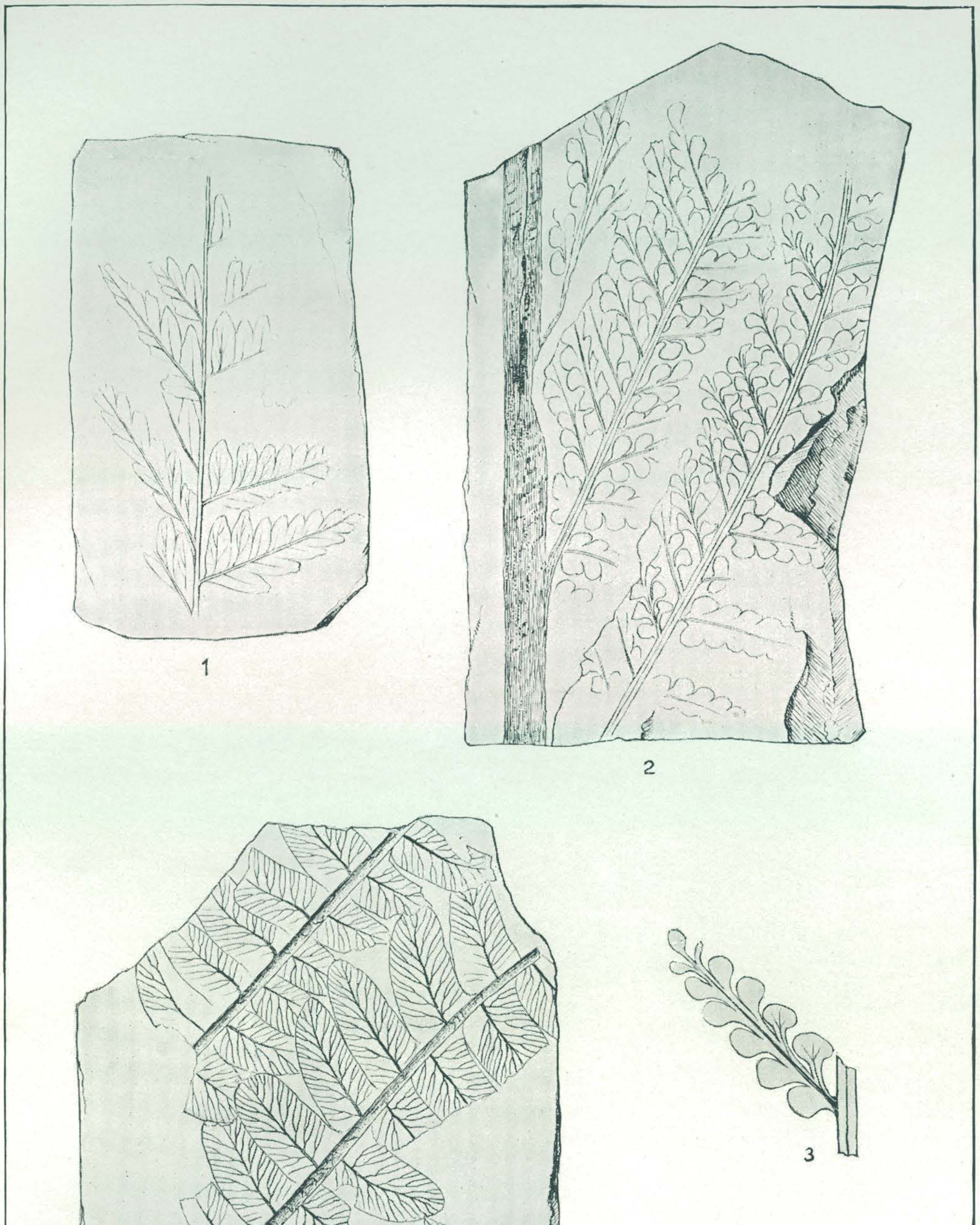
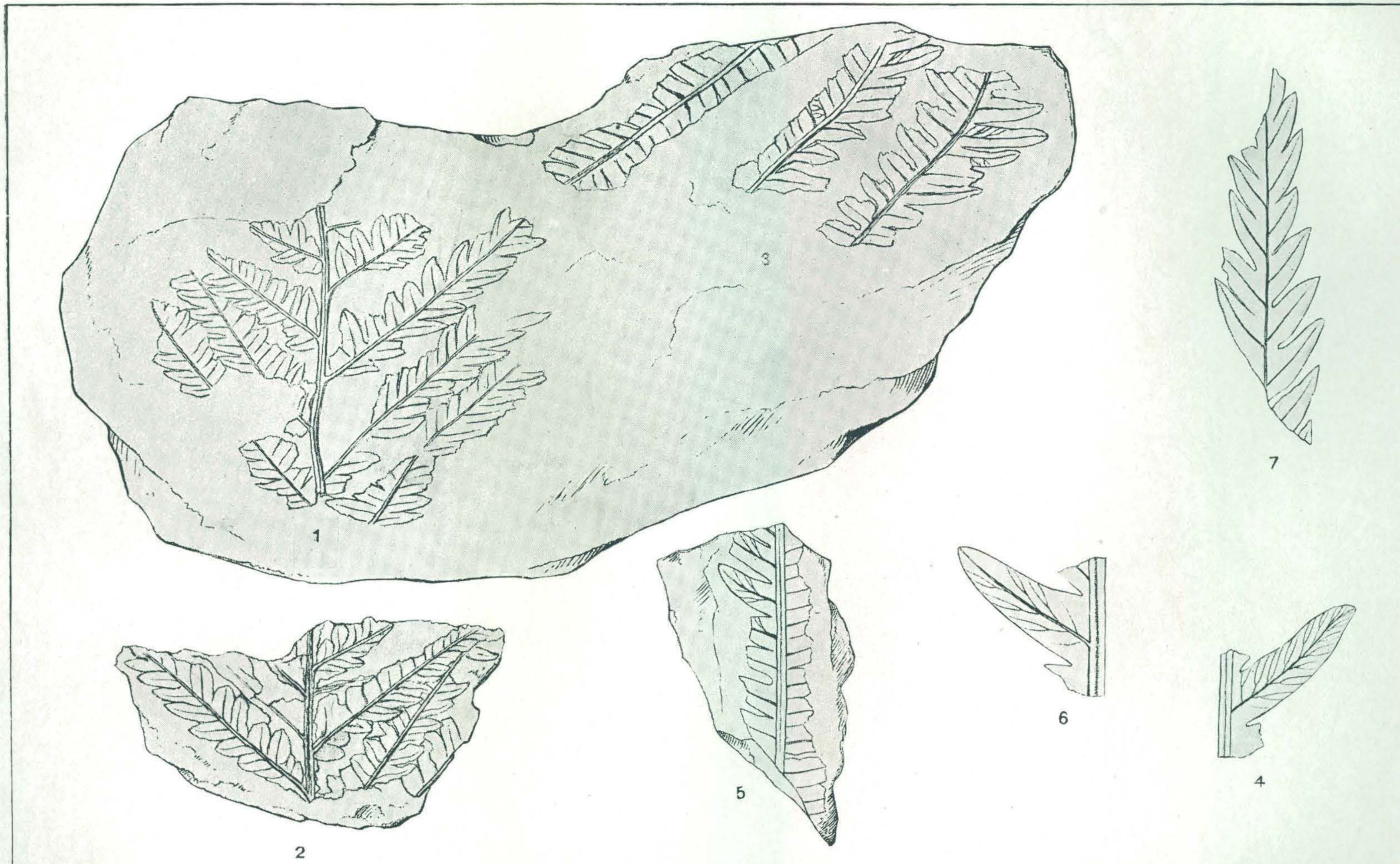
## PLATE XLIX.




FERNS FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE L.

## PLATE L.




CLADOPHLEBIS, FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

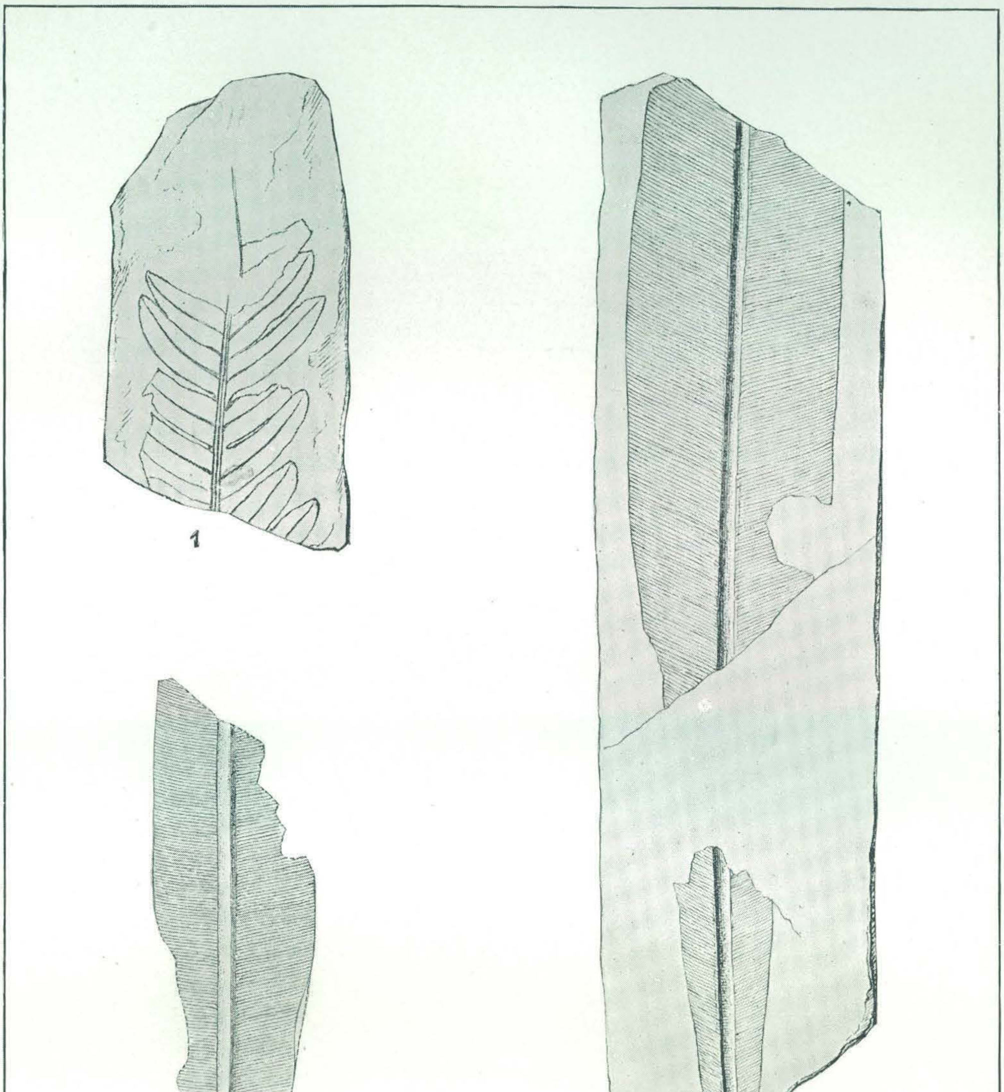
# PLATE LI.

## PLATE LI.


CLADOPHLEBIS DENSIFOLIA, FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LII.

## PLATE LII.




FERNS FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LIII.

# PLATE LIII.


FERNS AND CYCADACEOUS PLANTS FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LIV.

## PLATE LIV.

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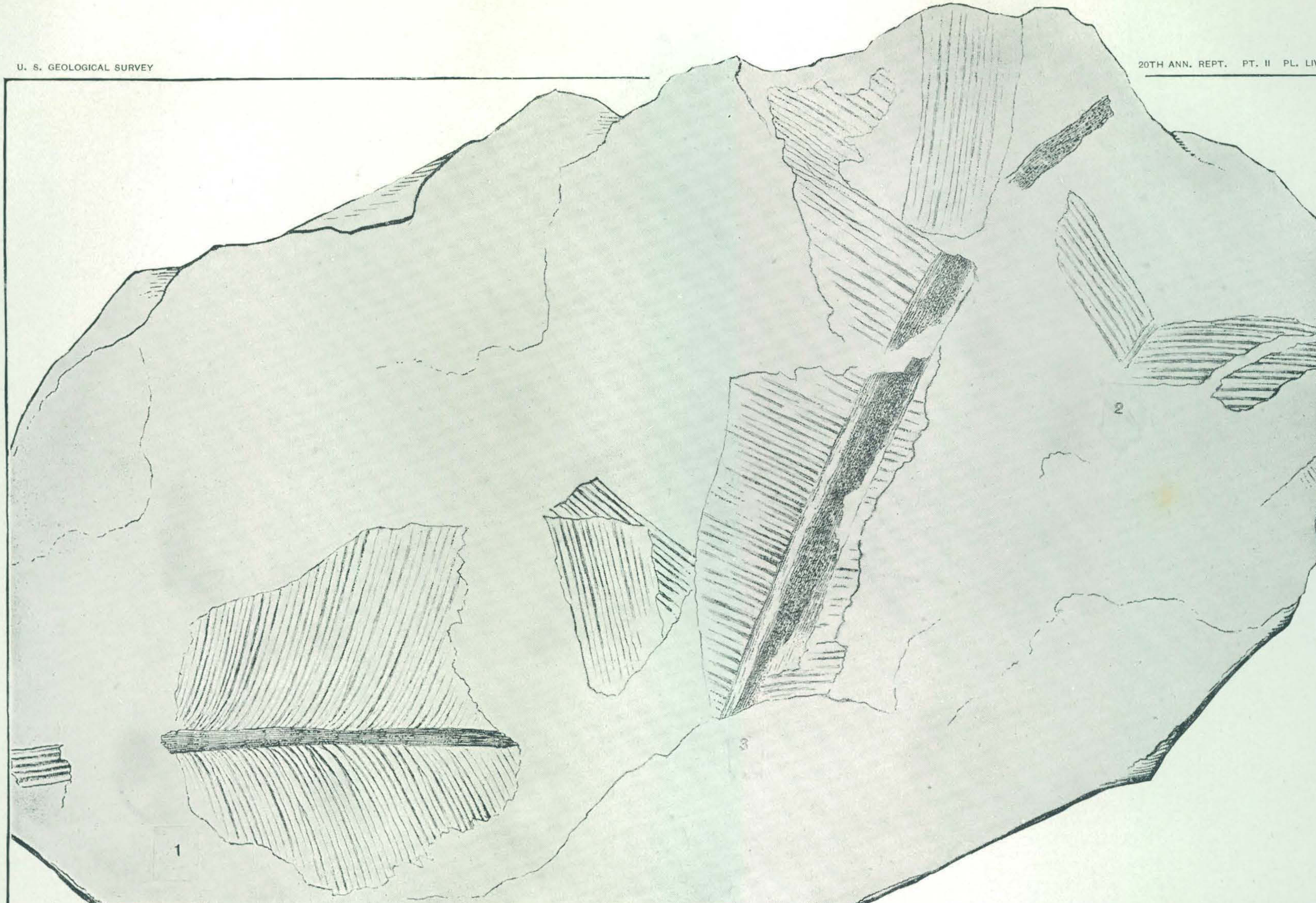
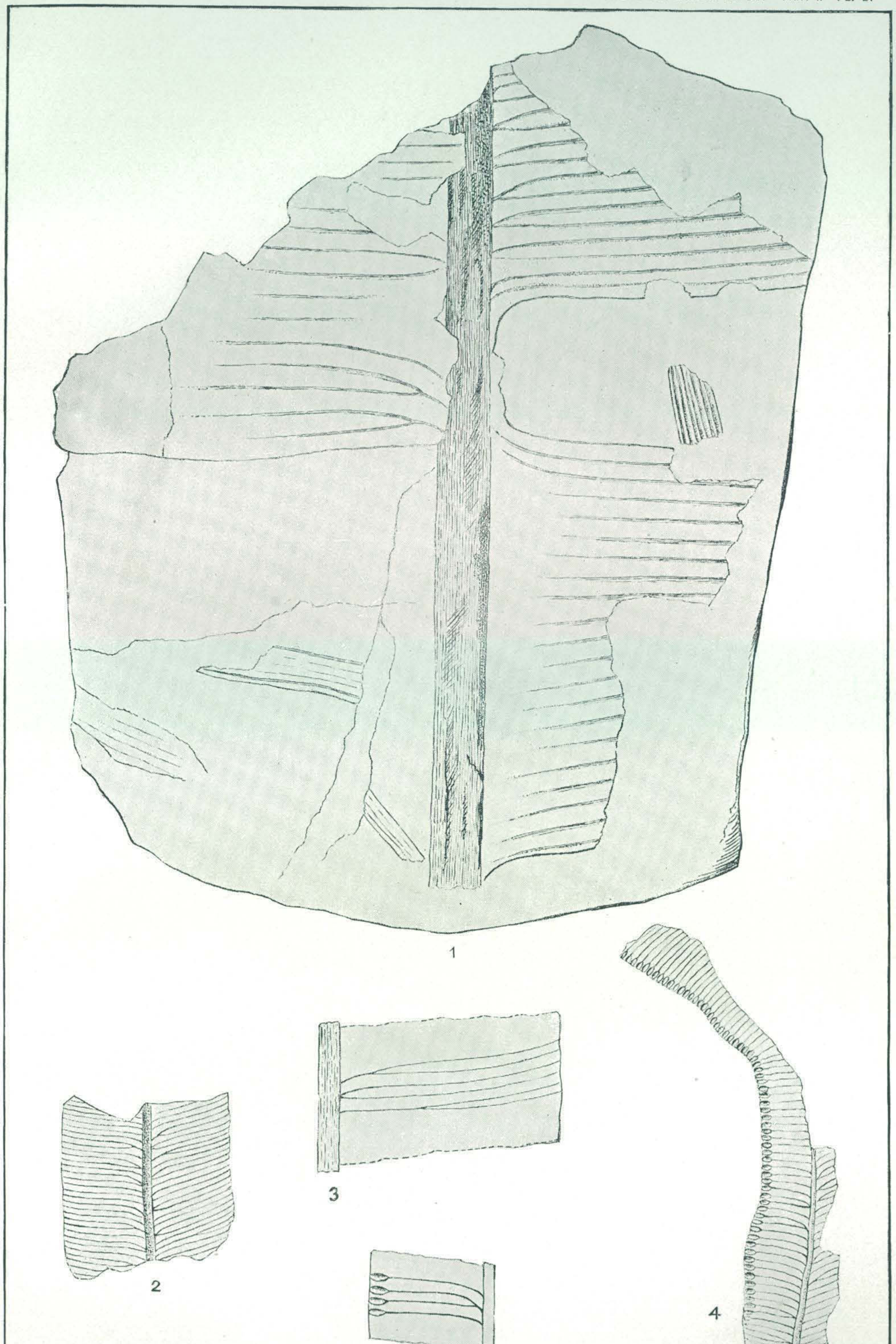
|---|---|---|
| Figs. 1, 2. | MACROTÆNIOPTERIS CALIFORNICA Font | 349 |
| Fig. 3. | MACROTÆNIOPTERIS NERVOSA Font | 350 |




MACROTÆNIOPTERIS, FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LV.

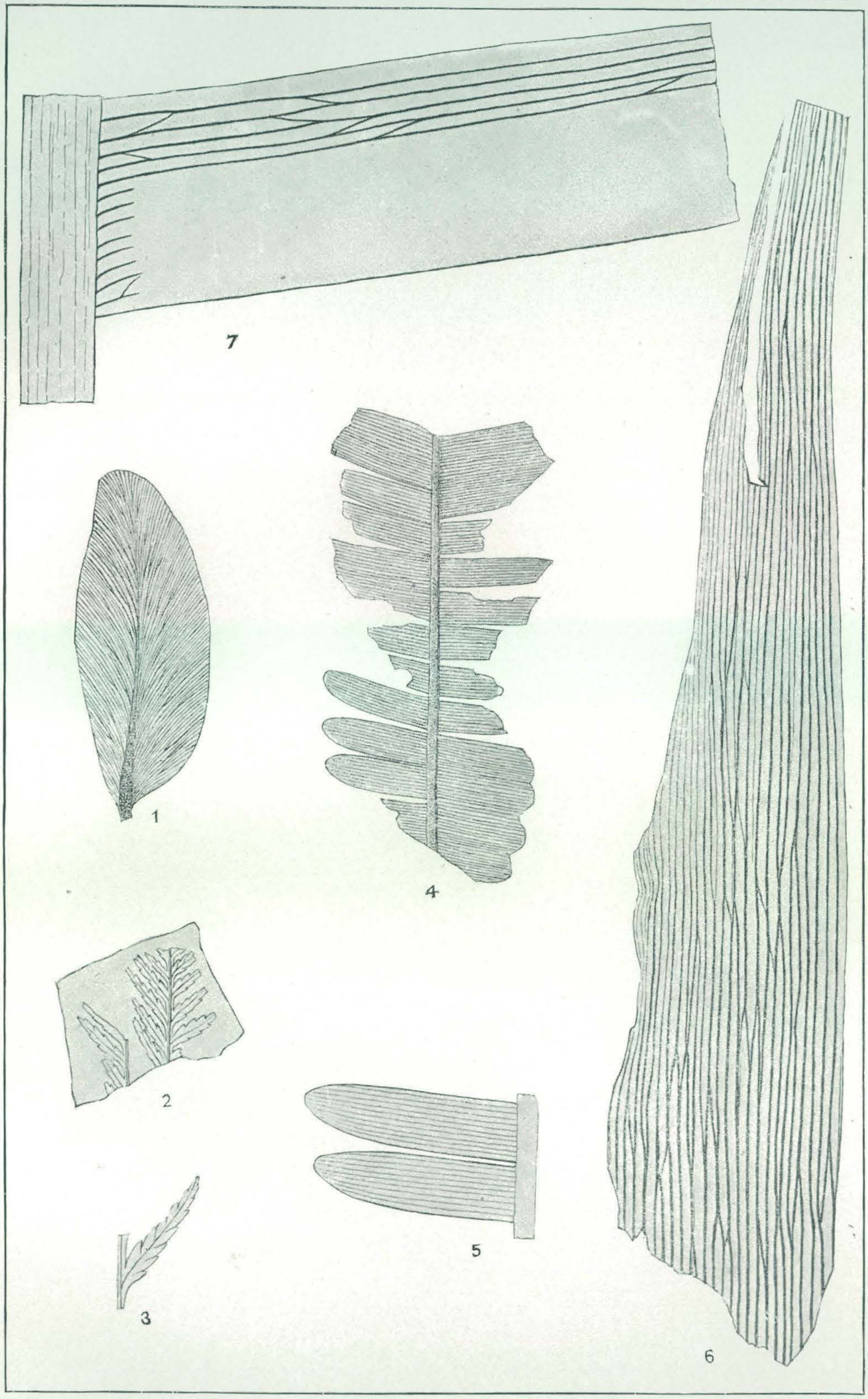
# PLATE LV.




FERNS FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LVI.

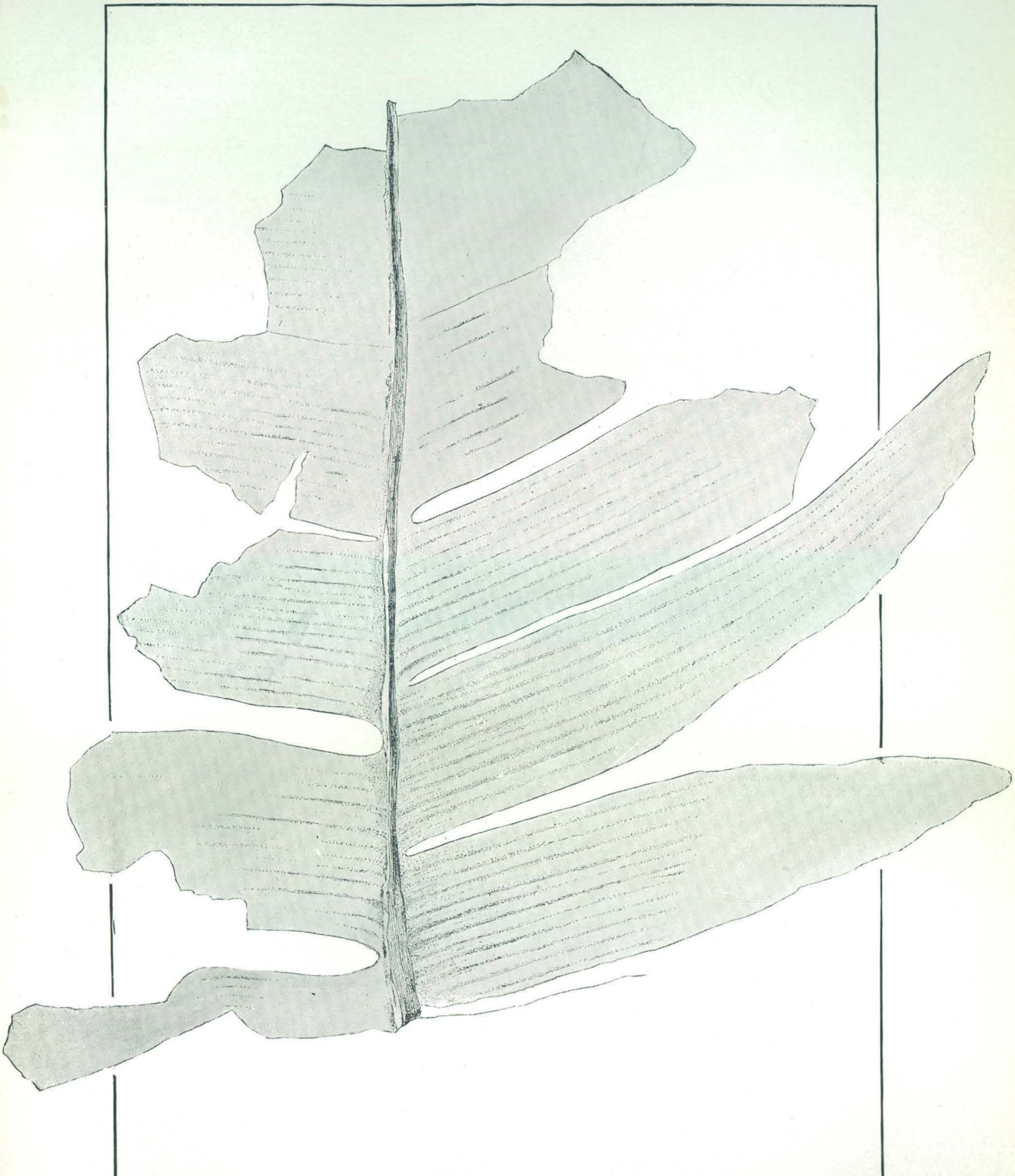
## PLATE LVI.




FERNS AND CYCADACEOUS PLANTS FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LVII.

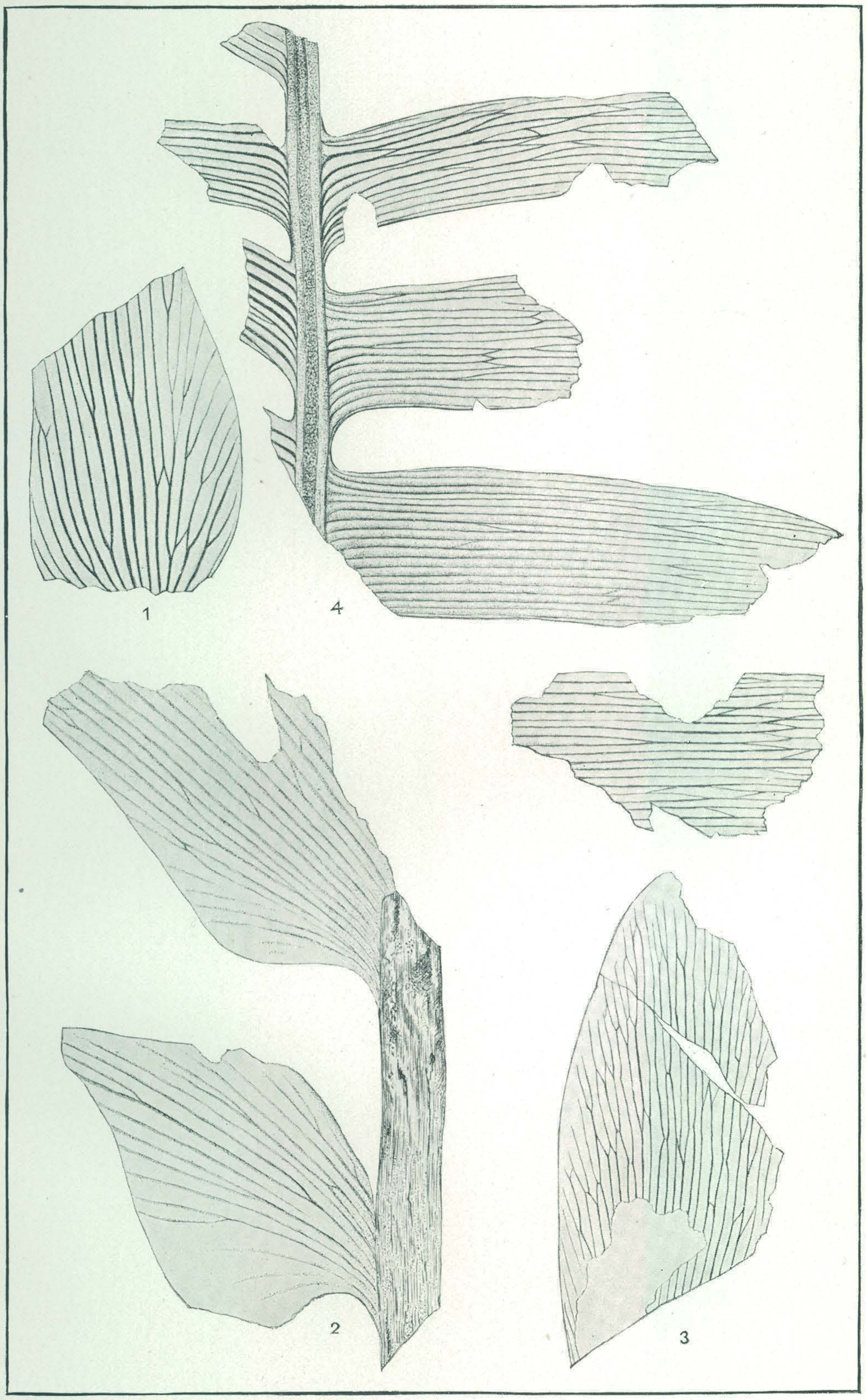
# PLATE LVII.



CTENIS GRANDIFOLIA, FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LVIII.

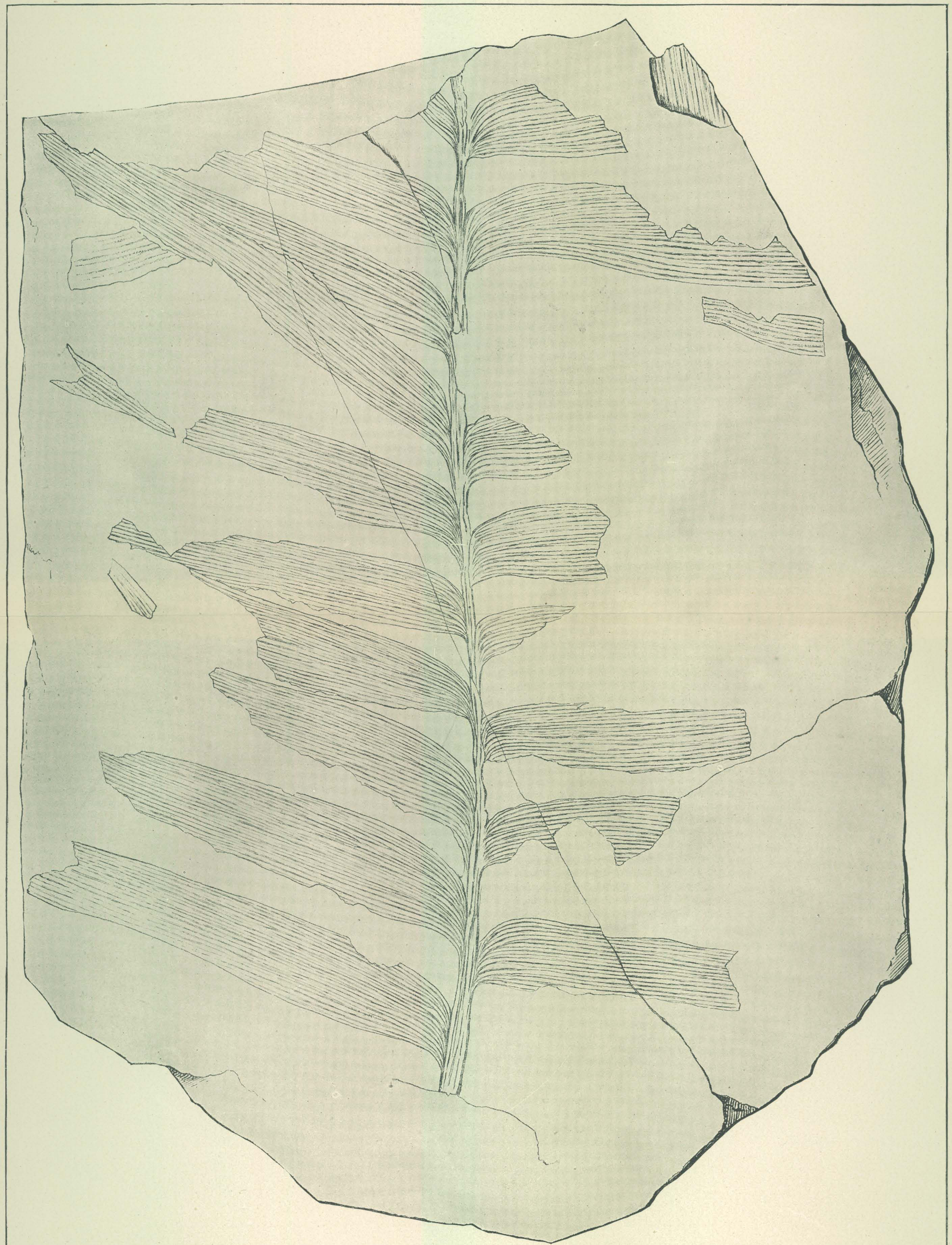
## PLATE LVIII.




ÇTENIS, FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LIX.

# PLATE LIX.



CTENOPHYLLUM WARDII, FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

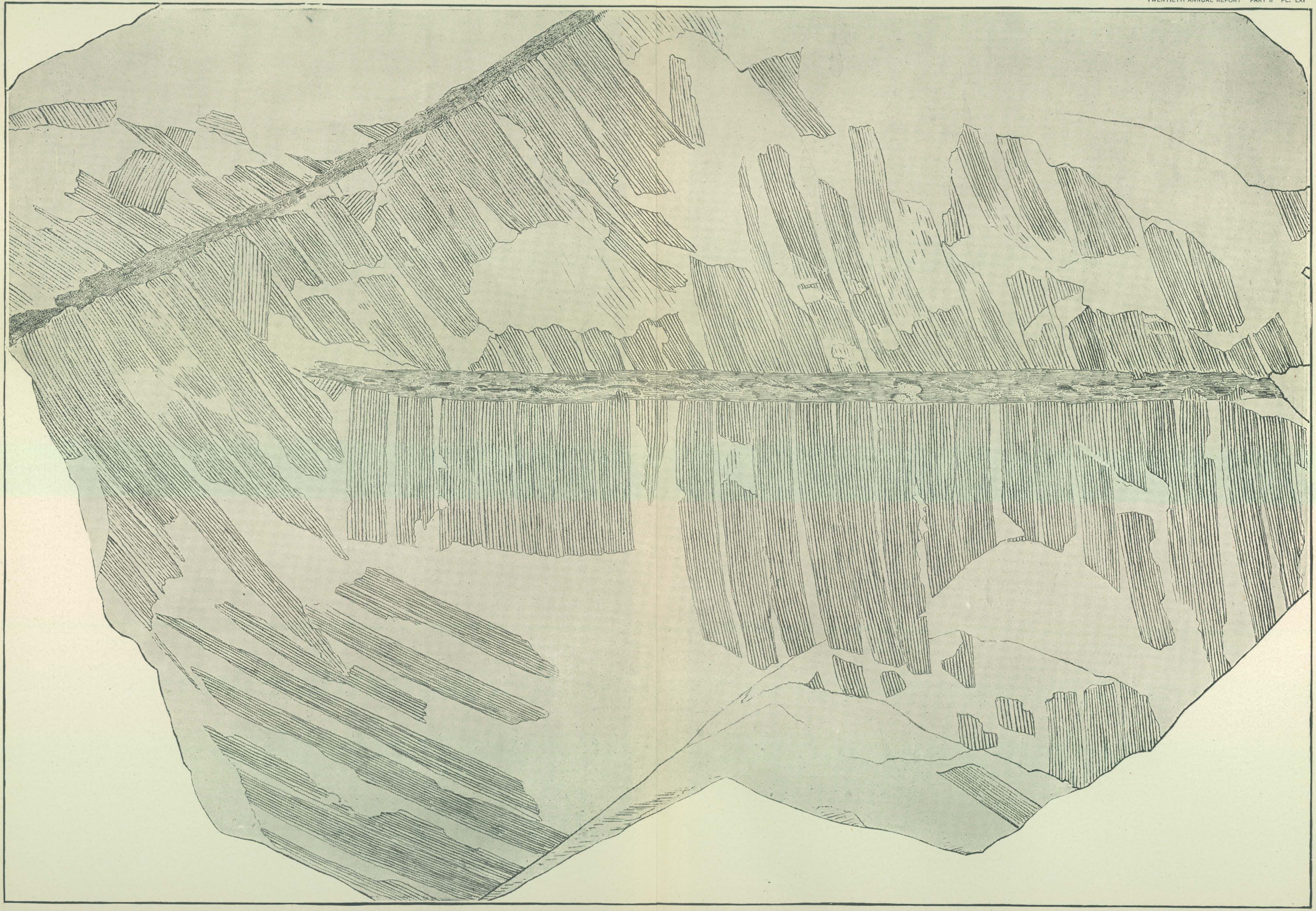
# PLATE LX.

## PLATE LX.

CTENOPHYLLUM WARDII, FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LXI.

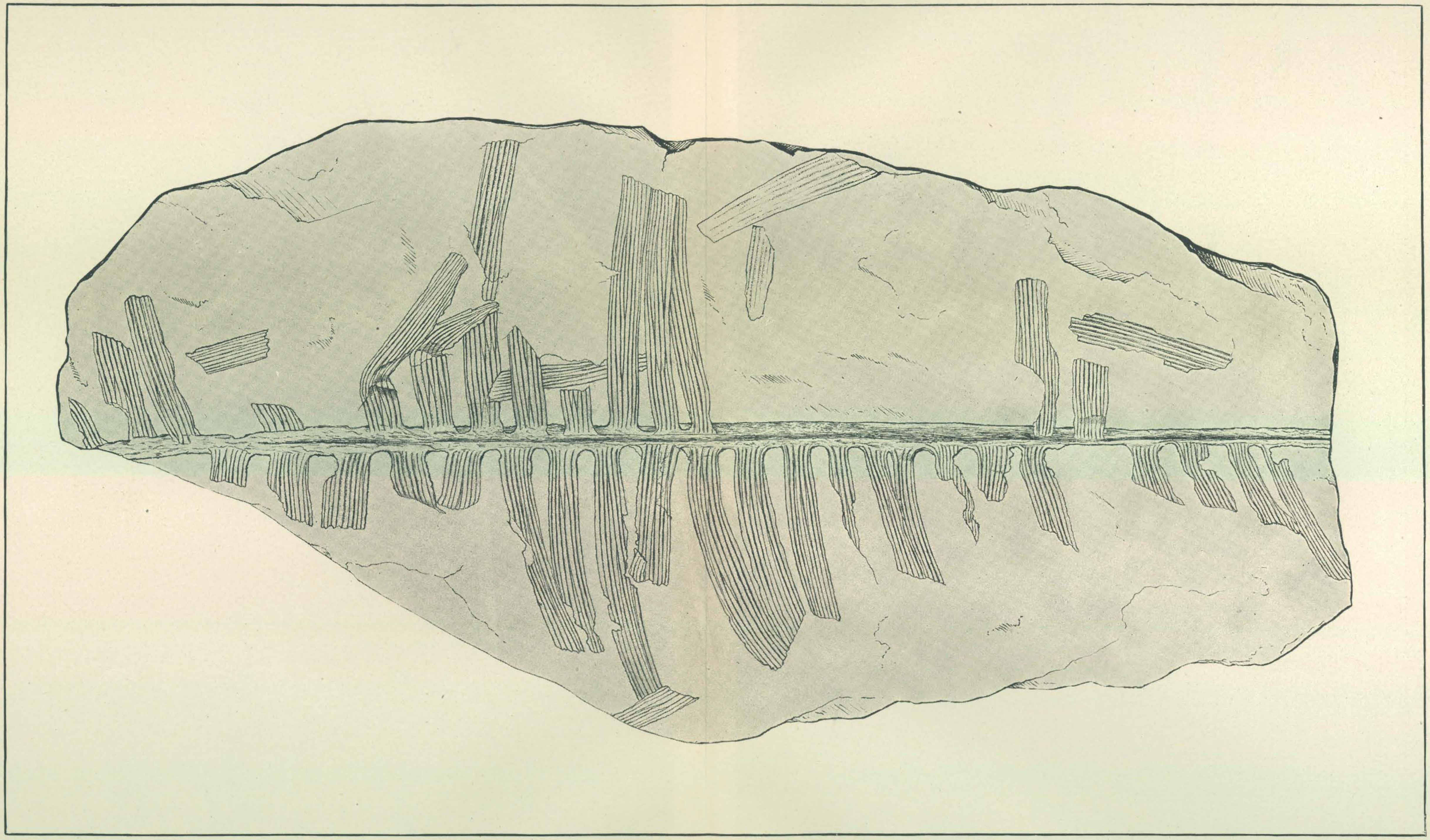
## PLATE LXI.



CTENOPHYLLUM DENSIFOLIUM, FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LXII.

## PLATE LXII.



CTENOPHYLLUM GRANDIFOLIUM STORRSII, FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LXIII.

# PLATE LXIII.

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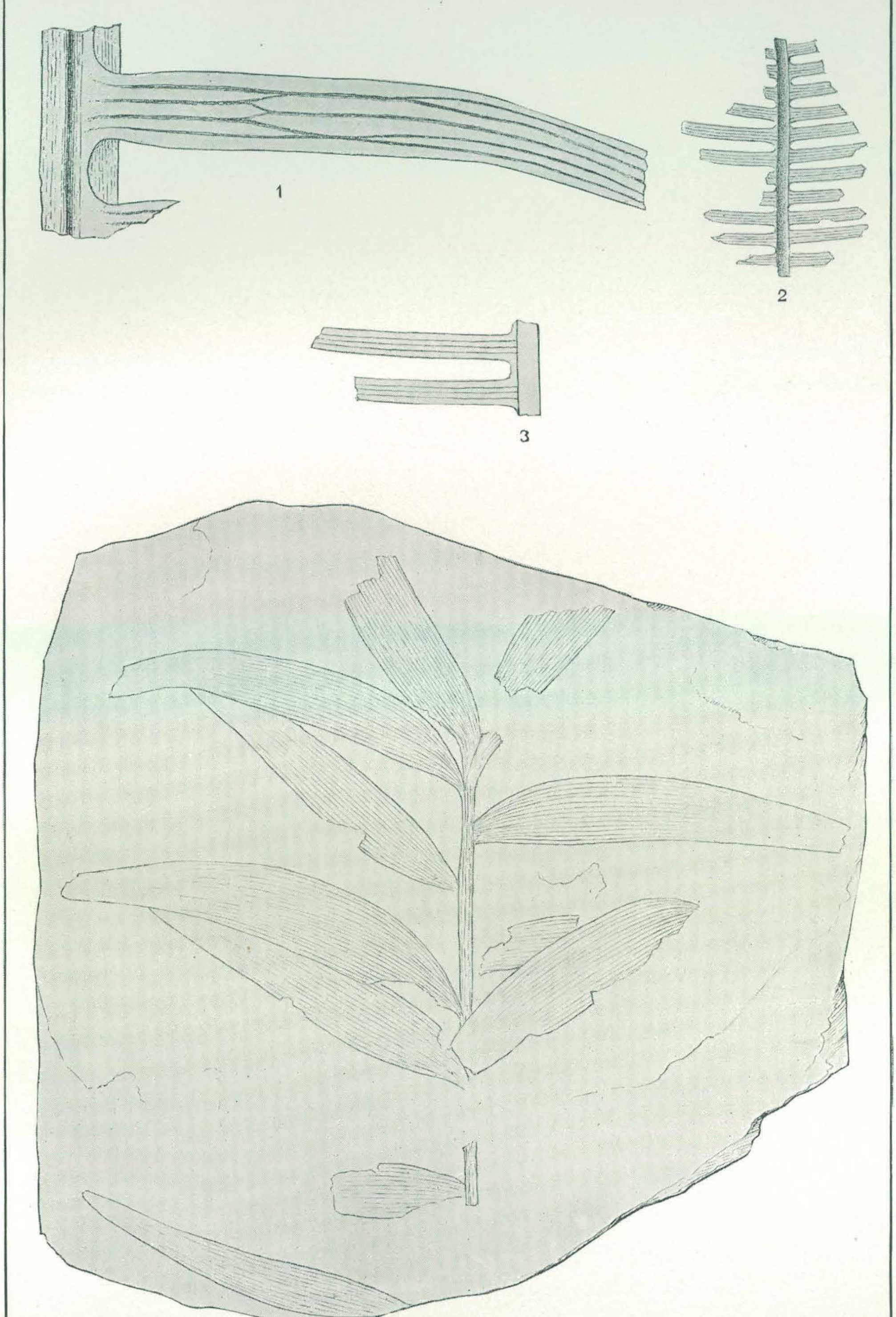
| | Fig. 3. Enlargement of portion of Fig. 2 (twice). | |
| Fig. 4. | PODOZAMITES LANCEOLATUS (L. and H.) Fr. Braun | 360 |




CYCADACEOUS PLANTS FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LXIV.

# PLATE LXIV.

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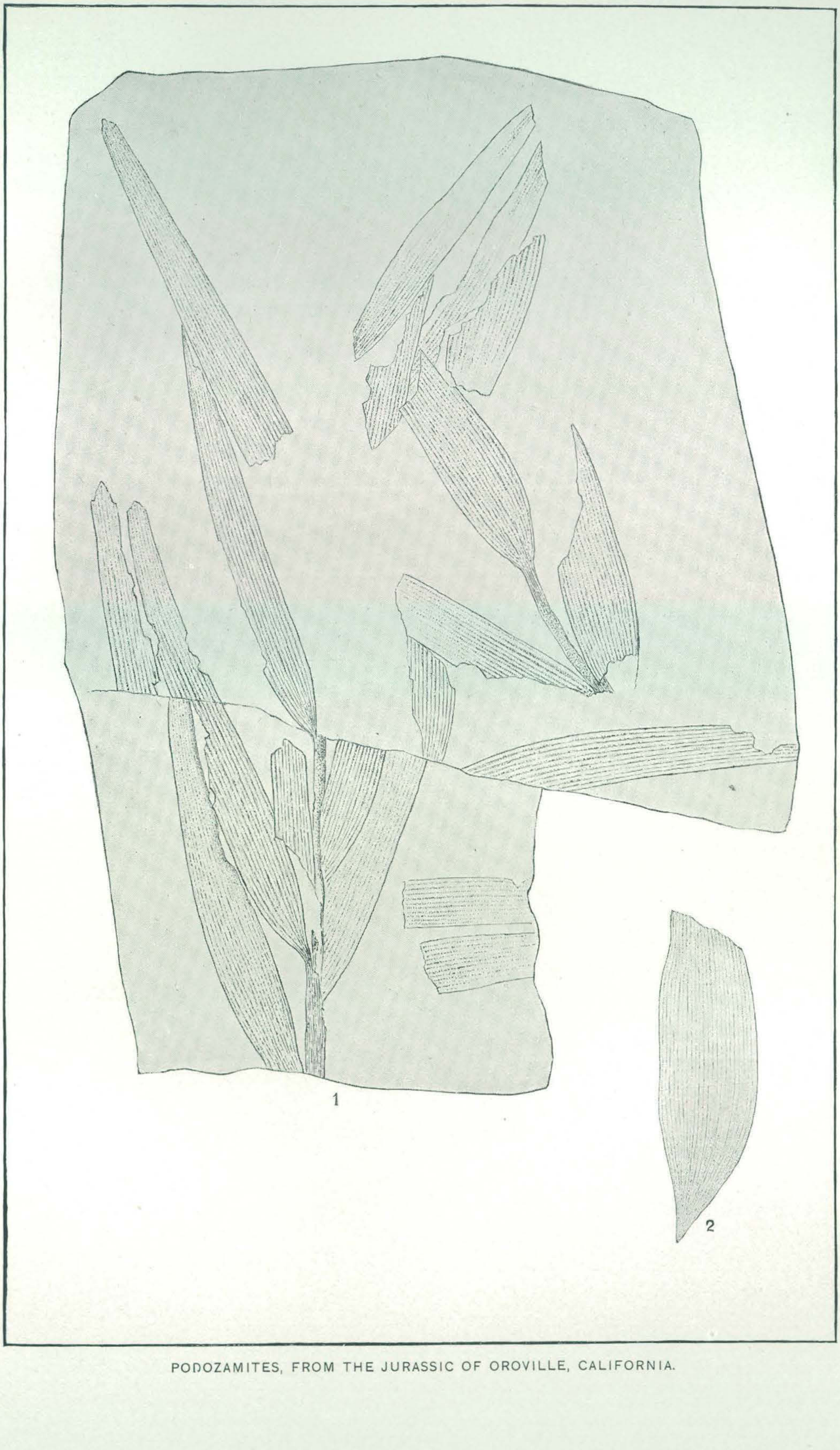
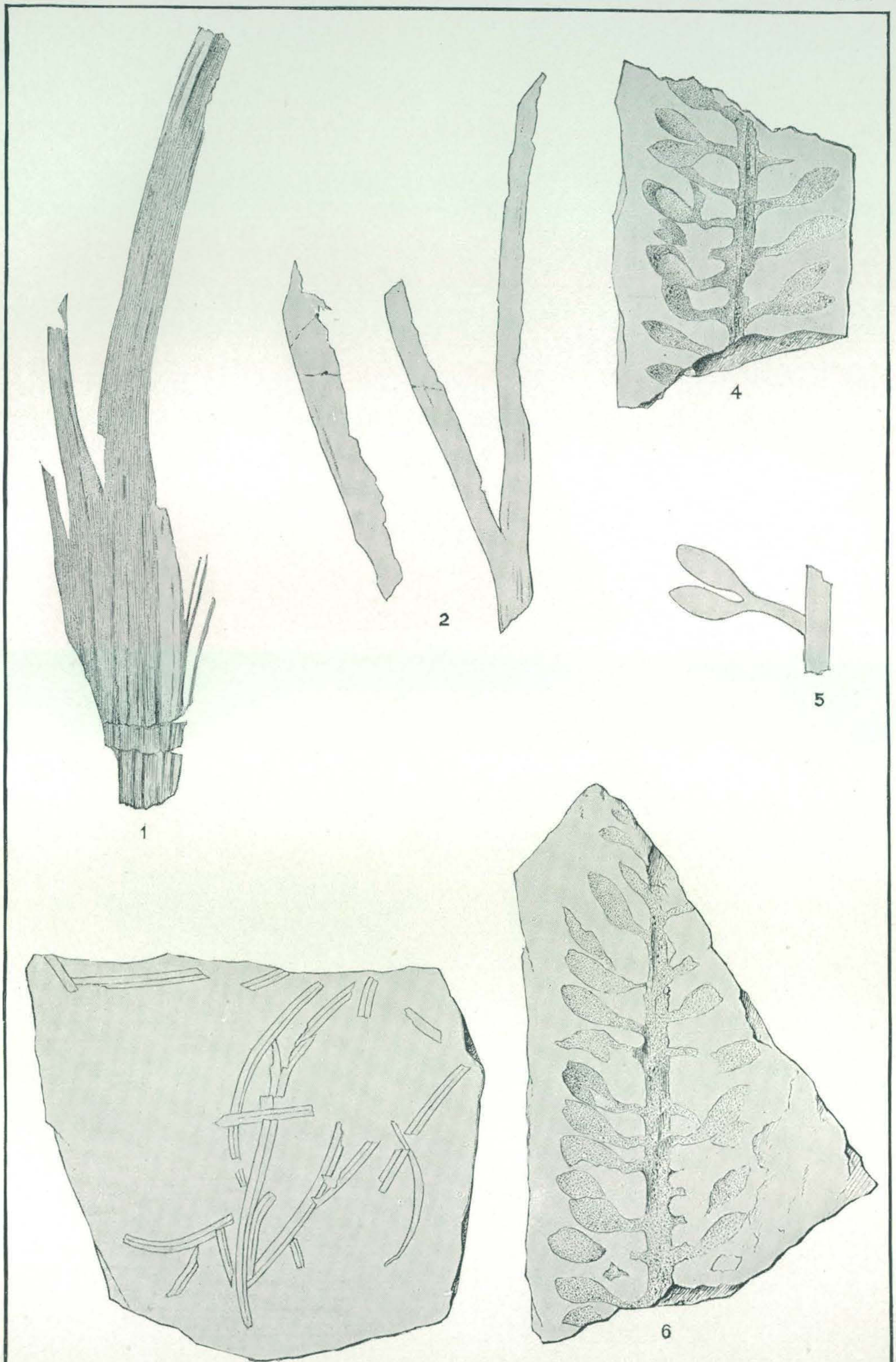
| Fig. 1. | Podozamites lanceolatus (L. and H.) Fr. Braun | 360 |
| Fig. 2. | Podozamites lanceolatus latifolius (Brongn.) Heer | 361 |




PODOZAMITES, FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LXV.

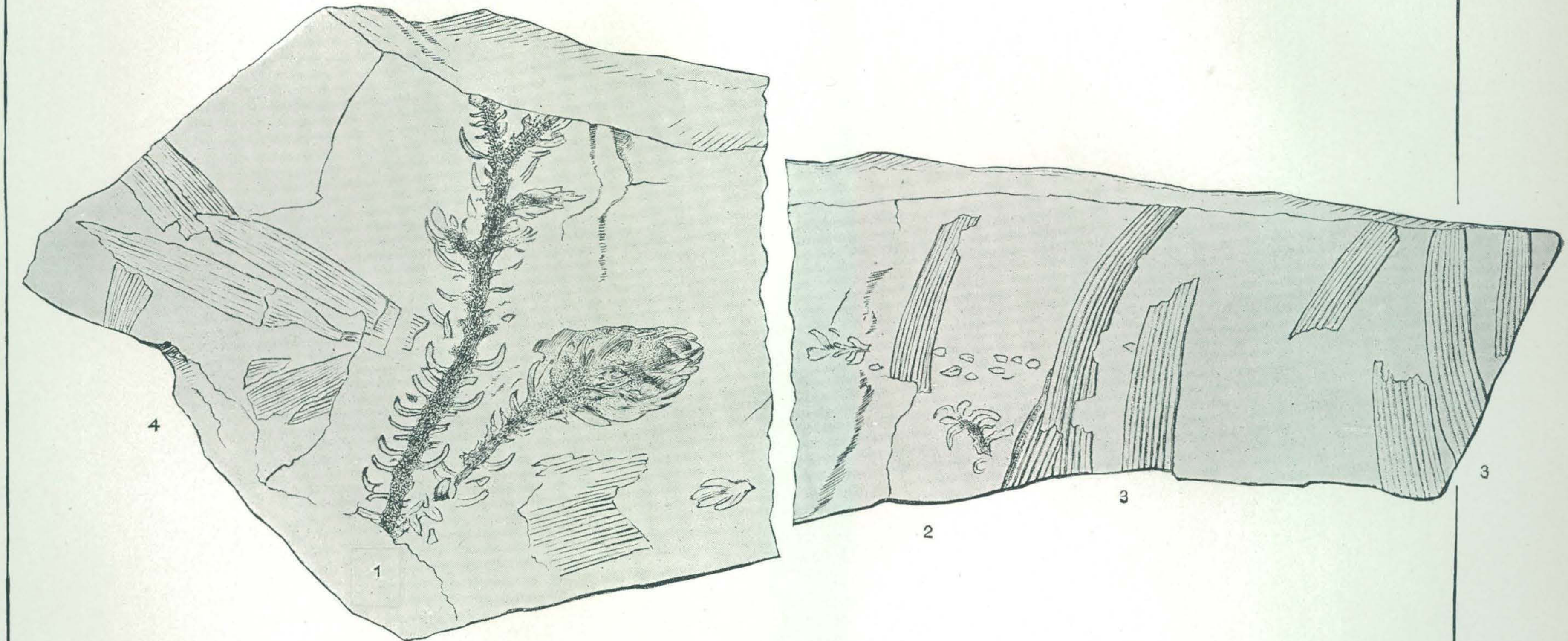
## PLATE LXV.




MISCELLANEOUS PLANTS FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LXVI.

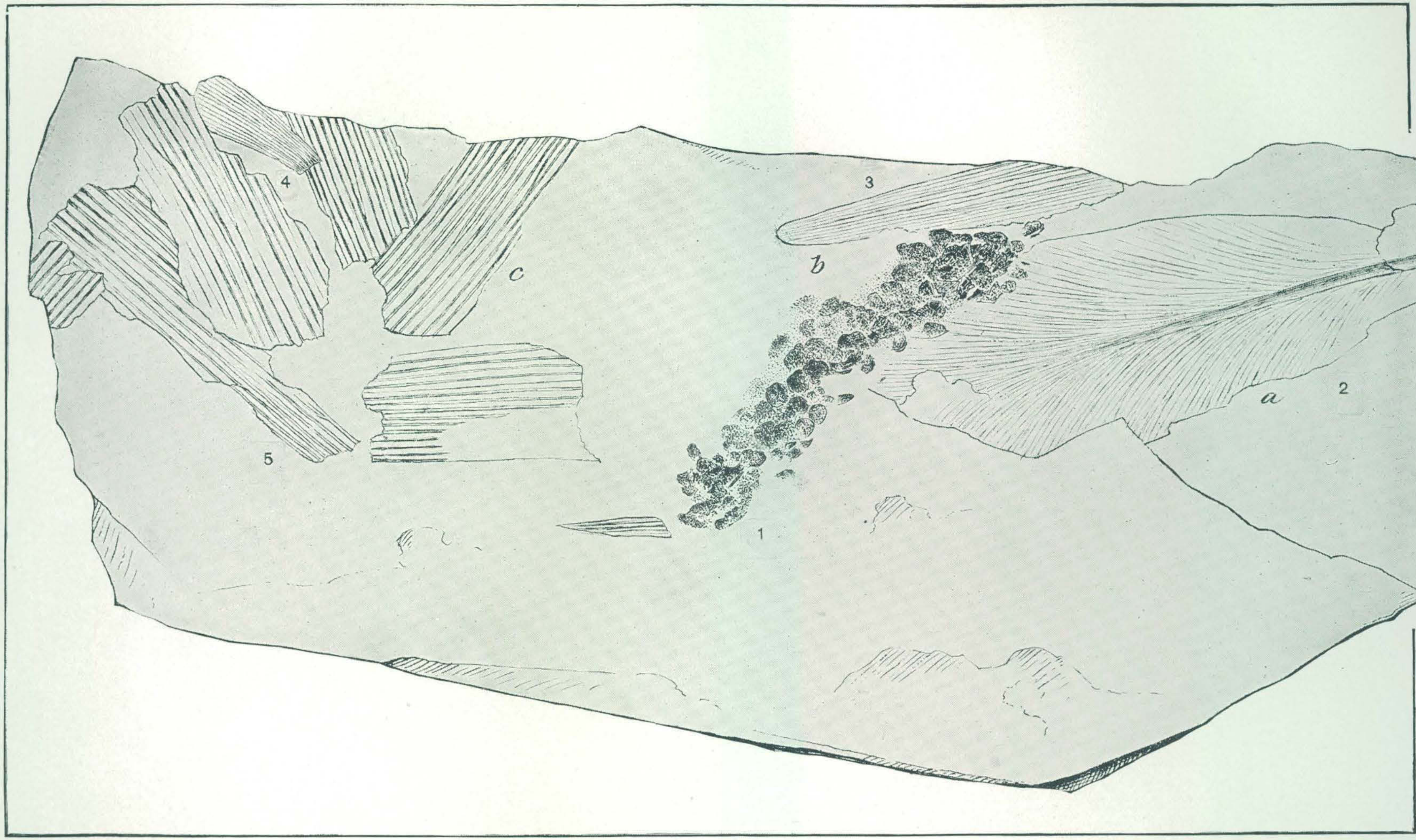
## PLATE LXVI.




PINACEOUS AND CYCADACEOUS PLANTS FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LXVII.

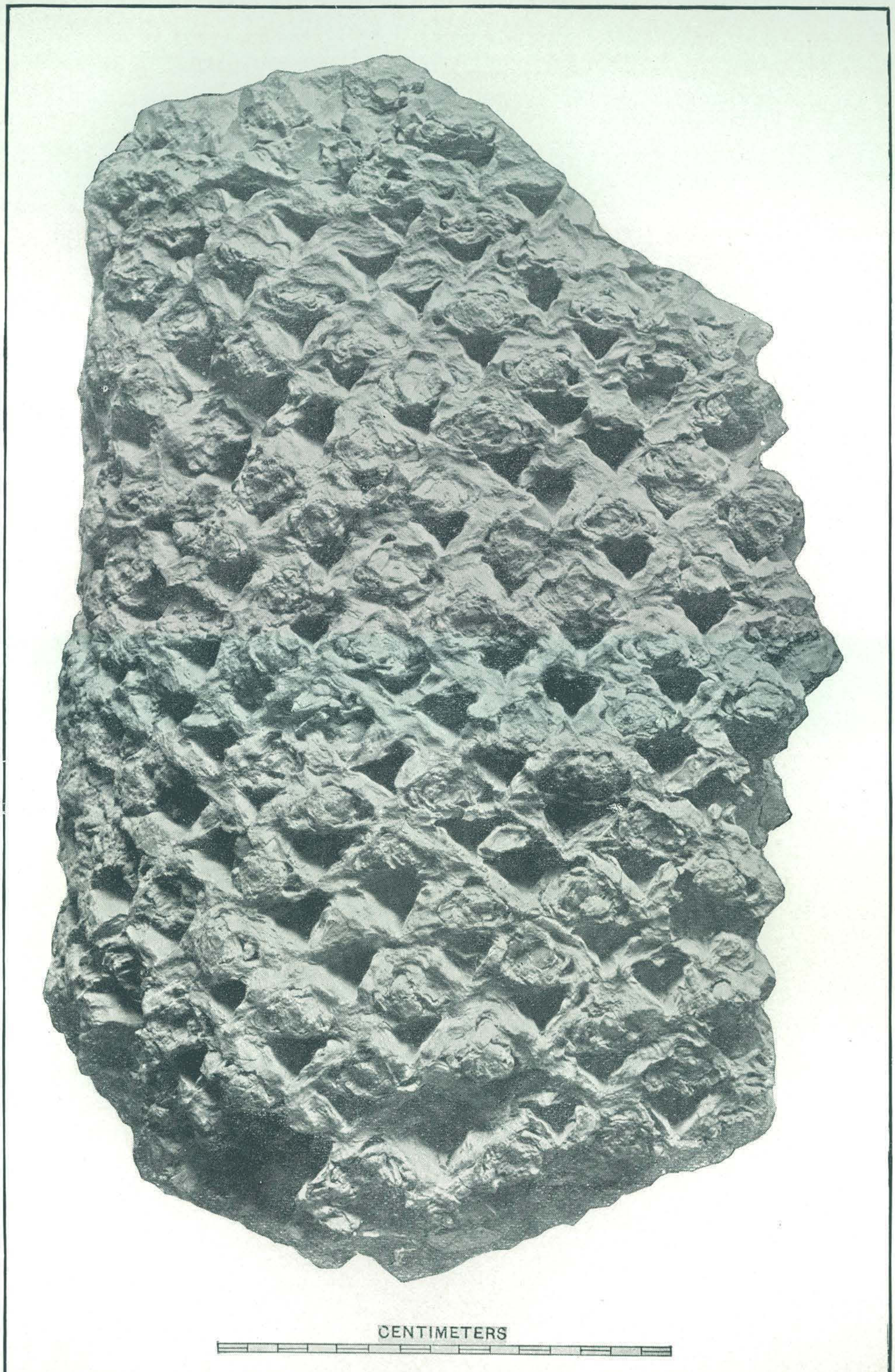
## PLATE LXVII.




MISCELLANEOUS PLANTS FROM THE JURASSIC OF OROVILLE, CALIFORNIA.

# PLATE LXVIII.

## PLATE LXVIII.




CYCADEOIDEA NIGRA, FROM THE SUPPOSED JURASSIC OF COLORADO.

# PLATE LXIX.

## PLATE LXIX.

Page.

Cycadeoidea nigra Ward n. sp ........................................ 378

View of the longitudinal fracture in the direction of the minor axis of the trunk.


ÇYCADEOIDEA NIGRA, FROM THE SUPPOSED JURASSIC OF COLORADO.

# PLATE LXX.

Note.—Figs. 1–3 were obtained from slides of No. 500.76 of the Museum of the University of Wyoming, and therefore belong to *C. Knowltoniana*. Figs. 4 and 5 are from No. 500.39, and therefore belong to *C. ramentosa*.

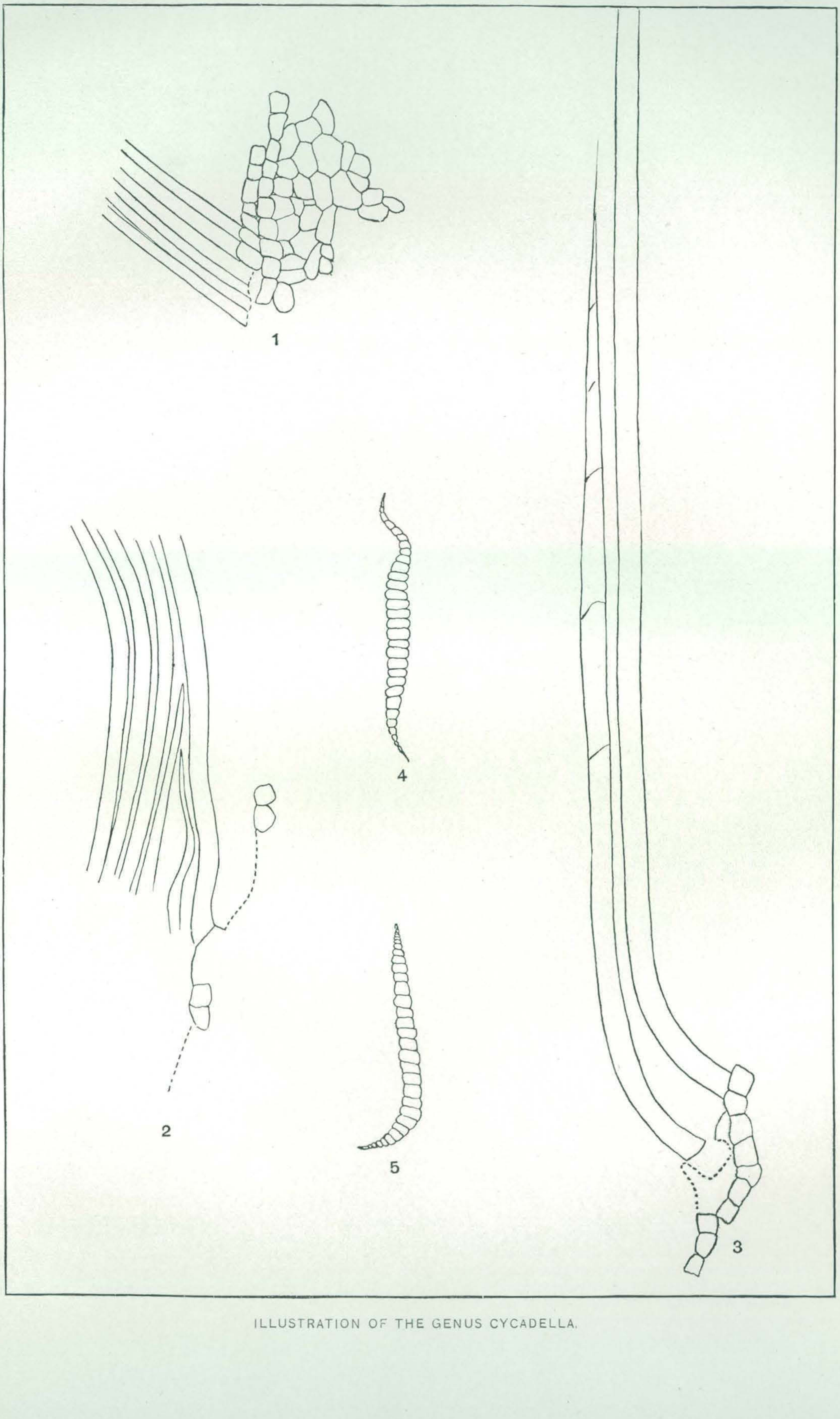
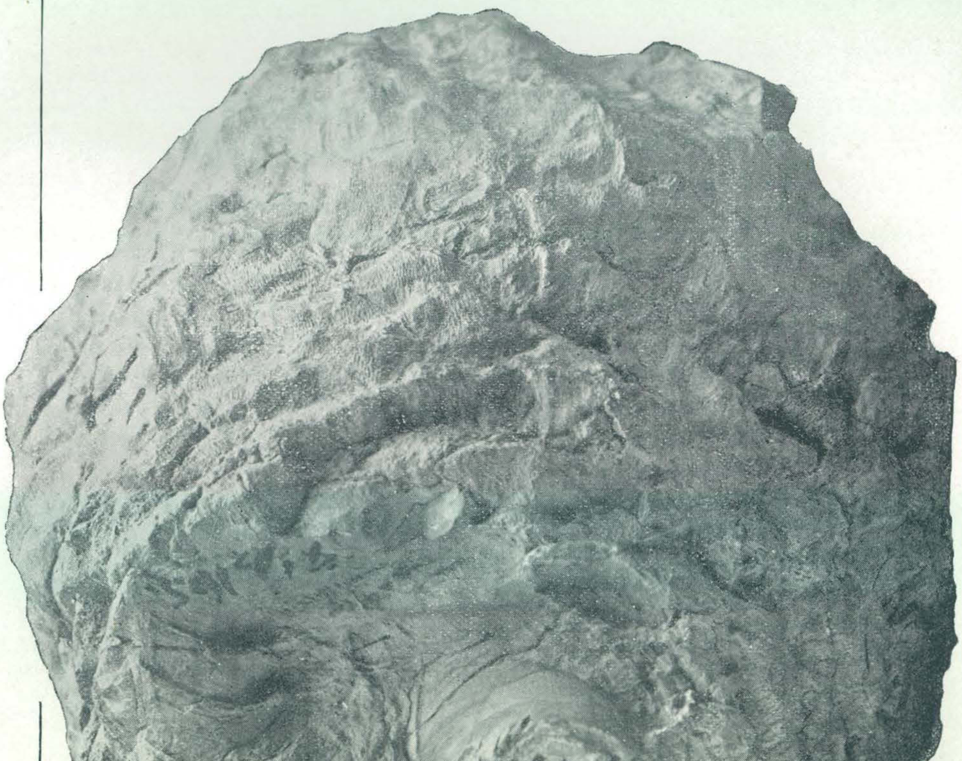



ILLUSTRATION OF THE GENUS CYCADELLA.

# PLATE LXXI.

## PLATE LXXI.




CYCADELLA REEDII, FROM THE JURASSIC OF WYOMING.

# PLATE LXXII.

## PLATE LXXII.


CYCADELLA REEDII, FROM THE JURASSIC OF WYOMING.

# PLATE LXXIII.

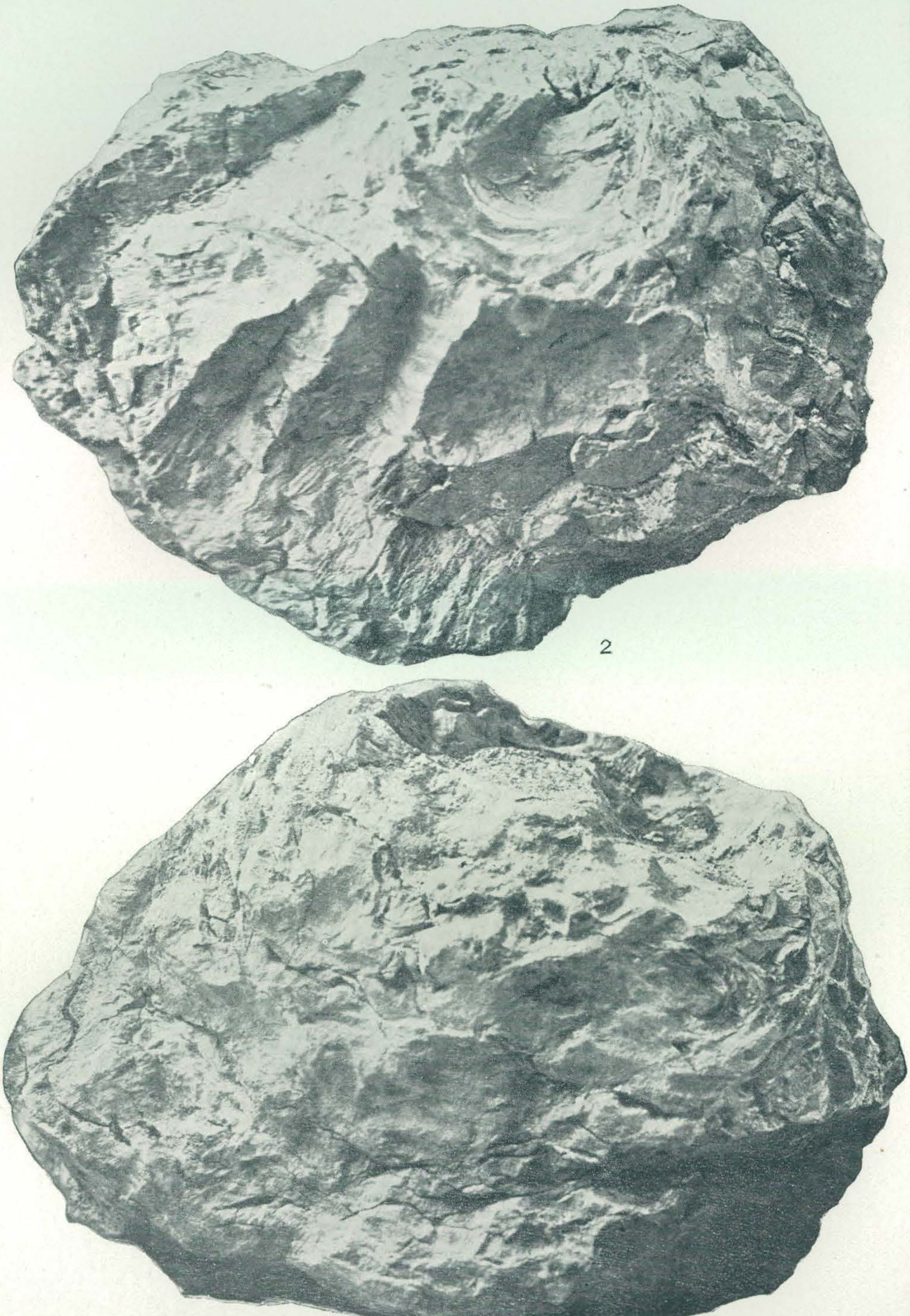
## PLATE LXXIII.

| | Page. |
|---|---|
| Cycadella Reedii Ward | 393 |

No. 500.29 of the Museum of the University of Wyoming.

Fig. 1. Side view.

Fig. 2. View of the base.




CYCADELLA REEDII, FROM THE JURASSIC OF WYOMING.

# PLATE LXXIV.

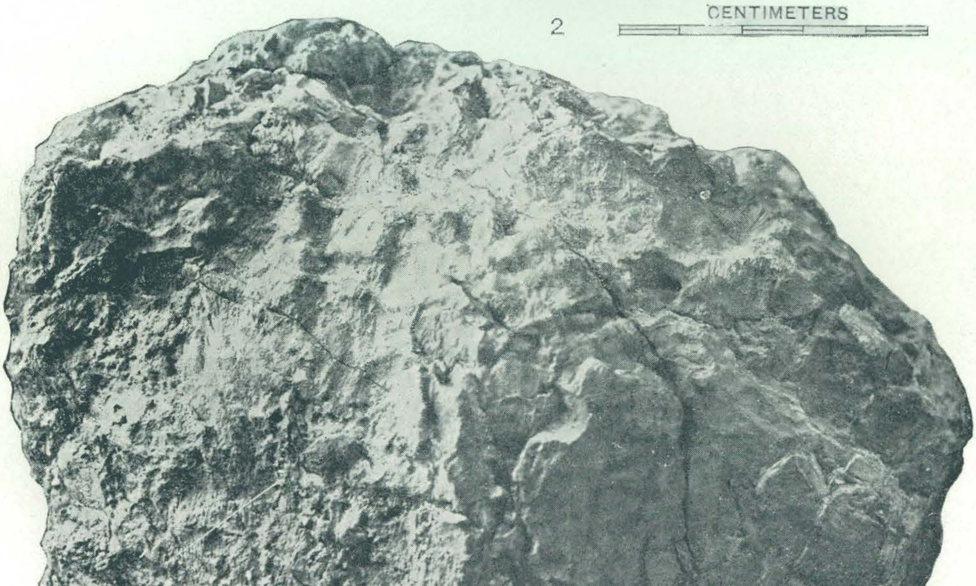
## PLATE LXXIV.



No. 500.6 of the Museum of the University of Wyoming.

Figs. 1 and 2. Views of the opposite broadest sides.

2 CENTIMETERS



1 CENTIMETERS

CYCADELLA REEDII, FROM THE JURASSIC OF WYOMING.

# PLATE LXXV.

## PLATE LXXV.



No. 500.19 of the Museum of the University of Wyoming.

Fig. 1. View of the best-preserved side.

Fig. 2. View of the base.

2

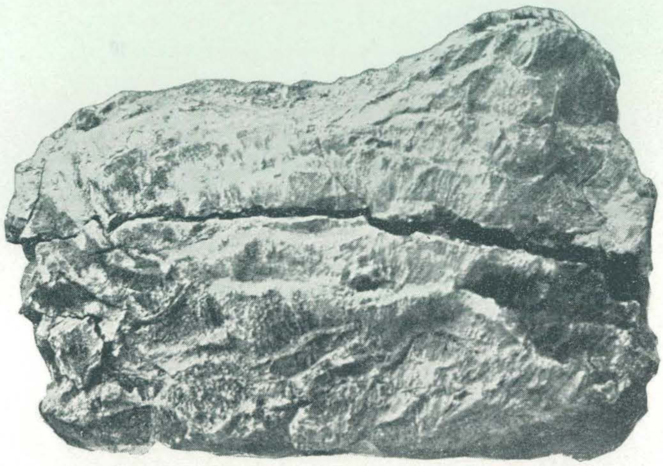
1

CENTIMETERS

CYCADELLA REEDII, FROM THE JURASSIC OF WYOMING.

# PLATE LXXVI.

## PLATE LXXVI.



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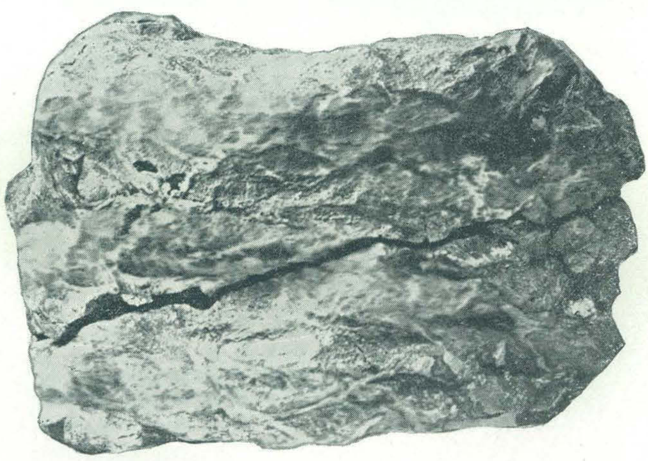

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CENTIMETERS

CYCADELLA REEDII, FROM THE JURASSIC OF WYOMING.

# PLATE LXXVII.

## PLATE LXXVII.

Page.

Cycadella Beecheriana Ward .......................................... 394

Fractured surface of No. 128 of the Yale collection (three upper pieces), and No. 500.54 of the Museum of the University of Wyoming (lower piece).


CYCADELLA BEECHERIANA, FROM THE JURASSIC OF WYOMING.

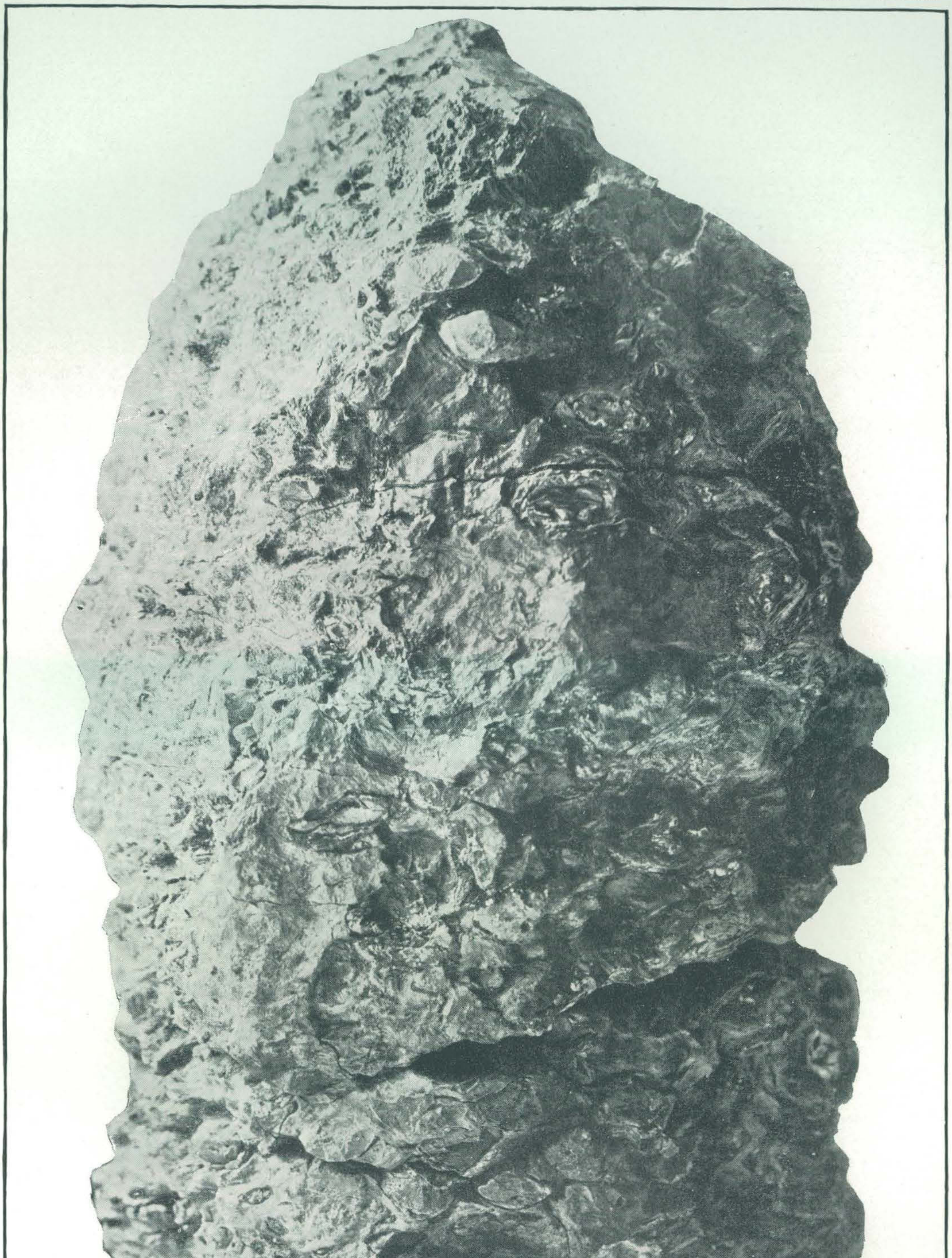
# PLATE LXXVIII.

## PLATE LXXVIII.

Page.

Cycadella Beecheriana Ward ........................................ 394

Outer surface of No. 128 of the Yale collection (three upper pieces) and No. 500.54 of the Museum of the University of Wyoming (lower piece).




CYCADELLA BEECHERIANA, FROM THE JURASSIC OF WYOMING.

# PLATE LXXIX.

# PLATE LXXIX.


CYCADELLA WYOMINGENSIS, FROM THE JURASSIC OF WYOMING.

# PLATE LXXX.

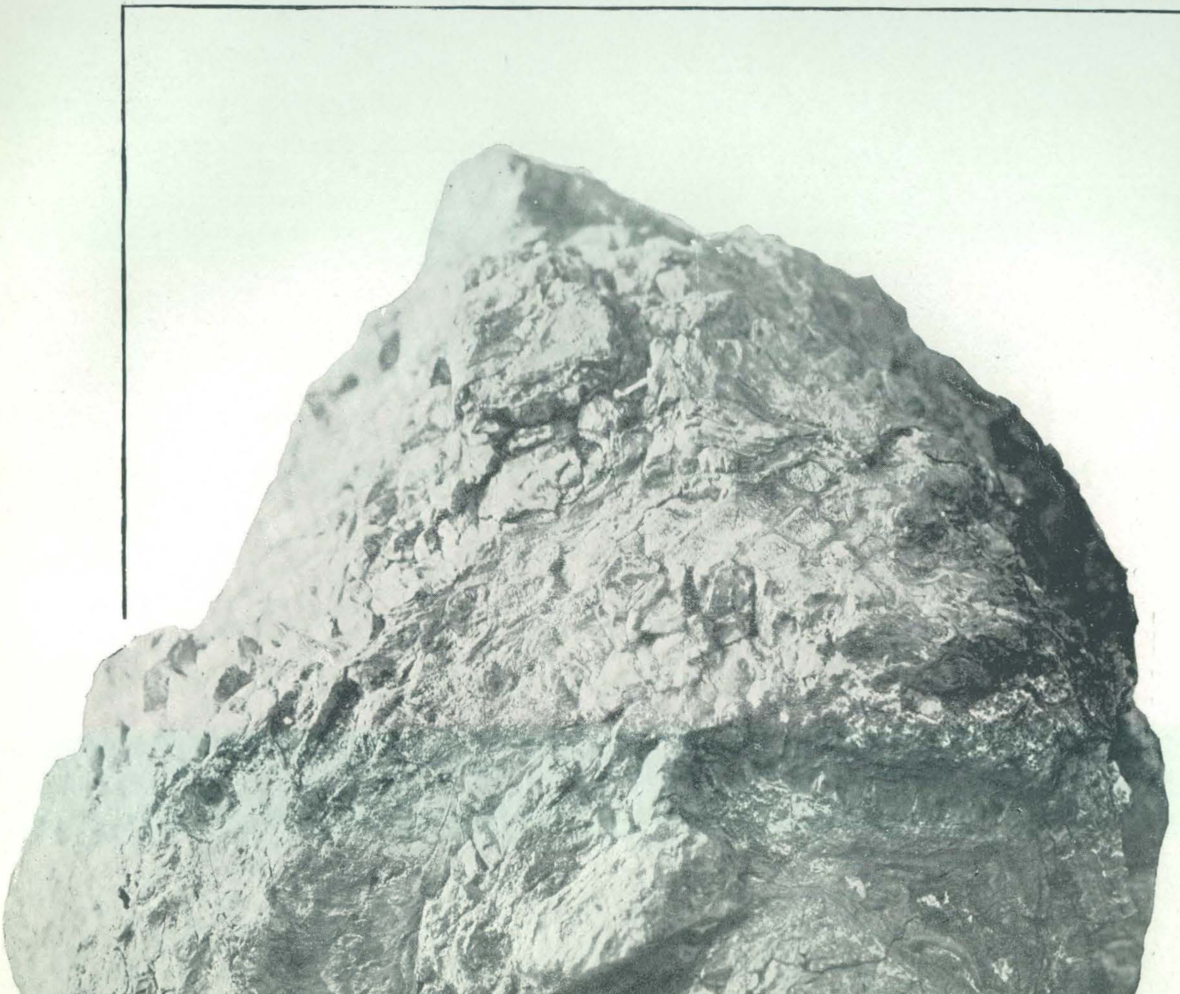
## PLATE LXXX.

Page.

Cycadella wyomingensis Ward .......... 395

View of the base and somewhat fractured side of No. 500.3 of the Museum of the University of Wyoming.

550




CYCADELLA WYOMINGENSIS, FROM THE JURASSIC OF WYOMING.

# PLATE LXXXI.

## PLATE LXXXI.



View of one of the sides of No. 500.14 of the Museum of the University of Wyoming, showing portions of the surface from which the outer coat has been scaled off.


CYCADELLA WYOMINGENSIS, FROM THE JURASSIC OF WYOMING.

# PLATE LXXXII.

## PLATE LXXXII.

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| CYCADELLA WYOMINGENSIS Ward | 395 |

View of the side of No. 500.14 of the Museum of the University of Wyoming, which is nearly all covered with the outer coat, but showing the terminal bud near the summit.


CYCADELLA WYOMINGENSIS, FROM THE JURASSIC OF WYOMING.

# PLATE LXXXIII.

## PLATE LXXXIII.


CYCADELLA WYOMINGENSIS, FROM THE JURASSIC OF WYOMING.

# PLATE LXXXIV.

# PLATE LXXXIV.

CENTIMETERS

CYCADELLA WYOMINGENSIS FROM THE JURASSIC OF WYOMING.

# PLATE LXXXV.

# PLATE LXXXV.

Page

CYCADELLA WYOMINGENSIS Ward . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 395

View of the base of No. 500.15 of the Museum of the University of Wyoming.


CYCADELLA WYOMINGENSIS, FROM THE JURASSIC OF WYOMING.

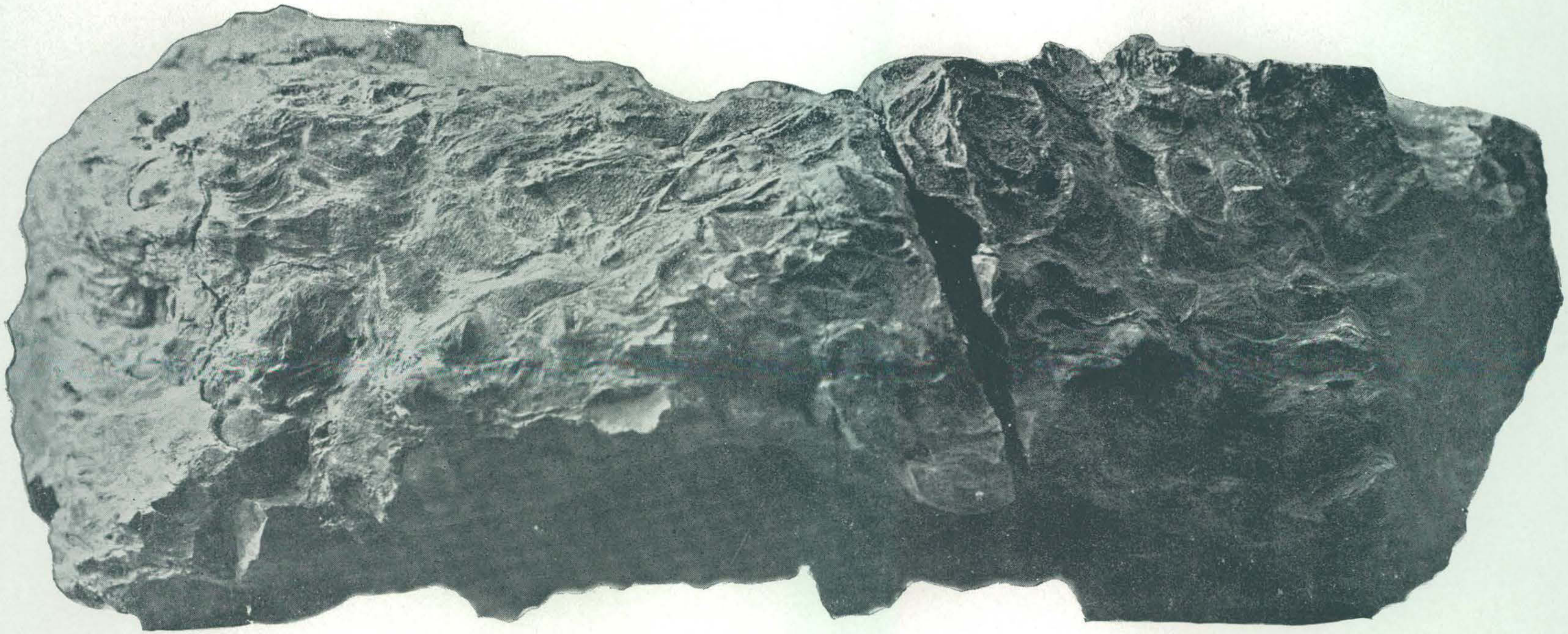
# PLATE LXXXVI.

# PLATE LXXXVI.

Page.

Cycadella wyomingensis Ward ........................................ 395

View of one side of the segment of a trunk, No. 500.26 of the Museum of the University of Wyoming.



CENTIMETERS

CYCADELLA WYOMINGENSIS, FROM THE JURASSIC OF WYOMING.

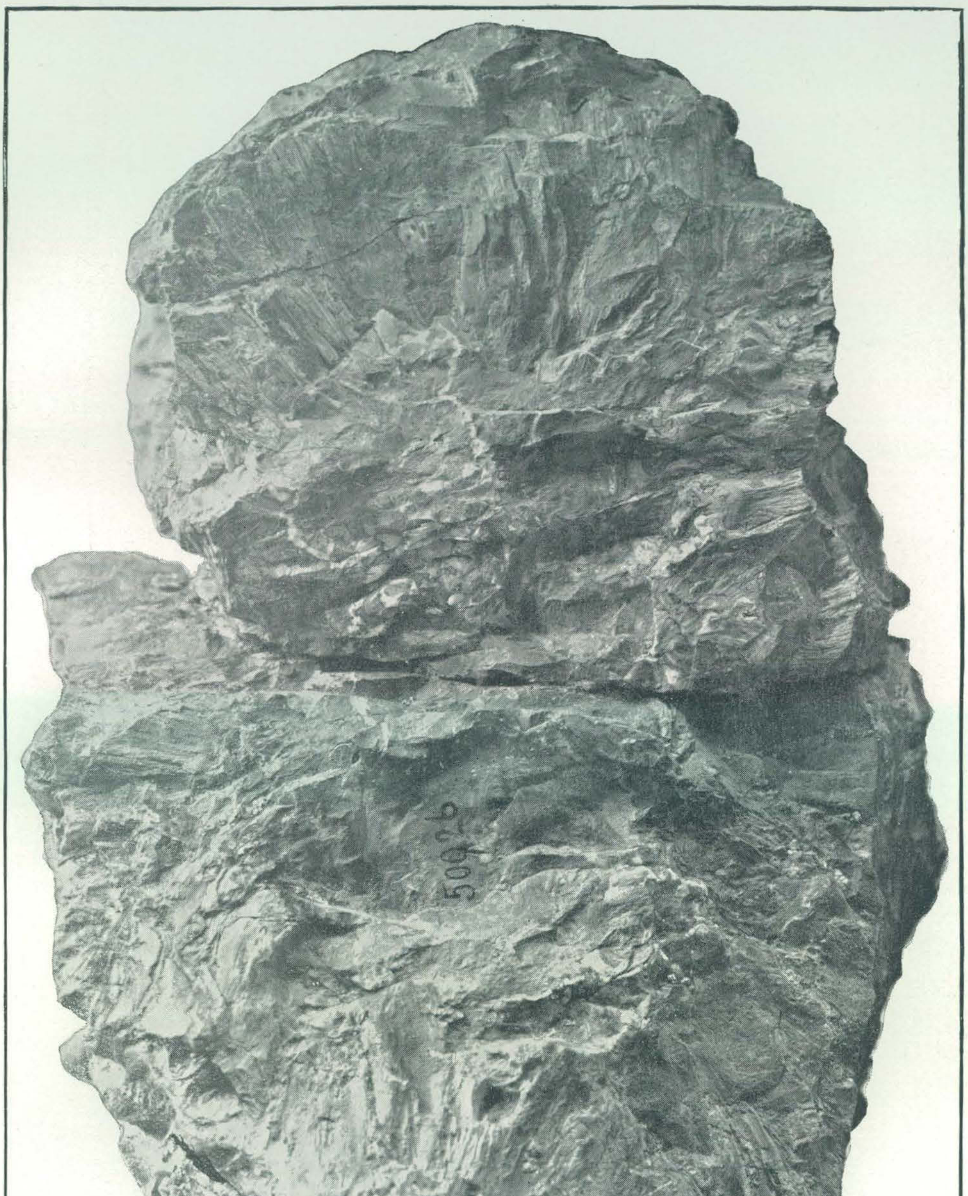
# PLATE LXXXVII.

## PLATE LXXXVII.

Page.

CYCADELLA WYOMINGENSIS Ward........................................ 395

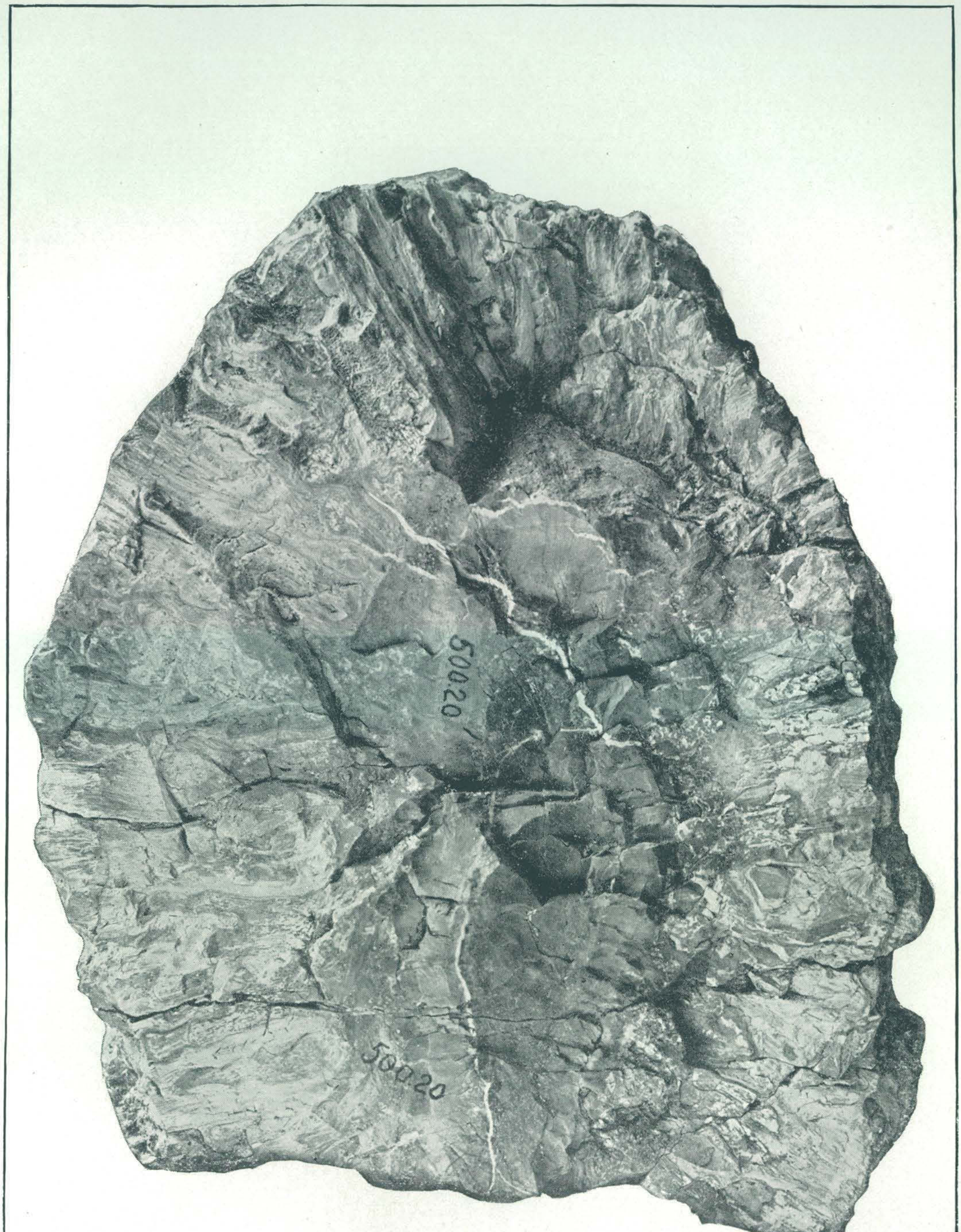
View of the upper fractured surface of No. 500.26 of the Museum of the University of Wyoming.




CYCADELLA WYOMINGENSIS, FROM THE JURASSIC OF WYOMING.

# PLATE LXXXVIII.

## PLATE LXXXVIII.




CYCADELLA WYOMINGENSIS, FROM THE JURASSIC OF WYOMING.

# PLATE LXXXIX.

## PLATE LXXXIX.

CENTIMETERS

CYCADELLA WYOMINGENSIS, FROM THE JURASSIC OF WYOMING.

# PLATE XC.

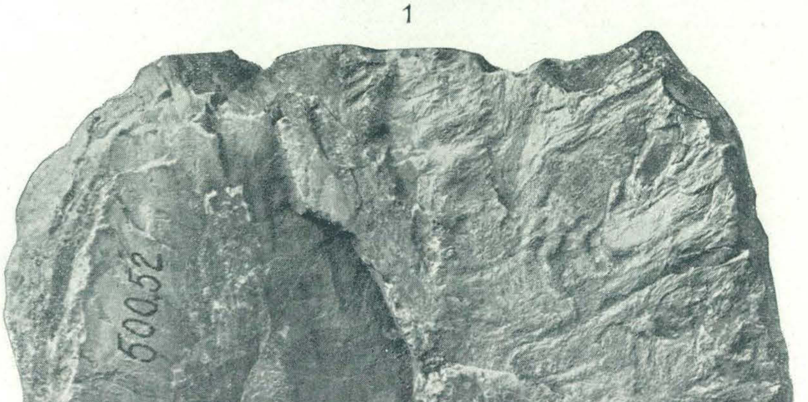
# PLATE XC.



Fig. 1. View of the upper fractured surface of the thin segment of a trunk No. 500.8 of the Museum of the University of Wyoming.

Fig. 2. View of one of the fractured surfaces of No. 500.52, supposed to belong to the same trunk as No. 500.8.

1



2

CENTIMETERS

CYCADELLA WYOMINGENSIS, FROM THE JURASSIC OF WYOMING.

# PLATE XCI.

# PLATE XCI.

Page.

CYCADELLA KNOWLTONIANA Ward........................................................ 396

No. 500.62 of the Museum of the University of Wyoming.

Fig. 1. Side view showing the outer ramentaceous layer completely investing the trunk.

Fig. 2. View of the inner wall of the woody zone, showing scars of the medullary rays.

1

2

CENTIMETERS

CYCADELLA KNOWLTONIANA, FROM THE JURASSIC OF WYOMING.

# PLATE XCII.

## PLATE XCII.

Page.

CYCADELLA KNOWLTONIANA Ward ........................................ 396

Fig. 1. View of the lower transverse fracture of No. 500.62 of the Museum of the University of Wyoming, showing the leaf bases and walls in longitudinal section overlain by the outer coating.

Fig. 2. View of the polished surface of the upper transverse fracture of No. 500.76, showing the attachment of the armor to the axis, the leaf bases emitting the ramentaceous chaff to form the walls and outer layer.


1

CENTIMETERS

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CENTIMETERS

CYCADELLA KNOWLTONIANA, FROM THE JURASSIC OF WYOMING.

# PLATE XCIII.

# PLATE XCIII.



No. 500.76 of the Museum of the University of Wyoming.

Fig. 1. View of the upper transverse fracture before polishing.

Fig. 2. View of the outer surface.


CYCADELLA KNOWLTONIANA, FROM THE JURASSIC OF WYOMING.

# PLATE XCIV.

## PLATE XCIV.

Page.

CYCADELLA KNOWLTONIANA Ward ........................................ 396

View of an area of the polished transverse surface of the upper end of No. 500.76 of the Museum of the University of Wyoming, taken from the left side of the specimen and enlarged four diameters.

578

CYCADELLA KNOWLTONIANA

THE MERIDEN GRAVURE CO.

# PLATE XCV.

# PLATE XCV.



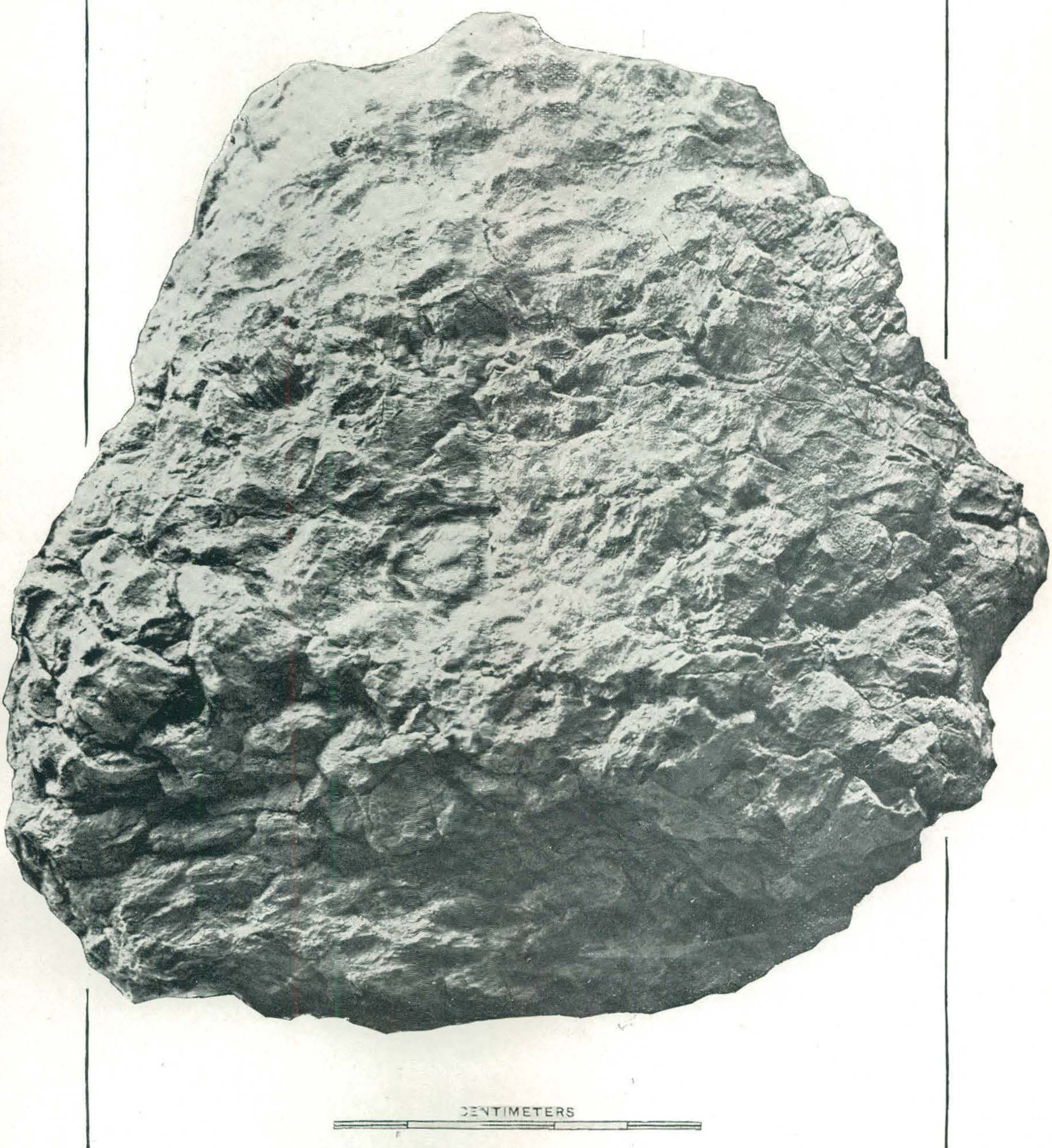
View of an area of the polished transverse surface of the upper end of No. 500.76 of the Museum of the University of Wyoming, taken from the right side of the specimen and enlarged four diameters.

CYCADELLA KNOWLTONIANA

THE MERIDEN GRAVURE CO.

# PLATE XCVI.

## PLATE XCVI.




CYCADELLA COMPRESSA FROM THE JURASSIC OF WYOMING.

# PLATE XCVII.

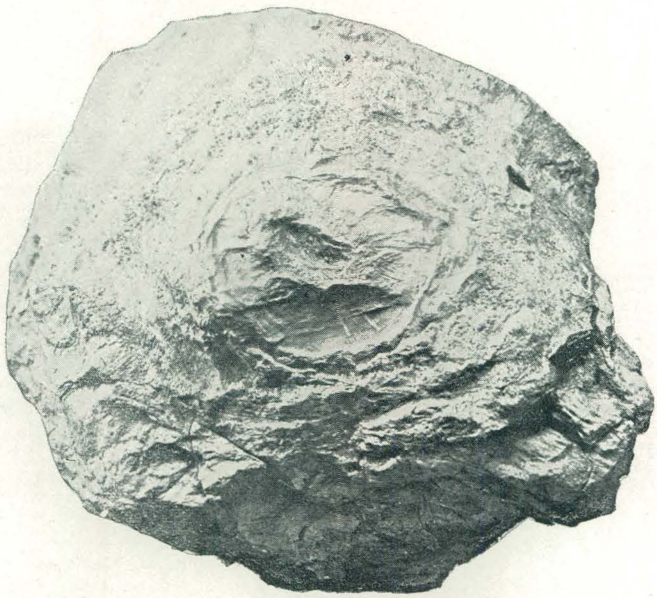
## PLATE XCVII.

| | Page. |
|---|---|
| Cycadella compressa Ward | 398 |

No. 500.18 of the Museum of the University of Wyoming.

Fig. 1. View of the side and apex. The terminal bud is indistinctly seen on the left above.

Fig. 2. View of the base.



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CENTIMETERS

1

CENTIMETERS

CYCADELLA COMPRESSA, FROM THE JURASSIC OF WYOMING.

# PLATE XCVIII.

## PLATE XCVIII.

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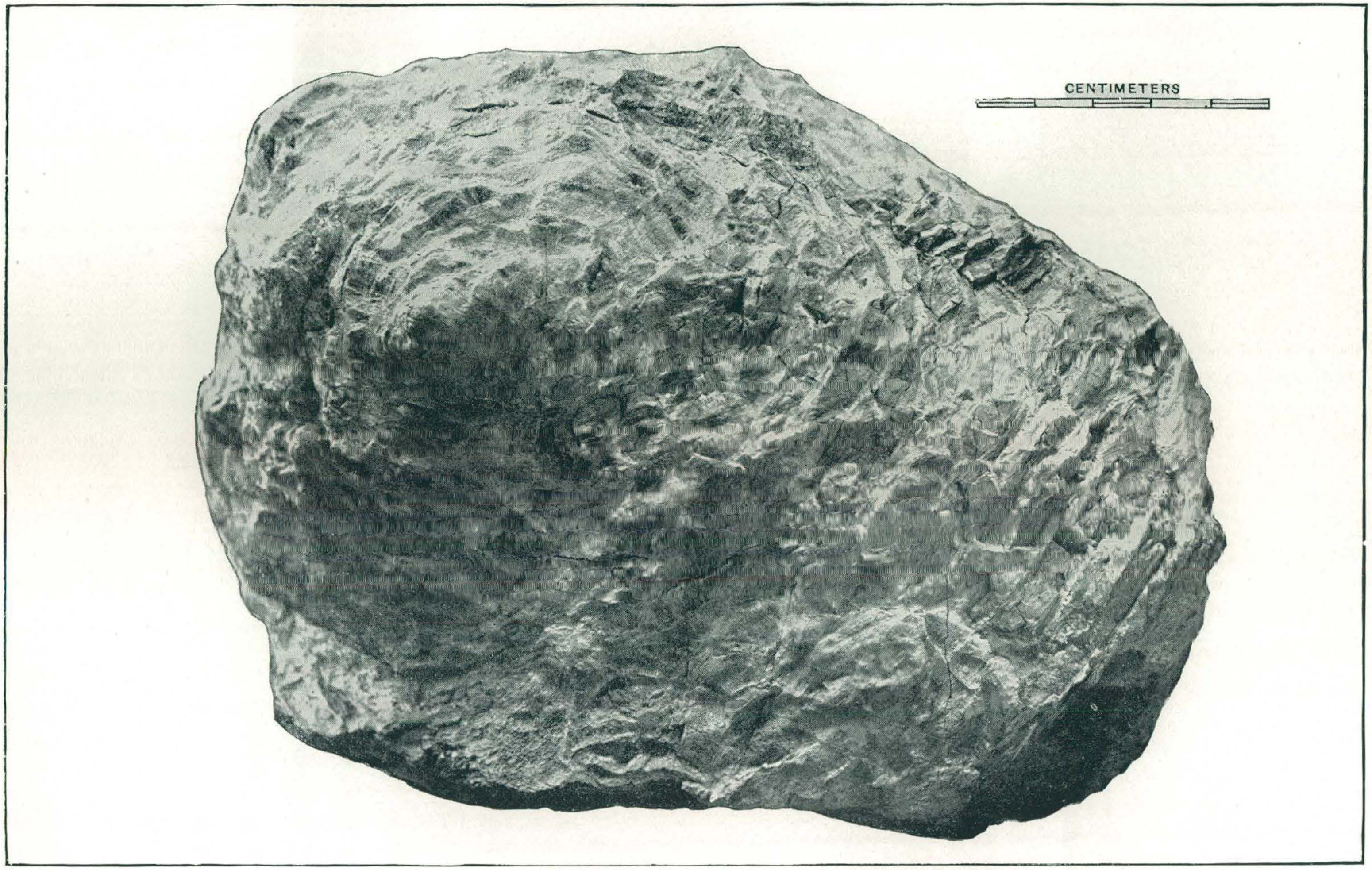
CYCADELLA JURASSICA Ward .......................................... 399

Side view of No. 500.5 of the Museum of the University of Wyoming.




CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING

# PLATE XCIX.

## PLATE XCIX.


CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE C.

## PLATE C.



Side view of No. 500.38 of the Museum of the University of Wyoming.


CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE CI.

## PLATE CI.


CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE CII.

## PLATE CII.



View of the fractured inner face of No. 500.38 of the Museum of the University of Wyoming.


CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE CIII.

## PLATE CIII.

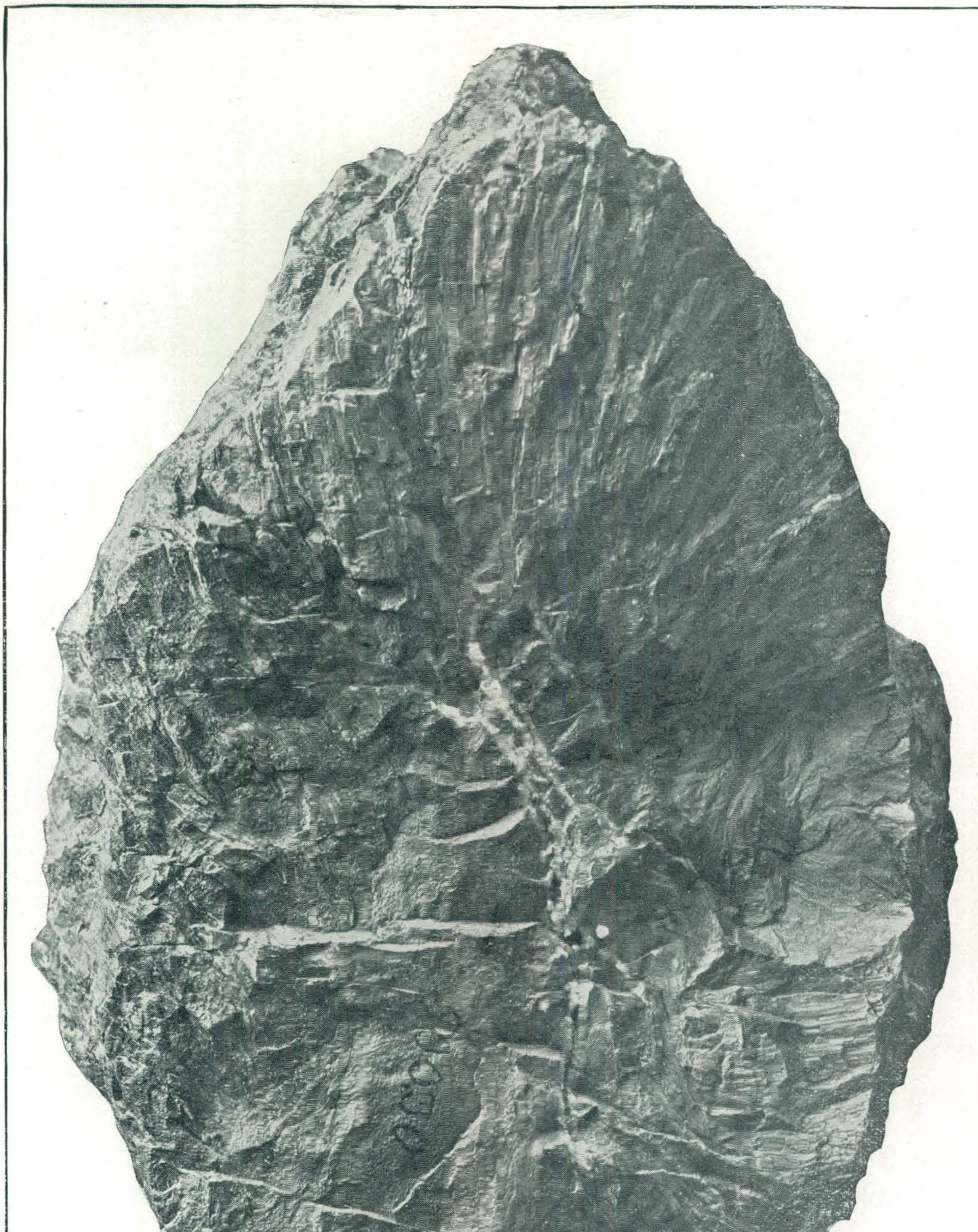
| | Page. |
|---|---|
| CYCADELLA JURASSICA Ward | 399 |

Side view of No. 500.30 of the Museum of the University of Wyoming.


CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE CIV.

## PLATE CIV.




CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE CV.

## PLATE CV.

| | Page. |
|---|---|
| CYCADELLA JURASSICA Ward | 399 |

View of one side and the broken summit of No. 500.36 of the Museum of the University of Wyoming.


CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE CVI.

# PLATE CVI.

Page.

CYCADELLA JURASSICA Ward .................................................. 399

View of the basal fracture and one side of No. 500.36 of the Museum of the University of Wyoming.


CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE CVII.

## PLATE CVII.


CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE CVIII.

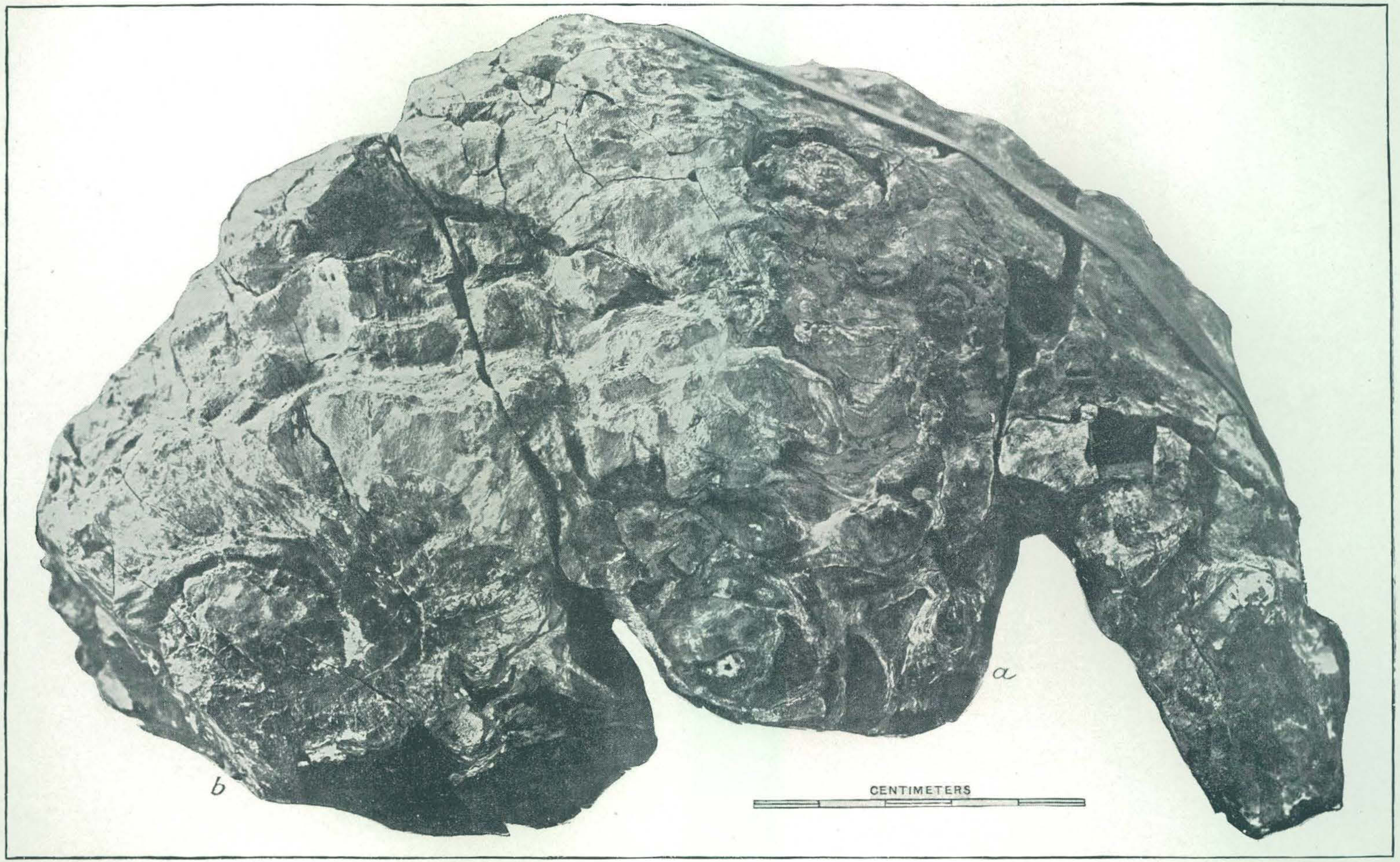
## PLATE CVIII.

Page.

Cycadella jurassica Ward ........................................................ 399

View of one side (the side opposite that shown on Pl. CVII) of the fragment restored by uniting the complementary Nos. 500.49 and 500.77 of the Museum of the University of Wyoming.

(*a*) No. 500.49; (*b*) No. 500.77.




CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE CIX.

## PLATE CIX.


CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE CX.

## PLATE CX.

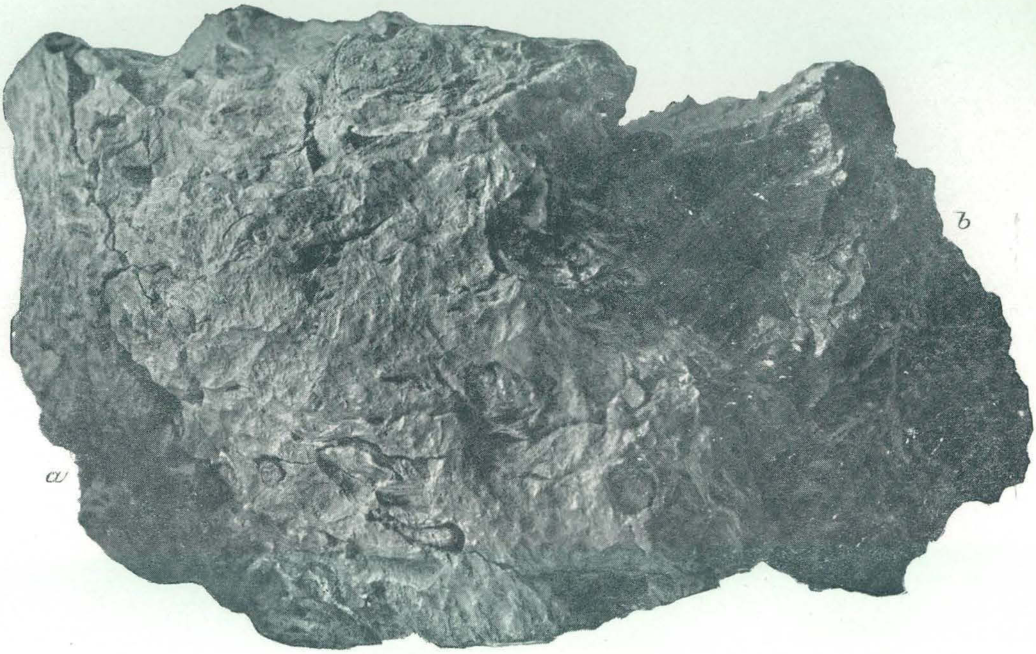


Views of the fragment restored by uniting the complementary Nos. 500.78 and 500.82 of the Museum of the University of Wyoming.

Fig. 1. The external surface.

Fig. 2. The interior as revealed by a longitudinal fracture.

(*a*) No. 500.78; (*b*) No. 500.82.

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CENTIMETERS

CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE CXI.

## PLATE CXI.

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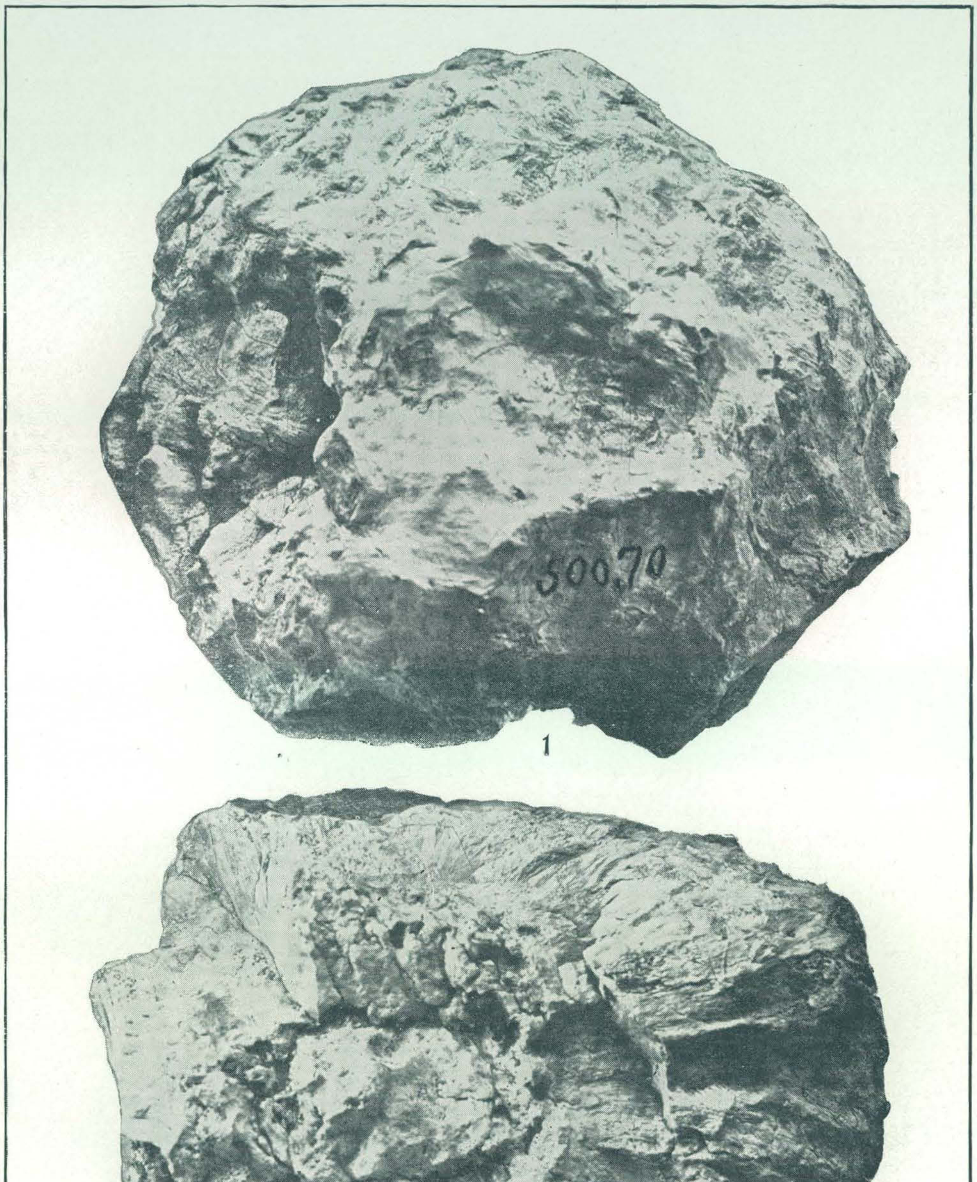
Cycadella jurassica Ward .......................................... 399

Views of the fragment No. 500.70 of the Museum of the University of Wyoming, supposed to form the apex of the trunk Nos. 500.78 and 500.82.

Fig. 1. View of the top.

Fig. 2. View of the lower side as broken, showing the internal structure.




CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE CXII.

# PLATE CXII.



No. 500.23 of the Museum of the University of Wyoming.

Fig. 1. View of the flat top.

Fig. 2. View of one side.

1

2

CENTIMETERS

CYCADELLA JURASSICA, FROM THE JURASSIC OF WYOMING.

# PLATE CXIII.

## PLATE CXIII.

Page.

CYCADELLA NODOSA Ward ... 401

Side view of No. 500.9 of the Museum of the University of Wyoming.


CYCADELLA NODOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXIV.

## PLATE CXIV.

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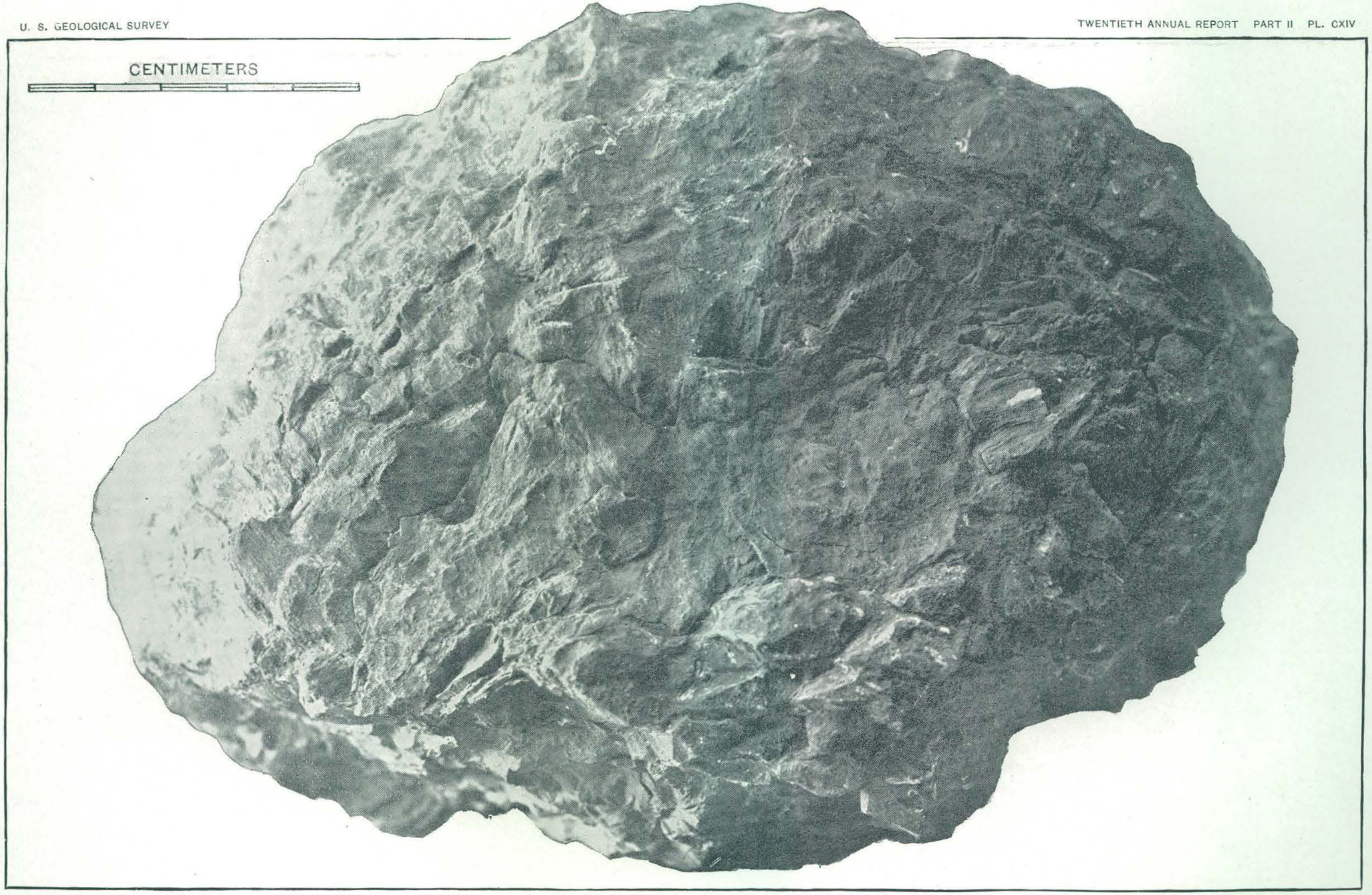
CYCADELLA NODOSA Ward .......................................................... 401

Side view of No. 500.9 of the Museum of the University of Wyoming (the side opposite that shown on Pl. CXIII).




CYCADELLA NODOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXV.

# PLATE CXV.


CYCADELLA NODOSA, FROM THE JURASSIC OF WYOMING.

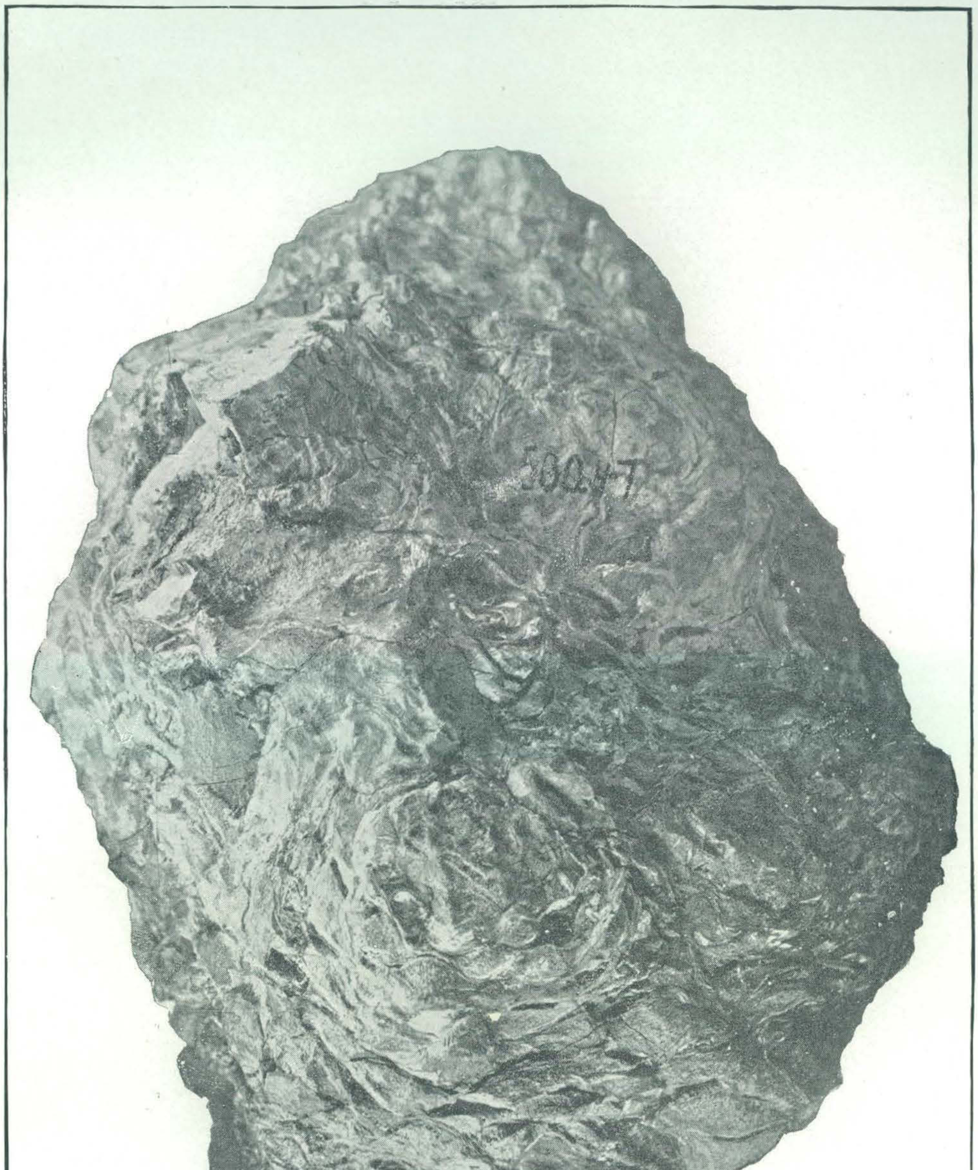
# PLATE CXVI.

## PLATE CXVI.

Page.

CYCADELLA NODOSA Ward........................................................ 401

Side view of No. 500 47 of the Museum of the University of Wyoming, showing the branches and organs of the armor.



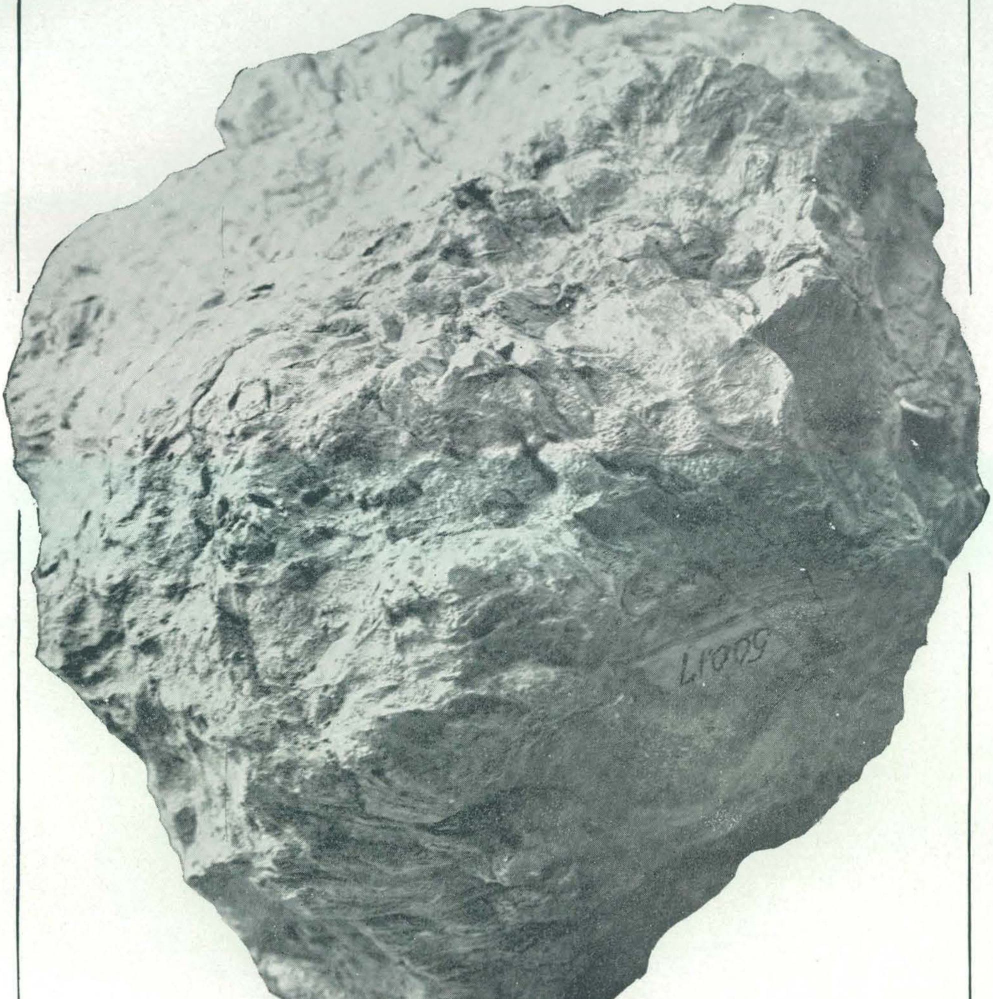

CYCADELLA NODOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXVII.

## PLATE CXVII.

| | Page. |
|---|---|
| Cycadella nodosa Ward | 401 |

View of the best-preserved side of No. 500.17 of the Museum of the University of Wyoming.




CYCADELLA NODOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXVIII.

# PLATE CXVIII.

Page.

CYCADELLA NODOSA Ward .............................................. 401

No. 500.21 of the Museum of the University of Wyoming.

Fig. 1. View of the rounded summit, showing the numerous branches.

Fig. 2. View of the transverse fracture.

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CENTIMETERS

CYCADELLA NODOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXIX.

## PLATE CXIX.

Page.

CYCADELLA NODOSA Ward ........................................ 401

View of the broadest side of No. 500.11 of the Museum of the University of Wyoming.


CYCADELLA NODOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXX.

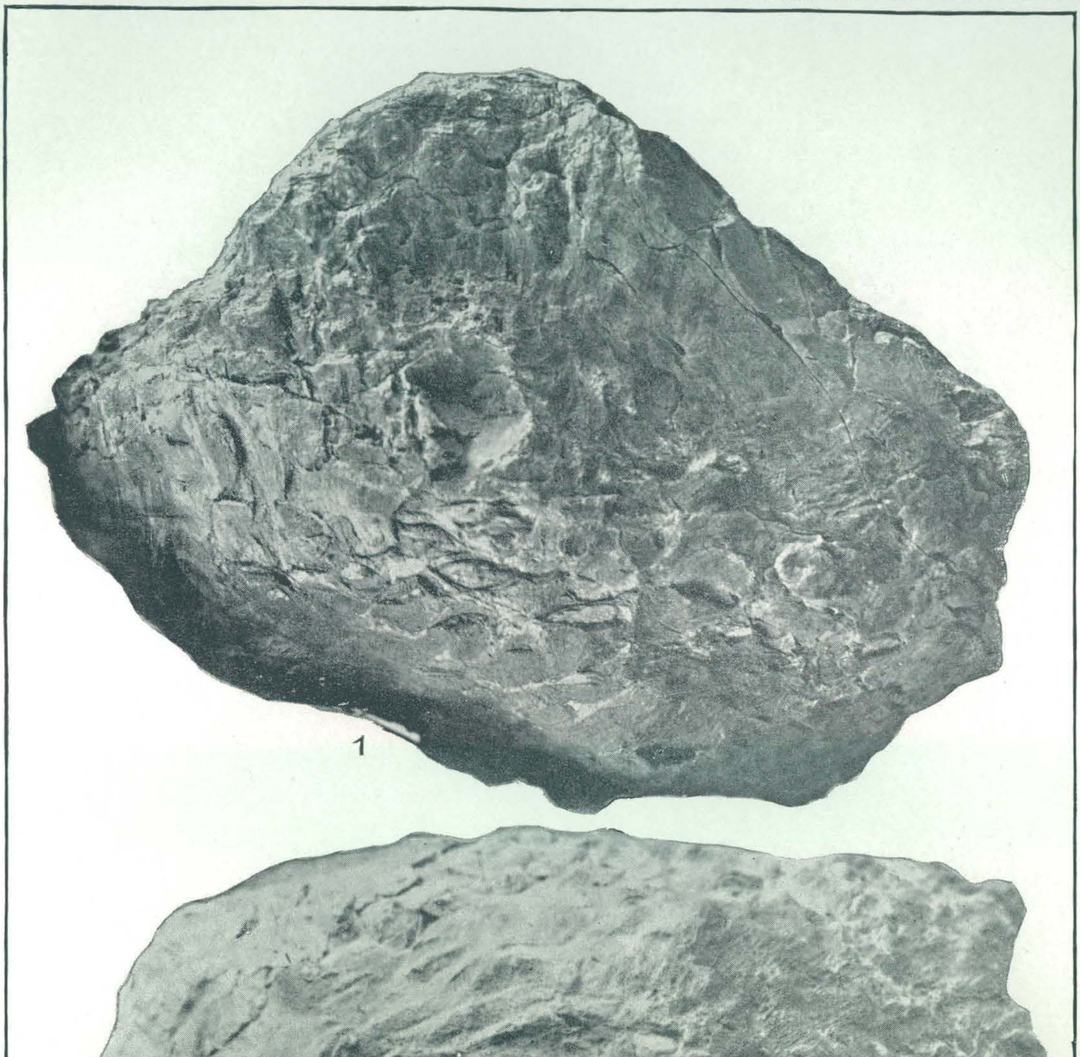
## PLATE CXX.



No. 500.11 of the Museum of the University of Wyoming.

Fig. 1. View of one side.

Fig. 2. View of the base.




CYCADELLA NODOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXI.

## PLATE CXXI.

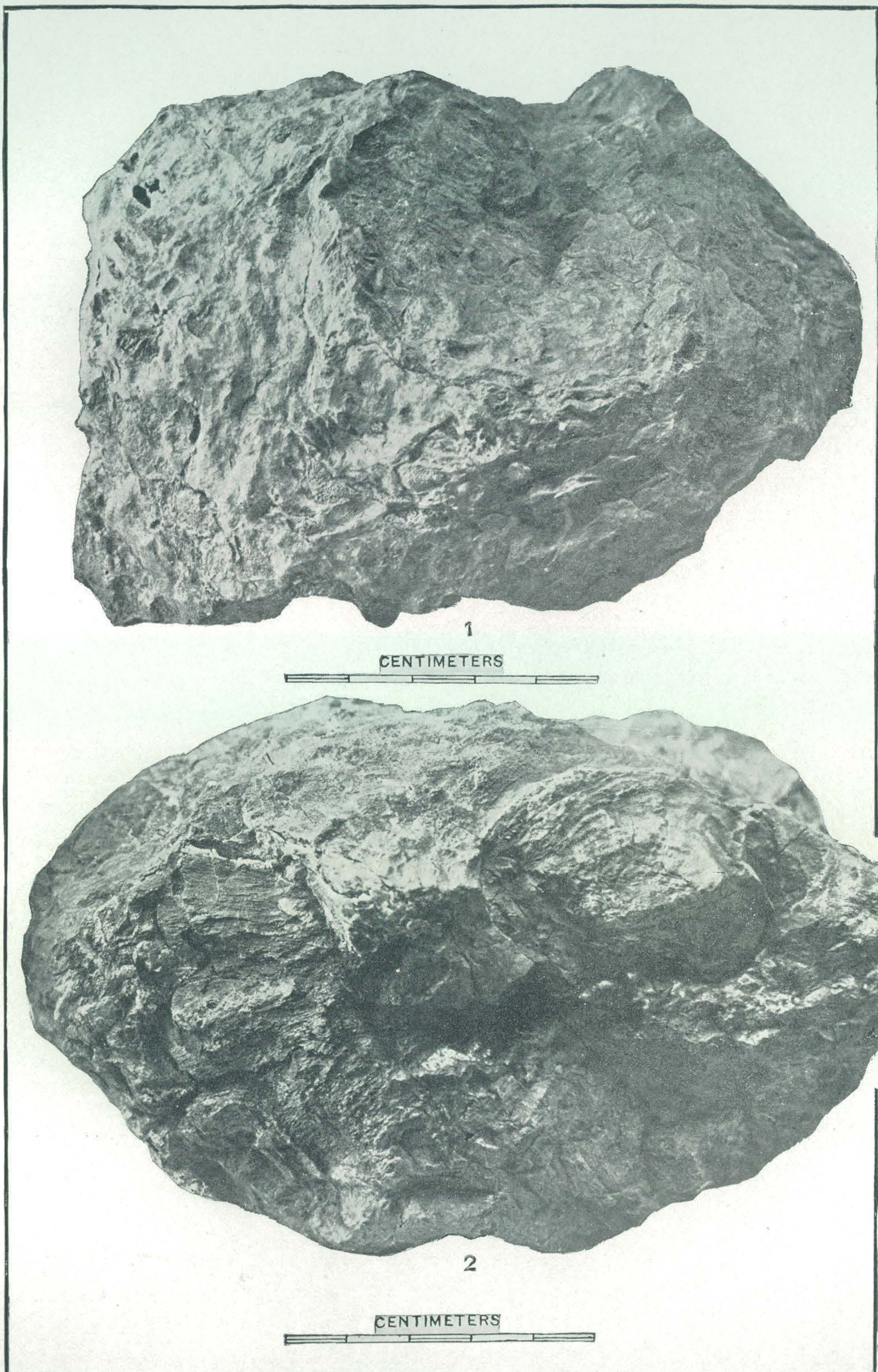
Page.



No. 500.48 of the Museum of the University of Wyoming.

Fig. 1. View of one side.

Fig. 2. View of the base.




CYCADELLA NODOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXII.

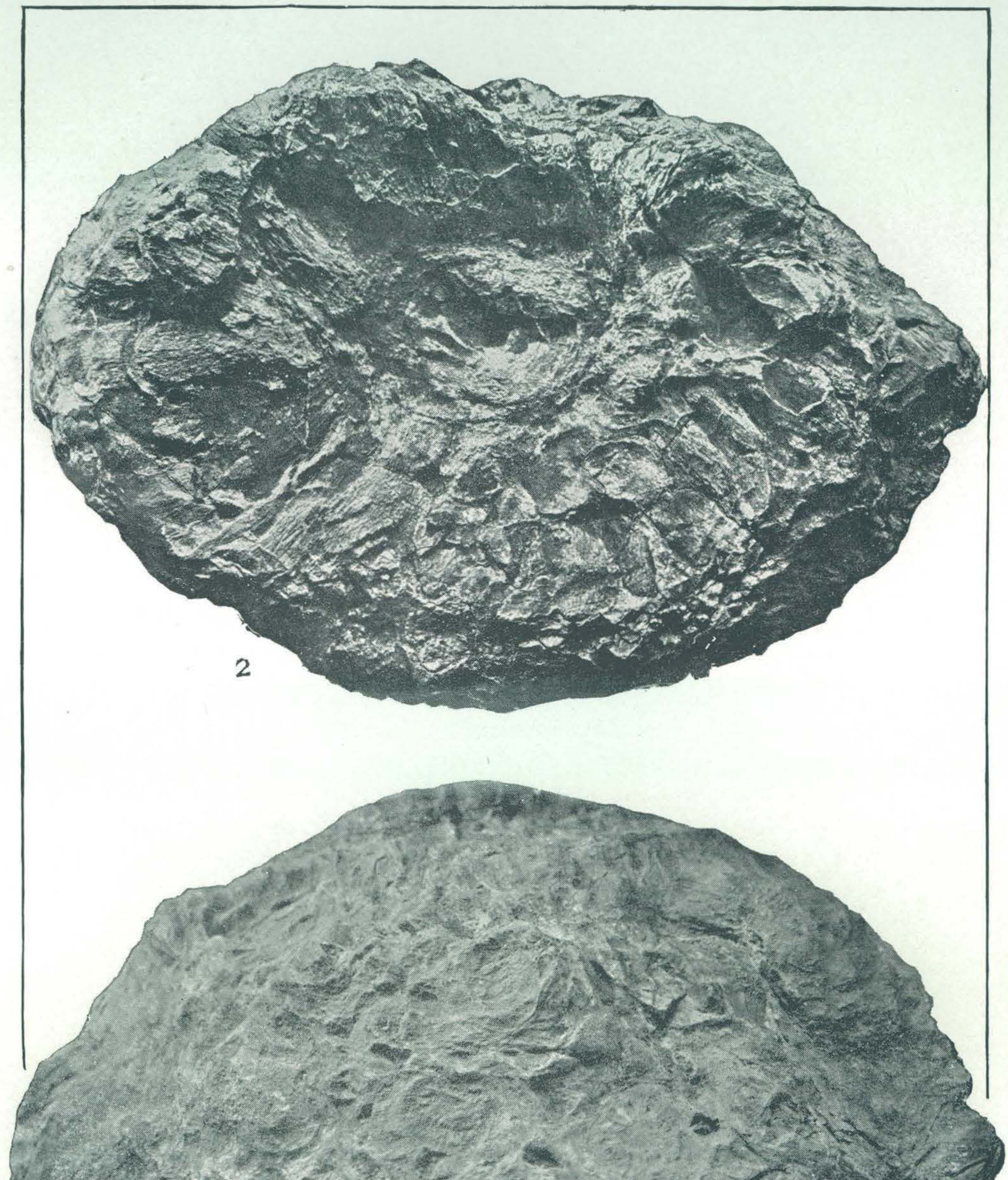
# PLATE CXXII.



No. 500.12 of the Museum of the University of Wyoming.

Fig. 1. View of one side.

Fig. 2. View of the concave base.




CYCADELLA NODOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXIII.

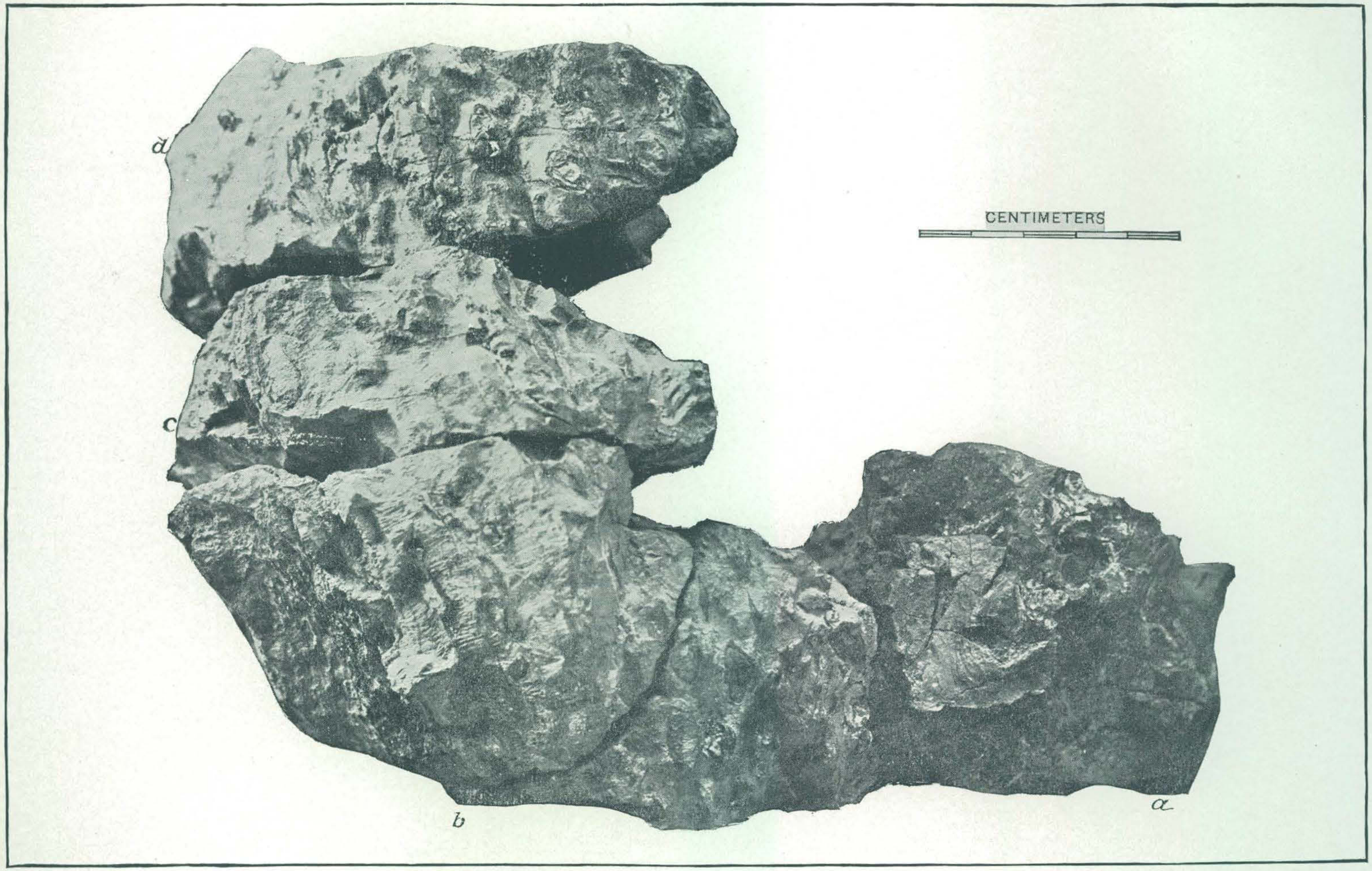
## PLATE CXXIII.

Page.

Cycadella cirrata Ward ........................................ 403

Side view of the portion of a trunk resulting from the union of the complementary Nos. 500.42, 500.46, 500.59, and 500.75 of the Museum of the University of Wyoming.

(*a*) No. 500.59; (*b*) No. 500.42; (*c*) No. 500.46; (*d*) No. 500.75.




CYCADELLA CIRRATA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXIV.

## PLATE CXXIV.

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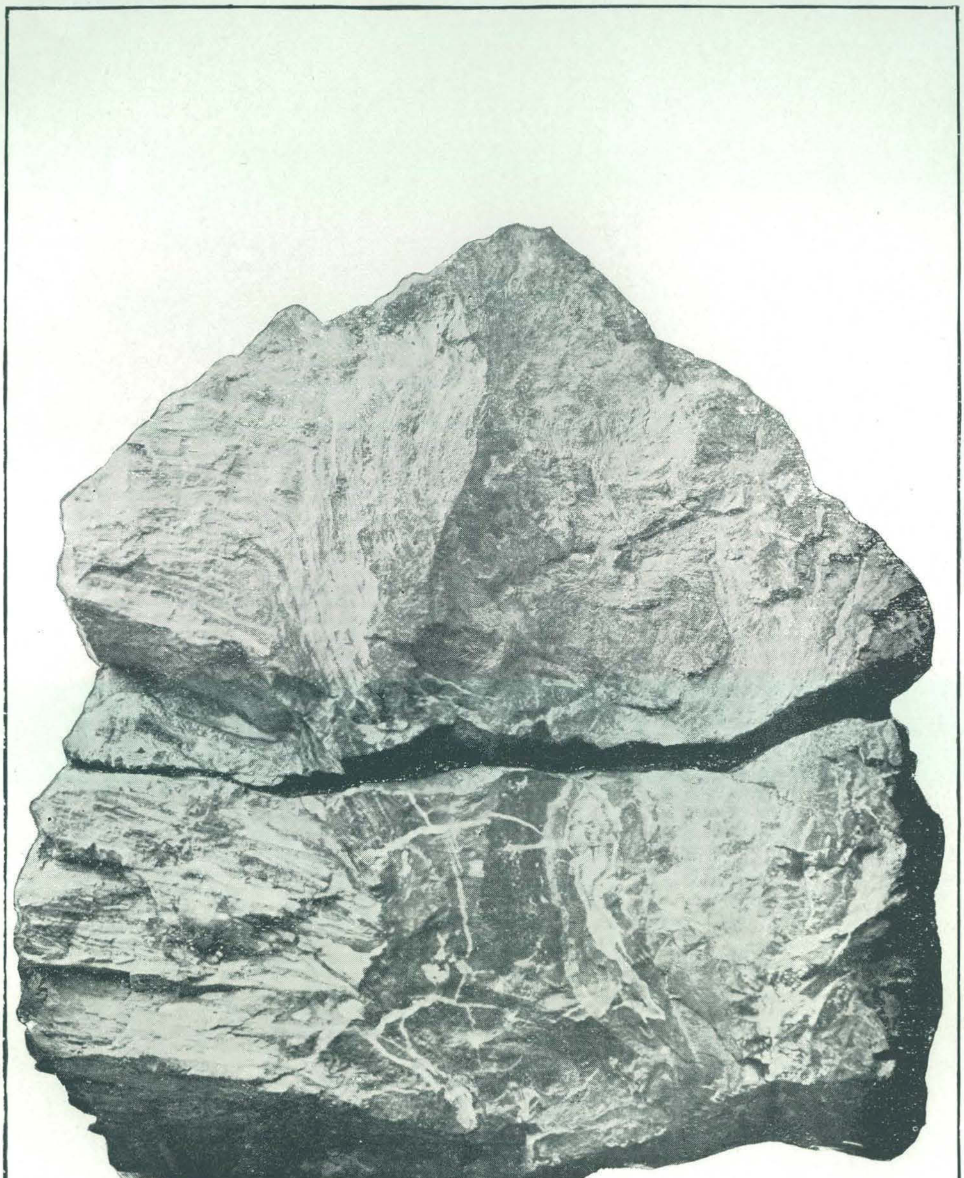
|---|---|
| CYCADELLA CIRRATA Ward | 403 |

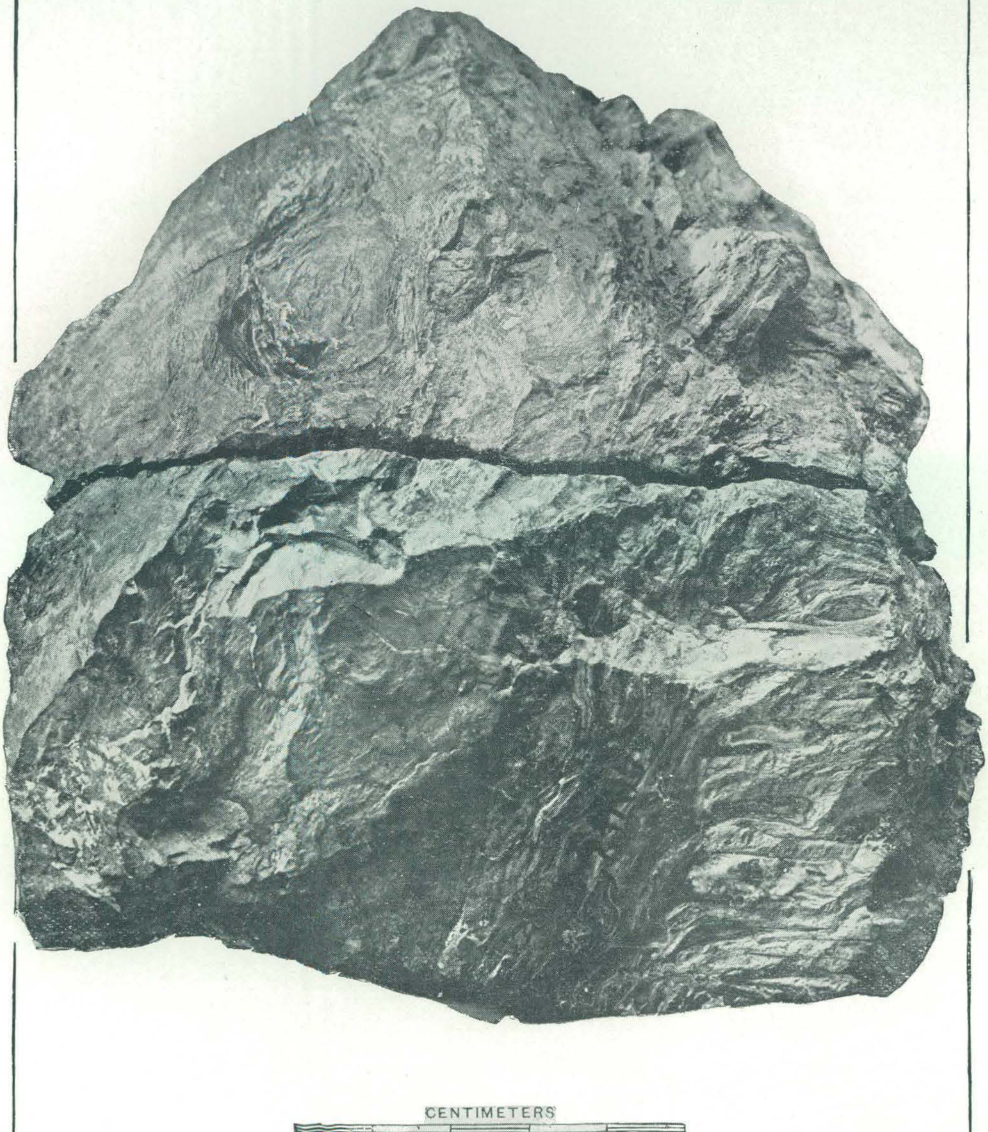
View of the central longitudinal fracture of No. 500.42 of the Museum of the University of Wyoming.




CYCADELLA CIRRATA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXV.

## PLATE CXXV.




CYCADELLA CIRRATA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXVI.

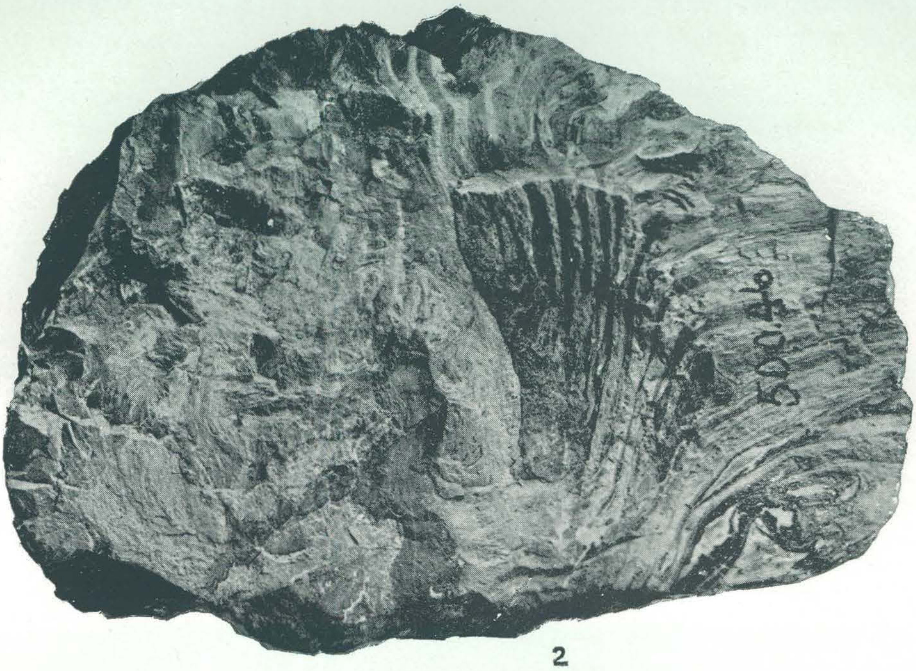
## PLATE CXXVI.



No. 500.46 of the Museum of the University of Wyoming.

Fig. 1. Fracture joining No. 500.42.

Fig. 2. Fracture joining No. 500.75.



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1

CENTIMETERS

CYCADELLA CIRRATA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXVII.

## PLATE CXXVII.



No. 500.75 of the Museum of the University of Wyoming.

Fig. 1. Fracture joining No. 500.42.

Fig. 2. Outer fracture.

1


2

CYCADELLA CIRRATA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXVIII.

## PLATE CXXVIII.

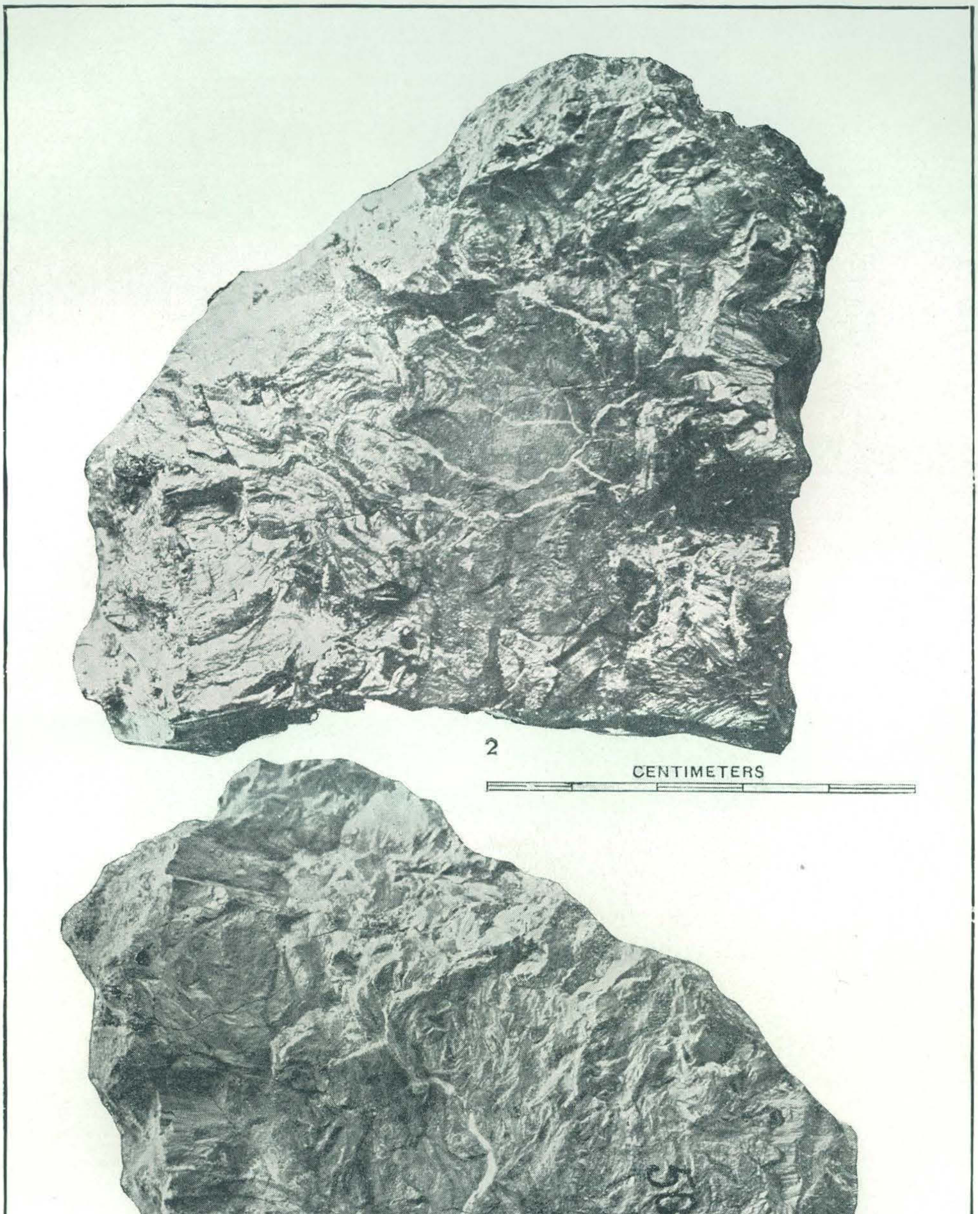
Page.

CYCADELLA CIRRATA Ward ........................................................ 403

No. 500.71 of the Museum of the University of Wyoming.

Fig. 1. The broader fracture.

Fig. 2. The narrower fracture.




CYCADELLA CIRRATA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXIX.

## PLATE CXXIX.



No. 500.59 of the Museum of the University of Wyoming.

Fig. 1. Central longitudinal fracture in same plane as that of Pl. CXXIV.

Fig. 2. Outer tangential fracture in same plane as that of Pl. CXXV.

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CYCADELLA CIRRATA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXX.

## PLATE CXXX.

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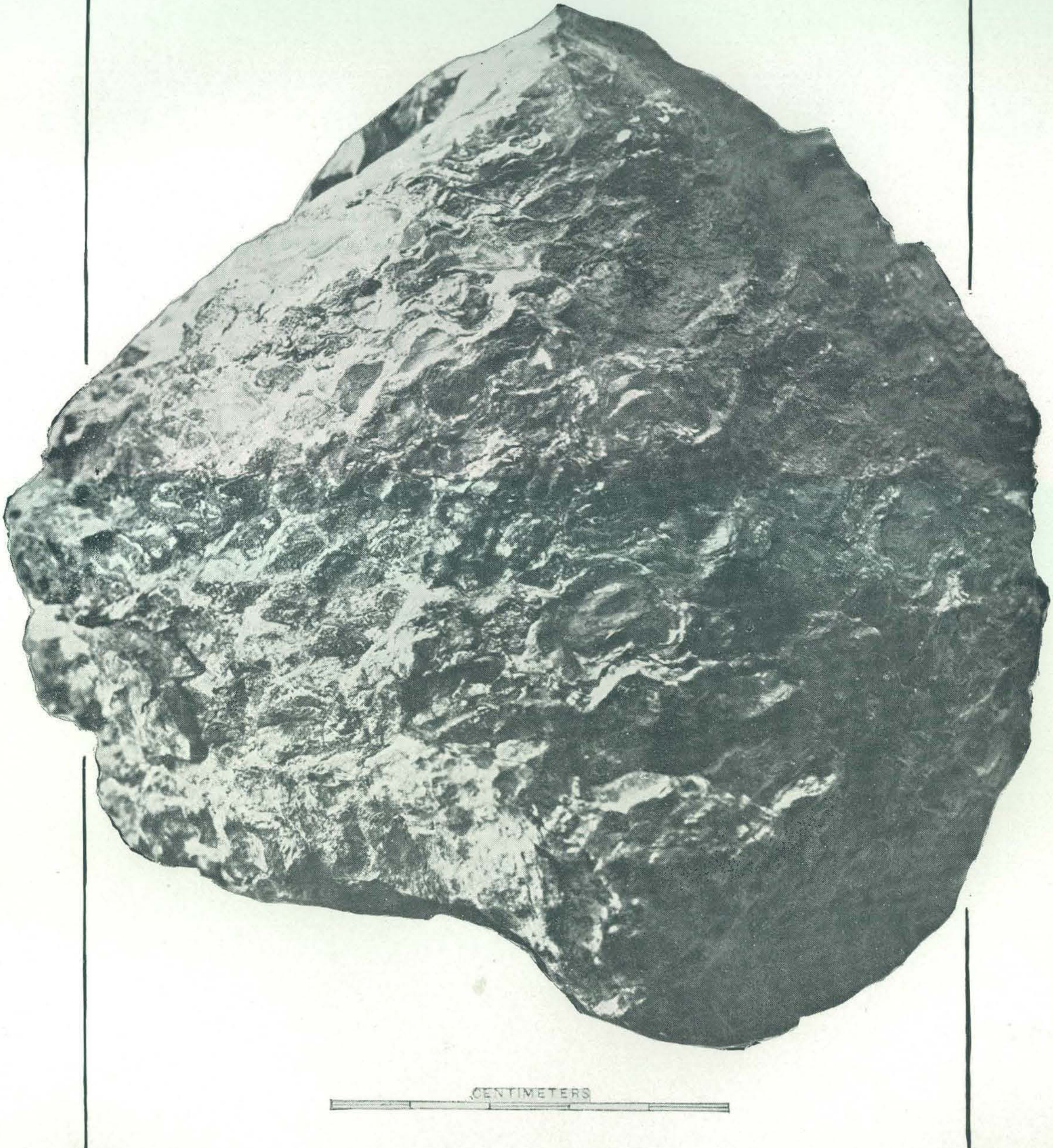
Cycadella exogena Ward .......................................... 404

View of the outer surface of the half trunk No. 500.53 of the Museum of the University of Wyoming.




CYCADELLA EXOGENA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXXI.

# PLATE CXXXI.


CYCADELLA EXOGENA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXXII.

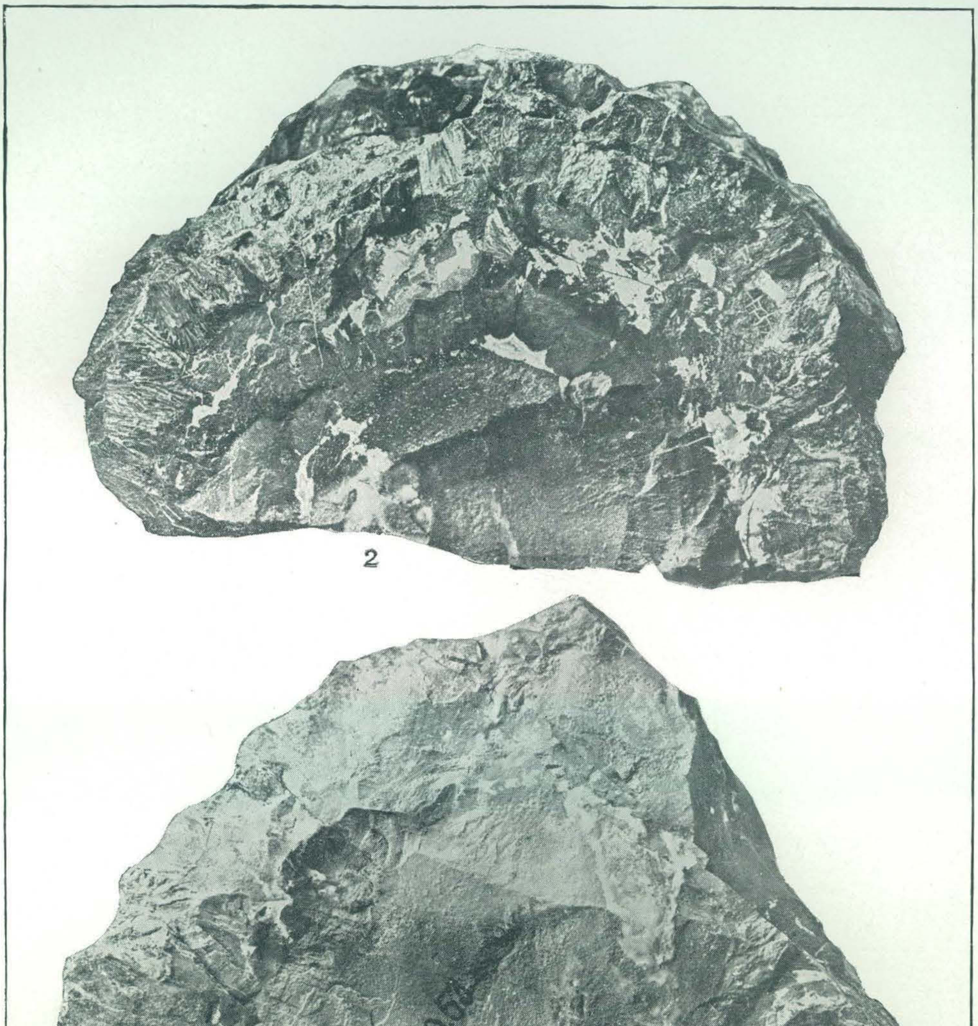
## PLATE CXXXII.



Longitudinal and transverse views of the trunk Nos. 500.53 and 500.61 of the Museum of the University of Wyoming.

Fig. 1. Central longitudinal fracture of No. 500.53.

Fig. 2. Transverse fracture of No. 500.61, showing the exogenous structure.




CYCADELLA EXOGENA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXXIII.

## PLATE CXXXIII.

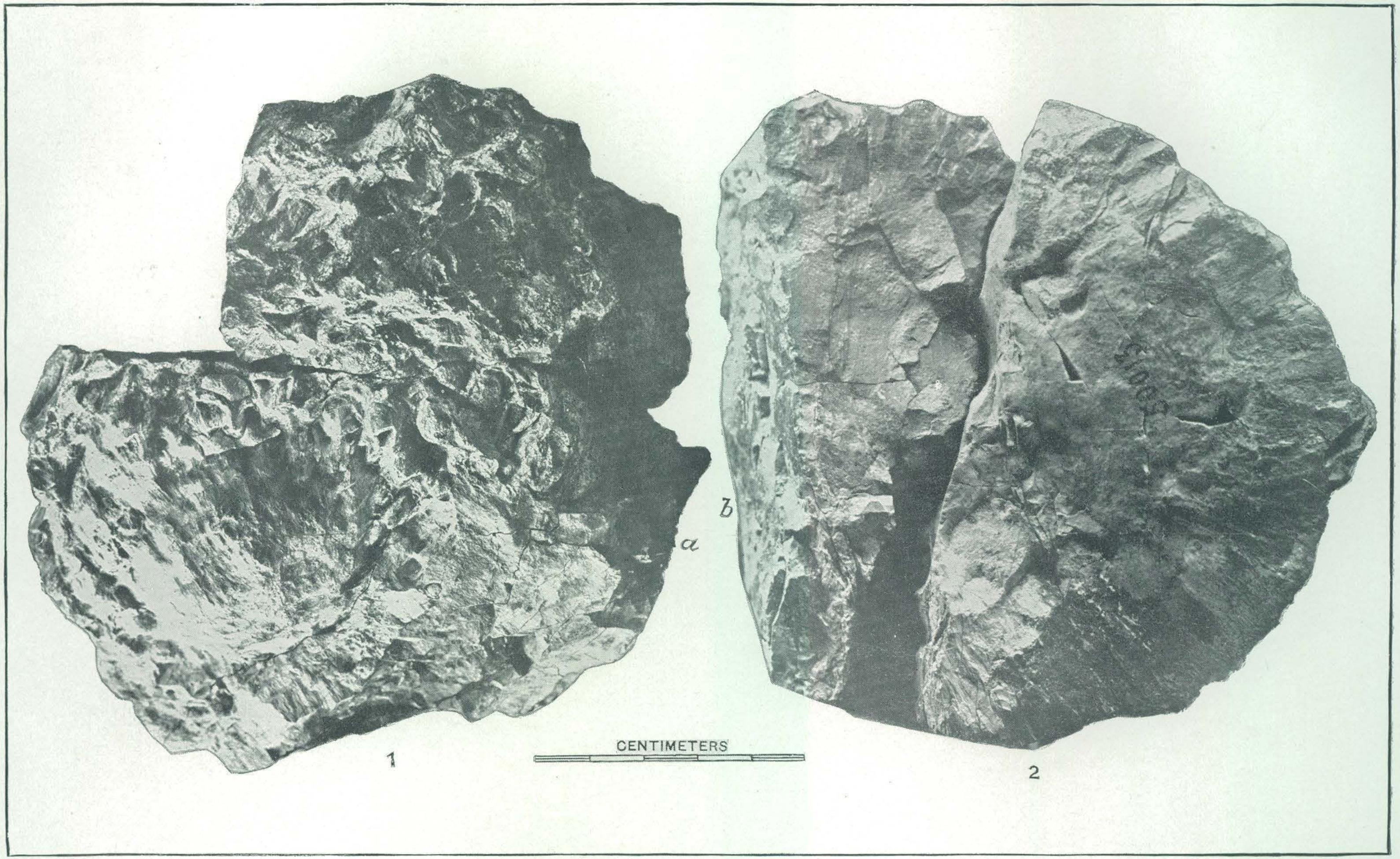
| | Page. |
|---|---|
| CYCADELLA EXOGENA Ward | 404 |

Nos. 500.13 and 500.72 of the Museum of the University of Wyoming, which are complementary of each other.

Fig. 1. Side and top view, showing the terminal bud.

Fig. 2. View of the fractured surface.

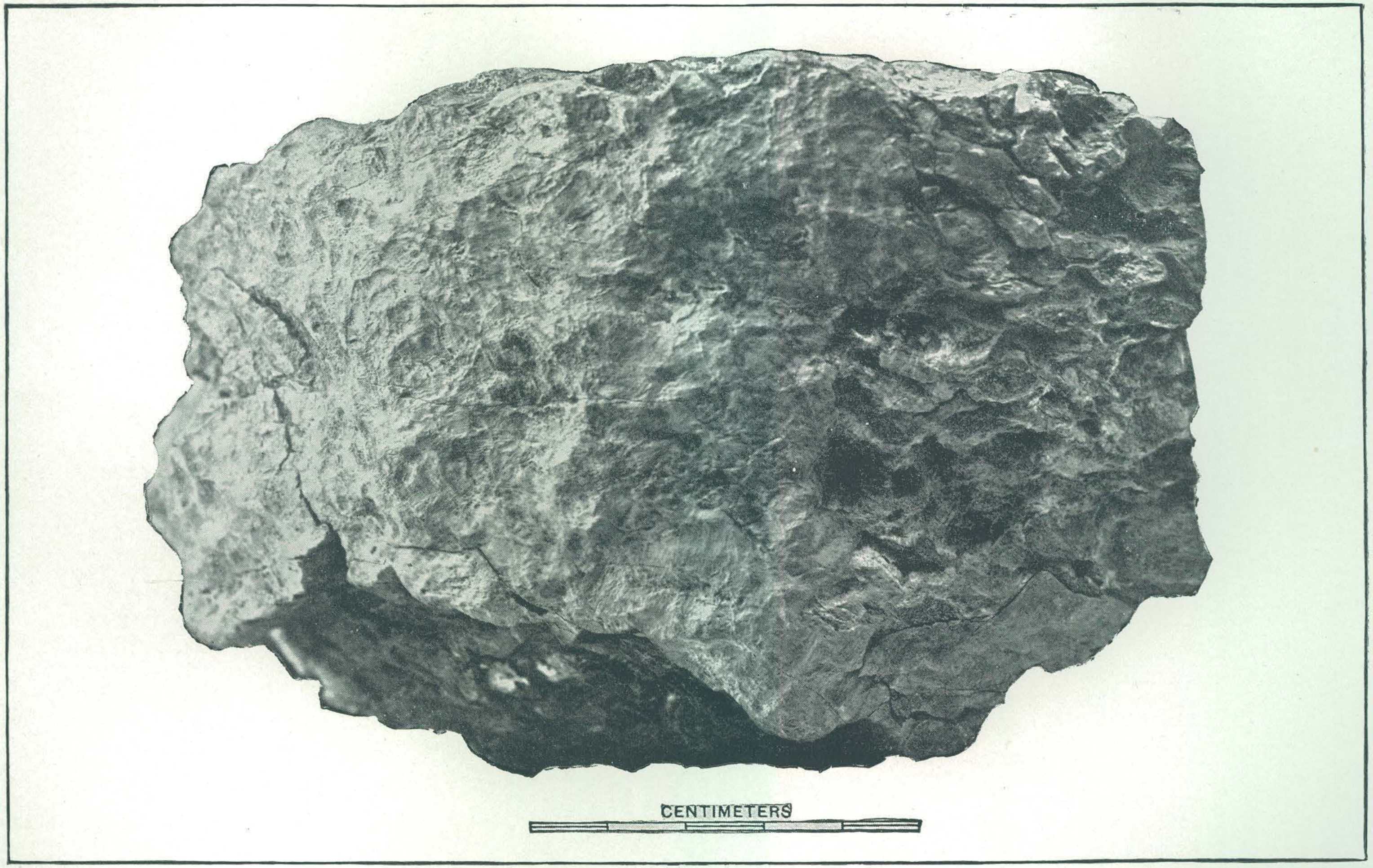
(*a*) No. 500.13; (*b*) No. 500.72.




CYCADELLA EXOGENA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXXIV.

## PLATE CXXXIV.




CYCADELLA EXOGENA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXXV.

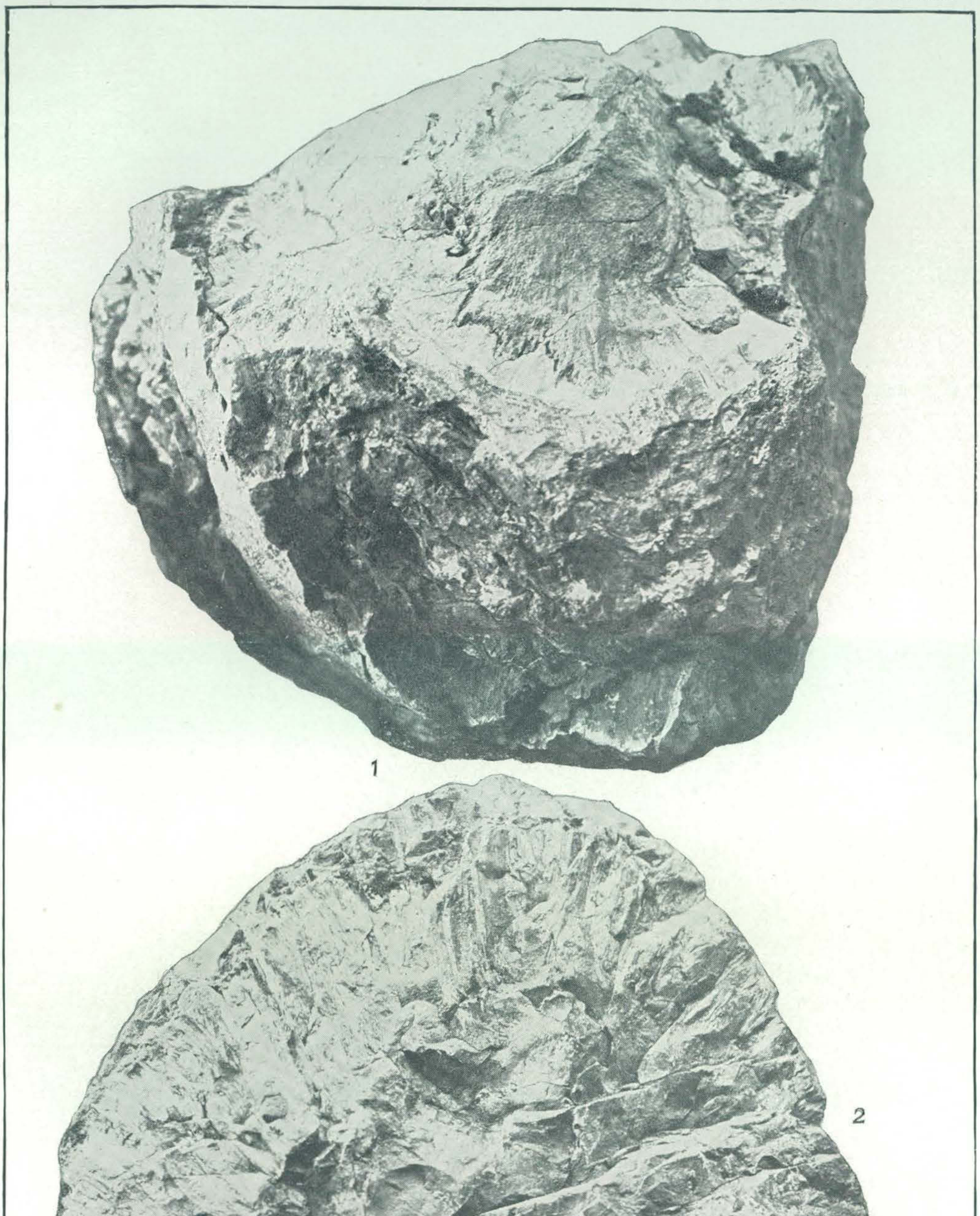
## PLATE CXXXV.



No. 500.37 of the Museum of the University of Wyoming.

Fig. 1. View of the base.

Fig. 2. View of the transverse fracture.




CYCADELLA EXOGENA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXXVI.

## PLATE CXXXVI.

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CYCADELLA EXOGENA Ward ........................................................ 404

Fig. 1. View of the external surface of the complementary fragments Nos. 500.44 and 500.73 of the Museum of the University of Wyoming. (*a*) No. 500.44; (*b*) No. 500.73.

Fig. 2. View of the upper transverse fracture of No. 500.44.


CENTIMETERS

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CENTIMETERS

CYCADELLA EXOGENA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXXVII.

## PLATE CXXXVII.

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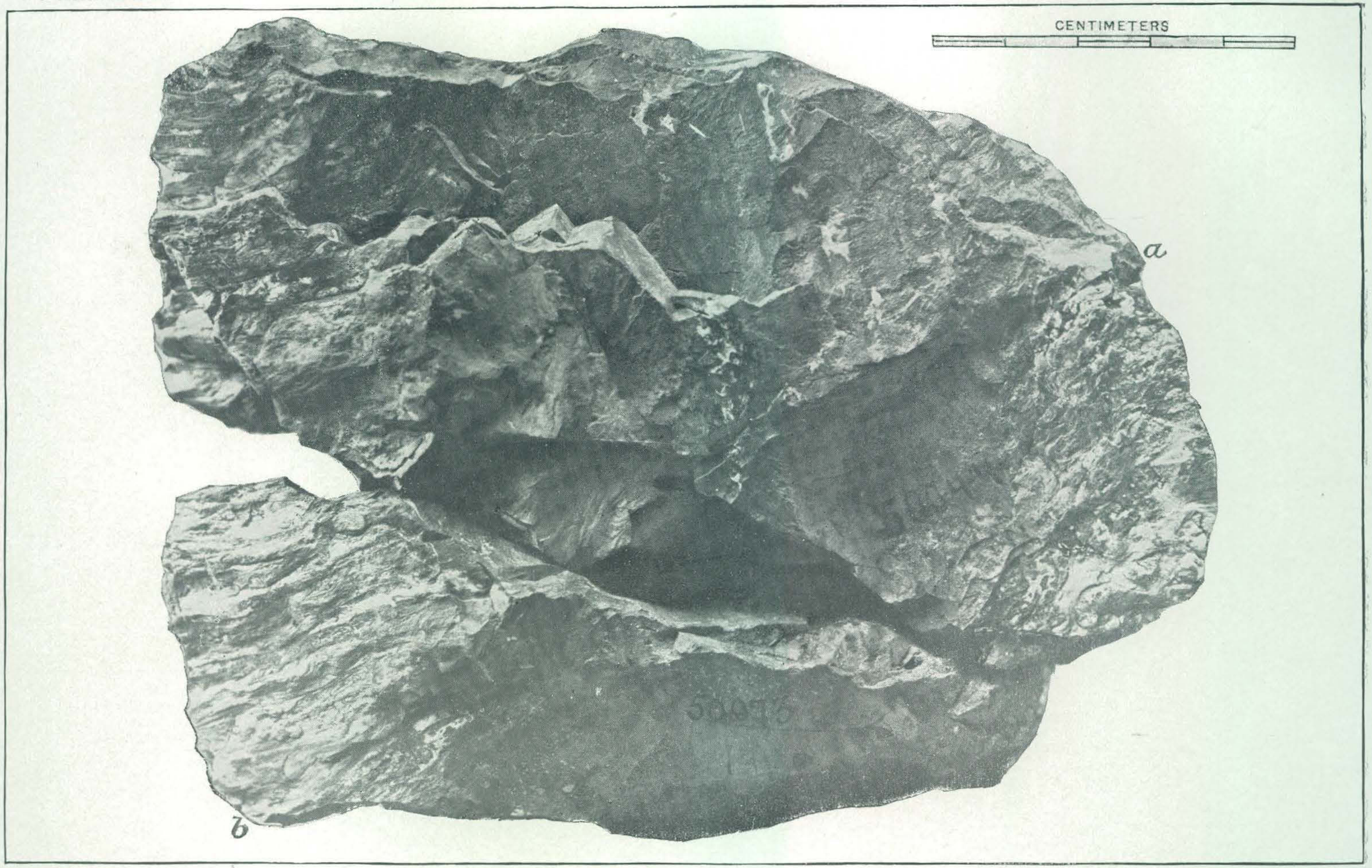
CYCADELLA EXOGENA Ward .......................................... 404

View of the longitudinal fracture of the complementary fragments Nos. 500.44 and 500.73 of the Museum of the University of Wyoming.

(*a*) No. 500.44; (*b*) No. 500.73.




CYCADELLA EXOGENA. FROM THE JURASSIC OF WYOMING.

# PLATE CXXXVIII.

# PLATE CXXXVIII.

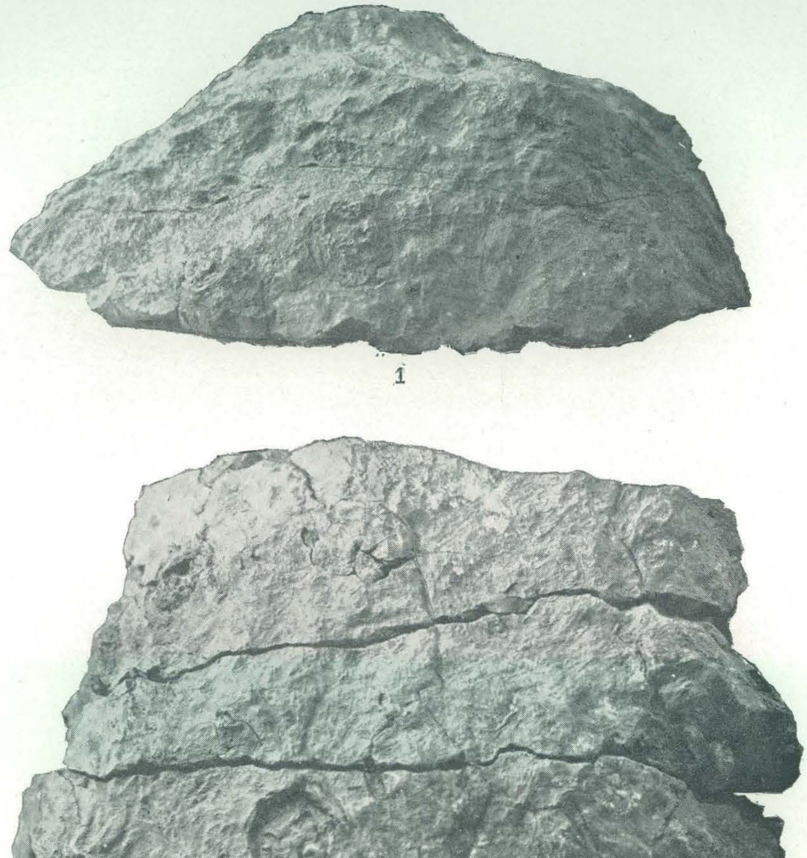


Fig. 1. Side view of No. 500.34 of the Museum of the University of Wyoming.

Fig. 2. View of the outer surface of No. 500.39, almost wholly covered with the ramentaceous layer.

Fig. 3. View of the outer surface of No. 500.55, mostly covered, but a few organs visible.

NOTE.—These views are arranged in the relations in which the parts they represent are supposed to have had, but the intervals between them were probably somewhat greater.




CYCADELLA RAMENTOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXXXIX.

## PLATE CXXXIX.

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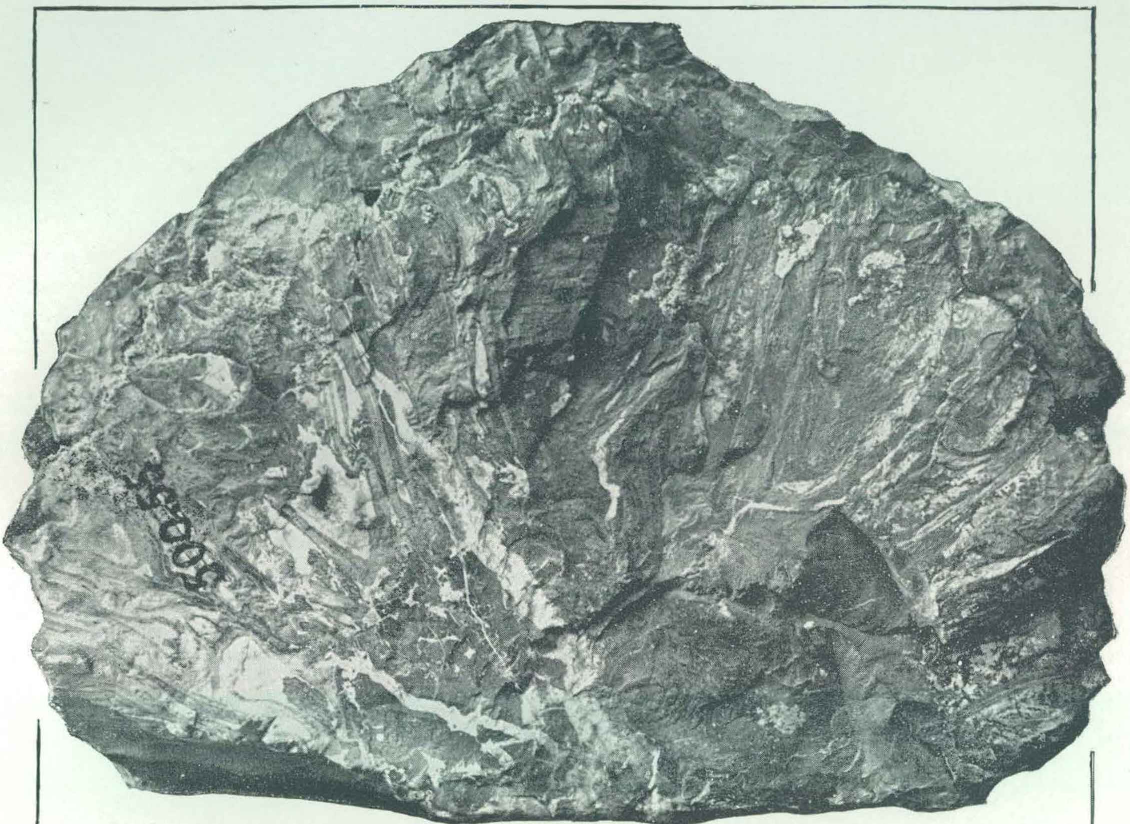
CYCADELLA RAMENTOSA Ward........................................................ 406

Fig. 1. View of the upper transverse fracture of No. 500.55 of the Museum of the University of Wyoming.

Fig. 2. View of the lower transverse fracture of No. 500.39.



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CENTIMETERS

CYCADELLA RAMENTOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXL.

## PLATE CXL.

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| CYCADELLA RAMENTOSA Ward | 406 |

View of the outer surface of the portion of a trunk resulting from joining the five complementary fragments, Nos. 500.40, 500.43, 500.45, 500.66, and 500.81 of the Museum of the University of Wyoming.

(*a*) No. 500.45; (*b*) No. 500.40; (*c*) No. 500.66; (*d*) No. 500.43; (*e*) No. 500.81.


CYCADELLA RAMENTOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXLI.

## PLATE CXLI.

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CYCADELLA RAMENTOSA Ward .............................................. 406

View of the inner fractured surfaces of the portion of a trunk resulting from joining the complementary fragments, Nos. 500.40, 500.43, 500.45, 500.66, and 500.81 of the Museum of the University of Wyoming.

(*a*) No. 500.45; (*b*) No. 500.40; (*c*) No. 500.66; (*d*) No. 500.43; (*e*) No. 500.81.


CYCADELLA RAMENTOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXLII.

## PLATE CXLII.



Fig. 1. Transverse fracture of the lower side of No. 500.66 of the Museum of the University of Wyoming.

Fig. 2. Longitudinal fracture of No. 500.40.

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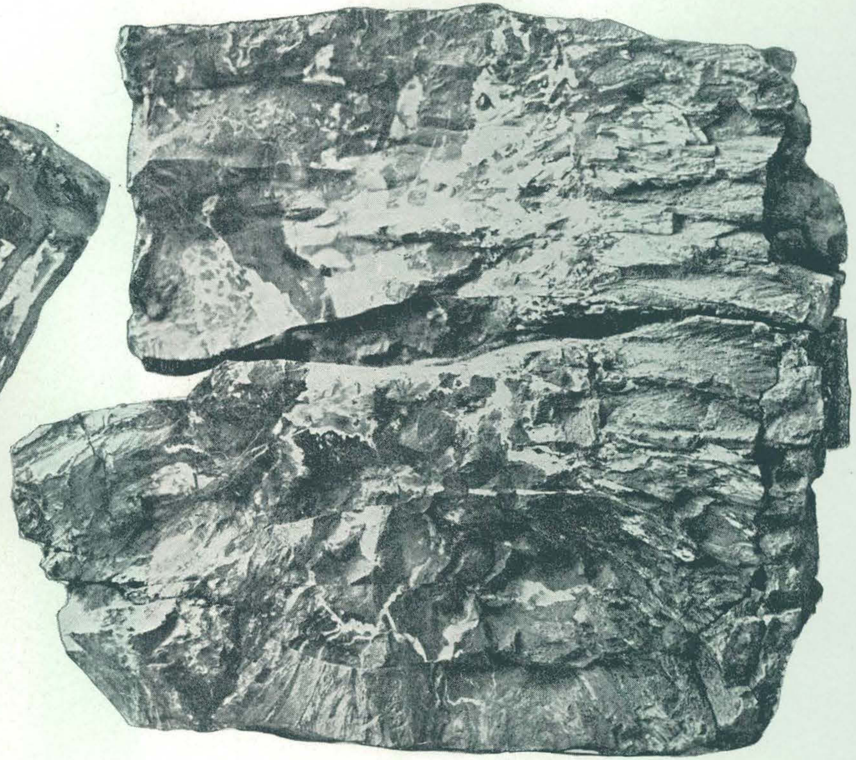

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CYCADELLA RAMENTOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXLIII.

## PLATE CXLIII.

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Cycadella ramentosa Ward ........................................ 406

Side view of the portion of a trunk formed by joining the complementary Nos. 500.50 and 500.60 of the Museum of the University of Wyoming.

(*a*) No. 500.50; (*b*) No. 500.60.


CYCADELLA RAMENTOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXLIV.

## PLATE CXLIV.

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CYCADELLA RAMENTOSA Ward.......................................... 406

View of the inner fractured surface of the portion of a trunk formed by the union of the complementary Nos. 500.50 and 500.60 of the Museum of the University of Wyoming.

(*a*) No. 500.50; (*b*) No. 500.60.


CYCADELLA RAMENTOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CXLV.

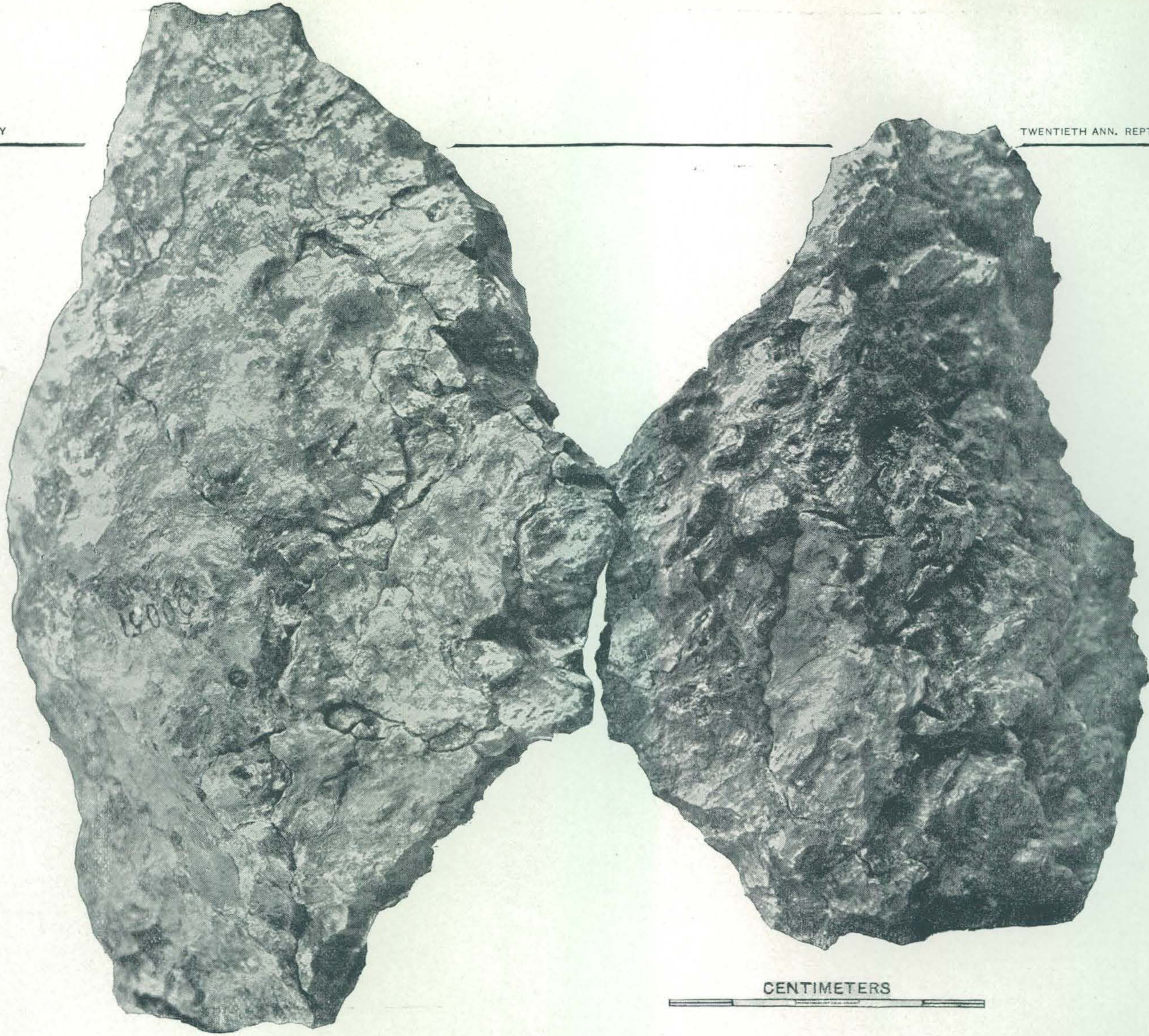
## PLATE CXLV.



Fig. 1. View of the outer surface of No. 500.51 of the Museum of the University of Wyoming.

Fig. 2. Similar view of No. 500.74.

NOTE.—These specimens are placed side by side in the position in which they are believed to belong, as constituting part of one and the same trunk.




CYCADELLA FERRUGINEA, FROM THE JURASSIC OF WYOMING.

# PLATE CXLVI.

## PLATE CXLVI.

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Cycadella ferruginea Ward........................................ 408

View of the longitudinal fracture of No. 500.51 of the Museum of the University of Wyoming.


CYCADELLA FERRUGINEA, FROM THE JURASSIC OF WYOMING.

# PLATE CXLVII.

## PLATE CXLVII.



No. 500.74 of the Museum of the University of Wyoming.

Fig. 1. View of the external surface.

Fig. 2. View of the longitudinal fracture.

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CENTIMETERS

CYCADELLA FERRUGINEA, FROM THE JURASSIC OF WYOMING.

# PLATE CXLVIII.

# PLATE CXLVIII.



No. 500.57 of the Museum of the University of Wyoming.

Fig. 1. View of the external surface.

Fig. 2. View of the longitudinal fracture.

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CYCADELLA CONTRACTA, FROM THE JURASSIC OF WYOMING.

# PLATE CXLIX.

## PLATE CXLIX.


CYCADELLA CONTRACTA, FROM THE JURASSIC OF WYOMING.

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Cycadella contracta Ward ............................................ 409

View of the longitudinal fracture of No. 500.58 of the Museum of the University of Wyoming.


CYCADELLA CONTRACTA, FROM THE JURASSIC OF WYOMING.

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# PLATE CLI.

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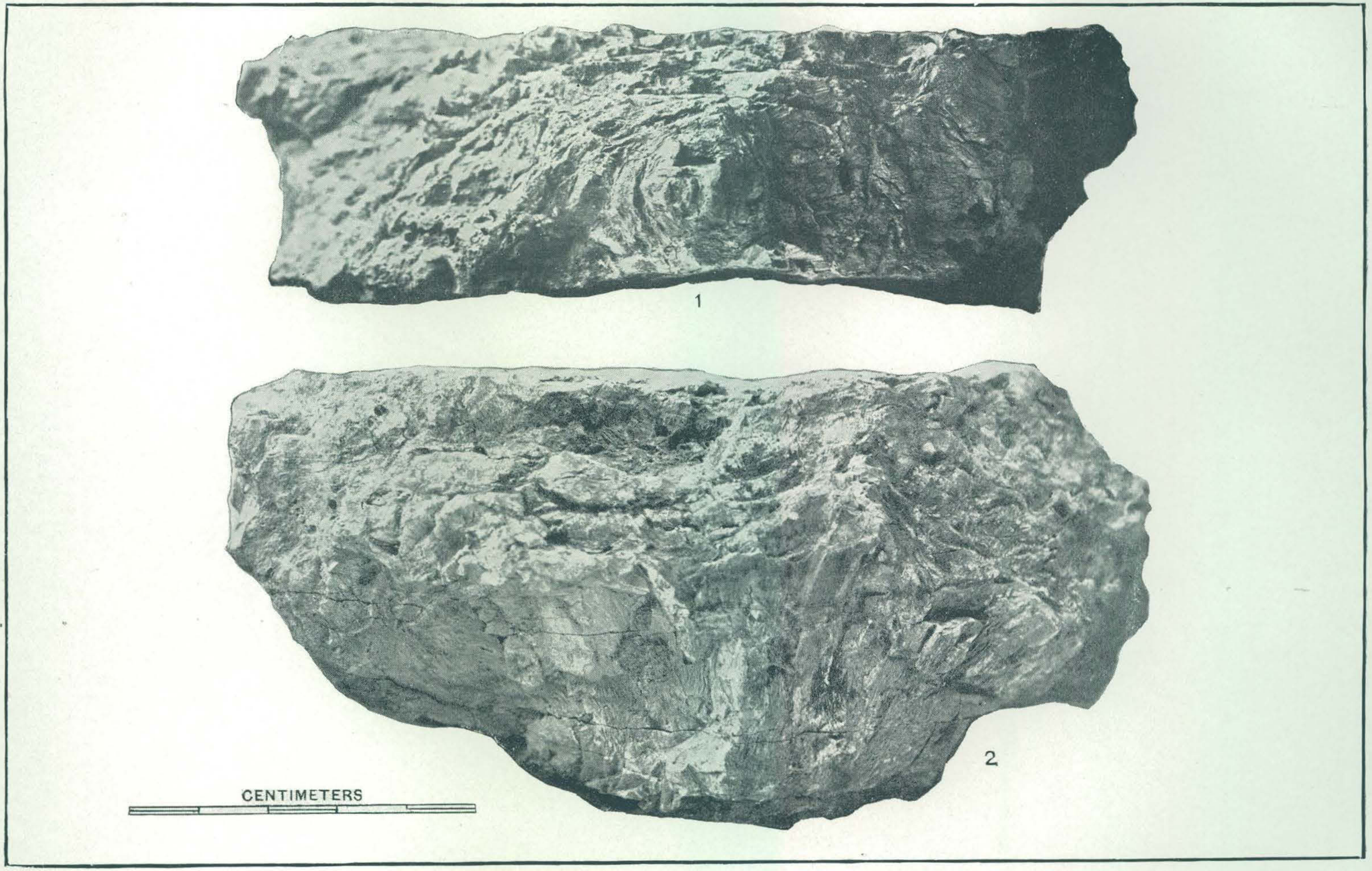
Cycadella contracta Ward .................................................. 409

Fig. 1. View of the external surface of one edge of the segment oi a trunk No. 500.79 of the Museum of the University of Wyoming.

Fig. 2. View of one side of No. 500.56, believed to be the basal portion of the same trunk and to represent the same side as Fig. 1, there being an interval between them.




CYCADELLA CONTRACTA, FROM THE JURASSIC OF WYOMING.

# PLATE CLII.

## PLATE CLII.

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Cycadella contracta Ward........................................... 409

View of the side of No. 500.56 of the Museum of the University of Wyoming.


CYCADELLA CONTRACTA, FROM THE JURASSIC OF WYOMING.

# PLATE CLIII.

## PLATE CLIII.

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| CYCADELLA CONTRACTA Ward | 409 |

Upper transverse fracture of No. 500.79 of the Museum of the University of Wyoming.


CYCADELLA CONTRACTA, FROM THE JURASSIC OF WYOMING.

# PLATE CLIV.

## PLATE CLIV.

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Cycadella gravis Ward . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 410

No. 500.63 of the Museum of the University of Wyoming.

Fig. 1. Side view.

Fig. 2. View of the base.

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CYCADELLA GRAVIS, FROM THE JURASSIC OF WYOMING.

# PLATE CLV.

## PLATE CLV.

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CYCADELLA VERRUCOSA Ward .............................................. 410

Fig. 1. Side view of No. 500.32 of the Museum of the University of Wyoming.

Fig. 2. Side view of No. 500.27, placed above the last in the position that it is supposed to have had originally.


CYCADELLA VERRUCOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CLVI.

## PLATE CLVI.

| | Page. |
|---|---|
| CYCADELLA VERRUCOSA Ward | 410 |

Fig. 1. Side view of No. 500.32 of the Museum of the University of Wyoming, side opposite that shown on Pl. CLV, Fig. 1.

Fig. 2. Side view of No. 500.27, placed above the last in the position that it is supposed to have had originally, side opposite that shown on Pl. CLV, Fig. 2.


CYCADELLA VERRUCOSA, FROM THE JURASSIC OF WYOMING.

# PLATE CLVII.

## PLATE CLVII.


CYCADELLA VERRUCOSA, FROM THE JURASSIC OF WYOMING.

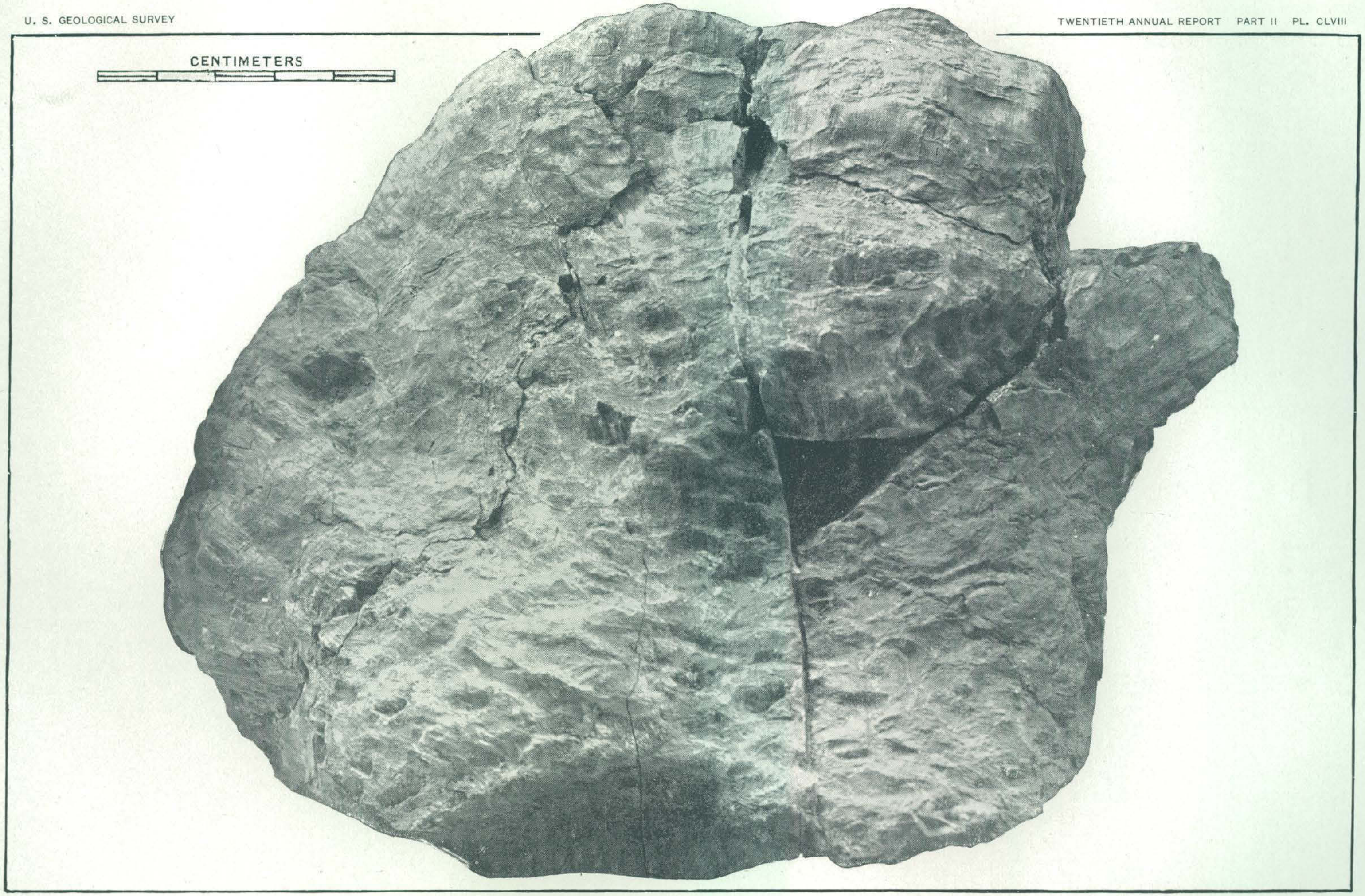
# PLATE CLVIII.

## PLATE CLVIII.

Page.

CYCADELLA JEJUNA Ward .......................................... 412

Side view of No. 500.28 of the Museum of the University of Wyoming.




CYCADELLA JEJUNA, FROM THE JURASSIC OF WYOMING.

# PLATE CLIX.

## PLATE CLIX.

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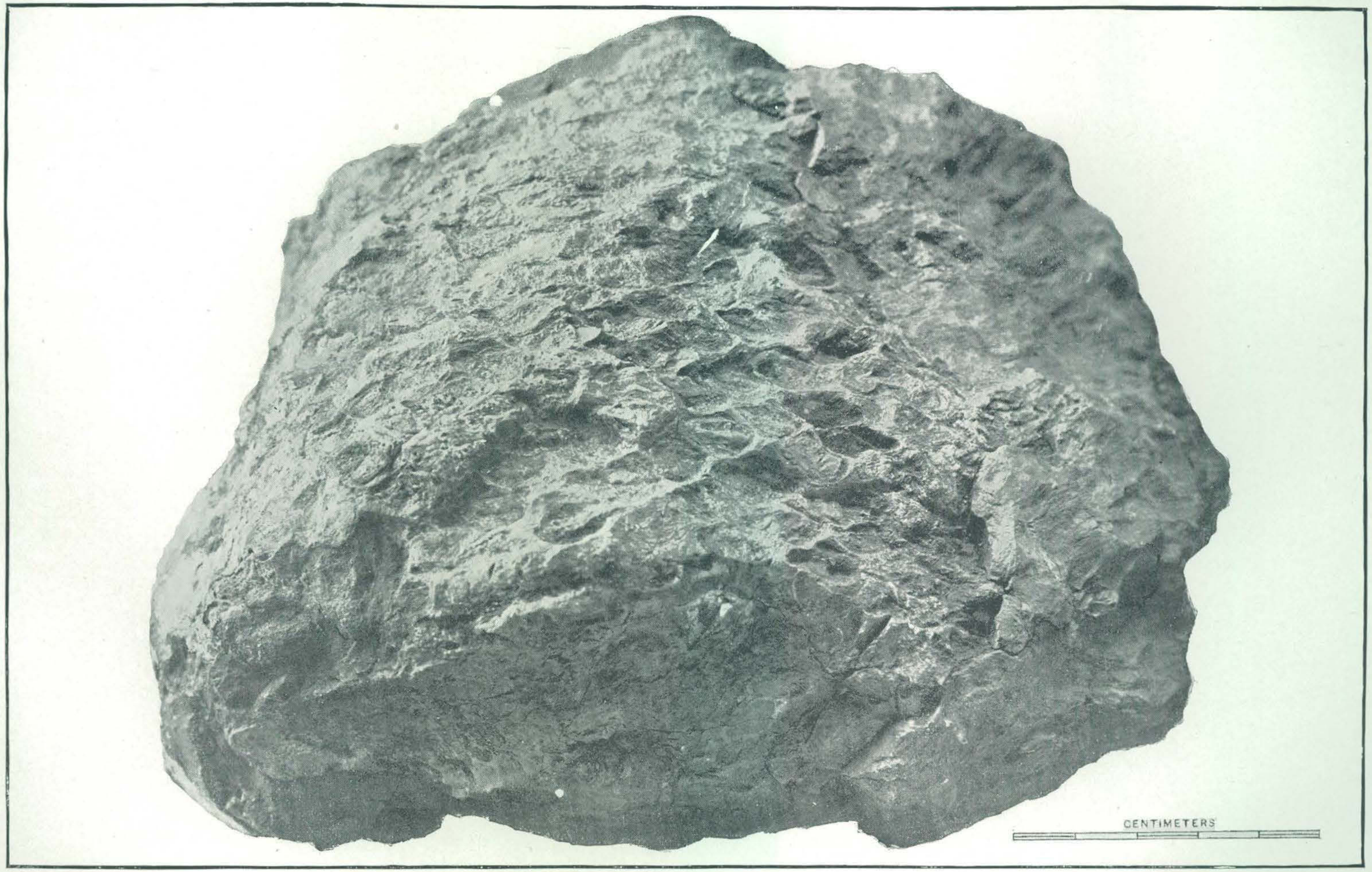
CYCADELLA JEJUNA Ward .......................................................... 412

Side view of No. 500.28 of the Museum of the University of Wyoming.


CYCADELLA JEJUNA, FROM THE JURASSIC OF WYOMING.

# PLATE CLX.

## PLATE CLX.




CYCADELLA JEJUNA, FROM THE JURASSIC OF WYOMING.

# PLATE CLXI.

## PLATE CLXI.

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| CYCADELLA JEJUNA Ward | 412 |

View of one side of No. 500.31 of the Museum of the University of Wyoming, showing the area from which the ramentum coat has been scaled off and the edge of the portion remaining.


CYCADELLA JEJUNA, FROM THE JURASSIC OF WYOMING.

# PLATE CLXII.

## PLATE CLXII.

Page.

CYCADELLA CONCINNA Ward ........................................................ 412

No. 500.16 of the Museum of the University of Wyoming.

Fig. 1. Side view.

Fig. 2. View of the base.

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CENTIMETERS

CYCADELLA CONCINNA, FROM THE JURASSIC OF WYOMING.

# PLATE CLXIII.

## PLATE CLXIII.

| | Page. |
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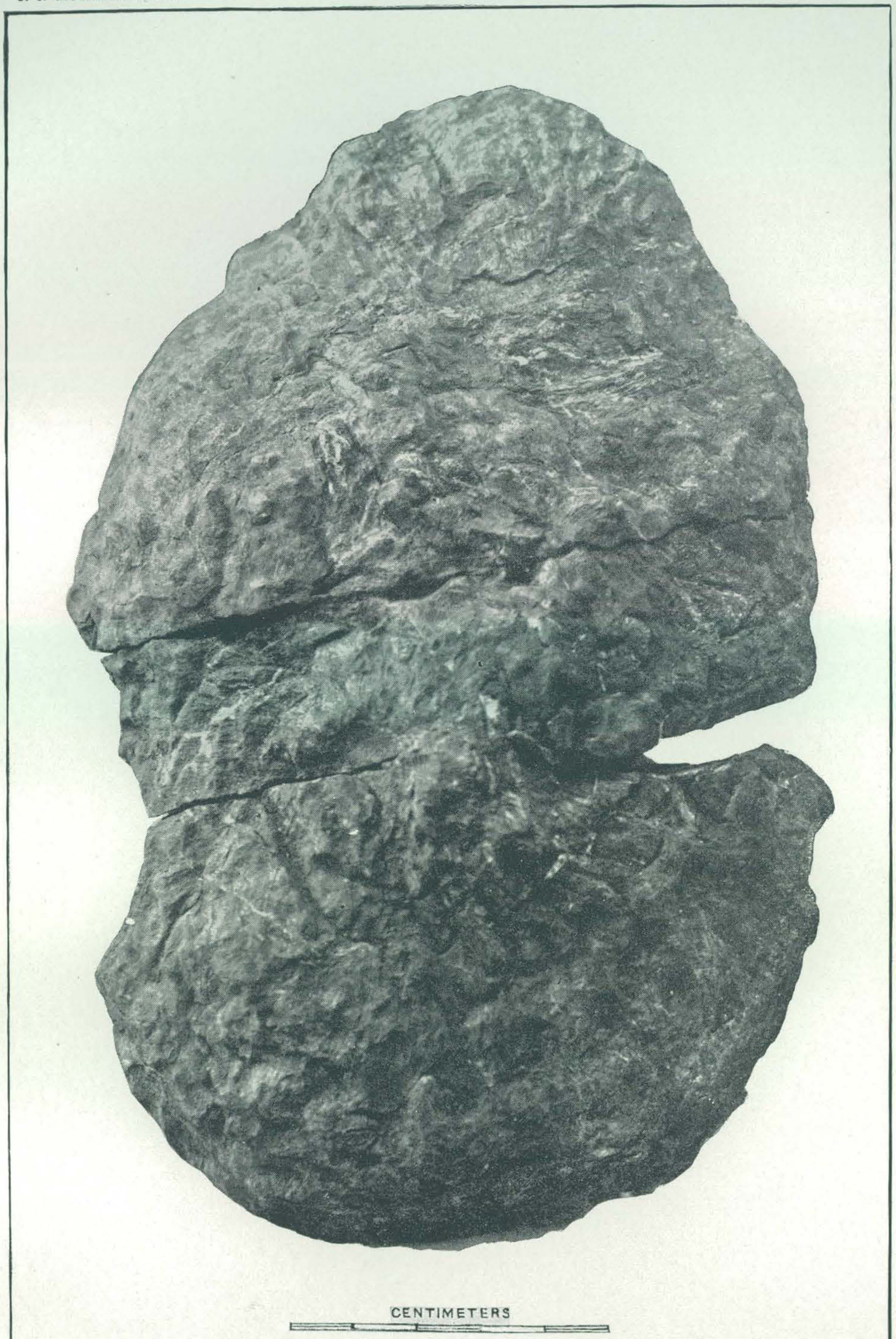
| CYCADELLA CREPIDARIA Ward | 413 |

View of the top of No. 500.83 of the Museum of the University of Wyoming.




CYCADELLA CREPIDARIA, FROM THE JURASSIC OF WYOMING.

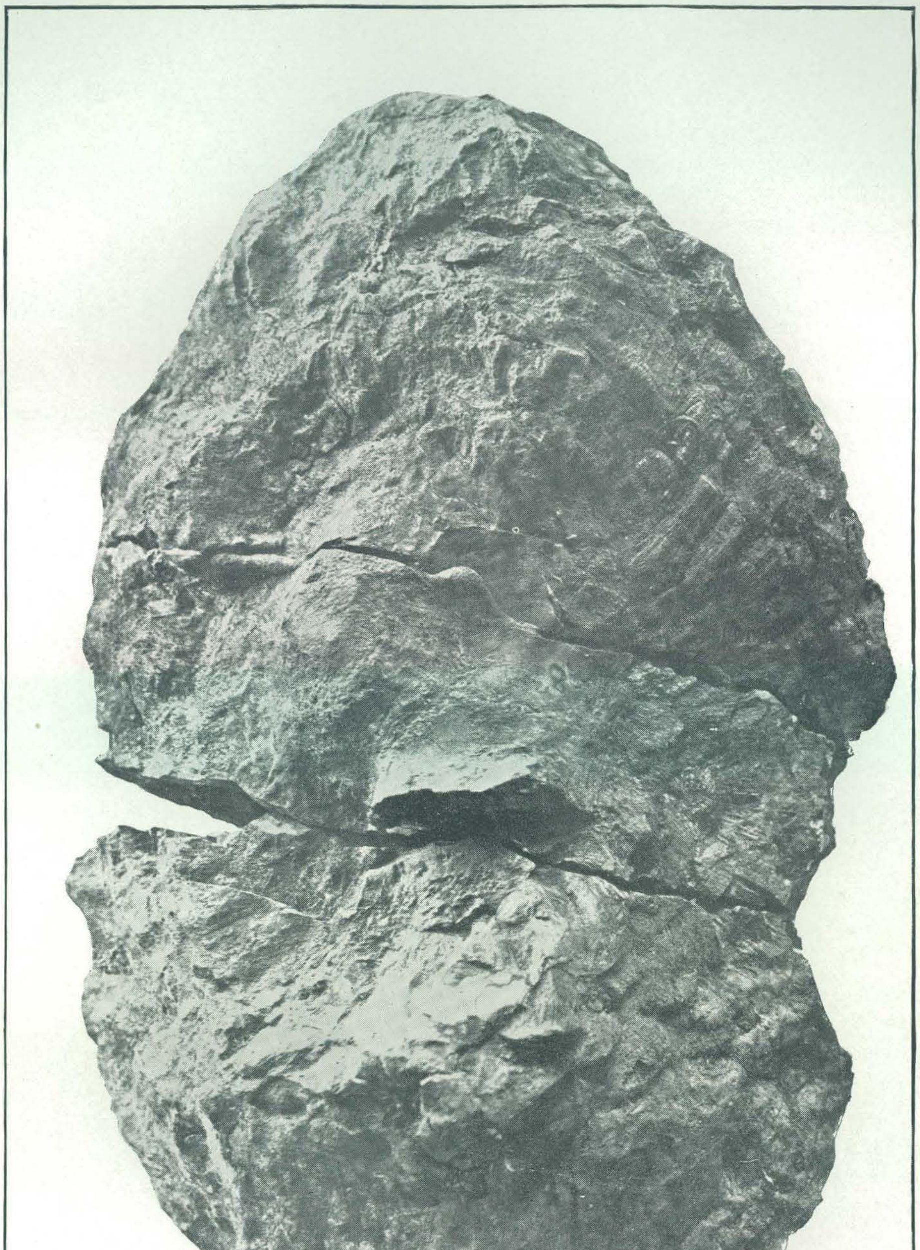
# PLATE CLXIV.

## PLATE CLXIV.

Page.

CYCADELLA CREPIDARIA Ward .......................................... 413

View of the base of No. 500.83 of the Museum of the University of Wyoming.




CYCADELLA CREPIDARIA, FROM THE JURASSIC OF WYOMING.

# PLATE CLXV.

## PLATE CLXV.


CYCADELLA GELIDA, FROM THE JURASSIC OF WYOMING.

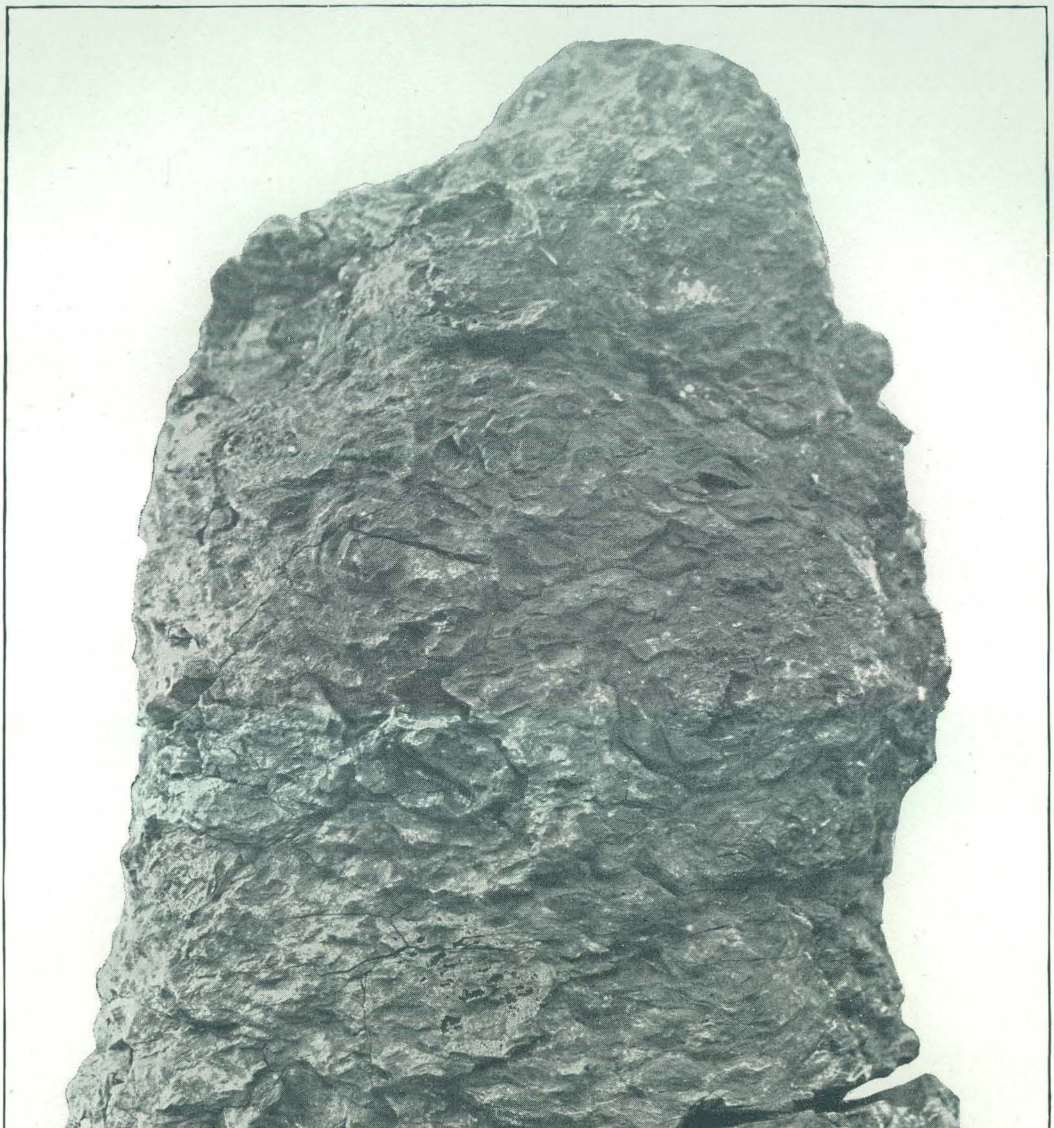
# PLATE CLXVI.

# PLATE CLXVI.

Page.

CYCADELLA GELIDA Ward ........................................................ 414

Side view of No. 5001 of the Museum of the University of Wyoming (side opposite that shown on Pl. CLXV.)




CYCADELLA GELIDA, FROM THE JURASSIC OF WYOMING.

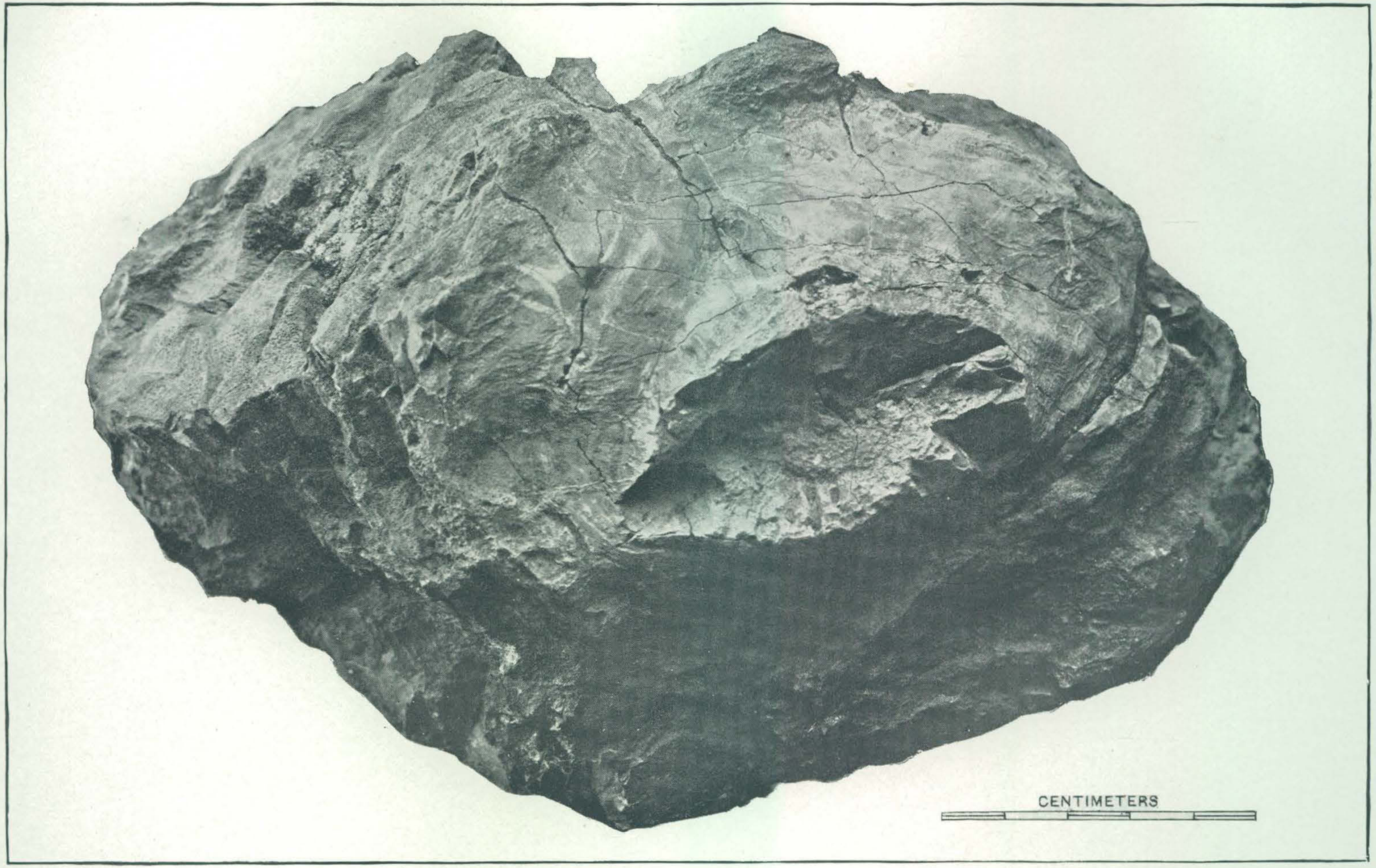
# PLATE CLXVII.

## PLATE CLXVII.

Page.

Cycadella gelida Ward .......... 414

View of the base of No. 500.1 of the Museum of the University of Wyoming.




CYCADELLA GELIDA, FROM THE JURASSIC OF WYOMING.

# PLATE CLXVIII.

## PLATE CLXVIII.

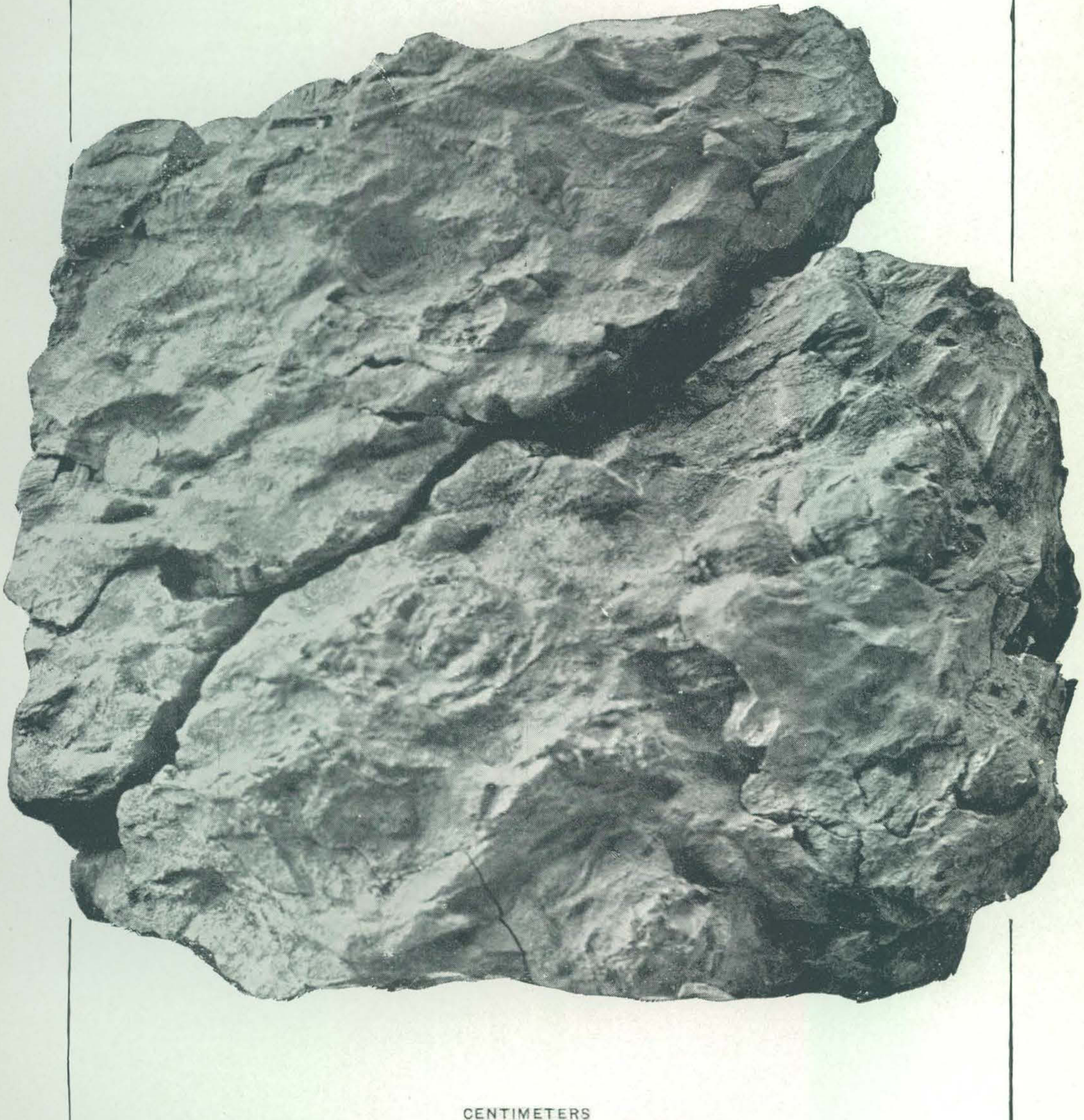

CYCADELLA GELIDA, FROM THE JURASSIC OF WYOMING.

# PLATE CLXIX.

## PLATE CLXIX.



Side view of No. 500.24 of the Museum of the University of Wyoming (side opposite that shown on Pl. CLXVIII).



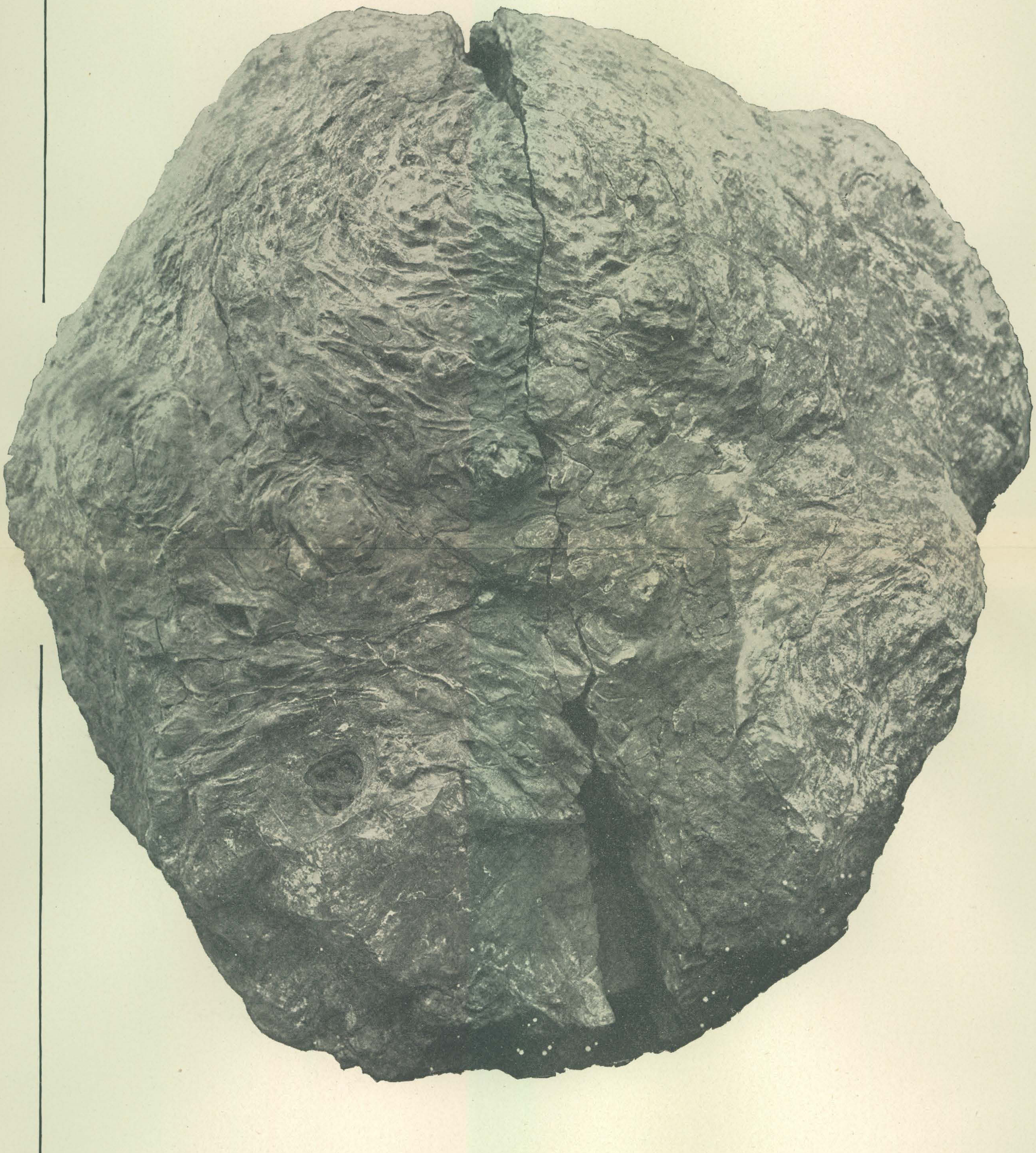

CYCADELLA GELIDA. FROM THE JURASSIC OF WYOMING.

# PLATE CLXX.

## PLATE CLXX.

| | Page. |
|---|---|
| CYCADELLA CARBONENSIS Ward | 415 |

View of the best side or back of No. 500.2 of the Museum of the University of Wyoming.



CENTIMETERS

CYCADELLA CARBONENSIS, FROM THE JURASSIC OF WYOMING.

# PLATE CLXXI.

## PLATE CLXXI.

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CYCADELLA CARBONENSIS Ward .......................................... 415

View of the lower side, including the base of No. 500.2 of the Museum of the University of Wyoming.


CYCADELLA CARBONENSIS, FROM THE JURASSIC OF WYOMING.

# PLATE CLXXII.

## PLATE CLXXII.

CENTIMETERS

CYCADELLA KNIGHTII, FROM THE JURASSIC OF WYOMING.

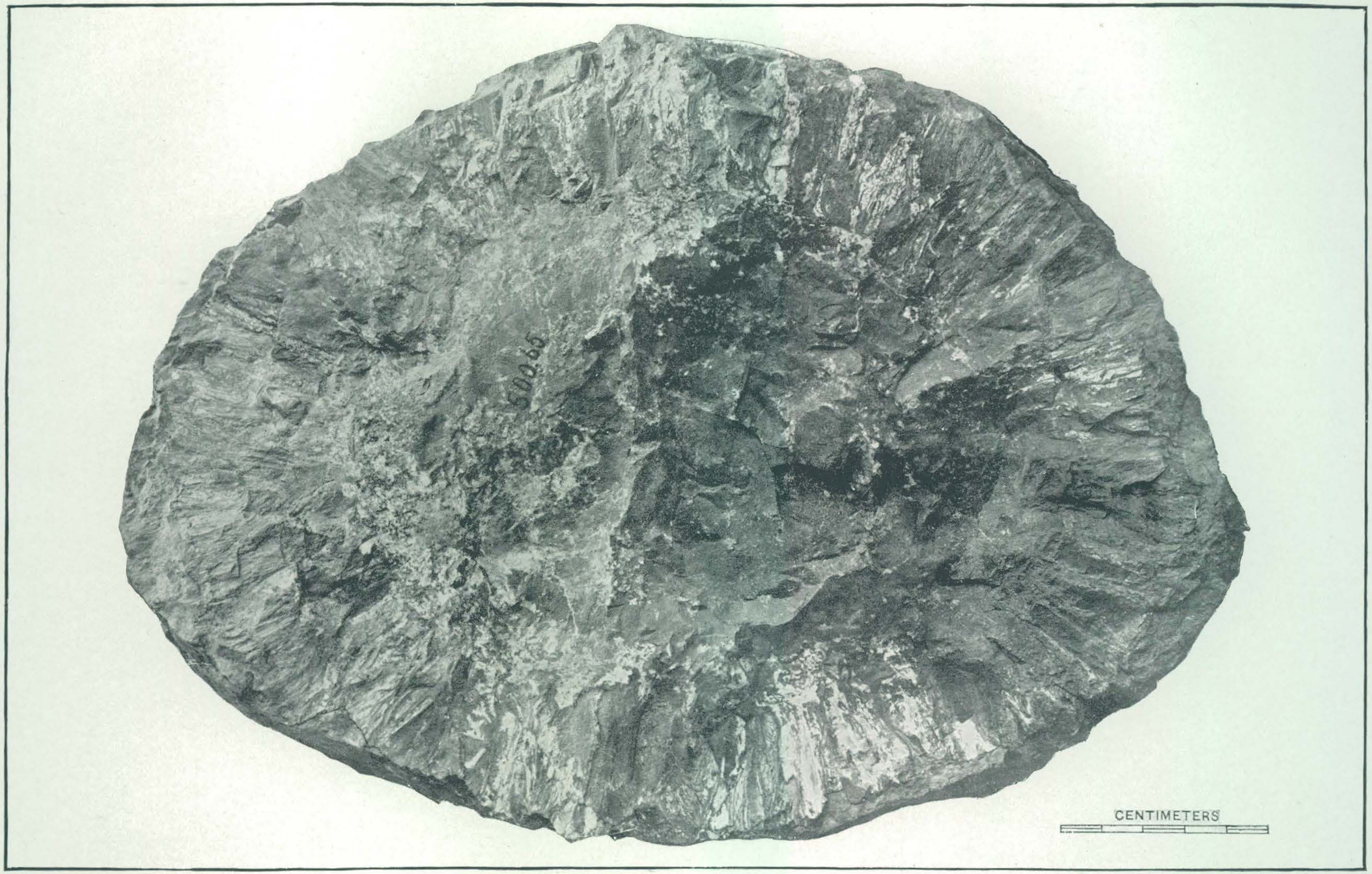
# PLATE CLXXIII.

## PLATE CLXXIII.


CYCADELLA KNIGHTII, FROM THE JURASSIC OF WYOMING.

# PLATE CLXXIV.

## PLATE CLXXIV.




CYCADELLA KNIGHTII, FROM THE JURASSIC OF WYOMING.

# PLATE CLXXV.

## PLATE CLXXV.

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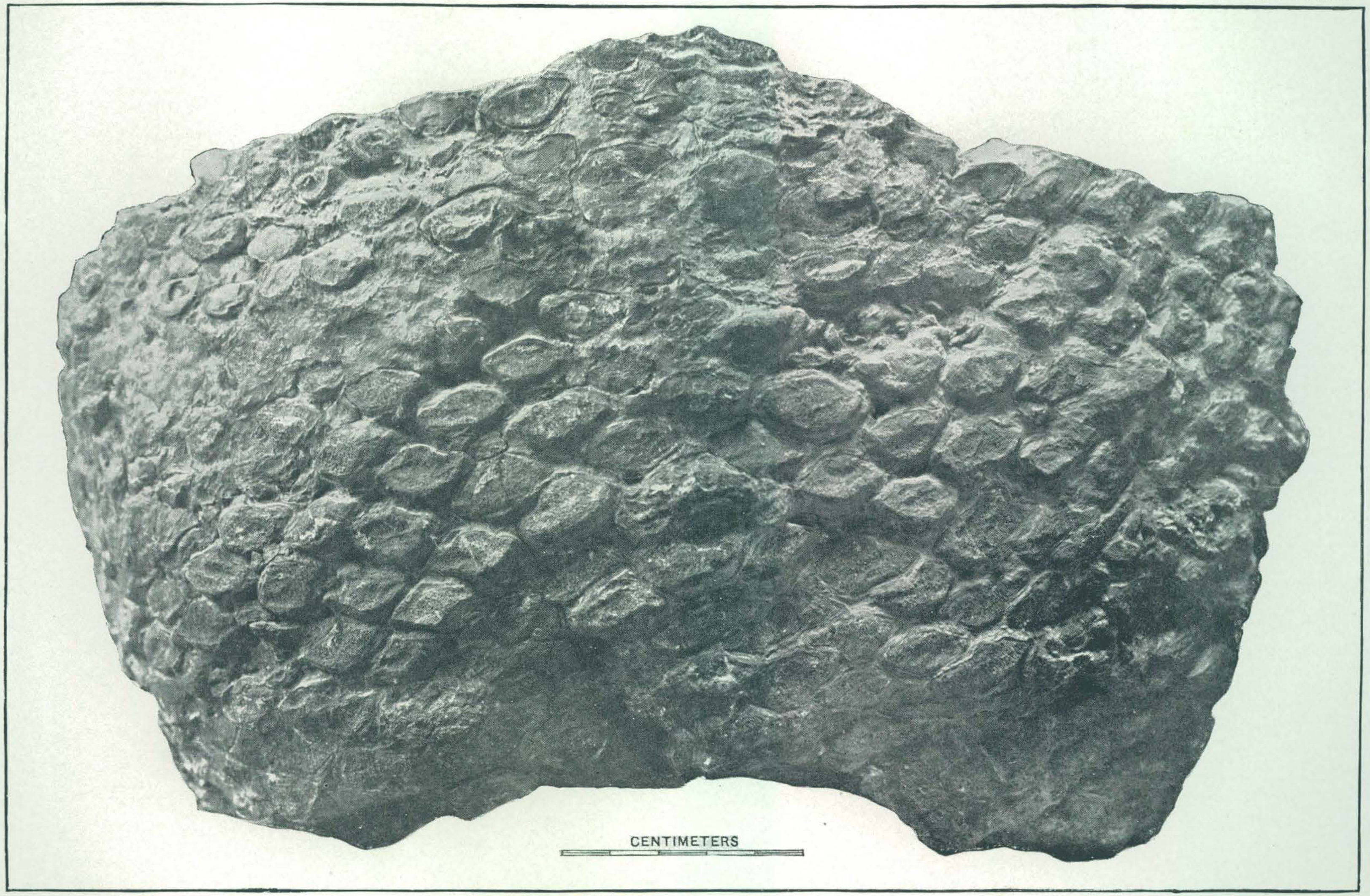
CYCADELLA KNIGHTII Ward ........................................ 416

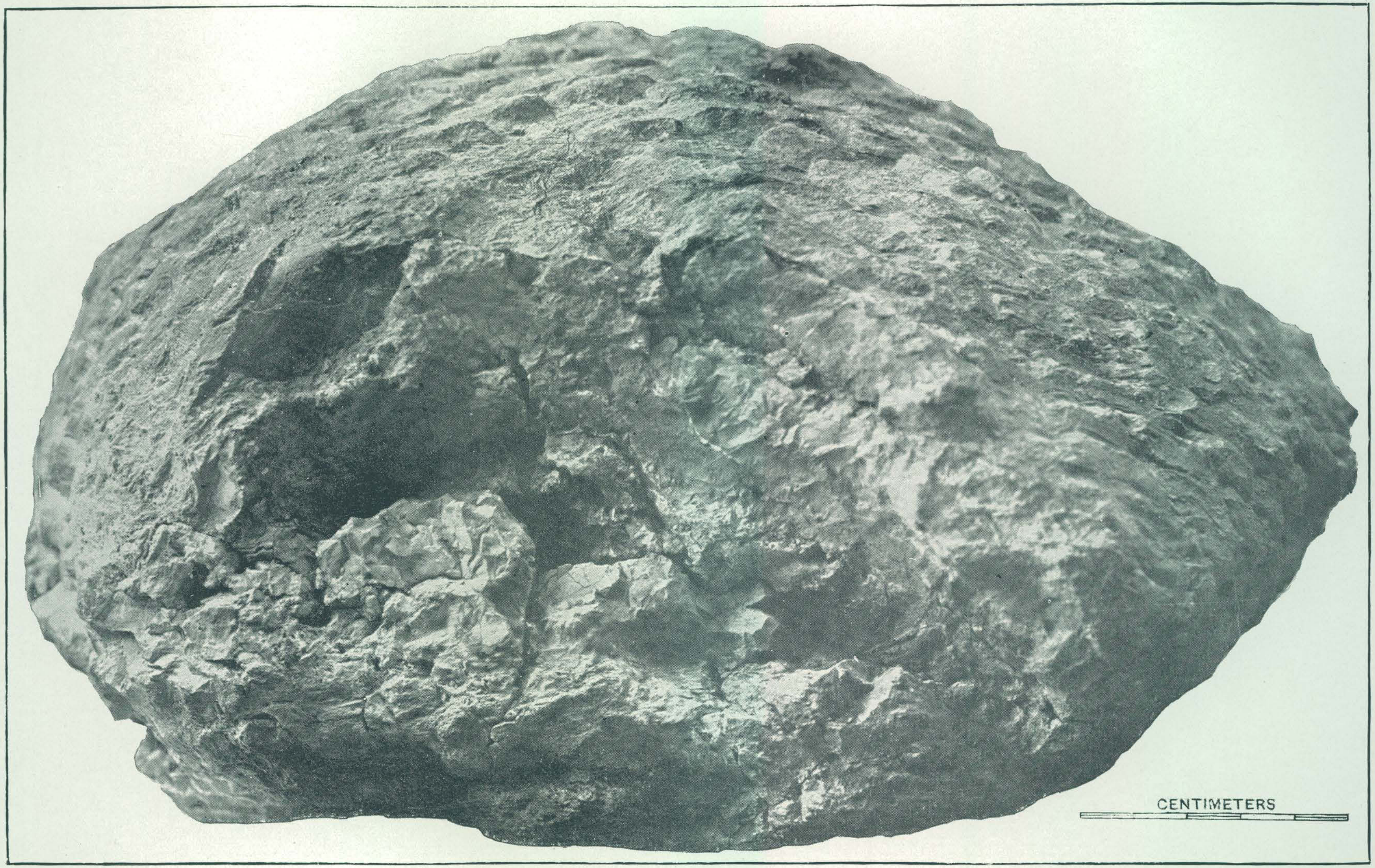
Side view of No. 500.33 of the Museum of the University of Wyoming.




CYCADELLA KNIGHTII, FROM THE JURASSIC OF WYOMING.

# PLATE CLXXVI.

## PLATE CLXXVI.




CYCADELLA KNIGHTII, FROM THE JURASSIC OF WYOMING.

# PLATE CLXXVII.

## PLATE CLXXVII.


CYCADELLA KNIGHTII, FROM THE JURASSIC OF WYOMING.

# PLATE CLXXVIII.

# PLATE CLXXVIII.

INTERNAL STRUCTURE OF FOSSIL WOOD FROM THE CYCAD BED OF THE FREEZEOUT HILLS, CARBON COUNTY, WYOMING, AS SHOWN BY SECTIONS MADE FROM NO. 500.85 OF THE MUSEUM OF THE UNIVERSITY OF WYOMING.

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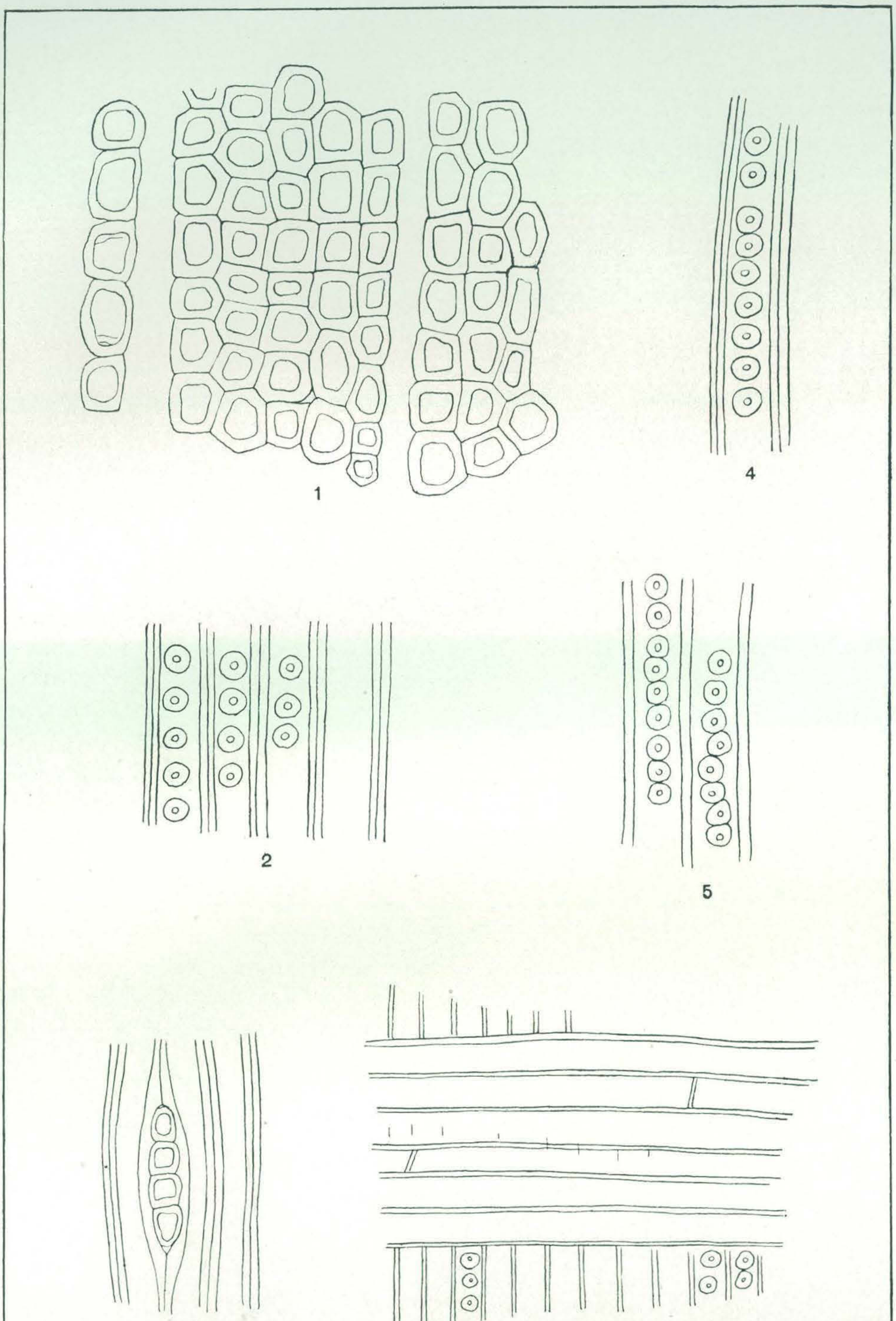
Figs. 1–6. ARAUCARIOXYLON ? OBSCURUM Kn. n. sp .......................... 418

Fig. 1. Transverse section, showing the uniform and thick-walled wood cells. × 320.

Figs. 2, 4, 5. Radial sections, showing the bordered pits in scattered or contiguous rows. × 320.

Fig. 3. Tangential section, showing a single medullary ray. × 320.

Fig. 6. Radial section, showing medullary rays and wood cells with remote bordered pits. × 320.




ARAUCARIOXYLON? OBSCURUM, FROM THE JURASSIC OF WYOMING.

# PLATE CLXXIX.

## PLATE CLXXIX.

### INTERNAL STRUCTURE OF FOSSIL WOOD FROM THE JURASSIC OF THE BLACK HILLS IN SOUTH DAKOTA.

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Figs. 1–6. PINOXYLON DACOTENSE Kn. gen. et sp. nov .......................... 420

Fig. 1. Transverse section, showing sharp line of demarcation between fall and spring wood. × 320.

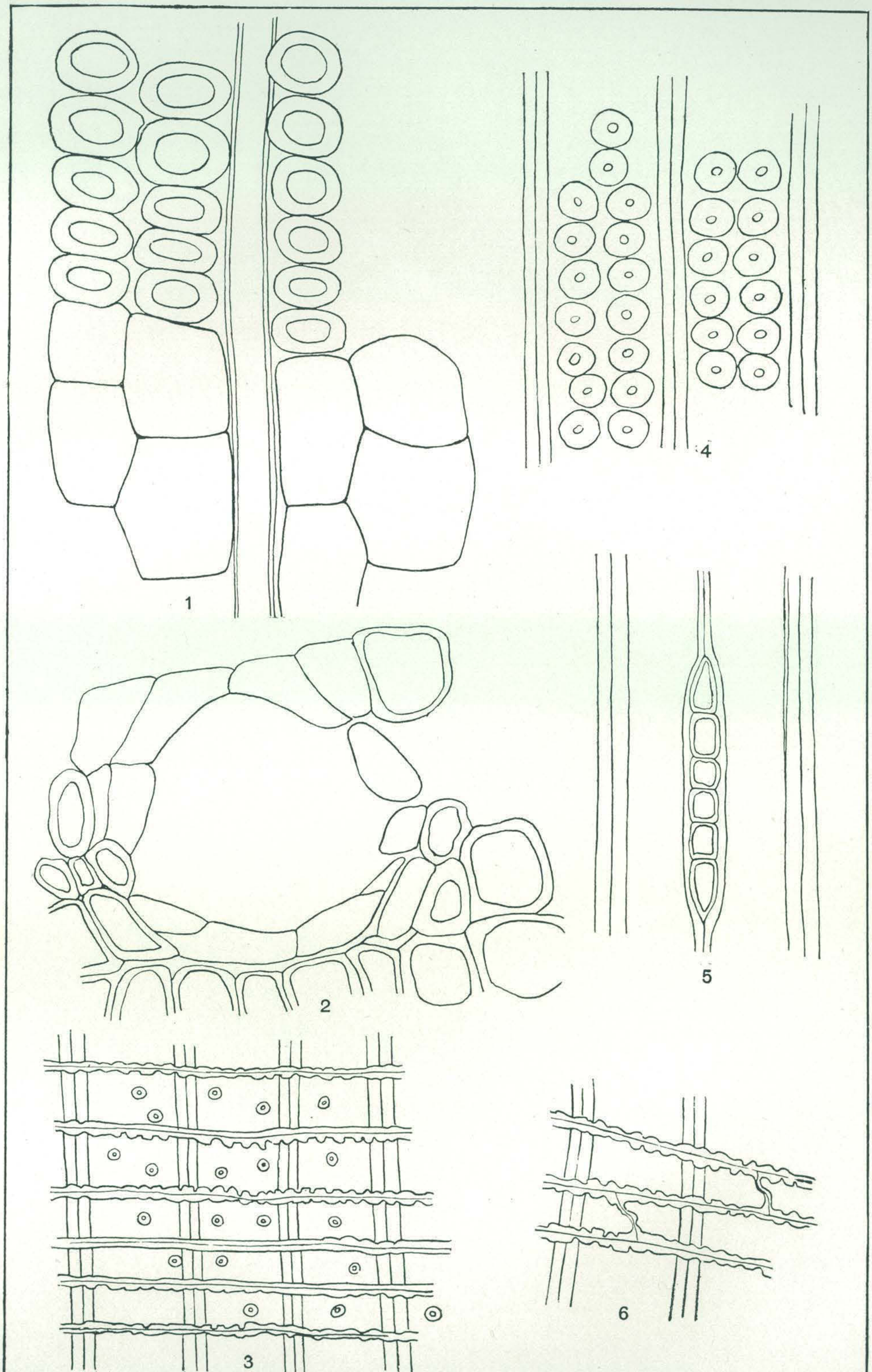
Fig. 2. Transverse section of resin passage in fall wood. × 320.

Fig. 3. Radial section, showing medullary rays with irregularly thickened walls and small bordered pits. × 320.

Fig. 4. Radial section, showing bordered pits on walls of spring wood. × 320.

Fig. 5. Tangential section, showing a single medullary ray. × 320.

Fig. 6. Radial section, showing manner in which the medullary rays are thickened and also the ends of the cells. × 320.




PINOXYLON DACOTENSE, FROM THE JURASSIC OF SOUTH DAKOTA.

# THE STRATIGRAPHIC SUCCESSION

OF THE

# FOSSIL FLORAS OF THE POTTSVILLE FORMATION IN THE SOUTHERN ANTHRACITE COAL FIELD

## PENNSYLVANIA

BY

DAVID WHITE

# CONTENTS.

# ILLUSTRATIONS.

# THE STRATIGRAPHIC SUCCESSION OF THE FOSSIL FLORAS OF THE POTTSVILLE FORMATION IN THE SOUTHERN ANTHRACITE COAL FIELD, PENNSYLVANIA.

By David White.

## INTRODUCTION.

### APPLICATION OF THE TERM "POTTSVILLE FORMATION."

The Pottsville formation, or "Pottsville series" or "Pottsville conglomerate," as it has more often been known, is a group of largely arenaceous beds of highly variable thickness which, in eastern Pennsylvania, lies between the Mauch Chunk red shale, or distinctly Lower Carboniferous, and the Lower Productive Coal Measures, or distinctly Upper Carboniferous. Besides the term employed for these terranes in this report, this formation has been otherwise designated the "Seral conglomerate" or "Great conglomerate," by the early Pennsylvania geological survey;[1] the "Pottsville conglomerate," and locally the "Lykens series," by the second geological survey;[2] the "Conglomerate series" by many other geologists;[3] and more recently it has been known in the northern portion of the Appalachian trough as the "Pottsville series," the modified name published by Dr. I. C. White.[4] The early name "Seral" is hardly adaptable to present use, since it was applied by Rogers to the entire Carboniferous series above the red shale in the anthracite region, the lower portion being distinguished from the remainder only by the addition of the word "conglomerate." The claims to consideration of "Great conglomerate" and "Conglomerate series" have been rejected by most geologists, since throughout the greater part of its extent the formation is found to be productively coal-bearing, while in certain districts it contains little or no conglomerate. Nevertheless, the magnificent development of the terranes displayed at Pottsville, which is cited by all authors as the type locality under the various names, and from which the later names "Pottsville conglomerate" and "Pottsville series" were derived, is overwhelmingly conglomeratic, as well as deficient in profitably workable coal. In the various districts of the

[1] Rogers, Geol. Pennsylvania, Vol. I, 1858, pp. vii, 109, 146, 148; Vol. II, Pt. I, pp. 16, 17.
[2] Annual Rept., 1886, Pt. III; Summary Final Report, 1895, Vol. III, Pt. I; Atlas Southern Anthracite Field, Pts. I-VI.
[3] Fontaine, Am. Jour. Sci., 3d series, Vol. VII, 1876, pp. 459, 573.
[4] Bull. U. S. Geol. Survey No. 65, 1891, p. 179.

bituminous basins a number of terms are used for individual terranes or local groups, which have often erroneously and without harmony been correlated with portions of, or with the whole of, the Pottsville formation. The extra-anthracitic nomenclature is not, however, involved in the immediate consideration of the formation in the type region. "Formation" is here used in a broad sense in preference to "series," in view of the subordinate rank of the collective terranes in the geologic column, their biologic unity, and their lack of individual persistence or continuity.

In general, the Pottsville formation has been understood as wholly or in part representing the Millstone grit of Nova Scotia, New Brunswick, and the Old World. This correlation is founded chiefly on the lithologic similarity and the coincidental occurrence of the two formations at the base of the Productive Coal Measures. In the case of the Pottsville the correlation has rested entirely on the order of stratigraphic occurrence and the lithology, a method of coordination that, as will be shown later, has resulted in the reference of a portion of the formation in the Southern States, where it contains the most valuable coals of the Southern Appalachian districts, to the Productive Coal Measures. It has, moreover, been the custom to consider the lithologic representative in each State or region as contemporaneous with and equivalent in toto to the lithologic member or group in every other region, including the type section. The studies, now in progress, of the plant fossils of the terranes in different regions, correlated by lithology with the Pottsville formation, clearly show the fallacy of regarding the lithologic section in each region as covering the same time interval as that covered by every other section. They also show that in certain regions considerable thicknesses of beds which, on account of the lithology, are referred to the post-Pottsville Coal Measures contain the well-marked and distinctly characteristic floras of various horizons in other sections which have been determined, on the lithologic basis, as Pottsville. It is clear that under such circumstances the correlation, especially between separate basins, must be by means of comparative paleontology.

## AGENCY OF FOSSIL PLANTS IN THE CORRELATION OF THE TERRANES.

From the foregoing it will be seen that the existing condition is one in which we have, under numerous names, a large number of terranes of supposed Pottsville age in both the interior or Mississippi basin and the eastern basins, the final correlation of which is largely or often wholly dependent on the results of paleontologic study. Since the organic remains in these beds are composed predominantly, if not exclusively, of plant fragments, the foremost questions involved in any correlation with the Pennsylvanian section are: Has the typical Pottsville formation any reliable and distinct paleontologic characters or aspect? is it satisfactorily distinguishable by means of fossils from the subjacent formations or the overlying Coal Measures? and does the plant life reveal such modifications in time, or such vertical distribution, as to constitute paleontologic subdivisions, zones, or horizons? In answer to these inquiries, it must be confessed that up to the present time nothing has been known of the plants or their associations in the type section. No one appears to have studied the fossils from the Pottsville formation in the vicinity of the type section in the Pottsville Basin, or even in the entire Southern Anthracite coal field. In taking up the task of the stratigraphic elaboration of the Pottsville flora,[1] it was further discovered that neither the upper nor the lower limits of the "Seral" conglomerate, or "Pottsville conglomerate," are closely defined by the earlier geologists, while the somewhat conventional lithologic boundaries proposed in the latest publications on this subject appear to lack general acceptance.

## PURPOSE AND SCOPE OF THIS PAPER.

As will have been inferred from the above statements of existing conditions and needs, the purposes of the studies, the immediate results of which are preliminarily reported in this paper, are:

(1) The exploitation and elaboration, from a stratigraphic standpoint, of the plant fossils of the Pottsville formation in the type region in the Southern Anthracite coal field. This involves the voluminous collection of fossils from as many horizons as possible, ranging throughout the entire thickness of the formation, as somewhat uncertainly defined on the lithologic basis.

(2) The critical analysis and comparative study of the plant material collected, with a view to the discovery of the existence of any natural paleontologic subdivisions, zones, or horizons, and their paleontologic characters, or the species of stratigraphic value, if any such are present.

(3) The discovery of the paleontologic limits as differing or as agreeing with the lithologic limits of the type section, and the consequent paleontologic definition of the formation. This entails the examination of the fossils in the terranes below the Pottsville, as well as in the lower portions of the Coal Measures above the lithologic Pottsville, and the determination of (*a*) their relations to the floras of the latter, and (*b*) the significance of those relations in both the geologic and the paleontologic grouping of the formation. Since, as has

[1] Lest the use of the word "paleontology" in this report be considered an unwarranted assumption by those who are accustomed to understanding the term as applying exclusively to animal remains, it should be explained that fossil plants in general are not only most widely distributed and frequently the only fossils in the terranes on the east side of the Appalachian trough, but also that in many of the sections, including the type section at Pottsville, no animal fossils, with the exception of Spirorbis, small, rare, crustacean fragments, and a few cockroach wings, have yet been discovered.

been remarked above, marine animal fossils are very rare in the terranes of the Pottsville along the eastern margin of the trough, the usually abundant plant fossils constitute the chief evidence on which correlations, in this region at least, must be based.

The primary result of this work should be the paleontologic definition, if such is practicable, of the Pottsville formation, and the establishment of a paleontologic section which shall constitute the type section of the formation, for comparison and reference in the study and correlation of other middle Carboniferous phytiferous terranes in the Appalachian province. Two other, largely concomitant, results that are either economic or scientific in their nature have also been reached in the process of the elaboration of the fossil plants of the formation in the typical region. The first, of some economic interest, is the correlation of groups of beds, or of individual coals wrought in disconnected or somewhat isolated portions of the Southern Anthracite field. The other, which concerns the question of general geologic correlation, is the acquisition of data for the determination of the age of the Pottsville formation—i. e., (*a*) the time interval represented by the type section, and (*b*) the equivalents, in a broad sense, of the formation in other basins of this province and in other parts of the world. Incidentally, also, through the discovery in the Pottsville of floras already more or less completely known from isolated and uncorrelated terranes in other regions of the United States, the way is opened to the proper reference and correlation of those terranes with the Pottsville, or with portions thereof. However, in this report no special effort will be made to correlate the formations of this age in the bituminous regions, except in certain special or important cases. Such a work of general correlation will be more naturally and effectively done in connection with a general study of the floras of the supposedly contemporaneous formations in the Appalachian trough and of their relations to the typical Pottsville, a work that of necessity is dependent on and consequent to that now in hand.

In this report the details of the geology of the Southern Anthracite field are considered only to the extent to which they are concerned in the ascertained occurrence, distribution, or relation of the fossils examined. Beyond a general description of the field, the stratigraphic data are largely confined to the orientation of coals or plant beds, or to the definition of the formations in certain sections. The details relating to the areal geology are limited, first, to questions of the area of certain coals as identified and correlated at different points by means of the fossils, and, second, to the correction of certain areal and stratigraphic errors in the existing maps, especially in those relating to the western part of the field. These errors were discovered in the course of paleontologic investigation and were worked out by the combined methods of stratigraphy and paleontology.

## GENERAL DESCRIPTION OF THE SOUTHERN FIELD.

### FORM AND EXTENT OF THE FIELD.

The Southern Anthracite field, known also as the Schuylkill or Pottsville, and as the First Anthracite field, is, as its name implies, the most southern of the four fields or regions into which the anthracite basins of Pennsylvania group themselves. It embraces an area of about 181 square miles, lying in Carbon, Schuylkill, Lebanon, and Dauphin counties. Its territory is mapped on the Hazleton, Mahanoy, Pottsville, Catawissa, Shamokin, Lykens, Hummelstown, and Harrisburg sheets of the Topographic Atlas of the United States. Its greatest longitudinal extent is a little over 70 miles, from the Lehigh River at Mauch Chunk, in a direction averaging nearly S. 60° W., to within 1½ miles of the Susquehanna River at Dauphin, 8 miles north of Harrisburg. Its maximum breadth is nearly 8 miles, from the crest of Sharp Mountain across Broad Mountain, in the region west of Pottsville. Eastward the field narrows to a width of about 2 miles at Tuscarora, whence it extends, between Sharp Mountain on the south and Locust Mountain on the north, in a linear-lanceolate prolongation, hardly exceeding 2¼ miles in width, to the Lehigh River. Owing to the structure, the margin on the northwest, in the central portion of the field, is cut in rounded westward-projecting lobes of Broad Mountain, so that at a point a short distance west of Tremont, or about 12 miles west of Pottsville, the field is reduced to a width of 4 miles. From this point the north and south borders diverge at an angle of about 20°. At the same time a very extensive arch, the Perry County anticline, penetrates the field from the west, causing the parting of the latter, as far as a point about 4 miles west of Tremont, into two narrow divergent arms or prongs, forming what is known as the "fish tail" of the Southern Anthracite field. The northern of these prongs, the Wiconisco Basin, lying between Bear and Big Lick mountains, is about 16 miles long, 2 miles in greatest breadth, and ends in a rather blunt point about 3 miles west of Lykens. The other prong, which also is about 2 miles wide at the base, and which tapers gradually from the latter for 30 miles to near the Susquehanna River, is known as the Dauphin Basin. It is bounded by Sharp Mountain on the south and by Stony Mountain on the north.

### GENERAL GEOLOGIC STRUCTURE.

Structurally, the Southern field is a synclinorium—a complicated group of synclines producing a great and, at points, irregular basin. Besides the numerous principal axes of folding, which are conformable with the usual Appalachian trend, there are other oblique, more nearly due east-west undulations, which have had much to do with the delimitation of the fields in their entirety, as well as in complicating the minor structure of the basins. The general geologic features of the region are shown in the large geologic map of the State, published in 1893, and in the county maps accompanying the descriptive reports of the second geological survey of the State. The relation of this region to the other anthracite regions is illustrated in the new General Map of the Anthracite Region, revised to 1890, published separately by the survey in reduced form, as one of the miscellaneous maps in Pt. I of the Atlas of the Southern Anthracite Field. The geology of the Southern field in particular has been worked out at great pains and expense by the late geological survey of Pennsylvania. The six parts or volumes, with two supplements, comprising the Atlas of this field, in which are presented in great detail the mine workings and the areal geology, on a scale of 800 feet to the inch; numerous cross sections, mostly on a scale of 400 feet to the inch, and a great number of columnar sections, chiefly at a unit of 40 feet to the inch, represent the latest and most experienced work of the survey. Notwithstanding the fact that the field methods were of necessity developed in the course of the work in order to meet existing conditions, and the presence of many errors in correlation, the Atlas of the Southern Anthracite Field in Pennsylvania represents the most minutely detailed and most excellent economic work on sedimentary deposits that has yet been accomplished over an extensive area in this country. To the abundant mine maps, profiles, and sections therein contained reference will frequently be made. Wherever the work here reported results in additions or corrections to the State mine maps, they will be so described that the changes or additional matter can in most cases be readily applied. The flexures of the field, which offer a most interesting study, were described at considerable length by H. D. Rogers in the Geology of Pennsylvania. The geographic features of the basin are incompletely represented in Pl. CLXXX of this report, which is here presented as an index to the State maps, as well as for the purpose of indicating the localities at which fossils have been collected.

On examining the maps referred to above, it will be noted that in general the folding of the strata is closer toward the southern border of the field and more open to the north. Thus the southern limit of the basin, along Sharp Mountain, is somewhat overturned throughout the greater part of its length, while in the widest part of the basin, near the northern border, the undulation of the beds is comparatively gentle. To this is possibly due the variable and interesting topography of the district; for where the strata are more steeply inclined the ridges caused by the erosion of the soft shales on either side of a hard formation are narrow and sharp, while the hard terranes, when but slightly flexed and nearly horizontal, form the resistant floor of a high plateau. Along the southern border of the coal field we accordingly find that the upturned and nearly vertical hard beds of the Pottsville formation compose the crest of a narrow mountain, Sharp Mountain, between which and the upturned wall of the Pocono (Vespertine, X), the basal member of the Eocarboniferous in the Second Mountain, extends a narrow parallel valley cut in the likewise upturned soft red shales of the Mauch Chunk formation (Umbral shale, XI), which, in the Schuylkill region, reaches its maximum thickness of over 3,000 feet. The steep inclination of the Pottsville floor is similarly accountable for the rigid and cristate character of the rim of the coal field in Sharp Mountain, in Stony or Fourth Mountain on the north side of the Dauphin Basin, in Bear and Wiconisco mountains in the northern prong of the "fish-tail," and in Locust Mountain. Its more enduring composition, as compared with the terranes of the Coal Measures, has resulted in the erosion of irregular valleys, generally corresponding to the axes of the basins. Throughout the Southern Anthracite field, wherever the elevation of the Pottsville has been sufficient to cause its complete erosion, the consequent erosion of the underlying Mauch Chunk shales has been so rapid as to form sharply defined valleys, varying in width according to the area uncovered or the inclination of the beds. It thus happens that Broad Mountain, on which is spread the northern dilation of the coal field, comprises essentially an elevated undulating plateau sustained by the rigid, flexuous Pottsville floor of the Coal Measures, which here, as in the Coal Measures of the other anthracite fields, prevailingly forms anticlinal ridges and synclinal valleys. The breaking through of the Pottsville on the anticlinal axes along the western portion of Broad Mountain is responsible for the deep cove-like valleys between the lobes of the field, as noted above, the borders being often formed by massive cliffs of the gently inclined Pottsville conglomerates. In the region north of Pottsville the elevated Pottsville formation is not entirely cut across at any point, the result being that there is a continuity of the conglomerates, which bridge the axis from the New Boston Basin into the Mahanoy Basin of the Western Middle Anthracite field. The line of division between these fields, which, as may be inferred, is somewhat conventional, is drawn along the axis south of the northward plunge of the conglomerates into the Mahanoy Basin.

The irregularity of the margin of the Southern coal field along Broad Mountain is quite in contrast with the relatively straight borders of the prongs of the "fish tail," or of the southern margin of the field along Sharp Mountain from the Susquehanna River to a point east of Middleport. This condition is largely due to the closer folding and increased depth of the Coal Measures toward the south, so that the soft shales beneath the Pottsville are not brought to light by the minor flexures. The effect of the latter is, however, evident along the border of the field, in the scallops at the west extremity of the Wiconisco Basin and in the angle of the "fish tail" west of Tremont, while it also appears in Sharp Mountain itself east of Middleport, and in the Summit Hill district. The occurrence of another lobe of the field along the apparently rigid Sharp Mountain, in the region of Lorberry Gap, seems only to have been escaped by an overthrust fault of the basal portion of the Coal Measures, as will be shown in a later portion of this report.

## DESCRIPTION OF THE POTTSVILLE FORMATION IN THE TYPE REGION.

As has already been remarked, the Pottsville formation is, in the type region, composed chiefly of massive siliceous conglomerates. It will be seen later, in the course of a comparison of various sections, that this topographically conspicuous formation, which constitutes the floor of the Coal Measures, comprises a series of ponderous conglomerates, which are more variable in color, composition, and assortment in the lower part, and more quartzose, dense, and light colored near the top. These conglomerates alternate near the base with washes of purple and olive mud or soft, greenish sandstone, and in the higher portion with thin beds of arenaceous shale, and are interspersed with a number of carbonaceous beds, some of which, in portions of the field, are workable over considerable areas, their product being the most valuable of the anthracite coals.

The formation, as a whole, varies greatly in thickness, the maximum of a little more than 1,200 feet being reached in the vicinity and to the west of the type section, east of which it thins remarkably. That it thins toward the west in the Southern field itself has more recently been doubted. It is clear, however, that the relative thickness of its divisions is quite different in some of the sections, if the total depth remains the same. The sandstones, like the coals, are extremely variable even within short distances.[1] Northwestward the formation thins rapidly in the anthracite regions, its development being about 850 feet in the Shamokin district of the Western Middle field, or an average of about 350 feet in the Eastern Middle field, while it is recorded as averaging 225 feet in the Northern Anthracite field.

In the Southern Anthracite field, the formation is apparently conformable with the Mauch Chunk shales, while the line of separation between it and the superimposed Coal Measures, which are also highly arenaceous, abounding in conglomerates, has for convenience been drawn at the lowest workable coal in the type region.

[1] Compare columnar sections on columnar-section sheet xi, Pt. IV B of the Atlas of the Southern Anthracite Field.

## COMPOSITION OF THE FORMATION.

The character and composition of the Pottsville formation and its relation to the Umbral shale (Mauch Chunk formation) below and the Productive Coal Measures above are well shown in the magnificent exposure in the cutting along the Pennsylvania Railroad through Sharp Mountain on the east side of the gap below Pottsville. A somewhat detailed section of this exposure, extending from Tumbling Run Valley to the Pottsville Valley is given on Pls. CLXXXI, CLXXXII. This section includes the upper portion of the Mauch Chunk red shales and extends to the Dirt bed, the third workable coal of the Coal Measures at this point. The Pottsville formation itself may, for the present, be considered as comprising that portion, nearly 1,200 feet in thickness, of the section between the topmost bed of red shale and the "Twin" coal, which in both the first and the second geological surveys of this State has been agreed upon as the boundary between the Pottsville formation and the succeeding Lower Coal Measures.

On referring to the section it will be observed that the lower portion represents a transition from the typical red, purplish-red, and olive-green shales of the Mauch Chunk to the almost exclusively arenaceous, ponderous quartz-conglomeratic terranes of the Pottsville formation. The conglomerates intercalated in increasing proportions in the upper beds of the Mauch Chunk consist of irregularly bedded, poorly assorted, or sometimes apparently unassorted pebble or bowlder accumulations in a matrix of coarse arkose sands colored by reddish or greenish shale washes. The pebbles are mostly of quartz, though sandstone, syenite, chloritic schist, limestone, and even red and green shales and conglomerate fragments are also present. Occasionally the pebbles, which are sometimes subangular, attain a diameter of 3 or 4 inches or more; but in most of the beds the coarsest materials do not exceed a goose egg in size. For a long distance from the base of the formation the conglomerate matrix consists of a micaceous, chiefly arenaceous medium, poorly cemented and often colored with a red or green argillaceous material.

In passing upward the beds of red shale are less conspicuous, and at about 1,200 feet below the Twin bed the last distinct stratum of typical Mauch Chunk red shale is seen. Above this the conglomeratic matter prevails almost exclusively through a long interval. Nevertheless, the olive-green shales occur here and there throughout an interval extending 200 or 300 feet higher, while most of the conglomerates in the lower portion of the section derive their color from the greenish or reddish mingled sediments. The irregular bedding and the variety of the rock materials in the pebbles, which are often imperfectly rounded, are interesting features of the lower portion of the Pottsville formation itself. This portion of the section is notably characterized by the occurrence of olive-green or slightly reddish mud beds, apparently redeposited from the older formation. These muds often conclude rapid transitions from greenish conglomeratic sandstones into fine argillaceous silts of no great thickness. On the conspicuously uneven surfaces of the latter, coarse conglomeratic strata or typical bowlder beds are directly imposed, in knife-edge contacts, at a number of horizons in the lower half of the section. These irregular, intercalated muds, which are similar to others in the upper part of the Mauch Chunk formation, sometimes appear as thin lenses interspersed among the irregular layers of the conglomerates. Without further detailed description of the type section, for which the reader is referred to Pls. CLXXXI, CLXXXII, it will appear that we have a series of beds of passage—i. e., a transition series—consisting of coarse, heterogeneous, semiassorted, conglomeratic materials, intercalated in the uppermost beds of red shale, above which, for a distance of several hundred feet, many of the conglomerates preserve essentially the same characters, although typical deposits of the red and green shales are wanting. Subangular pebbles in imperfectly bedded arkose conglomerates are not rare throughout the lowest third of the formation in this vicinity. Although the quartz material preponderates, pebbles of sandstone and shale are not infrequent. Occasionally some of the pebbles attain the proportions of goose eggs, and farther east, in a section near the Hacklebarney tunnel, some of them measure 5 to 6 inches in diameter.

As already indicated, the conglomerates in the lower portion of the Pottsville formation are prevailingly greenish, arkose, and poorly cemented. Usually, in the more freshly cut sections, they offer little resistance, and frequently they are but slightly displayed. When, however, the erosion has been very slow, as along the summit of Sharp Mountain, the ferruginous material so cements the pebbles that the lower ledges of the formation often predominate and form, for considerable distances, the crest of the mountain. This feature is more noticeable to the eastward of Swatara Gap. In the upper half of the formation the conglomerates become more rigid, more distinctly arenaceous, and more persistent, the pebbles being better rounded, more compactly disposed, and regularly assorted. Sandstone without pebbles is rare and is always thin in the section. Cross bedding, indicative of current movement from the northeast, is conspicuous. In the more shaly conglomeratic sandstones in the middle of the section concretionary weathering is especially noticeable.

Generally speaking, the relatively small amount of shales and of coaly matter in the type section is, for the most part, contained in the middle third. Toward the top the conglomeratic material becomes lighter colored, as well as more exclusive, and at a distance of 200 or 300 feet below the Twin coal, in that portion of the exposure opposite the

Pennsylvania Railroad bridge, occur the most massive, rigid, densely quartzitic, regularly bedded, and persistent conglomerates of the entire section. These conglomerates constitute a close group or plexus of ponderous ledges in which the formation culminates. They usually form the conspicuous beds in every exposure of the formation, and in every break in Sharp Mountain through which the waters of the basin find escape these steeply inclined ledges appear as jagged, irregular teeth, picturesquely defining the jaws of the gap. Exceptions to this, however, are Lorberry and Fishing Creek gaps, at which the entire Pottsville formation appears to be absent. Usually they also form the crest of the mountain, although, as was remarked above, the lower conglomerates predominate in the older exposures. It may be noted in this place that these uppermost white or light-gray conglomerate plates, which in both their lithologic and their paleontologic characters are distinctly comparable to the Homewood sandstone in the bituminous basins, appear to have the greatest geographic extent and regularity of all the strata in the formation. They are among the few individual beds which, although varying in thickness and in relative intervals, may be traced to sections in distant portions of the same field.

As shown in Pls. CLXXXI, CLXXXII, the type exposure at Pottsville exhibits a number of thin coals, none of which are profitably workable in this vicinity, although most of them have been diligently prospected. The exposure nearly 800 feet below the Twin bed appears to have been followed by a drift for some distance above the wagon road on the east side of the gap, while another coal, about 400 feet below the Twin, has been somewhat extensively tested, not only farther north in the same gap, but at two or more levels in the gap at Westwood. The consideration of the approximate and comparative age of some of these coals, with reference to the productive coals toward the western end of the field, will be continued in connection with the discussion of the fossil plants of the various horizons. Plant collections have been made from eleven different horizons, marked A–N in the section, as well as from the roof of the Twin coal, marked O.

Other published sections excellently illustrating the lithology of the Pottsville formation in the Southern Anthracite field are those at Hacklebarney,[1] Nesquehoning Gap,[2] and Locust Gap at Tamaqua,[3] in the region east of Pottsville. The character of the sedimentation in the region north of Pottsville is shown by the records of the diamond-drill bore holes near the Altamont collieries, throughout a distance of 5 or 6 miles along Broad Mountain.[4] The composition of the

[1] Atlas Southern Anthracite Field, Pt. I, mine sheet i, cross-section sheet i, columnar-section sheet i, section 4.

[2] Idem, Pt. I, mine sheet ii, columnar-section sheet ii, cross-section sheet ii.

[3] Idem, Pt. I, mine sheets iii and iv, columnar-section sheet ii, cross-section sheet iii, section 39, profile 12.

[4] Idem, Pt. IV, columnar-section sheet ix, sections 1–6.

beds in the western part of the field is well shown in the sections at Lincoln,[1] Kalmia,[2] and Lykens.[3] Portions of the first two named are reproduced in Pls. CLXXXIII and CLXXXIV of this report, in illustration of the formation in the Lincoln mining region.

### CONGLOMERATIC NATURE OF THE COAL MEASURES.

It may be remarked in this place that throughout the Southern Anthracite field the Lower Coal Measures also are largely conglomeratic. Frequently these conglomerates rival in size and rigidity individual beds of the Pottsville formation itself. Illustrations of the proportions of conglomeratic material, which in some cases constitutes nearly a third or more of the section, are found in columnar-section sheets i and vi, in Pts. I and II, respectively, of the Atlas of the Southern Anthracite Field; or in the sections at the tunnels in Wood's colliery and Dundas No. 6 colliery, at the north base of Sharp Mountain, between Pottsville and Tremont, shown in columnar-section sheet viii, Pt. IV of the Atlas. The same character is still better presented in the regions north and west of Tremont, the sections of which are given in columnar-section sheet x, Pt. IV B of the Atlas.

### THE LYKENS OR POTTSVILLE COALS.

It will be observed that in the section of the Pottsville formation at the gap south of Pottsville a number of thin coals are present, several of them having been prospected in the vicinity of the typical locality. Coals are to be found in varying numbers in every complete section of the formation, though in the neighborhood of the type section they have not proved to be of profitable thickness. However, to the north of Pottsville, on Broad Mountain, and to the west, throughout the Southern field, coals occur in greater development, especially locally, and have been extensively mined. Reference to several detached or somewhat isolated mines in those coals will again be made in connection with the consideration of the distribution of the fossil plants and the correlation of the coals. These coals of the Pottsville formation, which are commercially known as the "Lykens" coals, and which comprise the "Lower Red Ash" groups of the Southern field, appear to be best developed or most advantageously exploited in the districts west of Tremont, including the Lincoln region and the Wiconisco Basin.

In the anthracite fields, as well as in other coal fields of the Appalachian trough, the combustible of the Pottsville formation is generally

[1] Atlas Southern Anthracite Field, Pt. III, mine sheet xvii; Pt. IV B, columnar-section sheet xi; Pt. V, cross-section sheet xvii, section 24.

[2] Idem, Pt. III, mine sheets xxi and xxii; Pt. IV B, columnar-section sheet xi, columnar sections 10, 11, and 12; Pt. VI, cross-section sheets xxi, section 29.

[3] Idem, Pt. III, mine sheet xx; Pt. IV, columnar-section sheet vii, columnar sections 9, 10, 11, and 12; Pt. VI, cross-section sheet xx, section 28.

the most valuable of the entire series of Carboniferous coals; for, while as individual beds the Pottsville coals may be inferior in thickness and areal extent, their superior qualities create for them the highest demand and encourage their production even under conditions entirely unfavorable for the exploitation of other and thicker beds. To this formation belong the Sharon coal of northern Ohio and northwestern Pennsylvania; the Pocahontas and New River coals of Virginia and West Virginia, celebrated as steam and coking coals; the chief coal horizons of eastern Tennessee; the coals of Georgia; and the principal furnace and steam coals of Alabama. The special fitness for domestic use of the rather free-burning Lykens coals, which wins for them an advance of from 25 cents to $1.25 per ton over the prices of other coals of the anthracite series, has resulted in the establishment in the Lincoln-Lykens region of several of the largest mining plants in the anthracite fields, the capacity of the Lincoln and Brookside collieries,[1] which are exclusively occupied with the Lykens coals, being 2,900 tons a day of ten hours.

For a long time it was supposed that the Lykens coals were of the age of the Productive Coal Measures, the supra Pottsville series, but later and more systematic stratigraphic work has shown them to be distributed through the Pottsville formation itself. It requires but a glance at the plant fossils of these coals to detect their antiquity as compared with those of the coals of the higher formation.

Like the other members of the formation, the coals are exceedingly variable in thickness, often attaining a remarkable local development, though east of the Lincoln region they seldom reach a workable thickness except in isolated and restricted areas. Nevertheless, one of the lower coals appears to extend over a considerable territory in Broad Mountain, where it has been worked at a number of points, and whence it may be traced over the narrow arch into the Shamokin region of the Western Middle Anthracite field. The coals have been tested at many points to the eastward. One of the beds is still worked in a mine operated by Mr. Isaac Christ on the east side of Locust Gap, at Tamaqua, while the fossils obtained from a drift lately opened near the head of the incline on Mount Pisgah, at Mauch Chunk, show the coal to lie relatively high in the Pottsville. In the Dauphin Basin, westward from Rausch Gap and the Lincoln region, the Lykens coals are not worked at present. The basin, the central portion of which was extensively prospected in the early half of the century, has long been abandoned, for the reason that in passing westward the coals opened were found to be soft, crushed, semibituminous, and of generally inferior quality.

[1] Analyses of the West Brookside coals made by Dr. Cresson in 1879 show: Volatile matter, 5.4 per cent; ash, 8.78 per cent; sulphur, 0.36 per cent; phosphorus, none; fixed carbon, 85.636 per cent.

It will be shown in this report that the exploitations and provings on which was based the conclusion that the Lykens coals were of inferior quality or worthless in the Dauphin Basin were, in fact, confined to the softer and inferior coals of the Productive Coal Measures, in the interior of the basin. These coals are not in the Pottsville formation. All the coals mapped by the State geologist as "Lykens" throughout the greater part of the southern limb of that basin, including practically all the early developments east of the Big Flats, are, in fact, within the Productive Coal Measures. The entire Pottsville formation, with its scarcely prospected Lykens coals, not only lies to the south of the supposed approximate boundary of the "lowest Lykens coal," but a large portion of its steeply inclined terranes, including the lowest Lykens coals, outcrops for nearly a score of miles along a zone represented as red shale on the mine sheets.

## NOMENCLATURE OF THE COALS.

It is uncertain how many of the Lykens (Pottsville) coals are at one place or another workable, since some of them are evidently too thin for profitable mining in each of the mine sections. Certain of the sections may show as many as a dozen or more thin coals or coaly partings, but it is not probable that more than eight or nine at most are anywhere worked, and it is only in a few cases that as many as five coals in this formation can be productively worked at one locality. Usually not more than three are profitably mined at one point.

The number of the principal workable coals and their relative positions are best revealed at the Lincoln mines and in the Brookside-Lykens district, which is essentially continuous to the westward of the former. At the Lincoln mines, where the upper Lykens coals are best displayed, six coals are or have been worked. The columnar sections, earlier mine maps, and profiles of these mines are shown in mine sheets xvii to xxi, Atlas Southern Anthracite Field, Pt. III; columnar-section sheets vii and xi, Atlas Southern Anthracite Field, Pt. IV; and cross-section sheets xvii to xxi, Atlas Southern Anthracite Field, Pt. V. In several of the sections the Lykens No. 1 coal is shown at about 210 feet below the coal identified by the State geologist as the Buck Mountain bed, as at Good Spring, or at about 250 feet below a bed presumably the same, as at the Lincoln mine. (See Pl. CLXXXIII.)

Lykens coal No. 1½, formerly worked at the New Lincoln mine, is platted at approximately 240 feet below Lykens coal No. 1; while Lykens coal No 2 in the same mine is but 78 feet below the latter in the second lift tunnel. At this point Lykens coal No. 3, which at other points may diverge as much as 30 feet or more from No. 2, is separated from the latter by only 3 inches of dirt. Lykens coal No. 4, locally known as "White's bed," is about 245 feet below No. 3 at Lincoln. Lykens coal No. 5, the "Lykens Valley" bed, or, as it is also locally called, the "Big bed," is about 115 feet below coal No. 3 in the Lincoln tunnels, though the interval is 140 feet in the large tunnel at Williamstown. A thinner and less extensive coal, Lykens No. 6, or the "little bed," lies about 48 feet below No. 5 in the vicinity of the Lincoln mine, though at Williamstown the interval is over 65 feet. None of the upper Lykens coals, Nos. 1–3, are worked in the Wiconisco Basin, unless it be at Kohler's Gap, north of Brookside, where a coal, supposed to be Lykens bed No. 3, is dug for local use.

At the Brookside, Williamstown, and Short Mountain collieries only the lower coals (Nos. 4, 5, and 6) are worked, except at Williamstown, where a rather thin coal, the Zero bed, the thickness of which is given as 3 feet in the published section (columnar-section sheet vii, Atlas Southern Anthracite Field, Pt. IV), has been developed at 37 feet 7 inches below coal No. 6. This bed, if present at all in the Kalmia section, must be represented by only 6 inches of coal, but 5 feet 3 inches below the Lykens coal No. 6. The nomenclature of the coals given above is that employed by the Philadelphia and Reading Coal and Iron Company and adopted by the late State geological survey. In the vicinity of Lykens the coals were formerly numbered from the base upward in an opposite direction, and they are so designated in Rogers's discussion of this field in the Geology of Pennsylvania.

The above statements of the intervals between the coals are given as typical, without reference to the remarkable variation in the intervals as ascertained by the underground connections from mine to mine. The matter of this variation, as well as the stratigraphic position of the coals on Broad Mountain and in other portions of the field, will be touched upon when considering the thickness of the Pottsville formation and the evidence of the plants as to the correlation of the beds. For information as to the thickness of the coals the reader is referred to the State publications cited above, or to the typical section reproduced in Pls. CLXXXIII and CLXXXIV.

## THE TYPE PALEOBOTANIC SECTION OF THE POTTSVILLE FORMATION.

### FOSSIL-PLANT COLLECTIONS.

In the Southern Anthracite field fossil plants have been collected at 41 localities, from the Pottsville formation, or from the roof of the coal supposed to form the dividing line between the Pottsville formation and the overlying Productive Coal Measures. These may be grouped as follows:

1. Lower Lykens coals at Miller's drifts,[1] Big Run,[2] Wiconisco,[3] Big

[1] Pl. CLXXX, station 14. Atlas Southern Anthracite Field, Pt. III, mine sheet xx.
[2] Pl. CLXXX, station 13. Atlas Southern Anthracite Field, Pt. III, mine sheet xx.
[3] Pl. CLXXX, station 12. Atlas Southern Anthracite Field, Pt. III, mine sheet xx.

Lick,[1] Williamstown,[2] Brookside,[3] and East Brookside in the Wiconisco Basin; and from Kalmia,[4] Lincoln,[5] Rausch Gap (Pl. CLXXXV) Schuylkill County,[6] and Swatara Gap[7] of Sharp Mountain, in the Lincoln district.

2. Upper Lykens coals at Lincoln colliery, New Lincoln,[8] the North Brookside slope near Good Spring,[9] and the lower Eureka tunnel north of the old Colket mine.[10]

3. A third category, including detached points, or beds whose relations to the individual Lykens coals are subject to doubt, embraces collections from Kohlers Gap,[11] a shaft near the North Brookside slope, the upper Eureka tunnel, a prospect shaft near the mouth of the latter, the Kemble drift,[12] Altamont colliery No. 1,[13] two levels in the gap at Westwood,[14] the drift in Mount Pisgah,[15] and 12 levels in the type section at the Pottsville Gap.[16]

4. The collections from various levels at Lorberry Gap,[17] Fishing Creek,[18] Black Spring Gap (Mount Eagle),[19] Gold Mine Gap,[20] Rausch Gap (Lebanon County),[21] Yellow Springs Gap,[22] Rattling Run Gap,[23]

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[1] Pl. CLXXX, station 11. Atlas Southern Anthracite Field, Pt. III, mine sheet xix; Pt. VI, cross-section sheet xx.

[2] Pl. CLXXX, station 10. Atlas Southern Anthracite Field, Pt. III, mine sheet xix; Pt. IV, columnar-section sheet vii, section 8; Pt. VI, cross-section sheet xx, section 27.

[3] Pl. CLXXX, station 9. Atlas Southern Anthracite Field, Pt. III, mine sheet xviii; Pt. VI, cross-section sheet xix, section 26.

[4] Pl. CLXXX, station 41. Atlas Southern Anthracite Field, Pt. III, mine sheets xxi and xxii; Pt. IV B, columnar-section sheet xi, sections 10, 11, and 12; Pt. VI, cross-section sheet xxi, section 29.

[5] Pl. CLXXX, station 5. Atlas Southern Anthracite Field, Pt. III, mine sheets xvii and xxi; Pt. IV B, columnar-section sheet xi, sections 8–9; Pt. VI, cross-section sheet xvii, cross section 24.

[6] Pl. CLXXX, station 4. Atlas Southern Anthracite Field, Pt. III, mine sheet xvi.

[7] Pl. CLXXX, station 3. Atlas Southern Anthracite Field, Pt. III, mine sheet xvi.

[8] Pl. CLXXX, station 6. Atlas Southern Anthracite Field, Pt. III, mine sheet xvii; Pt. IV, columnar-section sheet vii, section 4; Pt. V, cross-section sheet xviii, section 24.

[9] Pl. CLXXX, station 7. Atlas Southern Anthracite Field, Pt. III, mine sheet xvii; Pt. IV B, columnar-section sheet x, section 8; Pt. VI, cross-section sheet xix, section 25.

[10] Pl. CLXXX, station 33. Atlas Southern Anthracite Field, Pt. III, mine sheet xvi; Pt. IV B, columnar-section sheet x, section 6; Pt. VI, cross-section sheet xvii, section 23.

[11] Pl. CLXXX, station 15. Atlas Southern Anthracite Field, Pt. III, mine sheet xviii; Pt. VI, cross-section sheet xix, section 26.

[12] Pl. CLXXX, station 16. Atlas Southern Anthracite Field, Pt. II, mine sheet xiii; Pt. V, cross-section sheet xviii, section 23.

[13] Pl. CLXXX, station 36. Atlas Southern Anthracite Field, Pt. II, mine sheet vii; Pt. IV, columnar-section sheet ix, section 1; Pt. V, cross-section sheet v, sections 16 and 17.

[14] Pl. CLXXX, station 2. Atlas Southern Anthracite Field, Pt. II, mine sheet xiv; Pt. IV B, columnar-section sheet xi, section 5; Pt. VI, cross-section sheet xii, section 19.

[15] Pl. CLXXX, station 40. Atlas Southern Anthracite Field, Pt. I, mine sheet i, cross-section sheet i, section 1.

[16] Pl. CLXXX, station 1. Atlas Southern Anthracite Field, Pt. III B, mine sheets xiv and xiva; Pt. IV, columnar-section sheet viii, section 3; Pt. V, cross-section sheet viii, section 17.

[17] Pl. CLXXX, station 17; Pl. CLXXXV, Fig. 1. Atlas Southern Anthracite Field, Pt. III, mine sheet xxi; Pt. VI, cross-section sheet xvi, section 24.

[18] Pl. CLXXX, station 18; Pl. CLXXXVI, Fig. 1. Atlas Southern Anthracite Field, Pt. III, mine sheet xxi.

[19] Pl. CLXXX, station 19; Pl. CLXXXVI, Fig. 2. Atlas Southern Anthracite Field, Pt. III, mine sheet xxi.

[20] Pl. CLXXX, station 20; Pl. CLXXXVI, Fig. 3; Pl. CLXXXVII, Fig. 1. Atlas Southern Anthracite Field, Pt. III, mine sheet xxii; Pt. IV, columnar-section sheet viii, section 7; Pt. VI, cross-section sheet xxi, section 29.

[21] Pl. CLXXX, station 21; Pl. CLXXXVII, Fig. 2. Atlas Southern Anthracite Field, Pt. III, mine sheet xxiii; Pt. IV, columnar-section sheet viii, section 9; Pt. VI, cross-section sheet xxi, section 30.

[22] Pl. CLXXX, station 23. Atlas Southern Anthracite Field, Pt. III, mine sheet xxiv; Pt. IV, cross-section sheet xxi, section 31.

[23] Pl. CLXXX, station 24. Atlas Southern Anthracite Field, Pt. III, mine sheet xxv; Pt. IV, columnar-section sheet viii, section 10.

Big Flats[1] north of Watertank Station, Fort Lookout,[2] and a number of the old drifts [3]to the westward, made in the early part of the century, will be considered in connection with the special discussion of the Dauphin Basin.

5. The fifth category includes plants from the "Buck Mountain" coal or a coal (the Twin coal) supposed to be its equivalent at Swatara Gap at Middle Creek,[4] Ebony colliery[5] north of Newcastle, Altamont colliery No. 2,[6] Locust Mountain and Sharp Mountain gaps,[7] near Tamaqua, and at the Pottsville Gap.

## SPECIES AND THEIR OBSERVED DISTRIBUTION WITHIN THE FORMATION AND FIELD.

In order to avoid the repetition of names which would result from an enumeration of the species from each locality or bed, the plants from the Pottsville formation in the region of Pottsville and westward in the Southern Anthracite field, exclusive of the Dauphin Basin, will be combined in one list, with a table showing their distribution so far as yet observed in that formation. Since the economic interest of the problem of stratigraphic paleontology centers primarily about the Lykens coals, the localities affording plants from the roof shales directly in connection with these coals, as definitely correlated between the large mines, are placed first. From an economic standpoint they constitute a typical paleontologic representation of the productive coal-bearing horizons, just as the Pottsville Gap section affords a typical paleontologic section of the formation as a whole. Since, also, it is at once clear that the species commonly in association with the lower Lykens coals are largely different from those over the upper Lykens coals, the principal coals of the mining region are naturally divided paleobotanically into two groups: An upper group, including coals 1–3, and a lower group, containing Lykens coal No. 4 and the remaining lower portion of the formation.

For the sake of easier comparison, the plant-bearing horizons A–M,[8] in ascending order, in the Pottsville Gap section, are placed next. To the right of these are a number of columns representing isolated developments of supposed Lower Lykens age; and beyond these are a few

[1] Pl. CLXXX, station 26. Atlas Southern Anthracite Field, Pt. III, mine sheet xxvi.

[2] Pl. CLXXX, station 27. Atlas Southern Anthracite Field, Pt. III, mine sheet xxvi; Pt. VI, columnar-section sheet viii, section 11; Pt. III, mine sheet xxvi.

[3] Pl. CLXXX, stations 28–32. Atlas Southern Anthracite Field, Pt. III, mine sheets xxvi and xxvii.

[4] Pl. CLXXX, station 34. Atlas Southern Anthracite Field, Pt. II, mine sheet xiii; Pt. IV B, columnar-section sheet x, section 4; Pt. VI, cross-section sheet xiii, section 22.

[5] Pl. CLXXX, station 35. Atlas Southern Anthracite Field, Pt. II, mine sheet vi; Pt. V, cross-section sheets v–viii, section 17.

[6] Pl. CLXXX, station 37. Atlas Southern Anthracite Field, Pt. II, mine sheet vi; Pt. IV, columnar-section sheet ix; Pt. V, cross-section sheet viii, section 16.

[7] Pl. CLXXX, stations 38 and 39. Atlas Southern Anthracite Field, Pt. 1, mine sheet iii, cross-section sheet iii, section 12, columnar-section sheet iii; Pt. II, mine sheet iv.

[8] The application of letters to the plant beds of the type section is only for convenience of reference in this report. The letters are not introduced in the nomenclatural sense, and are not intended for permanent use. They are, therefore, not to be confused with the nomenclature of the coals in the Panther Creek Basin or other portions of the anthracite regions.

localities apparently referable to the Upper Lykens group. To make clear the paleontologic significance of this division, the species are systematically grouped in two sections, the first including those observed in the Lower Lykens division, the other containing the remainder of the species.

Generally speaking, the collection of plants in the Pottsville formation is more difficult than in the succeeding Coal Measures, not only on account of the frequent occurrence of conglomeratic sandstone in the roof of the coals, but also on account of the usually fragmentary condition of the vegetable material, which prevailingly seems to have suffered severely, as might be expected from the composition of the environing terranes, through the exigencies of driftage. As is natural, the larger collections, containing the greater proportion of the species, were obtained from the rock dumps at the collieries, or from the more propitious plant beds in the gap sections, while the material from beds in which fossils are very scarce or poorly preserved is, in spite of considerable persistence in collection, often conspicuously scant. It thus happens that some of the examples from a bed are too fragmentary for certain specific identification with remains found elsewhere; and the presence of the species at these localities is, accordingly, doubtful and indicated by a query. Another difficulty affecting the stratigraphic reference of the species arises from the collection of large quantities of material, including the best fossils, from mine dumps receiving the roof shales from two or more coals, so that it was at first found impossible to ascertain from which of the coals a given fossil was derived. However, by a painstaking study of the plants and their associations on slabs obtained from definitely fixed beds at other points, or procured through the unfailing courtesy of the local engineers, superintendents, and mine foremen, directly from the interior of the mines, it later became possible to assign much of the material from the rock dumps, either definitely or approximately, to their original sources. Such references, made with great caution, are indicated in the respective columns by numbers referring to the coal from whose roof the specific fossil came.

A discussion of the significance of the composition of the flora and the range of the species will receive attention in connection with the subject of the age and equivalents of the formation. Economy of space forbids the description of the species in this report. Many of them are new, while many others have been the subject of careful revision. A few only will here receive any systematic biologic treatment. The descriptions of all the material in hand are now complete, and will form part of a monograph, in process of preparation, on the flora of the Pottsville formation in the Appalachian province. Their present publication would therefore lead to duplication.

## PALEONTOLOGIC DIVISIONS OF THE FORMATION.

An inspection of the table (p. 776) showing the distribution of the plants within the Pottsville formation itself in the Southern Anthracite field shows that the species are essentially divided into two groups, one of which is confined to the lower Lykens coals, or the lower part of the formation, the other being present in the upper Lykens coals, and the upper beds of the formation as a whole. For convenience in reference all the plants occurring at any point in the Lower Lykens group of coals are placed in the first list. It is not impossible that a number of these will eventually be found in the upper division of the formation. However, so far as my observation has gone, it appears that, except among the gymnosperms, but 3 to 5 of the 50 species of the older flora are present in the Upper Lykens, while 3 others occur in beds of the same period in the type section. If we next examine the distribution of the plants in the several fossiliferous beds of the type section at Pottsville, we find that of the plants in beds A–D, i. e., 700 feet or more below the Twin coal, all are common to the Lower Lykens coal group. In fact, all but 3 or 4 of the species represented in this division are included in and mostly confined to the Lower Lykens group in the mining region. We may therefore safely conclude that the highest bed, D, of this portion of the type section is not younger than the Lykens coal No. 4, with which its species are mostly in common. This portion of the type section appears to be clearly contemporaneous with the Lower Lykens group. The two corresponding sections will, therefore, be collectively included in what will be for the present designated the Lower Lykens division of the formation. Of the species in the Upper Lykens group, only 13 or 14, including 7 gymnosperms, occur in the lower group, either in the type section or in the mining region.

Passing again to that portion of the table relating to the type section, we find that the distribution of the plants occurring over Lykens coals Nos. 1–3 is confined almost exclusively to beds H–L of that section. The high degree of identity in the floras and the biologic evidence of the small balance of independent species unite in showing that each of the several beds in that portion of the type section is referable to, and probably lies within, the time interval marked by the Upper Lykens group of coals. We shall, accordingly, in further discussions, treat this group as belonging to an Upper Lykens division. Of the 125 species of plants found in this division, but 13 or 14, including the gymnosperms, are common to the Lower Lykens division, while 95 are, so far as observed, confined to the Upper Lykens division.

There remain two vertically restricted portions of the type section for further consideration. The lower of these two, embracing beds E–G, from 570 to 640 feet below the Twin coal, has furnished a flora of from 17 to 19 species, 10 of which are common to the Lower Lykens division, and 6 or 8 to the Upper Lykens division. The lowest of these beds, 640 feet below the Twin coal, is bound to the Lower Lykens division by the presence of *Neuropteris Pocahontas* var. *inæqualis*, which is not, I believe, present at any point in the Upper Lykens division. *Eremopteris Cheathami* belongs in the upper portion of the formation, or in the Upper Lykens division, as, by its general distribution in other regions, does also *Alethopteris grandifolia*. *Trigonocarpum Helenæ* is, in general, rare in the Upper Pottsville of other regions, it being largely characteristic of beds of nearly the age of Lykens coal No. 4. Similarly bed F, 50 feet higher, is bound by *Alethopteris protaquilina* and *Neuropteris Pocahontas* to the Lower Lykens division, and perhaps more closely by *Eremopteris decipiens*, *Neuropteris tennesseeana*, and *Callipteridium alleghaniense* to the Upper Lykens division. The Eremopterids and Mariopterids are largely characteristic of the upper Pottsville, while *Callipteridium alleghaniense* generally occupies a lower place in the sections in other regions. Considering the mixed composition of the floras of these two beds, it seems most expedient to regard them at present as belonging to the interval between the floras of Lykens coals No. 4 and No. 3. Bed G, which is but 20 feet higher than F, is temporarily placed in the same rubric—the Lower Intermediate division—between the Upper Lykens division and the Lower Lykens division, on account of ignorance of its flora. Should additional material come to light in this bed, which as yet has furnished but one fern species, *Neuropteris acutomontana*, it will probably be found referable to the Upper Lykens division.

The remaining uppermost plant beds, M and N, in the type section at 245 feet and 210 feet, respectively, below the Twin coal, have yielded as yet but 8 species, none of which occur in either the Lower Lykens division or the Lower Intermediate division. Four of the species are, however, common to the Upper Lykens division. Of the 8 species, viz, *Pseudopecopteris* cf. *squamosa*, *Pecopteris* sp., *Alethopteris Serlii*, *A. coxtoniana*, *Neuropteris ovata*, *N. Desorii?*, *Sphenophyllum cuneifolium* and *Sigillaria* cf. *lævigata*, the first named, *Pseudopecopteris* cf. *squamosa*, and *Alethopteris Serlii*, *Neuropteris ovata*, and *Sigillaria* cf. *lævigata*, are usually characteristic of the Coal Measures, while *A. coxtoniana* and the *Pecopteris* species appear to lie close below the base of the Lower Coal Measures at "Campbell Ledge" in the Northern Anthracite field. The phase of *Sphenophyllum cuneifolium* found in these beds is that common near the base of, but within, the Coal Measures. In brief, it is evident that, while several of the species from these beds are common to the Upper Lykens division, the flora as a whole is perhaps more closely united with that of the Buck Mountain coal and the succeeding Lower Coal Measures. These two beds, which are obviously younger than the Upper Lykens division, yet are not less than 200 feet below the Twin coal, will, therefore, be treated as representative of an Upper Intermediate division, which, as will appear later, in the discussion of the floras, seems to be transitional to the Lower Coal Measures as that formation was defined by Rogers and has since been commonly recognized.

The combined distribution of the species between the four divisions of the Pottsville formation somewhat temporarily proposed above is condensed in the four columns at the right-hand border of the table. It may be summarized as follows (p. 790):

*Table showing the observed geographic and stratigraphic*

[NOTE—The hyphens between the numbers of the coals indicate that the fossils were collected
the species associated on a slab or rock fragment to identify the horizon

| Names of species, stratigraphically arranged in two groups. | Lincoln-Lykens mining developments. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lower Lykens Coal group. | | | | | | | | | | | | Upper Lykens Coal group. | | | | |
| | Miller drifts, Coal 5. | Big Run mine, Coals 5-6. | Williamstown, Coals 5-6. | Brookside, Coal 6. | Kalmia, Coals 5-6. | Lincoln, Coal 5. | East Brookside, Coals 4-6. | Brookside, Coals 4-5. | Brookside, Coal 4. | East Brookside, Coal 4. | Lincoln, Coal 4. | Lincoln, Coals 1-5. | Lincoln, Coals 2-3. | North Brookside, Coal 2. | Eureka drift (Lower), Coal 2. | New Lincoln, Coals 1-3. | Lincoln, Coal 1. |
| GROUP NO. 1—*From Lower Lykens section.* | | | | | | | | | | | | | | | | | |
| Aneimites pottsvillensis D. W. | | | | | | | | | | | | 4 | | | | | |
| Aneimites sp | | | | | | | | | | | | | | | | | |
| Eremopteris sp. No. 1 | | | × | | | | | ×? | | | | | | | | | |
| Mariopteris eremopteroides D. W. | | × | × | | | | 5 | 5 | | | ? | 5 | | | | | |
| Mariopteris pottsvillea D. W. | | ×? | | | | | | | × | × | × | 4 | | | | ? | |
| Mariopteris sp | | × | | | × | | | | | | | 5 or 6 | | | | | |
| Sphenopteris umbratilis D. W. | | | | | | | | | | | | | | | | | |
| Sphenopteris asplenioides Stb. | | × | × | | | | 4-5 | × | × | × | × | | | | | × | |
| Sphenopteris Monahani D. W. | | | | | 4 or 5 | | | | × | × | | 4 or 5 | | | | | |
| Sphenopteris patentissima (Ett.) Schimp | | | × | × | | | 6? | × | × | × | × | 4 or 5 | | | | | |
| Sphenopteris novalincolniana D. W. var. antecedens | | | | | | | | | | | × | 4 or 5 | | | | | |
| Sphenopteris Lutheriana D. W. | | | | | | | | | × | | | 4 or 5 | | | | | |
| Sphenopteris dadeana D. W. | | | | | | | | | | | | | | | | | |
| Aloiopteris georgiana (Lx.) | | | × | | | | | | | | | 4? | | | | | |
| Pecopteris serrulata Hartt (non Heer) | | | | | | | | 4? | | | | | × | | | | |
| Alethopteris protaquilina D. W. | | | | | | | | 4? | | × | | | | | | | |
| Alethopteris composita D. W. | | | × | × | | | | | | | | | | | | | |
| Alethopteris sp | | | | | × | | | | | | | | | | | | |
| Megalopteris sp | | | | | | | | | | | × | | | | | | |
| Neuropteris Pocahontas D. W. | × | × | × | | 5? | | 5? | × | | | | | | | | | |
| Neuropteris Pocahontas var. pentias | | | × | ? | 5 or 6 | × | 5 | | | | | 5 | | | | | |
| Neuropteris Pocahontas var. inæqualis | | | × | | 5 | | | × | × | × | × | 4 or 5 | | | | | |
| Neuropteris Smithsii Lx | | | | | | | | 4 | 4 | 4 | 4 | 4 | | | | | |
| Asterocalamites scrobiculatus (Schloth.) Zeill | | | | | | | | | × | | | 4 | | | | | |
| Calamites Roemeri Goepp | × | | × | | | × | | | × | | × | + | | | | | |
| Asterophyllites parvulus Dn. | × | | × | | | | 5? | × | × | | × | 4 or 5 | | | | | |
| Calamostachys cf. lanceolata Lx. ? | | | | | | | × | | | | | | | | | | |

*range of plants within the Pottsville formation in the type region.*

from rock dumps of mingled material from those coals. Whenever it is practicable, by means of or coal, the number of the latter is placed opposite the species in question.]

| Beds not definitely correlated with Lykens groups. | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pottsville Gap—type section. | | | | | | | | | | | | | Sharp Mountain. | | | Broad Mountain. | | | | | | | | | | |
| Bed A. 1,195 feet below "Twin coal." | Bed B. 980 feet below "Twin coal." | Bed C. 770 feet below "Twin coal." | Bed D. 710 feet below "Twin coal." | Bed E. 640 feet below "Twin coal." | Bed F. 590 feet below "Twin coal." | Bed G. 570 feet below "Twin coal." | Beds HI. 550 feet below "Twin coal." | Bed J. 465 feet below "Twin coal." | Bed K. 445 feet below "Twin coal." | Bed L. 380 feet below "Twin coal." | Bed M. 245 feet below "Twin coal." | Bed N. 210 feet below "Twin coal." | Swatara Gap drifts. | Rausch Gap, east side. | Rausch Gap, west side. | North Brookside (shaft). | Eureka drift (upper). | Altamont No. 1 colliery. | Kemble drift. | Eureka drift (upper), pit near mouth. | Kohlers Gap. | Yellow Spring Gap slope, Dauphin Basin. | Lower Lykens Coal group, or lower group in type section. | Lower Intermediate group in the type section. | Upper Lykens Coal group, or upper group in type section. | Upper Intermediate group in the type section. |
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| | | | | | | | | | | | | | | | | | | | × | | | | × | | | |

*Table showing the observed geographic and stratigraphic range of*

| Names of species, stratigraphically arranged in two groups. | Lincoln-Lykens mining developments. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lower Lykens Coal group. | | | | | | | | | | | | Upper Lykens Coal group. | | | | |
| | Miller drifts, Coal 5. | Big Run mine, Coals 5-6. | Williamstown, Coals 5-6. | Brookside, Coal 6. | Kalmia, Coals 5-6. | Lincoln, Coal 5. | East Brookside, Coals 4-6. | Brookside, Coals 4-5. | Brookside, Coal 4. | East Brookside, Coal 4. | Lincoln, Coal 4. | Lincoln, Coals 1-5. | Lincoln, Coals 2-3. | North Brookside, Coal 2. | Eureka drift (Lower), Coal 2. | New Lincoln, Coals 1-3. | Lincoln, Coal 1. |
| GROUP NO. 1—*From Lower Lykens section*—Cont'd. | | | | | | | | | | | | | | | | | |
| Volkmannia crassa Lx | | | | | | | | | × | | | 4? | | | | | |
| Sphenophyllum tenue D. W. | | | | | | | | | × | × | | 4 | | ? | | ? | |
| Lepidodendron alabamense D. W. | | ? | | | 5? | | × | | | | | 4 or 5 | | | | | |
| Lepidodendron Veltheimii Stb | | | | | | | | | | | | | | | | | |
| Lepidodendron clypeatum Lx. | | | | | | | 4? | | × | | | 4 or 5 | | | | × | |
| Lepidophloios sp | | | | | 5? | | | | × | | | | | | | | |
| Lepidostrobus pennsylvanicus D. W | | | × | | × | | | | 4 | | | 2 or 3 | | | | 2 or 3 | |
| Lepidostrobus cf. ornatus L. & H | | | | | | × | × | | | | | | | | | | |
| Lepidophyllum quinnimontanum D. W. | | × | | | | × | | | | | | 4 or 5 | | | | | |
| Lepidophyllum lanceolatum L. & H. var. virginianum | | × | × | | 5? | | | × | | | | | | | | | |
| Sigillaria ichtyolepis (Presl) Corda | | | | | × | | | × | | | | | | | | | |
| Sigillaria kalmiana D. W. | | | | | 5 or 6 | | | | | | | | | | | | |
| Sigillariostrobus ? incertus D. W | | | | | | | | | | | | × | | | | | |
| Cordaites Robbii Dn | | | | | | | | × | × | | × | | | | | × | × |
| Cardiocarpon elongatum Newb. | | | | | | | | | | | var | | | | | × | |
| Trigonocarpum ampullæforme Lx | × | × | × | | var. | var | var | var | var | var | | 1 or 2 | var | | var | var | × |
| Trigonocarpum Helenæ D. W | | | × | | 5? | × | 5? | × | × | × | | 4 or 5 | × | | | × | |
| Trigonocarpum Dawsonianum D. W | | | | | | | × | | | | × | | | | | × | |
| Rhabdocarpos speciosus D. W. | | | | | | | | | × | | | | | | | | |
| Whittleseya Campbelli D. W. | | | × | × | × | × | × | × | | × | | × | | | × | × | × |
| Carpolithes orizæformis Lx. MSS | | | | | | | × | | | | × | | | | × | × | × |
| Carpolithes sp | | | | | | | | | | | × | | | | | | |
| Sporangites sp | | | | | | | | | × | | | | | | | | |
| GROUP NO. 2—*From Upper Lykens section.* | | | | | | | | | | | | | | | | | |
| Eremopteris subelegans D. W. | | | | | | | | | | | | | | | | | |
| Eremopteris sp. No. 2 | | | | | | | | | | | | | | | | | |

*plants within the Pottsville formation in the type region*—Continued.

| Beds not definitely correlated with Lykens groups. | | | | | | | | | | | | | | | | | | | | | | | Lower Lykens Coal group, or lower group in type section. | Lower Intermediate group in the type section. | Upper Lykens Coal group, or upper group in type section. | Upper Intermediate group in the type section. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pottsville Gap—type section. | | | | | | | | | | | | | Sharp Mountain. | | | Broad Mountain. | | | | | | | | | | |
| Bed A. 1,195 feet below "Twin coal." | Bed B. 980 feet below "Twin coal." | Bed C. 770 feet below "Twin coal." | Bed D. 710 feet below "Twin coal." | Bed E. 640 feet below "Twin coal." | Bed F. 590 feet below "Twin coal." | Bed G. 570 feet below "Twin coal." | Beds HI. 550 feet below "Twin coal." | Bed J. 465 feet below "Twin coal." | Bed K. 445 feet below "Twin coal." | Bed L. 380 feet below "Twin coal." | Bed M. 245 feet below "Twin coal." | Bed N. 210 feet below "Twin coal." | Swatara Gap drifts. | Rausch Gap, east side. | Rausch Gap, west side. | North Brookside (shaft). | Eureka drift (Upper). | Altamont No. 1, Colliery. | Kemble drift. | Eureka drift (Upper), pit near mouth. | Kohlers Gap. | Yellow Spring Gap slope, Dauphin Basin. | | | | |
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*Table showing the observed geographic and stratigraphic range of*

| Name of species, stratigraphically arranged in two groups. | Lincoln-Lykens mining developments. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lower Lykens Coal group. | | | | | | | | | | | | Upper Lykens Coal group. | | | | |
| | Miller drifts, Coal 5. | Big Run mine, Coals 5–6. | Williamstown, Coals 5–6. | Brookside, Coal 6. | Kalmia, Coals 5–6. | Lincoln, Coal 5. | East Brookside, Coals 4–6. | Brookside, Coals 4–5. | Brookside, Coal 4. | East Brookside, Coal 4. | Lincoln, Coal 4. | Lincoln, Coals 1–5. | Lincoln, Coals 2–3. | North Brookside, Coal 2. | Eureka drift (Lower), Coal 2. | New Lincoln, Coals 1–3. | Lincoln, Coal 1. |
| GROUP NO. 2.—*From Upper Lykens section*—Cont'd. | | | | | | | | | | | | | | | | | |
| Eremopteris dissecta D. W | | | | | | | | | | | | | | | | | |
| Eremopteris lincolniana D. W. | | | | | | | | | | | | 2 | | | | 2 | |
| Eremopteris Cheathami Lx | | | | | | | | | | | | 2 or 3 | | | | | |
| Eremopteris decipiens (Lx) | | | | | | | | | | | | 2 or 3 | | × | | 2 or 3 | ? |
| Eremopteris Aldrichi D. W. | | | | | | | | | | | | ? | | | | | |
| Mariopteris Phillipsi D. W. | | | | | | | | | | | | 2 or 3 | | | | | |
| Mariopteris Phillipsi var. intermedia | | | | | | | | | | | | | | | | | |
| Mariopteris pygmæa D. W | | | | | | | | | | | | 2 | 2 | | × | 2 or 3 | |
| Mariopteris nervosa (Brongn.) Zeill. var. lincolniana | | | | | | | | | | | | 1? | | | | × | |
| Mariopteris tennesseeana D. W. | | | | | | | | | | | | 2 or 3 | × | | | | |
| Mariopteris tennesseeana var. hirsuta | | | | | | | | | | | | 2 or 3? | | | | | |
| Mariopteris cf. acuta (Brongn.) Zeill | | | | | | | | | | | | | | | | | |
| Pseudopecopteris obtusiloba (Stb.) Lx. var. mariopteroides | | | | | | | | | | | | | | | | | |
| Pseudopecopteris cf. squamosa (Lx.) D. W. | | | | | | | | | | | | | | | | | |
| Sphenopteris Lehmanni D. W. | | | | | | | | | | | | | | × | | | |
| Sphenopteris Kaercheri D. W. | | | | | | | | | | | | | | | | 2 | |
| Sphenopteris simulans D. W. | | | | | | | | | | | | | | | | | |
| Sphenopteris sp | | | | | | | | | | | | | | × | | | |
| Sphenopteris divaricata (Goepp.) Gein. & Gutb | | | | | | | | | | | | | | | | 2? | |
| Sphenopteris microcarpa Lx. var. dissecta | | | | | | | | | | | | | | | | 2 or 3 | |
| Sphenopteris Harttii Dn | | | | | | | | | | | | | | | | 2? | |
| Sphenopteris subpinnatifida D. W | | | | | | | | | | | | | | | | | |
| Sphenopteris furcata Brongn | | | | | | | | | | | | | | | | × | |
| Sphenopteris Royi Lx | | | | | | | | | | | | | | | | 2 or 3 | |
| Sphenopteris novalincolniana D. W. | | | | | | | | | | | | | × | | | × | |
| Sphenopteris palmatiloba D. W. | | | | | | | | | | | | | × | | | | |

*plants within the Pottsville formation in the type region*—Continued.

| Beds not definitely correlated with Lykens groups. Pottsville Gap—type section. Bed A. 1,195 feet below "Twin coal." | Bed B. 980 feet below "Twin coal." | Bed C. 770 feet below "Twin coal." | Bed D. 710 feet below "Twin coal." | Bed E. 640 feet below "Twin coal." | Bed F. 590 feet below "Twin coal." | Bed G. 570 feet below "Twin coal." | Beds HI. 550 feet below "Twin coal." | Bed J. 465 feet below "Twin coal." | Bed K. 445 feet below "Twin coal." | Bed L. 380 feet below "Twin coal." | Bed M. 245 feet below "Twin coal." | Bed N. 210 feet below "Twin coal." | Swatara Gap drifts. | Sharp Mountain. Rausch Gap, east side. | Sharp Mountain. Rausch Gap, west side. | Broad Mountain. North Brookside (shaft). | Broad Mountain. Eureka drift (Upper). | Broad Mountain. Altamont No. 1, Colliery. | Broad Mountain. Kemble drift. | Broad Mountain. Eureka drift (Upper), pit near mouth. | Broad Mountain. Kohlers Gap. | Yellow Spring Gap slope, Dauphin Basin. | Lower Lykens Coal group, or lower group in type section. | Lower Intermediate group in the type section. | Upper Lykens Coal group, or upper group in type section. | Upper Intermediate group in the type section. |
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*Table showing the observed geographic and stratigraphic range of*

| Names of species, stratigraphically arranged in two groups. | Lincoln-Lykens mining developments. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lower Lykens Coal group. | | | | | | | | | | | | Upper Lykens Coal group. | | | | |
| | Miller drifts, Coal 5. | Big Run mine, Coals 5–6. | Williamstown, Coals 5–6. | Brookside, Coal 6. | Kalmia, Coals 5–6. | Lincoln, Coal 5. | East Brookside, Coals 4–6. | Brookside, Coals 4–5. | Brookside, Coal 4. | East Brookside, Coal 4. | Lincoln, Coal 4. | Lincoln, Coals 1–5. | Lincoln, Coals 2–3. | North Brookside, Coal 2. | Eureka drift (Lower), Coal 2. | New Lincoln, Coals 1–3. | Lincoln, Coal 1. |
| GROUP NO. 2.—*From Upper Lykens section*—Cont'd. | | | | | | | | | | | | | | | | | |
| Sphenopteris palmatiloba var. squarrosa | | | | | | | | | | | | | | | | 1? | + |
| Sphenopteris mixtilis D. W. | | | | | | | | | | | | 2 or 3 | | | | × | |
| Sphenopteris pilosa Dn. | | | | | | | | | | | | | | | | | |
| Zeilleria cf. avoldensis Stur | | | | | | | | | | | | 1 or 2 | | | | | |
| Oligocarpia crenulata D. W. | | | | | | | | | | | | | | | | | |
| Oligocarpia alabamensis Lx. | | | | | | | | | | | | × | | | | | |
| Pecopteris sp. | | | | | | | | | | | | | | | | | |
| Alethopteris Lacoei D. W. | | | | | | | | | | | | | | | × | 2 | |
| Alethopteris lonchitica (Schloth.) Stb. | | | | | | | | | | | | 1–3? | | | | | |
| Alethopteris lonchitica var. multinervis | | | | | | | | | | | | 2 or 3 | | | | × | |
| Alethopteris alata D. W. | | | | | | | | | | | | 2 or 3? | | | | | |
| Alethopteris lincolniana D. W. | | | | | | | | | | | | 2 or 3 | × | | | | |
| Alethopteris magnifolia D. W. | | | | | | | | | | | | × | | | | 2 | |
| Alethopteris grandifolia Newb. | | | | | | | | | | | | | | | | | |
| Alethopteris discrepans Dn. | | | | | | | | | | | | | | | | × | |
| Alethopteris Serlii (Brongn.) Goepp. | | | | | | | | | | | | | | | | | |
| Alethopteris coxtoniana D. W. | | | | | | | | | | | | | | | | × | |
| Alethopteris Evansii Lx. | | | | | | | | | | | | 2 or 3 | | | | | × |
| Alethopteris Evansii var. grandis | | | | | | | | | | | | 2 or 3? | | | | × | |
| Callipteridium alleghaniense D. W. | | | | | | | | | | | | 2 or 3 | | | × | 2 or 3? | |
| Callipteridium suspectum D. W. | | | | | | | | | | | | | | | | | |
| Callipteridium pottsvillense D. W. | | | | | | | | | | | | | | | | | |
| Megalopteris plumosa D. W. | | | | | | | | | | | | | | | | | |
| Neriopteris lanceolata Newb. | | | | | | | | | | | | | | | | | |
| Neuropteris Elrodi Lx. | | | | | | | | | | | | 2 or 3 | × | × | | 2 | |
| Neuropteris Aldrichi (Lx.) | | | | | | | | | | | | | | | | | |
| Neuropteris acutomintana D. W. | | | | | | | | | | | | 2 or 3 | × | | ? | | |

*plants within the Pottsville formation in the type region*—Continued.

| Beds not definitely correlated with Lykens groups. | | | | | | | | | | | | | | | | | | | | | | | Lower Lykens Coal group, or lower group in type section. | Lower Intermediate group in the type section. | Upper Lykens Coal group, or upper group in type section. | Upper Intermediate group in the type section. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pottsville Gap—type section. | | | | | | | | | | | | | | Sharp Mountain. | | Broad Mountain. | | | | | | | | | | |
| Bed A. 1,195 feet below "Twin coal." | Bed B. 980 feet below "Twin coal." | Bed C. 770 feet below "Twin coal." | Bed D. 710 feet below "Twin coal." | Bed E. 640 feet below "Twin coal." | Bed F. 590 feet below "Twin coal." | Bed G. 570 feet below "Twin coal." | Beds HI. 550 feet below "Twin coal." | Bed J. 465 feet below "Twin coal." | Bed K. 445 feet below "Twin coal." | Bed L. 380 feet below "Twin coal." | Bed M. 245 feet below "Twin coal." | Bed N. 210 feet below "Twin coal." | Swatara Gap drifts. | Rausch Gap, east side. | Rausch Gap, west side. | North Brookside (shaft). | Eureka drift (Upper). | Altamont No. 1, Colliery. | Kemble drift. | Eureka drift (Upper), pit near mouth. | Kohlers Gap. | Yellow Spring Gap slope, Dauphin Basin. | | | | |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | × | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | × | .... | .. | × | .. |
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| .... | .... | .... | .... | .... | .... | .... | .... | × | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | × | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | × | × | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | × |
| .... | .... | .... | .... | .... | .... | .... | × | × | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | × | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | × | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | × | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | × | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | ? | × | .. | .... | .... | × | .. | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | × | × | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | .. | × |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | × | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | × |
| .... | .... | .... | .... | .... | .... | .... | × | × | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | × | .... | × | .... | × | | | .... | .. | .... | .... | .... | .... | .... | .... | × | .. | .... | .... | × | × | .. |
| .... | .... | .... | .... | .... | .... | .... | × | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | × | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | × | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | × | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | × | × | .... | ? | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | × | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | × | .. | .. |
| .... | .... | .... | .... | .... | .... | × | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | × | .. | .... | .... | × | × | .. |

*Table showing the observed geographic and stratigraphic range of*

| Names of species, stratigraphically arranged in two groups. | Lincoln-Lykens mining developments. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lower Lykens Coal group. | | | | | | | | | | | | Upper Lykens Coal group. | | | | |
| | Miller drifts, Coal 5. | Big Run mine, Coals 5-6. | Williamstown, Coals 5-6. | Brookside, Coal 6. | Kalmia, Coals 5-6. | Lincoln, Coal 5. | East Brookside, Coals 4-6. | Brookside, Coals 4-5. | Brookside, Coal 4. | East Brookside, Coal 4. | Lincoln, Coal 4. | Lincoln, Coals 1-5. | Lincoln, Coals 2-3. | North Brookside, Coal 2. | Eureka drift (Lower), Coal 2. | New Lincoln, Coals 1-3. | Lincoln, Coal 1. |
| GROUP NO. 2—*From Upper Lykens section*—Cont'd. | | | | | | | | | | | | | | | | | |
| Neuropteris tennesseeana Lx. MSS | | | | | | | | | | | | | | | | 2 or 3 | |
| Neuropteris tenuifolia (Schloth.) Brongn. var. humilis | | | | | | | | | | | | | | | | 1 | |
| Neuropteris sp | | | | | | | | | | | | | | | | | |
| Neuropteris aff. heterophylla Brongn | | | | | | | | | | | | 2? | × | | | | |
| Neuropteris ovata Hoffm | | | | | | | | | | | | var. | | | | var. | |
| Neuropteris hirsutina D. W | | | | | | | | | | | | | | | | | |
| Neuropteris Desorii Lx.? | | | | | | | | | | | | | | | | | |
| Neuropteris fimbriata Lx | | | | | | | | | | | | | | | | | × |
| Neuropteris gigantea Stb | | | | | | | | | | | | | | 2 | | 2 | |
| Neuropteris lunata D. W | | | | | | | | | | | | 1 | | | | 1 | × |
| Calamites Haueri Stur | | | | | | | | | | | | | | | | × | |
| Calamites approximatus Schloth | | | | | | | | | | | | × | | | × | × | |
| Asterophyllites arkansanus D. W | | | | | | | | | | | | 1,2or3 | | | | × | |
| Asterophyllites pennsylvanicus D. W | | | | | | | | | | | | 2 or 3 | | | | × | |
| Asterophyllites cf. rigidus (Stb.) Brongn | | | | | | | | | | | | | | | | × | |
| Annularia platiradiata Lx. MSS | | | | | | | | | | | | | | | | × | |
| Annularia acicularis Dn | | | | | | | | | | | | | | | | 2 or 3 | |
| Annularia cuspidata Lx | | | | | | | | | | | | | | | | | × |
| Annularia latifolia (Dn.) Kidst | | | | | | | | | | | | | | | | | |
| Annularia laxa Dn | | | | | | | | | | | | × | | | | | |
| Calamostachys Knowltoniana D. W | | | | | | | | | | | | | × | | | | |
| Palæostachya alabamensis D. W | | | | | | | | | | | | | | | | | |
| Macrostachya sp | | | | | | | | | | | | | | | | | |
| Sphenophyllum tenerrimum Ett. var. elongatum | | | | | | | | | | | | 2 | | | | 2 | |
| Sphenophyllum bifurcatum Lx | | | | | | | | | | | | | | × | | | ? |

*plants within the Pottsville formation in the type region*—Continued.

| Beds not definitely correlated with Lykens groups. | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pottsville Gap—type section. | | | | | | | | | | | | | | Sharp Mountain. | | Broad Mountain. | | | | | | | | | | |
| Bed A. 1,195 feet below "Twin coal." | Bed B. 930 feet below "Twin coal." | Bed C. 770 feet below "Twin coal." | Bed D. 710 feet below "Twin coal." | Bed E. 640 feet below "Twin coal." | Bed F. 590 feet below "Twin coal." | Bed G. 570 feet below "Twin coal." | Beds HI. 550 feet below "Twin coal." | Bed J. 465 feet below "Twin coal." | Bed K. 445 feet below "Twin coal." | Bed L. 380 feet below "Twin coal." | Bed M. 245 feet below "Twin coal." | Bed N. 210 feet below "Twin coal." | Swatara Gap drifts. | Rausch Gap, east side. | Rausch Gap, west side. | North Brookside (shaft). | Eureka drift (Upper). | Altamont No. 1, Colliery. | Kemble drift. | Eureka drift (Upper), pit near mouth. | Kohlers Gap. | Yellow Spring Gap slope, Dauphin Basin. | Lower Lykens Coal group, or lower group in type section. | Lower Intermediate group in the type section. | Upper Lykens Coal group, or upper group in type section. | Upper Intermediate group in the type section. |
| .... | .... | .... | .... | .... | .... | .... | × | × | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | × | .. | × | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | × | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | × | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | ? | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | × | × | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | v. | × |
| .... | .... | .... | .... | .... | .... | .... | .... | × | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | × | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | .. | × |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | var | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | × | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | × | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | × | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | × | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | × | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | × | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | × | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | × | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | × | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | × | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | .... | .... | × | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | .. | .... | .... | .. | × | .. |
| .... | .... | .... | .... | .... | .... | .... | × | .... | .... | .. | .. | .... | .. | .... | .... | .... | .... | .... | .... | .. | × | .... | .... | .. | × | .. |

*Table showing the observed geographic and stratigraphic range of*

| Names of species, stratigraphically arranged in two groups. | Lincoln-Lykens mining developments. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lower Lykens Coal group. | | | | | | | | | | | | Upper Lykens Coal group. | | | | |
| | Miller drifts, Coal 5. | Big Run mine, Coals 5–6. | Williamstown, Coals 5–6. | Brookside, Coal 6. | Kalmia, Coals 5–6. | Lincoln, Coal 5. | East Brookside, Coals 4–6. | Brookside, Coals 4–5. | Brookside, Coal 4. | East Brookside, Coal 4. | Lincoln, Coal 4. | Lincoln, Coals 1–5. | Lincoln, Coals 2–3. | North Brookside, Coal 2. | Eureka drift (Lower), Coal 2. | New Lincoln, Coals 1–3. | Lincoln, Coal 1. |
| GROUP NO. 2—*From Upper Lykens section*—Cont'd. | | | | | | | | | | | | | | | | | |
| Sphenophyllum cuneifolium (Stb.) Zeill | | | | | | | | | | | | 1,2 or 3 | | | | × | |
| Bowmannites? sp | | | | | | | | | | | | | | | | | |
| Lepidophloios acutimontanus D. W | | | | | | | | | | | | | | | | | |
| Lepidophyllum campbellianum Lx | | | | | | | | | | | | 2 or 3 | | | | × | |
| Lepidophyllum linearifolium Lx. ? | | | | | | | | | | | | | | | | ? | |
| Lepidocystis fraxiniformis Lx | | | | | | | | | | | | 1 | | | | | |
| Bothrodendron arborescens (Lx.) | | | | | | | | | | | | | | | | | |
| Sigillaria lincolniana D. W | | | | | | | | | | | | 2 or 3 | | | | × | |
| Sigillaria cf. lævigata Brongn | | | | | | | | | | | | | | | | | |
| Sigillaria sp | | | | | | | | | | | | 2 | | | | | |
| Stigmariopsis Harveyi Lx. MSS | | | | | | | | | | | | | | | | × | |
| Cordaites Phillipsi D. W | | | | | | | | | | | | | | | | × | |
| Cordaites angustifolius Dn | | | | | | | | | | | | | | | | | |
| Cordaites grandifolius Lx | | | | | | | | | | | | | | | | × | |
| Artisia irregularis D. W | | | | | | | | | | | | | | | | | |
| Cordaianthus spicatus Lx | | | | | | | | | | | | | | | | | |
| Cardiocarpon bicuspidatum (Stb.) Newb. var. ohioense | | | | | | | | | | | | | | | | | |
| Cardiocarpon cuyahogæ D. W | | | | | | | | | | | | 2 | | × | × | × | |
| Cardiocarpon minus Newb | | | | | | | | | | | | | | | | | |
| Cardiocarpon late-alatum Lx | | | | | | | | | | | | | | | | | |
| Cardiocarpon disculum D. W | | | | | | | | | | | | | | | | × | |
| Cardiocarpon orbiculare Ett | | | | | | | | | | | | 1,2 or 3 | | | | | |
| Cardiocarpon cornutum Dn | | | | | | | | | | | | | | | | × | |
| Cardiocarpon elongatum Newb. var. intermedium | | | | | | | | | | | | | | | | | |
| Cardiocarpon annulatum Newb | | | | | | | | | | | | | | | | | |
| Cardiocarpon Wilcoxi D. W | | | | | | | | | | | | | | | | | |
| Cardiocarpon Girtyi D. W | | | | | | | | | | | | 1 or 2 | | | | | |
| Cardiocarpon obliquum Dn | | | | | | | | | | | | | | × | | × | |

*plants within the Pottsville formation in the type region*—Continued.

| Beds not definitely correlated with Lykens groups. | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pottsville Gap—type section. | | | | | | | | | | | | | Sharp Mountain. | | | Broad Mountain. | | | | | | | | | | |
| Bed A. 1,195 feet below "Twin coal." | Bed B. 980 feet below "Twin coal." | Bed C. 770 feet below "Twin coal." | Bed D. 710 feet below "Twin coal." | Bed E. 640 feet below "Twin coal." | Bed F. 590 feet below "Twin coal." | Bed G. 570 feet below "Twin coal." | Beds HI. 550 feet below "Twin coal." | Bed J. 465 feet below "Twin coal." | Bed K. 445 feet below "Twin coal." | Bed L. 380 feet below "Twin coal." | Bed M. 245 feet below "Twin coal." | Bed N. 210 feet below "Twin coal." | Swatara Gap drifts. | Rausch Gap, east side. | Rausch Gap, west side. | North Brookside (shaft). | Eureka drift (upper). | Altamont No. 1 colliery. | Kemble drift. | Eureka drift (upper), pit near mouth. | Kohlers Gap. | Yellow Spring Gap slope, Dauphin Basin. | Lower Lykens Coal group, or lower group in type section. | Lower Intermediate group in the type section. | Upper Lykens Coal group, or upper group in type section. | Upper Intermediate group in the type section. |
| | | | | | | | × | | | × | × | | | | | | | | | | | | | | × | × |
| | | | | | | | | × | | | | | | | | | | | | | | | | | × | |
| | | | | | | | | | | × | | | | | | | | | | | | | | | × | |
| | | | ? | | | | | | | | | | | | | | | | | | | | ? | | × | |
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| | | | | | | | | | | | | | | ? | | | | | | | | | | | × | |
| | | | | | | | | | | × | | | | | | | | | | | ? | | | | × | |
| | | | | | | | × | | | × | | | | | | | | | | | | | | | × | |
| | | | | | | | | | | | | | | | | | | ? | | | ? | | | | × | |
| | | | | | | | | × | | | | | | | | | | | | | | | | | × | |
| | | | | | | | | | | × | | | | | | | | | | | | | | | × | |
| | | | | | | | | | | × | | ×? | | | | | | | | | | × | | | × | × |
| | | | | | | | | | | | | | | | | | | | | | | | | | × | |
| | | | | | | | × | | | | | | | | | | | | | | | | | | × | |
| | | | | | | | | | × | | | | | | | | | | | | | | | | × | |
| | | | | | | | × | | | | | | | | | | | | × | | | | | | × | |
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| | | | | | | | × | | | × | | | | | | | | | | | | | | | × | |
| | | | | | | | | | | × | | × | | | | | | | | | × | | | | × | × |
| | | | | | | | | | | × | | × | | | | | | | | | | | | | × | × |
| | | | | | | | | | | | | | | | | | | | | | | × | | | × | |
| | | | | | | | | | | | | | | | | | | | | | | | | | × | |
| | | | | | | | | | | | | | | | | | | | × | | × | | | | × | |

*Table showing the observed geographic and stratigraphic range of*

| Names of species, stratigraphically arranged in two groups. | Lincoln-Lykens mining developments. Lower Lykens Coal group. Miller drifts, Coal 5. | Big Run mine, Coals 5-6. | Williamstown, Coals 5-6. | Brookside, Coal 6. | Kalmia, Coals 5-6. | Lincoln, Coal 5. | East Brookside, Coals 4-6. | Brookside, Coals 4-5. | Brookside, Coal 4. | East Brookside, Coal 4. | Lincoln, Coal 4. | Lincoln, Coals 1-5. | Upper Lykens Coal group. Lincoln, Coals 2-3. | North Brookside, Coal 2. | Eureka drift (Lower), Coal 2. | New Lincoln, Coals 1-3. | Lincoln, Coal 1. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GROUP No. 2.—*From Upper Lykens section*—Cont'd. | | | | | | | | | | | | | | | | | |
| Trigonocarpum Noeggerathi (Stb.) Brongn | | | | | | | | | | | | 1 or 2 | | | | | |
| Trigonocarpum ornatum Newb | | | | | | | | | | | | | | | | | |
| Rhabdocarpos Walcottianus D. W | | | | | | | | | | | | | | | | 1 or 2 | |
| Whittleseya Lescuriana D. W | | | | | | | | | | | | | | | | | |
| Whittleseya microphylla Lx | | | | | | | | | | | | | | | | 2 or 3 | |
| Whittleseya elegans Newb. var. minor | | | | | | | | | | | | 1,2 or 3 | × | | | | |
| Carpolithes fragarioides Newb | | | | | | | | | | | | | | | | × | |
| Carpolithes transsectus Lx | | | | | | | | | | | | | | | | × | |
| Fayolia sp | | | | | | | | | | | | | | × | | | |

*plants within the Pottsville formation in the type region*—Continued.

| Beds not definitely correlated with Lykens groups. | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pottsville Gap—type section. | | | | | | | | | | | | | Sharp Moun-tain. | | | Broad Mountain. | | | | | | | | | | |
| Bed A. 1,195 feet below "Twin coal." | Bed B. 980 feet below "Twin coal." | Bed C. 770 feet below "Twin coal." | Bed D. 710 feet below "Twin coal." | Bed E. 640 feet below "Twin coal." | Bed F. 590 feet below "Twin coal." | Bed G. 570 feet below "Twin coal." | Beds HI. 550 feet below "Twin coal." | Bed J. 465 feet below "Twin coal." | Bed K. 445 feet below "Twin coal." | Bed L. 380 feet below "Twin coal." | Bed M. 245 feet below "Twin coal." | Bed N. 210 feet below "Twin coal." | Swatara Gap drifts. | Rausch Gap, east side. | Rausch Gap, west side. | North Brookside (shaft). | Eureka drift (upper). | Altamont No. 1 colliery. | Kemble drift. | Eureka drift (upper), pit near mouth. | Kohlers Gap. | Yellow Spring Gap slope, Dauphin Basin. | Lower Lykens Coal group, or lower group in type section. | Lower Intermediate group in the type section. | Upper Lykens Coal group, or upper group in type section. | Upper Intermediate group in the type section. |
| | | | | | | | | | | × | | | | | | | | | | | | | | | × | |
| | | | | | | | | × | | | | | | | | | | | | | | | | | × | |
| | | | | | | | | | | | | | | | | | | | | | | | | | × | |
| | | | | | | | × | × | | | | | | | | | | | × | | × | | | | × | |
| | | | | | | | | | | | | | | | | | | | | | | | | | × | |
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*Analysis of the distribution of the species by divisions in the formation.*

| Division. | Total number of species therein. | Common to Lower Lykens division. | Common to Lower Intermediate division. | Common to Upper Lykens division. | Common to Upper Intermediate division. | Exclusively confined to the division. |
|---|---|---|---|---|---|---|
| Lower Lykens | 50 | .......... | 10 | 14–15 | 0 | 33 |
| Lower Intermediate | 17–19 | 10 | ....... | 13 | 0 | 2 |
| Upper Lykens | 125 | 14–15 | 11–13 | .......... | 7 | 95 |
| Upper Intermediate | 11 | 0 | 0 | 7 | ....... | 4 |

## FLORAS OF THE LOWER LYKENS DIVISION.

Before discussing the probable equivalents or approximate horizons, with reference to either the Lykens coals or the type section of the formation, of the more or less isolated beds or developments in the southern portions of the anthracite field, including those enumerated in the section of the table to the right of the Pottsville Gap beds, it is desirable to indicate as clearly as is practicable, without recourse to paleontologic descriptions, those species which, so far as has been observed, are apparently largely characteristic of the principal levels. It is also advisable to enumerate those which appear to especially attend and mark the vicinity of the economically important and therefore more interesting horizons of the several Lykens coals. The latter may be reviewed in ascending order.

### FLORA OF THE "ZERO" AND NO. 6 COALS.

Of the characters of the plants over the "zero" bed, the lowest of the Lykens coals, no precise information is at hand. At Williamstown,[1] the only point at which the bed has been exploited, but little mining was ever done in the coal, and the bed was so long ago abandoned that it has not been practicable to obtain any fossils therefrom. It appears probable, however, on account of its proximity to the succeeding coals (38 feet below No. 6), that little difference will be observed in its flora, fragments of which may possibly have been gathered from the rock dump at the Williamstown mine. Likewise the mingling of the roof shales from the Lykens coals No. 6, or the "Little bed," and coal No. 5, in the rock dumps, as at Big Lick, Williamstown, and the Brookside mines, renders it, for the most part, impossible to discriminate between the fossils from these coals at this point, although it has fortunately been possible to procure distinct collections from the higher coal. A small collection from the roof of Lykens coal No. 6, within the mine

[1]Atlas Southern Anthracite Field, Pt. III, mine sheet xix; Pt. VI, cross-section sheet xx; Pt. IV, columnar-section sheet vii, section 8.

at Brookside, was, however, obtained through the cooperation of the Philadelphia and Reading Coal and Iron Company.

Excluding *Whittleseya Campbelli*, which in some form is nearly everywhere present in the Pottsville formation, and *Sphenopteris patentissima*, which is more abundant in the neighborhood of coals No. 5 and 4, there remain *Neuropteris Pocahontas* var. *pentias* and *Alethopteris composita*, the latter of which has not been found in any other bed. The variety of *Neuropteris Pocahontas* has, perhaps, not been seen from a higher level than the roof of No. 5. Its presence, accordingly, in a coal but 50 feet lower is quite natural. It must therefore be understood that the shales attending coal No. 6 have not yet revealed any floral characters of value, though the default may be due to lack of specimens known to have come from this level, rather than entirely to its propinquity to coal No. 5.

## FLORA OF LYKENS COAL NO. 5.

The collective flora from the roof of Lykens coal No. 5, also known as the "Big bed," or the "Lykens Valley bed,"[1] may readily be compiled from the first section in the table of distribution. As will be noted in glancing at the vertical range of the species in the latter, a large portion of the plants are common to the flora of coal No. 4, while others, perhaps exclusively from this bed, are represented by specimens whose mingling in the rock dump with material from No. 6 deprives them of any present stratigraphic trustworthiness. Among the specimens definitely known to come from the roof of this coal the most important species are: *Mariopteris eremopteroides*, *Sphenopteris asplenioides*, *S. patentissima*, *Neuropteris Pocahontas* and its two varieties, *Calamites Roemeri*, *Asterophyllites parvulus*, *Lepidophyllum quinnimontanum*, *Lepidophyllum lanceolatum* var. *virginianum*, and *Sigillaria kalmiana*. *Eremopteris* sp. No. 1, *Calamostachys* cf. *lanceolata*, *Lepidodendron alabamense*, and a *Sigillaria* which I refer, with a little doubt, to *S. ichtyolepis*, are species of restricted range, but the circumstances attending the collection of some of the fossils make it uncertain whether their source is exclusively in the region of coal No. 5. The most abundant and characteristic species is *Neuropteris Pocahontas* var. *pentias*, which rarely fails to be present in large numbers, even in a small collection. The variety *inæqualis*, which is more common in the roof of Lykens coal No. 4, is also present. Another form, which throughout the Wiconisco Basin seems to be confined to the same stage, is the beautiful *Mariopteris eremopteroides* illustrated in Pl. CLXXXIX. *Sphenopteris asplenioides* here, as in other regions, exhibits the diminutive round-lobed or *Dicksonioides* type common in the

[1] "No. 2" in the nomenclature employed for this vicinity in Rogers, Geology of Pennsylvania, Vol. II, Pt. II, 1858, p. 192.

lower portion of the Pottsville formation. *Sphenopteris patentissima* appears to be present at this level, though more common in and characteristic of the roof of coal No. 4. *Calamostachys* cf. *lanceolata*, collected from the East Brookside rock dump, may be assumed to have come from No. 4, its occurrence in other regions being as high as the flora of No. 4, or even higher. The same is true of *Lepidodendron alabamense*. *Lepidophyllum lanceolatum* var. *virginianum* and *Lepidophyllum quinnimontanum* are essentially characteristic of the lower Pottsville in all regions, but the former is usually predominant in beds lower than those in which the latter is common.

From an examination of the table, as well as from the inspection of the collections, we may conclude that the almost invariable appearance of *Mariopteris eremopteroides* or the lax form, var. *inæqualis*, of *Neuropteris Pocahontas*, as well as the occasional presence of a number of the ferns slightly more characteristic of No. 4, serves to distinguish the stage of coal No. 5 from the basal portion of the Pottsville formation, while the species first mentioned, together with the always abundant *Neuropteris Pocahontas* var. *pentias*, *Neuropteris Pocahontas*, and *Lepidophyllum lanceolatum* var. *virginianum*, likewise assist in discriminating between the floras of coals No. 5 and No. 4. In the latter differentiation the absence of those plants which are characteristic of the roof shales of No. 4 is perhaps an equally valuable criterion, though negative in its nature.

## PALEONTOLOGIC FEATURES OF THE ROOF SHALES OF COAL NO. 4.

The flora of the roof shales of Lykens coal No. 4 is perhaps the most readily recognizable among those attending the series of the Lykens coals. While it contains a large percentage of species that are also found in the roof of No. 5, as may be noted by reference to the table, and while its facies is distinctly *lower* Pottsville as compared with floras of coals 2 or 3, it almost invariably contains several species which are not only restricted to nearly this level in the Southern Anthracite field, but which are also observed, similarly associated, and restricted as to vertical range, in other regions. These are *Aneimites pottsvillensis*, *Mariopteris pottsvillea*, *Alethopteris protaquilina*, *Neuropteris Smithsii*, *Volkmannia crassa*, and *Sphenophyllum tenue*. Additional species, hitherto found only at this level in the Southern Anthracite field, are *Sphenopteris novalincolniana*, *S. Lutheriana*, *Rhapdocarpos speciosus*, and a form of *Sporangites*. Of the species which are found at other horizons, *Sphenopteris patentissima*, the small form of *S. asplenioides*, *Aloiopteris georgiana*, *Lepidodendron alabamense*, and *Trigonocarpum Helenæ* are more especially common in this stage, where they are generally associated with the species first enumerated. In fact, *Aneimites pottsvillensis*, *Mariopteris pottsvillea*, *Neuropteris Smithsii*, *Sphenophyllum tenue*, *Lepidodendron alabamense*, and *Trigonocarpum Helenæ* are among the characteristic species of this stage of the Pottsville formation throughout the Appalachian region. The most common, and therefore the most useful of these in the Southern Anthracite field are *Mariopteris*, *Neuropteris*, and *Sphenophyllum*. In fact, if we were to employ a paleontologic term for this portion of the section, the latter might appropriately be designated the *Mariopteris pottsvillea* zone.

COMPARISON OF THE LOWER PORTION OF THE TYPE SECTION WITH REFERENCE TO THE LYKENS COAL HORIZONS.

Owing to the densely conglomeratic constitution of the basal portion of the formation at the type locality, comparatively few fossils have been obtained from beds A and B, which clearly belong to the Lower Lykens division; but while the materials from bed B of the section are quite insufficient to form a basis for horizontal comparisons, we find that the presence of *Mariopteris* sp. No. 1, which is perhaps inseparable from *Mariopteris eremopteroides*, *Neuropteris Pocahontas*, and *Sphenopteris patentissima* in bed C, 770 feet below the Twin coal, is entirely compatible with a stratigraphic position not far from Lykens coal No. 5. At the same time, the presence in bed D, 710 feet below the Twin coal, of *Mariopteris pottsvillea*, *Sphenopteris dadeana*, *Aloiopteris georgiana*, *Neuropteris Pocahontas* var. *inæqualis*, *Neuropteris Smithsii*, and *Sphenophyllum tenue* strongly points to a place near the level of Lykens coal No. 4. Although several species are known to occur in beds above No. 4, they are rare in higher horizons, while the more important percentage of species which appear to be largely characteristic of the Lower Lykens division more than counterbalances them. Of greater correlative value, however, are such species as *Mariopteris pottsvillea*, *Neuropteris Smithsii*, and *Sphenophyllum tenue*, which are in general characteristic of the horizon of No. 4 coal, and whose evidence is strengthened by the accompanying species enumerated above. In short, the plants of bed D indicate a horizon approximate to that of the Lykens coal No. 4 (White's bed), about 710 feet below the Twin coal in the type section. It is probably not higher; it may be slightly lower. Bed C, on the other hand, 770 feet below the Twin coal, is probably lower than the No. 4 coal, and may have been deposited at the same time as the Lykens coal No. 5.

I do not wish to be understood as regarding the coals adjacent to beds C and D in the type section as unquestionably identical with Lykens coals 5 and 4, respectively. The obvious variation in the beds of the Pottsville formation, especially as regards the number of the coals, as shown in sections located but a few miles distant, and the frequently observed entire disappearance of the principal coals of the field, as revealed by borings not far from the Lincoln region,[1] can not fail as convincing arguments against the free application, in the Pottsville formation of the Southern Anthracite field, of the correlative methods employed by geologists working in the interior of the Appalachian trough, where, in the several bituminous basins, the beds are relatively uniform and clearly persistent over great areas. That one of the thin coals occurring in the Pottsville Gap section nearly 700 feet below the Twin coal is contemporaneous with and equivalent in point of time to a portion of the No. 4 coal at Lincoln or Williamstown is perhaps not improbable, since the favorable conditions for exclusively carbonaceous deposition may have been synchronous at both points, and the testimony of the fossils points toward the latter. It is likewise possible that the 1-foot coal accompanying the 2 feet of dark shales at bed C may represent Lykens coal No. 5. It is, however, extremely improbable that either of these coals extends in a continuous carbonaceous terrane from the type section at Pottsville to the very valuable deposit in the Lincoln district.

The stratigraphic position of bed A in the topmost stratum of red shale at the base of the section probably justifies the assumption that it is older than any of the Lykens coals. Its very small flora, of Lower Carboniferous facies, appears to warrant this assumption, although it is too meager to serve as a foundation for satisfactory comparison.

## FLORA OF THE LOWER INTERMEDIATE DIVISION.

### BRIEF EXISTENCE OF A TRANSITION FLORA.

The relative distinctness, from a stratigraphic standpoint, of the floras of the Upper Lykens division, as compared with those of the Lower Lykens division, has already been remarked in connection with the proposed subdivision of the Pottsville formation according to the concomitant grouping of the economic coals and the fossils. It may be noted at this point that the paleontologic difference between the lower and the upper groups, which, excluding the gymnosperms and certain vertically widely distributed Lycopodiales, have comparatively few species in common, is probably due in part at least to the interval between Lykens coals Nos. 4 and 3, which is about 250 feet in the Lincoln region. This interval, of which we have from the Lincoln region no paleontologic representation in the collections, and which is therefore not assigned to either the upper or the lower division, still remains accordingly a paleontologically unknown quantity. Yet, notwithstanding the inferential conclusion that it contains a transitional mingling of Upper and Lower Lykens floral characters, such as occurs in the interval (Lower Intermediate division) between 570 and 700 feet below the Twin coal in the type section, the vertical distance involved is

[1] See the records of diamond-drill bore holes on Broad Mountain, platted in great detail on columnar-section sheet ix, Atlas Southern Anthracite Field, Pt. IV.

comparatively so little, when we at once take into view the entire section and the notable differences between the flora above and that below, as to strongly emphasize the rapidity of the specific floral changes which it masks. As has previously been mentioned, the plants of bed G of the Pottsville Gap section are probably referable to the Upper Lykens division. Should plants be collected from several beds between coals No. 3 and No. 4 in the Lincoln-Lykens mining districts, it is not improbable that some of the terranes will show closer paleontologic connections with one division or the other; but the plants in the interval in the type section, though few in number, indicate that within certain limits of a relatively thin zone of the sections the boundary, if drawn as between the Lower Lykens division and the Upper Lykens division, will be largely arbitrary through beds with a mixed flora. The case in hand well illustrates the rapidly changing facies of the floras of the Appalachian region during Pottsville time.

## FLORAS OF THE UPPER LYKENS DIVISION.

### FLORA OF LYKENS COALS NOS. 3 AND 2.

Fossil plants have been collected from the roof shales of Nos. 1, 2, and 3 of the upper Lykens coals in the vicinity of Lincoln. It has been impossible to make a collection from coal No. 1½, since the New Lincoln colliery, where it was formerly slightly worked, has for a number of years been abandoned, the mineral from the other beds on the property being brought to light at the Lincoln mine. Accordingly, while it is not impossible that stray specimens from this bed may still have been accessible in the rock dump, it is probable from the very small extent of the workings that few, if any, were collected. At least it has not been possible to recognize such, and the specimens, if present, are presumably included in the column of the table devoted to the stratigraphically undifferentiated material from coals 1 to 3, inclusive, at the New Lincoln mine.

Of the floras derived from the upper Lykens coals, by far the most interesting are those associated with the neighboring coals, Nos. 2 and 3. The proximity of these beds, which are separated by but 3 inches of dirt at the New Lincoln mine and by strata probably nowhere far exceeding 30 feet in the Lincoln workings, results generally in the removal of both coals at once and the mingling of the roof shales of No. 2 with the parting between Nos. 2 and 3. Separate collections were, however, obtained from both, that exclusively from the parting, which may be regarded as the roof of No. 3, being procured at the Lincoln mine, while specimens from the cover of coal No. 2 were gathered at the North Brookside slope[1] in that bed and from the lower

[1] Atlas Southern Anthracite Field, Pt. III, mine sheet xvii; Pt. IV B, columnar-section sheet x, section 8; Pt. VI, cross-section sheet xix, section 25.

Eureka drift.[1] Of the entire 125 species so far discovered in the shales over the coals of the Upper Lykens group, not more than 14 or 15, including the vertically widely distributed gymnosperms, are found in the Lower Lykens group. By reference to the preceding table of distribution, it will at once be seen that of the fern flora but 2 species, *Sphenopteris asplenioides* and *Pecopteris serrulata*, present in the Lower Lykens division, are also apparently present in the roof shales of the mined upper Lykens coals, or in the beds of the type section, which, on the paleontologic evidence, I refer to the same division as the upper Lykens coals. *Calamites Roemeri*, *Asterophyllites parvulus*, *Lepidodendron clypeatum*, *Lepidostrobus pennsylvanicus*, and the five gymnosperms, which occur in the Lower Lykens division, have a relatively wide distribution in the formation. *Sphenopteris asplenioides* appears to be extremely rare in this division of the Southern Anthracite field, though it occurs as a large form in beds of the same age in the southern Appalachian region. *Pecopteris serrulata* is usually common in beds of this age. *Sphenophyllum tenue* is, on the other hand, extremely rare at so high a level; it, like *Trigonocarpum Helenæ*, being usually characteristic of the zone of No. 4 coal, or lower.

The zone of coals Nos. 2 and 3 is, in general, especially characterized by the presence of broad- or round-pinnuled forms of *Eremopteris;* by forms of *Mariopteris* approaching the original *muricata* type; by the large number of Sphenopterids, especially of the Hymenophyllous group, as well as by a Pecopteroid form; by the presence of the large, lax, and distant-nerved Alethopterids of the types of *A. discrepans* and *A. grandifolia;* by the *Megalopteris* types; by the *Elrodi* and *gigantea* types of *Neuropteris;* by the delicate *Asterophyllites* forms; by the early *Annulariæ;* the dissected *Sphenophylla;* the numerous gymnosperms, including *Cordaites* and the broad-leafed *Whittleseyæ;* as well as by a great abundance and variety of fruits. As more peculiar to this zone, specific mention should be made of—

Eremopteris Cheathami.
Mariopteris pygmæa.
Mariopteris tennesseeana.
Sphenopteris Lehmanni.
Sphenopteris Kærcheri.
Sphenopteris divaricata.
Sphenopteris Harttii.
Sphenopteris Royi.
Sphenopteris palmatiloba.
Alethopteris Lacoei.
Alethopteris grandifolia.
Alethopteris Evansii.
Callipteridium alleghaniense.
Neuropteris Elrodi.
Neuropteris tennesseeana.
Asterophyllites arkansanus.
Sphenophyllum tenerrimum var. elongatum.
Sphenophyllum bifurcatum.
Stigmariopsis Harveyi.
Cardiocarpon Cuyahogæ.
Cardiocarpon minus.
Carpolithes transsectus.
Whittleseya microphylla.
Whittleseya elegans var. minor.

[1] Station 33, Pl. CLXXX. Atlas Southern Anthracite Field, Pt. III, mine sheet xvi; Pt. IV B, columnar-section sheet x, section 6; Pt. VI, cross-section sheet xvii, section 23.

In addition to the plants specially mentioned above, there remain a number of new species which are as yet unknown outside of the field, and which, as may be observed in the table, occur only in this zone.

The species enumerated above, which paleobotanists will at once recognize as preponderantly common to the flora accompanying the Sewanee coal in Tennessee,[1] are essentially characteristic of this zone of the Upper Lykens division. Many of them, such as *Eremopteris Cheathami*, *Mariopteris tennesseeana*, *Sphenopteris Royi*, *Sphenopteris pilosa*, *Alethopteris Evansii*, *Neuropteris tennesseeana*, *Carpolithes transsectus*, *and Whittleseya microphylla*, have, so far as I know, never yet been found at any considerable distance from this zone in the Appalachian trough.

The flora in the roof of Lykens coal No. 2 reveals, as compared with that in the roof of No. 3, a slight difference, consisting of the presence of a few species of usually slightly higher occurrence and several forms which, in the Southern Anthracite field, I have found at no other horizon. As referable to the former category the following may be mentioned:

Eremopteris decipiens.
Eremopteris dissecta.
Mariopteris pygmæa.
Alethopteris Lacoei.
Alethopteris magnifolia.
Neuropteris Elrodi.
Neuropteris gigantea var.
Asterophyllites arkansanus.
Sphenophyllum bifurcatum.
Sphenophyllum tenerrimum var. elongatum.
Cardiocarpon Cuyahogæ.
Whittleseya elegans.

The peculiar elements which characterize the flora of Lykens coal No. 2 at every locality from which a considerable collection of specimens has been obtained, and by which it would seem that, in the western portion of the Southern Anthracite field, the horizon may almost invariably be recognized, include *Mariopteris pygmæa*, *Sphenopteris Lehmanni Alethopteris Lacoei*, and *Neuropteris Elrodi*. To this group of species may also be added *Sphenophyllum tenerrimum* var. *elongatum*, although in other fields this species has a somewhat higher distribution, and such, we may anticipate, will be the case outside of a restricted area in the western portion of the Southern Anthracite field. It may be noted that even where drifted, at a point about 550 feet below the Twin coal, above the wagon road on the east side of the gap below Pottsville, and at a point along an abandoned tramway near the apex of the mountain on the west side of Westwood Gap, this horizon reveals the same association of species in their identical forms. These species appear to attend Lykens coal No. 2 in the Southern Anthracite field, just as *Eremopteris Cheathami*, *Sphenopteris Royi*, *S. palmatiloba*, *S. pilosa*, *Mariopteris tennesseeana*, *Alethopteris Evansii* and *Neuropteris tennesseeana* usually occur in the roof of Lykens coal No. 3.

[1] Coal Flora, Vol. III, p. 853.

FLORA OF LYKENS COAL NO. 1.

Lykens coal No. 1, it will be remembered, occurs at about 325 to 360 feet above coal No. 2, and about 250 feet below the "Buck Mountain" coal. The plant association in the roof shale of this, the highest of the Lykens coals worked in this region, is marked, as compared with the flora of the Lykens coal No. 2, by the disappearance of species known to be present in the latter, as well as by the introduction of new forms rapidly approaching the Coal Measures facies. Among the more interesting of the survivors are *Cordaites Robbii*, *Trigonocarpum ampullæforme*, *Whittleseya Campbelli*, and *Carpolithes orizæformis* from the Lower Lykens division, and a form of *Alethopteris Evansii* and *Sphenophyllum bifurcatum* from the Upper Lykens division. An examination of additional collections will no doubt largely increase this number, since it is possible that representatives of all the antecedent Coal Measures types, such as *Alethopteris lonchitica*, *Neuropteris* aff. *heterophylla*, and *N. gigantea*, present in the zone of No. 2 coal, will eventually come to light at the horizon of Lykens coal No. 1. At the same time, however, it is to be expected that the number of new forms will be correspondingly increased.

The forms which have not yet been found below the horizon of No. 1 include *Sphenopteris palmatiloba* var. *squarrosa*, *Neuropteris lunata*, *Annularia cuspidata*, *N. tenuifolia* var. *humilis*, and *N. fimbriata*. The first three of these appear to be characteristic of this zone, while the two last named continue into the Lower Coal Measures. *Annularia cuspidata* is most probably the precursor of *Annularia sphenophylloides*, which appears early in the Allegheny series.

UPPER LYKENS ZONES IN THE TYPE SECTION.

It needs but a glance at the names of the species recorded in the column representing the two approximate beds, H and I, about 550 feet below the Twin coal in the Pottsville Gap, to detect the floral characteristics of the zone of Lykens coals Nos. 2 and 3; while to paleobotanists who are acquainted with the Sewanee flora, whose nearly identical composition has already been noted, the preponderance of common features will at once indicate approximately the same age. The greater portion of the plants recorded from coals Nos. 3 and 2 are also found in the collective material from beds H and I, which have been somewhat thoroughly searched. It will also be observed that besides several new species, such as *Sphenopteris simulans*, *Callipteridium suspectum*, and *Whittleseya Lescuriana*, not found elsewhere, we have *Cordaites angustifolius* and *Cardiocarpon minus*, which are not reported from the vicinity of Lincoln.

Above the trolley road, on the east side of the gap at Pottsville, about 465 feet below the Twin coal, a drift has been driven some distance along a thin coal, and in dark coaly shales which contain *Mariopteris pygmæa*, *Alethopteris Lacoei*, and *Neuropteris Elrodi* in the facies and association characteristic of the horizon of Lykens coal No. 2 in the Lincoln district, and I have little hesitation in suggesting the probable approximate contemporaneity, if not equivalence, of the two beds.

As previously mentioned, the same horizon appears also to have been touched in a trial shaft on the west slope of Westwood Gap.

Among the more interesting or important additional species in bed J, the probable equivalent of this horizon in the type section in the railroad cut at Pottsville, which has been more thoroughly searched for fossils, are *Eremopteris Aldrichi*, *Sphenopteris palmatiloba*, *S. pilosa*, *Pecopteris serrulata*, *Alethopteris Evansii*, *Callipteridium pottsvillense*, and *Neuropteris hirsutina*. Of these, the first three are usually rather more common at a horizon a little higher than that of coal No. 3 in other coal fields. *Pecopteris serrulata*, which, if the specimen has not been misplaced, occurs in the shales over coal No. 4 at Brookside, has hitherto been unknown at any distance below the zone of coals Nos. 2 and 3. *Callipteridium pottsvillense* is very close to a species from the "coal-bearing shales" of Washington County, Arkansas, where it is associated, as in bed J, with a dilated, thin type derived from *Alethopteris Evansii*. The *Neuropteris hirsutina* is a new species with slender, acute, long-pointed pinnules, strongly suggesting *Neuropteris Scheuchzeri*, to which it appears to sustain an ancestral relation. It is the earliest-known hirsute *Neuropteris*.

The rather small number of plants from bed K is hardly worthy of special consideration, since their source is only about 25 feet higher than J, with whose flora they are in general agreement. It is, however, interesting to note the appearance at this level of an *Eremopteris* (*E. subelegans*) close to *E. elegans*, and a *Sphenopteris* (*S. mixtilis*) probably ancestral to the *S. mixta* of the Coal Measures.

The flora of bed L, about 380 feet below the Twin coal, like that of Lykens coal No. 1, is one of the most interesting in the type section on account of the antecedent Coal Measures forms mingled with typical Pottsville types. In *Calamites Roemeri*, *Whittleseya Campbelli*, and *Carpolithes orizæformis* we seem to have survivors from the Lower Lykens division, though it is possible that the name *Calamites Suckowii* should be substituted for that first mentioned. Omitting the enumeration of other species recorded from the Upper Lykens horizons, at other localities, in the table, it may be observed that, of the species present in bed L, *Eremopteris dissecta*, *Mariopteris Phillipsi*, *Annularia latifolia*, *Bothrodendron arborescens*, *Cordaianthus spicatus*, and *Cardiocarpon annulatum*, characteristic of the Pottsville formation in other regions as well, are unknown in the Lower Coal Measures of the bituminous or anthracite basins of the Northern

States. *Pseudopecopteris obtusiloba* var. *mariopteroides*, *Sphenopteris subpinnatifida*, *Oligocarpia crenulata*, and *Neuropteris tenuifolia* var. *humilis* seem to foreshadow as many Coal Measures types, while *Sphenopteris furcata*, frequently reported in the lower portion of the Lower Coal Measures, is, however, generally more common in the topmost beds of the Pottsville formation. As elsewhere remarked, I have not seen the typical form of *Alethopteris lonchitica* in the Lower Coal Measures of the Northern States; the same may be said of *Trigonocarpum Noeggerathi*. As to whether bed L represents approximately the horizon of Lykens coal No. 1 in the type section, little that is definite can be said. The fact is simply that the flora of each bears nearly the same relation to the older floras, and to those of the Lower Coal Measures, yet there are but few species common to the two. It is not unlikely, however, that the latter circumstance is largely due to the meagerness of the material from the roof of Lykens coal No. 1.

The general biologic evidence, treating the subject from the standpoint of the composition, vertical range, individual relations, etc., of the species, would seem to indicate a similar stage for both. Reasoning from the same evidence, we may conclude that the two beds are referable to horizons not far distant at most. It would also appear slightly more probable that the older terrane may be bed L in the type section. However, very little weight should be attached to so tentative a supposition, even though the latter is supported by the circumstance that the interval between bed L and the Twin coal in the type section is over 375 feet, while Lykens coal No. 1, about 300 feet from the "Buck Mountain" coal, the supposed equivalent of the Twin at Lincoln, approaches within 225 feet of the same horizon at Good Spring. The known variability of the Pottsville terranes is too great to entitle a relative distance of that extent to any serious consideration when the localities are so far removed.

## FLORA OF THE UPPER INTERMEDIATE DIVISION.

### PLANTS OF BEDS M AND N IN THE TYPE SECTION.

On passing to the consideration of the species in beds M and N of the type section, it is important to bear in mind that the floras of the roof of the upper Lykens coal No. 1, at the Lincoln mine, and of bed L, 380 feet below the Twin coal at Pottsville, are essentially very distinct specifically from the flora of the roof of the "Buck Mountain" (Twin) bed, as will be shown later. The plants of Lykens coal No. 1 and of bed L, which we have tentatively assumed were nearly contemporaneous, are, in fact, characteristic of a zone in the upper part of the Pottsville formation, and are closely bound to the flora of the preceding Lykens coals Nos. 2 and 3, or of beds H, I, and J, although having little in common with the plant associations of the Lower Lykens division. The small plant collections from the phytiferous terranes in the remaining upper portion of the lithologic type section, which collectively were designated on an earlier page (775) the "Upper Intermediate division," will be found to contain a still larger proportion of Coal Measures species, though yet exhibiting many forms which are common in the beds of supposed Pottsville age in other regions, and which are still unknown in the Lower Coal Measures. The two beds in question are but 35 feet apart, or 245 and 210 feet, respectively, below the Twin coal. They are both, as may be seen by reference to the section, Pl. CLXXXI, intercalated in the massive conglomerates which succeed the great white, egg conglomerate that underlies the south portion of the railroad bridge at the north end of the gap. The conglomerate last mentioned is, on account of its hardness, light color, thickness, and the regularity of its coarse quartz pebbles, one of the most easily recognized beds, lithologically, of the Pottsville formation over a large portion of the Southern Anthracite field. By glancing at the columns of the table showing the species furnished in the small collections, obtained with some difficulty from the coaly or shaly partings between the conglomerates, we find that *Alethopteris Serlii*, *A. coxtoniana*, *Neuropteris ovata*, *N. Desorii?*, *Sphenophyllum cuneifolium*, and *Sigillaria* cf. *lævigata* have been obtained from bed M, while *Pseudopecopteris* cf. *squamosa*, *Pecopteris* sp., *Neuropteris ovata*, *Alethopteris Serlii*, *Cardiocarpon elongatum* var. *intermedium*, *C. annulatum*, and, perhaps, *C. bicuspidatum* var. *ohioense* are present in bed N. The last identification is uncertain, since the specimens, which were obtained from coarse, conglomeratic sandstones, are very indistinct and fragmentary. The *Pecopteris* species comprises a villous type close to the ferns described by Professor Lesquereux as *Pecopteris vestita* from the Lower Coal Measures of Missouri, and as *P. Bucklandii* Brongn., from the Pottsville formation at Campbell Ledge, near Pittston, Pennsylvania.

With, perhaps, the exception of the *Alethopteris coxtoniana*, the flora of bed N is apparently as ancient as that of M. The combined list from these two beds, which, on account of their stratigraphic proximity and their similar plant contents, may for the present be treated as one flora, contains but 11 species, yet these are of a highly interesting and suggestive character. But one fern species,[1] *Alethopteris coxtoniana*, is represented in the collections from the Lykens groups. The remaining ferns are either identical with the species of the Lower Coal Measures of the same region, though varying somewhat in minor details, such as size, or are very closely bound to typical Coal Measures species. *Sphenophyllum cuneifolium* is repre-

[1] *Neuropteris ovata* is represented by a variety in the roof of one of the upper Lykens coals at New Lincoln.

sented by the more rigid, coarse-nerved, irregularly dissected, broad-toothed form more characteristic of the Lower Coal Measures; not by the very narrow, lax-leafed type, with thin nerves, described by Lesquereux[1] as *Sphenophyllum saxifragæfolium*, from beds of Upper Lykens age in Washington County, Arkansas. The *Sigillaria lævigata* is at once suggestive of the Coal Measures. The gymnosperms, on the other hand, belong to species which have generally a relatively wide range in the higher part of the Upper Lykens division in other coal fields, and which are hardly known from the Lower Coal Measures of the Northern States. These comprise species that are especially common in the upper portion of the formation, of which *Cardiocarpon annulatum* and *C. bicuspidatum* var. *ohioense* appear to be distinctly characteristic, the former being more restricted to the upper beds.

From the foregoing it appears that in beds M and N we have a flora the pteridophytic elements of which are, on the whole, generally distinct from those characteristic of the preceding zones of the Pottsville formation. The gymnosperms, on the other hand, are characteristic of the Upper Lykens division. Yet the ferns, though identical or closely related to those of the Lower Coal Measures, appear not to exhibit the forms and facies of the species found either in the roof of the Buck Mountain coal (Lower Coal Measures) or in the Brookville or Clarion coals of the Allegheny series, in the bituminous basins of the Northern States. The wide difference between the floras of the preceding zones of the Upper Lykens division of the Pottsville formation, on the one hand, and those of the Lower Coal Measures, on the other hand, has already been indicated, and will be further shown on a later page. Between these two sections—between the flora of Lykens coal No. 1, or of bed L of the type section, and the roof of the Buck Mountain coal, or base of the Lower Coal Measures in the anthracite fields—we have an interval of about 375 feet, within which occurs a very distinct, though perhaps gradual, change from the purely Pottsville plant life to the flora which, as we shall presently see, is distinctly that of the Lower Productive Coal Measures, as that group is recognized in the coal fields of the Northern States. The small collections obtained from the partings, beds M and N, in the upper plexus of massive conglomerates, which occurs within the top of the Pottsville formation as generally defined on a lithologic basis, apparently constitute fragments in evidence of this floral transition. For the present, when speaking of the type section and region, and until the subject is treated in a broader light, in connection with the Pottsville of the other portions of the Appalachian province, I shall continue to use the term "Upper Intermediate division" in referring to this portion of the Pottsville formation.

[1] Coal Flora, Vol. III, p. 726, pl. xciii, fig 9, 9a.

## CORRELATIONS.

It is not within the scope of this paper, whose primary purpose is to present a combined stratigraphic and paleontologic type section and definition of the Pottsville flora in the type region, to enter in detail into the subject of the correlation of the various terranes and groups in the Appalachian trough which have been or should be regarded as equivalent to the whole or a part of the Pottsville formation as developed in the Southern Anthracite field. Such a treatment of these extensive and complicated problems can be satisfactorily accomplished only in connection with the consideration of the detailed paleontologic evidence of all the terranes concerned in the comparisons.

In this report questions of contemporaneity will be confined to beds at isolated localities in the anthracite region, or to formations or groups in other regions whose floras are already more or less known, and which will be correlated only in a broad sense.

These cases will be divided into two groups: (1) Detached localities which are situated within the Southern Anthracite field itself and whose actual occurrence in the Pottsville formation in the typical region renders this correlation more important as well as certain, while at the same time adding to our knowledge of the distribution and range of the species in the Pottsville Basin. (2) Terranes or groups whose floras have been studied in other fields.

In discussing the beds of the first category greater confidence will be reposed in the occurrence, in a given bed, of the particular grouping or association of species which, in the beds or sections already discussed, appear to be characteristic of the several horizons, although the number of species from the locality in question may be small. On the other hand, in considering the relative age of formations geographically more remote, greater stress will be laid on the composition of the entire flora, and on the vertical range of its elements as well as the proportion of its identical species.

### PALEONTOLOGIC RELATIONS OF COALS DEVELOPED AT ISOLATED MINES IN THE SOUTHERN ANTHRACITE FIELD.

The principal detached localities, within the limits of the Southern Anthracite field, from which fossil plants have been obtained are those inscribed to the right of the columns devoted to the type section in the table of distribution. All of these have at some time been the scenes of coal exploitation or prospecting. In most cases the beds have been either tentatively or definitely, and, as will be further shown, sometimes erroneously, correlated with reference to the Lykens coals mined in the Lincoln-Lykens region. Several of these localities are but a few miles from the mining developments of the latter region, and nearly all are east of the mines. The correlation of these beds, so far as it can be made with precision or close approximation, has an important bearing on the geographic extent and economic condition of the several coals. With few exceptions the beds discussed are located on the mine maps, while generally they will be found approximately if not exactly identified in the cross-section and columnar-section sheets of the Atlas of the Southern Anthracite Field.

Proceeding along the upturned edge of the coal field in Sharp Mountain, west of Pottsville, we shall consider:

1. *Drifts in the Lower Lykens division in Swatara Gap.* Station 3, Pl. CLXXX. Two of the Pottsville coals have been drifted at a little above water level in this gap. The geographic positions of the openings are shown in mine sheet xvi, Atlas Southern Anthracite Field, Pt. III. The structure of this portion of the basin is illustrated in section 23, cross-section sheet xvi, Atlas Southern Anthracite Field, Pt. VI. From the upper of the coals, which is about 440 feet below the "Buck Mountain" (Twin) coal, as identified by the State survey in this gap, no fossil plants were obtained. The roof shales from the lower coal, mined to a slight extent on both sides of the gap, have furnished species as follows:

Mariopteris pottsvillea.
Neuropteris Pocahontas.
Neuropteris Pocahontas var. inæqualis.
Neuropteris Smithsii.
Whittleseya Campbelli.

These species, though few, are always common in the roof shales of Lykens coal No. 4, of which the first and fourth named are especially characteristic. The inference that this coal, which was mapped by the late State survey as Lykens coal No. 6, is more probably the Lykens coal No. 4, as indicated by the fossils, is further supported by the thickness of the rock (about 600 feet) between it and the Buck Mountain coal. That this coal is as old as Lykens coal No. 6 seems very improbable.

2. *Rausch Gap, Schuylkill County.* Station 4, Pl. CLXXX. At Rausch Gap, 1 mile west of Swatara Gap, two of the Lykens coals have been driven into for some distance. The district is shown on mine sheet xvi, Pt. III of the Atlas of the Southern Anthracite Field. The structure, consisting of a slightly overturned (70° dip) south limb of the deep Coal Measures basin, is similar to that at Swatara Gap. The section at this point, as compiled from the incomplete conglomerate exposures in the gap, is shown in Pl. CLXXXV, Fig. 1.

From the lower of the two coals mentioned, about 975 feet below the representative of the Buck Mountain coal, at the opening on the east side of the gap, there have been gathered the following:

Mariopteris eremopteroides?
Neuropteris Pocahontas var. inæqualis.
Lepidostrobus pennsylvanicus.
Trigonocarpum ampullæforme.

The other coal, about 70 feet higher, opened on the west side, has furnished fragments representing—

| | |
|---|---|
| Neuropteris Pocahontas var. pentias? | Trigonocarpum ampullæforme. |
| Neuropteris Pocahontas var. inæqualis. | Trigonocarpum Helenæ? |
| Calamites Roemeri. | |

Neither of these florulas is sufficiently complete to form the basis for definite correlation. Nevertheless, not only is it clear that both belong to the Lower Lykens division of the Pottsville formation, but it is also highly probable, from the absence of species characteristic of Lykens coal No. 4, as well as from the presence of *Mariopteris eremopteroides*, and, probably, of *Neuropteris Pocahontas* var. *pentias*, that we have here to do with Lykens coal No. 5, or a still lower coal. As already stated in the discussion of the floral characters of the horizon of Lykens coal No. 6, owing, perhaps, to the scantiness of material in the collections, no definite paleontologic distinctions can yet be drawn between it and coal No. 5. Taking into account the agreement of the florulas with Lykens coals Nos. 5 and 6, as well as the interval between the beds, it seems probable that the coal opened on the west side, which was mapped by the State geologists as Lykens coal No. 6, and correlated by them with the lower bed in the Swatara Gap, is really Lykens coal No. 5, in which case we may assume that the other, lower coal drifted on the east side of the gap represents the Lykens coal No. 6.

The interval between the coals, about 70 feet, as well as the general distances of the latter from the "Buck Mountain" coal, corresponds well with the stratigraphic relations of Lykens coals Nos. 5 and 6 at the Lincoln mine, about 3 miles to the northwest.

Though few in number, the plants in the Rausch Gap, which are distinctly characteristic of the Lower Lykens division, are especially interesting as compared with those from coals that have hitherto been supposed to be of the same age in Lorberry Gap, a mile to the west. The latter will later be especially treated in connection with the Dauphin Basin.

3. *Coal shaft northeast of the North Brookside slope.* At a distance of a little more than 200 yards northeast of the North Brookside slope on Lykens coal No. 2 (Station 7, Pl. CLXXX), a trial shaft was, several years since, sunk on a coal which has been supposed by the local engineers to be the Lykens coal No. 4, though the isolated position of the proving, on the north side of the Wiconisco Basin, opposite Good Spring,[1] left some doubt as to the accuracy of the correlation. The presence of *Mariopteris pottsvillea*, *Sphenopteris patentissima*, *Neuropteris Pocahontas* var. *inæqualis*, and *Neuropteris Smithsii* in the flora from the roof of the coal points clearly to its contemporaneity with the Lykens coal No. 4.

[1] Atlas Southern Anthracite Field, Pt. III, mine sheet xvii.

4. *The Eureka drifts.* Station 33, Pl. CLXXX. The two Eureka drifts or tunnels are, as shown in mine sheet xvi, Atlas Southern Anthracite Field, Pt. III, located on the slope of Broad Mountain, nearly 1½ miles northwest of Tremont. In both the mine map and the cross-section sheet, a portion of which is repeated, with a description, in the Summary Final Report[1] of the State geological survey, the upper Eureka tunnel is represented as starting from near the outcrop of the beds mined in the lower tunnel and traversing a thin relict of the Middle Creek anticline and a narrow basin beyond, so that, at a horizontal distance across the measures of about 375 feet from the coals mined by the lower drift or tunnel, the same coals were again reached and mined on nearly the same south dip (30°–38°). That this interpretation of the structure is almost certainly erroneous will at once be seen on referring to the fossils derived from the two long-abandoned mines.

The plants from the lower tunnel comprise the following species:

Mariopteris pygmæa.
Alethopteris Lacoei.
Callipteridium alleghaniense.
Neuropteris acutimontana?
Calamites approximatus.
Cardiocarpon Cuyahogæ.
Trigonocarpum ampullæforme.
Carpolithes orizæformis.
Whittleseya Campbelli.

This flora, as may be seen by an examination of the chart, is typical of the zone of Lykens coals Nos. 2 and 3, with which the beds in this drift have been correlated by the State geologists. The identity of No. 2 is indicated especially strongly by the presence of the three species first enumerated.

When, however, we examine the roof shales brought from the other (upper) tunnel we find—

Mariopteris pottsvillea.
Neuropteris Pocahontas var. inæqualis.
Neuropteris Smithsii.
Trigonocarpum Helenæ.

This flora, though small, is characteristic of the Lower Lykens division, to which all but *Trigonocarpum Helenæ* exclusively pertain. Furthermore, *Mariopteris pottsvillea* and *Neuropteris Smithsii* are, in the Southern Anthracite field, so far as known, exclusively in or near the horizon of coal No. 4, in which the variety *inæqualis* of *Neuropteris Pocahontas* is at home, while the *Trigonocarpum* is most common at, and essentially typical of, the same level. I have, therefore, little hesitation in referring the horizon of the shales, which are undoubtedly of Lower Lykens age, to the horizon of Lykens coal No. 4.

The shales from a prospect shaft a short distance to the east of the mouth of the upper drift have furnished—

Eremopteris lincolniana.
Eremopteris decipiens.
Alethopteris grandifolia var. obtusa.
Callipteridium alleghaniense.
Neuropteris acutomontana.
Neuropteris tennesseeana.

[1] Vol. III, Pt. I, p. 2120, pl. 384.

The species here associated are all, in general, typical of the zone of Lykens coals Nos. 2 and 3. If the horizon of the shales is on either side of this zone it is perhaps slightly higher. It appears most probable, however, that it is near the outcrop of the neighboring coals Nos. 2 and 3, in agreement with the mapping of the latter on mine sheet xvi of the Anthracite Atlas.

The correlation of the coal mined in the upper Eureka tunnel with Lykens coal No. 4 necessitates a very different structural interpretation of the beds. It strongly suggests a strict and regular parallelism in the same monocline of the coals in both drifts, in which case the interval between coals 3 and 4, about 250 feet, would be entirely in harmony with the corresponding interval, 245 feet, in the Lincoln mine, about 3 miles to the southwest. The Middle Creek anticline seems to have been either erroneously interpreted on the State mine maps as extending too far westward, or, as is quite possible, wrongly platted to the south of the coals in the upper tunnel instead of to the north. Neither the mine map nor the profile appears to contain evidence of importance in contradiction to either alternative.

5. *Valley View colliery, Kohlers Gap.* Station 15, Pl. CLXXX. At the gap in Bear Mountain, 2 miles north of Brookside, several of the Lykens coals have been located, one of the upper Lykens coals being now worked for local use at the Valley View colliery. The position of the developments and the stratigraphic relations of the beds in the north side of the Wiconisco Basin in this region are shown in mine sheet xviii, Atlas Southern Anthracite Field, Pt. III, and in section 26, cross-section sheet xix, Atlas, Pt. VI. The columnar section was described by H. D. Rogers.[1] The species from the heavy, sandy roof shales of the coal, which is mapped as Lykens coal No. 2 in the State mine maps, include among others—

Eremopteris decipiens.
Eremopteris Aldrichi.
Sphenophyllum bifurcatum.
Cordaites Phillipsi.
Cordaites grandifolius?
Cardiocarpon elongatum var. antholithoides.
Cardiocarpon obliquum.

The flora is unlike the floras found in the roof shales of the lower Lykens coals. The distribution of its species is essentially in the Upper Lykens division, and prevailingly in the zone of Lykens coals Nos. 2 and 3, though it appears to lack the species specially characteristic of either coal.

6. *Kemble drift.* Station 16, Pl. CLXXX. The Kemble drift is situated near the western spoon of the Peaked Mountain Basin, on the first of the large, shallow, synclinal, westward-projecting lobes of Broad Mountain. Its position and the general geologic environment are shown in mine sheet xiii, Atlas Southern Anthracite Field, Pt. II, and

[1] Geology of Pennsylvania, 1858, Vol. II, Pt. I, p. 190, Pl. VIII; Lykens coals correlated, by A. DW. Smith, in Summary Final Report, Second Geological Survey of Pennsylvania, Vol. III, Pt. I, p. 2130.

in section 23, cross-section sheet xviii, Atlas, Pt. VI, republished on a small scale, with a brief description, in the Summary Final Report of the late State geological survey.[1] From the rock dump at the mine, which has for many years been operated for country use, the following species were collected:

Mariopteris pottsvillea.
Sphenopteris Lutheriana.
Alethopteris grandifolia.
Neuropteris Pocahontas var. inæqualis.
Neuropteris gigantea var. clavata.
Calamites Roemeri.
Asterophyllites cf. rigidus.
Calamostachys cf. lanceolata.
Sphenophyllum tenue.
Whittleseya Lescuriana.
Whittleseya Campbelli.
Cardiocarpon disculum.
Cardiocarpon obliquum.
Trigonocarpum ampullæforme.
Trigonocarpum ampullæforme var. spectabile.
Trigonocarpum Helenæ.
Trigonocarpum Dawsonianum.
Carpolithes orizæformis.

By far the greater portion of the above names are familiar in the discussions of the floras of the Lower Lykens division. Nearly all the species occur in the shales of that group, while in *Mariopteris pottsvillea*, *Sphenopteris Lutheriana*, and *Sphenophyllum tenue* we seem to have species specially characteristic of Lykens coal No. 4, of which *Neuropteris Pocahontas* var. *inæqualis* and *Trigonocarpum Helenæ* also are largely typical. In fact, in view of the general agreement of the flora as a whole with that of Lykens coal No. 4, and of the presence of several of the species supposed to be typical of that horizon, we may consider the paleontologic evidence as pointing very strongly toward the assignment of the coal at the Kemble drift to an approximate level. As tending, however, to impair the strength of the evidence of these fossils, mention should be made of certain minor differences in the forms of the species. Thus the form of *Mariopteris pottsvillea* present at this mine is a rather lax type with somewhat dilated pinnules, while the form of *Neuropteris Pocahontas* var. *inæqualis* is both elongated and robust. Furthermore, *Alethopteris grandifolia*, *Whittleseya Lescuriana*, and *Cardiocarpon disculum* appear in other portions of the basin to be confined to the zone of Lykens coals Nos. 2 and 3, while *Asterophyllites* cf. *rigidus* is more at home in the upper division of the Pottsville formation. In view of the presence of these elements of generally later age, we may, I believe, safely conclude that the coal mined at the Kemble drift, which is mapped by the State geologists as Lykens No. 5,[2] can not be any older than Lykens coal No. 4. In the Summary Final Report,[3] the correlation of this coal, which is there described as "closely overlain" by coal No. 4, 4 feet thick, is expressed as uncertain. It seems possible that the lower coal is a new one occurring near Lykens coal No. 4, if it

[1] Vol. III, Pt. I, p. 2119, pl. 384.
[2] Atlas Southern Anthracite Field, Pt. II, mine sheet xiii.
[3] Vol. III, Pt. I, p. 2119.

is not, in fact, identical with the latter as mined in the Wiconisco Basin. That the Lykens coal No. 4 probably extends farther to the east on Broad Mountain will be suggested by the flora obtained at the old Altamont colliery No. 1.

7. *Altamont colliery No. 1, near Frackville.* Station 36, Pl. CLXXX. This colliery is situated on the south margin of the New Boston–Gordon Basin at the north border of Broad Mountain, on the northern limit of the Southern Anthracite fields. The areal geology is shown on mine sheet vii, Atlas Southern Anthracite Field, Pt. II. The structure is illustrated in section 17, cross-section sheet v, Atlas, Pt. V, the rock sequence being shown in columnar-section sheet ix, Part IV. As might be inferred from the columnar sections,[1] compiled from diamond-drill bore holes along the basin, the coal was found to be very "faulty," soon pinching too much for profitable mining.

The plants collected at this mine are:

Aneimites pottsvillensis.
Mariopteris pottsvillea.
Sphenopteris asplenioides.
Sphenopteris patentissima.
Alethopteris lonchitica?
Neuropteris Pocahontas var. inæqualis.
Neuropteris Smithsii (form).
Lepidodendron clypeatum.
Lepidostrobus cf. ornatus.
Lepidophyllum quinnimontanum.
Cordaites grandifolius?
Trigonocarpum ampullæforme.
Carpolithes orizæformis.

This flora, even more clearly than that from the Kemble drift, shows a composition distinctly characteristic of the Lower Lykens division, to which is added a small element of younger species. The two floras are of nearly the same general composition and significance, and represent, I believe, approximately, if not identically, the same stage. Therefore, notwithstanding the reported presence of a 4-foot coal, supposed to be Lykens coal No. 4, closely overlying the Kemble drift coal (but one coal appears in this portion of the diamond-drill borings in this vicinity on Broad Mountain), I am strongly disposed to regard the coal here as even slightly younger than, if not really contemporaneous with the Lykens coal No. 4.

It is probable that the same coal, which appears, as will next be shown, also to extend along the southern limb of the Western Middle field to the west of Frackville, is opened at the Gordon incline slope, Moser's drift,[2] and other points on the western lobes of Broad Mountain.

8. *Mount Pisgah, near Mauch Chunk.* Station 40, Pl. CLXXX. From a small drift recently driven on the north slope of Mount Pisgah, not far from the head of the incline of the Switchback Railway, the following species were collected:

Pecopteris serrulata.
Neuropteris sp. indet.
Lepidodendron clypeatum.
Cardiocarpon cornutum?
Cardiocarpon bicuspidatum var. ohioense.

[1] See also Summary Final Report, Vol. III, Pt. I, p. 2080, pl. 367.
[2] Atlas Southern Anthracite Field, Pt. II, mine sheet xiii.

Of these species, *Pecopteris serrulata* and the two Cardiocarpa are, in general, characteristic of and almost exclusively confined to the Upper Lykens division in the Southern Anthracite field and to the upper portion of the Pottsville formation in the bituminous basins. *Lepidodendron clypeatum*, also, is not generally found in beds below the same division except in the region under consideration. Its typical phase is developed near the base of the Coal Measures. The remaining species of the florula, although represented by material too fragmentary for satisfactory identification, appears to be allied to one of the forms of *Neuropteris* in the upper divisions of the Pottsville, rather than with the small, Callipteridioid, narrow-pinnuled types of the Lower Lykens division. Thus, from the composition and distribution of the flora, it seems probable, notwithstanding the small number of species, that the coal, which is here over 5 feet in thickness, is situated in the Upper Lykens division of the formation.

The geology of this portion of the field is shown on mine sheet i, Atlas Southern Anthracite Field, Pt. I. The structure of the east end of the region is illustrated in section 1, cross-section sheet i of the same atlas. The columnar section of the upper portion of the formation as measured in the Hacklebarney tunnel, about 3 miles distant, shown on columnar-section sheet ii, will, perhaps, serve in a general way to indicate the sequence of terranes at the top of Mount Pisgah, although the coal in question is not identified. If this coal is referable to the Upper Lykens division of the formation, as the fossils seems to indicate, we may conclude either that the Lower Lykens division at the eastern point of the field is much thinner than elsewhere or that the basin which, as mapped by the State survey, extends nearly to the level of the Central Railroad of New Jersey along the Lehigh River is deeper near its extremity than has generally been supposed.

### HORIZON OF THE LOWER LYKENS VALLEY COAL IN THE WESTERN MIDDLE ANTHRACITE FIELD BETWEEN FRACKVILLE AND SHAMOKIN.

About 1 mile east of the Altamont No. 1 colliery the Pottsville formation bridges the axis which forms the line of separation between the Southern Anthracite field and the Western Middle Anthracite field, and plunges into the steep Mahanoy Basin east of Mahanoy Plane.

A. For a long distance to the west of Frackville no coal of the Pottsville formation has been worked to any extent, but at the old Gordon (Franklin) mine, in the Western Middle Anthracite field, about 4 miles northwest of the old slope at the Gordon plane, which is within the north border of the Southern field, a coal designated on the mine sheets of the field[1] and in the Summary Final Report of the State

[1]Atlas Western Middle Anthracite Field, Pt. II, mine sheet v; columnar-section sheet ii; Pt. III, cross-section sheets v, vi, section 12.

survey[1] the Lower Lykens Valley coal was formerly worked to a considerable extent. From the rock dump at this mine were obtained the following species, which, though few, appear in the Southern Anthracite field to be either characteristic of or most common in the horizon of Lykens coal No. 4:

| | |
|---|---|
| Aneimites pottsvillensis. | Lepidodendron clypeatum. |
| Neuropteris Pocahontas. | Lepidostrobus pennsylvanicus. |
| Neuropteris Smithsii. | Trigonocarpum Helenæ. |

B. At the abandoned Helphenstein colliery,[2] 2 miles south of Locust Gap, there were collected a few species, as follows:

| | |
|---|---|
| Neuropteris Pocahontas. | Sigillaria sp. cf. dentata. |
| Neuropteris Pocahontas var. inæqualis. | Trigonocarpum ampullæforme. |
| Lepidostrobus pennsylvanicus. | |

C. About 2 miles farther west, along the southern border of the same field, a coal mapped as the same as that wrought at the Gordon and Helphenstein collieries was formerly worked rather extensively by Messrs. Douty and Baumgartner.[3] The species collected from the rock dump are—

| | |
|---|---|
| Eremopteris sp. | Neuropteris Smithsii. |
| Mariopteris pottsvillea. | Trigonocarpum ampullæforme. |
| Sphenopteris asplenioides. | Trigonocarpum Helenæ. |
| Neuropteris Pocahontas var. inæqualis. | Carpolithes orizæformis. |

D. Along the ravine extending up the mountain side above the site of the old Enterprise colliery, a coal supposed to be the same Lower Lykens Valley coal was formerly worked at the Mount Franklin and the Margie Franklin collieries,[4] between which lies a narrow anticline.

From the mine last mentioned the specimens collected include—

| | |
|---|---|
| Eremopteris sp. | Neuropteris Pocahontas var. inæqualis. |
| Mariopteris pottsvillea. | Neuropteris Smithsii. |
| Mariopteris cf. tennesseeana. | Lepidodenron alabamense. |
| Sphenopteris asplenioides. | Whittleseya Campbelli. |
| Sphenopteris microcarpa. | Trigonocarpum ampullæforme. |
| Alethopteris protaquilina. | Carpolithes orizæformis. |

A review of the species collected from these mines along the southern border of the Western Middle Anthracite field shows that we have to do with the same flora as that present at Altamont colliery No. 1, within the Southern Anthracite field. In all the collections we find representatives of *Mariopteris pottsvillea*, *Neuropteris Pocahontas* var. *inæqualis*, *Neuropteris Smithsii*, and *Lepidodendron alabamense*, characteristic in the Southern field of the zone of Lykens coal No. 4. The

[1] Vol. III, Pt. I, pp. 2058–2060.
[2] Atlas Western Middle Anthracite Field Pt. II, mine sheet v.
[3] Atlas Western Middle Anthracite Field Pt. II, mine sheet vi.
[4] Atlas Western Middle Anthracite Field, Pt. II, mine sheet vi; Pt. III, cross-section sheets v, vi, section 14.

evidence offered by these species is further strengthened by the presence in the combined flora of the rarer species *Aneimites pottsvillensis* and *Alethopteris protaquilina*, also typical of that level, as well as by *Sphenopteris asplenioides* and *Trigonocarpum Helenæ*, usually found associated with the former in the larger collections. In short, the testimony of the combined flora is so strongly indicative of the contemporaneity of the Lower Lykens Valley coal in this portion of the Western Middle field with Lykens coal No. 4 of the Southern field as to leave little doubt of its approximate synchronism or correlation therewith. The similarity in the stratigraphic position of the coal worked in the Shamokin Gap and at several other points in the western portion of the Western Middle field makes it seem probable that most of the small mines in the Pottsville formation in that region are developed in this coal. No fossils are at hand from the openings in this field on the "upper Lykens Valley" coal, which appears to be thin and unstable.

If the correlations more or less definitely proposed above are accurate, the Lykens coal No. 4 has a relatively wide distribution, not only in the Southern Anthracite field, but also in the Western Middle Anthracite field, and has the greatest extent in workable thickness of all the Lykens coals, though its thickness is generally less than that attained by Lykens coal No. 5 in the Lincoln-Lykens mining district.

## ZONES OF THE POTTSVILLE FLORAS IN OTHER REGIONS OF THE APPALACHIAN PROVINCE.

In discussing the distribution of the floras of the several divisions of the Pottsville formation in other basins of the Appalachian province, I shall assume that the dispersion and migration of the species along the shore of the interior Carboniferous sea were, under the favoring conditions of a continuous, broad, base-level coastal-plain shore and currents both strong and varying, so uniform and so rapid as compared with the geologic time required for the sedimentation of the terranes that the similar associations of identical species occurring at different points along the coast are to be regarded as approximately contemporaneous. In other words, when regarding the succession of terranes along the eastern border of the great Appalachian basin, in which we have in different districts the same regular succession of floras, we are justified in considering that beds, along a continuous and uniform coast, containing the same flora are, geologically speaking, synchronous, rather than that we have to do with homotaxy without contemporaneity.

As already remarked, in correlating beds in regions more distant from the locality of the type section, great weight is attached to the composition of the floras and the vertical range of their elements, as well as the proportion of identical species in other basins. Referring to the paleontologic features of the different coal horizons of the Pottsville formation, as outlined in an earlier part of this report (p. 773), it will be recalled that on the basis of the vertical distribution of the contained floras, so far as they have been brought to light, the formation was divided primarily into (1) a Lower Lykens division, including the roof shales of No. 4 in the mining region and bed D of the type section, and extending downward to the red shale; and (2) an Upper Lykens division, including Lykens coals Nos. 3 and 2 and the roof of Lykens coal No. 1, or beds H to L, inclusive, in the type section. In beds E and F (Pl. CLXXXI) of the type section, comprising what I have designated the Lower Intermediate division, there appears to be some intermingling of the Lower and Upper Lykens species, while in beds about 225 feet below the conventional base of the Lower Coal Measures, or perhaps nearly 100 feet below the paleontologic base, we find another flora of somewhat mixed composition, suggesting the term "Upper Intermediate division." The two intermediate divisions are thin as compared with the whole formation.

Of the two zones in the Lower Lykens division, the lower, including the horizon of Lykens coal No. 5, is characterized by a relatively simple flora. This, as indicated in the discussion of the floras of the several coals, consists principally of *Neuropteris Pocahontas*, which is always present and overwhelmingly abundant, its variety *pentias* being peculiar to this zone. It is also marked by the absence of the forms characteristic of and confined to the upper zone of the division, as the latter is represented in the roof shale of coal No. 4. The plants below coal No. 5, in the basal portion of the formation, are not sufficiently known for the discovery of any special zonal types. No attempt will therefore be made to determine in other regions any equivalents of this basal portion of the section, although certain inferences are unavoidable.

The continued study of the Paleozoic floras along the eastern margin of the Appalachian trough fully confirms the conclusion I stated some years ago,[1] that it is only in the lower portions of the very thick sections of the Pottsville formation in this province that the oldest floras are to be found, and that in general the very thin sections (e. g., along the northern and northwestern margins of the trough) correspond only to the upper portions of the sections of great thickness on the eastern and southeastern shores of the basin. The correlations suggested below will incidentally serve to illustrate this fact. However, since in this report, which is but preliminary to a monograph of the Pottsville flora of the Appalachian province, the correlative significance of the floras will be treated in briefest possible form, without enumeration of the characteristic species or the full presentation of the paleontologic,

[1] Bull. Geol. Soc. America, Vol. VI, 1895, pp. 319-320.

descriptive, and illustrative data, questions of equivalence or contemporaneity will be restricted to a few of the most important and best-known floras. In the later publication it is my intention to discuss the character, range, and sequence of the floras somewhat in detail, and to suggest such correlations of the numerous terranes of the formations, known often under different names in different regions and States, as are indicated by the very voluminous collections in hand, covering both the vertical range and the greater part of the areal extent of the formation in the Appalachian province.

### CLARK FORMATION.

In passing from the Southern Anthracite field southward by way of the thinner developments of the Pottsville formation in the Broad Top and Potomac regions, we do not, so far as is at present known, meet with so low a phytiferous horizon as that of Lykens coal No. 5 until we approach the basin of the New River in south-central West Virginia, where within the rapidly deepening sections the Pocahontas and Clark formations appear in the basal portion of the Pottsville formation. Paleontologically, one of the most interesting of the floral zones in this region is that represented by the plants in the roof shales of the Pocahontas coal (360 feet above the Mauch Chunk formation) in the Great Flat Top region of Virginia and West Virginia. In these shales, which comprise the basal portion of the Clark formation, we find a flora containing the greater number of the species found over Lykens coal No. 5 and presenting the precise facies of the latter, including the invariably and almost exclusively abundant *Neuropteris Pocahontas*. The preponderance of identical species, the composition of the flora, and the relations of the latter to the succeeding floras render it certain that the horizon of the flora of Lykens coal No. 5 is, in the great Flat Top region, not far from the Pocahontas coal. The question whether its more precise horizon is above or below the latter coal will be discussed in the monograph, when all the evidence is presented. It may, however, be here stated that it can not be far above the Pocahontas coal, nor is it likely to be over 200 feet below it. The zone of this flora, which has been identified through the Tazewell, Pocahontas, Oceana, and Raleigh quadrangles, might appropriately be designated the *Neuropteris Pocahontas* zone, though in the Virginia region, as in the Southern Anthracite field, varieties of this species are found in higher terranes of the Pottsville formation. This zone includes the basal portions of the Welch formation in the Tazewell quadrangle;[1] the Clark formation in the Pocahontas[2] and Oceana quadrangles; and a portion, above the middle, of a unit which Mr. M. R. Campbell in the manuscript folio relating to the Raleigh quadrangle has named the Thurmond formation.

[1] Geologic Atlas of the United States, folio 44.
[2] Op. cit., folio 26.

QUINNIMONT FORMATION.

The upper portion of the Clark formation, which is about 375 feet thick in the Pocahontas quadrangle, is marked by the enrichment of both the Sphenopterid and Neuropterid groups in the flora. The variety *inæqualis* of *Neuropteris Pocahontas* survives, and in passing upward into the base of the Quinnimont formation, or toward the middle of the Welch formation, the partial contemporary of the Quinnimont, we find it associated with the identical forms of *Aneimites pottsvillensis*, *Mariopteris pottsvillea*, *Sphenopteris patentissima*, *Neuropteris Smithsii*, *Sphenophyllum tenue*, *Lepidodendron alabamense*, and *Trigonocarpum Helenæ*, so common in and characteristic of the horizon of the roof of Lykens coal No. 4 in the Southern Anthracite field. In fact, the flora becomes practically identical with that in the anthracite region. To this zone, for which I have already suggested the term *Mariopteris pottsvillea*, on account of the common occurrence and very easy recognition of the latter therein, belong the fossils from the Dade coal in the Ringgold, Stevenson, and Chattanooga quadrangles[1] and the lower coal mined at Dayton in the Pikeville quadrangle,[2] all in the Tennessee-Alabama region. In fact, to the *Mariopteris pottsvillea* zone, giving the latter a broad interpretation so as to include a series of closely connected modifications of the types, belongs the entire succeeding Quinnimont formation, 300 feet thick in the type region represented in the Pocahontas quadrangle, and present in the Raleigh and Kanawha Falls[3] quadrangles; the upper portion of the Welch formation in the Tazewell quadrangle; a part of the Lookout sandstone, including the vicinity of the Dade coal, in the Chattanooga, Stevenson, Ringgold, Pikeville, and Kingston[4] quadrangles in the southern Appalachian region; and probably a portion at least of the Lee formation in the Estillville, Briceville, Wartburg, and, perhaps, also in the London quadrangles[5] in the northern Tennessee-Kentucky region. The flora of the Hindustan whetstone beds of Orange County, Indiana, is also referable to this zone, and indicates the contemporaneity of those beds with at least some portion of the Quinnimont formation.

The extent of the zones and the more definite relations and equivalents of the formations in the several quadrangles will be discussed in the later, monographic, treatment of the floras.

[1] Geologic Atlas of the United States, folios 2, 19, and 6, respectively.
[2] Op. cit, folio 21.
[3] Op. cit. These folios have not yet been published or numbered.
[4] Op. cit., folio 4.
[5] Op. cit., folios 12, 33, 40, and 47.

## SEWELL FORMATION.

The next higher general flora of marked characters and distinction in either the bituminous or the anthracite regions is that which I have indicated as characteristic of the proximate horizons of coals Nos. 3 and 2 in the Southern Anthracite field. The zone of this flora is characterized by the development of both the Rhacopteroid and the broad-lobed types of Eremopteris; by small, round, and inflated-pinnuled species of Mariopteris; by triangular Alethopterids; by small, palmate-lobed, and Pecopteroid Sphenopterids; by narrow Alethopteroid forms of Neuropteris, such as *N. Schlehani;* by *Megalopteris* species and the Megalopteroid types; by the broad-leaved *Whittleseyæ*, and by the introduction of the dentate Pecopterids, as well as a great diversity of gymnospermous fruits. The more explicitly distinctive species of the zone of Lykens coals Nos. 3 and 2—*Eremopteris Cheathami* and *E. decipiens*, *Mariopteris pygmæa* of the *M. inflata* group and *M. tennesseeana*, *Sphenopteris pilosa* and *S. palmatiloba*, *Alethopteris Evansii*, the Callipteridioid types, *Neuropteris acutimontana* and *N. tennesseeana*, *Sphenophyllum cuneifolium* (*saxifragæfolium* form), the Whittleseyas, and many of the fruits—are present in identical forms and associations in the shales over the Sewanee and Sewell coals. In fact, the elements of the flora from Lykens coal No. 3 are so preponderantly identical with those in the roof of the Sewanee coal in Tennessee and the Sewell coal in southern West Virginia that these coals can only be regarded as practically contemporaneous.[1] The paleontologic evidence for the identification of the horizon of the Sewell-Sewanee coals presents the most complete and convincing as well as the most interesting case that has yet come within my observation.

*Mariopteris pygmæa* and the identical forms of *Alethopteris Lacoei* and *Asterophyllites arkansanus*, which are especially typical of the roof of Lykens coal No. 2 in the Southern Anthracite field, have generally a somewhat higher occurrence and range in the bituminous fields.

The zone of the plants of Lykens coals Nos. 2 and 3, which, in recognition of the long-known flora of the Sewanee coal, at Sewanee and Tracy City, in Tennessee, I have in a previous paper[2] called the Sewanee flora, may be termed the Sewanee zone. The distinctly Sewanee flora is present above the Sewanee coal in the lower part of the Walden formation in the Sewanee,[3] Kingston, Pikeville, and Chattanooga quadrangles of the Tennessee-Alabama region, and over the Sewell coal in the Raleigh, Kanawha Falls, and Hinton quadrangles in West Virginia.

[1] The contemporaneity of the Sewell coal and the Sewanee coal, as well as the similarity of their stratigraphic relations in the Tennessee and Virginia sections, was pointed out in the description of the Pottsville section along New River, West Virginia: Bull. Geol. Soc. America, Vol. VI, p. 316.

[2] Loc. cit.

[3] Geologic Atlas of the United States, folio 8.

Very nearly contemporaneous with the same flora is that in the roof of the Sharon coal in northwestern Pennsylvania and northern Ohio, partially described by Dr. Newberry in 1872.[1] The "coal-bearing shales" of Washington County, Arkansas, whose species, ranging usually a little higher than those of the Sewanee coal, were described by Professor Lesquereux in his great work on the Coal Flora,[2] can not be of very much later date than the Sewanee coal, and are undoubtedly representative of the Sewell formation.

The lower portions of (*a*) the Sewell formation in the Pocahontas, Raleigh, and Kanawha Falls quadrangles, of (*b*) the Dismal formation in the Tazewell quadrangle, and of (*c*) the Norton formation in the Estillville and Bristol quadrangles, are included in the zone of the Sewanee flora, to which in its broader sense are also referable certain plant-bearing beds of the Briceville formation in the Briceville and Wartburg quadrangles,[3] in Tennessee. It also appears probable that large parts, perhaps the greater portions, of the Pickens and Blackwater formations in the Buckhannon and Piedmont quadrangles,[4] respectively, in West Virginia, are referable to the Sewell formation and are included within the Sewanee zone. However, the question of the existence of the lower horizons of the Pottsville in the relatively thinner sections in the Potomac region will receive particular attention in the later and more complete report.

### LOOKOUT FORMATION.

In those earlier published folios of the Geologic Atlas of the United States that relate to the Carboniferous formations of the southern Appalachian region the coal-bearing terranes included in the quadrangles are grouped in but two formations, the Lookout (lower) and the Walden (upper). The Lookout extends from the Bangor limestone (Mississippian) to the top of the great Sewanee conglomerate of Safford.[5] The oldest plants I have yet seen from this formation on the east side of the coal field, where it is thickest, are closely related to those from the roof of the Dade coal in northwestern Georgia, and are clearly referable to the *Mariopteris pottsvillea* zone. Whether the basal terranes of the formation in this region are as old as or older than the Pocahontas coal or the Lykens coal No. 5 is still uncertain. It is, however, highly probable that in the region included in the Kingston, Pikeville, Chattanooga, and Ringgold quadrangles the lowest beds of the Lookout are not older than the zone of the Lykens coal No. 5.

[1] Rept. Geol. Survey Ohio, 1873, Vol. I, Pt. II.
[2] Coal Flora, Second Geol. Survey of Pennsylvania, Report P, 3 vols. and atlas, Harrisburg, 1879-1884.
[3] Geologic Atlas of the United States, folios 33 and 40.
[4] Idem, folios 34 and 28.
[5] Geology of Tennessee, 1869, p. 366.

The study of the higher floras of the formation, including that of the Dade coal above referred to in these quadrangles, shows the higher shales of the Lookout, up to, or nearly to, the base of the Sewanee conglomerate, to be referable to the *Mariopteris pottsvillea* zone in its broad sense, and to the Quinnimont formation in the Pocahontas quadrangle. The fossils at the base of the Sewanee conglomerate in Tennessee, and of the Raleigh sandstone, about 100 feet in thickness, in southern West Virginia, show a slight mingling of Sewanee zone species, the flora being comparable to that of beds E and F of the Lower Intermediate division of the Pottsville Gap section. The Sewanee-Sewell or Upper Lykens flora appears immediately above the great conglomerates which comprise the Raleigh sandstone in the Pocahontas, Raleigh, and Kanawha Falls quadrangles in West Virginia, and which complete the Lookout sandstone in the Chattanooga, Pikeville, McMinnville,[1] Kingston, and Sewanee quadrangles in Tennessee and Alabama. The Lookout sandstone of Hayes seems, therefore, to essentially represent both the Lower Lykens division and the Lower Intermediate division of the type section in Pennsylvania, although I am slightly disposed to doubt the presence in the Lookout of beds as old as the lowest at Pottsville. The Sewanee conglomerate at the top of the Lookout formation of Tennessee and its contemporary, the Raleigh sandstone in West Virginia, appear to stand in the same relative position paleontologically to the Lower Lykens division as does the Lower Intermediate division in the Southern Anthracite field, and each similarly seems to fill the time break between the *Mariopteris pottsvillea* zone in its broad (Quinnimont) sense and the Sewanee (Sewell-Lykens coal No. 3) zone.

FAYETTE SANDSTONE.

The characteristic species so well marked in the lower portion of the Sewanee zone become modified in the later portion, while at the same time new forms are introduced, so that in the southern Appalachian region no sharp line will perhaps be drawn between the more restricted zone of the flora and that of the Lykens coal No. 1 or bed L of the section at Pottsville, into which the species in the upper portion of the Sewanee formation, about 400 feet thick in the Kanawha Falls quadrangle, gradually merge. In this quadrangle the horizon of coal No. 1 is certainly close beneath, if not actually within, the Fayette formation, a group of massive sandstones and shales which succeeds the Sewell formation in the vicinity of New River, and completes the Pottsville, as the latter naturally would be and has been defined on the lithologic basis. A flora possibly contemporaneous with that of Lykens coal No. 1 or bed L seems to be

[1] Geologic Atlas of the United States, folio 22.

present near the Gladeville sandstones in the Estillville quadrangle,[1] Virginia-Tennessee region; also in the Breathitt formation in the London quadrangle, Kentucky; and in the Fayette sandstone itself near Zela, in the Nicholas quadrangle in West Virginia. The Mercer coals of northwestern Pennsylvania are possibly near the same horizon.

### CAMPBELL LEDGE, NORTHERN ANTHRACITE FIELD.

The dark plant-bearing shales which lie within a few feet[2] of the supposed representative of the Mauch Chunk (No. XI) in the very thin section (56 feet, more or less) of the Pottsville formation at Campbell Ledge, near Pittston, Pennsylvania, contain a large flora,[3] which can not be older than Lykens coal No. 1 or bed L, and which has so much in common with beds M and N (Upper Intermediate division) of the type section at Pottsville as to strongly argue for a reference to the same time interval.

The question of the equivalence in the southern and central Appalachian regions of the Upper Intermediate division, including the uppermost 300 feet of the type section, involves a both complicated and difficult problem, which, on account of the great expansion of the terranes representing this period as we pass from Sutton in central West Virginia southward, can not be appropriately discussed without a careful presentation of the accompanying paleontologic evidence. Omitting all the details relating to this question, which will receive special consideration in a later paper,[4] it may suffice to say that in the southern Virginia region the time interval, which is represented by 250 to 300 feet of beds, consisting chiefly of the upper plexus of conglomerates, between Lykens coal No. 1 or bed L and the Twin coal in the Southern Anthracite field, appears, as indicated by the fossil plants, to measure over 800 feet of strata on the Kanawha River. It includes the lower half or "group" of the Kanawha formation. Within the lower portion of this interval, which is less argillaceous, there occurs a more gradual transition from the flora at the top of the Sewanee zone, or that of Lykens coal No. 1, to the typical flora of the Lower Kanawha group. The flora first recognized in the Brookville and Clarion horizons of the Northern Bituminous basins, or coal A at Tamaqua and the Twin seam in the Southern Anthracite field, does not appear in the Kanawha region until later Kanawha time. In the lower portion of the Kanawha formation the flora agrees exactly in characters with that of the Lower Coal Measures of the British coal fields, or the greater portion of the Westphalian in continental Europe.[5] In this

[1] Geologic Atlas of the United States, folio 12.
[2] I. C. White, Rept. Geol. Survey of Pennsylvania, G7, p. 143.
[3] Lesquereux, Coal Flora, Vol. III, pp. 855–856.
[4] Bull. Geol. Soc. America, Vol. XI, pp. 145–178.
[5] Loc. cit., p. 167.

connection it should be recollected that the flora of the lower portion of our Lower Coal Measures (Allegheny series), as, for example, at Mazon Creek, Illinois, or Henry County, Missouri, is generally recognized as referable to the Middle Coal Measures, or as near the base of the Upper Coal Measures of Europe.

## RELATIVE HORIZONS OF THE BASAL BEDS OF THE THIN SECTIONS AS COMPARED TO THE THICK EASTERN SECTIONS.

So far as the examination of the phytiferous beds in the Pottsville formation has extended, it appears that only the lowest beds of the formation in the Virginia region, where the formation attains a thickness of perhaps 2,500 feet, contain plants of greater antiquity than those of the lower beds in the Lower Lykens division of the type section. It is even possible that the oldest plants in the basal portion of the formation of Virginia are not of earlier date than those in the topmost red shale at the Pottsville and Westwood gaps. Further study is needed to determine this question. The oldest plants that have yet been found in the Lookout sandstone seem to be of later age than the Pocahontas coal, and to be referable to the *Mariopteris pottsvillea* zone. Beds possibly referable to the same zone appear to lie close to the red shale in the Pickens formation, in the Buckhannon quadrangle, in central West Virginia; and the lowest beds of the Pottsville, which is 270 feet in thickness,[1] at Hanging Rock, near Ironton, on the Ohio River, at the western margin of the Appalachian trough, are perhaps referable to the uppermost part of the same zone. North of these points the sections of the Pottsville formation seldom exceed 400 feet, and throughout the bituminous sections of Pennsylvania they are in most cases less than 300 feet in thickness, while in some cases they are less than 150 feet. In none of these sections have I yet found plants older than the upper beds of the Quinnimont formation. No phytiferous beds so low as the Lykens coal No. 4, in the *Mariopteris pottsvillea* zone, have yet come to light. On the other hand, the flora of the Sharon coal, which, along the northern margin of the Appalachian trough, is separated from the marine Lower Carboniferous by a conglomerate, and which at a few points seems to rest directly upon the Shenango shales, is, as has already been pointed out, accompanied by the Sewanee flora. The base of the Pottsville at Bernice, Sullivan County, Pennsylvania, where the formation is prob ably less than 100 feet thick, is apparently higher than the Sharon coal, while the lowest coal, within 20 feet of the red shale in the Mehoopany Basin in Wyoming County, Pennsylvania, is clearly within the Sewanee zone.

The measurements of the Pottsville at Campbell Ledge, in the

[1] I. C. White, Bull. U. S. Geol. Survey No. 65, p. 193.

Susquehanna Gap through the north wall of the Northern Anthracite field, seem to vary according to the horizon adopted as the upper limit of the formation at that point. But whatever the thickness of the formation, it is certain that the plant-bearing shales beneath the main conglomerate and within 20 feet of the supposed representative of the Mauch Chunk formation are younger than the zone of Lykens coals Nos. 3 and 2, and it is very probable that they are higher than Lykens coal No. 1 or bed L in the type section. In short, although these sections vary greatly by the expansion of the different divisions, there can be no doubt that, generally speaking, the thin sections of the Pottsville formation in the bituminous basins in Pennsylvania and Ohio, or along the western margin of the Appalachian trough in Tennessee and Kentucky, contain only the younger beds of the formation, the oldest beds of which appear to be present only in the deepest sections along the eastern margin of the trough in the Virginia region and in the Southern Anthracite field.[1]

The existence of the older floras in the lower portions only of the thick sections, or, in other words, the equivalence of the very thin sections to the upper portions only of the very thick sections, suggests alternative hypotheses in explanation of the conditions attending the sedimentation of the Pottsville formation. First, the lower portions of the very thick sections may be regarded as laid down in Mauch Chunk time and contemporaneous with the latest red shale or other Lower Carboniferous sediments in other regions, in which case the basal boundary of the Pottsville in those regions may be diagonal in time without unconformity. The second hypothesis assumes a case of overlap, by which the upper and relatively thinner northern and western deposits were spread beyond the limits of the deeper eastern basins in which the thicker deposits were accumulated. In the latter case the unconformity may or may not extend throughout the field.

At present we have no conclusive proof that the oldest Pottsville beds are synchronous with any portion of the marine Lower Carboniferous. This does not of itself, however, necessarily preclude the possibility, or even the probability, of a partial contemporaneity, since the conditions governing the deposition of the typical Pottsville sediments were those directly or indirectly causing the expulsion from the same region of the Lower Carboniferous faunas and promoting the introduction of the earliest Coal Measures invertebrate types. Moreover, the upper red shales of the Mauch Chunk formation in the anthracite regions are almost entirely destitute of marine molluscan fossils. Evidence in proof of such contemporaneity

[1] The lower horizons of the extraordinarily thick section of the Pottsville formation in Alabama have not been paleontologically studied. It is not, therefore, known whether the oldest floras of the Flat Top coal field or of the Southern Anthracite field are present in the lower part of the section in Alabama.

may be sought in the Mississippian regions, whence the slight indications at present in hand have been derived.

Distinct proof of unconformity between the Pottsville and the Mauch Chunk formations is almost unknown in the anthracite fields, except beneath the thin sections of the Pottsville in the Northern Anthracite coal field. Still, such an unconformity has generally been supposed to exist throughout the greater part of the extent of the formation. It must be admitted that the existence of the thick transition series throughout the central portion of the Southern Anthracite field is opposed to such a lack of continuity of the Mauch Chunk and the Pottsville, notwithstanding the large number of local irregularities, such as those indicated in the section, Pl. CLXXXII, all of which may be explained by shifting current action. My own observation in the Northern field convinces me of the discordant relations of the two formations, the lower of which, though very well developed on the eastern border, appears to be almost extinguished beneath Campbell Ledge, on the western margin, less than 5 miles distant. The discordance is frequently observable beneath the thin developments of the Pottsville formation in the more northern and western regions of the Appalachian province. Nevertheless, I hesitate to agree with those geologists who believe the unconformity to exist even beneath the thickest sections of the Pottsville. Such a conclusion seems to be dependent on the still prevalent hypothesis of the absolute time equivalence of the entire Pottsville in all sections and all regions.

For my own part I am slightly inclined to regard the lowest beds of the formation in the deepest sections, such as that in the Flat Top region in Virginia and West Virginia, in which the transition series is not conglomeratic, or that in the Southern Anthracite field, which is conspicuously conglomeratic, as continuous with the Mauch Chunk formation, with whose latest typical sediments in other regions the oldest Pottsville beds may be contemporaneous. From such a beginning the formation expanded to an enormous thickness of materials, supplied, for the most part, through the transportative agency of destructive wave and current action directed against not very distant coastal plain detrital accumulations, under the favoring conditions of a general, though frequently interrupted, submergence. Brief periods of stability or even slight reactive uplifts, in conjunction with bar-forming currents, may have assisted in producing lagoons, coastal swamps, or other conditions suited either to the accumulation of vegetable matter or to the deposition of thin beds of argillaceous material, while at the same time affording opportunities for the further extension of the frontal submarine Pottsville shelf. The gradual, though intermittent, subsidence of the bottom, which made possible the continued piling up of Pottsville strata over broad areas in these regions, while for a time marginal portions of the Mauch Chunk were yet subject to erosion in other areas, eventually resulted in the submergence of those portions of the coast where thinner Pottsville sections are now found, each of which contains its own paleontologic records marking the time of the submergence of that locality.

The relatively later ages of the lower beds of the Pottsville sections which we meet in approaching the northern and western margins of the Appalachian coal fields constitute conclusive evidence of the westward and northward transgression of the Carboniferous sea during Pottsville time.

## UPPER LIMIT OF THE POTTSVILLE FORMATION.

### THE FLORA AT THE BASE OF THE LOWER COAL MEASURES IN THE SOUTHERN ANTHRACITE FIELD.

As may readily be inferred from an examination of the columnar sections of the Coal Measures of the Southern Anthracite field, as developed, for example, in the Tremont-Lincoln district,[1] the alternation of conglomerates is so continuous from the typical "Seral conglomerate" into the Lower Coal Measures that it was found in general to be "impossible to assign a well-defined permanent horizon of separation" between the two formations. Not only are the sandstones exceedingly variable as to their thickness and limits, but their uncertain and often indefinite exposures poorly serve the needs of precise delimitation, such as is required for a detailed instrumental mineral survey. Accordingly, for reasons of expediency and necessity, the boundary was arbitrarily fixed by Rogers "at the bottom of the first or lowest considerable coal seam."[2] Under the more refined and exact methods of the succeeding geologists, who have made thorough examination of the region by the aid of abundant prospecting, the position of the lowest workable coal, or its supposed equivalent, has been locally ascertained throughout the greater portion of the field, and the correlations have been extended also to the Middle Anthracite fields.[3]

The practicability of this method is largely due to the occurrence of a coal generally of workable thickness over the greater portion of the fields not far above the great plexus of conglomerate plates at the top of the series. However, as may be supposed, where several thin coals are present in a given section between the lowest workable coal and the main conglomerates of the Pottsville, or where of several thin coals none is workable, the boundary is uncertain. In general, and especially in the central portion of the field, including the vicinity of the type section, it is possible to trace the Twin coal, adopted by

[1] Atlas Southern Anthracite Field, Pt. IVB, columnar-section sheet x; also Pt. II, columnar-section sheet vi; and Pt. I, columnar-section sheet i.
[2] Geol. Pennsylvania, Vol. II, Pt. I, 1858, p. 17.
[3] Ann. Rept. Geol. Survey Pennsylvania, 1886, Pt. III, p. 932; Summary Final Report, Vol. III, Pt. I, pp. 1854, 1920.

Rogers, for a long distance. It is probable that the errors, which undoubtedly exist, in the identification of this horizon in the more distant portions of the field fall within a vertical distance of 100 feet, except in the Dauphin Basin, which will be specially considered in a later section. As to the correlation of the A coal at Locust Gap, north of Tamaqua, there is still a difference of opinion; and again, in the western portion of the Wiconisco Basin, the place of the Buck Mountain coal is a matter of speculation.

The probable approximate position of the Twin coal, which has been agreed upon by all the State geologists who have worked in this region as the equivalent of the Buck Mountain coal, along Sharp Mountain throughout the central portion of the field, to which for the present we shall confine ourselves, is shown in mine sheets xiv, xiv*a*, xv, and xvi, in the third part of the Atlas of the Southern Anthracite Field.

### FLORA IN THE ROOF SHALES OF THE TWIN COAL.

Since the floor of the Buck Mountain coal, or its supposed equivalent, the Twin coal, forms the arbitrary line between the Pottsville formation and the succeeding Coal Measures, the flora in the roof shales of this coal may be regarded as representing the basal horizon of the Lower Coal Measures.[1] It therefore marks the upper limit of the Pottsville, as that formation has, so far as I can learn, been defined, with reference to the type section, by the various geologists of the State. The localities whose plants are listed below are all mines or drifts, chosen from the central regions of the field, between the Pottsville Gap on the east and Tremont on the west. Over these the Twin coal has been probably correctly recognized, it being of good body and quality over much of this territory.

(A) Pottsville Gap: Station 1, Pl. CLXXX.[2] From the Twin coal, whose position in the type section is illustrated in Pl. CLXXXI, were obtained the following species:[3]

| | |
|---|---|
| Pecopteris dentata Brongn. | Neuropteris Scheuchzeri Hoffm. |
| Pecopteris arguta Sternb. | Annularia stellata (Schloth.) Wood. |
| Pecopteris unita Brongn. | Sphenophyllum emarginatum Brongn. |
| Pecopteris Candolliana Brongn. | Lepidodendron sp. indet. |
| Pecopteris oreopteridia (Schloth.) Sternb. | Sigillaria tessellata (Steinh.) Brongn. |
| Pecopteris Miltoni Artis. | |

(B) Swatara Gap: Station 3, Pl. CLXXX. In this gap the Twin coal was formerly mined on both sides, the more extensive operation

[1] Rogers, Geol. Pennsylvania, Vol. II, Pt. I, p. 140.

[2] Atlas Southern Anthracite Field, Pt. II, mine sheets xiv, xiva.

[3] It should be distinctly understood that the identifications on which are based the following lists of species from the Productive Coal Measures in the Southern Anthracite field are merely temporary and provisional. As such they are subject to revision. Most of the names here given may be interpreted as designating the same forms to which they were applied by Professor Lesquereux.

being at Houser's drift,[1] on the east side. The following species were collected from this drift.

| | |
|---|---|
| Mariopteris muricata (Schloth.) Zeill. var. nervosa (Brongn.) Kidst. | Neuropteris fimbriata Lx. |
| Mariopteris Sillimanni (Brongn.). | Neuropteris Scheuchzeri Hoffm. |
| Pseudopecopteris squamosa (Lx.). | Calamites Cistii Brongn. |
| Pseudopecopteris obtusiloba (Brongn.) Lx. | Sphenophyllum emarginatum Brongn. |
| Sphenopteris cf. nummularia Gutb. | Lycopodites uncinnatus Schimp. |
| Pecopteris pennæformis [Lx.]. | Lepidodendron sp. indet. |
| Pecopteris villosa Brongn.? | Lepidostrobus cf. variabilis L. & H. |
| Alethopteris aquilina (Brongn.) Goepp. | Lepidostrobus cf. Geinitzii Schimp. |
| Odontopteris cf. osmundæformis (Schloth.) Zeill.? | Lepidophyllum cultriforme Lx. |
| Neuropteris ovata Hoffm. | Lepidophyllum oblongifolium Lx. |
| Neuropteris plicata [Lx.]. | Lepidocystis quadrangularis Lx. |
| Neuropteris vermicularis Lx. | Sigillaria cf. Brardii Brongn. |
| Neuropteris capitata Lx. | Trigonocarpum olivæforme L. & H.? |
| | Rhabdocarpos sp. |
| | Carpolithes transsectus Lx. |

(C) Middle Creek: Station 34, Pl. CLXXX. Along the ravine above the Middle Creek colliery a coal said to be the Buck Mountain bed is opened on both sides of the Middle Creek anticline by drifts,[2] from which were gathered the following:

| | |
|---|---|
| Mariopteris Sillimanni (Brongn.). | Annularia stellata (Schloth.) Wood. |
| Pseudopecopteris squamosa (Lx.). | Sphenophyllum emarginatum Brongn. |
| Sphenopteris mixta Schimp.? | Lepidodendron Brittsii Lx.? |
| Sphenopteris suspecta D. W. | Lepidodendron modulatum Lx. |
| Oligocarpia cf. Brongniarti Stur. | Lepidostrobus cf. Geinitzii Schimp. |
| Pecopteris dentata Brongn. | Lepidophyllum oblongifolium Lx. |
| Pecopteris unita Brongn. | Lepidophyllum cf. Mansfieldi Lx. |
| Pecopteris villosa Brongn.? | Lepidocystis vesicularis Lx. |
| Pecopteris oreopteridia (Schloth.) Sternb. | Sigillaria tessellata (Steinh.) Brongn. |
| Alethopteris aquilina (Schloth.) Goepp.? | Cordaicarpon cinctum Lx. |
| Alethopteris Serlii (Brongn.) Goepp. | Rhabdocarpos multistriatus (Presl) Lx. |
| Calamites Suckowii Brongn. | Rhabdocarpos mamillatus Lx. |
| Calamites Cistii Brongn. | Carpolithes cf. ellipticus Sternb. |

(D) Ebony colliery, north of Newcastle: Station 35, Pl. CLXXX. Along Wolf Creek, near the Ebony colliery, about 4 miles north of Pottsville, the Twin coal occurs in good thickness and is somewhat extensively worked.[3] From the roof shales, taken from the drifts near the Schuylkill River, the following flora was obtained:

| | |
|---|---|
| Mariopteris sphenopteroides (Lx.) Zeill. | Asterophyllites equisetiformis (Schloth.) Brongn. |
| Pseudopecopteris squamosa (Lx.). | Annularia stellata (Schloth.) Wood. |
| Pecopteris villosa Brongn.? | Sphenophyllum fasciculatum (Lx.). |
| Neuropteris ovata Hoffm. | Sphenophyllum emarginatum Brongn. |
| Neuropteris Scheuchzeri Hoffm. | |
| Cyclocladia sp. | |

[1] Atlas Southern Anthracite Field, Pt. III, mine sheet xvi; Final Summary Report, Vol. III, Pt. I, p. 2121.

[2] Idem, Pt. II, mine sheet xiii; Pt. VI, cross-section sheet xiii, section 22; Pt. IV B, columnar-section sheet x, section 4; Final Summary Report, Vol. III, Pt. I, p. 2120.

[3] Idem, Pt. II, mine sheet vi; Pt. V, cross-section sheets v–viii, section 17; Final Summary Report, Vol. III, Pt. I, p. 2083.

(E) Altamont colliery No. 2: Station 37, Pl. CLXXX. On the top of Broad Mountain, between Morea and Frackville, close to the northern edge of the Southern field, near the point where the Pottsville formation bridges the gap between the latter and the Western Middle field, the Buck Mountain and mammoth coals have been mined in a shallow basin at the now abandoned Altamont colliery No. 2.[1] The material from the shafts in the Buck Mountain coal contains the following species:

Mariopteris cf. Sillimanni (Lx.).
Pseudopecopteris squamosa (Lx.).
Neuropteris Scheuchzeri Hoffm.
Annularia stellata (Schloth.) Wood.
Sphenophyllum cuneifolium (Sternb.) Zeill.[2]
Sphenophyllum emarginatum Brongn.
Lepidodendron vestitum Lx.?
Lepidocystis (Sigillariostrobus?) quadrangularis Lx.?

The combined flora from these typical localities of the Twin or Buck Mountain coal is given in the following list:

Mariopteris sphenopteroides (Lx.) Zeill.
Mariopteris muricata (Schloth.) Zeill. var. nervosa (Brongn.) Kidst.
Mariopteris cf. Sillimanni (Brongn.).
Pseudopecopteris squamosa (Lx.).
Pseudopecopteris obtusiloba (Brongn.) Lx.
Sphenopteris pseudomurrayana Lx.?
Sphenopteris nummularia Gutb.?
Sphenopteris (n. sp.?).
Sphenopteris mixta Schimp.
Sphenopteris suspecta D. W.?
Oliogocarpia cf. Brongniarti Stur.
Pecopteris dentata Brongn.
Pecopteris arguta Sternb.
Pecopteris unita Brongn.
Pecopteris villosa Brongn.?
Pecopteris oreopteridia (Schloth.) Sternb.
Pecopteris pennæformis [Lx.].
Alethopteris aquilina (Schloth.) Goepp.
Alethopteris Serlii (Brongn.) Goepp.
Callipteridium Grandini (Brongn.) Lx.
Neuropteris rarinervis Bunb.
Neuropteris ovata Hoffm.
Neuropteris plicata [Lx.].
Neuropteris capitata Lx.
Neuropteris vermicularis Lx.
Neuropteris fimbriata Lx.
Neuropteris Scheuchzeri Hoffm.
Odontopteris cf. osmundæformis (Schloth.) Zeill.?
Calamites Suckowii Brongn.
Calamites Cistii Brongn.
Cyclocladia sp.
Asterophyllites equisetiformis (Schloth.) Brongn.
Annularia stellata (Schloth.) Wood.
Sphenophyllum emarginatum Brongn.
Sphenophyllum cuneifolium (Sternb.) Zeill.
Sphenophyllum fasciculatum (Lx.).
Lepidodendron Brittsii Lx.?
Lepidodendron modulatum Lx.?
Lepidodendron vestitum Lx.?
Lepidodendron sp. indet.
Lepidostrobus cf. variabilis L. & H.
Lepidostrobus cf. Geinitzii Schimp.
Lepidophyllum cultriforme Lx.
Lepidophyllum oblongifolium Lx.
Lepidophyllum cf. Mansfieldi Lx.
Lepidophyllum affine Lx.?
Lepidocystis vesicularis Lx.
Lepidocystis (Sigillariostrobus?) quadrangularis Lx.
Sigillaria cf. Brardii Brongn.
Sigillaria tessellata (Steinh.) Brongn.
Trigonocarpum olivæforme L. & H.?
Rhabdocarpos sp.
Rhabdocarpos multistriatus (Presl) Lx.
Rhabdocarpos mamillatus Lx.
Cordaicarpon cinctum Lx.
Carpolithes transsectus Lx.
Carpolithes cf. ellipticus Sternb.

[1] Atlas Southern Anthracite Field, Pt. II, mine sheet xiii; Pt. V, cross-section sheets v–viii, section 16; Pt. IV, columnar-section sheet ix; Final Summary Report, Vol. III. Pt. I, p. 2080.

[2] Broad, rigid, thick-nerved type present in the lower portions of the Allegheny series (XIII): Lower Productive Coal Measures.

It will be observed that of the 57 species enumerated above but 9 species, including *Mariopteris nervosa*, *Pseudopecopteris obtusiloba*, *Pseudopecopteris* cf. *squamosa*, *Alethopteris Serlii*, *Neuropteris ovata*, *Neuropteris fimbriata*, *Sphenophyllum cuneifolium*, *Lepidocystis vesicularis*, and *Carpolithes transsectus*, are represented even by varieties among the floras in hand from the Pottsville formation. In fact, it would seem from the examination of the specimens that only 5 of the species, viz, *Alethopteris Serlii*, *Neuropteris ovata*, *Neuropteris fimbriata*, *Lepidocystis vesicularis*, and *Carpolithes transsectus*, are represented in both series by identical forms, as may be noted by reference to the floras of beds L, M, and N. *Mariopteris nervosa*, *Pseudopecopteris obtusiloba*, and *Pseudopecopteris* cf. *squamosa* are found only in new varieties or doubtful forms in the Pottsville, while, as has previously been remarked, *Sphenophyllum cuneifolium* is represented by the broader, more rigid-leaved, and thick-nerved phase characteristic of the Lower Coal Measures. In short, a comparison of the lists shows that less than one-tenth of the ferns are represented by identical forms, both in the basal horizon of the Lower Coal Measures and in the upper phytiferous beds of the Pottsville formation. The species common to both formations are largely present in the upper 300 feet of the type section, i. e., the Upper Intermediate division. It must be evident even to one who is not familiar with Paleozoic fossil plants that the fern flora at the base of the Lower Coal Measures in the anthracite and other northern coal basins is almost totally different from that of the Upper Lykens division of the Pottsville.

That the paleontologic characterization of the Buck Mountain coal is similar in the adjoining territory of the Western Middle Anthracite field is indicated by the following combined list of the floras obtained at the Mahanoy Plane (M); at the Vulcan colliery, 1 mile west of Buck Mountain station (V); at the Buck Mountain mine (B), and from the Big Mine Run colliery, north of Ashland (A), in the latter field.

Pseudopecopteris squamosa (Lx.) (V).
Pseudopecopteris obtusiloba (Brongn.) Lx. (B).
Pecopteris pennæformis [Lx.] (M B).
Pecopteris oreopteridia (Schloth.) Sternb. (V B).
Pecopteris villosa Brongn.? (A).
Alethopteris Serlii (Brongn.) Goepp. (A B).
Callipteridium cf. Grandini (Brongn.) Lx. (B.).
Neuropteris ovata Hoffm. (M B A).
Neuropteris plicata [Lx.] (B A).
Neuropteris vermicularis Lx. (A).
Neuropteris fimbriata Lx. (B).
Neuropteris Scheuchzeri Hoffm. (A M).
Annularia stellata (Schloth.) Wood (B).
Sphenophyllum emarginatum Brongn. (V B).
Lepidodendron aculeatum Sternb. (B).
Lepidophyllum lanceolatum L. & H. ? (B).

(F) Toward the eastern end of the Southern Anthracite field, in the Sharp Mountain Gap, south of Tamaqua:[1] Station 39, Pl. CLXXX.

[1]Atlas Southern Anthracite Field, Pt. I, mine sheet iii; Pt. II, mine sheet iv; Pt. I, cross-section sheet iii, section 12; Pt. I, columnar-section sheet ii, columnar section 49; Summary Final Report, Vol. III, Pt. I, p. 2095.

Here the Twin coal has been apparently definitely identified at about 830 feet above the red shale, and is now being mined. From the roof shales over this coal was obtained a flora whose character will at once be recognized as similar to that contained in the Pottsville-Tremont district:

Eremopteris cf. artemisiæfolia (Sternb.) Schimp.
Pseudopecopteris squamosa (Lx.).
Sphenopteris nummularia Gutb.?
Sphenopteris (n. sp.?).
Pecopteris dentata Brongn.
Pecopteris oreopteridia (Schloth.) Sternb.?
Alethopteris Serlii (Brongn.) Goepp.
Callipteridium Grandini (Brongn.) Lx.
Neuropteris ovata Hoffm.
Calamites Suckowii Brongn.
Calamites Cistii Brongn.
Annularia stellata (Schloth.) Wood.
Sphenophyllum emarginatum Brongn.
Lepidophyllum affine Lx.?
Lepidocystis quadrangularis Lx.[1]

As has already been remarked, some doubt remains as to the indentity of the Twin or Buck Mountain coal in the Locust Gap, in the opposite side of the basin, about a mile and a half north of the last locality. At this point occur two coals, A and B, one or the other of which is supposed to represent the Buck Mountain coal. Coal A (16 feet in thickness), as shown in Pl. CLXXXV, Fig. 2, lies about 750 feet above the red shale. Coal B is reported as 202 feet above A on the west side of the gap, and 260 feet on the east side.[2]

From the roof shales of coal A a small flora was obtained, as follows:

Mariopteris muricata (Schloth.) Zeill. var. nervosa (Brongn.) Kidst.
Sphenopteris pseudomurrayana Lx.?
Neuropteris capitata Lx.
Neuropteris ovata Hoffm.
Pecopteris dentata Brongn.
Alethopteris aquilina (Schloth.) Goepp.

It is obvious that this, like the floras previously enumerated, is a distinctly Coal Measures flora; and I have no hesitation in concluding that the A coal, which has generally been regarded by the geologists who have worked in this region as belonging within the Pottsville formation, is referable rather to the Lower Coal Measures. It is important to mention in this connection that a flora, probably of no earlier age, is also present in the roof of a thin coal about 72 feet below the Twin coal in the type section at Pottsville. The shales at this horizon in the latter locality have not been systematically searched. They are crowded with great numbers of *Neuropteris Scheuchzeri*, among which are present *Neuropteris rarinervis*, and small fragments of *Asterophyllites* cf. *equisetiformis*, thus indicating a Lower Coal Measures age for this bed as well. It has been suggested by Mr. Smith[3] that the A coal, which, at the Nesquehoning railway tunnel, about 9 miles east of Locust Gap, has a thickness of but 1 foot, and which,

[1] Probably a Sigillariostrobus.
[2] Rept. Geol. Survey Pennsylvania, AA, p. 106; Summary Final Report, Vol. III, Pt. I, p. 2095. The interval is also given as but 115 feet by Ashburner in Report A, p. 80.
[3] Summary Final Report, Vol. III, Pt. I, p. 2096.

in one of the collieries a short distance west of the latter gap, was not discovered in a tunnel extending 400 feet below coal B, is in reality only a bottom split of the Buck Mountain coal.

THE PALEONTOLOGIC UPPER LIMIT OF THE POTTSVILLE.

The important fact embodied in the preceding lists of plants from the roof shales of the Twin coal, in both the Southern and the Western Middle Anthracite fields, is that they represent a typical and distinctive Coal Measures flora. The small element that this flora has in common with that of the Pottsville formation comprises species whose precursors, for the most part differing in their forms and phases from the normal types, have made their appearance only toward the close of Pottsville time. Compared, as a whole, with the flora of Lykens coal No. 1, about 300 feet below the Twin bed in the Lincoln region, or bed L, 380 feet below the Twin in the type section, the species of the latter coal are so different as even to suggest the existence of a time break between the intervening beds. As an argument against such a supposition, I have, however, only to cite the plants from beds N and M, whose floras, not less than 210 feet below the Twin coal at Pottsville, clearly presage the development of the Lower Coal Measures plant life by the introduction of a number of Coal Measures types of ferns, notwithstanding the generally stronger paleontologic bond which attaches these beds to the Upper Lykens division of the Pottsville formation. The transition already indicated in beds N and M seems to have been entirely completed within the time represented by the succeeding 200 feet of the section.

It is necessary in this connection to note the relations of the flora of the Twin coal to those of the Lower Coal Measures in other regions. If we compare that flora with those accompanying the lower coals of the Allegheny series[1] in the Northern States, we find that its composition, range, and development point definitely to a level as high as that of the well-known plant beds at Mazon Creek, Illinois; and that the horizon of the Twin coal should be nearly as high as that of the plants described from Henry County, Missouri,[2] and Cannelton, Pennsylvania. Compared with the better-known floras of the anthracite fields, the plants from the coal in question appear to indicate a level certainly not lower than that of coal C in the Northern Anthracite field, while it is perhaps safe to say that they are nearly as young as coal D (the Marcy coal) in the vicinity of Pittston.

According to the evidence of the plants, the beds of the basal portion of the Allegheny series, between the top of the Homewood sandstone and the Morris coal at Mazon Creek—an interval, probably including the Brookville coal, between the same sandstone and a level probably as high as the Clarion coal in the bituminous basins of western

[1] Bull. Geol. Soc. America, Vol. XI, p. 149.
[2] Mon. U. S. Geol. Survey, Vol. XXXVII.

Pennsylvania—and the terranes extending from coal A to at least as far as coal C in the Northern Anthracite field, were laid down prior to the deposition of the roof shales of the Twin coal.

The examination of the plants from the above-mentioned basal beds of the Allegheny series shows that they constitute a typical Coal Measures flora, with but a small proportion of Pottsville forms, though they lack so high a development of the Pecopteroid group, as well as several other more advanced types which appear in the Kittanning and Buck Mountain coals. The same is true of the flora of coal C in the Northern Anthracite field. In fact, like the flora of coal A at Tamaqua, or like that indicated in the coal 72 feet below the Twin bed in the Pottsville Gap, and that of the lower horizons of the measures in the Northern Anthracite field, the floras of the basal beds of the Allegheny series, which are above the lithologic Pottsville in the bituminous basins, are clearly referable, on paleontologic grounds, to the Lower Coal Measures. In short, the comparative paleontology of the terranes shows (*a*) that, as related to the Coal Measures of other regions of the Appalachian province, or other basins of the world, the flora of the roof of the Twin coal, which has been made the dividing line between the Pottsville formation and the Lower Coal Measures in the Southern Anthracite field, is of a pure and well-advanced Coal Measures type; and (*b*) that its horizon is distinctly above beds, generally of no great thickness in the northern basins, containing floras characteristic of not so high a level, but nevertheless having a composition which is distinct from that of the floras of the Pottsville formation and which is too thoroughly identical with the plant life of the Lower Coal Measures to permit of any other reference.

From the foregoing it appears: First, that the conventional upper limit of the Pottsville formation, in the Southern Anthracite field, is higher than the paleontologic upper limit. Second, that its horizon is also considerably above that of the same boundary as drawn, not only in the bituminous basins, but also in the Northern Anthracite fields. Third, that the paleontologic limit appears, so far as evidence has been obtained, to lie below, though perhaps very near to, the coal at 72 feet below the Twin coal in the type section, and probably above the plant beds 210 feet below the Twin coal. In other words, it also appears that in the type section the paleontologic upper limit of the Pottsville formation lies close within the upper outskirts of the great plexus of conglomerates in which the formation culminates. Thus, the paleontologic limit falls within and near the natural or lithologic limit.

It hardly need be repeated that the A coal at Tamaqua should, according to the evidence of the fossil plants, be included in the Lower Coal Measures, as should, also, the thin bed next below the Twin coal in the type section. It is not impossible that one or the other of these lower coals is the representative of the Scott Steel coal occurring at Mill Creek Gap, on the north side of the Heckscherville Valley Basin, in which case the latter should be of Coal Measures age rather than Pottsville age, as has generally been assumed. The reference of several of the thin coals not far below the Twin or Buck Mountain horizon to the Lower Coal Measures is not discordant with the opinion that they are but splits from the Buck Mountain bed,[1] though I do not so regard them. It appears more probable, however, that they are distinct and earlier beds, whose geographic extent may not be great, and whose individual correlation, in any event, is uncertain.

The difference between the positions of the conventional formation limit in the Southern as compared with that in the Northern Anthracite field is no doubt due to the continued deposition, with exceedingly slight intermissions, of heavy conglomerates above the main plexus of egg conglomerates in the Southern Anthracite field, which, in turn, is the result of the nearness of the latter to the abundant and rapid supply of coarse sediments.

## LOWER LIMIT OF THE FORMATION.

Owing to the transitional character of the passage beds from the typical red shale of the Mauch Chunk to the typical gray conglomerate phase of the Pottsville, as illustrated in Pl. CLXXXII, the discovery of a constant and recognizable boundary is a much more difficult matter than would at first appear, if indeed it is not an impossibility. Having observed that the upper beds of the red shale are, like the intercalated conglomerates, irregular, unstable, and subject to disappearance by wedging or pinching out,[2] the practice of selecting some arbitrary boundary in the conglomeratic upper portion of the red shale was inaugurated by the first State geological survey, and has been followed by the geologists of the second survey. As the result of this usage in the type region, where the transition is the most gradual, "the fixing of a precise limit between the two formations becomes, in many instances, a matter of individual preference and judgment,"[3] and it follows, not only that the thickness assigned to the sections varies with the geologists, but that it is often necessary to hold the published columnar section in hand in order to find the arbitrary boundary. To this element of uncertainty is probably due a portion of the apparent variations in the recorded thickness of the formation at certain points, as compared to that at other places, since in some sections several hundreds of feet below the topmost red shale have been included in the Pottsville formation, while in other regions the line has been drawn at or near the last stratum of red shale. Fortunately, toward the western end, and along the northern border of the Southern Anthracite

[1] Summary Final Report, Geol. Survey Pennsylvania, Vol. III, Pt. I, p. 2083.
[2] Rogers, Geol. Pennsylvania, Vol. II, Pt. I, pp. 22, 25.
[3] Smith, Summary Final Report, Vol. III, Pt. I, p. 1921.

field, as well as in the other anthracite coal fields, the contact of the Pottsville formation with the Mauch Chunk is very much more sharply defined.

As perhaps the less of two evils, I have adopted the topmost bed of normal red shale in each section as the lower boundary of the Pottsville formation, thus applying the method used under more favorable circumstances by the geologists who have worked in the bituminous regions of Pennsylvania. Though arbitrary and variable, since the topmost beds are possibly in certain cases mere washes or redepositions of the true Mauch Chunk, such a boundary line possesses at least the merit that when once seen it may usually be readily recognized by subsequent visitors to the locality.

The differences in the estimates of thickness, which are largely due to the lack of uniformity in selecting a basal boundary for the Pottsville, will be illustrated in the discussion of the thickness of the formation.

## THE POTTSVILLE FORMATION IN THE DAUPHIN BASIN.

Dauphin Basin and Schuylkill-Dauphin Basin are terms applied to the entire south prong of the "fish-tail" in the western portion of the Southern Anthracite field. It is a long, narrow trough extending about 30 miles west from Lorberry Gap to within 1½ miles of the Susquehanna River at Dauphin. From a width of about 1½ miles near the eastern end and of nearly a mile at Rattling Run, over half way toward the western end, it tapers to a narrow, relatively acute apex. Structurally the basin is essentially a simple close fold. The hard conglomerates of the Pottsville formation, which constitute the floor of the field, rise as rim walls on either side of the basin, forming the axes of Stony Mountain, the northern limb of the syncline, and Sharp Mountain, the southern limb. The profound erosion of the thick formation of soft red shales on either side of the basin causes the coal field to stand out topographically as an elevated trough. The beds of the north limb, Stony Mountain, whose crest dips southeast about 70°, are not so steep as those of Sharp Mountain, which, from a nearly vertical attitude in the region of Black Spring Gap, become overturned at Lorberry Gap to a dip of 73° N.

Westward from Black Spring Gap the Pottsville wall declines with gradually lessening dip as we approach the apex of the field. Stony Mountain presents a regular and unbroken crest. Sharp Mountain, on the other hand, is cut by six V-shaped gaps to the west of Lorberry Gap. The softer interior Coal Measures have been gently eroded to form a generally shallow, rounded interior valley in the trough, which is locally more deeply cut, but still broadly rounded, by the work of the small streams which escape through the jaws of Pottsville conglomerate in the gaps. At Big Flats, over 8 miles from the western apex of the field, Sharp and Stony mountains become confluent by the convex contents of the basin, and from that point westward, as the successive terranes "spoon out," the basin forms a single crest, known as Short Mountain. The topography of the basin is represented on the Pine Grove, Lykens, Hummelstown, and Harrisburg sheets of the Topographic Atlas of the United States.

The areal geology of the region, as shown in mine sheets xxi–xxvii, inclusive, of Pt. III of the Atlas of the Southern Anthracite Field, is essentially correct except as to the mapping of the Pottsville formation, which, as will presently be shown, is, together with the Lykens groups, located quite to the north of the Lykens groups as they actually exist in Sharp Mountain throughout the greater part of the length of the basin. Cross sections are shown on sheet xxi, Atlas Southern Anthracite Field, Pt. V; and several columnar sections, based principally on the work of R. C. Taylor and the first survey, are given on columnar-section sheet viii, Pt. IV B. Descriptions, usually of a fragmentary character, and based chiefly on Taylor's[1] reports of the explorations and developments of the field prior to 1840, are given by Rogers,[2] and in more complete form, with additions derived in part from Taylor's notes, by A. DW. Smith,[3] both of whom reproduce in modified form the sections published by Dr. Taylor.

It is to the southern or Sharp Mountain limb of the basin that the discussion in this paper will, for the most part, be confined. The key to the stratigraphic problem in hand is the Lorberry Gap section, at the eastern extremity of the basin, and this will first be considered.

## AGE OF THE COALS IN LORBERRY GAP.

### SECTION AT LORBERRY GAP.

(STATION 17, PL. CLXXX.)

On entering upon the study of the plants from the Pottsville formation in the type region, when endeavoring systematically to obtain fossils from the greater number of mines or more important drifts located in different parts of the field, Lorberry Gap, 4 miles south of Tremont and about 2 miles south of the Lincoln mine, was selected as a favorable locality, since in the latest published anthracite mine sheets several of the Lykens coals are represented as mined there. This point was also thought to be especially important, because it appeared to offer good facilities for securing fossils directly from drifts in Lykens coal No. 6, concerning which it is still desirable to obtain more paleontologic data.

[1] Two Reports on the Stony Creek Estate, 1840. See also: Report on the Swatara Mining District. Pennsylvania State legislature, 1839, p. 16, diagram.

[2] Geol. Pennsylvania, Vol. II, Pt. I, pp. 193–198.

[3] Summary Final Report, Vol. III, Pt. I, p. 2141.

The section at Lorberry Gap is described by Rogers and the geologists of the second State survey, on whose mine sheets (xvi and xxi) the coals have ostensibly been traced from Rausch Gap westward. The cross section is given in cross-section sheet xvi, Pt. VI of the Southern Anthracite Field Atlas. These mine sheets are valuable as showing the position and extent of the mine workings, and the dip as well as the direction of the strike of the coals. The topographic features of the district are shown on the Pine Grove sheet, Topographic Atlas of the United States.

Great was my surprise when, on inspecting a collection of plants from the roof shales of the southernmost coal opened in the gap—the bed mapped as Lykens coal No. 6, and apparently lying in the position of that coal with reference to the top of the red shale—I discovered the presence of a distinctively and unmistakably Productive Coal Measures flora, comprising species as follows:

Mariopteris muricata (Schloth.) Zeill. var. nervosa (Brongn.) Kidst.
Pseudopecopteris squamosa (Lx.).
Sphenopteris suspecta D. W.?
Pecopteris aspidioides Sternb.
Pecopteris unita Brongn.
Pecopteris oreopteridia (Schloth.) Sternb.
Pecopteris Miltoni Artis?
Alethopteris pennsylvanica Lx.?
Neuropteris ovata Hoffm.
Neuropteris vermicularis Lx.
Neuropteris fimbriata Lx.
Neuropteris Clarksoni Lx.
Neuropteris Scheuchzeri Hoffm.
Sphenophyllum emarginatum Brongn.
Lepidodendron dichotomum Sternb.
Lepidophyllum oblongifolium Lx.
Rhabdocarpos multistriatus (Presl) Lx.
Rhabdocarpos jacksonensis Lx.?

Search was then made in the shales accompanying the next higher coal, mapped as Lykens coal No. 4, mined both at Molley's slope, within the south end of the gap, and at Yoder's drift. The plants obtained at the slope are:

Mariopteris cf. cordato-ovata (Weiss).
Pecopteris emarginata Goepp.
Pecopteris polymorpha Brongn.
Alethopteris pennsylvanica Lx.?
Callipteridium Grandini (Brongn.) Lx.?
Neuropteris ovata Hoffm.
Neuropteris Scheuchzeri Hoffm.
Asterophyllites equisetiformis (Schloth.) Brongn.
Sphenophyllum emarginatum Brongn.

Those gathered at Yoder's drift include:

Pecopteris emarginata Goepp.
Pecopteris unita Brongn.
Pecopteris lepidorhachis Brongn.?
Pecopteris polymorpha Brongn.
Alethopteris pennsylvanica Lx.?
Neuropteris ovata Hoffm.
Neuropteris Scheuchzeri Hoffm.
Asterophyllites equisetiformis (Schloth.) Brongn.
Annularia ramosa Weiss.
Annularia stellata (Schloth.) Wood.
Sphenophyllum emarginatum Brongn.
Lepidodendron cf. dichotomum Sternb.
Lepidostrobus cf. variabilis L. & H.
Lepidophyllum hastatum Lx.?
Lepidocystis vesicularis Lx.
Sigillaria camptotænia Wood.
Sigillaria cf. alternans Sternb.

The flora of this coal indicates a still higher horizon in the Coal Measures. To this evidence may be added that of the fossils from the mine dump at the south end of the gap, though the latter are less trustworthy, on account of the liability of transportation along the outlet of the valley. The species are as follows:

Mariopteris sp.
Mariopteris cf. Sillimanni (Lx.).
Sphenopteris sp. (nov.?).
Sphenopteris cristata Brongn.?
Sphenopteris cf. flagellaris Lx.?
Oligocarpia missouriensis D. W.
Aloiopteris serrula (Lx.).
Pecopteris dentata Brongn.?
Pecopteris unita Brongn.
Pecopteris notata Lx.
Pecopteris cf. pusilla Lx.
Pecopteris oreopteridia (Schloth.) Sternb.
Pecopteris polymorpha Brongn.
Alethopteris aquilina (Schloth.) Goepp.
Alethopteris pennsylvanica Lx.
Callipteridium cf. Mansfieldi Lx.
Neuropteris minor Lx.
Neuropteris ovata Hoffm.
Neuropteris vermicularis Lx.
Neuropteris fimbriata Lx.
Neuropteris capitata Lx.
Neuropteris Scheuchzeri Hoffm.
Neuropteris Clarksoni Lx.
Neuropteris inflata Lx.
Neuropteris Desorii Lx.?
Odontopteris sp.
Linopteris obliqua (Bunb.).
Annularia stellata (Schloth.) Wood.
Annularia sphenophylloides (Zenk.) Gutb.
Sphenophyllum emarginatum Brongn.
Sphenophyllum cuneifolium (Sternb.) Zeill.?
Lycopodites Erdmanni [Lx.].
Lepidodendron dichotomum Sternb.?
Lepidodendron modulatum Lx.
Lepidostrobus Geinitzii Schimp.?
Lepidophyllum oblongifolium Lx.
Lepidophyllum affine Lx.?
Lepidophyllum majus Brongn.?
Rhabdocarpos multistriatus (Presl) Lx.
Rhabdocarpos jacksonensis Lx.?

A somewhat crude representation of the terranes in the Lorberry Gap including the coals referred to is shown on Pl. CLXXXV, Fig 3. In this section the "South" and "Peacock" coals are those mapped as Lykens coals Nos. 6 and 4, respectively, on the mine sheets.

Since the proximity of the Lower Coal Measures to the red shale clearly indicated the disappearance of a part or the whole of the Pottsville formation by faulting, a stratigraphic study was next made of Sharp Mountain in this district. The results of this examination will be stated only in brief form, since the local stratigraphic conditions are apparent when once the presence of a fault is recognized.

## THE FAULT IN SHARP MOUNTAIN.

The section of the Pottsville formation at Rausch Gap, Schuylkill County, shown on Pl. CLXXXV, Fig. 1, has been found to be normal, the formation being about 1,200 feet thick, and the lower coals, discussed on an earlier page, also found to belong to the Lower Lykens group. Proceeding westward from Rausch Gap,[1] which is a little over 1 mile from Lorberry Gap, the protruding edges of the nearly vertical hard conglomerates of the upper part of the formation may be readily traced for a short distance along a sharp knob. However, at about one-third of a mile from the gap the ledges become crushed, and the knob, topographically shown on mine sheet xxi, and on the Pine Grove

[1] This gap must not be confused with that of the same name farther west, along Sharp Mountain in Lebanon County, or with that in the north side of the Wiconisco Basin, formerly incorrectly designated Klingers Gap, and in a later State report Kohlers Gap.

sheet of the Topographic Atlas of the United States, is somewhat abruptly sheared in a direction apparently N. 15° E. Westward, instead of a dense talus of massive conglomerate bowlders, which never fails to mark the vicinity of the steeply outcropping Pottsville conglomerates, we find a gently rounded, smooth, broad ridge nearly devoid of all talus of a coarse type. Furthermore, over this smooth plateau surface there are scattered a number of prospect shafts, in one of which, less than 100 yards from the crushed ends of the conglomerates, and nearly in the probable strike of the horizon of Lykens coal No. 1, I collected fragments of *Annularia sphenophylloides*, *Sphenophyllum emarginatum*, *Neuropteris ovata*, *N. plicata* [Lx.], and fragments apparently referable to *N Scheuchzeri*, all species clearly indicative of the Productive Coal Measures. On passing southeastward from this point, across the line of displacement, the Mauch Chunk red shale is found in its normal place below the remnant of the lower conglomerates of the Pottsville formation. The line of the fault appears to be marked by a slight diagonal depression, by a zone of ferruginous brown earth, by numerous springs, and by occasional more or less obliquely or irregularly disposed trains of crushed sandstone or conglomerates. Beyond these, to the west, the shale and coal swales, or the trains of thin sandstone talus marking the outcrop of the Coal Measures shales, or of the relatively thin and less coarse Coal Measures conglomerates, may be traced to their more complete exposures and orientation in the upper portion of the Lorberry Gap.

The section shown in Pl. CLXXXV was not instrumentally measured by me, though a tapeline was used; but it shows the approximate relations of the beds exposed on the east side of the Lorberry Gap. The nomenclature of the coals is that found in the early Report on the Swatara Mining District.[1] The coals designated the South coal, the Peacock coal, and the Umbehauer coal are those respectively mapped on mine sheet xxi as Lykens coal No. 6, Lykens coal No. 4, and the Buck Mountain coal.[2]

The mantle of talus from the lower exposures of conglomerate effectually conceals the outcrop of the upper red shales of the Mauch Chunk formation in the immediate vicinity of the gap, though it may be found at some distance to the east as well as to the west of Lorberry Creek. On the mine sheet the boundary of this red shale, which appears to be somewhat hypothetically drawn, is given a gradual swing to the south, on the supposition that there is a gentle flexure of the formations. The nearly vertical ledges displayed at the lower end of the gap and situated below the coal (the South bed) mapped in the Atlas as Lykens No. 6 are successively found, when traced from the gap a very short distance eastward, to be somewhat abruptly transformed

[1] State legislature of Pennsylvania, 1839.

[2] For more exact data as to the intervals of the coals, the reader is referred to the published sections.

into crushed fragmentary talus, and to disappear on approaching the fault line, beyond which we find the ordinary red shale. Similarly, the South coal itself is cut off at a short distance beyond the point, less than 1,000 feet from the gap, where it was abandoned on account of its squeezed condition. The red shale of the Mauch Chunk is exposed 300 feet east of Yoder's drift (1,600 feet from the gap), which is in the next higher exposed coal (Peacock), mapped in the Anthracite Atlas as Lykens No. 4; and it is probable that had the mine gangway, which, in the miners' vernacular, "ended in fault," been driven 250 feet farther, it would have penetrated olive-green and red shales.

From the foregoing details it will be seen that the somewhat oblique fault crossing Sharp Mountain just west of the knob that abuts against Rausch Gap entirely cuts off the Pottsville formation and a portion, at least, of the Lower Coal Measures, so that Coal Measures, probably including the greater portion of the section shown on Pl. CLXXXV, Fig. 3, are thrust past the truncated Pottsville formation, or the red shales, against which the lower coals, carrying fossils clearly typical of the Productive Coal Measures, are found to abut.

The Pottsville, if any part of that formation is present in Lorberry Gap, must lie to the west of that fault and south of the lower coal (South bed) drifted in the gap. The cause of the displacement of the formations between Lorberry and Rausch gaps may perhaps be ascribed to the close group of folds to the north, and more immediately to the pressure-thrust resulting from the Georges Head anticline.

As interesting, as well as corroborative of the evidence of the plants of the lower coals, I may add that the fossils from near the coal mapped as the Buck Mountain bed at the north end of the gap comprise a Coal Measures flora containing *Odontopteris* of the type of *Brardii* and several small Pecopterids indicative of a very high stage in the Coal Measures.

That the strata on the east side of Lorberry Creek are continued on the west is proved by the extension of the lower levels in the Peacock and Umbehauer beds beneath the creek and for some distance beyond, one of the gangways in the higher coal having been driven nearly 1,500 feet west of the creek. The strike of the coal is nearly parallel to that of the crest of the mountain. The continuity of the series on the west side is also shown in a general way by the fossil plants. Thus the flora from the rock dump at the south end on the west side of the gap may also be cited in evidence:

Mariopteris cf. cordato-ovata (Weiss).
Pecopteris unita Brongn.
Pecopteris emarginata Goepp.
Pecopteris polymorpha Brongn.
Alethopteris pennsylvanica Lx.?
Neuropteris ovata Hoffm.
Neuropteris vermicularis Lx.
Neuropteris fimbriata Lx.
Neuropteris Clarksoni Lx.
Neuropteris Scheuchzeri Hoffm.
Annularia stellata (Schloth.) Wood.
Sphenophyllum emarginatum Brongn.
Lepidodendron sp. indet.
Lepidophyllum oblongifolium Lx.

To the latter may also be added the following species from a coal, probably the Peacock, on the west side, i. e., the coal mined at the Molley slope, and Yoder's drift on the east side of the gap, and mapped as Lykens coal No. 4:

Pecopteris pteroides Brongn.
Pecopteris polymorpha Brongn.
Neuropteris Scheuchzeri Hoffm.
Calamites Cistii Brongn.
Sigillaria camptotænia Wood.

The shales from the second coal, nearly 390 feet above the Peacock coal, are filled with *Annularia stellata*, *Pecopteris unita*, and vast quantities of *Pecopteris aborescens*. The plants in the shales over the individual coals of the Productive Coal Measures of the Southern Anthracite field have not yet been studied systematically and from a stratigraphic standpoint. No attempt will, therefore, at present be made to correlate the Lower Coal Measures in Lorberry Gap by means of fossils.

The conglomerates in the lower part of Lorberry Gap may easily be traced through the greater part of the distance across to Fishing Creek Gap, 2½ miles to the west, but owing to the subsidence of the crest in a broad and rounded ridge slope the individual beds can not be traced quite to the Fishing Creek Gap without the aid of a careful instrumental survey. The late State geological survey has indicated the approximate outcrop of the lower coal of Lorberry Gap as gradually diverging slightly from the crest beyond a point 1 mile west of Lorberry Gap, and as passing just south of the little knob facing Fishing Creek Gap. The boundary of the red shale was evidently thought to be necessarily parallel with that of the coal, and we find it thus traced on the mine sheet.

### SECTION AT FISHING CREEK GAP.

(STATION 18, PL. CLXXX.)

No detailed description of the section in Fishing Creek Gap appears to have been published. The geographic position of the three coals opened toward the lower end of the gap is shown in mine sheet xxi, Atlas Southern Anthracite Field, Pt. III.

In this map the lower coal is correlated with the lower coal (South) mined at Lorberry Gap, and the approximate outcrop of this supposed Lykens coal No. 6 is traced between the drifts in the two gaps. The upper coal (Peacock) is likewise mapped as Lykens No. 4, just as in the eastern gap. The relations of these lower coals to the outcropping sandstones in Fishing Creek Gap are shown in the section, Pl. CLXXXVI, Fig. 1, the position of the red shale being recorded as it appears, immediately on the east side of the gap, which, indeed, the section represents, the upper coal being projected from the west side. It will be observed from both the topography, which is low on the east, and from the columnar section, that the conglomerates are neither heavy nor numerous. The reason for this fact will appear upon an examination of the fossils obtained at the south drifts. The flora collected from the lower drift, the supposed Lykens No. 6, on the east side, includes:

| | |
|---|---|
| Sphenopteris cf. mixta Schimp. | Pecopteris Miltoni Artis. |
| Oligocarpia cf. Brongniarti Stur? | Pecopteris polymorpha Brongn. |
| Pecopteris pusilla Lx. | Neuropteris ovata Hoffm. |
| Pecopteris unita Brongn. | Annularia stellata (Schloth.) Wood. |

That from the drift, about 50 feet higher on the same side, reveals:

| | |
|---|---|
| Mariopteris cf. cordato-ovata (Weiss). | Neuropteris ovata Hoffm. |
| Pecopteris oreopteridia (Schloth.) Sternb. | Neuropteris plicata [Lx.]. |
| | Neuropteris Clarksoni Lx. |
| Pecopteris arborescens (Schloth.) Brongn. | Neuropteris Scheuchzeri Hoffm. |
| Alethopteris pennsylvanica Lx. ? | Calamites Suckowii Brongn. |

*Sphenopteris pinnatifida* (Lx.), *S.* cf. *Gravenhorstii* Brongn., and *Cordaites serpens* Lx. are additional species gathered from the rock dump, which may contain shale from both drifts.

The similarity of this flora to the floras listed from the Twin coal (Buck Mountain bed), in the central portion of the Southern Anthracite field, or to the flora of the lower coal in Lorberry Gap, is at once apparent. It, like those considered, is a pure Coal Measures flora.

### WESTERN LIMIT OF THE FAULT.

It will be observed that the red shale is shown in Pl. CLXXXVI, Fig. 1, as but 247 feet below the lower coal on the east side of the gap. It is not wholly improbable that the Mauch Chunk formation approaches along the line to the east of the section, even to within 120 feet of the coal. Unless the red shales in the old clearing, about 350 feet to the east of the gap, have been transported by human agency, as seems rather improbable under the local conditions, the Mauch Chunk lies at that point within 100 feet of the lower coal drifted in the gap.

As lending color of probability to the assumption of the existence of such a diagonal contact of the two formations, I will add that along the wagon road on the west side, below the gap, I have not seen the red shale above a point about 700 feet below the lower coal mined in the gap; this point is about 155 feet south of the forks in the wagon road. I do not, however, question the correctness in this respect of the mine map on which the shale is platted as nearly 140 feet north of the same road forks. To the west, and for a short distance to the north of this exposure, a zone of dark-brown ferruginous soil, accompanied by springs, extends in a direction apparently SSW. To the east of this zone no heavy conglomerates are seen in place, though the brown tract is strewn with loose blocks from the hillside on the west. This zone I believe to be along or near the fault line.

The most important fact, however, in connection with the trend of the fault at Fishing Creek Gap is the existence, at a short distance west of this brown zone and along the upper part of the mountain slope, of the characteristic shoulders, benches, and dense talus trains of fragments of the massive Pottsville conglomerates. The entire thickness of the formation seems to have appeared opposite the first knob, at but a short distance west of the Fishing Creek Gap. The more northern outcropping of the red shale on the east of the gap is quite in harmony with the apparently diagonal trend of the fault.

That the Lower Coal Measures are continuous across the gap in the vicinity of the mine drifts is shown not only by the alignment of the coal horizons and sandstones, but also by the character of the fossils. Those collected from the lower coal on the west side are:

Pecopteris polymorpha Brongn.
Danæites sp.
Alethopteris pennsylvanica Lx.?
Neuropteris ovata Hoffm.
Neuropteris Scheuchzeri Hoffm.
Calamites Cistii Brongn.

It should be recalled that *Pecopteris polymorpha* is not known in the lower coals of the Lower Coal Measures, either in the bituminous basins or in the Northern Anthracite field.

The species from the upper coal, about 170 feet higher, mapped as Lykens coal No. 4, on the west side of the gap are:

Pecopteris unita Brongn (cf. Newberryi F. & W.).
Pecopteris oreopteridia (Schloth.) Sternb.
Neuropteris ovata Hoffm.
Neuropteris fimbriata Lx.
Linopteris obliqua (Bunb.) Pot.
Annularia stellata (Schloth.) Wood.

*Pecopteris unita* is an exclusively Coal Measures species, while *Neuropteris ovata* and *Neuropteris fimbriata* are plants having a wide vertical distribution in the Lower Coal Measures.

On tracing the conglomerate, situated about 37 feet above this upper coal, Pl. CLXXXVI, Fig. 1, westward from the gap, it was found to pass along the side of the mountain about one-third of the way up the north slope. Roughly measured, it is about 610 feet from this upper conglomerate, over the second coal, or nearly 400 feet from the lower coal, to the upper massive benches of the Pottsville formation, which, for most of the way from this point to Rattling Run, form the narrow "backbone" or crest of Sharp Mountain. For the latter half of the distance from Fishing Creek to the Black Spring Gap, to which these upper ledges of the Pottsville may easily be traced, the second of the adjacent massive conglomerate plates projects vertically from the mountain crest to form an almost continuous series of highly picturesque "saw-teeth," which are often 50 feet in height and nearly as broad.

It is hardly necessary to cite the unquestionable identity of these ledges, which are also found at the top of the normal thickness of the

Pottsville in the Black Spring Gap, in order to confirm the relation of the coals in Fishing Creek Gap to the Pottsville formation, since an examination of the south slope of the mountain a half mile west of Fishing Creek Gap leaves little room to doubt that long before we reach a point in Sharp Mountain opposite the Fishing Creek Gap in the Second Mountain the entire thickness of the Pottsville formation is present in normal sequence between the Mauch Chunk and the Lower Coal Measures.

In this connection it is interesting to observe that the displacement involved in the reappearance of the Pottsville and the restoration in its normal attitude of the red shale is compensated by a marked offset of the Pocono (Vespertine) and Catskill in Second Mountain east of and at the Fishing Creek Gap in the latter. This feature is clearly brought out on the Pine Grove sheet of the Topographic Atlas of the United States.[1]

In passing it is proper to observe that the position of the "South" coal in the Fishing Creek Gap at 350 feet or more above the horizon of the Buck Mountain bed effectually precludes the existence of any considerable portion of the Pottsville formation at the south end of the section in the Lorberry Gap, provided the correlation of the lower coals in both gaps by the Pennsylvania geologists is well founded. For my own part, I am slightly disposed to consider the "South" bed at the latter gap as not very far above the base of the Lower Coal Measures.

If we hypothetically treat the South bed as a possible representative of the Skidmore coal, farther to the east along Sharp Mountain, the Lorberry Gap section may with great interest be better compared with that of the water-level tunnel at Dundas colliery No. 6, at the foot of Sharp Mountain, a few miles to the eastward, published in columnar-section sheet viii, Atlas Southern Anthracite Field, Pt. IV. If the Fishing Creek section, Pl. CLXXXVI, Fig. 1, be also compared with the Dundas section, the stratigraphic sequence in the region of the lower coals in the former will be found to be highly suggestive of that in the vicinity of the Homes and Primrose coals at Dundas.

## POSITION OF THE POTTSVILLE FORMATION ALONG SHARP MOUNTAIN.

To ignorance of the stratigraphic displacement at Lorberry Gap and Fishing Creek Gap, and the consequent erroneous identification of the coals in those gaps as Lykens coals, is directly due the omission of the true Pottsville formation from the region to the west mapped as coal-bearing. For, since, in tracing these Coal Measures coals westward, they were found to lie wholly to the north of the

[1] Lorberry Gap and the gaps occupied by Fishing Creek in both Sharp and Second mountains evidently owe their existence to the structural weakness near the displacements.

crest of Sharp Mountain, it was concluded that the crest of the mountain had shifted to the lower conglomerates of the Pottsville formation. Hence it was natural that, as we shall presently see, the approximate outcrop of the Buck Mountain bed, or its equivalent, should be mapped from Black Spring Gap to Rattling Run, a distance of over 12 miles, as the "lowest Lykens Valley" bed.

### SECTION AT BLACK SPRING GAP.

(STATION 19, PL. CLXXX.)

The section at Black Spring Gap has been described by both Taylor[1] and Rogers.[2] A somewhat complete representation of the coal beds above the Pottsville formation is given in section 7, columnar-section sheet viii, Atlas Southern Anthracite Field, Pt. IV. A cross section is given on cross-section sheet xxi, Pt. VI of the Atlas. Reference to these publications reveals the fact that the sections begin with the top bed of Pottsville conglomerates and extend upward in the Coal Measures. This, as was just remarked, is the natural result of the identification of the lower coals in the Lower Coal Measures with the Lykens coals. The section which I give in Pl. CLXXXVI, Fig. 2, is an imperfect one, since only a portion of the thickness of the massive conglomerates of the Pottsville is visible. It will be observed, however, that the upper bed of the red shale, which is fixed with a fair degree of precision in the section, is approximately 1,150 feet below the horizon of the coal I suppose to represent the Buck Mountain (Twin) bed. It will be noted, also, that the composition of the formation in the Dauphin Basin is essentially the same as that along Sharp Mountain, in the region of Pottsville. Especially noticeable is the great group of conglomerates which occur at the top of the formation, and which form the crest of Sharp Mountain from Fishing Creek nearly to the Big Flats. No evidence of serious search for the Lykens coals appears in this region within the limits of the Pottsville formation.

### SECTION AT GOLD MINE GAP.

(STATION 20, PL. CLXXX.)

The topography of Sharp Mountain in this district and the locations of the drifts at Gold Mine Gap are shown in mine sheet xxii, Atlas Southern Anthracite Field, Pt. IV. The topography may be seen on the Lykens sheet of the Topographic Atlas of the United States. Descriptions of the coals north of the crest of the mountain are given by Taylor,[3] Rogers,[4] and Smith,[5] the former of whom published a

[1] Report on the Stony Creek Estate, Pt. II, p. 16, pl. 147, fig. 6.

[2] Geol. Pennsylvania, Vol. II, Pt. I, p. 195, fig. 181. See also Taylor's Report on the Swatara Mining District, 1839, p. 18.

[3] Report on the Stony Creek Estate, Pt. II, p. 19, pl. 147, fig. 5.

[4] Geol. Pennsylvania, Vol. II, Pt. I, p. 195.

[5] Summary Final Report, Vol. III, Pt. I, p. 2144. Descriptive notes are also contained in the early Report on the Swatara Mine District, 1839, p. 18.

cross section. A more complete columnar section of the Productive Coal Measures is presented on columnar-section sheet viii, Pt. IV of the Anthracite Atlas. In Pl. CLXXXVI, Fig. 3, I give an imperfect section, which is extended in Pl. CLXXXVII, Fig. 1, to include the Pottsville formation. In this, as well as in the gaps on either side of Gold Mine, the immense amount of coarse conglomerate blocks, largely furnished by the upper plexus of conglomerates which form the sharp crest of the mountain, usually conceals everything but portions of the most enduring ledges. It is, therefore, only by some effort that outcrops of more than the most prominent beds are to be found. For the same reason I have not attempted to definitely show the upper boundary of the red shales, which I am convinced can hardly be less than 1,130 feet below the horizon of the Buck Mountain (Twin) coal.

It is interesting to note a certain degree of regularity in the group of conglomerates at the top of the Pottsville. This appears on a comparison of the Gold Mine Gap section with the sections at Rausch Gap (Pl. CLXXXVII, Fig. 2) and Black Spring Gap (Pl. CLXXXVI, Fig. 2), to both of which these outcropping backbone ledges may easily be traced. A similar development exists at the Rausch Gap in Schuylkill County (Station 4, Pl. CLXXX), in which the Buck Mountain coal is similarly disposed.

From the mine dump, consisting of material from probably more than one of the coals drifted on the east side of the gap, were obtained the following species, which evidently represent a characteristically Productive Coal Measures flora:

Pecopteris unita Brongn.
Pecopteris arguta Sternb.?
Pecopteris arborescens (Schloth.) Brongn.
Pecopteris squamosa Lx.
Pecopteris oreopteridia (Schloth.) Sternb.
Pecopteris cf. elliptica Bunb.?
Pecopteris polymorpha Brongn.
Alethopteris pennsylvanica Lx.?
Callipteridium Grandini (Brongn.) Lx.?
Neuropteris ovata Hoffm.
Neuropteris vermicularis Lx.
Neuropteris fimbriata Lx.
Neuropteris Clarksoni Lx.
Neuropteris Scheuchzeri Hoffm.
Neuropteris Rogersi Lx.
Lepidophyllum majus Brongn.?
Cordaites sp.

The following species were also collected on the west side in the gap:

Pecopteris polymorpha Brongn.
Pecopteris cf. Newberryi F. and W.
Neuropteris ovata Hoffm.
Neuropteris Scheuchzeri Hoffm.
Annularia sphenophylloides (Zenk.) Gutb.
Sphenophyllum cf. filiculme Lx.

### SECTION AT RAUSCH GAP, LEBANON COUNTY.

(STATION 21, PL. CLXXX.)

The Lower Coal Measures and the upper beds of the Pottsville formation at Rausch Gap, $3\frac{1}{4}$ miles west of Gold Mine Gap, have been the subject of fragmentary descriptions by Taylor,[1] Rogers,[2] and Smith.[3] The cross section given by the first-named author is repeated in more complete form by Rogers and the second geological survey, though in the publications of the latter the boundary of the red shale appears to have been drawn where it might theoretically lie if the Buck Mountain (Twin) coal were the lowest Lykens coal. The position and extent of the drifting in the vicinity of this gap are shown in mine sheet xxiii.

From the section which I give in Pl. CLXXXVII, Fig. 2, it appears that the Pitch bed, the next coal below Bill's bed, probably lies within the group of conglomeratic plates at the top of the Pottsville formation. The roof shales of the coal, which I interpret as the probable representative of the Buck Mountain coal, furnish the following species:

| | |
|---|---|
| Mariopteris muricata (Schloth.) Zeill. var. nervosa (Brongn.) Kidst. | Neuropteris Desorii Lx. |
| Mariopteris occidentalis D. W. | Neuropteris ovata Hoffm. |
| Pecopteris unita Brongn. | Neuropteris vermicularis Lx. |
| Pecopteris pusilla Lx.? | Neuropteris fimbriata Lx. |
| Alethopteris aquilina (Schloth.) Goepp. | Neuropteris Scheuchzeri Hoffm. |
| | Linopteris obliqua (Bunb.) Pot. |

The composition of this flora indicates a horizon in the basal portion of the Lower Coal Measures, or in the Allegheny series. A drift in the same horizon on the west side of the gap yields large numbers of *Alethopteris Serlii* (Brongn.) Goepp., *Neuropteris Scheuchzeri* Hoffm., and *Asterophyllites equisetiformis* (Schloth.) Brongn.

Below the Pitch bed there is but little, if any, evidence of search for coals in the Pottsville formation at Rausch Gap. Here, as well as in Gold Mine and Black Spring gaps, effort was made to find the coals of the Lorberry and Fishing Creek gap sections, which were seen to pass, in the Dauphin Basin, to the north of the crest of Sharp Mountain instead of to the south of the latter. In his discussion of the region under consideration, Dr. Taylor,[4] whose reports and notes form the basis of the later publications relating to the district, remarks that "no examination for veins [coals] south of the backbone ledge of Sharp Mountain has taken place hereabouts." Owing to the exceptionally favorable conditions at the southeast corner of the gap, the top of the red shale was located by me, with a probably high degree of certainty, at about 1,175 feet below Bill's coal, which I have assumed to be near the horizon of the Buck Mountain bed. The boundary can be hardly more than 75 feet higher.

### YELLOW SPRINGS GAP.

(STATION 23, PL. CLXXX.)

At Yellow Springs, 4½ miles west of Rausch Gap, there is a high gap in the mountain, through which a small stream, draining a section about

[1] Report on the Stony Creek Estate, Pt. II, p. 19, pl. 147, fig. 4.
[2] Geol. Pennsylvania, Vol. II, Pt. I, p. 195, fig. 182.
[3] Summary Final Report, Vol. III, Pt. I, p. 2144.
[4] Op. cit., p. 20.

2 miles in length of the Coal Measures valley, finds an escape. The topography of the vicinity is shown on the Hummelstown sheet of the Topographic Atlas of the United States and mine sheet xxiv of the Southern Anthracite Atlas, the latter of which locates the points of exploitation. Descriptions of the coals are given by Taylor,[1] and quoted by Rogers[2] and Smith.[3] Cross sections of the basin at this point are given by Taylor, and by the geological survey of the State in cross-section sheet xxi, Pt. VI of the Anthracite Atlas. All the information in the later reports relating to Sharp Mountain appears to have been derived from Taylor's report, printed in 1840.

At this gap the Pottsville appears to present its ordinary characters and its full thickness. The conditions for the discovery of the upper boundary of the Mauch Chunk shale are not favorable, but it is quite certain that the red shale is not present at 960 feet below the supposed horizon of the Buck Mountain coal. No prospecting appears to have been done in the Pottsville formation at this gap since the publication of the report by Taylor, who states that none of the coals on the south slope of Sharp Mountain had been opened or sought. However, in some early explorations, carried on in 1824, a tunnel driven through the upper portion of the Pottsville formation in the gap penetrated a bed of good coal, which, Dr. Taylor adds, was "not fully proven." The rock dump taken from a shaft which appears to have been located on this bed contains the following species:

Eremopteris decipiens.
Mariopteris tennesseeana var. hirsuta.
Sphenopteris palmatiloba var. squarrosa.
Megalopteris plumosa.
Neriopteris lanceolata.
Neuropteris tennesseeana.
Calamostachys Knowltoniana.
Bothrodendron arborescens.
Cordaites Robbii.
Cardiocarpon biscupidatum var. ohioense.
Cardiocarpon Wilcoxi.

This flora will at once be recognized as clearly referable to the Sewanee zone; and it can hardly be lower than Lykens coal No. 3. The variety of *Sphenopteris palmatiloba*, the variety of *Cardiocarpon bicuspidatum*, and *Bothrodendron arborescens* appear to bind the flora somewhat closely to that of the horizon of Lykens No. 1. Through *Eremopteris decipiens* and *Cardiocarpon Wilcoxi* the flora seems to be related to that of the Sharon coal of northwestern Pennsylvania, and it is worthy of mention that *Neriopteris lanceolata*, found at Yellow Springs, has hitherto been known only from the sandy shales at some distance above the Sharon coal, in northwestern Ohio. On the whole, I am slightly disposed to regard the horizon of the plants at Yellow Springs as higher than that of the Lykens coal No. 2.

The stratigraphic distance of this horizon below that of the Buck

[1] Reports on the Stony Creek Estate, Pt. I, p. 52.
[2] Geol. Pennsylvania, Vol. II, Pt. I, p. 196, fig. 183.
[3] Summary Final Report, Vol. III, Pt. I, p. 2145.

Mountain coal is about 210 feet; and as the latter is probably recognizable in this gap, this points toward the level of Lykens coal No. 1.

The plants from the Backbone bed, which appears to correspond to the Buck Mountain coal at Yellow Springs Gap, constitute a flora agreeing well with that listed from what I believe to be the same horizon at Rausch Gap. They are:

Sphenopteris sp.
Pecopteris villosa Brongn.?
Neuropteris ovata Hoffm.
Neuropteris plicata [Lx.].
Neuropteris capitata Lx.
Neuropteris fimbriata Lx.
Neuropteris Scheuchzeri Hoffm.
Linopteris cf. squarrosa (Ett.).
Sphenophyllum emarginatum Brongn.
Rhabdocarpos tenax Lx.?

Before passing farther toward the apex of the field, certain suggestions, resulting from a comparison of the columnar sections at Yellow Springs and the gaps to the eastward, deserve some attention, although it is not within the province of this paper to attempt the correlation of the coals of the Lower Coal Measures.

Referring to the section at Rausch Gap (Pl. CLXXXVII, Fig. 2), we may observe that Bill's bed, the "3-foot" bed, the "2-foot" bed, and probably "Dan's" bed, have been drifted in the Yellow Springs Gap, in which the intervals separating the coals are nearly the same as in Rausch Gap. A higher coal opened at Yellow Springs is probably equivalent to that designated the "Heister" in Rausch Gap, though it may possibly be the representative of the coal next below. We may safely conclude, therefore, on a comparison of these two sections, that the coal in the Pottsville formation from which the Lykens plants enumerated above were obtained lies approximately 210 feet below Bill's bed in Rausch Gap, 4½ miles to the eastward.

The section of the Lower Coal Measures at Gold Mine Gap exhibits, when compared with that at Rausch Gap, considerable variation. If the supposition that the coal which I have designated in the section (Pl. CLXXXVI, Fig. 3) the Buck Mountain (Twin) bed may be the equivalent of the Bill's bed at Rausch Gap is correct, then the bed known as "4-foot" bed in the Gold Mine Gap section would appear to be equivalent to one or both benches of "Dan's bed" at Rausch Gap; in which case the "Peacock" and the coal next above may be parallelized with coal "No. 1" and the "Heister" bed, respectively, in the Rausch Gap section, while the two coals next higher at Gold Mine may be considered as representatives of the "Gray" bed and "No. 2" bed at Rausch Gap. The "No. 4" bed in Rausch Gap lies at the approximate level, stratigraphically, of the "3-foot" bed in Gold Mine Gap. It is obvious that, if these tentative correlations, especially as they relate to the "No. 1(?)," the "Heister," the "Gray," and the "No. 2" beds at Rausch Gap, are not erroneous, the "Heister" bed, which, as designated in the published sections, is about 120 feet above the "3-foot" bed at Gold Mine Gap, can not possibly be the equivalent of the bed bearing the same name in the Rausch Gap section, less than 3½ miles distant.

In the former section the supposed Heister bed is nearly 870 feet above the horizon of Bill's bed, while in the latter section it is only about 420 feet, less than half as far.

Similarly, the section at the Black Spring Gap, often cited as Mount Eagle Gap, when compared with that in either Gold Mine Gap or Rausch Creek Gap, presents a series of intervals and coals which suggest several tentative correlations. Thus the horizon which I have designated in Pl. CLXXXVI, Fig. 2, as the place of the Buck Mountain (Twin) coal is probably on the same stratigraphic level as Bill's bed in Rausch Gap, or the lower coal at Gold Mine Gap. Likewise the horizon higher in Black Spring Gap, described by Taylor as "traces of a southern coal," would seem to correspond directly to the first coal above the Buck Mountain in Gold Mine Gap, while the "4-foot" beds in both gaps will, in that case, be on the same stratigraphic level; but if, as would seem naturally to follow, the "Peacock" coals in both sections are in reality equivalent, then we must conclude not only that the Pitch bed is not developed in the Gold Mine Gap, but also that the representative of the next coal above the "Peacock" bed at Gold Mine is identical, if exposed at all at Black Spring Gap, with the Black Spring coal. The Mount Eagle coal, the next higher in the latter gap, and the second coal opened above the "Peacock" coal in Gold Mine Gap, both of which are coincidently situated at the same distance from the Twin coal, probably represent the same bed. But, in order to illustrate the ease with which sections containing a number of well-distributed coals may be in different ways adjusted to one another, while at the same time pointing out certain other probable coincident similarities between the Black Spring section and that at Rausch Gap, let us assume that the horizon designated as "traces of a southern coal" in the former gap represents the Bill's bed in the latter. In that case, we shall find not only that the "4-foot" coal lies at essentially the same distance above the second coal in Gold Mine, but also that the "Peacock" coal is near the level of the "4-foot" bed at Gold Mine and the "Dan's bed" at Rausch Gap, in which case the Pitch coal at Black Spring Gap might, without too great a strain of the imagination, be correlated with the "2-foot" coal at Rausch Gap, and the "4-foot" coal at Black Spring might correspond to the "3-foot" coal at Rausch Gap. Continuing the same assumption as to the identity of the horizon of Bill's bed or the Buck Mountain coal at Mount Eagle Gap, it is evident at a glance that the Black Spring and Mount Eagle coals near the top of the section at Black Spring correspond, so far as stratigraphic intervals are concerned, almost exactly with the "No. 1" and the "Heister" coals, respectively, in the Rausch Gap section. The quoted names of coals represent the local identifications or correlations by the State geologists.

So far as the problems discussed in this report are concerned, the chief interest in the correlation of the coals of the Lower Coal Measures relates to the equivalence, in the western sections, of the coals mined in the Fishing Creek and Lorberry gaps. My own observations of the terranes in the Fishing Creek Gap (Pl. CLXXXVI, Fig. 1), combined with measurements across Sharp Mountain, less than a mile west of the creek, where the Pottsville formation is present in its normal constitution and thickness, lead me to the opinion that the horizons of the two lower coals mined in Fishing Creek Gap are comparable to those of the "Peacock" coal in the Black Spring and Gold Mine sections and the coal marked as "Heister" in the Rausch Gap section. In this case the upper coal at Fishing Creek may represent the "Gray bed" at Rausch Creek Gap, the second coal above the supposed "Peacock" in Gold Mine Gap, and probably the Black Spring coal at Black Spring Gap, the lowest coal at Fishing Creek being possibly comparable to the Pitch bed at Black Spring.

The coals in the section at Lorberry Gap, Pl. CLXXXV, Fig. 3, will appear to correspond most satisfactorily, with respect to the separating intervals, to the coals of the gaps to the westward, if we assume that the lowest bed (South coal) opened at Lorberry occupies the horizon of the supposed Buck Mountain, Backbone, and Bill's beds in the other gaps. If this hypothesis is correct, the bed designated "Peacock" coal in Lorberry, Black Spring, and Gold Mine gaps, which, in the first two sections, is approximately the same distance from the Buck Mountain bed, and which is scarcely farther in the Gold Mine Gap, may perhaps safely be considered as one coal. Next, the "Zimmerman" coal in Lorberry Gap would appear to deserve comparison with the Mount Eagle bed at Black Spring, with the second exposed coal above the "Peacock" bed in Gold Mine Gap, and with either the "Gray" bed or "No. 2" bed, next higher, in Rausch Gap.

On assuming that the South coal at Lorberry is at the horizon of the Buck Mountain (Twin) bed, it becomes probable that the developed coals above the "Zimmerman" bed are higher than those represented in the Rausch Gap section, unless the "No. 4" bed in the latter section, whose distance above the Buck Mountain bed is a little greater than the corresponding interval below the next coal[1] above the "Zimmerman" in the Lorberry Gap, is the representative of the latter unnamed coal. The next higher coals in the Lorberry section will then deserve comparison with the "Heister" and "Gray" beds in the Gold Mine Gap section. The Umbehauer and the Furnace beds at the north end of Lorberry Gap probably represent higher horizons than have been developed to the westward, and it is possible that they may not even be present in the basin at and to the westward of Rausch Gap.

It will be observed that in respect to the relative intervals between

[1] This appears to be identical with the bed named Peacock coal in cross-section sheet xvi, Pt. VI of the Atlas of the Southern Anthracite Field.

the coals in the sections, the Gold Mine section appears to present the highest degree of agreement with or similarity to the Lorberry Gap section; but, whether the comparison be with the Gold Mine Gap or the Mount Eagle Gap, or the Dundas No. 6 colliery tunnel,[1] a few miles to the east of Lorberry Gap, we must conclude that if the South coal represents the Buck Mountain bed the Lorberry Gap should, in addition, contain a number of the intermediate coals which have been opened in the Black Spring and Rausch gaps. With no other evidence than the measurements of the intervals between the discovered coals on which to base correlations of the latter, an almost equally satisfactory parallelization of the beds might be framed were we to assume that the "Peacock" coal in the Lorberry Gap corresponds with the first coal above the Buck Mountain bed in the longer sections to the westward. Such an assumption is, however, manifestly untenable, since it involves the reference of the South coal, whose fossils are fully as young as, if not younger than, those of the Buck Mountain bed, to the approximate horizon of the Lykens coal in the Yellow Springs Gap, the fossils from which are referable to the Sewanee zone of the Upper Lykens division of the Pottsville formation.

I would have little reliance placed in the foregoing suggestions as to the equivalence of the various coals of the Productive Coal Measures along Sharp Mountain. It needs but an examination of the columnar sections, showing the surprisingly great variation of the intervals between the coals as actually ascertained by direct connections between the mines in the Southern field,[2] to convince one that correlation of these beds by no other means than the comparison of columnar sections is, in the Southern Anthracite field, hardly less than jugglery.

### RATTLING RUN GAP.

(STATION 24, PL. CLXXX.)

Rattling Run, the most westerly gap in Sharp Mountain, is 15½ miles from Fishing Creek Gap and about 4 miles east of the point at which the Pottsville formation begins to spoon out, above Watertank Station. The description of this gap, which is about 3 miles west of Yellow Springs, is given with considerable detail in Dr. Taylor's report,[3] which is quoted in the later State reports.[4] The principal drifts in the Lower Coal Measures are platted on mine sheet

[1] Section 6, columnar-section sheet viii, Atlas Southern Anthracite Field, Pt. IV.

[2] The variability of the Coal Measures intervals, even between near localities, is well illustrated in the diagram prepared by Ashburner, and published on columnar-section sheet iii, Pt. I of the Atlas of the Southern Anthracite Field. It is also shown in columnar-section sheet vi, Pt. II of the Atlas. Good examples of this are found at the Wood's colliery, and at Dundas colliery, No. 6 tunnels, cited above, the sections of which are not more than 3 miles distant from each other.

[3] Report on Stony Creek Estate, pp. 44 and 50, pl. 147, fig. 2.

[4] Rogers, Geol. Pennsylvania, Vol. II, Pt. I, p. 197, Smith, Summary Final Report, Vol. III, Pt. I, p. 2145.

xxv of the Anthracite Atlas. That portion of the Dauphin Basin west of Yellow Springs was somewhat thoroughly explored by the owners, the Dauphin and Susquehanna Coal Company, under the direction of Dr. Taylor. It is to this fact that most of our knowledge of the coals in this region is due.

The entire thickness of the Pottsville formation, from the bed which I assume to represent the Twin (Buck Mountain) coal to the topmost beds of the red shale is given by Taylor as 1,100 feet. Within that interval twelve coals were found. Two thin coals are reported within 170 feet of the red shale. The sixth coal from the red shale, the Reliance bed, not over 3 feet in thickness, was drifted for 461 feet. Although a very "dry coal," it was not found to be at that time profitably workable. The distance, 410 feet, from this bed to the red shale suggests the position of Lykens coal No. 4. Twenty feet to the south of the Reliance bed another coal was opened, and still another bed was discovered 40 feet to the north. A coal at the supposed horizon of the Buck Mountain bed has been opened on both sides of the gap, it having been drifted for a considerable distance on the east side. No fossil plants were obtained at this gap.

### BIG FLATS.

(Station 26, Pl. CLXXX.)

As Sharp and Stony mountains, which form the two walls of the Dauphin Basin, converge toward the west, the interior valley becomes less marked, until at a point nearly opposite Watertank Station, about 9 miles from Dauphin, the Coal Measures completely fill the interval from rim to rim and form a low, slightly convex knob, the Big Flats, about 1 mile in length, the north and south faces being composed of the Pottsville formation. The topography is shown on the Harrisburg sheet of the Topographic Atlas of the United States, as well as on mine sheets xxv and xxvi, Pt. III of the Anthracite Atlas. The shaftings on the Big Flats, dating from the early part of the century, are described by Taylor, whose cross section was reproduced by Rogers.[1] Dr. Taylor reports the presence of three coals within an interval of 48 feet, from one of which several hundred tons of coal were hauled to the Susquehanna River at Dauphin prior to 1840. The three principal shafts, but a few yards apart, are platted on mine sheet xxvi. The shale from the shafts is now nearly disintegrated; yet fragments taken from the dump reveal the presence of *Neuropteris ovata* Hoffm., *N. Scheuchzeri* Hoffm., *Pecopteris villosa* Brongn. ?, *Annularia stellata* (Schloth.) Wood, and *Sphenophyllum emarginatum* Brongn., species characteristic of the Lower Coal Measures.

Although we have no measurements showing the thickness of the

[1] Geol. Pennsylvania, Vol. II, Pt. I, p. 198, fig. 184.

Pottsville formation west of Rattling Gun Gap, my observations show that the upper group of conglomerate plates which have been traced the entire distance from Fishing Creek Gap may be followed, by the exercise of proper caution, when the trees are bare, for at least 2 miles west of Rattling Run Gap. Westward from this point the amount of the error of the omission of the entire Lykens group of coals on the State maps diminishes gradually. Yet in view of the lessening of the dips from 73° to 17°[1] opposite the Big Flats shaftings, it is obvious that the supposed boundary of the lowest Lykens coal, which is represented at a distance of not over 800 feet from the shafts, is too far north to include more than the upper 200 or 300 feet of the Pottsville formation, even if we suppose the coal mined in the shafts to be the Buck Mountain bed, than which, as is shown by the plants, it can hardly be lower. Were the strata nearly vertical, it is probable that Lykens coals Nos. 2 and 3 would lie outside of the approximate boundary of the lowest Lykens bed as the latter is mapped in the mine sheet. That coals are present in both of the Lykens groups in this region is evident from the shaftings along Stony Mountain and Short Mountain, which will next be considered.

### SHORT MOUNTAIN SHAFTINGS WEST OF BIG FLATS.

The disappearance of the Lower Coal Measures and the commencement of the spooning out of the upper beds of the Pottsville formation occur not far west of the Big Flats and the head of Watertank Run. It is certain that, unless the folding is much closer than the apparent dips indicate and the axis is not far to the north side of the crest, the Pottsville alone remains at the Fort Lookout shafting, less than 1½ miles west of Big Flats. It should be remarked at this point that, with the exception of the Bayard shaftings on the north side of Short Mountain, no prospecting or exploitation of coal appears to have been made in this region since the earlier half of the present century. In the following brief notes reference will be for the most part confined to those old developments from which fossil plants have been obtained. The descriptive matter is derived from Taylor's report, the source of most of the information republished in the State reports.

A. The first of the developments west of the Big Flats are the Fort Lookout shaftings (Station 27, Pl. CLXXX), opened in 1838. The location of this operation is shown in mine sheet xxvi, Pt. III of the Anthracite Atlas, and a cross section of the basin at this point is contained on cross-section sheet xxi, Pt. VI of the same publication. The two shafts at this point are said to have reached a depth of 82½ feet. The coal was found too poor for mining. On searching the dump at the mouth of the shafts, a number of fossil plants were obtained,

[1] See mine sheet No. xxvi.

which, as will at once be discovered in glancing at the list, are distinctly of Pottsville age:

Mariopteris tennesseeana.
Neuropteris gigantea.
Neuropteris acutimontana.
Neuropteris sp. indet.
Asterophyllites arkansanus.
Annularia acicularis.
Whittleseya elegans var. minor.

Furthermore, nearly all of the species will be recognized as having a distribution in the Upper Lykens division. It is certain that this flora can not be below the horizon of Lykens coal No. 3, when *Neuropteris gigantea*, *Asterophyllites arkansanus*, and the peculiar form of *Mariopteris tennesseeana* strongly suggest a more intimate relation with the flora of Lykens coal No. 2. It is probable that the level of this flora is not lower than Lykens coal No. 2 or higher than Lykens coal No. 1.

B. Of the economic results obtained by the Bayard shaftings (Station 28, Pl. CLXXX) we have no other information than that given by mine sheet xxvi, which shows the location of four shafts, and by the fossils obtained from the rock dumps. From the lower of the shafts there were obtained an indeterminate species of *Mariopteris*, *Neuropteris Pocahontas* var. *inaequalis*, and a species of *Sporocystis*. From a higher shaft, not over 85 feet from the latter, the following-named species were obtained in shale mingled with waste coal:

Mariopteris pottsvillea.
Neuropteris Pocahontas var. inæqualis.
Lepidophyllum quinnimontanum.
Rhabdocarpos acuminatus.

A comparison of these florulas, both of which are distinctly referable to the Lower Lykens division, shows that while the plants from the lower drift contain no types indicative of a particular horizon, the species from the upper drift include, in *Mariopteris pottsvillea*, *Neuropteris Pocahontas* var. *inæqualis*, and *Lepidophyllum quinnimontanum*, three species characteristic of the *Mariopteris pottsvillea* zone, or the approximate horizon of Lykens coal No. 4. The association and facies of the individual plants from this drift are clearly suggestive of the level of the Kemble drift on Broad Mountain, which, as we have already seen, is most probably near the horizon of Lykens coal No. 4. If this correlation is valid, then it becomes probable that the horizon of the lower drift is near the level of Lykens coal No. 5.

C. The next locality at which fossil plants were obtained is a pit just above the "north vein drift" (Station 29, Pl. CLXXX), close to the divide in the saddle of the mountain, nearly due north of White Springs Station. The drift at this point was opened in 1827 for the distance of 100 feet on a dip 30° S. As might be expected, nearly all of the excavated material is now entirely disintegrated. Such plant fragments as were obtained plainly show the presence of a number of species which, though not clearly indicative of the approximate horizon of Lykens coal No. 4, are nevertheless strongly suggestive of that level. They are certainly from the Lower Lykens division.

| | |
|---|---|
| Mariopteris pottsvillea. | Neuropteris Pocahontas var. inæqualis. |
| Mariopteris sp. indet. | Whittleseya Campbelli. |

The geographic position of this drift is shown in mine sheet xxvi, Pt. III of the Anthracite Atlas; and a cross section of the mountain is included in cross-section sheet xxi, Pt. VI of the Atlas.[1]

D. On the south side of the crest of Short Mountain, but a short distance to the west of the "north vein drift," is located Kugler's drift (Station 30, Pl. CLXXX), opened in 1824. The positions of both Kugler's drift and Young's drift, the latter being a little to the west, are shown on mine sheet xxvi. In his report on the Stony Creek coal area, Dr. Taylor reports the presence of a good coal in the former, reaching a maximum thickness of 4 feet, its horizon being 25 feet below that of the coal at Young's drift, while a smaller bed, the "little vein," is said to have been discovered 20 feet lower than Kugler's. Although the shales from Kugler's drift are far decayed, they still reveal the presence of—

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|---|---|
| Mariopteris eremopteroides. | Cordaites Robbii. |
| Neuropteris Pocahontas var. pentias. | |

Although these species are insufficient in themselves to form the basis of an attempt at a precise correlation, their entire agreement with the flora of the region of Lykens coals Nos. 5 and 6, for which I have tentatively suggested the term *Mariopteris eremopteroides* zone, will at once be recalled. Such a tentative reference carries more weight than mere suggestion, when the stratigraphic intervals of the neighboring coals are taken into account. It seems, indeed, far from improbable that, if the measurements reported from these coal drifts are to be relied upon, the 51-inch coal in Young's drift, which is 25 feet above Kugler's, may represent Lykens coal No. 5, the Kugler's drift being in Lykens coal No. 6, while the "little vein," 20 feet below, might represent the "zero" coal of the Wiconisco Basin. It appears that in this region of Short Mountain three coals of the Lower Lykens division are present, two of which may attain a workable thickness, although the attitude of the beds near the axis of the syncline probably unfits them for profitable exploitation.

E. A small collection of fossil plants was obtained from the most westerly of the shafts shown on the immediate crest of the mountain on mine sheet xxvi of the Anthracite Atlas (Station 31, Pl. CLXXX). It contains the following species:

| | |
|---|---|
| Mariopteris eremopteroides? | Whittleseya Campbelli. |
| Neuropteris Pocahontas var. pentias. | Trigonocarpum ampullæforme. |
| Lepidophyllum quinnimontanum? | Trigonocarpum Helenæ. |

[1] Reproduced in Summary Final Report, Vol: III, Pt. I, pl. 394.

The composition of this flora conclusively proves its presence in the Lower Lykens division. The first three species mentioned are to a certain extent characteristic of the lower zone of that division and might be expected in the vicinity of Lykens coals Nos. 5 and 6. Against so low a reference as coal No. 6, however, is opposed the presence of *Lepidophyllum quinnimontanum* and *Trigonocarpum Helenæ*, which, though not unknown in the horizon of No. 5, are in general more characteristic of Lykens coal No. 4, and which have not yet been found so low as coal No. 6. It does not, therefore, appear permissible to refer this flora to a lower level than that of Lykens coal No. 5, on the one hand, while, on the other hand, there is no evidence of weight to lead us to regard it as high as Lykens No. 4. Accordingly, as between the three horizons, this flora should perhaps tentatively be referred to that of Lykens coal No. 5. Concerning the depth of the shaft or the thickness of the coal touched at this point I find no printed information.

F. The only other locality on Short Mountain from which fossils have been collected is a drift which, as shown on mine sheet xxvii of the Anthracite Atlas, is located near the extremity of the mountain, in the apex of the basin, and within 2,800 feet of the outcrop of red shale beneath the last of the conglomerates in the axis of the spoon of the Pottsville formation. This seems to be one of the shaftings opened in 1802. Naturally the shales are for the most part completely disintegrated, and no encouragement is offered for the collection of fossils. Some fragments of bone, however, still show traces of Calamarian stems and cortices of various types, as well as rather abundant fruits of *Trigonocarpum ampullæforme*.

### THE LYKENS COALS IN STONY MOUNTAIN.

Intelligent and thorough search for the Lykens coals seems to have been made at but two points between Big Flats and the Kalmia colliery, a distance of 16 miles. At the more western locality, on the Dull and Hoff lands (Station 25, Pl. CLXXX), but about 2 miles east of the Big Flats, four or five of the Lykens coals were located and shafted in 1888. The uppermost of these coals, which would appear from the description[1] to be 400 or 500 feet below the probable approximate horizon of the Buck Mountain bed, is said to be thin. About 200 feet below this a thin, clean, bright coal was discovered. The next bed, about 150 feet lower, contains 2 feet 7 inches of good coal, reported as the best found. One hundred feet lower, 5 feet 5 inches of crushed and dirty coal was opened, while a bed of impure coal and shale was located 40 or 50 feet below the last.

From the thickness and order of the intervals (see table, p. 864), we may tentatively assume that the lowest bed represents Lykens coal

[1] Summary Final Report, Vol. III, Pt. I, p. 2142.

No. 6; the thick bed, 40 or 50 feet higher, may then be the Lykens coal No. 5, and the 2-foot 7-inch bed of good coal 100 feet above the last will perhaps correspond to the place of Lykens coal No. 4, while the coal about 150 feet higher is possibly near Lykens coal No. 2 or No. 3. As corroborating to a certain degree, or as slightly indicative of the correctness of, these hypothetical correlations, the small collection of plants apparently derived from the roof of the third coal (numbering from the lowest), which we have assumed to be Lykens coal No. 4, may be enumerated:

Mariopteris pottsvillea.
Neuropteris Pocahontas.
Asterophyllites parvulus.
Trigonocarpum ampullæforme.

The first of these species seems to be characteristic of the zone of that coal, while the third is more common in the same horizon. On the whole, it appears very probable that the three principal lower Lykens coals have been opened in the prospect shafts on the Dull and Hoff lands.

At a point nearly north of Rausch Gap[1] two coals, which from surface appearances and the thickness of the intervals would seem to represent the supposed Lykens coals Nos. 4 and 5 at the locality last considered, have been opened by trial slopes (Station 22, Pl. CLXXX). The coal at the mouth of the upper of the two slopes is apparently of good quality and in good condition. No information is at hand as to the thickness of the beds in the slopes, which are now fallen shut. The lack of information is in itself indirectly indicative of no great thickness for the combustible.

At the Kalmia colliery (Station 41, Pl. CLXXX) Lykens coals Nos. 4, 5, and 6 were worked to some extent. Owing, however, both to the irregularity of the beds at this point in thickness and condition and to the more advantageous conditions for mining about the Georges Head anticline, the greater part of the "workings" were abandoned in favor of the latter area. The columnar section at this mine from the top of Lykens coal No. 5 downward into the red shale is shown on Pl. CLXXXIV in continuation with the section at the Lincoln colliery, from the connected gangways[2] of which a portion of the Kalmia territory is now directly mined.

## GENERAL CONDITIONS RELATING TO THE OCCURRENCE OF THE LYKENS COALS IN THE DAUPHIN BASIN.

A review of the foregoing brief descriptive notes concerning the Pottsville formation in the Dauphin Basin shows that along the north side of the narrow trough, which is nowhere more than 2 miles in width,[3] several of the Lykens coals, one or more of which, usually in

[1] Atlas Southern Anthracite Field, Pt. III, mine sheet xxiii.
[2] Idem, Pt. III, mine sheets xxi and xxii.
[3] This refers to the distance across the basin from margin to margin; not to the length of the curve.

the Lower Lykens group, is nearly or quite of workable thickness, have been found in every district where a thorough search has been made. They are also found to extend along the base of the rising axis in Short Mountain. Furthermore, it has been shown that, owing to the presence of an unobserved fault which cuts off the whole or nearly all of the Pottsville formation at Lorberry and Fishing Creek gaps, not only were the soft, inferior Productive Coal Measures coals exploited at these gaps mistaken for degenerate developments of the Lykens coals, and consequently pronounced inferior or worthless, but on account of the trend of the former coals along the north side of Sharp Mountain the entire Pottsville group of coals has been supposed to lie to the north of the crest of the mountain. The outcrop, or supposed approximate outcrop, of the lowest Lykens coal was therefore mapped by the late anthracite survey of Pennsylvania[1] along or near a horizon not lower in most places than the horizon of the Buck Mountain coal, the conventional base of the Lower Coal Measures, from Fishing Creek Gap to a point about 2 miles west of the Rattling Run Gap, an entire distance of over 17 miles. To the same misinterpretation at Lorberry and Fishing Creek gaps is also due the fact that no systematic search has ever been made for coals south of the crest of Sharp Mountain (where no coals were supposed to occur) between Fishing Creek Gap and Rattling Run Gap.

It must not be understood from the above statement of facts that Lykens coals in good condition lie awaiting the search of the prospector along the south slope of Sharp Mountain. On the other hand, the vertical or very highly inclined attitude and the often crushed or slipped condition of the other coals along Sharp Mountain render it probable that the Lykens coals will here also be found generally inferior in structure, and perhaps in composition, as compared with the present standard requisite for profitable mining. It is the purpose of this review of the stratigraphy of the region not merely to secure greater accuracy in the mine maps of the Dauphin Basin, or to add to our knowledge of the floras of the Pottsville formation in this region, but to call attention to the facts: (1) That the soft or semi-bituminous coals on the north slope of Sharp Mountain between Fishing Creek and Rattling Run gaps, hitherto regarded as the Lykens coals, are really in the Productive Coal Measures; (2) that practically no search[2] has been made for coals in the Pottsville formation through-

[1] Credit is due the opinion expressed by Mr. A. DW. Smith in a footnote to the Summary Final Report of the State Survey (p. 2140), that the outcrops of the red shale and the lowest Lykens coal are drawn 800 to 1,000 feet too far north between Lorberry Gap and Rattling Run Gap, most of the coals in the Lorberry and Fishing Creek gaps being referable to the Lower Coal Measures, although he assumes the full thickness of the Pottsville formation to be present at the latter gaps. This footnote, which I had not seen until the writing of the present paper, is quite at variance with all other portions of the text relating to the Dauphin Basin in Mr. Smith's report.

[2] Exceptions of little importance are the discoveries of the Reliance coal at Rattling Run Gap and the thin coal near the top of the Pottsville formation in Rausch Gap, section 2, Pl. CLXXXVII.

out this portion of Sharp Mountain, 17 miles in length, for the reason that no coals were expected to occur there; (3) that nearly the entire formation, including both groups of the Lykens coals, lies south of the general crest of the mountain; (4) that the discovery, especially in the Lower Lykens division, of several Lykens coals, one or more of which appears to be of good quality and of workable or nearly workable thickness at every point[1] at which a moderately thorough search has been made along the opposite side of the basin and along Short Mountain, offers every assurance of the presence of some of the coals on the south side of the basin, though the steep or nearly vertical position of the beds bespeaks a poorer condition and less easy exploitation of the coals. It is, however, within the range of probability that, should the consumption of anthracite continue at nearly the present rate, the demand for the Lykens red-ash coals, which are more highly appreciated for domestic purposes, will exhaust the richer and more favorably situated and profitably mined deposits, some of which are already far toward exhaustion, and cause the exploitation of Lykens coal in regions now regarded as wholly unprofitable; in which case the Lykens coals of Sharp and Stony mountains, though so often crushed, may enter into competition with the thinner coals of the Pottsville formation in other portions of the anthracite fields.

## THICKNESS OF THE FORMATION IN THE SOUTHERN ANTHRACITE FIELD.

In the discussion of the lower limits of the Pottsville formation attention was especially called (p. 831) to the great variations in the measurements of the section in the Southern Anthracite field, due to the indefiniteness of the method in use and the elements of personal opinion and preference consequently involved. As was then remarked, the method of fixing the boundary at the top of the highest bed of typical red shale or sandstone, which has been followed in the measurements hitherto given in this report, is only the application in the anthracite region of the custom in vogue in the geologic work of the bituminous basins of the State. The unsatisfactory features of this method, which have already been pointed out in the Southern Anthracite field, are appreciated in advance.[2] It is admittedly arbitrary and variable; yet in its application it not only assures an identical horizon over considerable distances, but it is definite in each exposure, and effectually disposes of the personal variations resulting from the choice of an individual horizon throughout a series representing a gradual

[1] Dull and Hoff lands north of Rattling Run Gap and drifts north of Rausch Gap, mine sheets xxv and xxiii, respectively.

[2] Concerning the variability of the horizon of the uppermost bed of red shale, Smith (Summary Final Report, Vol. III, Pt. I, p. 1921) remarks as follows: "In the Southern field these transition beds have, in places, a thickness of 500 to 600 feet. The transition beds and the lower beds of XII also exhibit decided variations in the materials composing them. At times heavy conglomerates predominate, with but few sandstones and shales, or again the whole series may be composed of coarse sandstones and of shales, with the green and reddish tinge running high in the formation, making it difficult,

transition, 400 or 500 feet in thickness, such as is exhibited in the sections at the Pottsville Gap, Pls. CLXXXI, CLXXXII, and in the Lincoln region, Pls. CLXXXII, CLXXXIII. It is purposed in the following pages to present the results obtained by both methods.

Beginning with Mauch Chunk, at the eastern apex of the Southern field, and proceeding westward, the measurements of the Pottsville formation (XII), as given by Rogers,[1] are: Mauch Chunk, about 950 feet; Nesquehoning, 792 feet; Tamaqua, about 803 feet; Pottsville, about 1,030 feet; Lorberry Gap, about 675 feet;[2] Yellow Springs, about 660 feet;[3] Kohlers Gap, 230 feet; Bear Gap, 460 feet. The measurements of all the intervals given by A. DW. Smith are of great value, since his statements are based on the enormous amount of instrumentally accurate data accumulated by the second geological survey of the anthracite regions, all of which were passed in review by him. As stated by Mr. Smith, in the Final Summary Report, the thickness of the formation is as follows: Locust Gap, Tamaqua, 1,296 feet; Sharp Mountain Gap, Tamaqua, 1,130 feet; Broad Mountain, about 1,200 feet; Pottsville Gap, 1,350 feet; Swatara and Rausch gaps, 1,100 or 1,200 feet; Lorberry Gap, 1,500 or 1,600 feet;[4] vicinity of the Lincoln mine, 1,475 feet; Kalmia region, 1,400 to 1,500 feet; Williamstown, about 1,400 feet.

The preceding measurements begin with an arbitrary boundary, usually within or below the transition series. The following measurements start from the topmost bed of red shale and extend to the supposed horizon of the Buck Mountain coal, except along Locust Mountain, in the Panther Creek Basin, where the measurements from both the A and B beds are given, it being nevertheless understood that the A coal at Tamaqua is referable to the Lower Coal Measures.[5] The measurements opposite the names of localities marked by an asterisk (*) are compiled from the sections published by the State geological survey.

even when a complete section is at hand, to decide where the line between the two formations should be drawn. It is not safe to always take the highest red shale bed as a limit, as beds of red shale, usually thin, but in appearance like the mass of No. XI, are not infrequently seen high up in the conglomerates of XII, and occasionally among the overlying Coal Measures; nor will it suffice to take the lowest conglomerate, as beds of conglomerate are often found well down in the red shales of XI. The fixing of a precise limit between the two formations becomes, in many instances, a matter of individual preference and judgment."

[1] Geol. Pennsylvania, Vol. II, Pt. I, pp. 146 and 147.

[2] This, as we have already seen, consists in part, if not wholly, of the beds of the Productive Coal Measures.

[3] It is difficult to account for this measurement by Rogers at Yellow Springs, except on the supposition that the dense, ferruginous surface deposits which occur in the lower end of the gap were mistaken by him as indicating the presence of the Mauch Chunk red shale.

[4] The terranes included in this measurement belong for the most part, if not exclusively, to the Productive Coal Measures.

[5] The Buck Mountain coal, or its supposed horizon, is taken as the upper limit in my measurements, both for the sake of the uniformity desired in the comparisons and because the true paleontologic base of the formation can not in many cases be fixed, because of the lack of collections of fossils from a number of horizons not far below the Buck Mountain level. The paleontologic upper limit of the Pottsville is probably within 200 feet, at most, of the conventional limit, the Buck Mountain bed, in all sections.

Nesquehoning Gap, (*) 1,150 feet, or 940 feet from the A coal; Lansford railroad tunnel, (*) 675 feet from the A coal, or 780 feet from the B coal; Sharp Mountain Gap, (*) Tamaqua, 850± feet; Locust Mountain Gap, Tamaqua, 750 feet from the A coal, or 880 feet from the B coal, according to the statement of Mr. Ashburner;[1] Pottsville Gap, 1,195 feet; Westwood Gap, 1,165 feet; Broad Mountain, in the region of Altamont colliery No. 2, (*) 1,210 feet from the horizon, which would seem to be referable to, and is, at least, probably not lower than, the Buck Mountain bed to the red shale; Swatara Gap,[2] 1,025± feet; Rausch Gap, Schuylkill County, 1,205± feet; Lincoln region, (*) 1,110 feet; Black Spring Gap, 1,160± feet; Gold Mine Gap, 1,130± feet; Rausch Gap, Lebanon County, 1,165± feet; Rattling Run, (*) 1,100 feet; Kohlers Gap, (*) 1,219 feet; Williamstown, (*) 1,460 (?) feet.

Since a number of the localities cited are either common to two or more of the preceding lists, or are so near as to leave little room for actual important variation, the measurements at these points may be combined in a table, which will show the thickness of the Pottsville formation as measured, first, by Rogers; second, by the second geological survey of Pennsylvania, an arbitrary lower limit being used; and, third, as either measured or compiled by me, the topmost bed of red shale being taken as the lower limit of the Pottsville formation.

*Measurements of the Pottsville formation in the Southern Anthracite field.*

| Location of section. | Measured by— | | |
|---|---|---|---|
| | Rogers. | Smith. | White. |
| Nesquehoning Gap | 792 | 1,155 | 940 A (1,150 B) |
| Lansford railroad tunnel | ........ | 878 | 690 A (802 B) |
| Locust Gap, Tamaqua | 803 | 1,296 | 750 A (952 B) |
| Sharp Mountain Gap, Tamaqua | | 1,130 | 850± |
| Pottsville Gap | 1,030± | 1,350 | 1,195 |
| Westwood Gap | ........ | ........ | 1,165 |
| Broad Mountain, near Altamont 2 | ........ | 1,200 | 1,210± |
| Swatara Gap | ........ | 1,100 to 1,200 | 1,025± |
| Rausch Gap, Schuylkill County | ........ | | 1,205± |
| Lincoln-Kalmia | ........ | 1,475 | 1,110± |
| Black Spring Gap | ........ | ........ | 1,160± |
| Gold Mine Gap | ........ | ........ | 1,130± |
| Kohlers Gap | 230 | ........ | 1,219 |
| Rausch Gap, Lebanon County | ........ | ........ | 1,165± |
| Williamstown | ........ | 1,400± | 1,460? |
| Rattling Run | ........ | 1,100 | 1,100 |

[1] Second Geol. Survey Pennsylvania, Anthracite Region, Rept. 1, 1883, p. 80.
[2] Perhaps not over 950 feet.

From the above table it appears that over 300 feet of transition series has been included within the Pottsville formation in some of the measurements published by the State survey. Among the deductions to be drawn from the table, perhaps the most important are: (1) Whatever the arbitrary base line employed in the measurements, the formation is found to be thickest in the central portion of the field, i. e., the region including Pottsville and Lincoln. (2) The formation appears to be as thick at 7 or 8 miles from the present southern border of the field as in Sharp Mountain. Thus on the Broad Mountain, near Altamont colliery No. 2, the diamond drill bore hole can hardly have begun much higher than the Twin coal, while the section at Kohlers Gap in Bear Mountain, which was carefully described and measured by Rogers, appears to be as thick as all those measured by myself in Sharp Mountain. It seems not improbable that the great thickness of the formation in the Williamstown tunnel, as platted in columnar-section sheet vii, may be due to error in the identification of the Buck Mountain bed, or in the computation of the the thickness of the beds. (3) The diminution of the thickness of the Pottsville between the type section at Pottsville Gap and the Lansford railroad tunnel in Locust Mountain is well marked, as appears to be also the rapid increase which is noted in the region of Nesquehoning Gap. I am disposed to believe that in the Panther Creek Basin the B bed is perhaps nearer the level of the Twin coal, or supposed Buck Mountain bed, than is coal A, which, although distinctly referable at Tamaqua to the Lower Coal Measures, seems to carry a rather less recent flora than that of the Twin coal. Neither is it certain that the A bed at the Nesquehoning Gap is identical with that similarly designated at Tamaqua. (4) Another diminution in the thickness of the section seems to occur along Sharp Mountain from Pottsville to Swatara Gap, where the interval from the supposed Twin bed to the top of the red shale is perhaps less than 950 feet. (5) One of the most interesting facts brought to light in this comparison is the apparently but slight decrease of the formation in Sharp Mountain in passing westward along the Dauphin Basin, where at Rattling Run, near the western end of the field, it still retains a thickness of 1,100 feet. This observation is of greater weight because it is based on careful measurements apparently extending only from the uppermost bed of red shales.

The more marked variations in the thickness of the Pottsville are perhaps due to differences in the horizons taken as the upper or the lower limits, or to changes in the thickness of the several terranes from point to point, rather than to the existence of an unconformity at the base of the formation. Even at Tamaqua, where the discrepancy between the thickness of the Pottsville, as measured in the two gaps, points, perhaps, toward discordance, the difference may be due either to variation, without unconformity at the base, or to the absolute failure of the Twin coal to appear in the Locust Gap section.[1] Allowance for reduction by pressure and crushing should also be made in some sections.

The relatively slight diminution in the thickness of the Pottsville in passing along the Dauphin Basin to Rattling Run, as conclusively shown in the table given above, renders the rapid decrease in the thickness of the formation before reaching the Broad Top Basin, about 75 miles distant, where it is said[2] to be only 160 feet thick, somewhat remarkable. In view of the geographic position of the Broad Top field on the east side of the Appalachian trough, between the very thick Virginia and the Schuylkill sections, the alternatives—unconformity, or diagonaling of the Pottsville base in time—discussed in connection with the subject of the lower limit of the formation in another part of this report are again called to mind. The surprising difference in the measurements of the sections seems not wholly satisfactorily explained by the theoretically farther offshore position of the Broad Top Mountain, although that may account for a large part of the difference. The more probable explanation, as it appears to me, is that Broad Top was not directly in the influence of the strong, fluctuating, detritus-laden currents, which may have built a large portion of the great, broad, shoal-water terrace in the Schuylkill-Swatara region, while red argillaceous shale was still being deposited in the Huntingdon County region. Unfortunately, no plants have been collected from the latter region to show the relative age of the lower beds.

The remarkable strength and the varying activity and directions of the movements of the early Pottsville sediments over the Mauch Chunk delta in the Schuylkill-Swatara region during a period of oscillating tide level are proved by the alternation and high degree of irregularity in the Pottsville beds, by the transportation of the conglomerate-building material to a long distance from the present margin—i. e., by the long radius of the fan—and by the size of the bowlders which are sometimes encountered far from the margin of the field. In illustration of the latter circumstance, the occurrence of bowlders 7 or 8 inches in diameter in Head Mountain, described by Rogers,[3] may be cited.

As illustrating the thinning of the beds to the northwest, as well as indicating the radius of the thickened formation of the Southern Anthracite field, it may be of interest to quote a number of measurements of the Pottsville in other regions, in both the anthracite and the bituminous basins. From a thickness of about 1,200 feet in the type section, or nearly the same on the Broad Mountain at the northern

[1]In this connection I should add that my measurement from the A coal to the top of the red shale agrees exactly with that published by Mr. Ashburner in section 49, in columnar-section sheet ii, Pt. I of the Atlas of the Southern Anthracite Field. Coal B, however, appears, as is described by Smith, to be at least 202 feet higher than A, instead of but 115 feet, as stated by Ashburner in his report of the Anthracite Survey for 1883, p. 80 [202 feet on p. 106].

[2]I. C. White, Bull. U. S. Geol. Survey No. 65, p. 185.

[3]Geol. Pennsylvania, Vol. II, Pt. I, p. 22.

margin of the Southern Anthracite field, the Pottsville formation decreases to about 850 feet at Shamokin Gap, toward the west end of the Western Middle Anthracite field, and to 830 feet, more or less, at the Mahanoy tunnel at the eastern end of the same field. Here the upper conglomerates often contain pebbles of the size of an egg, while the lowest beds are interlarded with red shale, as in the Southern Anthracite field. A very rapid change is to be observed in the basins of the Eastern Middle field, where the contact with the red shale becomes distinct. Thus in the Silver Brook Basin, on the southern border of that field, the formation is but 500 feet thick, while in the Upper Lehigh, on the north, it is said to be not over 200 feet in thickness. The measurements of the formation in the Northern Anthracite field vary, the average being about 225 feet. It is undoubtedly much less than this at points, such as the well-known fossil plant and insect locality at Campbells Ledge, near Pittston, where, if Dr. I. C. White is correct in the recognition of the equivalent of the Mauch Chunk formation, the Pottsville, assigned a thickness of but 54 feet by him, can hardly exceed 100 feet at most, as limited according to the standard employed in the bituminous basins.

The diminution of the formation from 1,100 feet at Rattling Run, in the Dauphin Basin, to 160 feet in the Broad Top field is perhaps less remarkable than the decrease in passing from the Southern field to Upper Lehigh, which is but 18 miles from Tamaqua and 14 miles from Nesquehoning. Both of the thinner sections may be considered as offshore stations, as compared with the thick sections farther to the southeast. It is, however, difficult to form an estimate of the relative remoteness of any of these points from the original coast of the interior Carboniferous sea.

In the Bernice Basin, Sullivan County, the Pottsville does not appear to exceed 125 feet in thickness, and a similar measurement is reported where the formation touches the New York State line. Throughout most of the bituminous basins in southern and western Pennsylvania, including the northern margin of the coal field, near the Ohio line, the formation averages about 250 feet, more or less, in thickness. Southwest of Broad Top, on the Potomac River, the section is somewhat thicker, and from that point the Pottsville shows a generally, though not invariably, increasing thickness until we reach the Kentucky-Virginia border, where it probably exceeds 2,500 feet.

## VARIATION IN THE CONSTITUENT TERRANES OF THE FORMATION.

It needs but a comparison of the carefully measured, detailed columnar sections of diamond-drill bore holes and of tunnels, published in Pts. IV and IV B of the Atlas of the Southern Anthracite Field, to demonstrate not only the variability in the thickness and composition of the Pottsville strata, but also the astonishing lack of continuity among even conspicuous and important strata. In fact, I know of no region in the Appalachian trough in which the local irregularities of the coal-bearing formations are more marked than in the Southern Anthracite field. It is not difficult to account for this irregularity on the hypothesis I accept in explanation of the conditions attending the deposition of the Schuylkill-Swatara and Virginia sections. The formation of beds of coal under such conditions seems to necessitate the assumption either that there existed, at various times on the surface of the Pottsville terrace or fan, coastal lagoons or protected basins, the sluggish water supply of which was laden for short periods with little else than vegetable matter, or, as appears more probable, that, as the result perhaps of occasional uplifts, large areas lying within bars or shoals were converted during short intervals of quiescent stability into Carboniferous swamps or lagoons in which considerable irregular deposits of plant matter accumulated before the current erosion of the barriers or the renewal of the general movement of submergence terminated the conditions favorable for coal formation and permitted the invasion of the coarsely detritus-laden waters. The interruption of the general subsidence by short periods of elevation and stability, while permitting at once the accumulation of vegetable matter in one region and the seaward extension of the submarine terrace in another during the periods of higher level, accounts also for the readiness with which the conglomeratic sediments, which usually almost directly, when not immediately, overlie every Lykens coal, were swept across the carbonaceous deposits on the recurrence of the general downward movement.

The variability in the thickness of the coals, their irregular intervals and distribution, as well as the fact that the areas containing the lower Lykens coals are so restricted, compared with the area of the anthracite fields, appear to sustain this hypothesis as explaining both the deposition of the coals and the extent of the formation.

As partially illustrating the variation of the several members of the Pottsville formation in the mining district of the Southern Anthracite field, while showing the prevailing intervals between the coals, the following incomplete table is presented, although it is extremely fragmentary and evidently insufficient to serve as the basis of any important generalizations.

*Table showing intervals between the principal Lykens coals in the Lincoln-Lykens mining region.*

[The intervals indicated are those between the horizons in whose columns the numbers occur.]

| Locality. | Distance from coal named below to next horizon under which record is placed. | Lykens coal No. 1. | Lykens coal No. 2 or 3. | Lykens coal No. 4. | Lykens coal No. 5. | Lykens coal No. 6. | Top of red shale. | Total from Buck Mountain coal to red shale. |
|---|---|---|---|---|---|---|---|---|
| Pottsville Gap | Buck Mountain. | 380 ? | 170 ? | 160 ? | 60 ? | ...... | 425 ? | 1,195 |
| Broad Mountain (near Gordon plane). | .....do ..... | ...... | ..... | 480 | ...... | ...... | ...... | ........ |
| Swatara Gap | .....do ..... | ...... | ..... | 640 | ...... | ...... | 385± | 1,025± |
| Rausch Gap (Schuylkill County). | .....do ..... | ...... | ..... | ...... | 910 | 65 | 230 | 1,205± |
| Colket | .....do ..... | 103 | ..... | ...... | ...... | ...... | ...... | ........ |
| Lincoln | .....do ? ..... | 250± | 370 | 245 | 120 | 48 | ...... | ........ |
| New Lincoln | .....do ..... | 250± | 320 | 250 | 130 | 47 | ...... | ........ |
| Good Spring | .....do ..... | 210 | ..... | ...... | ...... | ...... | ...... | ........ |
| Kalmia | .............. | ...... | ..... | (+) | 110 | 75 | 25 | ........ |
| Kohlers Gap | Buck Mountain. | 372 | 288 | 322 ? | 87 | 90 | 60 | 1,219 |
| Williamstown | .....do ..... | ...... | ..... | 980 | 140 | 75 | 270 ? | 1,460 ? |
| Gratz | .............. | ...... | ..... | ...... | (+) | ...... | 100+ | ........ |
| Shiro tunnel | .............. | ...... | ..... | (+) | 70 | 66 ? | 50?+ | ........ |
| Rattling Run | Buck Mountain. | ...... | 410 | ...... | ...... | ...... | 690 | 1,100 |
| Dull and Hoff shafts, near Big Flats. | .....do ..... | 500± | 200? | 160? | 100 ? | 45± | ...... | ........ |

It is of interest, however, to note a few of the variations, such as that in the interval between the Buck Mountain coal and Lykens coal No. 1, which at Colket is 103 feet; at Good Spring, 4 miles west, 210 feet, while at New Lincoln, farther south, but in reality about 2½ miles from either Good Spring or Colket, it is 250 feet. Similarly, the interval between the Lykens coals 5 and 6, which is but 47 or 48 feet in the New Lincoln and Lincoln mines, measures 75 feet at Kalmia, with which direct underground connection is made, while the same thickness is observed at Williamstown.

In passing from the subject of the variability of the terranes of the Pottsville formation, it should be observed that the succeeding Coal Measures also, especially in the Panther Creek Basin and the regions west of Pottsville, show the continuation of conglomerate sedimentation in enormous quantities, though the formation is generally softer than the Pottsville. In certain instances conglomeratic sandstones and conglomerates compose about one-third or more of the entire section. As might be expected, this feature, which is well illustrated in the sections located in the Tremont region[1] and in the Panther Creek Basin, is not less striking than the astonishing variability in the thickness of the intervals separating the coals of the Productive Coal Measures in the same regions. In this connection it is both interesting and instructive to make a comparison of the columnar sections published in columnar-section sheets x of Pt. IV, vi of Pt. II, and iii of Pt. I, of the Atlas of the Southern Anthracite Field.

## NOTES ON OR DESCRIPTIONS OF SOME OF THE MORE CHARACTERISTIC SPECIES OF FOSSIL PLANTS OF THE POTTSVILLE FORMATION IN THE SOUTHERN ANTHRACITE FIELD.

It was my original purpose to have the description of the stratigraphy of the Pottsville formation in the Southern Anthracite field accompanied by full descriptions and illustrations of the fossil plants, which, with the exception of *Spirorbis*, rare crustacean fragments, or still rarer cockroach wings, appear to constitute the sole organic remains yet brought to light. When, however, it was found not only that the manuscript and plates were too voluminous for the present form of publication, but also that the subsequent preparation of a complete report covering the fossil plants of the formation in other portions of the Appalachian province would include the republication of many of the descriptions of the fossils from the Southern Anthracite field, it was determined to confine this report to the description, limitation, and definition of the Pottsville formation as found in the type section and region, and such economic or general geologic results as had been reached in the course of the paleontologic and stratigraphic studies in the field, as well as such general or broad correlations as might be proper in a preliminary paleontologic publication.

The following pages are devoted to descriptions of some of the more important stratigraphic species of the several zones of the Pottsville formation or to notes, either relating to species already known elsewhere or concerning forms closely allied to well-known types. Following is a list of the entire flora.

[1] See columnar-section sheet x, Atlas Southern Anthracite Field, Pt. IV B; and columnar-section sheets i and ii, respectively, of Pt. I of the Atlas.

## LIST OF FOSSIL PLANTS FROM THE POTTSVILLE FORMATION IN THE SOUTHERN ANTHRACITE FIELD.

Aneimites pottsvillensis D. W.
Aneimites sp.
Eremopteris subelegans D. W.
Eremopteris sp. No. 1.
Eremopteris sp. No. 2.
Eremopteris dissecta Lx.?
Eremopteris lincolniana D. W.
Eremopteris Cheathami Lx.
Eremopteris decipiens (Lx.).
Eremopteris Aldrichi D. W.
Mariopteris eremopteroides D. W.
Mariopteris pottsvillea D. W.
Mariopteris Phillipsi D. W.
Mariopteris Phillipsi var. intermedia D. W.
Mariopteris pygmæa D. W.
Mariopteris nervosa (Brongn.) Zeill. var. lincolniana D. W.
Mariopteris tennesseeana D. W.
Mariopteris tennesseeana var. hirsuta D. W.
Mariopteris cf. acuta (Brongn.) Zeill.
Mariopteris sp.
Pseudopecopteris obtusiloba (Sternb.) Lx. var. mariopteroides D. W.
Pseudopecopteris cf. squamosa Lx.
Sphenopteris umbratilis D. W.
Sphenopteris Lehmanni D. W.
Sphenopteris Kaercheri D. W.
Sphenopteris simulans D. W.
Sphenopteris asplenioides Sternb.
Sphenopteris sp.
Sphenopteris dadeana D. W.
Sphenopteris divaricata (Goepp.) Gein. & Gutb.
Sphenopteris (Renaultia) microcarpa Lx. var. dissecta D. W.
Sphenopteris Harttii Dn.
Sphenopteris subpinnatifida D. W.
Sphenopteris Monahani D. W.
Sphenopteris (Diplothmema) patentissima (Ett.) Schimp.
Sphenopteris (Diplothmema) furcata Brongn.
Sphenopteris Royi Lx.
Sphenopteris novalincolniana D. W.
Sphenopteris novalincolniana var. antecedens D. W.
Sphenopteris palmatiloba D. W.
Sphenopteris palmatiloba var. squarrosa D. W.
Sphenopteris Lutheriana D. W.
Sphenopteris mixtilis D. W.
Sphenopteris pilosa Dn.
Zeilleria cf. avoldensis Stur.
Aloiopteris (Corynepteris) georgiana (Lx.).
Oligocarpia crenulata D. W.
Oligocarpia alabamensis Lx.
Pecopteris serrulata Hartt (non Heer).
Pecopteris sp.
Alethopteris Lacoei D. W.
Alethopteris protaquilina D. W.
Alethopteris lonchitica (Schloth.) Brongn.
Alethopteris lonchitica var. multinervis D. W.
Alethopteris alata D. W.
Alethopteris lincolniana D. W.
Alethopteris magnifolia D. W.
Alethopteris grandifolia Newb.
Alethopteris discrepans Dn.
Alethopteris composita D. W.
Alethopteris Serlii (Brongn.) Goepp.
Alethopteris coxtoniana D. W.
Alethopteris Evansii Lx.
Alethopteris Evansii var. grandis D. W.
Alethopteris sp.
Callipteridium alleghaniense D. W.
Callipteridium suspectum D. W.
Callipteridium pottsvillense D. W.
Megalopteris plumosa D. W.
Megalopteris sp.
Neriopteris lanceolata Newb.
Neuropteris Pocahontas D. W.
Neuropteris Pocahontas var. pentias D. W.
Neuropteris Pocahontas var. inæqualis D. W.
Neuropteris Smithsii Lx.
Neuropteris Aldrichi (Lx.).
Neuropteris Elrodi Lx.
Neuropteris acutimontana D. W.
Neuropteris tennesseeana Lx. MSS.
Neuropteris tenuifolia (Schloth.) Brongn. var. humilis D. W.
Neuropteris sp.
Neuropteris aff. heterophylla Brongn.
Neuropteris ovata Hoffm.
Neuropteris hirsutina D. W.
Neuropteris Desorii Lx.?
Neuropteris fimbriata Lx.
Neuropteris gigantea Sternb.
Neuropteris lunata D. W.

Asterocalamites scrobiculatus (Schloth.) Zeill.
Calamites Roemeri Goepp.
Calamites Haueri Stur.
Calamites approximatus Schloth.
Asterophyllites parvulus Dn.
Asterophyllites arkansanus D. W.
Asterophyllites pennsylvanicus D. W.
Asterophyllites cf. rigidus (Stb.) Brongn.
Annularia platiradiata Lx. MSS.?
Annularia laxa Dn.
Annularia acicularis Dn.
Annularia cuspidata Lx.
Annularia latifolia (Dn.) Kidst.
Calamostachys cf. lanceolata Lx. ?
Calamostachys Knowltoniana D. W.
Palæostachya alabamensis D. W.
Macrostachya sp.
Volkmannia crassa Lx.
Sphenophyllum tenerrimum Ett. var. elongatum D. W.
Sphenophyllum bifurcatum Lx.
Sphenophyllum cuneifolium (Stb.) Zeill.
Sphenophyllum tenue D. W.
Bowmannites ? sp.
Lepidodendron alabamense D. W.
Lepidodendron Veltheimii Sternb.
Lepidodendron clypeatum Lx.
Lepidophloios acutomontanus D. W.
Lepidophloios sp.
Lepidostrobus pennsylvanicus D. W.
Lepidostrobus cf. ornatus L. & H.
Lepidophyllum quinnimontanum D. W.
Lepidophyllum campbellianum Lx.
Lepidophyllum lanceolatum L. & H. var. virginianum D. W.
Lepidophyllum linearifolium Lx.?
Lepidocystis fraxiniformis Lx.
Triletes sp.
Bothrodendron arborescens (Lx.).
Sigillaria ichtyolepis (Presl) Corda.
Sigillaria kalmiana D. W.
Sigillaria lincolniana D. W.
Sigillaria cf. lævigata Brongn.
Sigillaria sp.
Sigillariostrobus ? incertus D. W.
Stigmaria verrucosa (Mart.) S. A. Mill.
Stigmariopsis Harveyi Lx. MSS.
Cordaites Robbii Dn.
Cordaites Phillipsi D. W.
Cordaites angustifolius Dn.
Cordaites grandifolius Lx.
Artisia irregularis D. W.
Cordaianthus spicatus Lx.
Cardiocarpon bicuspidatum (Stb.) Newb.
Cardiocarpon bicuspidatum var. ohioense D. W.
Cardiocarpon Cuyahogæ D. W.
Cardiocarpon minus Newb.
Cardiocarpon late-alatum Lx.
Cardiocarpon disculum D. W.
Cardiocarpon orbiculare Ett.
Cardiocarpon cornutum Dn.
Cardiocarpon elongatum Newb.
Cardiocarpon elongatum var. intermedium D. W.
Cardiocarpon annulatum Newb.
Cardiocarpon Phillipsi D. W.
Cardiocarpon Wilcoxi D. W.
Cardiocarpon Girtyi D. W.
Cardiocarpon obliquum Dn.
Trigonocarpum Noeggerathi (Sternb.) Brongn.
Trigonocarpum ampullæforme Lx.
Trigonocarpum Helenæ D. W.
Trigonocarpum Dawsonianum D. W.
Trigonocarpum ornatum Newb.
Rhabdocarpos (Pachytesta) speciosus D. W.
Rhabdocarpos (Pachytesta) Walcottianus D. W.
Whittleseya Campbelli D. W.
Whittleseya Lescuriana D. W.
Whittleseya microphylla Lx.
Whittleseya elegans Newb. var. minor D. W.
Carpolithes fragarioides Newb.
Carpolithes orizæformis Lx. MSS.
Carpolithes sp.
Carpolithes transsectus Lx.
Sporangites sp.
Fayolia sp.

## NOTES ON CERTAIN OF THE PREVIOUSLY KNOWN SPECIES, AND DESCRIPTIONS OF THE STRATIGRAPHICALLY MOST IMPORTANT FORMS.

### ANEIMITES POTTSVILLENSIS sp. nov.

Pl. CXC, Figs. 1, 2.

Fronds lax, bi- or tri- (?) pinnate; pinnæ slender, slightly flexuose or subgeniculate, loose, slightly irregular, with very slender, sulcate, lineate, narrowly bordered (?) rachis.

Pinnules alternate, distant, open near the base, oblique above, polymorphous, usually asymmetrically ovate or rhomboidal-ovate, sometimes obovate, obtuse, 7 to 18 mm. long, 3 to 11 mm. wide, the lower ones neuropteroid or even triangulo-semicircular, the terminal pinnules cuneate-obovate, generally broad and truncate-rounded, the lowermost sometimes dissected to the base to form young pinnæ of three pinnules, of which the middle one is similar to the ordinary terminal ones, the lateral being rhomboidal, all the pinnules being constricted to a very narrow point of attachment, with straight proximal margins, and very finely lineate lamina between the nerves.

Nervation a little coarse, radiating flabellately from a single basal fascicle, forking three to five times while passing straight to the border, and counting about 25 to the centimeter along the distal margin.

The most common form of pinnule met in the fragments of this polymorphous species is the rhomboidal type, such as is shown in Pl. CXC, Fig. 2, which represents the normal lateral pinnule. In this illustration, which will be supplemented by others in the larger work, the characteristic rhomboidal shape is very imperfectly shown. The sides, especially the superior proximal and the inferior distal margins, are in general nearly parallel. The distal angle is nearly always well marked except in the terminal pinnules, which are cuneate and roundly truncate. An example of the last is seen in Pl. CXC, Fig. 1.

Of the species heretofore published, that to which our species is most similar and most nearly related is *Aneimites adiantoides* (L. and H.) Ett. The extremely close affinity of these two forms may be readily noted by a comparison of the original figure of *Sphenopteris adiantoides*,[1] or that described by Sauveur[2] as *Sphenopteris obtusiloba*, with the specimens in hand.

The Pottsville plant seems to be distinguished from the fern from the Jarrow colliery by its more rhomboidal and angular lateral pinnules, the less dilated or capitate terminals, and, to judge from the figure in the Fossil Flora, by the rather closer, more rigid nervation. One of the specimens from the Culm, figured by Dr. Stur as

[1] Lindley & Hutton, Foss. Fl. Gt. Brit., Vol. II, pl. cxv.
[2] Vég. foss. terr. houill. Belgique, pl. xxv.

*Adiantites tenuifolius* (Ett.) Stur,[1] is also very suggestive of the American species. Still another species from the coal fields of southern Europe, *Aneimites* (*Cyclopteris*) *rhomboidea* Ett. sp.,[2] whose lateral pinnules are very much like some of those in the Pennsylvania plant, has very different terminals, while the lateral ones are more lanceolate.

*Aneimites pottsvillensis*, which in the Southern Anthracite field has been found only in the roof of Lykens coal No. 4, appears to constitute one of the characteristic species of the upper zone of the Lower Lykens division or Horsepen group (Clark formation), where, in southwestern Virginia and West Virginia, it is represented by numerous examples either identical or differing but slightly. The species occurs at the Old Lincoln mine; roof of the Lykens coal No. 4.

### EREMOPTERIS DISSECTA Lx.

One of the most interesting species of *Eremopteris* in the Southern Anthracite field is the *Eremopteris dissecta* described by Lesquereux[3] from the Pottsville series at the Helena mines in Alabama. It is, in general, characteristic of the Sewanee zone in the Upper Division of the Pottsville series. In the Pottsville Gap this species occurs at a horizon probably 380 feet below the Twin coal.

### EREMOPTERIS LINCOLNIANA sp. nov.

Pl. CXCII, Figs. 1, 1a.

Pinnæ compound, somewhat geniculate, very open, slightly lax; penultinate pinnæ alternate, open, the lowermost at nearly a right angle or slightly reflexed, the upper somewhat oblique, usually a little distant, rather slender, slightly rigid, though often curved, linear or linear-lanceolate; ultimate pinnæ or compound pinnules alternate, very open below, rather oblique above, usually hardly touching, generally triangular, the lowest very broadly triangular, approaching a palmate form, the uppermost often rather narrow, very deeply dissected into compound lobes or subdivided pinnules, slightly decurrent at the narrow attachment, and bordering the very slightly flexuose and ventrally canaliculate rachis by a narrow wing; subdivisions or compound lobes separated to near the rachis, hardly touching, affecting a slightly trifoliate arrangement, inflated, usually rather broadly cuneate or obovate-cuneate, laterally more or less distinctly convex, obtuse or obliquely denticulo-truncate at the apex, or cut, often obscurely, in two or three unequal, short, obtuse teeth, the apical lobes becoming, especially near the apex of the pinna, sublobate or sometimes narrow; lamina not very thick, dull, somewhat inflated between the nerves, and distinctly so at the margins of the normally disposed specimens.

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[1] Culm-Flora, Vol. I, p. 65, pl. xvi, fig. 7.
[2] Steinkohlenfl. v. Stradonitz, 1852, p. 12, pl. ii, fig. 5.
[3] Coal Flora Atlas, p. 9, pl. liii, fig. 4; text (1880), p. 293.

Nervation distinct, smooth, depressed in the lower portions of the pinnules; primary nerve rather coarse, distinctly derived somewhat obliquely from the depressed axis of the rachis, forking at a more or less open angle in the base of each lobe or division, and passing with very slight geniculation, while diminishing, to its vanishment at the apex of the pinnule; nervil of each compound lobe or division forking pinnately at a rather open angle, usually in the lower part of the division, to supply a nerve for each ultimate lobe or tooth.

The plant described above differs from other species of the genus yet known to me by its relatively short, broad, laterally convex ultimate divisions, which are, nevertheless, well separated. The final pinnæ are relatively short and compact. This feature as well as the form of the lobes, which in the inferior basal pinnules are sometimes palmately spread, as in *Eremopteris missouriensis* Lx., is one of the more prominent characters by which the plant differs from *Eremopteris artemisiæfolia* (Brongn), to which, as identified in our American collections, *E. lincolniana* is closely related, or possibly ancestral.

Although from the habit and mode of division of the tertiary pinnæ the fern is apparently referable to the Sphenopteroid division of the genus *Eremopteris*, the basal ramification, so far as it can be determined from the specimens before me, imparts a suspicion that the frond of this species, like that from Missouri, may divide in the same manner as the fronds of *Diplothmena*. As stated in the discussion of the ferns from the Lower Coal Measures of Missouri, I believe both species to have been derived from the Archæopteroid stock through the genus *Triphyllopteris*. It seems far from improbable that *Eremopteris*, *Rhacopteris*, *Aneimites*; *Asplenites*, *Sphenopteridium dissectum* (Goepp.) Schimp., and *Sphenopteris excelsa* L. and H. are members of an early comprehensive group of Paleozoic ferns.

This species has not yet been found above the top of the Pottsville series, although it appears to occupy a period near the close of that formation, and to be most closely related to an undescribed form in the lower portion of the Kanawha series in West Virginia. The type specimens are from the New Lincoln mine, where its association in the matrix with *Neuropteris Elrodi* Lx. renders it nearly certain that it comes from Lykens coal No. 2 or No. 3; probably No. 2. With it is also found the *E. Lehmanni*. *E. lincolniana* is also present from the Lincoln mine, where it is associated with the same species as at New Lincoln. In the Pottsville Gap the species occurs 550 feet below the Twin coal; i. e., near the supposed horizon of Lykens coal No. 3.

### Eremopteris Cheathami Lx.

This plant, described by Lesquereux from Rockwood and Tracy City, Tennessee, is one of the most clearly marked and well differentiated fern species of the entire formation. Its most prominent features are the relatively short, remote, ultimate pinnæ, the minutely rugose-striate limb, and the broadly cuneate, compact pinnules and lobes, cut on the oblique distal margins into short, irregular, blunt, claw-like, erect teeth. Unfortunately the presence of the latter, concealed for the most part by their backward curvature in the matrix of the type specimens, is almost wholly ignored in the figures, accompanied by details, published in the Coal Flora.[1]

The pinnules of the species vary conspicuously in size, the largest seen, in terminal fragments, being nearly one-fourth larger than those figured, while the smallest fragment yet observed is that illustrated in pl. civ., fig. 3, of the Coal Flora. The specimens from 550 feet below the Twin coal in the Pottsville Gap are specifically indistinguishable from the typical Tennessee form, though the northern representatives of the species seem more delicate and less coriaceous than the southern originals.

In our Paleozoic plant collections *Eremopteris Cheathami* has sometimes been confounded with *E. decipiens* on the one hand and *Triphyllopteris Lescuriana* (Meek) Schimp. on the other hand. The species described by Meek from the Pocono or Vespertine series, which, judged by its flora, is nearly contemporaneous with and certainly not later than the Calciferous sandstones of Scotland, is easily distinguished by its clearly lanceolate pinnules or lobes, which are often slightly fasciculate in the impression, the Archæopteroid nervation, and the margins not crenulate or sinuate. Besides its occurrence at the Pottsville Gap this species is also found at the horizon of Lykens coal No. 3 at the Lincoln mine.

### EREMOPTERIS DECIPIENS (LX.)

The form which I have described as *Eremopteris decipiens* (Lx.) constitutes, with its several variations near the top of the Pottsville series in northern Tennessee, in southern West Virginia, and in Arkansas, one of the most interesting types of our upper Pottsville flora, combining as it does, in its general aspect, some of the characters of the broad-lobed species of *Eremopteris* with other details common in certain forms of *Pseudopecopteris*. In the general habit of the lower or pinnatifid pinnules of the frond it is distinctly a member of the group represented by *Eremopteris Cheathami* Lx. The flabellate-cuneate mode of division of the pinnatifid ovate-triangular pinnules or young pinnæ, as well as the emarginate-sublobate upper borders of the lobes, bind the plant to the above-named group, although the nervation, which is also consonant with the latter, is seen to develop the Pseudopecopteroid type in the more broadly dilated, trifoliate forms. Among the hitherto-published American types our species is probably most nearly related to the plants figured or identified as *Pseudopecopteris macilenta*

[1] Vol. III, pl. civ., figs. 2-4, p. 770.

[Lx.], from one form of which the differentiation is hardly more than varietal in importance.

*Eremopteris decipiens* differs from *Eremopteris Cheathami*, typically represented in abundant material from Tracy City, Tennessee, by the generally more distant and more distinctly cuneate lobes, which are always crenulate-denticulate along the distal margin, by the rather straighter nerves, and by the generally somewhat larger lobes of the latter. *E. Cheathami*, which seems also to be present in the anthracite region, occupies there, as is usually the case in other regions, a somewhat lower stage than the Pseudopecopteroid group.

The species occurs at both the Lincoln mines, at the North Brookside slope, near Good Spring, and at the prospect drift, near the mouth of the upper Eureka tunnel, as well as at several horizons in the Upper Lykens division at the Pottsville Gap.

### Mariopteris eremopteroides sp. nov.

Pl. CLXXXIX, Figs. 1, 2, 3, 3a.

Frond quadripartite(?), polypinnate, very large, rather dense; primary pinnæ large, very long, of unknown form, with lineate rachis attaining a diameter of 1.5 cm. or more; secondary (?) pinnæ alternate, open, often at a right angle to the rachis, close, sometimes overlapping nearly one-third their width, linear, or linear-lanceolate, tapering to an acute apex, with rather slender, ventrally concave, dorsally terete, very finely lineate, slightly flexuose or flexuose-geniculate rachis; penultimate pinnæ alternate, open nearly if not quite at a right angle to the rachis, close, usually touching, or slightly overlapping, but sometimes, especially in the upper part of the pinna, a little distant, lanceolate or linear-lanceolate, acute, hardly constricted at the base, slightly flexuose-subgeniculate, the lower inferior pinna not specially heteromorphous; ultimate pinnæ alternate, or sub-opposite, open, often nearly at a right angle to the rachis, close, generally touching or slightly overlapping, the smaller and basal ones triangular-ovate, inequilateral, sometimes broadly deltoid, compact, and but little constricted at the bases, becoming lanceolate, somewhat acute, generally slightly subfalcate, the apices inclined upward, the rachis round-sulcate, ventrally terete, dorsally minutely lineate, and bordered by a narrow wing decurring from the limb of the pinnules.

Pinnules alternate, very oblique or nearly erect in the younger pinnæ, distinct to near the apex of the larger pinnæ, close, generally ovate or rhomboidal, rarely obovate, obtuse or obtusely rounded, the upper ones connate for a little distance, the terminal ovate or ovate-triangular, obtuse, obscurely sublobate, the lower ones attached by very broad, oblique, often produced bases, only the lowest lobed pinnules becoming pinnatifid, they being narrowly constricted at the bases, all the pinnules showing at an early stage a marked tendency to division in two to five obtuse, rounded lobes, which, appearing at first as one or two rounded teeth a little above the middle, are gradually cut one-half way to the rachis, sometimes, especially in the somewhat heteromorphous basal pinnules, appearing slighly obovate as the pinnule becomes pinnatifid in its development into a pinna, though generally the ovate or ovate-rhomboidal form, with confluent or hardly constricted bases, is preserved to an advanced stage; lamina of the pinnules not thick, very slightly depressed over the primary nerve in the pinnatifid pinnules, very faintly rugose, especially on the dorsal, minutely striated, surface, and rolled rather strongly backward at the margins so as frequently to make the pinnules or lobes appear more acute than they really are.

Nervation of moderate strength, distinct and very slightly depressed on the ventral surface, very close and in relief on the dorsal surface of the pinnule; primary nerve originating at a narrow angle, nearly opposite the proximal basal sinus of the pinnule, forking at an open angle near its point of origin, and curving strongly outward in the base of the pinnule, then forking pinnately and a little widely to supply a secondary nerve for each lobe, the secondary nerves forking one to four times, at a moderate angle, in passing, a little distant, in a gentle, slight curve to the distal border.

The relation of this graceful and beautiful fern to the genus *Mariopteris* appears to be shown by the development of the frond as well as by the general details of the pinnæ. Nevertheless, the aspect of the pinnatifid portions of the frond, particularly when seen in small fragments, showing the spreading, lobed, relatively unconstricted, extended pinnules, such as that shown in Pl. CLXXXIX, Fig. 3, as well as the nervation, is often so similar to the corresponding parts in some of the smaller, more compact forms of *Eremopteris* as to call in question its generic attitude to the latter. The examination of a large series of specimens shows the species in hand to be, however, one of easily recognized individuality. The very large size of the plant is evidenced by portions of its rachis over 3 cm. in diameter, fragments of rachis, apparently representing one of the larger of the four divisions of the frond, being about 1.5 cm. in diameter when compressed. The rachises of the lateral pinnæ are more slender than in most species of this genus, and are slightly flexuose, in correspondence with the pinnation, even where the axes have attained considerable development.

The salient features which are to be observed at the first glance at small fragments of the fern are a relatively close pinnation, with a tendency to curve upward in the smaller pinnæ, the closeness or connateness of the obtuse pinnules, and the marked tendency to lobation, which shows even in the small and half-developed pinnules, the lobes appearing as one or two or three inconspicuous shoulders, or broad, obtuse, or rounded teeth on the sides of the limb. When further developed this sublobation, which may be seen in specimens from nearly every part of the frond, becomes conspicuous, giving the pinnule in its pinnatifid stage a Sphenopteroid or Eremopteroid phase.

Probably the only species of the genus in our flora with which *Mariopteris eremopteroides* is liable to be confused is *M. pottsvillea.* But although there is a resemblance in portions of the fronds of the two species, sometimes appearing close on a casual glance, it is rarely difficult to distinguish the two forms, even in small fragments bearing simple pinnules, from the upper part of the penultimate pinnæ. The pinnules of *M. eremopteroides* are not so constricted at the base, not so triangular or dilated just above the point of attachment, and, as may almost invariably be noted, they are more or less distinctly lobate or sublobate, even in a younger stage, in which they are still attached by the whole base or even slightly connate. In general, the short pinnæ of the latter species are more dilated toward the base, both the pinnæ and the pinnules being usually smaller, the latter being more frequently connate, as well as lobate and alate. Very often, too, the pinnules are set out from the rachis by a slight elongation of the basal portion or attachment so as to suggest a very short, broad pedicel, sometimes nearly equaling the pinnule in width. The nervation of *M. pottsvillea* is somewhat coarser and noticeably more distant and arched.

The species is abundant at all mines in the horizon of the roof shales of Lykens coal No. 5. Possibly it is present also in the roof of Lykens coal No. 6.

MARIOPTERIS POTTSVILLEA sp. nov.

Pl. CXC, Figs. 3, 3a, 4, 4a, 5, 6.

Fronds quadri- or poly- (?) pinnate, robust, not very dense; penultimate pinnæ alternate, open, the lower at a right angle to the rachis, the upper slightly oblique, rather distant, lanceolate, or linear-lanceolate, slightly contracted at the base; rachis somewhat flexuose, coarsely lineate in the major divisions, more finely and irregularly lineate in the smaller divisions, while in the penultimate and ultimate pinnæ they are slender, slightly flexuose-geniculate, ventrally sulcate, dorsally round, and broadened by narrow decurrent wings of the lamina; ultimate pinnæ alternate or subopposite, open at a right angle or slightly oblique, distant, usually one-half their width or more apart, lanceolate or linear-lanceolate, clearly constricted at the base, with a narrow decurring border.

Pinnules alternate or subalternate, usually distant, oblique, broadly ovate, or ovate-triangular, asymmetrical, obtuse, or obtusely rounded, ventrally arched, distinctly constricted at the broad base, which is marked in all the well-developed examples by an inferior rounded sinus, the uppermost pinnules becoming confluent, more oblique and rounded, blending into the rather long terminal, which often has its obscurely sublobate or sinuate margins rolled back so as to make it appear acute or even muricate; lamina of the pinnules not very thick, dull, becoming decurrent in a very narrow wing along the rachis.

Nervation rather strong, distinct; primary nerve originating low at an acute angle, arching outward, not rigid, forking repeatedly at a moderately wide angle; nervils a little distant, forking one to three times and curving more or less in passing, with diminishing distinctness, to the margin.

The examination of the collections from the geological sections of the Pottsville series, from Pottsville in Pennsylvania to the southern extremity of the Appalachian coal field in Alabama, shows the species described above, with its minor variations, to be one of the most ubiquitous as well as the earliest American representatives of the genus *Mariopteris*. Under the name *Pseudopecopteris muricata* (Schloth.) Lx., it has long been known in the collections from the whetstone beds of Indiana, the Dade coal (Lookout sandstone of Hayes) in Georgia and various points in Alabama. Recent studies in the field show it to be specially prevalent in the middle division of the Pottsville series, to which I have given the name Horsepen group. It is more particularly characteristic of the upper part of this group.

The ordinary ultimate divisions of *Mariopteris pottsvillea*, such as are illustrated in Pl. CXC, Fig. 4, are clearly characterized (1) by the comparative remoteness of the pinnæ and pinnules; (2) by the form of the pinnules, which are broadly ovate, obtuse or obtusely rounded at the apex, dilated above the base, and plainly constricted at the base, and arched ventrally; (3) by the large size of the pinnules, which is greater than any of the earlier round-ovate, inflated-pinnuled forms yet found in what may for convenience be called the *Mariopteris muricata* group; and, finally, by (4) the rather coarse, distinct, curved, rather close nervation, which approaches near to that of *Mariopteris tennesseeana*, a form intermediate between *M. pottsvillea* and *M. muricata* or *M. nervosa*.

The present status of *Filicites muricatus* Schlotheim,[1] or of the types of Brongniart's *Pecopteris muricata*,[2] seems slightly ambiguous, since the *P. muricata* has latterly been united by Zeiller[3] and other European paleobotanists with *Mariopteris nervosa* (Brongn.) Zeill., a form quite distinct from the American material hitherto recognized as Schlotheim's species.

It is true that the difference between the forms originally described under the two names is much less than we have been led to believe from the American interpretations of the illustrations and figures.

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[1] Petrefactenk., p. 409; Flora d. Vorwelt, pl. xii, figs. 21, 23.
[2] Hist. vég. foss., Vol. I, p. 352, pl. xcv, fig. 34; pl. xcvii, fig. 1.
[3] Fl. Foss. bassin houill. Valenciennes, p. 173.

Still, while there is scarcely room for doubt that *M. nervosa* was either derived from *M. muricata* or a common, slightly earlier stock, the analogies of the vertical distribution of the American species of *Mariopteris* lead naturally to the expectation that the latter type will be found to occur considerably lower in the stratigraphic series of Europe and to disappear much earlier than the former, although through a portion of the Coal Measures they may have existed side by side. In the American sections the form designated in this report *M. tennesseeana*, which is possibly nearest to the plant figured as *Pecopteris muricata* by Brongniart, predominates at the base of the Sewanee group and hardly survives in the normal type to mingle with the small, delicate, thin-nerved variety which appears, in the American Carboniferous, to be the earliest representative of *M. nervosa*, occurring in the uppermost portion of the Pottsville series.

The relations of *Mariopteris muricata* and the type designated in our American literature *M. nervosa* have been specially discussed in my remarks on the forms occurring in the McAlester, Indian Territory, coal field.[1]

The characters enumerated above readily distinguish *Mariopteris pottsvillea* from those European forms known as *M. muricata* and *M. nervosa.* The form typically described in the American literature as *Pseudopecopteris nervosa* (Brongn.) Lx. has larger, broad, triangular, acute, closer, unconstricted pinnules, with much stronger, more distant, straighter nerves. The species described in manuscript by Dr. Newberry as *Pecopteris inflata* is a much smaller plant, with sessile, close, thin pinnules and finer nervation. Finally, *M. tennesseeana* is a more robust fern, with compact, close pinnules or lobes, the upper ones confluent, very oblique, and not so contracted at the base.

This species is common at all localities in the horizon of the roof shales of Lykens coal No. 4, and is apparently unknown at any considerable distance from that level.

The plant is found in good examples at the Lincoln mine, the Brookside mines, Williamstown, the upper Eureka drift, and in a shaft about 200 yards northeast of the north Brookside slope, Good Spring; at the Broad Mountain mines, at Swatara Gap, and in the Pottsville Gap.

### MARIOPTERIS PYGMÆA sp. nov.

Pl. CXCII, Fig. 2–6.

Frond small, compact; rachis relatively strong, lineate, deeply depressed, ventrally canaliculate; penultimate pinnæ alternate, nearly at a right angle to the rachis, close, touching or overlapping, lanceolate or linear-lanceolate, acute or acuminate; ultimate pinnæ alternate,

[1] Nineteenth Ann. Rept. U. S. Geol. Survey, Pt. III, p. 475.

very compact, very open, usually touching or slightly overlapping, lanceolate or oblong-lanceolate, acute or sometimes obtusely acute, somewhat rigid.

Pinnules very small, 1.25 to 8 mm. long, 1 to 6 mm. wide, alternate, usually contiguous or slightly overlapping, crowded, very highly inflated, generally ovate, the lowest reniform-ovate, slightly distally apiculate, dilated near the base, conspicuously constricted at the inferior side of the rather broad attachment, those of the middle portions dilated-ovate or ovate-triangular, apiculate or obtuse, the terminal usually short and obtuse or apiculate, or, at the end of the penultimate pinnæ, slightly sinuate-margined, acute or mucronate; lamina thick, very much inflated or arched and smooth ventrally, the margins curving strongly backward, and decurring in a narrow wing along the rachis.

Nervation rather coarse, the nervils concealed on the ventral surface, but somewhat distinct on the concave dorsal surface of the pinnules; primary nerve strong, originating at a narrow angle and sharply marked in the largest pinnules by a vanishing furrow on the ventral surface of the lamina; nervils originating at a rather narrow angle, those in the lower part of the pinnule arching near the primary nerve, and passing, straight or curved, relatively close together, the lower ones forking once, or rarely twice, the upper nervils often simple.

This, the smallest form of the *Mariopteris* group known to me, is unique not only for the minuteness of its pinnules, but for the degree of their inflation and for the crowded arrangement of the pinnules and pinnæ. The fragments represented in Pl. CXCII, Figs. 2–6, are of the average form and size, such examples being abundantly dispersed on some of the shale slabs from the Lincoln mine.

Both *Mariopteris pygmæa* and *M. Phillipsi* belong to a group of small forms of *Mariopteris* that is almost exclusively confined to the Sewanee or Upper Lykens division of the Pottsville series. The smallest representatives are seldom found outside of the uppermost beds of the Sewanee division. The fern from the Tremont region, which is hardly more than varietally different from a form abundant in the roof shales at Lemon's coal mine, in the "coal-bearing shale" of Washington County, Arkansas, is evidently closely related to that described in manuscript by Dr. Newberry as *Pecopteris inflata* from the Sharon coal of northeastern Ohio. Both plants, each of which is very abundant in its own localities, are very rarely found at the same locality, *M. inflata* being generally confined to lower beds in the Sewanee zone.

The genetic relations of the plant from New Lincoln and that from the Sharon coal are corroboratively indicated in the Pottsville Basin itself by the presence of the Arkansas form mentioned above in the rock dump at New Lincoln. The latter is distinguished from the normal *M. pygmæa* by the rather larger, thinner, less inflated, more strongly apiculate pinnules, the nervation being clearer on the ventral surface.

This singular little species is nearly always found in abundance associated with *Neuropteris Elrodi* L., *Alethopteris Lacoei*, and *Sphenophyllum tenerrimum* Ett. var. *elongatum* in the roof shales of Lykens coal No. 2. It has been collected at the lower Eureka drift, the old Lincoln mine, the New Lincoln mine, and at the corresponding horizon in the type section at Pottsville.

### MARIOPTERIS TENNESSEEANA sp. nov.

The fossils which I shall eventually describe in full as *Mariopteris tennesseeana* comprise the unpublished Tennessee material included by Lesquereux in *Pseudopecopteris dimorpha.*

The comparison of the specimens from the horizon of the Sewanee coal at Rockwood, Tennessee, and from the zone of Lykens coals Nos. 2 and 3 in the Southern Anthracite field, with the specimens from the higher Coal Measures at Mount Hope, Rhode Island, and Oliphant, Pennsylvania, which constitute the originals of the species, shows the former to be undoubtedly specifically distinct. They are easily recognized by the open, a little distant, constricted pinnæ, and especially by the obtuse or rounded pinnules, generally ovate-triangular in form, distinctly oblique, never constricted at the base except in the largest, which are becoming pinnatifid; and, though separated almost to the base in the lower portion of the pinnæ, they are seen to be more and more broadly confluent in passing upward, blending in the obtusely sublobate, usually rather blunt terminal portion of the pinnæ. The Tennessee species is further distinguished by the not very strong nervation, which is usually indistinct beneath the rather thick epidermis.

This species occurs in its normal form or as a variety in the Sewanee zone at the Lincoln mine and in the Pottsville Gap.

### SPHENOPTERIS KAERCHERI sp. nov.

Under this name I have described a fern which, in pinnation, size, and general form and arrangement of the pinnules very closely resembles *Eremopteris microphylla* of Lesquereux, from beds presumably in the Sewanee zone at the Helena mines in Alabama. The salient features of this species are the slender pinnæ, the oblique, distant, slightly irregular, somewhat Eremopteroid, often trifoliate pinnules, and the moderately straight and nearly parallel nerves, which are often concealed by the interneural striation of the somewhat inflated limb.

The plant is found at both the Pottsville Gap and at the New Lincoln mine, where it is associated with *Neuropteris Elrodi*, *Sphenophyllum tenerrimum* and *Eremopteris lincolniana*, species indicative of the horizon of the roof of Lykens coal No. 2.

### SPHENOPTERIS ASPLENIOIDES Sternb.

It is much to be regretted that a consistent observance of the law of priority in nomenclature appears to necessitate the use of *Sphenopteris asplenioides* Sternberg in place of the more familiar name *Sphenopteris Hœninghausi* Brongn., under which the former name is inscribed by most authors as a synonym.

Although the species seems, in the Southern Anthracite field, to be very rare in the zone of Lykens coals Nos. 2 and 3, its more common occurrence being in the roof shales of Lykens coal No. 4, in the Lower Lykens division, it has generally a wide range in the thick sections of the Pottsville in the Southern Appalachian region. In the Clark formation, below which it does not yet seem to have been found, the fern is represented by a form with small, compact, round-lobed pinnules and very narrow pinnæ, close to if not identical with *Sphenopteris dicksonioides* Stur, with which it was identified by Professor Lesquereux. In the Quinnimont formation the species becomes developed in its typical form, the plant being abundant and of large size. Above this stage of the Pottsville, in the Sewanee zone, or the Sewell formation, which, as we have seen, is essentially contemporaneous with the flora of the zone of the Lykens coals Nos. 2 and 3, this species is found in a more robust phase, with elongated lobes of the pinnules, often resembling *Sphenopteris elegans*, to which it seems to bear a genetic relation. From this large, cuneate-lobed form, in the upper part of the Sewell formation, the species seems to have very rapidly waned, so that, in the overlying Fayette formation in the Virginia region, it is but very rarely met, and then in a depauperate condition. The fructification on the lobes of the typical form of *Sphenopteris asplenioides* is probably referable to the genus *Renaultia*. As such it may be regarded as generically identical with *Sphenopteris microcarpa* Lx., which it resembles in its punctate rachis and the mode of the development of its pinnules.

In the Southern Anthracite field this species is found chiefly in the horizon of the roof shales of Lykens coal No. 4, at East Brookside, and the Lincoln collieries. Examples of a very small form are present in the roof shales of Lykens coal No. 5 at Williamstown and Big Lick, while the normal form is present in the Pottsville Gap.

### SPHENOPTERIS DADEANA sp. nov.

The specimens which will eventually be described as *Sphenopteris dadeana* comprise several of the types which were included by Lesquereux under the name *Sphenopteris Gravenhorstii* var. *β* Brongn. They differ from the examples figured under the above name[1] by the

[1] Coal Flora, Vol. III, pl. ci, figs. 1, 1a, 1b, p. 763.

punctate rachis, by the broader-lobed, shorter pinnules, the texture of which is more delicate or membranous, and by the relatively simple nervation, the nerves forking more distantly at a narrower angle and curving upward so as often to become nearly parallel in the lobe. The species is quite distinct from the *Sphenopteris fragilis* Sternb., which is cited by Brongniart[1] as a synonym of *Sphenopteris Gravenhorstii*. This plant, which occurs at 710 feet below the Twin coal in the gap at Pottsville, appears to be characteristic of, though of rare occurrence in, the *Mariopteris pottsvillea* zone in the Southern Appalachian region.

SPHENOPTERIS DIVARICATA (Goepp.) Gein. & Gutb.

This species probably bears the closest relation to *Sphenopteris asplenioides*, and appears, as represented by specimens in the Sewanee zone (Upper Lykens division), to be distinguished from the latter chiefly by the short, thick, obtuse, cuneate, often half-flabellate lobes of its more distant pinnules. Even in small fragments it is much coarser than the Larischiform *Sphenopteris asplenioides*.

SPHENOPTERIS MICROCARPA Lx.

This fern, which in its typical form appears to be more or less characteristic of the Clark and Quinnimont formations in the Southern States, is represented in the Upper Lykens division, in the Southern Anthracite field, by a very delicate, deeply cut variety, which I have termed *dissecta*. This variety, which occurs at the New Lincoln mine, is also rarely found in the Sewell formation, in the Virginia region.

SPHENOPTERIS HARTTII Dn.

The specimens from the New Lincoln mine and from the Pottsville Gap, which I refer to *Sphenopteris Harttii*, appear to agree in all respects with examples of that species from the supposed middle Devonian beds at the type locality, St. John, New Brunswick.

SPHENOPTERIS PATENTISSIMA (Ett.) Schimp.

Pl. CLXXXVIII, Fig. 1.

Primary pinnæ probably arranged pinnately along an axis; principal divisions bipinnate or tripinnatifid, ovate-triangular or triangular-acute, inequilateral, lax, with relatively slender, more or less flexuose, narrowly alate rachial axis, which is lineate, narrowly sulcate ventrally, subcarinate dorsally; ultimate pinnæ alternate, distant, open, often at a right angle, flexuose, linear or linear-lanceolate, acute, or somewhat obtuse.

Pinnules alternate, usually distant, very open, often nearly at a

[1] Hist. vég. foss., p. 191.

right angle, ovate, round-ovate, or frequently more or less narrowly triangular, elongate and acute, generally briefly subpetiolate, cut alternately to near the base or midrib into one to five close or distant, more or less divergent, cuneate or rhomboidal divisions, which in turn are once or twice deeply or laciniately incised in narrow, simple, bifid or trifid divergent lobes, each simple linear lobe or tooth having its margins parallel or but slightly converging upward to the very narrow, obtusely rounded apex; lamina not very thick, finely longitudinally lineate, apparently by rows of scaly epidermal cells parallel to the nerves, which are often partially obscured.

Nervation usually visible and of moderate strength; primary nerve curving strongly outward from a very acute-angled, decurrent origin, forking low, the divisions forking repeatedly to furnish a single nervil for each lobule or tooth.

Representatives of this interesting species are not rare in the lower portions of the very thick sections of the Pottsville series in the Virginia, Tennessee, and the Alabama regions, as well as in the Southern Anthracite field of Pennsylvania. While, however, the specimens from some of the localities in the Southern Appalachian coal fields are typical of the form delineated by Ettingshausen, the form described above from the collection before me appears to differ slightly from the Old World types[1] by the generally slightly more flexuose pinnæ, a little greater coherence of the lobes, and a rather less marked tendency of the latter to curve outward. In the second particular they are extremely close to the fragments illustrated by Stur.[2] As may be noted in the fragments illustrated in Pl. CLXXXVIII, Fig. 1, considerable difference exists in the form and elongation of the pinnules in different portions of the frond.

The essential characters of the species are the lax habit, the distant, large, very open, and short pedicellate pinnules, the elongated and loose development, with deep, open sinuses, of the subdivisions, and the linear, very blunt or round-pointed lobules which are hardly contracted below the middle. The somewhat irregular lineation seen in the lamina of the Pennsylvania specimens is clearly visible with a weak lens. Frequently the apices are partly buried in the matrix, or the margin is a little revolute, so as to give the lobules a sharp profile on the rock, but when carefully worked out the tip is found to be rounded. The large pinnules seen in Pl. CLXXXVIII, Fig. 1, are comparable to figs. 7 and 8, pl. ix of the first part of the Culm-Flora.

*Sphenopteris furcata* Brongn., a species whose pinnules resemble those of *S. patentissima*, is distinguished from the latter by the more rigid pinnæ, the closer and more compact pinnæ and pinnules, which

[1] Ettingshausen, Foss. Fl., Mährisch-Schlesischen Dachschiefers, p. 26, pl. vii, fig. 4, text-fig. 13.

[2] Culm-Flora, I; Die Culm-Flora d. Mährisch-Schlesischen Dachschiefers, p. 36, pl. ix, figs. 1-9.

are sessile, often less deeply dissected; and the relatively shorter, less divergent, and frequently slightly constricted lobules of the former species. In *Sphenopteris Royi* the lobules are more oblique, more broadly coherent, and acute. Finally *Sphenopteris patentissima* is in general more characteristic of the Culm or Carboniferous limestone of the Old World or of the lower Pottsville in the New, while *S. furcata*, its probable descendant, is later in its appearance, passing from the upper Pottsville into the Lower Coal Measures.

*Sphenopteris patentissima* is common in the roof shales of Lykens coal No. 5, and more especially of Lykens coal No. 4, of which it is largely characteristic, at the Brookside and Lincoln mines, as well as at the mines in the Lower Lykens division, on Broad Mountain. It is also present in the zone of Lykens coal No. 4 at the Pottsville Gap.

### SPHENOPTERIS (DIPLOTHMEMA) FURCATA Brongn.

The examination of the American material belonging to the group represented by *Sphenopteris furcata* shows an interesting series of slight modifications. The earlier forms, characteristic of the uppermost beds of the Pottsville formation, are so closely related to *Sphenopteris Royi* that the two are sometimes difficult to distinguish. The pinnules of the former are, however, generally more dilated, the laciniæ more divergent, acute, and less coherent. The species appears to have diminished in size in the Lower Coal Measures, where it is perhaps inseparable from the type described by Lesquereux as *Sphenopteris trichomanoides* Brongn. Frequently the reduced size and the obliquity of the pinnules and lobes appear to distinctly relate it to *Sphenopteris dissecta* and *S. alata*. The species is readily separated from *Sphenopteris patentissima*, of the Lower Lykens division, by the very distant and deeply palmately lobed lower pinnules of the latter, the lobes being relatively long and hardly contracted near the base. In the Southern Anthracite field, *Sphenopteris furcata* occurs in the upper part of the Sewanee zone at the Pottsville Gap and at the New Lincoln mine.

### SPHENOPTERIS ROYI Lx.

The salient feature of this species, which was described by Lesquereux,[1] from the roof of the Sewanee coal at Rockwood, Tennessee, is the obliquity of the rather distant, pinnatisect pinnules, whose very narrow lobes are fixed on a somewhat more elongated axis than in *S. furcata*, or *S. patentissima*, while at the same time they are very oblique, tapering from a slightly coherent base to an acuminate point. Superficially, this species seems to be intermediate between *S. alata* on the one hand and *S. furcata* on the other hand. It is found with *S. palmatiloba* at the New Lincoln colliery. A small and doubtful fragment comes from the Upper Lykens division in the Pottsville Gap.

[1] Coal Flora, Vol. III, p. 768, pl. civ, figs. 7-10.

### Sphenopteris pilosa Dn.

The specimens, including the types, from the upper portion of the Pottsville in Washington County, Arkansas, described by Lesquereux[1] as *Sphenopteris communis*, appear to present the identical specific characters seen in examples of *Sphenopteris pilosa* from the so-called middle Devonian beds at St. John, New Brunswick. In the Sewanee zone, which includes the Arkansas beds, of which the species is characteristic, we find it associated, as at St. John, with *Pecopteris serrulata*. The specimens from the Southern Anthracite field are found near the supposed horizons of Lykens coals No. 2 or 3, at about 465 feet below the Twin coal, in the gap at Pottsville.

### Aloiopteris georgiana (Lx.).

The material described by Lesquereux as *Pecopteris georgiana*[2] is generically identical with the *Aloiopteris Sternbergii*, *A. Winslovii*, and *A. erosa* of the Productive Coal Measures. The species is notable for the great length and proportionate narrowness of the rather distant ultimate pinnæ. The pinnules are nearly always at least tridentate, the primary nerve forking below the middle, and once or twice again in the upper part of the pinnule. The species which is, I believe, the antecedent representative of this group in our American Carboniferous is readily distinguished from *A. Winslovii* by its narrower ultimate pinnæ, the small pinnules, and the coriaceous texture. The pinnules are proportionately a little farther distant, narrower, and distinctly curved, the teeth sharp and directed forward, the nerves curved and strong. Compared with *A. Sternbergii*, the Georgia species is much more cristate, the teeth more acute, the nerves stronger, more open, and more upturned. The normal type is apparently characteristic of the *Mariopteris pottsvillea* zone in the Lookout formation in northwestern Georgia. The specimens in hand are from the roof of Lykens coal No. 4, at the Lincoln colliery.

### Oligocarpia alabamensis Lx.

Specimens from the Lincoln colliery agree in all respects with typical material from Helena, Alabama, the original locality of the species. The plant appears to be, on the whole, characteristic of the basal portion of the Sewanee zone, though it may be found in the upper part of the *Mariopteris pottsvillea* zone.

### Pecopteris serrulata Hartt.

The representatives of this species in the Pottsville formation appear to be in all respects in agreement with those from the type locality at

[1] Coal Flora, Vol. III, p. 762, pl. xciv, figs. 1 and 1a.
[2] Ibid., p. 759, pl. xcviii, figs. 6 and 6a.

St. John, New Brunswick. With the exception of a few fragments supposed to have come from the roof of Lykens coal No. 4 at Brookside, the species is not known below the Sewanee zone in the United States. Its geographic distribution in this zone is wide, the same form being collected in the shales over the Sharon coal in northwestern Pennsylvania, the Sewell coal in the Virginia region, the Sewanee coal in Tennessee, and in the coal-bearing shale in Washington County, Arkansas. In the upper part of the Sewanee zone this plant appears to merge into the form commonly known as *Pecopteris plumosa* Artis. In fact, in the region of the Fayette formation the latter appears to have succeeded the New Brunswick fern.

ALETHOPTERIS LACOEI sp. nov.

Pl. CXCIII, Figs. 1, 2.

Secondary pinnæ linear-lanceolate, very long, acute, slightly narrowed at the base, often gently curved, with a distinctly lineate rachis; ultimate pinnæ of moderate size, usually alternate, but often sub-alternate, sub-opposite, or rarely opposite, open at nearly a right angle to the rachis, usually close, sometimes slightly overlapping, more rarely a little distant, somewhat curved, linear-lanceolate, or linear, tapering to a slender, acute point; rachis finely lineate, rather deeply depressed, strongly concave and canaliculate ventrally, dorsally terete.

Pinnules alternate or sub-alternate, the lowest open nearly to a right angle, close or a little distant, slender, linear-triangular, or ovate-triangular when small, hardly constricted at the base, tapering gently through the lower third, the margins converging a little more rapidly in the upper two-thirds, acute or slightly obtusely pointed, cut to near the rachis with a rather broad, acute sinus, regularly and strongly crenulate-inflated in all portions of the frond; lamina rather thin, very strongly ventrally convex, alternately strongly inflated and transversely depressed at regular intervals of from 1 to 2 mm., according to the size of the pinnules, the margins being often slightly infolded dorsally so as to give the pinnules a tapering acuminate apex.

Nervation distinct, regular; midrib moderately strong, hardly decurrent, straight, deeply depressed, tapering gradually, but distinct to the apex; nervils slender, relatively regular, rather close, hardly decurrent, simple or forking once close to the base, and passing nearly straight and parallel to the border.

*Alethopteris Lacoei* is one of the smaller or more delicate species of the genus, its form and general proportions being closely comparable to *A. Mantelli*,[1] or the smaller, narrow-pinnuled phases of *A. lonchitica*. It is, however, very well marked by the alternating strong

[1] Brongniart, Hist. vég. foss., p. 278, pl. lxxxiii, figs. 3, 3a, 4.

inflations of the ventrally convex lamina, which gives the margin a slightly sinuate trend. This alternately inflated development of the lamina, suggesting a series of rectangular cushions on either side of the midrib, or the expressions of distant sori through the substance of the fern, is a constant character plainly discernible in all parts of the frond.

The aspect of the larger pinnules is very much like that represented by Brongniart[1] in *Pecopteris marginata.* But, while the resemblance of the undulate surface and sinuate margins is close, the species from Pennsylvania differs by its smaller size, greater delicacy, narrower pinnules, longer and narrower terminals, as well as by the absence of the flat border of the Old World type. Quite independent of the inflation of the lamina, *A. Lacoei* is separable from the *A. Mantelli* and *A. lonchitica* series by the form of the pinnules, which are hardly narrowed at the base, but which taper from the base upward, the apices generally appearing as acute. The nerves, which may fork close to the midrib, are nearly straight and regular in passing at a right angle to the margin, thus differing from those of the *A. Serlii* or *A. grandifolia* types. The latter, however, are too distinct in other respects to require further comparison.

Although this species is common at the horizon of Lykens coal No. 2 in the Southern Anthracite field, it is generally rare in other regions of the Appalachian province. Yet when present it is usually represented by large numbers of individuals. In the anthracite region the species has been found at the New Lincoln mine, the lower Eureka tunnel, and at the supposed horizon of Lykens coal No. 2 in the gap at Pottsville.

### ALETHOPTERIS PROTAQUILINA sp. nov.

The essential features of this species are the small proportions of the pinnæ and the close, very compact, oblong, or linear-lanceolate, obtuse pinnules, in which the limb is of about equal breadth at the base, the terminal being small, rather short, undulate and sub-lobate, while the curved nervation is often concealed within the thick, strongly inflated lamina. The fern belongs to the straight-pinnuled group represented by *A. aquilina*, *A. ambigua*, *A. Gibsoni*, and *A. pennsylvanica.* It is in most cases easily distinguished from the *A. Lacoei* by the tapering, corrugated, more acute, and thicker pinnules of the latter, in which the nervation is more distant. The species is for the most part confined to the roof shales of Lykens coal No. 4, at which horizon it occurs at the Brookside mines and in the Pottsville Gap.

[1] Op. cit., p. 291, pl. lxxxvii, figs. 2, 2a.

### ALETHOPTERIS LONCHITICA (Schloth.) Sternb.

The specimens from the roof of the Sharon coal in Ohio, described by Dr. Newberry under the above name, are probably in closer agreement with the original type than any of the other forms that have been identified under the same name from the Allegheny series of this country. Most of the latter are probably referable to *Alethopteris Serlii* or *A. aquilina*. A form with narrow pinnules, sometimes approaching *Alethopteris decurrens*, is found in the coals of the Kanawha series in southern West Virginia. The species is represented by the normal form, or by varieties, in the Upper Lykens division at the Pottsville Gap and at the Lincoln mines.

### ALETHOPTERIS GRANDIFOLIA Newb.

This species, described by Newberry[1] from the roof of the Sharon coal, is, in general, characteristic of that horizon throughout the Appalachian province. *Alethopteris Helenæ* Lx. and *Callipteridium Oweni* Lx., both occurring in the Sewanee zone, are so closely related to Newberry's species as to render their specific individuality very doubtful. The group is, in general, characterized by the lax, irregular, and uneven open pinnules, the relatively thin midribs, and the distantly and irregularly flexuose thin nervation. The flora of the Kemble drift constitutes the oldest plant association in which this species has yet been found.

### ALETHOPTERIS DISCREPANS Dn.

The specimens from the New Lincoln mine, which I refer to Sir William Dawson's species, appear to agree in all respects with specimens from the fern ledges at St. John, New Brunswick. The occurrence of this species, together with *Sphenopteris Harttii*, *S. pilosa*, and *Pecopteris serrulata*, in the Upper Lykens division of the Pottsville formation points strongly to the close relationship between the flora of the latter and that of the supposed middle Devonian beds at St. John, a relationship so close as to convince me that no appreciable difference in age exists between the plant beds at the two localities.

### ALETHOPTERIS COXTONIANA sp. nov.

The material which will be described under this name includes the types provisionally referred by Lesquereux[2] to *Callipteridium Dournaisii*. The originals are from Campbell Ledge, in the Northern Anthracite field. The specimens from the Southern Anthracite field were found in the thin parting of the conglomerates at 245 feet below the

[1] Report Geol. Survey Ohio, 1873, Vol. I, Pt. II, p. 384, pl. xlviii, figs. 1, 1a, and 2.
[2] Coal Flora, Vol. III, p. 747.

Twin coal in the Pottsville Gap, while doubtful fragments, representing a rather more elongated form of pinnule, with rather more distant nerves, come from one of the upper Lykens coals at the New Lincoln mine.

ALETHOPTERIS EVANSII LX.

Pl. CXCII, Figs. 7, 7a, 8, 8a.

This species, which was described by Lesquereux[1] from the shales accompanying the Sewanee coal in Tennessee, resembles *Lonchopteris* in the form of its pinnæ and pinnules, while the nervation suggests one of the more oblique-nerved, straight-pinnuled species of *Alethopteris*, or *Callipteridium*. The surface of the lamina is rugose and distinctly, though finely, punctate. The nerves are close, regular, rather oblique, forking once or twice. The normal form of this species appears to be generally confined to the region of the Sewell and Sewanee coals of the Southern Appalachian regions and to the approximate horizon of Lykens coal No. 3, in the Pottsville Gap. A later form, with very much larger, semi-membranous pinnules, occurs at higher horizons in the Sewanee zone, both in Arkansas and in the Southern Anthracite field. Typically, this species occurs 550 feet below the Twin coal in the Pottsville Gap and in the dump from the upper Lykens coals at the Lincoln mine. A variety *grandis* appears to have come from the roof of Lykens coal No. 1, at the latter locality.

CALLIPTERIDIUM POTTSVILLENSE sp. nov.

In this species we have one of the composite Pottsville types, presenting at once characters of *Megalopteris* and *Alethopteris*. The pinnules are elongate, acute, and thick, resembling very closely those of *Megalopteris marginata* Lx.[2] It is also apparently related to *Neriopteris lanceolata* of Newberry.[3] The fern is closely allied to *C. tracyanum* Lx., from which it differs by the oblong, acute, or acuminate pinnules, which are more unequal at the base, and the less distant and generally oblique nerves. The plant occurs in the Upper Lykens division in the Pottsville Gap.

MEGALOPTERIS PLUMOSA sp. nov.

The species of the rare genus *Megalopteris*, including the *Megalopteris Dawsoni* described from St. John, New Brunswick, appear to be characteristic of the Pottsville formation. Furthermore, the greater number of species thus far described are confined to the Sewanee zone in Arkansas, Tennessee, West Virginia, and Ohio, as well as in

[1] Coal Flora, Vol. III, p. 834.
[2] Idem, Vol. I, p. 152, pl. xxiv, figs. 4, 4a.
[3] Rept. Geol. Survey Ohio, 1873, Vol. I, Pt. II, pp. 378–381, pl. xlv, figs. 1, 2, 3, 3a.

Pennsylvania. The most interesting species of this genus occurring in the Pottsville formation of Pennsylvania, *Megalopteris plumosa*, closely resembles *M. Dawsoni* Hartt from the so-called middle Devonian of New Brunswick. It differs from the latter chiefly by the very oblique nervation. The specimens were obtained from a slope in the Upper Lykens division at Yellow Springs Gap.

NEUROPTERIS POCAHONTAS sp. nov.

Pl. CLXXXIX, Figs. 4, 4a; Pl. CXCI, Figs. 5, 5a.

Fronds large, tri- or quadri-(?) pinnate, with very broad, strongly lineate, slightly flexuose rachis, which may attain a diameter of 4 cm. or more; penultimate pinnæ generally alternate, open nearly at a right angle, becoming somewhat oblique above, close, often touching or slightly overlapping, linear-lanceolate or linear, very slightly narrowed at the base, the margins nearly parallel in the middle portions, tapering a little rapidly near the top to an acute apex, the ultimate pinnæ being followed by a few large pinnules, rapidly succeeded by a narrow, basally sublobate, small, obtuse, inequilateral, ovate-triangular terminal, the rachis being rather strong, slightly depressed ventrally, lineate, and a little flexuose near the apex; ultimate pinnæ, alternate or subalternate, open at a right angle below, slightly oblique above, usually slightly overlapping or touching, rarely a little distant, the smallest narrowly oblong, becoming linear, 5 to 30 mm. wide, 12 to 15 mm. in length, the lower small pinnæ very obtuse, the more elongated being rather narrowly obtuse; rachis strong, depressed, lineate, slightly curved or flexuose.

Pinnules small, slightly polymorphous and irregular, alternate or subalternate, rarely subopposite, those in the lower portion of the largest pinnæ or the basal pair in the small pinnæ at a right angle to the rachis, the others more or less oblique, usually touching or even overlapping, more rarely a little distant, laterally unequal, often ovate-round when very small, the lowest pair in the very small pinnæ being often nearly reniform, the succeeding pinnules broadly ovate, narrowly ovate to ovate-oblong, round at the apex, only the lowest pair in the smaller pinnæ, or the lower large pinnules in the large pinnæ, or those a little below the apex of the penultimate pinnæ, constricted to near the midrib, the others being less constricted, especially at the proximal angle, those near the top of the large pinnæ or throughout the greater part of the small pinnæ being attached by more than one-half the width, often nearly the whole width, of the pinnæ, after the type of *Callipteridium*, the terminal being ovate or ovate-oblong in the smaller pinnæ, laterally unequal, sublobate by confluence with the last pinnule on one side, slightly undulate, usually obtuse or rounded at the apex, the terminals of the very large pinnæ being rather more elongated and less broadly rounded or obtuse; lamina thick, slightly coriaceous, a little concave along the middle, somewhat convex ventrally at the border.

Nervation rather coarse, distinct, regular, usually slightly in relief, more or less flabellate in all except the lowest pinnules or the lower part of the largest ultimate pinnæ; primary nerve but slightly differentiated in the small pinnules, or of moderate strength, vanishing near the middle in those pinnules of intermediate size, or passing three-fourths the length of the largest pinnules, decurrent in the smallest, nearer the distal sinuses of the laterally unequal pinnules; nervilles very oblique, often nearly equally close in all parts of the lamina, a large portion springing directly from the rachis, especially in the proximal half of the pinnule in all but the very large or the lowest pair of pinnules, forking twice at a very narrow angle, one or more of the divisions forking again even in the very small pinnules, usually forking three times, sometimes four, in the largest pinnules, while passing, with slight or sometimes no curvature in the smaller pinnules, obliquely to the margin.

The group of modifications or very nearly related forms which is typified by the fern just described is at once the most predominant, interesting, and complex in the fern flora of the entire Pottsville series. The genus is typically distributed in the lower division of the Pottsville series of the Appalachian trough, and wherever fossil ferns are to be found in that division some form or other of the group is present and constitutes by far the most abundant, if not the exclusive, fern species of the flora. Essentially this type is characteristic of the lower division of the Pottsville, it being especially abundant in the vicinity of the Pocahontas coal in the greatly expanded section of that formation in southwestern Virginia. The distribution of the allied forms, as well as the typical form, will receive special attention in another place.

The typical form, described above, the illustrated specimens of which were collected from the roof of the Pocahontas coal in the Flat Top or Pocahontas coal field of southwestern Virginia and southern West Virginia, is especially distinguished from the related forms of the same group by its broadly attached or Callipteridioid pinnules and the obliquity of its nervation, which is close, regular, coarse, and derived in part from the rachis, the midrib being very poorly defined in the small pinnules. Like the other forms from the basal portion of the Pottsville series, it is essentially a *Neurocallipteris*. This synthetic character of the group of old Neuropterids in the earlier Pottsville is particularly important as indicating the common origin of the genera *Neuropteris*, *Callipteridium*, and *Mixoneura*. Certain other Neuropterids of the type of *N. biformis*, which is a typical *Neuralethopteris*, similarly serve as connecting links between the genera

*Neuropteris* and *Alethopteris*. The subject of the origin and relations of these genera to *Megalopteris* and other Paleozoic types has been discussed by me in connection with the description of a somewhat composite form from the Des Moines series of Missouri.[1]

The pinnules of the typical *Neuropteris Pocahontas* are, in general, rather broadly ovate when small, and rounded at the top. The form of the terminal pinnules of the younger pinnæ resembles that of the true *N. Smithsii* as originally described and figured from Alabama, but the latter is considerably smaller and less sublobate, besides being rather narrower. The species in hand is in reality readily distinguished from *N. Smithsii* by its generally larger pinnules, which are broadly attached, more ovate, instead of oval or nearly round, when small; by the far less developed median nerves, and especially by the much less curved nervilles, which are oblique, springing in part from the rachis, and which seldom meet the border at a right angle.

Throughout the Appalachian trough the typical *N. Smithsii* has hitherto been found to occur in later beds than the typical *N. Pocahontas*. The former is, in the central and southern Appalachian districts, fairly characteristic of the next higher divisions of the Pottsville series, the Clark and Quinnimont formations, or the Horsepen group.

The *Neuropteris Schlehani* Stur is with little difficulty distinguished by its narrower pinnules, which are constricted at the base, the midrib well developed, the nervation strongly curved and meeting the margin at nearly a right angle. The form described by Stur as *N. Dluhoschi*, which Zeiller regards as inseparable from the preceding species, has much that is suggestive of the largest phase of the *N. Elrodi* of Lesquereux.

Among the several modifications or variations of *N. Pocahontas* found in different regions of the Appalachian trough two fairly well-marked forms are present in the Lykens coal region of the Southern Anthracite field. One of these is so different from the ordinary type as perhaps to entitle it to more than a varietal distinction. But since its shape and mode of development are so similar to the normal type, since its earlier examples are somewhat intermediate, and because it is often difficult to discriminate between small fragments of the latter and material apparently derived from young fronds or apical portions of primary pinnæ of the normal form, it seems most practicable to give it only formal or varietal rank. It may be termed and characterized as follows:

NEUROPTERIS POCAHONTAS var. INÆQUALIS n. var.

Pl. CLXXXVIII, Fig. 5; Pl. CXC, Fig. 7; Pl. CXCI, Figs. 1–4.

Ultimate pinnæ and pinnules much larger than those of the normal form, often twice as large, somewhat lax, rarely opposite, the pinnules

[1] A new Tæniopteroid fern and its allies: Bull. Geol. Soc. America, Vol. IV, 1893, pp. 119–132, pl. i.

a little more distant, oblique, slightly polymorphous, though generally ovate to oblong-ovate when small, becoming oblong and gradually constricted at the base, the largest attached at the midrib, narrowed a little toward the usually very unequal, obliquely rounded, asymetrical base, the attitude and form a little variable, tapering somewhat in the upper two-thirds, obtusely rounded or rounded at the apex, the terminal often elongate-ovate, often nearly acute, the margins, as in the largest pinnules, more or less distinctly sinuate; lamina thin, very slightly convex ventrally at the border; nervation thin, but very distinct; midrib, when developed, becoming flexuose and vanishing in the upper part of the largest pinnules; secondary nerves a little distant, very oblique, usually forking close to the point of origin, the divisions forking twice or three times in passing to the margin, which, even in the largest pinnules, they meet at varying degrees of obliquity.

This variety presents certain phases which would appear to entitle it to full specific rank, though the presence, at one point or another in the Appalachian trough, of other forms showing every degree of transition or genetic connection renders its specific separation impracticable. It affords a fine illustration of unquestionable modification. Thus, certain of the largest of the pinnules are less obliquely narrowed at the base, more distinctly oblong, and even-margined. Such have in our collections sometimes been confused with *Neuropteris biformis* Lx., and accordingly so recorded in the distribution of that really Alethopteroid and very rare form.[1] The phase whose fragmental (often detached pinnules) representatives have been the subject of this error is somewhat characteristic of the middle portion of the Pottsville series.

Another variation, which can be considered as only varietally or perhaps formally distinct from the one in hand, is seen in the plants from the Dade mines in northwestern Georgia, described and illustrated as secondary types of *Neuropteris Smithsii*.[2] While the Dade plants show an outline and habit hardly distinguishable from the variety in hand, they reveal a rather coarser nervation, which is more open near the midrib, often slightly flexuose, and usually a little more distant. A comparison of the types, or even of figs. 1 and 2, pl. xiii, of the Coal Flora, the originals of *N. Smithsii*, with the illustration of the Dade specimen, pl. xcvi, fig. 3, of the same work shows at a glance the specified differences in the fossils. The true *N. Smithsii* has small pinnules open at a right angle, quite constricted at the base, well

[1] The latter, as seen in examples from Alabama, some of which were identified by Professor Lesquereux, have long, tapering pinnules, thick, persistent midribs, strongly arched close nervation, the terminal and preceding pinnules being almost typically Alethopteroid. These features, slightly imperfectly shown in the Coal Flora (p. 121, pl. xiii, fig. 7) will later be more fully illustrated from typical material.

[2] Lesquereux, Coal Flora, Vol. III, p. 734, pl. xcvi, figs. 3, 3a. No. 1156 Lacoe Collection, United States National Museum.

developed midribs even in the small pinnules, with very open nervation originating from the midrib. It is, moreover, a much smaller species.

Many of the larger pinnules, with strongly oblique, unequal bases, are possibly suggestive of the *Neuropteris antecedens* of Stur, from the Hainichen-Ebersdorf beds. The very strong resemblance of specimens from the Kalmia mine to *Cardiopteris eriana* Dawson[1] is worthy of note, as is also the association of the latter with the *Odontopteris squamosa* Dn.,[2] which deserves a special comparison with the *Neuropteris Pocahontas* group of Pottsville forms.

NEUROPTERIS POCAHONTAS var. PENTIAS n. var.

Pl. CLXXXVIII, Figs. 2, 3, 3a, 4; Pl. CLXXXIX, Figs. 5, 5a, 5b.

The other Lykens form of *Neuropteris Pocahontas*, to which reference has been made above, is, so far as I have observed, nearly everywhere slightly older than the one above mentioned, its habitat in the southern field being essentially in the lowest of the Lykens beds, coals Nos. 5 and 6. It may be distinguished from the normal type and other forms as follows:

Pinnules smaller than the normal type, very broadly attached, hardly so crowded, more distinctly triangular, laterally unequal, oblique, the terminals as well as the largest pinnules more elongate, often sinuate-margined, narrower and more acute, the proximal basal pinnule situated in the angle of the pinna, the nerves regular, more slender, rather closer, often less oblique at the border, the lamina being thick and faintly irregularly striated between the nervilles, very many of which, in all but the large pinnules, spring directly from the rachis.

Occasionally the younger pinnules of this variety assume a distinctly and rather broadly triangular form, while the pinnæ are much more slender and acute, the narrow terminal being not infrequently sinuate-margined. The nervation of this form is fairly distinct, though thin, the nerves close, regular, and in the larger pinnules often nearly at a right angle to the border, although occasionally they turn upward slightly just before reaching the margin. The surface of the rather thick pinnules is often shiny, though when viewed under the lens it is seen to be irregularly striate as though impressed by minute scaly hairs nearly parallel to the nervation, as indicated in Pl. CLXXXIX, Fig. 5b. The terminal pinnules of the larger pinnæ are slender and acute, those of the smaller lateral pinnæ being proportionately long.

This, the more apiculate variety of *Neuropteris Pocahontas*, is not likely to be confused with any of the other forms or varieties of the species, on account of the form and attachment of the pinnules and the nervation. *N. Smithsii*, which at times it somewhat resembles, differs, among many characters, by its basally constricted, short pin-

[1] Foss. Pl. Erian, Pt. II, 1882, p. 114, fig. 4. [2] Op. cit., p. 114, fig. 2.

nules, the obtuse, short terminals, the distinct midrib, and the open, slightly flexuous nervation.

The normal form of *Neuropterus Pocahontas* is not so abundant in the Lower Lykens division of the Southern Anthracite field as in the vicinity of the Pocahontas coal in the Southern Appalachian region. It is, however, found at the Brookside mines, at Kalmia, at Williamstown, at the Swatara Gap, and in the gap at Pottsville. The variety *inæqualis*, though often difficult to distinguish from the normal form in small fragments, is more readily discernible in specimens from the roof of the Lykens coal No. 4, where it occurs at the Brookside mines, at the Lincoln mine, at Kalmia, at the upper Eureka drift, at Rausch Gap, at the shaft 160 yards northeast of the North Brookside slope, at the Swatara Gap, and at the Pottsville Gap. The variety *pentias* is, as has several times been remarked, confined, so far as is known, to the roof shale of Lykens coal No. 5, or to lower horizons. Typically, at least, it does not seem to occur so high as Lykens coal No. 4. Specimens of this variety are present in the collections from the Lincoln colliery, from the Brookside mines, from the Kalmia colliery, from the west side of Rausch Gap, Schuylkill County, and from a low bed in the Pottsville Gap.

NEUROPTERIS SMITHSII LX.

The typical form of this species, first described by Professor Lesquereux from the Warrior coal field in Alabama, is illustrated in pl. xiii, figs. 1, 2, 3, and 3[a] of the atlas to the first volume of the Coal Flora, page 106. The original or true form is characterized by the very small oval pinnules, which are completely constricted at the base; by the development of a distinct though not strong midrib; and by the open angle of origin of the nervilles, which pass slightly irregular to the margin, meeting the latter nearly at a right angle. The terminal pinnules are always short, obtusely rounded, and inequilateral. This form, which is common in the upper part of the Clark formation in West Virginia, and which appears to be represented by a slight modification in the horizon of Lykens coal No. 4 in the Southern Anthracite field, is quite distinct from the plant of Callipteridioid habit, with broadly attached pinnules, and flabellate, oblique nervation, from the Dade coal in Georgia, figured in the third volume of the Coal Flora under the above name.

*Neuropteris Smithsii* is without difficulty distinguished from *Neuropteris Pocahontas* by essentially the same differences as those indicated above in speaking of the Dade fern. The pinnules of the variety *pentias*, while often of the same size as those of *N. Smithsii*, are conspicuous for their broad attachment, trianguloid form, and Odontopteroid nerves, while the terminals are elongated and more acute. *Neuropteris Elrodi*, which is characteristic of the Sewanee zone of the Pottsville formation, is distinguished from *Neuropteris Smithsii* by its triangular, more unequal, inflated pinnules, with persistent midribs, and more open, strongly backward-curved nervation. *Neuropteris Smithsii* has been collected at the Brookside and Lincoln mines; at Kalmia, the upper Eureka tunnel, the Broad Mountain mines, and the Lower Lykens division in the Pottsville Gap.

### NEUROPTERIS ELRODI LX.

The plants from the Southern Anthracite field identified under this name agree with the original specimens described and figured by Lesquereux[1] as having been derived from the Montevallo coal in Alabama. The character of the matrix is, however, very distinct from that of other material in the collection from that locality, it being in very close agreement with specimens from the Whetstone beds of Indiana, in which this species is also said to have been found. I suspect that the types originated in the Whetstone beds. The originals represent a species quite different from that in the roof of the Sewanee coal in Tennessee, later figured[2] by Lesquereux under the same name. The latter is, perhaps, inseparable from *Neuropteris Schlehani* Stur. The differences between this species and *Neuropteris Smithsii*, the only species in the Pottsville flora with which *Neuropteris Elrodi* is liable to be confused, have been noted in the remarks on the former. *N. Smithsii*, it will be remembered, is characteristic of the *Mariopteris pottsvillea* zone in the Lower Lykens division, while *Neuropteris Elrodi* is almost exclusively confined to the Sewanee zone of the Upper Lykens division, though in its typical form it is not common at so low a horizon as that of the Sewell-Sewanee coal.

The fern has been found in the horizon of Lykens coal No. 2, at the Lincoln mines, at the North Brookside slope, and in beds at approximately the same horizon in the Pottsville and Westwood gaps.

### NEUROPTERIS ALDRICHI (LX.).

This species, which was described by Lesquereux[3] as *Callipteridium Aldrichi*, from the Black Creek coal at the Jefferson mines in Alabama, represents a peculiar form, rather closely related to *Neuropteris Smithsii* and *Neuropteris Elrodi*, although sometimes suggesting *Oligocarpia* or *Pecopteris* in the form of its pinnæ and pinnules. It constitutes one of the singular composite types in the Pottsville formation, and it will be described and further illustrated in connection with the monographic treatment of the flora of the Pottsville formation in the Appalachian province.

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[1] Coal Flora, Vol. I, p. 107; Atlas, p. 3, pl. xiii, fig. 4.
[2] Ibid., Vol. III, p. 735, pl. xcvi, figs. 1, 2.
[3] Ibid., Atlas, p. 7, pl. xxxviii, figs. 1, 1a, 1b, 2, 3; text, Vol. I (1880), p. 171.

NEUROPTERIS TENNESSEEANA Lx. MSS.

The fragments representing this species, from a bed about 550 feet below the Twin coal in the gap at Pottsville, appear to agree in all respects with the types described in manuscript by Professor Lesquereux as *Neuropteris tennesseeana*. This species, which seems to have been derived from the original *Neuropteris Pocahontas* stock, and which has many features in common with *Neuropteris heterophylla*, appears to be characteristic of the lower portion of the Sewanee zone, in both the Walden formation in Tennessee and the Upper Lykens division in the Southern Anthracite field.

NEUROPTERIS OVATA Hoffm.

The normal form of this species, which elsewhere is not known at so low a horizon as the uppermost beds of the Pottsville formation, appears to be present in the Southern Anthracite field in one of the shale partings in the topmost group of conglomerates, at 245 feet below the Twin coal. The variety *antiqua*, which is characterized by slender, apiculate pinnules, very broadly attached to the rachis, and by the unusually oblique nervation, is present in material from the rock dumps at the Lincoln collieries, although I am not certain to which of the Upper Lykens coals the fragments should be referred.

NEUROPTERIS GIGANTEA Sternb.

Under this name I provisionally refer the material described by Professor Lesquereux[1] as *Neuropteris subfalcata*. The original form, as described and figured by Sternberg, if present in our Carboniferous basins, appears, so far as yet known, to occur only in the topmost beds of the Pottsville formation. Most of these specimens from the roof shales of Lykens coal No. 2, or from the higher horizons of the Sewanee zone, are generally more elongated than the Old World type. The examples from the Kemble drift appear to represent a new variety, *clavata*, the most salient or distinctive features of which are the generally greatly elongated, though somewhat polymorphous, pinnules, which are frequently broader in the upper third than in any other portion of their length; the extremely slender and poorly defined median nerve; and the very oblique, close, hair-like, parallel nervation, a portion of which springs directly from the rachis.

NEUROPTERIS LUNATA sp. nov.

Pl. CXCIII, Figs. 3–7.

Frond and mode of development of the pinnæ probably similar to those of *Neuropteris gigantea*, the rachis attaining a width of 12 mm. or more, very distantly but coarsely punctate, the penultimate rachis being

[1] Coal Flora, Atlas, p. 3, pl. xiii, figs. 5, 6; text, Vol. I (1880), p. 102.

provided, between the ultimate pinnæ, with polymorphous broad, short pinnules.

Pinnules of the ultimate pinnæ linear-, or slightly triangular-linear-subfalcate, usually short, four to six times as long as broad, with narrow cordate or slightly squarrose base, tapering upward toward the obtuse or obtusely acute apex, and usually turned upward with a uniform curve throughout the whole length, though often nearly straight; the rachial pinnules triangular, triangular-ovate, cordate, or even cordo-reniform, and very small; lamina a little thick, depressed in a narrow, rather shallow furrow along the median line, slightly convex ventrally, especially at the margin.

Nervation sharply distinct, ventrally depressed, dorsally in relief; median nerve not very strong, but distinct and traceable to very near the apex; nervilles originating at a moderately open angle, a little distant, forking at a slightly open angle near the base, and similarly once or twice again, according to the size of the pinnule, in curving toward the margin, which they meet obliquely, except in the lower part of the pinnule, counting about 30 to 38 per centimeter.

Although the pinnules of this species occur in great abundance on the surface of the shales, no large segments of pinnæ have been found. Nevertheless, the presence of the small and somewhat polymorphous pinnules, corresponding to those from the rachis in the preceding species, as well as the phases and similar characters of the large pinnules, strongly indicates a development of the pinnæ in the same general manner as in *Neuropteris gigantea*, to which it is undoubtedly closely related.

The most noticeable features of the pinnules are their slenderness, the crescentic curvature, the squarrose-cordate base, the distinct midrib, and the slightly distant nerves, which fork a little widely, although the divisions may at once assume a nearly parallel direction.

The pinnules of *N. lunata* are more slender than those of *N. gigantea*, and proportionately less acute, the curvature, when present, being generally more uniformly distributed, slightly crescentic, through the whole length instead of being expressed as an upward turn near the apex. Often, however, they are but slightly curved or nearly straight. The midrib is much stronger and more persistent even than in *N. Zeilleri* Pot.,[1] it being clearly traceable, though thin, very nearly to the apex. The angle of division of the nerves, as noted above, appears greater than in the last species, and is certainly much greater, while the nerves are less oblique, than in *N. gigantea* var. *clavata*. Some of the small roundish rachial pinnules seem, when detached, to be not separable from similar small basal pinnules in some other species of *Neuropteris*. But the average pinnules may be

[1] Jahrb. d. k. Pr. Geol. Landesanst u. Bergakad., Vol. XII, p. 22, pls. ii-iv, text fig. 1-4.

easily differentiated by their form and nervation from any other species with which I am familiar. Occasionally a small narrow pinnule, such as that in Fig. 7, suggests, particularly in its nervation, pinnules of *N. rarinervis*. Even these may be separated by recalling the dilated and distinctly cordate bases and the slightly concave lateral margins of the latter.

This species is abundant in the roof shales over Lykens coal No. 1 at the Lincoln mines.

### ASTEROPHYLLITES PARVULUS Dn.

The specimens from the Southern Anthracite field which I refer to this species appear to be in complete agreement both with the plant originally described under the above name from the supposed middle Devonian beds at St. John,[1] New Brunswick, and with the material from Rushville, Ohio, described by Andrews[2] as *Asterophyllites? minutus*.

Subsequent stratigraphic and paleontologic study of the deposit of dark leathery shales at Rushville shows them to be probably not far from the horizon of the Sharon coal in Ohio. Many of the examples of the *Asterophyllites* from the Southern field are even smaller than those figured by Sir William Dawson and Professor Andrews. This species, perhaps the smallest of its genus, is closely related to *Asterophyllites arkansanus* and *A. grandis*. Although to a certain extent characteristic of the Sewanee zone throughout the central Appalachain region, the *Asterophyllites parvulus* is not only common in the same zone of the anthracite region, but it is often abundant in the roof shales of Lykens coal No. 4, in which horizon it is found at the Brookside and Lincoln mines.

### ASTEROPHYLLITES ARKANSANUS nom. nov.

The species to which I give the name *Asterophyllites arkansanus* is that known in the American literature as *Asterophyllites gracilis*, a name which, unfortunately, must be abandoned, the *A. gracilis* (Sternb.) Brongn. having priority. As originally described[3] by Lesquereux, from the coal-bearing shales of Arkansas, the species is especially characterized by the thick axes of the branchlets, the angularity and dilation of the internodes, and the strongly reflexed, outward-curved, slightly angular, and rapidly tapering, small, acute leaves. The plant is found associated with the Upper Lykens coals at the Lincoln mines and at the supposed approximate horizon of Lykens coal No. 3 in the gap at Pottsville.

[1] Dawson, Acadian Geology, 1868, p. 540, fig. 188 A[a-c]; Fossil Plants of the Devonian and Upper Silurian Formations of Canada, 1871, p. 27.

[2] Rept. Geol. Survey Ohio, 1875, Vol. II, Pt. II, p. 424, pl. li, figs. 4, 4[a].

[3] Rept. Geol. Surv. Arkansas, Vol. II, 1860, p. 310, pl. ii, figs. 4 and 4[a].

ANNULARIA ACICULARIS (Dn.) Ren.

This species, which is, perhaps, most closely related to *Annularia radiata* Brongn., and which was described by Dawson from the fern ledges (Lancaster formation) at St. John, New Brunswick, as *Asterophyllites acicularis*, is not rare in the Sewanee zone of the Pottsville formation, its most frequent occurrence being in the upper part of that zone. Its salient features are the slender axis and the very slender leaves, which are distinctly narrowed, in tapering form, both toward the base and toward the apex. It has been very well illustrated in the publications of Sir William Dawson.[1] The plant occurs in the Sewanee zone at the Lincoln mine and in the Pottsville Gap.

ANNULARIA CUSPIDATA Lx.

The typical form of this species, as illustrated by Lesquereux,[2] from the dark shales at Rushville, Ohio, has a rather wide geographic distribution throughout the Appalachian region, in the uppermost part of the Sewanee zone, or in the zone of Lykens coal No. 1, it being one of the characteristic forms of that portion of the sections. In the Southern Anthracite field it occurs in the roof of Lykens coal No. 1 at the Lincoln mine, and in the plant beds 380 feet below the Twin coal in the Pottsville Gap.

ANNULARIA LATIFOLIA (Dn.) Kidst.

A comparison of the material in hand with specimens from the middle Devonian at St. John[3] unquestionably shows the specific identity of the American material with that from New Brunswick. It is, perhaps, specifically indistinguishable from the leaf verticils from Campbell Ledge described by Lesquereux[4] as *Calamites ramifer* Stur. In the Pottsville formation this species, which appears to stand in an ancestral relation to *Annularia stellata*, occurs near the horizon of the Lykens coal No. 1—i. e., near the base of the Fayette formation in the Virginia region and in bed L, 380 feet below the Twin coal, in the Pottsville Gap.

SPHENOPHYLLUM TENERRIMUM Ett. var. ELONGATUM n. var.

Pl. CXCIII, Figs. 8, 9.

This variety differs from the species as described by Ettingshausen[5] chiefly by the considerably larger size of the verticils and the more

[1] Quart. Jour. Geol. Soc. Lond., Vol. XVIII, 1862, p. 310, pl. xiii, fig. 16a 16b; Acadian Geol., 1868, p. 555, fig. 194 H[1]; Fossil Plants of the Devonian and Upper Silurian Formations of Canada, 1871, p. 28, Pl. V, figs. 54a-c, 57.

[2] Coal Flora, Vol. III, p. 725, pl. xcii, fig. 7, 7a.

[3] Dawson, Quart. Jour. Geol. Soc. Lond., Vol. XVIII, p. 311, pl. xiii, fig. 17a-c; Acadian Geol., 1868, p. 538, fig. 187 A and D[1]; Geol. Hist. Plants, 1888, pp. 78, 265, fig. 28a, D., D[1].

[4] Coal Flora, Vol. III, p. 703, pl. xci, figs. 4 and 4a.

[5] Helmhacker, Beitr. Kenntn. Südrandes Oberschl. Pol. Steinkohlenf., p. 28, pl. iii, figs. 5-16; Stur Culm.-Flora, Pt. II, p. 108, pl. vii, text figs. 21a-c, p. 110; 22, p. 111; 23 A-F, p. 114; 24, p. 115.

frequent dichotomy. The proportions of the variety are very nearly those of the form described by Stur[1] from the Schatzlar series. The plant in hand differs from *Sphenophyllum bifurcatum* by its more slender stems, by its more delicate, narrower, more rigid, and deeply dissected leaves, and by the linear, obtuse form of the lobes. *S. bifurcatum* is more nearly connected by its variable leaf, which is often much less divided, to the *S. cuneifolium* group than is the above-named variety, all of whose leaves are of the more linear, entirely dissected, delicate type. In the Southern Anthracite field this variety appears to be one of the plants characteristic of the horizon of the roof shales of Lykens coal No. 2, where it is almost invariably associated with *Neuropteris Elrodi*, *Mariopteris pygmæa*, and a small species of *Eremopteris*. It is especially common in this horizon at the Lincoln mines.

SPHENOPHYLLUM BIFURCATUM Lx.

This species, as originally described by Lesquereux, from beds now known to lie within the Sewanee zone of the Pottsville formation in Arkansas, appears, as has already been suggested, to be intermediate between *Sphenophyllum tenerrimum* and *S. cuneifolium*. The less-divided leaves of the Arkansas plant might easily be mistaken in some cases for the latter species. It differs, however, in the position of the leaves and their aspect in the verticils, in the wider form of the leaf, and in the more distant and generally more rigid teeth. The distinctions between *Sphenophyllum bifurcatum* and *S. tenerrimum* have already been indicated. The former is not infrequent in the upper part of the Sewanee zone; more rarely it is found in the lower part of the same zone. In the Southern Anthracite field it is found over the coal mined at Kohlers Gap; at the horizon of the roof of Lykens coal No. 2, at the North Brookside slope; and in the Pottsville Gap at the approximate level of Lykens coal No. 3. A form of doubtful specific identity occurs at a level supposed to be not far above that of the roof of Lykens coal No. 4 at the Kemble drift on Broad Mountain.

SPHENOPHYLLUM CUNEIFOLIUM (Sternb.) Zeill.

As has already been noted in the discussion of the floras in the several horizons of the Pottsville formation, two forms which appear to be referable to this species occur in this formation. The first, which is represented by the type figured by Lesquereux in fig. 9, pl. xciii, Vol. III, of the Coal Flora, is especially characterized by its slender, narrow, lax form, thin, rather membranous texture, equal teeth, and slender, fine nervation, the forking of which occurs mostly in the lower part of the leaf. The second form may be briefly described as more closely resembling the smaller, narrower, and often dissected leaves

[1] Die Calamarien d. Schatzlarer Schichten, 1887, p. 202, pl. xv, figs. 1a, 1b, 4.

of *Sphenophyllum emarginatum*. It exhibits the more rigid type of leaf, with the coarse nervation of the latter, to which the Pottsville form appears to stand in an antecedent relation. The leaves of the first type, which is more typical of the horizon of the Sewell-Sewanee coal, or Lykens coals Nos. 2 and 3, in the Southern Anthracite field, are relatively rarely dissected, while those of the second or more rigid type, which occurs in the Upper Intermediate division in the anthracite region, are nearly always unevenly dissected.

SPHENOPHYLLUM TENUE sp. nov.

Pl. CXCI, Figs. 6, 7.

Stems slender, distinctly though not very prominently ribbed, carinate, 1 to 3 mm. in diameter, branching a little freely, the branches, often in verticils of three, springing from within the bases of verticils of very deeply dissected leaves; nodes distinct, 1 to 5 cm. distant, usually having the leaves still attached; leaves in verticils of six, oblique at the base, very rapidly spread in nearly equidistant radiation, broadly cuneate, 1 to 2 cm. in length, usually about 8 mm. in width, very thin or membranous, lax, the apices round-truncate, more rounded near the angles, sometimes with a faint sinus at the center, crenulo-denticulate in 12 to 24 short, broad, round-obtuse teeth, or rarely more or less dissected in broad, very lax, obtuse, usually bi or tri dentate laminæ, the lateral margins distinctly, sometimes rather strongly, concave and converging downward in a slender, very narrow, relatively long, slightly thickened base; primary nerve single and rather strong for some distance in the lower part of the leaf, forking four or five times at a slightly narrow angle in passing upward, slender and delicate, to furnish one nerville for each tooth or denticulate crenulation.

The salient features of this species are the large, membranous, very broadly cuneate, crenulate-denticulate, slightly rounded leaves, with distinctly if not conspicuously concave lateral margins and long slender bases, in verticils of six, on very slender stems. The aspect of the somewhat rounded, rarely sinused apex, the transparent lamina, and the narrow, slender bases, below such broad apices, make the plant easily recognizable among the other species of its genus. The nervation is thin and delicate, derived by numerous bifurcations from a rather thick, single, primary bundle that passes for some distance through the narrow base of the leaf before dividing. Leaves of the dissected type, such as that shown in Pl. CXCI, Fig. 7, are more rare. Although they bear a closer resemblance to the laciniate forms of other large-leafed species, they are easily distinguished by the irregular, very broad, obtuse, and lax type of the lacineæ, which show a markedly broad spread at the top, and by the concave lateral profile and the slender, almost stalk-like base, as in the normal form. The leaves at the base of the branch verticil are much more elongated and deeply and narrowly cut than in the normal type.

*Sphenophyllum tenue* appears to be related to the *S. majus* of Bronn, though the differences noted above seem to readily distinguish it from that as well as other species. It is also closely allied to another very large-leafed species, not yet described, from the Vespertine or Pocono series (basal Carboniferous) of southwestern Virginia, between which and the former it appears to be intermediate.

The species here described is one of the most beautiful as well as widely distributed plants of the Pottsville series, ranging in identical forms along the Appalachian trough from Pennsylvania southward to Warrior, Alabama. In general it is quite characteristic of the middle or Horsepen division (Clark formation) of the Pottsville series, to which its horizon in the roof of Lykens coal No. 4 also belongs. Although several fragments from near coal No. 2 or No. 3 at the New Lincoln mine appear so nearly in agreement with the types as to be not readily distinguishable from the typical form, I have not met it elsewhere in the Upper Lykens division or the Sewanee zone. It is not certain that the specimen is from the Upper Lykens division. In the Southern Anthracite field the species occurs in the roof shales of Lykens coal No. 4, at the Brookside and Lincoln collieries, the Kemble drift, the North Brookside prospect shaft, and in the gap at Pottsville.

### Lepidodendron alabamense sp. nov.

The species which will later be described in full and illustrated under the above name includes the specimens from the upper part of the Clark and from the Quinnimont formations in the Virginia region, and from the vicinity of the Warrior coal in the Alabama section, included by Lesquereux[1] in *Lepidodendron Sternbergii*. It belongs to a Lepidodendroid type presenting several phases or modifications in the different zones of the formation. Typically, however, as seen in the region of Lykens coal No. 4, or in the Quinnimont formation, in which it is generally found in association with *Mariopteris pottsvillea*, *Neuropteris Smithsii*, *Sphenophyllum tenue*, *Lepidophyllum quinnimontanum*, and *Trigonocarpum Helenæ*, it is especially characterized by the robust, thick branchlets, densely clothed with thick, rigid, rather short leaves, which, though very oblique at the bases, rapidly curve outward, upward, and then inward, while tapering gradually, so that their upper portions assume a distinctly incurved or somewhat uncinate form. Stems and branches of this type are present in the roof shales of Lykens coal No. 4 at the Brookside mines and at Kalmia, and in the Pottsville Gap at a horizon about 775 feet below the Twin coal.

[1] Coal Flora, Vol. II, p. 366.

LEPIDODENDRON CLYPEATUM LX.

To this species, which has been well illustrated by Professor Lesquereux,[1] I refer most of the specimens from the Sewanee zone in Arkansas and Alabama labeled in our collections as *Lepidodendron Veltheimianum* Sternb. Some of its phases are only with difficulty distinguished from the type described by Sternberg as *Lepidodendron Rhodeanum*,[2] which, in turn, appears to be closely related to and often confused with *Lepidodendron obovatum* of Sternberg. The forms I refer to *Lepidodendron clypeatum* have a wide distribution in the Pottsville formation in the Southern Anthracite field, their range being from the horizon of the roof shales of Lykens coal No. 4, or possibly No. 5, to the level of Lykens coals Nos. 2 and 3, from which the specimens are specially abundant as well as typical.

LEPIDOPHYLLUM QUINNIMONTANUM sp. nov.

This species of *Lepidophyllum* constitutes one of the characteristic types of the *Mariopteris pottsvillea* zone throughout the Appalachian region, although it rarely occurs in the horizons of the roof shales of either the Pocahontas coal or the Lykens coal No. 5. The collections from the Southern Anthracite field contain one or two specimens which may possibly have come from the shales of Lykens coals Nos. 2 and 3. The species is especially characterized by the linear-lanceolate form of the bracts, which are 5.5 to 8 cm. long and 10 to 13 mm. wide at the widest point—some distance above the middle. The sporangiophores are cuneate and proportionately long, their length being usually over one-fourth that of the blade, which is dilated and auriculate at the base, slightly contracted just above, and which tapers with slightly convex borders from its widest point, above the middle, to an unusually narrow acuminate apex. The midrib is broad and strong throughout, while the lamina is obscurely lineate longitudinally, the lines slightly diverging toward the margin. The most important differentiative features are the relative length of the base, the dilation in the upper part of the blade, and the acute apex. The bracts are much larger and generally longer than those of *Lepidophyllum campbellianum*,[3] the sporangiophores of which are short, small, and generally rather broadly cuneate. So far as the distribution of these two species has yet been observed in the Pottsville formation, it appears that *L. campbellianum* is characteristic of the Sewanee zone and the Upper Intermediate division, while *L. quinnimontanum* is, in general, almost exclusively confined to the Lower Lykens division. The latter species is present in the roof shales of the Lykens coal No. 5 at the

[1] Geol. Pennsylvania, Vol. II, Pt. II, p. 875, pl. xv, fig. 5; pl. xvi, fig. 7. Coal Flora, Atlas, p. 12, pl. lxiv, figs. 16 16a (not figs. 17, 18).

[2] See Stur, Culm-Flora, Pt. II, p. 283, pl. xxiii, fig. 1; pl. xxiv, fig. 1-3.

[3] Lesquereux, Coal Flora, Vol. III, p. 786, pl. cvii, figs. 6, 7.

Lincoln colliery, though its frequent occurrence at other localities is at or near the horizon of Lykens coal No. 4.

BOTHRODENDRON ARBORESCENS (LX).

The examination of the stem fragments in the types described by Lesquereux as *Lycopodites arborescens*[1] reveals leaf scars showing the typical characters of the genus *Bothrodendron*. The collections in hand from the lower portion of the Kanawha series in West Virginia show that this genus is not rare at that stage in the Coal Measures in the United States. *Bothrodendron arborescens*, the originals of which are from the Sewanee zone in Washington County, Arkansas, while the Pennsylvania representatives occur in the plant beds 380 feet below the Twin coal in the Pottsville Gap, appears to constitute the oldest representative of the genus yet discovered on this continent.

CORDAITES ROBBII DN.

The identity of the leaves from the Pottsville formation with the species described by Dawson[2] from the fern ledges at St. John, New Brunswick, seems to be fully assured by a comparison of material from the type locality. The species appears to be especially common in the Upper Lykens division of the formation, although it has a wider vertical range. It is quite possible that the form which will eventually be described as *Cordaites Phillipsi* is not more than varietally distinct from the St. John type. In the Southern Anthracite field the species occurs, as at St. John, in association with *Cardiocarpon cornutum*. It is found at the supposed horizon of Lykens coals 2 or 3, about 550 feet below the Twin coal, in the Pottsville Gap, in the shales accompanying the upper Lykens coals at the Lincoln mines, in the Lower Lykens division at the Brookside mines, and in the Lincoln mine. It is also found accompanying the upper Lykens coal in Yellow Springs Gap.

CORDAITES ANGUSTIFOLIUS DN.

The material which I refer to this species appears to be in agreement with the species figured by Sir William Dawson from the fern ledges at St. John,[3] rather than with the material earlier described[4] from the Devonian at Gaspé. If the Gaspé fossils are specifically different from those at St. John, as appears to be the case from an inspection of the figures, the name should be retained for the Gaspé

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[1] Coal Flora, Vol. III, p. 778, pl. cvi, fig. 1. Lacoe collection, United States National Museum, Nos. 5559, 5560, and 5567.

[2] Quart. Jour. Geol. Soc. Lond., Vol. XVIII, p. 316, pl. xiv, fig. 31a-c; Acadian Geol., 1868, pp. 534 and 544, fig. 190; Fossil Plants of the Devonian and Upper Silurian Formations of Canada, 1871, p. 43, pl. xiv, figs. 156-162, 156a.

[3] Quart. Jour. Geol. Soc. Lond., Vol. XVIII, p. 318; Fossil Plants of the Devonian and Upper Silurian Formations of Canada, 1871, p. 44, pl. xiv,, fig. 163a-e.

[4] Canadian Naturalist, Vol. VI, pp. 170 and 176, fig. 11c; Logan, Geol. Canada, 1863, p. 399, fig. 428.

types. From an examination of examples from St. John, I am disposed to regard the latter as possibly young leaves of *Cordaites Robbii*, to which they are undoubtedly at least very closely related. In the anthracite field, as at St. John, both species occur in the same beds.

CORDAITES GRANDIFOLIUS Lx.

The most conspicuous features of this interesting species are the great breadth and broadly cuneate form of its large leaves. The base is narrow, the lateral margins always more or less strongly concave, and the distal margin, or top, rounded or round-truncate, and cut, in the older examples, into short, broad, unequal, round-truncate lobes. In fact, the general form, texture, nervation, and the mode of lobation at the apex are suggestive of the Ginkgoales. This species appears to be present in the material from the west side of Kohlers Gap in Bear Mountain, and from the rock dump from one of the upper Lykens coals at the New Lincoln mine. The originals described by Lesquereux[1] are from Campbell Ledge, near Pittston, Pennsylvania.

WHITTLESEYA ELEGANS Newb. var. MINOR n. var.

The interesting type of vegetation described by Dr. Newberry[2] from the roof of the Sharon coal at Tallmadge, Ohio, as *Whittleseya elegans*, has been discovered at a number of other points in the Sewanee zone, throughout the Appalachian province. At various localities and horizons a number of additional species or varieties have also come to light. The leaves of the variety *minor* are much smaller than those of the normal form, and are proportionately broader, they being usually a little broader than long. The nerve fascicles are also a little more crowded, numbering about fifteen to the centimeter at the top. The form, texture, and nervation of this species, which can hardly be else than a gymnosperm, are such as to appear to justify its reference to the Ginkgoales. The variety was obtained from the parting between Lykens coals Nos. 2 and 3 at the Lincoln mine.

WHITTLESEYA MICROPHYLLA Lx.

The salient features of this species, described by Lesquereux,[3] are the small size, the distinctly cuneate form, and the fasciculately fibrous texture of the leaves, which range from 5 to 15 mm. in length and average about 6 mm. in width. The fasciculate nerve bundles, which, as in *W. elegans*, are in part derived from the thickened lateral margin in the base of the leaf, constitute rather poorly defined longitudinal ribs, each of which enters a usually obscure, rounded tooth in the

[1] Proc. Am. Philos. Soc., Vol. XVII, 1878, p. 318, pl. xlviii, figs. 1, 2, 2a. Coal Flora, Atlas, p. 16, pl. lxxvii, figs. 1, 2, 2a; text, Vol. I, p. 530.

[2] Annals Sci., Cleveland, Vol. I, 1858, p. 116, figs. 1, 2a-b. Lesquereux, Coal Flora, Atlas, p. 2, pl. iv, figs, 1, 1a. Renault, Cours. bot. foss., Vol. IV, p. 69, pl. v, figs. 9 and 10.

[3] Coal Flora, Vol. III, p. 843.

distal margin. The latter appears slightly crenulate. The distinctly cuneate form and small size of this species, which is intermediate to the broad *W. elegans* on the one hand and the lineate *W. Campbelli* on the other, readily separate the leaf from those of other species in the genus. From a stratigraphic standpoint this type appears to be one of the most important, since it seems almost exclusively confined to a small vertical range above the level of the Sewanee coal.

The representatives of this species in the anthracite field are from the roof of Lykens coals 2 or 3 at the New Lincoln colliery.

### WHITTLESEYA CAMPBELLI sp. nov.

Pl. CXC, Figs. 9, 10, 11.

Leaves, very small, linear or slightly oblong-linear, 12 to 22 mm. long, 2.25 to 5 mm. wide, generally 12 to 15 mm. long and 2.5 to 2.75 mm. wide, often very slightly cuneate, straight or slightly arched laterally, acuminate at the rapidly contracted base, the lateral borders nearly parallel from a point less than one-fourth of the way from the base upward to very near the truncate, acutely though very obscurely denticulate apex, where they normally converge somewhat, the outer teeth being inclined inward and usually crowded against or overlapping the interior teeth; texture densely fibrous, thick, more or less distinctly rounded-ribbed by 3 to 5 longitudinal, parallel, finely lineate ridges produced by the very thick contiguous fascicles of nerves, each of the dense, broad fascicles entering a tooth; petiole filamentoid, lax, very faintly striate, blending with the slightly thickened margins of the acuminate base of the leaf; nervation distinct, dividing at or near the base in 3 to 5 or 6 close, greatly thickened fascicles, giving the leaf a parallel-ribbed and striated surface, the nerves of each fascicle being slightly connivent in one of the apical teeth of the leaf.

The species described above is one of the most widely distributed plants in the Pottsville series, in which it ranges horizontally from northern Ohio and northeastern Pennsylvania to the overlap of the Cretaceous in Alabama, and vertically from near the base of the Pottsville to the base of the main upper plexus of conglomerates. So far as is yet known, this species was the earliest of the representatives of its genus to appear, it being found, in the deepest section of the Appalachian Basin, nearly 1,000 feet below the levels of *Whittleseya elegans* or *W. microphylla*, and several hundred feet lower than any of the other closely related, more or less linear forms.

In general it presents a great uniformity in its features, there being no marked variation in either form or size among the abundant examples which are to be found at nearly every locality. Some modifications are, however, to be seen in the course of its vertical range, as well as in its local development. Thus the oldest observed forms were prevailingly small, not over 13 mm. long, and narrow, though the species soon assumed its normal proportions in the Clark and Quinnimont divisions of the Pottsville in the central Appalachian region, and near the horizons of the Lykens coal No 4 and the lower Lykens coals of the Southern Anthracite field. Occasionally larger or longer leaves occur locally in the Lower Lykens division; but in the Sewanee-Sewell zone, or Upper Lykens division, a larger form is somewhat characteristic, while in the upper part of the series, at certain points in the Southern States, and in the roof of Lykens coal No. 2, a very much elongated slender form is found to prevail, almost if not quite exclusively, locally. It is also possible that the large, arcuate leaves which occur near Birmingham, Alabama, and at the Kemble drift and Kohlers Gap, are hardly specifically separable from the species in hand, notwithstanding their local abundance and exclusiveness.

The characters of the bases and petioles of these leaves are shown in Pl. CXC, Fig. 9. Typical examples are illustrated from the Lykens coal No. 5 in Pl. CXC, Figs. 10 and 11. The specimen seen in Fig. 10 is below the average in size. As will be observed on an inspection of the drawings, the mode of origin of the nerve fascicles, the slightly ribbed character of the leaf, its dense fibrous texture, the teeth, in which the nerves of each fascicle appear to be somewhat connivent, and the nature of the petiole, all indicate its common generic relation to *Whittleseya microphylla* and *W. elegans.* Owing to the thickness and inward inclination of the teeth, the latter are often obscured by imbrication or superposition. Not infrequently, however, they are spread out erect, when the clearness of the dentation, the vascular system, and the slightly cuneate outline show their congeneric relation to the species considered in the preceding sections, some of the cuneate forms thus approaching the *W. microphylla.* Remark should be made of the presence, about 470 feet below the Buck Mountain coal, of a straight, normally cuneate-linear form attaining a length of 35 mm. and a width of 6 mm.

As with the other species of the genus, none of the leaves of *Whittleseya Campbelli* have yet been seen with absolute certainty to be attached to any branch or axis, though they are sometimes found in large numbers matted together, their bases obliquely converging toward a common axis. I suspect the fruits of the plant to be referable to *Rhabdocarpos.*

*Whittleseya Campbelli*[1] is at once distinguished by its linear form and small size from all the species of the genus yet described.

The species occurs at nearly all localities of the Pottsville formation in horizons below the Fayette sandstone of Virginia, the Conoquen-

[1] The species is named in honor of my esteemed colleague, Mr. M. R. Campbell, geologist in charge of the areal cartography of the Central Appalachian coal fields, to whom I am greatly indebted for abundant assistance in the collection of fossil material from all possible localities in that region as well as for valuable stratigraphic data.

nessing sandstone of northwestern Pennsylvania, and the upper plexus of conglomerates in the anthracite regions. In the Southern Anthracite field it is found at a number of horizons in the Pottsville Gap, the Swatara Gap, Rausch Gap, the Lincoln and Brookside mines, the Eureka tunnels, Williamstown and Big Lick mines, Millers drift, Kalmia mine, and the Kemble drift. A very large form occurs at about 450 feet below the Twin coal in the Pottsville Gap. The elongated type mentioned above occurs in the roof of Lykens coal No. 2 at the lower Eureka tunnel and at the New Lincoln mine. A type probably representing the same form occurs at 380 feet below the Twin coal in the Pottsville Gap.

### CARDIOCARPON GIRTYI sp. nov.

Pl. CXCIII, Fig. 11.

Seeds flat, or nearly so, not very large, ovate-cordate, 10 to 11 mm. long, 10 mm. in diameter at the broadest point, a very little below the middle, with rather shorter nucleus, rounded at the base, apiculate at the top, and bordered by an extremely broad wing; wing nearly circular in form, 9 to 13 mm. in width, slightly cordate by a shallow sinus at the point of contact with a not very distinct chalaza, a little broader on either flank of the base, and a little narrower at the immediate top, where it is cut to a depth of 2 mm., with rounded edges, in a narrow, acute, micropylar sinus.

The conspicuous features of this species are the nearly circular form of the wing and the great breadth of the latter, which nearly equals, if not exceeds, the longer diameter (1 cm.) of the nucleus. As may be observed by an inspection of the figure, Pl. CXCIII, Fig. 11, the nucleus is somewhat shorter than the outer test. From the intermediate space at the apex the micropylar tube passes, as a thickened double line, to the angle of the sinus. A slight, somewhat cuneate, thickening of the chalaza at the base of the nutlet may also be seen. *Cardiocarpon Girtyi*, together with *Cardiocarpon Phillipsi*, *C. Newberryi*,[1] *C. samaræforme*,[2] *C. annulatum*,[3] *C. dilatatum*,[4] and *C. ingens*,[5] constitute a group of large, broad-winged species of the genus, whose occurrence is characteristic of the Upper Lykens division or the Sewanee zone of the Pottsville, although some of the species occur very near to the upper limit of the formation. *Cardiocarpon Baileyi*,[6] from the so-called middle Devonian at St. John, New Brunswick, appears to be a very closely related species. This group seems also to bear a close affinity to the Old World fossils described by Fiedler[7] as *Jordania bignonioides* and *J. oblonga*.

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[1] Andrews, Rept. Geol. Survey Ohio, 1875, Vol. II, Pt. I, p. 425, pl. xliv, fig. 2.

[2] Newberry, Rept. Geol. Survey Ohio, 1873, Vol. I, Pt. II, p. 375, pl. xliii, figs. 11, 11a.

[3] Op. cit., p. 374, pl. xlii, fig. 8.

[4] Coal Flora, Vol. III, p. 806, pl. cx, fig. 2.

[5] Op. cit., Vol. II, p. 563, pl. lxxxv, figs. 34, 35.

[6] Dawson, Fossil Plants of the Devonian and Upper Silurian Formations of Canada, 1871, p. 60, pl. xix, fig. 219.

[7] Foss. Früchte d. Steinkohlenfl., p. 51, pl. xxvii, figs. 36, 37, 43–45.

### CARDIOCARPON CORNUTUM Dn.

Pl. CXCIII, Fig. 10.

Specimens agreeing with material from the type locality at St. John, New Brunswick,[1] occur in the Southern Anthracite field in the vicinity of Lykens coals 2 and 3 at the New Lincoln mine, and at 550 feet below the Twin coal in the Pottsville Gap.

### CARDIOCARPON BISCUPIDATUM (Sternb.) Newb. var. OHIOENSE n. var.

The doubt expressed by Dr. Newberry[2] as to the identity of the fruits in the roof of coal No. 1 (Sharon) with the type described by Sternberg[3] seems to be fully justified by a comparison of the material representing the American form from Ohio, Pennsylvania, Tennessee, and Arkansas with the figures published by Sternberg. The specimens from the Sewanee zone in our Coal Measures are much broader proportionately, and larger, while but the slightest trace of a cusp is seen at the base in any example, the slight cusp at the apex being often situated in the midst of the somewhat concave profile of the upper margin of the nucleus. The Amercan type, as figured by Newberry, and as represented in figs. 20 and 22, pl. cx of the Coal Flora, I have distinguished as the var. *ohioense.* This form, which deserves additional illustration, I have nowhere seen below the Sewell formation, or the Upper Lykens division, although it ascends to near the top of the Pottsville. Typical examples are found in the Southern Anthracite field at the drift in the upper Lykens coal in Yellow Springs Gap, and in the shale from a drift below the trolley road on the east side of the gap at Pottsville, in a horizon 380 feet below the Twin coal.

### CARDIOCARPON ELONGATUM Newb.

The species described by Newberry[4] under this name represents one of the most widely distributed and characteristic as well as comprehensive types of the Sewanee zone. Between it and the broader forms, such as *Cardiocarpon late-alatum*[5] Lx., there is a series of intermediate forms, although few of the latter are at any point found in the same beds. In the Southern Anthracite field, as in the region of the Sharon coal in northwestern Pennsylvania and northern Ohio, the species is sometimes found associated with *Cardiocarpon minus*[6] and *C. annulatum.*

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[1] Dawson, Quart. Jour. Geol. Soc. London, Vol. XVIII, 1862, p. 324, pl. xiii, figs. 23, 24; Fossil Plants of the Devonian and Upper Silurian Formations of Canada, p. 60, pl. xix, figs. 214–218.

[2] Rept. Geol. Survey Ohio, 1873, Vol. I, Pt. II, p. 373, pl. xliii, figs. 9, 9a.

[3] Flora d. Vorwelt, Vol. 1, fasc. 1, pl. vii, fig. 8.

[4] Annals Sci., Cleveland, Vol. I, p. 153, fig. 6: Rept. Geol. Survey Ohio, 1873, Vol. I, Pt. II, p. 373, pl. xliii, fig. 5.

[5] Lesquereux, Coal Flora, Vol. II, 1880, p. 568, pl. lxxxv, figs. 46, 47.

[6] Newberry, Rept. Geol. Survey Ohio, 1873, Vol. I, Pt. II, p. 373, pl. xliii, fig. 4.

CARDIOCARPON OBLIQUUM Dn.

The identification in the Southern Anthracite field of this species, hitherto known only from the so-called middle Devonian at St. John, New Brunswick,[1] rests upon the entire agreement of the American examples with specimens from the type locality of the species. This fruit, which appears to me to be unquestionably distinct from *C. acutum* L. and H., is especially common at the drift in the upper Lykens coal at Kohlers Gap, in Bear Mountain. It is also found in the roof of Lykens coal No. 2 at the North Brookside slope, and in the rock dump from the Upper Lykens coals at the New Lincoln mine.

CARDIOCARPON CUYAHOGÆ nom. nov.

This name is here proposed for the fruits which were described by Newberry[2] as *Cardiocarpon orbiculare*, the latter name having been employed in the preceding year by Ettingshausen[3] for a similar fruit. The species occurs in the roof of Lykens coal No. 2 at North Brookside, at the lower Eureka tunnel, and at the New Lincoln mine. It has also been found in the rock dump from the upper Lykens coals at the Lincoln mine.

TRIGONOCARPUM AMPULLÆFORME Lx.

Pl. CXCI, Fig. 8.

Examples of this species from the anthracite regions appear to agree in all respects with the types described by Lesquereux[4] from the Sewanee zone in Tennessee and Arkansas. Throughout the greater portion of the Appalachian region this type of fruit is more common in and slightly characteristic of the Sewanee zone. I have not yet seen the species in the Lower Coal Measures.

TRIGONOCARPUM HELENÆ sp. nov.

The species of fruit which will eventually be described under this name includes a portion of the types described by Lesquereux[5] from the Pottsville formation in Alabama as *Rhabdocarpos clavatus?* Gein. *Trigonocarpum Helenæ* is distinguished from *Trigonocarpum ampullæforme* var. *spectabile* by the generally narrower nuclei, the very much narrower and less prominent ribs, and the proportionately thicker envelopes with their relatively much broader, shorter, micro-

[1] Dawson, Quart. Jour. Geol. Soc. London, Vol. XVIII, 1862, p. 324, pl. xiii, fig. 25; Fossil Plants of the Devonian and Upper Silurian Formations of Canada, 1871, p. 61, pl. xix, figs. 225–226.

[2] Annals Sci., Cleveland, Vol. I, 1853, p. 153; Rept. Geol. Surv. Ohio, Vol. I, Pt. II, 1873, p. 374, pl. xliii, fig. 10.

[3] Steinkohlenfl. v. Stradonitz, 1852, p. 16, pl. vi, fig. 4.

[4] Coal Flora, Vol. III, p. 823, pl. cix, figs. 18–21. Nos. 16536–16538, Lacoe Coll., U. S. National Museum,

[5] Coal Flora, Atlas, p. 18, pl. lxxxv, fig. 20 (not fig. 14); text, Vol. II, 1880, p. 581 (part).

pylar necks. *T. pusillum* Brongn. is much shorter and more pointed, besides having less distinct ribs. The type from St. John, New Brunswick, which I have designated *T. Dawsonianum* differs from *T. Helenæ* by its still more slender form and narrower acuminate valves. This species is, in the central and southern Appalachian regions, apparently confined to the Clark and Quinnimont formations; and more particularly to the basal portion of the latter. In the Southern Anthracite region the fruit has, however, a much greater range, examples having been collected from the roof shales of Lykens coals Nos. 4 or 5 at the Lincoln, Brookside, and Kalmia mines, and from the upper Eureka tunnel. It also occurs in the rock dump from the upper Lykens coals at the New Lincoln mine, as well as at the supposed horizon of Lykens coals Nos. 2 and 3 in the Pottsville Gap.

TRIGONOCARPUM DAWSONIANUM sp. nov.

Accompanying the specimens of a very narrow and rather small *Trigonocarpum*, there occur in the same matrix numerous detached valves which agree so completely with the fragments figured by Dawson from the "Fern Ledges" at St. John as "fruits or bracts of uncertain nature," that I have ventured to include a portion of the latter material as well, in the same species. The figures given in the "Devonian flora"[1] will serve to illustrate the Pottsville material which I name in honor of the late distinguished paleobotanist of America. The differences between *T. Dawsonianum*, which will later be more fully described and illustrated, and *T. Helenæ* have already been indicated. The species is found in the roof of Lykens coal No. 4 at the Lincoln mine and at the Kemble drift. It also occurs in the rock dumps at East Brookside and at the New Lincoln mine. Examples probably belonging to the same type occur in the plant beds 550 feet below the Twin coal in the gap at Pottsville.

CARPOLITHES TRANSSECTUS Lx.

Detached semicircular bracts, or possibly sporangiophores, identical in form with those described by Lesquereux[2] from the "coal-bearing shale" of Washington County, Arkansas, occur at a number of localities in the shales from the coals of the Upper Lykens division. The structure of the organ from which these small semidiscoid fossils are derived is still uncertain. From their mode of occurrence and their association, I am, however, disposed to regard them as possibly belonging to a strobile similar to or identical with that described by Lesquereux[3] as *Lepidocystis quadrangularis.*

[1] Fossil Plants of the Devonian and Upper Silurian Formations of Canada, 1871, pp. 64, 92, pl. xix, figs. 230a, 231, 231a–b (not fig. 230).

[2] Coal Flora, Vol. III, p. 826, pl. cxi, figs. 27, 27a–b.

[3] Op. cit., Vol. II, p. 455, pl. lxix, fig. 5.

FAYOLIA sp.

Although the collections in the National Museum already contain specimens from the Allegheny series (XIII) at Mazon Creek, Illinois, referable to this genus, it is represented, so far as I know, in the collections from the Pottsville series by only two obscure specimens.

From an examination of the material from Mazon Creek, and of the types from the Chemung of northwestern Pennsylvania, described by Dr. Newberry as *Spiraxis*,[1] I am convinced that the latter genus is essentially identical with the *Fayolia*[2] of the Old World.

## AGE OF THE POTTSVILLE FORMATION.

In the absence of the full descriptive paleontologic evidence, I should prefer to refrain from a definite statement of conclusions as to the age or the equivalents of the Pottsville formation. Since, however, the questions of age and correlation directly affect the classification and nomenclature of the formations now being mapped in the Appalachian province, it is proper to offer a few brief generalizations which may be considered as preliminary and, so far as they relate to European coal fields, as tentative or suggestive.

The persistency of the formation, or some portion of it, in some phase or other throughout the American Carboniferous basins, its generally well-marked lithologic characters, the different conditions governing its deposition, its thickness, which may exceed 2,500 feet in the Virginia-Tennessee region, and its mostly very distinct vegetable contents, as compared with the basal portion of the Lower Coal Measures, or the Allegheny series, in Pennsylvania and Ohio, appear to me to merit for these terranes distinct recognition as a formation or series, coordinate not only with the Allegheny series, Conemaugh series, etc., but with Lower, Middle, and Upper Coal Measures, as those terms are used in this country. It is to be regretted that while under the name "Pottsville series" the formation is ranked by most geologists with Allegheny series,[3] etc., many authors treat it as a part of the Lower Coal Measures, although it was originally distinguished by Rogers as coordinate with the latter. Its occasional inclusion by geologists in the more comprehensive, but equivocal, "Coal Measures" is perhaps not wholly satisfactory, even when that term is used in the broader sense of "Upper Carboniferous." As has already been remarked, no conclusive proof that the oldest beds of the Pottsville may be contemporaneous with the last beds of the red shale, or other marine Lower Carboniferous sediments, has yet come to light. Nevertheless, if the explanation of the conditions of the deposition of the

[1] Newberry, Annals New York Acad. Sci., Vol. III, 1885, p. 217.

[2] Renault and Zeiller, Comptes Rendus Acad. Sci., Vol. XCVIII, p. 1393; Fl. Foss. bassin houill. Commentry, 1888, Pt. I, p. 15; Pt. II, 1890, p. 369.

[3] Bull. U. S. Geol. Survey No. 65, p. 129.

formation here accepted is correct, it is possible that there is a slight overlap of Pottsville time on that of the Mauch Chunk formation, in which case its designation as Coal Measures would be lithologic and economic only, rather than strictly accurate from the chronologic standpoint.

The flora of the Vespertine (Pocono X), which has received attention from Lesquereux[1], Meek[2] and Fontaine,[3] like that of the corresponding Horton series of Nova Scotia, studied by Sir William Dawson, consists of an almost exclusively *Triphyllopterid* or *Aneimites* flora, with several laciniate-lobed *Sphenopterids*, and great numbers of *Lepidodendron* of the *corrugatum* type. The flora of the Mauch Chunk formation is as yet but little known; but such material as has come to hand from the upper portion of the formation shows a marked affinity with the Pottsville flora. The Chester limestone of Illinois is said to have furnished some fossils which are closely related to those of the basal Pottsville beds. I may add that the *Aneimites* from the topmost bed (bed A, Pl. CLXXXII) of the red shale at the Westwood and Pottsville gaps appears to be more closely bound to the Lower Carboniferous types than to the ordinary plant life of the Pottsville formation, and should, therefore, perhaps be excluded, together with the accompanying *Sphenopteris umbratilis*, from the flora under consideration.

The plants of the Lower Lykens division, as a whole, appear to stand in the closest relation to the flora of the Ostrau-Waldenburg beds described by Stur[4] and generally regarded as Lower Carboniferous ("Culm"), though many geologists and paleontologists are strongly disposed to refer the terranes to the Millstone grit. The intimacy of the relationship, and the probable contemporaneity of our flora with the Upper Culm flora will be more fully indicated when the Pottsville flora is treated more at length, in the monographic report.

The flora of the Upper Lykens division seems to be directly related to that of the Millstone grit of Canada and portions of the Carboniferous basins of the Old World, though the data for comparison are hardly satisfactorily complete. The upper horizons of this division have also much in common with the flora of the Lower Coal Measures of Great Britain. The latter, it may be noted, are, for the most part, paleobotanically older than the formation known by the same name in the Northern States of this country.

The Upper Intermediate division would seem, from the identities and distribution of its plant species, to be as late as the Lower Coal Measures of Great Britain, or the lower zones of the Westphalian in continental Europe.

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[1] Geol. Pennsylvania, 1858, Vol. II, Pt. II.
[2] Bull. Philos. Soc. Washington, 1879, Appendix.
[3] Am. Jour. Sci., 3d series, Vol. XIII, 1877, pp. 35, 115.
[4] Abh. d. k.-k. geol. Reichsanst., Vol. VII, 1877, Pt. II.

One of the most surprising, as well as interesting, facts observed in the study of the Pottsville floras is the large element that is common to the latter and to the flora described by Sir William Dawson from the supposed middle Devonian beds at St. John, New Brunswick. In fact, taking into view the entire flora of the Pottsville formation in the Appalachian province, the identities in the composition of the floras are so great, with respect to both genera and species, as to leave little room for doubt that we have in the "Fern Ledges" at St. John beds of nearly the same age as the Pottsville formation in Pennsylvania. In fact, as has been remarked in the preceding notes, the characteristic forms of the St. John flora, such as *Megalopteris*, *Neuropteris retorquata*, *Alethopteris discrepans*, *Alethopteris ingens*, *Sphenopteris pilosa*, *Sphenopteris Harttii*, *Sphenopteris marginata*, *Pecopteris serrulata*, *Annularia latifolia*, and *Annularia acicularis*, as well as the numerous gymnospermous fruits, are so far identical with, or obviously most intimately related to, the upper Pottsville types as to render it highly probable that a flora contemporaneous with that of the Sewanee zone is present in the section along the St. John Harbor.

On the whole, as may already have been inferred, while recognizing in the Pottsville formation a group of terranes equal in rank to Lower Coal Measures, Allegheny series, etc., I not only do not favor a classification which relegates the entire formation hard and fast to the Upper Carboniferous, but I even anticipate a possible necessity for its permanent division into two groups, the lower of which may eventually perhaps be referred to the Lower Carboniferous. From the paleobotanic standpoint the Pottsville formation is the beginning of the Mesocarboniferous.

## SUMMARY OF CONCLUSIONS.

1. The Pottsville formation in the Southern Anthracite field is composed chiefly of massive conglomerates and conglomeratic sandstones of varying composition, the lower terranes being somewhat heterogeneous and irregular, the upper generally more uniform and persistent, with better assorting of materials. The coals (Lykens), locally of great economic importance, exhibit the general variability of the formation, though they sometimes appear to extend over relatively large areas.

2. In the Schuylkill region the passage from the Mauch Chunk (XI) to the Pottsville (XII) is by a transition of heterogeneous conglomerates, intercalated in red and green shales, the proportion of sandstones increasing to the top of the red shales, which are later represented by red and green argillaceous materials washed into the soft but more distinctly arenaceous conglomerates and bowlder beds of the lower portion of the Pottsville.

3. The irregularity and the lack of selection in the materials interlarded with the upper beds of red and green shales (Mauch Chunk) appear to be natural results of the submergence and somewhat imperfect working-over of an intermittently subsiding coastal plain under the action of strong and varying detritus-laden currents.

4. No evidence of a marked or general unconformity between the Pottsville and Mauch Chunk is noticeable in this region, though at various points within several hundred feet of strata beds of small bowlders or coarse conglomerates are imposed, in a knife-edge contact, on the distinctly uneven surfaces of olive-green mud beds.

5. The conditions are such that it is impossible to determine upon a persistent stratigraphic basal line of division which can be traced or recognized throughout the basin. Different geologists have taken different horizons. In this report the topmost bed of typical red shale or sandstone in the section is arbitrarily taken as the upper limit of the Mauch Chunk. This is the usage of geologists in the bituminous fields, where, it should be noted, an unconformity probably exists in most areas.

6. The upper limit of the Pottsville formation has, for reasons of necessity or practicability, been placed by the various geologists and surveys of Pennsylvania at the base of the lowest "considerable coal," which usually occurs not far above the main plexus of massive conglomerates at the top of the Pottsville formation. Such a horizon, though usually traceable for a distance of several miles, is not always definite where, as happens in portions of the field, the distinctly conglomeratic character of the terranes continues into the Coal Measures and a number of thin coals are interspersed. Yet this mode of delimitation, employed in conjunction with the knowledge of the stratigraphic relations of the low coals to the main upper group of conglomerates, has probably rarely led to any considerable vertical error throughout the central portion of the field, including the vicinity of the type section; and, from the standpoint of field practicability, it is probably the most satisfactory method of definition at present available.

7. The flora in the roof of the Buck Mountain coal, or its supposed equivalents, at the very base of the Lower Coal Measures at Pottsville is a typical Coal Measures flora, very distinct from the floras typical of the Pottsville formation, although a few of its species appear in the upper 250 feet of beds in the latter, which contain a mixed flora. It is even slightly later than that of the basal beds of the "Lower Coal Measures"[1] in the Northern Anthracite field or of the Allegheny

[1] The term Lower Coal Measures is used in the anthracite fields in the original sense as proposed by Rogers for the series next above the Seral (Pottsville) conglomerate. It is similarly applied in the northern bituminous basins, where it is, in part at least, synonymous with Allegheny series, Desmoines series, etc. It is, however, shown by the fossil plants to be as a whole somewhat later than the Lower Coal Measures of the Old World. See Bulletin of the Geological Society of America, Vol. XI, pp. 145-178.

series in the northern bituminous basins. Furthermore, the plants from the thinner coals in the type region, in some cases about 100 feet or more lower than the "Buck Mountain" (Twin) bed, and close to or partly within the top of the upper dense complex of conglomerates, with which the formation culminates, are also clearly paleontologically referable to the Lower Coal Measures, they being comparable to the lowest floras above the Homewood sandstone in the bituminous basins. In other words, the conventional stratigraphic boundary between the Pottsville formation and the Lower Coal Measures is, in the Southern Anthracite field, slightly higher than the paleontologic boundary. The paleontologic boundary appears to lie close within the outskirts of the upper plexus of conglomerates which form the most conspicuous feature of the formation from the Pottsville Gap westward.

8. In the central districts of the field the formation probably attains its maximum thickness of a little more than 1,200 feet. Westward it thins very gradually on the whole, the thickness at Rattling Run Gap being 1,100 feet. Eastward it appears to rapidly decrease to about 830 feet at Tamaqua, and perhaps less than 800 feet at the Lansford railroad tunnel, though it seems to expand somewhat to the eastward of this point near the apex of the field. Little, if any, diminution is observed within this field in passing from south to north.

9. The fossil plants of the Pottsville formation in the type region exhibit a rapid development and series of changes or modifications, which, if treated with great systematic refinement, are of high stratigraphic value. With the exception of the species from the topmost beds of the formation, the ferns are, in general, readily distinguished specifically from those at the base of the Lower Coal Measures, or Allegheny series, as recognized in the northern United States, while the floras of the lower portions of the section are found, in passing downward, to bear still less resemblance to those of the Lower Coal Measures. Two principal divisions of the formation, to which comparatively few fern species are common, are recognized. These divisions, which coincide with the natural grouping of the Lykens coals, are here termed the Lower Lykens division and the Upper Lykens division. A portion, including about 200 feet of the type section between these two paleontologic divisions, contains a mixed flora, and has been temporarily designated the Lower Intermediate division. A portion of the type section, at about 200 feet below the Buck Mountain coal, contains floras largely characteristic of the Pottsville, but in association with a number of the earliest Coal Measures species. This is temporarily termed the Upper Intermediate division. The Lower Lykens division includes two floral zones, (1) that of the lowest beds, up to and including the roof shales of Lykens coal No. 5, and (2) that of the vicinity of Lykens coal No. 4. The first contains

relatively few ferns, and is specially characterized by the invariable abundance of a species of *Neuropteris*, as well as by the absence of the forms typical of the other zone. The Upper Lykens division reveals a principal zone of the Sewanee-Sewell coal flora, typically present in the vicinity of Lykens coals Nos. 3 and 2, but extending in modified form up to Lykens coal No. 1. The flora of the latter horizon is characterized by modified survivors from the older horizons of the Sewanee zone, accompanied by elements apparently peculiar to this portion of the section.

10. The flora of the lower zone of the Lower Lykens division is found in the vicinity of the Pocahontas coal in the very thick section of the Pottsville formation in the Virginia-Tennessee region. It is unknown in the thinner sections along the northern and western borders of the Appalachian trough. Beds contemporaneous with the upper zone of the same division are present in the upper portion of the Clark and in the Quinnimont formations of Virginia and West Virginia and in the Lookout formation of the Tennessee-Alabama region. The Lower Intermediate division of the formation in the Southern Anthracite field is shown by the fossils to occupy nearly the position of the Raleigh sandstone in the Virginia region and of the Sewanee conglomerate, the top of the Lookout, in Tennessee. The flora ("Sewanee") in the lower portion of the Upper Lykens division is essentially identical with that in the vicinity of the Sewanee coal in the lower portion of the Walden sandstone in the Alabama-Tennessee region, the Sewell and the Dismal formations and a portion of the Norton formation in the Virginia region, and the Sharon coal of northern Pennsylvania and Ohio. The lowest phytiferous horizons of the formation yet studied in the bituminous basins of Pennsylvania and northern Ohio appear to be distinctly referable to this zone. It is doubtful whether beds older than the upper portion of the Quinnimont formation are present in these regions. The upper and less distinct zone of the Upper Lykens division appears to be represented in the greatly expanded later modification of the Sewell formation of Virginia and southern West Virginia, near the base of the Fayette formation. The time of the upper 200 or 300 feet of ponderous conglomeratic plates at the top of the formation, constituting the Upper Intermediate division in the Southern Anthracite field, is apparently represented by over 800 feet of sediments in the southern Virginia region, only the lower portion of which, including, probably, a part of the Fayette formation, has the lithologic characters of the Pottsville. The horizon of the well-known plant bed at Campbell Ledge, which is within a few feet of the supposed Mauch Chunk, in the Northern Anthracite field, is probably not lower than this division of the type section.

11. Further paleobotanic study of the Pottsville formation appears to fully confirm the earlier conclusion, based on the examination of the plants, that the thinner sections of the formation along the northern and western borders of the Appalachian trough do not contain beds as old as those in the lower portions of the thick sections along the eastern border, e. g., in the Schuylkill and Great Flat Top regions. The positions of the respective floras in the sections plainly indicate a transgression of the sea toward the north and west during Pottsville time.

12. Both lithologically and paleontologically the Pottsville formation constitutes a division of the Carboniferous coordinate with the "Lower Coal Measures," "Allegheny series," etc. As such it forms the lower member of what may, in a broad sense, be termed the Mesocarboniferous in the Appalachian province.

13. The lowest beds in the thickest sections, which appear to be continuous by transition with the deposition of the Mauch Chunk red shales, are perhaps to be regarded as coarse, coast-detrital redepositions, contemporaneous with the uppermost beds of red shale or other marine Lower Carboniferous sediments in other regions. The flora of the Lower Lykens division appears to be contemporaneous, in part at least, with that of the Ostrau-Waldenburg (Culm) beds of the Old World. The flora of the Sewanee zone of the Upper Lykens division is perhaps contained in the Millstone grit of Canada and portions of the Old World coal fields, while it is probable that the Upper Intermediate division is contemporaneous with a part of the Lower Coal Measures (Westphalian) of Europe.[1]

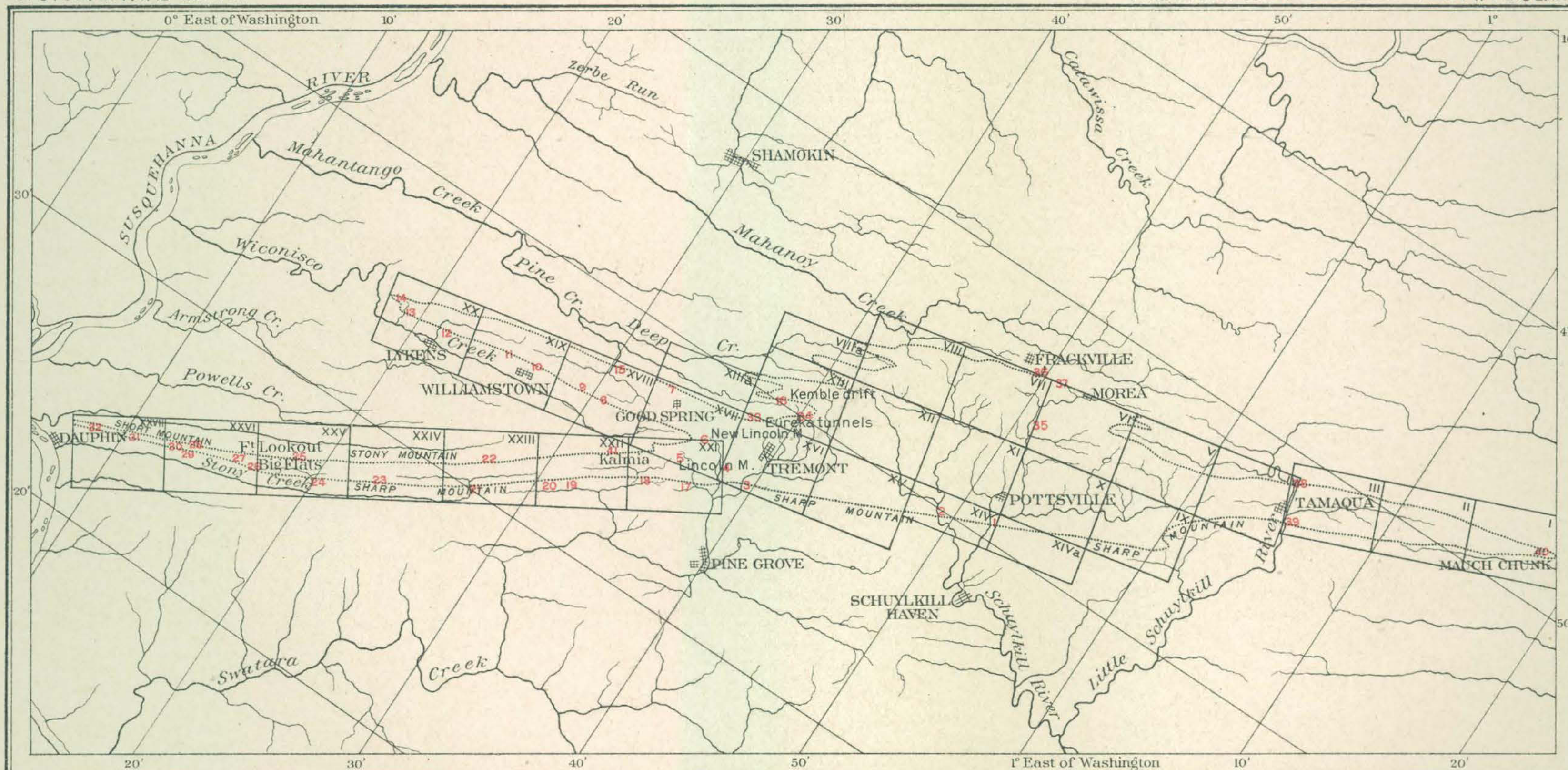
14. The flora of the Pottsville formation is so far identical, in both its generic and its specific composition, with that from the supposed middle Devonian beds at St. John, New Brunswick, as to leave no room for a great difference in the age of the latter. In fact, the plants from the "fern ledges" include a flora essentially equivalent to that of the Sewanee zone, which appears to be represented by a portion of the section at St. John.

15. Owing to the hitherto unrecognized presence of an overthrust in Sharp Mountain in the vicinity of Lorberry Gap,[2] and the consequent misidentification of the less valuable coals in Lorberry and Fishing Creek gaps with the Lykens coals, the boundary of the lowest Lykens coal has been represented from Fishing Creek Gap westward, on the State mine maps, as close to or north of the crest of

[1] The base of the Lower Coal Measures or Allegheny series in this country appears paleontologically to be nearer the stage of the Middle Coal Measures of Great Britain, or the upper zone of the Westphalian in continental Europe.

[2] The discovery of the fault at Lorberry and Fishing Creek gaps was the direct result of the testimony of the fossil plants, which was later completely corroborated by the ordinary stratigraphic method.

Sharp Mountain, i. e., near the place of the Buck Mountain bed, whereas the outcrop of nearly the entire Pottsville formation, in its full thickness, including both of the groups of Lykens coals, extends from near Fishing Creek Gap nearly to the Big Flats, a distance of over 17 miles along the south face of Sharp Mountain, quite outside of the "approximate boundary of the lowest Lykens coal" and partly within the territory represented on the anthracite maps of the recent State geological survey as Mauch Chunk red shales.




# KEY MAP OF THE SOUTHERN ANTHRACITE COAL FIELD IN PENNSYLVANIA

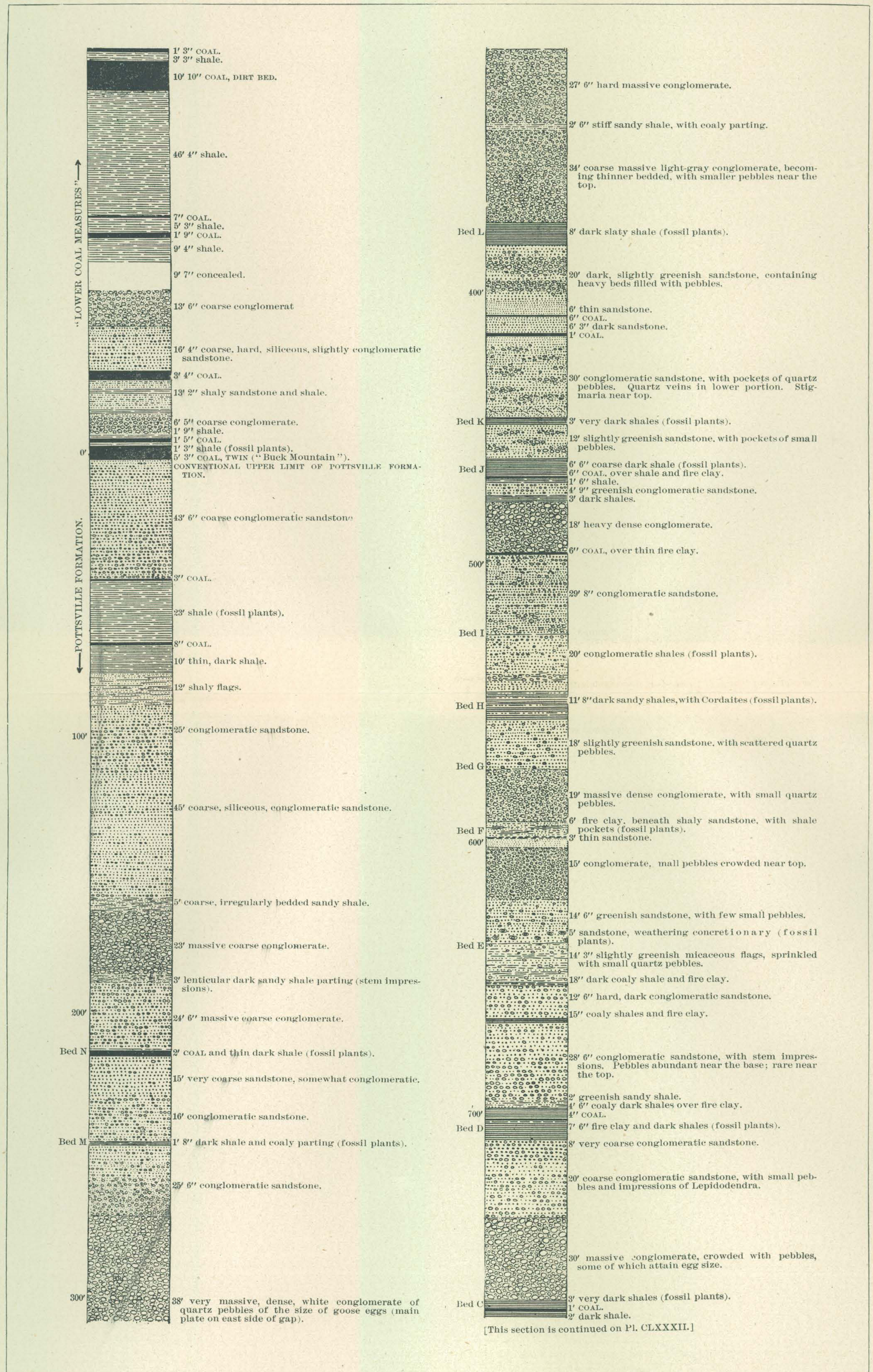
Showing locations of sections and collections, and areas included in the state mining maps

Scale

5 0 5 10 15 MILES

Compiled from the Anthracite reports of the state geological survey

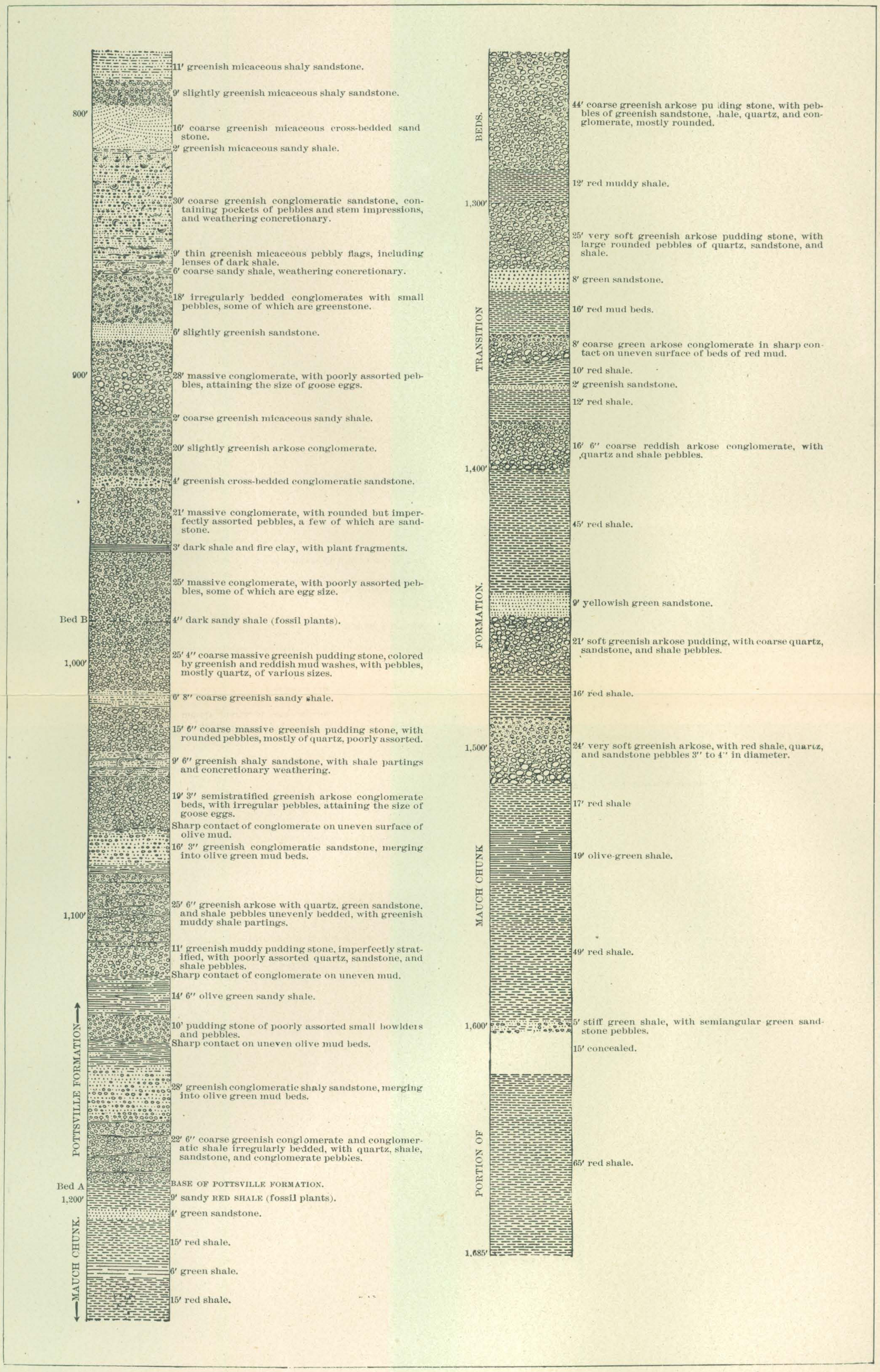
1898.




[This section is continued on Pl. CLXXXII.]

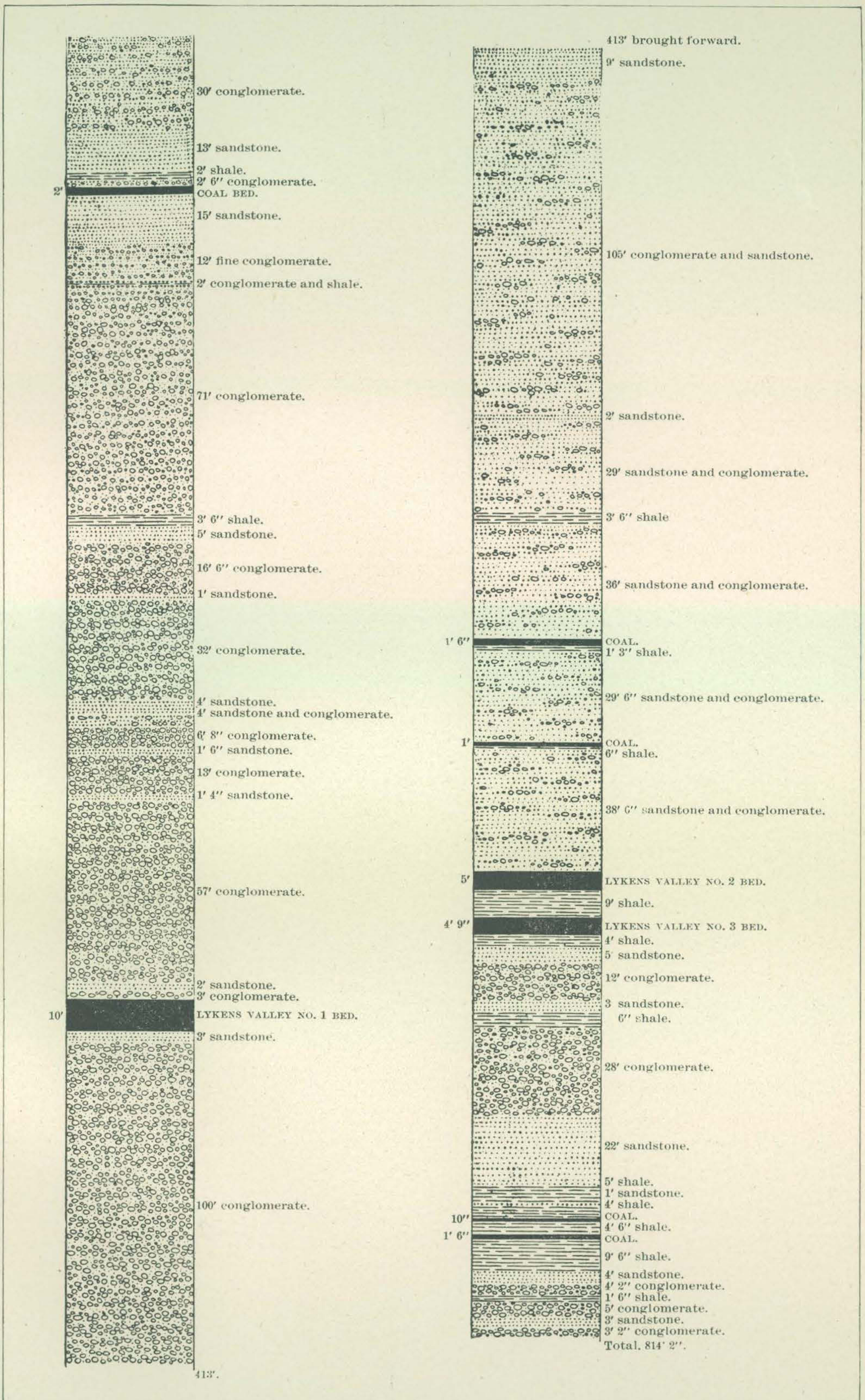
SECTION IN SHARP MOUNTAIN GAP, POTTSVILLE, PENNSYLVANIA.

From the "dirt" bed downward into the red shale, including the type section of the Pottsville formation and portions of the overlying "Lower Coal Measures" and of the underlying Mauch Chunk formation.




SECTION IN SHARP MOUNTAIN GAP, POTTSVILLE, PENNSYLVANIA. (CONTINUED FROM PL. CLXXXI.)

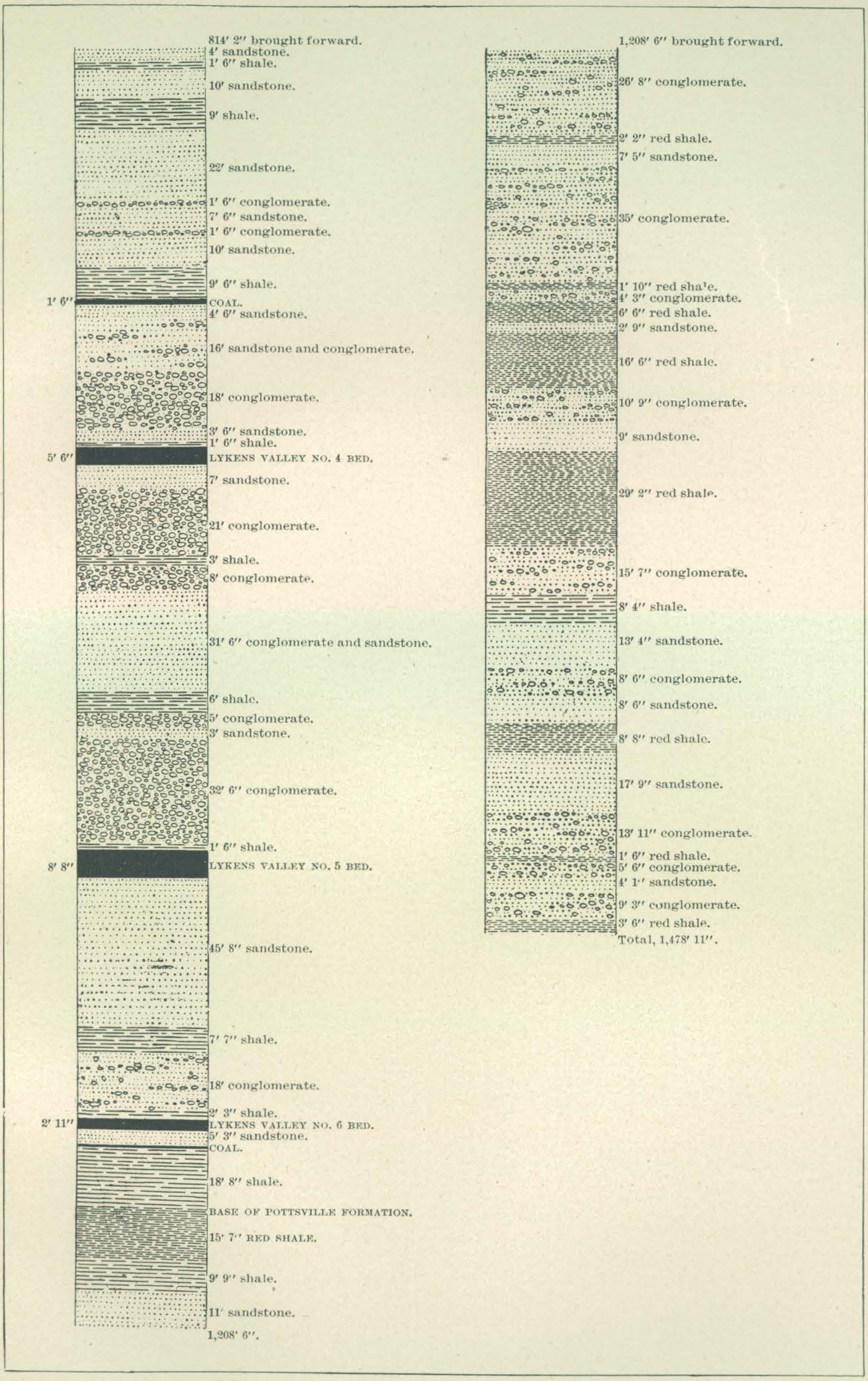
This plate represents the lower portion of the type section of the Pottsville formation and a portion of the Mauch Chunk (red shale) formation, including the transition beds.




SECTION OF THE POTTSVILLE FORMATION IN THE LINCOLN MINING DISTRICT.

Surface to roof of Lykens coal No. 5 in Lincoln colliery water-level tunnel, top of coal No. 5 downward into Mauch Chunk formation, Kalmia colliery water-level tunnel.

Scale: 1 inch=50 feet.




SECTION OF THE POTTSVILLE FORMATION IN THE LINCOLN MINING DISTRICT. (CONTINUED FROM PL. CLXXXIII.)

This plate represents the lower portion of the Pottsville formation and the upper portion (transition beds) of the Mauch Chunk formation, Kalmia colliery water-level tunnel. Compiled from the State anthracite survey.

Scale: 1 inch=50 feet.

FIG. 1. RAUSCH GAP, SCHUYLKILL COUNTY, PENNSYLVANIA.

Section from the Twin coal to the top of the Mauch Chunk formation, showing the Pottsville formation.

1 inch=200 feet.

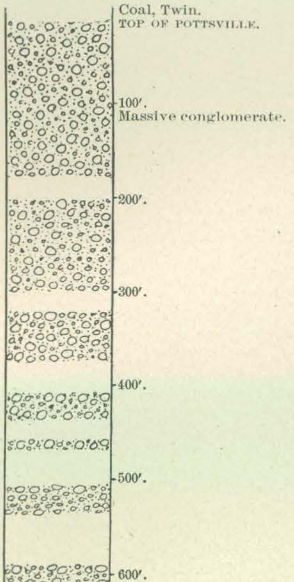



FIG. 2. LOCUST MOUNTAIN GAP, TAMAQUA, PENNSYLVANIA.

Section of the Pottsville formation, from the "A" coal to the top of the Mauch Chunk red shale.

1 inch=200 feet.

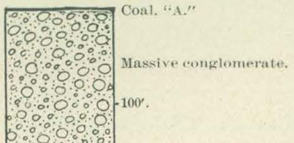



FIG. 3. LORBERRY GAP IN SHARP MOUNTAIN.

Section of exposed beds from the "furnace" coal downward. Datum line is "South" coal.

1 inch=200 feet.

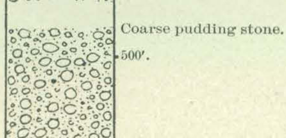
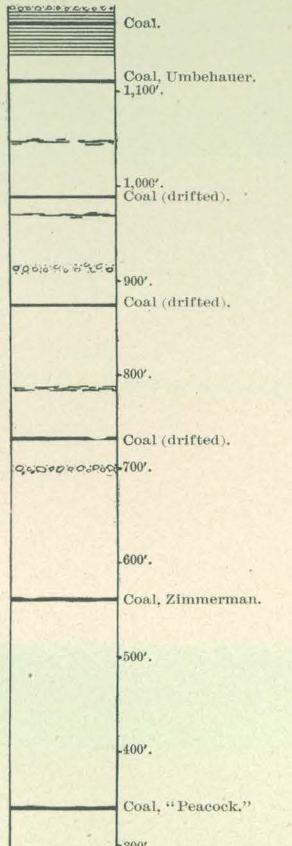



FIG. 3—Continued.




SECTIONS OF LOCUST MOUNTAIN AT TAMAQUA AND OF SHARP MOUNTAIN AT RAUSCH GAP, SCHUYLKILL COUNTY, AND AT LORBERRY GAP.

FIG. 1. FISHING CREEK GAP, TWO MILES NORTH OF ELLWOOD, PENNSYLVANIA.

Section including the coals opened within 500 feet of the red shale on the east side of the gap. Datum line is lower coal mined.

1 inch=200 feet.

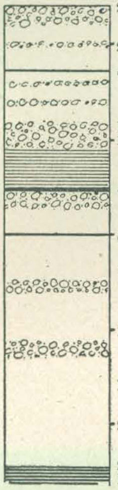



FIG. 2. BLACK SPRING GAP (MOUNT EAGLE), LEBANON COUNTY, PENNSYLVANIA.

Section from the "Black Spring" coal to the Mauch Chunk red shale, including the Pottsville formation and a portion of the succeeding Coal Measures. Datum line is the approximate horizon of the Twin coal.

1 inch=200 feet.

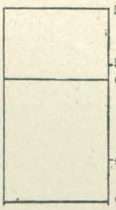



FIG. 2—Continued.

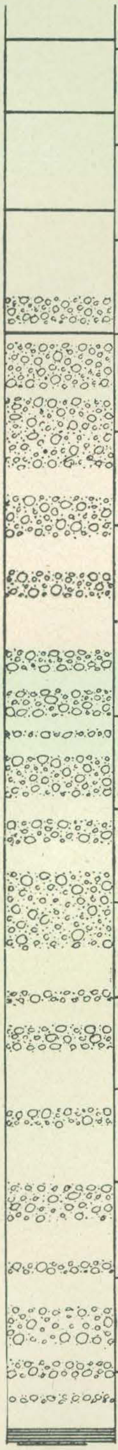
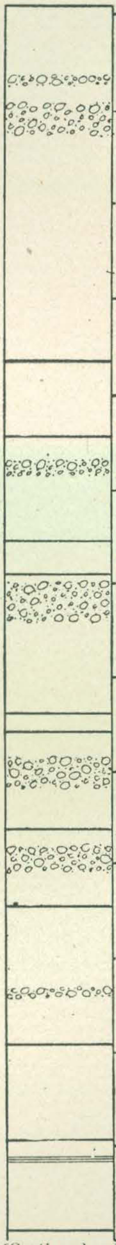



FIG. 3. GOLD MINE GAP, LEBANON COUNTY, PENNSYLVANIA.

Section showing exposed terranes of the Pottsville formation and a portion of the overlying Coal Measures. Datum line is approximate horizon of the Twin coal.

1 inch=200 feet.




[Continued on Pl. CLXXXVII, fig. 1.]

SECTIONS AT FISHING CREEK GAP, BLACK SPRING GAP, AND GOLD MINE GAP.

FIG. 1. GOLD MINE GAP, LEBANON COUNTY, PENNSYLVANIA—Continued from Pl. CLXXXVI, fig. 3.

Portion comprising the Pottsville formation between the Twin coal and the Mauch Chunk red shale.

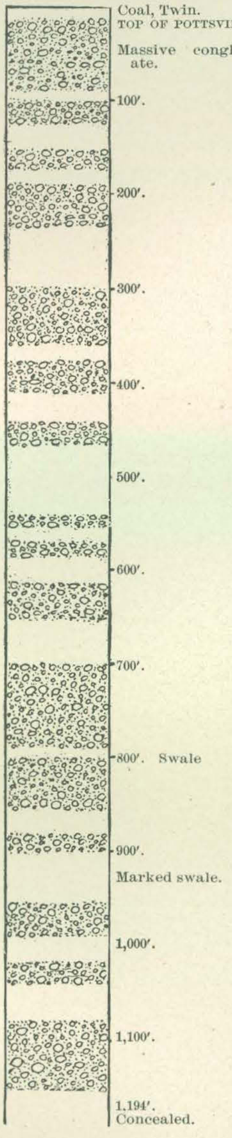
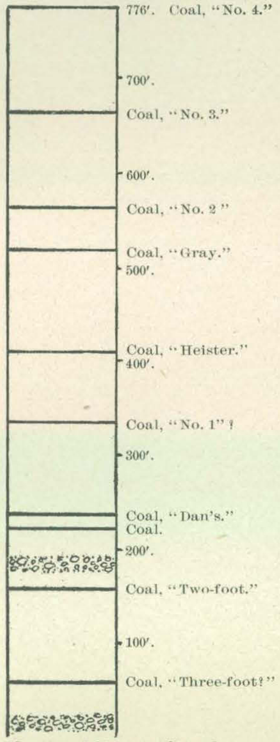



FIG. 2. RAUSCH GAP, LEBANON COUNTY, PENNSYLVANIA.

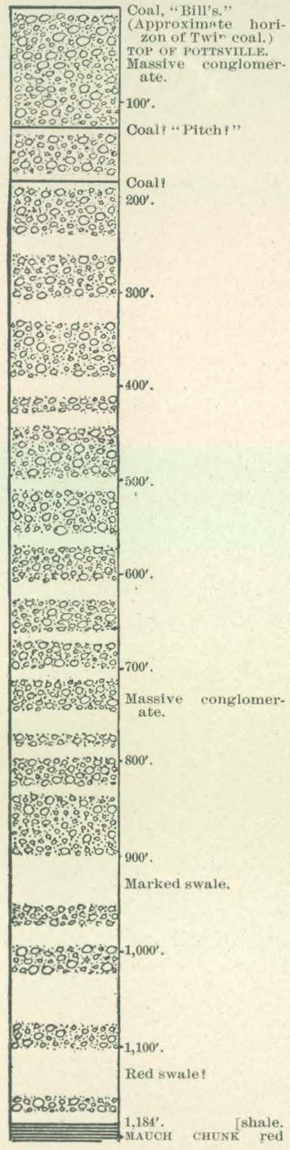
Section showing exposures of the Pottsville formation and a portion of the succeeding Coal Measures. Datum line is approximate horizon of the Twin coal.

1 inch = 200 feet.




[Continued in next column.]

FIG. 2—Continued to show that portion comprising the Pottsville formation between the approximate horizon of the Twin coal and the Mauch Chunk red shale.




SECTIONS AT GOLD MINE GAP AND RAUSCH GAP, LEBANON COUNTY, PENNSYLVANIA.

# PLATE CLXXXVIII.

## PLATE CLXXXVIII.

SPHENOPTERIS PATENTISSIMA (Ett.) Schimp.

(Page 880.)

Fig. 1. This specimen shows the lax habit of the species and the deeply dissected distant pinnules. Lykens coal No. 5 (?), Lincoln colliery.

*Lower Lykens division—Lower zone.*

NEUROPTERIS POCAHONTAS var. PENTIAS D. W.

(Page 892.)

Fig. 2. Apical fragment, showing triangular form of upper pinnules. From Lykens coal No. 6 at East Brookside colliery.

Fig. 3. From Lykens coals No. 5 or 6 at Kalmia colliery.

Fig. 3*a*. Pinnule from the original of fig. 3, showing the fine nervation, which is Callipteridioid at the base. Twice the natural size.

Fig. 4. A fragment with lobate pinnules. From Lykens coal No. 5 at the Lincoln mine.

*Lower Lykens division—Lower zone.*

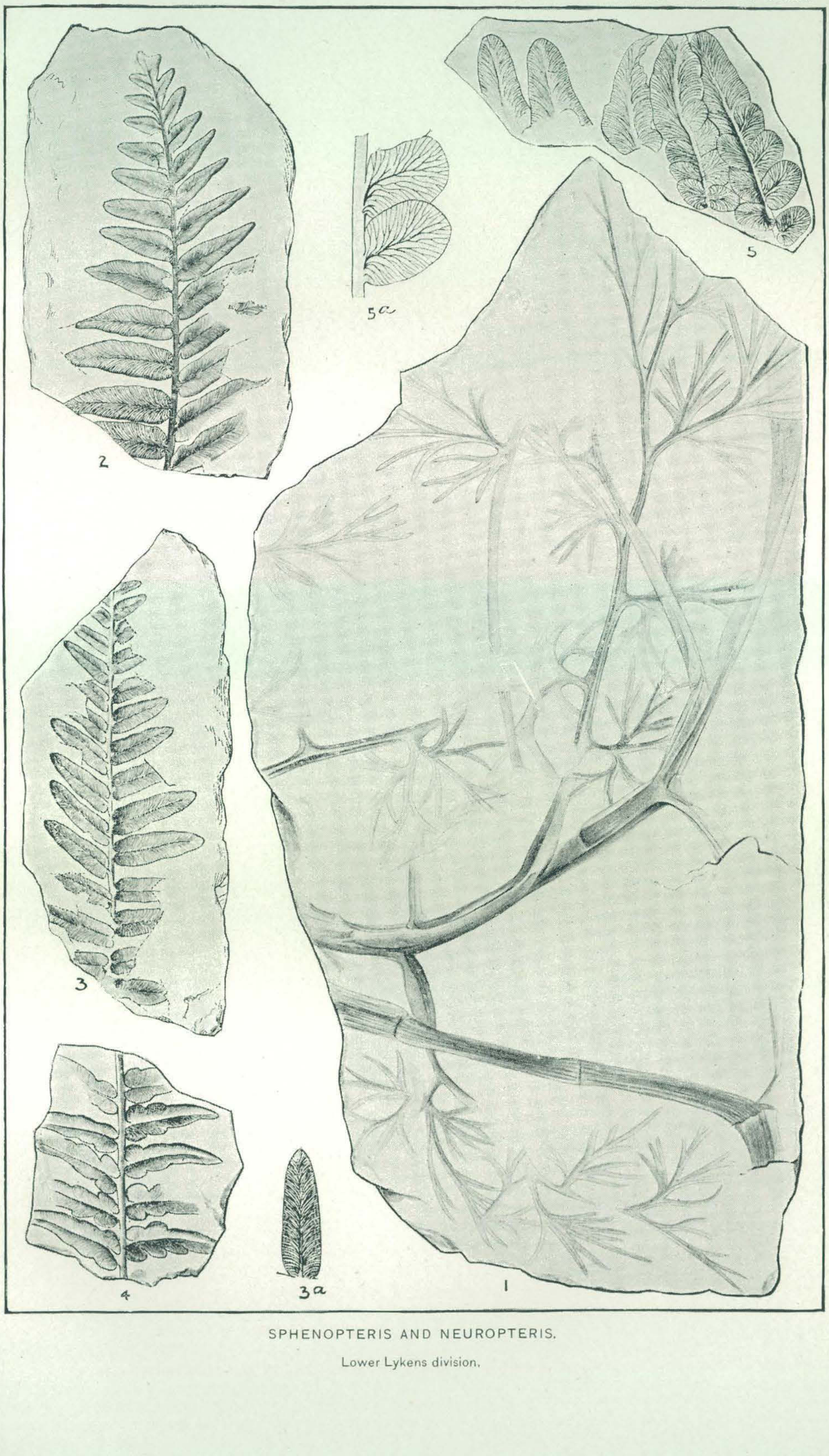
NEUROPTERIS POCAHONTAS var. INÆQUALIS D. W.

(Page 890.)

Fig. 5. Fragment showing Odontopteroid pinnules of the upper pinnæ. Bed D, 710 feet below the Twin coal in the gap at Pottsville.

Fig. 5*a*. Enlarged detail showing the nervation of two of the pinnules illustrated in fig. 5. Twice the natural size.

*Lower Lykens division.*




SPHENOPTERIS AND NEUROPTERIS.

Lower Lykens division.

# PLATE CLXXXIX.

## PLATE CLXXXIX.

MARIOPTERIS EREMOPTEROIDES D. W.

(Page 872.)

Fig. 1. Portion of slab containing segment of rachis, showing lateral compound pinnæ. Lykens coal No. 5, Brookside colliery.
Fig. 2. Fragment in which the pinnules are more deeply dissected and flattened. From the same locality.
Fig. 3. Fragment from the large lateral pinnæ shown in fig. 1.
Fig. 3*a* Pinnule of the same specimen enlarged to show the nervation. Twice the natural size.

*Lower Lykens division—Lower zone.*

NEUROPTERIS POCAHONTAS D. W.

(Page 888.)

Fig. 4. Specimen showing the characteristic form and development of the pinnules of this species. From the roof of the Pocahontas coal near Crozers, in the Great Flat Top coal field, West Virginia.
Fig. 4*a*. Pinnule of the same specimen enlarged to show the nervation. Twice the natural size.

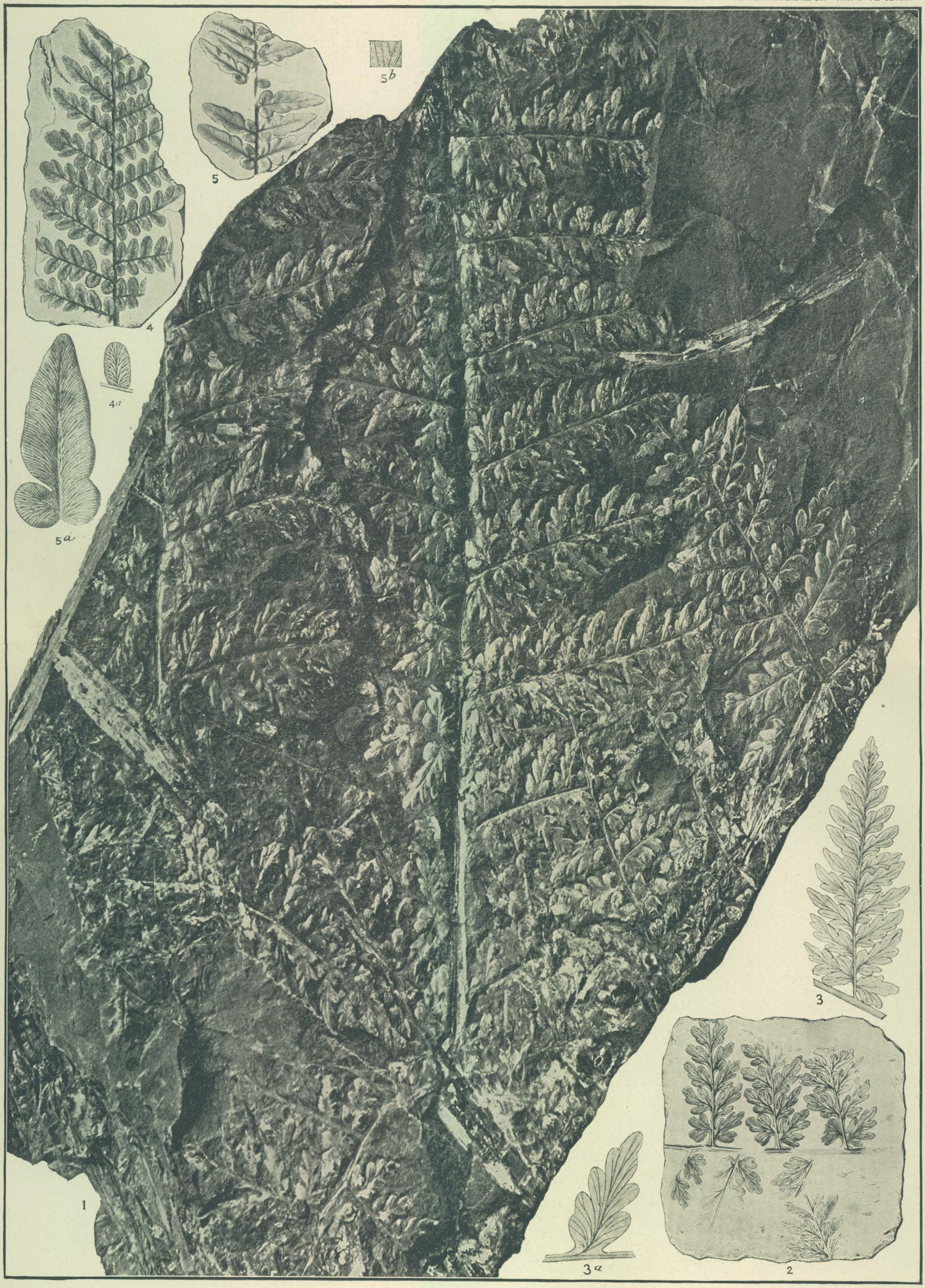
*Age of the Lower Lykens division.*

NEUROPTERIS POCAHONTAS var. PENTIAS D. W.

(Page 892.)

Fig. 5. Upper pinnæ and succeeding sublobate pinnules. From the roof of Lykens coals 5 or 6 at the Brookside colliery.
Fig. 5*a*. Sublobate pinnule, enlarged to show close, relatively parallel nervation. Three times the natural size.
Fig. 5*b*. Fragment from the lamina of the same pinnule. Enlarged to illustrate the interneural striation.

*Lower Lykens division—Lower zone.*




MARIOPTERIS AND NEUROPTERIS.

Lower Lykens division.

# PLATE CXC.

# PLATE CXC.

ANEIMITES POTTSVILLENSIS D. W.

(Page 868.)

Figs. 1 and 2. The fragments show the small cuneate upper pinnules and the larger Adiantitoid form. From the roof of Lykens coal No. 4, at the Lincoln colliery.

*Lower Lykens division—Mariopteris pottsvillea zone.*

MARIOPTERIS POTTSVILLEA D. W.

(Page 874.)

Figs. 3, 4, 5, and 6. Figs. 3 and 4 represent the typical developments of the pinnæ and pinnules of this well-marked species; fig. 5 shows the apex of a compound pinna, while fig. 6 represents a fragment in which the pinnules are much more than usually close. Specimens from the roof of Lykens coal No. 4, at the Lincoln colliery.

Fig. 3*a*. Enlarged detail of one of the pinnæ shown in fig. 3, illustrating the lobes and nervation. Twice the natural size.

Fig. 4*a*. Similar detail from the original of fig. 4. The fossil is somewhat distorted by pressure in the shales. Twice the natural size.

*Lower Lykens division—Mariopteris pottsvillea zone.*

NEUROPTERIS POCAHONTAS var. INÆQUALIS D. W.

(Page 890.)

Figs. 7 and 8. These specimens show the elongated pinnules with Callipteridioid bases, such as occur in the middle and upper portions of the pinnæ. The specimen shown in fig. 7 is from bed D, 710 feet below the Twin coal in the gap at Pottsville; the original of fig. 8 is from the Kalmia colliery.

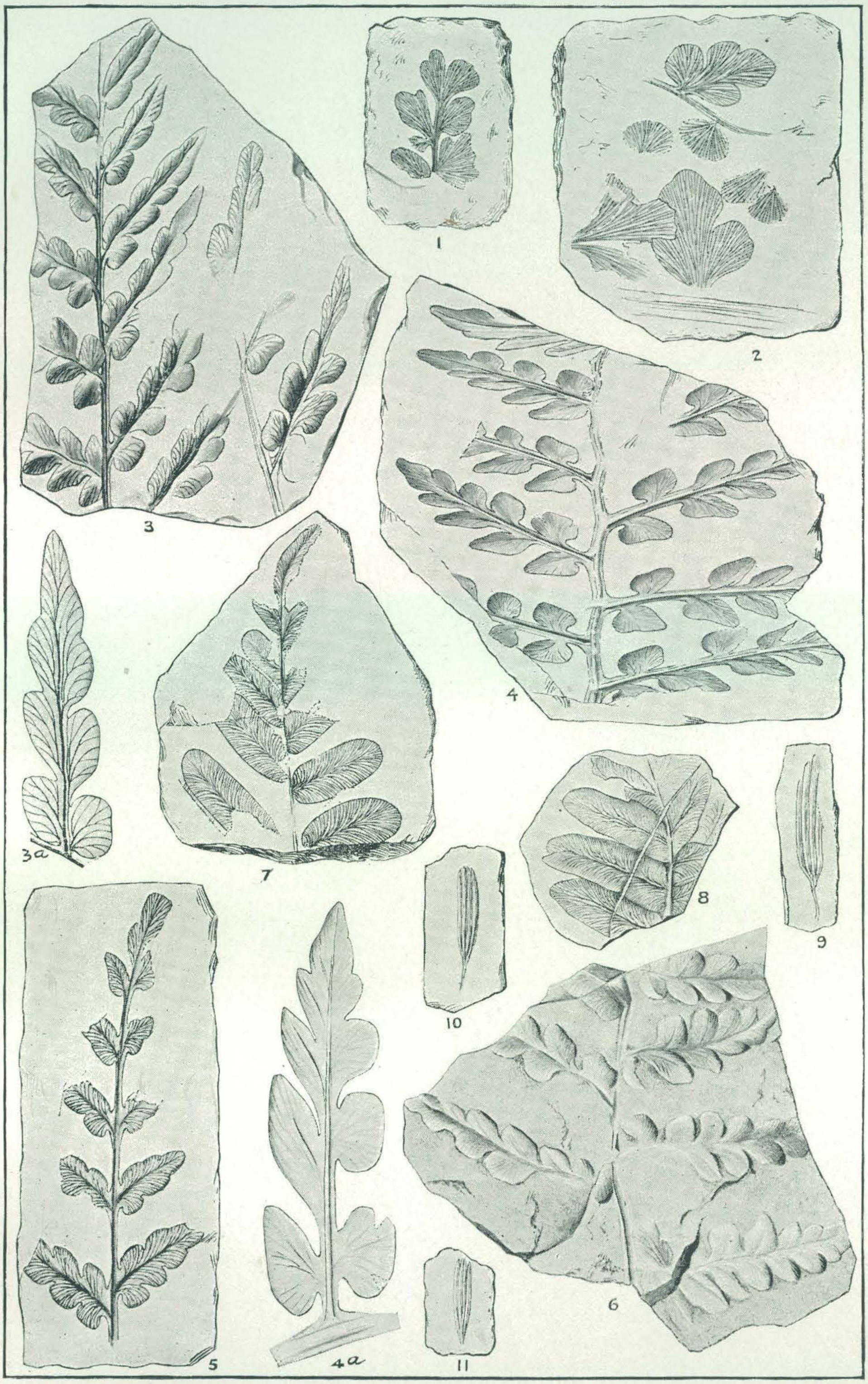
*Lower Lykens division.*

WHITTLESEYA CAMPBELLI D. W.

(Page 905.)

Figs. 9, 10, and 11. These specimens show the characteristic aspect of the fasicular ribs terminating in blunt, often obscure teeth, and the very slender petioles of the leaves of this species. The originals of figs. 9 and 11 are from beds H and D, respectively, in the section of the gap at Pottsville; the specimen shown in fig. 10 comes from the roof of Lykens coal No. 5 or No. 6 at the Lincoln colliery.

*Lower and Upper Lykens divisions.*




ANEIMITES, MARIOPTERIS, NEUROPTERIS, AND WHITTLESEYA.

Figs. 1–8. Lower Lykens division.

PLATE CXCI.

# PLATE CXCI.

NEUROPTERIS POCAHONTAS var. INÆQUALIS D. W.

(Page 890.)

Figs. 1–4. Figs. 1 and 2 show the characteristic development of the pinnules in the small pinnæ. Fig. 2a shows a pinnule from the original of fig. 2, enlarged to twice the natural size, to illustrate the nervation. Fig. 3 includes pinnules with the elongated form, constricted at the base, immediately above the pinnatifid pinnules. The specimen shown in fig. 4 is drawn twice the natural size, to show the characteristic outline of the base of the pinnule and the nervation. The original of fig. 1 is from the drift on the east side of Rausch Gap; that of fig. 2 is from the Kalmia colliery; that of fig. 3 was obtained from the roof of Lykens coal No. 4 at the Lincoln mine; the original of fig. 4 comes from bed D, 710 feet below the Twin coal, in the gap at Pottsville.

*Lower Lykens division.*

NEUROPTERIS POCAHONTAS D. W.

(Page 888.)

Fig. 5. This specimen shows the smaller upper lateral pinnæ, suggestive in form and size of the *Neuropteris Smithsii* Lx. The lateral pinnules are, however, clearly seen to be broadly attached to the rachis, the nervation being Odontopteroid, the midrib scarcely developed. From the roof of the Pocahontas coal at Gilliam, West Virginia, Pocahontas quadrangle.

Fig. 5a. Enlarged detail of pinna in the original of fig. 5, showing the form of the pinnules and the nervation. Twice the natural size.

*Age of the Lower Lykens division.*

SPHENOPHYLLUM TENUE D. W.

(Page 901.)

Figs. 6 and 7. The figures show the slender, narrowed bases of the pinnules and the round-truncate, crenulate, distal margins. A fragment of one of the deeply dissected leaves from a verticel at the point of ramification is shown in fig. 6. The original of fig. 6 is from the Clark formation at Smith's Store, Virginia, Pocahontas quadrangle; that of fig. 7 is from the Pottsville at Warrior, Alabama (No. 8501 of the Lacoe collection, United States National Museum).

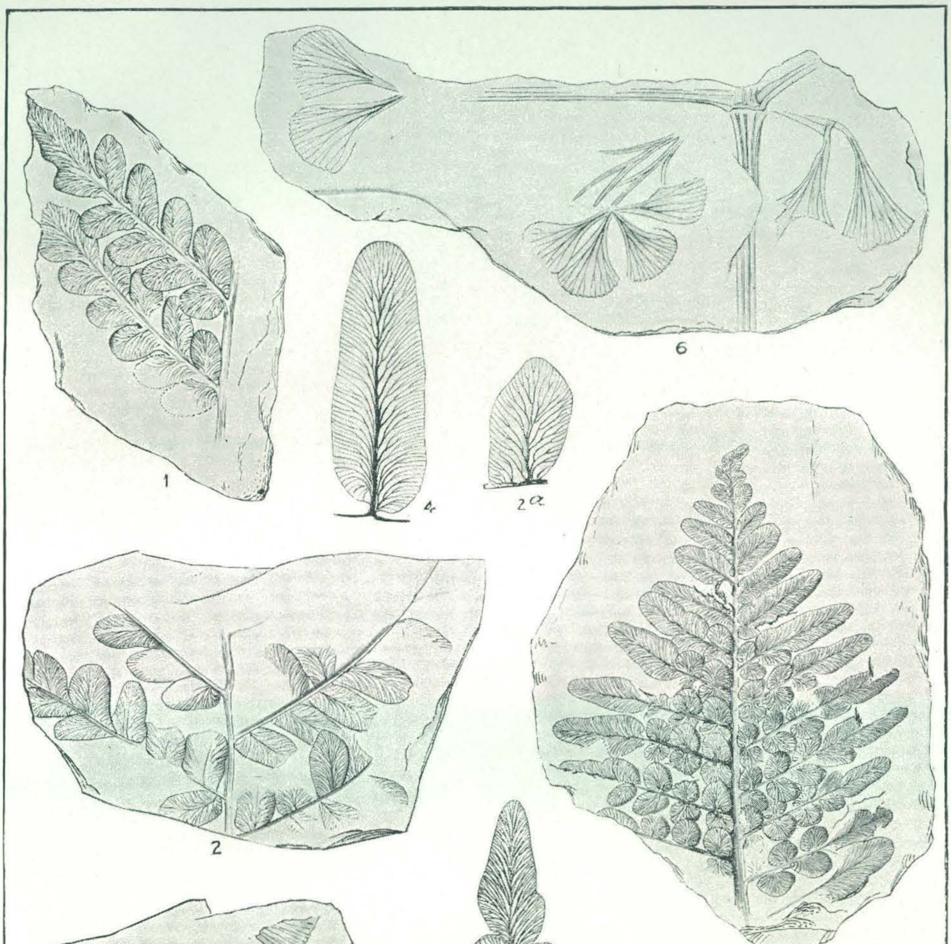
*Lower Lykens division—Mariopteris pottsvillea zone.*

TRIGONOCARPUM AMPULLÆFORME LX. var. SPECTABILE D. W.

(Page 909.)

Fig. 8. This specimen shows well the thin, rather broad wings, the elongated micropylar neck, and the faint subordinate costæ. The specimen is from the Lincoln colliery.

*Upper Lykens division.*




NEUROPTERIS, SPHENOPHYLLUM, AND TRIGONOCARPUM.

Figs. 1–7. Lower Lykens division.

# PLATE CXCII.

# PLATE CXCII.

EREMOPTERIS LINCOLNIANA D. W.

(Page 869.)

Fig. 1. Fragment imperfectly showing the development of the pinnæ and pinnules in the lower lateral pinnæ. From the roof of Lykens coal No. 2 (?) at the New Lincoln mine.

Fig. 1a. Enlarged detail from the same specimen, showing the nervation. Twice the natural size.

*Upper Lykens division.*

MARIOPTERIS PYGMÆA D. W.

(Page 876.)

Figs. 2, 3, 4, 5, and 6. These specimens show the ordinary form and aspect of the pinnæ and pinnules of this species. The originals of figs. 2, 4, 5, and 6 are from the horizon of Lykens coal No. 2 at the New Lincoln colliery; the original of fig. 3 is from nearly the same horizon, at about 500 feet below the Twin coal, in the Pottsville Gap.

Figs. 4a and 6a. Enlarged details of pinnules of the originals of figs. 4 and 6, showing the subdivision of the pinnules and the nervation. Twice the natural size.

*Upper Lykens division.*

ALETHOPTERIS EVANSII LX.

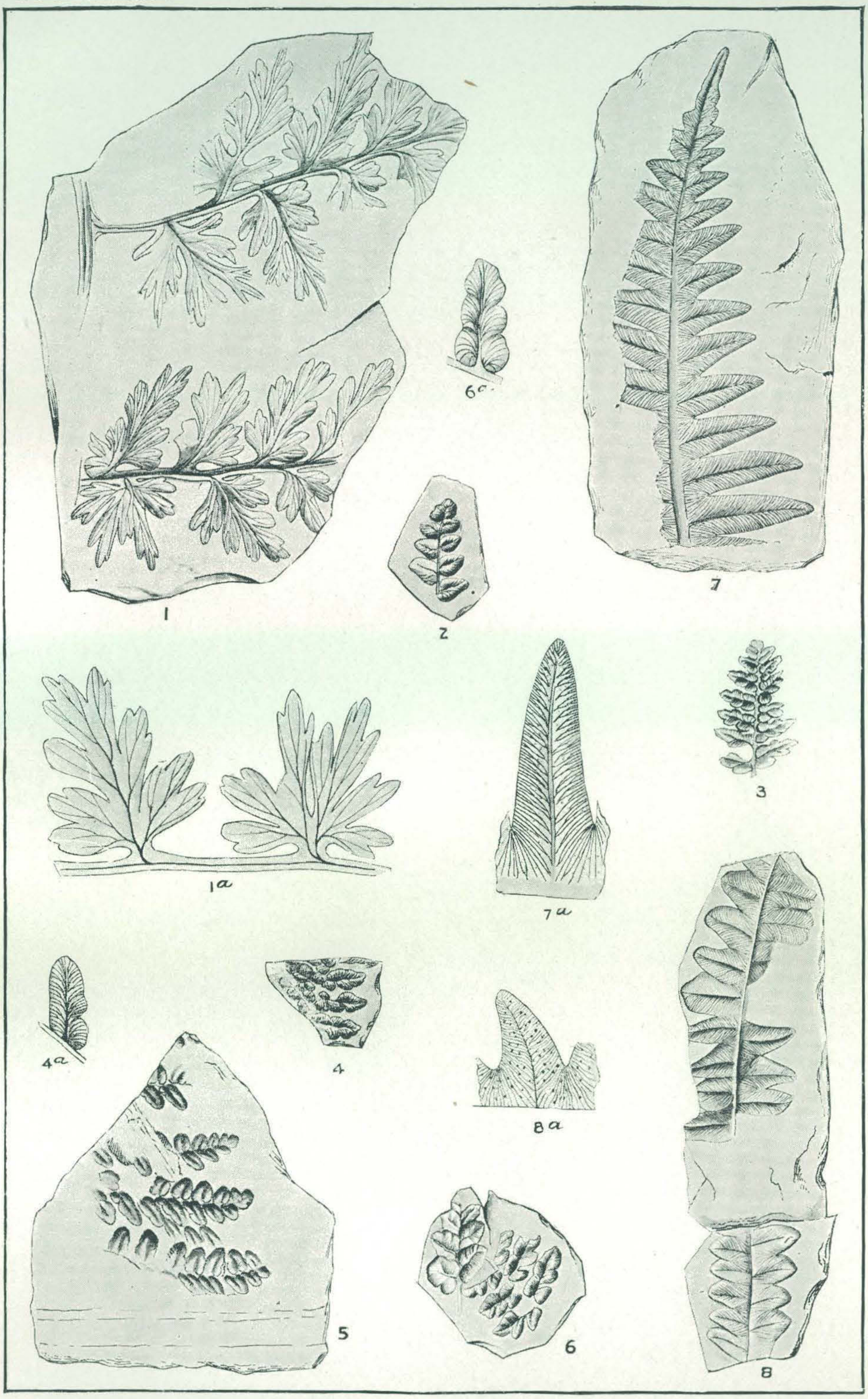
(Page 887.)

Figs. 7 and 8. Fig. 7 represents the terminal portion of the compound pinna, while in fig. 8 fragments of lateral ultimate pinnæ are seen. Fig. 7 is from the Lincoln colliery; fig. 8 was found in bed H, 550 feet below the Twin coal, in the gap at Pottsville.

Fig. 7a. Enlarged detail of pinnule shown in fig. 7. Twice the natural size.

Fig. 8a. Detail of pinnule from the original of fig. 8, showing the nervation and the punctation of the lamina. Twice the natural size.

*Upper Lykens division—Sewanee zone.*




EREMOPTERIS, MARIOPTERIS, AND ALETHOPTERIS.

Upper Lykens division.

# PLATE CXCIII.

# PLATE CXCIII.

ALETHOPTERIS LACOEI D. W.

(Page 884.)

Figs. 1 and 2. Typical fragments of the pinnæ of this species. From the roof of Lykens coal No. 2 at the lower Eureka tunnel.

Fig. 1a. Enlarged pinnule from the fragment shown on the left of fig. 1, illustrating the nervation. Twice the natural size.

*Upper Lykens division—Sewanee zone.*

NEUROPTERIS LUNATA D. W.

(Page 895.)

Figs. 3–7. Specimens showing the variation in form and size of the pinnules of this species. The originals of figs. 3, 4, and 5 are from the roof of Lykens coal No. 1 at the Lincoln colliery; the type of fig. 6 is from the rock dump at the same colliery; that of fig. 7 is from probably the same horizon at the New Lincoln colliery.

Figs. 5a, 6a, 7a. Enlarged details from the originals of figs. 5, 6, and 7, showing the thin, outward-curved nervation. Twice the natural size.

*Upper Lykens division.*

SPHENOPHYLLUM TENERRIMUM Ett. var. ELONGATUM D. W.

(Page 898.)

Figs. 8 and 9. Specimens illustrating the aspect of fragments of this species, in which the apices of the slender, rather lax, leaflets are usually buried in the matrix or broken away. The specimens are from the New Lincoln colliery, where they probably occur in the roof of Lykens coal No. 2.

Fig. 8a. Enlarged detail, showing the division and nervation of a young leaflet of this species. Twice the natural size.

*Upper Lykens division.*

CARDIOCARPON CORNUTUM Dn.

(Page 908.)

Fig. 10. Ordinary example; from bed H, 550 feet below the Twin coal, in the gap at Pottsville.

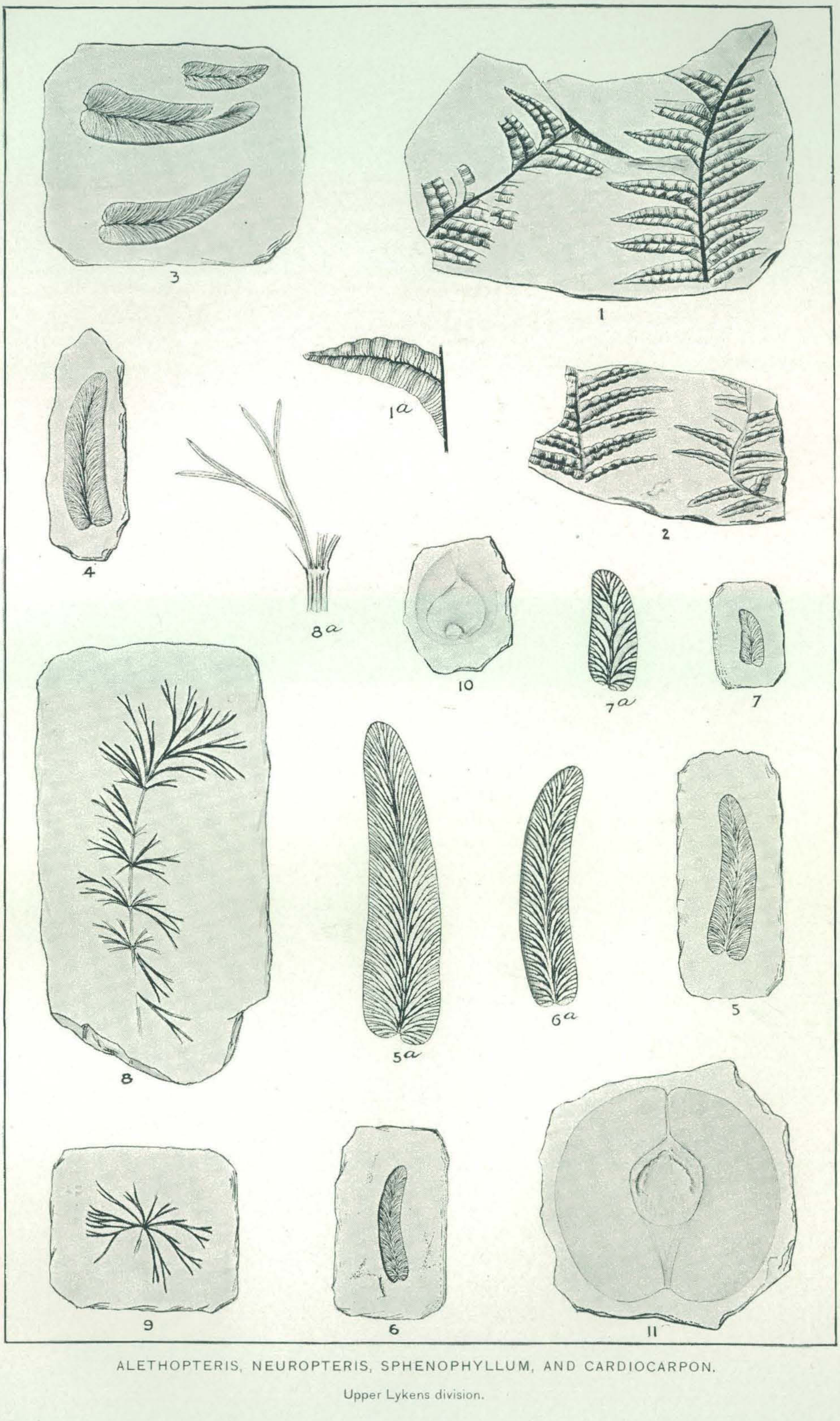
*Upper Lykens division.*

CARDIOCARPON GIRTYI D. W.

(Page 907.)

Fig. 11. This specimen shows the very broad, thin wing, dilated in the lower portion, which is traversed by an obscure cuneate chalaza. The latter is delineated more distinctly than it appears in the original. The specimen is from the roof of Lykens coal No. 2 (or 1?) at the New Lincoln colliery.

*Upper Lykens division.*




ALETHOPTERIS, NEUROPTERIS, SPHENOPHYLLUM, AND CARDIOCARPON.

Upper Lykens division.

# INDEX.

Numbers in *italic* are those of pages on which illustrations (plates or figures) appear; numbers in **black-faced** type are those of pages on which detailed descriptions of species are given.

B.

## C.

N.

## R.

## T.

O