# SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY, 1925

## GEOLOGY OF THE LATAH FORMATION IN RELATION TO THE LAVAS OF COLUMBIA PLATEAU NEAR SPOKANE, WASHINGTON

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### SUMMARY

The name Latah formation is proposed for a series of beds consisting mostly of clay and shale and of fresh-water origin that are found near Spokane, Wash., and that contain an abundant middle or lower Miocene flora. The formation is found in Latah Creek valley for 10 miles south of Spokane, on tributaries of Little Spokane River for 20 miles north of the city, and in places in Spokane Valley for 8 miles northwest and 5 miles east of the city. It occurs also in at least one place in the broad, open valleys of the mountains near Coeur d'Alene, Idaho. These beds rest upon a rough surface of granitic and schistose rocks of unknown age, attain a maximum thickness of 1,500 feet, and are overlain by "rim rock" basalt flows, probably Miocene; "valley" flows, probably later Tertiary; and gravel of Pleistocene age. Sills and dikes, which represent some of the conduits through which the "rim rock" basalt rose to the surface, cut and to a small extent deform the Latah beds, which otherwise retain their original horizontal attitude.

During Latah time the lava floods of the Columbia Plateau, advancing from the west, were held back from the Spokane area by a ridge, the highest parts of which now form the hills near Cheney, Marshall, and Medical Lake. The drainage outlet of this area was thus gradually obstructed by the lava, and the sediments here described were accumulated. Eventually the lava piled up until the "rim rock" flows were enabled to cross the protecting ridge and to overspread the area of Latah sediments.

The "rim rock" flows consist of olivine basalt that shows very conspicuous columnar jointing. They are considered to be of Miocene age but are doubtless younger than the Yakima basalt. West of the submerged ridge they are apparently indistinguishable from the great series of flows that make up the Columbia Plateau.

After a time interval measured by the cutting of valleys through the "rim rock" basalt and to a known depth of 800 feet into the Latah formation another series of basalt flows, referred to as "valley" flows, were extruded. These flows occupy parts of the erosional valleys and rest unconformably upon the Latah, exhibiting at the contact "pillow structure" and other characteristic features. They are distinguished from the "rim rock" flows largely by their topographic position, by a more varied jointing, and by the absence of olivine.


### INTRODUCTION

The Latah formation, as a whole, has been studied only in the general vicinity of Spokane, Wash., although there is evidence, from collections of fossil leaves, that it extends eastward into the open valleys near Coeur d'Alene, Idaho. Much information concerning this formation has been gathered by local students, whose work in collecting fossil leaves is further noted below. The work of the writers has been incidental to or a part of other geologic work and consisted in a study of the Pleistocene features of Spokane Valley by Mr. Pardee at times during 1922 and 1923 and a geologic examination of the general area by Mr. Bryan, in connection with his work on the Columbia Basin irrigation project, in 1923. The unexpected extent of the leaf-bearing beds and their interesting relations to the lava flows seem to justify as complete a description of the formation as is now possible and an account of its fossil localities. The large flora is described by F. H. Knowlton on pages 17–50. As elsewhere noted, specimens of the basalts were studied under the microscope by F. C. Calkins, who also read the text and offered helpful criticisms. Edward Sampson studied under the microscope specimens from the Latah formation and from the fragmental rock inclosing the "pillows" of the "valley" flows.

### COLLECTION AND OCCURRENCE OF THE FOSSILS

The fossil plant remains from the beds described were mostly collected and given to the United States Geological Survey and the United States National Museum by Mr. Henry Fair, Mr. C. O. Fernquist, and Prof. T. A. Bonser, of Spokane, and by Mr. H. J. Rust, of Coeur d'Alene. A small but valuable part of the collection was contributed by Prof. Thomas Large, of Spokane, who shares the credit for collecting it with Miss Doris Burchett, a high-school student. Dr. R. W. Chaney, of the Carnegie Institution of Washington, added a valuable lot of these plant remains which he had collected several years before, and the whole was further enriched by a large number of specimens obtained by Mr. Bryan in 1923. To all the local collectors much credit is due for the discrimination and care with which they selected and marked the specimens.

The fossils are unusually well preserved. As described by Mr. Knowlton, they represent an ancient and varied flora that was very different from the native vegetation growing about Spokane to-day. The collection is of particular value because it comes from a locality not before studied in detail and gives evidence bearing on the geologic age of the vast lava flows that form the Columbia Plateau of Oregon, Washington, and Idaho.

Fossil plant remains have been known in the neighborhood of Spokane for a considerable time and were mentioned by Russell [1] as long ago as 1897, but so far as the writers are aware no description of the fossils or their occurrence has been published heretofore. From time to time the excavation of street and railroad cuts has exposed fossil-bearing beds, and a few years ago local interest in fossils was somewhat stimulated by the finding in the Division Street cut of a charred tree trunk inclosed between two ancient lava flows. Recently Professor Bonser, aided by his pupils, has collected a large number of the fossil leaves and other remains, which he has placed on exhibition in the Spokane Public Museum. The field work of the other collectors was done at odd times from 1920 to 1923.

The larger part of the collection was obtained at the following places: Deep Creek half a mile above its mouth; in the cuts of the Spokane, Portland & Seattle Railway and the Chicago, Milwaukee & St. Paul Railway in Spokane west of Latah Creek; at Thor Street and Twelfth Avenue, Spokane; and at the Edwards ranch, Stanley Hill, near Coeur d'Alene, Idaho. The remainder came from a clay pit at the edge of the Spokane Valley, 2 miles south of Vera; from a well a quarter of a mile west of Mica; and from outcrops at the Schuele ranch and in a ravine, on the slopes south and southeast respectively of Fivemile Prairie. Fossil plant remains have also been found on the south side of Indian Canyon just above the falls, in Biglow Gulch about 2 miles northeast of Hillyard, in road cuts in sec. 31, T. 52 N., R. 44 E., and sec. 29, T. 51 N., R. 44 E., and in Spokane between Cannon Hill and Union Park and at the intersection of Thirteenth Avenue and Perry Street.

Most of the fossil-bearing localities mentioned are within a radius of 10 miles from Spokane, and all may be included in an area 10 or 20 miles wide that extends from Coeur d'Alene, Idaho, westward 35 to 40 miles along Spokane River. All the localities are shown on the index map (fig. 1). This area of fossiliferous beds lies about 150 miles east of Ellensburg, Wash., the nearest place at which plant-bearing beds associated with similar lavas have been found.[2] Other more distant areas in the general region that contain floras of somewhat similar occurrence are mentioned in the paper by Mr. Knowlton.

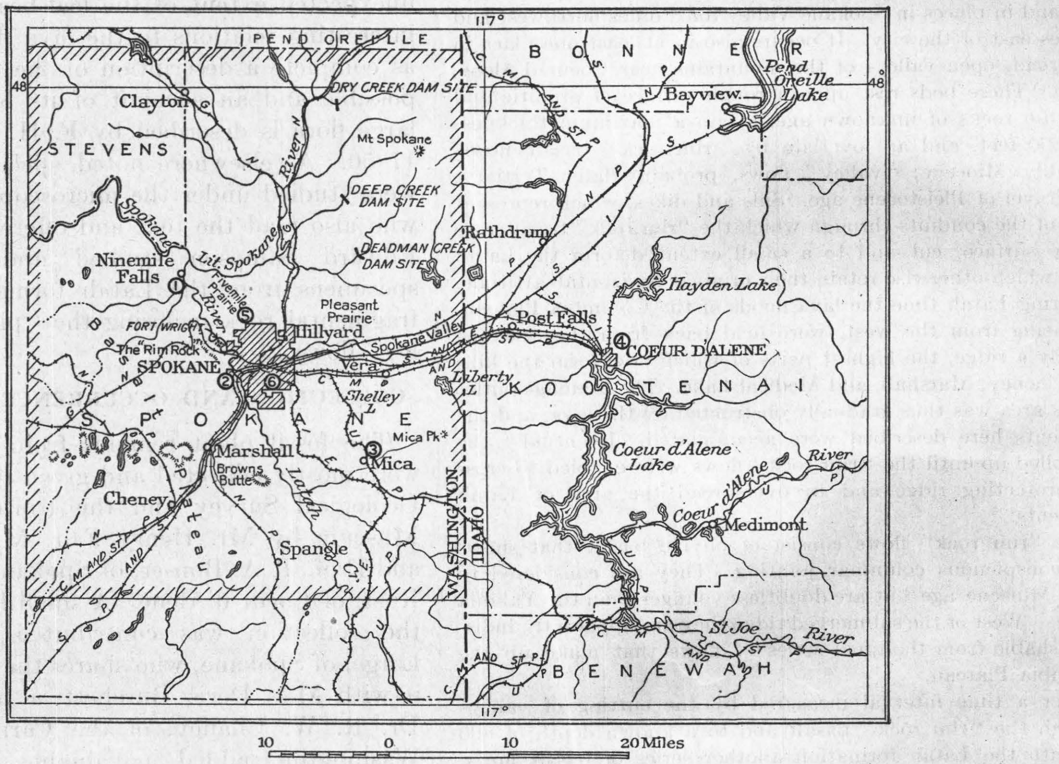


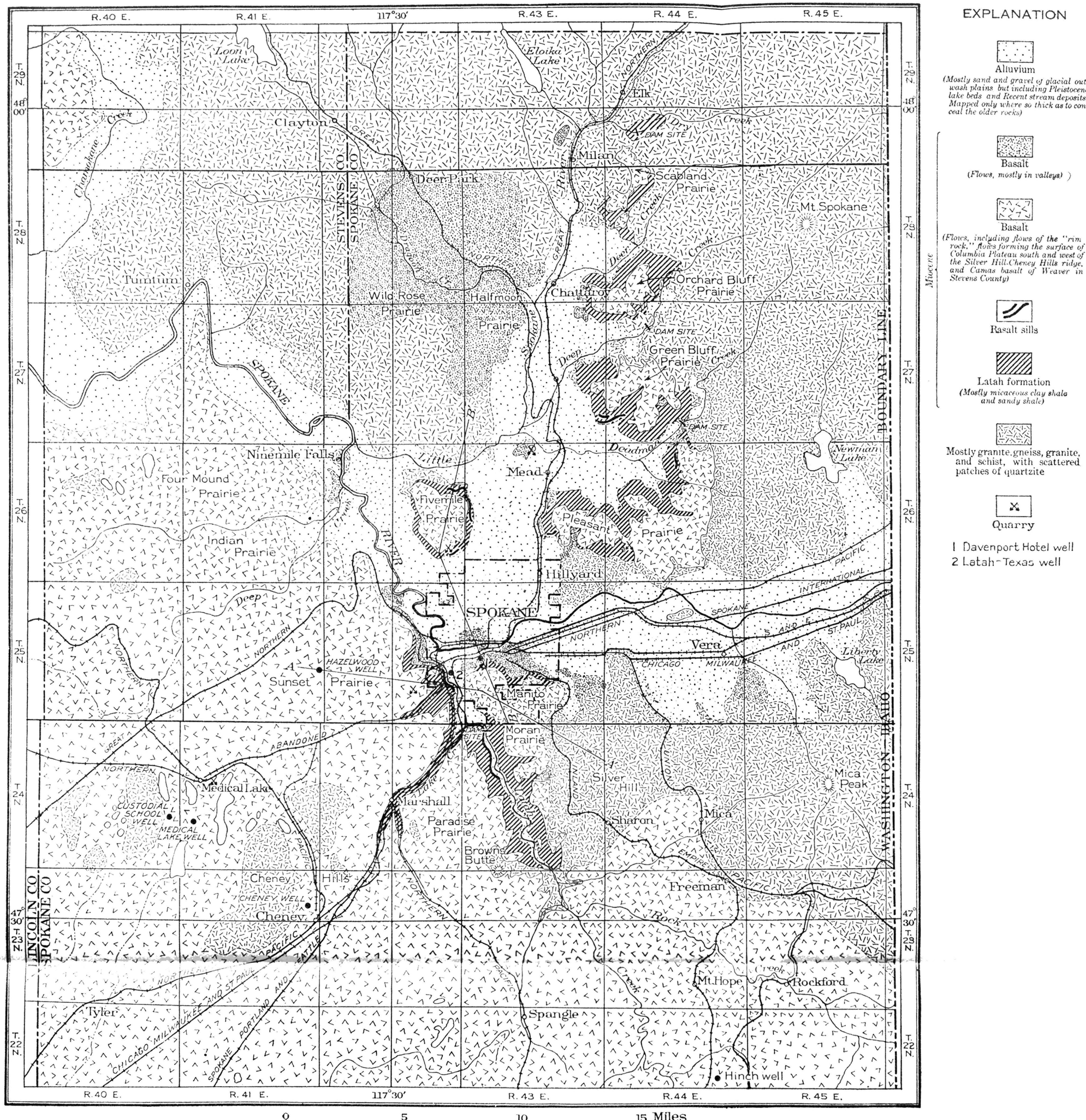

FIGURE 1.—Index map showing position of fossil localities near Spokane, Wash., and location of area covered by Plate I

## SURFACE FEATURES OF THE REGION.

The area considered herein lies along the border between the Great Plains of the Columbia, or the Columbia Plateau, and the mountains of northern Idaho and northeastern Washington. It includes parts of the valleys of Spokane and Little Spokane rivers, together with adjoining parts of the mountains

[1] Russell, I. C., A reconnaissance in southeastern Washington: U. S. Geol. Survey Water-Supply Paper 4, p. 53, 1897.

[2] Smith, G. O., U. S. Geol. Survey Geol. Atlas, Ellensburg folio (No. 86), p. 3, 1902, Russell, I. C., A geological reconnaissance in central Washington: U. S. Geol. Survey Bull. 108, p. 103, 1893.




RECONNAISSANCE GEOLOGIC MAP OF AREA NEAR SPOKANE, WASH.

*A—A', B—B', lines of sections in Figures 2 and 3* and the plateau. The general setting of the area is shown in Figure 1, and the area immediately adjacent to Spokane is shown on the geologic map (Pl. I).

Spokane lies at the northeast corner of the Columbia Plateau. From the hills east of the city this feature appears as a plain stretching away to the horizon on the south and west. It owes its general character to the fact that it is built up of vast lava flows that remain nearly as level as when they cooled. Because the liquid masses advanced upon a mountainous region the edge of the plateau is sinuous and irregular. South of Spokane it projects into the mountain valleys and retires around the intervening spurs like the coast line of a sea, and this fancied resemblance is increased by the fact that here and there isolated hills rise above the plain like off-shore islands. Westward from Spokane the present northern boundary of the plateau is the valley of Spokane River, a feature of more recent origin. North and east of the river isolated mesas or plateaus capped by basalt show that before the valley of Spokane River and its tributaries were cut that part of the plateau margin, like the stretch south of Spokane, was exceedingly sinuous.

In the neighborhood of Spokane the general altitude of the plateau is about 2,400 feet above the sea; its surface appears to be level or to slope gently northward, and it drains toward Spokane River. At a distance of 10 or 12 miles west of Spokane is an inconspicuous divide, beyond which the plateau descends gradually to the southwest for more than 100 miles. Considered in detail the plateau surface near Spokane is considerably roughened. The streams tributary to Spokane River have cut valleys into it several hundred feet deep, which exhibit crags, cliffs, and terraces at different levels.

The area immediately east and north of the Columbia Plateau is characterized by wide valleys, smoothly contoured slopes, and mountains of moderate height. Between Spokane and Coeur d'Alene the local relief ranges from 100 to as much as 3,000 feet. Farther east it is greater. The change from plateau to hills or mountains is generally abrupt, definite, and without gradations, but commonly a small depression is found between the edge of the basalt and the foot of the mountain slope.

From Spokane a wide depression extends east-northeastward into the mountainous area as far as the head of Pend Oreille Lake. It contains a level floor that in the vicinity of Spokane is about 2,000 feet above the sea, or 400 feet below the Columbia Plateau. Eastward the floor rises gradually, its general altitude in the neighborhood of Coeur d'Alene, about 30 miles from Spokane, being 2,300 feet. Along the sides of this depression in tributary valleys are several beautiful lakes, including Coeur d'Alene Lake, that are well known as summer resorts. So far as the writers are aware there is no name in use for this depression as a whole. For a distance of 15 or 20 miles east of Spokane it is known as Spokane Valley. Beyond this a part lying between Coeur d'Alene and Rathdrum, Idaho, is called Rathdrum Prairie, and the remainder is known by different names.

Spokane River, the outlet of Coeur d'Alene Lake, flows through Spokane Valley in a shallow trench to the falls at Spokane. Below this point it occupies a deep gorgelike valley, bordered by prominent cliffs and terraces, that extends northwest along the edge of the Columbia Plateau. This valley, which by reason of its generally rugged character contrasts strongly with the valley above the falls, or Spokane Valley proper, is commonly known as the gorge or "lower valley" of Spokane River.

On the north side of Spokane Valley opposite Spokane is a small table-land or plateau known as Fivemile Prairie (Pl. I). Its flat summit is nearly 2,400 feet in altitude, and its upper part is composed of two or more horizontal sheets of lava. Evidently it once formed a part of the Columbia Plateau, from which it has been cut off by Spokane River. Pleasant, Green Bluff, Orchard Bluff, and Scabland prairies are similar outliers of the plateau that extend north from Spokane on the east side of the valley of Little Spokane River. The general appearance of these table-lands or mesas may be judged from Plate II, *A*, a view of the northwest slope of Pleasant Prairie. Here and there east of Spokane on both sides of the valley are shelves at or near the 2,400-foot contour formed by patches of lava clinging to the sides of the valley. The most extensive one observed is at the north of Hayden Lake. Others appear on the shores of Coeur d'Alene Lake and along the lower courses of Coeur d'Alene and St. Joe rivers. All are interpreted as remnants of the highest and last of the lava flows that built the Columbia Plateau and once overspread Spokane Valley and its tributaries.

Patches of lava that form small masses and benches from 1,800 to 2,100 feet in altitude occur along Spokane River at Spokane, near Milan, near Chattaroy, on Half Moon Prairie, and near Deer Park. These isolated outcrops are interpreted as remnants of the plain formed by the most recent flow of the region as described on page 13.

Latah Creek and Deep Creek, which join the river below Spokane and drain adjoining parts of the Columbia Plateau, have excavated deep valleys similar in character to the valley of Spokane River below Spokane Falls. Viewed from Manito Prairie, the plateau remnant south of Spokane, across the deep valley of Latah Creek, the Columbia Plateau, bounded by its black cliffs, stretches out to the horizon, as shown in Plate II, *B*.

Out on the plateau 8 or 10 miles from Spokane are several hills that stand out faintly on the sky line. These "islands" or "steptoes" are knobs and ridges of granite and similar rocks that project through the lava. Together they form a broken chain of hills extending from Silver Hill west and northwest to Browns Butte, Marshall, Cheney, and Medical Lake. Probably to be included with them are two small knobs farther northwest, beyond Deep Creek. (See Pl. I.) These hills, as explained on page 10, mark the position of a buried ridge that for a time held back the advancing lava flows and permitted the leaf-bearing sediments to accumulate undisturbed in the neighborhood of Spokane. Finally, however, the lava overflowed and submerged the ridge until only its highest summits stood above the igneous flood.

## ROCKS

### GRANITE-SCHIST GROUP

The mountainous part of the area considered is composed chiefly of crystalline and metamorphic rocks, such as granite, gneiss, and schist, with small masses of quartzite. In addition rocks of this group form the encircling chain of hills that rise above the plateau from Silver Hill to Medical Lake. On the north side of Fivemile Prairie, in numerous places in the other "prairies" east and north of Spokane, and down the gorge on Spokane River, granite and granite gneiss crop out beneath the lava and the fossil-bearing shale, as shown on the geologic map (Pl. I). It is evident, therefore, that in addition to composing the hilly areas these rocks extend beneath the plateau as a basement or floor upon which the sediments and lavas rest. To judge by the degree of crumpling and metamorphism it exhibits, the schist is very ancient. The granitic rocks that intrude it are younger, but all members of this group are much older than the lava, the fossil-bearing shale, and the gravel that lie unconformably upon them. A detailed description of the granite-schist group as it occurs at Silver Hill, southeast of Spokane, is given by Collier,[3] and for Stevens County by Weaver.[4]

### LATAH FORMATION

#### GENERAL FEATURES

The fossil-bearing beds that overlie the granite-schist group are distributed through an area extending from the mouth of Deep Creek east-southeastward to Coeur d'Alene, Idaho, and 20 miles north of Spokane to Dry Creek, near the town of Elk. Owing to the fact, however, that they are composed of soft and easily erodible materials, they have been largely washed away wherever they were not protected by a covering of basalt, and their areal extent therefore is small. (See Pl. I.) The vertical range of their exposures amounts to as much as 800 feet, the lowest, which is near the mouth of Deep Creek, being at an altitude of about 1,650 feet, and the highest, near Mica, at about 2,450 feet.

The fossil-bearing beds consist mostly of shale or clay, with a few layers of sand and gravel. The colors range from pale yellowish gray to lead-gray or bluish gray, the prevailing shades being rather dull. Locally the beds show pale tints of brown and streaks of rusty red. Glistening specks of white mica occur abundantly in most of the beds. The coarser layers are composed chiefly of quartz and feldspar grains derived by erosion from the rocks of the granite-schist group. No beds were observed to contain pebbles or grains of basalt. Approximate analyses made in the laboratory of the Geological Survey show the clays to contain from 45 to 70 per cent of silica and from 15 to 30 per cent of alumina.

A microscopic examination by Edward Sampson of specimens of the shale from the neighborhood of Latah Creek indicates that much of the finer-grained material composing the shales is of volcanic origin. These specimens contained sharp-edged grains of quartz and fresh grains of plagioclase feldspar and biotite mica that can hardly have been derived from the rocks of the granite-schist group and seem more likely to have been derived from showers of volcanic ashes of an andesitic type that fell in the region during the period of sedimentation. The lack of volcanic glass, so far unidentified in the specimens, is difficult to explain. The lamination of the beds indicates that the material of the ash showers was thoroughly reworked by streams and probably more or less mixed with the products of the erosion of the granite-schist highlands to the east.

In weathering the shale usually becomes brownish yellow and loses its lamination and jointing. Stains, spots, and seams of limonite are formed. Usually also there is a surface crust from a quarter of an inch to 2 inches thick composed of sand and limonite so hard that pieces ring under the hammer. The crust is frequently broken in plowing, and the flakes are picked up and piled in heaps at the edges of the fields. The clayey character of the weathered shale makes it a notable soil in a region where most of the soils are sandy. In some places the weathered surface of the shale is leached to a white impure kaolin, which retains, however, flakes of mica and leaf impressions. This white phase of the weathered surface and also the ordinary type are used near Spokane and at Vera for making common brick and tile.

Where the beds rest on the underlying granite gneiss they usually consist of arkosic gravel that grades by interbedding into the characteristic clay

[3] Collier, A. J., Tin ore at Spokane, Wash.: U. S. Geol. Survey Bull. 340, pp. 295-305, 1908.

[4] Weaver, C. E., The mineral resources of Stevens County, Wash.: Washington Geol. Survey Bull. 20, 1920.

shale. Clay with scattered small pebbles and clayey gravel were found interbedded with the typical clay shale in the test holes drilled in 1923 at the Latah Creek dam site of the Columbia Basin project.

## LOCAL DETAILS

### SECTION AT DEEP CREEK

On the west bank of Deep Creek about half a mile above its mouth, at a locality that is shown in Plate III, *A*, and that has yielded a large part of the collection of fossil leaves described by Mr. Knowlton, the shale is exposed as follows:

*Section on Deep Creek half a mile above its mouth*

| | Feet |
|---|---|
| Sand, rusty red; contains quartz pebbles and flakes of white mica | 15 |
| Shale or clay, thin bedded, lead-gray, with a few rusty-red layers. Contains abundant fossil leaves. At bottom a thin layer with fragments of wood partly changed to lignite | 15 |
| Shale, massive, bluish gray | 20 |
| Clay, containing fragments of tree stumps and stems that are partly altered to lignite | 2 |
| Bottom not exposed. | |

As determined by aneroid the altitude at the base of this exposure is 1,650 feet. Above the rusty red sand at the top are basalt cliffs and talus-covered slopes rising 600 feet or more to the summit of the plateau. The beds appear to be horizontal.

### SECTIONS WEST OF LATAH CREEK IN SPOKANE

Several cuts along the Spokane, Portland & Seattle and Chicago, Milwaukee & St. Paul railways in the city of Spokane west of Latah Creek expose the fossil-bearing shale. About three-quarters of a mile south of the Sunset Highway bridge over Latah Creek are cuts near each other on these two railways, which for convenience will be referred to as S., P. & S. cut No. 1 and Milwaukee cut No. 1. The following section was measured in S., P. & S. cut No. 1 at an altitude of about 1,950 feet above the sea:

*Section in cut of Spokane, Portland & Seattle Railway in Spokane*

| | Feet |
|---|---|
| Surface mantle containing large masses of basalt | 6 |
| 1. Sand, white to red, moderately fine, composed of rather sharp grains of quartz, feldspar, and other minerals | 5 |
| 2. Shale; rusty yellow, yields fossil leaves | 10 |
| 3. Hardened clay; massive, light gray | 12 |
| Bottom not exposed. | |

Bed 1 is cleanly washed stream sand that fills a channel eroded in the other layers. Many of the plant remains described by Mr. Knowlton were obtained from bed 2. There is no break between beds 2 and 3, and despite the erosional unconformity beneath bed 1 all are considered as belonging to the same series. Apparently the two lower beds were deposited in a pond or other low place so as to form a mud flat across which a gently flowing stream later spread the sand of bed 1. In places in this and some of the other cuts, as mentioned farther on, dikes and sills have intruded the beds, causing them to dip at moderate angles. Away from these disturbing features the beds appear to be horizontal and undeformed.

On the slope directly above this cut, along a road that passes through a subway on the abandoned electric-railroad grade, yellowish-gray clay and layers of cross-bedded sand are exposed. These beds are similar in composition and appearance to those in the railway cut and are regarded as belonging to the same series. They are overlain by the lowermost of the basalt flows known as the "rim rock," described on page 11, the base of which is at an altitude of about 2,250 feet.

Between the two exposures the slope is covered and the underlying formations are concealed by a rather thick mantle containing fragments and scattered large masses of basalt that apparently are the weathered remnants of later flows. Presumably the shale formation is continuous beneath this mantle; if so, its total thickness from the floor of the railway cut to the base of the "rim rock," exclusive of a 50-foot sill, is about 250 feet.

South of S., P. & S. cut No. 1 other cuts on both this railway and the Chicago, Milwaukee & St. Paul Railway expose the shale at successively higher altitudes up to about 2,050 feet, the highest being at a distance of 2 miles in the third cut to the south on the Spokane, Portland & Seattle Railway. Here 20 feet or more of light-gray shale that yields abundant plant remains is exposed.

At the contact with the intrusive dikes and sills the shale commonly appears darkened, but in places it is nearly white and baked almost to the consistency of porcelain. In Milwaukee cut No. 1 a mass of shale nearly surrounded by the intrusive rock (Pl. IV, *B*) shows a peculiar jointing that causes it to separate into slender curved columns, the size of a pencil or smaller, radially arranged about the centers of ordinary joint blocks a foot or less in size.

On the front of the spur between Latah and Lake creeks half a mile east of a cut on the Spokane, Portland & Seattle Railway a sand pit shows the following:

*Section in sand pit of H. Feise, south of Spokane*

| | Feet |
|---|---|
| Talus composed chiefly of basalt fragments | 10 |
| Clay, massive, yellowish gray | 5 |
| Clay, sandy, micaceous, dull gray, indistinctly bedded; fragmentary plant remains near top | 10 |
| Sand, cross-bedded, medium-sized grains, cleanly washed, composed chiefly of quartz and feldspar grains and flakes of mica | 20 |

The cross-bedding in the 20-foot layer inclines northwestward, as if the sand had been deposited by a stream flowing in that direction. The altitude at the base of the exposure is about 2,100 feet. A second sand about 20 feet lower has been uncovered in a small pit below which is a spring that is obviously fed by water stored in the two sand beds. The slope below is covered by soil and terrace gravel to an altitude of about 1,980 feet, and at that level a sill crops out that at the Latah Creek dam site, about a quarter of a mile away, has a thickness of more than 250 feet.

#### OTHER EXPOSURES

A particularly valuable part of the fossil collection came from a well on the Edwards ranch, about 2 miles northeast of Coeur d'Alene, Idaho. When this place was visited by Mr. Pardee early in July, 1923, no exposures of the fossiliferous beds were to be seen. The well is on a bench on the south slope of Stanley Hill, at an altitude of 2,400 feet. It is said to be 43 feet deep, and the plant remains were found near the bottom. Remnants of basalt flows that appear to overlie the shale crop out near by, and granite and schist that form the bedrock are exposed a little farther away. The matrix of the specimens from this well is of a dull-gray color, resembling that from most of the other fossil localities, but an approximate analysis shows it to contain less silica and more iron and alumina than the average.

At Thirteenth Avenue and Perry Street, in the southeastern part of Spokane, thin-bedded soft sediments that range from clay to fine sandstone are exposed to a thickness of 8 feet. The beds are gray, dip about 4° N., contain grains of quartz and flakes of white mica, and are stained rusty red on bedding planes and joints. Fossil leaves are present but not abundant or well preserved. The altitude is about 2,050 feet.

Very light-colored beds that contain abundant fossil leaves and are composed of clay, fine quartz sand, and white mica crop out at an altitude of about 2,100 feet in a ravine at the Schuele ranch, on the slope south of Fivemile Prairie, and in the cuts of the new county road on the north slope of the same "prairie," where fragmentary plant remains were found. The beds are about horizontal and are overlain by basalt, but their base is not exposed. A deposit of similar clay described by Shedd[5] occurs on the farm of W. G. Lake, 6 miles north of Spokane.

In a gulch on the slope southeast of Fivemile Prairie, about 1½ miles east of the Schuele ranch locality, 40 feet of shale that contains leaf-bearing layers is exposed. It shows the dull-gray shades and other features common to the shale elsewhere. The altitude at the base of the exposure is 2,120 feet. Slopes above and below are covered with loose fragments of basalt and soil. A flow in place corresponding to the "rim rock" crops out at 2,240 feet.

Somer's clay pits, about 2 miles south of Vera, expose 20 or 30 feet of compact micaceous white, yellow, and red clay in nearly horizontal beds that contain fossil plant remains. The clay lies upon rocks of the granite-schist group and occurs at an altitude of about 2,100 feet. The basalt cover has been stripped away by erosion, and the beds are now overlain by a thin cover of valley gravel.

Specimens obtained at Mica, Wash., are said to have come from a well at an altitude of 2,450 feet. They consist of brownish-gray clay or shale that is noticeably light in weight. The microscope shows it to be composed largely of very small cylinders and other hollow forms that are the siliceous skeletons of the minute water plants known as diatoms, described by Mr. Mann on pages 51–55. In addition the shale contains fine grains of quartz, mica, and other minerals derived from the granite and schist of the adjoining hills. Evidently the deposit was formed in a pond or marsh. It may be classified as impure diatomaceous earth and also as brick clay, but it is of different origin from the residual clays at Mica and Freeman, near by, which have been described by Shedd.[6] Evidently this deposit rests upon rocks of the granite-schist group.

Along the road up Biglow Gulch about 2 miles northeast of Hillyard the shale is exposed at an altitude of 2,200 feet. It lies upon granite and beneath a basalt flow at 2,300 feet corresponding to the "rim rock."

In Indian Canyon, above the falls, is a small exposure of fossiliferous shale at an altitude of 2,200 feet, just above the outcrop of a basalt flow. The field relations suggest that the shale lies upon the flow, which, if this is true, should be correlated with the upper one of the two flows encountered in the Hazelwood well (p. 10). However, the evidence is not decisive, and the basalt may belong to the "valley" flows and rest unconformably on the shale.

Sediments that doubtless are equivalent to the fossil-bearing beds described above are penetrated by several drilled wells—the Hazelwood well, 7 miles west of Spokane; the Hinch well, 18 miles southeast of Spokane; and the Davenport Hotel and Latah-Texas wells, in the city. The information derived from these wells is given on pages 8–9.

Above Medimont in the valley of Coeur d'Alene River, about 35 miles east-southeast of Spokane, are fine white and variegated sediments described by Hershey[7] as having accumulated in a lake caused by a dam formed of basalt. Apparently the basalt referred to is a remnant of the last or highest flow of Columbia Plateau. No fossils are reported from these beds.

#### DEFINITION

From the foregoing descriptions it appears certain that, except for some later intrusive rocks, the slope west of Latah Creek from the railway cuts to the

[5] Shedd, Solon, The clays of the State of Washington, their geology, mineralogy, and technology, pp. 172–174, Washington State College, 1910.

[6] Shedd, Solon, op. cit., pp. 181–194.

[7] Hershey, O. H., Geol. Soc. America Bull., vol. 23, p. 529, 1912.

"rim rock" is underlain by the fossil-bearing shale and associated beds, which aggregate at least 250 feet in thickness. Although there is no continuous exposure of such a thickness, the different places at which horizontal beds are shown at successively higher levels are comprised within so small an area that there is little room for doubt that all the exposures are parts of a continuous formation.

Inspection of the several "prairies" north and south of Spokane reveals similar relations. Each of these pleateau remnants has a cap or "rim rock" at an altitude of about 2,400 feet. Below the "rim rock" there are smooth soil-covered slopes, mostly in cultivation, as illustrated in Plate II, *A* and *B*. These smooth slopes are underlain by the clay beds, as shown by the clayey texture of the soil, by the presence of flakes of limonite characteristic of the weathered surface of the beds, and by scattered exposures in wells and road cuts.

In these localities the beds lie unconformably upon the rocks of the granite-schist group. They consist chiefly of fine sediments. Their fossils, as described farther on, indicate that they are all of the same age; and therefore all are regarded as parts of the same formation, for which the name Latah is proposed. The Latah formation, consequently, may be defined as consisting chiefly of clay and shale with some beds of sand and gravel and one or more beds that contain sufficient quantities of diatom skeletons to be classed as an impure diatomaceous earth. Many of the shale beds appear to be composed largely of very fine volcanic ash. The shale generally contains plant remains, which, as described by Mr. Knowlton in the following paper, are of middle or lower Miocene age. The formation is at least 250 feet thick in the area of typical exposure on the slope west of Latah Creek, and its range in thickness in the Spokane-Coeur d'Alene area is from 1,500 feet to the vanishing point. In the Spokane area, so far as known, it rests everywhere upon the granite-schist group, and apparently it is or was at one time covered everywhere by the lava flows composing the "rim rock." Formerly it extended continuously over the area from the Silver Hill-Cheney ridge north and east to the mountains, except for the "islands" or "steptoes" of crystalline rock, many of which were not covered even by the highest lava flow. South and west of the ridge the extent of the formation is not definitely known and the upper beds are surely absent. (See p. 10.)

## STRUCTURE

Where exposed by the railway cuts west of Latah Creek the shale of the Latah formation has been deformed by intrusive bodies of igneous rock. A sill 50 feet or more thick, particularly well shown in S., P. & S. cut No. 1 and Milwaukee cut No. 1 has forced its way along a bedding plane, lifting and tilting the overlying shale. In places the intrusive rock takes the form of dikes that break across the beds and displace them slightly. This deformation, however, is confined to the vicinity of the intrusive bodies. In Biglow Gulch northeast of Hillyard and at Thirteenth Avenue and Perry Street and on Thor Street in Spokane the shale dips 4°–10° N. Whether this attitude is the result of an intrusive igneous body is not shown, but there is no reason to think it may be due to any other cause. Elsewhere from Deep Creek to Coeur d'Alene and from Duncan to Milan the beds of shale, wherever they can be seen, are horizontal.

## ORIGIN

Before the Latah formation was deposited and the lava of the Columbia Plateau was extruded the rocks of the granite-schist group formed the surface in this area, the topography of which was apparently even more rough than the mountainous lands north and east of the plateau are at present. The section along the northern border of the plateau made by Spokane and Columbia rivers shows the relief of the old surface to be as much as 1,600 feet. At Spokane, as indicated by the Latah-Texas well (p. 8), there is a submerged valley at least 1,000 feet deeper than the present one. The 1,100 feet of lava and sediments penetrated by the Hazelwood well (p. 10) probably fill the ancient prolongation of this old valley. At the south of this buried valley is a ridge whose summits project through the lava to form the chain of hills that extends from Silver Hill by way of Marshall and Cheney to Medical Lake and, as suggested by the smaller but otherwise similar hills of granite northwest of Deep Creek, probably continues 20 or 30 miles farther northwest. (See Pl. I.) At Duncan the present valley of Latah Creek crosses this ridge, cutting deeply into the granite and schist.

Most persons familiar with the Spokane area have been of the opinion that the fossil-bearing sediments described herein accumulated because the drainage was obstructed by lava flows advancing upon a mountainous region. Under this condition sediments brought down from the lands to the north and east would be deposited at the borders of the flows. Successive flows would result in a succession of sedimentary deposits, each one farther east or north and at a higher level than its predecessors. Thus it would be supposed, for example, that after the beds at Deep Creek were laid down a lava flow extended eastward beyond that point, causing a new pond in which the beds at S., P. & S. cut No. 1 accumulated. After this process was repeated there would be a succession of lava flows alternating with layers of sediment partly extending in front of them and partly interbedded with them. The information recently obtained in this area by the writers, however, makes necessary a modification of that idea so far as details are concerned. North of the buried ridge represented by the Cheney Hills no interbedded lava flows were found, except possibly at Indian Canyon (p. 6), and such flows are known only in the Hazelwood well, mentioned on page 10. The sediments appear to belong to a single formation that was completely deposited before any of the flows near Spokane and their related sills and dikes came to place. They accumulated in a basin that extended from the buried ridge north and northeast to the limits of the area surveyed. As shown by the character of the sediments, this basin was at times occupied by ponds and at times became drained so that streams flowed across its floor. Leaves and wood of the forests growing on the neighboring lands and on the alluvial plains of the basin fell into the streams and, on being buried in the mud and sand, were preserved.

The materials that form the leaf-bearing Latah formation were derived from explosive volcanoes and from the erosion of the granite gneiss of the mountains adjacent on the east. The finer beds are composed largely of volcanic ash of an andesitic type. The coarser beds are generally composed of grains of quartz and feldspar, but in some localities black and gray quartzite makes up about half of the grains, as shown by a study of samples from the drill holes at the Latah Creek dam site. At the Dry Creek dam site, near Milan, however, no quartzite was found, and this fact was used to distinguish the Latah gravel from the overlying flood-plain deposits. No basalt pebbles were found in any material from the Latah formation.

The character of the material and the type of rock composing the larger grains indicate that the formation as a whole was derived from the erosion of the region to the east but that local streams draining areas with slightly different bedrock carried on the work of deposition in different places. It appears also that the formation was deposited in a basin at the foot of the mountains and in a period preceding that of any of the basalt flows now exposed on the surface in the Spokane region. Some beds were doubtless deposited in still water, as shown by their fine grain and delicate lamination. The leaves that are so beautifully preserved in many beds are generally quite perfect and lie parallel to the lamination of the shale. They were evidently floated into place rapidly but gently. Such beds must have been deposited in quiet ponded water and seem to indicate the presence of lakes. Other beds, however, contain the macerated remains of vegetation such as now accumulates in the bottoms of swamps. The sand and fine gravel were deposited by currents, as shown by their cross-bedding, and doubtless represent the channels of streams. The Latah formation seems therefore to have been deposited in a broad plain of alluviation containing lakes and swamps, over which the streams from the mountains on the east found their way through sluggish channels toward the west.

The cause of this ponding of the streams might, so far as evidence from the fossil-bearing beds is concerned, be attributed either to local subsidence or to the building of a dam across the lower courses of the streams by the earlier and lower members of the basalt series that occupies the basin to the west. The idea of subsidence during deposition is unsupported by any evidence, but ponding of the drainage by lava flows is a hypothesis based on a number of ascertained facts and logical inferences. The sediments of the Latah formation are earlier than any of the basalt flows that crop out in the immediate neighborhood of Spokane, except possibly the flow at Indian Canyon. (See p. 6.) On the other hand, the data derived from wells presented on page 10 indicate interbedding of the clay shale with flows west of Spokane. This seeming discrepancy has already been explained as due to the presence of the submerged ridge now represented by the Cheney Hills and similar knobs, which acted as a barrier during the time of extrusion of the basalts of the plateau to the west and held back the advancing lava. Thus while flow after flow desolated the general region of the Columbia Plateau, the Spokane area, owing to the protection afforded by the Silver Hill-Cheney ridge, was the scene of uninterrupted and quiet sedimentation until it too was finally overwhelmed by the flows of the "rim rock."

Though the Spokane area was free of lava flows, showers of volcanic dust were sufficiently frequent to supply much of the material composing the shale. Mr. Knowlton, as set forth in the succeeding paper, believes that the Latah formation is of middle or lower Miocene age and that it is to be correlated with the Ellensburg and Mascall formations. These formations consist in part of tuff beds. Volcanic débris in the Latah formation is to be expected, but the Spokane area doubtless lies at a great distance from the centers of eruption, for all the material attributable to volcanic explosions so far found is of microscopic size.

### THICKNESS

As shown in the geologic cross section of Figure 2, the top of the Latah formation in the Latah Creek valley is at an altitude of 2,250 feet, and the floor of the valley is at 1,750 feet. These figures indicate a thickness, including the intruded sills, of 500 feet. The Latah-Texas well, however, according to the drill samples shown to Mr. Bryan, after passing through the gravel of the flood plain and a thin layer of basalt, penetrated gray shale, dirty gravel, sand, and gravel, similar to material found elsewhere in the Latah formation, for 1,089 feet before entering the underlying granite gneiss. The total thickness of the Latah in this locality must therefore be from 1,400 to 1,500 feet.

In the city of Spokane the well in the Davenport Hotel, after passing through 430 feet of gravel and basalt, entered shale and sand and ended in gravel at a depth of 668 feet. (See fig. 3.) The sediments found in this well below the basalt are correlated with the shale that has been exposed in excavation at several localities in the north slope of Manito Prairie up to the base of the overlying lava, at an altitude of 2,150 feet, or about 250 feet above the Davenport Hotel. A minimum thickness of 918 feet is thus indicated beneath the central part of the city of Spokane. Between the mouth of Deep Creek, 8 miles northwest of Spokane, and Mica, about 12 miles southeast of the city, the vertical range of exposures, as already mentioned on page 4, is about 800 feet. Several wells, about which conflicting stories are current and much misinformation exists, were drilled in a vain search for oil near the intersection of Twenty-ninth Avenue and Southeast Boulevard. Information obtained by Mr. Henry Fair during the period of drilling indicates that one well reached a depth of 1,400 feet and penetrated 264 feet of basalt and 286 feet of clay and shale of the Latah formation before entering the underlying rocks. This well is on Manito Prairie at a point about 400 feet higher than the collar of the Davenport Hotel well. It shows that the pre-Latah surface rises rapidly toward the eastern hills (fig. 3), a condition also indicated by other field evidence.

It is evident from the foregoing considerations that the Latah formation attains a considerable thickness, but in Pleasant Prairie, Greenbluff Prairie, and other localities the formation decreases in thickness to the vanishing point in the direction of the hills that existed at the time of deposition, and there the overlying basalt flows rest directly on the granite gneiss.

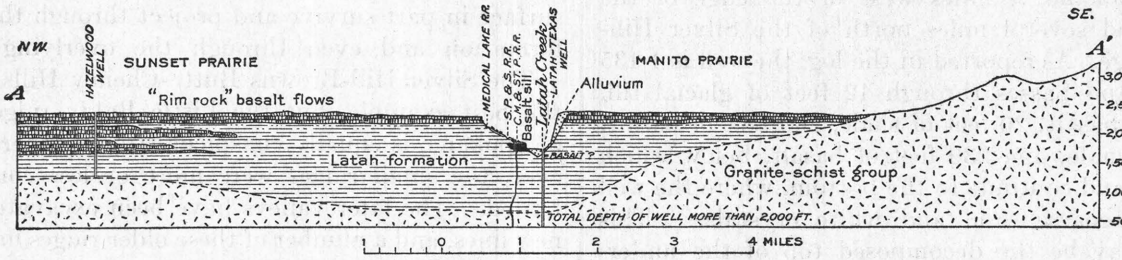



FIGURE 2.—Geologic cross section from Sunset Prairie to ridge east of Manito Prairie, Wash., along line *A-A'*, Plate I

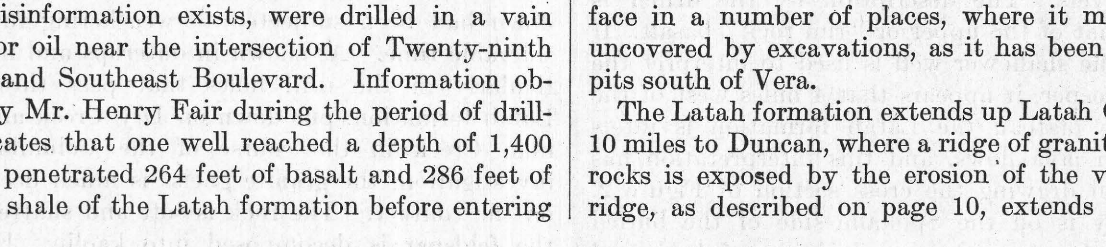



FIGURE 3.—Geologic cross section from Manito Priaire though Fivemile Prairie to ridge north of Little Spokane River, Wash., along line *B-B'*, Plate I

EXTENT

The distribution of the Latah formation is shown on the accompanying map (Pl. I). In many places on the slopes of the "prairies" it is concealed by talus, glacial till, and terrace gravel. In the Latah Creek valley the only good exposures are in the railway cuts previously described. In general a deep mantle of glacial gravel conceals the slopes, but an unusually detailed search for outcrops of the shale and the intruded sills, together with the results of drilling at the Latah Creek dam site, permits the mapping of the formation in this valley with entire confidence. In the valleys of Spokane and Little Spokane rivers the underlying formations are masked by glacial gravel, but doubtless the Latah formation is close to the surface in a number of places, where it may be later uncovered by excavations, as it has been in the clay pits south of Vera.

The Latah formation extends up Latah Creek about 10 miles to Duncan, where a ridge of granite and other rocks is exposed by the erosion of the valley. This ridge, as described on page 10, extends from Silver Hill, east of Latah Creek, west through Browns Butte and the hills north of Cheney to a point beyond Medical Lake. (See Pl. I.) South of the ridge Latah Creek has cut its valley wholly in basalt, of which nearly 500 feet is exposed (Pl. III, *B*). The Hinch well, near Mount Hope, east of the creek, in the SW. ¼ sec. 14, T. 22 N., R. 44 E., penetrates 53 feet of soil, 271 feet of basalt, 20 feet of shale, 572 feet of basalt with streaks of clay, sand, and gravel, and 530 feet of shale and sand. Entirely different conditions of deposition from those near Spokane are indicated by this log. The overlying lavas are 843 feet thick and are divided into upper and lower portions by 20 feet of shale. The 530 feet of shale and sand at the bottom of the well, if considered as equivalent to the Latah, must represent only the lower part.

The well of the State Normal School at Cheney is also south of the ridge. Below 32 feet of gravel and clay, doubtless of Pleistocene age, the well penetrates basalt for 470 feet. Clay beds from 6 to 12 inches thick and zones of vesicular lava separate this 470 feet of basalt into not less than seven distinct lava flows.

The deep well at the Hazelwood farm lies 7 miles west of Spokane, 4 miles west of the edge of the plateau, and several miles north of the Silver Hill-Cheney ridge. As reported in the log, the well is 1,135 feet deep and passes through 12 feet of glacial till, 159 feet of basalt, 20 feet of shale, 200 feet of basalt, 67 feet of shale, and 230 feet of basalt, below which shale and sand continue to the bottom, where the well ended in "coarse sand and white crystals." This material may be the decomposed top of the underlying granite gneiss. So little information is given by the log that the two thick beds of basalt below the "rim rock" may be interpreted either as flows or as sills. However, a shallow well in the same locality has a more perfect log from which it is evident that the first of the two lower basalts consists of alternating hard and soft layers. The description by the driller is similar to that of the upper or "rim rock" basalt. If the log of the shallower well is used to interpret the log of the deeper, it appears that 4 miles west of the edge of the plateau the Latah formation is interbedded with lava flows, and this interpretation has been used in drawing the cross section of Figure 2. This locality is on the Spokane side of the buried ridge, and therefore the interbedding of lava and sediments is exceptional. It may be explained as caused by a low gap at one point in the protecting ridge which permitted flows earlier than the "rim rock" to enter and overspread a small part of the Spokane area. These early flows must have constituted the dams against which the upper beds of the Latah formation accumulated, the locations of these dams being somewhere along the drainage outlet of the Spokane area at that time and beyond the limits of the region here considered.

Farther west the lavas are more continuous and there is less intervening shale. At Palouse Falls, 70 miles southwest of Spokane, a well 951 feet deep, as reported by the driller, passed through 59 feet of soil, sand, and gravel and then through 892 feet of basalt in which beds of shale spaced at uneven distances and ranging from 5 to 16 feet in thickness were found. In the Columbia Basin, west of the buried ridge, 1,200 to 1,500 feet of basalt without intervening shale is exposed. The transition between the geologic sections in the Spokane and Basin areas is partly revealed in the logs of wells at Medical Lake and Davenport. At Medical Lake, 13 miles southwest of Spokane, only 14 feet of shale can be certainly identified in the upper 465 feet of the well for which a log is available. A well 503 feet deep at Davenport, 33 miles west of Spokane, after passing through gravel and clay for 24 feet, went into rock that, from the log, is evidently a series of basalt flows.

### PRE-LATAH SURFACE

The Latah formation was laid down on a surface consisting of hills and valleys that had a relief greater than that of the present day. The ridges of that surface in part survive and project through the Latah formation and even through the overlying basalt. The Silver Hill-Browns Butte-Cheney Hills ridge is the best example, but the Little Baldy ridge, north of Spokane, is equally conspicuous. In general, however, the small ridges were more or less completely buried. The later valleys have been excavated along new lines, and a number of these older ridges have been exposed (Pl. II, *A*). Where the present valleys cross these ridges they are relatively narrow and steep. At the Deep Creek and Deadman Creek dam sites, north of Spokane, pre-Latah ridges are exposed. Other ridges are entirely buried beneath the Latah and the overlying basalt.

The surface on which the Latah formation was laid down had been subjected to weathering for a considerable time. As shown in outcrops and more particularly in the drill holes that pass through the Latah formation, put down on Dry Creek and Deadman Creek in the course of the Columbia Basin investigation, the granite gneiss is much decomposed on the contact. The rock is soft and shattered, and the feldspar is decomposed into kaolin. Evidently the climate of the time just preceding the Latah deposition was more humid than at present and resembled that of Latah time, when sequoias, oaks, maples, and similar trees grew abundantly.

## BASALT GROUP

### DESIGNATION

Under the older usage all the basalts that underlie the great plateaus of the Columbia region were known collectively as the Columbia River basalt. This term, as defined by Russell,[8] included all of the series, from 1,200 to 1,500 feet in thickness, that occupies the central region of Columbia Basin, as well as several groups of flows in the foothills of the Cascade Mountains from Yakima to Wenatchee. It was shown by Smith,[9] however, that in the region northwest of Ellensburg Eocene sandstone and shale are interbedded with the lower flows. The Columbia River basalt obviously required subdivision; the name

[8] Russell, I. C., A geological reconnaissance in central Washington: U. S. Geol. Survey Bull. 108, pp. 20-22, 1893.

[9] Smith, G. O., op. cit., pp. 1-4.

Columbia, moreover, was preoccupied. The basalt flows that overlie the late Eocene beds and were overlain by the Ellensburg formation, of Miocene age, were accordingly named by Smith the Yakima basalt. Since that time all the basalts of the Columbia Plateau have generally been correlated with the Yakima basalt, of supposed Miocene age. As pointed out on page 12 the recent studies of the Latah formation cause this correlation to be modified so far as the Spokane area is concerned. Doubt has also been cast upon the general correlation in the neighborhood of Pasco by the work of Merriam and Buwalda.[10] It therefore seems best at present to consider the basalts under a general term, and to subdivide them into local groups without attempting to assign formation names.

### FLOWS OF THE "RIM ROCK"

In the neighborhood of Spokane the Columbia Plateau is underlain by two or perhaps three basalt flows that aggregate at least 200 feet in thickness. These flows rest upon the horizontal upper surface of the Latah formation at an altitude of about 2,200 feet. Within the limits of their thickness they submerge the older rocks that project above this level. As a rule the outcropping edges of these flows form the prominent dark vertical cliffs and crags that surmount the slopes leading up to the plateau. The conspicuous cliff known as the "rim rock," which forms the edge of the plateau southwest of Fort Wright, though it does not measure their entire thickness, fairly represents them and affords them a convenient name.

The "rim rock" flows show a pronounced vertical jointing that causes them to separate readily into the five or six sided columns that decorate nearly every cliff-like exposure. Particularly fine columns 2 or 3 feet in diameter are to be seen in the cut on the Sunset Highway just west of Dead Man's Curve (Pl. IV, *B*) and in the quarry of the Washington Water Power Co. near by. Within the area immediately adjacent to Spokane this jointing appears to be more characteristic of the "rim rock" flows than of the "valley" flows described farther on and thus in a measure serves to distinguish them. In a few localities shattered material with large "pillows" occurs, but rock of this type is not so abundant as in the "valley" flows (p. 14).

Vesicles, or gas holes, which are common at the top and bottom of the flows, are in natural exposures empty or contain a little iron rust or calcium carbonate. In a road cut and quarry near the corner of Twenty-ninth Avenue and Southwest Boulevard, Spokane, aragonite in slender clear crystals and sphaerosiderite occur in the vesicles. In a quarry on the southeast face of Fivemile Prairie the vesicles are large and shaped much like a collapsed tennis ball. There sphaerosiderite and calcite occur. Limonite replacing sphaerosiderite is common in most localities. It has been found in association with green and brown opal 10 miles south of Spokane on the Palouse Highway, on Pleasant Prairie, and at the north edge of Fivemile Prairie.

Representative specimens of the "rim rock" flows from four different localities—the southwest edge of Fivemile Prairie, the plateau half a mile west of Fort Wright, Biglow Gulch east of Hillyard, and the quarry of the Washington Water Power Co. south of Dead Man's Curve on the Sunset Highway—are all basalts consisting essentially of plagioclase feldspar and pyroxene with subordinate olivine and more or less glass. As determined by F. C. Calkins,

> Most of these contain at least a few small roundish blowholes, and all contain small irregular pores from the walls of which crystals of feldspar project. All appear well crystallized. Under the microscope it is seen that all contain a moderate amount of olivine. The augite forms interstitial granules or larger individuals inclosing or molded upon the laths of plagioclase. A good deal of brown glass, crowded with particles of iron ore and with other microlites, is present in all specimens.

Flows correlated with those of the "rim rock" form cliffs at the same level on the opposite side of the valley, at the edges of Fivemile Prairie and the other plateau remnants along Little Spokane River, on the west side of the Latah Creek valley, and elsewhere, as shown on the geologic map (Pl. I). Before these valleys were cut the flows must have extended continuously across the area. Within the limits indicated the flows appear to be horizontal and to be confined to altitudes between 2,200 and 2,400 feet. East and southeast of Spokane, however, basalt that is apparently the same as the "rim rock" flows occurs at higher levels. Near Mica it reaches an altitude of 2,600 feet but its base is not exposed. In the neighborhood of Coeur d'Alene it occurs between the 2,300 and 2,500 foot levels. Possibly this difference in height is to be explained as a result of a later slight elevation of the earth's crust toward the southeast, an idea that is supported by the fact that in several places in the Columbia Plateau outside of the Spokane area the lava is moderately deformed.

This basalt is thought to have risen through fissures to the surface, where it spread out in the form of sheets. For the reason that no adequate vents are known outside the borders of the plateau, the bulk of the lava is thought to have come from fissures within its area and therefore to the south and southwest of Spokane. Presumably the dikes exposed in the railway cuts west of Latah Creek described on page 12 represent vents through which a small part of the lava composing the "rim rock" flows reached the surface. The bulk of the lava, however, must have risen through larger fissures situated farther southwest.

[10] Merriam, J. C., and Buwalda, J. P., Age of strata referred to the Ellensburg formation in the White Bluffs of the Columbia River: California Univ. Dept. Geology Bull., vol. 10, pp. 255-266, 1917.

The flows of "rim rock" lie upon the beds of the Latah formation and show no angualr discordance with them. The contact can be observed in only one locality, a road cut on Pleasant Prairie near the line between secs. 29 and 30, T. 24 N., R. 44 E. At this place, as shown in Plate IV, *C*, the much weathered basalt rests on a black soil zone from 2 to 4 inches thick containing lignitized twigs and other vegetable litter. Below the soil the Latah shale, easily identified by scattering and imperfect plant remains, is weathered and iron stained for 2 to 3 feet. The contact is slightly uneven but does not give any definite indication of erosion of the shale. Apparently the soft beds of the Latah formation had been exposed to erosion only long enough to produce slight irregularities in the surface and a soil zone before the lava covered them. The conclusion seems to be that the flows of the "rim rock" are but little younger than the Latah formation.

The "rim rock" flows of the Spokane area form a definite group, but a thicker series of basalt flows underlies the plateau to the south and west of this area. On the surface the "rim rock" flows appear to be continuous with the top flows of this thicker series. In the Hazelwood well the lower flows are thought to belong to the thicker series.

In the Ellensburg quadrangle, about 150 miles west-southwest of Spokane, the geologic section [11] includes, in ascending order, the Yakima basalt, Ellensburg formation, and Wenas basalt. The Yakima basalt submerges an uneven surface of older rocks and consists of many flows piled one on the top of another to a thickness of 2,000 feet or more. The overlying Ellensburg is composed of sediments having a total thickness of as much as 1,600 feet. The Wenas basalt comprises two or three flows of rather small extent that range from a few feet to 200 feet in aggregate thickness. It overlies the Yakima basalt, from which it is separated by Ellensburg sediments ranging from 84 to 135 feet in thickness. The bulk of the Ellensburg beds lie above it.

In the general vicinity of Yakima the Ellensburg formation overlies the Yakima basalt, which is generally regarded as equivalent to the bulk of the basalt of the Columbia Plateau. Likewise the Mascall overlies the main body of basalt in central Oregon, which also is regarded as a part of the basalt of the Columbia Plateau. In the Spokane area no flows were found in a position corresponding to the Yakima basalt, namely, beneath sediments corresponding to the Ellensburg, or in other words, the Latah. The "rim rock" flows, which overlie the Latah, are therefore later than the Yakima basalt. However, there is nothing to suggest that they are much later.

The area north of Spokane River and west of the valley of Little Spokane River shown on the geologic map (Pl. I) has not been examined in detail by the writers. The geology has been generalized from the excellent map of Weaver,[12] and his Camas basalt has been considered equivalent to the flows of the "rim rock." For this correlation the only evidence is that the Camas basalt of Weaver is also olivine bearing, attains similar altitudes, and consists of small patches that appear to be outliers of the Columbia Plateau.

### BASALT SILLS AND DIKES

The Latah formation has been intruded by igneous rocks, as may be observed at intervals along the slope west of Latah Creek from S., P. & S. cut No. 1 and Milwaukee cut No. 1 southward and also in the slopes of several of the "prairies" north of Spokane and elsewhere.

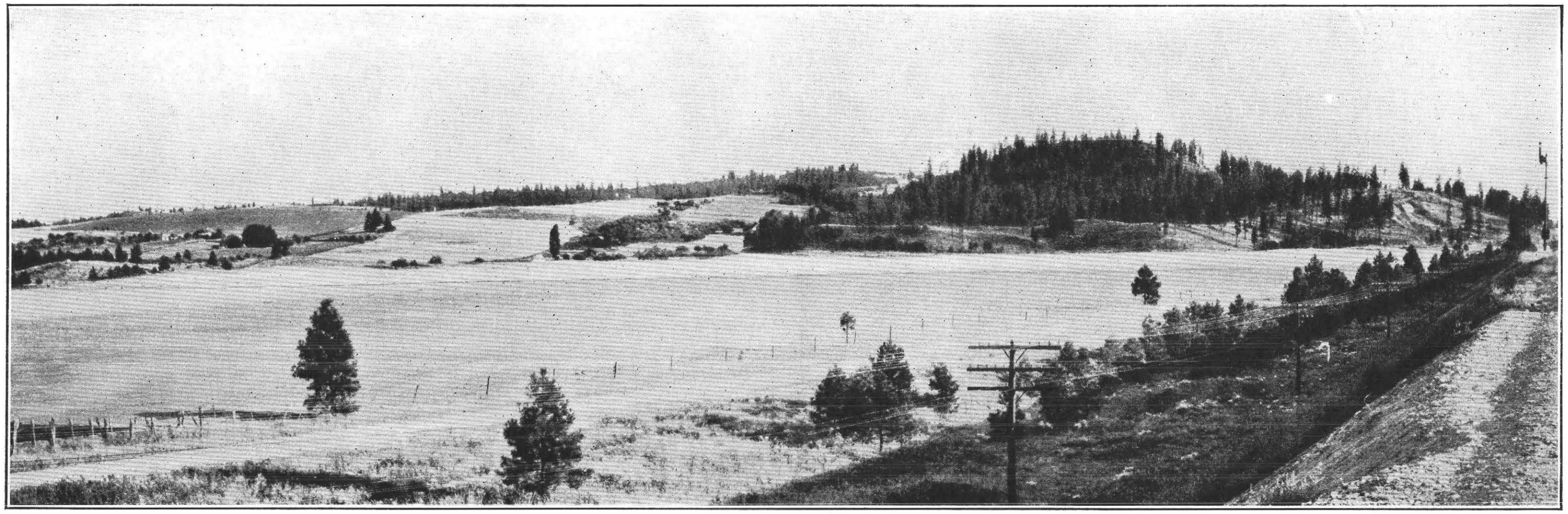
In the railway cuts of the Latah Creek valley three dikes from 2 to 10 feet wide and several dikes merging into sills are exposed. The type of dike is shown in Plate V, *A*, the base of one of the sills in Plate V, *B*, and the end of another in Plate V, *C*. The rock in both dikes and sills is a fine-grained dense blue-gray basalt similar in hand specimen to the overlying basalt of the "rim rock." The similarity in mineral composition, particularly in the presence of olivine, as shown below, between the rock of the dikes and that of the "rim rock" flows lends support to the supposition that the dikes were feeders in the eruption of the flows. Both the dikes and the sills have a fine-grained or glassy exterior where they cooled quickly in contact with inclosing shale. The grain of the interior is fine in small bodies and becomes coarser in the central parts of large bodies. Near the contact the shale is slightly hardened and changed in color. This influence on the shale extends from 6 inches to 10 feet. Beyond this zone the shale is entirely unchanged.

Specimens representing three of these intrusive bodies exposed in the railway cuts west of Latah Creek are described by Mr. Calkins as follows:

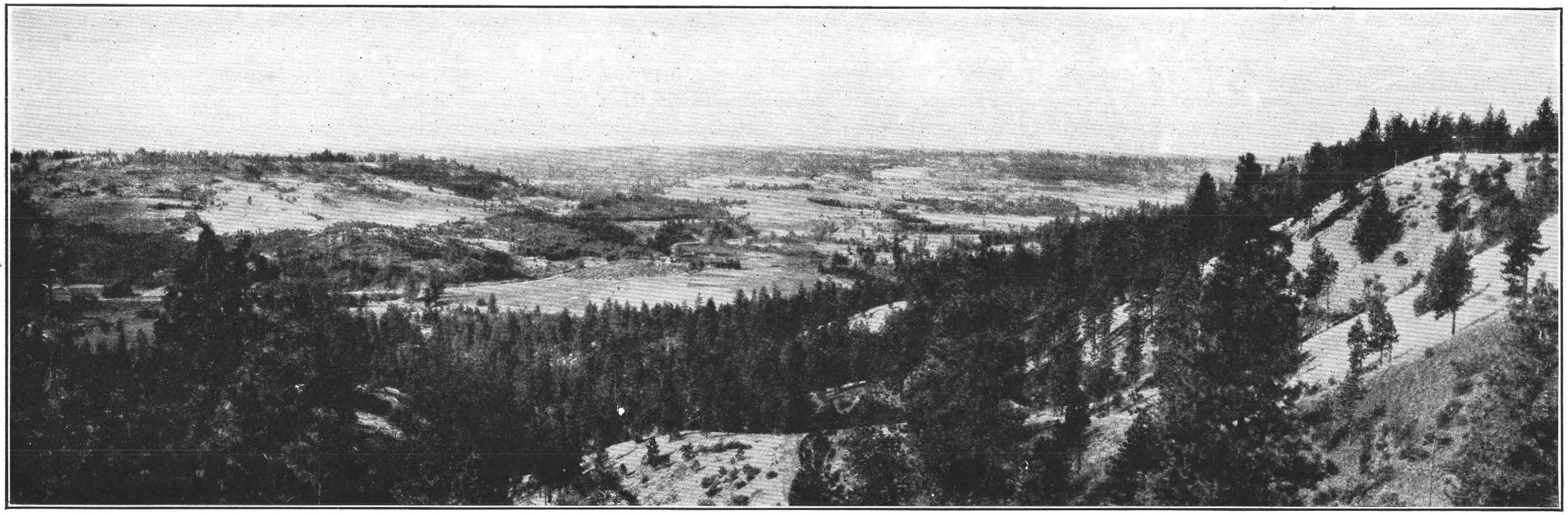
> Specimens taken several feet from contacts either are quite compact or contain only minute irregular pores not readily visible without the aid of a hand lens. The textures are moderately fine and might be taken for holocrystalline. Under the microscope, however, a little residual glass is found in even the most crystalline specimen (No. 10), taken from the middle of a 40-foot sill. Except for the presence of this glass, the texture of the specimen is typically ophitic. The most abundant constituents in all are of course plagioclase and augite; and olivine, though subordinate to plagioclase and augite, is present in all the specimens having a crystalline appearance but No. 7. This specimen is further remarkable in containing uniformly scattered grains of siderite which shows no evidence of being secondary; I regard it as having been the last original constituent to form.
>
> Two specimens from the margins of a sill and a dike have a wavy surface and a visibly glassy selvage about half an inch thick. A thin section from the selvage shows plagioclase laths as the only identifiable crystals in a cloudy glass base.

[11] Smith, G. O., op. cit.

[12] Weaver, C. E., op. cit., pp. 99-101.

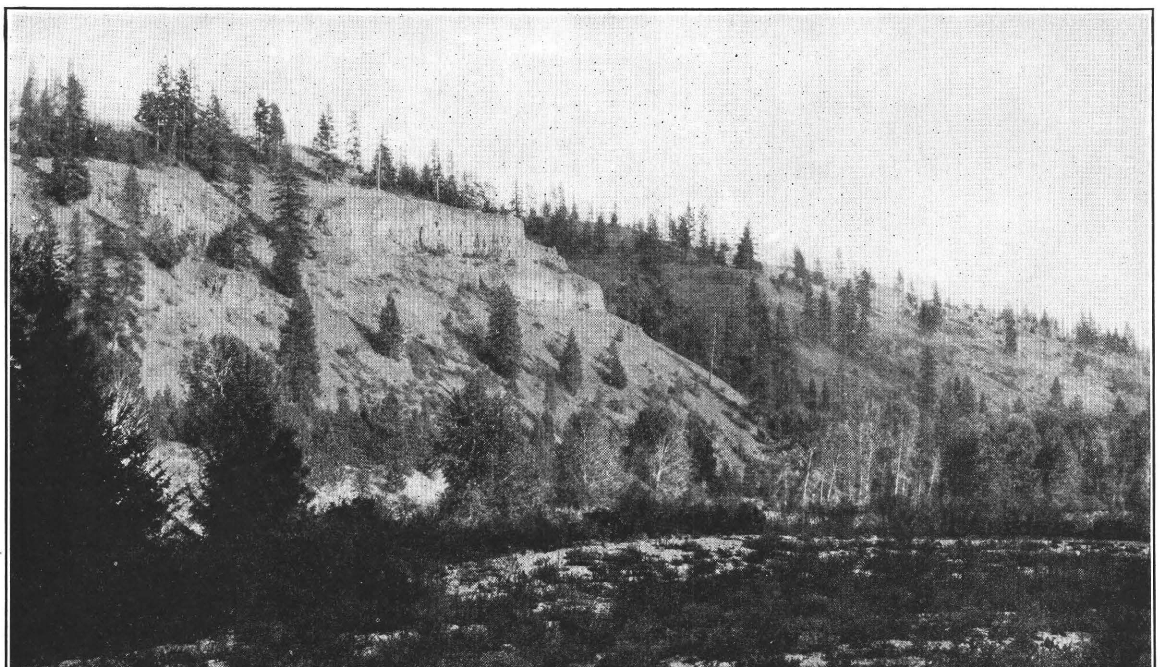


*A*. PLEASANT PRAIRIE, WASH.

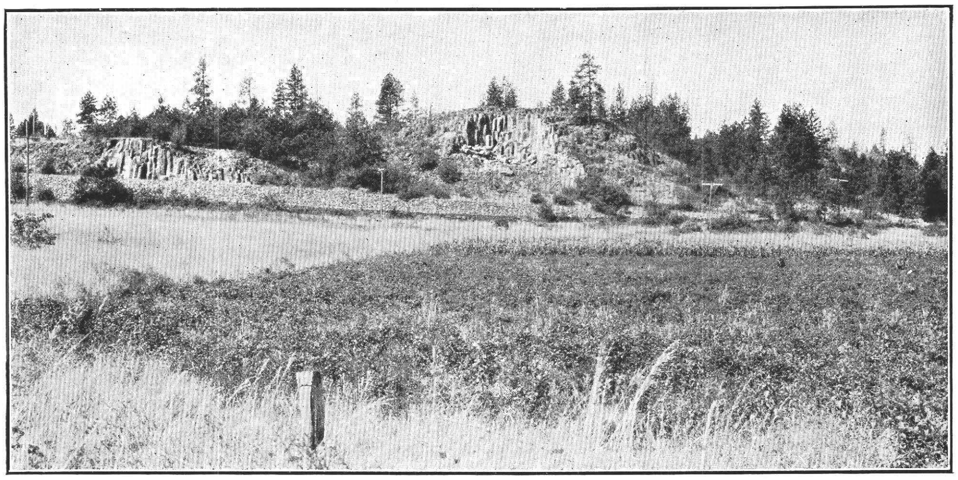


*B*. LATAH CREEK VALLEY AND THE COLUMBIA PLATEAU, WASH.

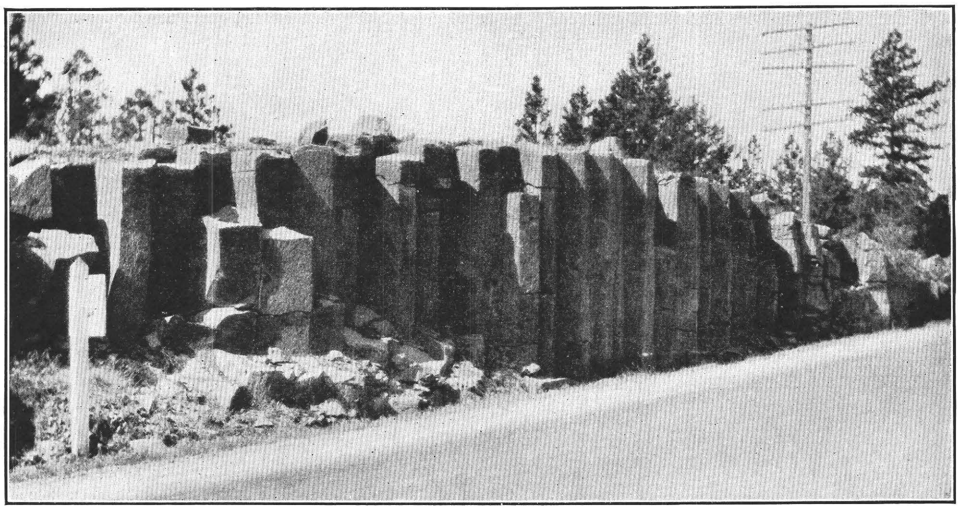
*A.* LATAH FORMATION AND FOSSIL LOCALITY OF DEEP CREEK CANYON, WASH.



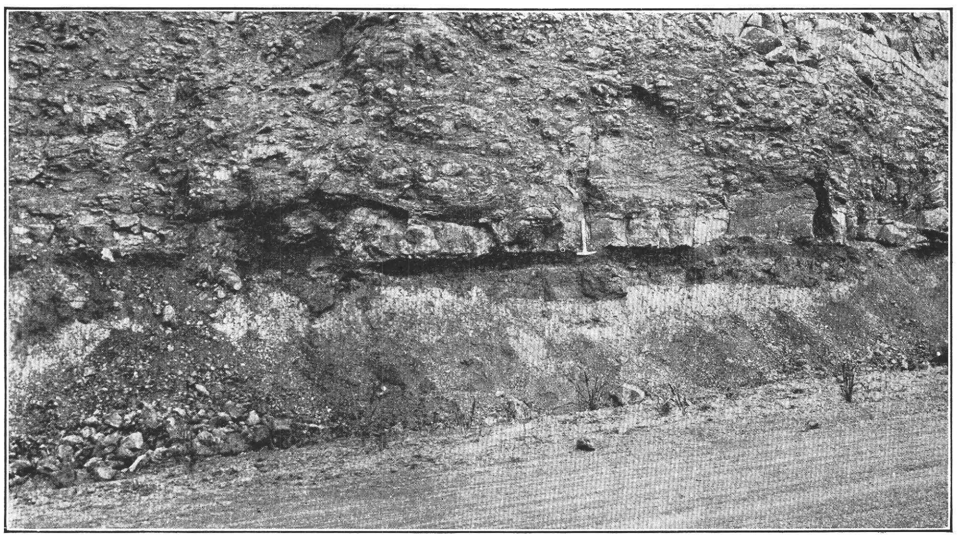
*B.* EAST SIDE OF LATAH CREEK VALLEY SOUTH OF DUNCAN, WASH.



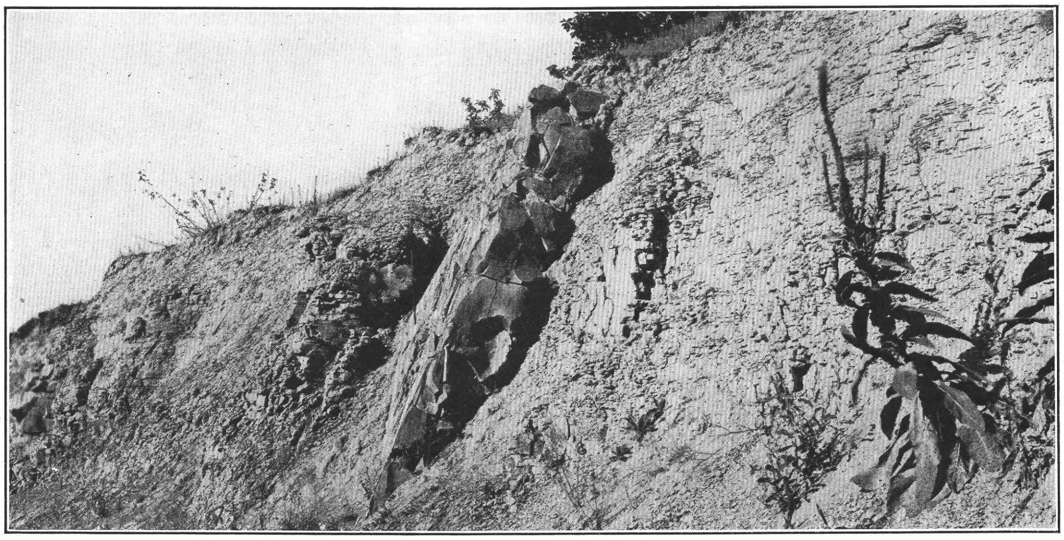
*A.* "RIM ROCK" FLOWS, SUNSET HIGHWAY WEST OF SPOKANE, WASH.



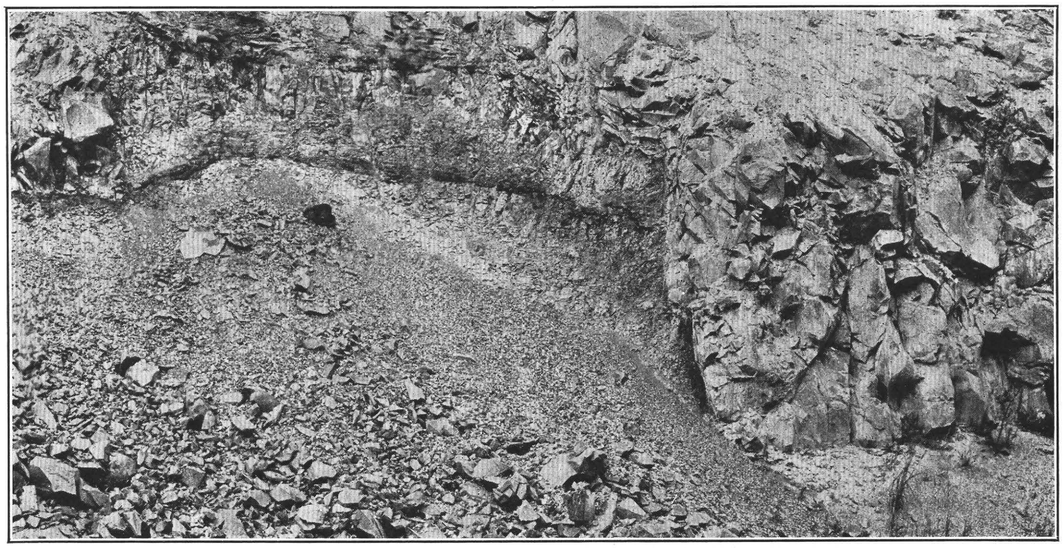
*B.* DETAIL OF COLUMNAR JOINTING IN CUT ON SUNSET HIGHWAY



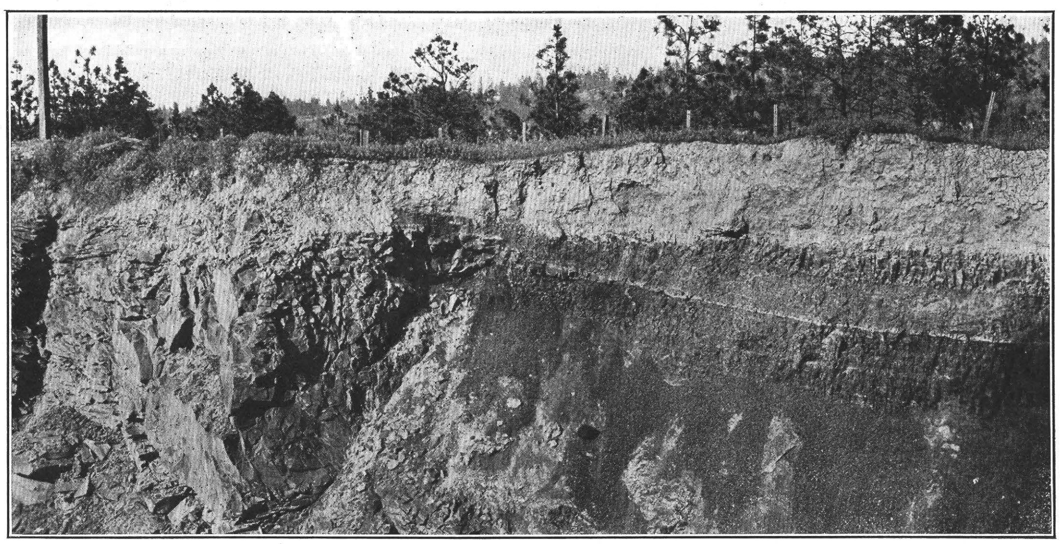
*C.* CONTACT OF "RIM ROCK" FLOWS ON LATAH FORMATION ON PLEASANT PRAIRIE, WASH.



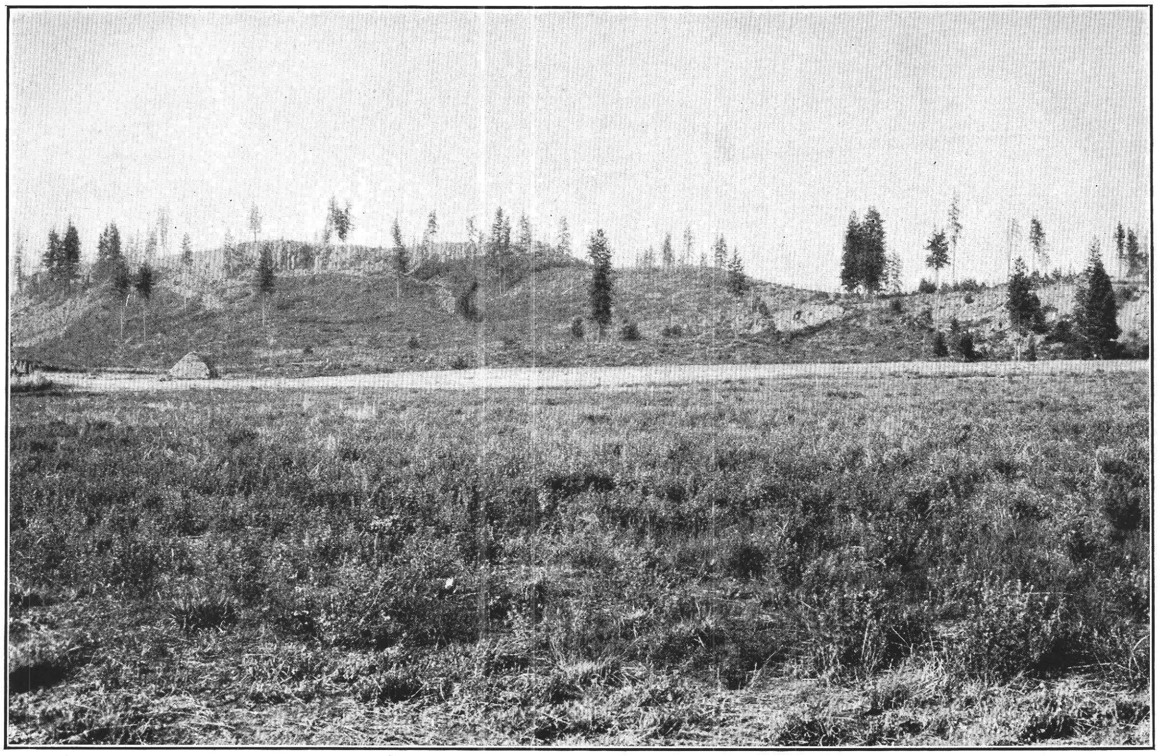
*A.* BASALT DIKE INTRUDED INTO SHALE, S., P. & S. CUT NO. 4, SPOKANE, WASH.



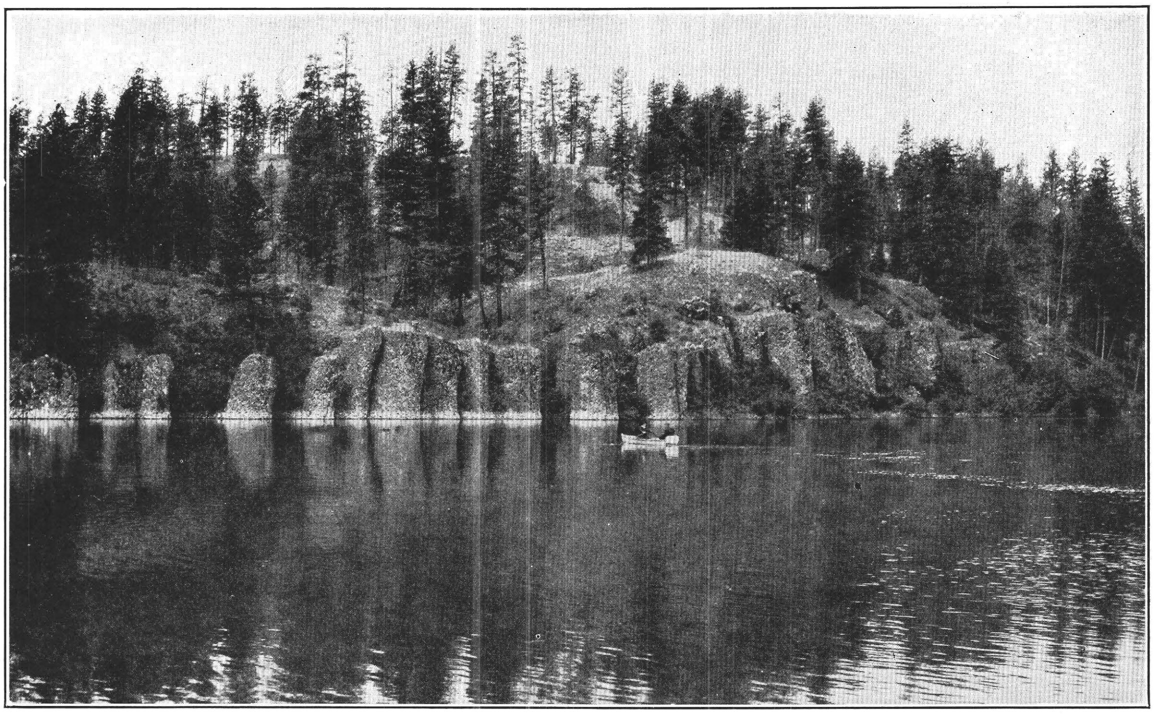
*B.* LOWER CONTACT OF BASALT SILL WITH SHALE, MILWAUKEE CUT NO. 1, SPOKANE, WASH.



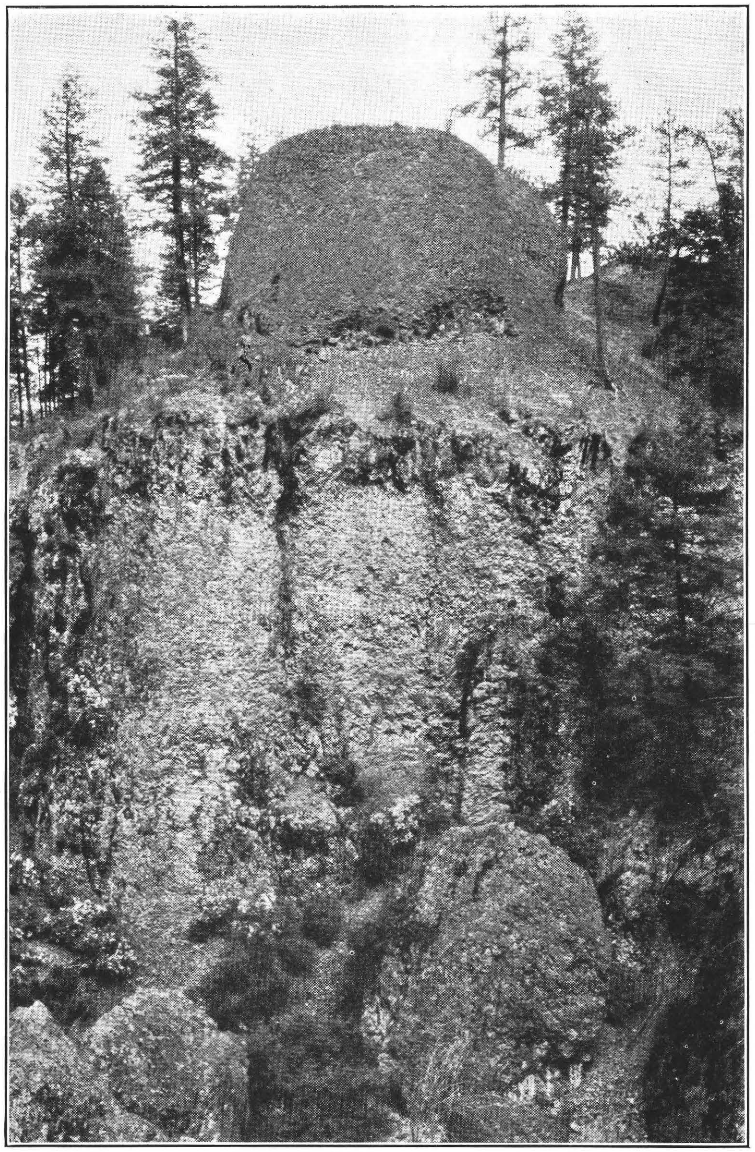
*C.* END OF BASALT SILL, SPOKANE, WASH.



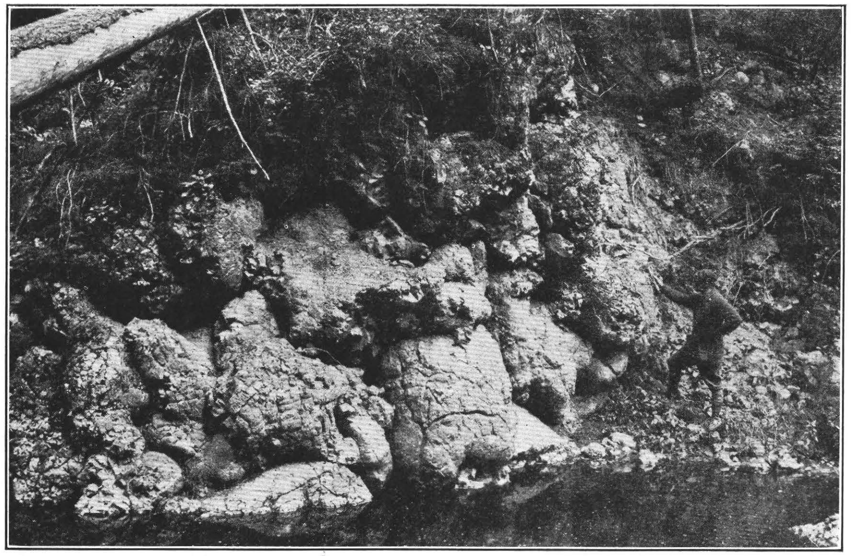
*A.* "THE CLIFF," NEAR MILAN, WASH



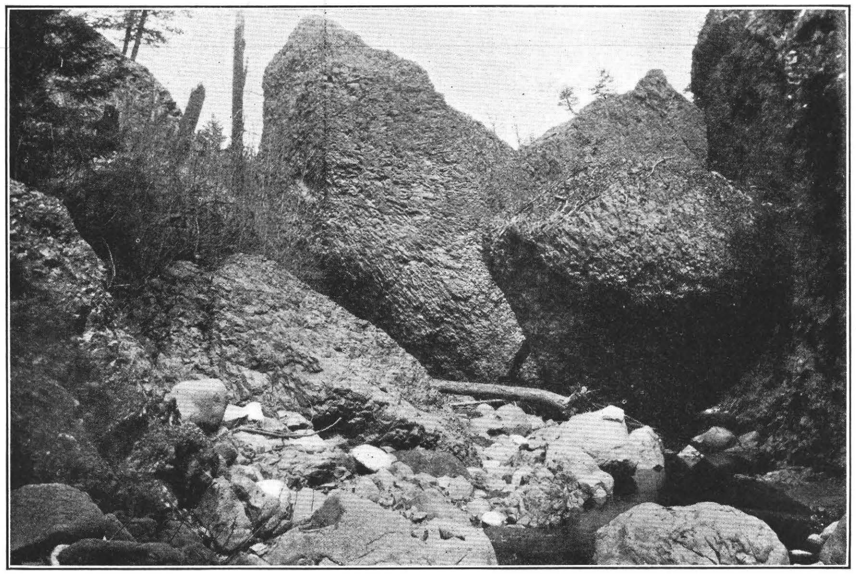
*B.* VALLEY FLOWS ON LEFT BANK OF SPOKANE RIVER NEAR SEVENMILE, WASH.



*A.* BASALT CLIFFS AT MOUTH OF CREEK



*B.* "PILLOW" STRUCTURE IN THE VALLEY FLOWS OF THE CANYON



*C.* DEVILS TOP

Photograph by William Donahue

VIEWS ON DEEP CREEK, WASH.

The dikes arose along joint planes and caused no disturbance of the shale, but the sills have wedged themselves between beds and have broken and crumpled the shale for distances of 50 to 100 feet.

In the Latah Creek valley the number of sills is large. Most of them were intruded at altitudes between 1,800 and 2,000 feet. Many are 25 to 50 feet thick and from 300 to 500 feet long. All that could be observed end abruptly. The lower sill shown in the cross section of Figure 2 is at least 100 feet thick, and it crops out along the valley for about half a mile. The sill on the west abutment of the Latah Creek dam site (Pl. II, *B*) is more than 250 feet thick, yet, as was brought out in striking fashion during drilling operations at this place, it ends abruptly on the east.

Basalt sills are common features of the slopes developed on the Latah formation in all the "prairies" north of Spokane. These sills are irregular in position, thickness, and length, and their outcrops are in many places more or less concealed by soil or glacial till. A few of the more prominent sills are represented on Plate I.

Because the sills intruded in the Latah formation lie approximately horizontal, there is some difficulty in distinguishing in the field the outcrops of such bodies from those of interbedded lava flows. The mineral composition and texture of the two, so far as can be seen by the unaided eye, are almost identical. But the sills cooled under cover and under pressure and therefore, except for the thin glassy crust, which is seldom seen except in artificial exposures, they are massive and free from scoriaceous and vesicular portions. Near the margin some sills have small scattered gas holes. The flows, however, owing to the expansion of gases expelled from the lava during cooling, have scoriaceous and vesicular layers at the top and usually similar layers at the bottom. Some of the sills have well-marked columnar jointing, the joints being tight and the columns large and regular, but as a rule jointing is not well marked in these bodies. Generally the flows show a jointing that is variable or irregular but usually open and conspicuous. The most useful criterion is perhaps the discontinuity of the sills. Interbedded flows would have more or less continuous outcrops at the same altitude for long distances. The end of a flow, moreover, is marked by a characteristic rubble or by scoriaceous material or, as in the "valley" flows described in the next section, by "pillow" structure.

#### FLOWS IN THE VALLEYS

The basalt flows that underlie the city of Spokane and cause Spokane Falls occur, so far as now known, only in valleys eroded in the "rim rock" flows and the Latah formation.

In the city of Spokane, along the gorge of Spokane River, and in the valleys of Latah Creek, Deep Creek, and Little Spokane River the slope below the "rim rock" exhibits cliffs and other rugged outcrops of basalt that, in one place or another, include parts of all the flows of a complete series built up from the bottom. In general the areas in which these lavas crop out are small, but on the geologic map (Pl. I) a large area is shown west of the valley of Little Spokane River near Deer Park. This area was not examined in detail. It is generally flat and has an altitude of about 2,000 feet, or about that of the most prominent glacial terrace (p. 15). Half Moon Prairie is underlain by basalt, and so also are large areas southeast of Deer Park. The cover of gravel belonging to the terrace makes mapping a long and tedious task and makes the identification of the basalt with the younger series uncertain. The inclusion of this area with the area of "valley" flows must be considered tentative.

The highest of these "valley" flows reaches an altitude a little greater than 2,100 feet. It forms the cliff at the falls in Indian Canyon and low cliffs near the head of the small valley tributary to Latah Creek north of S., P. & S. cut No. 1. Large loose masses of basalt on the slope above this cut, in Spokane at Cannon Hill and elsewhere, probably are remnants of this flow. At Ash and Fairview streets, in the northwestern part of Spokane, and at places down Spokane River there are remnants of a flow at an altitude of about 2,000 feet. At the next lower level is the thick mass of basalt composed of two or three separate flows across which Spokane River descends in the famous cataract of Spokane Falls.

The base of the "valley" flows at Spokane is located by the well at the Davenport Hotel (p. 9 and fig. 3). Farther north, however, it may be lower. If the bottom of the lava in the Davenport Hotel well is the maximum depth, the valley eroded in the "rim rock" flows and the Latah formation had a depth of at least 880 feet at Spokane. The erosion of this valley must have required considerable time. It is a measure of the difference in age of the "valley" and "rim rock" flows.

Contacts between the "valley" flows and the Latah formation have been observed by the writers in only three places. At Deep Creek, in 1922, the basalt could be observed resting against a slope covered by 5 feet of rubble and soil, which in turn rested on the shale of the Latah formation. This contact was buried as a result of the spring floods in 1923. In a cut on the Spokane, Portland & Seattle Railway in the western outskirts of Spokane, near Fort Wright, the contact of the lavas on the Latah is well exposed. The contact has irregularities of 5 to 10 feet, but the general slope is to the north and east. Much of the lava at this place is a breccia or rubble of broken material and "pillows." The higher parts of each flow and the higher flows extend farther to the south and west. It is evident that the lava was extruded in an ancient valley and that each succeeding flow rose higher against the hill slope. At Twelfth Avenue and Thor Street, Spokane, the street cut exposes a similar contact. Here a single bed of fragmented lava and "pillows" rests with a very irregular contact on shale with fossil leaves of the Latah formation.

Russell,[13] in 1896, observed the contact in a cut made in grading for the street-car line where it turns east from Barnard Street on Eighth Avenue. This exposure is no longer visible, but as described by Russell and shown in his sketch the basalt rested on the shale with an uneven contact. Gravel and sand resting on micaceous clay, together with detached masses of the clay, extended upward into the inequalities of the under surface of the basalt. Russell believed that this basalt flow moved from west to east into a shallow lake, the bottom of which was disturbed and forced up into the ridges described above.

The lowest exposure of the "valley" flows is at the canyon of Deep Creek on Spokane River, at an altitude of about 1,650 feet. The higher flows reach an altitude of 2,100 feet in several localities in the eastern outskirts of Spokane and also near Mead and near Milan. These facts indicate a thickness for the flows of 450 feet. However, the well of the Davenport Hotel, after penetrating 60 feet of sand and gravel, passed through 370 feet of basalt, the base of the flows in this well being therefore at an altitude of about 1,520 feet. The difference between this altitude and 2,100 feet is 580 feet, which may be taken as the maximum known thickness.

These flows are generally massive and thick. Commonly they are separated into small irregular blocks by shrinkage cracks that cut them in different directions. They contrast with the older basalt in their general lack of vesicles and frothy lava. So far as observed they do not show a columnar jointing comparable to that of the flows composing the "rim rock." Small irregular columns occur, but large regular columnar jointing is rare. Locally the rock at Spokane Falls breaks into columns, but the columns are curved and comparatively small, and they stand at various angles. It is thought that the lack of regularity is due largely to the fact that the exposures most commonly observed in the vicinity of Spokane are near the margin of the flows, for in "The Cliff," a small remnant near Milan, columnar jointing is well developed (Pl. VI, *A*). A characteristic feature of the valley flows is a tendency to weather along widely spaced joints into columns, rounded pinnacles, and other forms, some of which assume an odd or fantastic appearance (Pls. VI, *B*, and VII, *A*). At the mouth of Deep Creek there is an unusually fine display of these huge masses loosened from their parent ledges and tumbled together in grand confusion (Pl. VII, *C*).

[13] Russell, I. C., U. S. Geol. Survey Water-Supply Paper 4, pp. 52-54, 1897.

Apparently they are the result of weathering along two or more sets of widely spaced joints.

The basalt is generally a fine-grained gray or black rock, but there is some variation between flows. Beds of a peculiar breccia occur along the margin of the basalt where it rests against the Latah formation. In this material, like plums in a pudding, are rounded masses of basalt from 1 to 6 feet in diameter (Pl. VII, *B*). They have a glassy outside coating from a quarter to half an inch thick and dense or vesicular interiors. These masses are of the type known as "pillows" and evidently broke free from the advancing flows as big drops of liquid lava. The exteriors cooled suddenly and therefore are glass, but the interiors cooled more slowly and are largely crystalline. In most of the masses the gases contained in the molten lava separated as bubbles, forming the vesicular and scoriaceous interior. "Pillow" structure in lava is usually attributed to extrusion of the lava into or under water.[14] The general presence of lava of this type near contacts and the change from solid sheets of basalt to "pillow" lava may be considered part of the evidence that the basalt of the younger series was extruded in valleys where the advancing flows moved into temporary water bodies near the sides of the valleys.

In the summer of 1924 Edward Sampson visited Deep Creek, and he has furnished the following account of the unique basalt breccia associated with the "pillow" lava.

> The pillow lava is displayed in great perfection on the east side of the Deep Creek canyon. In some places individual pillows, as is common in such lava, fit over the irregularities of those beneath, so that there is very little space between them. In other places the pillows are not closely packed but form only about half the total mass, and a few pillows are apparently wholly detached and surrounded by fragmental rock or breccia. This breccia is a loosely coherent mass of rough fragments averaging about a quarter of an inch across. The color is generally gray but in places is buff to yellow.
>
> Through the skill of C. S. Ross, both polished and thin sections were prepared by impregnation with a balsam-kololith mixture and with bakelite. Microscopic study of these sections shows that the fragments of the breccia are composed of basalt glass containing a few phenocrysts of plagioclase and a much less number of augite grains. Almost every fragment contains one or more vesicles through which the boundaries of the fragments pass at random. Obviously the fragments have been formed by the disruption of a glass that was already vesicular. Most of the fragments bear no oriented relation to adjacent fragments, but a few show only slight displacement from their neighbors.
>
> The fragments of the brown or buff rock are surrounded by a thin shell of material of unknown composition. In thin sections it is orange-colored and contrasts with the glass, which is dark brown. Part of the shell is moderately birefringent, and part appears isotropic, but the isotropism may be due to an extreme fineness of grain in an anisotropic substance. It seems unquestionable that the shell is formed by the alteration of the glass of the fragments, as feldspar laths project from unaltered glass into the yellow crust.

[14] Russell, I. C., Geology and water resources of the Snake River Plains of Idaho: U. S. Geol. Suryve Bull. 199, pp. 113-117, 1902.

In the spaces between the fragments is a substance which from its optical properties is probably halloysite ($Al_2O_3.2SiO_2.nH_2O$) or allophane ($Al_2O_3.SiO_2.nH_2O$). It is gray to cream-colored, very soft and cheesy, with a hardness of about 3 in the Mohs scale. In thin section the mineral is opaque, but when crushed to a size passing a 200-mesh screen it is transparent. Such pieces are dark brown, perhaps owing to included air, but 24 hours' immersion in oil did not appreciably change the color. The mineral appears to be perfectly isotropic and has an index ranging from 1.46 to 1.47, owing to lack of uniformity. According to Larsen's tables, the properties recounted above are common to the minerals halloysite and allophane. The mineral does not completely fill the interstices, and it also has relatively wide cracks within its mass. Thus it appears to have shrunk in volume as if through the dehydration of a gel.

The present writer believes the view fairly well established that pillow lavas have formed by lava flowing into, over, or under water. It seems not improbable that the associated breccia has formed by the disruption of a basalt flow through the violent physical reaction of highly heated lava and water. Gas released from within the lava may have aided in this disruption, as indicated by the large number of vesicles.

From collections made by Mr. Henry Fair, Shannon [15] has identified a long list of minerals obtained from the vesicles in this basalt. The principal species are cristobalite, black opal, hyalite, and sphaerosiderite. The sphaerosiderite occurs as an incrustation similar to that found in the flows of the "rim rock," and also as hemispheres from a quarter to half an inch in diameter that are secondary and later in origin. Limonite and goethite replacing the sphaerosiderate are found.

At Deep Creek, 8 miles northwest of Spokane, black opal, opal and chalcedony replacing aragonite, and hyalite are present in cracks in "pillow" lava. Sphaerosiderite occurs alone in small gas holes of the basalt in a quarry near Milan. The minerals found in the younger flows all occur in artificial exposures except at the Deep Creek locality.

Specimens of the "valley" flows from the foot of Spokane Falls, the cut on Division Street, and the mouth of Deep Creek were examined by Mr. Calkins, who says:

> They show to the unaided eye no consistent difference from the "rim rock" flows, though they are perhaps a little duller and more bluish. The blow holes in No. 15 (the specimen from Division Street) are almost wholly filled with hard iron oxide (goethite?). Their appearance under the microscope is highly characteristic. All are without olivine, which occurs in all the "rim rock" specimens; and the augite occurs in splintery or prismatic forms and seems to be nearly contemporaneous with the plagioclase, instead of distinctly later, as in the "rim rock" lava. These later flows are probably less magnesian than the older.

So far as positive evidence goes the flows in the valleys may be as young as early Pleistocene. Probably, however, they belong to the same period of volcanism that produced Columbia Plateau and other igneous features in the Northwest that are thought generally to belong within the Tertiary.

[15] Shannon, E. V., On siderite and associated minerals from the Columbia River basalt at Spokane, Wash.: U. S. Nat. Mus. Proc., vol. 62, pp. 1-19, 1923.

## GRAVEL GROUP

Large deposits of unconsolidated or loosely coherent gravel occur in Spokane Valley and the valleys of Latah Creek and other streams. These deposits lie upon the eroded surface of the rocks previously described and are mostly of glacial origin. In the valley of Latah Creek and in that of Lake Creek near Marshall are large terraces at an altitude of about 2,300 feet built of gravel that contains much basalt and here and there a boulder of the fossiliferous shale. This gravel was deposited during a comparatively early Pleistocene stage of glaciation, described by Bretz [16] as the Spokane glaciation. The ice advanced from the north, crossing Fivemile Prairie, Pleasant Prairie, and other areas, from which it plucked masses of basalt and shale.

The floor of Spokane Valley and the extensive terraces along the river below Spokane up to an altitude of 2,000 feet are composed chiefly of gravel derived from granite and metamorphic rocks. This deposit is later than the other. Traced eastward it leads to a moraine at the south end of Pend Oreille Lake. Evidently it is outwash from a glacier that at a late stage, presumably Wisconsin, occupied the basin of that lake.

Both the older and younger members of the gravel group lie upon surfaces eroded across the valley flows. Evidently they were not deposited until after the greater part of these flows—all except the present remnants—had been cleared from the valleys.

## SUMMARY OF THE GEOLOGIC HISTORY

The events of geologic time prior to the Tertiary period have left a record in the Spokane area only in the rocks of the granite-schist group. The story, doubtless much obscured, has not yet been deciphered, and so far as the events recorded in the rocks described in this paper are concerned the pre-Tertiary history is a closed chapter. The recital begins anew with the form of the pre-Latah surface, which indicates that by Miocene time the area was a mountainous land. Hills and mountains greater than those of to-day extended westward beyond Spokane, where now lie the relatively smooth plains of the Columbia Plateau. This mountainous region was doubtless wooded and well watered, for, wherever found, the ancient surface is composed of deeply weathered rock.

With the beginning of volcanism and the outpouring of basalt to the south and west, the drainage of the area became obstructed. In the ponded stream channels débris stripped from the mountains and dropped from the air as ash showers resulting from the explosions of distant volcanoes accumulated in the form of extensive sheets of gravel, sand, and clay. As basalt was built up sheet by sheet and as one lava

[16] Bretz, J. H., Glacial drainage on the Columbia Plateau: Geol. Soc. America Bull., vol. 34, pp. 573-608, 1923.

flow followed another, the Columbia Plateau was constructed. The flows, moving northeastward, extended farther with each successive outpouring and buried much of the old rugged highland, entering valleys, swinging around headlands, and completely surrounding isolated hills. Against this flood of lava the Silver Hill-Cheney Hills ridge and the doubtless more isolated hills to the west and north formed a barrier that almost wholly prevented the entrance of the molten lava into the Spokane area.

Behind this encircling ridge the streams poured sediment into quiet ponds, shallow swamps, and slowly-moving channels. Here the Latah formation was gradually built to a maximum thickness of 1,500 feet, and here were entombed in the clay the leaves, fruits, and twigs of the plants that grew in the area and also some remains of those that occupied higher ground.

Twice this area was partly invaded by lavas, as indicated by the record of the Hazelwood well, before it was finally overwhelmed by the flows of the "rim rock." When in this catastrophe the encircling ridge was overtopped the lavas not only covered the plain of alluviation but extended beyond it onto the lower slopes of the bordering mountains. These flows were fed from the west, but in addition there were local vents from which molten rock welled up from below through the Latah formation to augment the volume of the overlying lava.

After the invasion of the "rim rock" flows valleys deeper than those of to-day were cut in the basalt and the underlying shales of the Latah formation. Here new outpourings of basalt built up a plain nearly to the height of the "rim rock" flows.

Again the streams cut through these flows to a level below that of the present. Next they were obstructed by glacial deposits, first by débris deposited directly by a glacier from the north and next by gravel washed down from a glacier at Lake Pend Oreille. Immense floods carried the gravel from this source down Spokane Valley, filling it at Spokane to the 2,000-foot level. The Spokane Falls are an indirect result of this last filling. After clearing its valley up to the falls and incidentally producing extensive gravel terraces below Spokane, the river found itself placed at one side of its former channel and hung up, so to speak, on a ridge of basalt.

Thus it appears that since the old and rough surface of the granite-schist group of rocks became buried beneath the fossil-bearing shale and that formation was in turn covered by the flows of the "rim rock," the valleys of this area have been excavated, filled, and reexcavated, time after time. When Spokane River, therefore, has finally completed its task of reexcavating its valley, Spokane Falls, Coeur d'Alene Lake, and many other of the beautiful water bodies that form one of the chief attractions of this region will have disappeared. Save then for the "prairies" with remnants of leaf-bearing shale and their "rim rock" of basalt, the region will be largely restored to its condition before any of these events took place, and the cycle will be complete.

# FLORA OF THE LATAH FORMATION OF SPOKANE, WASHINGTON, AND COEUR D'ALENE, IDAHO

By F. H. Knowlton

With a report on the diatom deposit by Albert Mann

## INTRODUCTION

The geologic conditions under which the flora of the Latah formation occurs have been set forth at length in the preceding paper by J. T. Pardee and Kirk Bryan. Briefly summarized these conditions are as follows:

The area which has supplied the fossil flora herein described lies along the Columbia Plateau and the mountains of northern Idaho and northeastern Washington. It includes parts of the valleys of Spokane and Little Spokane rivers and adjoining parts of the mountains and the plateau.

The mountainous part of the area is composed principally of crystalline and metamorphic rocks, such as granite, gneiss, and schist, but includes small masses of quartzite. The topography is very rugged. The city of Spokane stands at the northeast corner of the Columbia Plateau, which stretches far away to the south and west and owes its general character to the fact that it is built up of vast lava flows that remain nearly as flat as they were when cooled.

The plant-bearing beds, to which the name Latah formation has been given by Messrs. Pardee and Bryan, consist mostly of shale or clay but include a few layers of sand and gravel. The colors of the beds range from pale yellowish gray to lead-gray or bluish gray, the prevailing shades being rather dull. These beds rest uncomformably on the granite-schist group and are overlain by the basalt flows. As they are very soft they are easily eroded and have been largely removed except where protected by the basalt, and consequently they are of rather small areal extent. The maximum thickness of the Latah formation is approximately 1,500 feet, though this thickness can not be noted at any one place.

Further details concerning the geologic and other relations will be found in the preceding paper.

## SPECIES INCLUDED

As a preliminary to the consideration of the flora the following complete list of the forms thus far identified is given:

Archaeomnium patens E. G. Britton, n. gen. and sp.
Polytrichites washingtonensis E. G. Britton, n. gen. and sp.
Moss, genus and species?
Fern, fragment.
Ginkgo adiantoides (Unger) Heer.
Equisetum, underground stem.
Lycopodium hesperium Knowlton, n. sp.
Tumion bonseri Knowlton, n. sp.
Pinus sp.
Sequoia langsdorfii (Brongniart) Heer.
Sequoia? sp.
Taxodium dubium (Sternberg) Heer.
Taxodium, male aments.
Libocedrus praedecurrens Knowlton, n. sp.
Typha? sp.
Potamogeton sp.
Grass, leaf.
Grass?, genus?
Arisaema hesperia Knowlton, n. sp.
Populus heteromorpha Knowlton, n. sp.
Populus fairii Knowlton, n. sp.
Populus lindgreni Knowlton.
Populus washingtonensis Knowlton, n. sp.
Salix remotidens Knowlton, n. sp.
Salix elongata O. Weber.
Salix perplexa Knowlton.
Salix inquirenda Knowlton, n. sp.
Salix bryani Knowlton, n. sp.
Salix dayana Knowlton.
Salix sp.
Alnus, cones.
Betula fairii Knowlton, n. sp.
Betula nanoides Knowlton, n. sp.
Betula heteromorpha Knowlton.
Betula thor Knowlton, n. sp.
Betula? largei Knowlton, n. sp.
Betula bryani Knowlton, n. sp.
Carpinus sp.
Castanea castaneaefolia (Unger) Knowlton.
Quercus merriami Knowlton.
Quercus bonseri Knowlton, n. sp.
Quercus cf. Q. pseudo-lyrata Lesquereux.
Quercus rustii Knowlton, n. sp.
Quercus spokanensis Knowlton, n. sp.
Quercus payettensis Knowlton.
Quercus praenigra Knowlton, n. sp.
Quercus simulata Knowlton.
Quercus chaneyi Knowlton, n. sp.
Quercus obtusa Knowlton, n. sp.
Quercus, cup.
Quercus, acorn.
Ulmus speciosa Newberry.
Ulmus fernquisti Knowlton, n. sp.
Ficus? washingtonensis Knowlton, n. sp.
Laurus similis Knowlton.
Laurus princeps Heer.
Laurus californica Lesquereux.
Laurus grandis Lesquereux.
Magnolia dayana Cockerell.
Magnolia sp.
Liquidambar pachyphyllum Knowlton.
Liquidambar, fruit.

Hydrangea bendirei (Ward) Knowlton.
Prunus rustii Knowlton, n. sp.
Cercis? spokanensis Knowlton, n. sp.
Sophora alexanderi Knowlton, n. sp.
Sophora spokanensis Knowlton, n. sp.
Robinia? sp.
Meibomites lucens Knowlton, n. gen. and sp.
Celastrus fernquisti Knowlton, n. sp.
Rhus typhinoides Lesquereux.
Acer bendirei Lesquereux.
Acer merriami Knowlton.
Acer minor Knowlton.
Acer chaneyi Knowlton, n. sp.
Vaccinium salicoides Knowlton, n. sp.
Diospyros andersonae Knowlton n. sp.
Diospyros? microcalyx Knowlton, n. sp.
Malva? hesperia Knowlton, n. sp.
Phyllites amplexicaulis Knowlton, n. sp.
Phyllites crustacea Knowlton, n. sp.
Phyllites pardeei Knowlton, n. sp.
Phyllites sophoroides, n. sp.
Phyllites peculiaris Knowlton, n. sp.
Phyllites relatus Knowlton, n. sp.
Phyllites sp.
Carpites menthoides Knowlton, n. sp.
Carpites boraginoides Knowlton, n. sp.
Carpites polygonoides Knowlton, n. sp.
Carpites spokanensis Knowlton, n. sp.
Carpites ginkgoides Knowlton, n. sp.
Carpites magnifica Knowlton, n. sp.
Carpites paulownia Knowlton, n. sp.
Branchlet and bud?

## RELATIONS OF THE FLORA

As already set forth in detail in the geologic account by Messrs. Pardee and Bryan, the plants of the Spokane area occur in layers of clay associated with basalt flows. The stratigraphic relations of the plants from the Coeur d'Alene area are not so definitely known, but as a number of the species are identical with those of the Spokane area the age and structural relations are also presumably nearly identical.

The primary object of the study of this flora was to ascertain its bearing on the age of the basalt flows with which the plant-bearing beds are so intimately associated. Spokane is at practically the northeastern limit of the great basalt flow, the so-called Columbia River basalt, one of the greatest bodies of lava in the world, which has an area of approximately 250,000 square miles, including the greater part of Washington, eastern Oregon, much of northern California, and the great Snake River Plain in Idaho. As the fossil plants obtained from the sediments associated with these flows afford the most extensive paleontologic data for the determination of their age, the study of the present collection is of great stratigraphic value.

Before discussing the floras from Spokane and Coeur d'Alene it is necessary briefly to review certain floras and formations with which these may be compared.

## COMPARABLE FLORAS IN OTHER FORMATIONS

### PAYETTE FORMATION

The Payette formation, named by Lindgren,[1] is a series of lake-bed deposits having a maximum thickness of 1,000 feet in the lower part of the Snake River valley, Idaho. Fossil plants were found in these beds at four localities. The total flora then recognized numbered 32 species, of which 17 were regarded as new to science and 5 were not named specifically, leaving, as then known, only 10 species having an outside distribution. As 6 of these 10 forms were regarded as identical with described species from Bridge Creek, Oreg., and several others as closely related to Bridge Creek species, it was concluded that the Payette formation was of the same age as the beds at Bridge Creek, which were then regarded as upper Miocene.

The age determination of the plant-bearing beds in the John Day Basin, Oreg., that was then current was based largely on the earlier work of Lesquereux, but the localities were not differentiated, all being grouped under the designation "John Day Basin." Although it was of course noted that there were marked differences in the matrix bearing the plants, the specimens were all supposed to be of approximately the same age—that is, upper Miocene.

Subsequently (1900) John C. Merriam visited the John Day Basin and worked out in detail the stratigraphic relations of the Tertiary deposits. To the oldest of these deposits, a series of beds some 400 feet in thickness, composed of rhyolite and andesite flows and ash and tuff beds resting on Cretaceous rocks, Merriam gave the name Clarno formation. The Bridge Creek locality is in the extreme upper part of the Clarno formation and the age was considered to be upper Eocene.

The next higher plant-bearing beds above the Clarno were named by Merriam the Mascall formation. This formation is a series of sediments from 800 to 1,000 feet in thickness, composed largely of ash and tuff, generally light in color. Near the base of this formation is the well-known Van Horn or Belshaw ranch locality. The Mascall was considered to be of middle Miocene age.

With this digression we may now return to the Payette formation. In my "Fossil flora of the John Day Basin"[2] I discussed certain floras that are more or less closely related to those of the John Day region, among them that of the Payette formation. As this flora is clearly related to that of the Bridge

[1] Lindgren, Waldemar, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 632, 1898.
[2] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 110, 1902.

Creek locality, which had in the meantime been relegated to the upper Eocene instead of the upper Miocene, I felt justified in regarding the age of the Payette as the same, namely, upper Eocene. This reassignment was met with protest by the geologists, but on the basis of the material then available this was the logical conclusion to be drawn.

The matter has been held in abeyance pending the discovery of additional data, and these have now in a measure been supplied by the investigations of Dr. R. W. Chaney, of the Carnegie Institution of Washington. In 1921 Chaney visited the Snake River valley and procured collections from one or two of the original localities as well as from some four or five other points, with the result that the original flora of 32 species is increased by 17 species, bringing the total flora now recognized up to 49 species. The preliminary results of Chaney's studies are set forth in a short paper[3] published in 1922. First it may be pointed out that he is now of the opinion that a further change in the age assignment of the flora from Bridge Creek is probable. He says:

> The writer has not yet brought together all the necessary evidence, but recent field studies in the John Day Basin and at other points in eastern and central Oregon point to the placing of the Upper Clarno formation in the Oligocene rather than in the Eocene. If this is correct, and the supporting evidence will be brought forth in a subsequent paper, there are no atypical Eocene plants in the Payette flora.

At the time of the original discussion of the Payette flora only 10 of the 32 species had a known distribution beyond this formation, but by the work of Chaney the number has been increased to 21. His analysis discloses that 12 of the 21 species occur in the Mascall formation (middle Miocene) and only 5 species in the flora from Bridge Creek (upper part of the Clarno formation). Although mere numerical superiority may not be the safest criterion for correlation, it has distinct value.

There are, however, other criteria that point to the Miocene age of the Payette formation. Thus the position of the formation, above basalt lavas, is in accord with the relations of the Mascall formation to the Columbia River lavas in the John Day Basin. Further, vertebrate remains from the Payette found by J. P. Buwalda are pronounced by him to be of middle or upper Miocene age. It seems, therefore, that the conclusion reached by Chaney must be accepted, namely, that the Payette formation is probably of Miocene age. He says:

> So far as the plants are concerned, the age would not be younger than middle Miocene, and in view of the inclusion of Oligocene and possibly Eocene forms, it might better be considered as lower Miocene. The present knowledge of the western floras does not justify an attempt to draw the line of age too sharply, and at the present time the writer is satisfied to make the reference to the Miocene without further specification.

[3] Chaney, R. W., Notes on the flora of the Payette formation: Am. Jour. Sci., 5th ser., vol. 4, pp. 214-222, 1922.

### EAGLE CREEK FORMATION

The Eagle Creek formation is a very thick series of beds of volcanic conglomerate, ash, and tuff, with some intrusions of basalt, exposed in the Columbia River gorge, mainly in Multnomah County, Oreg., and across the river in Skamania County, Wash. The flora, described by Chaney,[4] is a comparatively rich one, comprising 72 species, of which 38 are described as new and 14 are not named specifically, leaving 20 species with an outside distribution. An analysis of the range of these species shows that the greater number are found in the flora from Bridge Creek, in the John Day Basin, and that a considerable number are common also to the Mascall flora. At the time Chaney's paper was written the flora from Bridge Creek was considered to be upper Eocene.

From a comparison of the species having an outside distribution, as well as the distribution of species obviously closely related to certain of the new forms, Chaney concluded that the Eagle Creek flora seemed to show a transition between Eocene and Miocene. He says:

> While most closely related to floras of upper Eocene age, the Eagle Creek flora is also definitely related to those of Miocene age, if these formations have been correlated correctly. On the basis of these relations it has seemed proper to consider the Eagle Creek flora as transitional between the upper Eocene and Miocene, or, in other words, of Oligocene age.

In view of what was brought out above regarding the flora from Bridge Creek, to which that of the Eagle Creek is obviously related, it is probable that the Eagle Creek would now be regarded by Chaney as of Miocene age.

### AURIFEROUS GRAVELS IN CALIFORNIA

In 1878 Lesquereux[5] published a paper on the fossil plants of the auriferous gravel deposits of the Sierra Nevada, in which he describes over 50 species. From their apparent close affinity with living species, their more or less close agreement with certain European floras, and their association with vertebrate remains, they were considered to be of Pliocene age. In later years, as additional stratigraphic data and collections of plants became available, it came to be accepted that the plant-bearing beds, or at least those which supplied most of Lesquereux's material, were upper Miocene. As more and more intensive stratigraphic work was done in the Sierra Nevada it became evident that the so-called auriferous gravels represent a phase of sedimentation that was comparatively long, extending from upper Eocene time well into and possibly through the Miocene. The localities most frequently mentioned (such as Table Mountain, Tuolumne County, and Chalk Bluffs, Nevada County) fall within the Miocene.

[4] Chaney, R. W., Flora of the Eagle Creek formation: Chicago Univ. Walker Mus. Contr., vol 2, No. 5, pp. 1 5-181, pls. 5-22, 1920.

[5] Lesquereux, Leo, Harvard Univ. Mus. Comp Zoology Mem , vol. 6, No. 2, pp. i-vi, 1-62, pls. 1-10, 1878.

### MASCALL FORMATION

The position of the Mascall formation is briefly referred to above in the section on the Payette formation. The flora of the Mascall formation was described in 1902 in my "Fossil flora of the John Bay Basin, Oregon," [6] and embraces about 80 species. As already pointed out, the affinity of this flora is with the Miocene, and from its stratigraphic position, as well as from the vertebrate remains, the position is fixed with much certainty as middle Miocene.

### ELLENSBURG FORMATION

The Ellensburg formation, which was named by Geo. Otis Smith,[7] comprises certain fluviatile deposits of stratified silt, sand, and gravel of volcanic materials near Ellensburg, Wash., about 150 miles west of the Spokane area. The older of these beds are overlain by or interbedded with the Wenas basalt. Fossil plants have been found in the formation at two localities, one about 6 miles southeast of Ellensburg and the other in Kelly Hollow, Wenas Valley, some 15 miles south of Ellensburg. The matrix is a white, generally fine-grained volcanic ash, identical in appearance with that from the Van Horn ranch (Mascall formation), in the John Day Basin, Oreg.

[6] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 106, 1902.
[7] Smith, G. O., U. S. Geol. Survey Geol. Atlas, Ellensburg folio (No. 86), p. 2, 1903.

The Ellensburg flora numbers 15 species, 13 of which are found in greater or less abundance in the Mascall formation of the John Day Basin, and on this basis the Ellensburg formation is considered to be of the same age, namely, middle Miocene. Four or five of the species from the Spokane area are identical with or closely allied to species identified in the Ellensburg formation.

### FLORAS OF THE SPOKANE AND COEUR D'ALENE AREAS

With the above background we may now consider the floras of the Spokane and Coeur d'Alene areas. The most striking feature of these floras at first glance is their very modern appearance, and the apparent living analogues are at once suggested for many of the forms, especially in *Ginkgo*, *Sequoia*, *Taxodium*, *Populus*, *Castanea*, *Quercus*, *Ulmus*, and *Acer*. It was the very modern aspect of the flora of the auriferous gravels of California, as well as its resemblance to certain European floras, that led Lesquereux originally to refer it to the Pliocene.

An analysis of the 95 forms that make up the Spokane and Coeur d'Alene floras shows that 25 species have a distribution outside these areas. The following table shows the vertical distribution of these 25 species:

*Vertical distribution of the extralimital species of the Spokane and Coeur d'Alene floras*

| | Lance formation | Fort Union formation | Kenai formation | Clarno formation | Eocene | Payette formation | Oligocene | Eagle Creek formation | Mascall formation | Auriferous gravels | Miocene | Pliocene |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ginkgo adiantoides | × | × | × | | × | | × | × | | | | |
| Sequoia langsdorfii | × | × | × | × | | | | | × | | × | |
| Taxodium dubium | × | × | × | × | | | | | × | | × | × |
| Populus lindgreni | | | | | | × | | | × | | | |
| Salix elongata | | | | | | | | | | | × | |
| Salix perplexa | | | | | | | ×? | | × | | | |
| Salix dayana | | | | | | | | | × | | | |
| Betula heteromorpha | | | | × | | | | × | | | | |
| Castanea castaneaefolia | | | | | | | | | × | × | | |
| Quercus merriami | | | | | | | | × | × | | | |
| Quercus cf. Q. pseudo-lyrata | | | | | | | | × | × | | | |
| Quercus payettensis | | | | | | × | | | | | | |
| Quercus simulata | | | | | | × | | × | | | | |
| Ulmus speciosa | | | | × | | | ×? | × | | | | |
| Laurus similis | | | | | ×? | | | × | | | | |
| Laurus princeps | | ×? | | | | | | | | × | | |
| Laurus californica | | | | | | | | | | × | × | |
| Laurus grandis | | | | | | | | | | × | × | |
| Rhus typhinoides | | | | | | | | ×? | | × | | |
| Magnolia dayana | | | | × | | | | | | × | × | |
| Acer minor | | | | | | | | | × | | | |
| Acer bendirei | | | | | | | | | × | | × | |
| Acer merriami | | | | | | | | | × | | | |
| Liquidambar pachyphyllum | | | | | | | | × | × | | | |
| Hydrangea bendirei | | | | | | | | | × | | | |
| | 3 | 4 | 3 | 5 | 2 | 3 | 3 | 9 | 13 | 6 | 7 | 1 |

The first three species in the above list have so wide a vertical range that they are of comparatively little value in fixing the age. Another possible element of uncertainty may hinge upon the correctness of all the identifications. Conifers are not always easy to identify with certainty unless they are exceptionally well preserved. As the three species now stand they range from Lance to Miocene—indeed, one (*Taxodium dubium*) persists into the Pliocene, and this one connects with the living species (*Taxodium distichum*) with very little if any change. As a matter of fact it is difficult to draw a satisfactory line between what is now called *Taxodium dubium*—which was long known as *Taxodium distichum miocenum*—and the living species.

A glance at the above table discloses the fact that the flora of the Spokane and Coeur d'Alene areas finds its closest agreement with the floras of the Mascall formation, the auriferous gravels, and the Miocene in general, 13 of the 25 species being common to the Mascall, 6 to the auriferous gravels, and 7 to the undifferentiated Miocene, or altogether no less than 19 species. The Latah formation has 5 species found in the upper part of the Clarno formation (Bridge Creek locality) 3 in the Payette formation, and 2 in the Eagle Creek formation, or 9 species in these three formations.

As already pointed out, the Mascall formation of the John Day Basin, Oregon, is now very definitely fixed as middle Miocene in age, and as the latest determination seems to place the upper part of the Clarno, the Payette, and the Eagle Creek floras also in the Miocene the conclusion seems justified that the Spokane and Coeur d'Alene floras (Latah formation) are of Miocene age. This flora is therefore regarded as not younger than middle Miocene and not older than lower Miocene.

This assignment of position is still further emphasized by the distribution of the species to which certain of the new species are obviously related. This is shown in the following table:

*Horizons of species related to the Spokane and Coeur d'Alene plants*

| | Most closely related fossil species | Horizon |
|---|---|---|
| Pinus sp | Pinus knowltoni | Eagle Creek. |
| Taxodium, male aments | Taxodium, male aments | Mascall. |
| Carpinus sp | Carpinus grandis | Mascall and Eocene. |
| Quercus bonseri | Quercus pseudo-lyrata<br>Quercus merriami | Mascall. |
| Quercus cf. Q. pseudo-lyrata | Quercus pseudo-lyrata | Do. |
| Quercus rustii | Quercus payettensis<br>Quercus merriami | Payette.<br>Mascall. |
| Quercus spokanensis | Quercus cowlesi | Eagle Creek. |
| Quercus chaneyi | Quercus simplex | Upper part of Clarno. |
| Ulmus fernquisti | Ulmus californica | Auriferous gravels. |
| Ficus? washingtonensis | Ficus sordida | Do. |
| Prunus sp | Prunus? tuffacea | Mascall. |
| Celastrus fernquisti | Celastrus taurinensis | Fort Union. |
| Acer chaneyi | Acer angustilobatum | Swiss Miocene. |

Of the 13 species in this list 6 are more or less closely related to forms in the Mascall formation, 2 each to species in the Eagle Creek and auriferous gravels floras, and 1 each in the Payette, upper part of Clarno, Fort Union, and Swiss Miocene.

Many of the forms found in the floras from Spokane and Coeur d'Alene are so modern in appearance that it may be of interest to note the obvious living affinities of the new species. This is brought out in the following table:

*Relation of new species of Spokane and Coeur d'Alene plants to species now living*

| New fossil species | Related living species |
|---|---|
| Archaeomnium patens | Aulacomnium palustre. |
| Polytrichites washingtonensis. | Polytrichum sp. |
| Lycopodium hesperium | Lycopodium carolinianum. |
| Tumion bonseri | Tumion californicum. |
| Libocedrus praedecurrens | Libocedrus decurrens. |
| Typha sp | Typha latifolia. |
| Potamogeton sp | Potamogeton heterophylla. |
| Arisaema hesperia | Arisaema triphyllum. |

*Relation of new species of Spokane and Coeur d'Alene plants to species now living*—Continued

| New fossil species | Related living species |
|---|---|
| Populus heteromorpha | Populus alba.<br>Populus canescens. |
| Salix bryani | Salix discolor. |
| Alnus, cones | Alnus incana. |
| Betula nanoides | Betula humilis. |
| Betula? largei | Betula papyrifera. |
| Betula bryani | Betula papyrifera. |
| Betula thor | Betula papyrifera. |
| Quercus spokanensis | Quercus michauxii.<br>Quercus prinos. |
| Quercus praenigra | Quercus nigra. |
| Quercus chaneyi | Quercus virginiana. |
| Quercus obtusa | Quercus virginiana. |
| Quercus, cup | Quercus lyrata. |
| Ulmus fernquisti | Ulmus fulva. |
| Magnolia sp | Magnolia foetida. |
| Prunus sp | Prunus americana. |
| Cercis? spokanensis | Cercis canadensis. |
| Robinia | Robinia pseudoacacia. |
| Meibomites lucens | Meibomia arenicola. |
| Diospyros andersonae | Diospyros virginiana. |
| Diospyros? microcalyx | Diospyros texana. |
| Malva? hesperia | Malva spp. |
| Vaccinium salicoides | Vaccinium pennsylvanicum. |
| Carpites paulownia | Paulownia tomentosa. |

## COMPARISON OF THE FLORAS FROM THE SPOKANE AND COEUR D'ALENE AREAS

Most of the plants described in this report came from the Spokane area, but a single large and interesting collection, submitted by Mr. H. J. Rust, was obtained near the bottom of a well 43 feet deep on the south slope of Stanley Hill, about 2 miles northeast of Coeur d'Alene, Idaho. No detailed stratigraphic study has been made of the Coeur d'Alene area, but at my suggestion Mr. Pardee made a hasty examination in July, 1923. He states that no exposures of the fossiliferous beds were seen, but "remnants of basalt flows that appear to overlie the fossil-bearing shale crop out near by, and a little farther away granite and schist that form the bedrock are exposed." Mr. Pardee is therefore of the opinion that the relations at Coeur d'Alene are in general similar to those at Spokane.

The Coeur d'Alene flora comprises 25 forms, of which 13 are regarded as new, 3 are not named specifically, and 9 are previously known species. It is especially rich in oaks, as regards both species and individuals, probably more than half of the individuals belonging to the oaks. Only the following 6 species are common to the Spokane area:

Taxodium dubium.
Sequoia langsdorfii.
Betula heteromorpha.
Quercus merriami.
Ficus? washingtonensis.
Prunus rustii.

In one way it seems rather strange that there is not more in common between the two areas, which are separated by only 25 miles, but comparison of the lists of plants from the several Spokane collections shows that there are few species common to two localities that are separated even by only a few feet vertically or a few miles areally. This localization is doubtless to be ascribed to two sources—the accident of fossilization and the extent of exploitation. In one locality a shower of oak leaves may fall or be blown into the water and if not transported to any great distance may dominate the deposits. In another locality scattered leaves of many kinds may find a resting place in proximity.

## ECOLOGIC CONDITIONS

The accompanying illustrations show that many of the species, such as the poplars, oaks, elms, and alders, have a very modern appearance. By using their obvious affinities with living species it is possible to deduce certain conclusions regarding the probable ecologic conditions and climate under which these plants lived.

The physical setting that preceded and accompanied the entombment of these plant remains has been fully discussed by Messrs. Pardee and Bryan in the preceding paper and will be only briefly recapitulated here. The basement or floor on which the lavas and associated sediments rest is composed mainly of crystalline and metamorphic rocks, such as granite, gneiss, and schist, and had developed a topography which "was apparently even more rough than the mountainous lands north and east of the plateau are at present." When the lava was extruded it spread in a broad sheet, filling the depressions, and as it advanced upon the mountainous region it projected into the mountain valleys and retired around the intervening spurs "like the coast line of a sea." As it pressed up the valleys it obstructed the streams, producing ponds and possibly small lakes. The appearance and composition of the fossil-bearing shale are described by Messrs. Pardee and Bryan (pp. 4–10).

In this flora three fairly well differentiated ecologic types can be distinguished—hydrophytes, mesophytes, and xerophytes. The hydrophytes include what appears to be a leaf of *Potamogeton*, of a type growing in shallow water with leaves both submerged and floating. There are also leaves of *Typha*, which presumably lived in very shallow water or in flats continually or periodically inundated. At one of the localities, the well at Mica, there are numerous fresh-water diatoms. A report on these diatoms, with an interpretation of the probable conditions under which they lived, is given by Dr. Albert Mann on pages 51–55.

The mesophytes are apparently the most abundant element in the flora. The species represented by the greatest number of individuals are *Populus heteromorpha* and *Taxodium dubium*, of which there are literally hundreds of specimens. Their abundance and their perfect preservation shows that they must have grown very near where they were entombed. The *Taxodium*, if it has been correctly interpreted, probably grew in swamps either along streams or on the borders of the ponds. The poplars probably grew along the streams, together with the several species of willows and the alders, and their leaves fell directly into the ponds or lakes, as they show little effect of transportation. On slightly higher ground back from the streams were the magnolias, maples, and chestnuts and possibly some of the oaks, together with the huckleberries, laurels, and elms.

The xerophytes or semi-xerophytes probably clothed the ridges. These are the several species of oaks that have more or less coriaceous leaves. The oak leaves are perhaps third in abundance of individuals, and the fact that only a few acorns are preserved would seem to indicate that the trees were some distance from the streams or ponds, into which the leaves could be easily transported by winds.

It is not always easy to differentiate between mesophytic and xerophytic assemblages, for in the living floras it usually happens that there is more or less of a commingling of the two elements. As Chaney [8] has said:

[8] Chaney, R. W., Chicago Univ. Walker Museum Contr., vol. 2, No. 5, p. 246, 1920.

In modern forests there is a degree of mixture of ecological types, due to the lagging behind of certain relict xerophytes after the plant association has become mesophytic, or to the advance into a xerophytic association of certain pioneer mesophytes. In the first case mentioned the plants would be dominantly mesophytic with scattered xerophytes; in the second case the plants would be dominantly xerophytic with scattered mesophytes.

We may now draw a picture of the probable physical setting in the Spokane area when these plants were entombed. The area was a broad valley flanked by rolling hills and ridges, some of which rose 1,500 feet or more above the general level, with considerable streams coming down from the north or northeast. Then came the lava flow, which completely dammed the streams, throwing the water back into shallow lakes or ponds. As the lava was eroded slowly the ponding continued for a sufficient length of time for a considerable growth of trees, shrubs, and smaller herbaceous plants. The open bodies of water were teeming with microscopic diatomaceous life. Here and there pondweeds floated on the surface, and about the borders were patches of cattails, grasses, and sedges. In the swamps adjacent to the open water were the forests of bald cypress and an occasional soft maple. Overhanging the streams and in places along the borders of the ponds were the alders and willows and also the poplars, of which there were several kinds, some of them doubtless forming groves back from the water. On the slopes and foothills there were forests of deciduous trees, including elms, maples, magnolias, laurels, and some oaks. In the moist, rich, shaded parts were Indian turnips and doubtless other more or less herbaceous growth. Still higher were the groves of oaks of several kinds, with a few chestnuts and scattered clumps of pine. It is hard to place the position of the sequoia and ginkgo, but probably they were on the middle slopes.

## CLIMATE

The composition of the flora of the Spokane and Coeur d'Alene areas indicates that it was distinctly a temperate assemblage, if the plants had approximately the same climatic requirements as their living allies, as there is every reason to suppose they had. It was a flora very similar to that now living in the northeastern part of the United States.

## INSECT REMAINS IN THE LATAH FORMATION

Although the clay shale in which the plants are preserved with such remarkable fidelity is very fine grained and in every way fitted for the preservation of insect remains, such remains are exceedingly rare—in fact, so far as has come to my knowledge, only three specimens have been found. These are the elytra of a large carabid beetle, apparently of a single species. The first one found was submitted to Prof. T. D. A. Cockerell, of the University of Colorado, who named and described it as *Calosoma fernquisti*.[9] It was named in honor of the collector.

## SUMMARY

The flora herein described comes from the vicinity of Spokane, Wash., and Coeur d'Alene, Idaho. It occurs mainly in clay shale associated with the lava flows of the Columbia Plateau. These plant-bearing beds, to which the name Latah formation has been given, have a minimum thickness in the Spokane area of approximately 1,500 feet.

This flora comprises 95 forms, of which 51 are regarded as new to science, 18 are not named specifically, and 25 are found in other areas.

As a whole this flora is very modern in appearance, the ginkgo, cypress, sequoias, oaks, elms, maples, poplars, and others being especially similar to certain living analogues.

This flora has been compared with floras from the auriferous gravels of California, the Eagle Creek formation of Oregon and Washington, the upper part of the Clarno formation (Bridge Creek locality) and the Mascall formation of the John Day Basin, Oregon, the Payette formation of Idaho, and the floras at Elko, Nev., and Ellensburg, Wash., as well as with more distant Eocene and Miocene floras.

Of the 25 species having an outside distribution, 3 occur in the Lance formation, 4 (1 doubtful) in the Fort Union, 3 in the Kenai, 5 in the Clarno, 2 (1 doubtful) in the Eocene, 3 in the Payette, 3 in the Oligocene, 9 in the Eagle Creek, 5 in the Ellensburg, 13 in the Mascall, 6 in the auriferous gravels, 7 in other Miocene beds, and 1 in the Pliocene. Six (1 doubtful) of the 25 species occur in beds of established Eocene age, but only one is confined to these beds. On the other hand, 19 of the 25 species occur in accepted Miocene or higher beds. This leaves the upper part of the Clarno, the Payette, and the Eagle Creek formation, with 9 species in common, which have usually been considered as of upper Eocene age but which are now regarded as probably lower Miocene.

The affinity of the floras from the Spokane and Coeur d'Alene areas is undoubtedly with the higher beds, and the conclusion is reached that they are of Miocene age. They are not younger than middle Miocene nor older than early Miocene.

## THE FLORA

### Phylum BRYOPHYTA

#### Class MUSCI

In the collections made by various people in the Spokane region there are a number of fairly well preserved mosses. These were all submitted to Mrs. E. G. Britton and Dr. Arthur Hollick, of the New

[9] Cockerell, T. D. A., U. S. Nat. Mus. Proc., vol. 64, p. 14, pl. 2, fig. 8, 1924.

York Botanical Garden, and Mrs. Britton has been kind enough to prepare the following identifications and diagnoses.

#### Family MNIACEAE

#### Genus ARCHAEOMNIUM E. G. Britton, n. gen.

With the characters of the species.

#### Archaeomnium patens E. G. Britton, n. sp.

Plate VIII, Figures 1, 2

Plants up to 2 centimeters high by 3 millimeters broad; stems simple or branched, erect, apparently tomentose, with one branch bearing a curved, leafless apical prolongation about 1 centimeter in length; leaves crowded and spreading, larger and more numerous at the apex of the stems, lanceolate-acuminate, about 1.5 millimeters long by 0.5 millimeter broad, seemingly entire and costate to apex, with revolute margin.

Resembles the living species *Aulacomnium palustre* (Linné) Schwaeger in the leafless prolongation of the stem with a slight induration of a capitate tip, the presence of tomentum, and the larger crowded apical leaves.

Occurrence: Latah formation, cut No. 1 on Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, June, 1922.

#### Family POLYTRICHACEAE

#### Genus POLYTRICHITES E. G. Britton, n. gen.

With the characters of the species.

#### Polytrichites spokanensis E. G. Britton, n. sp.

Plate VIII, Figures 3, 4

Plant erect or slightly decumbent at base; stems up to 2 centimeters high, branching; leaves not crowded except at the summit of the stems, composed of two distinct portions—a paler basal part, which is erect, appressed, and clasping the stem, and an apical part, which is bent outward and spreading, which measures 3 to 4 millimeters in length, is evidently strongly veined and keeled, apparently entire and sharply subulate.

Although much resembling, when magnified, certain living species of *Polytrichum*, the actual size of the plant precludes any definite reference to this genus.

Occurrence: Latah formation, Deep Creek, northwest of Spokane, Wash., collected by Henry Fair and C. E. Fernquist, June, 1922.

#### Moss, genus and species?

Plate VIII, Figures 5, 6

Notwithstanding the extensive collecting that has been done in the Spokane area mosses appear to be but poorly represented though evidently diversified, for of the three specimens thus far found two are described above as new genera; the third specimen is here figured. It consists of several densely leafy stems that it seems to me might without violence be referred to *Polytrichites*, described above, but it has passed under the critical eye of Mrs. Britton, and she considers it too obscurely preserved to permit adequate diagnosis, and it must therefore remain without a name. It is presented simply to show that this type of vegetation is present.

Occurrence: Latah formation, Deep Creek, northwest of Spokane, Wash., collected by Henry Fair and C. E. Fernquist, April, 1922.

#### Phylum PTERIDOPHYTA

#### Fern, fragment

Plate IX, Figure 10

Among several hundreds of specimens that have been studied from the Spokane area this is the only fern observed, and it, of course, has no value beyond indicating the presence of this plant type. It is the basal portion of a pinna or pinnule that was evidently coriaceous and has a very strong midvein and numerous strong veins that arise at an angle of about 45°. The veins fork just as they emerge from the midvein and twice or three times before reaching the margin. None of the margin is retained except the base, and this is entire.

Occurrence: Latah formation, cut No. 2 on Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash., collected by Henry Fair and Kirk Bryan, May, 1923.

#### Class EQUISETALES

#### Family EQUISETACEAE

#### Equisetum, underground stem

Plate IX, Figure 1; Plate XXVI, Figure 5; Plate XXIX, Figure 8

*Equisetum* was apparently a rare element in this flora, as only three specimens have been found thus far. The best preserved is a segment of an underground stem with three groups of opposite, sessile, large tubercles. The stem has four or five strong, somewhat irregular longitudinal ridges. The tubercles are unusually large, spherical or nearly so, marked with strong ridges.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway in Spokane, Wash., collected by Henry Fair and C. E. Fernquist, June, 1922.

#### Order LYCOPODIALES

#### Family LYCOPODIACEAE

#### Lycopodium hesperium Knowlton, n. sp.

Plate VIII, Figure 7

Sterile stems unknown; fertile spike erect, very slender, over 3.5 centimeters long, about 3 millimeters in diameter; bracts apparently cordate, short acuminate at apex, the margins entire, with the oval sporangia in their axils.

The fragmentary specimen, the only one found in the collections, lacks both base and apex and was probably at least 4 centimeters long. It is unfortunate that a leaf-bearing portion of the stem is not preserved. Among living species it appears to approach most closely *Lycopodium carolinianum* Linné, of the moist pine barrens from New Jersey to Florida and Louisiana, especially near the coast. This species has the bracts cordate, short acuminate, and mostly entire, thus agreeing with the fossil so far as the latter can be made out.

Only five species of *Lycopodium* have been reported in a fossil state in this country.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

### Phylum SPERMATOPHYTA

### Class GYMNOSPERMAE

### Order GINKGOALES

### Family GINKGOACEAE

### Ginkgo adiantoides (Unger) Heer

Plate VIII, Figures 10, 11

*Ginkgo adiantoides* (Unger) Heer, Flora fossilis arctica, vol. 5, Abt. 3, p. 21, pl. 2, figs. 7–10, 1870.
Ward, U. S. Geol. Survey Sixth Ann. Rept., p. 549, pl. 31, figs. 5, 6, 1886; idem, Bull. 37, p. 15, pl. 1, figs. 5, 6, 1887.
Chaney, Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 159, pl. 5, fig. 1, 1920.

Thus far only three leaves of *Ginkgo* have been found in the Spokane area. One was collected in 1910 and the others in April and June, 1923, and as collecting in the area has been intensive between these dates it is safe to assume that *Ginkgo* was not a very conspicuous element of this flora.

In all the specimens the leaf substance is so well preserved that the leaf can be removed from the matrix intact and mounted between small plates of glass. This condition is unusual—in fact, these are the only leaves of *Ginkgo* that I have seen that could be completely removed from the matrix. There are, however, a few coniferous leaves in the Spokane material that are equally well preserved. (See *Tumion*, pp. 25–26.) Their thick, leathery texture and resinous nature are doubtless the reason for their excellent preservation.

*Ginkgo* is a very ancient type that has come down to the present with very little change, at least in the leaves. There is a considerable range in the degree of lobation in the leaves of *Ginkgo biloba*, the only living species, some being practically entire and others so deeply lobed as to be almost bisected. *Ginkgo* was a very abundant element in the Jurassic flora, and a good many nominal "species" have been differentiated, yet it is seemingly possible to duplicate many of these forms among the various forms of the living species, and differentiation is increasingly difficult as we ascend in the geologic time scale. Although the leaves from Spokane appear to be identical with what has been called *Ginkgo adiantoides* (Unger) Heer, they are practically identical with certain forms of the living species. The margin is undulate with but slight indentation of the central sinus, and in this particular the form agrees with specimens so identified by Chaney [10] from the Eagle Creek formation, where it is abundant.

Occurrence: Latah formation, in S., P. & S. cut No. 1, Spokane, Wash., collected by T. A. Bonser, specimen now in the U. S. Nat. Mus., No. 37192; in S., P. & S. cut No. 3, Spokane, collected by Leland Hirst, April, 1923 (Pl. VIII, fig. 10); in the gully at Fivemile Prairie, east of Spokane, collected by Miss Arleen Schmidt, June, 1923 (Pl. VIII, fig. 11). The last two specimens preserved in the Spokane Public Museum.

### Order CONIFERALES

### Family TAXACEAE

### Subfamily TAXEAE

### Tumion bonseri Knowlton, n. sp.

Plate X, Figure 3

This species is based on the fragment of branchlet figured. It is a segment about 5 centimeters long, broken from what was evidently a long, stout branchlet which is nearly 3 millimeters in diameter. The leaves are scattered at remote and somewhat unequal distances and are inserted spirally but become two-ranked by a twist of the petiole. They are 2.5 to 3 centimeters long and about 3 millimeters wide. They are broadest at the base, whence they are abruptly narrowed below and gradually above to what appears to be a short callous point. The leaf substance is so well preserved that a whole leaf may be separated from the matrix, and when it is mounted in glycerine or Canada balsam the details of its cell structure can be studied under a compound microscope almost as well as those in a living leaf. The under side of the leaf shows a rather strong midrib, and on either side of it a broad band on which the stomata are borne. Altogether there are about 25 longitudinal rows of stomata, each with two large guard cells. The bands containing the stomata are darker in color than the remainder of the leaf, but whether the rows of stomata are in grooves could not be made out with certainty. The cells outside the bands of stomata are rectangular and mainly about twice as long as they are broad.

The genus *Tumion* of Rafinesque (*Torreya* of Arnott) comprises four species, two of which are American and two are natives of Japan and China. Of the American species, *Tumion taxifolium* Greene is found only in a very small area along Apalachicola River in Florida and *Tumion californicum* Greene is pretty well distributed over the State of California, being most abundant and of the largest size in the northern Coast Ranges. The California species is a tree from 50 to 70 or occasionally 100 feet in height and from 1 to 2 or exceptionally 4 feet in diameter.

[10] Chaney, R. W., Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 159, pl. 5, fig. 1, 1920.

The fossil species from Spokane appears to be nearest to *Tumion californicum*, from which it differs in its much smaller leaves, with broader stomatiferous bands. Otherwise the general appearance is much the same in both.

Six nominal fossil species of *Tumion* from North America have been described, all from Cretaceous rocks. The two species (*Torreya falcatum* and *T. virginicum*) from the Patuxent formation of Virginia described by Fontaine [11] are very doubtfully allocated to *Tumion*—in fact, they are quite different from the living species. *Tumion oblanceolatum* Lesquereux,[12] from the Dakota of Colorado, with the leaves attached by their whole base and thence decurrent down the branchlet, is also doubtfully referred to this genus, and the two species described by Dawson [13] (*Tumion densifolium* and *T. dicksonioides*), from the Upper Cretaceous of Alberta, are even more remote from the living *Tumion*. Dawson's species are said by Lesquereux to resemble certain of Heer's species from the Cretaceous of Greenland, but even so it is evident that all are greatly in need of revision.

The form from the Spokane area here described is clearly more closely related to the living forms than any previously described from this country—in fact, it hardly differs except in size from the living *Tumion californicum*.

This species is named in honor of Prof. T. A. Bonser, curator of the Public Museum of Spokane, who not only submitted the type specimen but has been especially generous in supplying material and information for this study.

Occurrence: Latah formation, Spokane, Wash., collected by T. A. Bonser.

### Subfamily ABIETINEAE

### Pinus sp.

Plate VIII, Figure 9

Leaves in clusters of three, the sheath deciduous; leaves more than 4.5 centimeters in length, about 1 millimeter wide, each with a faintly indicated median nerve or midrib.

I have hesitated to give this form a new specific name, as it is the only specimen of a pine that is present in the collections, and proper characterization of a species on such meager data is difficult. So far as can be made out the sheath at the base of the cluster of leaves is absent, and hence it is believed to belong to the group of so-called white or soft pines. Most of the American species belonging to this section of the genus have the leaves in clusters of five, but there is a small group of species in which the leaves are in one to four leaved clusters, and there is also a single North American species (*Pinus chihuahuana* Engelmann) belonging to the pitch or hard pines, which has the sheath deciduous and the leaves in threes.

This cluster of leaves from the Spokane area is similar to *Pinus knowltoni* Chaney, [14] from the Eagle Creek formation of Multnomah County, Oreg., and may indeed be identical with it. The description given by Chaney agrees very well with the specimen in hand, though he says nothing about the sheath. The figure of *Pinus knowltoni* showing the leaves is so obscure that nothing can be made out of it, and it is impossible to compare it with the Spokane specimen. Nothing like the staminate cones has been noted in the Spokane material.

Occurrence: Latah formation, well near Mica, southeast of Spokane, Wash., collected by Thomas Large for J. T. Pardee, August, 1922.

### Subfamily TAXODIEAE

### Sequoia langsdorfii (Brongniart) Heer

Plate IX, Figures 3–6

*Sequoia lan sdorfii* Brongniart) Heer, Flora tertiaria Helvetiae, vol. 1, p. 54, pl. 20, fig. 2; pl. 21, fig. 4, 1855.

Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 240, pl. 50, figs. 2–4, 1883.

Knowlton, U. S. Geol. Survey Bull. 204, p. 25, 1902.

*Sequoia langsdorfii* has almost as wide a distribution, both vertical and areal, as *Taxodium dubium* (*T. distichum miocenum*), and as with that species it seems more than possible that several forms of this type have been confused, as otherwise considerable variation must be accounted for.

This form is fairly abundant in the Spokane area and, as may be seen from the figures, agrees with the usual figures of this species. One specimen (fig. 5) has the male aments at the tip of the branchlet and hardly emergent from the apical leaves. This proves conclusively that it is a *Sequoia* and not a *Taxodium*, with which it is associated.

The branchlet shown in Figure 4 is quite similar to the lower portion of the branchlet figured by Lesquereux [15] from the auriferous gravels of California under the name *Sequoia angustifolia* and should perhaps be identified with that form, though it seems improbable that two species so closely allied as these seem to be should occur in the same beds. The other specimens here figured are certainly not to be distinguished from Lesquereux's figures of *Sequoia langsdorfii* from the John Day Basin.[16]

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust,

[11] Fontaine, W. M., U. S. Geol. Survey Mon. 15, pp. 234, 235, pl. 109, fig. 8; pl. 113, fig. 4, 1889.

[12] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 30, pl. 1, fig. 2, 1883.

[13] Dawson, J. W., Roy. Soc. Canada Trans., vol. 1, pp. 21, 25, pl. 2, fig. 4; pl. 5, figs. 20, 20a, 1882.

[14] Chaney, R. W., Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 160, pl. 5, figs. 3, 4, 1920.

[15] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 252, pl. 58, fig. 3, 1883.

[16] Idem, pl. 50, figs. 2, 3.

July, 1920; west bank of Deep Creek half a mile above mouth, northwest of Spokane, Wash., cut 1 mile west of Shelly Lake, about 10 miles east of Spokane, and well at Mica, 10 miles southeast of Spokane, collected by Henry Fair and C. E. Fernquist, 1922.

#### Sequoia? sp.

The material from the Spokane area submitted by T. A. Bonser and Thomas Large includes two lots of fossil wood. One is a solid block about 7 centimeters long and nearly 6 centimeters in diameter and was cut from a log about 15 feet long and 2 or 3 feet in diameter found at Division Street and the Spokane International Railway, in the city of Spokane. It was found in a pocket of clay, sand, and gravel between two lava flows. The other material consists of several fragments brought up from shale interbedded with lava 400 feet below the surface in a deep well at the State Custodial School near Medical Lake, southwest of Spokane.

The specimen from the large log is dark brown, almost black, and heavy and has apparently undergone considerable mineralization; the other specimens are light brown and show little or no evidence of infiltrating minerals.

No thin sections of these specimens have been cut, and the identification must be considered tentative, though so far as can be judged from examination with a low-powered microscope the structure is that of *Sequoia*.

Occurrence: Latah formation, between lava flows at Division Street and the Spokane International Railway, Spokane, Wash., from a log 15 feet long and 2 to 3 feet in diameter, collected in 1909 and submitted by T. A. Bonser; small fragments from depth of 400 feet in well at State Custodial School, Medical Lake, 20 miles southwest of Spokane, collected by Thomas Large, 1922

#### Taxodium dubium (Sternberg) Heer

Plate IX, Figures 2, 7–9; Plate X, Figure 2

*Taxodium dubium* (Sternberg) Heer, Flora tertiaria Helvetiae, vol. 1, p. 49, pl. 17, figs. 3, 15, 1855.

Berry, U. S. Geol. Survey Prof. Paper 91, p. 171, pl. 15, figs. 4–16, 1916.

*Taxodium distichum miocenum* Heer, Miocene baltische Flora, p. 18, pl. 2, pl. 3, figs. 6, 7, 1869.

Newberry, U. S. Geol. Survey Mon. 35, p. 22, pl. 47, fig. 6; pl. 51, fig. 3; pl. 52, figs. 2, 3; pl. 55, fig. 5, 1898.

Knowlton, U. S. Geol. Survey Bull. 204, p. 27, 1902; Alaska, vol. 4, p. 152, Harriman Alaska Expedition, 1904; Washington Acad. Sci. Proc., vol. 11, pp. 204, 207, 1909.

Penhallow, North American gymnosperms, p. 217, 1907; Report on Tertiary plants of British Columbia, p. 91, 1908.

The plant here designated *Taxodium dubium* is by far the most abundant species in the collections, occurring literally in hundreds. They are practically all detached branchlets with only a few detached leaves. There is a considerable range in the length and shape of the leaves, but they agree in a number of essential particulars. Most of the branchlets are slender, with a number of thin longitudinal lines or ridges. The leaves are attached at points all around the branch but by torsion at the base they are disposed in a two-ranked flat spray. The leaves are rather narrow, 1.5 to 2.5 centimeters long, obtusely pointed at the apex, and contracted at the base to a very short petiole or almost sessile. The leaves are not decurrent, though there is a line running down the branchlets for a short distance. They have a very distinct midrib.

The propriety of referring these branchlets to *Taxodium dubium* may be discussed. Under the name *Taxodium distichum miocenum* or occasionally as *Taxodium dubium*, branchlets of this type have been identified from a great number of localities throughout the Northern Hemisphere ranging in age from lower Eocene to Pleistocene and thence through many Pleistocene deposits to the living bald cypress of the coastal swamps of the Eastern and Gulf States. To judge by the figures given by the several authors there is a considerable variation in size and appearance, and it may be that more than one species has been confused, but as it is impossible without an adequate series of specimens to determine the specific limits, the species may be taken as a type of tree that had this wonderful geologic and geographic distribution. The specimens from the Spokane area agree well with many of the figures from both European and American localities, and there is no doubt that they can properly be classed with *Taxodium dubium*. They are also very much like some of the smaller examples of *Taxodium tinajorum* Heer,[17] from the Kenai formation of Alaska and the Miocene of Spitzbergen.

In 1872 Lesquereux [18] described some coniferous branchlets from Elko, Nev., under the name *Sequoia angustifolia*. This species was figured in 1878 in his "Tertiary flora" [19] and characterized as follows:

> Branches short, slender; leaves at unequal distances, sometimes very close, two or three together, or very distant, often dimorphous, linear-lanceolate, taper-pointed, open or curved backward, decurrent; middle nerve indistinct.

To this description he added the following comment:

> This form, though very variable, preserves its peculiar characters: the narrow, lanceolate, acute leaves, decurrent but not narrowed at base, with thin scarcely distinguishable middle nerve.

Unfortunately only one of the figured types of *Sequoia angustifolia* ("Tertiary flora," pl. 7, fig. 6) is preserved in the United States National Museum, and as this happens to be the smallest and least perfectly

[17] Heer, Oswald, Flora fossilis alaskana, p. 22, pl. 1, figs. 1–5, 1869.

[18] Lesquereux, Leo, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 372, 1873.

[19] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 77, pl. 7, figs. 6–10, 1878.

preserved one, Lesquereux's diagnosis can not be confirmed.

A few years later Lesquereux [20] identified his *Sequoia angustifolia* from the auriferous gravels at Corral Hallow, Calif., and gave a single figure, and in 1902 I admitted a specimen from the Mascall formation in my "Flora of the John Day Basin,"[21] largely on the basis of its resemblance to the specimen from California.

I have a large number of specimens of coniferous branchlets recently collected at Elko, Nev., and they do not agree at all with Lesquereux's diagnosis and figures of his *Sequouia angustifolia.* One of the Elko specimens has been figured for comparison (Pl. IX, fig. 7), and from this it will be noted that the leaves are irregular and open or spreading, are obtuse at the apex instead of acuminate, and are distinctly contracted at the base and have a very distinct midrib. This form is distinctly a *Taxodium* and not a *Sequoia.* If the diagnosis and type figures of *Sequoia angustifolia* are correct, it obviously can not be the form that is now so well known from Elko.

Although the specimens of *Taxodium dubim* are so abundant in the present collections, only one example in the flowering state has been noted. This is shown on Plate IX, Figure 5, and is clearly the staminate inflorescence of a *Taxodium* and in all probability belongs with this species, but as there is no absolute connection between them, it has been figured without specific designation.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920 (Pl. IX, fig. 8); Deep Creek half a mile above mouth, northwest of Spokane, Wash. (Pl. IX, fig. 2), and cut 1 mile west of Shelly Lake, 10 miles east of Spokane, collected by Henry Fair and C. E. Fernquist, 1922; cut along Spokane, Portland & Seattle Railway, Spokane (Pl. IX, fig. 9; Pl. X, fig. 2), collected by T. A. Bonser.

**Taxodium, male aments**

Plate X, Figure 4

Among the several hundred coniferous branchlets the one here figured is the only one showing organs of reproduction. These are undoubtedly the staminate flowers of a *Taxodium* and probably belonged to the species here designated *Taxodium dubium.* They agree perfectly with those from the Mascall formation figured under the same caption in my "Flora of the John Day Basin." [22]

Occurrence: Latah formation, Deep Creek half a mile above mouth, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

[20] Lesquereux, Leo, U. S. Geol. Survey Terr, Rept., vol. 8 (Cretaceous and Tertiary floras), p. 240, pl. 50, fig. 5, 1883.

[21] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 24, 1902.

[22] Idem, p. 27, pl. 1, figs. 4 6.

**Subfamily CUPRESSINEAE**

**Libocedrus praedecurrens Knowlton, n. sp.**

Plate VIII, Figure 8

Similar to the living *Libocedrus decurrens* Torrey but more robust, the branches and branchlets nearly twice as thick as in the ordinary living specimens.

The little fragment figured is all that has been found of this form. It is small to serve as the basis of a supposed new species, and this assignment must be considered tentative and must await more complete material before it can be positively settled.

The incense cedar (*Libocedrus decurrens* Torrey) is found in the mountains of southern Oregon, the Sierra Nevada and Coast Ranges of California, the western edge of Nevada, and northern Lower California. It is a tree from 75 to 100 feet high and is 2½ to 4 feet (exceptionally 5 or 6 feet) in diameter. According to Sudworth it attains an age of some 500 to 700 years. It does not now live within some hundreds of miles of the Spokane area, but if the fragment here figured is correctly identified, the immediate forerunner of the species existed in Miocene time far to the north of its present habitat.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected for and submitted by the Spokane Public Museum.

**Class ANGIOSPERMAE**

**Subclass MONOCOTYLEDONES**

**Order PANDANALES**

**Family TYPHACEAE**

**Typha? sp.**

Plate IX, Figure 11

The collection made by R. W. Chaney in the Spokane area includes a single fragment of a monocotyledonous leaf. It was evidently a long, narrow, cattail-like leaf about 1 centimeter wide and has parallel veins of three degrees. The major nerves are strong and are about 1.5 millimeter apart. Between these are three less strong veins, and between these one to three very fine veins. The cross veins are usually between the veins of the second degree, though here and there a cross vein may pass over two of the second-rate parallel veins.

This fragment is so small that it is possible only to characterize it in a general way. It appears to be a leaf of *Typha*, but as this is not certain the reference to *Typha* has been questioned. It simply serves to direct attention to the fact that a plant of this type was present.

Occurrence: Latah formation, Spokane, Wash., collected by R. W. Chaney, July, 1921, specimen in the University of California, No. $\frac{3940}{22843}$.

### Order NAIADALES

### Family POTAMOGETONACEAE

### Potamogeton sp.

Plate X, Figures 5, 6

This appears to be a fragment of the basal portion of a thin, pellucid, grasslike submerged leaf of *Potamogeton*. It is narrowly linear, narrowed below to a long wedge-shaped point of attachment, and of unknown shape above. There is a fairly strong midvein, and on each side of it there are three or four very thin, somewhat irregular veins, connected by more or less irregular cross veins.

As nearly as I may judge from so small a fragment it appears to resemble most closely the submerged leaves of the living *Potamogeton heterophyllus* Schreber. This is a highly variable species, occurring in different forms throughout almost all of North America except the extreme north and also in Europe. Its submerged leaves are linear-lanceolate, from 1 to 6 or 7 inches long and 1 to 8 lines wide.

As this flora was deposited in ponds or slow-moving streams it is reasonable to suppose that the habitat would be congenial for *Potamogeton*—in fact, it is surprising that there is not more evidence of the presence of this genus.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

### Order GRAMINALES

### Grass, leaf

Plate X, Figure 7

The small specimen here figured is of little value except to indicate the undoubted presence of this group of plants. It is a fragment of the apical portion of a leaf about 5 centimeters long and 2.5 millimeters wide. It is deeply channeled in the middle.

Specimens that are little if any better preserved than this have received both generic and specific names, but there is hardly one chance in a thousand that such a form could be correctly allocated or identified subsequently.

Occurrence: Latah formation, cut on Chicago, Milwaukee & St. Paul Railway near Spokane, Wash., collected by Kirk Bryan, June, 1923.

### Grass?, genus?

Plate X, Figures 8, 9

This small and rather obscurely preserved specimen appears to be a small, creeping grass. The basal part apparently consists of a radicle from which two or three rhizomes arise. These rhizomes were apparently procumbent or creeping, with short, erect, compact, leafy or scaly branches.

Dr. Arthur Hollick has been kind enough to compare this specimen with living material in the herbarium of the New York Botanical Garden, especially in those genera of grasses with creeping stems, such as *Eragrostis*, *Syntherisma*, *Dactyloctenium*, *Elusine*, and *Capriola*, and although there is a general resemblance it is not sufficiently close to warrant even a generic identification. This specimen seems most like a grass and has been figured in the hope that someone may be able to place it.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, April, 1922.

### Order ARALES

### Family ARACEAE

### Arisaema hesperia Knowlton, n. sp.

Plate X, Figure 1

The material from the Spokane area includes the single specimen of this plant that is here figured. It is a globose head of fruits or "berries" borne on a long, naked peduncle. The head is about 2 centimeters in diameter and bears a number (nine are shown in the side view of the specimen) of globose fruits or berries that are about 4 millimeters in diameter. The surface of these berries is more or less corrugated or irregularly wrinkled, as if they had been fleshy or had had a fleshy covering with perhaps a hard "stone" beneath. Of the supporting organ or peduncle 3.5 centimeters is preserved, but it was longer than this, as it runs off the matrix without evidence of attachment. It is slightly more than 2 millimeters broad and is striate or wrinkled longitudinally, a feature which indicates that it was fleshy.

So far as I am able to determine this specimen is closely similar to the fruit of the living *Arisaema triphyllum* (Linné) Torrey, the Indian turnip of the eastern United States, which ranges from Nova Scotia to Florida and west to Ontario, Minnesota, Kansas, and Louisiana, delighting especially in moist woods and thickets. The fossil form has a longer, more uniform-sized peduncle than the living species. the head is globose rather than ovoid, and the berries are apparently wrinkled instead of being smooth and shining. Whether these differences are sufficient to warrant a generic separation seems doubtful, and if the form is correctly interpreted, as it seems to be, the presence of the genus in this flora is placed on a secure footing.

Two other fossil species from this country have been described under the name *Arisaema*—namely, *Arisaema cretacea* Lesquereux, from the Dakota sandstone of Kansas and the Magothy formation of Cliffwood, N. J., and *Arisaema? mattawanense* Hollick, also from the Magothy formation at Cliffwood, N. J.

However, both these are based on portions thought to represent the spathe and can not be compared with the present specimen, quite aside from the marked difference in age. The genus has not been reported in a fossil state outside of the United States. No other portion that can be referred to *Arisaema* has been found in the Spokane area.

Occurrence: Latah formation, Deep Creek, northwest of Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

### Subclass DICTOTYLEDONES

### Order SALICALES

### Family SALICACEAE

#### Populus heteromorpha Knowlton, n. sp.

Plate XII, Figures 8–10; Plate XIII, Figures 1–7; Plate XIV, Figures 1–3; Plate XV, Figures 3–5

This form is represented by approximately 200 specimens, and it is without exception one of the most polymorphous species that I have ever studied. If it were not for connecting forms it would be easy to select a number that are seemingly so distinct as to merit specific separation, but when the specimens are viewed as a whole it seems impossible to draw any definite lines. From the carbonaceous substance that is still present in many specimens it is evident that the leaves were rather thick and coriaceous. They had a fairly stout petiole about 2.5 centimeters in length. In perhaps a majority of the specimens the leaves are ovate or ovate-elliptical, with a rounded or very obtusely wedge-shaped or nearly truncate base. They are all more or less obtuse, and some of them are rounded at the apex. From the ovate form there is variation in two directions. In one, shown in Plate XII, Figure 10, the apical portion is proportionally more elongated, a form reached through the forms shown in Plate XIII, Figure 6, and Plate XIV, Figure 2. In the other type the apical portion is short and obtuse, and the basal portion is expanded until the outline is almost circular or even reniform, as shown in Plate XIII, Figures 2 and 5, and Plate XV, Figure 3.

In the configuration of the margin there is considerable variation. In the smallest leaf noted, which is only 2 centimeters long and 1.75 centimeters broad, shown in Plate XII, Figure 9, the margin is slightly undulate. In the leaf shown in Plate XII, Figure 8, it is entire except for two slight basal lobes. A few of the large leaves have a similar marginal outline, as shown in Plate XV, Figure 5; or, as shown in Plate XIII, Figure 2, there may be two small lobes on each side. In some of the broader forms the effect is to become three-lobed with perhaps undulations or slight minor lobes.

The principal nervation in these leaves is essentially the same—three-ribbed from the top of the petiole. The midrib is slightly larger than the ribs and has usually three or four pairs of secondaries in the upper portion, these curving upward and arching near the border. The lateral ribs are usually much curved and pass upward for varying distances, some of them nearly or quite reaching the apex, others joining the lowest pair of secondaries on the midrib. In the very broad leaves these ribs may reach up for only half the length of the blade. They have several branches on the outside which arch near the margin, some of them with two or three series of loops. The nervilles are numerous, thin, and nearly always broken. The finer nervation forms irregularly quandrangular areas.

This species does not appear to be very closely similar to any living North American form, but it is suggestive of *Populus alba* Linné and *Populus canescens* Smith, of western and southern Europe. In diversity of form it is especially like *Populus alba*, which has leaves ranging from ovate or elliptical to markedly three-lobed with variously toothed margins. The primary nervation in *P. alba* shows three ribs from the top of the petiole, but the lateral ribs do not ascend so high as they do in many of the leaves of *Populus heteromorpha*.

Certain fossil American species, however, show strong points of agreement with the leaves of *P. heteromorpha*. These are leaves of the type of *Populus arctica* Heer, which are so abundant in the Arctic Eocene and especially in the Fort Union formation. In these the lateral ribs arch around and terminate in or near the apex of the blade. This feature, as already pointed out, is to be noted in the leaves under consideration, but it is not so marked as in *Populus arctica* and its more or less close relatives. It seems possible that the leaves of *P. heteromorpha* are showing a transition from the three-ribbed *arctica* type to the pinnate-veined leaves of most modern forms. It is held by some students that the forms of the *arctica* type are not properly referred to *Populus*—that they represent, for instance, archaic survivals from the Trochodendraceae—but if the above interpretation is correct there may be an actual transition between the palmately ribbed Eocene types and the modern pinnate types.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

#### Populus fairii Knowlton, n. sp.

Plate XV, Figure 2; Plate XVI, Figures 1–3

Leaves evidently coriaceous, large (8 to 12 centimeters broad, 6.5 to 8 or 9 centimeters long), from nearly circular to very broadly ovate, truncate, or slightly heart-shaped at the base, obtuse and rounded at the apex; margin entire below, with three or four large, obtuse lobes on each side separated by shallow sinuses; petiole stout, at least 4 centimeters long; nervation palmately five-ribbed from the top of the petiole; midrib with two or three pairs of thin, alternate, often irregular secondaries above the middle of the blade, which arch around nearly or quite to the midrib in the upper part; lateral ribs nearly as strong as the midrib, arising at an angle of 40° or 50°, much curved upward and joining the lowest pair of secondaries on the midrib, each with several tertiary branches on the outside, these mainly arching around and each joining the one next above; lowest pair of ribs (these are virtually basal secondaries on the lateral ribs which arise with the ribs at the top of the petiole) thin, usually at right angles to the midrib, occasionally stronger (as shown in Pl. XVI, fig. 3), nearly as strong as the other pair of ribs; nervilles thin, broken, breaking up into the finer quadrangular areolations.

This form is represented by five leaves, four of which are figured. They were found in association with the numerous leaves of *Populus heteromorpha*, and it is possible that they should be referred to that species, but they are so very much larger and show so strongly marked a tendency toward five ribs instead of three that it hardly seems as if they could be that species, especially as there are no intermediate forms. They are certainly closely related to *P. heteromorpha*, however, and subsequent collections may show them to intergrade in size and nervation.

I take pleasure in naming this species in honor of Mr. Henry Fair, of Spokane, Wash., who assisted in collecting these and many other excellent specimens.

Occurrence: Latah formation, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, March, 1922.

**Populus lindgreni Knowlton**

Plate XIV, Figures 4–7

*Populus lindgreni* Knowlton, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 725, pl. 100, fig. 3, 1898; U. S. Geol. Survey Bull. 204, p. 29, pl. 2, fig. 1, 1902.

The type of this species came from the Payette formation near Marsh post office (now Montour), Boise County, Idaho. A single example was subsequently found in the Mascall formation of the John Day Basin, Oreg. The material from Coeur d'Alene includes four finely preserved leaves, all of which have been figured, as well as several less perfect specimens. These specimens permit a revision or amplification of the description. In the type specimen there are five ribs that arise at the top of the petiole, the second pair being by far the stronger. In the new specimens there are three principal ribs, the lateral ones with several secondary branches on the outside. In some specimens the first pair of secondaries arise from the ribs at or near the base, thus appearing to be five-ribbed, but in most specimens the first secondaries arise a short distance above the base. The lowest pair of secondaries in the broader leaves have several tertiary branches that supply the lower portion of the blade. Many of the upper secondaries on the midrib as well as the lateral ribs and the secondary and tertiary branches from them are forked, the ultimate branches ending in the marginal teeth. The nervilles are strong, mainly broken and irregular, some of them not reaching across the space between the major nervation.

It is now evident that there is a considerable range in size and in the shape of the base of this species. The smallest leaf found (fig. 7) is 4.5 centimeters long and 4.5 centimeters wide; it has the petiole preserved for a length of 1.5 centimeters. The next in size (fig. 5) is a little more than 6 centimeters long and is 7 centimeters broad. The one shown in Figure 4 is about 6.75 centimeters wide and 6.5 centimeters long. The largest specimen (fig. 6) is fully 8 centimeters broad and nearly 8 centimeters long.

It will be seen that two of the specimens figured are practically truncate at the base, but a third (fig. 5) is slightly and the fourth (fig. 6) markedly heart-shaped at the base. In all the specimens the margin is finely and evenly undulate-toothed. In one of the specimens (fig. 5) there is a slight lobe on one side in which the lateral rib terminates.

Among living forms this appears to approach most closely the European *Populus tremula* or its American relative *P. tremuloides* Michaux, especially in marginal dentation, but they differ considerably in shape.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

**Populus washingtonensis Knowlton, n. sp.**

Plate XV, Figure 1

Leaf thick and coriaceous, nearly circular, broadly truncate at the base and rounded obtuse at the apex; margin with few large, low, rounded lobes; petiole very stout, probably flattened; nervation pinnate, the midrib straight, very thick below, thin above, with about five pairs of strong, opposite, parallel secondaries, the lowest pair arising at the top of the petiole and thus simulating a three-ribbed appearance; the lowest pair of secondaries with three or four tertiary branches and the middle secondaries with two or three branches, which terminate in the margin; nervilles rather sparse, mainly broken; finer nervation not well retained.

This species is represented only by the specimen figured. It is about 6.5 centimeters long and nearly 8 centimeters wide; the petiole is 2.5 centimeters long and was either flattened or was thick and fleshly and has been crushed flat. It is fully twice the thickness of the base of the midrib.

This leaf was found in association with leaves of *Populus lindgreni* and may be an extreme form of it, but the differences are so many and so marked that the leaves must seemingly be separated. Thus in place of the evenly and finely undulate-toothed margin of *P. lindgreni* we have the few large rounded lobes with entire margins in *P. washingtonensis*. The nervation in *P. washingtonensis* is more strict and more obviously pinnate than it is in *P. lindgreni*, and the petiole is obviously stouter.

The margin in *P. washingtonensis* is most like the margin of the living *P. grandidentata* Michaux; the shape of the leaf is different. It does not approach very closely any fossil form described from the region.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

### Salix elongata O. Weber

Plate XII, Figure 4

*Salix elongata* O. Weber, Palaeontographica, vol. 2, p. 177, pl. 19, fig. 10, 1852.

Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 169, pl. 22, figs. 6, 7, 1878.

Knowlton, U. S. Geol. Survey Mon. 32, pt. 2, p. 698, 1899.

The leaf here figured, which is absolutely perfect, appears to be the same as specimens from Elko, Nev., identified by Lesquereux as *Salix elongata* O. Weber. Whether or not they are correctly referred to the European species is a question that need not be answered at this time.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

### Salix perplexa Knowlton

Plate XII, Figure 5

*Salix perplexa* Knowlton, U. S. Geol. Survey Bull. 204, p. 31, pl. 2, figs. 5–8, 1902.

Chaney, Am. Jour. Sci., 5th ser., vol. 4, p. 216, 1922.

The specimen figured agrees well with one of the figured types of this somewhat variable species. This species is very abundant in the Mascall formation of the John Day Basin, and recently Chaney has found it in the Payette formation of western Idaho.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

### Salix dayana Knowlton

Plate XII, Figures 1, 2

*Salix dayana* Knowlton, U. S. Geol. Survey Bull. 204, p. 31, pl. 2, figs. 9, 10, 1902.

There are several specimens that appear to belong to this species. Of the two examples illustrated the one seen in Figure 1 is the under side of the leaf, showing the finely reticulated ultimate nervation. The other (fig. 2) shows the upper side of the leaf and the disposition of the secondaries.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

### Salix remotidens Knowlton, n. sp.

Plate XII, Figure 7

Leaf of finer texture, lanceolate, 11 centimeters long, 2.7 centimeters wide, broadest below the middle, thence tapering to the obtuse base and above to a long, slenderly acuminate apex; margin entire for the lower and upper thirds of the blade, the middle third with a few very small, blunt teeth; petiole stout, 1.5 centimeters long; midrib moderately strong for the size of the blade, straight; secondaries 12 or 15 pairs, thin, mainly alternate, the basal pair opposite, at an angle of about 45°, the others nearly at a right angle, all much curved upward and running for a considerable distance near the margin; in the lower and middle portions of the blade there are a few intermediate secondaries; finer nervation obscure.

This leaf appears to be very well characterized by the few, blunt teeth in the middle of the blade, but in size, shape, and nervation it is so characteristically a willow leaf that it would be difficult to diagnose it so that it could be readily distinguished from numerous others.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

### Salix inquirenda Knowlton, n. sp.

Plate XI, Figures 1, 2

Leaves firm in texture, large, lanceolate-acuminate, rather abruptly rounded at base, long and slenderly acuminate at apex; margin evenly toothed throughout, even near the base, the teeth rather remote, some of them fairly sharp but most of them blunt and rounded; midrib very strong below, very thin above; secondaries numerous, arising at a low angle, some of them almost at a right angle, then curving upward along the borders and often each joining the one next above and sending thin branches, almost nervilles, to the teeth; intermediate secondaries between most of the secondaries, especially in the lower and middle portions of the blade; finer nervation producing a fine irregular network.

This species is represented by several more or less perfect leaves, three of which are figured. The largest leaf (fig. 2) is nearly 3 centimeters wide and has the base well preserved. The others (fig. 1) lack the base but have the apex almost complete. The lower of these two, preserved on the same piece of matrix, is about 13 centimeters long and 2.25 centimeters wide. The upper one was at least 12 centimeters long and is nearly 2.5 centimeters wide.

In size, shape, and nervation these leaves are so characteristic of *Salix* that the generic reference can be considered settled, but decision as to the species is quite another matter. Many living species can not be separated by the leaves alone, and many fossil species are equally difficult to characterize.

Of the several forms of willow leaves described in the present paper the species that seems to be nearest to the leaves under discussion is *Salix remotidens*, which has the few remote, blunt teeth confined to the middle of the margin, whereas in these the teeth are present throughout, although of much the same character. Among described species the leaves under discussion are very similar in size, shape, and nervation to some of the leaves from the Swiss Miocene, described and figured by Heer [23] under the name *Salix varians* Göppert, but they differ in the character of the teeth.

*Salix varians* Göppert is accepted as present in the Mascall formation, as well as in the beds at Ellensburg, Wash., the Miocene of the Yellowstone National Park, and supposedly in the Kenai formation of Alaska.

Occurrence: Latah formation, Twelfth Avenue and Thor Street, Spokane, Wash., collected by Henry Fair and Kirk Bryan, June, 1923.

### Salix bryani Knowlton, n. sp.

Plate XII, Figure 6

Leaf firm in texture, rather narrowly lanceolate, apparently acuminate at both base and apex, though these parts are missing; margin with very small, remote, sharp, appressed teeth; midrib very strong, especially below; secondaries numerous, probably 15 or more pairs, alternate, at a low, almost right angle in the lower part, at an angle of about 30° in the middle and upper part of the blade, all camptodrome, each curving and joining the one next above, forming an intramarginal "stitch"; finer nervation forming a close network of irregularly quadrangular areas.

The leaf figured must have been about 8 centimeters in length when perfect and is 1.5 centimeters wide near the middle, whence it narrows in about equal degree to base and apex. The secondary nervation is characteristically that of *Salix*.

This leaf, as regards size and shape, belongs to the nondescript type that is very hard to characterize, but the peculiar type of marginal teeth is unusual and should make it easy to recognize in future. The living *Salix discolor* Muehlenberg has teeth of this kind.

Occurrence: Latah formation, cut on Chicago, Milwaukee & St. Paul Railway near Spokane, Wash., collected by Kirk Bryan, June, 1923.

### Salix sp.

Plate XII, Figure 3

In the collection from Coeur d'Alene I find this little leaf, which appears to be different from any of the other *Salix* leaves. It was evidently rather thin in texture, lanceolate, with an apparently rounded base and probably acute apex. It was 5 centimeters in length and nearly 1.5 centimeters in width. The margin is entire and slightly undulate. The nervation is delicate, consisting of a thin, straight midrib and about 10 pairs of thin, alternate, camptodrome secondaries, which arch upward and each joins the one next above, often by several large loops. The finer nervation produces rather large irregular areolae.

This form could be compared with a number of described species, but the difficulty of establishing identity on a single incomplete leaf is so great that it has seemed best not to assign a specific name. If more complete leaves are found later it will be an easy matter to name them and characterize them more fully.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

## Order FAGALES

## Family BETULACEAE

### Alnus, pistillate cones

Plate XVIII, Figures 3–5a

The two specimens figured are undoubtedly the mature pistillate aments or "cones" of an *Alnus*. The shape and margins of the individual scales can not be made out with certainty, but the nutlets appear to be ovoid, though the presence or absence of a wing can not be determined.

Among living species these "cones" seem to resemble most closely those of *Alnus incana* (Linne) Willdenow, the hoary alder, a species widespread in northern North America as well as in Europe and Asia.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

### Betula fairii Knowlton, n. sp.

Plate XVII, Figure 4

Leaves small, about 23 millimeters long, 13 millimeters wide, apparently coriaceous, elliptical, about equally rounded to both base and apex; margin entire at the base, thence finely toothed, the teeth somewhat irregular, mainly sharp-pointed, the point indurated or thickened; nervation strong, especially the midrib; there is a thin pair of basal secondaries at right angles to the midrib, then about six pairs of alternate secondaries at an angle of 45°, straight and ending in the teeth; nervilles numerous, mainly percurrent and at right angles with the secondaries; finer nervation abundant, forming an irregularly quadrangular network.

This little leaf, the only one observed, is absolutely perfect, including the petiole. It may be known by its elliptical shape with obtuse and rounded apex and rounded, almost truncate base, irregularly toothed margin, and very strong nervation. It is most closely related to *Betula heteromorpha* Knowlton,[24]

[23] Heer, Oswald, Flora tertiaria Helvetiae, vol. 2, pl. 65, figs. 1–3, 6–16, 1856.

[24] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 39, pl. 3, figs. 6, 7, 1902.

from the upper part of the Clarno formation (Bridge Creek locality), from which it differs in its smaller size, elliptical shape with rounded and obtuse apex and more truncated base, and fewer secondaries.

This species is named in honor of Mr. Henry Fair, of Spokane, who not only collected the type specimen but has rendered invaluable aid in collecting throughout the Spokane area.

Occurrence: Latah formation, cut on Chicago, Milwaukee & St. Paul Railway near Spokane, Wash., collected by Henry Fair and Kirk Bryan, June, 1923.

**Betula nanoides Knowlton, n. sp.**

Plate XVIII, Figure 2

Leaves small, about 15 millimeters long and 12 millimeters broad, broadly ovate, abruptly rounded and slightly heart-shaped at base, almost equally rounded above to the acuminate apex; margin finely serrate, the teeth sharp-pointed, probably glandular tipped; midrib relatively very strong; secondaries six or seven pairs, the lowest pair nearly at right angles with the midrib, with tertiary branches on the lower side, other secondaries at an angle of about 40°, nearly straight, lower and middle ones with one or two branches, all craspedodrome and ending in the teeth; nervilles numerous, mainly at right angles to the secondaries, broken or percurrent.

This little leaf seems certainly referable to *Betula.* The margin is finely serrate, and in addition there is a faint indication of its being doubly serrate—that is, there are slight projections beyond the general outline where the secondaries and their branchlets enter the teeth, but they are of little prominence.

This species does not seem to approach very closely any living American birch, perhaps the nearest in shape being *Betula occidentalis* Hooker, but that species has leaves 7 or 8 centimeters long that are more acute at the apex. The European *Betula humilis* Schrank, however, is very similar both in size and shape. This is a small shrub from 3 to 6 feet high growing on peat bogs in the Tyrol and elsewhere in central Europe, but the leaves are less truncate at the base and have fewer and larger teeth, with no tendency to be doubly serrate.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

**Betula heteromorpha Knowlton**

Plate XVII, Figures 5, 6

*Betula heteromorpha* Knowlton, U. S. Geol. Survey Bull. 204, p. 39, pl. 3, figs. 6, 7; pl. 5, fig. 1, 1902.

Several leaves were noted in the collections that must be referred to this species. Except for its slightly larger size the larger specimen here figured is not to be distinguished from the leaf figured on Plate V, Figure 1, of my "Flora of the John Day Basin," and the smaller one (fig. 5) is the same as Figures 6 and 7 of Plate III of that work.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920; cuts on Spokane, Portland & Seattle Railway and Chicago, Milwaukee & St. Paul Railway, Spokane, Wash., collected by R. W. Chaney, 1922. Specimen in University of California Museum, No. $\frac{3946}{22871}$.

**Betula? largei Knowlton, n. sp.**

Plate XVII, Figures 1, 2

Leaves large, 12 to 15 centimeters long, 6 to 8 centimeters wide, fairly firm in texture, elliptical or broadly ovate-elliptical, abruptly rounded below to a truncate or slightly heart-shaped base and above to an apparently acuminate apex; margin obscurely doubly serrate—that is, the teeth entered by the secondaries are slightly larger than the others, of which there are usually two or three between two of the larger ones; all are sharp-pointed; midrib thick, straight; secondaries 10 or 12 pairs, at an angle of 40°–50°, parallel, nearly straight, entering the larger teeth; nervilles rather sparse, mainly unbroken and at right angles to the secondaries, finer nervation producing a fine network between the nervilles.

This form is represented by several leaves, two of the best of which are figured. I am uncertain as to the generic reference. There is some resemblance to certain living leaves of *Alnus* and *Corylus,* but altogether they agree best with larger leaves of *Betula,* such as especially long, slightly heart-shaped leaves of *Betula papyrifera* Marshall. However, considering the uncertainty the generic reference has been questioned.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922; well at Mica, Wash., southeast of Spokane, collected by Thomas Large for J. T. Pardee, August, 1922.

**Betula bryani Knowlton, n. sp.**

Plate XVIII, Figure 1

Leaf thin, ovate-elliptical, abruptly rounded below to the slightly heart-shaped base, apparently acuminate at the apex; margin entire at the base, then strongly toothed, the teeth entered by the secondaries slightly larger than the two or three intermediate ones, all deltoid in shape; midrib strong; secondaries six pairs alternate, at an angle of about 45°, very little curved upward, craspedodrome, entering the larger teeth; nervilles numerous, mostly simple and at right angles to the secondaries; finer nervation producing a fine quadrangular network.

The little leaf figured is the only one noted in the collections. It is about 5.5 centimeters long and nearly 3.5 centimeters wide. It is not exactly doubly serrate, though there is a tendency for the teeth entered by the secondaries to be slightly larger than the intermediate ones. Among living species it seems to approach most closely certain of the broader, heart-shaped forms of *Betula papyrifera* Marshall, the well-known canoe or paper birch. The teeth, however, are not so sharp-pointed as in most living species of *Betula*. The species is named in honor of Mr. Bryan.

Occurrence: Latah formation, Twelfth Avenue and Thor Street, Spokane, Wash., collected by Henry Fair and Kirk Bryan, 1923.

### Betula thor Knowlton, n. sp.

Plate XVII, Figure 3

Leaf of medium size, about 6.5 centimeters long and 4 centimeters wide, with a petiole at least 2 centimeters long, membranaceous, ovate, very obtusely wedge-shaped at the base and acuminate at the apex; margin entire at base, then distinctly doubly serrate, the teeth sharp, pointing upward; petiole and midrib strong; secondaries eight or nine pairs, alternate, at an angle of about 40°, straight, parallel, ending in the larger teeth, and usually with two or three light branches which enter the smaller teeth; nervilles numerous, thin, irregular, mainly oblique to the secondaries; finer nervation producing an intricate, fine network.

Among living American species the present species appears to approach most closely certain of the narrower, more normal leaves of *Betula papyrifera* Marshall, the common paper birch, which ranges widely from Labrador, the southern shores of Hudson Bay, and Great Slave Lake westward to Montana and northwestern Washington, though not very abundant in the Rocky Mountains.

Among fossil species known from the general region *Betula thor* shows points of agreement with several. Thus, *Betula heteromorpha* Knowlton,[25] from the upper part of the Clarno formation at Bridge Creek, Oreg., agrees in size, but its marginal teeth are almost invariably rounded instead of sharp, and it is less obviously doubly serrate.

The species described above under the name *Betula bryani* is from the same locality as the present species, but it is distinctly heart-shaped at the base and has the teeth deltoid instead of sharp-pointed; it is also less obviously doubly serrate. If a series of leaves were available from this locality it might show these two forms to be the same, but as at present known they seem to be quite distinct. It may be that these correspond to the type and the variety *cordifolia* of *Betula papyrifera*.

Occurrence: Latah formation, Twelfth Avenue and Thor Street, Spokane, Wash., collected by Henry Fair and Kirk Bryan, 1923.

[25] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 39, vol. 3, figs. 6, 7; pl. 5, fig. 1, 1902.

### Carpinus sp.

This specimen is a fragment of what appears to be a leaf of *Carpinus*. It is a small leaf, apparently between 6 and 7 centimeters in length and a little over 2 centimeters in width. It is lanceolate, apparently long wedge-shaped at the base and narrowly acuminate at the apex. The margin is sharply doubly serrate, though the distinction between the major teeth, or those entered by the secondaries, and the intermediate teeth is not very pronounced. The number of secondaries can not be made out from this fragmentary specimen, but there must have been 10 or 12 pairs. They are close, parallel, at an angle of 45° or 50°, and nearly straight. The nervilles are numerous, rather strong, at right angles to the secondaries.

This specimen is so fragmentary that it can not be compared very successfully with other forms. It is nearest to the living *Carpinus carolinensis* Walter but is apparently longer and narrower. In some particulars it agrees with *Alnus carpinoides* Lesquereux,[26] from Bridge Creek, Oreg., but that is a much larger species and has the margin much more pronouncedly doubly serrate. The present specimen is also similar to certain of the smaller, narrower leaves of *Carpinus grandis* Unger, such for instance as some of those figured by Heer[27] from the Miocene of Sakhalin.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

### Castanea castaneaefolia (Unger) Knowlton

Plate XVIII, Figures 7, 8; Plate XIX, Figure 1

*Castanea castaneaefolia* (Unger) Knowlton, U. S. Geol. Survey Bull. 152, p. 60, 1898.

*Castanea ungeri* Heer. Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 246, pl. 52, figs. 3–7, 1883.

These specimens agree with those previously reported from the John Day Basin, Oreg.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

### Quercus merriami Knowlton

Plate XIX, Figures 4, 5

*Quercus merriami* Knowlton, U. S. Geol. Survey Bull. 204, p. 49, pl. 6, figs. 6, 7; pl 7, figs. 4, 5, 1902.

*Quercus pseudo-lyrata angustiloba* Lesquereux, U. S. Nat. Mus. Proc., vol. 11, p. 17, pl. 11, fig. 2, 1888.

The nearly perfect leaf figured is not to be distinguished from the smaller of the leaves figured among the types of *Quercus merriami* Knowlton, except that the teeth are not quite so sharp-pointed. The tip of a leaf shown in Figure 4 has the teeth bristle-

[26] Lesquereux, Leo, U. S. Geol. Survey Terr., vol. 8 (Cretaceous and Tertiary floras), p. 243, pl. 50, fig. 11; pl. 51, figs. 4, 5, 1883.

[27] Heer, Oswald, Flora fossilis arctica, vol. 5, Abt. 4, pl. 8, figs. 3, 4, 6; pl. 9, figs. 1, 2, 1878.

pointed, as in the types, though the teeth are not quite so large.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

### Quercus cognatus Knowlton, n. sp.

Plate XX, Figures 1–4; Plate XXI, Figures 1, 2

Leaves variable in size, coriaceous, lanceolate or elliptical-lanceolate, rather obtusely wedge-shaped at the base, moderately acute at the apex; margin entire for a short distance at the base, then provided with 6 to 10 large teeth separated by rounded sinuses; the lower teeth are the smaller and are usually rounded; the upper ones are the larger and usually sharp-pointed; petiole strong; midrib very strong; secondaries strong, straight, mainly alternate, as many as the teeth and entering them; nervilles numerous, strong, mainly broken, forming with the smaller veins a fine network.

This is one of the most abundant species in the collections, being represented by not less than 25 more or less perfect leaves. The largest specimen (Pl. XX, fig. 1) must have been at least 18 centimeters in length exclusive of the petiole, which is 1.5 centimeters long; its greatest width is 6.5 centimeters. The next size (Pl. XX, fig. 2) was probably about 13 or 14 centimeters long and only 4 centimeters wide. A nearly similar example (Pl. XXI, fig. 1) was 11 or 12 centimeters long and about 4.5 centimeters wide. This specimen, which has somewhat sharper lobes than those already mentioned, has a petiole 2.5 centimeters long. The one shown in Figure 1 of Plate XXI has all the lobes sharper pointed than the majority. Still another specimen was only about 10 centimeters long. Plate XX, Figure 3, shows the nearly complete apical portion.

At first it was presumed that these Spokane leaves could be referred to one of the forms of the polymorphous *Quercus pseudo-lyrata* Lesquereux, which is so abundant in the Mascall formation of the John Day Basin, but a careful comparison convinces me that they are not identical. Some of the Spokane leaves approach more closely what has been segregated as *Quercus merriami* Knowlton,[28] but that species differs so much that they can not be placed together.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920 (Pl. XX, fig. 3); Spokane, Wash.

### Quercus cf. Q. pseudo-lyrata Lesquereux

Plate XXII, Figure 2

The specimen here figured, a mere fragment, is all that was noted of this form. It was a large leaf probably not less than 15 centimeters long and 8 or 9 centimeters wide. The margin is very deeply cut into probably three or four large, upward-pointing, rather acute lobes. The sinuses between the lobes are very deep and rounded. The nervation is preserved with remarkable fidelity and is well shown in the figure. The midrib is very strong and shows little diminution within the fragment present. The secondaries are also strong; they pass nearly straight well into the lobes and then turn slightly upward. The intermediate secondaries are numerous, at irregular distances, and of various sizes, all nearly at right angles with the midrib and camptodrome, arching for considerable distances just inside the margin, especially around the sinuses. The finer nervation is irregularly quadrangular.

This leaf is of the type of *Quercus lyrata* Walter and in fact may be a large leaf of *Quercus pseudo-lyrata* Lesquereux,[29] which is an abundant form in the Mascall formation of the John Day Basin. It would probably do no great violence to identify this leaf directly with Lesquereux's species, but as it is so fragmentary it seems best to question the determination.

*Quercus pseudo-lyrata* is probably more closely related to *Quercus velutina* Lamarck and *Quercus californica* Cooper; the latter is the largest and most abundant species of the valley of southwestern Oregon and of the Sierra Nevada.

Occurrence: Latah formation, 1 mile west of Shelley Lake, half a mile south of "Apple Way," and about 10 miles east of Spokane, Wash., collected by Henry Fair, October, 1922.

### Quercus rustii Knowlton, n. sp.

Plate XXI, Figures 3, 4

Leaves evidently coriaceous, lanceolate, narrowed from a point near or above the middle to the long wedge-shaped base and prolonged above into a slender, acuminate apex; margin with three remote, rather small, sharp-pointed teeth on each side; the teeth are separated by long, shallow sinuses; petiole short, stout; midrib very strong for the lower half of the blade, thence greatly reduced; secondaries 10 or 12 pairs, at an angle of 60° or 70°, the lower ones curving along the margin, those in the middle and upper part remote, entering the teeth; finer nervation producing a fine quadrangular network.

The best preserved of these leaves (fig. 3) is 10 centimeters long and about 2.5 centimeters wide. The other one figured (fig. 4) was probably nearly 12 centimeters long and about 3.5 centimeters wide between the points of the largest teeth.

This species is probably most closely related to *Quercus payettensis* Knowlton but differs in the long wedge-shaped base, the fewer, remote teeth, and the slenderly acuminate apex. This species is also very similar to certain of the narrower leaves of *Quercus*

[28] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 49, pl. 6, figs. 6, 7; pl. 7, figs. 4, 5, 1902.

[29] Lesquereux, Leo, Harvard Univ. Mus. Comp. Zoology Mem., vol. 6, pl. 2, figs. 1, 2, 1878.

*ıerriami* Knowlton [30] but differs in having fewer and naller lobes and in the peculiar wedge-shaped base.

The species is named in honor of Mr. H. J. Rust, rho collected all of the splendid material from the ;oeur d'Alene locality.

Occurrence: Latah formation, Edwards ranch, Stan-ey Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, uly, 1920.

### Quercus spokanensis Knowlton, n. sp.

Plate XIX, Figure 3

This form is represented by the single specimen gured, which is the upper portion of a leaf that is now bout 8 centimeters long but must have been 12 entimeters or more when complete. It is 6 centi-ıeters wide in the middle. It appears to have been lliptical or possibly slightly obovate-elliptical. The ıargin is almost undulate-toothed, or in any event he teeth are regular, obtuse or very obtusely pointed, nd separated by shallow sinuses. The midrib is ıoderately strong, and the secondaries are regular, venly spaced, alternate, and as many as the marginal eeth, which they enter. The finer nervation is rregularly quadrangular and distinctly quercoid in ppearance.

This species is quite unlike any of the other oaks ı the collections. It is of the type of a group of ving species which includes *Quercus michauxii* Nuttall, *Q. prinus* Linné, *Q. acuminata* Sargent, and thers.

Among fossil species this is very close to *Quercus owlesi* Chaney,[31] from the Eagle Creek formation of Multnomah County, Oreg.—in fact, it may be iden-ical with that species. However, *Quercus cowlesi* has ewer, less prominent teeth and fewer, less regular econdaries. A series of specimens might well enough how these comparatively slight differences breaking own.

Occurrence: Latah formation, cut along Spokane, Portland & Spokane Railway, Spokane, Wash., ollected by Henry Fair and C. E. Fernquist, 1922.

### Quercus payettensis Knowlton

Plate XXI, Figures 5–7

*uercus payettensis* Knowlton, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 730, pl. 102, fig. 9, 1898.

This species was based on a leaf from the Payette ›rmation of Idaho that lacks both base and apex but ; well characterized by its lanceolate outline and large eltoid teeth. None of the nervation is preserved xcept the midrib and secondaries.

The collection from Coeur d'Alene, Idaho, includes everal specimens that, though slightly larger, must e referred to *Quercus payettensis*. The best preserved example, shown in Figure 7, is nearly perfect. It is long wedge-shaped at the base and rather abruptly deltoid pointed at the apex. It is 7 centimeters long and about 2.5 centimeters wide. Another specimen (fig. 5) is also nearly perfect. It shows the wedge-shaped base with one or two very small teeth, and in the middle of the leaf are the strong teeth, one of which is distinctly spine-tipped. The other specimen figured (fig. 6) is a segment from the middle of a leaf that must have been at least 10 centimeters long; it is nearly 3.5 centimeters wide between the points of the lobes. This is precisely the same as the type, except for its larger size.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

### Quercus sp.

Plate XIX, Figure 7; Plate XXII, Figure 9

Leaves coriaceous, ovate or ovate-elliptical, very obtusely wedge-shaped at the base, obtusely pointed at the apex, with two or three large, obtusely acuminate lobes on each side; midrib strong, more or less irregular and zigzag; principal secondaries as many as the lobes, at a low angle, much curved upward toward the margin; intermediate secondaries numerous, at irregular distances and angles, curving upward and disappearing along the margin; nervilles numerous, strong, irregular, mainly broken; finer nervation strong, irregularly quadrangular.

The two figured specimens are referred to this form. The larger one (Pl. XIX, fig. 7) was probably 9 or 10 centimeters long and 7 centimeters wide between the largest lobes. The other specimen (Pl. XXII, fig. 7) is 8 centimeters long and 5 centimeters wide.

This species seems to be quite distinct from the other forms found in these beds, though it may possibly be represented by somewhat distorted or abnormal leaves of one of the common forms.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

### Quercus praenigra Knowlton, n. sp.

Plate XIX, Figure 6

Leaf coriaceous, narrowly obovate, broadest above the middle, whence it is gradually narrowed to an abruptly rounded base; margin perfectly entire; petiole very stout; midrib very strong; secondaries mainly alternate, thin, at irregular distances, arising at a low angle (about 20° or 25°), much curved upward along the margins; nervilles mainly oblique to the secondaries, broken and irregular, and forming with the finer nervation a complicated network.

The incomplete specimen figured is the only one noted in the collections. It probably lacks the upper

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[30] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 49, pl. 6, figs. 6, 7, 1902.

[31] Chaney, R. W., Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 169, pl. , fig. 5, 1920.

third and when perfect was presumably about 14 centimeters long. It is about 4.5 centimeters wide at the point where it is broken, and the missing portion was probably 5 centimeters or slightly more in width. Only a short portion of the thick petiole is retained.

This leaf is quite distinct from the other oaks of the collection, but among living species it seems fairly close to *Quercus nigra* Linné, the water oak of the eastern and southern United States. It is somewhat more obtuse at the base but otherwise is very similar.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, 1920.

**Quercus simulata Knowlton**

Plate XXII, Figures 3, 4

*Quercus simulata* Knowlton, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 728, pl. 101, figs. 3, 4; pl. 102, figs. 1, 2, 1898;

Chaney, Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 168, pl. 12, fig. 1, 1920.

This species is represented by several examples, two of which have been figured. These, it will be seen, agree perfectly with the entire-leaved specimens from the type locality—that is, the Payette formation of Marsh, Idaho. In the type specimens the finer nervation was not well preserved, but in the present specimens it is perfectly retained. It is well shown in Figure 4.

A poorly preserved leaf found in the Eagle Creek formation of the gorge of Columbia River, Oregon, has been identified as *Quercus simulata* by Chaney. It has more marginal teeth than any of the type specimens, and the details of nervation are missing.

Occurrence: Latah formation, Deep Creek half a mile above mouth and cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

**Quercus chaneyi Knowlton, n. sp.**

Plate XXII, Figure 1

This interesting species is well represented by the little leaf figured, which fortunately is nearly perfect. It was evidently very thick and coriaceous and is narrowly lanceolate, being slightly broader at a point about one-fourth its length from the apex. It was about 9 centimeters long and 1.5 centimeters wide, with the petiole preserved for a length of 0.5 centimeters, but is evidently not complete. From the broadest point in the blade it narrows gradually above to what was apparently an obtusely acuminate apex and downward to a long, narrow basal portion. The margin is entire or slightly undulate for the lower two-thirds and thence with four or five teeth on each side, these low and rounded below but one or two sharp-pointed higher up. These teeth are so small that they are hardly perceptible to the naked eye, though they are plain enough under a glass. The midrib is very thick and strong and is perfectly straight, but the secondaries are thin and immersed in the leaf substance. The secondaries number about 12 pairs. They arise at an angle of 40° or 45° and are close together in the lower part of the blade but remote in the upper part. They curve upward for a long distance, each usually joining the one next above and sending a thin branch to one of the marginal teeth or slight swellings. The nervilles are inconspicuous, being immersed in the leaf substance; they are mainly percurrent. The finer nervation is peculiar in that it forms a complete network of small, equal-sized arms.

This leaf is probably correctly referred to *Quercus*. At first glance its shape might suggest a leaf of *Salix*, and the peculiar netlike finer nervation is very much like that of certain lauraceous types, such as *Persea*, but the thick substance of the leaf and the few, small marginal teeth point to *Quercus*. It appears to belong to the group of so-called live oaks, in which the old leaves persist until the spring of the next year. It is perhaps closest to *Quercus virginiana* Miller, though longer and narrower than most leaves of that species.

Among fossil American species *Quercus chaneyi* most closely resembles *Quercus simplex* Newberry,[32] from the upper part of the Clarno formation of the John Day Basin, Oreg., and it has also been reported[33] from the Raton formation of northeastern New Mexico and southeastern Colorado. It differs, however, in being longer and narrower, broadest above instead of below the middle, in the sparsely toothed instead of entire margins, and in the netlike, finer nervation.

I take pleasure in naming this species in honor of Dr. Ralph W. Chaney, of the Carnegie Institution of Washington, who collected a part of this Spokane material.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

**Quercus obtusa Knowlton, n. sp.**

Plate XXII, Figure 8

Leaf small, about 5.5 centimeters long and 2 centimeters broad, coriaceous, obovate-lanceolate, broadest in the upper third, whence it rounds above to an obtuse apex and below to a long, regularly wedge-shaped base; margin entire except very near apex, where there are two or three small, sharp-pointed teeth; petiole very strong; midrib exceptionally strong, perfectly straight; secondaries about 12 pairs, mostly alternate, thin, immersed, slightly curved upward, camptodrome, arching well inside the margin, each joining the one next above and sending an outside nerve to one of the teeth; nervilles fairly numerous,

[32] Newberry, J. S., U. S. Geol. Survey Mon. 35, p. 78, pl. 43, fig. 6, 1898.

[33] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 298, pl. 70, fig. 3, 1918.

n, approximately at right angles to the secondaries, egular but mainly percurrent; finer nervation ming a fine, irregularly quadrangular network, eply immersed.

This species seems to be quite distinct from any ner found in the collections from the Spokane area from the Pacific coast region. It was evidently a ick, coriaceous leaf, probably an evergreen leaf of e type of *Quercus virginiana* Miller—in fact, it is ite like some of the leaves of this somewhat variable ecies.

Occurrence: Latah formation, cut along Spokane, rtland & Seattle Railway, Spokane, Wash., colted by Henry Fair and C. E. Fernquist, 1922.

**Quercus, cup**

Plate XXI, Figure 10

The collections contain a number of acorn cups, t most of them are so crushed that it is impossible make out any satisfactory characters. The present ecimen, however, is very well preserved and shows e arrangement and shape of the scales clearly. is cup appears to belong to the white-oak group, d there is some evidence to show that the acorn s practically immersed, as in the living *Quercus ata*, but this is not certain. It was of course the it of one of the species characterized from the ves, but there is no means of connecting them.

Occurrence: Latah formation, Edwards ranch, Stan- Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, ly, 1920.

**Quercus, acorn**

Plate XIX, Figures 8, 9; Plate XXI, Figures 8, 9

This is clearly the impression of a small acorn. is ovoid, with a rather broad, truncated base. The gth is about 12 millimeters and the width or meter about 7 millimeters. There are no prounced surface markings.

This is presumably the fruit of one of the forms scribed from the leaves, but as there is no way of nnecting them, it is best retained as above.

Occurrence: Latah formation, cut on Spokane, rtland & Seattle Railway, Spokane, Wash., colted for and submitted by the Spokane Public useum.

**Order URTICALES**

**Family ULMACEAE**

**Ulmus speciosa Newberry**

Plate XVIII, Figure 6

*nus speciosa* Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 507, 1883; U. S. Geol. Survey Mon. 26, p. 80, pl. 45, figs. 3, 4, 1898.

The specimen figured is the only one noted in these lections. It is nearly perfect, being about 12 ntimeters long and 5.5 centimeters wide. The rgin is not as well preserved as could be desired, but so far as can be noted the teeth are large, sharp-pointed, and with only a few secondary teeth. Many of the teeth are without a trace of a smaller tooth, and those present are only very slight projections. The secondaries, of which there are about 15 pairs, are both opposite and alternate, close, parallel, and ending in the teeth. The nervilles are numerous, somewhat irregular but mainly percurrent, and at right angles to the secondaries. The finer nervation forms an irregular fine-meshed, quadrangular areolation.

I do not see how this leaf can be held distinct from the larger of the leaves referred by Newberry to his *Ulmus speciosa*, from Bridge Creek, Oreg. Newberry described his species as doubly serrate, but in the figures he gives only a few of the teeth near the middle of the leaf have additional smaller denticulations, thus agreeing with the Spokane leaf. *Ulmus speciosa* was reported by Penhallow [34] from beds supposed to be of Oligocene age in British Columbia.

This species is of the same type and, indeed, is very closely related to *Ulmus pseudo-fulva* Lesquereux,[35] from the auriferous gravels of California, and also reported from the Miocene of Lamar River, Yellowstone National Park. It is a smaller leaf—8.5 centimeters long and 3.5 centimeters wide—than the leaves now referred to *Ulmus speciosa* and is also described as being doubly serrate, but the secondary teeth are an inconspicuous feature. If a series of specimens from California and Oregon and Washington could be assembled it might well enough be shown that these supposed distinct species should really be merged.

*Ulmus tanneri* Chaney [36] also belongs to this group—in fact, it is in part based on two of the smaller leaves of *Ulmus speciosa* as figured by Newberry. It is still smaller than *Ulmus pseudo-fulva* Lesquereux but does not greatly differ otherwise.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway west of Latah Creek, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

**Ulmus fernquisti Knowlton, n. sp.**

Plate XIX, Figure 2

Leaf small, about 4.5 centimeters long, 1.5 centimeters wide, evidently coriaceous, lanceolate, slightly unequal-sided at the base, acuminate at the apex; margin coarsely and simply dentate, the teeth deltoid and large for the size of the leaf; petiole about 5 millimeters long; midrib straight, very strong; secondaries about 16 pairs, mostly opposite, close, parallel, little curved upward, each ending in a marginal tooth; finer nervation not retained.

[34] Penhallow, D. P., Report on the Tertiary plants of British Columbia, p. 94, 1908.

[35] Lesquereux, Leo, Harvard Univ. Mus. Comp. Zoology Mem., vol. 6, No. 2, p. 16, pl. 4, fig. 3, 1878.

[36] Chaney, R. W., Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 172, pl. 14, figs. 1, 2, 1920.

This little leaf, the only one noted in the collections, seems to belong to *Ulmus*, but it differs from most of the elms in having the margin simply instead of doubly serrate. All the living American species are doubly serrate, but some of the European forms are simply serrate. It also resembles *Planera* in that the leaves are simply serrate, but the general facies is more that of *Ulmus*.

Several long, narrow leaves representing species of *Ulmus* from this region have been described, but they all differ in being conspicuously doubly serrate. Thus *Ulmus tanneri* Chaney,[37] from the Eagle Creek formation of Oregon, is a small-leaved species but is much larger and broader than the one from Spokane and moreover is doubly serrate. The smaller of the two leaves of *Ulmus californica* Lesquereux[38] as figured by Lesquereux, from the auriferous gravels of California, is very much like the leaf under consideration, being only slightly broader, and furthermore it is described as simply serrate. The other type specimen as figured by Lesquereux is very much larger and broader than the one just mentioned and is of course quite different from the Spokane leaf. Although it would perhaps do no great violence to refer this leaf to *Ulmus californica*, it seems advisable to give it a different name pending the collection of additional material, with the admission that it is very closely related to if not indeed identical with *Ulmus californica*. It is named in honor of C. E. Fernquist, the collector.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

### Family MORACEAE?

#### Ficus? washingtonensis Knowlton, n. sp.

Plate XXV; Plate XXVI, Figures 1–3

Leaves large, 9 or 10 centimeters wide, 10 or 12 centimeters long, firm, perhaps coriaceous, broadly ovate or nearly circular, equal-sided at the base, which is rounded and truncate in most specimens but in some very obtusely wedge-shaped, the apex apparently rounded and obtuse; the margin is entire with one specimen showing a pronounced boss on one side; petiole stout, more than 3.5 centimeters long; palmately five-ribbed from the top of the thick petiole, the midrib much the stronger, with about three pairs of camptodrome secondaries in the upper part; second pair of ribs strong, at an angle of about 45°, slightly curved upward, joining the lower pair of secondaries on the midrib, each with several branches on the outside; lower pair of ribs very slender, at a right angle or very low angle with the midrib; nervilles numerous, irregular, forming a large meshed, irregular-sized network.

This form is represented by four specimens, one from the Spokane area and the others from Coeur d'Alene. It seems to be congeneric and may indeed be conspecific with what Lesquereux called *Ficus sordida*,[39] from the auriferous gravels of California, since detected in the Miocene of the Yellowstone National Park. It is very much to be doubted, however, that these leaves were correctly referred to *Ficus*. Lesquereux compared his species to *Ficus grönlandica* Heer,[40] from Greenland, but the resemblance is not very close—in fact, Heer's species resembles certain forms that have been referred to *Populus*.

It has been suggested that these leaves from Spokane and vicinity may be referable to the genus *Menispermites* as established by Lesquereux on leaves from the Dakota sandstone. Of the 20 species of *Menispermites* described 9 are found in the Dakota and the others in several Cretaceous formations except a single species, *M. wilcoxensis* Berry,[41] from the Wilcox formation of Louisiana. The typical Cretaceous species of *Menispermites* are more or less three-lobed or with undulate margins and have the major nervation craspedodrome, ending in the lobes or undulations. This last-mentioned character clearly excludes the leaves under consideration and apparently also *Menispermites wilcoxensis*, in which all the ribs and secondaries are distinctly camptodrome. The Wilcox species may be congeneric with the Spokane leaves. Some of the Cretaceous leaves included in *Menispermites* are more nearly circular and distinctly peltate. These have a camptodrome nervation, thus disagreeing with the type species of the genus. The whole aggregation seems in need of revision.

A careful comparison of the Spokane leaves with *Ficus sordida* discloses some differences. Thus the California species is somewhat larger, and the lateral and basal pairs of ribs have a greater number of secondaries, especially the basal pair, and those are more regular. The finer nervation also differs somewhat.

Although it is probable that those leaves do not belong to *Ficus*, in the absence of any other probable generic designation I am constrained to refer them to *Ficus* but with a distinct mark of interrogation. They are easily recognizable, and when more data are available they can easily be transferred to another genus.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920 (Pl. XXVI, figs. 1–3); Spokane, Wash., collected by C. E. Fernquist May, 1922 (Pl. XXV).

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37 Chaney, R. W., op. cit., p. 172, pl. 14, figs. 1, 2.

38 Lesquereux, Leo, Harvard Univ. Mus. Comp. Zoology Mem., vol. 6, p. 15, pl. 4, fig. 2, 1878.

39 Lesquereux, Leo, Harvard Univ. Mus. Comp. Zoology Mem., vol. 6, p. 17, pl. 4, figs. 6, 7, 1878.

40 Heer, Oswald, Flora fossilis arctica, vol. 2, No. 4, pl. 54, fig. 2, 1869.

41 Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 218, pl. 115, figs. 1, 2; pl. 116, figs. 2, 3, 1916.

### Order THYMELALES

#### Family LAURACEAE

**Laurus similis Knowlton**

Plate XXIII, Figures 4–6; Plate XXIV, Figure 2

*urus similis* Knowlton, U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, p. 48, pl. 5, figs. 1–4, 1900.
Chaney, Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 173, 1920.

This species was described from specimens collected Comstock, Douglas County, Oreg., in beds interdded with lavas on the west side of the Cascade ınge and was also noted by Chaney in the Eagle ·eek formation at several localities in Multnomah ›unty, Oreg. The two specimens here figured do ·t appear to differ essentially.

Occurrence: Latah formation, cut along Spokane, ›rtland & Seattle Railway and Deep Creek half a ile above mouth, Spokane, Wash., collected by enry Fair and C. E. Fernquist, 1922; cut on Chicago, ilwaukee & St. Paul Railway, Spokane; collected R. W. Chaney, 1922; specimen in University of alifornia Museum, $\frac{3940}{22859}$.

**Laurus princeps Heer**

Plate XXIII, Figures 1–3

*urus princeps* Heer. Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 250, pl. 58, fig. 2, 1883.

Except for the fact that the Spokane leaves are a tle narrower they do not differ from the leaf from e auriferous gravels of Corral Hollow, Alameda ›unty, Calif., figured by Lesquereux. Whether or t the American leaves are identical with European aves is a matter that need not be discussed here.

Another very perfectly preserved example is still ırrower but does not otherwise differ essentially.

Occurrence: Latah formation, cut along Spokane, ortland & Seattle Railway, Spokane, Wash., collected Henry Fair and C. E. Fernquist, 1922; well at ica, southeast of Spokane, collected by Thomas ırge for J. T. Pardee, August, 1922.

**Laurus californica Lesquereux**

*urus californica* Lesquereux, U. S. Geol. Survey Terr., vol. 8 (Cretaceous and Tertiary floras), p. 252, pl. 57, fig. 3; pl. 58, figs. 6–8, 1883.

Occurrence: Latah formation, cut along Spokane, ortland & Seattle Railway, Spokane, Wash., colcted by Henry Fair and C. E. Fernquist, 1922.

**Laurus grandis Lesquereux**

Plate XXIV, Figure 1

*urus grandis* Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 251, pl. 58, figs 1, 3, 1883.

The specimen here figured appears to approach most osely *Laurus grandis* as figured by Lesquereux. It not so broad as the larger of Lesquereux's two types but is close to the smaller one. It may be only a very broad leaf of *Laurus princeps* Heer as identified by Lesquereux [42] and as also identified from this collection, but as it is so much larger and has the secondaries fewer and ascending for long distances it seems nearer *L. grandis*.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922; cut 1 mile west of Shelley Lake, 10 miles east of Spokane, collected by Henry Fair, 1922.

### Order RANALES

#### Family MAGNOLIACEAE

**Magnolia dayana Cockerell**

Plate XXIV, Figure 3

*Magnolia dayana* Cockerell, Am. Naturalist, vol. 44, p. 35, 1910.
*Magnolia lanceolata* Lesquereux, Harvard Univ. Mus. Comp. Zoology Mem., vol. 6, p. 24, pl. 4, fig. 4, 1878.

The Spokane material includes a single magnolia leaf—the one here figured—that is almost an exact duplicate of the original figure given by Lesquereux of a leaf from the auriferous gravels at Chalk Bluff, Nevada County, Calif. The California leaf was named *Magnolia lanceolata* by Lesquereux, but this name was found to be preoccupied, and it was renamed *M. dayana* by Cockerell. The Spokane leaf is nearly perfect, lacking only the apical portion. It must have been about 17 or 18 centimeters long when perfect and is 6 centimeters wide. The type is about 21 centimeters long and 6 centimeters wide. The nervation of the Spokane leaf agrees perfectly with that of the type, and there can be no doubt of their identity. As Lesquereux pointed out, this species agrees closely, except for its slightly smaller size, with the living *Magnolia acuminata* Linné, the well-known cucumber tree of eastern North America.

Occurrence: Latah formation, Spokane, Wash., collected by T. A. Bonser.

**Magnolia sp.**

Plate XXVII, Figure 1

In one of the collections procured in 1923 within the city limits of Spokane there are a number of more or less fragmentary large leaves that appear to belong to *Magnolia*. One of the best preserved of these, here figured, lacks the apical portion and most of one side. It appears to have been nearly elliptical, probably at least 15 centimeters in length and about 6 centimeters in width. The petiole is preserved for a length of nearly 2 centimeters, but it was presumably somewhat longer. The midrib is extremely strong. The secondaries are numerous, a dozen pairs or more, thin,

[42] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 250, pl. 58, fig. 3, 1883.

irregular, and at various angles, those near the base being nearly at a right angle, increasing above to an angle of approximately 45°; they are camptodrome, arching just inside the margin. Except for an occasional nerville the finer nervation is not preserved.

This leaf has the appearance of having been thick and coriaceous, in this respect resembling the living *Magnolia foetida* Sargent (*Magnolia grandiflora* of authors), the well-known evergreen magnolia of the Middle Atlantic and Gulf States, with which it also agrees in size and shape, in the thick midrib, and in other features. It is of course presumptuous to assume that this was an evergreen species, perhaps the forerunner of *Magnolia foetida*, but it certainly most resembles that species.

There is another less perfect leaf in the collection that seems to have been more nearly obovate-elliptical and has the secondaries more widely spaced in the upper portion. It is too fragmentary to figure.

Of the several species of *Magnolia* that have been reported from deposits associated with the Columbia River lavas this is most like what has been identified as *Magnolia inglefieldi* Heer,[43] as found in the Mascall formation,[44] but it appears to differ in its more elliptical outline and in the thicker midrib and more numerous secondaries, though a larger series might show less difference.

The specimens available are so fragmentary that it has seemed best not to give a specific name until more and better material is available.

Occurrence: Latah formation, Twelfth Avenue and Thor Street, Spokane, Wash.. collected by Henry Fair and Kirk Bryan, 1923.

### Order ROSALES

#### Family HAMAMELIDACEAE

**Liquidambar pachyphyllum Knowlton**

Plate XXII, Figure 7; Plate XXIX, Figure 1

*Liquidambar pachyphyllum* Knowlton, U. S. Geol. Survey Bull. 204, p. 63, pl. 9, fig. 1, 1902.
Chaney, Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 174, pl. 15, figs. 2, 3, 1920.

Several more or less fragmentary leaves of *Liquidambar* are included in the Spokane material and are believed to be identical with *Liquidambar pachyphyllum* Knowlton, from the Mascall formation of the John Day Basin, Oreg. The example here figured is a little larger than any heretofore referred to this species, but it does not differ otherwise in essential particulars. The average size before reported is from 6.5 to 7.5 centimeters long and 7 centimeters broad, whereas the specimen here figured must have been nearly 10 centimeters broad and probably about 8 or 9 centimeters long. A thick carbonaceous film represents the thick substance of the leaf in the type specimen as described. Where this substance has crumbled away along the margins of the lobes it has obscured the teeth, but where well preserved the teeth can be seen as in the type.

*Liquidambar pachyphyllum* was found by Chaney[45] at a number of localities in the Eagle Creek formation of Multnomah County, Oreg. An additional well-preserved specimen was found by Messrs. Fair and Bryan in 1923. This specimen (Pl. XXII, fig. 7) is indistinguishable from the smaller of the two leaves figured by Chaney. In the same beds with this leaf is the finely preserved fruit (Pl. X, fig. 10) that is probably the fruit of this species, though there is no possibility of connecting them organically.

Occurrence: Latah formation, well near Mica, southeast of Spokane, Wash., collected by Thomas Large for J. T. Pardee, August, 1922; cut No. 2 on Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash., collected by Henry Fair and Kirk Bryan, May, 1923.

**Liquidambar, fruit**

Plate X, Figure 10

This fruit was found in the same beds as the species last discussed and in all reasonable probability belongs to it, but as they are not organically connected they are perhaps best kept separated. This head is very perfectly preserved and shows many of the individual fruits around the outer margin. These are somewhat shorter and not so pointed as in the living species (*Liquidambar styraciflua* Linné).

Occurrence: Latah formation, cut No. 2 on Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash , collected by Henry Fair and Kirk Bryan, May, 1923.

#### Family SAXIFRAGACEAE

**Hydrangea bendirei (Ward) Knowlton**

Plate XXIV, Figure 6

*Hydrangea bendirei* (Ward) Knowlton, in Merriam, California Univ. Dept. Geology Bull., vol. 2, No. 9, p. 309, 1901.
Knowlton, U. S. Geol. Survey Bull. 204, p. 60, pl. 9, figs. 6, 7, 1902.
*Marsilea bendirei* Ward, U. S. Geol. Survey Fifth Ann. Rept., p. 446, 1885.
*Porana bendirei* (Ward) Lesquereux, U. S. Nat. Mus. Proc., vol. 11, p. 16, pl. 8, fig. 4, 1888.

The example figured is the only one thus far observed. It is absolutely indistinguishable from the type specimens and has not before been found except at the type locality.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected for and donated by the Spokane Public Museum.

[43] Heer, Oswald, Flora fossilis arctica, vol. 1, pl. 15, figs. 4, 5; pl. 18, figs. 1–3, 1868.
[44] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 58, 1902.
[45] Chaney, R. W., Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 174, pl. 15, figs. 2, 3, 1920.

### Family DRUPACEAE

#### Prunus rustii Knowlton, n. sp.

Plate XXIV, Figures 4, 5

Leaves small, evidently rather thin and membrana-)us, lanceolate or slightly ovate-lanceolate, rounded d obtusely wedge-shaped at the base; apex missing t probably acuminate. The margin is finely and arply serrate, with a slight tendency for the teeth tered by the secondaries to project beyond the line the others, the teeth apparently glandular-tipped. ıe petiole is long and slender, nearly 1.5 centimeters ıg, and the midrib rather thin and straight. There e probably eight or ten pairs of thin, opposite or bopposite secondaries that stand at an angle of out 45°, regularly spaced and craspedodrome, many them with three or four short tertiary branches ıich pass to marginal teeth; nervilles numerous, th broken and percurrent; finer nervation produc-g a fine, irregularly quadrangular network.

This species is represented by two specimens, both which are figured. The smaller specimen (fig. 4), om Coeur d'Alene, lacks the apex and most of one le. It was probably about 4.5 centimeters long and 25 centimeters wide. The other example (fig. 5), om Spokane, lacks only the apical portion, the re-ainder being exceptionally well preserved. It was obably 6 centimeters or more in length and is 2.5 ntimeters wide. This leaf has the secondaries at a ghtly more acute angle than the smaller leaf, but herwise there is no essential difference.

Among living species *Prunus rustii* suggests *Prunus gustifolia* Marshall, of the Atlantic and Gulf States om Delaware southward, except that there is no idence of glands at the top of the petiole. Among ssil species from this region it is perhaps closest to *unus? tuffacea* Knowlton,[46] from the Mascall forma-on, but in that species the secondaries are more ımerous and at a lower angle of divergence, and not l the secondaries end in marginal teeth.

I take pleasure in naming this species in honor of r. H. J. Rust, who collected one of the types.

Occurrence: Latah formation, Edwards ranch, anley Hill, Coeur d'Alene, Idaho, collected by H. J. ust, July, 1920; cut No. 2 on Chicago, Milwaukee & . Paul Railway, Wash., collected by Henry Fair and irk Bryan, 1923.

### Family CAESALPINIACEAE

#### Cercis? spokanensis Knowlton, n. sp.

Plate XXIX, Figure 9

Pod linear or linear-oblong, flat, with a short stalk, e valves apparently thin, thickened along the upper ture, reticulate-veined, apparently with several eds.

This little pod is now about 3.5 centimeters long (including the stalk, which is 4 millimeters in length) and 1.5 centimeters wide. The valve, as may be seen from the drawing, is finely reticulate-nerved, and there is a faint indication of the presence of three large round seeds.

Although the apparent affinity of this species is with the living *Cercis canadensis* Linné, it has seemed best to question the generic reference, for the identification is more or less uncertain.

Occurrence: Latah formation, Deep Creek half a mile above mouth, northwest of Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

### Family PAPILIONACEAE

#### Sophora alexanderi Knowlton, n. sp.

Plate XXVIII, Figures 3–5

Leaflets thin, elliptical or slightly ovate-elliptical, 2.5 to 3.25 centimeters long, 12 to 16 millimeters wide, broadest near or just below the middle, abruptly rounded or even slightly heart-shaped at the base, obtuse, with a distinct tendency to be slightly emarginate, at the apex; margins entire; petiole short, stout; midrib relatively very strong; secondaries about eight or nine pairs, at somewhat irregular distances, considerably curved upward, strongly camptodrome, arching well below the margin and each passing to the secondary next above; finer nervation producing a rather large, irregularly quadrangular network.

There is considerable variation in the size and shape of the three examples referred to this species, but as they come from the same locality and have certain characters in common it is assumed that they are only variants of a single species. Thus, the leaf shown in Figure 4 is relatively long, truncate at the base, and minutely emarginate at the apex. That shown in Figure 5 is slightly heart-shaped at the base and also minutely emarginate. The one shown in Figures 3 and 3a is shorter, relatively broader, rounded at the base, and distinctly emarginate at the apex. The thick midrib and irregularly spaced camptodrome secondaries are the same in all.

Little leaves or leaflets of this type are difficult to place satisfactorily, yet these appear to agree well with others that have been referred to *Sophora*. For example, the present species is very similar to *Sophora wilcoxiana* Berry,[4] from beds of Wilcox age in the Lagrange formation of Tennessee, though there are minor differences in the nervation.

I take pleasure in naming this little species in honor of Mr. A. C. Alexander, of Spokane, who has done much to develop the mineral resources of the region and who has been especially interested in finding and collecting fossil plants.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

[46] Knowlton, F. H., U. S. Geol. Survey Bull. 204, pl. 11, figs. 2, 3, 6, 7, 1902.

[4] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 241, pl. 47, figs. 1–13, 1916.

**Sophora spokanensis Knowlton, n. sp.**

Plate XXVIII, Figure 6

To found a species on this little fragment is perhaps unwise, but it appears to differ from anything else from these beds and can probably be recognized if again found. It is elliptical-lanceolate, with a rounded and obtuse apex and probably a somewhat similarly rounded base. The length was probably not far from 4 centimeters and the width a little over 1 centimeter. The nervation consists of a relatively very thick midrib and numerous alternate thin camptodrome secondaries at a low angle of emergence. The finer nervation can not be made out with certainty.

This little leaflet is the only one found. It differs from the preceding species, *Sophora alexanderi*, in being relatively longer and narrower and in the more numerous, lower-angled secondaries. It is very similar to certain of the intermediate-sized leaflets of *Sophora wilcoxiana* Berry,[48] from beds of Wilcox age in the Lagrange formation of Tennessee—in fact, it is difficult to note characters for their separation.

Occurrence: Latah formation, Deep Creek, northwest of Spokane, Wash., collected by Henry Fair and Kirk Bryan, June 3, 1923.

**Robinia? sp.**

Plate XXVIII, Figures 7, 7a

Leaflet thin, elliptical-ovate, 15 millimeters long, 9 millimeters wide, rounded and truncate or almost heart-shaped at the base, obtuse at the apex; petiolule very short, slightly over 1 millimeter; nervation light, consisting of a straight midrib and about seven pairs of thin camptodrome secondaries at an angle of about 50°; finer nervation not discernible.

Isolated leaflets of this character are so small and generally nondescript that it is almost impossible to place them satisfactorily. The most that can be said in the present instance is that it resembles the leaflets of certain living species of *Robinia*, such for example as *R. pseudacacia* Linné, of eastern North America, but it is difficult to establish identity. It will at least call attention to the presence of this type of plant, but the future will have to settle its identity.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

**Genus MEIBOMITES Knowlton, n. gen.**

Characters of the species.

**Meibomites lucens Knowlton, n. sp.**

Plate XXVIII, Figure 10

This appears to be of the type of the lateral leaflet in many living species of *Meibomia*. It was clearly thin. It is very broadly ovate, being abruptly rounded below to the nearly truncate base and above to a slender acute tip. The margin is perfectly entire, and the petiolule if ever present is not now preserved. The nervation is very thin and delicate, consisting of a slender, straight midrib and eight or nine pairs of camptodrome secondaries. The lowest pair arise at the extreme base of the blade at an angle of approximately 45°; the others are at irregular distances and at an angle of 30° or 40°; all are curved upward, and each joins the one next above, far inside the margin. Between these loops and the margin is a series of large and small loops. The nervilles are not very numerous and are very thin, mainly percurrent. The finer nervation produces very irregular areas.

The genus *Meibomia* comprises about 160 species, natives of warm and temperate North and South America, South Africa, and Australia. They are perennial herbs, often woody at the base, mainly with trifoliolate leaves. The terminal leaflet is short-petioled, but the lateral ones are almost always closely sessile. The fruit consists of a flat loment of several coriaceous jointed indehiscent segments. No part of the plant has apparently been found in a fossil state.

The present specimen appears to me to be a sessile lateral leaflet very similar at least to those of a number of living species, such as *Meibomia arenicola* Vail and *M. ochroleuca* (Curtis) Kuntze, but as those species seem to have a more regularly pinnate nervation it seems best not to refer the Spokane form to the living genus direct, hence I have erected the new genus *Meibomites* for it.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

**Order SAPINDALES**

**Family CELASTRACEAE**

**Celastrus fernquisti Knowlton, n. sp.**

Plate XXVIII, Figure 2

Leaf evidently thin, elliptical or elliptical-ovate, about 7 centimeters long and 5 centimeters wide, broadest about the middle, rather abruptly rounded to the truncate, slightly heart-shaped base and apparently to a moderately pointed apex; margin entire at base, thence serrate, the teeth somewhat irregular, sharp; midrib strong, particularly below; secondaries about seven pairs, subopposite, all but the lowest pair at an angle of about 40°, slightly curved upward, craspedodrome, those in the middle of the blade with several tertiary branches which also terminate in the teeth; nervilles numerous, thin, often broken.

This species is represented by the half of a leaf as figured, which shows the base very well but lacks the extreme tip. The petiole is not retained. The marginal teeth and the nervation are well shown in the figure.

[48] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 241, pl. 47, figs. 1–13, 1916.

This species seems undoubtedly congeneric with a number of species from the Fort Union formation described by Ward[49] as *Celastrus*. These forms were abundant in the Fort Union formation, and one of the species (*C. taurinensis*) was recognized by Berry[50] in the Wilcox formation of Louisiana. The leaf under consideration agrees very well with some of the Fort Union forms, especially *C. taurinensis*, but differs in having fewer secondaries, which are not so much curved upward.

In his original discussion of *C. taurinensis* Ward debated whether or not it might better be referred to *Grewiopsis* or *Pterospermites*, and Berry states that if it had to be described anew he would be inclined to place it in *Grewiopsis*, but, be this as it may, the present form seems near enough to be considered congeneric with it, and thus it is left until a revision and full consideration of the Fort Union flora is made.

I take pleasure in naming this species in honor of Mr. C. E. Fernquist, of Spokane, who collected it.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway west of Latah Creek, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

### Family ANACARDIACEAE

### Rhus typhinoides Lesquereux

Plate XXVII, Figure 5

*Rhus typhinoides* Lesquereux, Harvard Univ. Mus. Comp Zoology Mem., vol. 6, No. 2, p. 29, pl. 9, figs. 1–6, 1878.

The single specimen figured appears to belong to this species. It lacks the upper half, but in size, inequilateral base, marginal teeth, and nervation it agrees well with Lesquereux's figures, except that the secondaries are not so numerous in the basal portion.

Occurrence: Latah formation, north side of clay pit 2 miles south of Vera, Wash., collected by Henry Fair, June 29, 1923.

### Family STAPHYLEACEAE

### Acer bendirei Lesquereux

Plate XXVII, Figure 3

*Acer bendirei* Lesquereux, U. S. Nat. Mus. Proc., vol. 11, p. 14, pl. 5, fig. 5, 1888.

Although the specimen here figured is rather fragmentary, enough of it is retained to show clearly that it is indistinguishable from the leaf figured by Lesquereux, as noted above. In the same paper Lesquereux figured several other much larger leaves, and in a still earlier paper[51] specimens even larger were figured under the name *Acer trilobatum productum* Heer. They are all from the Mascall formation of the John Day Basin, Oreg.

It has been suggested that these leaves figured by Lesquereux, especially the larger ones, are more properly referable to *Platanus* than to *Acer*. Be that as it may, the present leaf certainly agrees with the specimen quoted above.

Occurrence: Latah formation, well at Mica, southeast of Spokane, Wash., collected by Thomas Large for J. T. Pardee, August, 1922.

### Acer merriami Knowlton

Plate XXVIII, Figure 1

*Acer merriami* Knowlton, U. S. Geol. Survey Bull. 204, p. 74, pl. 14, fig. 7, 1902.

Hardly more than the basal portion of this leaf, with the petiole complete, is preserved, but as it agrees with the type leaf of *Acer merriami*, it is so identified.

Occurrence: Latah formation, well at Mica, southeast of Spokane, Wash., collected by Thomas Large for J. T. Pardee, August, 1922.

### Acer minor Knowlton

Plate XXVII, Figure 4

*Acer minor* Knowlton, U. S. Geol. Survey Bull. 204, p. 76, pl. 14, figs. 2, 3, 1902.

Although it may be more or less hazardous to identify species of maple from fruits, the present identification seems fairly certain. Three species based largely on size of fruits were characterized from the Mascall formation of the John Day Basin, and as no intermediate sizes were noted it was assumed that the species were valid, each perhaps corresponding to one of the three species characterized from the leaves.

Maples do not seem to have been as abundant in the Spokane area as they were in the John Day Basin, the fruit figured being the only one that has come to my attention.

This species is similar to *Acer aquilum* Chaney,[52] from the Eagle Creek formation of the Columbia River region, but is considerably narrower.

Occurrence: Latah formation, Deep Creek, northwest of Spokane, Wash., collected by Henry Fair and Kirk Bryan, June 24, 1923.

### Acer chaneyi Knowlton, n. sp.

Plate XXVII, Figure 2

Leaf rather thin, rudely triangular, truncate at the base, very deeply three-lobed, the basal lobes lanceolate, sharp-pointed, with a small basal lobe and in the middle a larger few-toothed lobe on either side, the upper part sharply toothed; middle lobe with a pair of opposite toothed lobes high above the sinus and probably a toothed margin still above this (apex destroyed); sinuses very deep, rather sharp; nervation

[49] Ward, L. F., U. S. Geol. Survey Sixth Ann. Rept., p. 555, pl. 52, 1886; U. S. Geol. Survey Bull. 37, p. 79, 1887.

[50] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 267, pl. 60, figs. 1–3, 1916.

[51] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 253, pl. 59, figs. 1, 2, 4, 1883.

[52] Chaney, R. W., Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 178, pl. 18, fig. 2, 1920.

This species seems undoubtedly congeneric with a number of species from the Fort Union formation described by Ward[49] as *Celastrus.* These forms were abundant in the Fort Union formation, and one of the species (*C. taurinensis*) was recognized by Berry[50] in the Wilcox formation of Louisiana. The leaf under consideration agrees very well with some of the Fort Union forms, especially *C. taurinensis*, but differs in having fewer secondaries, which are not so much curved upward.

In his original discussion of *C. taurinensis* Ward debated whether or not it might better be referred to *Grewiopsis* or *Pterospermites*, and Berry states that if it had to be described anew he would be inclined to place it in *Grewiopsis*, but, be this as it may, the present form seems near enough to be considered congeneric with it, and thus it is left until a revision and full consideration of the Fort Union flora is made.

I take pleasure in naming this species in honor of Mr. C. E. Fernquist, of Spokane, who collected it.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway west of Latah Creek, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

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Plate XXVII, Figure 5

*Rhus typhinoides* Lesquereux, Harvard Univ. Mus. Comp Zoology Mem., vol. 6, No. 2, p. 29, pl. 9, figs. 1–6, 1878.

The single specimen figured appears to belong to this species. It lacks the upper half, but in size, inequilateral base, marginal teeth, and nervation it agrees well with Lesquereux's figures, except that the secondaries are not so numerous in the basal portion.

Occurrence: Latah formation, north side of clay pit 2 miles south of Vera, Wash., collected by Henry Fair, June 29, 1923.

### Family STAPHYLEACEAE

#### Acer bendirei Lesquereux

Plate XXVII, Figure 3

*Acer bendirei* Lesquereux, U. S. Nat. Mus. Proc., vol. 11, p. 14, pl. 5, fig. 5, 1888.

Although the specimen here figured is rather fragmentary, enough of it is retained to show clearly that it is indistinguishable from the leaf figured by Lesquereux, as noted above. In the same paper Lesquereux figured several other much larger leaves, and in a still earlier paper[51] specimens even larger were figured under the name *Acer trilobatum productum* Heer. They are all from the Mascall formation of the John Day Basin, Oreg.

It has been suggested that these leaves figured by Lesquereux, especially the larger ones, are more properly referable to *Platanus* than to *Acer.* Be that as it may, the present leaf certainly agrees with the specimen quoted above.

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Hardly more than the basal portion of this leaf, with the petiole complete, is preserved, but as it agrees with the type leaf of *Acer merriami*, it is so identified.

Occurrence: Latah formation, well at Mica, southeast of Spokane, Wash., collected by Thomas Large for J. T. Pardee, August, 1922.

#### Acer minor Knowlton

Plate XXVII, Figure 4

*Acer minor* Knowlton, U. S. Geol. Survey Bull. 204, p. 76, pl. 14, figs. 2, 3, 1902.

Although it may be more or less hazardous to identify species of maple from fruits, the present identification seems fairly certain. Three species based largely on size of fruits were characterized from the Mascall formation of the John Day Basin, and as no intermediate sizes were noted it was assumed that the species were valid, each perhaps corresponding to one of the three species characterized from the leaves.

Maples do not seem to have been as abundant in the Spokane area as they were in the John Day Basin, the fruit figured being the only one that has come to my attention.

This species is similar to *Acer aquilum* Chaney,[52] from the Eagle Creek formation of the Columbia River region, but is considerably narrower.

Occurrence: Latah formation, Deep Creek, northwest of Spokane, Wash., collected by Henry Fair and Kirk Bryan, June 24, 1923.

#### Acer chaneyi Knowlton, n. sp.

Plate XXVII, Figure 2

Leaf rather thin, rudely triangular, truncate at the base, very deeply three-lobed, the basal lobes lanceolate, sharp-pointed, with a small basal lobe and in the middle a larger few-toothed lobe on either side, the upper part sharply toothed; middle lobe with a pair of opposite toothed lobes high above the sinus and probably a toothed margin still above this (apex destroyed); sinuses very deep, rather sharp; nervation

[49] Ward, L. F., U. S. Geol. Survey Sixth Ann. Rept., p. 555, pl. 52, 1886; U. S. Geol. Survey Bull. 37, p. 79, 1887.

[50] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 267, pl. 60, figs. 1–3, 1916.

[51] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 253, pl. 59, figs. 1, 2, 4, 1883.

[52] Chaney, R. W., Chicago Univ. Walker Mus. Contr., vol. 2, No. 5, p. 178, pl. 18, fig. 2, 1920.

relatively strong, three-ribbed from the very base of the blade; midrib with a slender nerve passing up to and forking around the sinus, with about three pairs of camptodrome secondaries below the first pair of lobes, then a strong pair that end in the apex of the lobes, and above these probably other camptodrome secondaries; lateral ribs nearly as strong as the midrib, at an angle of about 45°, with both camptodrome and craspedodrome secondaries; nervilles slender, forming an irregular network.

This very characteristic species is represented by the single example here figured, which is nearly perfect except for the upper portion of the middle lobe. The length was probably 8 or 9 centimeters and the width between the lateral lobes about 8 centimeters. The lateral lobes are about 5 centimeters long and 1 centimeter wide at the base. The width of the middle lobe just above the sinuses is slightly less than 1 centimeter. The petiole is not preserved.

This species does not appear to approach very closely any living American species, nor is it like any fossil species thus far described from the region. It is, however, similar in many respects to *Acer angustilobum*,[53] from the Swiss Miocene. This European species is of about the same size as ours and is three-lobed and cut deeply by the sinuses, but it differs in having all the lobes evenly and sharply toothed.

I take pleasure in naming this species in honor of Dr. Ralph W. Chaney, who collected it.

Occurrence: Latah formation, Spokane, Wash., collected by R. W. Chaney, July, 1921. Type in the University of California, No. $\frac{3940}{22862}$.

### Order ERICALES

### Family VACCINIACEAE

#### Vaccinium salicoides Knowlton, n. sp.

Plate XXVIII, Figures 9, 9a

Leaf small (about 2 centimeters long, 6 millimeters wide), very thick, linear-lanceolate, broadest at about the middle, wedge-shaped at the base and rather obtuse at the apex; margin perfectly entire; midrib very thick, especially where it passes into the petiole; secondaries five or six pairs, thin, curving upward for long distances, camptodrome, each joining the one next above by several loops; finer nervation producing a regular, deeply impressed quadrangular network.

With only a single small rather nondescript leaf for comparison it is difficult to place this form with certainty. It is not unlike leaves of the living *Vaccinium pennsylvanicum* Lamarck, though apparently somewhat thicker. It also resembles certain species of *Salix* but is thicker than is usual in willow leaves.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

[53] Heer, Oswald, Flora tertiaria Helvetiae, vol. 3, pl. 118, fig. 7, 1859.

### Order EBENALES

### Family EBENACEAE

#### Diospyros andersonae Knowlton, n. sp.

Plate XXVII, Figure 6

This species, based on the splendid calyx figured, is so close to the living persimmon (*Diospyros virginiana* Linné) that separation is hardly possible, but it is so far outside the present range of this living species that its persistence since the Miocene seems improbable. The fossil form, however, is somewhat smaller than the usual-sized calyx in *Diospyros virginiana* and has the lobes relatively broader and shorter, but at most the differences are not great. It has a spread over all of 3 centimeters, and the greatest width of the lobes is 11 or 12 millimeters. The length of the lobes is about the same as their width. This calyx is preserved right side up, so to speak, and was evidently mature when fossilized, for the central depression or "cup" in which the berry rested is pronounced. In the living species the berry adheres to the calyx with great tenacity until maturity, when it readily separates.

*Diospyros virginiana*, the well-known persimmon, is very common in the South Atlantic and Gulf States, ranging from Connecticut west to Iowa and thence south through eastern Kansas to Arkansas and Louisiana. It is not known west of the Mississippi basin. It is evident that the type almost in its present form was in existence in middle Miocene time and at least a thousand miles west of its present western limit.

The Spokane persimmon is named in honor of Miss Alice Anderson, who collected it.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Alice Anderson for the Spokane Museum, from which the specimen is contributed.

#### Diospyros? microcalyx Knowlton, n. sp.

Plate XXII, Figures 5, 6

This species is represented by the two examples figured. They clearly represent a dry, leathery calyx from which the berry or fruit of some kind has fallen. They are regularly five-lobed, the individual lobes being obovate or oblong and very obtuse and rounded at the apex and cut within a short distance of the central disk. The nervation of the lobes is obscure but apparently consists of fine veins that run through the whole length. The central disk or point of attachment for the berry is over 1 millimeter in diameter and shows faint outlines of five vascular bundles. The width between the tips of the lobes is 8 or 9 millimeters.

I am less certain about the correctness of this generic reference than for the species last described, but it seems to approach most closely the calyx of the black persimmon (*Diospyros texana* Scheele, *Brayodendron texanum* (Scheele) Small) of Texas and Nuevo Leon, Mexico. It is, however, very much smaller and has the lobes relatively broader and more obtuse than in this living species.

These Spokane specimens also resemble certain species of *Porana* from the lake beds at Florissant, Colo., such as *Porana cockerelli* Knowlton,[54] although the latter is many times larger and has the ovoid capsule preserved in the center. The lobes of the calyx in *Porana cockerelli* have only about three strong nerves running from the base to the apex, whereas in the specimens under consideration there are a great number of fine veins or wrinkles that simulate veins. Another species of *Porana* (*P. similis* Knowlton), also from Florissant, is similar to *P. cockerelli* but has the calyx lobes pointed instead of obtuse. This also has the capsule preserved.

Altogether the Spokane specimens seem more like *Diospyros* than *Porana*, but considering the uncertainty it has appeared best to question the generic reference.

Occurrence: Latah formation, deep cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected for and contributed by the Spokane Public Museum.

### Order MALVALES

### Family MALVACEAE

#### Malva? hesperia Knowlton, n. sp.

Plate XXIX, Figure 11

Fruit depressed globose, about 1 centimeter in diameter, made up of a ring of about 20 indehiscent, smooth carpels that are without apparent beak or reticulations.

The specimen figured, the only one observed, is fortunately preserved in a normal position, so that all the carpels are exposed. It is certainly malvaceous and seems to be generically identical with the fruits of species of *Malva*, such as *Malva alcea* Linné and *M. moschata* Linné, but *Malva* is not a native of North America. The genus comprises about 30 Old World species, five or six of which are more or less widely naturalized in this country. It is also like *Althea*, but this is an Old World genus of some 15 species, only one of which (*A. officinalis* Linné) has been introduced into North America.

There are a number of native genera with the fruit more or less like the Spokane specimen, such as *Callirrhoë*, but the carpels of *Callirrhoë* are beaked and are also more or less reticulated. Others, such as *Malvastrum* and *Sida*, are eliminated for similar reasons.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected for and submitted by the Spokane Public Museum.

[54] Knowlton, F. H., U. S. Nat. Mus. Proc., vol. 51, p. 287, pl. 27, fig. 3, 1917.

### PLANTS OF UNCERTAIN SYSTEMATIC POSITION

#### Phyllites amplexicaulis Knowlton, n. sp.

Plate XXIX, Figure 3

This is a very peculiar organism, the exact nature of which has not yet been interpreted. It consists of a stout stem, of which 7.5 centimeters in length is preserved, on which are at irregular intervals (2 to 3 centimeters) pairs of small opposite, sessile, flat expanded organs. These are approximately circular, from 7 to 10 millimeters in width or diameter, and with the margin cut into regular strong deltoid teeth. From the center or point of attachment there are some eight or nine strong, straight ribs, which enter the teeth. No finer nervation can be detected. These organs seem to be coriaceous and to be stipular rather than strictly foliar in function. At the points of attachment the stem is constricted or disorganized, as if there had been other organs that have now disappeared.

I am not able to suggest any affinity for this organism.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

#### Phyllites crustacea Knowlton, n. sp.

Plate XXIX, Figure 6

This little leaf, the only one of its kind observed in the collection, is narrowly lanceolate, broadest well above the middle, whence it narrows below to a long wedge-shaped base and above to the acutely pointed tip. It is about 5 centimeters long and 1 centimeter wide. It was evidently rather thick, for over most of the leaf the carbonaceous film still remains. This carbonaceous matter has checked and wrinkled in such a manner that the nervation is obscured, and where it has been removed the impression of the nervation is hardly discernible. If correctly interpreted there appear to have been a large number of light, close, parallel secondaries that are apparently craspedodrome. The midrib seems strong for the size of the leaf. None of the finer nervation can be made out.

This little leaf has some resemblance, in shape at least, to certain narrow, entire-leaved species of *Salix*, but the nervation is so uncertain that it is best placed in *Phyllites*. It also agrees in shape with the smaller of the figured types of *Laurus salicifolia* Lesquereux [55] (now *L. saliciformis* Knowlton and Cockerell), but it has more secondaries and no evidence of the very fine nervation of that species.

Occurrence: Latah formation, well at Mica, southeast of Spokane, Wash., collected by Thomas Large or J. T. Pardee, August, 1922.

[55] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 252, pl. 58, fig. 3, 1883.

**Phyllites pardeei Knowlton, n. sp.**

Plate XXIX, Figure 13

Leaf apparently very thick, elliptical, abruptly rounded to the obtuse base and apex; margin with about four very low, obtuse teeth or lobes on each side; petiole moderately strong, about 1 centimeter long; midrib very strong for the size of the leaf, slightly irregular or bent; secondaries three pairs, all strong and more or less zigzag, the lower pair strongest, subopposite, arising a considerable distance above the top of the petiole, ending in a marginal tooth, each with a series of large loops on the lower side; middle pair of secondaries subopposite, forking and sending the branches to the marginal teeth; upper secondaries alternate, ending in the upper of the four marginal teeth; nervilles few, strong; finer nervation very strong and well marked, producing a network of large, irregular meshes throughout the blade.

This leaf is well characterized by its elliptical shape, the four low, obtuse teeth or lobes on each side, the three pairs of craspedodrome secondaries, the lowest of which are so far above the base of the blade, and above all by the peculiar large-meshed network of finer veins. Nevertheless, I am not now able to suggest a satisfactory generic reference. The shape and the manner in which the lower pair of secondaries arise, as well as the finer nervation, suggest the genus *Oreodaphne*, but the presence of the low marginal teeth or lobes is not in accord with this genus. I am therefore constrained to place it in *Phyllites* until it can be more satisfactorily allocated.

This species has been named in honor of Mr. J. T. Pardee, of the United States Geological Survey, who was especially instrumental in procuring the collections that are the basis of this report.

Occurrence: Latah formation, cut along Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and C. E. Fernquist, 1922.

**Phyllites peculiaris Knowlton, n. sp.**

Plate XXIX, Figure 2

Leaf evidently very thick, as the nervation is all deeply impressed; presumably elliptical, though the upper portion is missing; margin apparently entire; midrib extremely strong for the size of the leaf and slightly irregular. The number of pairs of secondaries can not be determined, though there are at least four pairs. The lower pair is rather thin and passes upward for only a short distance; they arise from the top of the petiole. The other secondaries are alternate, at an angle of about 20°, camptodrome, and curving upward for long distances, each joining the one above by a series of loops. There are a number of strong intermediate secondaries and an occasional nerville, but most of the finer nervation is obsolete.

This leaf has some resemblance to *Phyllites pardeei*, but that form has three or four low marginal teeth or lobes, and the lower secondaries arise at a distance above the top of the petiole. This leaf also resembles in a general way certain leaves that have been referred to *Ficus*, but in the absence of more complete data I think best to refer it to *Phyllites*. It can be easily recognized if again found.

Occurrence: Latah formation, Twelfth Avenue and Thor Street, Spokane, Wash., collected by Henry Fair and Kirk Bryan, June, 1923.

**Phyllites sophoroides Knowlton, n. sp.**

Plate XXVI, Figure 8

This little leaf or leaflet, as it probably is, is the only one of its kind observed. It was apparently thin and is long elliptical, being about equally rounded at both ends. The base appears to be slightly unequal-sided, and the apex is abruptly apiculate. The midrib is fairly strong, and the secondaries are very thin and delicate. There are nine or ten pairs of rather remote secondaries that curve near the margin, and each passes in a series of bows to the one next above. The nervilles are numerous, very irregular, and with the finer nervation producing a very irregular delicate network. The specimen is 4.75 centimeters long and 2.5 centimeters wide near the middle.

This appears to be a leaflet of a leguminous plant, being, for instance, similar to many that have been referred to *Sophora*, but as there is only a single example, and this not quite perfect, it is best referred, at least, temporarily, to the noncommital genus *Phyllites*.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

**Phyllites relatus Knowlton, n. sp.**

Plate XXVIII, Figure 8

Leaf small, probably about 5 centimeters in length and 2 centimeters in width, ovate-lanceolate; the shape of the base is not known, but the apex is drawn out into a long, slender point; the margin is provided with numerous rather large, slender, sharp-pointed teeth; the midrib is very strong, even to the tip of the blade; the number of secondaries can not be made out, as the basal portion of the leaf is missing, but there must have been nine or ten pairs; they are alternate, mainly irregular or zigzag, slightly curved upward, craspedodrome, often forked, with each branch entering a tooth; nervilles numerous and strong, approximately at right angles to the secondaries, both broken and percurrent; finer nervation producing an irregular network.

I am uncertain as to the generic reference for this little leaf. It is well marked by its thick substance and strong nervation, and particularly by its strong slender teeth, which extend even to the slender acuminate apex. In some ways it suggests *Ilex*, but this resemblance is probably only accidental and not a mark of affinity. It seems best under the circumstances to place the leaf in *Phyllites* for the present, or until better material can be procured.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

**Phyllites sp.**

Plate XXIX, Figure 5

This little leaf is the only one observed. It is apparently rather thick, possibly fleshy, and elliptical, with a rounded, almost truncate base and obtusely acuminate apex; length about 13 millimeters and width about 7 millimeters; petiole only about 1 millimeter long as preserved and very broad and thick; nervation somewhat obscure, but there are five very thin veins or ribs that arise in the petiole and then pass up into the leaf, one of them becoming the midrib and the others becoming vague near the middle of the blade; there is some evidence that several similarly thin veins arise from the middle and upper part of the midrib, but it is not conclusive. The finer nervation is not distinctly preserved.

The affinity of this little leaf is hard to determine. In size and shape it is very much like the floating leaves of some small-leaved species of *Potamogeton*, such as *Potamogeton diversifolius* Rafinesque and *P. spirillus* Tuckerman, but the nervation is not quite so regular.

Occurrence: Latah formation, cut No. 2 on Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash., collected by Henry Fair and Kirk Bryan, May, 1923.

**Carpites menthoides Knowlton, n. sp.**

Plate XXVI, Figure 4

This is a very peculiar fruit that is difficult to interpret. It is apparently a globular head approximately 2 centimeters in diameter, with an axis that is small below or toward the point of attachment and much swollen above. From all parts of this axis radiate narrow, finer, possibly coriaceous bracts, or something of the kind, that are now concave or possibly they were tubular like the calcyces of the heads of certain menthaceous plants such as *Monarda*. These organs seem to be too firm for the flowers of a composite, though that may be their relationship.

Occurrence: Latah formation, Spokane, Wash., collected by R. W. Chaney, 1921. University of California Museum No. $\frac{3940}{22855}$.

**Carpites boraginoides Knowlton, n. sp.**

Plate XXIX, Figure 7

This little specimen, although seemingly well preserved, is difficult to interpret, because it can not be viewed on all sides. It consists of a stout pedicel or peduncle about 18 millimeters in length, somewhat enlarged at the top, with what appear to be deflected portions of calyx lobes. On this receptacle are oblong, hard-shelled, perhaps berry-like seeds or nutlets. These are about 5 millimeters long and 4 millimeters broad. There is a hard outer rim or shell, now carbonaceous, and a light-colored inner area that shows faint lines and markings. There is some indication of a columella or axis between the seeds, but this is obscure.

The number of these seeds, nutlets, or whatever they are can not be made out with certainty. If it is assumed that there are four, which seems reasonable, it would suggest certain Boraginaceae in which there are usually four 1-seeded nutlets, but if there were a greater number it might be closer to the Malvaceae. The essential characters that remain in doubt make further speculation hazardous.

Occurrence: Latah formation, Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho, collected by H. J. Rust, July, 1920.

**Carpites polygonoides Knowlton, n. sp.**

Plate XXVI, Figure 7

As may be seen from the figure, this species is based on a cluster of some 50 or more detached fruits that presumably all came from the same plant. They are flat, circular "seeds" 2 or 3 millimeters in diameter, some of them with a slight point on one side. There seems to be a nucleus in the center, and thus the "seed" seems to be winged. The margin is entire. There are no pronounced or interpretable markings or ribs on the surface.

These fruits suggest the fruits of certain of the larger-seeded species of *Rumex*. Their uniform size, with a central nucleus and apparent winged margin, and above all the close grouping of so large a number are what might be expected of the clustered ripe fruits of *Rumex*, such as *Rumex venosus* Pursh, *R. patentia* Linné, and *R. occidentalis* Watson.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Henry Fair and Kirk Bryan, June, 1923.

**Carpites spokanensis Knowlton, n. sp.**

Plate XXVI, Figure 6

This organism is difficult to describe, because its nature and affinity are not recognized. It is slightly obovoid, about 12 millimeters long and about 6 millimeters broad, and attached by a base that is nearly 5 millimeters broad. At the base there is no apparent differentiation between integument and what seems to be a large ovoid, pointed "seed." From a point about 2 millimeters above the base the differentiation is complete from what appears to be a thick outer envelope. The central body or "seed" is irregularly longitudinally striate.

There is another example by the side of the one just described that is so folded as to give the impression that the outer envelope was two-valved and split apart, exposing the "seed." This may not be the correct interpretation, but it is given for what it is worth.

Occurrence: Latah formation, cut No. 2 on Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash., collected by Henry Fair and Kirk Bryan, June 10, 1923.

**Carpites ginkgoides Knowlton, n. sp.**

Plate XXIX, Figure 4

This specimen is clearly a spherical, hard-shelled seed standing on a short, fleshy axis, which is cup-shaped at the top, where stands the seed. The seed is about 11 millimeters in diameter and was undoubtedly spherical, though now one side is crushed down. The shell is about 0.05 millimeter thick and perfectly black. There is no evidence of the presence of an outer flesh, though this might well enough have been present. The seed is now filled with the clay of the matrix and is without further differentiation.

This seed certainly strongly suggests the fruit of the living *Ginkgo biloba* Linné, although it is smaller than the usual-sized fruits of this species. As leaves of *Ginkgo* have been found in these beds there is warrant for this being the fruit, though there is no absolute proof, and hence it seems best to place this form in *Carpites* pending fuller information.

Occurrence: Latah formation, cut No. 2 on Oregon-Washington Railroad & Navigation Co.'s line, Spokane, Wash., collected by Henry Fair and Kirk Bryan, June 10, 1923.

**Carpites magnifica Knowlton, n. sp.**

Plate XXIX, Figure 10

This specimen is difficult to interpret, although seemingly well preserved. It is ovate or ovoid, slightly over 4 centimeters in length and 2.3 centimeters in width. It is abruptly rounded below to the short, stout point of attachment, within which there are three grooves that become ridges a short distance above the base and can be traced upward for two-thirds the length of the specimen. A thin carbonaceous layer 1 millimeter or more thick surrounds the whole specimen and possibly represents a fleshy substance. There are a few irregular ribs or corrugations over the body of the specimen, but otherwise the surface is smooth and unmarked.

This form suggests superficially the nut of a butternut (*Juglans cinerea* Linné), but the resemblance is doubtless fancied rather than real. Its affinity is not known.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected by Don Engdahl for the Spokane Public Museum.

**Carpites paulownia Knowlton, n. sp.**

Plate XXIX, Figure 12

This is apparently a woody capsule, splitting into two equal valves. It is oblong or slightly obovoid, about 3.3 centimeters in length and 1.7 centimeters in diameter. It stands on a stout, woody axis, which is enlarged or saucer-shaped at the apex. The axis or branch, as well as the enlarged expansion in which the capsule sits, is deeply impressed and is now changed to a coaly mass.

The resemblance of this specimen to the mature fruit of the living *Paulownia* is striking. In the living species the calyx is trumpet-shaped and deeply 5-cleft, with short, moderately acute lobes; it is leathery in texture when mature. The capsule is coriaceous, ovoid, acute, and loculicidally dehiscent; it is about 5 centimeters long and 2.5 centimeters in diameter. *Paulownia* is a monotypic Japanese genus. It is a large tree with broad leaves 15 to 40 centimeters long and 10 to 20 centimeters wide. It is frequently cultivated in the Eastern States and has now escaped from cultivation in many places from New York and New Jersey southward.

Only a single fossil species of *Paulownia* has been described—*P. europaea* Laurent,[56] from the Pliocene of Cantal, France, based on a leaf that is almost identical with the living *P. tomentosa* (Willdenow) Baillion. The genus has not been detected as fossil in North America. It is possible but not certain that at least one of the leaves described in this paper under the name *Ficus? washingtonensis* (Pl. XXV) may be a leaf of *Paulownia*.

Occurrence: Latah formation, cut on Spokane, Portland & Seattle Railway, Spokane, Wash., collected for and contributed by the Spokane Public Museum.

**Branchlet and bud?**

This specimen is obscure but is apparently a large bud. It is borne on a rather slender stem a little over 1 centimeter in length and about 2 millimeters in diameter. It is slightly enlarged at the base of the "bud," which appears to have relatively large, strongly striated scales about 12 millimeters long and 5 or 6 millimeters broad. It does not appear to be a capsule, though it may be. In any event its affinity is unrecognized.

Occurrence: Latah formation, Deep Creek, northwest of Spokane, Wash., collected by Henry Fair, June, 1923.

[56] Laurent, L., Faculté sci. Marseille Annales, vol. 14, p. 4, text fig. 1, 1904.

## THE FOSSIL DIATOM DEPOSIT AT SPOKANE

By Albert Mann

The shale from Mica, near Spokane, Wash., a sample of which was submitted to me, proves to be moderately rich in fossil diatoms and to differ in several respects from any other diatom deposit located in that part of the world. There are several diatom beds in the Northwest, some covering large areas. All are of fresh-water origin, thus contrasting with the beds in California and Mexico, which are uniformly marine. But although the Spokane strata, like the others, were laid down in inland lakes, the formation has otherwise little similarity.

It is not unusual for contiguous diatom formations to show dissimilarity in their flora. The subfossil deposit of the Klamath Lake district of southern Oregon is characteristically local, but neither it nor any of the other deposits is as distinctive as this one at Spokane. For example, the fossil diatoms of the Northwest are largely made up of one species, a minute but robust filament-forming diatom, *Melosira granulata* (Ehrenberg) Ralfs, and in some beds it composes practically the entire mass. In fact, it may be said to characterize the diatom earths of that part of the world. But in the Spokane material this species is so rare that it is practically negligible; on the other hand, the Spokane flora comprises a number of species that are strikingly odd and some that have never been found before in this country.

This singularity of the Spokane deposit is apparent also in the greatly modified condition of the entire diatom mass. Most of the specimens are badly decayed or "rotten," a condition usually met with wherever a deposit has been subjected to long periods of alkaline corrosion. But in this area the caustic action of the water appears to have been somewhat operative during the time when the diatoms were living and the strata were being laid down, as well as during some long subsequent period. For not only are the specimens as a whole corroded, but many of them were originally misshapen in form and blurred in their ornamentation, indicating that their growth took place under unfavorable influences. Such an assemblage of crippled and malformed individuals is known to be the result of a high percentage of mineral salts in the water during the period of diatom growth, and several papers on this condition and its effect have been published.

But there is a curious and quite exceptional phase of this growth of malformations observable in the Spokane material, namely, a tendency in several of the species to develop twin specimens—that is to say, two complete diatoms, inseparably grown together. That such twins represent a real growth product and not the subsequent gluing together of two adjacent diatoms nor their partial fusion by means of geologic heat is easily seen. An examination of the illustrations of such twins which accompany this report and still more a microscopic study of the specimens themselves will make this fact evident. I think it is safe to infer that these twin diatoms were caused by some effect of certain mineral constitutents of the water acting on the diatoms during the plastic period of their vegetative reproduction—that is to say, during that well-known process by which each individual diatom becomes two individuals by the formation of two new valves developed back to back within the two older valves of each parent plant.

From the foregoing facts it is permissible to conclude that the Spokane diatom deposit was formed in a comparatively shallow inland lake, nominally a fresh-water lake but holding in solution a considerable amount of mineral constituents, probably derived from surface drainage and gradually increased by the absence of any adequate outlet; furthermore, that these conditions continued not only during the period of diatom growth, as is indicated by the malformations of the individuals, but also after the deposit had been laid down, as is shown by the corrosion and rottenness of a great part of the diatom mass.

The following is a list of the genera and species of diatoms found in the Spokane material. It is practically complete, so far as the sample examined is concerned; but this does not imply that other species might not be found in samples taken some distance from the location of this one, or from other strata above or below this one at the same locality. Diatomists are familiar with the fact that two samples taken at different places in the same bay at the present time may show considerable variation in the species they contain; and samples taken at exactly the same spot after a lapse of several years are even more likely to be dissimilar. Of course the same tendency to variation existed in those remote periods of time when the diatom beds now represented by fossils were being laid down. It is therefore obvious that a list of species found in a single fossil sample of diatoms is presumably somewhat fragmentary.

The list contains references to the particular illustrations in well-known works which most accurately represent the specimens found in the Spokane deposit. The following abbreviations are used:

Cl. Nav. Diat.—Cleve, P. T., Synopsis of the naviculoid diatoms, 1894–1895.

Donk. Brit. Diat.—Donkin, A. S., The natural history of the British Diatomaceae, 3 pts., 1871–1872.

Ratt. Rev. Cosc.—Rattray, John, A revision of the genus *Coscinodiscus*, 1889.

Reise F. Nov.—Grunow, Albert, Reise der Fregatte *Novara*, 1857–1859, Bot. Theil, Band 1, Heft 1, 1870.

Sch. At.—Schmidt, A., Atlas der Diatomaceen-Kunde, 1874–1921.

S. B. D.—Smith, William, A synopsis of the British Diatomaceae, 2 vols., 1853, 1856.

V. H. Syn.—Van Heurck, Henri, Synopsis des diatomées de Belgique, 1880–1885.

References to illustrations are given in the form 26/29-30—that is, Plate 26, figures 29-30.

*Achnanthes* (*Achnanthidium*) *flexella* (Brebisson). V. H. Syn., 26/29-30.

*Actinella brasiliensis* Grunow. V. H. Syn., 35/19.

*Amphipleura pellucida* var. *oregonica* Grunow. Cl. Nav. Diat., vol. 1, p. 126; V. H. Syn., 17/14-15.

*Coscinodiscus subaulacodiscoidalis* Rattray. (See Pl. XXX, fig. 1.) This ordinarily very rare diatom is rather abundant in the Spokane material. It seems to have never been found before in this country. Its type is figured in Sch. At., 57/8 without name and is named in Ratt. Rev. Cosc., p. 521; the specimen was found at Baldjik, on the Black Sea. My specimens have only three or four processes.

*Cymbella americana* Schmidt. Sch. At., 9/15, 71/78. (See Pl. XXX, fig. 2.)

*Cymbella amphicephala* Naegeli. Sch. At., 9/56 (no name), 66.

*Cymbella cuspidata* Kuetzing. V. H. Syn., 2/3. Found together with very small and robust varieties.

*Cymbella lunula* (Ehrenberg) Rabenhorst. Sch. At., 10/42-43. The variety found in the Spokane area approaches *C. ventricosa* Kuetzing, with which this species is sometimes united.

*Cymbella partita* Mann, n. sp. (See Pl. XXXI, fig. 1.)

*Cymbella sagittarius* Mann, n. sp. (See Pl. XXXI, fig. 2.)

*Desmogonium raberhorstianum* Grunow. Sch. At., 293/1-11.

*Diatoma grande* W. Smith. S. B. D., 40/310. Perhaps this is a variety of *D. vulgare* Bory.

*Diatoma tenue* var. *hybrida* Grunow. V. H. Syn., 50/10-13.

*Diatoma vulgare* Bory, type form. Sch. At., 268/24.

*Diatoma vulgare* var. *ehrenbergii* Grunow. Sch. At., 268/36.

*Eunotia faba* (Ehrenberg) Grunow. Sch. At., 270/33-41.

*Eunotia gracilis* (Ehrenberg) Rabenhorst. (See Pl. XXX, fig. 3.) V. H. Syn., 33/1-2. Shows several interesting malformations.

*Eunotia incisa* Gregory. V. H. Syn., 34/35a.

*Eunotia minor* (Kuetzing) Rabenhorst. V. H. Syn., 33/20-21.

*Eunotia parallela* Ehrenberg. V. H. Syn., 34/16. Perhaps this is a variety of the next.

*Eunotia pectinalis* (Kuetzing) Rabenhorst. V. H. Syn., 33/15-16.

*Eunotia robusta* var. *diadema* (Ehrenberg) Ralfs. V. H. Syn., 33/12.

*Eunotia robusta* var. *papilio* Grunow. V. H. Syn., 33/8.

*Fragilaria undata* W. Smith. S. B. D., 60/377.

*Frustulia rhomboides* (Ehrenberg) De Toni. (See Pl. XXXI, fig. 3.) V. H. Syn., 17/1-2 (misnamed).

*Gomphonema acuminatum* var. *suecica* Grunow. V. H. Syn., 23/32 (misnamed). This is essentially the same as *G. acuminatum* var. *turris* Ehrenberg in Sch. At., 239/34.

*Gomphonema gracile* Ehrenberg. Sch. At., 236/16-30, especially fig. 20.

*Gomphonema parvulum* Kuetzing. V. H. Syn., 25/10.

*Melosira biseriata* Ehrenberg. Sch. At., 180/22.

*Melosira distans* Kuetzing. Sch. At., 181/7-11.

*Melosira granulata* (Ehrenberg) Ralfs. Sch. At., 181/63.

*Melosira granulata* var. = *M. crenulata* var. *tenuis* in Sch. At., 181/56.

*Melosira lyrata* Grunow. Sch. At., 181/75.

*Melosira teres* Brun? Sch. At., 179/13. Whether or not this is Brun's diatom is somewhat uncertain. The reference for the type merely says that it occurs in "Maine"; but where, and whether recent or fossil, marine or fresh water, is not stated.

*Melosira undulata* (Ehrenberg) Kuetzing. Sch. At., 180/6-9.

*Navicula americana* Ehrenberg. V. H. Syn., 12/37. Both the typical form and a narrow variety occur here.

*Navicula amphigomphus* Ehrenberg. Sch. At., 49/33-34. A species sometimes but unwisely united with *N. iridis* Ehrenberg.

*Navicula angusta* Grunow. V. H. Syn., 7/17.

*Navicula bacillum* Ehrenberg. V. H. Syn., 13/8. A variety occurs here that lacks the typical hyaline apical area.

*Navicula commutata* Grunow. Sch. At., 45/37.

*Navicula contendens* Mann, n. sp. (See Pl. XXXI, fig. 4.)

*Navicula dubia* Ehrenberg. (See *N. iridis* var. *dubia*.)

*Navicula elegans* W. Smith. S. B. D., 16/137; Donk. Brit. Diat., 4/1.

*Navicula formosa* Gregory. Sch. At., 50/14-15. Also a variety approaching *N. subsalina* Donkin. V. H. Syn., 11/6.

*Navicula gibba* (Ehrenberg) Donkin. S. B. D., 19/180; Sch. At., 45/50. This species should not be united with *N. stauroptera* Grunow, which see.

*Navicula gracillima* (Gregory) Schmidt. (See Pl. XXX, fig. 4.) Sch. At., 45/62. The specimens found agree closely enough for specific union with the illustration cited, but there is doubt if the name is correctly assigned. Gregory's species has no stauros. But the name is preferable to *N. mesolepta* var. *angusta*, which Cleve offers as a substitute.

*Navicula hilseana* (Janisch) Schmidt. Sch. At., 45/65. Twin forms of this species are common in the Spokane material.

*Navicula instabilis* Schmidt. Sch. At., 43/36. Twin forms of this also occur here. The species is close to *N. hemiptera* Kuetzing.

*Navicula iridescens* Mann, n. sp. (See Pl. XXX, fig. 5.)

*Navicula iridis* Ehrenberg var. *subampliata* Grunow. (See Pl. XXXI, fig. 5.) Sch. At., 49/19.

*Navicula iridis* Ehrenberg var. = *N. dubia* Ehrenberg in Sch. At., 49/7 and Donk. Brit. Diat. 5/5. The doubt expressed in Ehrenberg's specific name is justified, the form being merely a variety of *N. iridis*. Another variety that occurs here is something like *N. bisulcata* Lagerstedt in Sch. At., 49/15, but is much more delicate, narrow, and finely marked and measures only 0.091 millimeter in length and 0.013 millimeter in width.

*Navicula major* Grunow. Sch. At., 42/10. The true type form has not been found in the Spokane material, but there are two varieties, one with a very narrow median area and one intermediate between this species and *N. viridis* (Nitzsch) Kuetzing.

*Navicula mesotyla* (Ehrenberg) J. Schumann. Sch. At., 45/54-55.

*Navicula nodosa* Kuetzing. Sch. At., 45/56-58.

*Navicula pauper* Mann., n. sp. (See Pl. XXXI, fig. 6.)

*Navicula placentula* Ehrenberg. V. H. Syn., 8/26, 28.

*Navicula pontifica* Mann n. sp. (See Pl. XXXI, fig. 7.)

*Navicula protrudens* Mann, n. sp. (See Pl. XXXI, fig. 8.)

*Navicula pseudo-affinis* Mann, n. sp. (See Pl. XXX, fig. 6.)

*Navicula pseudo-bacillum* Grunow. V. H. Syn., 13/9.

*Navicula pusilla* W. Smith. S. B. D., 17/145. The specimens vary slightly from the type form.

*Navicula radiosa* Kuetzing. Sch. At., 47/52. Nearly all the specimens are modified into twin forms.

*Navicula reversa* Mann, n. sp. (See Pl. XXX, fig. 7.)

*Navicula rupestris* (Hantzsch) Schmidt. Sch. At., 45/38-44. Malformations and twin forms of this species were found abundantly.

*Navicula scutiformis* Grunow. Sch. At., 70/62. This species has not been found in America before. It occurs at Stavanger, Norway, and in a fossil deposit at Umca, Sweden. It is abundant here and affords several varieties.

*Navicula stauroptera* Grunow. Sch. At., 44/41.

*Navicula stauroptera* var. = *N. parva* (Ehrenberg) Van Heurck, in V. H. Syn., 6/6 (misnamed). The species should be kept separate from *N. gibba* (Ehrenberg) Donkin, which see.

*Navicula subacuta* (Ehrenberg) Schmidt. Sch. At., 43/31

*Navicula substauroneis* Mann, n. sp. (See Pl. XXXI, fig. 9.)
*Navicula tabellaria* (Ehrenberg) Kuetzing. Sch. At., 43/4.
*Navicula transversa* Schmidt. Sch. At., 43/5. The typical form occurs and a variety passing into *N. major* Grunow, to which this species is rather too close.
*Navicula viridis* (Nitzsch) Kuetzing. Sch. At., 42/13. Twin specimens are not uncommon.
*Stauroneis* (*Navicula*) *acutissima* Mann, n. sp. (See Pl. XXX, fig. 8.)
*Stauroneis* (*Navicula*) *anceps* Ehrenberg. Sch. At., 242/11–12. (See Pl. XXXI, fig. 11.)
*Stauroneis* (*Navicula*) *phoenicenteron* Ehrenberg. (See Pl. XXXI, fig. 12.) V. H. Syn., 4/2; Sch. At., 242/16. Nearly all specimens of this and the foregoing species were twin forms.
*Surirella bifrons* Kuetzing. Sch. At., 22/12.
*Surirella inducta* Schmidt, var. Sch. At., 24/25.
*Surirella striatula* Turpin. Sch. At., 24/20. This species seems to flourish in waters high in mineral content. It often holds its place in lakes that show a gradual increase in salinity after other species have been exterminated by the high percentage of salts. Thus in samples of borings made at the site of a prehistoric lake in the Black Rock district of Nevada, which slowly changed from fresh water to salt water, this species was the last diatom to succumb to the growing salinity. It is also sometimes the dominant species in such saline waters as Devils Lake, N. Dak., and Salt Lake, Utah.
*Tabellaria binalis* (Ehrenberg) Grunow. V. H. Syn., 44/23. The generic assignment of this well-known species is doubtful.
*Tabellaria fenestrata* Kuetzing. S. B. D., 43/317. Most of the specimens in the Spokane material are misshapen.
*Tabellaria flocculosa* (Roth) Kuetzing. S. B. D., 43/316.
*Tetracyclus ellipticus* (Ehrenberg) Grunow var. *latissima*. Sch. At., 281/20–23.
*Tetracyclus ellipticus* (Ehrenberg) Grunow var. *linearis*. Sch. At., 281/12.
*Tetracyclus lacustris* Ralfs. Sch. At., 269/7–8.
*Tetracyclus rupestris* (Brun) Grunow. Sch. At., 297/96, 101.

The new species are described below.

**Cymbella partita Mann, n. sp.**

Plate XXXI, Figure 1

Valve moderately bowed, its apices rounded, not bent upward or extended; the dorsal side evenly convex, the ventral barely convex and slightly enlarged at the middle; an unusually wide, hyaline median area, enlarged at the center, extends from that point straight to each apex, thereby exactly bisecting the valve, whence the specific name here given; rhaphe strong, straight, its central ends separated by the large central nodule, its apical ends also straight and entering the bulbous terminations of the median area; markings of fine closely set rows of beading, transverse to the median area. Length, average, 0.184 millimeter; width, 0.036 millimeter; 8 lines in 0.01 millimeter.

This species is near that phase of *C. gastroides* Kuetzing figured in Sch. At., 9/2, but is too wide to be grouped with it as a variety. It occurs in this material in both the normal and the twin conditions.



**Cymbella sagittarius Mann, n. sp.**

Plate XXXI, Figure 2

Valve with extended and acute ends, the dorsal side strongly convex in its middle part and rapidly tapering to the ends; the ventral side slightly convex from end to end; rhaphe median, straight; markings of very fine beaded rows, the beads so spaced as to show both transverse and longitudinal interlines; median area wide, tapering, distended at the middle, especially on the ventral side, where it nearly reaches the margin; central nodule prominent. Length, 0.114 millimeter; width, 0.022 millimeter; 16 lines in 0.01 millimeter.

This graceful and sharp-ended species is quite distinct from any known form. Its name refers to the perfect bow formed by the rhaphe and the dorsal margin.

**Navicula contendens Mann, n. sp.**

Plate XXXI, Figure 4

Valve fusiform, with slightly enlarged, rounded apices; markings of strong, closely set moniliform costae, radial at the middle of the valve, reversed near and at the apices; hyaline median area widely distended at the middle of the valve, tapering to near the apices, where the markings closely approach the rhaphe; outer ends of the rhaphe slightly hooked and surrounded by small hyaline areas, middle ends of the rhaphe bent to one side. Length, 0.078 millimeter; width, 0.0194 millimeter; 11.5 lines in 0.01 millimeter.

This species resembles the one figured in V. H. Syn., 6/17, incorrectly named as a variety of *N. legumen* Ehrenberg. Cleve (Nav. Diat., II, p. 84) groups it with the similar form in Sch. At., 45/30, the less similar form in Sch. At., 45/29, and *N. scythica* Pantocsek in Pant. Hung. Diat., III, 23/335, under *Pinnularia subsolaris* Grunow. Although the figure in Sch. At., 45/30, might be united with the others above mentioned, the species here represented is too dissimilar to admit of the same assignment.

**Navicula iridescens Mann, n. sp.**

Plate XXX, Figure 5

Valve delicate, narrow, spindle-shaped, with slightly protruding ends that are capped at the tip with a lunate thickening, like the other members of the *N. iridis* group; markings of fine, closely set beaded lines, transverse and reaching close to the rhaphe, except at the center, where there is a small diamond-shaped area; a single wavy line close to each side traverses the entire length of the valve; rhaphe perfectly straight, not bent on hooked at the center. Length, 0.128 millimeter; width, 0.021 millimeter; 22 lines in 0.01 millimeter. It has a remote resemblance to the unnamed form shown in Sch. At., 49/40.

**Navicula pauper Mann, n. sp.**

Plate XXXI, Figure 6

Valve narrow, almost linear, slightly tapered to the blunt, enlarged ends, which are thickened internally into a lunate cap, characteristic of the *N. iridis* group; markings confined to a narrow, somewhat ragged band of fine, beaded, transverse lines along each side, the beads on the inner edge of each band being larger than the rest; rhaphe strong, straight, its middle ends not bent or enlarged. Length, average, 0.110 millimeter; width, 0.016 millimeter; 7 lines in 0.01 millimeter. The specimens showed many cases of malformation and twin forming.

**Navicula pontifica Mann, n. sp.**

Plate XXXI, Figure 7

Valve elongated, robust, barely tapering from the slightly distended middle to the rounded ends; markings of strong, smooth costal lines, radially oblique at the middle and halfway to the ends, then reversed oblique, reduced to mere traces at the ends and wanting at the middle, thereby producing a broad, somewhat flaring stauros; a single wavy line runs the length of the valve on either side close to the margin; longitudinal median area fully one-third the width of the valve, dilated at the ends; rhaphe straight, its central ends slightly bent, its apical ends strongly hooked. Length, 0.189 millimeter; width, 0.026 millimeter; 10 lines in 0.01 millimeter. Distinguished from minute specimens of *N. major* readily by its strong stauros.

**Navicula protrudens Mann, n. sp.**

Plate XXXI, Figure 8

Valve very convex, narrow, elongated, dilated at the middle, otherwise straight, with rounded, not swollen ends; markings of fine, transverse, beaded lines, reaching almost to the rhaphe except at the middle, where there is a large diamond-shaped median area; a strong, longitudinal line running midway between the rhaphe and each side; rhaphe straight, its outer ends terminating in large protuberant beads, whence the specific name. Length, average, 0.082 millimeter; width, 0.012 millimeter; 9 lines in 0.01 millimeter.

**Navicula pseudo-affinis Mann, n. sp.**

Plate XXX, Figure 6

Valve elongated, gently narrowed from the middle to near the ends, then abruptly compressed, so that the last part at each end is protuberant, with wedge-shaped apex; markings of fine and closely set rows of slightly elongated beads, the rows radial at the center and oblique to near each end, where they become transverse, not reaching inward to the rhaphe line, but leaving a wide longitudinal median area, dilated at the center of the valve; a distinct line running longitudinally on each side near the margin until the two merge into the two forks extending inward from a hyaline area at each apex of the valve; rhaphe strong, straight, its inner ends bent into minute hooks, both turned toward the same side. Length, 0.168 millimeter; width, 0.031 millimeter; 12 lines in 0.01 millimeter.

The nearest relatives are the unnamed form shown in Sch. At., 49/1, called *N. affinis* var. *genuina* Cleve in Fricke's index of that work; also fig. 19 on the same plate, having the questionable name *N. firma* var. *subampliata* Grunow. But both differ from this species in the direction and composition of their markings.

**Navicula reversa Mann, n. sp.**

Plate XXX, Figure 7

Valve broad, stout, with practically parallel sides and rounded ends; marked with closely set and fine beading in strongly divergent, wavy rows at the middle, which continue radially oblique to near the ends, then reversing to strongly convergently oblique, as in *N. oblonga* Kuetzing; central area large, rectangular, merging into a narrow median line running to the apices; rhaphe slightly undulate, its two middle ends joined across the central nodule by a thin line, its two terminal ends hooked. Length, 0.107 millimeter; width, 0.022 millimeter; 8 lines in 0.01 millimeter.

This approaches several known species but without sufficient nearness to warrant a union: *N. commutata* Grunow as figured in Sch. At., 45/35, and the variety of *N. major* Grunow shown in Sch. At., 42/8—a good illustration of how a species may serve as a bridge between two quite dissimilar forms. It stands even nearer to the form which Grunow calls *N.* (*Pinnularia*) *leptogonglya* Ehrenberg in Sch. At., 45/26 and which Schmidt there claims to be quite different, and rightly so. I have therefore found it convenient to assign a name.

**Navicula substauroneis Mann, n. sp.**

Plate XXXI, Figures 9, 10

Valve narrow, lanceolate, sides straight from the middle to the blunt, rounded ends; markings of strongly beaded lines, barely oblique to near the ends, there transverse, reaching nearly to the rhaphe but leaving an evident central area extended into a strong stauros across the middle to the sides; rhaphe delicate, its inner ends slightly bent and bead-tipped, its outer ends hooked. Length, average, 0.105 millimeter; width, 0.015 millimeter; 10 lines in 0.01 millimeter.

**Stauroneis (Navicula) acutissima Mann, n. sp.**

Plate XXX, Figures 8, 9

Valve narrow, lanceolate, with much elongated, needle-sharp ends and slightly undulate sides; markings of very fine, closely set beaded lines, somewhat radially oblique to the long axis, reaching from the sides to the rhaphe; a broad, slightly depressed stauros across the middle; rhaphe straight, delicate, each half beginning at the stauros and running to the extreme tip of the valve; the tips thickened internally as in *S. acuta* W. Smith, so that the inner cavity of the diatom is remote from the very pointed tips. Length, 0.070 millimeter; width, 0.010 millimeter; 29 lines in 0.01 millimeter.

It would be permissible to classify this as a very wide variety of *S. smithii* Grunow, but its larger size, much more acicular shape, and broad stauros are in favor of a separate name. Many malformed specimens were found, one of which is here illustrated.

# PLATES VIII-XXXI

## PLATE VIII

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FIGURE 1. *Archaeomnium patens* E. G. Britton. Cut No. 1, Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36869 ---- 24

2. Same, × 3.

3. *Polytrichites spokanensis* E. G. Britton. Deep Creek northwest of Spokane, Wash. U. S. Nat. Mus. No. 36870 ---- 24

4. Same, × 3.

5. Moss, genus and species? Deep Creek, northwest of Spokane, Wash. U. S. Nat. Mus. No. 36871 ---- 24

6. Same, × 3.

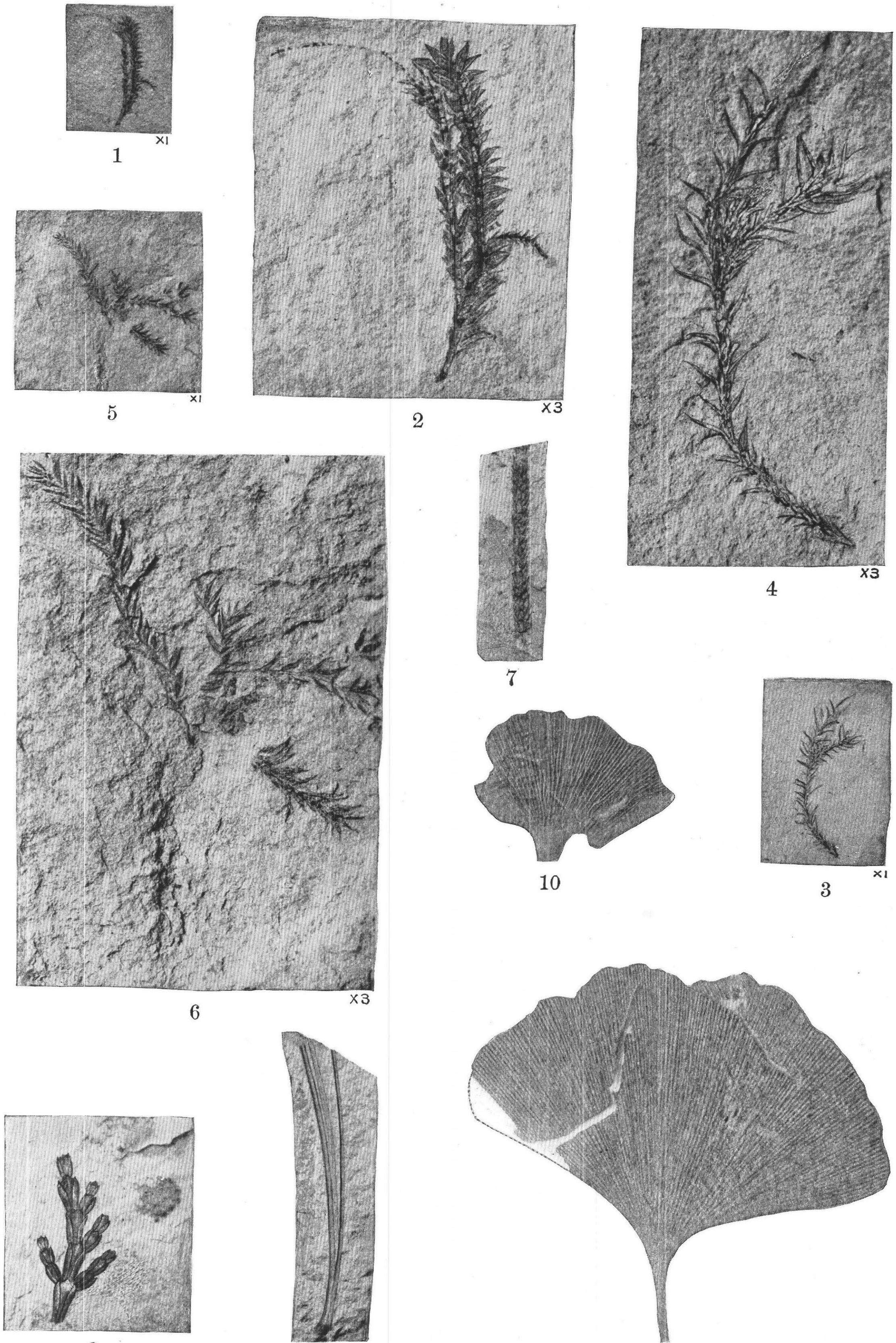
7. *Lycopodium hesperium* Knowlton. Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho. U. S. Nat. Mus. No. 36872 ---- 24

8. *Libocedrus praedecurrens* Knowlton. Cut on Spokane, Portland & Seattle Railway, Spokane, Wash. U. S. Nat. Mus. No. 36873 ---- 28

9. *Pinus* sp. Well near Mica, southeast of Spokane, Wash. U. S. Nat. Mus. No. 36874 ---- 26

10. *Ginkgo adiantoides* (Unger) Heer. Third cut on Spokane, Portland & Seattle Railway, Spokane, Wash, U. S. Nat. Mus. No. 37192 ---- 25

11. *Ginkgo adiantoides* (Unger) Heer. Fivemile Prairie, near Spokane, Wash. Specimen in Public Museum, Spokane ---- 25

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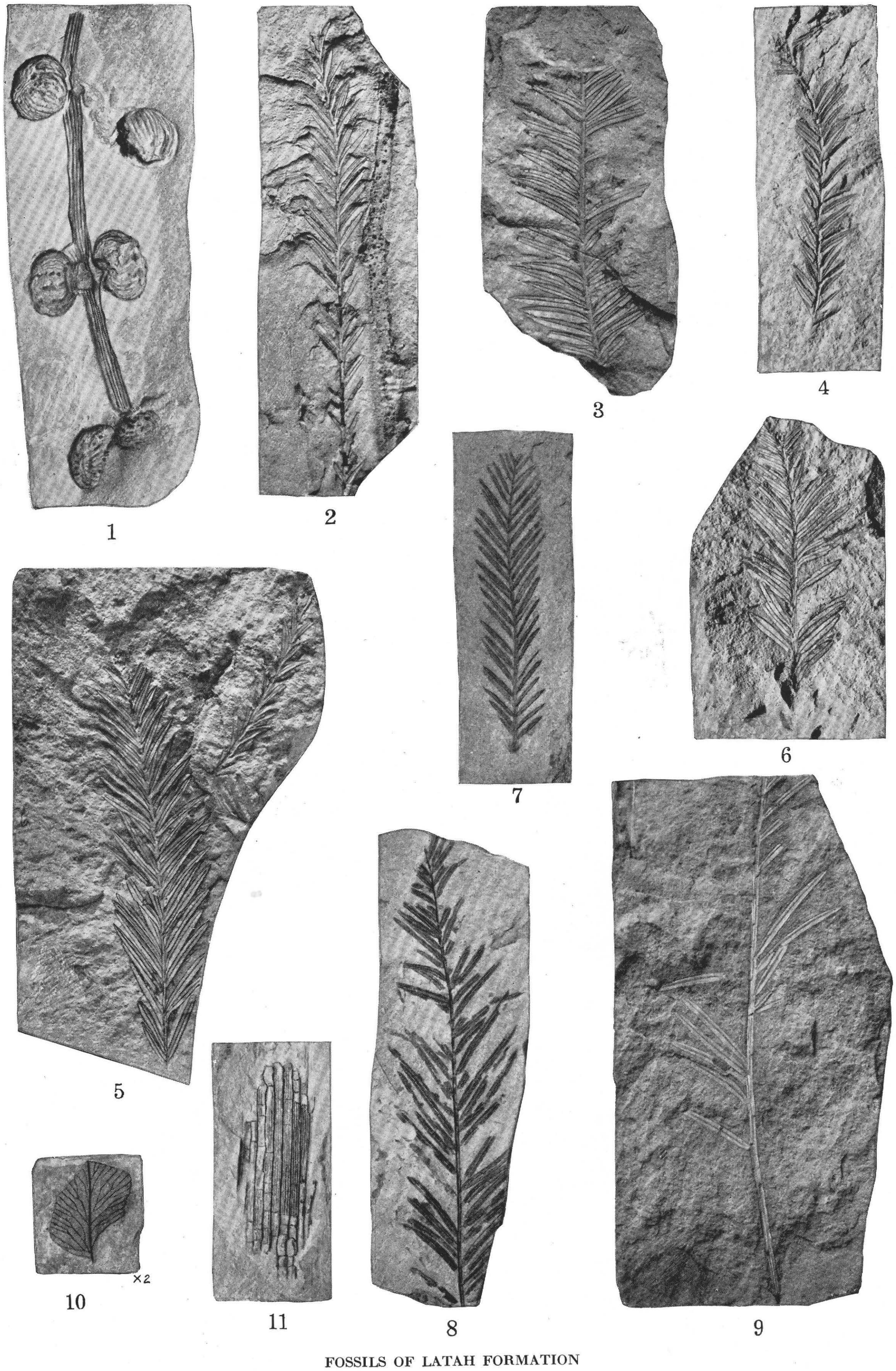


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# PLATE IX

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| 3–6. | *Sequoia langsdorfii* (Brongniart) Heer. Figs. 3, 4, 5, from Deep Creek half a mile above mouth, northwest of Spokane, Wash. (U. S. Nat. Mus. Nos. 36880, 36881, 36882); fig. 6 from Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho (U. S. Nat. Mus. No. 36879) | 26 |
| 7–9. | *Taxodium dubium* (Sternberg) Heer. Fig. 7 from Elko, Nev. (U. S. Nat. Mus. No. 36883) (introduced for comparison); fig. 8 from Edwards ranch, Stanley Hill, Coeur d'Alene, Idaho (U. S. Nat. Mus. No. 36878); fig. 9 from cut on Spokane, Portland & Seattle Railway, Spokane, Wash. (U. S. Nat. Mus. No. 36877) | 27 |
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| 11. | *Typha?* sp. Spokane, Wash. Specimen in University of California, No. $\frac{3940}{22843}$ | 28 |

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| FIGURE 1. *Arisaema hesperia* Knowlton. Deep Creek, northwest of Spokane, Wash. U. S. Nat. Mus. No. 36885 | 29 |
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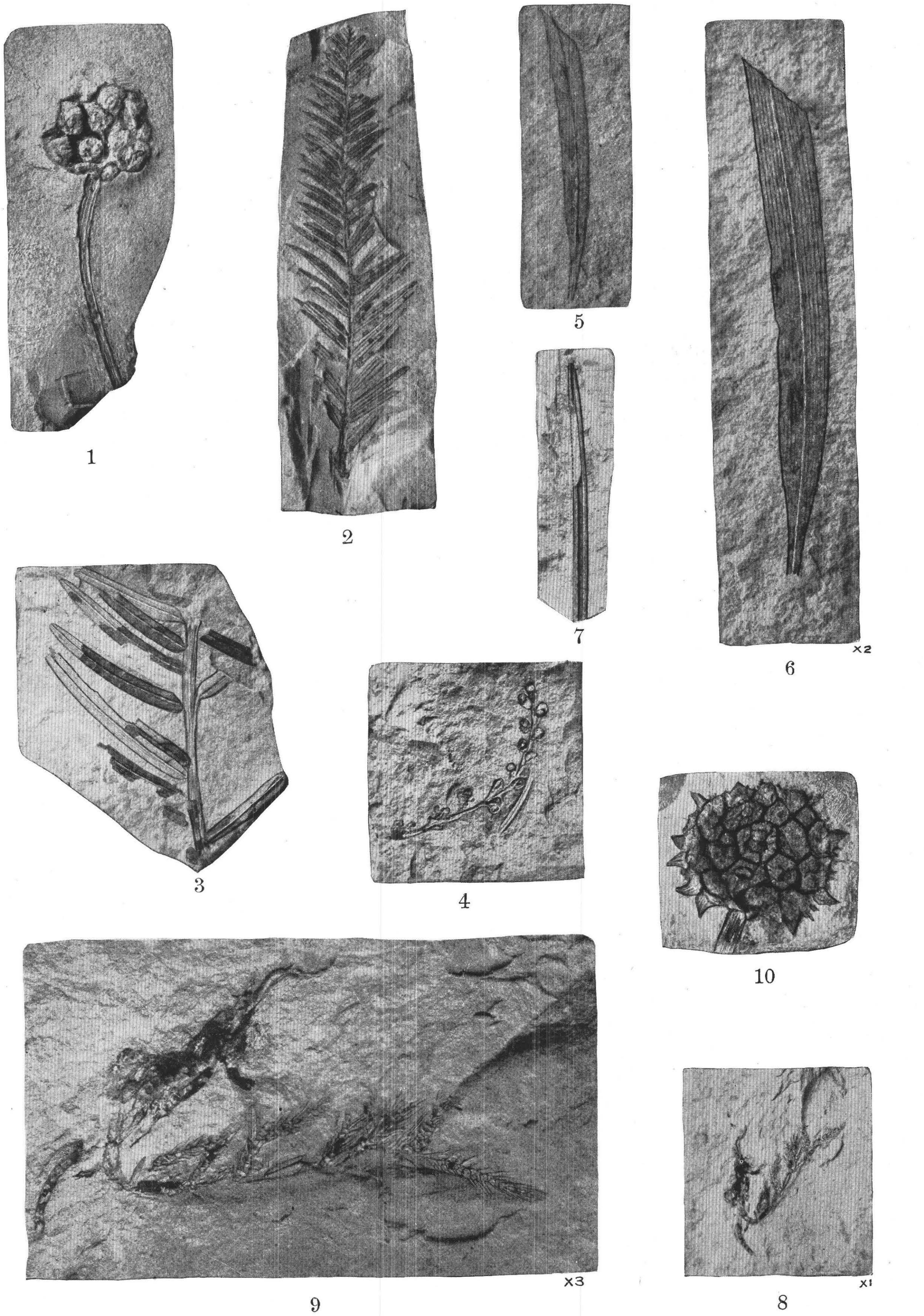


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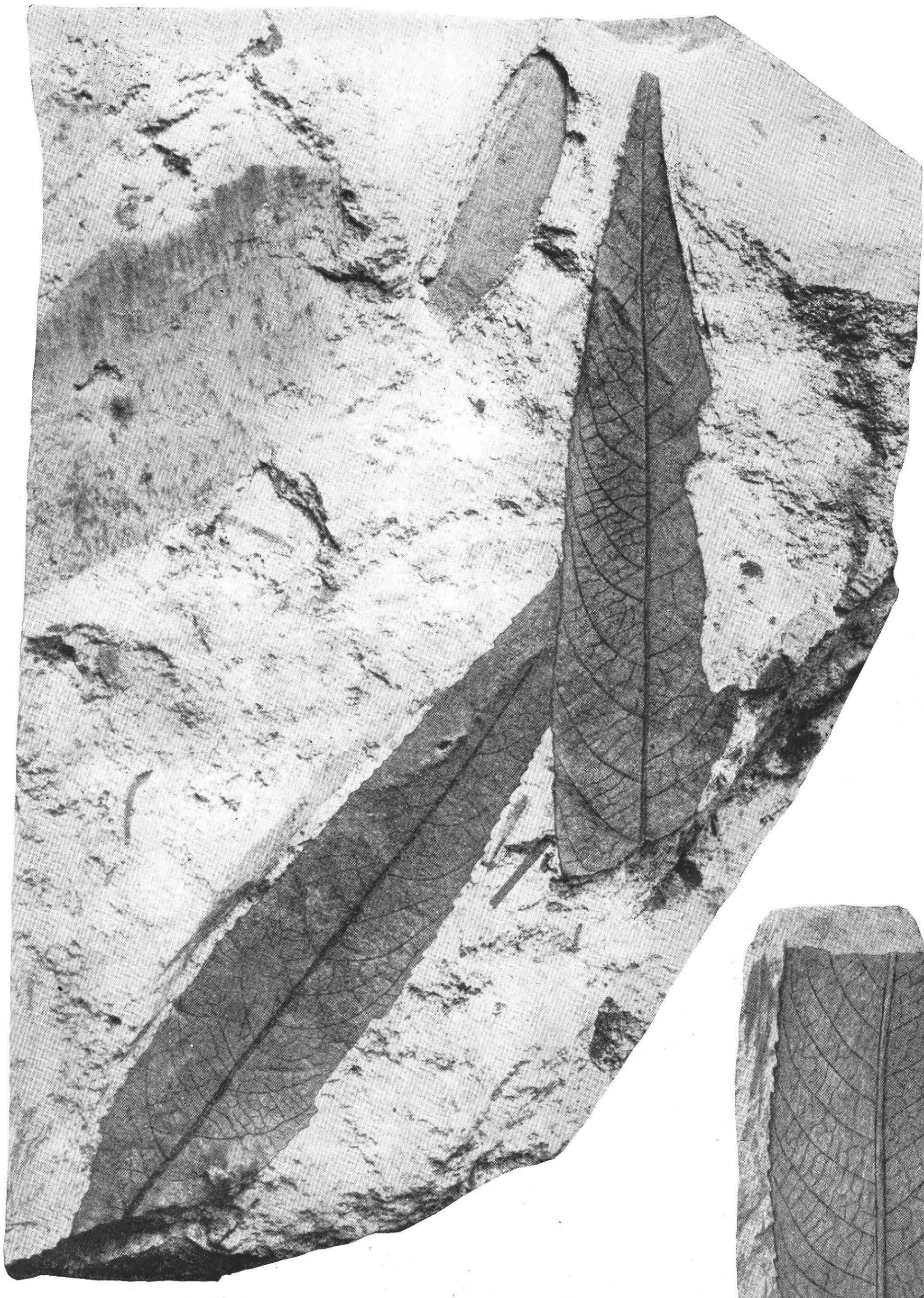

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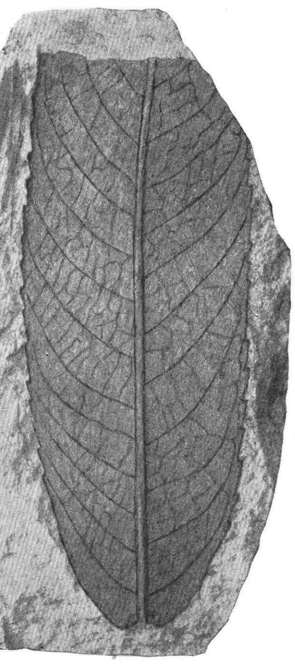

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## PLATE XI

## PLATE XII

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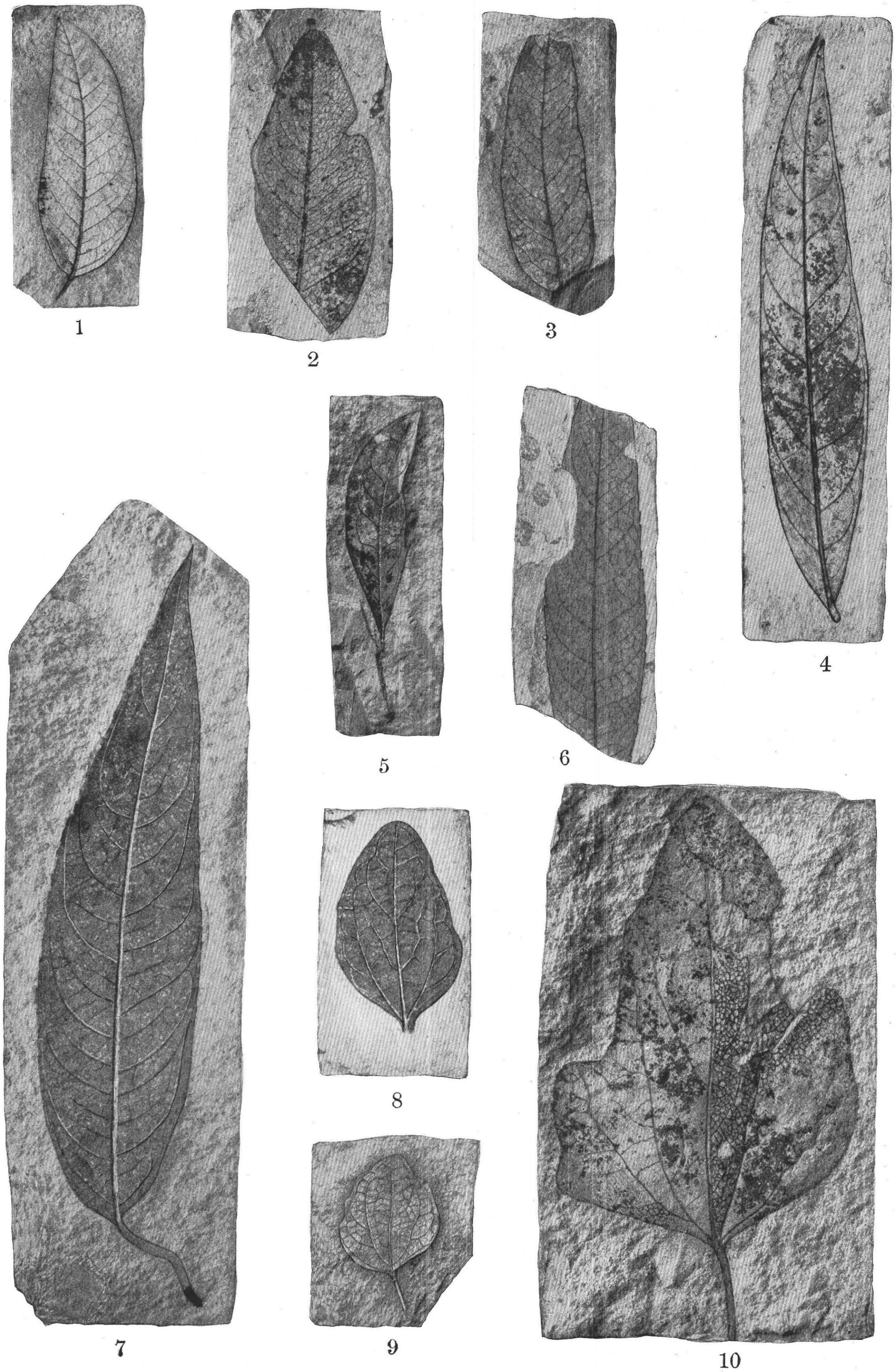


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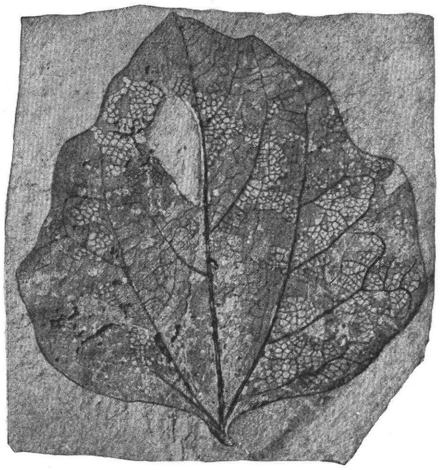
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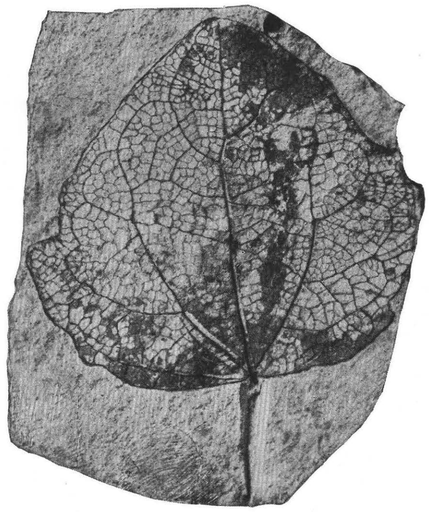
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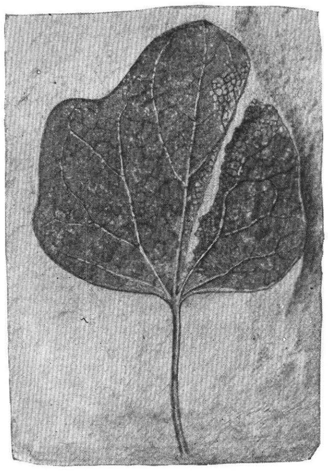
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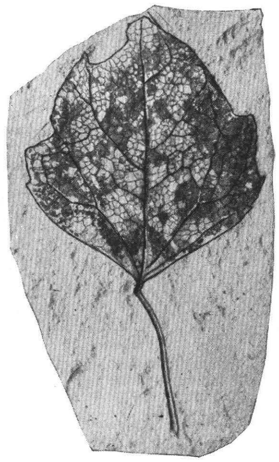
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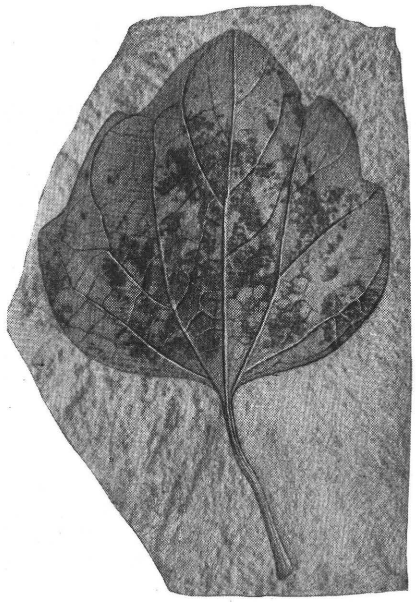
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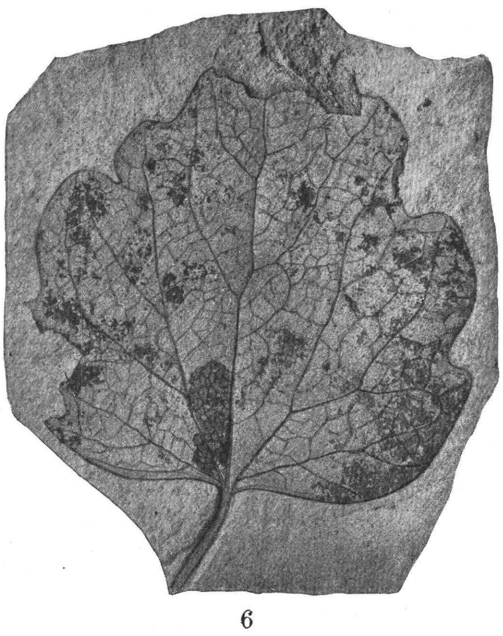
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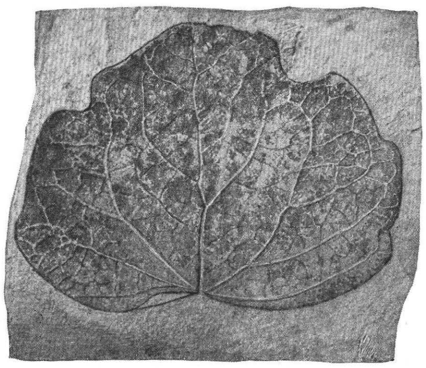
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## PLATE XIII

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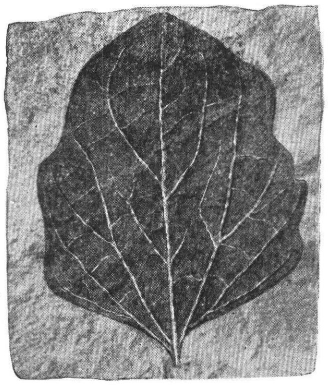
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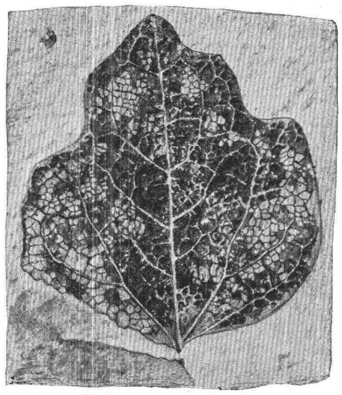
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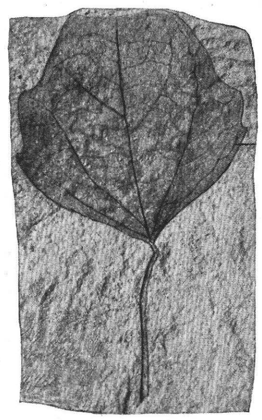
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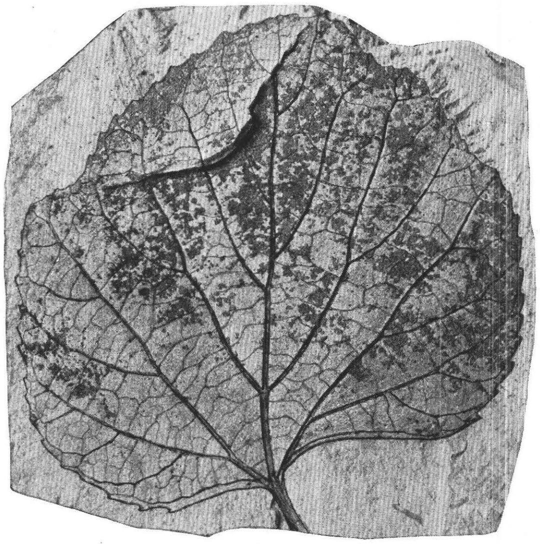
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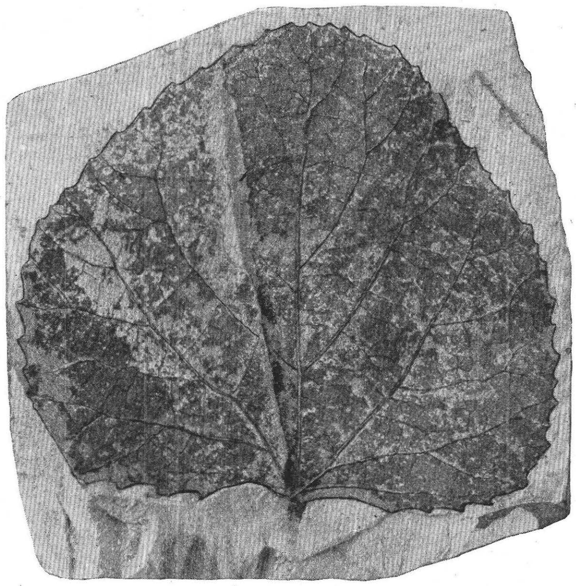
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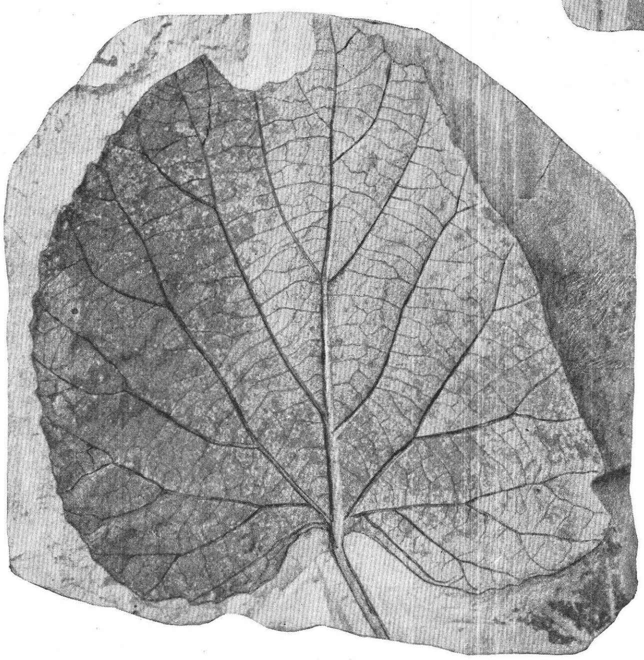
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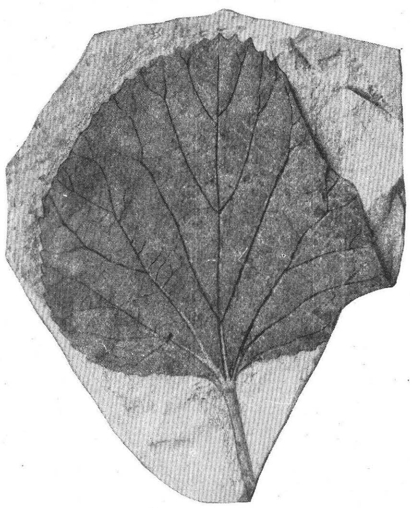
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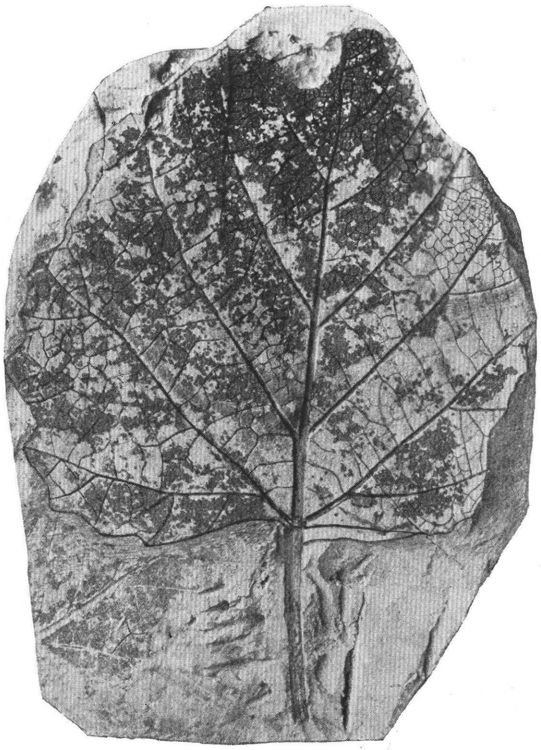

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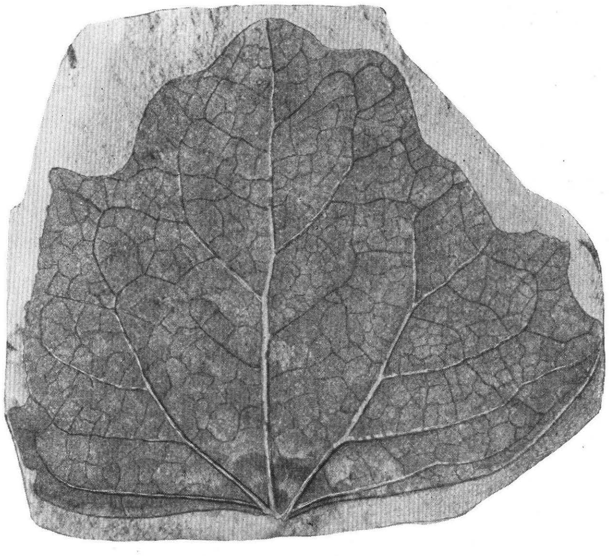

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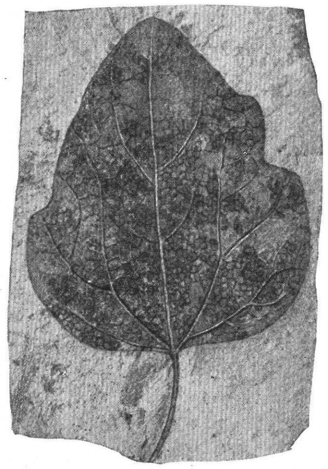

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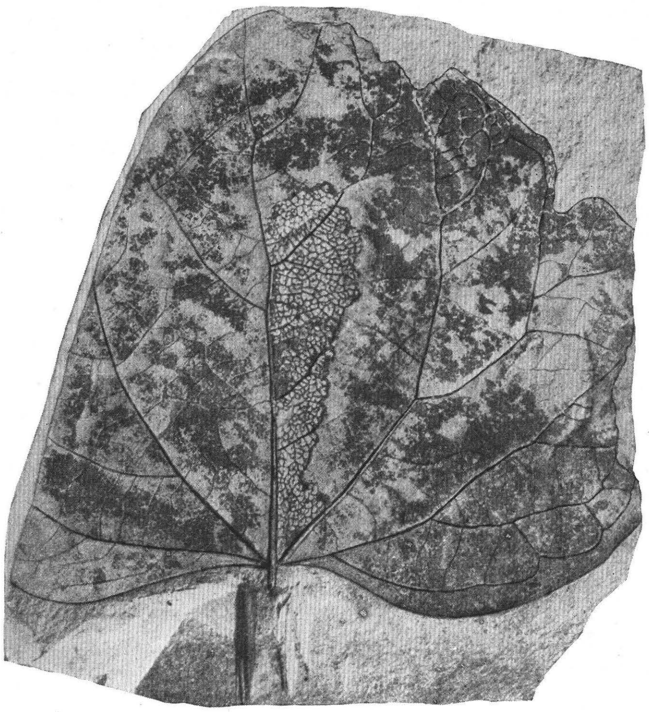

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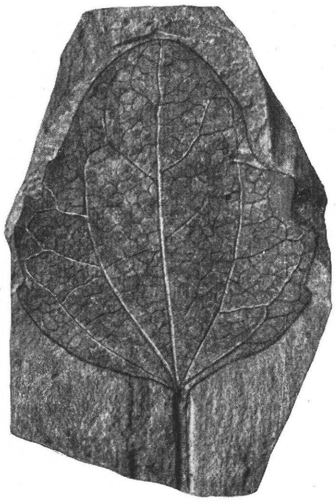

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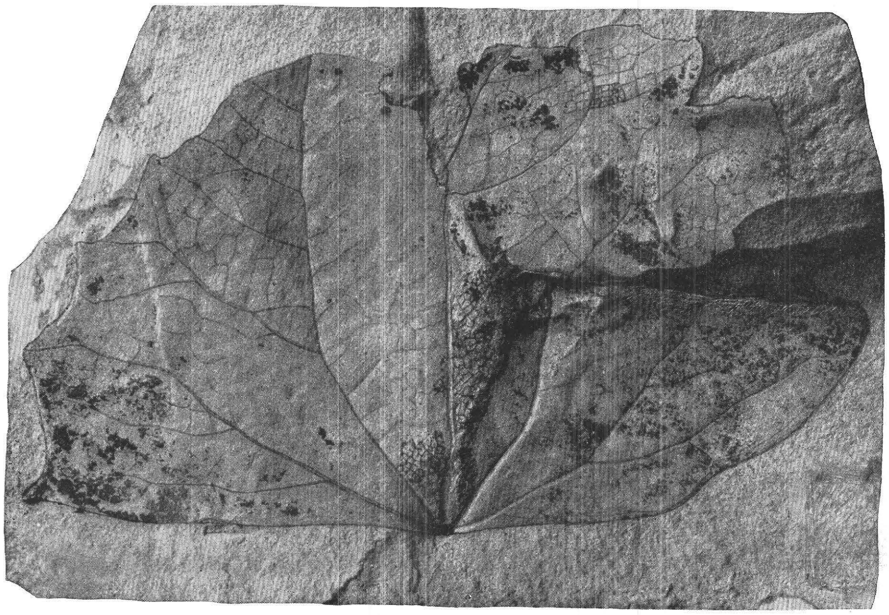

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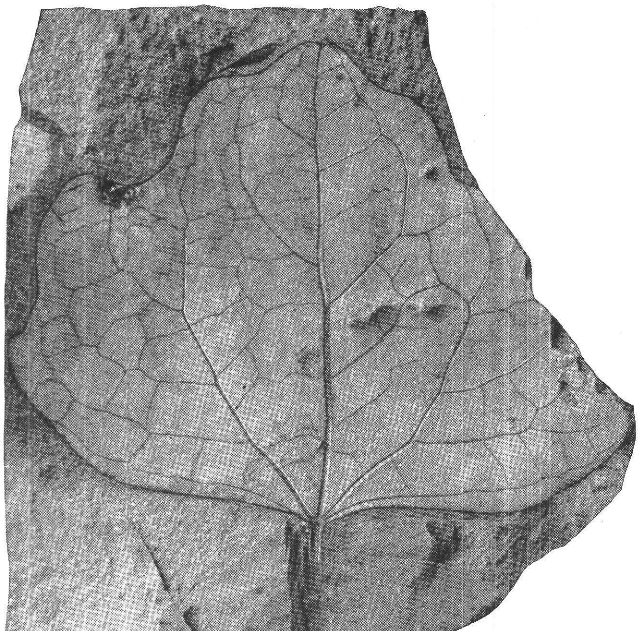

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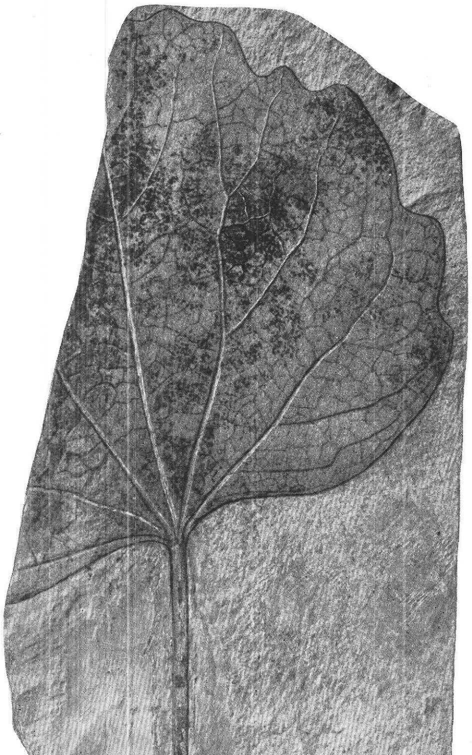

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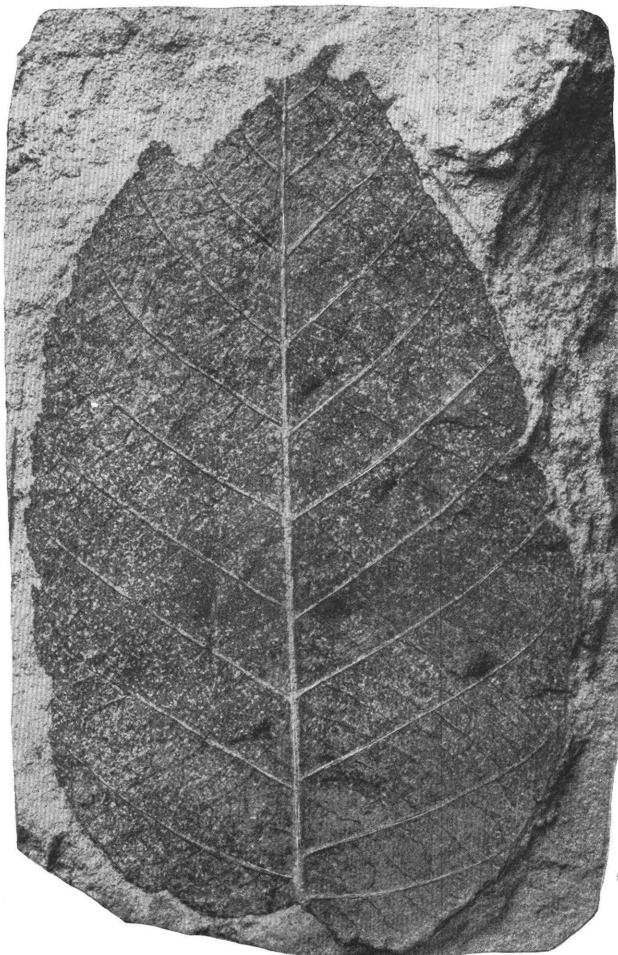

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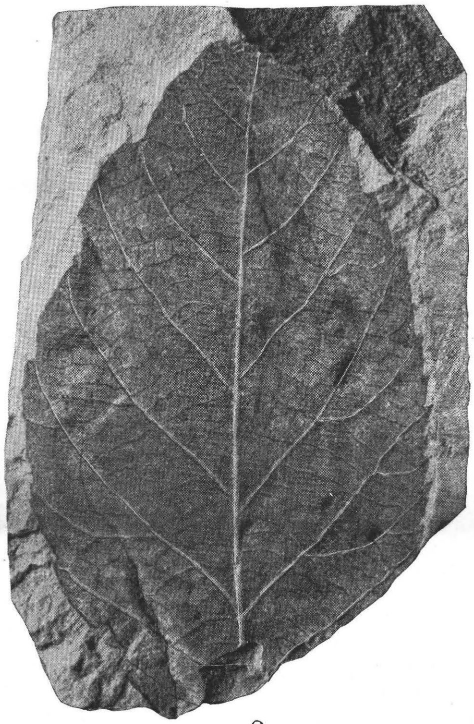

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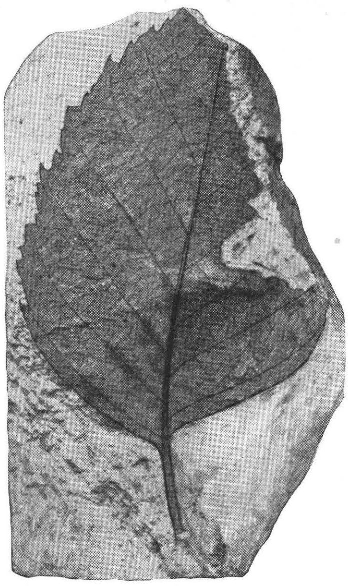

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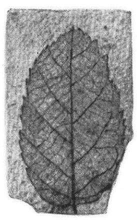

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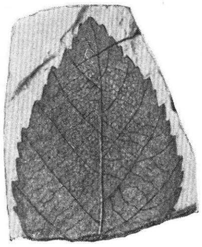

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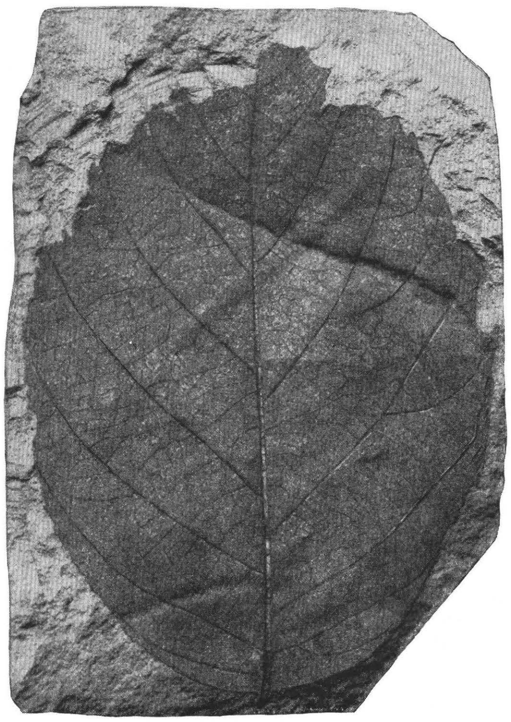

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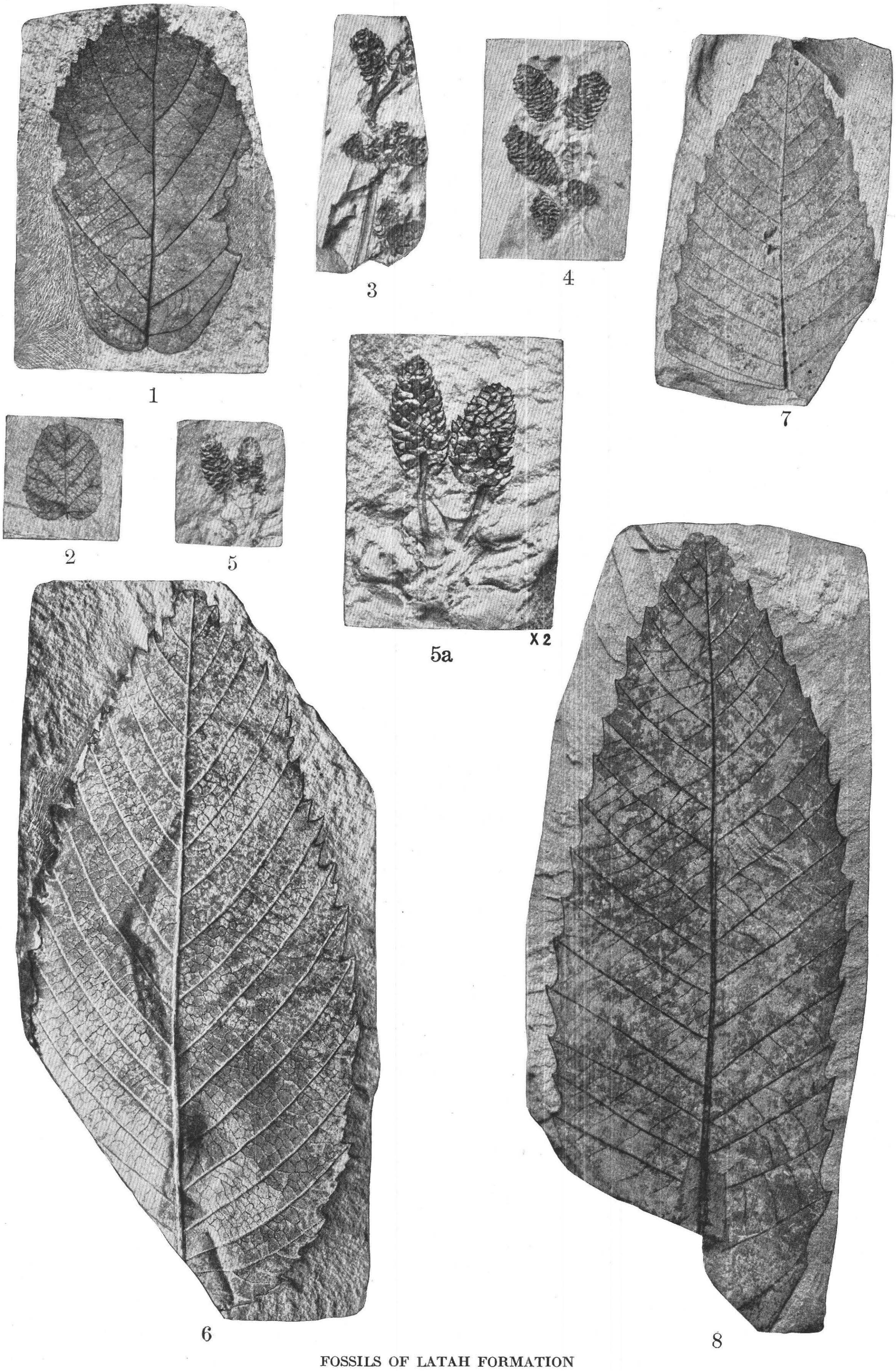


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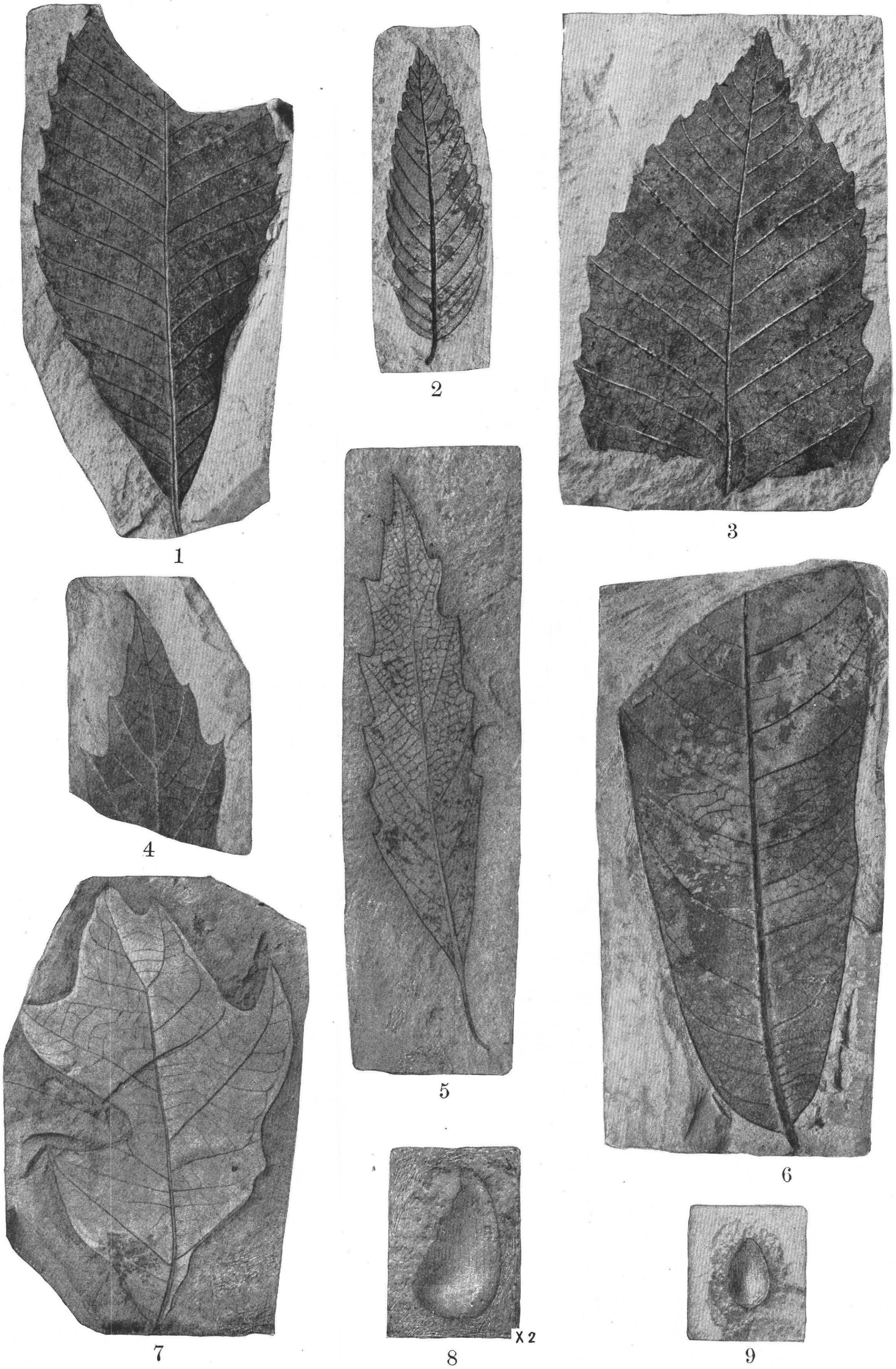


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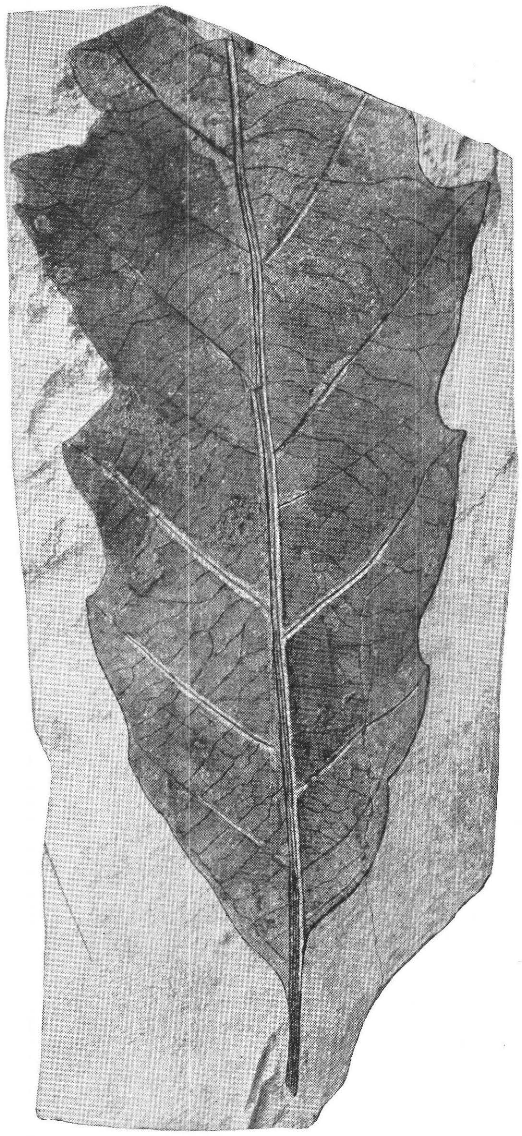

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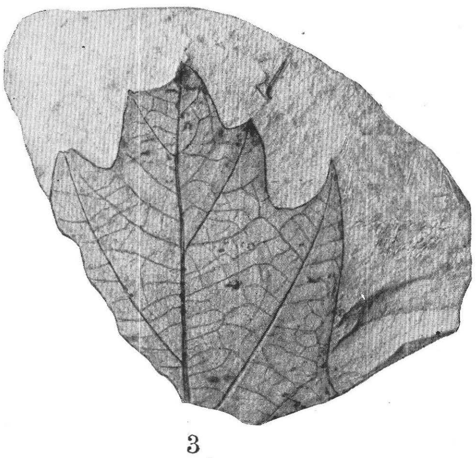

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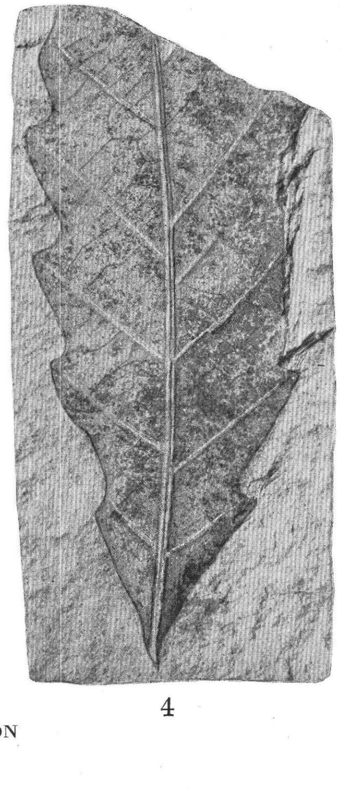

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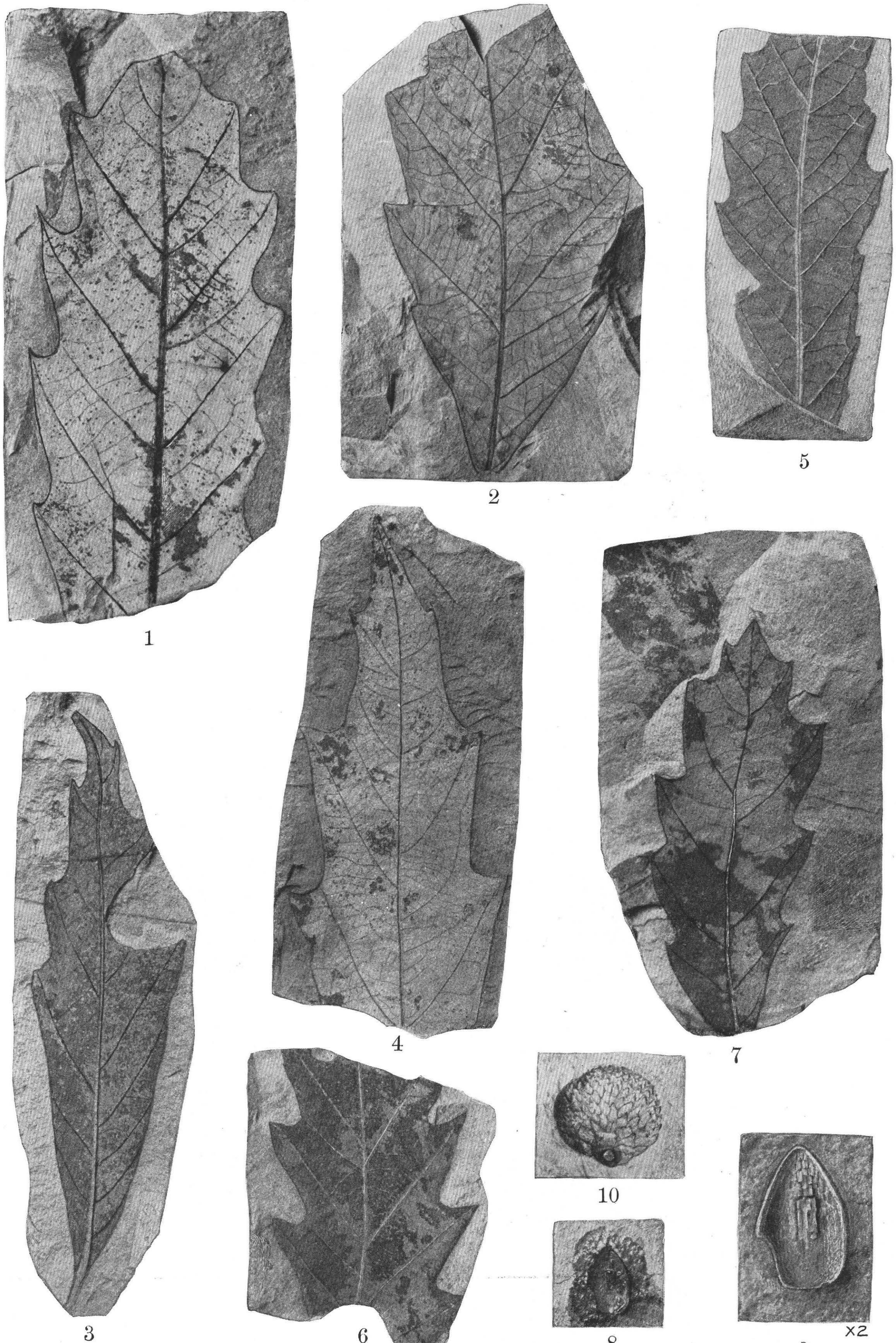


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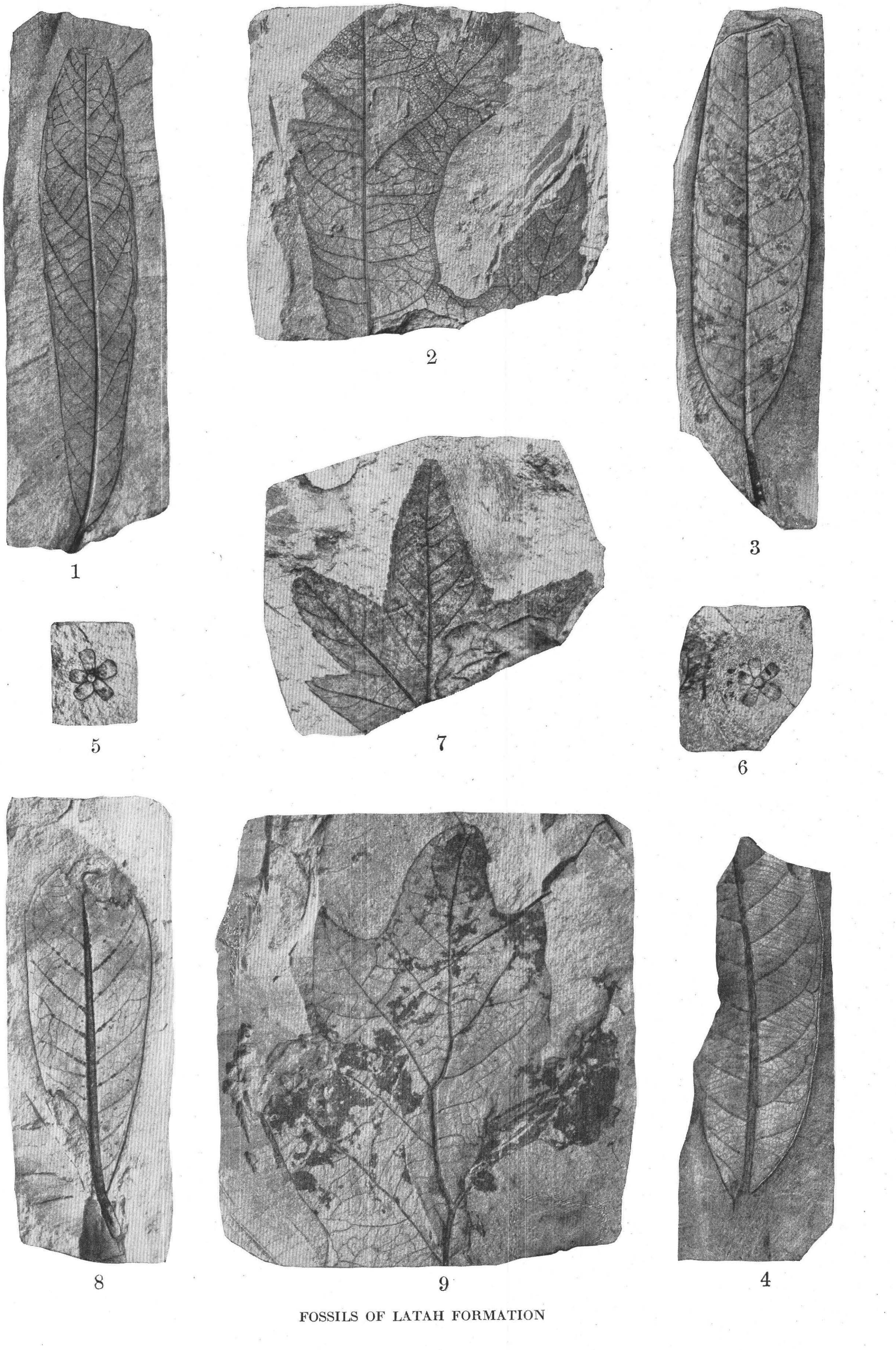


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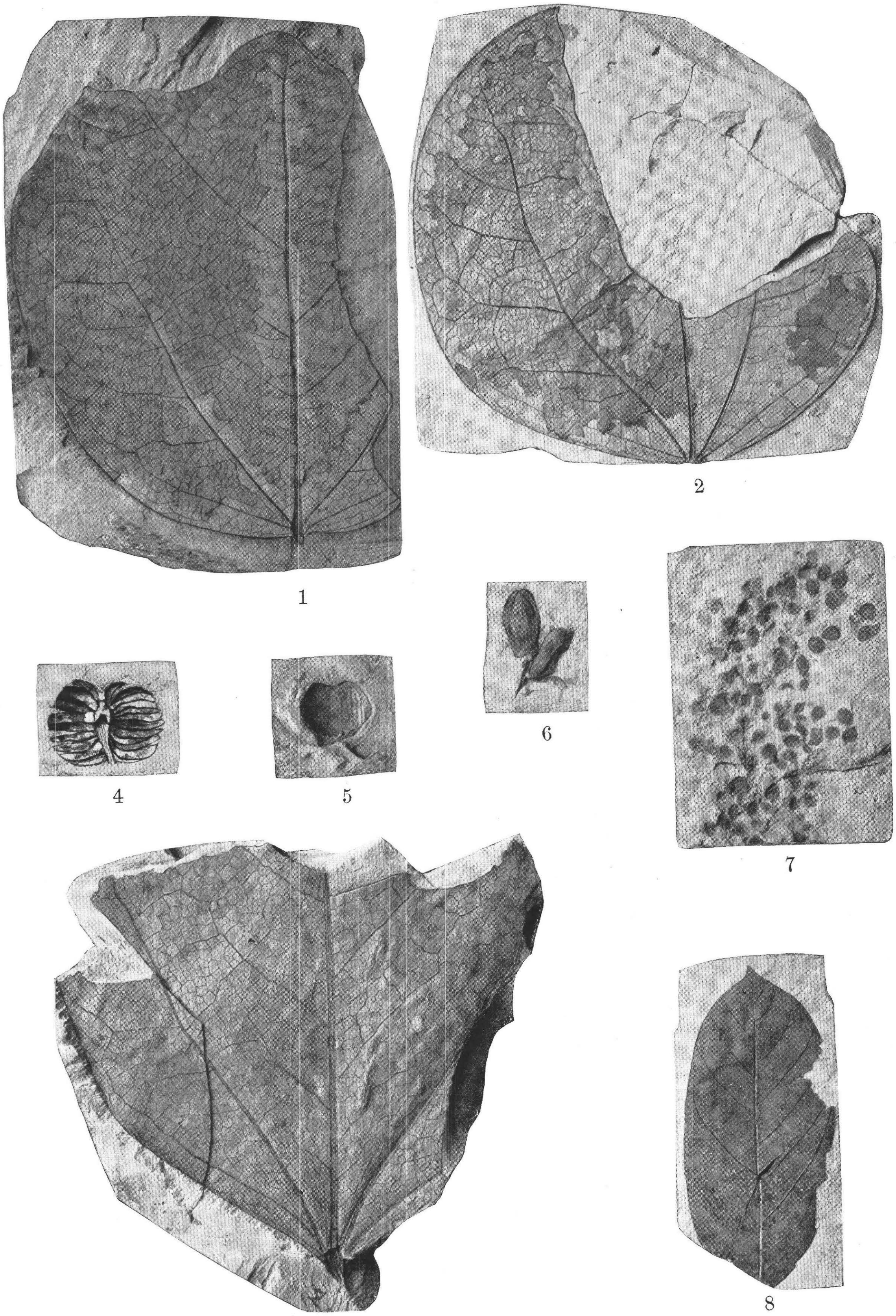


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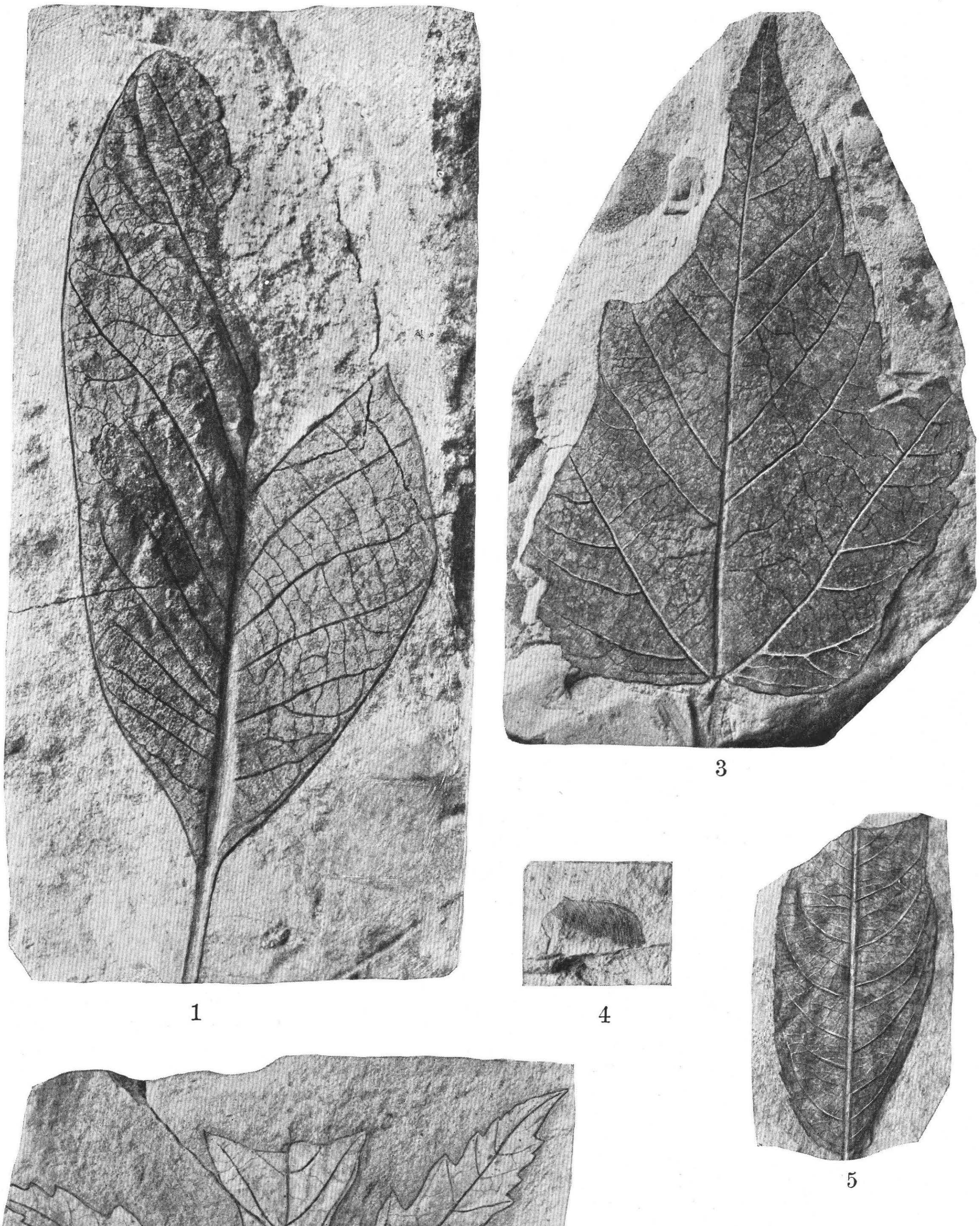


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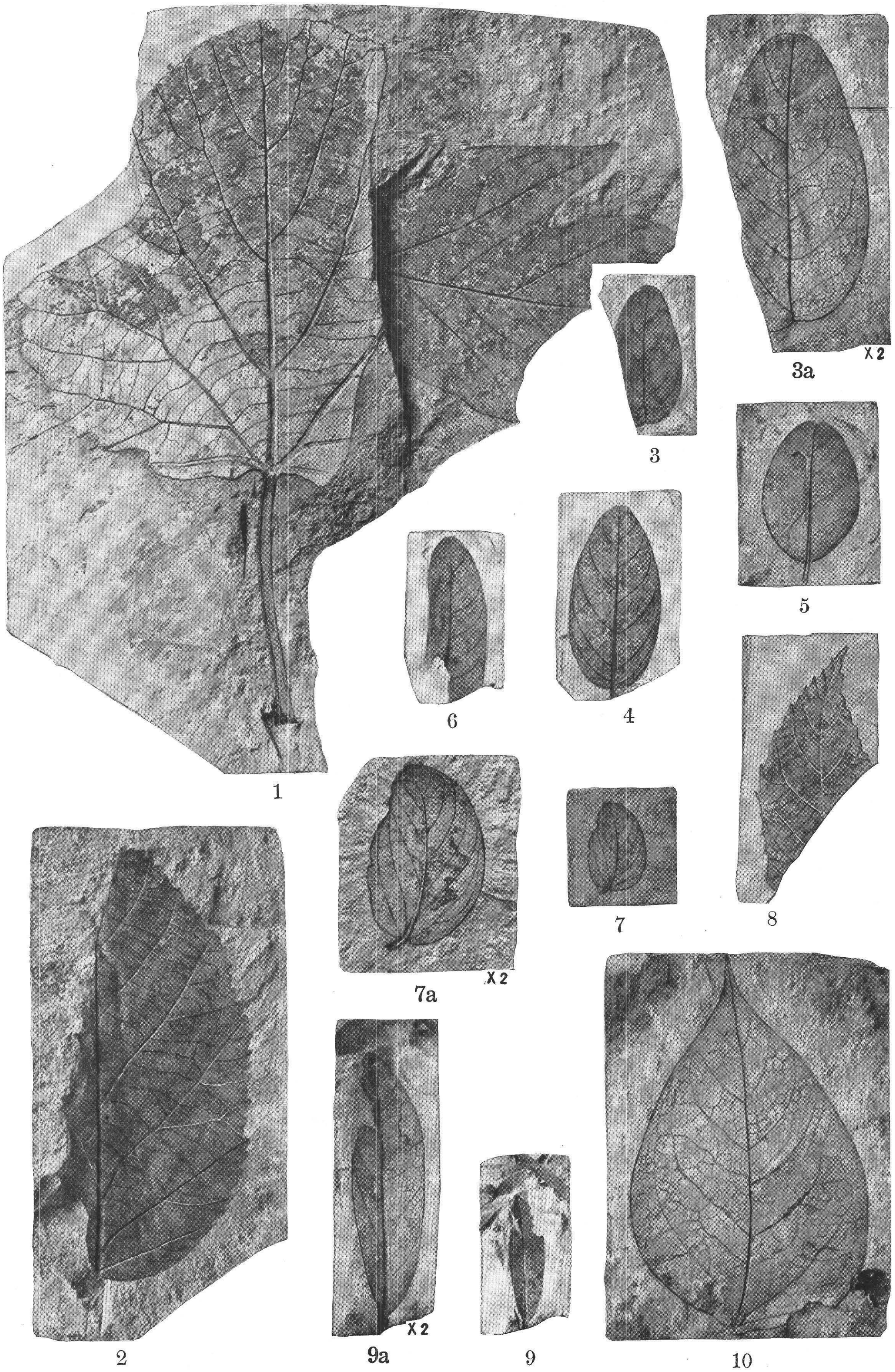


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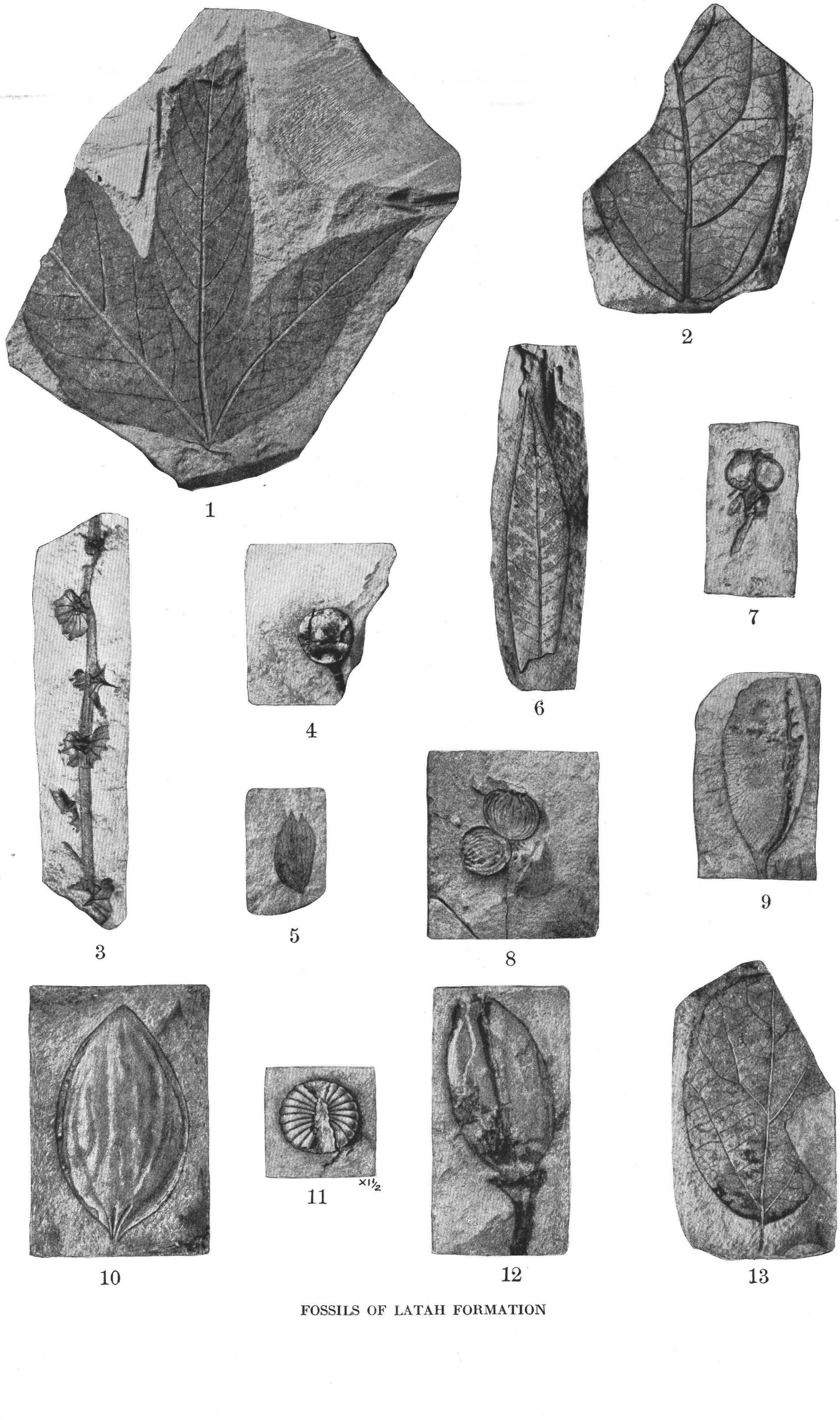


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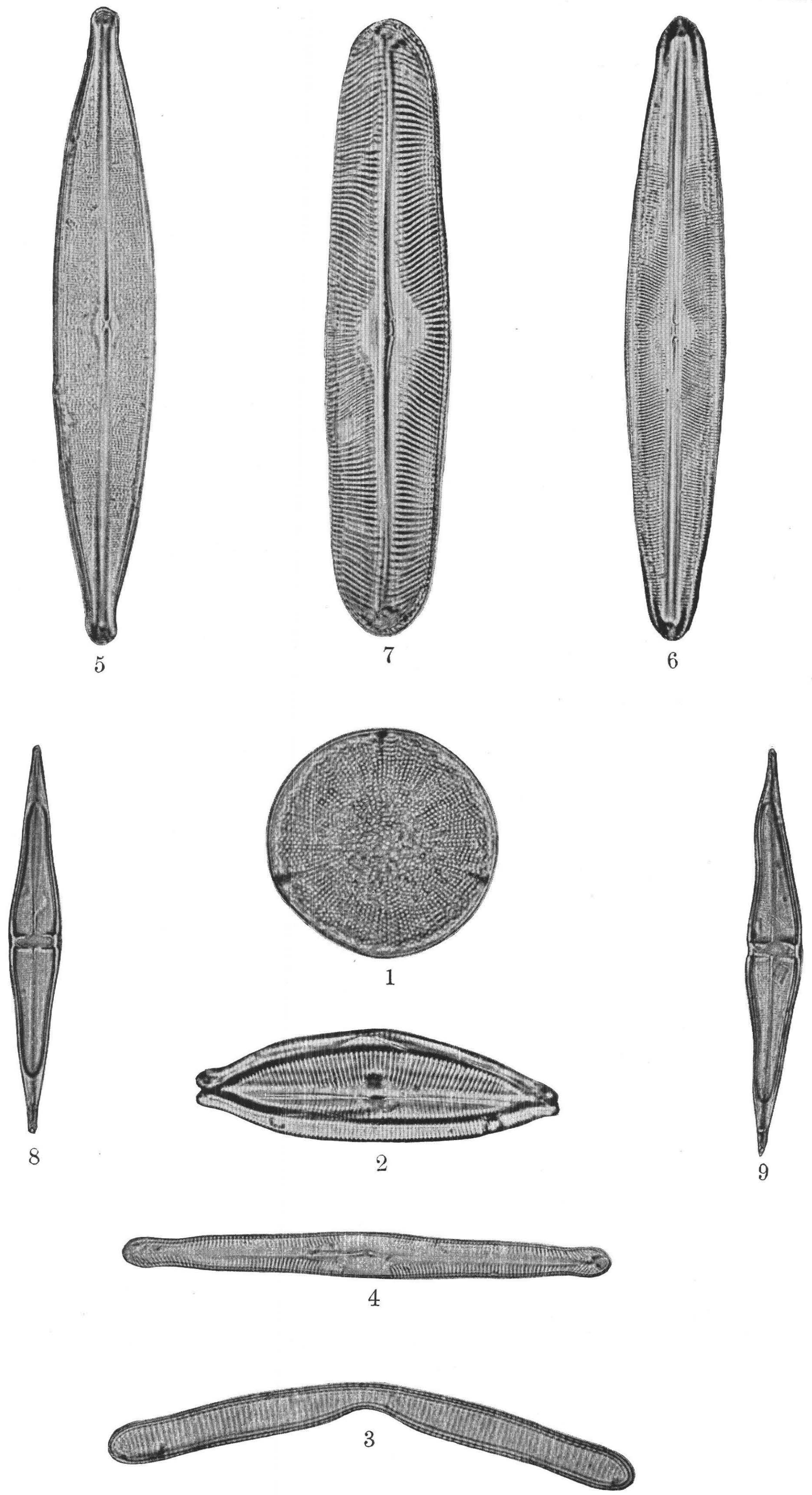
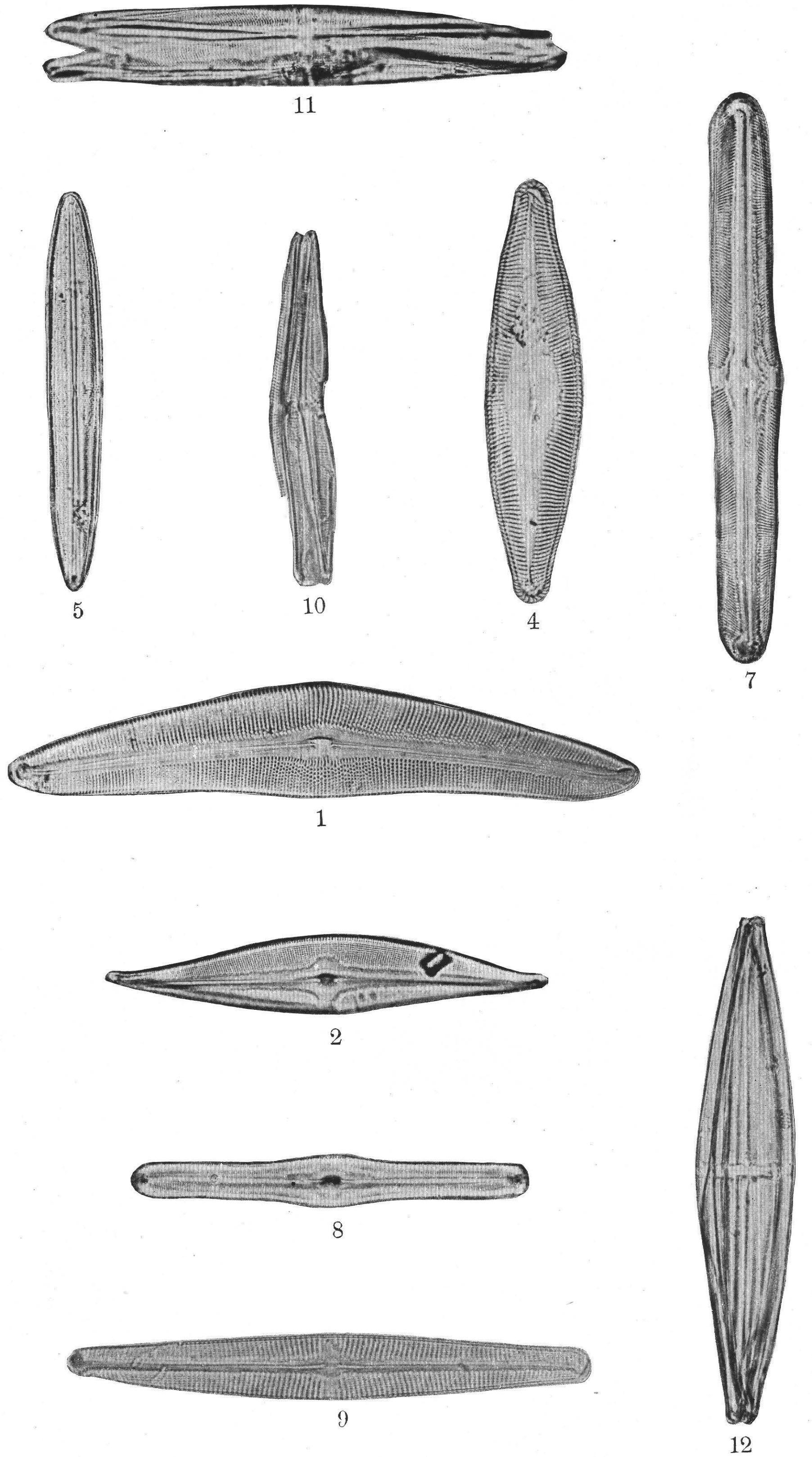



FOSSILS OF LATAH FORMATION




FOSSILS OF LATAH FORMATION

# PLATE XXXI

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|---|---|---|
| FIGURE 1. | *Cymbella partita* Mann, n. sp., × 500 | 53 |
| 2. | *Cymbella sagittarius* Mann, n. sp., × 570 | 53 |
| 3. | *Frustulia rhomboides* (Ehrenberg) De Toni, twins, face view, × 860. | |
| 4. | *Navicula contendens* Mann, n. sp., × 800 | 53 |
| 5. | *Navicula iridis* Ehrenberg, delicate dwarf variety, × 650. | |
| 6. | *Navicula pauper* Mann, n. sp., × 540 | 54 |
| 7. | *Navicula pontifica* Mann, n. sp., × 450 | 54 |
| 8. | *Navicula protrudens* Mann, n. sp., × 710 | 54 |
| 9. | *Navicula substauroneis* Mann, n. sp., × 680 | 54 |
| 10. | Same, twins, girdle view, × 440. | |
| 11. | *Stauroneis anceps* Ehrenberg, twins, girdle view, × 620. | |
| 12. | *Stauroneis phoenicenteron* Ehrenberg, twins, face view, × 410. | |