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GLACIATION IN ALASKA

By Stephen R. Capps

INTRODUCTION

The history of glaciation in Alaska offers a fascinating field for study. Because of the remarkable development and easy accessibility of valley and piedmont glaciers in the coastal mountains, Alaska has long been popularly conceived as a land of ice and snow, a concept that is only slowly being corrected. To the student of glaciation, however, Alaska affords a unique opportunity to observe the formation, movement, and dissipation of the many living glaciers, to examine the results of glacial erosion on a gigantic scale, and to discover and work out the sequence of Pleistocene events as shown by the topographic forms in both glaciated and unglaciated areas and by the deposits left by ice and water during earlier stages of glaciation.

The evidence for successive glacial advances in many parts of the world during Pleistocene time has been largely obtained in regions not far from the outer margin reached by the glaciers during the different stages. This is necessarily so, for that evidence consists mainly of the superposition of till deposits and their relations to one another, to preglacial, interglacial, and postglacial deposits, and to outwash materials laid down beyond the ice edge. Morainal deposits are best developed near the margins of glaciated areas, and it is therefore in such areas that observations having a significant bearing on recurrent glaciation are most likely to be made.

Alaska would thus seem to be a promising region for the study of the events of Pleistocene time. The Territory lies just west of the border of the great continental ice sheet, and although it was never itself overridden by glaciers of the continental type, its climate so closely approached that necessary for continental glaciation that all the higher mountain masses were severely glaciated. From the coastal mountains along the entire Pacific littoral of Alaska [1] glaciers descended to the sea. There, unfortunately, the evidence of the limits reached by the ice edge, as displayed by moraines, is submerged and not available for direct examination. Interior Alaska, on the other hand, presents a great driftless area, in the basins of the Yukon, Tanana, and Kuskokwim Rivers, where low relief and dry climate prohibited the formation of glaciers. This unglaciated region was encroached upon by the continental ice sheets from the east and by mountain glaciers from the north and south. Along its margins at several localities there have already been found evidences of glacial advances preceding the last great glaciation, and it seems certain that future studies will bring additional observations that will shed much light on the glacial history of the continent.

There is an extensive literature on glaciation in Alaska, yet in view of the great area of the Territory, the number and size of its living glaciers, and the extensive area covered by ice during Pleistocene time, it must be confessed that little more than a beginning has been made toward an adequate understanding of its glacial history. Each year since 1898 there have been a number of Geological Survey parties in the field, engaged for the most part in reconnaissance or exploratory surveys, with the result that about half the Territory has been mapped, and a fair knowledge of the extent of glaciation in the surveyed areas has been obtained. Many descriptions of living glaciers have also been published, and Tarr and Martin, as the result of three years of study under the auspices of the National Geographic Society, prepared an imposing volume [1a] that deals largely with the living glaciers along the Pacific coast and the lower Copper River. The literature is widely scattered, however, and it seems worth while to review our present knowledge of the subject. The details of mapping, as shown in the illustrations presented herewith, are in large part taken from the observations of members of the Alaskan branch of the Geological Survey.

EXISTING GLACIERS

Existing glaciers in Alaska cover an area of less than 20,000 square miles, or slightly more than 3 per cent

[1] As used in this paper the term "Pacific" does not include Bering Sea.

[1a] Tarr, R. S., and Martin, Lawrence, Alaskan glacier studies, 498 pp., Nat. Geog. Soc., 1914.

of the total area of the Territory. Plate 1 shows the largest of these glaciers, but there are probably several thousand small glaciers, from a fraction of a mile to several miles in length, that lie in unsurveyed areas or are too small to be shown on a map of this scale. The glaciers are almost exclusively confined to the coastal mountains, the Wrangell Mountains, and the Alaska Range. This distribution is in large part a response to high topographic relief but in part also to heavy precipitation. The coastal mountains reach altitudes of 15,300 feet at Mount Fairweather, 18,008 and 19,850 feet at Mounts St. Elias and Logan, and 6,000 feet in the southern part of Kenai Peninsula. The Wrangell Mountains have many peaks of 12,000 to 14,000 feet, and the more heavily glaciated portions of the Alaska Range reach 10,000 to 11,050 feet near Mount Spurr, 13,740 feet at Mount Hayes, and 20,300 feet at Mount McKinley. In the Brooks Range few peaks reach altitudes of more than 8,000 feet, with a possible maximum of 10,000 feet. The most active centers of glaciation to-day are therefore in places where high mountains lie within areas of heavy rainfall, as along the coast. High mountain areas of moderate rainfall are represented by the Wrangell and Talkeetna Mountains, which carry less extensive glaciers, and by the Alaska Range. The fairly high mountains of the Brooks Range, lying in a belt of scanty precipitation, have only a few small glaciers. That the extent of glaciation in past times was strongly influenced by the amount of rainfall, as it is to-day, is certain, and a realization of that fact is important to the understanding of the peculiarities of ice distribution during the last great ice advance in Pleistocene time.

For size, accessibility, and beauty the coastal glaciers of Alaska are in many ways unique. They have been studied by many competent geologists, and much has been written about them. Data concerning their movements are rapidly accumulating, and during the summer of 1929 the lower portions of nearly all the larger glaciers of southeastern Alaska were photographed from the air. These photographs will prove invaluable for the purpose of checking future changes in the positions of the ice fronts. Any adequate description of the hundreds of imposing glaciers of Alaska is far beyond the scope of this paper, but it should be kept in mind that the glaciers of to-day are but the shrunken remnants of the much greater glaciers of the past, that they have probably existed continuously from Wisconsin time to the present, and that many high valleys may have been continuously occupied by ice since early Pleistocene time.

FORMER GLACIAL ADVANCES

Plate 1 shows the areas in Alaska covered by glacial ice during the last great ice advance. During the time of maximum glaciation there were in Alaska two major areas of glaciation and many smaller ones. The largest area includes the Pacific coastal region and embraces all of southeastern Alaska, the Chugach, Wrangell, Talkeetna, and Kenai Mountains, the Alaska Range and its southern extension into the Alaska Peninsula, and the great basins of the Copper and Susitna Rivers and upper Cook Inlet. Next in size was the great glacier that occupied the entire Brooks Range, in northern Alaska. The other areas in which glaciers occurred are scattered throughout central and southwestern Alaska and Seward Peninsula, and all are small.

The great ice mass that occupied southern and southeastern Alaska, though connected toward the east with the continental ice sheet, was entirely independent of that sheet as to its source of ice supply, the directions of ice movement, and its persistence. It was fed solely by glaciers that had their origin within its own area, and its lines of flow were directed by the mountain topography within that area. Throughout Alaska as a whole the balance between temperature and precipitation was such that glaciers could form and grow only in the higher mountains, and even there the size and vigor of the glaciers depended in large degree upon the abundance of precipitation. The distinction, therefore, between the Alaska glaciers and the contemporary continental glaciers in former stages of ice expansion was that in Alaska each of the larger glaciers was formed by the coalescing of a great number of individual valley glaciers, each of which responded to the accretion of ice within its own basin and moved down its own mountain valley in a way that was largely independent of the movement of its neighboring ice streams. It was only because these adjoining mountain glaciers grew to so large a size that they coalesced to form nearly continuous ice caps. Even at their maximum, however, there were high peaks and dividing ridges that separated them from one another, and it was only in those places where the individual ice streams emerged from the mountains onto the lowlands that they joined and lost their individuality.

In Plate 2 an attempt has been made to show the lines of flow in the two larger glaciated areas. The arrows indicate the direction of flow of various threads of ice within the areas where the ice formed a practically continuous cap, with only the highest peaks and ridges projecting above its surface. The dotted lines indicate the divides between the glaciers that moved south and those that moved north and west.

In southeastern Alaska, south of Cross Sound, the threads of flow had in general a southerly direction, being influenced by the preglacial topography, which in turn was determined by the trend of the rock structure. I know of few more striking physiographic features than the great fiord formed by Chatham Straits and Lynn Canal, cutting obliquely across a rugged mountain region in a straight line for 250 miles. The riddle of this great fiord has not yet been entirely solved, but it is known that a great preglacial structural valley was widened, deepened, and straightened by ice scour and that faulting had much to do with the establishment of the preglacial drainage lines.

On the southern slope of the St. Elias, Chugach, and Kenai Mountains the ice threads in general followed direct courses to the sea. On the inland slopes more complex flow patterns were developed. Between the arc of the Chugach Mountains, which form a barrier along the coast, and the great curve of the Alaska Range, farther north, there is a region of milder relief containing the basins of the Susitna and Copper Rivers but broken by two separate mountain groups, the Wrangell and Talkeetna Mountains. Into these basins ice poured down from all the surrounding highlands and from the Wrangell and Talkeetna Mountains as well, until the lowland was filled with ice that sought outlets through the gaps that offered themselves. The lowest outlet to the coast was by way of the Susitna Basin, toward which most of the threads of flow converged, but at the time of maximum ice development lobes spilled over the basin margins into the valleys now occupied by the Copper, Nenana, and Delta Rivers, through Mentasta and Suslota Passes, and probably also into the valley of the Nabesna River by way of Jack and Platinum Creeks. Through the rim of the intermontane basin these overflow lobes eroded deep valleys, which were later utilized by the draining streams of the glaciers as the ice shrank in retreat. This eventually resulted in the capture, by the Copper, Nenana, and Delta Rivers, of drainage areas within the intermontane basin, and we now have the unusual condition of rivers draining mature headward basins through youthful canyons carved directly across high mountain ranges. Although the Copper River now drains a large area between the Chugach and Alaska Ranges, it is quite evident, from the topographic youth of the part of its valley cut through the Chugach Mountains as compared with the maturity of the part north of the coastal range, that the drainage discharge from the upper basin of the river formerly found some other course to the sea. That course doubtless was by way of the Susitna Basin and probably lay north of the Talkeetna Mountains. The working out of this great change of drainage has been complicated by Pleistocene or post-Pleistocene warping, and the details are not yet known.

Another anomaly occurs at the head of the Delta River, which has its origin in a large glacier. That glacier lies on the south slope of the Alaska Range and would normally be expected to drain to the Copper River. The Delta River has built up a gravel train that splits, a part sloping southward toward the Copper River and a part draining into the Delta, which flows northward through a narrow glacial valley directly across the Alaska Range to empty into the Tanana River. The waters from the melting Delta Glacier therefore flow at times by way of the Copper River to the Pacific and at times by way of the Yukon tributaries to Bering Sea. On occasion the stream splits, part flowing one way and part the other, so that a salmon could conceivably ascend the Copper and Gulkana Rivers, enter the head of the Delta, and descend to Bering Sea, crossing a great mountain range on the way.

In Plate 2 the dotted line indicates the divide between the ice streams that drained to Bering Sea and those that sent their waters to the Pacific. In a general way this divide follows the crest of the Alaska Range. As plotted it ignores the ice spillways through the range at the passes noted above, as it is impossible to estimate how large an area of the ice in Copper and Susitna Basins drained northward through these passes. For a part of the way the ice divide follows the crest of the Wrangell Mountains, whose northward-flowing glaciers crossed the Nutzotin Mountains through the canyons of the Nabesna and Chisana Rivers.

A striking fact is the meager development of the Pleistocene glaciers on the north side of the Alaska Range between the Tonzona River and Mentasta Pass as compared with those on its south side. This same discrepancy is shown by the glaciers of to-day. It is due in part to the asymmetrical position of the crest of the range. On the north slope the mountains rise steeply from the lowlands to the summit peaks, and the belt of high mountains in which ice accumulation can take place is narrow. Furthermore the mountain glaciers within a few miles of their source move out into a relatively low, arid lowland, where dissipation is rapid. By contrast, the mountain belt on the south side of the range is wider from the divide to the lowlands, there is a greater area for ice accumulation, and the basins into which the glaciers emerge are higher and less arid. A second fact, perhaps of equal importance, is the difference in the amount of precipitation on the two slopes. No accurate records are available for points on the mountain slopes, but throughout the Susitna Basin as a whole the average precipitation is several times as great as in the Tanana Basin. The winds that strike the Alaska Range from the west have already passed over several hundred miles of dry, rolling country and have lost a considerable part of their moisture content. The moist winds from the Pacific, on the other hand, blowing up Cook Inlet, are trapped between high surrounding mountains and drop much of their moisture on them.

The great ice cap that covered the Brooks Range was likewise independent of the continental ice sheet in supply and in direction of movement. It may or may not have been connected with the continental sheet near the mouth of the Mackenzie River. The Brooks Range lies in a difficultly accessible part of

Alaska, and the geologic studies made there have all been of reconnaissance or exploratory character, so that many details of its glacial history are yet unknown. The outline of the glaciated area as shown on Plate 2, however, is believed to approximate the truth. Like the great ice cap to the south, this one was composed of numerous valley glaciers which flowed out radially from the mountains but which at the time of their greatest extent filled adjoining valleys and coalesced to form a nearly continuous ice cap, above whose surface only the highest summits projected. In general, the southward-flowing ice threads appear to have been longer than those that flowed to the north. The direction of flow of each thread was entirely controlled by the topography of its mountain valley.

Between the northern and the southern ice caps have been found about a score of localities in which glaciers of minor extent existed during the time of the last great ice advance. All but one or two of these places consist of a high mountain or group of mountains upon which one or two small valley glaciers were able to form during the period of maximum glaciation. These glaciers were comparatively short-lived and have now disappeared entirely. A single area of considerable size is that lying between Bristol Bay and the lower Kuskokwim River, where such scanty information as is at hand indicates a center of notable mountain glaciation.

Plates 1 and 2 portray the distribution of glaciers in Alaska during the Wisconsin glacial stage in so far as they covered land areas. An interesting but more difficult problem is that of determining how far the ice of southern and southeastern Alaska pushed out to sea at that time. An examination of maps of the Antarctic ice cap and the adjacent ocean basins shows that the ice barrier there, in places where its face is 50 to 80 feet high and its thickness therefore not more than 400 to 600 feet, projects out into oceans that are as much as 2,000 feet or more deep. The glacial ice therefore projects as an overhanging shelf far out over deep water, although still firmly attached to the landward portion of the glacier.

On the Pacific coast of Alaska there is abundant evidence that during Wisconsin time glaciers pushed out to the open sea at many places. Even now the great piedmont lobes of Malaspina and Bering Glaciers extend close to the open coast, and very little expansion would be necessary for them to advance to the sea. Similarly many glaciers between Cross Sound and Yakutat Bay, as well as many ice tongues in southeastern Alaska, Prince William Sound, and Kenai Peninsula now extend almost or quite to tidewater. Any increase in size of the glaciers along the coast comparable to that which took place elsewhere in Alaska in Wisconsin time would have caused hundreds of glaciers to push their snouts out to sea and there to expand and coalesce into an ice barrier comparable to that now found along the borders of the Antarctic Continent. It seems to me very likely that such a barrier did exist. Plate 2 indicates the position of the 100-fathom contour along this coast. At most localities where large valleys emerge at the coast there are deep channels across the continental shelf, such as those between Afognak Island and the mainland of Kenai Peninsula; at the entrance to Prince William Sound between Hinchinbrook and Montague Islands; and at Yakutat Bay, Cross Sound, Christian Sound. Iphigenia Bay, and Dixon Entrance. The formation of these channels seems to demand some strong erosive force, and glacial ice is known to have moved out from shore at many if not all of these places. Tarr and Martin [2] concluded that no ice more than 400 feet thick issued out to sea between Hinchinbrook and Montague Islands, basing this conclusion upon the height to which they found erratic boulders on the south end of Hinchinbrook Island. They also concluded that ice passing southward along the west shore of Montague Island barely issued into the open sea. I am inclined to doubt the validity of their conclusions on these points. A study of the glacial smoothing on the south end of Hinchinbrook Island, as seen from a ship passing into Prince William Sound, seems to indicate rather distinctly that ice scoured the south end of that island to a height of several times 400 feet, at least. The 100-fathom channel extending southward from that entrance certainly suggests glacial erosion of the bottom, and reported deposits of glacial till and boulders on Middleton Island indicate the possibility that ice pushed out some 60 miles to sea across the shoal within the 50-fathom line, shown on Plate 2.

At a great number of places within the glaciated areas of Alaska observations have been made as to the thickness reached by the ice during the time of maximum Pleistocene glaciation. This information is difficult to show on maps of the small scale necessary for publication here, but the glaciated mountain forms, hanging valleys, erratic boulders, and many other accepted types of evidence indicate convincingly that valleys now free of ice held in Wisconsin time glaciers 5,000 feet and more in thickness, and it seems reasonable to believe that over the entire glaciated area, as shown in Plate 1, the Wisconsin ice had an average thickness of half a mile.

EVIDENCE OF WISCONSIN AGE OF LAST GREAT ICE ADVANCE

It has been assumed in the foregoing pages that the last great ice advance in Alaska was contemporaneous with the Wisconsin stage of glaciation in the northern United States. There is evidence of several kinds to support this assumption. The uneroded character of morainal deposits, which still show kettle and hummock topography little modified by postglacial ero-

[2] Tarr, R. S., and Martin, Lawrence, Alaskan glacier studies, p. 469, 1914.

sion; the abundance of polished and striated rock surfaces and erratic boulders in a region where exfoliation and weathering are rapid; and the unoxidized character of the glacial till all point to a relatively recent date for the last great glaciation. All such evidence indicates comparative youth but is not sufficient to assign to these phenomena an age stated in years.

In the basin of the White River, near the international boundary, however, excellent exposures along a newly cut river bluff reveal evidence that makes it possible to date rather accurately the time of the glacial retreat past that place.[3] The locality is not far from the source of the river in Russell Glacier. This glacier is a large and vigorous ice stream that draws its ice supply from the high mountains of the Wrangell and St. Elias group. It may fairly be considered an average example of the glaciers of that region, and its history must have been much the same as that of similar glaciers in that part of Alaska.

About 8 miles below Russell Glacier, on the north bank of the White River, that stream has cut a bluff over a mile long and 50 to 70 feet high. A typical section there exposed is shown in Figure 1. At the base of the bluff is 30 feet of unconsolidated and unoxidized glacial till, with an uneven, rolling surface. Above the till and extending to the top of the bluff is 39 feet of fibrous, peaty vegetable material, full of spruce stumps and roots but composed for the most part of the remains of sphagnum moss. This heavy deposit of peat is interrupted, some 7 feet below the top of the bluff, by a 2-foot layer of white volcanic ash. The surface of the bench, back from the bluff, is covered with living sphagnum moss and a dense forest of spruce trees. At the time of visit, in July, till, peat, and ash were frozen within a few inches of the surface along the face of the bluff, and in the forest permanent ground frost was found 6 inches beneath the surface of the growing moss. The cut bank has a vertical to overhanging face, and erosion takes place by the formation of great, clean vertical cracks through the frozen peat and the falling outward of large tree-covered blocks, which tumble down to the stream level and are gradually thawed and removed.

The peculiar appearance of the roots of the spruce trees that grow on the edge of the bluff and of the stumps that occur through the peat deposit suggested that it might be possible to determine approximately

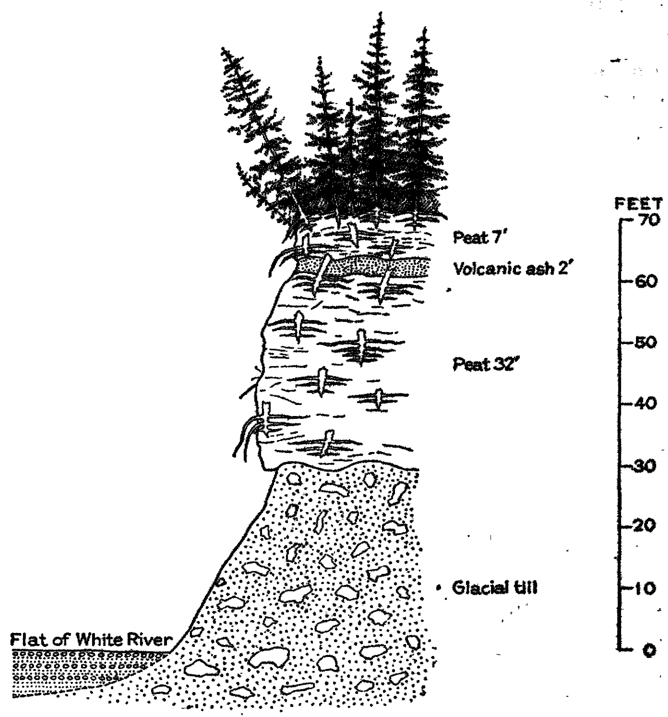

FIGURE 1.—Typical section of peat and glacial till on the White River, Alaska, 8 miles below the terminus of Russell Glacier

the rate of accumulation of peat at this place and so determine the time that has elapsed since the ice withdrew from its moraine here and thus permitted reforestation. The ordinary spruce tree, growing on solid ground, either frozen or unfrozen, sends its roots out radially, parallel with the surface of the ground and only a few inches below the surface. (See fig. 2.)

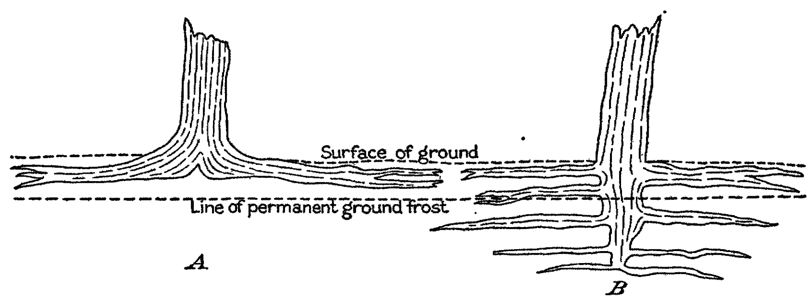

FIGURE 2.—Diagrams showing the character of the roots of a spruce tree (A) growing normally on solid ground and (B) growing on rapidly forming peat, White River, Alaska

Uprooted stumps of this kind are a familiar sight. In the White River locality here described, however, the roots of the spruce trees, both those growing at the edge of the bluff, or recently overturned, and those deeply buried within the peat mass, show quite different characteristics. Instead of a single, flat-based set of radial roots, each of these trees shows a central stem, a sort of taproot, from which radial roots branch off at irregular intervals, with an upper set of roots near the surface corresponding to those of the normal tree. Around the living trees the ground was frozen 6 inches below the top of the moss. Below the frost line the roots were sound and undecayed, but they were of a darker color than the live surface roots and were apparently not functioning. It is evident that the living tree derives its nourishment from the ground only

[3] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pp. 69–75, 1916.

through the roots in unfrozen ground near the surface, and that the lower roots cease to function as soon as the line of permanent frost rises above them.

From the facts stated above it appears that a seedling spruce, having established itself on the mossy soil of this area of rapidly accumulating vegetable material, sent out a set of radial, flat-based roots in the ordinary way, but the constantly thickening moss and the consequent rise in the level of ground frost cut off the food supply from the lowest roots and forced the tree, in its efforts to survive, periodically to throw out new sets of roots into the unfrozen surface soil. If these premises are correct, then the vertical distance between the lowest set of horizontal roots of a living tree and the surface of the ground represents the thickness of the peaty accumulation during the lifetime of the tree, and the rate of accumulation can be determined by ascertaining the age of the tree, as shown by the annual rings.

Any figures for the rate of accumulation of the peaty deposit that were obtained in the way outlined are subject to a number of uncertainties. Most of the qualifying factors, however, fall on the side of conservatism and result in a minimum rather than a maximum figure. Among the unweighed factors is the possibility that the peaty material is compressed after burial. The amount of such compression, however, is probably very small, for the peat is permanently frozen within a foot or less of the surface and has remained so since its formation. Another factor that might affect the rate of accumulation is the quantity of wind-blown sand, which is noticeably present near the edge of the timbered bench. Throughout the deposit as a whole, however, the percentage of wind-blown material seems to be fairly uniform. Other elements of uncertainty appear to be of so small importance as to affect the calculation but little.

From ring counts on a number of trees and from measurements of the distance between the lowest and uppermost radial roots on the same trees, it was determined that the peaty material is now accumulating at a rate of about 1 foot in 200 years. It seems that this factor may be safely applied to the whole thickness of 39 feet of peat, from which we arrive at a figure of 7,800, or, in round figures, 8,000 years since the ice of Russell Glacier withdrew beyond this point. Even if this figure is admitted to be 50 per cent in error, it still gives a basis for calculation.

At the time of its maximum extension Russell Glacier, according to Hayes, extended northeastward about 130 miles beyond its present terminus. Its retreat to the peat deposits described above, which lie about 8 miles below the end of the present glacier, was therefore 94 per cent of its total retreat. So far as time is concerned, it is quite possible that the glacier retreated much more rapidly during the earlier stages of shrinking than during the later stages. For the last 35 years the ice edge has remained practically stationary.

Various estimates have been made of the length of time since the Wisconsin continental ice sheet began its retreat, but the consensus of opinion seems to place that time as somewhere between 30,000 and 60,000 years. The determination made in the White River Valley, at a point that was not bared until a large part of the retreat had been accomplished, is of the same order of magnitude, and it seems safe to say that the last great ice advance in Alaska was contemporaneous with the late Wisconsin continental glaciation.

PRE-WISCONSIN GLACIATION

As the last great glaciation in Alaska is thus regarded as of late Wisconsin age, the question arises as to what were the conditions in this region during the earlier stages of Pleistocene glaciation elsewhere on the continent. Information on that question must be sought mainly in the superposition of glacial and interglacial deposits, and in a frontier country where road, railroad, and other extensive excavations are few and where little more than a beginning has been made in the study of such subjects, facts that bear on this problem come to light only infrequently. Furthermore, there is evidence in Alaska, where the Pleistocene glaciation was almost entirely mountain glaciation, that the last ice advance was more vigorous than the earlier ones, with the result that the last glaciers destroyed much of the evidence of the work that may have been done by their predecessors. Nevertheless, at several localities evidence has been found of Pleistocene glaciation that antedated the ice of the Wisconsin stage. (See pl. 1.)

On the southern flanks of the St. Elias Mountain mass there occurs in the Chaix Hills, as described by Russell,[4] and in the Robinson Mountains, as described by Maddren,[5] a thickness of 2,000 to 5,000 feet of beds that are, in part, at least, of glacial origin, and that carry Pleistocene marine fossils. These beds are now uplifted to altitudes as great as 5,000 feet and are interesting in showing the active growth of the St. Elias Mountain mass. As evidence of a glacial stage earlier than the Wisconsin, however, they have less significance, and unless a more accurate determination of the age of the inclosed fossils can be made, their correlation must be vague. Both these ranges of hills lie within an area that is even now severely glaciated, and they are at least partly surrounded by the great piedmont ice lobes of Bering and Malaspina Glaciers. In other words, that area of high mountains is even now in a glacial period and may well have endured glacial conditions continuously since the beginning of the

[4] Russell, I. C., Second expedition to Mount St. Elias, in 1891: U. S. Geol. Survey Thirteenth Ann. Rpt., pt. 2, pp. 24–26, 1893.

[5] Maddren, A. G., Mineral deposits of the Yakataga district: U. S. Geol. Survey Bull. 592, pp. 131–132, 1914.

Pleistocene epoch or even longer. The glacial beds of the Robinson and Chaix Hills are therefore as likely to have been laid down during a time of small ice development as during a time of ice expansion and thus can not be correlated with any definite stage of Pleistocene glaciation.

Another locality at which evidence of glaciation antedating the Wisconsin has been found [6] is in the valley of the White River, 5 miles north of the snout of Russell Glacier. Foothills adjoining the main mountain mass of Carboniferous lavas and sediments show a section of more than 3,000 feet of tilted beds of glacial and glacio-fluvial origin. Ten distinct beds of tillite or of till were recognized, separated by beds of gravel and of finer clastic sediments. Most of the beds of till have been indurated to form hard tillite and have been etched into high relief by erosion. They contain abundant beautifully striated and faceted boulders, cobbles, and pebbles. In places the tillite was overridden and smoothed by glacial ice during the Wisconsin ice advance. It is, therefore, old enough to have been indurated, uplifted, and eroded before Wisconsin time. It is impossible, with the information now at hand, to correlate this older glacial material with any definite stage of Pleistocene glaciation. Indeed, there is no positive evidence that it is of Pleistocene age, though I am inclined so to assign it. Certainly it greatly antedates the Wisconsin stage. In view of the known activity of mountain growth in this part of Alaska, the uptilting could have occurred in Pleistocene time, and comparatively recent volcanism in this region, together with the stresses of tilting, may have resulted in the induration of some of the beds.

As regards the evidence from this locality in respect to the extent of the glaciation represented by those beds, no great extension of the ice from its present stand would be required to reach the localities where the older tillite occurs. Indeed, the whole aspect of this deposit suggests that it may have been formed near the oscillating edge of a glacier, repeated advances being represented by layers of till and retreats by deposits of gravel, sand, and silt. The deposit can be said to show only that glacial conditions existed in that part of Alaska at some time long before the Wisconsin advance.

A third area in which older glacial deposits have been found occurs along the valley of the Nenana River, some distance beyond the point where that river leaves the mountains but where it is still bordered by foothills. High ridges of Tertiary gravel, standing 2,600 feet above the level of the Nenana River, contain on their surface numerous large boulders and erratic blocks that many geologists agree are of glacial origin. These boulders are found as far as 25 miles north of the recognized moraines of Wisconsin age and indicate that during some pre-Wisconsin glacial stage a vigorous ice tongue pushed northward from the range at least 25 miles farther than the Wisconsin ice and that at the point where the Wisconsin ice terminated the older glacier had a thickness of at least 2,600 feet. Although the erratic boulders left by this earlier glacier have suffered somewhat from weathering and are less fresh in appearance than glacial boulders of Wisconsin age, they are nevertheless still firm and little decayed and are more likely to belong to a late pre-Wisconsin stage than to an early one.

Still another locality at which evidences of pre-Wisconsin glaciation have been found is on the west flank of the Alaska Range, in the basin of the Mulchatna River. During the summer of 1929 the writer found there a deposit of deeply oxidized and weathered material that in composition, lack of assortment, and shape of included boulders and blocks seems certainly to represent a glacial moraine. The included boulders and rock fragments, however, are all so weathered and decomposed that their original surfaces have been lost. No striae were found, but few of the rocks were firm enough to retain striae. I believe this deposit to be a remnant of an ancient glacial moraine. It is now overlain by several hundred feet of fresh, unoxidized glacial till that forms a lateral moraine left by the Wisconsin glacier. This weathered deposit also, though certainly representing a stage of Pleistocene glaciation older than the Wisconsin, can not be definitely correlated with any particular glacial stage.

SUMMARY OF KNOWN FACTS CONCERNING PRE-WISCONSIN GLACIATION IN ALASKA

The main purpose of this paper is a discussion of Pleistocene glaciation in Alaska, but it seems well to mention briefly here reported occurrences of pre-Pleistocene ice invasions.

Cairnes [7] in 1914 described a conglomerate, thought by him to be of Carboniferous age, occurring at a locality on the Alaska side of the international boundary just north of the Yukon River. He thought that this formation might be of glacial origin, though he admitted that the question was still open. Mertie,[8] after later studies of the same formation, determined its age to be Cambrian or pre-Cambrian and concluded that its glacial origin was not yet established. If this material is glacial, it represents the oldest glaciation of which evidence has so far been found in Alaska.

Unpublished manuscript notes by Eliot Blackwelder refer to a body of tillite, containing polished and scratched pebbles, on the Yukon River near Woodchopper Creek and to an unbedded clay slate, studded with chunks and pebbles of other rock, on Beaver

[6] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pp. 63-69, 1916.

[7] Cairnes, D. D., The Yukon-Alaska international boundary, between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, pp. 91-93, 1914.

[8] Mertie, J. B., jr., Geology of the Eagle-Circle district, Alaska: U. S. Geol. Survey Bull. 816, pp. 24-28, 1930.

Creek. He thought that both these occurrences represented glacial deposits and tentatively guessed their age to be Cambrian. Mertie,[9] thinks that the first of these formations is of Devonian age and the other late Silurian, and he doubts the validity of Blackwelder's conclusion as to their glacial origin.

Kirk[10] describes a Silurian conglomerate occupying a considerable area on Prince of Wales Island and neighboring islands in southeastern Alaska which has locally a thickness of 1,000 to 1,500 feet and in which he found abundant faceted and striated boulders. He entertained no doubt that this is a glacial deposit.

Kirk further describes faceted pebbles in a limestone of Middle Devonian age on Prince of Wales Island and rounded boulders in Lower or Middle Devonian sediments near the north end of Chichagof Island, to which he doubtfully attributes a glacial origin.

At still other localities in southeastern Alaska, as at Pybus Bay, on Admiralty Island, and on the Screen Islands, off the west shore of Etolin Island, Kirk found faceted but no striated pebbles in beds of Permian age that he thinks may be glacial.

Blackwelder[11] considers certain conglomerates of the Yakutat series, in the mountains east of Yakutat Bay, to be glacial deposits, and the boulders in associated shales to have been dropped by icebergs. These rocks, according to Blackwelder, have been assigned to the Jurassic by Ulrich, though C. W. Wright thought they were probably of late Carboniferous age.

It will thus be seen that the evidence of pre-Pleistocene glaciation in Alaska includes a questionable tillite of Cambrian age near the international boundary in Yukon Basin; one fairly well established occurrence of tillite in the Silurian of southeastern Alaska, and a less certain one in the late Silurian of the Yukon Basin; questionable occurrences of Devonian age in the Yukon region and in southeastern Alaska; a doubtful occurrence of glacial material near Yakutat that may be of Carboniferous or of Jurassic age; and a possible glacial deposit of Permian age in southeastern Alaska.

To summarize the evidences of glaciation in Pleistocene time before the Wisconsin stage, we now know of tillite, indurated and uplifted to a height of 5,000 feet above sea level, on the south flank of the St. Elias Mountains, but occurring in the midst of great present-day glaciers and so having no certain correlation with early great ice transgression; of an uplifted and tilted succession of tillite, gravel, and silt beds in the White River Basin, at a locality that lies close to the terminus of an active glacier and therefore does not prove an ice expansion much beyond that of present glaciers; of glacial boulders in the Nenana Valley that lie many miles north of the limit reached there by Wisconsin glaciers; and of an old till in the Mulchatna Basin that was deeply oxidized before the Wisconsin advance but that lies well back within the area covered by ice in Wisconsin time.

[9] Mertie, J. B., jr., oral communication.

[10] Kirk, Edwin, Paleozoic glaciation in southeastern Alaska: Am. Jour. Sci., 4th ser., vol. 46, pp. 511-515, 1918.

[11] Blackwelder, Eliot, The probable glacial origin of certain folded slates in southeastern Alaska: Jour. Geology, vol. 15, pp. 11-14, 1907.

CONCLUSION

It is probable that in Alaska, as in other parts of the world, there have been recurrent glacial periods from mid-Paleozoic time to the present. This was to have been expected, for unless the earth's poles have wandered much farther than has been determined, the high latitude of Alaska would always have favored glaciation there as compared with more temperate lands. Furthermore, for much of geologic time there have probably been high mountain areas in Alaska, and in these areas local glaciers might have been fostered even when glaciers could not exist in the lowlands.

Pleistocene glaciation in Alaska was severe, probably during several stages but certainly during Wisconsin time. The surprising fact is that so large an area in subarctic and arctic Alaska should have remained unglaciated while the remainder of northern North America was submerged beneath successive continental ice sheets. The restriction of Pleistocene glaciation in Alaska to mountainous areas was due mainly to a semiarid climate in the lower country.

If the climate of to-day may be considered to be as mild as the average climate during the several Pleistocene interglacial stages, then there is every likelihood that mountain glaciers have survived continuously in the higher mountains of Alaska from the beginning of Pleistocene time to the present and that the Pleistocene ice advances were merely expansions and the interglacial stages contractions of continuously existing glaciers. In other words, in Alaska glaciation has been continuous since the beginning of the Pleistocene epoch.

If the conclusions set forth above are justified, it follows that the present time of restricted glaciation is possibly only an interglacial stage. The time that has elapsed since the Wisconsin ice invasion is probably shorter than half the average duration of the Pleistocene interglacial stages. Whether or not the maximum stage of deglaciation has been reached is not known, but it is entirely possible that sometime within the next 50,000 or 100,000 years or so the northern part of the continent may again be subjected to submergence beneath a continental ice sheet.

THE UPPER CRETACEOUS AMMONITE GENUS BARROISICERAS IN THE UNITED STATES

By John B. Reeside, Jr.

INTRODUCTION

The ammonite genus *Barroisiceras* Grossouvre is noteworthy because of its wide geographic distribution and its apparently small stratigraphic range. It is reported from deposits of Coniacian age in Europe, Africa, South America, and North America. In the North American Upper Cretaceous it is rather rare, authentic species having been recognized hitherto only in the Austin chalk of Texas, in the Coniacian beds of Zumpango del Rio, Guerrero, Mexico, and, with doubt as to the source, in New Jersey. The Texan species, *B. dentatocarinatum* (Roemer), is by no means an abundant form, though among those described in early work in the region. The Mexican representatives of the genus thus far described include only fragmentary specimens not specifically named. The occurrence ascribed to New Jersey is based on a fragment that seems to belong to *Barroisiceras* but whose source is very doubtful.

The present paper records, in addition to *B. dentatocarinatum*, five new species from the Interior Province and one from Texas. Five of these are represented by single specimens and one by two specimens, but all are well characterized and deserving of recognition in spite of scant material. Three of the new species are associated with other invertebrates of early Niobrara (early Coniacian) age and come from one locality in the Mancos shale of central Utah. A fourth is likewise associated with invertebrates of Niobrara age and comes from the Frontier sandstone near Lander, Wyo. The fifth new species is from the Timpas limestone, the lower formation of Niobrara age, near Carlile Springs, Colo. The sixth is from the Austin chalk north of Sabinal, Tex.

Mr. W. O. Hazard photographed the specimens shown in the plates, and Miss Frances Wieser retouched the photographs and assembled the plates.

TAXONOMIC HISTORY OF THE GENUS BARROISICERAS GROSSOUVRE

The genus *Barroisiceras* was instituted by Grossouvre [1] in 1894, with *Ammonites haberfellneri* Hauer [2] as the first species and chief basis of the genus. The name was printed in the original text as *Barroisia*, but as this name had been applied to a genus of sponges in 1882 by Munier-Chalmas, Grossouvre in an added note altered the form of his new term to *Barroisiceras*. Grossouvre's characterization of the genus consisted chiefly of a comparison of the suture with that of *Tissotia* Douvillé, in which it was stated that *Barroisiceras* differed in having fewer lobes, greater incision of the elements, and the larger member of the unsymmetrically bifid external saddle on the siphonal side. Grossouvre's figures and discussion of the species afforded other characters, however, useful for recognition of the genus. The species *haberfellneri* was given a very wide scope and included besides the typical form the varieties *alstadenensis* Schlüter,[3] *desmoulinsi* Grossouvre, and *harlei* Grossouvre. The other species recognized were *B. nicklesi* Grossouvre, *B. sequens* Grossouvre, and *B. boisselleri* Grossouvre. Under *B. haberfellneri* Grossouvre included—in addition to Schlüter's *Ammonites alstadenensis*—*A. petrocoriensis* Coquand,[4] *A. neptuni* Fritsch, and Schlönbach (not Geinitz),[5] *A. dentato-carinatus* Fritsch and Schlönbach (not Roemer),[6] *A. paeon* Redtenbacher,[7] and *Buchiceras nardini* Fallot.[8] Grossouvre suggested also that *Schloenbachia tunetana* Peron [9] may be a *Barroisiceras* but stated that he did not know any Indian or American species.

Peron [10] in 1897 noted *B. haberfellneri* Grossouvre in Algeria, doubting, however, the validity of uniting with it *Ammonites petrocoriensis* Coquand.

Anderson [11] in 1902 included *Barroisiceras* in *Schloenbachia*, referring to it two species, *S. (B.) siskiyouensis*

[1] Grossouvre, Albert de, Les ammonites de la Craie supérieure: Carte géol. France Mém., Recherches sur la Craie supérieure, pt. 2, Paléontologie, pp. 80–81, 1893 [1894].

[2] Hauer, Franz von, Neue Cephalopoden aus den Gosaugebilden der Alpen: K. Akad. Wiss. Wien Sitzungsber., Band 53, Abt. 1, p. 301, pl. 1, figs. 1–5, 1866.

[3] Schlüter, Clemens, Cephalopoden der oberen deutschen Kreide: Palaeontographica, Band 24, p. 151, pl. 40, figs. 13–16, 1876.

[4] Coquand, Henri, Synopsis des animaux et des végétaux fossiles observés dans la formation crétacée du sud-ouest de la France: Soc. géol. France Bull., 2d ser., vol. 16, p. 995, 1858.

[5] Fritsch, Anton, and Schlönbach, Urban, Cephalopoden der böhmischen Kreideformation, p. 30, pl. 15, fig. 3, Prague, 1872.

[6] Idem, p. 32, pl. 16, figs. 1–3.

[7] Redtenbacher, Anton, Die Cephalopodenfauna der Gosauschichten in den nordöstlichen Alpen: K.-k. geol. Reichsantsalt Abh., Band 5, p. 103, pl. 23, fig. 3, 1875.

[8] Fallot, J. E., Étude géologique sur les étages moyens et supérieurs du terrain crétacé dans le sud-est de la France: Annales sci. géol., vol. 18, p. 241, pl. 3, figs. 3–4, 1885.

[9] Peron, Alphonse, Description des invertébrés fossiles des terrains crétacés de la région sud des hauts-plateaux de la Tunisie recueillis en 1885 et 1886 par M. Philippe Thomas, pp. 21–23, pl. 17, figs. 6–8, 1893.

[10] Peron, Alphonse, Les ammonites du Crétacé supérieur de l'Algérie: Soc. géol. France Mém. 17, p. 48, 1897.

[11] Anderson, F. M., Cretaceous deposits of the Pacific coast: California Acad. Sci. Proc., 3d ser., vol. 2, no. 1, pp. 119–120, 1902.

Anderson and *S.* (*B.*) *knighteni* Anderson, from the lower part of the Chico formation of Oregon and California. It is difficult to judge Anderson's figures and descriptions, but the assignment to *Barroisiceras* seems doubtful because of the sigmoid curvature of the ribs, weak marginal tubercles, and other features. It is also highly probable that the lower Chico is older than any beds containing true *Barroisiceras*.

Hyatt [12] in 1900 in a general arrangement of the Ammonoidea assigned *Barroisiceras* to the family Mammitidae, giving only a brief discussion of the family. He included with *Barroisiceras* and *Mammites* his new genera *Calycoceras* and *Metacanthoplites*, the latter based on *Ammonites rhotomagensis* Defrance, now generally accepted as the genotype of *Acanthoceras*.

Hyatt [13] in 1903 interpreted the genus, apparently on the basis of Grossouvre's published data only, as possessing smooth, compressed young with continuous keel; successive later stages with ribs and a smooth keel; with ribs, nodes, and a nodose keel; finally with a smooth keel again. He considered the several varieties of *B. haberfellneri* to be distinct species and named one of Grossouvre's figured but unnamed variants of this species *B. haueri*.

Shattuck [14] in 1903 referred to *Barroisiceras* two species from the Buda limestone of Texas as *B. texanum* Shattuck and *B. hyatti* Shattuck. The horizon of these forms is considerably below that of other species included in the genus, and both have since been placed in *Budaiceras* Böse, as noted below.

Solger [15] in 1904, in a discussion of fossils from Kamerun, gave the first real description of *Barroisiceras*, which may be translated as follows:

Shell high-whorled and with rather narrow umbilicus except in the old-age stages of some forms. Periphery with a smooth or nodose keel accompanied on either side by a row of nodes or a smooth slope.

Flanks smooth or bearing rounded ribs, sometimes also umbilical nodes and a row of median-lateral nodes, both in smaller number than the marginal nodes, to which they send rounded ribs.

Suture with three saddles of about equal height, sometimes the beginning of a fourth. Lobes plump, toothed over the entire outline or running out into short, toothed branches. First lateral more strongly dissected on the external side than on the internal (umbilical) side. Saddles rounded, more or less clearly bifid.

Type: *Barroisiceras haberfellneri* (F. v. Hauer).

Solger thought *Barroisiceras* better separated from *Tissotia* by the general form of the lobes and the entire saddles of the second genus. He also considered it close to *Mortoniceras*, but separable by its smaller umbilicus and forked ribs, and to *Gauthiericeras*, but separable by its lesser involution, shallow furrows bordering the median keel, and the sharp decrease inward in the height of the sutural elements. Solger raised the variety *desmoulinsi* Grossouvre to specific rank because specimens from Africa studied by him and assigned to it possess a smooth keel at all stages, and he described the new species *B. brancoi*, dividing it into the two varieties *mitis* and *armata*.

Lasswitz [16] in 1904 assigned to *Schloenbachia* (*Barroisiceras*) a number of species from Texas, supposing them to be of Coniacian age. They have since been found to be much older and recently have been placed by Böse [17] for the greater part in his genus *Budaiceras*. Only the species *dentatocarinatum* Roemer [18] appears to be an authentic *Barroisiceras*.

Pervinquière [19] in 1907 accepted Solger's diagnosis of the genus; added a new species, *B. romieuxi*, and a new variety, *byzacenicum*, of *B. haberfellneri*; and, following Grossouvre's suggestion, assigned to the genus *Schloenbachia tunetana* Thomas and Peron with a new variety, *inerme*, under it. He listed as species of *Barroisiceras* *B. haberfellneri* (Von Hauer), with varieties *alstadenense* (Schlüter), *harlei* Grossouvre, and *byzacenicum* Pervinquière; *B. nicklesi* Grossouvre; *B. desmoulinsi* Grossouvre; *B. tunetanum* (Thomas and Peron), with variety *inerme* Pervinquière; *B. sequens* Grossouvre; *B. boisselleri* Grossouvre; *B. brancoi* Solger, with varieties *mite* Solger and *armatum* Solger; and *B. romieuxi* Pervinquière. He rejected *B. texanum* Shattuck and *B. hyatti* Shattuck as doubtful, a procedure justified by their later inclusion in *Budaiceras*. He did not note *B. haueri* Hyatt and ignored the forms cited by Lasswitz from Texas.

Weller [20] in 1907 refigured and described as *Barroisiceras dentato-carinatus* Roemer a fragment of a whorl of an ammonite which Whitfield [21] had earlier figured as *Ammonites dentato-carinatus*. The specimen is hardly *B. dentatocarinatum*, for it is described as showing on the flanks "two lines of nodes which divide the surface into three nearly equal spaces," though it seems surely to be a *Barroisiceras*. The horizon and locality of the specimen are unknown, though Whitfield stated that it was labeled "Cretaceous of New Jersey" and suggested from the lithology that it might have come from the base of the "Lower Green Marls." This horizon is well above that of any species of *Barroisiceras* yet recorded from any part of the world, and the

[12] Hyatt, Alpheus, in Zittel, K. A. von, Textbook of paleontology, 1st ed. (translated by C. R. Eastman), Ammonoidea, p. 588, 1900.

[13] Hyatt, Alpheus, Pseudoceratites of the Cretaceous: U. S. Geol. Survey Mon. 44, p 104, 1903.

[14] Shattuck, G. B., The Mollusca of the Buda limestone: U. S. Geol. Survey Bull. 205, pp. 35–36, pl. 25, 1903.

[15] Solger, Friedrich, Die Fossilien der Mungokreide in Kamerun und ihre geologische Bedeutung, in Esch, Ernst, and others, Beiträge zur Geologie von Kamerun, pt. 2, pp. 163–179, Stuttgart, 1904.

[16] Lasswitz, Rudolf, Die Kreide-Ammoniten von Texas: Paleont. Abh., n. F., Band 6, pp. 246–250, 1904.

[17] Böse, Emil, Cretaceous ammonites from Texas and northern Mexico: Texas Univ. Bull. 2748, pp. 91, 162, 255, 1927.

[18] Roemer, Ferdinand, Die Kreidebildungen von Texas und ihre organischen Einschlüsse, p. 33, pl. 1, fig. 2, Bonn, 1852.

[19] Pervinquière, Léon, Études de paléontologie tunisienne, pt. 1, Céphalopodes des terrains secondaires, pp. 379–385, Paris, 1907.

[20] Weller, Stuart, Cretaceous paleontology of New Jersey: New Jersey Geol. Survey, Paleont. ser., vol. 4, p. 836, pl. 101, figs. 5–6, 1907.

[21] Whitfield, R. P., Gasteropoda and Cephalopoda of the Raritan clays and greensand marls of New Jersey: U. S. Geol. Survey Mon. 18, p. 250, pl. 41, figs. 3–4, 1892.

description of the lithology suggests to the writer that the specimen did not originate in New Jersey but came from some other source, possibly even as far away as the Austin chalk of Texas. The record is so doubtful that it would best be left out of consideration.

Boule, Lemoine, and Thevenin [22] in 1907 included *Barroisiceras* in *Schloenbachia* and reduced to the status of a variety of *B. haberfellneri* Grossouvre's *B. nicklesi*. They noted *B. haberfellneri* from Madagascar in the typical form and in the varieties *harlei* and *nicklesi* Grossouvre. A Senonian species described by them as *Acanthoceras* (*Prionotropis*) *allaudi* seems to the present writer almost surely a *Barroisiceras*.

Brüggen [23] in 1910 cited *Barroisiceras haberfellneri* and *B. brancoi* var. *mite* Solger from Peru, viewing the first species in the broad sense of Boule, Lemoine, and Thevenin.

Douvillé [24] in 1911 included *Barroisiceras* in the subfamily Mortoniceratinae under the family Pulchellidae, considering chiefly the suture. He placed the genus close to *Prionocyclus* and *Prionotropis* because of the dentate keel.

Smith [25] in 1913, in a general arrangement of the Ammonoidea, included *Barroisiceras* both in the subfamily Acanthoceratinae under the family Cosmoceratidae and in the family Prionotropidae. As the work was a revision of Hyatt's earlier arrangement of the genera of ammonites, possibly the first assignment was an accidental inheritance from Hyatt and the second Smith's real opinion.

Lüthy [26] in 1918 identified *Schloenbachia* (*Barroisiceras*) *brancoi* var. *mite* Solger in Peru and a second, new but unnamed species.

Burckhardt [27] in 1919 described many fragmentary specimens of *Barroisiceras* from Mexico. He divided his specimens into four groups—(1) forms comparable to typical *B. haberfellneri* and to *B. neptuni* Fritsch and Schlönbach (not Geinitz), with ribs well developed and strong umbilical and marginal tubercles; (2) forms comparable to *B. haberfellneri* var. *harlei* Grossouvre, with ribs almost entirely suppressed and with umbilical and marginal tubercles fine and like short, delicate ribs; (3) forms comparable to *B. petrocoriense* Coquand and *B. haberfellneri* var. *nicklesi* Boule, Lemoine, and Thevenin (not Grossouvre), with weak ribs but strong umbilical and marginal tubercles; (4) forms comparable to *B. alstadenense* Solger (not of authors) and *B. alstadenense* (Schlüter), with ribs fairly well marked but in some forms weak and with median-lateral tubercles in addition to the marginal tubercles, especially in youth.

Broili [28] in 1924 included *Barroisiceras* in the Prionotropidae, giving the brief diagnosis:

> Umbilicus narrow. Ribs mostly with lateral nodes, at which they fork, ending in marginal nodes. Saddles and lobes broad, little dissected.

Under the family diagnosis the suture is characterized as having bifid lateral lobes and one auxiliary lobe.

Scott [29] in 1926 assigned to *Barroisiceras haberfellneri* (Hauer) Roemer's *Ammonites dentato-carinatus*.

Adkins [30] in 1926 briefly characterized *Barroisiceras* as having a coarsely serrated carina and accepted *B. dentatocarinatum* (Roemer) as a valid species.

SPECIES RECORDED IN THE LITERATURE

The species and varieties recorded in the preceding summary of the literature and those described in this paper (pp. 15–19) constitute a rather varied assortment of forms. It has seemed worth while, as an aid in studying the genus, to state briefly the chief characters of each species and to attempt an arrangement into convenient groups on the basis of form and sculpture, even though the writer has had in hand material representing only the North American species and has had to use published descriptions and figures alone for the others. The species already removed from *Barroisiceras* and assigned to *Budaiceras* need no further consideration. Others originally called varieties seem in large part deserving of independent rank and are so treated. Some forms originally placed under a single name are separated, though in the absence of specimens new names are not applied. The groups, together with brief notes on the included species, are as follows:

I. Median-ventral nodes equal in number to the marginal nodes.
  1. Ribs straight.
    A. Strong umbilical and marginal nodes.
      a. Ribs well developed.
        haberfellneri (Hauer), s. s. Hauer, p. 300, pl. 1, figs. 1–4, 1866; Grossouvre p. 51, pl. 1, figs. 1–3, 5 (not 4), 1894; Boule, Lemoine, and Thevenin, p. 43, pl. 11, fig. 3, 1907. Shell moderately stout; nodes strong, 6 to 9 per whorl at umbilicus, 18 to 20 on venter. Large individuals lose the median-ventral nodes and acquire a concave venter bordered by the marginal nodes. Umbilicus one-sixth diameter.
        haueri Hyatt. Grossouvre, p. 51, pl. 2, fig. 1, 1894; Hyatt, p. 105, 1903. Much stouter than *haberfellneri* and with coarser sculpture. Umbilicus one-fifth diameter.

[22] Boule, Marcellin, Lemoine, Paul, and Thevenin, Armand, Paléontologie de Madagascar; III, Céphalopodes crétacés des environs de Diégo-Suarez: Annales de paléontologie, vol. 2, pp. 14, 23–25, 1907.

[23] Brüggen, Hans, Die Fauna des unteren Senons von Nord-Peru: Neues Jahrb., Beilage-Band 30, pp. 730–733, 1910.

[24] Douvillé, Henri, Évolution et classification des pulchellidés: Soc. géol. France Bull., 4th ser., vol. 11, p. 295, 1911.

[25] Smith, J. P., in Zittel, K. A. von, op. cit., 2d ed., Ammonoidea, pp. 669, 672, 1913.

[26] Lüthy, Jacob, Beitrag zur Geologie und Palaeontologie von Peru: Soc. paléont. Suisse Mém., vol. 43, pp. 48–50, pl. 4, figs. 1–2, 1918.

[27] Burckhardt, Carlos, Faunas jurásicas de Symon (Zacatecas y faunas cretácicas de Zumpango del Rio (Guerrero): Inst. geol. México Bol. 33, pp. 99–108, pls. 24–25, 1919.

[28] Broili, Ferdinand, in Zittel, K. A. von, Grundzüge der Paläontologie (Paläozoologie), Abt. 1, Invertebrata, 6th ed., p. 593, Munich, 1924. Previous editions of this work treat *Barroisiceras* in the same manner.

[29] Scott, Gayle, Études stratigraphiques et paléontologiques sur les terrains crétacés du Texas: Grenoble Univ. Annales, new ser., Sci. sec., vol. 3, p. 109, 1926.

[30] Adkins, W. S., Handbook of Texas Cretaceous fossils: Texas Univ. Bull. 2838, pp. 203, 252, 1928.

I. Median-ventral nodes equal in number to the marginal nodes.
1. Ribs straight—Continued.
A. Strong umbilical and marginal nodes—Continued.
a. Ribs well developed—Continued.

neptuni (Fritsch and Schlönbach) (not Geinitz). Fritsch and Schlönbach, p. 30, pl. 14, fig. 3, 1872. Much like *haberfellneri* but with weaker sculpture. Umbilicus one-sixth diameter.

dentatocarinatum (Fritsch and Schlönbach) (not Roemer). Fritsch and Schlönbach, p. 32, pl. 16, figs. 1–3, 1872. Rather compressed, ribs on flanks weaker than in *haberfellneri;* nodes about same number as in *haberfellneri,* but umbilical nodes accentuated. Umbilicus one-fourth diameter.

paeon (Redtenbacher). Redtenbacher, p. 103, pl. 23, fig. 3, 1875. Rather compressed; in earlier whorls 9 umbilical nodes and 24 ventral nodes; in later whorls ventral nodes unite in a high, smooth keel and marginal nodes weaken. Umbilicus one-eighth diameter.

b. Ribs weak.

dentatocarinatum (Roemer). Roemer, p. 33, pl. 1, fig. 2, 1852. Shell much compressed; ventral nodes high and sharp; 5 umbilical, 25 ventral nodes per whorl; in large adults the marginal nodes pass into distant blunt spines. Umbilicus one-fourth diameter.

petrocoriense (Coquand). Grossouvre, p. 51, pl. 2, fig. 5, 1894. In early stages ribs and nodes distinct, 8 umbilical and 18 ventral nodes per whorl; in later stages ribs and umbilical nodes vanish. Umbilicus one-sixth diameter.

dartoni Reeside. This paper, p. 16, pl. 6, figs. 8–10; pl. 5, figs. 8–9. Shell compressed, cross section of whorl high oval; 11 umbilical, 20 marginal and ventral nodes per whorl, persisting to end of shell. Umbilicus two-sevenths diameter.

nicklesi Grossouvre. Grossouvre, p. 63, pl. 3, fig. 2, 1894. Shell much compressed; 8 coarse umbilical and 20 ventral nodes per whorl; ribs obscure; keel faint and scarcely tuberculate in later stages. Mature cross section subquadrate. Umbilicus one-fourth diameter.

nicklesi Boule, Lemoine, and Thevenin (not Grossouvre). Boule, Lemoine, and Thevenin, p. 45, pl. 11, fig. 2, 1907. Shell stouter than in *nicklesi* s. s., umbilicus smaller and umbilical nodes weaker; median-ventral nodes persist to a larger stage. Umbilicus one-fifth diameter.

nardini (Fallot). Fallot, p. 241, pl. 3, figs. 3–4, 1885. Shell compressed; 8 coarse umbilical and 16 marginal nodes per whorl; former on sharp umbilical shoulder; ribs weak in early stages and absent in middle and later stages. Mature cross section subquadrate. Umbilicus one-fifth diameter.

I. Median-ventral nodes equal in number to the marginal nodes.
1. Ribs straight—Continued.
B. Median-lateral as well as umbilical and marginal nodes.
a. Ribs distinct; median-lateral nodes not stronger than others; shell relatively compressed.

alstadenense (Schlüter). Schlüter, p. 151, pl. 40, figs. 13–16, 1876; Grossouvre, p. 51, pl. 1, fig. 4, pl. 2, fig. 4, 1894. In earlier stages 7 umbilical and median-lateral nodes and 21 ventral nodes per whorl; in later stages ribs and nodes disappear except marginal nodes. Umbilicus one-sixth diameter.

alstadenense Solger (not Schlüter). Solger, p. 170, pl. 5, fig. 6, 1904. Umbilical and median-lateral nodes weak, marginal and median-ventral nodes strong; ribs persist longer than in *alstadenense* s. s.; only 2 marginal nodes for each umbilical node. Umbilicus one-fifth diameter.

sevierense Reeside. This paper, p. 16, pl. 4, figs. 4–8. Nodes and ribs moderately strong; 10 umbilical and median-lateral nodes, 16 marginal and median-ventral nodes per whorl, all persistent. Umbilicus one-fifth diameter.

b. Ribs very weak; median-lateral nodes prominent; shell relatively stout.

forresteri Reeside. This paper, p. 17, pl. 5, figs. 2–7. Blunt spinelike median-lateral and marginal nodes, weak umbilical and median-ventral nodes; 12 umbilical and median-lateral nodes, 18 marginal and median-ventral nodes per whorl. Umbilicus one-fourth diameter.

allaudi (Boule, Lemoine, and Thevenin). Boule, Lemoine, and Thevenin, p. 32, pl. 8, figs. 6–7; text fig. 17, 1907. Blunt spinelike median-lateral and marginal nodes, weak umbilical and median-ventral nodes; 15 umbilical and median-lateral nodes, 23 marginal and median-ventral nodes per whorl. Umbilicus one-fourth diameter.

stantoni Reeside. This paper, p. 17, pl. 7, figs. 1–7; pl. 6, figs. 1–3; pl. 7, fig. 1. In early stages median-lateral nodes not much more prominent than the others; in later stages umbilical and median-lateral nodes are joined by high rib and become conspicuous; all the nodes persistent. Umbilicus one-third diameter.

hobsoni Reeside. This paper, p. 18, pl. 9, figs. 2–4; pl. 8, figs. 1–2. In early stages umbilical nodes fairly strong, others of same size; in later stages umbilical nodes disappear, each third median-lateral node becomes a strong blunt spine, and the median-ventral nodes weaken somewhat. Umbilicus one-third diameter.

I. Median-ventral nodes equal in number to the marginal nodes.
1. Ribs straight—Continued.
C. Sculpture very weak; ribs weak or absent; marginal nodes strongest, median-ventral next, umbilical nodes weak or absent. Shell compressed.
a. Small species with small umbilicus and sharp-ventered adults.
harlei Grossouvre. Grossouvre, p. 51, pl. 2, figs. 2, 7, 8, 1894; Boule, Lemoine, and Thevenin, p. 43, pl. 11, fig. 4, 1907. In early stages faint ribs, very weak elongated umbilical nodes, marginal and median-ventral nodes; in later stages flanks, ventral slope, and keel smooth, only marginal nodes remain. Cross section of whorl subtriangular, widest near umbilicus. Umbilicus one-eighth diameter.
byzacenicum Pervinquière. Pervinquière, p. 381, 1907. Like *harlei* but with 6 rounded umbilical nodes per whorl.
castellense Reeside. This paper, p. 19, pl. 6, figs. 1–5. Ribs and nodes weak but persistent; 8 rounded umbilical nodes per whorl. Cross section of whorl suboval, widest at the middle. Umbilicus one-eighth diameter.
b. Large species with round-ventered adults; umbilicus large.
brancoi var. *mite* Solger. Solger, p. 174, pl. 5, figs. 4–5, 1904. In early stages umbilical nodes very weak, marginal and ventral nodes distinct, ribs 35 per whorl; in later stages ribs fade, nodes weaken, and venter becomes subrounded. Umbilicus one-sixth diameter.
brancoi var. *armatum* Solger. Solger, p. 177, pl. 5, figs. 1–2, 1904. In early stages ribs weak, 25 per whorl, umbilical nodes absent, marginal and ventral nodes strong; in later stages distantly spaced marginal spines replace marginal nodes, venter is rounded. Umbilicus one-fifth diameter.
romieuxi Pervinquière. Pervinquière, p. 383, pl. 12, fig. 12, 1907. Ribs only on outer half of flank, marginal and median-ventral nodes distinct at large stage. Cross section of whorl subquadrate. Umbilicus one-fourth diameter.
2. Ribs sigmoid.
A. Keel nodose; ribs strong and coarse.
siskiyouense Anderson. Anderson, p. 119, pl. 1, figs. 19–20, 1902. Umbilical and marginal nodes, 25 marginal nodes per whorl; some intercalated ribs; marginal shoulder ill-defined. Umbilicus one-fourth diameter.
knighteni Anderson. Anderson, p. 119, pl. 1, figs. 1–4, pl. 2, figs. 39–40, 1902. Umbilical and marginal nodes, 30 marginal nodes per whorl; no intercalated ribs; marginal shoulder ill-defined. Umbilicus one-third diameter.

I. Median-ventral nodes equal in number to the marginal nodes.
2. Ribs sigmoid.—Continued.
B. Keel smooth; ribs weak.
sequens Grossouvre. Grossouvre, p. 64, pl. 3, fig. 1, 1894. Ribs broad, persistent into late stages; marginal nodes persistent. Umbilicus one-fourth diameter.
boisselleri Grossouvre. Grossouvre, p. 65, pl. 3, fig. 3, 1894. Ribs narrow, persistent, fewer than in *sequens;* marginal nodes persistent. Umbilicus one-third diameter.
II. Median ventral nodes two or three times as numerous as marginal nodes.
tunetanum (Thomas and Peron). Peron, p. 21, pl. 17, figs. 6–8, 1893. Ribs and nodes persistent; 6 umbilical nodes, 24 marginal nodes, 58 median ventral nodes per whorl. Umbilicus one-fifth diameter.
inerme Pervinquière. Pervinquière, p. 382, pl. 12, fig. 11, 1907. Ribs and nodes distinct in earlier stages, only umbilical nodes persist in later stages and venter becomes rounded. Umbilicus one-fourth diameter.
III. Keel smooth at all stages.
desmoulinsi Grossouvre. Grossouvre, p. 51, pl. 2, fig. 6, 1894; Solger, p. 167, text figs. 53 a–b, 1904.

SCOPE OF THE GENUS

Barroisiceras as conceived both by the proposer and by later authors seems to have an exceedingly wide scope and to include species departing much from the genotype species *Barroisiceras haberfellneri.* Some of this diversity in form and sculpture is due to ignorance of the stages of development of certain species—that is, only early stages of some species are known and only late stages of others, to the effect that they seem more strikingly unlike than they would be if similar stages were compared. Possibly some of the range of difference is accidental and is due to greater or lesser mechanical deformation of the specimens, presence or absence of the shell, difference in degree of corrosion by weather, or other accidental conditions. Some of it is undoubtedly real.

Groups that seem to the writer to be inappropriate associates of *Barroisiceras haberfellneri* are (1) the species which have a continuous keel throughout life, as *B. desmoulinsi* (according to Solger); (2) the species with sigmoid ribs, as *B. siskiyouense, B. knighteni, B. sequens,* and *B. boisselleri;* and (3) the species with median-ventral nodes several times as numerous as the marginal nodes, as *B. tunetanum* and *B. inerme.* These groups are here excluded from the genus.

When these forms are removed from *Barroisiceras* the remaining six groups of species show marked similarities, though there are still some rather striking differences among them. In general the earlier stages are much more alike than the later stages. The mature *B. haberfellneri*, for example, has a rather broad and concave venter, *B. paeon* has a smooth persistent high keel, *B. harlei* has an obtusely angulate venter, and *B. brancoi* has a rounded venter, though the earlier stages have many features in common. Some adults develop strong sculpture, others are nearly smooth. Some are much compressed shells, some are relatively stout.

All species of *Barroisiceras* have, at least in the early and middle stages, three rows of subequal nodes on the venter—one on the median line and one on each margin, forming a more or less sharply defined ventrolateral shoulder. Each median node is set forward of its corresponding pair of marginal nodes. Most species have also a row of nodes on the umbilical shoulder and some a row on the middle of the flank. The ribs are invariably straight, directed radially, and increase both by forking and intercalation. The suture is moderately dissected, has three or four rounded lateral saddles, all high, and a first lateral lobe as long as or longer than the siphonal lobe. The other lobes are small.

The six groups may be conveniently looked upon as subgenera, though doubtless some of the present-day students of ammonites would consider several of them genera.

The typical group, that of *Barroisiceras haberfellneri* (Hauer), contains small to medium-sized species, usually not much more than 100 millimeters in diameter. The cross section of the whorl is high and moderately compressed. The umbilicus is small, one-fifth to one-eighth the diameter. The ribs are fairly strong and are ornamented by strong umbilical and marginal nodes. Large adults differ much. In *B. haberfellneri* the median-ventral nodes fade out, but the marginal nodes remain and the venter is broad and concave; in *B. paeon* the median nodes fuse into a high smooth keel, but the marginal nodes weaken; in both species the ribs weaken greatly. Here belong *B. haberfellneri*, *B. haueri*, *B. neptuni* (Fritsch and Schlönbach), *B. dentatocarinatum* (Fritsch and Schlönbach), and *B. paeon*. This group is, of course, *Barroisiceras* s. s.

The group of *Barroisiceras dentatocarinatum* (Roemer) contains species that may reach a relatively large size, as much as 200 millimeters in diameter. The cross section of the earlier whorls is subtriangular, of the later whorls high and much compressed, subquadrate in most forms, oval in others. The umbilicus is relatively large, one-fourth or one-fifth the diameter. The ribs are weak in the early stages and disappear later, but the umbilical and marginal nodes remain strong and persistent. The median-ventral nodes remain throughout, becoming a faintly nodose keel. Here belong *B. dentatocarinatum*, *B. petrocoriense*, *B. dartoni*, *B. nicklesi* (Grossouvre), *B. nicklesi* (Boule, Lemoine, and Thevenin), and *B. nardini*. For this subgeneric group the name *Texanites* is here proposed.

The group of *Barroisiceras alstadenense* contains small to medium-sized species, probably not exceeding 100 millimeters in diameter. The cross section of the whorl is high and moderately compressed. The umbilicus is of medium size, one-fifth or one-sixth the diameter. The ribs are fairly strong and ornamented by a median-lateral row of nodes as well as umbilical, marginal, and median-ventral nodes. Here belong *B. alstadenense* (Schlüter), *B. alstadenense* (Solger), and *B. sevierense*. For this subgeneric group the name *Alstadenites* is proposed.

The group of *Barroisiceras forresteri* contains species that attain a large size, as much as 200 millimeters in diameter. The cross section of the whorl is stout, subquadrate. The umbilicus is relatively large, one-third or one-fourth the diameter. The ribs are weak, but the umbilical, median-lateral, marginal, and median-ventral nodes are strong, the median-lateral nodes in the later stages of some species becoming blunt spines. Here belong *B. forresteri*, *B. allaudi*, *B. stantoni*, and *B. hobsoni*. For this subgeneric group the name *Forresteria* is proposed.

The group of *Barroisiceras harlei* contains small to medium-sized species, not much exceeding 100 millimeters in diameter. The cross section of the whorl is high and much compressed. The umbilicus is small, one-eighth the diameter. The sculpture is very weak; ribs weak or absent, marginal nodes only moderately strong, median-ventral weak, umbilical weak or absent. In late stages the shell is nearly smooth, with venter obtusely angulate. Here belong *B. harlei*, *B. byzacenicum*, and *B. castellense*. For this subgeneric group the name *Harleites* is proposed.

The group of *Barroisiceras brancoi* Solger contains fairly large shells, as much as 200 millimeters in diameter. The cross section is high and much compressed. The umbilicus is relatively large, one-fourth or one-fifth the diameter. The sculpture is very weak; ribs weak, the marginal and median-ventral nodes somewhat stronger, umbilical nodes very weak or absent. In adults the median-ventral nodes disappear and the venter is rounded. Here belong *B. brancoi* var. *mite* and *B. romieuxi*. *B. brancoi* var. *armatum* develops large, distant, blunt spines but otherwise agrees and may be tentatively included. For this subgeneric group the name *Solgerites* is here proposed.

Barroisiceras is superficially much like certain forms assigned to *Prionotropis* Meek of the Turonian. It has been much debated, for example, whether to admit *Ammonites fleuriausianus* D'Orbigny[31] into

[31] D'Orbigny, Alcide, Paléontologie française, Terrain crétacé, Céphalopodes, p. 350, pl. 107, 1841.

Barroisiceras, but it would seem better placed in *Prionotropis*, though certainly not typical. *Prionotropis* has simple ribs inclined forward on the flanks and bent sharply forward on the venter, of unequal prominence in the early stages, more nearly equal in the later stage. There are no umbilical nodes, but double marginal nodes; and the ventral nodes in early stages form a true, individualized keel. The umbilicus is relatively large. Several other genera also have been brought into comparison by authors. *Gauthiericeras* Grossouvre is separable by its continuous keel at all stages, simple ribs, and wide umbilicus. *Tissotia* Douvillé is easily separated by the suture, particularly by the entire saddles, and the continuous keel. *Heterotissotia* Peron has a truncated venter and lacks the median-ventral nodes. *Pseudotissotia* Peron has a continuous keel and very small umbilicus and differs in sutural detail.

NORTH AMERICAN SPECIES OF BARROISICERAS

Barroisiceras (Texasia) dentatocarinatum (Roemer) Lasswitz

Plate 3, Figures 1–10; Plate 4, Figures 1–3; Plate 5, Figure 1

1849. *Ammonites dentato-carinatus* Roemer, Texas, p. 417.
1852. *Ammonites dentato-carinatus* Roemer, Die Kreidebildungen von Texas, p. 33, pl. 1, figs. 2a, b, c.
1904. *Schloenbachia* (*Barroisiceras*) *dentato-carinata* (Roemer). Lasswitz, Paleont. Abh., n. F., vol. 6, p. 249.
1926. *Barroisiceras haberfellneri* (Hauer) (part). Scott, Grenoble Univ. Annales, new ser., sci. sec., vol. 3, p. 109.
1928. *Barroisiceras dentatocarinatum* (Roemer). Adkins, Texas Univ. Bull. 2838, p. 252.

Not 1872. *Ammonites dentato-carinatus* Roemer. Fritsch and Schlönbach, Cephalopoden der böhmischen Kreideformation, p. 32, pl. 16, figs. 1–3.

Not 1892. *Ammonites dentato-carinatus* Roemer. Whitfield, U. S. Geol. Survey Mon. 18, p. 250, pl. 41, figs. 3–4.

Not 1907. *Barroisiceras dentato-carinatus* (Roemer). Weller, New Jersey Geol. Survey Paleont. Ser., vol. 4, p. 836, pl. 101, figs. 5–6.

Diameter of shell, 3 inches (75 millimeters); height of last whorl, 1 inch 5 lines (35 millimeters); height of next to last whorl, 8 lines (17 millimeters).

Shell discoid, compressed, umbilicate, keeled on the back (venter), ornamented on the flanks with nodes and poorly defined ribs. The whorls increasing rapidly in height, slowly in width, two-thirds covered. The flanks flat, almost parallel. The keel is interrupted and consists of large sharp-edged compressed teeth with rounded points. The back (venter) is bordered on either side by a row of nodes, which stand opposite the teeth of the keel and are 24 per whorl in number. From each of these nodes a weak fold runs toward the umbilicus. The most of these disappear, however, on the middle of the flank or beyond it. Only a few folds, indeed each third or fourth, reach the umbilicus and end in a blunt node standing on the edge of the steeply descending umbilical wall. Six such nodes are present on each side of a whorl. The lobes of the septum are strongly dissected and branched. Individual branches of the lobes are very slender and run out into pointed ends. The dorsal (ventral) lobe almost as deep as the first lateral lobe; the second lateral lobe much less deep and narrower than the first. In addition an oblique-lying small auxiliary lobe.

This beautiful species, excellently characterized by its flat, discoid form and its keel of distant, compressed teeth, is different from all other known species. * * *

Occurrence: Waterfall of the Guadalupe near New Braunfels. (Translated from Roemer, 1852.)

The great compression of the whorls, at least in part secondary, of all the available specimens and figures of this species makes comparisons of form difficult. It was very likely a much compressed species at all stages, however, even before fossilization. In sculpture its weak ribs from a diameter of 20 millimeters to that of 150 millimeters and the development of blunt spines in the very large stages separate it from most other species with only marginal and umbilical nodes. From *B. petrocoriense* Coquand [32] it differs in the earlier stages in its weaker ribs, larger umbilicus, and higher, coarser keel.

One of the specimens here figured, an internal mold collected by L. W. Stephenson, is from the type locality. It is smaller than the type and differs, if Roemer's figure and description are accurate, in that the median-ventral nodes are not opposite those of the margins of the venter, but each lies somewhat forward of the corresponding marginal nodes, as in other species of *Barroisiceras*. Possibly the original description is faulty in this detail, but only the type itself can settle the matter. The umbilicus is a trifle wider and the ribs and nodes somewhat fewer—20 as against 24 noted by Roemer.

A large internal mold, probably representing a nearly complete shell and associated with *Inoceramus* aff. *I. deformis* Meek, was collected by N. H. Darton at a locality north of Hondo, Tex. The earliest whorls exposed, at a diameter of 80 millimeters, are at a larger stage than the type or the other specimens in hand but agree sufficiently well with them to warrant the assignment of the specimen to *B. dentatocarinatum*. The later stages present features of considerable interest. The cross section of the whorl is high, subrectangular. The sculpture continues with little change to the stage at a diameter of 150 millimeters. There the marginal nodes, instead of remaining subequal, begin to differ in size, each third one on the remainder of the shell becoming a prominent blunt spine, whereas the intervening nodes become even smaller than those on the earlier parts of the shell. A little more than the last half whorl of this specimen is unseptate, the maximum diameter being 210 millimeters. The aperture is not preserved.

Another internal mold of part of a whorl, collected by T. W. Stanton at a locality in the Rio Grande Valley, agrees well with the species.

Formation and localities: Austin chalk at the falls of the Guadalupe River, 2 miles below the bridge east of New Braunfels, Comal County, Tex.; Cow Creek below Pinto Creek, about 24 miles below Del Rio,

[32] Grossouvre, Albert de, op. cit., p. 51, pl. 2, fig. 5.

Tex.; Verde Creek, 8 miles north of Hondo, Medina County, Tex.

Barroisiceras (Texasia) dartoni Reeside, n. sp.

Plate 6, Figures 8–10; Plate 7, Figures 8–9

One internal mold, somewhat compressed and not showing the sutures, is the basis of this species. Probably the last three-fifths of a whorl represents the living chamber, as the preceding part of the shell is much more compressed. The maximum diameter preserved is 145 millimeters; the earliest stage showing the venter, a volution earlier, is about 70 millimeters in diameter, though the flanks of the next preceding whorl, to a diameter of perhaps 25 millimeters, show in the umbilicus.

Shell a moderately stout disk. Very early stages unknown. Cross section of the whorl oval, twice as high as wide, with flanks evenly convex from the umbilical shoulder to the marginal nodes of the venter and with the ventral slope nearly flat. Umbilicus 41 millimeters wide at the maximum diameter, or two-sevenths the diameter; 25 millimeters at 70 millimeters diameter, or one-third the diameter; umbilical shoulder distinct, slightly rounded; umbilical wall high and at right angles to the flank. Aperture unknown.

Sculpture of the whorl shown in the umbilicus, ending at the diameter of 70 millimeters, consists of 9 poorly defined umbilical nodes and 9 broad, fairly high primary ribs. The next whorl, to the end of the specimen, shows 11 umbilical nodes, some high and distinct, others obscure, perhaps owing to the manner of preservation. The 11 primary ribs on each flank of the whorl are broad and ill defined, though nearly all of them clearly fork, and the resulting secondary ribs end in 20 conical marginal nodes. Corresponding to each transverse pair of marginal nodes and slightly forward of them is a median-ventral node, high, much elongated. In the type specimen, as it now stands, most of these median-ventral nodes are suggested rather than actually represented on the median line, but there is no doubt that they were originally present and perhaps were high and bladelike on the shell itself. The sculpture as a whole is weak.

Suture dimly suggested at several places but nowhere enough to show the gross form.

B. dartoni is characterized by the ovate cross section of the whorl and by the weak sculpture, with only two rows of nodes on the flanks. It is not very much like any of the American species except possibly *B. dentatocarinatum* but differs from it in the shape of the cross section of the whorl and the lesser prominence of the marginal nodes of the later stages. Possibly the form noted on page 19 as *Barroisiceras* sp. is the young of *B. dartoni*, but the writer prefers to hold them separate for the present. None of the European species seems close to *B. dartoni.*

This species is named for Mr. N. H. Darton, who collected the type specimen.

Formation and locality: Austin chalk near the Sabinal-Utopia road, 5 miles north of Sabinal, Uvalde County, Tex., associated with *Inoceramus* aff. *I. deformis* Meek and *Gryphaea* aff. *G. aucella* Roemer.

Barroisiceras (Alstadenites) sevierense Reeside, n. sp.

Plate 4, Figures 4–8

One entirely septate internal mold showing a full whorl and the umbilical part of the preceding whorl is the basis of this species. Maximum diameter preserved is 60 millimeters; earliest stage showing the venter is at 25 millimeters diameter.

Shell a moderately stout disk. Very early stages unknown. Cross section of whorl at 25 millimeters diameter roughly hexagonal; at 60 millimeters somewhat higher and with the flanks somewhat less convex. Umbilicus 14 millimeters wide at 60 millimeters diameter, between one-fourth and one-fifth the diameter; umbilical shoulder distinct, slightly rounded; umbilical wall high and at right angles to the flank. Living chamber and aperture unknown.

Sculpture of the visible part of the whorl, from a diameter of 12 millimeters to that of 25 millimeters, consists of 9 umbilical nodes connected by coarse rounded primary ribs with 9 median-lateral nodes, which lie on the line of involution. The succeeding whorl bears 10 conical umbilical nodes; 10 low, rounded primary ribs; and 10 conical median-lateral nodes, at not quite half the distance across the flank. At the line of the median-lateral nodes several of the ribs fork and several secondary ribs are intercalated, with the effect that there are 16 secondary ribs which end at 16 marginal nodes, somewhat elongated transversely. On the median-ventral line there are 16 elongated nodes only faintly connected with the corresponding pairs of marginal nodes. The ribs are of even height throughout and the sculpture as a whole only moderately strong.

Suture moderately dissected, the first lateral lobe subequal to the siphonal lobe and the second lateral lobe much smaller; no distinct third lobe. First lateral saddle about one and one-half times the width of the first lateral lobe. Lobes and saddles both rounded in contour, though the lobes are trifid.

B. sevierense is characterized by its moderate stoutness, narrow umbilicus, and evenness and persistence of the sculpturing, with its three rows of nodes and connecting ribs. It resembles the younger stages of *B. stantoni*, but differs in its more compressed shell, less numerous ribs, and small umbilicus. From *B. hobsoni* it differs at all stages in its compressed shell and narrower umbilicus; in later stages it lacks the large spines of *hobsoni*. It is most like *B. alstadenense* (Schlüter) [33] but is stouter and has more persistent, stronger, and coarser sculpture. From *B. alstadense*

[33] Schlüter, Clemens, op. cit., p. 151, pl. 40, figs. 13–16. Grossouvre, Albert de, op. cit., p. 51, pl. 1, fig. 4; pl. 2, fig. 4.

Solger (not Schlüter) [34] it differs in its more persistent and coarser sculpture, having scarcely two-thirds as many ribs and nodes.

The specific name is derived from Sevier County, Utah, where the specimen was found by the late Robert Forrester, of Salt Lake City, Utah.

Formation and locality: Mancos shale, 200 feet above the Ferron sandstone member, at a locality in Sevier County, Utah, 4 miles east of Oak Spring and about 12 miles west of south of Emery. In the same beds were *Barroisiceras forresteri*, *B. castellense;* species as yet unnamed of *Scaphites*, *Baculites*, *Placenticeras*, "*Helicoceras*," and *Eutrephoceras; Inoceramus deformis* Meek, and other pelecypods. At near-by localities the upper part of the Ferron sandstone member contains *Prionocyclus wyomingensis* Meek, *P. macombi* Meek, *Prionotropis hyatti* Stanton, *Scaphites warreni* Meek and Hayden, *Ostrea lugubris* Conrad, and *Inoceramus fragilis* Hall and Meek.

Barroisiceras (Forresteria) forresteri Reeside, n. sp.

Plate 5, Figures 2–7

One entirely septate internal mold showing parts of two whorls is the basis of this species. The entire whorl from a diameter of 13 millimeters to that of 28 millimeters is present, though only about half of it is completely exposed; and the half whorl from a diameter of 42 millimeters to that of 55 millimeters is preserved.

Shell a very stout, spinose ovoid. At a diameter of 14 millimeters the width of the whorl is three-fourths the height (4.5 by 6 millimeters) but gradually changes until at the diameter of 28 millimeters the whorl is as wide as high, excluding the nodes, and one-fifth wider than high, including the nodes (16 by 13 millimeters). At about 50 millimeters diameter the whorl is 25 millimeters high and 25 millimeters wide, excluding the nodes, and 33 millimeters wide across the nodes. The general aspect of the later cross-section is depressed hexagonal. Umbilicus between one-third and one-fourth the diameter; umbilical shoulder fairly distinct and somewhat rounded; umbilical wall steep. Living chamber and aperture unknown.

Sculpture from 14 millimeters diameter to 20 millimeters diameter, a half whorl, shows no umbilical nodes; 6 rounded primary ribs which end in conical median-lateral nodes and there mostly divide into secondary ribs, which in turn, end in conical marginal nodes 10 in mumber; median-ventral nodes, each placed somewhat forward of the corresponding marginal nodes. On the succeeding half whorl, to 28 millimeters diameter, weak umbilical nodes appear and the median-lateral and marginal nodes increase in relative strength. On the final half whorl preserved in the type the umbilical nodes are still weak, the ribs very weak, but the median lateral nodes have become blunt spines; the marginal nodes are still strong, but the median-ventral nodes are relatively weaker.

The suture shows the siphonal and first lateral lobes subequal in length, the second lateral lobe short, and the third very small; the first lateral saddle a little wider than the siphonal lobe; the first lateral lobe rounded-trifid, the second lateral lobe almost on the umbilical shoulder.

Barroisiceras forresteri is characterized by its stout shell and strong sculpture, particularly the development of the median-lateral and marginal nodes into blunt spines. The writer knows no close American relatives. *B. desmoulinsi* Grossouvre [35] has the general aspect of *B. forresteri* but lacks the median-lateral nodes and is said to have a smooth, continuous keel at all stages.[36]

B. forresteri seems very close indeed to the form from the Senonian of Diego-Suarez, Madagascar, described by Boule, Lemoine, and Thevenin [37] as *Acanthoceras* (*Prionotropis*) *allaudi*, which seems to the writer to be a species of *Barroisiceras*. *B. forresteri* differs chiefly in its fewer ribs and nodes.

The species is named for the late Robert Forrester, of Salt Lake City, Utah, who collected the type.

Formation and locality: Same as for *B. seviercnse*.

Barroisiceras (Forresteria) stantoni Reeside, n. sp.

Plate 7, Figures 1–7; Plate 8, Figures 1–3; Plate 9, Figure 1

This species is based on two internal molds from the same locality—a larger one, chosen as the type, with a maximum diameter of 130 millimeters, and a smaller one, with a maximum diameter of 39 millimeters. The part of the shell at less than 50 millimeters diameter shows only in the umbilicus of the larger specimen, and that below 14 millimeters only in the umbilicus of the smaller specimen.

Shell a thick disk, of medium size for the genus. Cross section roughly hexagonal from a diameter of 14 millimeters to 80 millimeters (about the position of the last septum of the type), being relatively high in the early stages and much more depressed and broad-ventered in the later stages; cross section of the living chamber subquadrate. Umbilicus 40 millimeters wide at the end of the type, a little less than one-third the diameter, but in the earlier stages it is proportionately smaller, being a little more than one-fifth the diameter at 39 millimeters. Umbilical shoulders abrupt at all stages seen, with inner wall nearly at right angles to the flank. Living chamber of type occupies three-fourths of last whorl, aperture unknown.

[34] Solger, Friedrich, op. cit., p. 170, pl. 5, fig. 6.

[35] Grossouvre, Albert de, op. cit., p. 51, pl. 2, fig. 6.

[36] Solger, Friedrich, op. cit., p. 167.

[37] Boule, Marcellin, Lemoine, Paul, and Thevenin, Armand, op. cit., p. 32, pl. 8, figs. 6–7, text fig. 17.

Sculpture at the diameter of 10 millimeters shown only in the umbilicus of the smaller specimen, where there are rather coarse primary ribs without well-defined umbilical nodes; any other nodes that may be present are covered by the succeeding whorl. At 14 millimeters diameter umbilical, median-lateral, marginal, and median-ventral nodes are present, numbering on the succeeding whorl (to 39 millimeters diameter) 11 umbilical, 12 median-lateral, 19 marginal and median-ventral; the umbilical and median-lateral nodes are conical, the marginal and median-ventral elongated; 5 of the primary ribs fork at the median-lateral line of nodes (outside the mid line of the flank), and there are two intercalated secondary ribs; ribs of even height throughout. At a diameter of 50 millimeters the umbilical and median-lateral nodes, both blunt conical, and the connecting ribs begin to increase in relative prominence and the median row shifts toward the umbilicus; on the other hand the secondary ribs on the outer part of the flank decrease much in prominence, though the marginal tubercles remain high; the median-ventral nodes decrease somewhat in height. The last half whorl of the type, from 80 millimeters to 130 millimeters diameter, is much corroded, but apparently the median-ventral nodes are distinct to the end of the shell, the umbilical and median-lateral nodes and the primary ribs fuse into a lateral rib, and the marginal nodes become more prominent.

The suture at 25 millimeters diameter shows the usual character of moderate dissection; first lateral lobe subequal to the siphonal lobe; second lateral lobe much smaller; an ill-defined, broad third lobe; first lateral saddle about twice as broad as the first lateral lobe. At 65 millimeters diameter the suture is much the same, with all the elements rather rounded terminally.

B. stantoni is characterized by its relatively wide umbilicus in the later stages, its stout shell with hexagonal cross section of the whorl passing into subquadrate, the prominence of the umbilical and median-lateral nodes and the connecting primary ribs, and the persistence of the marginal and median-ventral nodes. In the early stages it resembles *B. sevierense* somewhat but is much stouter at equal diameters and has more numerous ribs. In the later stages it is somewhat like *B. hobsoni* but differs in its broader venter, the lack of large spines, and coarser sculpture. No species outside of America is very close in the later stages, though *B. alstadenense* (Schülter) [38] resembles it in the early stages,being separable by weaker sculpture and more compressed shell. *B. alstadenense* Solger (not Schlüter) [39] also is more compressed and has less conspicuous median-lateral nodes.

[38] Schlüter, Clemens, op. cit., p. 151, pl. 40, figs. 13-16. Grossouvre, Albert de, op. cit., p. 51, pl. 1, fig. 4, pl. 2, fig. 4.

[39] Solger, Friedrich, op. cit., p. 170, pl. 5, fig. 6.

The species is named for Dr. T. W. Stanton, who collected the type and paratype.

Formation and locality: A sandstone in T. 33 N., R. 99 W., southeast of Lander, Wyo., included in the Frontier formation. The associated species include *Scaphites ventricosus* Meek and Hayden, *Scaphites* sp. undescribed, *Inoceramus* aff. *I. fragilis* Hall and Meek, *I. stantoni* Sokolow, and other pelecypods and gastropods. A sandstone 200 feet higher contains *Scaphites ventricosus*, *Scaphites* sp. undescribed (same as above), *Placenticeras pseudoplacenta* Hyatt, *Inoceramus stantoni*, *I.* aff. *I. erectus* Meek, and other mollusks. A third sandstone, apparently 300 feet higher still but possibly a duplication of the last, constituting the highest member of the Frontier, contains *Scaphites ventricosus*, *Mortoniceras shoshonense* Meek, *Baculites codyensis* Reeside, *Inoceramus stantoni*, *I. umbonatus* Meek and Hayden, and other mollusks. A sandstone 150 feet below that containing *B. stantoni* contains *Inoceramus* sp. and fossil plants [40] and is the base of the Frontier formation.

Barroisiceras (Forresteria) hobsoni Reeside, n. sp.

Plate 9, Figures 2–4; Plate 10, Figures 1–2

A single entirely septate internal mold with a maximum diameter of 170 millimeters is the basis of this species.

Shell a stout disk, large for the genus, for a complete shell would certainly exceed 225 millimeters in diameter. Early stages unknown. At a diameter of 75 millimeters the cross section of the whorl is roughly hexagonal, but in the succeeding whorl (to 170 millimeters) it becomes more nearly subquadrate. Living chamber and aperture unknown. Umbilicus wide for the genus, 58 millimeters at a diameter of 170 millimeters or one-third the diameter; umbilical shoulder distinct and rather sharp; umbilical wall at right angles to the flank.

Sculpture at earliest stage seen, the half whorl from 70 millimeters to 90 millimeters diameter consists of 7 primary ribs passing from a very weak umbilical node to the middle of the flank, where each bears a low but distinct node; 4 of the primary ribs fork at the median-lateral node and the ribs then pass to the 11 rather high marginal nodes; from these faint ribs run diagonally forward to the high, much elongated, median-ventral nodes, which form a coarsely serrate keel. On the succeeding three-fourths of a whorl (to 170 millimeters diameter) the umbilical nodes and primary ribs fade out completely; the median-lateral nodes gradually change in prominence, so that each third node becomes a large blunt spine and the others weaken; the spines move outward, so that the last preserved is nearly flush with the ventral surface; the

[40] Berry, E. W., The flora of the Frontier formation: U. S. Geol. Survey Prof. Paper 158, pp. 129-135, pls. 20-21, 1930.

marginal nodes become coarser and blunt but relatively lower; the median-ventral nodes begin to lose their distinctness, at least on the internal mold, and appear to unite in a nearly smooth low keel.

Suture not well preserved, but enough may be discerned to show a long, slender first lateral lobe; first lateral saddle nowhere clear but seems to be about twice as wide as the first lateral lobe; second lateral lobe small and near the umbilical shoulder.

B. hobsoni is best characterized by its relatively wide umbilicus, fairly stout shell with hexagonal cross section passing into subquadrate, and the stout, widely spaced spines of the later stages. It is not very close to any species outside of America. *B. stantoni* is most like *hobsoni* in the earlier stages but may easily be separated by its broader venter and coarser sculpture—fewer ribs per whorl, more conspicuous umbilical nodes and primary ribs. In the later stages the umbilical nodes persist, and most other features of the ornamentation differ. *Barroisiceras* sp. No. 7 of Burckhardt[41] has stout median-lateral nodes but seems to have a rather small umbilicus.

The species is named for Mr. W. A. Hobson, of Carlile Springs, Colo., who found the type specimen.

Formation and locality: The exact locality and horizon are not recorded, but there is little doubt because of the constitution of the matrix, that it came from the Timpas limestone, of Niobrara age, somewhere in the vicinity of Carlile Springs, Colo. The matrix contains abundant fragments of the shell of *Inoceramus* and abundant *Globigerina*.

Barroisiceras (Harleites) castellense Reeside, n. sp.

Plate 6, Figures 1–5

One entirely septate internal mold showing a complete whorl from the diameter of 20 millimeters to that of 48 millimeters and small parts of the inner whorls is the basis of this species.

Shell a compressed disk. Cross section of the whorl a high oval, nearly symmetrical, with widest part about the middle; at latest stage preserved the cross section is 28 millimeters high and 16 millimeters wide. Inner whorls below 16 millimeters diameter much stouter in proportions, though still oval in cross section. Umbilicus narrow, 5 millimeters wide at 48 millimeters diameter—that is one-ninth the diameter; umbilical shoulder sharp and inner wall steep. Living chamber and aperture unknown.

Sculpture of the outer whorl of the type shows 8 low but distinct conical umbilical nodes, from each of which a flattened low primary rib passes outward to the middle of the flank, there passing into several obscure secondary ribs; other secondary ribs are intercalated. All these ribs are plainer on the early part of the whorl and decrease in distinctness toward the later part, suggesting that still later whorls would be smooth. The parts of the earlier whorls seen, particularly from 4 to 11 millimeters diameter, show about 25 distinct ribs per whorl on the outer part of the flank, though the umbilical part shows only weak, distant ribs and no nodes. On the outer whorl the rather obscure ventrolateral shoulder is marked by a row of 38 rounded nodes, from which weak ribs run diagonally forward to the median-ventral nodes.

The suture shows a relatively slender first lateral lobe only slightly longer than the siphonal lobe, small second lateral lobe, and very small third lateral lobe. First lateral saddle about one and one-half times as wide as the siphonal lobe.

B. castellense is characterized by its compressed form, the weak sculpture, umbilical nodes, and the oval cross section of the whorl. It is most like *B. harlei* Grossouvre [42] but differs in the umbilical nodes, greater persistence of both ribs and nodes, lesser distinctness of the ventrolateral shoulder, and the oval cross section of the whorl. From *B. byzacenica* Pervinquière [43] it differs in the oval cross section of the whorl and the relatively persistent ribs and nodes, though resembling it in the presence of umbilical nodes.

The name is derived from that of Castle Valley, Utah, the physiographic feature formed by the Mancos shale of the region where the type was found by the late Robert Forrester.

Formation and locality: Mancos shale, 200 feet above the Ferron sandstone member, at a locality in Sevier County, Utah, 4 miles east of Oak Spring and 12 miles south of Emery.

Barroisiceras sp.

Plate 6, Figures 6–7

A single much compressed, entirely septate internal mold preserving nearly half a whorl with a maximum diameter of 80 millimeters is related to *B. dentatocarinatum* in its possession of weak ribs but differs in lacking well-defined, strong umbilical and marginal nodes, though both are present in feeble development. The suture is much like that of *B. dentatocarinatum*. Better material is needed before adequate description may be made, and the specimen would best remain unnamed, though it is possibly a new species.

Formation and locality: Austin chalk on Cow Creek below Pinto Creek, about 24 miles below Del Rio, Tex., associated with *B. dentatocarinatum*.

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[41] Burckhardt, Carlos, op. cit., p. 107, pl. 25, figs. 16, 17.

[42] Grossouvre, Albert de, op. cit., p. 51, pl. 2, figs. 2, 7, 8. Boule, Marcellin, Lemoine, Paul, and Thevenin, Armand, op. cit., p. 49, pl. 11, fig. 4. Solger, Friedrich, op. cit., p. 172, text figs. 58–61.

[43] Pervinquière, Léon, op. cit., p. 381.

PLATES 3–10

PLATE 3

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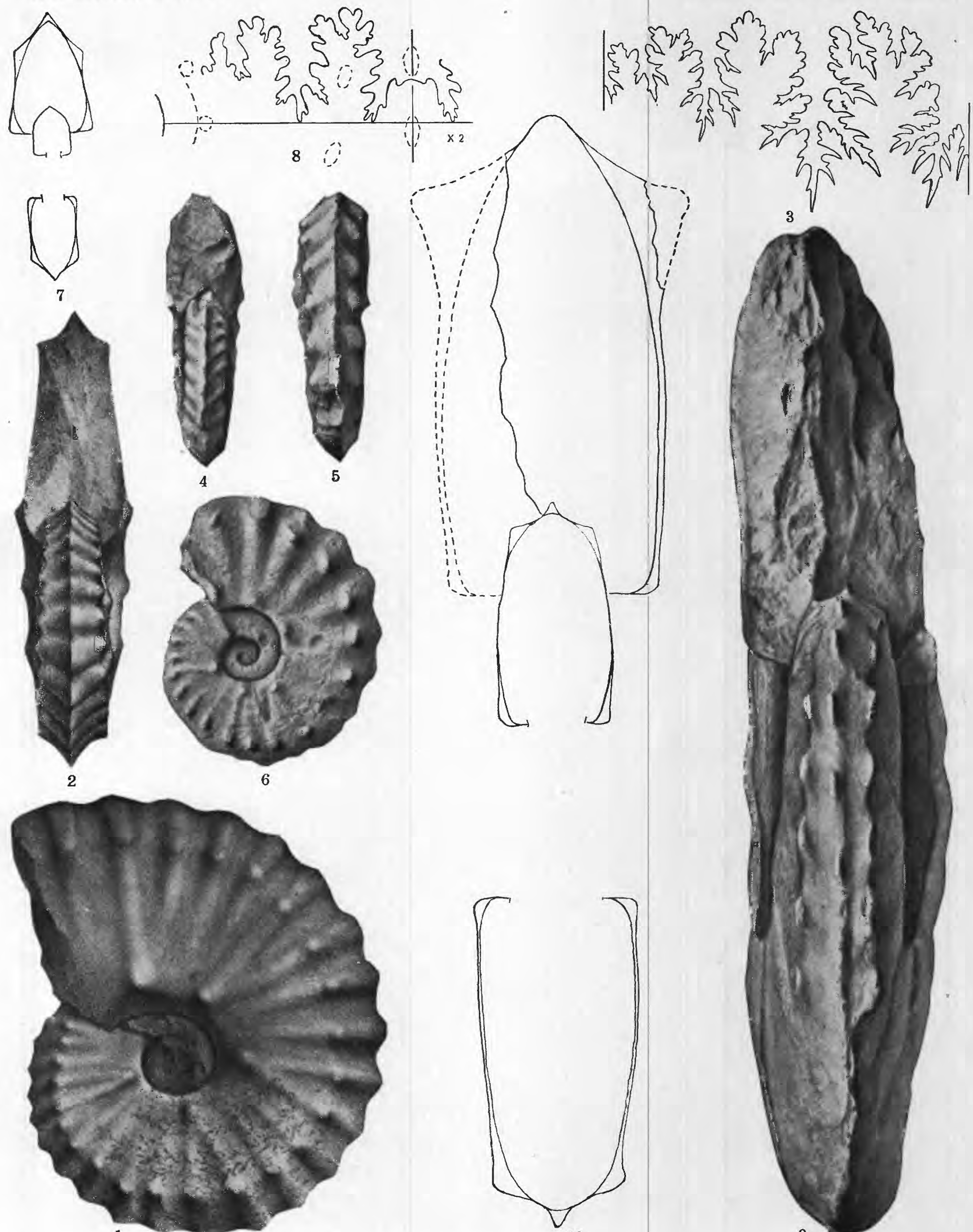
1–10. *Barroisiceras* (*Texasia*) *dentatocarinatum* (Roemer) Lasswitz 15

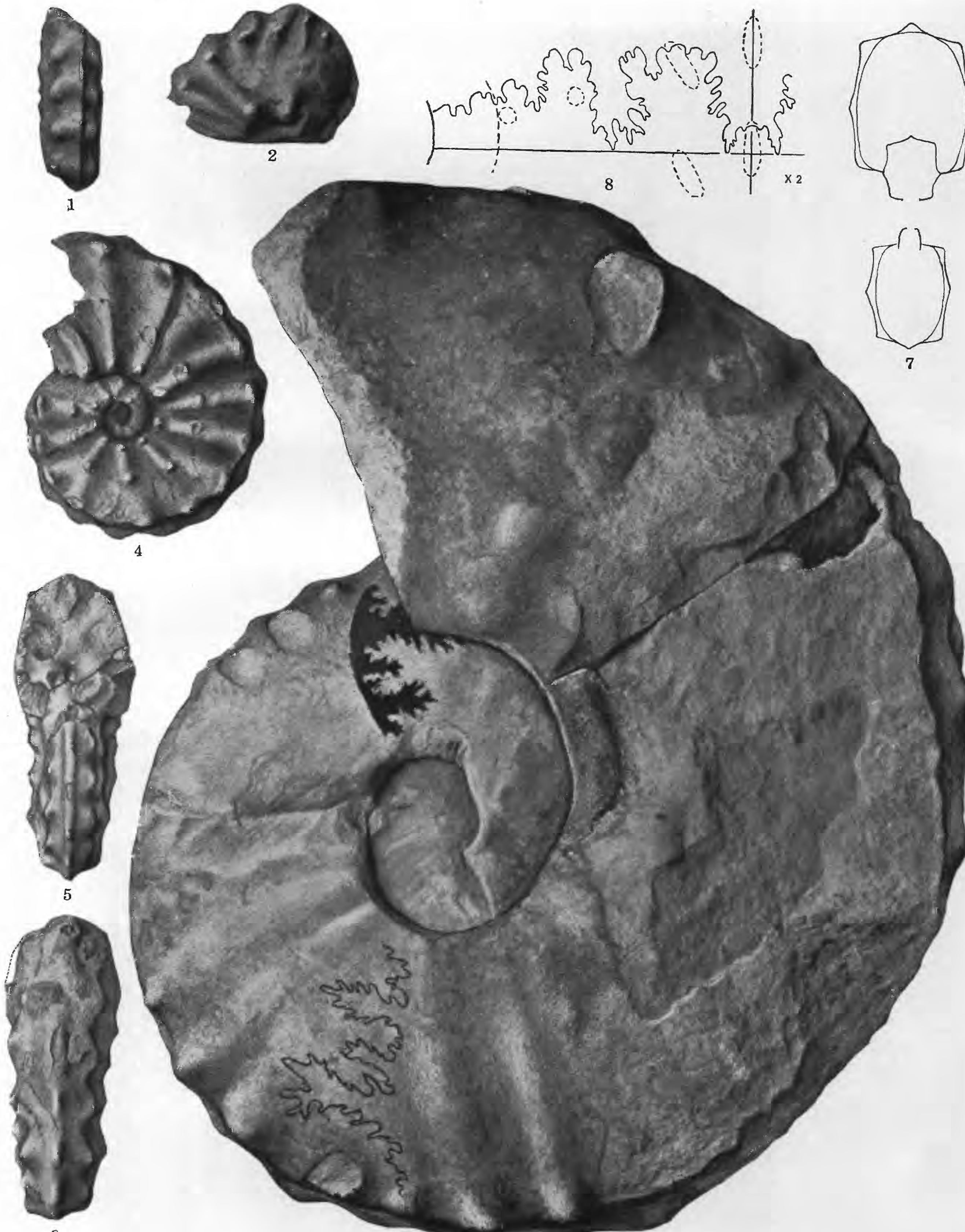
1–3. Side and front view and suture of the type specimen, from the Austin chalk at the falls of the Guadalupe River, 2 miles below the bridge east of New Braunfels, Comal County, Tex. (Copied from Roemer, Die Kreidebildungen von Texas, pl. 1, figs. 2a–c, 1852.)

4–8. Front, rear, and side views, cross section, and suture at diameter of 45 millimeters of a small, entirely septate internal mold from the type locality of the species. U. S. Nat. Mus. catalogue No. 73753.

9–10. Front view and cross section of a nearly complete internal mold from the Austin chalk on Verde Creek, 8 miles north of Hondo, Medina County, Tex. U. S. Nat. Mus. catalogue No. 73754.



SPECIES OF BARROISICERAS



SPECIES OF BARROISICERAS

PLATE 4

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1–3. *Barroisiceras* (*Texasia*) *dentatocarinatum* (Roemer) Lasswitz ---------- 15

1–2. Peripheral and side views of a fragment from the Austin chalk on Cow Creek below Pinto Creek, about 24 miles below Del Rio, Tex. U. S. Nat. Mus. catalogue No. 73755.

3. Side view of specimen shown in Plate 3, Figures 9–10.

4–8. *Barroisiceras* (*Alstadenites*) *sevierense* Reeside, n. sp., side, front, and rear views, cross section, and suture at diameter of 42 millimeters of the type, an entirely septate internal mold from the Mancos shale, 200 feet above the top of the Ferron sandstone member, at a locality in Sevier County, Utah, 4 miles east of Oak Spring and 12 miles southwest of Emery. U. S. Nat. Mus. catalogue No. 73756 ---------- 16

PLATE 5

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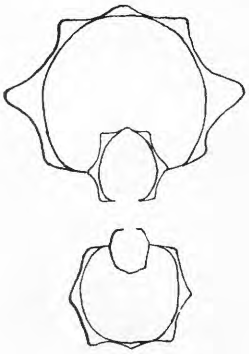
1. *Barroisiceras (Texasia) dentatocarinatum* (Roemer) Lasswitz, side view of specimen shown in Plate 3, Figures 9–10, with part of outer whorl removed 15

2–7. *Barroisiceras (Forresteria) forresteri* Reeside, n. sp., two side views, front and rear views, cross section, and suture at diameter of 36 millimeters of the type, an entirely septate internal mold from the Mancos shale, 200 feet above the top of the Ferron sandstone member, at a locality in Sevier County, Utah, 4 miles east of Oak Spring and 12 miles southwest of Emery. U. S. Nat. Mus. catalogue No. 73757 17



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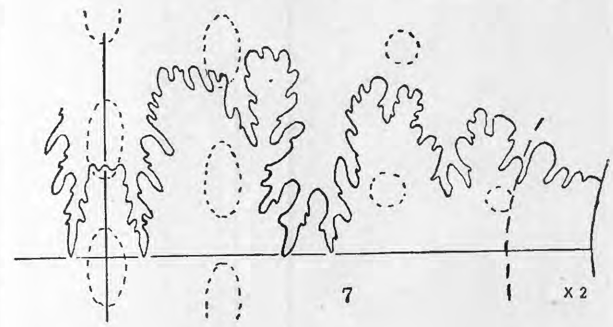

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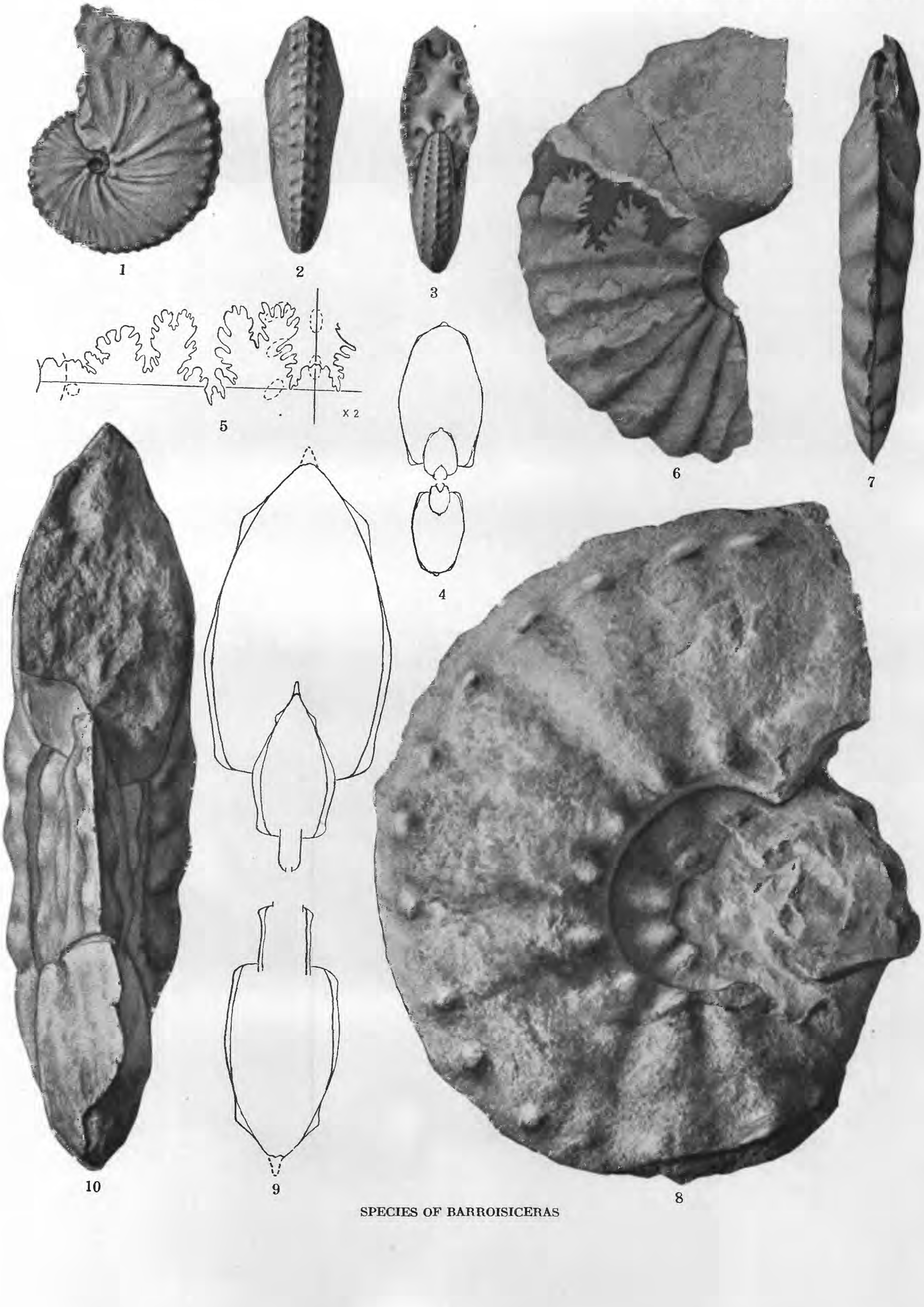
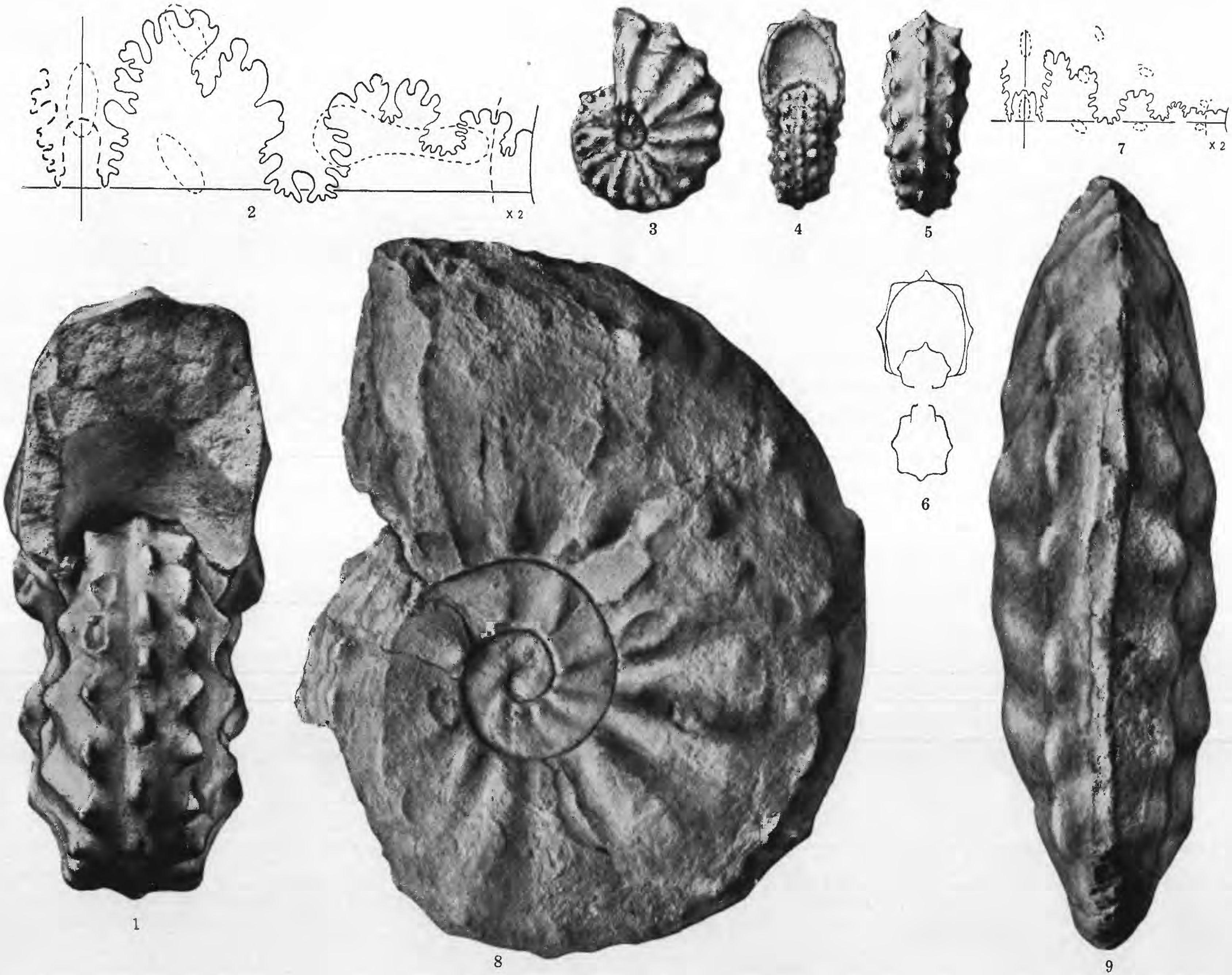
SPECIES OF BARROISICERAS



SPECIES OF BARROISICERAS

PLATE 6

PLATE 7



SPECIES OF BARROISICERAS

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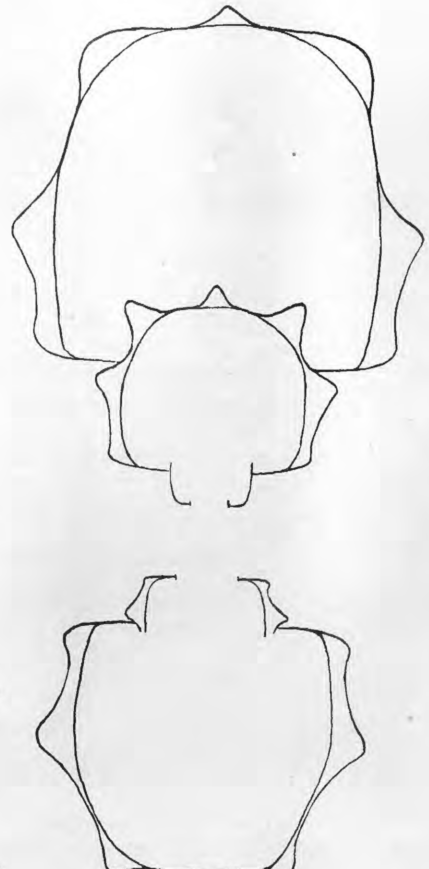

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SPECIES OF BARROISICERAS

PLATE 8

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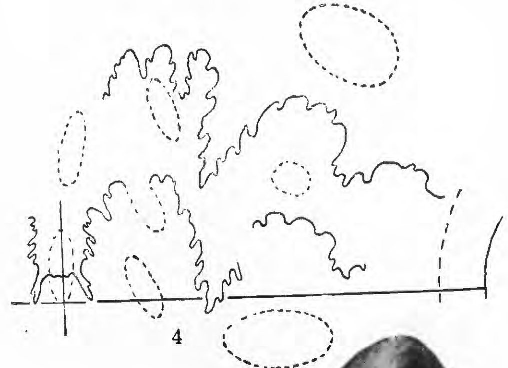
1–3. *Barroisiceras* (*Forresteria*) *stantoni* Reeside, n. sp., side and rear views and cross section of the specimen shown in Plate 7, Figures 1–2 ---- 17

PLATE 9

		Page
1.	*Barroisiceras* (*Forresteria*) *stantoni* Reeside, n. sp., side view of the specimen shown in Plate 7, Figures 1–2	17
2–4.	*Barroisiceras* (*Forresteria*) *hobsoni* Reeside, n. sp., front and rear views and suture of the type, an entirely septate internal mold from the Timpas limestone, of Niobrara age, near Carlile Springs, Colo. U. S. Nat. Mus. catalogue No. 73762	18



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SPECIES OF BARROISICERAS

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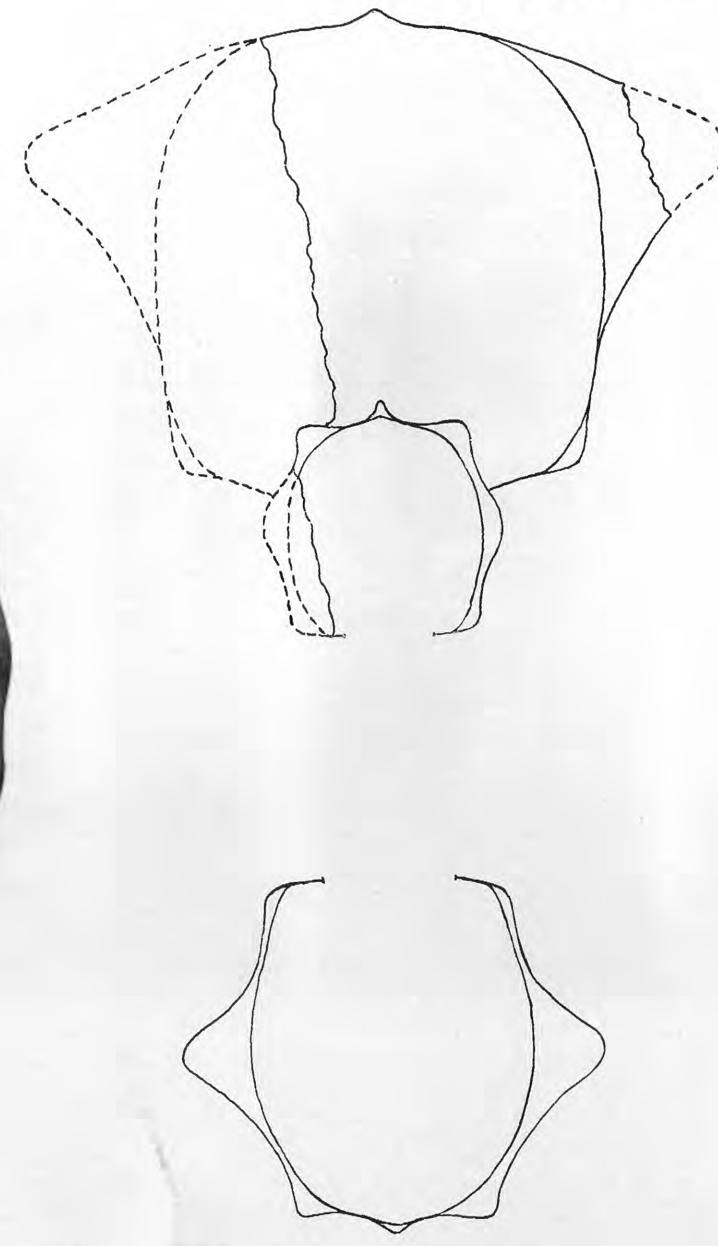

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SPECIES OF BARROISICERAS

PLATE 10

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1–2. *Barroisiceras (Forresteria) hobsoni* Reeside, n. sp., side view and cross section of the specimen shown in Plate 9, Figures 2–4	18

A MIOCENE FLORA FROM GRAND COULEE, WASHINGTON

By Edward Wilber Berry

INTRODUCTION

The fossil plants described in the present report were collected at the north end of Grand Coulee during the summer of 1927 by Messrs. T. A. Bonser, F. A. Roberts, and Walter Bruce, of Spokane, and F. W. McCann, of Coulee City. The locality is in the big bend of the Columbia River near the northern boundary of Grant County, Wash., about 85 miles west of the plant-bearing Latah sediments around Spokane. The outcrop in Grand Coulee is about the same distance east of the crest of the Cascade Mountains, about 100 miles northeast of the plant beds at Ellensburg, which are of approximately the same age, and some 200 miles west of beds in Idaho yielding a similar flora and assigned to the Payette formation by Knowlton and others.

The material in which the plants occur is of two not very dissimilar sorts. One is a buff diatomaceous matrix which I am informed occurs as boulders in glacial till. The other is a ferruginous clay found in place, which might well be a more silty phase of the diatomaceous rock.

The following details concerning the geography and geology of the plant-bearing deposit were furnished by Mr. T. A. Bonser, of the Spokane Public Museum:

> The clay deposit in which the fossil leaves occur is at the extreme north end of the coulee, just at the top of the hill that leads down to the Columbia River. It is on a level with the floor of the north end of the coulee and about 500 or 600 feet above the river. The winding road from the floor of the coulee to the river is about 2 miles long, but the actual distance from the deposit to the river is not more than half a mile. The deposit rests upon granitic rocks, just as the Latah formation does in the neighborhood of Spokane. Detached clay boulders in a glacial till about half a mile down the hill along the road also contained fossil leaves.
>
> The principal exposure is about 200 yards long and 15 to 20 feet deep at the highest point, but there is evidently a much greater depth below the level of the road. On a ranch about a quarter of a mile northwest of the exposure and about 50 to 80 feet higher fossil leaves were found in an excavation for a cellar.
>
> To the southeast of the plant locality there is a basaltic rock wall standing 800 to 1,000 feet above the floor of the coulee, and several miles southwest is the locally famous Steamboat Rock, about 800 or 1,000 feet high.

The plant material is not as abundant, as varied, or as well preserved as that of the Latah formation at Spokane, Wash., but it is of considerable interest in that it furnishes several species that are new to the flora of our western Miocene. In addition, it greatly extends the range of many of the already known species and shows that essentially similar physical conditions prevailed over a very great area of country in Idaho, Washington, and Oregon during late Miocene time.

In all 55 different types of plants have been recognized in the material from Grand Coulee, or about one-third the number described from the Latah formation. Several of these, however, are not distinct species but comprise such things as maple keys, taxodium cone scales and staminate catkins, oak acorns and cupules, poplar bud scales, and a sycamore flower head, which undoubtedly appertain to the associated botanic species based on foliage.

They represent 34 genera in 25 families and 16 orders. Five of the genera are gymnosperms; the remainder are angiosperms. All but one of the angiosperms are dicotyledons, and all of these except the *Viburnum* belong to the choripetalous division. The most abundant individually are the leaves of birch, chestnut, elm, poplar, and oak. Seven different species of oaks have been named, but it should be pointed out that there has probably been an overrefinement in species due to the personal equations of the different students who have worked on Miocene floras, to the great variability of the leaves in this and other genera, such as *Betula*, *Ulmus*, and *Acer*, and to the practical impossibility of drawing specific lines throughout where large amounts of material are available for study.

The flora thus far discovered at Grand Coulee does not add anything to the conclusions regarding environmental conditions, which were set forth at some length in my discussion of the Latah flora.[1] Most of the genera represented no longer occur in this general region. Many have become entirely extinct in western North America since the Miocene epoch, and a few, such as *Glyptostrobus* and *Paliurus*, are confined to the Old World in existing floras.

Inasmuch as the flora discovered at Grand Coulee can be rather closely correlated as to age and as it is but a small part of the Miocene flora of western North America as a whole, an attempt to discuss the broader questions of its antecedents, environment, extinction, and bearing on the geologic history of the region does not seem worth while. This has been done to some extent in connection with the Latah flora, and permanent results can be reached only after the large amount of material from the Pacific States which is being studied by Chaney, me, and others has been fully worked up and published.

[1] Berry, E. W., A revision of the flora of the Latah formation: U. S. Geol. Survey Prof. Paper 154, pp. 233–234, 1929.

AGE OF THE GRAND COULEE PLANTS

The Grand Coulee flora can be correlated with great precision. Of the 55 objects enumerated in the accompanying table of distribution 48 occur in the Latah flora around Spokane, those that have not as yet been recorded from the Latah being *Glyptostrobus europaeus*, *Hicoria washingtoniana*, *Juglans egregia*, *Lysichiton washingtonense*, *Platanus* flower head, *Ptelea miocenica*, *Quercus mccanni*, and *Vitis bonseri*. Of these the *Hicoria*, *Lysichiton*, *Ptelea*, *Quercus*, and *Vitis* are new and are likely to turn up at any moment in the Spokane area. Moreover, the *Platanus* flower head, the fragment of a *Lysichiton* spadix, and the *Vitis* seed may be classed as more or less exceptional and accidental, both as to original preservation and as to subsequent discovery. *Juglans egregia* is a species of the California Miocene, and I have seen it in collections from Idaho. The *Glyptostrobus* has thus far unaccountably not been found in the Spokane region, but it will probably turn up there eventually, for it is not uncommon in the western Miocene and is present in the Payette formation of Idaho. Consequently there can be no doubt that the Grand Coulee flora is of the same age as the Latah flora of eastern Washington.

Next to the practical identity of the Grand Coulee flora with that of the Latah the greatest resemblance is shown to floras recently collected by Kirkham in west-central Idaho and submitted to me for identification. The localities with lists of species have been described in a recent paper by Kirkham and Johnson.[2] These authors consider the Latah a series rather than a formation and extend the name to include not only their Idaho localities but the Grand Coulee locality, which they had heard of through Mr. McCann, of Coulee City. In the accompanying table of distribution I have listed the Idaho occurrences as from the Payette formation, though I believe the plant-bearing beds in Idaho represent several horizons, and I question the propriety of using the name Latah there. If all the disconnected basins of sedimentation associated with the Columbia River lava are to be called by a single name, which I do not believe is the proper procedure, there are other and earlier names than Latah—for example, Payette (1898), Ellensburg (1900), and Mascall (1901). But it is not clear that the Payette beds are more than partly equivalent to the Latah. Certain plants from the Idaho section suggest a Pliocene age, and there are some elements identical with the Bridge Creek flora which do not occur in the Spokane area and which suggest that a part of the Idaho section is older than the typical Latah. This is not the place to attempt a discussion of these Idaho floras beyond making clear the qualification required by the present state of our knowledge in comparing the Grand Coulee plants with those identified or reported from Idaho localities.

Twelve of the Grand Coulee plants are recorded from the Mascall formation of Oregon, and it seems probable that this number will be increased when Chaney completes his revision of this standard flora and especially when the personal equations of various students in connection with such genera as *Acer*, *Liquidambar*, *Betula*, and *Ulmus* are taken into account.

Seven of the Grand Coulee plants are recorded from the Eagle Creek formation, and these seem to me to indicate that the Eagle Creek is somewhat younger than it is generally held to be.

Only four of the Grand Coulee plants are recorded from Florissant, Colo., but of these the *Populus* and *Liquidambar* are significant. As the Grand Coulee flora is practically identical with that from Spokane its real similarity to the Florissant flora must be greater than it seems, for the Spokane flora has a great many elements in common with that at Florissant and the later and unpublished collections from Spokane indicate that this resemblance is still stronger.

I consider that five of the Grand Coulee plants are represented in the flora from the St. Eugene silt of the Kootenay Valley, in British Columbia, described by Hollick.[3] I have already commented briefly on this,[4] and a more complete discussion is not called for in the present connection, but the great abundance of *Cebatha heteromorpha* in both floras seems to me to settle beyond dispute the age of the Canadian deposit.

The position to be assigned to the Grand Coulee flora in the world section of the Tertiary is tied up with the results of the study of the other scattered Miocene floras of the western United States. In my published account of the Latah flora I stated my belief that although the Latah might be as old as middle Miocene it was more probably upper Miocene. In the several years that have elapsed since the manuscript for that account was prepared I have studied numerous additional collections from the Spokane area, and nothing I have seen in these later collections has served to modify this statement. On the other hand, the evidence for an upper Miocene age is constantly becoming more convincing. This being the case for the Spokane flora, so much more extensive and better preserved than the Grand Coulee flora, the same conclusion holds equally for the Grand Coulee.

[2] Kirkham, V. R. D., and Johnson, M. M., The Latah formation in Idaho: Jour. Geology, vol. 37, pp. 483–504, 1929.

[3] Hollick, Arthur, The flora of the St. Eugene silts, Kootenay Valley, British Columbia: New York Bot. Garden Mem., vol. 7, pp. 389–464, pls. 29–47, 1927.

[4] Berry, E. W., The age of the St. Eugene silt in the Kootenay Valley, British Columbia: Roy. Soc. Canada, sec. 4, Trans., 3d ser., vol. 23, pp. 47–48, 1929.

Flora from Grand Coulee, Wash., compared with Miocene floras from other localities

	Latah formation, Spokane and vicinity	Mascall formation	Ellensburg formation	Payette formation of Idaho	Bridge Creek flora	Eagle Creek formation	Miocene of Yellowstone Park	Florissant, Colo.	California	St. Eugene silt, British Columbia
Acer merriami	×	×		×						
Acer, fruit	×	×								
Betula heteromorpha	×					×				(?)
Betula largei	×			×						
Carpites boraginoides	×			×						
Carpites ginkgoides	×									
Cassia spokanensis	×									
Castanea castaneaefolia	×	×		×					×	
Cebatha heteromorpha	×			×						×
Euonymus knowltoni	×			×						
Ficus washingtonensis	×			×						
Ficus interglacialis	×									×
Glyptostrobus europaeus				×						
Gordonia hesperia	×									
Hicoria washingtoniana										
Juglans egregia										
Laurus similis	×			×		×				
Libocedrus praedecurrens	×	(?)		×						
Liquidambar, fruits	×	×		×		×		×	×	
Lysichiton washingtonense										
Menispermites latahensis	×									
Nyssa hesperia	×			×						
Nyssa magnifica	×									
Paliurus hesperius	×			×						
Phyllites amplexicaulis	×									
Phyllites couleeanus										
Platanus aspera	×					×				
Platanus dissecta	×	×	×	×					×	(?)
Platanus, flower head										
Populus lesquereuxi	×							×		
Populus lindgreni	×	×	×	×						
Populus washingtonensis	×									
Populus, bud scales	×			×						
Prunus rusti	×									
Ptelea miocenica										
Quercus cognata	×			×						
Quercus mccanni										
Quercus merriami	×	×				×				
Quercus payettensis?	×			×						
Quercus pseudolyrata	(?)	×	×							
Quercus simulata	×			×		×				
Quercus treleasi	×			×						
Quercus, acorns and cupules	×			×						
Ribes fernquisti	×									
Sequoia langsdorfii	×	×		×	×			×		
Sophora alexanderi	×			×						
Sophora spokanensis	×			×						
Taxodium dubium	×	×		×				×		
Taxodium, cone scales				×						
Taxodium, staminate aments	×	×								
Tsuga latahensis	×									
Ulmus speciosa	×			×		×				
Umbellularia lanceolata	×			×						
Viburnum fernquisti	×									
Vitis bonseri										

A systematic list of the species identified in the Grand Coulee flora is given below, as it has not seemed necessary to describe any except those that are new or afford some addition to our knowledge.

Coniferophyta:
- Pinales:
  - Cupressinaceae:
    - Sequoia langsdorfii (Brongniart) Heer.
    - Taxodium dubium (Sternberg) Heer.
    - Taxodium, cone scales.
    - Taxodium, staminate aments.
    - Libocedrus praedecurrens Knowlton.
    - Glyptostrobus europaeus (Brongniart) Heer.
  - Pinaceae:
    - Tsuga latahensis Berry.

Spermatophyta:
- Angiospermae:
  - Monocotyledonae:
    - Arales:
      - Araceae:
        - Lysichiton washingtonense Berry.
  - Dicotyledonae:
    - Choripetalae:
      - Juglandales:
        - Juglandaceae:
          - Juglans egregia Lesquereux.
          - Hicoria washingtoniana Berry.
      - Salicales:
        - Salicaceae:
          - Populus lesquereuxi Cockerell.
          - Populus washingtonensis Knowlton.
          - Populus lindgreni Knowlton.
          - Populus, bud scales.
        - Betulaceae:
          - Betula heteromorpha Knowlton.
          - Betula largei Knowlton.
        - Fagaceae:
          - Castanea castaneaefolia (Unger) Knowlton.
          - Quercus payettensis Knowlton?
          - Quercus pseudolyrata Lesquereux.
          - Quercus merriami Knowlton.
          - Quercus cognata Knowlton.
          - Quercus mccanni Berry.
          - Quercus, acorns and cupules.
          - Quercus treleasi Berry.
          - Quercus simulata Knowlton.
      - Urticales:
        - Ulmaceae:
          - Ulmus speciosa Newberry.
        - Moraceae:
          - Ficus washingtonensis Knowlton.
          - Ficus interglacialis Hollick.
      - Platanales:
        - Platanaceae:
          - Platanus dissecta Lesquereux.
          - Platanus aspera Newberry.
          - Platanus, flower head.
      - Ranales:
        - Menispermaceae:
          - Menispermites latahensis Berry.
          - Cebatha heteromorpha (Knowlton) Berry.
      - Rosales:
        - Grossulariaceae:
          - Ribes fernquisti Berry.
        - Hamamelidaceae:
          - Liquidambar, fruits.

Spermatophyta—Continued.
- Angiospermae—Continued.
  - Dicotyledonae—Continued.
    - Choripetalae—Continued.
      - Rosales—Continued.
        - Drupaceae:
          - Prunus rusti Knowlton.
        - Caesalpiniaceae:
          - Cassia spokanensis Berry.
        - Papilionaceae:
          - Sophora alexanderi Knowlton.
          - Sophora spokanensis Knowlton.
      - Geraniales:
        - Rutaceae:
          - Ptelea miocenica Berry.
      - Sapindales:
        - Celastraceae:
          - Euonymus knowltoni Berry.
        - Aceraceae:
          - Acer merriami Knowlton.
          - Acer, fruit.
      - Rhamnales:
        - Rhamnaceae:
          - Paliurus hesperius Berry.
        - Vitaceae:
          - Vitis bonseri Berry.
      - Parietales:
        - Ternstroemiaceae:
          - Gordonia hesperia Berry.
      - Laurales:
        - Lauraceae:
          - Laurus similis Knowlton.
          - Umbellularia lanceolata Berry.
      - Umbellales:
        - Cornaceae:
          - Nyssa magnifica Knowlton.
          - Nyssa hesperia Berry.
    - Gamopetalae:
      - Rubiales:
        - Caprifoliaceae:
          - Viburnum fernquisti Berry.

Position uncertain:
- Carpites ginkgoides Knowlton.
- Carpites boraginoides Knowlton.
- Phyllites amplexicaulis Knowlton.
- Phyllites couleeanus Berry.

SYSTEMATIC DESCRIPTIONS

Phylum CONIFEROPHYTA

Order PINALES

Family CUPRESSINACEAE

Genus TAXODIUM L. C. Richard

Taxodium dubium (Sternberg) Heer

Plate 11, Figure 1

The more or less complete synonymy of this ubiquitous species has been repeatedly published in recent years and need not be repeated in the present connection.

This species was discussed and a number of illustrations were given in Knowlton's account of the Latah flora.[5]

[5] Knowlton, F. H., Flora of the Latah formation of Spokane, Wash., and Coeur d'Alene, Idaho: U. S. Geol. Survey Prof. Paper 140, p. 27, pl. 9, figs. 2, 7-9; pl. 01, fig. 2, 1926.

The leafy twigs are sparingly represented at Grand Coulee. Associated with these are excellently preserved cone scales, which do not differ appreciably from those of the recent species of southeastern North America. One of these from Grand Coulee is figured on the accompanying plate.

There also occur in the Grand Coulee deposits staminate aments of *Taxodium* exactly like those that have proved to be so common in the Spokane region.

Phylum SPERMATOPHYTA

Class ANGIOSPERMAE

Subclass MONOCOTYLEDONAE

Order ARALES

Family ARACEAE

Genus LYSICHITON Schott

Lysichiton washingtonense Berry, n. sp.

Plate 11, Figure 2

This species is based upon the impression of a tiny specimen which appears to represent parts of a crushed spadix of some aroid similar to or identical with *Lysichiton*. It shows the impression of the surface, which is seen to consist of small individuals (carpels?) closely packed and polygonal in outline, about 1 millimeter in diameter, highly convex distad, with a pronounced central umbilicus. The type and only specimen is shown enlarged in the accompanying illustration.

The genus *Lysichiton*, the sole survivor of the Araceae in western North America, has but one or two existing herbaceous species, ranging from eastern Siberia through Alaska and western Canada to California and Idaho. It is unfortunate that more complete material of the fossil form is not available, but it must be considered to be a matter of extreme luck that even a fragment was preserved and discovered.

Subclass DICOTYLEDONAE

Series CHORIPETALAE

Order JUGLANDALES

Family JUGLANDACEAE

Genus JUGLANS Linné

Juglans egregia Lesquereux

Plate 11, Figure 3

Juglans egregia Lesquereux, Harvard Coll. Mus. Comp. Zoology Mem., vol. 6, p. 36, pl. 9, fig. 12; pl. 10, fig. 1, 1878.
Knowlton, in Lindgren, Jour. Geology, vol. 4, p. 889, 1896.

This species was described by Lesquereux from the auriferous gravel of California and was based upon a considerable amount of fairly complete material showing much variation in size and some variation in form, particularly respecting the obtuseness or pointedness of the base. As might be expected, the broader leaves are obtuse and the narrower acute, but such variations as have been observed are well within the limits of a single botanic species as illustrated among existing forms.

Genus HICORIA Rafinesque

Hicoria washingtoniana Berry, n. sp.

Plate 11, Figure 4

This species is based upon the single incomplete specimen figured. The material scarcely warrants an attempt at a diagnosis, but as it differs from the large amount of material of this age from Washington and Idaho which I have studied it seems worthy of record. The specimen is interpreted as a terminal leaflet of a large-leaved species of hickory, although it is not possible to be sure that *Hicoria* and *Juglans* have not been confused in this case as they have been in the past by other authors. The specimen indicates an ovate leaf about 16 centimeters in length and 6 centimeters in maximum width. The midvein is stout and prominent. The secondaries are relatively widely spaced, stout, diverging at angles of 45° or slightly more, regularly ascending, and camptodrome. The tertiaries are indistinct but form an open areolation. The margins are beset with fairly large, uniform, closely spaced crenate teeth. The texture is fairly coriaceous.

Comparison of such incomplete material with either living or fossil species is worth little. In some respects it suggests the leaves of the Ternstroemiaceae, but it is larger and relatively wider than the members of this family in the western Miocene which I have referred to the genus *Gordonia*.

The genus *Hicoria* has been recorded in the Pacific region from the Miocene of Colorado, California, Spokane, Wash., British Columbia, and Oregon. It is, of course, present also in beds representing earlier horizons in this general region.

Order SALICALES

Genus POPULUS Linné

Populus lesquereuxi Cockerell

Populus heeri Lesquereux, The Cretaceous and Tertiary floras, p. 151, pl. 30, figs. 1–8; pl. 31, fig. 11, 1883. [Not Saporta.]
Populus lesquereuxi Cockerell, Torrey Bot. Club Bull., vol. 33, p. 307, 1906; Colorado Univ. Studies, vol. 3, p. 172. 1906; Am. Naturalist, vol. 44, p. 44, fig. 8, 1910.
Knowlton, U. S. Nat. Mus. Proc., vol. 51, p. 261, 1916.
Salix inquirenda Knowlton, U. S. Geol. Survey Prof. Paper 140, p. 32, pl. 11, figs. 1, 2, 1926.
Berry, U. S. Geol. Survey Prof. Paper 154, p. 242, 1929.

The Latah species named *Salix inquirenda* by Knowlton is represented by very large leaves at Grand Coulee and appears to me to be identical with the common Florissant form which Lesquereux determined as *Populus heeri* Saporta but which Cockerell has shown to be different from that European species. The extremely long and stout petiole, which is preserved in much of my material, is also confirmatory of the reference to *Populus* instead of to *Salix*.

Order FAGALES

Family FAGACEAE

Genus QUERCUS Linné

Quercus mccanni Berry, n. sp.

Plate 11, Figures 5–7

Leaves lanceolate to obovate, with an abruptly pointed apex and a base that varies from cuneate to truncately rounded and in many specimens is inequilateral. Most of the specimens are preserved as impressions, but in the two or three that show something of the leaf substance the texture appears to have been subcoriaceous, though less so than in the associated species of oaks. Margin entire for a very short distance above the base; elsewhere with regular spaced and sized teeth. These increase regularly in size upward to the widest part of the leaf and then decrease toward the apex. They are usually oblique and rounded and are separated by rounded sinuses, the counterpart of the teeth in form. In one or two of the more elongated and narrower leaves the teeth are more ascending and pointed, and these leaves are very similar to those of *Quercus horniana* Lesquereux, of the Mascall formation of Oregon, but the Grand Coulee leaves are connected by insensible gradations with the round-toothed forms with which they are associated and undoubtedly represent a single botanic species. Petiole stout, expanding proximad, 1.2 to 2 centimeters in length. Midvein stout, prominent on the underside of the leaf, becoming thin distad. Secondaries medium stout, regularly spaced, and subparallel; their angle of divergence from the midvein depends on the width of the leaf, varying from 40° to 60°; they are prevailingly straight, curving slightly distad and ending craspedodromely in the tips of the marginal teeth. The tertiary venation is quercoid, not prominent and seen with difficulty. Length 6.5 to 10 centimeters; maximum width, above the middle, 2.75 to 5 centimeters.

This characteristic species, which is named for F. W. McCann, president of the Coulee City Commercial Club, is obviously distinct from previously described forms, although it exhibits a certain resemblance to *Quercus horniana* Lesquereux,[6] of the Mascall formation, *Quercus spokanensis* Knowlton,[7] of the Latah formation, and *Quercus clarnensis* Trelease,[8] of the Clarno formation. This resemblance is greatest between these species, which are narrower forms with more pointed and more ascending teeth, and the more elongate and narrow specimens of *Quercus mccanni*.

In all its features *Quercus mccanni* is exceedingly like the leaves of the chestnut oaks of southeastern North America, and this agreement is so close that it would seem to indicate a close relationship and the former presence in the late Miocene of the West of a type of oak which subsequently became restricted to the East. A second alternative is indicated by the resemblance of these leaves to those of the existing *Quercus martensiana* Trelease, of the eastern Sierra Madre, *Quercus prinopsis* Trelease, of the Mexican table-land, and *Quercus chartacea* Trelease, of the Cordilleran region of Mexico.

Quercus simulata Knowlton

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; U. S. Geol. Survey Prof. Paper 140, p. 38, pl. 22, figs. 3, 4, 1926.
Chaney, Walker Mus. Contr., vol. 2, No. 5, p. 168, pl. 12, fig. 1, 1920.
Berry, U. S. Geol. Survey Prof. Paper 154, p. 246, pl. 51, figs. 6, 7, 9–11, 1929.
Salix elongata Knowlton [not O. Weber], U. S. Geol. Survey Prof. Paper 140, p. 32, pl. 12, fig. 4, 1926.
Quercus chaneyi Knowlton, idem, p. 38, pl. 22, fig. 1, 1926.
Quercus praenigra Knowlton, idem, p. 37, pl. 19, fig. 6, 1926.

This species was described by Knowlton from the Payette formation of Idaho and was identified by the same author from the Latah formation and by Chaney from the Eagle Creek formation. I have recently detected it in the Esmeralda formation of Nevada.

It is exceedingly common and variable in both the Payette and Latah formations. At Grand Coulee it is probably the most abundant species, and here again it shows its characteristic great variability both in form and in size. It ranges from narrowly to broadly lanceolate, with entire or sparingly toothed margins, either acuminate or bluntly tipped and with the base ranging from rounded to narrowly cuneate. Formerly I suggested comparisons with the existing *Quercus hypoleuca* Engelmann of the West or *Quercus phellos* Linné of the East.

I have subsequently had occasion to compare this and our other western Miocene oaks with the existing species of Mexico and Central America, with the result that I find a great similarity between *Quercus simulata* and a group of Mexican species, many of them shrubs or small trees, largely described in recent years by Trelease. These are *Quercus acapulcensis* Trelease, *Quercus obscura* Trelease, *Quercus transmontana* Trelease, *Quercus viminea* Trelease, and *Quercus hypoleuca* Engelmann, the last already mentioned in the preceding paragraph. All of these are forms of the western Sierra Madre. In addition *Quercus mexicana* Humboldt and Bonpland is also similar to the fossil form. This is a species of the Mexican table-land and adjacent cordillera. This resemblance between several of the oaks of the western Miocene and existing species of Mexico seems to be more than fortuitous, and I believe that it is of real significance.

[6] Lesquereux, Leo, U. S. Nat. Mus. Proc., vol. 11, p. 17, pl. 5, fig. 6, 1888.
[7] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 140, p. 37, pl. 19, fig. 3, 1926.
[8] Trelease, William, Brooklyn Bot. Garden Mem., vol. 1, p. 499, 1918.

Quercus treleasii Berry

Quercus treleasii Berry, U. S. Geol. Survey Prof. Paper 154, p. 247, pl. 52, figs. 1–3, 1929.

This species is abundant in the Latah formation and also in the recent collections from beds assigned to the Payette formation of Idaho. It is represented at Grand Coulee by a single specimen. Like some of the associated oaks, *Quercus treleasii* shows similarities to several existing Mexican species. These are *Quercus repanda* Humboldt and Bonpland, a shrub of the Mexican table-land; *Quercus chihuahuensis* Trelease and its varieties, of the western Sierra Madre; and *Quercus lecomteana* Trelease and *Quercus oleoides* Chamisso and Schlechtendal, the first a shrub and the second a small tree, both found in the eastern Sierra Madre.

Order URTICALES

Family MORACEAE

Genus FICUS Linné

Ficus interglacialis Hollick

Ficus interglacialis Hollick, New York Bot. Garden Jour., vol. 16, p. 44, pls. 152, 153, 1915; New York Bot. Garden Mem., vol. 7, p. 405, pls. 34, 35, 1927.

Equisetum, underground stem, Knowlton, U. S. Geol. Survey Prof. Paper 140, p. 24, pl. 9, fig. 1; pl. 26, fig. 5; pl. 29, fig. 8, 1926.

I am satisfied that the objects described from the Latah formation by Knowlton as underground tuber-bearing stems of *Equisetum* are the same as those described by Hollick from the St. Eugene silt of British Columbia as the fruits of a *Ficus*. They are present in the later collections from Spokane and vicinity and occur in the collections from Grand Coulee.

It is perhaps not possible to decide conclusively in favor of Hollick's identification, and a priori one would be more apt to expect *Equisetum* in the latitude and supposed environment than *Ficus*, especially as the abundant associated leaves referred to *Ficus washingtonensis* are not beyond suspicion. At the same time the axes have more the appearance of aerial stems than of rhizomes, and the supposed tubers, many of which are found detached, are conspicuously longitudinally ridged, entirely unlike any *Equisetum* tubers that I have seen, and I have seen a great many, both recent and fossil. On the other hand, they are similar to the fruits of a number of small hard spherical-fruited recent species of *Ficus*.

The specific name *interglacialis* was given because its author supposed that he was dealing with remains from an interglacial deposit, but for this there is no geologic or paleobotanic evidence.

Order PLATANALES

Family PLATANACEAE

Genus PLATANUS Linné

Platanus, flower

Plate 12, Figure 1

Little that is definite can be said of this specimen, which appears to represent a flower of *Platanus*, leaves of two species of which are found in association with it. It shows a more or less flattened central base from which radiate masses of more or less discrete objects that are interpreted as flowers. What appears to be the peduncle is preserved for a length of nearly 5 centimeters, but of course the association may represent nothing more than superposition of the supposed flower head and a pine needle or leaf petiole.

Order RANALES

Family MENISPERMACEAE

Genus CEBATHA Forskal

Cebatha heteromorpha (Knowlton)

Populus heteromorpha Knowlton, U. S. Geol. Survey Prof. Paper 140, p. 30, pl. 12, figs. 8–10; pl. 13, figs. 1–7; pl. 14, figs. 1–3; pl. 15, figs. 3–5, 1926.

Populus fairii Knowlton, idem, pl. 15, fig. 2; pl. 16, figs. 1–3.

Cebatha multiformis Hollick, New York Bot. Garden Mem., vol. 7, p. 406, pl. 38, figs. 1–6; pl. 39, figs. 1–3, 1927.

Cissampelos dubiosa Hollick, idem, p. 408, pl. 37, figs. 4, 5 (6, 7?); pl. 39, fig. 4.

This exceedingly variable species is the most abundant form in the Latah collections and is also found in the westward extension of this horizon in Grant County, Wash., and in the Payette of Idaho. It occurs in all sizes and shapes and shows a corresponding range of variation in its marginal characters. These have been sufficiently illustrated in the large suite of specimens figured by Knowlton and Hollick. As Knowlton suspected, the forms called *fairii* are not distinct from the type, but every gradation is represented, and leaves with three, four, or five primaries are not distinctive. Every locality in the recent collections that contains one contains the other. Hollick, in describing the flora from the St. Eugene silts of British Columbia, recognized the botanic affinity of these leaves but refrained from including Knowlton's supposed *Populus* of the Latah formation with the British Columbia material because he thought there was a great difference in age between the two outcrops. It has since been shown that the Latah is younger than Knowlton supposed it to be, and the evidence is fairly strong that the St. Eugene silts are much older than Hollick thought.

The older paleobotanists referred to *Populus* a great many fossil leaves which show no relationship to that genus. Knowlton in his account of *Populus heteromorpha* recognized that it was unlike any existing *Populus* but convinced himself that it was a *Populus* because it resembled *Populus arctica* Heer of the early Tertiary, a species which I have shown is also not a *Populus*.

Genus MENISPERMITES Lesquereux

Menispermites latahensis Berry

Plate 12, Figures 4–6

Menispermites latahensis Berry, U. S. Geol. Survey Prof. Paper 154, p. 249, pl. 52, fig. 4, 1929.

Leaves relatively small, about as long as their maximum width, trilobate, with a wide central lobe and a pair of basal lateral lobes. Sinuses rounded, extending inward about halfway to the midvein. Margin with shallow, irregularly spaced dentate teeth, most prominent toward tip of central lobe and on the proximal side of the lateral lobes. Apex rounded. Tips of lateral lobes rounded, asymmetric. Base perfoliate. Texture thin. Length about 4.8 to 6 centimeters; maximum width, across lateral lobes, 5.25 to 8 centimeters. Petiole stout, presumably long, though preserved for only 1.25 centimeters. Primaries stout, diverging from the base at angles of about 45° to 50°, the laterals curving outward to the tips of the lateral lobes. Secondaries numerous, ascending, indifferently camptodrome or craspedodrome according as the margin at their extremities is entire or toothed. Areolation large, polygonal.

This species was apparently not uncommon at Grand Coulee in late Miocene time, and the three specimens collected are about 50 per cent larger than the type material from Spokane, with which they agree perfectly in form and venation. They are not unlike some of the modern forms that American botanists refer to the genus *Cebatha* Forskal, which the Europeans generally include in the large genus *Cocculus* De Candolle. They are also similar to some of the forms referred to *Menispermum* Linné, which, as now restricted, includes an existing species in eastern North America and another in eastern Asia. In view of the uncertainty of the generic affinity I prefer to refer the fossil to the form genus *Menispermites*, proposed by Lesquereux to fit just such cases.

Leaves of this family are common in the Upper Cretaceous of western North America but are extremely rare in the Tertiary of that region. The present species is not only a link with the past but also a link between eastern Asia and eastern North America, where its descendants still survive.

Order ROSALES

Family GROSSULARIACEAE

Genus RIBES Linné

Ribes fernquisti Berry

Plate 12, Figure 2

Ribes fernquisti Berry, U. S. Geol. Survey Prof. Paper 154, p. 251, pl. 63, fig. 21, 1929.

This species was described as follows:

Leaves relatively small, trilobate. Margin, except at base and in the sinuses, with coarse dentate teeth. Texture subcoriaceous. Length about 5 centimeters, as is also the maximum width. Apical lobe about as broad as it is long, bluntly pointed at apex. Base of the leaf truncate. Sinuses narrow and not deep. Primaries, three from the top of the petiole, stout and prominent. Secondaries stout, prominent, diverging from the primaries at acute angles. There are three or four subopposite to alternate secondaries in the central lobe, curved proximad and more straight distad, and craspedodrome. In the lateral lobes the basal secondary on the outside diverges close to the base and is relatively straighter and more prominent than its fellows and might be termed a subprimary. There is a second secondary on the outside below the basal secondary on the inside, and the latter is much curved, ascending inside the sinus margin and ending camptodromely if the margin is entire and craspedodromely if it has ascended to a point where there is a tooth on the margin. The primaries, particularly the lateral ones, are slightly flexuous with respect to the alternate divergence of the secondaries. The tertiary branches from the distal parts of the secondaries are well marked, and the ultimate ones are usually craspedodrome. Internal tertiaries are transverse and percurrent or inosculating in the middle region. The areolation is an open mesh that agrees precisely with that in leaves of existing members of the genus.

The single specimen detected in the collections from Grand Coulee is still smaller than the type material, measuring 2.5 centimeters in length and 2.6 centimeters in maximum width. Otherwise it is identical with the material from Spokane.

Ribes has not often been recognized in the fossil state. Two species have, however, been recorded from Florissant, Colo., but both of these are unlike the Latah form. There are over 60 existing species of *Ribes*, all shrubby and widely distributed in the North Temperate Zone and in the Andes of South America. Fully 50 species are known from North America.

Family HAMAMELIDACEAE

Genus LIQUIDAMBAR

Liquidambar, fruit

Liquidambar, fruit, Knowlton, U. S. Geol. Survey Prof. Paper 140, p. 42, pl. 10, fig. 10, 1926.

Knowlton described and figured a rather well preserved fruit from the Latah formation at Spokane and suggested its probable relationship to the associated leaves, which he identified as *Liquidambar pachyphyllum* Knowlton but which I regard as simply a variant of the common Miocene *Liquidambar californicum* Lesquereux. Subsequently additional fruits have been collected from the Latah formation. I have no doubt that these fruits belong to this species.

The material from Grand Coulee is especially interesting, as there are no traces of leaves in the collection and over a dozen of the fruits. In several specimens more or less of the peduncle is preserved. This is unusually stout, and in one small specimen in which it appears to be complete it is only 4 centimeters in length. The presence of fruits and no leaves may be explained as due to water transportation of the material, for the fruits are dry when shed and readily float, and the leaves decay in water more rapidly than leaves of most other genera.

Order GERANIALES

Family RUTACEAE

Genus PTELEA Linné

Ptelea miocenica Berry, n. sp.

Plate 12, Figure 7

Samara broadly winged, subcircular in outline, emarginate at both the apex and base. Peduncle slender, incomplete, preserved for a length of about 6 millimeters. Seed cavity fusiform, widest above the middle and more tapering proximad than distad. It has the appearance of being 2-celled. Length about 1 centimeter; maximum width about 6 millimeters. The whole, including wing, about 1.75 centimeters long and 2.4 centimeters in maximum width. The wing is thin but of firm consistency and is faintly radiately reticulate veined.

This characteristic fruit is very close to that of the existing *Ptelea trifoliata* Linné and is the first representative of this genus found fossil on the Pacific slope. The genus makes its appearance in the lower Eocene of the Mississippi embayment and is sparingly represented in the geologic record. A Miocene species based upon the trifoliate leaves has been recorded from Florissant, Colo.,[9] and it is quite possible that the present fruit represents the same botanic species as the leaves found at Florissant. The genus is not uncommon in the Miocene of Europe.

Ptelea has four or five existing species of shrubs or small trees confined to the United States and Mexico, ranging northward to southern Ontario and westward to Colorado and New Mexico.

[9] Cockerell, T. D. A., Am. Mus. Nat. Hist. Bull., vol. 24, p. 98, 1908.

Order SAPINDALES

Family ACERACEAE

Genus ACER Linne

Acer merriami Knowlton

Plate 13, Figure 13

Acer merriami Knowlton, U. S. Geol. Survey Bull. 204, p. 74, pl. 14, fig. 7, 1902; U. S. Geol. Survey Prof. Paper 140, p. 45, pl. 28, fig. 1, 1926.

The maples from the western Miocene are in a state of confusion, too many species have been described, and specific names have also usually been given to the detached fruits. The present specimens are referred to *Acer merriami* because they are decidedly 3-lobed and have but three primaries, although I do not regard either of these features as good specific characters. The specimen figured differs from the type in the narrower lateral lobes, in consequence of which the base is cuneate instead of cordate, a very simple variation and of no specific value. In this last feature it resembles the leaf from the Latah formation which Knowlton referred to this species.

Order RHAMNALES

Family RHAMNACEAE

Genus PALIURUS Jussieu

Paliurus hesperius Berry

Plate 13, Figures 1–5

Paliurus hesperius Berry, Am. Jour. Sci., 5th ser., vol. 16, p. 40, figs. 1–3, 1928; U. S. Geol. Survey Prof. Paper 154, p. 257, pl. 57, fig. 1, 1929.

It was my original intention to describe the leaves and fruits of this *Paliurus* as separate species. The fruits were discovered and described in 1928, after the manuscript for my revision of the Latah flora (Professional Paper 154–H) had been prepared, and in the proof of that paper (published in 1929) the name given to the fruit was used for the leaves without any description of the fruits, a citation to the earlier description being inserted. As leaves and fruits are associated at Spokane and at Grand Coulee, nearly 100 miles west of Spokane, it is a reasonable conclusion that both belong to the same botanic species. Under the circumstances the collective species should be redescribed.

Leaves of medium size, broadly ovate, widest below the middle; the apex pointed but not extended; base broadly rounded or slightly cordate. Texture subcoriaceous. Margins with closely spaced, prevailingly small, crenate teeth. Length about 7 centimeters; maximum width about 4.5 centimeters. Petiole not preserved. Midvein stout, prominent. Lateral primaries diverge from the base at acute angles; these are as stout as the midvein and curve upward and barely escape being acrodrome by uniting with short secondaries from the distal part of the midvein. The lateral primaries give off on the outside several camptodrome secondaries. The areolation is a fine mesh indistinctly preserved.

These leaves are not uncommon in the Latah formation at Spokane; they occur sparingly at Grand Coulee and also in the Payette formation of Nez Perce County, Idaho, about 85 miles east of south of Spokane.

The fruits are discoidal, peltate, pedunculate; the essential part depressed turbinate, the margin extended horizontally as a broad scarious, veined wing.

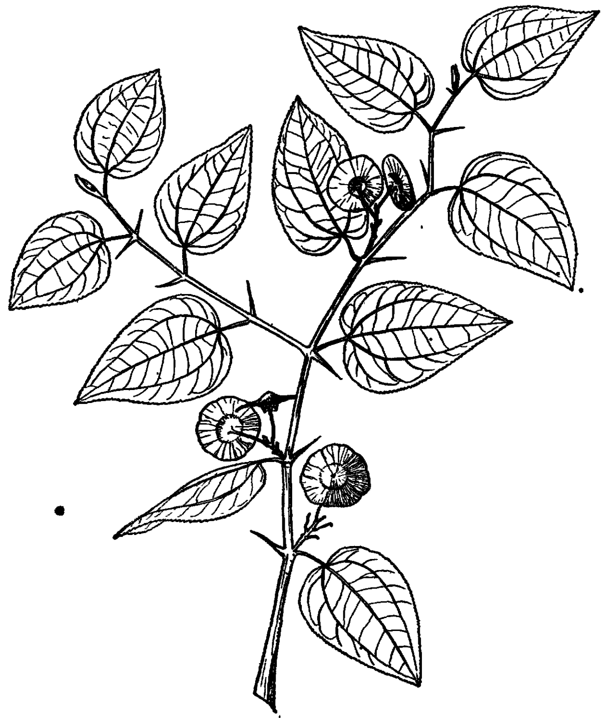


FIGURE 3.—Restoration of *Paliurus hesperius*

The wing margin is irregularly sinuate. The veins are radial in direction, are slightly undulate, and may be simple or once or twice forked.

As preserved the whole fruit departs slightly from circular in outline, being about 1.2 by 1.6 centimeters in diameter. The type comprises two specimens that are counterparts, split in the plane of the wing, which is well preserved. The fruit substance is gone in the central part of both specimens and was probably lost when the specimen was split open, as one counterpart shows the cast of the apical umbo above the wing and the other shows a cast of the proximal part below the wing. These are slightly deformed by pressure during fossilization but preserve the details in a remarkable way and have served for the reconstructed median longitudinal section shown in the accompanying Figure 3. Figure 1 on Plate 13 shows the fruit viewed from below pressed down over the peduncle, which is seen projecting below the wing margin. In the center is the cast of the rounded apex, with a prominent conical tip from which impressions of the veins radiate. The impression is darkened around the margin of the umbo, where the substance is preserved at the inner margin of the wing.

The counterpart is similar except in the center, where the deep cast of the conical part of the fruit below the wing, somewhat offset, is preserved. This shows clearly the collar around the upper expanded end of the peduncle and the scar where its distal end was attached to the base of the fruit. The material is almost as good as a recent *Paliurus* fruit and is much better for having the resistant substance of the fruit proper gone, because both surfaces can be studied, one of which would have inevitably been concealed had it not dropped out when the clay was split. The foregoing description is based upon the type specimen. Subsequently several somewhat smaller specimens have been collected from the same locality as well as from the Latah formation in the brickyard exposure at Spokane. A restoration of the species is attempted in the accompanying text figure.

The fossil agrees with the fruits of the recent species of *Paliurus* in every feature except that it is slightly smaller, in this respect being closest to the extising *Paliurus aculeatus* Lamarck, although the existing forms show considerable variation in the size of their fruits, and I have not enough material to be sure of the limits of variation in either the existing or the fossil forms. The fruits of *Paliurus aculeatus* which I have seen are more robust, with a larger essential part, which is much more massive proximad below the wing, thicker wings, less visible venation, and shorter peduncle. The fossil is more like the fruits of *Paliurus orientalis* Franchet that I have seen, in relative proportions, in the thinner wing with greater visibility of the veins, and in the relative length of the peduncle. No leaves are associated with the fossil, but at approximately the same horizon both at Grand Coulee and in the Latah formation at Spokane there are leaves of a *Paliurus* which are nearer to *Paliurus orientalis* than they are to the other existing species. It is very probable that leaves and fruit represent the same Miocene species, but this can not yet be demonstrated.

The genus *Paliurus* of Jussieu contains two or three existing species of shrubs or small trees with cordate or ovate, palmately 3-veined, usually small leaves with stipular thorns. The fruits are coriaceous, peltate, umbonate, with a horizontal marginal radiately veined wing. In existing floras they are restricted to dry-soil habitats from Spain on the west to Japan on the east. *Paliurus aculeatus* Lamarck extends from Spain through southern Europe, Asia Minor, Crimea, the Caucasus, and Persia to China (Szechwan). *Paliurus ramosissimus* Poiret extends from about 27°

north latitude in Kiangsi to Japan, and *Paliurus orientalis* Franchet, sometimes united with the preceding, reaches the stature of a thin tree sometimes 50 feet tall in eastern Szechwan and Shensi, China. Whatever the taxonomic distinction of the three, the ranges overlap, and the geologic record is sufficiently complete to show that their present range is a restricted one and that they represent relict species.

Turning now to the geologic record, we may note that a considerable number of fossil species have been described, based for the most part on leaves and therefore subject to the uncertainties attending the identification of remains of this class. The oldest records embrace 13 species, so called, of leaves from the Upper Cretaceous. These include four from the Dakota sandstone of Kansas, one from the Patoot beds of Greenland, two from the Mill Creek beds of western Canada, one from Vancouver Island, one from the Eutaw formation of Georgia, three from the Magothy formation of New Jersey and contemporaneous beds on Staten and Long Islands, and one from the so-called "Laramie" of Yellowstone Park. Many of these are very similar to the leaves of the existing species but lack the corroboration of associated fruits or structural remains.

The Eocene has furnished at least 10 nominal species, including occurrences in western Greenland, Svalbard (Spitzbergen), Siberia, and Alaska on the north and in British Columbia, Montana, Colorado, and Wyoming in the western part of North America. I have described three species from the Wilcox group (lower Eocene) of the Mississippi embayment, and one of these is represented by characteristic fruits.[10] Seward [11] has described a large fruit from the supposed Eocene of southeastern Nigeria which has the appearance of a *Paliurus* but which is not certainly such.

The Oligocene contains at least three species—one from Louisiana represented by very characteristic leaves and thorny stems and two from southeastern France represented by both leaves and fruit.

At least 13 nominal species have been recorded from the Miocene. These include identifications based upon leaves from Alsace, Switzerland, Bohemia, Italy, France, Silesia, and two from Florissant, Colo., the last not conclusive in themselves but highly probable in view of the occurrence of typical fruits at the same Miocene horizon in the State of Washington. Miocene species based upon fruits include occurrences in Bohemia and Styria,[12] Switzerland,[13] and southern Russia. The last, which comes from the Sarmatian stage, is scarcely if at all distinguishable from the existing *Paliurus aculeatus*.[14] The Pliocene record consists of a typical fruit from central France (Cantal), which is also indistinguishable from the existing *Paliurus aculeatus*.[15]

In view of what we know of the plant history of the Tertiary it is surely of interest that the Miocene species from Washington should be most similar to the restricted species of south-central China (*P. orientalis*), as are also the leaves associated with the fruit, and that there should be earlier (late Eocene) species in the intervening region in Alaska and Siberia.

Family VITACEAE

Genus VITIS Linné

Vitis bonseri Berry, n. sp.

Plate 13, Figure 6

A very characteristic seed. Somewhat compressed, broadly obovate in profile, stoutly obtusely pointed at the base, broadly rounded above. Hilum large and circular midway between the apex and the base; raphe narrow. Testa thin. Length 4.25 millimeters; maximum width 3.5 millimeters. The single specimen is split medially, and the type consists of the original and counterpart, which show the opposite sides of the seed viewed from within.

In size and form the fossil is indistinguishable from the seeds of a number of existing species of *Vitis*, so that comparisons are without significance.

The occurrence of these characteristic seeds is of considerable interest because no leaves of this genus are associated with them; in fact, except for very doubtful leaf material from the Latah formation at Spokane and equally doubtful material from Contra Costa County, Calif., the only Miocene occurrences of *Vitis* recorded from western North America are two species from Florissant, Colo. The genus is considered by Knowlton to be present in the late Upper Cretaceous of New Mexico and Wyoming, and several species have been recorded from the early Tertiary of the western United States, British Columbia, and Alaska. None have been recognized in eastern North America in beds earlier than the Pliocene Citronelle formation of Alabama.

Order PARIETALES

Family TERNSTROEMIACEAE

Genus GORDONIA

Gordonia hesperia Berry

Plate 13, Figures 7, 8

Gordonia hesperia Berry, Am. Jour. Sci., vol. 18, p. 430, figs. 1, 2, 1929.

Although the specimens of this species from Grand Coulee are relatively shorter and wider than the specimens figured from the Latah formation at

[10] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 279, pl. 71, fig. 4, text fig. 14, 1916.

[11] Seward, A. C., Nigeria Geol. Survey Bull. 6, p. 75, pl. 1, fig. 5, 1924.

[12] Ettingshausen, C. von, Die fossil Flora des Tertiär-Beckens von Bilin, pt. 3, p. 39, pl. 50, figs. 6, 7, 1869.

[13] Heer, Oswald, Flora tertiaria Helvetiae, vol. 3, p. 76, pl. 122, figs. 27–39, 1859.

[14] Kryshtofovich, A., Acad. imp. sci. St.-Pétersbourg Bull. 9, p. 592, pl. 1, fig. 1.

[15] Langeron, Maurice, Soc. hist. nat. Autun Bull., vol. 15, p. 85, pl. 6, text fig. 1, 1902.

Spokane, the abundance of material from the Spokane locality shows that they fall within the limits of variation of the species.

It is an interesting fact, already discussed in the paper above cited, that our northwestern Miocene contains two species of *Gordonia* based upon leaves and two based upon seeds and that the latter are more similar to existing Asiatic species than to the existing species of southeastern North America.

Order UMBELLALES

Family CORNACEAE

Genus NYSSA Linné

Nyssa hesperia Berry, n. sp.

Plate 13, Figures 9–11

Stones of medium size, prolate spheroidal or slightly compressed in form, widest medially and about equally rounded at both ends, with about 10 prominent wide rounded ribs separated by narrow deep sulci. About 1.5 centimeters or slightly less in length and about 7.5 millimeters in diameter. All the specimens collected are preserved as casts in the clays, and they show various degrees of flattening. The type comes from the brickyard exposure of the Latah formation, but they are also not uncommon in the Miocene deposits of Idaho usually referred to the Payette formation. They are very much smaller, more rounded at the ends, and with fewer ribs than *Nyssa magnifica* (Knowlton) Berry [16] of the Latah formation. They are associated with the leaves described as *Nyssa knowltoni* Berry [17] both in the Latah and in the Payette.

The stones of *Nyssa* are very abundant in the earlier Tertiary of North America, a great variety having been described from the Eocene lignites of Brandon, Vt., but for some reason they are much rarer in the later Tertiary, where we know only this and one other species from the Latah and its equivalents and a third species from the Miocene Calvert formation of Virginia. Only two American Miocene species based upon leaves are known—the one mentioned above and a second from the Eagle Creek formation and the Bridge Creek shales of Chaney in Oregon.

Species of *Nyssa* based upon the stones alone are always of doubtful specific distinctness, and I might mention a great many so-called species of stones from other and very different horizons, both in this country and abroad, which resemble the present species, but such comparisons lack any real value.

[16] Berry, E. W., U. S. Geol. Survey Prof. Paper 154, p. 261, 1929.

[17] Idem, p. 261, pl. 59, fig. 7.

POSITION UNCERTAIN

Phyllites couleeanus Berry, n. sp.

Plate 13, Figure 12

This single specimen seems to me so obviously to represent an abnormal leaf that I have not ventured to attempt a determination. It is elliptical in general outline, about 6.5 centimeters long and 4 centimeters in maximum width. Apex rounded truncate. Base cuneate. Margins entire for their lower two-thirds; above with a few subequal prominent teeth. Midvein stout and prominent. Secondaries nine or ten pairs, medium stout; the basal diverge at wide angles approaching 90° and become progressively more ascending upward, the angle of divergence in the tip being about 45°. The lower four or five secondaries are camptodrome; the remainder are craspedodrome, ending in the teeth. The tertiaries are indistinct.

My belief is that this leaf is an abnormal leaf of some oak, quite likely the common form at this outcrop which I have described as *Quercus mccanni*.

1

X 4

2

4

6

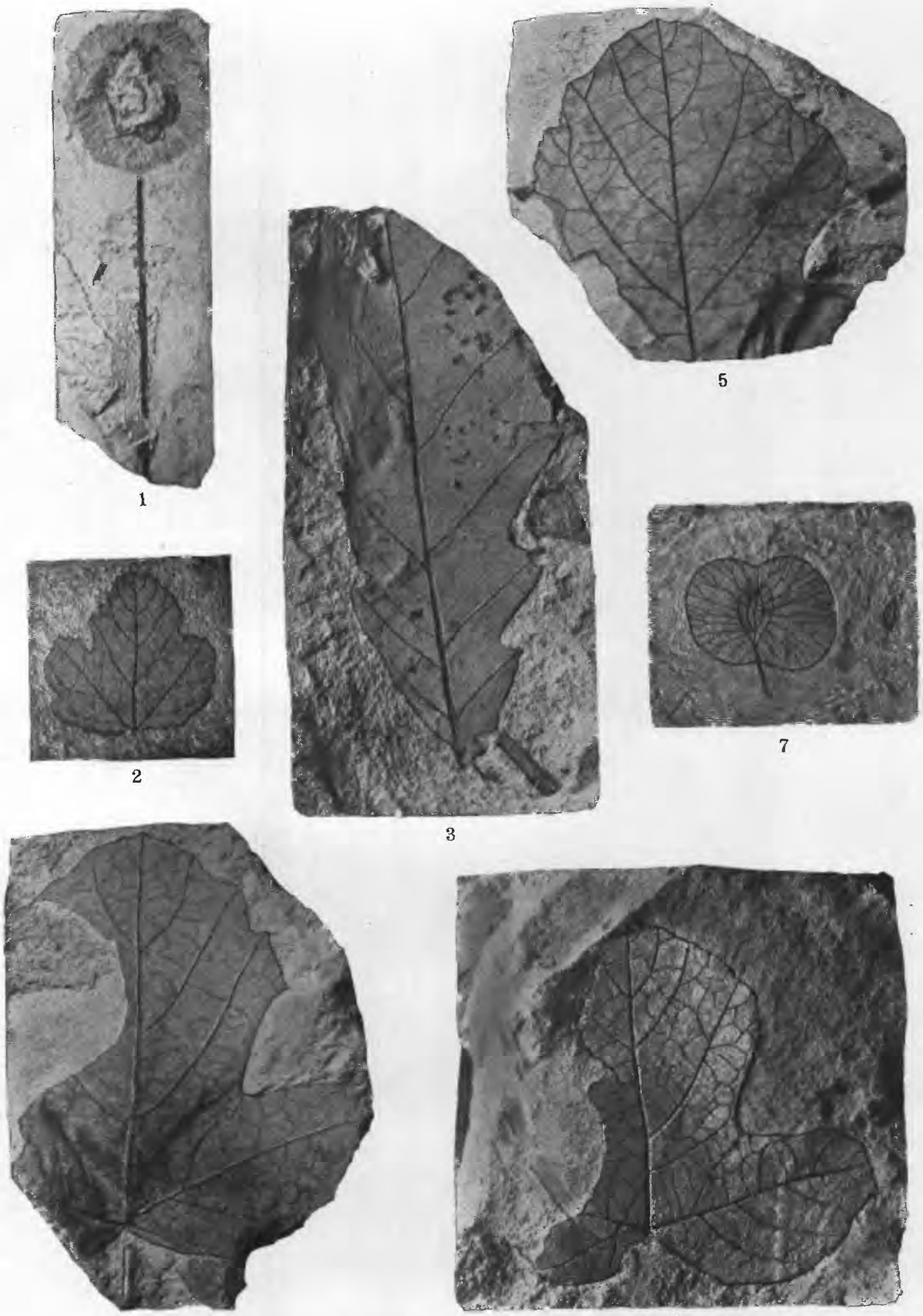
3

5

7

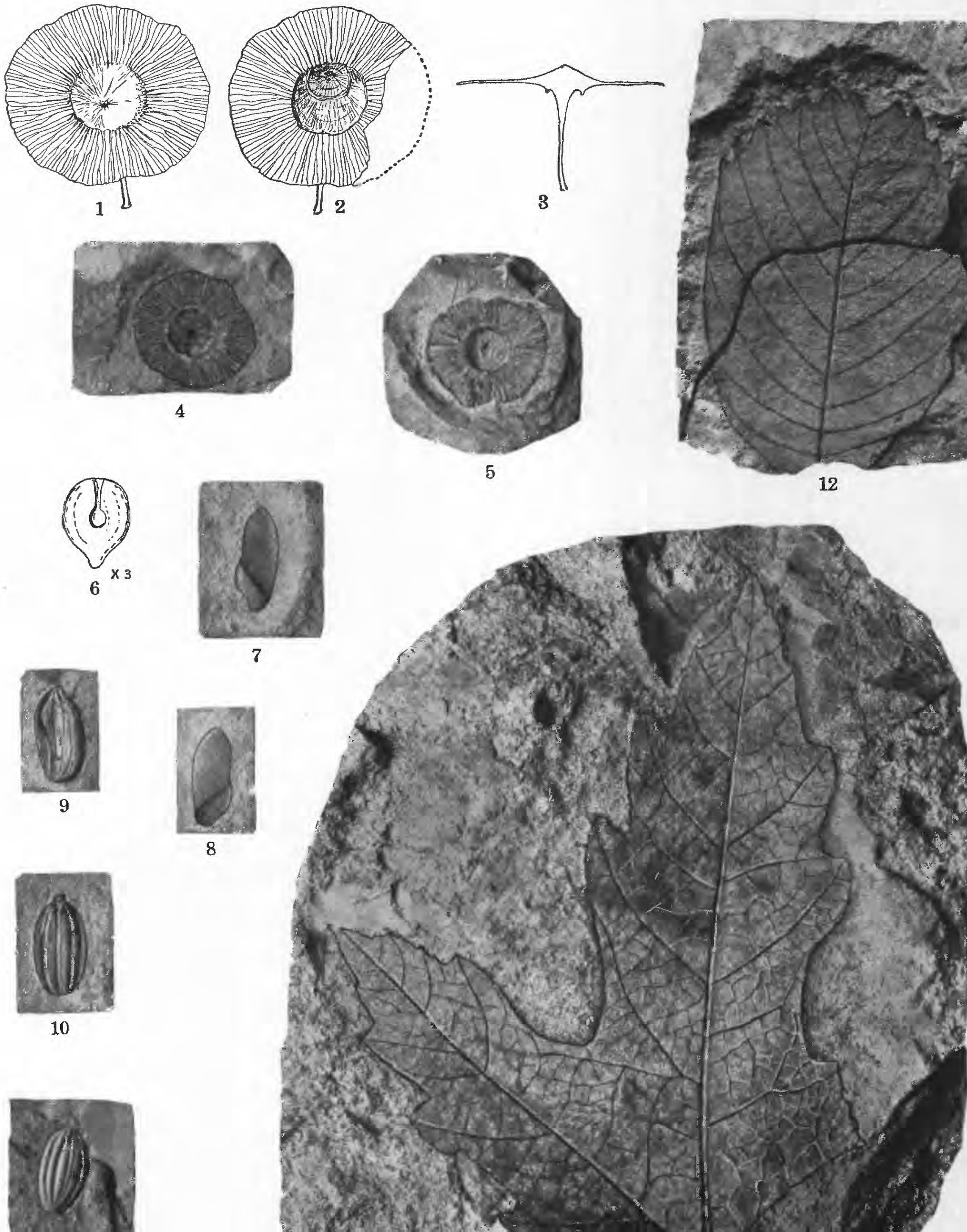
MIOCENE FLORA FROM GRAND COULEE, WASH.

1. Cone scale of *Taxodium dubium* (Sternberg) Heer.
2. *Lysichiton washingtonense* Berry, n. sp., fragment of a spadix.
3. *Juglans egregia* Lesquereux, terminal leaflet.
4. *Hicoria washingtoniana* Berry, n. sp., terminal leaflet.
5–7. Leaves of *Quercus mccanni* Berry, n. sp.



MIOCENE FLORA FROM GRAND COULEE, WASH.

1. Flower head of *Platanus*.
2. *Ribes fernquisti* Berry.
3. *Quercus cognatus* Knowlton, fragment with leaf spot fungi.
4–6. *Menispermites latahensis* Berry.
7. *Ptelea miocenica* Berry, n. sp.



MIOCENE FLORA FROM GRAND COULEE, WASH.

1–5. *Paliurus hesperius* Berry. 1, 2, Opposite views of the type; 3, side view restored; 4, 5, photographs of smaller specimens.
6. *Vitis bonseri* Berry, n. sp., seed, inside view.
7, 8. *Gordonia hesperia* Berry.
9–11. *Nyssa hesperia* Berry, n. sp. 9, 10 from Grand Coulee; 11 from Spokane.
12. *Phyllites couleeana* Berry, n. sp.
13. *Acer merriami* Knowlton.

PLIOCENE FOSSILS FROM LIMESTONE IN SOUTHERN FLORIDA

By WENDELL C. MANSFIELD

ABSTRACT

This paper describes the mollusks and echinoids found in limestone dredged from ditches along the Tamiami Trail in southern Florida, in the area mapped as "Lostmans River limestone (Quaternary)" by Sanford but included in the Pliocene Caloosahatchee formation by Cooke and Mossom on the evidence of these fossils as identified by Mansfield. The matrix of the fossils is unlike the typical Caloosahatchee formation, which is sandy, but the fauna is closely related to that of the upper part of the Caloosahatchee formation and is regarded as a facies of the Caloosahatchee. The fauna shows considerable resemblance to that of the Imperial formation of California but may not be contemporaneous with it.

INTRODUCTION

The fossils upon which this paper is based were collected in February, 1927, by C. Wythe Cooke, geologist, of the United States Geological Survey, Stuart Mossom, then assistant on the Florida Geological Survey, and W. C. Mansfield. The five collections here reported upon were obtained along the Tamiami Trail within a northwest-southeast distance of about 34 miles, in Collier and Monroe Counties, Fla. The fossils were embedded in white or gray limestone, here referred to the Caloosahatchee marl, which had been dredged from shallow ditches to form the roadbed of the Tamiami Trail and which was not observed in place. Cooke and Mossom[1] give a brief account of these collections, referring them to the Pliocene. These collections are of considerable interest because they extend the range of Pliocene faunas much farther south than they had been known before.

I wish to express my sincere thanks to L. W. Stephenson and C. Wythe Cooke, of the United States Geological Survey, and to Austin H. Clark, of the United States National Museum, for helpful assistance.

The photographs for the illustrations of this paper were made in the laboratory of the United States Geological Survey by W. O. Hazard, and the prints were retouched by Miss Frances Wieser.

FORMER WORK IN THE AREA

The fossils described in this report were collected in the area formerly mapped under the name "Lostmans River limestone," proposed by Sanford[2] for a dark to light crystalline to brittle limestone that is sandy in places. The type locality of the "Lostmans River limestone" is on the Lostmans River, Collier County, about 15 miles south of station 1/1179, one of the localities at which the fossils described in the present paper were collected. Sanford referred the "Lostmans River limestone" to the Pleistocene. Cooke and Mossom,[3] however, did not adopt this name but mapped the area formerly outlined by Sanford for this limestone in part as Miami oolite (Pleistocene) and in part as Caloosahatchee marl (Pliocene). The area in which the fossils here described were collected is mapped by Cooke and Mossom as the Caloosahatchee marl, and the area at the type locality of the "Lostmans River limestone" as the Miami oolite. Cooke and Mossom evidently considered the "Lostmans River limestone" equivalent in age to the Miami oolite.

Dall and Harris[4] described the rock at the Lostmans River as being very hard and compact and consisting of large masses of Polyzoa more or less completely changed into crystalline limestone, the cavities filled with crystals of calc spar. The only mollusk reported from this limestone was a single valve of *Chione cancellata* (Linnaeus), a species ranging in age from the Pliocene to the Recent. This species was found only at one locality (station 1/1177) among the collections described in the present paper.

As I have not seen samples of limestone or organic remains from the type locality of the "Lostmans River limestone," I do not know whether the rock in which the fossils here described were found is the same as the "Lostmans River limestone" or a different limestone, but I am of the opinion that it is different.

GEOGRAPHIC OCCURRENCE, MATRIX, AND FAUNAL COMPOSITION

The following is a brief description of the material in which the fossils were embedded, based on the matrix attached to the fossils, and a brief account of the kinds of organisms found at each locality.

Station 1/1176. Tamiami Trail, about 11 miles east by north of Marco, Collier County. Dirty-white to gray, rather hard, porous, nonoolitic limestone with inclusions of clear angular quartz grains. The cavities were originally occupied by the tests of organisms, mainly mollusks. Some of these cavities are now partly filled with small, rounded, attached

[1] Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida Geol. Survey Twentieth Ann. Rept., p. 156, 1929.

[2] Sanford, Samuel, The topography and geology of southern Florida: Florida Geol. Survey Second Ann. Rept., p. 222, 1909.

[3] Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida Geol. Survey Twentieth Ann. Rept., p. 207, 1929.

[4] Dall, W. H., and Harris, G. D., The Neocene of North America: U. S. Geol. Survey Bull. 84, p. 100, 1892.

limy bodies. The fauna consists of small and large mollusks, bryozoans, and barnacles. To judge from the nature of the matrix, all the organisms came from the same bed.

Station 1/1178. Tamiami Trail, about 6 miles west of the crossroads leading to Everglades, Collier County. The matrix is similar to that at station 1/1176. The fauna consists of large mollusks, bryozoans, foraminifers, and echinoids. The nature of the matrix indicates that all the fossils came from the same bed.

Station 1/1180. Tamiami Trail at Carnestown, 4 miles north of Everglades, Collier County. The matrix is similar to that at stations 1/1176 and 1/1178. The fauna consists of large mollusks, echinoids, bryozoans, and many small foraminifers. The nature of the matrix indicates that all the fossils came from the same bed.

Station 1/1177. Tamiami Trail, 5 miles east of Carnestown and about 7 miles northeast of Everglades, Collier County. The matrix is similar to that at the localities above described. The fauna consists of large mollusks, bryozoans, foraminifers, and echinoderms. The presence of the species *Chione cancellata* (Linnaeus) in this collection may indicate that it came from a stratigraphically higher limestone, as this species was not recognized with certainty in the other collections.

Station 1/1179. Tamiami Trail, 9 miles west of Pinecrest, in sec. 13, T. 54 S., R. 32 E., Monroe County. The matrix is mainly similar to that at station 1/1177 but slightly more compact and harder. The fauna consists of large mollusks, one species of echinoid, bryozoans, and barnacles. To judge from the nature of the matrix, probably most if not all the fossils came from the same bed.

GEOLOGIC OCCURRENCE

Although the conditions at the localities at which the fossils were collected did not afford data for determining the thickness of the limestone, Sanford[5] reports that a well drilled at Everglades, 4 miles south of station 1/1180 of this paper, passed through 30 feet of limestone (presumably the same as the fossil-bearing limestone farther north) and 40 feet or more of fine gray sand beneath it.

Fossils, either of upper Miocene or Pliocene age, have been collected by members of the Florida Geological Survey along the Tamiami Trail 42 miles west of Miami (about 13 miles east of station 1/1179) in a beachlike sand, which is overlain by a 3-foot bed of hard yellow limestone containing *Chione cancellata*. The limestone may be a little younger than the fossil-bearing limestone treated in this paper, and the sandy bed may represent the sandy bed beneath 30 feet of limestone at Everglades. If these sands are contemporaneous, the overlying limestone bed or beds thicken westward. Sufficient information has not been obtained to determine definitely whether there is one limestone or more in this area.

[5] Sanford, Samuel, The topography and geology of southern Florida: Florida Geol. Survey Second Ann. Rept., pp. 208, 223, 1909.

Species and geologic range

	1/1176	1/1178	1/1180	1/1177	1/1179	Miocene	Pliocene	Recent
GASTROPODS								
Terebra dislocata Say		×				×	×	×
Fasciolaria sp	?	×						
Strombus sp		×						
Turritella, n. sp.? aff. T. perattenuata Heilprin			×					
Calyptraea sp		×						
Crucibulum sp			×					
PELECYPODS								
Glycymeris americana (Defrance)			×			×	×	×
Glycymeris pectinata (Gmelin)?			×					
Arca (Anadara) sp		×						
Arca occidentalis Philippi?					×			
Pinna sp		×		×				
Ostrea sculpturata Conrad	×					×	×	
Ostrea sp., group of O. trigonalis Conrad [a]	×		?					
Ostrea tamiamiensis Mansfield, n. sp	×		×	×	×			
Ostrea tamiamiensis monroensis Mansfield, n. subsp					×			
Pecten (Plagioctenium) evergladensis Mansfield, n. sp	×	×	×	×	×		×	
Pecten (Nodipecten) pittieri collierensis Mansfield, n. subsp	×	×	×					
Pecten (Lyropecten) tamiamiensis Mansfield, n. sp		×			×			
Pecten (Pecten) sp	×		×					
Spondylus sp		×			×			
Plicatula marginata Say	×	×	×			×	×	
Anomia simplex D'Orbigny			×	×		×	×	×
Thracia (Cyathodonta) tristana Olsson?		×						
Cardita (Carditamera) sp			×	×				
Divaricella sp				×				
Cardium sp					×			
Chione intapurpurea Conrad?	×	×	×	?				
Chione cancellata (Linnaeus)				×	?		×	×
Venus? sp					×			
Metis magnoliana Dall?		×						
Spisula sp		×						
Gastrochaena sp				×				
ECHINOIDS								
Encope macrophora tamiamiensis Mansfield, n. subsp.[a]		×	×	×				
Cassidulus (Rhynchopygus?) evergladensis Mansfield, n. sp				×	×			

[a] Same form as in the Pliocene at Alligator Creek, Fla.

NATURE OF THE FAUNAS

The faunas include 6 genera of gastropods, 15 genera of pelecypods, and 2 genera of echinoids. Aside from these, Foraminifera, barnacles, and Bryozoa were observed at a few localities. Among the pelecypods the scallops and oysters are the most conspicuous forms, both in the number of species and individuals and in the rather large size which some of them attained. The echinoid, *Encope macrophora tamiamiensis* Mansfield, n. subsp., was found at three localities, and the new species *Cassidulus evergladensis* at two localities.

The character of the faunas indicates that they lived near the shore in comparatively shallow water.

AGE OF THE FAUNAS

Although fossils collected from spoil banks may come from more than one bed, nevertheless most of the fossils obtained at these five localities appear to have come from the same bed. However, the occurrence of *Chione cancellata* at station 1/1177 may indicate that it came from a higher bed at that place; and the occurrence of the new subspecies *Ostrea tamiamiensis monroensis* at station 1/1179 may indicate that it came from the higher of two beds at that place. The ditches were partly filled with water at the time the fossils were collected, and a full section of the cut was not revealed.

The age of the faunas is believed to be Pliocene. Although the collections include some forms that were not found elsewhere and consequently are of little aid in correlation, a few are like or closely allied to Pliocene forms, such as *Ostrea*, group of *O. trigonalis*, *Pecten evergladensis*, and *Encope macrophora tamiamiensis*. On the other hand, one form, *Cassidulus evergladensis*, apparently shows some relationship to a species occurring in the Oligocene. Nevertheless, one specimen, borrowed for comparison from the Florida Geological Survey, collected at Moore Haven, Glades County, Fla., and probably dredged from the canal, agrees in detail with *C. evergladensis*. No fossils older than Pliocene have been dredged from the canal in the vicinity of Moore Haven. However, the faunal facies and the apparent stratigraphic relation of the fossiliferous bed to other formations in southern Florida suggest strongly a Pliocene rather than an earlier age.

Some poorly preserved specimens of Foraminifera from stations 1/1177 and 1/1180 were submitted to Dr. Joseph A. Cushman for identification. Those from station 1/1177 were unidentifiable, but in the lot from station 1/1180 were found *Amphistegina lessonii* D'Orbigny, *Eponoides* sp.? (probably the same as one of our living species off the coast), and some internal casts of *Quinqueloculina* and *Triloculina*. Doctor Cushman states that "these are not sufficient to place the material with any degree of accuracy, but it is apparently Pliocene or Pleistocene."

RELATIONSHIP TO OTHER FAUNAS

The faunas from the Tamiami Trail compare most closely with those at Alligator Creek, Charlotte County, Fla., which Dall [6] regarded as younger than the fauna occurring at Shell Creek, a tributary of Prairie Creek, Charlotte County, Fla., and assigned to the Pliocene Caloosahatchee marl.

The faunas of southern Florida appear to be related to those occurring in the Imperial formation—the marine deposits bordering Carrizo Mountain (sometimes called Coyote Mountain), Imperial County, Calif.; in fact, they appear more closely related to the Imperial faunas than to any other remote fossil faunas I have seen.

The Imperial formation, proposed by Hanna in 1926, was redefined by Woodring [7] and made to embrace the entire series of marine deposits bordering Carrizo Mountain, and to exclude the overlying nonmarine beds. In referring to this formation I have followed Woodring's definition of it.

The marine beds of the Imperial formation have been called "doubtfully Cretaceous," Miocene, and Pliocene.

Vaughan,[8] relying upon two species of coral, originally referred them doubtfully to the Cretaceous.

Arnold [9] first called them lower Miocene, or simply Miocene, but later [10] referred them to the upper Miocene and correlated them with the Etchegoin formation of California. The Etchegoin formation is now considered of Pliocene age.

Vaughan, in a later paper,[11] concluded that "the systematic affinities of the fauna of Carrizo Creek are with the Caloosahatchee Pliocene of Florida and the Pleistocene and living faunas of the Antilles."

Dickerson [12] states: "Several species appear to be identical with forms which are characteristic of the Gatun formation, of Miocene age."

Kew,[13] in his studies of the echinoids, referred the beds to the Pliocene.

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[6] Dall, W. H., Contributions to the Tertiary fauna of Florida: Wagner Free Inst. Sci. Trans., vol. 3, pt. 6, p. 1604, 1903.

[7] Woodring, W. P., Distribution and age of the marine Tertiary deposits of the Colorado Desert: Carnegie Inst. Washington Pub. 418, p. 7, 1931.

[8] Vaughan, T. W., The Eocene and lower Oligocene coral faunas of the United States: U. S. Geol. Survey Mon. 39, p. 19, 1900.

[9] Arnold, Ralph, The faunal relations of the Carrizo Creek beds of California [abstract]: Science, new ser., vol. 19, p. 503, 1904; The Tertiary and Quaternary pectens of California: U. S. Geol. Survey Prof. Paper 47, p. 21, 1906.

[10] Arnold, Ralph, Paleontology of the Coalinga district, Calif.: U. S. Geol. Survey Bull. 396, p. 44, 1909. Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Coalinga district, Calif.: U. S. Geol. Survey Bull. 398, p. 139, 1910.

[11] Vaughan, T. W., The reef-coral fauna of Carrizo Creek, Imperial County, Calif., and its significance: U. S. Geol. Survey Prof. Paper 98, p. 367, 1917.

[12] Dickerson, R. E., Mollusca of the Carrizo Creek beds and their Caribbean affinities [abstract]: Geol. Soc. America Bull., vol. 29, p. 148, 1918.

[13] Kew, W. S. W., Cretaceous and Cenozoic Echinoidea of the Pacific coast of North America: California Univ. Dept. Geology Bull., vol. 12, No. 2, pp. 32, 33, 56, 60, 61, 137, 1920

Hanna[14] has more recently published a paper in which he gives formational names to the series of deposits about Coyote Mountain, records the faunas, and describes eight new species of mollusks. He concludes that the age is not greater than lower Pliocene and is inclined to believe that the greater portion of the series is middle and upper Pliocene. The illustrations in Hanna's paper were found very helpful for comparison with the faunas of southern Florida.

The latest contribution to the paleontology of the Imperial formation has been made by Woodring,[15] who says:

> The paleontological evidence points to the conclusion that the marine beds of the Colorado Desert are of Miocene age, and the other two lines of evidence passively support this conclusion. There is little on which to base a conclusion as to what part of the coastal Miocene section is represented, but the evidence that is now apparent indicates late Vaqueros age—that is, late lower Miocene.

I have not studied the faunas of the Imperial formation sufficiently to express a definite opinion as to their age or the relative stratigraphic position of these beds with respect to those lying along the Tamiami Trail in Florida. However, I have observed certain species in the Florida faunas that appear to be related to species occurring in the Imperial formation and also to species now living in the Gulf of California. This apparent relationship may be a facies similarity rather than a genetic similarity.

Species collected from the Pliocene along the Tamiami Trail that are apparently related to those in the Imperial formation and to those now living in the Gulf of California are listed below. The species named in the middle column were either originally described as from the Imperial formation or have been reported to occur there.

Pliocene, southern Florida	Imperial formation, California	Recent, Gulf of California
Ostrea tamiamiensis Mansfield, n. sp.	Ostrea heermanni Conrad	Ostrea jacobaea Rochebrune.
Pecten tamiamiensis Mansfield, n. sp.	Pecten mediacostatus Hanna	
Pecten pittieri collierensis Mansfield, n. subsp.	Pecten subnodosus Sowerby	Pecten subnodosus Sowerby.
Pecten evergladensis Mansfield, n. sp.	Pecten deserti Conrad	Pecten circularis Sowerby.
Thracia (Cyathodonta) tristana Olsson?	Cyathodonta undulata Conrad	
Encope macrophora tamiamiensis Mansfield, n. subsp.	Encope tenuis Kew	Encope grandis (L. Agassiz).

DESCRIPTIONS OF NEW SPECIES

Ostrea tamiamiensis Mansfield, n. sp.

Plate 14, Figures 1, 3

Shell large, rather thin, nearly flat, orbicular, with fluted margins. Exterior surface of holotype partly concealed by matrix but reveals about six rather strong undulating radials. Hinge area rather narrow and furrowed with a rather narrow and shallow channel. Submargins with elongate corrugations. Muscle scar orbicular and situated slightly to the left of the center of left valve.

Dimensions: Holotype, left valve (catalogue No. 371320, U. S. Nat. Mus.), length, 139 millimeters; height, 131 millimeters.

Type locality: Station 1/1177, Tamiami Trail, 5 miles east of Carnestown and 7 miles northeast of Everglades, Collier County, Fla.

The closest related Recent species appears to be *Ostrea jacobaea* Rochebrune,[16] a species occurring in the Gulf of California.

Occurrence: Pliocene. Station 1/1177 (type locality, 1 valve); station 1/1180 (1 valve); station 1/1176 (1 valve); station 1/1179 (2 valves).

The specimens collected at stations 1/1179 and 1/1176 are much smaller than those collected at stations 1/1177 and 1/1180 but have the same general outline and appear to belong to the same species.

Ostrea tamiamiensis monroensis Mansfield, n. subsp.

Plate 14, Figure 2; Plate 15, Figures 1–4

Shell rather thick and heavy, ovate, moderately convex, with fluted ventral margins in adult specimens. Exterior marked with rather sharp, subspinose ribs separated by deep and narrow valleys. Hinge area moderately wide and furrowed with a rather wide channel. Submargins with weak elongated crenulations. Muscle scar prominent and rounded in outline.

Dimensions: Cotypes (catalogue No. 371321, U. S. Nat. Mus.): Left valve, length, 89 millimeters; height, 102 millimeters. Right valve, length, 76 millimeters; height, 96 millimeters.

Type locality: Station 1/1179, Tamiami Trail, 9 miles west of Pinecrest, in sec. 13, T. 54 S., R. 32 E., Monroe County, Fla.

This new subspecies differs from *O. tamiamiensis* in having a heavier, more inflated, and less rounded shell.

[14] Hanna, G. D., Paleontology of Coyote Mountain, Imperial County, Calif.: California Acad. Sci. Proc., 4th ser., vol. 14, No. 18, pp. 427–502, 1926.

[15] Woodring, W. P., Distribution and age of the marine Tertiary deposits of the Colorado Desert: Carnegie Inst. Washington Pub. 418, pp. 1–25 (especially p. 25), 1931.

[16] Rochebrune, A. T. de, Mus. hist. nat. Paris Bull., vol. 1, p. 241, 1895.

Ostrea sculpturata Conrad has more prominent crenulations on the submargins and lower and more rounded ribs than the new subspecies.

Occurrence: Pliocene. Found only at the type locality.

Pecten (Nodipecten) pittieri collierensis Mansfield, n. subsp.

Plate 16, Figures 3, 5

Shell large, orbicular, moderately ventricose, equivalve, and nearly equilateral, the posterior region being slightly more produced. Sculptured with broad, nearly flat, weakly undulating ribs (seven on the left valve and eight on the right) separated by little wider interspaces. The ribs are broader over the middle of the disk and narrower on each side. Top of ribs sculptured with five to eight coarse, raised threads separated by narrower interspaces. Spaces between major ribs marked with three to five coarse, weakly undulating threads and occasionally with a finer thread. Submargins sculptured with six to eight radial threads, which are equal in strength to the intercostal threads. Ears ornamented with rather coarse radiating riblets.

Dimensions: Holotype (catalogue No. 371326, U. S. Nat. Mus.), left valve, length, 142 millimeters; height, 125 millimeters. Paratype, right valve (catalogue No. 371327, U. S. Nat. Mus.), length, 100 millimeters; height, 104 millimeters.

Type locality: Station 1/1176, Tamiami Trail, about 11 miles east by north of Marco, Collier County, Fla.

The subspecies differs from *Pecten* (*Nodipecten*) *pittieri* Dall,[17] a species collected from Moin Hill, near Port Limon, Costa Rica, horizon *a*, in having a more ventricose shell which is ornamented with wider and fewer (by two) ribs. The surface of the ribs on the subspecies, although slightly corroded, does not distinctly indicate the vaulted scales, which are strongly developed on the left valve of *P. pittieri.* Dall, in his original description of *P. pittieri*, placed it in the section *Lyropecten*, but it appears to be more closely related to the section *Nodipecten* than to *Lyropecten.*

Pecten pittieri Dall and the new subspecies appear to be more closely related to *Pecten* (*Nodipecten*) *nodosus* Linnaeus, of the east coast, than to *Pecten* (*Nodipecten*) *subnodosus* Sowerby, of the west coast.

The new subspecies appears to be an intermediate form between *Pecten pittieri* and *Pecten nodosus.*

Pecten (*Nodipecten*) *veatchii* Gabb, a Pliocene species from Cerros Island, off Lower California, appears from the illustration to be closely related to my new subspecies.

[17] Dall, W. H., New species of fossil shells from Panama and Costa Rica: Smithsonian Misc. Coll., vol. 59, No. 2, p. 10, 1912.

Occurrence: Pliocene. Station 1/1176 (type locality, 2 valves), station 1/1180 (paratype locality, 1 valve), and station 1/1178 (2 valves).

Pecten (Lyropecten) tamiamiensis Mansfield, n. sp.

Plate 16, Figures 4, 6

Shell rather small, ovate, moderately ventricose, equivalve, and nearly equilateral. Both valves similarly sculptured. Right valve sculptured with 23 major ribs, which are stronger over the middle of the disk and weaker on the lateral areas. The two marginal posterior ribs are paired and much weaker than the others. Interspaces occupied by a single strong, rounded riblet. Surface of shell ornamented with fine concentric, beakward-reflected imbrications. Anterior ear with a rather deep byssal notch and externally marked with six rather coarse radials; posterior ear with finer radials than anterior.

Dimensions: Holotype (catalogue No. 371325, U. S. Nat. Mus.), length, 69 millimeters; height, 74 millimeters. One right valve with the margins broken off and occurring at the type locality is a little larger than the holotype, its length being 82 millimeters and height 83 millimeters.

Type locality: Station 1/1178, Tamiami Trail, 6 miles west of crossroads leading to Everglades, Collier County, Fla.

Pecten mediacostatus Hanna,[18] collected from "Alverson Canyon, on the south side of Coyote Mountain, Imperial County, Calif., in the Pliocene coral reef about midway up the canyon," apparently is the nearest related fossil species, but by a comparison made from the illustration, it appears to have a narrower shell with smaller ears than the new species.

Occurrence: Pliocene. Station 1/1178, type locality (3 valves), station 1/1179 (6 valves).

Pecten (Plagioctenium) evergladensis Mansfield, n. sp.

Plate 17, Figures 1, 2, 4, 5

Shell small, broadly orbicular, probably nearly equivalve, inequilateral, the posterior region being more produced. Right valve of holotype inflated and swollen behind the umbo; posterior region more gently sloping to submargins than anterior; base broadly rounded. Sculptured with 22 nearly flat laterally sloping ribs separated by much narrower interspaces. Sides of ribs and submargins of shell marked with moderately coarse, nearly erect, concentric lamellæ. Submargins without any distinct radials. Right ear with a shallow byssal notch and ornamented with six radials; left ear bearing weak radials on the lower

[18] Hanna, G. D., Paleontology of Coyote Mountain, Imperial County, Calif.: California Acad. Sci. Proc., 4th ser., vol. 14, No. 18, p. 472, pl. 22, fig. 6, pl. 24, fig. 2, 1926.

half. Left valve of immature and slightly corroded paratype sculptured with 20 ribs, which are a little lower than those on right valve; submargins without distinct radials.

Dimensions: Holotype, right valve (catalogue No. 371323, U. S. Nat. Mus.), length, 58 millimeters; height, 52 millimeters. Paratype, left valve (catalogue No. 371324, U. S. Nat. Mus.), length, 29 millimeters; height, 28 millimeters.

Type locality: Station 1/1178, Tamiami Trail, 6 miles west of crossroad leading to Everglades, Collier County.

The new species differs from *Pecten gibbus gibbus* Linnaeus in the absence of any distinct radials on the submargins and in having a much more inequilateral shell. In the latter feature it more closely resembles *Pecten circularis* Sowerby, a Recent species geographically ranging on the west coast from Monterey, Calif., to the Gulf of California and Paita, Peru. *Pecten* (*Plagioctenium*) *comparilis* Tuomey and Holmes, an upper Miocene species, appears to be the ancestral form of the new species. *Pecten mendenhalli* Arnold, a Pliocene species collected at Santa Rosalia, Lower California, and also occurring at Alverson Canyon, San Diego County, Calif., is nearly related to the new species.

Occurrence: Pliocene. Station 1/1178 (type locality, 2 valves), station 1/1177 (paratype locality, 3 valves), station 1/1180 (5 valves), station 1/1176 (2 valves), 1/1179 (4 valves).

Specimens occurring in the Caloosahatchee marl, Florida, have the same characteristics as the new species and appear to belong to it. The Caloosahatchee specimens appear to have been referred to *P. gibbus gibbus* Linnaeus by Dall,[19] but they are unlike the Recent species referred to that variety.

Cassidulus (Rhynchopygus?) evergladensis Mansfield, n. sp.

Plate 18, Figures 1–10

Test large, suborbicular, and moderately high; upper surface convex and broadly rounded, the posterior surface more gently inclined than the anterior; lower surface nearly flat except in the area surrounding the peristome, where it is shallowly concave. Apical system, situated opposite the peristome, is rather large, granular, and slightly elevated; so far as revealed, a genital pore is at the juncture of the petals and a smaller radial pore is opposite each petal. Ambulacral areas petaloid at dorsal portions. Petals rather long, extending nearly to the ambitus, expanding to about one-third their length from the apical system, then gradually contracting distally, and nearly closing at their extremities; poriferous zones rather wide, shallowly depressed; pores nearly equal in size and rounded in outline; pairs of pores conjugate. Interporiferous areas weakly tumid. Posterior interambulacrum weakly medially arched. Periproct rather large, longest transversely; supramarginal, the lower margin being about 4 millimeters above the ambitus; the upper arched margin slightly overhangs the aperture. Peristome excentric anteriorly, pentagonal, transversely elongate, and surrounded by a large well-defined floscelle with prominent bourrelets. The outer pores of the floscelle are more direct and more regularly placed; the inner ones are more irregularly placed and some of them are arranged in two rows. The surface of the test is closely set with scrobiculate tubercles.

Dimensions: Cotypes (catalogue No. 371329, U. S. Nat. Mus.): Larger slightly crushed cotype with preserved periproct, length, 73 millimeters; width, 74 millimeters; height, 29 millimeters. Smaller cotype (posterior end broken off), width, 57 millimeters; height, 32 millimeters. Paratype (catalogue No. 371330, U. S. Nat. Mus.), length, 75 millimeters (posterior end broken); width, 64 millimeters; height, 35 millimeters.

Occurrence: Station 1/1177, Tamiami Trail, 5 miles east of Carnestown and about 7 miles northeast of Everglades, Collier County, Fla. (type locality); station 1/1179, Tamiami Trail, 9 miles west of Pinecrest (sec. 13, T. 54 S., R. 32 E.), Monroe County, Fla. (paratype locality). Near Moore Haven, Glades County, Fla.; probably dredged from the canal. Only one fairly well preserved specimen, which was embedded in limestone, has been collected near Moore Haven; it is in the collection of the Florida Geological Survey.

Cassidulus evergladensis resembles, in a general way, the figured type of *Cassidulus* (*Pygorhynchus*) *alabamensis* Twitchell,[20] a species collected at the Natural Bridge, St. Stephens, Washington County, Ala., but the lower surface of the test of that species is more concave longitudinally, and the periproct is at a greater distance above the ambitus. The same authors[21] refer the "St. Stephens limestone" (upper part) to the lower Oligocene.

Encope macrophora tamiamiensis Mansfield, n. subsp.

Plate 17, Figure 8

In the report by Cooke and Mossom[22] I referred this form to *Encope macrophora* Ravenel, but I now believe, after more study, that it represents a new subspecies of *E. macrophora*.

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[19] Dall, W. H., Contributions to the Tertiary fauna of Florida: Wagner Free Inst. Sci. Trans., vol. 3, pt. 4, p. 745, 1898.

[20] Clark, W. B., and Twitchell, M. W., The Mesozoic and Cenozoic Echinodermata of the United States: U. S. Geol. Survey Mon. 54, p. 172, pl. 80, figs. 3a–d, 1915.

[21] Idem, p. 173.

[22] Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida Geol. Survey Twentieth Ann. Rept., p. 156, 1929.

E. macrophora tamiamiensis appears to be an intermediate form between *E. macrophora* and *E. grandis* (L. Agassiz). It differs from *E. macrophora* in having a proportionately wider and thinner test, a concave instead of convex posterior margin, and a much smaller interambulacral lunule. It differs from *E. grandis*, a Recent species reported by A. Agassiz [23] to occur in the Gulf of California, in having in general a shallower anterior marginal notch and less incised lateral marginal notches. The posterior margin on both forms is very similar in the degree of convexity, indicating a close relationship.

The test of the new subspecies is usually wider than long, rather thin, but not having sharp edges. The region directly in front of the lunule is the thickest part of the test. The lunule is elliptical and is surrounded on its upper surface by a raised border.

Dimensions: Holotype (catalogue No. 371328, U. S. Nat. Mus.), length, 84 millimeters; width, 87 millimeters; height, 11 millimeters; thickness of margins, about 6 millimeters.

Type locality: Station 1/1177, Tamiami Trail, 5 miles east of Carnestown and about 7 miles northeast of Everglades, Collier County.

Occurrence: Pliocene. Type locality (abundant), station 1/1180 (abundant), station 1/1178 (rare?). Small specimens that have been referred to *Encope macrophora* from the Pliocene Caloosahatchee marl at Alligator Creek, Monroe County, Fla., appear to be more closely related to the new subspecies than to *E. macrophora*.

[23] Agassiz, Alexander, Revision of the Echini: Harvard Coll. Mus. Comp. Zoology Illus. Catalog, No. 7, pt. 3, p. 545, pl. 13d, figs. 5, 6, 1873.

PLATES 14–18

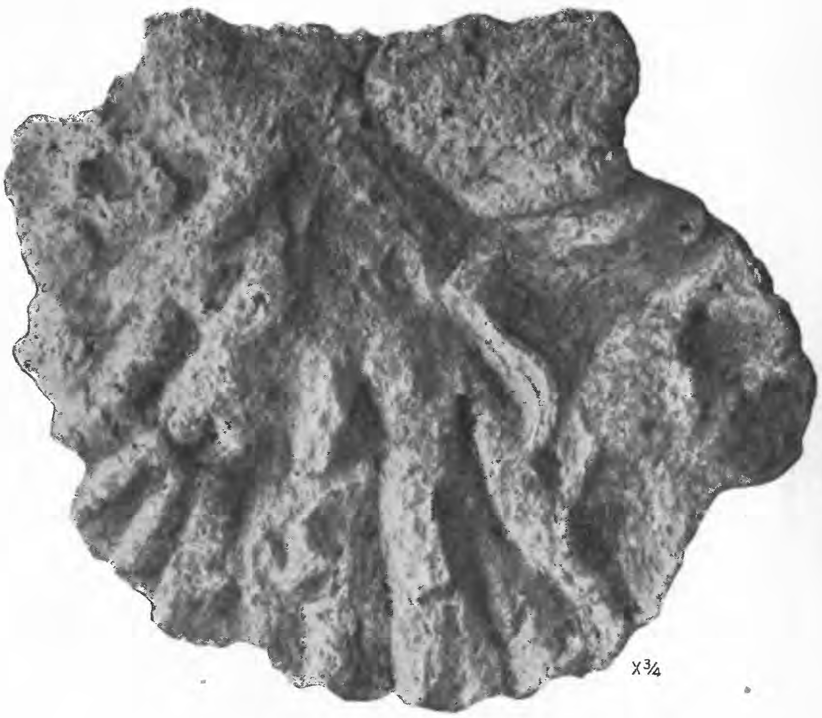
PLATE 14

FIGURES 1, 3. *Ostrea tamiamiensis* Mansfield, n. sp., holotype (p. 46).

1. Exterior of left valve.
3. Interior of same valve.

FIGURE 2. *Ostrea tamiamiensis monroensis* Mansfield, n. subsp., paratype, left valve, catalogue No. 371322, U. S. Nat. Mus. (p. 46).

FIGURE 4. *Turritella* sp. aff. *Turritella perattenuata* Heilprin, catalogue No. 371319, U. S. Nat. Mus., figured specimen. Collected at station 1/1180, Tamiami Trail, Carnestown, 4 miles north of Everglades, Collier County, Fla.



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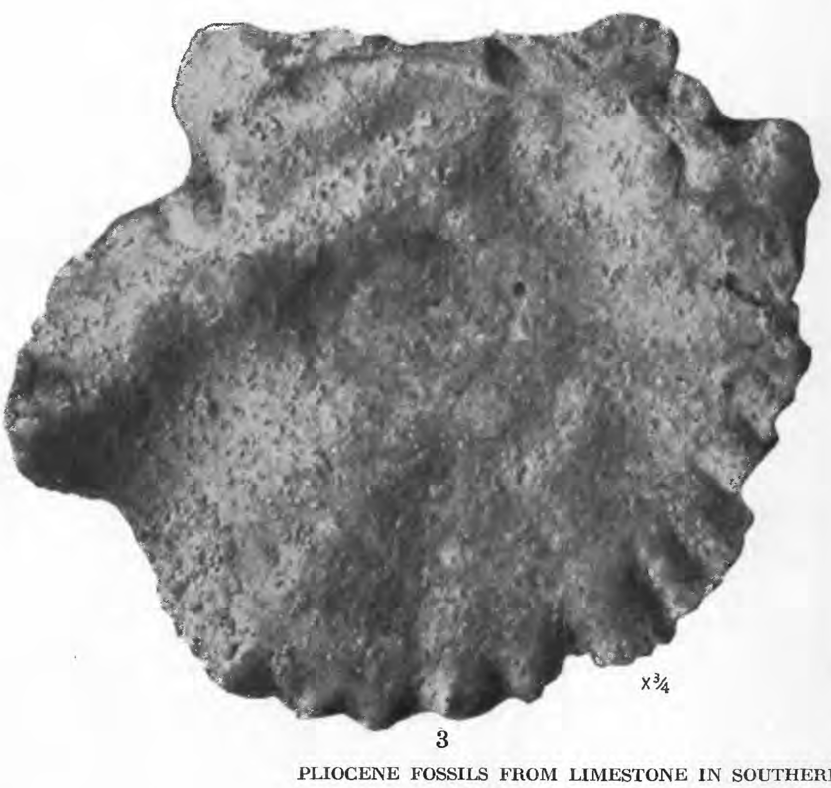

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4

PLIOCENE FOSSILS FROM LIMESTONE IN SOUTHERN FLORIDA

1

2

3

4

PLIOCENE FOSSILS FROM LIMESTONE IN SOUTHERN FLORIDA

PLATE 15

FIGURES 1–4. *Ostrea tamiamiensis monroensis* Mansfield, n. subsp., cotypes (p. 46).
1, 3. Exterior and interior of right valve.
2, 4. Exterior and interior of left valve.

PLATE 16

FIGURE 1. *Pecten subnodosus* Sowerby. (After Hanna, California Acad. Sci. Proc., 4th ser., vol. 14, No. 18, pl. 25, fig. 6, 1926.) Hanna's figured specimen was collected in a branch of Alverson Canyon, at the base of Coyote Mountain, Imperial County, Calif. The photograph is used here for comparison with Figures 3 and 5 of this plate.

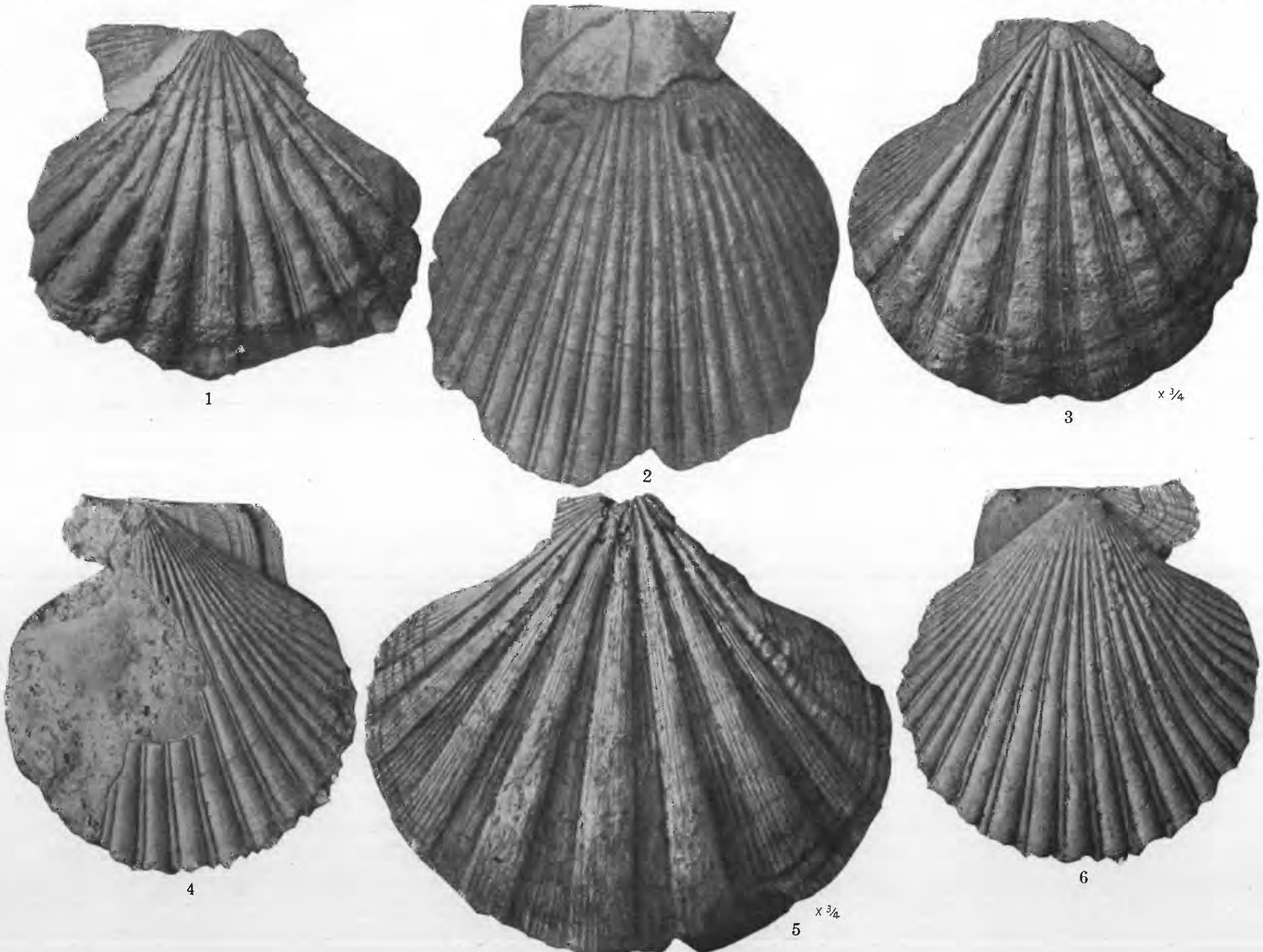
FIGURE 2. *Pecten mediacostatus* Hanna. (After Hanna, California Acad. Sci. Proc., 4th ser., vol. 14, No. 18, pl. 24, fig. 2, 1926.) The photograph, taken from the original, is that of the holotype, which was collected from "Alverson Canyon, on the south side of Coyote Mountain, Imperial County, Calif., in the Pliocene coral reef about midway up the canyon." The illustration is used here for comparison with Figures 4 and 6 on this plate.

FIGURES 3, 5. *Pecten* (*Nodipecten*) *pittieri collierensis* Mansfield, n. subsp. (p. 47).

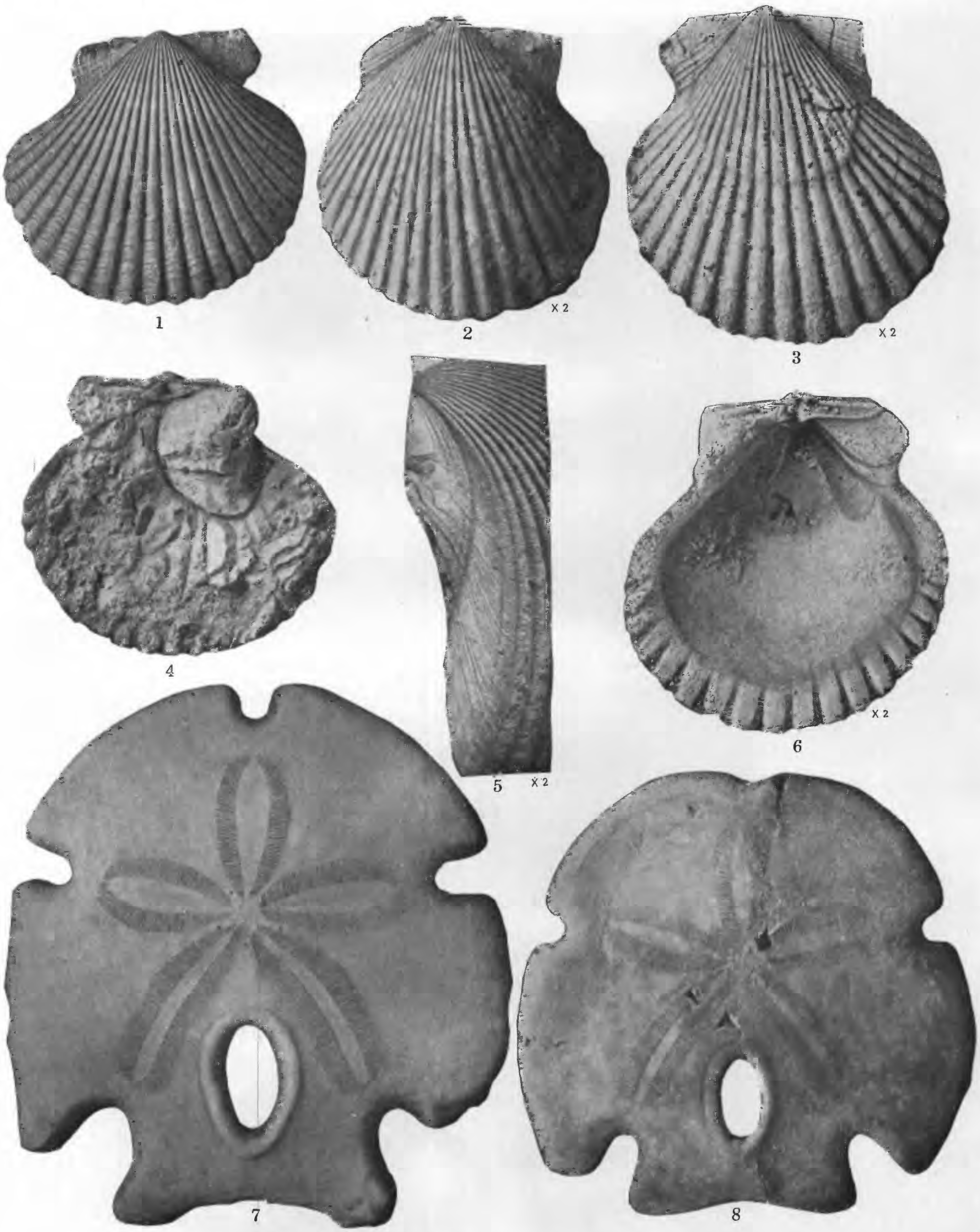
3. Paratype, right valve.
5. Holotype, left valve.

FIGURES 4, 6. *Pecten* (*Lyropecten*) *tamiamiensis* Mansfield, n. sp., holotype (p. 47).

4. Left valve of specimen.
6. Right valve of specimen.



PLIOCENE FOSSILS FROM LIMESTONE IN SOUTHERN FLORIDA
Shows also, for comparison, specimens obtained elsewhere



PLIOCENE FOSSILS FROM LIMESTONE IN SOUTHERN FLORIDA

Shows also, for comparison, specimens obtained elsewhere

PLATE 17

FIGURES 1, 2, 4, 5. *Pecten (Plagioctenium) evergladensis* Mansfield, n. subsp. (p. 47).

1, 4, 5. Holotype, right valve: 1, 4, Exterior and interior of same valve; 5, posterior submargin, showing the nearly smooth area.

2. Paratype, left valve. Collected at station 1/1177, Tamiami Trail, 5 miles east of Carnestown and about 7 miles northeast of Everglades, Collier County, Fla.

FIGURES 3, 6. *Pecten (Lyropecten) deserti* Conrad, left valve, catalogue No. 324564, U. S. Nat. Mus. Collected at station 3919 east end of Coyote Mountain, Imperial County, Calif., by Stephen Bowers, 1904. Illustrated for comparison with Figures 1, 2, 4, 5 on this plate.

FIGURE 7. *Encope grandis* (L. Agassiz), upper surface of test, catalogue No. 10013, U. S. Nat. Mus. Photograph of a specimen collected at La Paz, Gulf of California. Illustrated for comparison with Figure 8 on this plate.

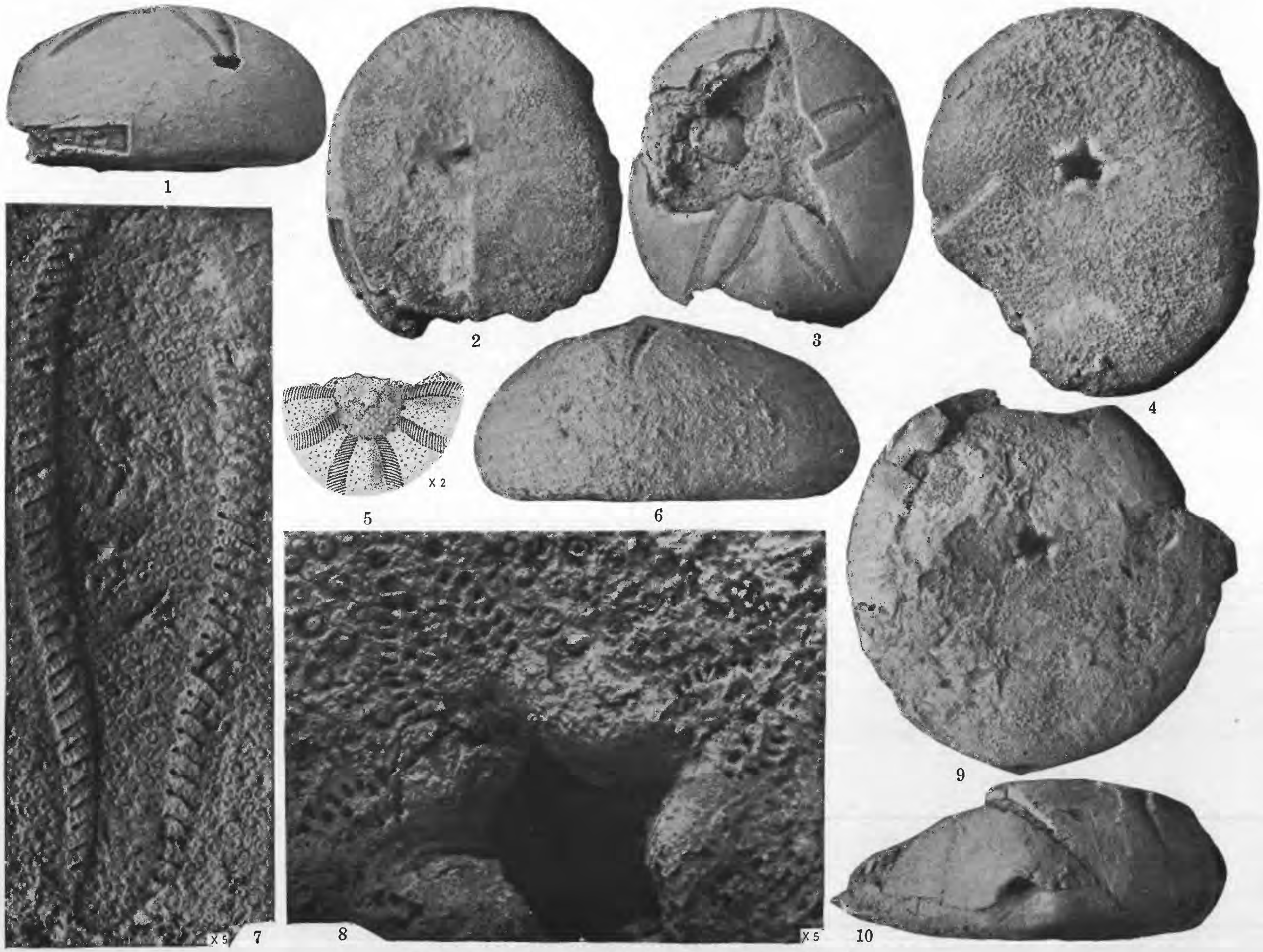
FIGURE 8. *Encope macrophora tamiamiensis* Mansfield, n. subsp., holotype, upper surface of test (p. 48).

62508°—32——4

PLATE 18

FIGURES 1–10. *Cassidulus* (*Rhynchopygus?*) *evergladensis* **Mansfield**, n. sp. (p. 48).

1. Right lateral surface of test of smaller cotype.
2. Lower surface of test of smaller cotype.
3. Upper surface of test of smaller cotype.
4. Lower surface of test of paratype, catalogue No. 371330, U. S. Nat. Mus.
5. Diagrammatic view of the preserved part of the apical system, based on the paratype.
6. Left lateral surface of test of paratype.
7. Portion of the anterior ambulacrum on upper surface of paratype.
8. Part of the ambulacral pores around the peristome of paratype.
9. Lower surface of test of larger cotype.
10. Posterior surface of test of larger cotype.



PLIOCENE FOSSILS FROM LIMESTONE IN SOUTHERN FLORIDA

THE GEOLOGIC IMPORTANCE OF THE LIME-SECRETING ALGAE

WITH A DESCRIPTION OF A NEW TRAVERTINE-FORMING ORGANISM

By Marshall A. Howe

The agency of microscopic algae, especially blue-green algae, in depositing lime in calcareous hot springs and calcareous streams has long been recognized. Ferdinand Cohn [1] was one of the first to investigate the matter in a scientific way, in studying the deposits in the famous hot springs of Carlsbad, in Bohemia.

In America, in 1889, Walter Harvey Weed,[2] then a member of the United States Geological Survey, published a striking report on the formation of travertine and siliceous sinter by the vegetation of hot springs, with special reference to the remarkable conditions found in the Yellowstone National Park. The deposits of most of the springs in that region are "siliceous sinter," but the extensive one of the Mammoth Hot Springs, covering a total area of about 2 square miles and having a maximum depth of about 250 feet, consists chiefly of calcium carbonate or "travertine," partly precipitated in a mechanical way, but probably to a much larger degree by the action of microscopic algae. The waters of the Mammoth Hot Springs carry a saturated or supersaturated solution of calcium bicarbonate, and much of the lime is deposited by the evaporation and cooling of the water. Yet much or most of what geologists call "travertine" at the Mammoth Hot Springs, as has been demonstrated macroscopically and microscopically by Weed and others, is due to the action of the abundantly present algae or their chlorophyll in consuming or decomposing the CO_2 that is present in the water and thus reducing the amount of calcium bicarbonate that may be held in solution. The precipitated lime is a by-product of the photosynthesis of the little plants. And the same process evidently goes on in both fresh and salt water in which calcium bicarbonate is dissolved in much less than saturation proportions.

In 1895 George Murray [3] published critical notes on calcareous pebbles formed by algae, based on material from a pond in Michigan separated from Lake Michigan by a sand bar. Murray found that these pebbles had been built up by a mixture of blue-green algae, of which the predominating kind was *Schizothrix* (*Inactis*) *fasciculata* (Naegeli) Gomont, as determined by the eminent authority Gomont. However, Gomont [4] describes the trichomes of *S. fasciculata* as 1.4μ to 3μ in diameter, while Murray's figures, according to the magnifications indicated, show trichomes 2.5μ to 8μ in diameter. Murray mentions *Dichothrix* as intermingled with his *Schizothrix*, and it seems possible that some of his figures represent *Dichothrix* rather than *Schizothrix*.

In 1897 Josephine E. Tilden [5] described some new species of Minnesota algae which live in a calcareous or siliceous matrix. Most of the algae formed crusts of various colors, with a maximum thickness of 1 centimeter, on the sides of a large wooden tank on the bank of the Mississippi River. New species were described in the genera *Dichothrix*, *Lyngbya*, *Schizothrix*, and *Chaetophora*, the last a green alga, the others blue-green. An examination of specimens distributed by Professor Tilden indicates the presence also of the plant that is now referred to *Inactis pulvinata* Kützing. It may be the same as the *Lyngbya nana* Tilden, the filaments of which are described as only 1.9μ in diameter.

In 1900 John M. Clarke,[6] State paleontologist of New York, published a brief illustrated paper on the water biscuit of Squaw Island, Canandaigua Lake, N. Y. Doctor Clarke states:

> The north shores of Squaw Island and the lake bottom about it and over its northward sand bar are covered with flat, whitish calcareous cakes of circular or oval shape, in size ranging from a dime to a half dollar. To pick up one of these, well dried on the surface of the island, and break it in half, seems enough to convince the reflective mind at once of their nature and mode of formation. It often contains as a central nucleus a beach pebble of shale or limestone, a twig, or a bit of charcoal from some youngster's campfire. About this a white or greenish travertine has been deposited in concentric layers, which show themselves with distinctness. * * * On picking one of the water biscuits

[1] Ueber die Algen des Carlsbad Sprudels, mit Rücksicht auf die Bildung des Sprudelsinters: Schlesische Gesell. vaterl. Cult. Abh., Abt. Naturwiss. u. Medicin, 1862, Heft 2, pp. 35–55.

[2] U. S. Geol. Survey Ninth Ann. Rept., pp. 619–676, pls. 78–87, figs. 52–56, 1889.

[3] Phycological Memoirs, pp. 74–77, pl. 19, 1895.

[4] Monographie des Oscillariées: Ann. sci. nat., Bot., 7th ser., vol. 15, p. 299, 1892.

[5] Bot. Gaz., vol. 23, pp. 95–104, pls. 7–9, 1897.

[6] New York State Mus. Bull., vol. 8, pp. 195–198, pls. 13–15, 1900; New York State Mus. 54th Ann. Rept., vol. 3, pp. 195–198, pls. 13–15, 1902.

from the lake bottom, its surface is found to be smooth, slimy, and often greenish; exposure on the shore bleaches it white. The calc-carbonate being dissolved in dilute acid and entirely removed, there remains a soft, spongy organic residuum of precisely the volume of the original biscuit.

C. H. Peck, the State botanist, to whom specimens were submitted, reported that the felted mass was made up of several kinds of fresh-water algae and diatoms. He identified one of the species as "probably *Isa[c]tis fluviatilis*."

In 1903 C. A. Davis,[7] after the appearance of three shorter papers with similar titles, published a "contribution to the natural history of marl," based chiefly on studies of vast deposits of calcium carbonate in Michigan lakes, which form the basis of the cement industry in that State. In connection with the origin of these extensive accumulations of lime, he ascribes great importance to the green algal genus *Chara*, though admitting that blue-green algae are largely concerned in forming both the massive beds of lake tufa and concentric calcareous pebbles.

The importance of certain lime-secreting marine algae in the building of so-called "coral reefs" has received increasing attention and emphasis since the publication by the Royal Society of London, in 1904, of a large quarto work on Funafuti,[8] which was selected for this study because it was considered to be a "typical coral" reef or island. Several borings were made here by members of three successive expeditions. The main boring was finally driven down to a depth of more than 1,100 feet. The cores thus obtained were brought back to England for study and analysis. A. E. Finckh, who wrote the chapter on the biology of reef-forming organisms at Funafuti, groups the various lime-secreting organisms at Funafuti in order of their reef-building importance as follows:

1. *Lithothamnium*,[9] by which Finckh means stone-like, unsegmented, branched or crustaceous red algae (Rhodophyceae) of the family Corallinaceae. These calcareous plants are commonly referred to by geologists and zoologists, and occasionally by botanists, as "nullipores."

2. *Halimeda*. This is a genus of lime-secreting green algae (Chlorophyceae) of the family Codiaceae. It includes several species, of which *Halimeda opuntia* appears to be the one that occurs in most abundance. All are of macroscopic dimensions. Species of *Halimeda* are confined to the warmer seas, while representatives of the *Lithothamnium* group occur in local profusion in Arctic waters also.

[7] Michigan Geol. Survey, vol. 8, pt. 3, pp. 65–96, 1903.

[8] The atoll of Funafuti—borings into a coral reef and its results, being the report of the coral-reef committee of the Royal Society.

[9] This is the original and now commonly used spelling of the generic name that has often appeared in print as *Lithothamnion*. In the broad sense in which the name is employed by Finckh, it is doubtless intended to include species that would now be referred not only to *Lithothamnium* but also to *Lithophyllum*, *Porolithon*, *Goniolithon*, etc. These are all plants of considerable size.

3. Foraminifera. Recent studies by T. Wayland Vaughan and J. A. Cushman have emphasized the geologic importance of this group of microscopic animals.

4. Corals. There are doubtless "true coral reefs" and islands that have been actually built in a predominant way by corals, but Funafuti is evidently not one of them.

That Funafuti is not an isolated example of the building of reefs by plants rather than by animals is attested by the observations of Finckh, Gardiner, Setchell, and others. Gardiner[10] remarks that "the importance of the incrusting nullipores in the formation of the reefs of the central Pacific can not be overestimated." Again,[11] in discussing the foundation of atolls in general, Gardiner says:

> The chief building organism is *Lithothamnium*, the bathymetrical zone of which must be limited to a large degree by the extent to which light can penetrate sea water.

In another publication[12] Gardiner says:

> This nullipore [*Porolithon craspedium*], Finckh says, is actually the reef former at Onoatoa [Gilbert Islands]. He saw no live coral there, but everywhere on the lagoon and ocean face immense masses of this particular nullipore.

That lime-secreting plants rather than corals are sometimes, at least, the dominant reef formers in the Indian Ocean as well as in the Pacific is attested by the following observation by Gardiner:[13]

> The reefs of the Chagos are in no way peculiar save in their extraordinary paucity of animal life. * * * However, this barrenness is amply compensated for by the enormous quantity of nullipores (Lithothamnia, etc.), incrusting, massive, mammillated, columnar, and branching. The outgrowing seaward edges of the reefs are practically formed by their growths, and it is not too much to say that, were it not for the abundance and large masses of these organisms, there would be no atolls with surface reefs in the Chagos.

Mme. Dr. A. Weber-van Bosse[14] describes and publishes photographs of extensive *Lithothamnium* banks near the southwest point of Timor, in the Dutch East Indies.

In 1921 Mayor,[15] writing of Rose Atoll, American Samoa, states that

> There are a few fossil corals, chiefly *Pocillophora*, embedded in the rock of the atoll rim and the boulders, but the whole visible rock of the atoll consists so largely of *Lithothamnium* that we may call it a "*Lithothamnium* atoll" rather than a "coral atoll."

[10] Gardiner, J. S., The coral reefs of Funafuti, Rotuma, and Fiji, together with some notes on the structure and formation of coral reefs in general: Cambridge Philos. Soc. Proc., vol. 9, p. 477, 1898.

[11] Idem, p. 501.

[12] Gardiner, J. S., The fauna and geography of the Maldive and Laccadive Archipelagoes, vol. 1, p. 462, 1901.

[13] Quoted by Foslie, M., The Lithothamnia: Linnean Soc. London Trans., Zoology, 2d ser., vol. 12, pp. 177, 178, 1907; The Percy Sladen expedition in H. M. S. *Sealark*: Nature, vol. 72, pp. 571, 572, where a photograph of this *Lithothamnium* reef is published.

[14] Siboga-Exped. Mon. 61, p. 4, 1904.

[15] Mayor, A. G., Am. Philos. Soc. Proc., vol. 60, p. 67.

Setchell,[16] who has made several visits to the South Sea Islands, largely for the purpose of studying the reefs, has in a succinct paper summed up the present status of our knowledge of the origin of so-called "coral reefs" in part as follows:

> In closing his article on the building of coral reefs Howe[17] says: "Much evidence has accumulated tending to show that the importance of corals in reef building has been much overestimated and that final honors may yet go to the lime-secreting plants." It seems to me that the final honors can now be bestowed, and, without minimizing the contributions of the corals, there may be added:
>
> 1. That without nullipores no "coral reefs" can be or would have been formed.
>
> * * * * *
>
> 5. That the animal components of the reef of next importance after the nullipores are the various incrusting species, especially of *Polytrema*, a genus of Foraminifera.

Later James B. Pollock,[18] in a paper on the fringing and fossil reefs of Oahu, states that

> The organisms chiefly contributing calcium carbonate to both fossil and fringing reefs are corals and coralline algae. The algae contribute more than the corals. The algae are called by the general name of *Lithothamnium*.

Calcareous algae of the coralline group occur as well-preserved fossils in limestone rock of Tertiary and Quaternary strata. There is evidence[19] that the *Lithothamnium* structure may become gradually obliterated, perhaps by the action of percolating water, resulting in a structureless limestone.[20] In America beautifully preserved fossils of the *Lithothamnium* group have been described and figured by the present writer[21] from Oligocene and Pleistocene strata of the Panama Canal Zone, from the Eocene of St. Bartholomew, the middle Oligocene of Antigua, the upper Oligocene of Anguilla, and the lower Miocene of Trinidad. *Lithothamnium jurassicum* Gümbel[22] has been described from the Jurassic of Switzerland, and the more or less doubtful *Lithothamnium? ellisianum* Howe and Goldman[23] from the Jurassic Ellis formation of Montana. *Archaeolithothamnium marmoreum* (Munier-Chalmas) Foslie and *Lithophyllum belgicum* Foslie[24] have been currently referred to the Calcaire Carbonifère of Namur, Belgium, but Mme. Lemoine has shown that *L. belgicum* came in reality from the Aptian (Cretaceous) of the French Pyrenees.[25]

Fossil organisms of Silurian and Cambrian origin that have been described under the generic name *Solenopora* have usually been referred to the corallinaceous algae, but in the writer's opinion the Ordovician type of the genus does not belong in this family, if it is, in fact, an alga. However, there can be no serious doubt that Urgonian and Jurassic fossils more recently placed under *Solenopora*[26] are true algae, closely related to *Lithothamnium*.

Although rhodophyceous algae of the coralline (*Lithothamnium*) group may not be of great antiquity, in a geologic sense, algae of a lower group, the Myxophyceae (or Cyanophyceae), more popularly referred to as the "blue-green algae," were probably among the first forms of life. There is superficial evidence that many, at least, of the most ancient limestones, of Cambrian and pre-Cambrian age, were laid down by the agency of these blue-green algae and that in mass production of limestone these lowly organisms were much more active then than they are at the present time. The existence of several kinds of blue-green algae in hot springs[27] shows their adaptation to the higher temperatures that doubtless prevailed in the earlier stages of the development of life on the earth.

The blue-green algae are always of colonial habit. The individuals are of microscopic size, and individuality is often poorly defined, but the colonial masses of the present age are commonly of macroscopic dimensions, and in the geologic past such masses apparently helped to make deposits of lime that are now conspicuous features of extensive geologic formations. It is to be freely conceded, however, that no one of these supposed algal limestones of Cambrian or pre-Cambrian age, when examined microscopically, either decalcified or in ground section, shows any incontestable evidence of an algal nature. In view of the extreme age of these supposed plants and the extreme delicacy of the gelatinous cell walls of the Myxophyceae, even when more or less calcified, it seems unreasonable to expect any preservation of their microscopic cell structure. The firm, always strongly calcified cell walls of the Lithothamnieae, so perfectly

[16] Setchell, W. A., Nullipore versus coral in reef formation: Am. Philos. Soc. Proc., vol. 65, pp. 136–140, 1926.

[17] Howe, M. A., Science, new ser., vol. 35, pp. 837–842, 1912.

[18] Bernice P. Bishop Mus. Bull. 55, pp. 1–56, pls. 1–6, 1928.

[19] Seward, A. C., Algae as rock-building organisms: Sci. Progress, vol. 2, pp. 10–26, 1894.

[20] Walther, J., Die gesteinbildenen Kalkalgen des Golfes von Neapel und die Entstehung structurloser Kalke: Deutsch. Geol. Gesell. Zeitschr., Bd. 37, 1885. See also Science, vol. 7, pp. 575, 576, 1886.

[21] Howe, M. A., On some fossil and recent Lithothamnieae of the Panama Canal Zone: U. S. Nat. Mus. Bull. 103, pp. 1–13, pls. 1–11, 1919; Tertiary calcareous algae from the islands of St. Bartholomew, Antigua, and Anguilla: Carnegie Inst. Washington Pub. 291, 1919; Two new Lithothamnieae, calcareous algae, from the lower Miocene of Trinidad, British West Indies: U. S. Nat. Mus. Proc., vol. 62, art. 7, pp. 1–3, pls. 1–4, 1922.

[22] Gümbel, C. W., Die sogenannten Nulliporen: K. bayerisch. Akad. Wiss., Math.-phys. Klasse, Abh., vol. 11, Abt. 1, p. 43, pl. 2, figs. 9a, 9b, 1871.

[23] Howe, M. A., and Goldman, M. I., Am. Jour. Sci., 5th ser., vol. 10, pp. 314–324, figs. 1–11, 1925.

[24] Foslie, M., Remarks on two fossil Lithothamnia: K. Norske Vidensk. Selsk. Skr., 1909, No. 1, pp. 3–5.

[25] Lemoine, Mme. Paul, Contribution à l'étude des Corallinacées fossiles, VIII, Mélobésiées de l'Aptien et de l'Albien: Soc. géol. France Bull., 4th ser., vol. 25, pp. 5–6, 1925.

[26] Pfender, J., Sur la présence d'une Solénopore dans l'Urgonien du sudest de la France—*Solenopora urgoniana*, n. sp.: Soc. géol. France Bull., 4th ser., vol. 30, pp. 101–105, pl. 8, 1930; Les Solénopores du Jurassique supérieur en Basse-Provence calcaire et celles du Bassin de Paris: Idem, pp. 149–164, pls. 16–19.

[27] Setchell, W. A., The upper temperature limits of life: Science, new ser., vol. 17, pp. 934–937, 1903.

preserved in various Tertiary and Quaternary strata, are in a very different category. In the calcareous travertine or tufa now being laid down by various blue-green algae in lakes and streams in the United States, it is commonly difficult to demonstrate and identify the contributing organisms except in the superficial layers. Why should one expect their delicate structure to persist for millions of years? Nevertheless, one who is accustomed to see and to handle the algae of the present day may feel convinced from their macroscopic characters that certain laminated ancient limestones were laid down by algae, even while admitting more or less subconsciously the possibility of being deceived.

In Great Britain the writings of A. C. Seward [28] and E. J. Garwood [29] have emphasized the geologic importance of the algae, though Seward is dubious as to the algal nature of so-called organisms referred to the genus *Cryptozoon* and of the Algonkian limestones described and figured by Walcott. The literature relating to the geologic significance of the algae is becoming extensive, and it is not the writer's purpose to attempt any complete review of it at this time. A valuable bibliography of the subject, even though notably incomplete in its American references, is given by J. Pia.[30]

In the United States, in 1913, Eliot Blackwelder [31] made a notable contribution to the subject, in which he published photographs showing a remarkable resemblance of deposits of Ordovician dolomite to modern reefs of calcareous algae of the *Lithothamnium* group. The probability of calcareous algae having something to do with the formation of magnesian limestone and dolomite is heightened by chemical analyses [32] of various lime-secreting marine organisms, showing high percentages of magnesium carbonate in the lithothamnioid algae, whereas the madreporian corals are notably deficient in magnesium. A similar inference may be drawn from the biologic and chemical analyses of the borings at Funafuti, to which reference has already been made. Clarke and Wheeler [33] have already stated that

> In short, all the evidence goes to prove the importance of the algae as limestone builders and the subordinate character of the corals. This importance is now fully recognized by students of marine limestones and by paleontologists generally.

In 1914 G. R. Wieland,[34] accepting the various species of *Cryptozoon* as algae, refers to the pre-Cambrian, Cambrian, and Ordovician ages as characterized by the " reign of algae " and adds:

> Nor does it even seem too much to say that no dominant organisms of later ages, whether plant or animal, ever exceeded the Paleozoic seaweeds or left a bulkier record.

A little later in 1914 Charles D. Walcott, distinguished Secretary of the Smithsonian Institution, published his striking paper on pre-Cambrian Algonkian algal flora,[35] in which he takes the ground that the extensive (nonmarine?) magnesian limestones of Algonkian age (chiefly in the Belt Mountains of Montana) were laid down by algae of the blue-green group, much as deposits of lime are now being made, on a smaller scale, by blue-green algae in fresh-water streams, ponds, and lakes in various parts of the United States. Walcott gave several new generic and specific names to these supposed fossil algae, although there seems to be scarcely any definitely conclusive evidence in their microscopic structure that these formations are due to algae at all. However, from their general macroscopic characteristics it seems probable to the present writer that some, perhaps most, of these new generic names were applied to real algae or to their very ancient forerunners. The magnitude of some of these limestone deposits is indicated by Walcott's remark that " in the Camp Creek section of Montana *Collenia* was found to range up through 2,500 feet (760 meters) of strata." [36] There are also extensive deposits of Algonkian limestones in Arizona, in the Grand Canyon of the Colorado. The study of the supposed fossil algae of that region, begun by Walcott and by Dawson, is being continued by David White.[37]

E. S. Moore [38] has directed attention to massive strata of ancient presumably algal limestones, more or less silicified, on the Belcher Islands, Hudson Bay, and the adjacent mainland. These strata attain a thickness of 428 feet and are considered to be of pre-Cambrian age. The contributing organism shows concentric layers, somewhat as in the *Cryptozoon proliferum* from the Cambrian of Saratoga County, N. Y., and the *Collenia frequens* from the pre-Cambrian of Meagher, Mont. Professor Moore has found [39] similar calcareous concretions in pre-Cambrian rock from the vicinity of Port Arthur, Ontario.

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[28] Op. cit.; Fossil plants, pp. 122, 123, 1898; The earlier records of plant life: Geol. Soc. London Proc., vol. 79, pp. lxvi–civ, 1923; Plant life through the ages, 1931.

[29] On the important part played by calcareous algae at certain geological horizons: Geol. Mag., new ser., dec. 5, vol. 10, pp. 440–446, 490–498, 545–553, 1913; Nature, vol. 92, pp. 111–121, Sept. 25, 1913.

[30] Geologisches Alter und geographische Verbreitung der wichtigsten Algengrupper: Oester. Bot. Zeitung, Band 73, pp. 174–190, 1924.

[31] Origin of the Bighorn dolomite of Wyoming: Geol. Soc. America Bull., vol. 24, pp. 607–624, pls. 28–35, 1913.

[32] See Clarke, F. W., and Wheeler, W. C., The inorganic constituents of marine invertebrates: U. S. Geol. Survey Prof. Paper 102, 1917. Pages 44–50 are devoted to analyses of calcareous Rhodophyceae and Chlorophyceae, none of which are properly " invertebrate."

[33] Op. cit., p. 54.

[34] Further notes on Ozarkian seaweeds and oolites: Am. Mus. Nat. Hist. Bull., vol. 33, pp. 237–260, Apr. 14, 1914.

[35] Smithsonian Misc. Coll., vol. 64, pp. 77–156, pls. 4–23, July 22, 1914.

[36] Idem, p. 98.

[37] Study of the fossil floras of the Grand Canyon, Arizona: Carnegie Inst. Washington Yearbook Nos. 26, 27, 28 and 29; Algal deposits of Unkar Proterozoic age in the Grand Canyon, Arizona: Nat. Acad. Sci. Proc., vol. 14, No. 7, pp. 597–600, 1928.

[38] The iron formation on Belcher Islands, Hudson Bay, with special reference to its origin and its associated algal limestones: Jour. Geology, vol. 27, pp. 412–438, 1918.

[39] Letters of April 10 and April 26, 1924.

A very important recent contribution to the literature of algal reefs is W. H. Bradley's beautifully illustrated paper on algal reefs and oolites of the Green River formation.[40] These reefs and beds are of the Eocene epoch and they show manifest algal structure, microscopically as well as macroscopically. Bradley identifies the dominant alga as *Chlorellopsis coloniata* Reis, originally described in 1923 from the Miocene lake beds of the Rhine Valley. The limestone beds formed by these algae in the Green River region of Wyoming, Coloradó, and Utah are locally as much as 18 feet thick.

The deposition of lime in Green Lake, near Kirkville, N. Y., a few miles east of Syracuse, has been referred to by C. D. Walcott[41] and W. H. Bradley.[42] Walcott published photographs illustrating the external appearance of the deposits and sections, without magnification. Bradley illustrated the gross appearance (op. cit., pl. 29, *B*) and sections under low magnifications (op. cit., pl. 30, *A*, *B*). He also ventured to name the various algae that are disclosed by dissolving out the calcium carbonate. "Of these," he says, "*Microcoleus* [*paludosus* Kützing], by reason of its greater bulk, predominates, yet the minute cells and colonies of *Palmella* are vastly more numerous. *Palmella* cells are probably the unidentified 'rounded or oval, very small cells' that C. A. Davis referred to in his notes on the lime deposits of Green and Round Lakes, N. Y., published in Walcott's description of some pre-Cambrian algal deposits."

The writer has examined excellent material of this calcareous deposit collected in Green Lake by William R. Maxon October 21, 1914. The mass, or its surface, is distinctly blue-green, and several species and genera of Myxophyceae are represented in it and on it. The dominant form appears to be a filamentous one, much more delicate than *Microcoleus paludosus* mentioned by Bradley, having trichomes only 1μ to 2μ broad; it is coarser, more entangled, less compacted, less erect than the similar plant from Furnace Creek, W. Va., that is referred below to *Inactis pulvinata* Kützing. It is probably to be identified with *Inactis fasciculata* (Naegeli) Grunow [=*Schizothrix fasciculata* (Naegeli) Gomont], which is normally a lime precipitator. Associated with it are species of *Gloeocapsa*, *Gloeothece*, and *Aphanocapsa*, and very numerous minute brownish or nearly colorless cells which appear to be identical with the organism described on page 63 as new from Furnace Creek, near Harpers Ferry, W. Va. These may well be the "rounded or oval, very small cells" mentioned by C. A. Davis.

A most important contribution to the field of the present paper was made in 1915 by H. Justin Roddy,[43] who described the calcareous concretions of Little Conestoga Creek, in Lancaster County, Pa., from the points of view of both botanist and geologist. In his introduction he states:

My search was amply rewarded by finding them [concretions] in great quantities and distributed throughout nearly the entire length of the Little Conestoga. I found also that they not only occur in the creek itself, but that quite large deposits of the concretions underlie the flood-plain meadows along the creek banks. One of these, in Kendig's Woods, 2 miles southwest of Millersville, Pa., is made up wholly of concretionary materials on the top of which forest trees of large size and considerable age are growing. This deposit covers nearly an acre to the depth of about 8 feet in the middle, thinning out lenslike toward its edges. Another deposit along the same stream near Fruitville, in Evans's Meadow, more extensive in area but of slighter depth, forms a substratum under a thick soil cover and has an average depth of about 2 feet. * * * The concretions, both in the stream and in the deposits, vary in size from peas to masses nearly a foot in diameter.

Later Donegal Creek, another stream in the same county, was found to possess these objects in even greater abundance.

One meadow of fully 12 acres bordering the stream about 1 mile northeast of Marietta was found to be underlain with a bed of concretions not less than a foot in average thickness throughout its entire extent.

In 1918 James B. Pollock[44] published a scholarly and exhaustive paper on blue-green algae as agents in the deposition of marl in Michigan lakes. He traversed, from a more strictly botanical viewpoint, the ground previously covered by C. A. Davis, and he reached somewhat different conclusions, minimizing and localizing the importance of *Chara* and emphasizing the importance of the blue-green algae. From the calcareous incrustations on the shells of living clams, having a life span of 8 to 10 years, he estimated that the blue-green algae deposit marl at the rate of about 1 foot in thickness in 75 years.

Other known instances of the more or less manifest agency of the algae in forming limestones might be mentioned, but the above, with others that are referred to in the literature cited, may suffice for the present occasion. Evidence of the important, often dominant rôle of the algae in this connection is cumulative.

In February, 1930, David White, of the United States Geological Survey, brought to the writer concentrically laminated calcareous pebbles from Furnace Creek, a tributary of the Potomac River about 1½

[40] U. S. Geol. Survey Prof. Paper 154, pp. 203–223, pls. 28–48, 1929.

[41] Pre-Cambrian Algonkian algal flora: Smithsonian Misc. Coll., vol. 64, p. 86, pl. 4, figs. 3, 4, 1914.

[42] Algae reefs and oolites of the Green River formation: U. S. Geol. Survey Prof. Paper 154, pp. 203–223, pls. 28–48, 1929.

[43] Concretions in streams formed by the agency of blue-green algae and related plants: Am. Philos. Soc. Proc., vol. 54, pp. 246–258, figs. 1–2, 1915.

[44] Michigan Acad. Sci. Ann. Rept., vol. 20, pp. 247–260, pls. 16, 17, 1918.

miles above Harpers Ferry, W. Va. He brought also, from more rapidly flowing water in the same stream, more extensive rocklike deposits of lime, of the general kind commonly known to geologists as "travertine." The first microscopic examinations of ground sections and of decalcified preparations showed a mixture of minute plants—diatoms, unicellular Chlorophyceae, unicellular and filamentous Myxophyceae (Cyanophyceae), and possibly bacteria—and, in parts exposed to rapid water, the filamentous prothallus of a *Lemanea.* In parts of the deposit there was a dominance of a minute filamentous blue-green alga, with colored parts (trichomes) only 1μ or a little more in width. These apparently belong to the genus *Inactis* (a section of *Schizothrix* of some authors) and to the species *Inactis pulvinata* Kützing, originally described from Germany in 1849, since reported from cataracts in North America, and known to form hard deposits of lime. Mixed with the more or less erect filaments of the *Inactis* and in places predominating were much coarser filaments (trichomes 6μ to 7μ in diameter) with firm, rigid sheaths; these filaments appear to be referable to *Lyngbya martensiana calcarea* Tilden, originally described from Minnesota. There are, however, wide areas of this Furnace Creek deposit that show no traces of either the *Lyngbya* or the *Inactis,* and further studies indicated that very numerous minute particles which had at first been passed over as bacteria or granules of an inorganic nature often showed in mass traces of a light blue-green or yellowish-green color. The conviction grew that they were representatives of the Myxophyceae, smaller, perhaps, than any previously known, and that they were the actively important agents in precipitating lime and in forming a kind of limestone. In the older layers of the deposit the chlorophyll doubtless vanishes, and on the lower shaded surfaces of the irregularly eroded or built-up rock in rapids its presence is difficult or impossible to demonstrate, yet, a priori, it may be assumed to be there, for lime is precipitated, and the precipitation of lime is held to be linked with photosynthetic action of chlorophyll in decomposing the CO_2 (apparently HCO_3 in this case) in the water and thus reducing the amount of calcium bicarbonate that may be held in solution.

On December 7, 1930, under the guidance of David White and Charles B. Read, of the United States Geological Survey, the writer enjoyed the privilege of visiting Furnace Creek and inspecting the deposits in place. An extreme deficiency of rainfall during the preceding six months had left the stream very low, and the calcareous pebbles in the slower parts and the expansive calcareous travertine in the more rapid parts were readily accessible. There had been a rain (about one-third of an inch in Washington) the afternoon and evening before, and the stream was higher than the former low levels, though the water was still clear. A sample of the water, thus presumably diluted from the concentration of the preceding day, was taken to Washington by Mr. White for analysis, which showed the following constituents, in parts per million:

CO_3	0
HCO_3	237
Iron	.1
Mn	.7
Ca	66
Total hardness	255

In the rapids, especially in the shaded recesses, the superficial crust is conspicuously black or at least dark or rust-colored. Mr. White states (in a letter) that the lime is here associated with manganiferous iron oxides. Sections show a laminated structure, with dark layers occurring at irregular intervals, and Mr. White suggests that the deposits of iron and manganese accompany the greater concentrations of these metals in the water in seasons of drought, the year 1930, in which the deposit was very notable, being one in which the annual rainfall in the Washington region was only about half the normal.

In spite of the differences in appearance between the olive-brown, ash-colored, or subfuscous concentric pebbles of the moderately quiet water and the expanded harder black or ferruginous crusts of the rapids, the writer believes that the organism that is chiefly responsible for the precipitation is specifically the same in both situations. In the well-aerated rapids, for some reason, especially in the shaded caverns, the iron and manganese are deposited more obviously and copiously than on the pebbles of the better-lighted floor of the quiet stream. The organism seems to differ only in being browner or yellower, and this is apparently due to the presence of the darker metals.

In view of the manifest importance of this minute organism in depositing lime and the difficulty of trying to identify it definitely with previously described genera, it seems desirable to give it a new generic as well as a new specific name. Descriptions follow.

Class MYXOPHYCEAE

Family CHROOCOCCACEAE

Genus LITHOMYXA, n. gen.[45]

Cells subglobose, ovoid, or short cylindric, very minute, associated in great numbers in an extended layer, precipitating lime and forming a rocklike crust. Cell membranes soft, very inconspicuous, confluent. Cell division apparently in one direction; cells solitary, in twos, irregularly in fours, or often few or many conglobate. Chromatophore not definite; chlorophyll very little, in dark places perhaps wanting.

The genus shows points of contact with *Aphanothece*, *Aphanocapsa*, *Synechococcus*, *Synechocystis*, *Oncobyrsa*, and *Chlorogloea*. Perhaps it may be placed provisionally between *Oncobyrsa*[46] and *Chlorogloea*, from both of which it differs in the essential lack of radial arrangement of its cells. The type and only known species is described below:

Lithomyxa calcigena Howe, n. sp.

Plates 19–23

Cells mostly 0.4μ to 1.5μ long and 0.3μ to 1μ wide, before division usually about twice as long as wide, the young very pale blue-green, losing color with age, forming a hard laminate crust 1 millimeter to a few or many centimeters in thickness, the surface sordid, olivaceous, ash-colored, fuscous, or black, nearly smooth, verrucose, foveolate, scrobiculate, irregularly nodose or clivulose, or coarsely mammillate.

In a stream known as Furnace Creek, a tributary of the Potomac River, 1½ miles above Harpers Ferry, W. Va. Type in the herbarium of the New York Botanical Garden, collected by David White, Charles B. Read, and Marshall A. Howe, December 7, 1930. The technical type is considered to be one of the concentric pebbles found on the bed of the stream in rather quiet water. The more extensive and more massive, usually black or fuscous crusts found in the more rapidly moving water may be considered as deposited by the form *ferrifera*, if a distinctive name is required. This appears to differ from the type only in color (which may be looked upon as a sort of stain) and in its ability to precipitate considerable quantities of iron and manganese, which may be conditioned on its occurrence in rapidly moving, well-aerated, and perhaps well-shaded water. The same organism in different surroundings appears to have different physiological or chemical effects. In ground vertical or radiovertical sections the margin (surface) sometimes shows 2, 3, or 4 cells in an anticlinal row, but in general the cells are without order, their longer axes lying in any direction.

In the quiet water the *Lithomyxa* is often associated with Diatomaceae, Protococcaceae, and Chroococcaceae, rarely with *Inactis*. In the rapid water it is frequently found with *Gloeocapsa*, the filamentous protonema of *Lemanea*, *Inactis pulvinata* Kützing, and *Lyngbya martensiana calcarea*. The *Inactis* and *Lyngbya* sometimes occupy extended areas in more or less pure culture. Occasionally fields of the *Inactis* and *Lyngbya* and of the ferriferous form of the *Lithomyxa* meet and are sharply delimited at the line of juncture, as is often the case with crustaceous lichens. Plate 20, *A*, shows the black crust of the *Lithomyxa* impinging on the gray or ash-colored crust of the *Inactis* and *Lyngbya*, the line of demarcation being especially sharp at the top and bottom of the photograph and more broken in the middle.

That both iron and manganese are relatively much more abundant in the dark crusts than in the gray is shown by analyses kindly supplied by R. C. Wells, chief chemist of the United States Geological Survey. In the black crusts, in which *Lithomyxa calcigena* is the dominant organism, the analysis shows 12.3 per

[45] *Lithomyxa*, gen. nov. (fam. Chroococcacearum, class. Myxophycearum).

Cellulae subglobosae, ovoideae, vel brevi-cylindricae, minutissimae, in strato expanso numerosissimae confertae, calce induratae, crustam lithoideam efficientes. Membranae mollissimae, valde inconspicuae, confluentes. Cellularum divisio per speciem in directionem ad unam dimensionem, cellulis solitariis, binis, irregulariter quaternis, saepe paucis, vel multis conglobatis. Chromatophora haud definita, chlorophyllo minimo, in locis obscuris forsitan carente. Genus specie *Aphanothecae, Aphanocapsae, Synechococco, Synechocystidi, Oncobyrsae*, et *Chlorogloeae* affine est. *Lithomyxa calcigena*, species typica.

Lithomyxa calcigena sp. nov.

Cellulis plerumque 0.4μ–1.5μ longis, 0.3μ–1μ latis, juvenilibus pallide aerugineo-viridibus, luteis, vel luteo-brunneis, in aetate pallescentibus, crustam duram laminatam, 1 mm. ad mult. cm. crassam, superficie sordidam, olivaceam, cineream, fuscam, vel nigram, sublaevem, verrucosam, foveolatam, scrobiculatam, irregulariter nodosam, aut plus minusve grosse mammillatam efficientibus.

In rivulo "Furnace Creek" dicto ad "Harpers Ferry" Virginiae Occidentalis: in aquis placidioribus lapillos olivaceos, cinereos, vel subfuscos concentrice laminatos; in locis obscuris in aquis rapide fluentibus crustam latam crassam fuscam vel nigram *Lithomyxa* effecit. In aquis plus rapide fluentibus cum *Inacti pulvinata* Kuetzing, *Gloeocapsae* specie, et *Lemaneae* prothallo saepe consocia est. Species lapillos laminatos quoque in rivulo "Little Conestoga Creek" dicto in comitate "Lancaster" Pennsylvaniae (J. P. Roddy legit) effecit.

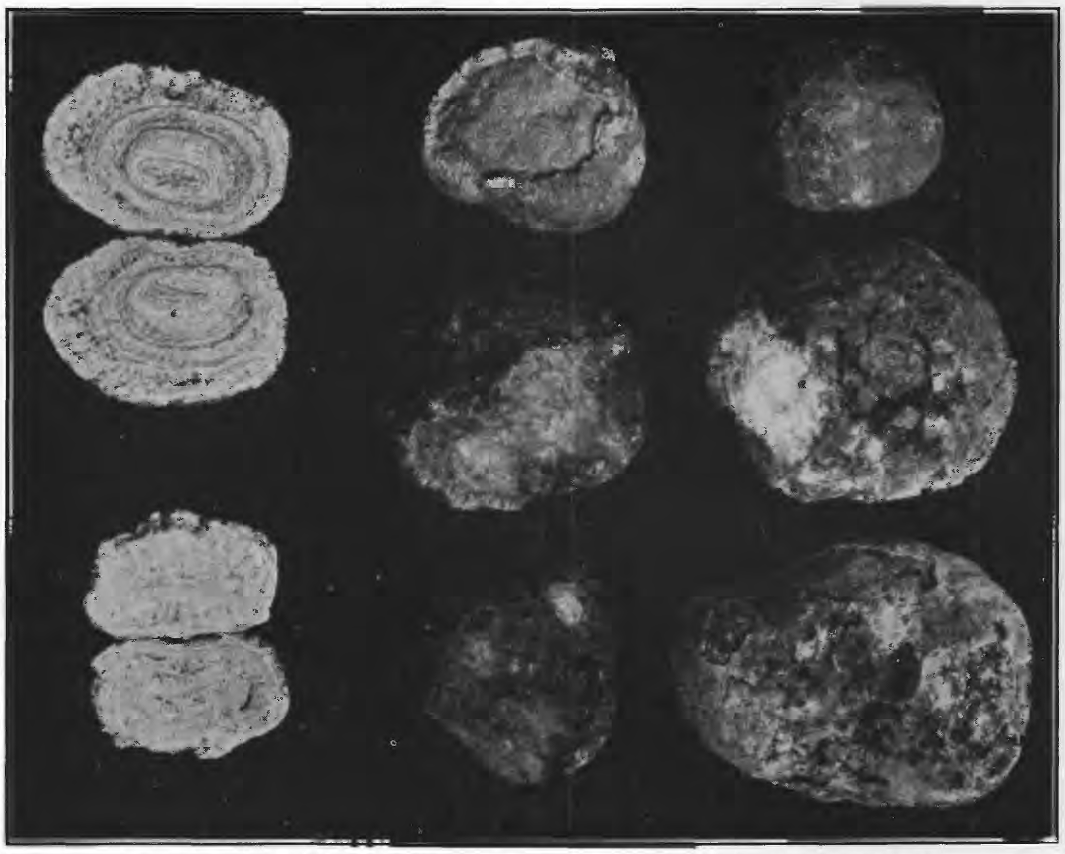
[46] Kützing (Phycologia generalis, p. 172, 1843) states that *Oncobyrsa fluviatilis* Agardh, the monotype of Agardh's genus *Oncobyrsa*, which Agardh himself placed among the Diatomeae, is the same as *Inoderma lamellosum* Kützing, a member of the Chlorophyceae. If this is true, the name *Oncobyrsa* (1827) should replace *Inoderma* (1843), and the genus Myxophyceae now currently known as *Oncobyrsa* should receive a new name, which may possibly be found among its alleged synonyms. A critical examination of Agardh's type specimen of *Oncobyrsa fluviatilis* is desirable.

cent of Fe_2O_3 and 4.5 per cent of MnO; in the gray crust, in which *Inactis pulvinata* and *Lyngbya martensiana calcarea* are dominant, Fe[47] is only 0.14 per cent and MnO is only 0.03 per cent.

The concentrically laminated calcareous pebbles described by Roddy as occurring in two streams in Lancaster County, Pa., are evidently more abundant there than in Furnace Creek, near Harpers Ferry, W. Va. However, Roddy's description and published photographs and a sample pebble that he has kindly sent to the writer show that the pebbles of these two not very widely separated areas are essentially the same in physical characteristics and that they have been built up by essentially the same kinds of blue-green algae, of which *Lithomyxa calcigena* is the principal or dominant lime-precipitating organism.[48]

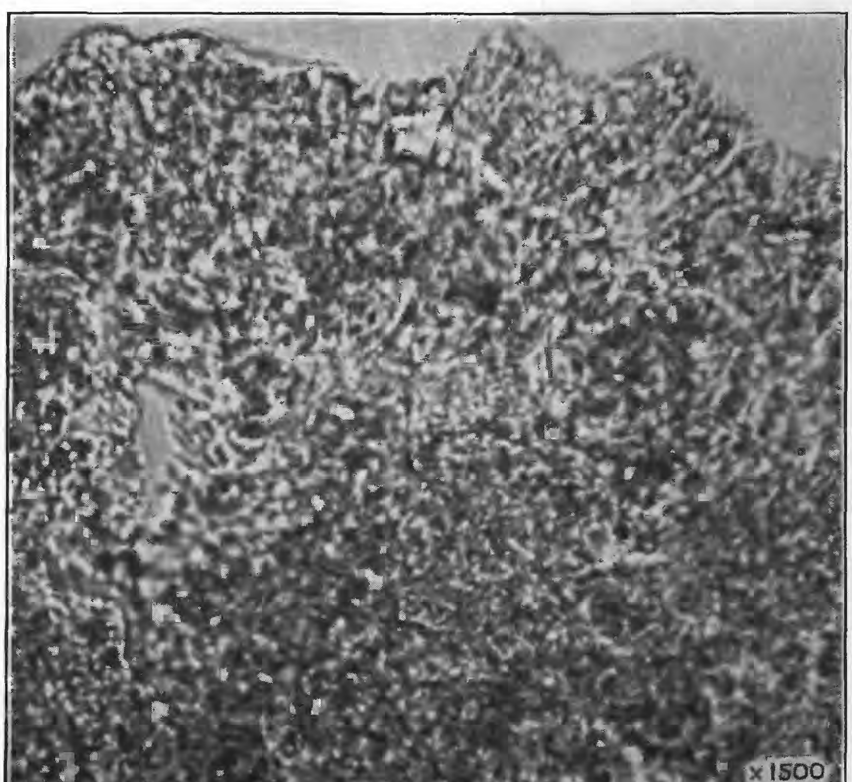
[47] Equivalent to 0.17 per cent FeO. The iron is probably in the ferrous condition, but the differentiation of ferrous and ferric iron is uncertain in the presence of organic matter.—R. C. Wells.

[48] The above paper, in a condensed form and illustrated by lantern slides, was presented at a meeting of the National Academy of Sciences held at Washington April 28, 1931.



A. CALCAREOUS CONCRETIONS FORMED CHIEFLY BY *LITHOMYXA CALCIGENA*

From bottom of Furnace Creek, in rather quiet water, near Harpers Ferry, W. Va.; collected by White, Howe, and Read December 7, 1930. A decalcified preparation, made from the superficial crust of the bisected pebble shown in the upper left-hand corner and preserved in the herbarium of the New York Botanical Garden, is specified as the technical type of *Lithomyxa calcigena*.

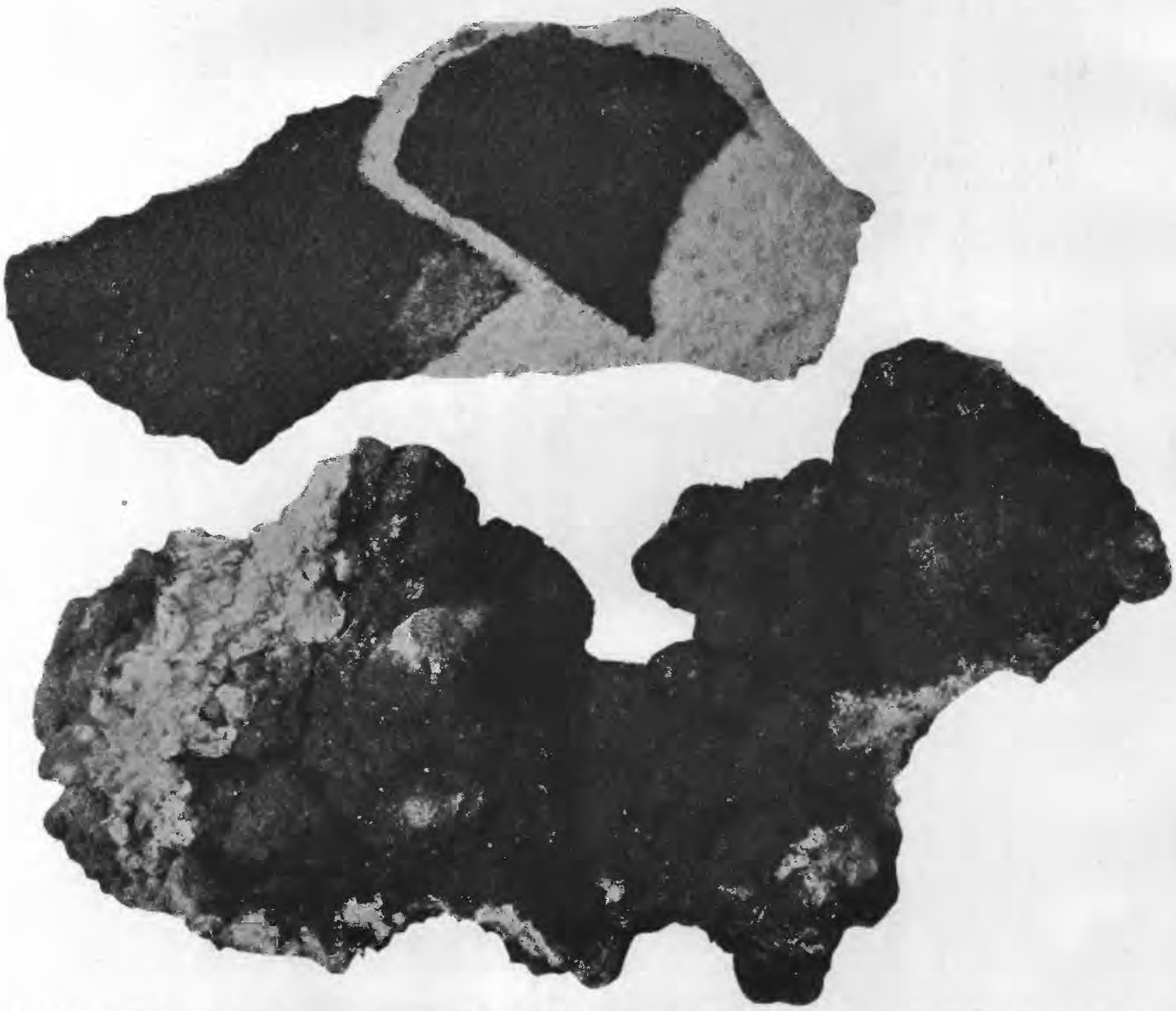


B. A PORTION OF A GROUND SECTION OF ONE OF THE PEBBLES FROM FURNACE CREEK

Showing, especially in the lower central region, outlines of the *Lithomyxa* cells, with incrusting lime; at the upper margin (surface) the cells sometimes appear to be in rows of two, three, or four.

A. A PORTION OF A GROUND VERTICAL SECTION OF THE BLACK CRUST ILLUSTRATED IN *B*

Showing outlines of the calcified *Lithomyxa* cells.

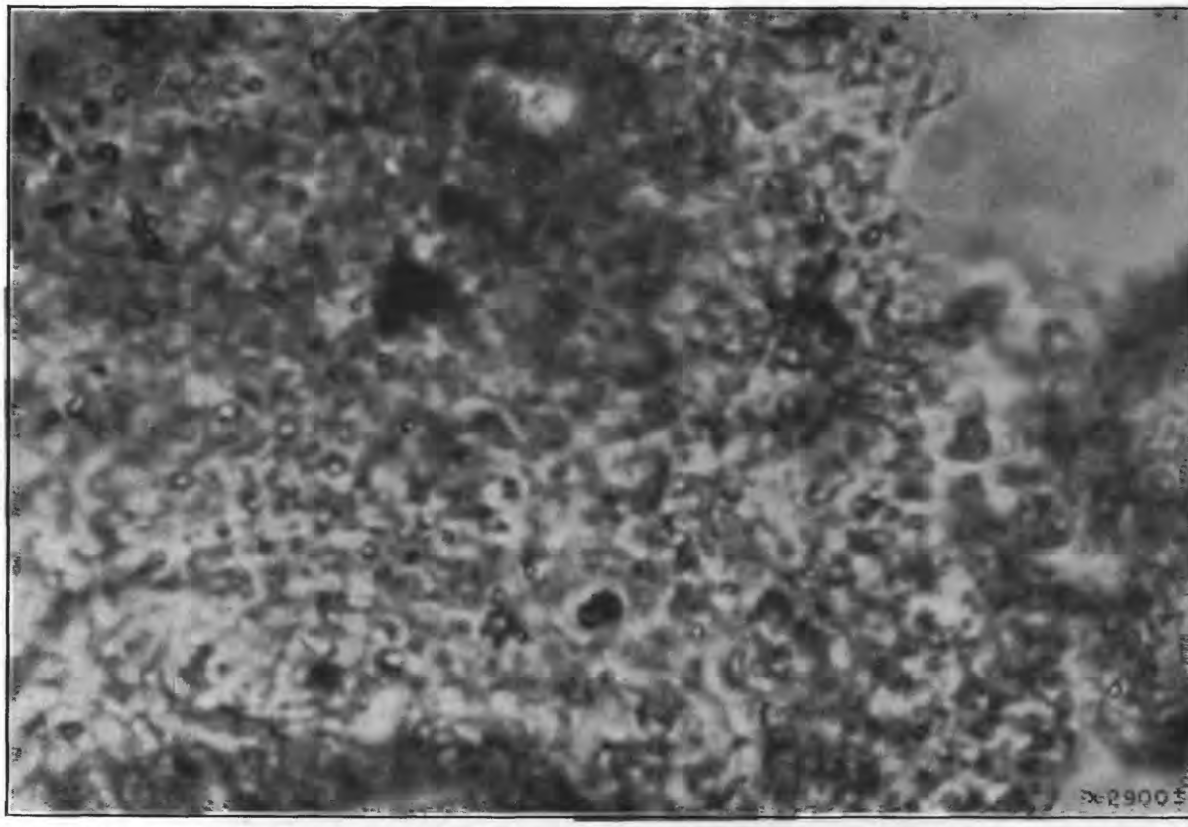


B. DARK OR BLACK CRUST, FORMED CHIEFLY BY *LITHOMYXA CALCIGENA* FORM *FERRIFERA*, IN SHADED OR PARTLY SHADED PLACES IN RAPIDLY MOVING WATER, FURNACE CREEK, W. VA.

Collected by White, Howe, and Read December 7, 1930. The darkening of the crust is apparently due to the presence of iron and manganese. The upper view indicates the readiness with which the superficial dark crust (a loose fragment here dislocated) separates from the underlying white crust, which also has been laid down by the *Lithomyxa*.

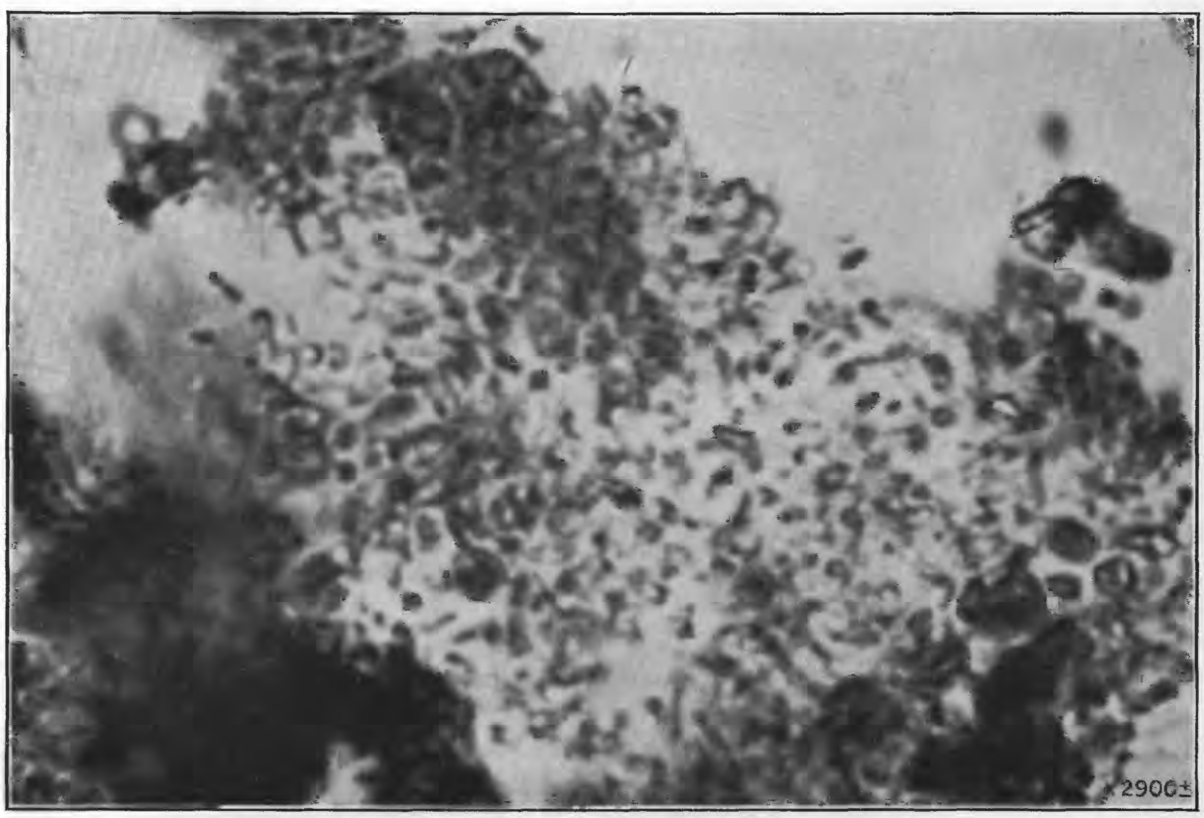
CALCAREOUS TRAVERTINE FORMED CHIEFLY BY *LITHOMYXA CALCIGENA* FORM *FERRIFERA*, IN MORE OR LESS SHADED PLACES IN RAPIDLY MOVING WATER, FURNACE CREEK, W. VA.

Collected by White, Howe, and Read December 7, 1930.

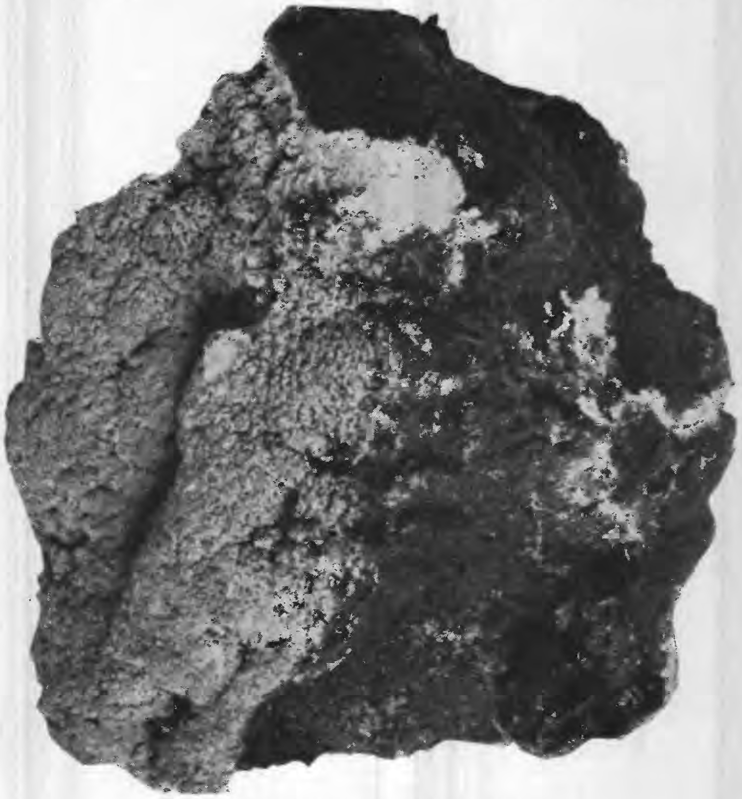


A. LITHOMYXA CALCIGENA, DECALCIFIED, MORE OR LESS EMBEDDED IN COLLOIDAL JELLY, FROM SURFACE LAYER OF A CALCAREOUS PEBBLE, FURNACE CREEK, W. VA.

Collected by White, Howe, and Read December 7, 1930.

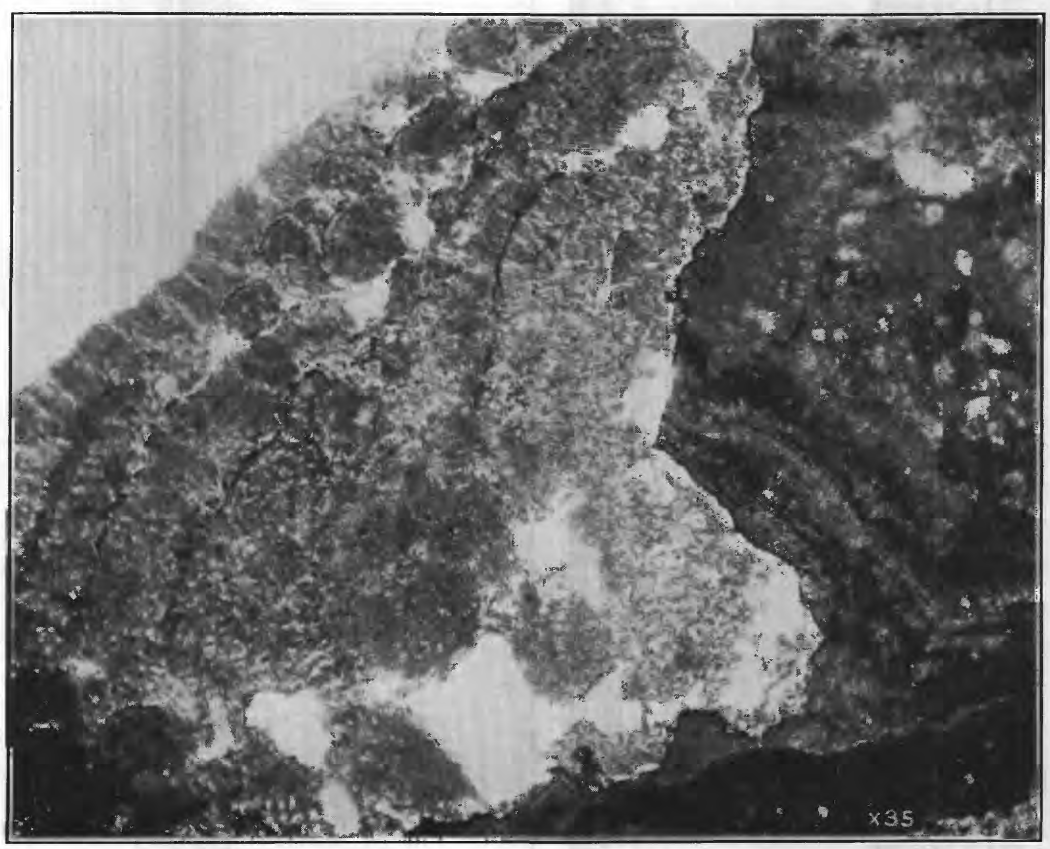


B. A SIMILAR PREPARATION OF *LITHOMYXA CALCIGENA* FORM *FERRIFERA*, FROM THE BLACK CRUST



A. SPECIMEN OF TRAVERTINE

The gray travertine at the left is made chiefly by two filamentous blue-green algae, *Lyngbya martensiana calcarea* and *Inactis pulvinata;* the black travertine at the right was laid down chiefly by the more minute unicellular organism, *Lithomyxa calcigena.*



B. A GROUND SECTION AT THE LINE OF JUNCTURE OF THE GRAY TRAVERTINE AND THE BLACK

The *Lyngbya* and *Inactis* form the looser and (in section) flabellate crusts at the left. The *Lithomyxa* forms the more compact and homogeneous crust at the right.

PLATES 19-23

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