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MISSISSIPPIAN FORMATIONS OF SAN SABA COUNTY, TEXAS

BY

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INTRODUCTION

By P. V. Roundy

Deep drilling for oil is now in progress in many fields, in spite of its great cost—a cost so great that the operators can no longer ignore the importance of using science to its fullest degree to reduce the cost of drilling and the risk of failure. Both in wildcat operations and in work in proved fields the identification of the formations penetrated by the drill is essential to intelligent development. Many wells have probably been drilled more than a thousand feet below the lowest point at which there is a chance of obtaining oil, and many other wells have been abandoned before they had reached the oil-bearing beds of near-by producing fields. Several methods of studying and correlating the strata penetrated by the drill are now used by the more progressive oil producers. Among these methods are (1) the plotting and comparison of the drillers' logs; (2) the preparation and study of accurate logs by inspection of drill cuttings; (3) the study of the heavy minerals in drill cuttings from different formations; and (4) the study of fossils found in drill cuttings and the comparison of such fossils with those found in known formations at their surface exposures. The first of these methods is probably more widely used and less accurate than any of the others. The next two are of great use in fields where a knowledge of the stratigraphy is well established, but the fourth method is of most service in fields where the subsurface beds lack distinctive lithologic characteristics and in exploratory work.

This paper is the first of a projected series that will describe several micro-faunas (associations of microscopic fossils known to occur in a single formation or in selected groups of formations) from different parts of the Mid-Continent field, in order to furnish other students of such organisms a basis for comparison and identification. Where diamond core drills are used it is comparatively easy and not uncommon to obtain many specimens of the larger fossil invertebrates that have been studied in this country for over half a century. In cuttings from a well drilled with cable tools it is very unusual to obtain the large fossils in other than a fragmentary, unidentifiable condition. The very small fossils, however, are usually present unbroken in some of the cuttings from deep wells that penetrate marine strata, such as prevail in much of the Mid-Continent region. Although most of them are visible to the naked eye when separated from the rock fragments, a microscope is required to study them successfully. For this reason they are called micro-fossils.

In the Carboniferous rocks, micro-fossils consist of representatives of the Protozoa, Coelenterata, Vermes, Mollusca, Crustacea, plants, and conodonts. Below is briefly set forth the value of these groups for correlation and identification of horizons.

Of chief importance under the phylum Protozoa are the Foraminifera, which are very abundant in some of the Pennsylvanian and Permian formations and not uncommon in some of the Mississippian formations. From our present knowledge of these forms, the species of some genera appear to be valuable horizon markers, but those of other genera are so variable that they appear to be worthless for this purpose.

In the phylum Coelenterata only the sponges need be considered. In certain beds, such as the Marble Falls limestone, sponge spicules are exceedingly abundant. Very little has been done with these forms, but it appears that they may be of great regional importance as auxiliary evidence in stratigraphic work.

Although several kinds of worm tubes have been found they either represent long-range species or else, if in reality they belong to many species, they do not preserve well-defined specific characters. Consequently they appear to be of comparatively minor importance in correlation. Annelid worm jaws may prove to be of stratigraphic significance, but they are so rare in Carboniferous rocks that they need not be considered here. Conodonts, according to some authorities, should be classed under the phylum Vermes, but until more is definitely known of their zoologic position I prefer to consider them an independent group.

In the phylum Mollusca some of the gastropods, though very minute, are yet apparently mature, and I believe that when more carefully studied they will prove to be of considerable aid in determining horizons. Although minute specimens representing other classes of this phylum are often found, they appear to be immature or else so lacking in character that they might well represent the young of any one of several larger species. The last statement applies also to most of the brachiopods, which, however, belong to the phylum Molluscoidea.

In the class Crustacea, which is a part of the phylum Arthropoda, the ostracodes are decidedly the most important in correlation. They were abundant throughout the Carboniferous period.

Of the fossil plants, seeds and spore cases may prove to be of great importance. Naturally, they may be found in strata that do not contain marine forms.

The conodonts, small, jawlike fossils whose zoologic position is still a matter of conjecture, occur in both the Pennsylvanian and the Mississippian rocks. These forms I believe will prove to be of considerable importance in stratigraphic work when they have been more fully studied.

In the identification and correlation of horizons, especially over considerable geographic distances, the use of faunas (associations of species) is more to be relied upon than the use of individual species.

In the two faunas described in this paper, the ostracodes and conodonts include most of the micro-fossils. *Ammodiscus* is the only foraminifer present. These micro-fossils are described in Part II. A few minute Mollusca are present, but they appear to be the young of larger forms and therefore are not described. The larger forms obtained from the lower formation are described by George H. Girty in Part III. These fossils are much smaller than the usual macro-fossils, and therefore might sometimes be obtained in an identifiable condition from well cuttings.

The Mississippian rocks of San Saba County, Tex., consist of two distinct formations—a limestone of Boone age and the Barnett shale. The lower formation is a gray, medium-hard, somewhat crinoidal limestone exposed, so far as I am aware, only along the road to Chappel about 3 miles southeast of the courthouse at San Saba. This limestone, which is only about a foot thick, at first glance appeared to be the top part of the Ellenburger limestone, as it is not conspicuously separated from the top of the true Ellenburger and gave evidence of unconformity with the Barnett shale. Numerous fossils collected by K. C. Heald and me from this limestone show it to be of Boone age. The line of contact between the two limestones is hard to determine, as there appears to be a transition from the light-colored Ellenburger (Cambrian and Ordovician) limestone into the darker Mississippian limestone. This interesting contact is discussed by Marcus I. Goldman in Part IV.

The upper formation of the Mississippian in this area consists of black shale with some limestone beds in its upper part. Plummer and Moore in 1921 gave the name Barnett shale to the "shale and limestone strata between the massive beds of the Marble Falls limestone above and the Ellenburger (Ordovician) limestone."

In Part I of this paper George H. Girty discusses the age and correlation of these formations. The evidence furnished by the micro-fossils, described in Part II, strongly confirms the reference of these beds to the Mississippian, despite the fact that most of the forms are new.

Part I. GEOLOGIC AGE AND CORRELATION

By George H. Girty

The Mississippian rocks of San Saba County, Tex., consist of two formations. The upper is the Barnett shale, which has always been included in the "Bend series," and the lower is an undescribed limestone which has always been excluded from the "Bend series" and, if observed at all, considered to be a part of the Ellenburger limestone, of Ordovician and Cambrian age.

The fauna of the lower limestone is wholly unknown and is in many respects peculiar. On this account I have, in Part III, described it in detail, both because such treatment seemed essential as a warrant for the conclusions as to geologic age whose acceptance is asked and because the fauna may prove of economic importance as well as of scientific interest, for all the species are small, almost minute, and thus expectable of preservation in drillings from wells, so that the information thus supplied may prove useful to the oil producer.

The other formation referred to the Mississippian is the Barnett shale. The Barnett shale as originally defined by Professor Moore[1] is not exactly the same as his "lower Bend shale" but includes at the top some calcareous beds that were formerly included in the Marble Falls limestone of this region. Stratigraphically the change is immaterial; paleontologically it is highly important, as it turns both formations into units, faunally considered, and makes the content of the Marble Falls limestone here the same, so far as we can tell, as in the typical section at Marble Falls.

The geologic age of the Barnett shale has been considerably debated. It contains abundant fossils, but its fauna is not especially varied and is not comparable with any of the typical faunas of the American Carboniferous section. If it were more closely allied to our typical Mississippian faunas such difference of opinion could not well exist, and, I might add, it would likewise in large measure melt away if all the evidence at present unpublished were generally known. To present this evidence for the consideration of anyone who is interested in it is impossible at this time; I can do no more than outline its general character.

The most striking elements of the Barnett fauna are *Leiorhynchus* in great abundance, goniatites closely allied to the European species *G. crenistria* and *G. striatus*, and *Posidonia*-like shells that I have referred to the genus *Caneyella*. There are other types that in a less cursory treatment would be important, but these are the salient ones. This fauna at once recalls that found in the lower part of the Caney shale,[2] and one can hardly doubt that both are of the same geologic age. Thus far there is very little to indicate whether this age is Mississippian or Pennsylvanian, unless we transfer our consideration to certain faunas of Europe, for, as just noted, the Barnett and lower Caney faunas contain very little that would aid in establishing their place in the American Carboniferous section. They are, however, strikingly similar to the Moorefield fauna in northern Arkansas and the "Mayes fauna" (or part of it) in northeastern Oklahoma, and the Mississippian age of the Moorefield and "Mayes" formations is beyond possibility of question; the Moorefield is overlain by rocks that contain a whole series of faunas which, although they present a number of peculiar features, are universally recognized as of Chester age.

These are by no means isolated facts. Faunas of this general type are widely distributed on the North American continent; they occur in the Appalachian region, in Utah, in Nevada, and in Alaska, and everywhere they are of Mississippian age. This does not mean, as it might, merely that I have classified them in the same way; it means that in most instances more or less conclusive Mississippian evidence, and in no instance any Pennsylvanian evidence exists, for the age of these faunas. It should be borne well in mind that I am using the term fauna in a broad way, for as no two collections, even though they are made at the same place, bring to light exactly the same series of species, still less do two collections from beds at the same horizon at different places. Thus *Moorefieldella eurekensis* is not known in either the Barnett shale or the Caney shale, but it is abundant in northern Arkansas, in northeastern Oklahoma, in the Appalachian region, and in Nevada; and so with other forms, such as *Productella hirsutiformis*. As nearly as the facts are known to me this type of fauna is apt

[1] Plummer, F. B., and Moore, R. C., Stratigraphy of the Pennsylvanian formations of north-central Texas: Texas Univ. Bull. 2132, p. 24, 1922.

[2] Girty, G. H., The fauna of the Caney shale of Oklahoma: U. S. Geol. Survey Bull. 377, 1909.

to have lived where black shales or black shaly limestones were forming; it varies from place to place but is always restricted to Mississippian time. In other words, of the numerous faunas coming under my observation all that seem related to the Barnett (or the lower Caney) fauna, or that secondarily are related to one of those so related, are of Mississippian age, whereas of the faunas determined as Pennsylvanian none seem related to the Barnett (or the lower Caney) fauna. Detailed study of the collections when they are brought together and compared may show that these statements are too sweeping, but the preponderance of evidence in this sort is at present practically overwhelming.

On the opposite side, I know of very few facts or arguments deserving comment. I shall mention but not in this place discuss the fact that the Jackfork sandstone, which underlies the Caney shale, and the Stanley shale, which underlies the Jackfork, have by some writers been referred to Pennsylvanian time. The paleontologic evidence from the Stanley is hardly worth considering. The fauna on which the Jackfork has been assigned to Pennsylvanian time is probably Pottsville, as claimed, but it also probably does not come from the Jackfork but from another sandstone, which is locally superimposed on the Jackfork and which, by a more than doubtful usage, has been included under the same formation name.

Returning to the Barnett shale from a wide digression, I find its fauna to be related to faunas of Mississippian age and only to faunas of Mississippian age so far as known. From the overlying Marble Falls fauna it is separated by an abrupt and profound change at a horizon marked in San Saba County by an obscure unconformity, the evidence for which is presented by Mr. Goldman.[1] Though the unconformity is far from obvious in this region it is more manifest at Marble Falls, where the Barnett shale is apparently absent, so that the Marble Falls limestone, which is of Pennsylvanian age, seems to rest directly on the Ellenburger limestone. One might feel justified in believing this to be the widespread unconformity that is so generally found between Mississippian and Pennsylvanian rocks in eastern North America.

[1] U. S. Geol. Survey, Prof. Paper 129, pp. 1–22, 1922.

Although the close relationship between the Barnett and certain Mississippian faunas can not be disputed, the suggestion has sometimes been made that in this region faunas of the Barnett type survived into Pennsylvanian time. One would be rash to deny that such a survival could take place, while wondering on what grounds it is supposed to have taken place in San Saba County. Certainly such a hypothesis should not be adopted in any case without weighty evidence and almost as a last resort, but the facts here point very much the other way. Evidence for or against this hypothesis might perhaps best be looked for in northeastern Oklahoma and in adjacent parts of Arkansas, where exposures are numerous, where fossils are abundant, and where the boundary between Mississippian and Pennsylvanian is well recognized. This region is known in considerable detail both stratigraphically and paleontologically, but in no instance has a fauna even remotely resembling the fauna of the Moorefield, Caney, and Barnett formations been found above the top of the Mississippian. In other words, out of many hundred collections none having a Moorefield facies has been found stratigraphically above one having a Morrow or any other Pennsylvanian facies.

The fauna of the Barnett shale would tend to link that formation with the lower part of the Caney shale, and on similar grounds the lower part of the Caney shale would be linked with the Moorefield shale. I have hesitated to restrict the correlation of the lower Caney to the Moorefield alone, however, because, although the prevailing fossils of the Fayetteville shale, fossils which determine its age quite definitely as Chester, do not occur in the Caney, certain of the characteristic Caney forms do occur in the Fayetteville. Caneyellas and goniatites like those of the Caney shale are found near Fayetteville, and *Leiorhynchus* occurs in abundance near Marshall. It seems possible, therefore, that the lower Caney may represent the whole Moorefield-Fayetteville interval of the Arkansas section. The upper Caney, or beds that have been included in the upper part of the Caney, are without much doubt of Pennsylvanian (Pottsville) age.

Part II. THE MICRO-FAUNA

By P. V. Roundy

FORAMINIFERA

Family LITUOLIDAE[1]

Genus AMMODISCUS Reuss

Ammodiscus sp.

The only Foraminifera found in the collections from the Barnett shale are a few poorly preserved specimens of *Ammodiscus*. They are minute flat, disklike forms. The central part of the disk is undeterminable, but the outer part shows on the best specimens from four to six coils. The tube appears to be without constrictions and to be very gentle in its tapering. Although clearly belonging to the genus *Ammodiscus*, these specimens do not warrant the establishment of a specific name. They range from 0.25 to 0.35 millimeters in diameter.

Horizon and locality: Barnett shale, San Saba County, Tex., (stations 7011A and 7687).

OSTRACODA

Ostracodes belong to the same class as the trilobites. They are small indistinctly segmented Crustacea with not over seven pairs of appendages, inclosed in a horny or calcareous bivalved shell. The Carboniferous ostracodes are usually less than 2 millimeters in length. These forms have been studied extensively in Europe, T. Rupert Jones, of England, having published from 1855 to 1895 over 50 papers, most of which deal with Paleozoic ostracodes. Other authors have added to the literature of these interesting forms until there is now a vast amount of knowledge available. Occasionally some American material has been described by some of these workers, but on the whole the American ostracodes from Carboniferous strata are mainly still undescribed. The greatest amount of work on these forms has been done by G. H. Girty, E. O. Ulrich, and R. S. Bassler. Ulrich and Bassler have also written papers on many of the pre-Carboniferous species and probably the best text on the Paleozoic ostracodes.[2]

[1] The genus *Ammodiscus* is placed in the family Lituolidae by Frederick Chapman (The Foraminifera, an introduction to the study of the Protozoa, 1902). Joseph A. Cushman places this genus in the family Astrorhizidae (U. S. Nat. Mus. Bull. 100, vol. 4, 1921).

[2] Paleozoic Ostracoda; their morphology, classification, and occurrence: Maryland Geol. Survey, Silurian, pp. 271–322, 1923.

In the Barnett shale ostracodes are comparatively rare. In the subjacent limestone of Boone age, however, ostracodes are abundant. As many of these ostracodes are new I have described some about which my present conclusions seem rather definite. Other forms that probably represent several genera and species, mainly new, I feel are inadequate to serve as types and therefore I am passing them with this brief mention.

In the erection of two new genera in this paper, I have described two species of ostracodes from the Pennsylvanian so that I might have better and more typical genotypes.

Family APARCHITIDAE Ulrich

Genus SANSABELLA Roundy, n. gen.

Carapace small, less than 2 millimeters in length; outline varying somewhat from a parallelogram; greatest thickness in anterior half. Left valve larger than right, overlapping on ends and ventral margin. Hinge line straight, equal in both valves and, in part, slightly lower than the dorsal margins of the two valves, giving an excavated or channeled appearance in the dorsal view of a bivalved specimen. The hinge structure consists of a longitudinal groove and tongue on each valve. On the left valve the upper or dorsal margin of the groove is slightly larger and forms the tongue; on the right valve the lower margin of the groove is considerably stronger and forms the tongue.

Genotype, *Sansabella amplectans*.

All the specimens of the two species of *Sansabella* described in this paper are bivalved specimens, which do not show the hinge structure. However, in a collection from the Caney shale there are some single valves which show the character of the hinge structure clearly.

This genus is evidently related to *Jonesina* in relative size of valves. In the figure of the type species of that genus, *Jonesina fastigiata*, the left valve is shown as overlapping on the dorsal as well as on the end and ventral margins. This would seem to indicate that the genotype of that genus could not have possessed a cardinal V groove such as is characteristic of *Sansabella*. In *Sansabella amplectans* the valves are without sulcus or node; in *S. sulcata* a simple sulcus and deep central pit are present.

Of the species now placed under *Jonesina*, *J. bolliiformis*, originally described as *Beyrichiella bolliiformis*, should probably be placed under *Sansabella* on account of its excavated or channeled dorsum. This transfer should certainly be made if the relative size and manner of joining of the two valves are of more importance than the sculpture of the sides, especially as the sculpture of the species now placed under *Jonesina* are so far from uniform.

Sansabella amplectans Roundy, n. sp.

Plate I, Figures 3a–5

Shell small, outline resembling a parallelogram. Hinge line straight, slightly excavated. Posterior end somewhat rounded. Anterior end slightly more rounded. Backward swing pronounced. Left valve larger than right, broadly overlapping it on the anterior, posterior, and ventral margins. A portion of the dorsal margin of each valve projects slightly above the hinge line and then is sharply reflexed so that the two meet evenly at the hinge line, giving the excavated appearance to the dorsal aspect of the species. Greatest thickness just in front of and slightly above the middle of the shell. The left valve is slightly depressed a short distance back from the anterior end, producing, in dorsal view, symmetry with the overlapped anterior end of the right valve. Surface smooth. About one-tenth of the specimens faintly suggest a median pit. All specimens are nearly uniform in size, the average dimensions being, length, 0.88 millimeter; height, 0.55 millimeter; greatest thickness, 0.40 millimeter.

Horizon and locality: Marble Falls limestone; San Saba County, Tex. (station 2690).

Sansabella sulcata Roundy, n. sp.

Plate I, Figures 6a–7

Shell small, outline resembling a parallelogram, ends somewhat rounded. Hinge line straight and about two-thirds as long as greatest length of carapace. Left valve larger than right, overlapping broadly on ventral margin and moderately on anterior and posterior margins. Valves reflexed on dorsal edge so as to form a V channel along the hinge line, which lies in the bottom of channel, the two valves meeting equally at the hinge line. A deep distinct pit occurs on each valve slightly above and behind the center of the carapace. A shallow but distinct sulcus extends from the pit part way toward the dorsal edge. Greatest thickness of the shell near middle of the anterior half. Average dimensions of most specimens: Length, 1.28 millimeters; height, 0.76 millimeter; greatest thickness, 0.60 millimeter. A few specimens, evidently young, are much smaller but they also show the pit and sulcus.

This species is distinguished from *S. amplectans* by the deep pit and shallow sulcus, by its large size, and by its more elongated appearance due in part to its straighter ventral edge.

Horizon and locality: Barnett shale, San Saba County, Tex. (station 2618).

Genus AURIGERITES Roundy, n. gen.

Shell small, subovate, left valve overlapping the right on the ends and ventral margin. In the ventro-posterior quarter of each valve is a simple loop ridge with the two ends pointing anteriorly. As only one species is known, the complete generic characters probably have not been determined.

Genotype, *Aurigerites texanus*.

Aurigerites texanus Roundy, n. sp.

Plate I, Figures 8–10

Shell small, subovate. Hinge line straight and short, being slightly over half the greatest length of the shell. Dorso-anterior angle gently rounded; dorso-posterior angle slightly more angular. Ends of shell and ventral angles smoothly rounded; middle of ventral margin nearly straight. Posterior end of shell both thicker and higher than anterior end. Left valve larger and overlapping the right valve on all margins except along hinge line, where the two meet evenly. In the ventro-posterior quarter of each valve is an elevated horseshoe-like ridge, highest at its middle, which projects nearly as far back as the shell margin. The ridge diminishes gradually in strength from the center and the ends become obsolete about half-way to the middle of the shell. The shell surface inclosed by the loop is flat. This loop ridge causes the shell to appear as if it had an ear on each valve. Surface of shell smooth. The specimens of this species vary but little in size, the average dimensions being, length, 0.84 millimeter; height, 0.51 millimeter; thickness, 0.39 millimeter.

Horizon and locality: Limestone of Boone age underlying the Barnett shale, San Saba County, Tex. (station 2623).

Genus PARAPARCHITES Ulrich

Paraparchites sp.

Three poorly preserved specimens probably belong to this genus, but they do not appear to conform with any of the described species and their imperfect condition does not warrant a detailed description.

Horizon and locality: Limestone of Boone age underlying the Barnett shale, San Saba County, Tex. (station 2623).

Family KIRKBYIDAE

Genus KIRKBYA Jones

Kirkbya lindahli Ulrich?

1891. *Kirkbya lindahli* Ulrich, Cincinnati Soc. Nat. Hist., Jour., vol. 13, p. 207, pl. 18, figs. 6a–6c. St. Louis group: Columbia, Ill.

Two separate right valves appear to be much nearer to this species than to any described form. In shape and convexity they are nearly identical with the type as figured. They are smaller, however, being approximately half the size. The specimens are poorly preserved, apparently etched by weathering, so that it is not possible to determine if the surface was originally smooth or reticulate. A marginal rim is definitely present.

Horizon and locality: Barnett shale, San Saba County, Tex., (station 2613D).

Kirkbya lindahli var. arkansana Girty

Plate I, Figures 14a–16

1910. *Kirkbya lindahli* var. *arkansana* Girty, New York Acad. Sci. Annals, vol. 20, p. 234, Basal Fayetteville shale, Fayetteville quadrangle, Ark.

Shell small, subrhomboidal, narrowing slightly toward the front, and with a distinct backward swing. Hinge line straight. Anterior end well rounded and narrow, posterior end broad and rounded on lower two-thirds, nearly straight on upper third. Greatest height posterior to the middle of the shell. The faint surface sculpture is preserved only on specimens from station 2623; the other specimens, being somewhat weathered, appear to be smooth. A slight depression, probably the remains of a central pit, is faintly discernible. Length, 1.5 millimeters; height, 0.8 millimeter.

As the original description of this variety appeared without illustrations I am also giving figures of the type specimen here.

Horizon and locality: Barnett shale and the underlying limestone of Boone age, San Saba County, Tex. (stations 2613D, 2618, 2623).

Genus AMPHISSITES Girty

1910. *Amphissites* Girty, New York Acad. Sci. Annals, vol. 20, No. 3, pt. 2, p. 235.

This genus has as its type *Amphissites rugosus* Girty, described in the same paper with the generic definition, but not illustrated. For that reason I am giving figures of the genotype (Pl. I, figs. 1a–c).

The original definition of the genus is as follows:

A number of ostracode shells in the fauna of the basal Fayetteville shale belong to types which have been loosely referred to the genus *Kirkbya*, but they really appear to represent three generic or subgeneric groups. *Kirkbya* itself is described as having the right valve larger than the left and overlapping it. This is the condition of *K. lindahli* var. *arkansana*. The shell described below as *Amphissites rugosus* has the two valves equal, meeting each other along a line, neither one overlapping the other. It is furthermore distinguished by having the surface marked by a number of tubercles in addition to the fine reticulations. On both these accounts it seems that this form can readily and advantageously be distinguished from *Kirkbya* proper. The third type is represented by *Glyptopleura inopinata*, which has the left valve overlapping the right. Conjoined with this difference in configuration is one of sculpture, the sides being without knobs or plications but ornamented with oblique, inosculating costae instead of the fine reticulations and flanges of the other types.

This genus is rather common in the Carboniferous rocks of America, from which I have several undescribed species. Besides the genotype, two described species, *Kirkbya centronatus* Ulrich and Bassler and *Kirkbya tricollina* Jones and Kirkby, belong under this genus.

Amphissites chappelensis Roundy, n. sp.

Plate I, Figure 2

Shell small, subquadrate. Hinge line straight, posterior angle rather sharp, anterior angle more rounded. Ends and ventral margin gently curved; middle of ventral margin nearly straight and parallel to hinge line. A smooth narrow flange extends along the ends and ventral margin, completely concealing the valve margin in side view. However, there is a narrow area of the shell between this flange and the edge of the shell, perpendicular to the plane of the valve juncture. The flange is slightly reflexed near the ventro-anterior margin, a feature probably due to accident to the shell before fossilization. Within this flange occurs a second, slightly heavier though not wider smooth flange. It is nearly parallel to the first except near the posterior cardinal angle, where it approaches the angle with diminishing size and becomes obsolete before touching the outer flange, and near the anterior cardinal angle it merges with the outer flange. A central low, well-rounded broad tubercle is slightly posterior to the center of the valve. At its front edge is a very slight depression corresponding to the usual central pit of this genus. However, it is not of the definite character usually noted in other species of this genus. Midway between this tubercle and the anterior end of the valve but nearer the dorsal margin is a gentle elevation or swelling of the shell surface surmounted by a low, short, smooth, slightly curved ridge, nearly parallel to the corresponding portion of the second flange. A similar ridge occurs on the central part of the posterior half of the valve, but it is about twice as long as the anterior one, and without the special swelling of the shell surface beneath it. Surface of the valve finely reticulate. Length, 0.80 millimeter; height, 0.46 millimeter.

This species is based on a single well-preserved right valve. The species it nearest resembles is *A. centronatus*. In *A. centronatus* the central node is directly above the central pit, much nearer the dorsal margin, and more central as regards the ends. The short ridges anterior and posterior to the central tubercle are of nearly equal length and strength, and there appears to be no special swelling of the shell surface under either of them.

Horizon and locality: Barnett shale, San Saba County, Tex. (station 7011A).

Family BAIRDIIDAE?

Genus HEALDIA Roundy, n. gen.

Shell usually small. Dorsal margin curved, almost angular in the middle, the posterior slope in most species straight as if the dorso-posterior corner were removed by truncation. The anterior dorsal slope gently curved and rounding off into the broadly curved anterior end. Posterior margin more sharply rounded. Slightly in front of that end is a swollen area on each valve, not well differentiated from the shell contour in front but more conspicuous at its rear end. The ventral margin is nearly straight in its middle portion, rounding off into the ends. Left valve larger than the right, conspicuously overlapping it on all sides except on the dorso-posterior slope, where the overlap is usually slight. Separate left valves show a distinct groove for the reception of the right valve. Surface of the valves smooth; most species have on the posterior swollen area of each valve two backward-pointing spines, and one species has a small punctate area in front of the two spines.

Jones and Kirkby[3] described under the name *Bythocypris? cornigera* a species that probably belongs to this genus. This form, however, is clearly distinct from the typical *Bythocypris*, as originally proposed by Brady.

Genotype *Healdia simplex*.

Healdia simplex Roundy, n. sp.

Plate I, Figures 11a–11c

Shell very small. Dorsal margin gently curved in the anterior half, nearly straight in the posterior half, and subangular near the middle point. Ventral margin nearly straight but curving gradually into the rounded ends. The carapace viewed from above is wedgelike, the anterior end being thin and sharp. The thickened or swollen posterior end and the rather peculiar dorso-posterior slope are characteristic of the genus. In this species the dorso-posterior portion appears as if it were flattened by a hammer. On the outward posterior portion of the swollen area no spines are developed, although in most of the species of this common Carboniferous genus spines in this region are a normal part of the shells. Left valve larger, overlapping the right on all sides. On the flattened dorso-posterior margin, however, the overlap is almost negligible in its exterior expression. Although there is a slight variation in the greatest dimensions of the individuals, all are fairly close to the average, which is, length, 0.67 millimeter; height, 0.42 millimeter; thickness, 0.29 millimeter.

Horizon and locality: Graham formation (Cisco group), Stephens County, Tex. This species also occurs in other Pennsylvanian formations.

Healdia ampla Roundy, n. sp.

Plate I, Figures 12a–13

This species differs from *H. simplex* by having its dorso-posterior slope less conspicuously flattened, by its much larger size, and by its more pointed posterior end. In addition it has the stumps of two rather large spines on the outward posterior part of the swollen portion of each valve. These spines are broken on all the specimens from San Saba County, but specimens from other localities show them to be large and conspicuous. Length, 1.51 millimeters; height, 0.84 millimeter; thickness, 0.63 millimeter.

Horizon and locality: Limestone of Boone age, underlying the Barnett shale, San Saba County, Tex. (station 2623).

Family CYTHERIDAE

Genus XESTOLEBERIS Sars

Xestoleberis? subcorbuloides Jones and Kirkby?

1886. *Xestoleberis? subcorbuloides* Jones and Kirkby, Annals and Mag. Nat. Hist., 5th ser., vol. 18, p. 264, pl. 9, figs. 8 a–b.

A single specimen in my collections appears to be nearly identical with the English form in outline and contour. Its great tumidness and flattened dorsal and ventral margins with rounded ends distinguish it at once from the other species in the San Saba collections. The overlap is much less pronounced in my specimen than in Jones and Kirkby's figure. My specimen is 0.84 millimeter long; theirs is 0.75 millimeter.

Horizon and locality: Limestone of Boone age, underlying the Barnett shale, San Saba County, Tex. (station 2623).

CONODONTS

The name conodont was given by Pander[4] to certain minute toothlike fossils, of which he described

[3] Annals and Mag. Nat. Hist., 5th ser., vol. 18, p. 251. pl. 6, figs. 8–9, 1886.

[4] Pander, C. H., Monographie der fossilen Fische des silischen Systems der russisch-baltischen Gouvernements, St. Petersburg, 1856.

13 genera and many species. The zoologic relationship of conodonts has been a subject of much controversy, and they have been regarded by various authors as parts of gastropods, fishes, annelid worms, and crustaceans. Until more is known about these organisms their zoologic position must remain unproved.

Hinde[5] described several conodonts and grouped together under one name, *Polygnathus dubius*, many diverse forms. His reason for considering that these various forms belonged to one species was that he found crushed together in a small ball-like mass many teeth and plates. (See his description quoted under *Polygnathus*, p. 13.)

Probably the grouping of this great variety of forms under a single species by Hinde and later by Clarke[6] has tended to discourage a systematic study of the conodonts and to retard the development of a detailed classification of these forms. As the character of the organisms bearing these teeth is not known, a classification of them must at best be very artificial. Yet such a classification must be established in order to study and determine the value of these forms as horizon markers. Therefore, I believe that many of the genera already recorded in the literature should be more or less redefined and restricted.

Conodonts are classed as simple or compound. The simple conodont consists of a single minute tusklike, usually more or less conical tooth, the lower or larger end of which is the base. No simple conodonts are described in this paper. The compound conodont consists of two or more teeth attached to a straight, bent, or irregularly shaped bar, rod, or plate which is known as the base. The teeth may be like short or long, slender or robust spines, like sawteeth, like knobs, or like wedges. The teeth on a single specimen may be of similar or various types and sizes. The base usually bears on its under side an excavation or depression, which is called by some authors a pulp cavity, although in reality its function may have been far from that of the pulp cavity in the true teeth of the higher vertebrates. The San Saba County conodonts are mostly more or less translucent, some being almost transparent, and are mainly of a light amber color. Chemically they appear to be a phosphatic carbonate of lime.

Accurate and concise description of animal remains of complicated structure or contour requires some system of orientation. In dealing with remains such as the conodonts, whose zoologic relationship is unproved, any system of orientation must of necessity be purely artificial. For the purpose of more exactly and concisely depicting the characters of these fossils, I am considering that each conodont occurred in the side of an imaginary lower jaw with the sharp ends of the teeth or of the largest tooth pointing upward, inward, or backward, and with the base, when like a rod or bar, parallel with the side or front of the jaw. Consequently the descriptive terms I have used are without anatomic or zoologic significance.

Although conodonts occur in several of the Carboniferous formations of Texas they appear to be abundant only in the Barnett shale, where from comparatively few collections I have obtained many hundred individuals. From the Strawn formation, Marble Falls limestone, and Canyon and Cisco groups, with many times the number of collections, I have obtained but a comparatively small number of individuals. Therefore, a well cutting or shale sample from north-central Texas that contains several conodonts at once suggests but not necessarily proves the age to be Barnett. However, I believe that when the conodonts from the higher horizons are more perfectly known, very few of the species described here will be found to occur in the higher rocks.

A bibliography of conodont literature is given below. It includes everything except textbooks on paleontology, which in general give but a brief mention and reproduce a few previously published figures.

1856. Pander, C. H., Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements, St. Petersburg, 91 pp., 9 pls. (Original definition of conodonts. Many species and genera described.)

1861. Harley, J., London Geol. Soc. Quart. Jour., vol. 17, pp. 543–552, pl. 17. (Discusses zoologic position. Probably several specimens that he described are not conodonts.)

1861. Owen, Richard, Paleontology, 2d ed., Edinburgh, p. 117. (Brief discussion of systematic position.)

1863. Von Eichwald, C. E., Soc. imp. nat. Moscou Bull., vol. 36, p. 375. (Brief discussion of systematic position.)

1870. Moore, Charles, British Assoc. Adv. Sci. Rept. 39th Meeting, 1869, pp. 375–377. (Conodonts discussed but no specific descriptions or figures.)

1875. Newberry, J. S., Ohio Geol. Survey Rept., vol. 2, pt. 2, Paleontology, pp. 41–44, pl. 57. (Discusses zoologic position and illustrates several specimens without generic or specific names.)

1878. Ulrich, E. O., Cincinnati Soc. Nat. Hist. Jour., vol. 1, pp. 87–91, pl. 4. (Describes some true annelids and briefly discusses conodonts.)

1879. Hinde, G. J., Geol. Soc. London Quart. Jour., vol. 35, pp. 351–369, pls. 15–17. (Gives a general review of conodonts. Discusses zoologic relations and describes many new forms.)

1880. Young, John, Glasgow Nat. Hist. Soc. Proc., vol. 4, pp. 5, 74. (Abstract of paper read recording the discovery of conodonts in Carboniferous of Scotland and discussing zoologic position. Notice of occurrence of conodonts in Silurian and Devonian strata in England.)

[5] Hinde, G. J., Geol. Soc. London Quart. Jour., vol. 35, pp. 351–369, 1879.

[6] Clarke, J. M., New York State Geologist Sixth Ann. Rept., pp. 30–33, 1887.

1881. Mason, Robert, Glasgow Nat. Hist. Soc. Proc., vol. 4, p. 190. (Notes the finding of conodonts at a new locality in Scotland.)

1882. Rolle, Fr., Handworterbuch der Mineralogie, Geologie und Palaeontologie, Band 1, p. 408. (Short discussion.)

1884. James, U. P., Cincinnati Soc. Nat. Hist. Jour., vol. 7, pp. 143–149, pl. 7. (Describes two conodonts and two annelid jaws, all new.)

1886. Rohon, J. V., and Zittel, V., K.-k. Akad. Wiss. München, Math.-phys. Classe, Sitzungsber., Band 16, pp. 108–136, pls. 1–2. (Mainly a discussion of the zoologic position of the conodonts from a chemical and physical standpoint.)

1887. Clarke, J. M., New York State Geologist Sixth Ann. Rept., for 1886, pp. 30–33, pl. A 1. (Good plate of figures. Description very general and short.)

1898 Girty, G. H., Am. Jour. Sci., 4th ser., vol. 6, pp. 393, 395. (Describes and figures a conodont from Devonian shale of Kentucky.)

1899. Grabau, A. W., Buffalo Soc. Nat. Sci. Bull., vol. 6, pp. 150–158. (Rather poor reproductions of Hinde's figures, reduced in size, with condensed descriptions.)

1900. Smith, John, Glasgow Nat. Hist. Soc. Trans., new ser., vol. 5, pp. 336–338. (Discusses occurrence of conodonts in Carboniferous limestone of Scotland.)

1900. Hinde, G. J., Glasgow Nat. Hist. Soc. Trans., new ser., vol. 5, pp. 338–346, pls. 9–10. (Describes and figures 13 species of Scotch Carboniferous conodonts.)

1907. Smith, John, Glasgow Nat. Hist. Soc. Trans., new ser., vol. 7, pt. 3, pp. 235–252, pls. 5–9. (Long discussion of occurrence of conodonts in Silurian rocks of Scotland and short descriptions of about 40 species, mostly new. Four new genera introduced.)

1912. Girty, G. H., New York Acad. Sci. Annals, vol. 22, p. 304. (Notes the occurrence of conodonts in Bedford shale of Ohio.)

1913. Hadding, Assar, Lunds Universitets Arsskrift, N. F., Afd. 2, Band 9, Nr. 15; Kongl. fysiografiska Sällskapets Handlingar, N. F., Band 24, Nr. 15, pp. 30–32, pl. 1. (Describes several new species from the Ordovician of Sweden.)

1921. Thomas, A. O., Bull. Geol. Soc. Amer., vol. 32, p. 131. (Notes the occurrence of conodonts in Devonian of Iowa.)

1921. Bryant, W. L., Buffalo Soc. Nat. Sci. Bull., vol. 13, No. 2, pp. 1–58, pls. 1–16. (Reviews the literature on conodonts and discusses zoological position. Describes and figures over 30 species, part of which are new.)

1923. Parks, A. W., Ontario Dept. Mines Thirty-first Ann. Rept., pt. 9, pp. 35–37, pl. 6. (Reproduces Hinde's descriptions and figures of five species.)

1925. Roundy, P. V., Bibliography of Conodont and Paleozoic annelid jaw literature, 4 pp. (mimeographed; distributed by the Division of Geology and Geography, National Research Council, Washington, D. C.)

Genus PRIONIODUS Pander

1856. *Prioniodus* Pander, Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements, p. 29.

A free translation of the original description is given below:

We unite under this designation all those teeth or jaws in which a very large tooth juts forth, with a row of smaller ones arranged against it on one or both sides. The excavated base extends the entire length under these teeth to a certain height.

First species, *Prioniodus elegans*.

Pander placed five species under this genus, and other authors have added 26 more species until now the genus contains several distinct types of conodonts. In order to simplify the classification from a purely paleontologic point of view it would seem advisable to restrict the genus to types close to *P. elegans* and establish new genera for those markedly different from that species.

Pander's figures of the genotype are here reproduced (Pl. IV, figs. 3a–4).

Prioniodus healdi Roundy, n. sp.

Plate IV, Figures 5a–5b

Main tooth slender, elongate, and slightly curved in two directions (backward? and inward?). Tooth has a slight yet distinct longitudinal carina on its two more acute margins. The base of this tooth expands very rapidly, forming a large, in part thin-walled pulp cavity. The expansion is mainly inward(?) and to the two sides (backward? and forward?) On each side of the main tooth a smaller slender elongate tooth arises. Originally the base may have been prolonged further and bore more of the smaller teeth. This conodont is of a clear, almost transparent amber color.

Horizon and locality: Barnett shale, San Saba County, Tex. (stations 2688, 2613E?).

Prioniodus peracutus Hinde

Plate IV, Figures 6–8

1900. *Prioniodus peracutus* Hinde, Glasgow Nat. Hist. Soc. Trans., new ser., vol. 5, pt. 3, p. 343, pl. 10, figs. 21–23. Upper, Middle, and Lower limestones, Carboniferous, Scotland.

Hinde's description is given below:

A single straight or slightly curved compressed main tooth, which extends below a small horizontal base to an obtuse point; the outer margin and both margins below the horizontal process are acute. There are a few minute, closely set denticles on the horizontal base. This form differs from *P. spicatus* in its larger size, the sharp edges of the main tooth, and in the very short horizontal base. * * * Specimens measure from 0.8 to 1.5 millimeters in length.

The description and my specimens agree best with Hinde's Figure 22 (reproduced here, Pl. IV, fig. 6). The other figures appear to represent what I would consider distinct species, or at least varieties, so I am designating Hinde's Figure 22 as representing the type specimen. The description of my specimen is as follows:

A broad, rather flat elongate tooth with a nearly straight, sharp knifelike front edge and with the back edge rounded in section, nearly straight in its upper half, and rapidly curving in its lower third, forms the main part of this conodont. These two margins meet above and below in sharp points. Somewhat below the middle of the tooth a small, rather thin, slender base extends backward, bearing several small, upright, rounded, sharp-pointed teeth. A small pulp cavity lies partly in the bottom of this base and partly in the adjacent portion of the large tooth. The entire conodont is thin, and the lateral aspects are slightly different in the convexity. My specimens are all incomplete.

Horizon and locality: Barnett shale, San Saba County, Tex. (stations 2609, 2613 E, 2613 G).

Prioniodus sp. A

Plate IV, Figure 9

This form, represented by a single specimen, consists of a long, almost straight, slender, slightly flattened main tooth. The pulp cavity, which lies directly under this tooth, is relatively small and without flaring walls. From one side of the main tooth a slender base projects outward and downward, bearing the lower parts of five small teeth. Its lower end is incomplete. On the other side of the main tooth there is a short part of a broken base bearing the stubs of two teeth. This base may have been similar to the opposite one.

Horizon and locality: Barnett shale, San Saba County, Tex., (station 2609).

Prioniodus sp. B

Plate IV, Figure 10

Like *P. peracutus*, described above, this conodont consists chiefly of a rather flat elongate main tooth. This tooth, however, is subtriangular in outline. The front margin is sharp and practically straight. The back margin is slightly rounded, and the first tooth on the small base that juts from it in part coalesces with the main tooth. The apex of the main tooth is missing in all my specimens. The bottom of this large tooth, instead of being a point formed by the union of the back edge extending downward from the edge of the pulp cavity for some distance and then uniting with the front edge, as in *P. peracutus*, is formed by the direct union of the front margin of the pulp cavity with the bottom of the front margin. The pulp cavity itself is much larger than in *P. peracutus*, both in length and width. The small base evidently bore several small teeth, of which my specimens show only the one adjacent to the large tooth and (in my best specimen) the lower parts of five others. These lower parts, although completely embedded in the base, are yet distinct, owing to their slightly whiter color and less transparent condition.

Horizon and locality: Barnett shale, San Saba County, Tex. (stations 2609, 2688).

Prioniodus sp. C

Plate IV, Figure 11

Of a still different character is the single incomplete specimen I am describing under this heading. It consists of a long tooth with rounded lateral sides meeting in two distinct blunted knifelike edges or carinae. The apex is broken, and the bottom is occupied by the central portion of the pulp cavity. From each side of this tooth, in line with the carinae, bases jut outward and slightly downward. On one side there is a long, slender, sharp-pointed, slightly curved tooth, partly coalesced with the main tooth. The base is broken at this point, so whether it originally bore more teeth is impossible to determine. On the other side of the main tooth the base has parts of four teeth, three broken off close to the base and the fourth (adjacent to the main tooth) broken at some distance from the base. This base terminates also in a broken end.

Horizon and locality: Barnett shale, San Saba County, Tex. (station 2609).

Prioniodus sp. D

Plate IV, Figures 12–13b

Main tooth elongate, with two edges (front and back ?) rather sharp. One side of the tooth (outside?) is very gently convex, both transversely and longitudinally. The other side (inside?) is rather concave longitudinally—that is, the tooth curves inward. Transversely this side is very convex. The pulp cavity, which is large, occupies the area below the main tooth. From the lower part of the main tooth bases jut both forward (?) and backward (?) and bear very small teeth.

Under this species I have placed about 20 specimens which although varying in minor characters could not in their present imperfect condition be satisfactorily classed as distinct species or varieties.

Horizon and locality: Barnett shale, San Saba County, Tex. (stations 2609, 2613E, 2613G, 2613H, 7011A?, 7687).

I have described these specimens of *Prioniodus* somewhat at length because I believe that they can be recognized and used in stratigraphic work despite their imperfect condition.

Prioniodus sp.

Under this heading I am including about 60 incomplete specimens which do not appear to warrant detailed descriptions in the present paper. These specimens undoubtedly represent a large number of species, but without better reference material than is now available it is not possible even to definitely establish the generic relations of several of them. Several large tusklike teeth may belong either to *Prioniodus* or to *Drapanodus* if the part broken away was originally either a side base bearing small teeth or merely a piece of the pulp-cavity side wall. Likewise in some other specimens a restoration of the missing portion might show a relationship to *Prioniodus*, *Lonchodus*, or some other genus.

Horizon and locality: Barnett shale, San Saba County, Tex. (stations 2609, 2610B, 2610C, 2613D, 2613E, 2613G, 2613H, 2618, 2688).

Genus GNATHODUS Pander

1856. *Gnathodus* Pander, Monographie der fossilen Fische des silurschen Systems der russisch-baltischen Gouvernements, p. 33.

The following is a translation of Pander's description:

In the marls of the lowest shales of the Mountain limestone in Tula and the higher Governments of Mosca well-preserved jawlike fossils are found, which by their configuration and by their base are distinguished from those as yet described, but which are closely joined to them by their microscopic structure. From a high, narrow, compressed base, constructed of double walls, arise in a row minute teeth, giving it the appearance of being bordered with a denticulate margin. Below, these walls at one end diverge strongly from one another and build a cavity, while at the opposite end they remain close together. This cavity, which represents the pulp cavity, lengthens out laterally and, as would be expected, affords for each denticle an ascending continuation.

Only one species, *G. mosquensis*, is given, and Pander evidently considered that his generic description was sufficient for the species, as under the species name he gives only the locality and horizon with plate references. His figures are reproduced here (Pl. II, figs. 6a–d).

Gnathodus seems to be essentially a Carboniferous genus. Only one species, *G. americanus*, a Genesee shale form, has been described from pre-Carboniferous rocks. Specimens of this genus are perhaps among the most common conodonts in the Barnett shale, one shale sample furnishing 99 specimens of a single species.

The most striking characters of this genus appear to be the very thin, high bases and the character of the teeth on the higher end, which seem, under low magnification, to be merely the crenulated edge of the base. Under high magnification, however, the minute structure lines shown by Pander are visible.

Gnathodus texanus Roundy, n. sp.

Plate II, Figures 7a–8b

Seen from above, this species consists of a long, nearly straight row of thin, short, sharp-edged teeth which resemble somewhat saw teeth without any set. Near the center the wide-spreading upper surface of the pulp chamber is conspicuous, and from its top, a little to one side of the row of teeth, there arises a single tusk or tooth, whose top usually but not in all specimens is slightly depressed in the middle, giving it the appearance of having two small nodes.

Seen in side view, the bottom is rather straight, and the top, starting nearly straight at the wide end, gradually bends downward on the sharper or thinner front (?) end. The teeth are largest on the back or higher end and show a gradual though not constant reduction in size until at the front end they are not much more than mere points on some specimens.

Seen from below, this species shows the higher or posterior (?) end to consist of a narrow projection with a very fine line in the center. Under strong magnification this line is shown in fractured specimens to be the lower contact of two thin plates actually in contact but not fused until in the vicinity of the base of the individual teeth. About the middle of the base these plates rapidly separate to form the pulp cavity. At the front end the bottoms of the two plates again unite but only at the point.

This species is very delicate and easily broken, the base and walls of the pulp cavity being very thin. The only massive structure of this conodont is the large tusk or tooth arising from the top of the pulp cavity at one side of the elongate crenulated base. *G. texanus* is the most common species in the Barnett shale, six collections furnishing over 200 specimens. This species is strikingly like the illustrations of *G. mosquensis*, differing mainly in having the side tusk or tooth mentioned above. Length of a large incomplete specimen, 1.30 millimeters; greatest height of posterior end, 0.50 millimeter; thickness of this end at the same point, 0.13 millimeter.

Horizon and locality: Barnett shale, San Saba County, Tex. (stations 2609, 2613D, 2613G, 2613E, 2688, 2613H).

Gnathodus texanus var. bicuspidus Roundy, n. var.

Plate II, Figures 9a–9b

One broken specimen of *Gnathodus* is very similar to *G. texanus* except that it has a tusk or tooth arising from the top of the pulp cavity, on each side of the main row of denticles, instead of on only one side, as in that species. This additional tooth is more nearly circular in cross section, pointed, and not quite as high as the opposite tusk.

This form may prove to be a distinct species, but until more evidence is obtained I feel that it should rank as a variety.

Horizon and locality: Barnett shale, San Saba County, Tex. (station 2613E).

Genus POLYGNATHUS Hinde, emended by Bryant

1879. *Polygnathus* Hinde, Geol. Soc. London Quart. Jour., vol. 35, p. 361.

1921. *Polygnathus*, emended under description of *Centrodus invalidus* Bryant, Buffalo Soc. Nat. Sci. Bull., vol. 13, No. 2, p. 22.

Hinde's original description is quoted here in full:

> I propose this genus for an animal possessing numerous minute and variously formed conodont teeth and similarly minute tuberculated plates grouped together, but of which the natural arrangement is not at present known.
>
> This meager definition is all that is afforded by the single example of the genus met with, in which about 24 entire and fragmentary teeth and 6 plates have been crushed together in a small patch of about one-fourth of an inch in diameter, in black shale. The specimen was discovered in splitting open a slab of the rock, the division taking place in the center of the specimen. No indication can be seen of the natural position of the teeth and plates; but it can hardly be doubted that they all belonged to one individual, as it would be beyond all reasonable probability that so many diversely formed teeth, of such delicate structure, could have been thus brought together into so small a space by mechanical means, more particularly when it is a very rare circumstance to find, in the same rock, even two detached teeth at all close together; and in only one other instance have I found two conodonts partially connected together, and these are forms which are present in this compound example. If, however, these various teeth and plates were attached to their natural positions by soft tissues merely, by the decay of these they would be liable to be crushed together into a shapeless mass like that presented by the specimen.

The following is Bryant's emendation:

> In the present uncertainty, even as to the class of animals which bore these teeth, it seems to me advisable to retain Pander's generic names for forms described by him and to restrict Hinde's genus *Polygnathus* to those crested crushing or tritoral plates so characteristic of his type specimen.

Although I have not seen the material described by Hinde, I agree with Bryant[7] that this "small patch," in which many teeth and plates, some fragmentary, are crushed together, is very probably the ejecta of some fish. However, if this assemblage of various teeth and plates had proved to belong to a single individual, then the generic name *Polygnathus* would have become a synonym of *Lonchodus*, as it contained teeth which were identical with some previously described by Pander under that genus.

As *Polygnathus* is now restricted to the crested crushing or tritoral plates and many of the various teeth described and figured under the type species, *P. dubius*, have been referred to previously described genera, it is necessary to select the genotype. Of the forms figured by Hinde as *P. dubius* but three (Pl. 16, figs. 16, 17, and 18) could now remain under the genus. Bryant, however, says that figure 17 is only a differently oriented view of the form described by Hinde as *Polygnathus pennatus*, and that figures 16 and 18 show different aspects of the form described as *P. cristatus*. I therefore propose that the genotype *Polygnathus dubius* Hinde be restricted to the specimen shown on his Plate 16 as figure 17. Hence *Polygnathus pennatus* Hinde becomes a synonym of *P. dubius*. Hinde's figure is reproduced on Plate III as Figure 9.

[7] Bryant, W. L., Buffalo Soc. Nat. Hist. Bull., vol. 13, No. 2, pp. 9, 21, 23, 1921.

Polygnathus bilineatus Roundy, n. sp.

Plate III, Figures 10a–10c

Seen from above, the nearly parallel ridges surmounted by small teeth or denticles converge slightly on the forward end of this form. The anterior end is broken, but these ridges probably met in a sharp point, as shown by other fragments. One of these ridges projects backward considerably beyond the main part of the conodont, where it also is broken. The portion of the base between these ridges forms a more or less shallow V-shaped valley. At one side of the longer ridge and somewhat forward of the center of the conodont a portion of the pulp cavity is seen standing out as a prominent platform with small rounded denticles on its upper surface, forming what may be considered a tritoral plate. Where this platform joins the side of the long ridge a line of denticles is visible on the forward portion. Some of my fragmentary specimens suggest that either in a variation or a variety of this species a third denticle-surmounted ridge is developed on the anterior part of the form.

Seen from below, the pulp cavity occupies most of the base, and the backward-projecting portion of the longer ridge is composed of two closely folded plates. These are fused in the upper or denticle-bearing portion. Length, 1.0 millimeter; width, 0.46 millimeter.

Horizon and locality: Barnett shale, San Saba County, Tex. (stations 2609, 2688, 2613E).

Polygnathus taffi Roundy, n. sp.

Plate III, Figures 11a–11b

Seen from above, this form consists of an elongate plate with the two lateral edges bent upward, slightly more in the middle than at the ends of the sides. The edges are very slightly scalloped. The plate is smooth and nearly transparent. A median ridge has denticles or small teeth on its upper edge and extends backward beyond the end of the plate a short distance, beyond which it is broken. Evidently, as in the typical specimens of the genus, this ridge originally extended as far again as in this imperfect specimen, the only one found in the Barnett shale.

Seen in side view, the top appears as a nearly straight line with the bent-up edges of the plate concealing all but the teeth on the top of the forward portion of the median ridge. This ridge extends backward and its base swings downward, so that the height increases rather rapidly.

Seen from below, a somewhat spindle-shaped pulp cavity occurs in the middle portion of the end of the plate. The backward-projecting end of the median ridge evidently is a double plate, as in the genus *Gnathodus*. Length, 0.62 millimeter; width of plate, 0.26 millimeter.

Horizon and locality: Barnett shale, Lampasas County, Tex. (station 7016).

Polygnathus texanus Roundy, n. sp.

Plate III, Figures 13a–13b.

Upper aspect unsymmetrical, with a long median keel whose fractured end projects a slight distance backward beyond the plate. The forward end of the keel joins the pointed end of the plate. This keel has minute rounded tubercles. On one side of the keel (the right in the figure) is a broad area with the upper surface covered with small irregular grinding ridges, some with papilli-like nodes on the crest. The downward-sloping edges are smooth. On the other side of the keel the grinding ridges are more irregular, and the area is longer but not as wide as the right. When viewed from the broad-area side of the plate the outer grinding ridge conceals the other grinding ridges of this area. The entire top of the median keel is visible, as is a portion of the outer part of the far area. A view of the under side shows that the pulp cavity spreads out under the entire plate. Greatest length, 1.05 millimeters; greatest width, 0.67 millimeter.

This species, based on a single individual, is distinct from any species previously described.

Horizon and locality: Barnett shale, San Saba County, Tex., (station 2618).

Polygnathus sp. A

Plate III, Figures 12a–12b

Seen from above, the plate is elongate, unsymmetrical, with front and back ends broken. A little to one side of the middle of the plate is a sinuate ridge surmounted by bluntly pointed rounded teeth. The central tooth is the largest, and there is a very small one on each side. The smaller teeth gradually increase in size from the very small one adjacent to the big central one to the forward (?) end. To the left (?) of this row of teeth is a shorter ridge culminating in an elevated point, about the height of the intermediate-sized teeth. The remaining upper part of the plate is slightly roughened by microscopic irregular reticulate lines. In side view this form, if embedded in matrix, might easily be classed as another genus, being an elongate form with various sized close-set teeth. A delicate threadlike cavity appears to extend from the base nearly to the apex of the teeth. On the under side the central part has a slight longitudinal groove and is slightly depressed. This description is based on a single specimen; and were it not for the broken ends I would give it a new name, as it appears to be distinct from any form previously described. Greatest length, 1.01 millimeters; width, 0.51 millimeter.

Horizon and locality: Barnett shale, San Saba County, Tex. (station 2609).

Polygnathus? claviger Roundy, n. sp.

Plate IV, Figures 1a–2b

Seen from above, base massive, elongate, pointed at one end, broad and blunted at the other. Base smooth, with a row of large elongate teeth. Each tooth has about equally convex sides, which meet in a sharp edge or carina on the front and rear. For purposes of description the sharp end of the base is considered the front. Individuals vary as to the relative size of the teeth and the space between them. Some are in contact in their lower third, some only at their base, and occasionally two adjacent teeth have a perceptible distance between their bases. There is also a variation in the length of the teeth, the shorter ones usually being nearly straight and the longer ones curved slightly backward. This backward curve is the main reason for my considering the pointed end of the base as the anterior. In position, the row of teeth is in the center of the base at the front end, then gradually swings to one side of the base toward the broad end, where a solitary tooth occurs on the other edge opposite the last tooth of the row. These teeth so resemble in miniature the old-style farmer's spike drag that I have given them the name *P. claviger* (*clavus*, spike; *gero*, I bear). Adjacent to the abovementioned solitary teeth a small portion of the base is broken, so that it is possible that another tooth might originally have been present.

In side view the base seems to be about equal in thickness except at the extreme ends.

Seen from below, a pulp cavity wider than long, subrectangular in outline, is located near the posterior end, and a narrow groove extends in the center of the base nearly to the extreme front end.

This description is based on several incomplete individuals, and consequently a misconception of the species may have arisen. Therefore, I designate the best specimen of the rear or broad end of the base as the type. This species probably represents a new genus, but my specimens do not warrant the erection of a new genus, so I am placing it under *Polygnathus?*.

Greatest width of type specimen, 0.63 millimeter; length, 1.2 millimeters, which I believe would be about half the length of a complete individual.

Horizon and locality: Barnett shale, San Saba County, Tex. (stations 2609, 2618, 2613E, 2613G?, 2613D, 2610C).

Genus LONCHODUS Pander

1856. *Centrodus* Pander, Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements, p. 31.

1856. *Lonchodus* Pander, idem, p. 80.

A translation of Pander's description is as follows:

On Plate 2a, Figures 2–9, are represented several apparently different forms of similar internal structure, which could nevertheless be separated from one another. In Figures 2, 3, 5, and 6 (*C. simplex*) we see very slender teeth standing vertically or obliquely and bending more or less, turned in one or two different directions, and situated upon a horizontal base. Between these in Figures 7 and 8 (*C. duplicatus*) and especially in Figure 9 (*C. lineatus*) arise smaller teeth. If we compare the larger teeth with those represented in Figure 4 (*C. convexus*), the agreement is certainly very striking, although they here rest upon a convex base. If we then establish the character of the genus in this general way, that it includes large, slender, pointed, lamellose teeth, quite alone or alternating with smaller ones of various size and number, attached to a horizontal or convex base, we can very well unite all together and at any rate make specific separations that have perhaps more paleontologic than zoologic value.

On page 80 of Pander's report he states that the name *Centrodus* had previously been used and names this genus *Lonchodus*. This note appears to have been overlooked by both Hinde and Bryant, for both have used the name *Centrodus* without comment. First species, *Lonchodus simplex*.

It is not uncommon to find many fragments of conodonts, consisting of several teeth on a base, which as found could with propriety be placed only under the genus *Lonchodus*. Yet some of these specimens may well be parts of conodonts which if complete would be placed under other genera. However, as a means of aiding in the classification and range determination of the conodonts for stratigraphic purposes I believe it desirable to describe more of these fragmentary specimens than would be desirable so far as their mere zoologic aspect is concerned.

Lonchodus simplex Pander

Plate III, Figures 1–5

1856. *Centrodus simplex* Pander, Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements, p. 31, pl. 2A, figs. 2, 3, 5, 6. (Changed to *Lonchodus* on p. 80). Mountain limestone, Tula, Russia.

1879. *Polygnathus dubius* (part) Hinde, Geol. Soc. London Quart. Jour., vol. 35, p. 362, pl. 16, figs. 10, 11. Genesee shale, North Evans, N. Y.

A translation of Pander's original description is as follows:

Long, sharp-pointed, straight, oblique, or bent teeth projecting vertically from a generally horizontal base.

My collections include many specimens which correspond with this species as figured and described by Pander. All have both ends of the comparatively slender horizontal bases broken, and they bear from two to five sharp-pointed straight or oblique teeth. The relative size and length of teeth of these specimens vary considerably. Although my forms may represent several species, in their present condition I can hardly do other than tentatively refer these specimens to this species.

Horizon and locality: Barnett shale, San Saba County, Tex. (stations 2609, 2613E, 2688, 2613G, 2613D?, 2610C, 2613H?).

Lonchodus? lineatus Pander

Plate III, Figures 6–8

1856. *Centrodus lineatus* Pander, Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements, p. 31, pl. 2A, fig. 9 (*Lonchodus*, p. 80). Mountain limestone, Russia.

?1875. Conodont. Newberry, Ohio Geol. Survey Rept., vol. 2, pt. 2, Paleontology, pl. 57, fig. 8. Cleveland shale, Bedford, Ohio.

?1879. *Polygnathus dubius* (part) Hinde, Geol. Soc. London Quart. Jour., vol. 35, p. 362, pl. 16, fig. 14 (fig. 13?). Genesee shale, North Evans, N. Y.

1900. *Centrodus lineatus* Hinde, Nat. Hist. Soc. Glasgow Trans., new ser., vol. 5, pt. 3, p. 341, pl. 9, figs. 13, 14. Carboniferous limestone, western Scotland.

Long, slender, straight base with several large, slightly oblique, round, slender teeth. These large teeth are separated by two to five similar-shaped but much smaller teeth. Some specimens show nearly the complete variation in number, but most specimens show only three or four small teeth between the larger ones. The base in cross section (excluding the teeth) is oval, being in one specimen, which is but slightly below the average size, 0.05 millimeter thick and 0.08 millimeter high. All my specimens, like Pander's type, have both ends missing, so that the character of the extremities is not known. No pulp cavity has been noted. On the bottom of the base some specimens faintly show a very shallow groove.

With these specimens I have tentatively placed some other specimens, which uniformly have a much higher though thinner base. These are perhaps a variety and in shape of the base might be considered intermediate between this form and the form below described as *Ctenognathus* sp. A. However, they have the larger teeth separated by three or four smaller ones, as in this species. Also they lack the cellular structure so clearly shown by transmitted light in the teeth of specimens of *Ctenognathus*.

One of the individual specimens included in Hinde's species *Polygnathus dubius* seems to be an example of this species. One end appears to be complete and exhibits two teeth, which are much larger than the ordinary large teeth that separate the smaller ones on the main portion of the base. I am not yet ready, however, to place Hinde's specimen definitely in the synonymy of this species.

Of the specimens from the Carboniferous of Scotland figured by Hinde I can form only a very general opinion, because of the generalized description and rather indefinite character of the figures. I see no objection to including these in the synonymy of this species.

Newberry's specimen is figured but not named, though briefly described. Hinde considers it to be the same as his species. I think, however, that it is distinct from Pander's and the Scotch forms.

Horizon and locality: Barnett shale, San Saba County, Tex. (stations 2609, 2613D, 2613E, 2613H, 7016).

Genus CTENOGNATHUS Pander

1856. *Ctenognathus* Pander, Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements, p. 32.

A translation of the original description follows:

> Small teeth, pressed closely together in a row, solidly mounted on a horizontal or convex hollow base and continuing to the end without change, in their for the most part cellular structure. Not found in the Lower Silurian shale. * * * Not rare in the Mountain limestone of Tula. * * * Closely related to the foregoing genus; we distinguish it chiefly on account of the character of the internal structure, which in all, without exception, appears to stand at a higher stage of development. In *Ctenognathus* the cellular structure rules.

The "foregoing genus" referred to above is *Lonchodus* (*Centrodus*). The first species described is *Ctenognathus murchisoni*. The description is very short, being as follows: "Small pointed teeth of varied size rise from their hollow base and form a connected row." I am reproducing one of Pander's figures of the type (Pl. II, fig. 2).

Ctenognathus sp. A

Plate II, Figure 3

Base thin, high, elongate and nearly straight. Near one end there is what appears to be the base of a large, very flat, wide tooth. In front of this surely one small tooth and perhaps two or more were present. Back of this supposed main tooth there are, in one specimen, over 30 small, slender rounded teeth, all broken and most of them broken off close to the top of the base. They are all at an angle of about 50° with the base. Viewed by reflected light under high magnification with a black background, the teeth appear like light-colored round teeth set well into the very faintly amber-colored transparent base. Viewed by transmitted light, however, the teeth appear to be made up of distinct cells, which appear as black spots, while the base substance remains structureless except for very fine, rather indistinct lines. The aspect under this magnification is strikingly like that shown by Pander in a greatly enlarged view of *C. verneuilli*. However, the shape of the base and the relative proportions of the teeth in my specimens show it to be distinct from that species. The teeth are embedded in the base about half the height of the base. The base is solid and has on its under side a very shallow rounded groove, which could hardly be classed as a pulp cavity. As both ends of all my specimens are broken away, a pulp cavity may have been present without my specimens showing it.

Although I can find no trace of a hollow base such as Pander's descriptions show to be present in his form, I feel quite confident that this form belongs in his genus. I am reproducing one of Pander's figures of *C. verneuilli* (Pl. II, fig. 1).

Dimensions of my best specimen: Length, 1.8 millimeters; height of base near center, 0.60 millimeter; thickness at same place, 0.08 millimeter.

Horizon and locality: Barnett shale, San Saba County, Tex. (stations 2609, 2610C, 2613D, 2613E, 2613G, 2618).

Ctenognathus sp. B

Plate II, Figures 4–5

Base thin but high, elongate, the lower margin slightly convex. In the central part of the base is a small well-developed elongate pulp cavity, which in width does not exceed the average thickness of the base. Directly above this cavity is the main tooth or denticle. On each side of this tooth there are several somewhat smaller teeth. All are flattened and crowded together, and many are broken, but the few complete teeth are rather sharply pointed.

This form is comparatively rare, being represented by three specimens, all of which show the characteristic tooth structure of this genus.

This species resembles *C. verneuilli* as figured by Pander [8] but differs decidedly in having the cellular structure of the teeth penetrating only a short distance into the base. It also resembles the form described and figured by Hinde [9] as *Polygnathus radiatus*. Bryant also figures several specimens which he

[8] Pander, C. H., op. cit., pl. 2 A, figs. 16 and 17.
[9] Hinde, G. J., op. cit. (1879), pl. 16, fig. 20.

says are the same as Hinde's, and on account of the lack of the *Ctenognathus* structure he refers the form to *Prioniodus*. Under the name *Polygnathus dubius* Hinde [10] figures two specimens which may be true examples of *Ctenognathus* and which appear to be close to the species here described.

Horizon and locality: Barnett shale, San Saba County, Tex. (stations 2609, 2613).

FISH REMAINS

One collection that contained many conodonts included also a few rather small fish teeth, but no fish scales. The specimens are too fragmentary to warrant description at the present time.

Horizon and locality: Barnett shale, San Saba County, Tex. (station 2609).

REGISTER OF LOCALITIES

2609. South side of road to Bend post office about 6 miles from San Saba. Lower part of Barnett shale.

2610B, 2610C. Across the road from locality 2609, about 30 to 40 feet below the top of the Barnett shale.

[10] Idem, pl. 16, fig. 8; op. cit. (1900), pl. 9, fig. 1.

2613D–2613H. On southwest side of road to Chappel, about 3 miles southeast of San Saba courthouse, at first sharp turn well up hill. Several collections made in one shale cut, from 9 inches to 14 feet above the limestone of Boone age, which here lies in contact with the Ellenburger limestone.

2618. About 1,000 feet east of locality 2613D. Barnett shale from 5 to 10 feet above the limestone of Boone age.

2618A. Same locality as 2618. Limestone of Boone age.

2623. Very near locality 2613D. Thin limestone of Boone age between the Ellenburger limestone and the Barnett shale.

2688. 4.9 miles east and 0.9 mile south from the courthouse at San Saba. Upper part of Barnett shale.

2690. In cut just above bridge over small stream 1.3 miles west of the courthouse at San Saba, along road to Richland Springs. Marble Falls limestone.

7011A. 4 miles southwest of Chappel on road to Cherokee, San Saba County. From 25 to 30 feet above base of Barnett shale.

7016. 5¼ miles west of Lampasas on Sulphur Creek road to Llano. Barnett shale.

7687. Probably the same locality as 7011a but collection made several years later by another collector.

Locality 7016 is in Lampasas County; the others are all in San Saba County, Tex. The collections were made during a period of about 17 years by George H. Girty, E. O. Ulrich, J. W. Beede, K. C. Heald, and P. V. Roundy.

PLATES I–IV

PLATE 1

FIGURES 1a–1c. *Amphissites rugosus* Girty (p. 7). The genotype; the first time figured. 1a, Right valve; 1b, ventral view; 1c, dorsal view. From Fayetteville quadrangle, Ark.; basal Fayetteville shale.

FIGURE 2. *Amphissites chappelensis* Roundy, n. sp. (p. 7). The only specimen; right valve. From station 7011A; Barnett shale.

FIGURES 3a–5. *Sansabella amplectans* Roundy, n. gen. and sp. (p. 6).

3a–3b. Bivalve specimen, genotype. 3a, Right valve; 3b, dorsal view.

4. Bivalved specimen, genotype; left valve.

5. One of the few specimens showing a faintly suggested median pit, specimen somewhat crushed, left valve.

All three specimens from station 2609; Marble Falls limestone.

FIGURES 6a–7. *Sansabella sulcata* Roundy, n. sp. (p. 6).

6a–6b. Bivalve specimen, cotype. 6a, Right valve; 6b, dorsal view.

7. Bivalved specimen, cotype; left valve.

Both specimens from station 2618, Barnett shale.

FIGURES 8–10. *Aurigerites texanus* Roundy, n. gen. and sp. (p. 6).

8. Bivalve specimen, cotype; left valve.

9a–9b. Bivalve specimen, cotype. 9a, Right valve; 9b, dorsal view.

10. The thinnest specimen; shows the nearest approach to having the dorsal and ventral edges parallel; right valve.

All three specimens from station 2623; limestone of Boone age underlying the Barnett shale.

FIGURES 11a–11c. *Healdia simplex* Roundy, n. gen. and sp. (p. 8). Bivalve specimen, the genotype. 11a, Right valve; 11b, left valve; 11c, dorsal view. From station 2915; Graham formation (Cisco group).

FIGURES 12a–13. *Healdia ampla* Roundy, n. sp. (p. 8).

12a–12b. Slightly imperfect bivalve specimen, type. 12a, Left valve; 12b, dorsal view in outline.

13. Fragmentary specimen showing part of spine bases; right valve.

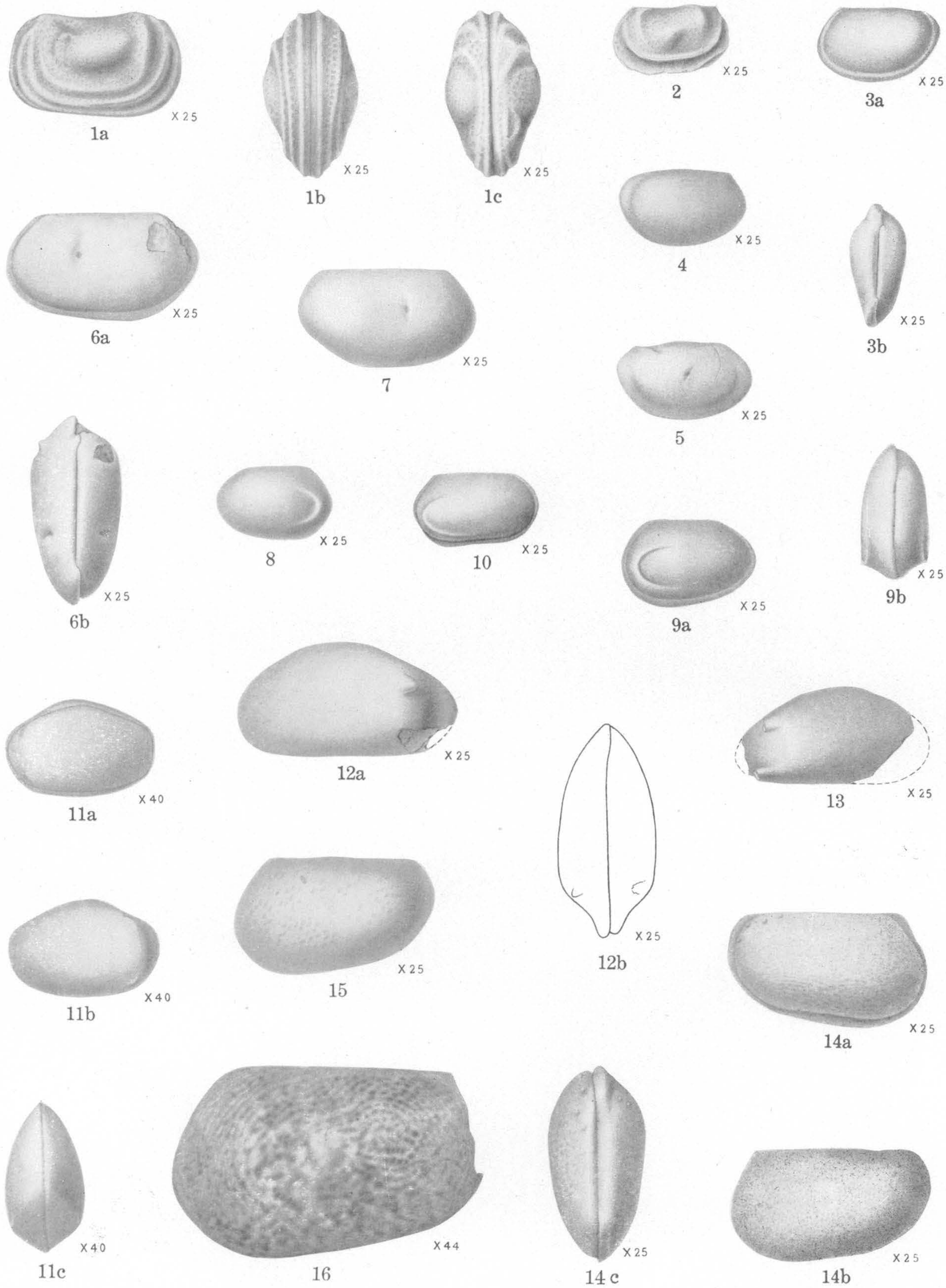
Both specimens from station 2623; limestone of Boone age underlying the Barnett shale.

FIGURES 14a–16. *Kirkbya lindahli* var. *arkansana* Girty (p. 7).

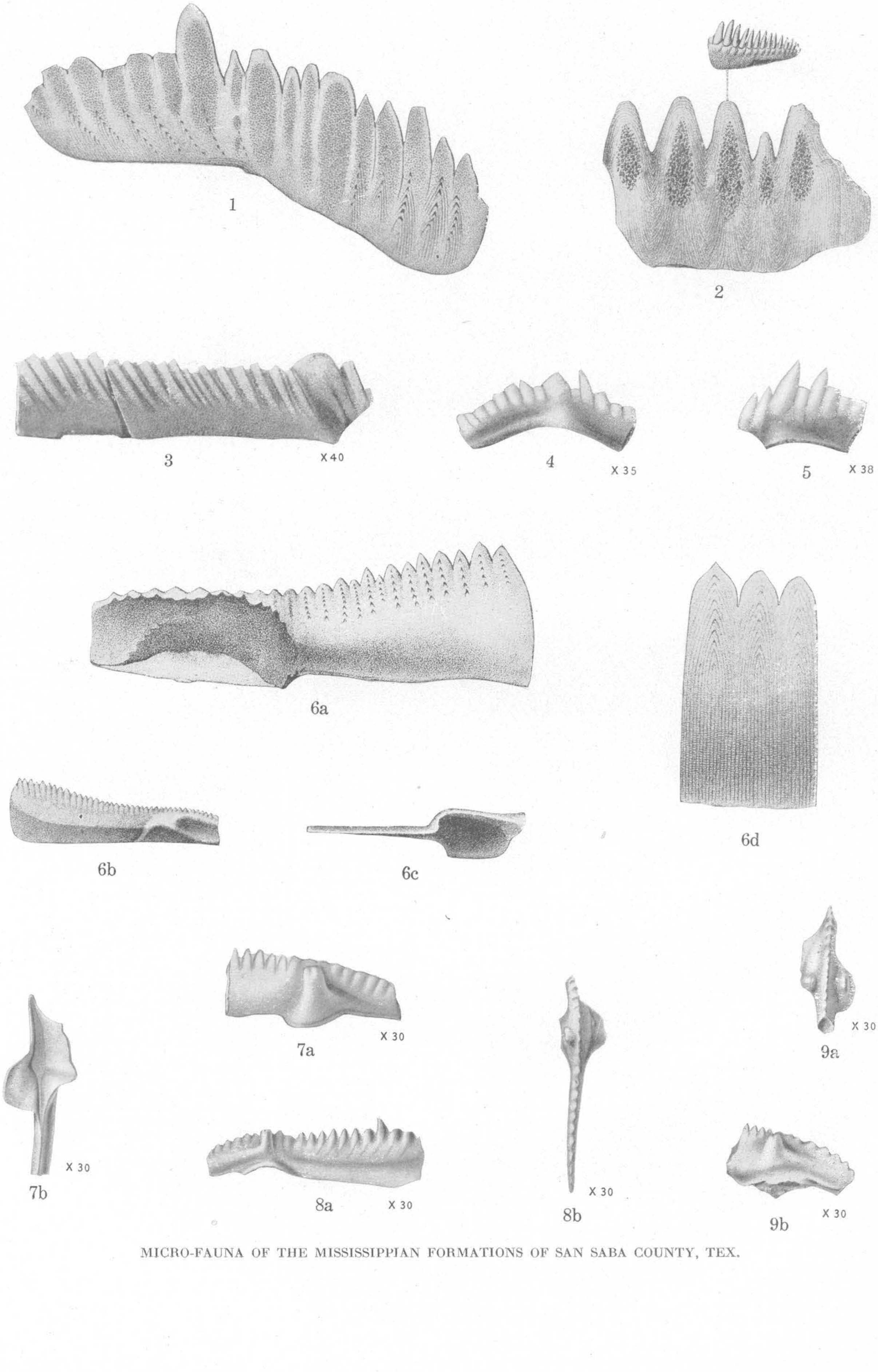
14a–14c. The type specimen. 14a, Left valve; 14b, right valve; 14c, dorsal view. From Fayetteville quadrangle, Ark.; basal Fayetteville shale.

15. A single valve somewhat weathered; right valve. From station 2618; Barnett shale.

16. An imperfect valve showing faint surface sculpture; right valve. From station 2623; limestone of Boone age underlying the Barnett shale.



MICRO-FAUNA OF THE MISSISSIPPIAN FORMATIONS OF SAN SABA COUNTY, TEX.



MICRO-FAUNA OF THE MISSISSIPPIAN FORMATIONS OF SAN SABA COUNTY, TEX.

PLATE II

FIGURE 1. *Ctenognathus verneuilli* Pander (p. 16). Reproduction of Pander's figure, illustrating the cellular structure characteristic of this genus. Magnification not known.

FIGURE 2. *Ctenognathus murchisoni* Pander (p. 16). Reproduction of one of Pander's figures of the genotype. Magnification not known.

FIGURE 3. *Ctenognathus* sp. A (p. 16). Seen from the side. From station 2609; Barnett shale.

FIGURES 4–5. *Ctenognathus* sp. B (p. 16).

4. Seen from the side. From station 2609; Barnett shale.
5. Seen from the side. From station 2613E; Barnett shale.

FIGURES 6a–6d. *Gnathodus mosquensis* Pander (p. 12). Reproduction of Pander's figures of the genotype. 6a and 6b, seen from the side; 6c, base seen from below; 6d, fragment seen from side with greater enlargement. Magnification not known.

FIGURES 7a–8b. *Gnathodus texanus* Roundy, n. sp. (p. 12).

7. Specimen with part of large end and part of pulp cavity broken. 7a, Seen from side with large tusk; 7b, seen from below. From station 2609; Barnett shale.
8. Nearly complete specimen, the type. 8a, Seen from side with tusk; 8b, seen from above (looking down on points of teeth). From station 2688; Barnett shale.

Figures 7 and 8 represent conodonts from opposite sides of the mouth.

FIGURES 9a–9b. *Gnathodus texanus* var. *bicuspidus* Roundy, n. sp. (p. 12). The type and only specimen. 9a, Seen from above; 9b, seen from the side. From station 2613E; Barnett shale.

PLATE III

FIGURES 1–5. *Lonchodus simplex* Pander (p. 15).

1–4. Reproduction of Pander's figures of the genotype. Magnification not known.

5. An incomplete specimen seen from the side. From station 2609; Barnett shale.

FIGURES 6–8. *Lonchodus? lineatus* Pander (p. 15).

6. Reproduction of Pander's figure, seen from the side. Magnification not known.

7. An incomplete specimen seen from the side. From station 2609; Barnett shale.

8. Another incomplete specimen seen from the side. From station 2613E; Barnett shale.

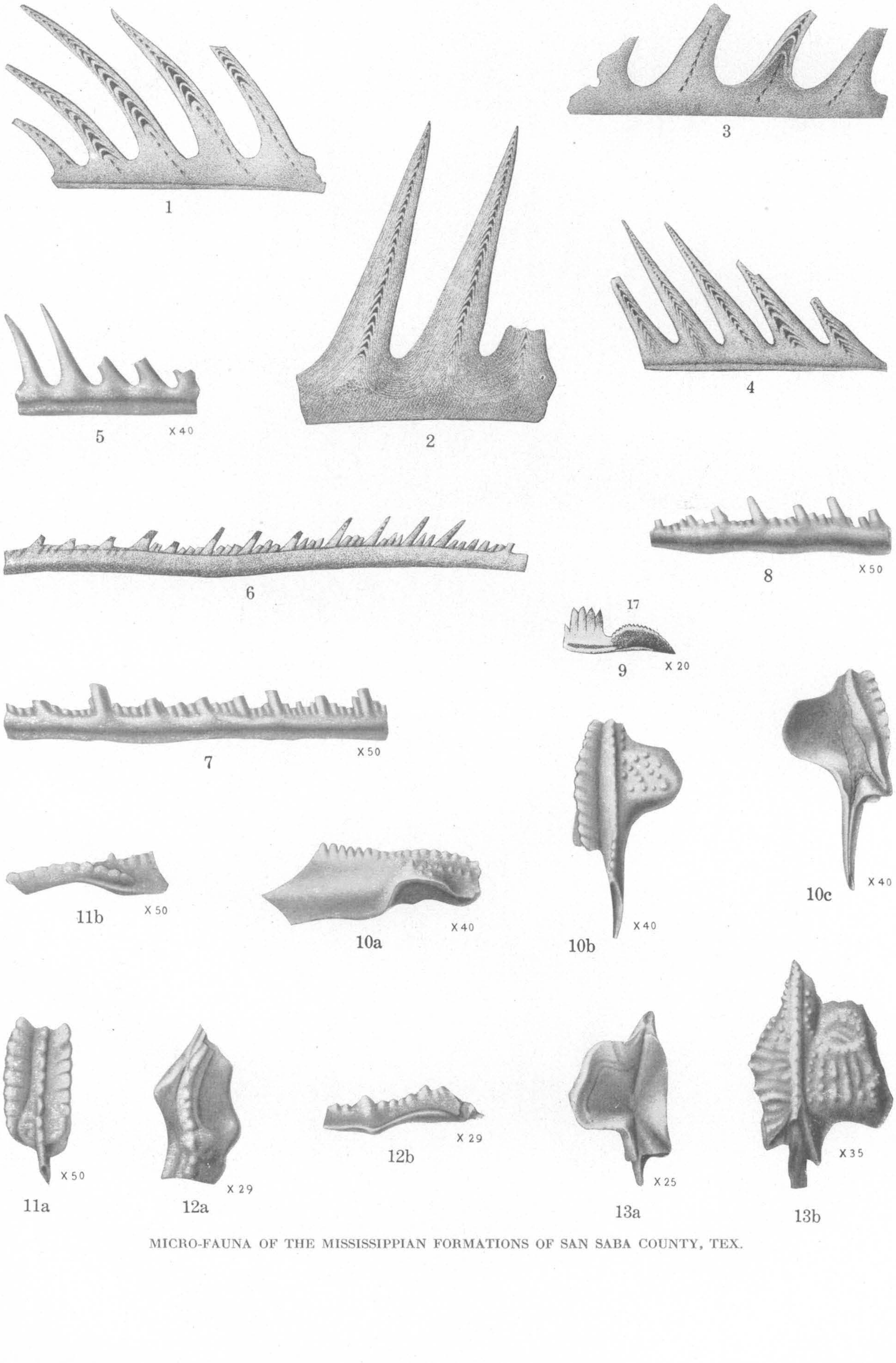
FIGURE 9. *Polygnathus dubius* Hinde (p. 13). Reproduction of Hinde's figure 17 of his Plate 16, which I am taking as the genotype; seen from the side.

FIGURES 10a–10c. *Polygnathus bilineatus* Roundy, n. sp. (p. 13). The type specimen. 10a, Seen from the side, which is the right side shown in figure 10b; 10b, seen from above; 10c, seen from below, a small amount of matrix conceals the bottom of the center part of the pulp cavity. From station 2609; Barnett shale.

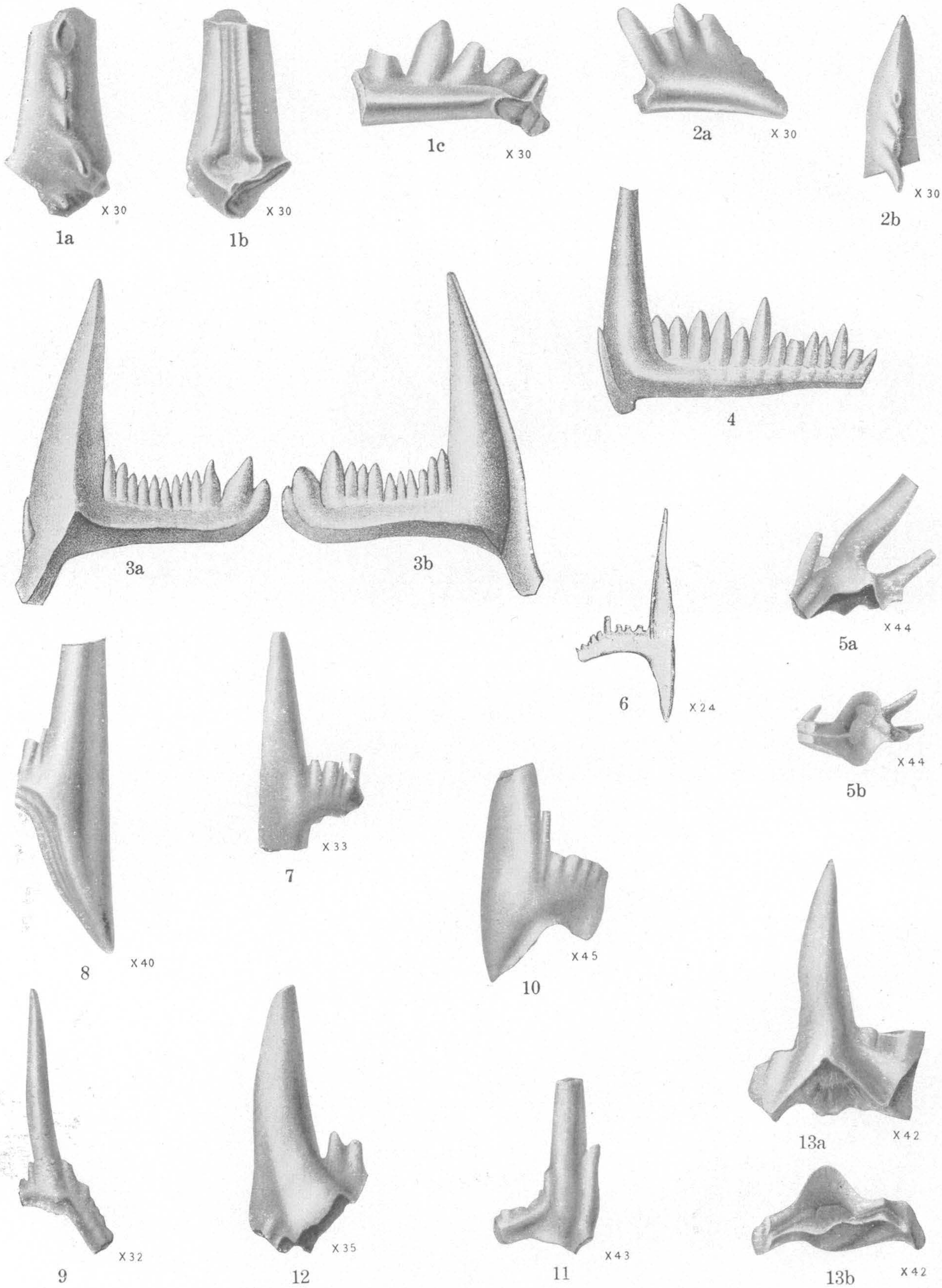
FIGURES 11a–11b. *Polygnathus taffi* Roundy, n. sp. (p. 13). The type specimen. 11a, Seen from above; 11b, seen from the side (left side shown in fig. 11a). From station 7016; Barnett shale.

FIGURES 12a–12b. *Polygnathus* sp. A (p. 14). The only specimen (incomplete). 12a, Seen from above; 12b, seen from the side (right side shown in fig. 12a). From station 2609; Barnett shale.

FIGURES 13a–13b. *Polygnathus texanus* Roundy, n. sp. (p. 14). Type specimen. 13a, Seen from below; 13b, seen from above From station 2618; Barnett shale.



MICRO-FAUNA OF THE MISSISSIPPIAN FORMATIONS OF SAN SABA COUNTY, TEX.



MICRO-FAUNA OF THE MISSISSIPPIAN FORMATIONS OF SAN SABA COUNTY, TEX.

PLATE IV

FIGURES 1a–2b. *Polygnathus? claviger* Roundy, n. sp. (p. 14).

1a–1c. The type specimen (incomplete). 1a, Seen from above; 1b, seen from below; 1c, seen from the side (the left side of figure 1a). From station 2609; Barnett shale.

2a–2b. Specimen which I believe represents the front end of this species; 2a, seen from the side; 2b, seen from above. From station 2613E; Barnett shale.

FIGURES 3a–4. *Prioniodus elegans* Pander (p. 10). Reproduction of Pander's figures of the genotype. 3a, 3b, Views of opposite sides; 4, side view of another specimen. Magnification not known.

FIGURES 5a–5b. *Prioniodus healdi* Roundy, n. sp. (p. 10). The type. 5a, Seen from the side; 5b, the top of the specimen as shown in 5a is tipped backward 90° giving the view seen from below. From station 2688; Barnett shale.

FIGURES 6–8. *Prioniodus peracutus* Hinde (p. 10).

6. Reproduction of one of Hinde's three figures which I am designating the type specimen.

7. An incomplete specimen seen from the side. From station 2613G; Barnett shale.

8. Seen from the side. From station 2609; Barnett shale.

FIGURE 9. *Prioniodus* sp. A (p. 11). The only specimen, seen from the side. From station 2609; Barnett shale.

FIGURE 10. *Prioniodus* sp. B (p. 11). An incomplete specimen, seen from the side. From station 2609; Barnett shale.

FIGURE 11. *Prioniodus* sp. C (p. 11). The only specimen, seen from the side. From station 2609; Barnett shale.

FIGURES 12–13b. *Prioniodus* sp. D (p. 11).

12. An incomplete specimen seen from the side. From station 2613E; Barnett shale.

13a–13b. An incomplete specimen. 13a, Seen from the side; 13b, top of specimen as shown in 13a tilted backward 90°, giving a view seen from below. From station 2609; Barnett shale.

Part III. THE MACRO-FAUNA OF THE LIMESTONE OF BOONE AGE

By George H. Girty

COELENTERATA

Family AULOPORIDAE

Genus CLADOCHONUS McCoy

Cladochonus? sp.

In general appearance the few specimens cited in this way resemble those referred to *Cyathaxonia minor?*, but so far as observed (though this is not very conclusive) they lack septa on the inside and longitudinal striae on the outside and indeed even the transverse growth lines and corrugations of the rugose coral. Furthermore, one of them has a stolon-like projection which might be, though it probably is not, an extraordinary irregularity due to attachment to some foreign object.

Locality: San Saba, Tex. (station 2623 [1]).

Family CYATHAXONIIDAE

Genus CYATHAXONIA Michelin

Cyathaxonia minor Weller?

Two specimens are referred here. The more perfect one has a length of 6 millimeters and a diameter of about 3 millimeters; the other must have had originally about the same proportions. The shape is, as usual, that of an elongated cone, distinctly though not strongly curved. The specimens are rather conspicuously marked by fine, more or less regular incremental striae, which are intensified here and there in varying degrees, the strongest forming distinct constrictions. The surface is also marked by regular faint longitudinal striae corresponding to the septa. As shown by the imperfect specimen, the septa are relatively numerous, slender, and persistent to the center, where they appear to unite with a styliform columella, though this is far from assured. The septa themselves can not well be counted, but as determined by the longitudinal corrugations that correspond to them on the outside they number 24.

In all the observed characters this form approaches nearest to *C. minor*, though my specimens have not attained the extreme elongation of some specimens of that species. The septa also are less numerous by 2 to 5. Furthermore, it is not certain that the present form belongs to the same genus, though all the indications point that way.

Locality: San Saba, Tex. (station 2623).

Family EUPSAMMIIDAE

Genus PALEACIS Milne-Edwards and Haime

Paleacis? sp.

This name is used for a single specimen whose real nature and relations are problematic but whose characters, so far as determined, suggest a coral of the genus *Paleacis*. The specimen is small, having about 5 millimeters for the longest diameter, and its original shape is uncertain. It has a porous or spongy structure very similar to that of *Paleacis*, and this character, in default of any that would help to place it more definitely, is the reason for the reference adopted.

Locality: San Saba, Tex. (station 2623).

BRACHIOPODA

Family DISCINIDAE

Genus LINGULIDISCINA Whitfield

Lingulidiscina aff. L. minuta Mather

The single specimen referred here is an upper or brachial valve characterized by its very small size (less than 2.5 millimeters in diameter), by its rather depressed shape, and by its distinctly though not strongly eccentric apex, which is small and relatively inconspicuous. The surface shows fine obscure concentric markings.

This specimen does not have the phosphatic look nor the sharply lirate surface of the common Carboniferous discinoid, although it has the general expression of "Orbiculoidea." On the other hand, it does not show the punctate structure nor the characteristic expression of *Crania*. Being without doubt one or the other, it probably belongs in the group commonly cited as "Orbiculoidea." As regards the generic name, it can be shown that without making a change in our rules of nomenclature or else without making an exception of this particular name, Orbiculoidea can not properly be applied to the "Orbicu-

[1] For a close description of this locality and other localities cited by number, see the register of localities on p. 17.

loidea" group. It is now equally clear that the name *Lingulidiscina* also properly belongs to a different group of shells, but as I have for some time been employing it for this one and am at present unable to turn to a better term, or at least to give my reasons for such a change, I am continuing the use of *Lingulidiscina* provisionally in the same sense.

In its specific relations the form in hand is quite similar to that which Mather called *O. minuta*. That species, of which I have many specimens, seems, however, to have the brachial valve as a rule more elevated and its apex more eccentric, so that an identification can not really be made. Few other species are comparable to this in minute size. *O. limata* and *O. parva*, both of Rowley, are the only ones that meet this specification, and to neither, apparently, does my form belong.

Locality: San Saba, Tex. (station 2623).

Family CRANIIDAE

Genus CRANIA Retzius

Crania pertenuis Girty, n. sp.

Plate V, Figures 1a–3b

It is difficult to describe this form without to some extent describing individual specimens, for each of the six individuals in my collections is more or less peculiar. To this method, then, I shall have recourse. All the specimens are upper valves.

One rather striking individual has an outline conspicuously quadrate though with rounded angles. The posterior end is considerably narrower than the anterior end, and the width, which may be a little greater than the length, is 4 millimeters. The general shape is therefore depressed pyramidal, the apex of the pyramid being conspicuously posterior. A narrow longitudinal groove divides the posterior side of the specimen, which is an internal mold, while broad undefined deflections occur on the three other surfaces.

Another smaller specimen has the same general characters but is more irregular. The posterior side, which is relatively narrow, bears a median groove, and the three other sides also are more or less impressed, especially the anterior side. The apex, which is pointed, is strongly posterior and appears to be directed backward, so that the outline on the posterior side is gently concave while that on the anterior side is gently convex.

A third specimen, which is testiferous, agrees in a general way with those just considered.

A fourth specimen, mostly testiferous, is conical rather than pyramidal, only the posterior side being distinguished as a broad oblique plane which is not modified by a median groove. The height of this specimen is especially low, and the apex is especially posterior in position.

A fifth specimen is rather similar to the foregoing except that it is a little more elevated and a little more inflated, so that the outlines from the apex to the front and to the sides are distinctly convex.

A sixth specimen is generally conical, but its elevation is especially low. Its apex appears to be central or even anterior (if the shell is not broken at the anterior margin); the anterior side is slightly convex, while the posterior side is gently concave.

The surface of all these specimens where not exfoliated is marked by fine, rather irregular lines of growth of varied intensity.

The shell is thin and apparently punctate, but this character is far from certain.

Several features of this species bring its reference to the genus *Crania* somewhat in doubt. It can not, of course, be a *Crania* if the shell structure is impunctate. The thinness of the shell and the absence of muscle scars, which in *Crania* are usually large and represented by prominent nodes, are also adverse to this reference.

If not a *Crania*, I should consider this form a gastropod of the general relationship (in form, at least) of *Patella* or *Acmaea*. If the shell structure is really punctate, however, it would debar this relationship and almost conclusively corroborate that with *Crania*.

This *Crania*, if such is its character, is quite distinct from any of the described species. It clearly belongs to the group of smooth forms and by this fact is immediately distinguished from *C. blairi* and others like it. The smallness of its size suggests such species as *C. delicata* and *C.? lemoni*, but in other respects it is notably different.

Locality: San Saba, Tex. (station 2623).

Family ORTHIDAE

Genus RHIPIDOMELLA Oehlert

Rhipidomella perminuta Girty, n. sp.

Plate V, Figures 4a–6

Shell very small, the largest specimens being only 5 or 6 millimeters in length. Length and width about equal. Shape broadly ovate or subcircular.

Pedicle valve rather gibbous in the umbonal region, depressed toward the cardinal angles and toward the front. Cardinal line short, one-third to one-fourth of the greatest width. Cardinal area moderately high and more or less coincident with the plane of the shell margin. Beak small, pointed, strongly incurved, and projecting beyond the beak of the brachial valve.

Brachial valve more nearly circular than the pedicle and less convex; somewhat inflated in the umbonal region, with a small, distinct, strongly incurved beak.

A median sinus begins in the umbonal region as a narrow depression and widens rather strongly to the front, where it is a conspicuous feature.

Surface marked by the usual radiating lirae, which are sharply defined, though low, and are rather coarse for the size of the shell. About four occur in 1 millimeter. The shell is relatively thick, and when it is exfoliated the liration appears finer than when it is well preserved.

A pedicle valve from station 2618A shows the large flabelliform muscle scars characteristic of *Rhipidomella.* They extend about halfway to the front margin.

These shells are so small that one might at first be led to regard them as merely immature. Nevertheless, I have about 100 specimens, the largest of which are only 5 or 6 millimeters long. This fact and certain others, such as the thick test and the well-developed sinus of the brachial valve, indicate that the specimens, in spite of their small size, are fully grown. It is quite possible, of course, to have a species represented by a large aggregation of young shells without any mature ones, but it must be borne in mind that all the specimens of all the species of the present fauna are minute. That there should be an entire fauna of young shells without any mature ones of any species is a possibility too remote to contemplate, and the more likely hypothesis is that we have here a fauna of generally mature shells all of which are very small. It may be that these specimens represent a species of *Rhipidomella* that elsewhere reached a large size but here was dwarfed by some unfavorable condition in the environment. If so, I am unable to trace this form to its normal one. It is distinguished by its small size, its short hinge line, and its gibbous valves, at least in the umbonal region.

Locality: San Saba, Tex. (station 2623).

Rhipidomella perminuta var.

Plate V, Figures 7-9

The shells referred to *Rhipidomella perminuta* show considerable variation in shape, especially with regard to fullness of outline in the region of the cardinal angles. In some specimens the outline narrows so gradually at the posterior end that the shape suggests a triangle rather more than a circle. Such specimens might be referred to the *dubia* group of *Rhipidomella.* In other specimens the outline at the posterior end is more full or rounded and the shape is more oval.

A few specimens are especially ample in the region of the cardinal angles and have a more nearly circular outline. The valves are less gibbous than in the typical variety, and there are perhaps other differences. It is difficult to tell from the material at hand whether these more circular shells represent a distinct species or an unimportant modification of the other form.

As just intimated, there seems to be a gradual transition from shells of one shape to those of another, and only a few and only the most conspicuous examples of the rounded shape have been set aside to represent this variety. A nicer discrimination might have increased this number by specimens that, if less fully rounded than those selected, were yet too round for the other form.

Locality: San Saba County, Tex. (stations 2618A, 2623).

Family STROPHOMENIDAE

Genus SCHUCHERTELLA Girty

Schuchertella morsei Foerste?

This is one of the rarer species, and the few specimens that have been examined do not show enough to sustain a definite identification.

The size is small, a width of 7 millimeters not being exceeded by the specimens seen. The pedicle valve is low and not quite regular in growth. The brachial valve is almost flat. The surface markings are of the usual type and are quite comparable to those of *S. lens* and other species. One pedicle valve seems to show that there is present neither a median septum nor dental plates.

The generic reference of this form to *Schuchertella* seems fairly safe if I have correctly determined the structure of the pedicle valve, while the very small size and the general appearance indicate a close specific relationship to *S. morsei.* On the other hand, except for its small size, it might with equal reason find place with *S. lens.* It probably is not identical with either species, though distinctive characters would be hard to find in the present material.

Locality: San Saba, Tex. (station 2623).

Schuchertella? sp.

Two specimens, in a large way similar to those placed under *Schuchertella morsei?*, are distinguished by having the radii paired. In other words, the grooves separating two radii of the same pair are narrower and shallower than those separating adjacent pairs. If this feature is persistent, one can hardly doubt that it marks an as yet undescribed species. As to this vital point, my evidence is unsatisfactory, and in any event the material is too imperfect for descriptive purposes.

Locality: San Saba, Tex. (station 2623).

Family PRODUCTIDAE

Genus CHONETES Fischer-de-Waldheim

Chonetina subcarinata Girty, n. sp.

Plate V, Figures 10a–16

Shell small, rarely more than 6 millimeters in width, deeply semicircular, the length in some specimens being nearly if not quite equal to the greatest width, which occurs at or near the hinge line. The cardinal angles are quadrate or slightly acute; the outline contracts below and is strongly rounded across the front.

The pedicle valve is inflated, especially the median half, and the auricles, which comprise about one-fourth of the shell on either side, are large and much depressed. In conformity with the inflated mesial region, the umbo is unusually prominent. The strong convexity from front to back, the prominent umbonal parts, the large depressed auricles, and the remarkable length of the shell, which is nearly as great as the width, gives this form an expression unusual for *Chonetes* and one recalling in many respects the kindred genus *Productus*. The cardinal spines are large and suberect. Two, or rarely three, are to be counted on each side.

The brachial valve follows in configuration the pedicle valve, but it is much less strongly arched in the umbonal region. More specifically, the median half of the shell is concave both in a transverse and more strongly in a longitudinal direction, and about one-fourth on each side is reflexed into a somewhat large auricle, itself gently concave.

The surface of both valves appears to be nearly or quite without radial costae and to be marked only by fine incremental lines, a few of which are somewhat stronger than the rest and faintly lamellose. A more or less distinct cleft can sometimes be seen on the pedicle valve along the median line in the umbonal region, and, corresponding to this, the slight convexity that in many species of *Chonetes* marks the umbo of the otherwise concave brachial valve tends in this one to take on an elongated or linear shape, appearing as a short evanescent ridge.

On the inner surface the pedicle valve shows the small spines or prickles that are characteristic of *Chonetes*. A median septum, especially stout in the umbonal region, is also regularly present. In the brachial valve these internal spinules are developed to an exaggerated degree and become connected into strong continuous radial ridges having a definite and constant arrangement. They are restricted to about the median half (or to the strongly arched portion) of the shell, but a strip down the middle is plain or traversed by only one or two fine obscure ridges. The other ridges begin abruptly. They are developed to the number of five to seven on each side and are succeeded laterally, on the auricles, by large spinules radially arranged. The ridges and rows of spinules tend to graduate into one another, the anterior parts of the more lateral ridges being replaced by spinules similar to those on the auricles.

The inner surface of the brachial valve presents a peculiar and striking appearance, and evidently the soft parts by which it was secreted could not have had quite the same structure as in the ordinary *Chonetes*. This fact and the configuration of the valves, which is likewise out of the ordinary, indicate that the present species, though related to *Chonetes*, is not a true *Chonetes* at all. It seems, indeed, to possess many of the distinctive characters of *Chonetina*. *Chonetina* is known to me only through Hall and Clarke's description, and they in turn consulted Oehlert instead of Krotow, the original author. My form agrees with *Chonetina* in that the pedicle valve is very convex, although it does not possess a "profound sinus." The most significant point of agreement, however, is found in the brachial valve, of which the inner surface in *Chonetina* is said to be covered with tubercles "arranged in radiating series which unite to form high, compact lamellae, extending from the beak to the anterior margin; two of these, more prominent than the rest, limit the surface occupied by the sinus of the larger valve." In my form this arrangement of the lamellae is somewhat modified, probably because the pedicle valve is without a sinus, but even in the arrangement of these ridges or lamellae a certain agreement can be traced.

The foregoing description is based upon specimens from the dark silicious shales of western Tennessee. In the fauna under consideration this is one of the rarer brachiopods. Only 12 specimens have come to hand, and each leaves something to be desired in the way of preservation. My description, then, must needs be more than usually composite, picked up in part from one specimen and in part from another.

All the specimens are small; the largest may have been 6 millimeters in width, but most are smaller. The length for a shell of this genus is uncommonly great, being nearly equal to the width, though probably always less. The outline of a brachial valve is somewhat four-sided, or it is like a triangle truncated at the apex, being widest near the hinge line and narrow across the front and having sides that contract strongly forward. The entire outline is of course made up of curves, except the long straight hinge line. The cardinal angles are abruptly rounded. The pedicle valve would have a similar outline except for the projection of the umbonal parts, which would be relatively though not actually great.

The pedicle valve is strongly convex, especially along the median line and in the umbonal region. As a result the beak is unusually prominent and incurved, while in a transverse direction the surface tends to have a steep descent from the median part to large depressed alar regions on either side. A faint sulcus sometimes traverses the median line for a short distance near the beak.

The configuration of the brachial valve follows in general that of the pedicle valve except that its concave curvature is much less strong than the convex curvature of the other, especially in the umbonal region. Indeed, the umbonal region is rather conspicuously flattened and bears a short ridgelike elevation corresponding to the sulcus of the other valve.

The surface appears to be smooth except possibly for very faint incremental lines. Suggestions of radiating costae can sometimes be seen, though not on the best specimens, and this appearance, where present, seems to be due to minute spinules on the inner surface of the shell, which are arranged in radiating rows and are made partly visible by exfoliation.

This form is inconspicuous by reason of its small size and the small number of specimens that represent it, but it is of exceptional interest. It appears to be a species which I have described in manuscript under the name *Chonetina subcarinata.* The agreement amounts almost to identity in all essential characters, and the species itself is so peculiar that I can scarcely attribute the present form to a different species, even if a kindred one. *C. subcarinata* occurs in the Boone formation at more than one horizon. It is very abundant in the fauna having a Moorefield facies which Snider includes in his Mayes formation, and it is also present in the blackish siliceous shales of early Mississippian age in western Tennessee. It is by no means an undiscovered species, but if cited at all it has commonly been cited as *Ambocoelia*, a genus for which, owing to its peculiar configuration, it is readily mistaken if the specimens do not happen to show the characters that really determine its generic position.

Locality: San Saba, Tex. (stations 2618A, 2623).

Genus PUSTULA Thomas

Pustula inconspicua Girty, n. sp.

Plate V, Figures 17–21b

Shell very small. Width about 5 millimeters or in the largest specimens somewhat more, but in most specimens somewhat less. Length decidedly less than the width. Outline semicircular with quadrate cardinal angles.

Pedicle valve gently convex, more or less inflated in the umbonal region. Auricles large, depressed, and poorly differentiated.

Surface marked by fine incremental lines and at more or less irregular and remote intervals by concentric grooves or striae, which, though moderately strong for the size of the shell, are actually rather inconspicuous. Costae none. Spines very small and apparently scarce. They are so difficult to observe that I was for some time uncertain whether they were present at all, and they may be more numerous than my observations would indicate.

The brachial valve in general follows the curvature of the pedicle valve, though in diminished strength, while a variable area in the umbonal region is planate or even slightly convex instead of concave. External molds, therefore, are gently convex except for the umbonal region, which is flattened or somewhat concave.

The surface is marked by fine growth lines and by small angular concentric ridges, which appear to have been lamellose. The ridges occur at rather regular intervals, but they are farther apart on some specimens than on others and also less distinct. The banded effect which they produce is more pronounced on this valve than on the other, while the bands are not only somewhat more distinct but somewhat narrower. No evidence whatever of radial costae has been observed nor any evidence of spines. Spines may actually be present, however; all the conditions are unfavorable to their being observed.

The uncommonly minute size of these specimens and their general character suggest that they are young shells belonging to some species that at maturity would have quite a different appearance. They constitute, however, the most abundant species in the entire fauna, and of the 200 specimens (more or less) that I have examined all are nearly uniform in size. If these shells are considered as representing a species in a mature stage, then there are few other species with which they can profitably be compared, while if they are considered as a dwarfed species, their relations are speculative. *Pustula inconspicua* may be compared to *Productella hirsutiformis* in miniature, but that species is relatively more depressed and lacks the concentric corrugations in any corresponding degree. The same character would also distinguish it from *Productella concentrica*, young specimens of which it resembles in many ways. The species to which it seems more nearly related than to any at present known is one that occurs in the Ridgetop shale of the Waynesboro quadrangle in Tennessee. That species, which I have described in manuscript as *Pustula planiconvexa*, though resembling this in many ways, and especially in being marked only by concentric corrugations without any evidence of radial costae, is considerably larger and has a nearly planate brachial valve.

Locality: San Saba, Tex. (station 2623).

Pustula moorefieldana var. pusilla Girty?

A small *Pustula* occurs in the collection from station 2618A which differs from *P. inconspicua* and appears to be more nearly related to the species named above. The material consists of an imperfect pedicle valve and three brachial valves.

Of the pedicle valve only the surface markings can be described. These consist of fine incremental lines and of coarser striae which are neither very pronounced nor equal nor regular and which consequently produce corrugations that are, if quite distinct, more or less faint and sporadic. Spine scars are rather large and numerous, and as they occur upon the raised zones between the striae, they form themselves, though imperfectly, along concentric lines across the shell. The shell appears to be slightly elevated around the bases of the spines, which are therefore conspicuous.

The best of the three brachial valves has a subquadrate shape, somewhat wider than long. The convexity is moderate and rather regular, the umbonal region being depressed and the greatest convexity occurring about the mid-length. The surface is marked by fine striae of growth and by coarser ones of varying strength. In the more marginal parts there are also a few angular ridges that appear to be lamelliferous. In addition to these structures, there are scattered nodes (as seen on external molds) corresponding to spines on the pedicle valve, and not a few small spines proper to this valve itself. The other brachial valves agree in a general way with this one, although they do not agree completely. One of them is less convex and has all its markings more subdued.

This form is obviously closely similar to *P. moorefieldana* var. *pusilla*. It is or appears to be considerably smaller—only about half as large, in fact. The spines on the pedicle valve have small spine bases, but the bases are not elongated as they commonly are in the Moorefield form. In the brachial valve the nodes are fainter and less numerous than they are in the typical specimen represented by Figures 7 and 7a.

From *P. inconspicua* the differences are more pronounced. In the pedicle valve the spine scars are larger and far more numerous. The brachial valve is less wide in proportion to its length; it has spines of its own, and it has distinct nodes scattered over the surface. As the nodes correspond to spines on the pedicle valve, nodes are obscure or lacking in the brachial valve of *P. inconspicua*, in keeping with the small obscure spines of the pedicle valve of that species.

Locality: San Saba, Tex. (station 2618A).

Pustula aff. P. indianensis Hall

Of this form but a single specimen has come to hand. It is a pedicle valve, very small and highly arched. In length it measures but 2.5 millimeters, and though but half as large, it simulates very closely in other respects the specimens of *P. indianensis* figured by Weller. It is a rather elongate shell with small depressed auricles, the outlines at the sides being nearly parallel and the cardinal angles subquadrate, so far as one can make out. The surface is entirely without longitudinal costae. It is marked transversely by incremental lines and striae, a few of which are strong enough to make conspicuous constrictions. Spine bases are rather sparse and extremely small, and they tend to form transverse rows, although few rows contain many bases.

Locality: San Saba, Tex. (station 2623).

Family PENTAMERIDAE

Genus CAMAROPHORIA King

Camarophoria? aff. C. bisinuata Rowley

Among the numerous indeterminata in the collection this one is especially striking and deserving of mention. It is an imperfect pedicle valve, about 6 millimeters in length and the same in width. Its shape is broadly ovate, its convexity low, the beak suberect, and the sinus broad, shallow, and abruptly inflected. The surface is without plications, except in the sinus, where a rib is indicated, or possibly two, this part of the shell being broken and the characters not clear.

The internal structures are imperfectly known, but at least the presence of a median septum can be vouched for, though whether this septum supported a spondylium is not known. The presence of the septum, however, and the general resemblance superficially to *C. bisinuata* lend much probability to the generic reference and a possibility at least to the specific relation indicated.

Locality: San Saba, Tex. (station 2623).

Family TEREBRATULIDAE

Genus DIELASMA King

Dielasma? sp.

That the form under consideration is a terebratuloid is evidenced by its punctate shell; that it belongs in the genus *Dielasma* is much more doubtful—indeed, somewhat unlikely. The specimen taken, as it were, for the type of this group is a brachial valve, and one of the largest shells in the collection. It is about 7.5 millimeters in length and essentially the same in width, having a broadly ovate shape and a low convexity. No internal characters are shown.

With this specimen I am including some smaller shells having a similar broad shape. One of these which retains both valves deserves special mention. It has a length of less than 5 millimeters in the pedicle valve. It is lenticular, the convexity of both valves being low. The pedicle valve, which is the more convex, has a small, suberect beak pierced apparently by a triangular foramen. The small beak, its erect shape, and the characters of its foraminal opening are more suggestive of some other group than the terebratuloids, yet the shell is punctate, even if obscurely so, and the characters just recited, though out of keeping with a mature condition, would not be out of keeping with a youthful one.

It might be questioned whether the form described as *Selenella subcircularis* does not consist merely of young specimens of this species. Such a relation is quite possible. Yet those smaller, more slender shells are very abundant; the larger ones very rare. It would perhaps seem more probable that there are two species present, but that some of the young shells of the large form have in my grouping been included with the smaller *Selenella? subcircularis.* There exists no criterion for distinguishing the two species in their younger stages so far as I am aware except their proportions, and this criterion, which at best is not conspicuous, probably would not serve in all cases.

Locality: San Saba County, Tex. (station 2623).

Family CENTRONELLIDAE

Genus SELENELLA Hall and Clarke

Selenella? subcircularis Girty, n. sp.

Shell small, 5 millimeters or less in length. Proportions variable; width distinctly less than the length or nearly equal to it. The greatest width is about midway or a little below; consequently the outline is broadly ovate. The convexity is rather low and about equal in the two valves. A faint sinus is commonly developed in the brachial valve and sometimes in the pedicle valve as well. The beak of the pedicle valve is small, moderately incurved, and truncated by a round foramen. The pedicle valve bears the usual dental plates, but the internal structure of the brachial valve is not shown. The shell is finely punctate.

The position of this little species among the terebratuloids is beyond question, as is attested by the punctate shell and the configuration of the beak of the pedicle valve. Some of the specimens covered under this title, however, do not satisfactorily show the shell structure, which at best is finely and obscurely punctate, and these might really belong to unrelated genera, for the configuration of the beak of the pedicle valve, even if it is shown at all, is not sufficiently distinctive to locate the specimen in this group, or, on the other hand, debar it from some others.

Though most of the specimens can confidently be identified as terebratuloids, it could with much better reason be claimed that they are not mature shells, but young ones of some larger species. Their diminutive size, low convexity, and small and suberect or at least not strongly incurved beak all suggest this inference. Opposing it are the facts that these shells are numerous, that they are essentially uniform in size, and that although a larger terebratuloid is known in the fauna it is very rare. No characters are shown which would lead to the assignment of this form to one genus among the terebratuloids more than to another and it is cited under *Selenella* only because of its resemblance—purely external, too—to *S. pediculus*, whose position under *Selenella* is none too secure. It seems to be on the average somewhat broader than *S. pediculus* and to have the widest part somewhat farther forward.

In this connection a comment may be permitted upon one or two other species included by Weller among the terebratuloids, though they are not similar to the present form. The species that I have in mind are *Centronella louisianensis* and *Trigeria? currieri*. Chance rather than purpose has made me familiar with immature shell forms in several brachiopod genera, and I am almost sure from Weller's excellent figures that the species mentioned are not terebratuloids but young rhynchonelloids. In their very young stages rhynchonelloids have a spatulate shape, and the relative convexity of the valves is just the reverse of what it is at maturity. As is well known, in these shells the brachial valve is characteristically convex and has the median part raised into a fold, while the pedicle valve has the median part depressed into a sinus, these features being more pronounced, perhaps, than in any other type of Paleozoic brachiopod. Somewhat paradoxically, very young rhynchonelloids have the pedicle valve convexly arched from side to side and the brachial valve depressed into a concave curve. Plications appear earlier in some species than in others, so that the two forms from the Louisiana limestone would apparently belong to different species. The posterior region alone of *Trigeria? currieri* is without plications; on the other hand, incipient plications appear to be shown by Weller's figure of *Centronella louisianensis* close to the margin. Other characters of young rhynchonelloids are the pointed and erect beak of the pedicle valve and the triangular pedicle opening, both of which are characteristically shown in Figure 29, representing *Centronella louisianensis*. I doubt if terebratuloids even at this young stage would have such a configuration. Furthermore Weller notes that in neither species was he able to detect punctate shell structure, a circumstance which is not, perhaps, very conclusive in either direction; though even if punctate structure were eventually to be found, the fact would not militate against the rhynchonelloid relationship of these shells, because the rhynchonelloid genus *Rhynchopora* has this as a distinguishing character.

Locality: San Saba, Tex. (station 2623).

Family SPIRIFERIDAE

Genus AMBOCOELIA Hall

Ambocoelia laevicula Rowley?

It is a noteworthy fact that the genus *Ambocoelia*, somewhat like the genus *Chonetes*, is abundant in rocks of lower Mississippian age and again in rocks of Pennsylvanian age, but is, according to the records, almost absent from the intermediate faunas. This statement must, however, be qualified in two particulars. In the early Mississippian strata these shells are not perhaps so abundant as they are highly differentiated, whereas in the Pennsylvanian they are highly abundant but are practically all of one species, though in the Permian again greater diversity appears. From the faunas of the lower Burlington and Kinderhook no less than five species have been described; in strong contrast with these appears the single Pennsylvanian species, *A. planiconvexa*, which exhibits a much longer range and a wider distribution. Whether the facts are as they appear to be or whether the species recognized in the Mississippian are too many and those in the Pennsylvanian too few are questions open to discussion.

The other qualification that might be made to my opening statement is that in the upper Mississippian rocks of the Southwest (in Missouri, Arkansas, and Oklahoma) *Ambocoelia* is by no means a rare genus, and *Chonetes* also in certain places and horizons is almost incredibly abundant.

These shells are abundant also in the fauna under consideration, being scarcely if at all second to *Pustula inconspicua* in numbers. They belong with little doubt to *Ambocoelia*, yet as a matter of speculation very young Spirifers and especially very young specimens of *Brachythyris* would present much the same appearance externally, while of the internal characters not enough is known to place the generic reference in an unassailable position. The small and essentially uniform maximum size of the specimens suggests that they represent a mature condition and makes the natural reference to *Ambocoelia* a very probable one.

The form under consideration possesses a number of distinctive characters, which, however, are subject to material variation in different specimens so as to raise the question (especially if we consider the small differences by which some of the early Mississippian species are distinguished) whether the specimens would not better be referred to several specific groups than to one. As compared with species of the *planiconvexa* type, the pedicle valve has a rather low elevation and the brachial valve a rather high, though, of course, the elevation of the one greatly exceeds that of the other. The umbonal parts of the pedicle valve are rather tumid than attenuated, but they do not project far beyond the hinge line. The shape is ordinarily transverse, but some specimens are, for the genus, uncommonly long in proportion to their width. The cardinal angles are rather conspicuously rounded. As a rule a median sinus, narrow but not deep and commonly sharply depressed along the median line, indents the pedicle valve and the brachial valve as well, producing a distinct emargination in the anterior outline. These structures may be, however, though somewhat rarely, all but obsolete.

Most of the specimens seem to have more characters in common with *A. laevicula* than with any of the four other lower Mississippian species, and to have least of all in common with *A. minuta*, being larger, more nearly equivalve, and more distinctly marked by a median sinus on either valve. The relative convexity of the valves and the projection of the umbo of the pedicle valve beyond the hinge line seem to be more as in *A. laevicula*, though these shells are on the average more elongate and have apparently deeper sinuses, especially the sinus in the brachial valve. *A. unionensis* is a much larger species, and the type specimens at least have larger, blunter umbonal parts in the pedicle valve. The umbonal parts of *A. parva*, on the other hand, are more prominent and more pointed, at least in one of the specimens figured, and the brachial valve of that species is unknown. In the size and shape as well as in the pronounced sinuses in both valves, the present shell suggests *A. norwoodi*, but the beak of the pedicle valve is more erect and less prominent than in the side view given by Foerste, which, be it noted, does not seem to agree very well with the other figure of the same specimen. Differences of this character shown in corresponding views by comparisons with figures are, however, not altogether conclusive, because of the difficulty of posing two specimens in the same way and the very appreciable differences in the apparent bulk and prominence of the umbonal parts made by slight inequalities in the pose. If the factor of size were relegated to the unimportant position where it probably belongs, the present form, in view of the variation shown by different specimens and also in view of the variation shown by the figures of typical specimens, might be almost equally well referred to any of the five species of early Mississippian age, except *A. minuta*. Some specimens agree rather closely with one, others with another, though perhaps no specimen completely with any.

As to the Pennsylvanian *A. planiconvexa* and the upper Mississippian form which I described as a variety of that species (*fayettevillensis*), a few words will suffice. Both those types differ in being relatively broader, in having a flatter brachial valve, and in having the umbonal part of the pedicle valve narrower and more pointed.

Locality: San Saba, Tex. (station 2623).

Genus SPIRIFER Martin

Spirifer sp.

The shells included here are for the most part pedicle valves, and they are not only small but imperfect. In configuration they much resemble some of our species of *Brachythyris*, so that I at first included them under that genus. More careful examination, however, has shown that they possess well-developed dental lamellae; thus they are at once excluded from *Brachythyris*. Other differences, though of less moment, can also be pointed out, for these shells have no plications in the very distinct sinus, such as are found in many though not all species of *Brachythyris*, and in addition one specimen seems to show superficial markings of exceedingly fine radial striae.

It would be hard to say that these were not older shells of the same species, of which those described as *Brachythyris? simulans* are young ones. *B.? simulans* is smaller; it has apparently a lower pedicle valve with a less prominent umbo; and, so far as known, it is without dental plates, a very important difference if it really exists. Some of the differences, however, are such as might characterize young stages and old stages of the same species. Comparisons based on the brachial valve can not be made between this form and *B. simulans*, as the brachial valves collected are few and poor and as none of them occurs attached to a pedicle valve, a fact precluding a comparison between the two forms on equal terms.

In general appearance this form is very similar to *Brachythyris peculiaris*.

To specify their main characters, these pedicle valves have a rather strong simple median sinus, and each of the lateral areas thus separated from one another bears, in the larger specimens at least, six lateral costae, gradually decreasing in size and distinction toward the sides. The beak is pointed but prominent and upstanding, and the configuration is strikingly spiriferoid.

The brachial valves that would appear to belong with these pedicle valves have a low convexity, and the mesial fold is defined more by having grooves on either side that are stronger than those elsewhere on the surface, than by being elevated above the general contour. Indeed, in some specimens the fold is slightly depressed, so that the configuration, like that of *Brachythyris? simulans*, might be described as a broad, shallow sinus nearly occupied by a low mesial fold. The fold in some specimens has the appearance of being divided by an obscure sulcus down the median line.

A single specimen of this type (a pedicle valve) has been found in lot 2618A and has been provisionally included with these others. It agrees with them, indeed, quite closely in a superficial way but seems to show almost conclusively that dental plates are not present. Though small doubt seems possible on this head, the evidence does not show that dental plates were not present at one time. They might conceivably have been broken from a single specimen, though scarcely from a series of them, and as I have only this one, it seems better to adopt this explanation for an otherwise anomalous situation.

Locality: San Saba, Tex. (station 2623).

Spirifer sp. var.

A few specimens (also pedicle valves) resemble those cited as *Spirifer* sp. but seem to differ in having somewhat larger and less numerous lateral plications. It is not possible to state the degree of this difference or even that it actually exists, the specimens being so small and imperfect, but the distinction here suggested may prove to be a valid one.

Locality: San Saba, Tex. (station 2623).

Genus RETICULARIA McCoy

Reticularia sp.

This type is represented by a single specimen, a pedicle valve, which has little to distinguish it except its small size. It measures about 6 millimeters in width and somewhat less in length. In its specific relations it might belong, so far as one can tell, to almost any of our Mississippian species, and for this reason, though to me it recalls an early Mississippian species like *Reticularia cooperensis*, I have refrained from suggesting a specific identification, which might carry definite stratigraphic implications.

To the generic assignment a few words may be spared. The specimen shows a low but distinct median septum, but I have been unable to ascertain the presence of dental plates. These internal structures (especially the dental plates) are likely to be feebly developed in the early Mississippian Reticularias, and consequently one of those species is especially suggested by my specimen. The feeble development, however, might be ascribed to immaturity, and in the case of a single specimen the significance of this fact is slight. The specimen could hardly be taken out of *Reticularia* and assigned to *Squamularia*, but even were that possible it is obviously a different species from our common *S. perplexa*.

Locality: San Saba, Tex. (station 2618A).

Genus BRACHYTHYRIS McCoy

Brachythyris? simulans Girty, n. sp.

Plate VI, Figures 10a–10c

Somewhat paradoxically certain characters found in this species suggest a relationship to *Hustedia? parvicostata*, although others indicate an altogether different generic reference. This shell is relatively broader than *H.? parvicostata* and has a distinct and rather long hinge line, which is, however, shorter than the width below. It is even more inequivalve than *H.? parvicostata*, the brachial valve in fact being almost flat. The pedicle valve, however, is well arched, especially in the umbonal region, and the beak is prominent "topographically," although it does not project far beyond the hinge and is not prominent in the outline. Consequently the cardinal area in this form has a direction almost at right angles to that in the other, being here more or less perpendicular to the plane of the shell margin, there more or less parallel to that plane. The pedicle valve is divided in the middle by a rather broad, shallow simple sinus, and each of the lateral areas bears five or six rather slender, rather ill-defined costae. The brachial valve has a corresponding shape. The broad simple fold is much larger than the lateral plications, but (and in this it is especially reminiscent of *H.? parvicostata*) it lies in a gentle depression instead of being elevated as the brachiopod fold normally is. The lateral plications number five or six and are rather small and feebly developed.

It is impossible to say anything positive about the structure of the pedicle valve in the umbonal region, but the configuration is strongly spiriferoid, whereas that of *H.? parvicostata* is apparently quite otherwise.

Locality: San Saba, Tex. (station 2623).

Family RHYNCHOSPIRIDAE

Genus HUSTEDIA Hall and Clarke?

The small shells referred under this genus present a problem in their general relationship which I have found it impossible to solve in a satisfactory manner. Here, as in most other unsolved problems, the obstacle consists in the difficulty of ascertaining facts. *Hustedia? texana* is fairly abundant, and consequently its characters are more fully and more definitely known than those of the rarer species here referred to the same genus. Its general relations are fairly clear. It apparently belongs to a group of retzioid shells that occur in our early Mississippian faunas with some persistence and resemble *Hustedia* rather than *Eumetria* in their coarser plications and possibly in other characters. Weller has in fact referred these shells tentatively to *Hustedia*, but we still lack substantial evidence as to their exact generic relations.

Although the general relations of *Hustedia? texana* are fairly clear, the same may not be said of the less known and less characteristic *H.? problematica*, *H.? subaequalis*, and *H.? parvicostata*. It is to these, then, that the following discussion relates.

Slight metamorphism of the shell substance has obscured the structure in all the specimens of whatever species, so that it was only after careful examination, several times repeated, that I was able to satisfy myself of the punctate structure of the form described as *Hustedia? texana*. Several times I have thought that I found evidence of punctate shell structure in specimens of some of the other species, but examination under higher magnifications seemed rather to discredit than to corroborate the first impression. It is true that a few specimens which seem to belong with *H.? inaequalis* show punctate structure that can not be doubted, but their specific identity is not beyond question. If we may conclude that they belong at least to the same group and that all of these forms are related to one another, I can not doubt that all possessed this same character of a punctate shell.

The configuration of the beak and of the pedicle opening would have an important bearing upon the generic affinities of these shells, but they occur in a rather hard limestone, and when recovered, as they must be, by being broken out of the rock, they are exfoliated. The shells themselves are so small and the rostral part so small a portion of the whole that if the beak still remains concealed by rock it can scarcely be uncovered by manipulation, or if it happens to have come free, the beak, even if not broken off entirely, has been disfigured by exfoliation so that its original characters can not be determined. My observations suggest that the beak of the pedicle valve was suberect and pierced by a round foramen, but this character also can not be definitely asserted, as it was definitely ascertained for only one of the specimens.

The scarcity of material, which is by no means abundant, has prevented the determination of any internal characters, an attempt to do which would be discouraged in advance by the small size of all the specimens seen.

The small size of the specimens, which has thwarted the determination of several essential characters, has also complicated the interpretation of the characters that can be determined. The general expression of brachiopod shells is often sufficient to indicate their generic relations, even if actual generic characters can not be made out. This is true, however, only of shells that have reached their mature form, and one might go far astray in using such evidence if the specimens were thought to be mature when they were really very immature.

All these specimens are very small, a fact which suggests that they represent an immature stage. On the other hand, all the specimens of all the species in this collection are equally small, a fact which would tend to suggest that we are considering a whole fauna of small species rather than a whole fauna of immature specimens. The latter alternative would furthermore be discredited by the fact that many of the specimens possess characters which usually indicate a mature condition, such as convexity, inflection of the beak of the pedicle valve, and development of the fold and sinus. On these criteria some of the shells in the present group also represent a mature or at least a not very immature condition.

One of the peculiar features found in all three species under discussion concerns the fold and sinus. The sinus is not sharply distinguished from the other plications of the pedicle valve; it is merely a little larger and a little deeper and is situated on the median line. The corresponding elevation on the brachial valve, which would consequently be the fold, is, in contrast to the normal brachiopod fold, not elevated but depressed. This peculiarity is shared by several widely different groups of brachiopods and points to as many different relationships, all of which must naturally be false except one. It is shared by the associated shell described as *Brachythyris? simulans*, but it is, for *Brachythyris* or for types related to it, so anomalous that its possession by the form just mentioned tends less to translate these three species to *Brachythyris* than to translate *Brachythyris? simulans* from *Brachythyris* to this group of shells. The configuration of the pedicle valve of *Brachythyris? simulans* appears to be very different from that of these shells and characteristically spiriferoid, and I believe that *Brachythyris? simulans* and the three species under consideration are fundamentally unlike.

Some of the Atrypidae share in the peculiarity to which I have referred, the subordination of the median rib or ribs of the brachial valve, and furthermore their sculpture is characterized by the development of lamellose concentric striae to which the sculpture of *H.? problematica* is in a measure comparable. If the present group possesses a punctate shell structure, as on the whole seems probable, the Atrypidae need no further consideration.

The same peculiarity occurs also in the Rhynchospiridae and is perhaps more characteristic of them than of the Atrypidae, and furthermore the Rhynchospiridae construct punctate shells. Thus the true relations of the Texas forms appear to be with the Rhynchospiridae, or at least rather with the Rhynchospiridae than with the Atrypidae. The peculiarity of the depressed "fold" appears in the Carboniferous rhynchospirid genera *Ptychospira* and *Hustedia*, but it is absent in *Eumetria* or at least is confined to so early a stage of development that it appears to be absent altogether. It is shown conspicuously by the species associated with these which I have described as *Hustedia? texana*.

The three species under consideration show little of generic value by which one could determine whether they belong under *Ptychospira*, *Hustedia*, or some other genus, possibly one not yet described. It may be that on the basis of configuration alone diverse relations are suggested. *Hustedia? problematica*, with its few strong plications and even its lamellose concentric striae, suggests *Ptychospira*, for concentric striae are strongly developed in *Ptychospira* and conspicuously absent from the common types of *Hustedia;* in this *Hustedia* agrees with *Eumetria*. On the other hand, *Hustedia? subequalis* and possibly *H.? parvicostata* are more semblable to *Hustedia* than to *Ptychospira*.

Hustedia? texana Girty, n. sp.

Plate VI, Figures 1-4d

Shell small, about 5 millimeters in length, elongate, ovate, the anterior outline more or less straightened or indented across the middle.

Pedicle valve narrowing gradually backward and somewhat acuminate at the posterior end. Cardinal line short, less than half the width of the shell. Convexity strong, somewhat inflated posteriorly, but much diminished toward the front. The median part is commonly depressed into a narrow sinus, which is never strong and may be obsolete.

Brachial valve in general like the pedicle valve, except that it is truncated by the cardinal line and that its beak is much smaller and less prominent. The umbonal region is rather conspicuously inflated, and the convexity is generally about equal to that of the other valve. This valve also bears a median sinus, which, though narrow, is persistently present and may be rather strong.

The costae are slender and sharply raised from dividing striae of about the same width. They are broadly rounded on top, as are the striae at bottom. They gradually decrease in size toward the sides, the final ones being very small. The exact number is difficult to ascertain because of this fact, and it is difficult to state in general terms, because it varies with the size of the shell. Ten or eleven costae are commonly to be found on mature specimens on each side of the sinus, and one or more somewhat smaller costae are also developed in the sinus itself. On some specimens as many as fourteen occur on each side, making the total number as many as thirty. Individual variation, exfoliation by which some of the costae are obscured, and the degree of magnification (according as one uses a hand lens or a binocular) would cause considerable variation in the total count. Some specimens are more finely costate than others—apparently the narrower ones.

The shell structure is finely punctate. This feature is not easily observed, but it has been determined with certainty on a number of specimens. The process by which the specimens have been obtained, small as they are, by breaking them from solid rock, has caused imperfections in the umbonal parts of the pedicle valve, so that the original configuration of the beak is shown by very few specimens. So much is manifest, however, that the beak was incurved and truncated by a round foramen in the way common among the retzioids.

The generic position of this little shell can not be exactly determined, but one can scarcely doubt that it belongs with a limited group of species that have been variously referred under *Retzia* or *Hustedia*, to neither of which it may actually belong. It differs from *Hustedia pygmaea* and *H. triangularis* in having more numerous costae and especially in having a pronounced sinus in the brachial valve. By the latter character, as well as by its smaller size, it is also distinguished from *H. multicostata*. The fine striation and the large number of costae suggest a generic reference to *Eumetria*, but the strength of the costae, with their wide interspaces, as well as the median sinus that is developed on both valves but especially on the brachial valve, are more or less alien to *Eumetria*, and distinguish the present species, if not from the genus itself, at least from any American species referred to it.

Locality: San Saba, Tex. (station 2623).

Hustedia? problematica Girty, n. sp.

Plate VI, Figures 6a–7c

Shell small, elongate, subpentagonal to subovate. The type specimen is somewhat less than 5 millimeters in length, but in this measurement is included a certain restoration at the posterior end. Though oval in general shape, the outline is straightened across the front and also at the sides in the umbonal region, so that a somewhat pentagonal effect is produced. The convexity is rather strong, that of the pedicle valve being greater than that of the brachial valve. The beak of the pedicle valve (as shown by a second specimen) is but slightly incurved, and for this reason, though small and pointed, it is prominent in the outline. The beak is apparently not truncated by a round foramen such as is characteristic of genera like *Hustedia*, *Eumetria*, and others similarly shaped, and, on the other hand, it is apparently not provided with a distinct cardinal area like that of *Spirifer*, though this is far from certain. The beak of the brachial valve is small and not at all prominent. The hinge line is short.

The shell is marked by a few large, strong, radial plications. One of these on the pedicle valve, as it occupies the median part, may be considered the sinus, though it is not especially distinguished from the other plications, which are graduated in size and strength. A strong rib bounds the sinus on either side, with a fairly strong rib beyond and a faint one beyond that, making six in all, three on each of the lateral areas. The grooves or sulci number five (including the median sinus), or seven if the final rib can be said to have a boundary on the outer side. Corresponding to this arrangement there are on the brachial valve five ribs and six sulci, but there the median rib (or fold) is subordinate to those on either side of it, being smaller and less prominent and not continued backward quite to the beak. The configuration of this valve, considered in another way, might be described as comprising a large, strong sinus which has a plication in the middle of it, for the "fold" is distinctly depressed below the adjacent parts.

The surface characters are not shown by the type specimen, which is exfoliated, but other specimens have the surface concentrically marked by regularly arranged, relatively strong, sublamellose striæ.

The internal structures are not known. In the type specimen the broken beak of the pedicle valve affords no evidence of dental plates. The shell structure may be punctate. It has so appeared to me at times, but examination under higher powers has failed to corroborate this appearance. It would hardly be safe, however, to conclude that the shell was impunctate.

Locality: San Saba, Tex. (station 2623).

Hustedia? subaequalis Girty, n. sp.

Plate VI, Figures 8–9c

Shell subovate, varying in proportions, but as a rule rather broad.

Pedicle valve having a small round foramen in a small, suberect, and pointed beak. Surface marked by rounded plications separated by grooves of the same size and shape, except that the median line is occupied by a groove larger than the others and that all the plications gradually diminish in size and intensity toward the side. The typical specimen has five rounded plications on each side of the median groove.

In a second specimen referred here the median groove is more conspicuously stronger than the others. The median plication answering to it in the brachial valve is, however, weaker than the adjacent ones, being depressed below them and, as it were, rising from a gentle sinus.

The shell structure of the typical pedicle valve is of doubtful character. I can not say that it is punctate, much less that it is not. One of the associated specimens gives evidence of being finely punctate; another specimen is distinctly punctate, though it may not be of the same species.

Locality: San Saba, Tex. (station 2623).

Hustedia? parvicostata Girty, n. sp.

Plate VI, Figures 5a–5c

This species may possibly graduate into *H.? problematica*, although the differences are pronounced as between typical specimens. The outline is relatively broader and more nearly circular, tending to oval. The plications are smaller, feebler, and more numerous.

As in *H.? problematica*, the pedicle valve has a small, pointed, suberect beak. The convexity is moderate. The "sinus" is rather broad. Each of the lateral areas supports four or five feeble costae, which are separated by sulci much smaller than the median one, or sinus. The brachial valve is somewhat depressed, distinctly lower than the pedicle valve. The median part is depressed into a broad sinus, most of which is occupied by a median plication or fold somewhat larger than the lateral plications, of which there are four on each side. The evidence as to the shell structure is not clear, and the character of the pedicle opening is also uncertain. The suberect and pointed beak almost precludes a structure comparable to that of the retzioids.

Locality: San Saba, Tex. (station 2623).

Family ATHYRIDAE

Genus CLIOTHYRIDINA Buckman

Cliothyridina? sp.

The group of little shells included under this title is probably composite, for even much care could hardly eliminate the possibility that imperfect specimens of several other species, especially specimens of *Selenella? subcircularis* that failed to show the punctate structure, might have found their way here. The shells that I have especially in mind and that are especially beyond suspicion, however, are none of these, but something distinct. They are broadly ovate and about 4 millimeters in length. The convexity is fairly strong, and the beak of the pedicle valve is rather small and not much incurved. The surface in its present exfoliated condition appears to be smooth or nearly so, and the shell substance rather fibrous than lamellose and punctate.

The generic position of these shells, if they may be treated as of one genus, is doubtful. They suggest, as the most probably related, the genus *Composita*, or better, because of the small beak of the pedicle valve, the allied genus *Cliothyridina*. The absence of distinct fold and sinus would also harmonize with *Cliothyridina*, though not incompatible with the interpretation that the shells are young Compositas. Another genus that is suggested by the general configuration is *Nucleospira*, and only a more accurate knowledge of the internal and other structures would lead to a satisfactory conclusion as to where this form really belongs.

Locality: San Saba, Tex. (station 2623).

PELECYPODA

Family PLEUROPHORIDAE

Genus CYPRICARDINIA Hall

Cypricardinia? aff. C. subcuneata Weller

The two specimens included here are small, 5 millimeters or less in width, and they are not sufficiently perfect to permit a satisfactory generic reference even on the criteria of shape and general expression. A reference to the genus *Sphenotus* would, perhaps, have as much to recommend it. Among the species referred under *Cypricardinia* none is so similar as *Cypricardinia subcuneata;* though only about half as large, my specimens resemble Weller's figures of that species quite closely.

Locality: San Saba, Tex. (station 2623).

GASTROPODA

Family PLEUROTOMARIIDAE

Genus BEMBEXIA Oehlert

Bembexia aff. B. lativittata Girty

If we except the few forms that are extremely abundant, the present species may be called fairly common in the fauna under consideration. Yet of the five or six specimens at my command, none is sufficiently complete to be available as a type specimen, although enough can be determined to indicate that the species is probably new.

This is a small shell, about 3 millimeters in height and not far from 3 millimeters in diameter. The general shape is ovate or conical, but the whorls are sufficiently distinct to make it somewhat turreted. The volutions are more or less inflated and have a broad, prominent carina about midway on the outer side, the surface above being somewhat flatter than the surface below. The carina, which is the site of the slit band, is defined on both sides by raised lines and is accentuated by a slight sulcus adjacent to its lower boundary. The volutions overlap to the carina or to a line just below it, and this gives the shell its slightly turreted shape already mentioned.

The whorls are marked by regular transverse lirae, which are linear and sharply elevated from the broader interspaces. These markings are distinctly coarser on the upper surface (above the carina) than on the lower. In shape they are gently convex on the upper surface, strongly concave on the slit band, and gently convex on the lower surface, the strongest part of the curve occurring immediately below the sulcus, which in turn is immediately below the carina. The general direction of the lirae (and of the aperture) is gently backward from the suture.

A pronounced difference in the fineness of the transverse lirae is shown by different specimens, a circumstance that suggests the possible presence of more than one species, or, if only one, of a rather variable species.

This form is clearly distinct from *B. nodimarginata*, having a less conical (or more turreted) shape and finer sculpture, less distinctly or indeed not at all fasciculate near the suture. It seems to show a closer agreement, in fact, with the form from the Fayetteville shale that I described as *B. lativittata*. On the other hand, the Boone cherts contain a species that is possibly identical with this and is equally variable. Shells of this general type are, in fact, rather characteristic of the Mississippian faunas of Arkansas and Oklahoma. They show great variation, especially in the strength and fineness of the sculpture, and, as most of the specimens are imperfect, it is difficult to judge whether they should be classed as several species or as only one. If the entire series including *B. nodimarginata* is held in mind, one can hardly doubt that several species are really present, though one gains the impression that they intergrade.

Locality: San Saba, Tex. (station 2623).

Genus PLEUROTOMARIA Sowerby

Pleurotomaria several sp.

Sculptured gastropod shells of several different types are represented in the collection, but though they retain characters by which this fact is shown, they do not retain enough for an intelligent consideration of the specific relations of these types or even of their superficial resemblances. The sculptured surface and its general characters suggest that all the specimens, if they could be completely described, would find place among the Pleurotomarias, but beyond that it would not be profitable to go.

Locality: San Saba, Tex. (station 2623).

Family CAPULIDAE

Genus PLATYCERAS Conrad

Platyceras aff. P. nasutum Miller

The single specimen referred here is less complete than those cited under *Platyceras* aff. *P. glenparkense* and may differ in other characters than the one upon which it has been provisionally distinguished from them. It is more compressed and is somewhat angular down the anterior side instead of broadly rounded. This gives it a certain resemblance to *P. nasutum* and, somewhat less, to *Capulus occidens*.

Locality: San Saba, Tex. (station 2623).

Platyceras aff. P. glenparkense Weller

Very few of the *Platyceras* group of shells are small enough to be compared with the present species on at all equal terms, for my specimens measure but little more than 5 millimeters in length. There are several, however, which it resembles in miniature.

The shell expands rapidly and is strongly curved, but even the apical part probably does not make a closed coil. Transversely the shell is broadly arched over the anterior side, and the width and length of the aperture do not differ greatly. The surface is crossed by growth lines which are rather strong, if the small size of the shell is considered, and which have a sinuous course. Whether the size and distribution of the lobes indicated by the growth lines is a constant feature has not been determined. The surface also shows a few minute scarlike impressions, which may have been the bases of small spines. Both specimens bear these tiny nicks, but they can hardly be interpreted as being more than a possible indication of spines. That a few of the Platycerata bore spines is well known, but the present form is not identical with any of these spinose species.

The shape in a general way is like that of *P. erectoides*, but the apical parts are less inrolled and less turned to one side, while the anterior parts are somewhat fuller and less detached. My form is similar to Weller's figures of *P. glenparkense*, but Weller says that the apical part of that species is closely coiled for one to one and a half volutions, which I believe is not the condition of my specimens. His figures of *P. paralius* are also similar, though, of course, far larger. His figures of *P. paralius* resemble those of *Capulus capax*, which consequently my own specimens resemble. My form is likewise similar to *Capulus nasutus*, though it is less compressed and more broadly rounded across the anterior side. These resemblances do not take into account great difference in size; and, to repeat, if the present form really did bear spines (which is open to question), the resemblances are accidental and do not indicate real relations.

Locality: San Saba, Tex. (station 2623).

PTEROPODA

Family HYOLITHIDAE

Genus HYOLITHES Eichwald

Hyolithes parvulus Girty, n. sp.

Plate VI, Figures 18a–19d

This species is represented by two specimens, both of them somewhat incomplete and one preserved as an internal mold.

The shell is straight and much elongated. The original length must have been about 8 millimeters and the width at the anterior end 3 millimeters. Thus the outline tapers very gradually. The cross section is somewhat triangular, one side being much more strongly arched than the other. It may be thought of as formed either by two surfaces of which one is much more convex than the other or by three surfaces two of which (the two narrower) meet indefinitely in a curve. The cross section may be compared to a triangle having a broad base and two short equal sides. If the shell is thought of as composed of two surfaces, the less convex surface is gently and regularly curved from side to side; the other has the locus of greatest curvature along the median line, which, however, is arched, not angular. The two surfaces meet at the sides abruptly, almost in an angle. Both sides, especially the more convex one, may be slightly compressed close to the lateral margin. This description, which is drawn from the testiferous specimen, applies also to the decorticated specimen, except that on the latter a groove is developed close to the margin of the gibbous side, causing the edge of the shell to appear (in side view) as if formed by a sort of ridge.

The decorticated specimen is complete at the anterior end, at least so far as the flat side is concerned. This side extends well beyond the other, and its margin is boldly arched, the outline retreating strongly on each side. The anterior outline of the gibbous side, on the other hand, is a gentle curve, as will shortly appear.

The testiferous specimen shows the surface markings with reasonable distinctness. The flatter side is essentially smooth, though it may have been marked by delicate incremental lines not now visible. The gibbous side is crossed by sharp transverse striae, the incised markings being narrower than the raised ones which they separate. Of the raised lines, about six come within the space of 1 millimeter. These markings, which are very sharp across most of the surface, subside somewhat abruptly as they near the lateral margins, along which apparently a narrow strip is nearly or quite smooth. These striations do not pass directly across the shell in a straight line, but are perceptibly arched (the convex side toward the aperture), with a flattening of the arch or perhaps a slight reversal of direction near the lateral margins.

This species appears to be a veritable representative of the genus *Hyolithes*, a type which is extremely rare in the Carboniferous faunas of this continent. At present only two species can be referred to it, *H. carbonarius* Walcott, from the Eureka district of Nevada, and *H. aculeatus*, from the "Goniatite limestone" of Rockford, Ind. The present form is clearly not *H. carbonarius;* so much is certain. Hall's description of *H. aculeatus*, on the other hand, gives so little that is definite and is so difficult to comprehend in what it does give that his species can not be dealt with until more is known about it. The present form might prove to be the same as *H. aculeatus*, but on the other hand, it might prove to be widely different, depending upon characters not specifically given by Hall or not given at all.

Locality: San Saba, Tex. (station 2623).

CEPHALOPODA

Family ORTHOCERATIDAE

Genus ORTHOCERAS Breyn

Orthoceras sp.

Only one of the objects included here is certainly an *Orthoceras;* the others, being without septa, might represent either the living chamber of an *Orthoceras* or one of the *Dentalia.* The chambered shell, which, as usual, is only a fragment, is perhaps 5 millimeters long and 3 millimeters in diameter. The chambers are rather long (about 1.5 millimeters), and the rather large siphuncle is conspicuously eccentric, though by no means marginal.

Locality: San Saba, Tex. (station 2623).

Family GLYPHIOCERATIDAE

Genus GONIATITES de Haan

Goniatites? sp.

Of this form the collection contains but a single specimen, which is so small and fragmentary as scarcely to deserve even this brief mention. Its chief character and the one that suggests the form of citation employed is a constriction so like the constrictions that are periodically developed by the Goniatites as vividly to recall that group.

Locality: San Saba, Tex. (station 2623).

TRILOBITA

Family PROETIDAE

Genus PROETUS Steininger

Proetus roundyi Girty, n. sp.

Plate VI, Figures 11a–12b

As all the trilobites in the collection are represented by separated parts whose relation to each other can at present only be surmised, it seems necessary to base the present species upon one specified member, and for the purpose of typification I am using the pygidium.

Pygidium.—The pygidium is small and generally semicircular. The width of the largest specimen is about 6 millimeters and the length considerably less. The surface is divided longitudinally into five well-defined parts—an axial lobe in the middle with a pleural lobe and a broad border on each side of it. The axial lobe rises high above the pleural lobes, to which it descends steeply at the sides and from which it is defined by a sharp groove. The pleural lobes also descend steeply at the outer side and are distinctly defined from the border both by a groove, more or less faint, and by the segmentation, which is distinct on the one and absent on the other. The border is narrow anteriorly and broadest where it passes around the end of the pygidium. The pleural and axial lobes, on the other hand, contract posteriorly. This is especially true of the pleural lobes, which at the same time become more and more oblique toward the posterior end, where they unite with the abruptly terminated pygidium into a relatively long and steep descent to the border.

The axial and pleural lobes are segmented, but the segments are low and flat, distinctly defined, but not much elevated. This is especially true of the pleural lobes. The segments decrease in size and definition toward the posterior end, and the final ones are so obscure that a personal factor is introduced in counting them. About eleven can be counted on the axial lobe and about seven on each of the pleural lobes, the seventh segment being more or less obsolete and the sixth but faint. The segmentation of the axial and pleural lobes does not correspond. The pleural lobes are defined by grooves that pass inward from the border but die down before reaching the axial furrow. On the other hand, the grooves that separate the axial segments cross the axial furrow and pass out on the median line of the lateral lobes but die down before reaching the border. This process affects only the first three or four of the pleural segments, which accordingly appear to be double or to be subdivided. The more posterior pleural segments are more discrepant with the axial ones and are subdivided by the axial grooves little, if at all. The definition of the lobes and of the segments composing them varies considerably, part of the variation being apparently due to difference in age. As the pygidium grew older, it apparently became lower and more spreading and correspondingly lost definition in all its parts.

The superficial markings are highly inconspicuous. The surface is roughened by minute punctae or granules, it is difficult to tell which. The axial segments are marked by coarser granules along the posterior margin, the granules becoming coarser and more numerous on each segment, so that while the more anterior segments are mostly smooth the more posterior segments are wholly granulate. The granules there also tend to become confluent, so that the final part of the axis may appear to be marked by irregular inosculating longitudinal striae. The pleural lobes lack any special surface characters except that where the pleural segments are subdivided by prolongations of the grooves that separate the axial segments, the granulation that occurs just in front of those grooves in the one is faintly continued onto the other.

P. roundyi is nearest in its characters to *P. ellipticus* of the American species referred to *Proetus*. It is even smaller than *P. ellipticus*, itself a small species, and differs in other ways. *P. roundyi* has a broad and well-defined border; *P. ellipticus* one that is narrow and ill-defined. In *P. ellipticus* the axial lobe is said to be about as broad as the pleural lobes, whereas in *P. roundyi*, if we include the narrowed border with the lateral lobe, the axial lobe is considerably narrower. Of the other species at present included in *Proetus*, *P. missouriensis* and *P. swallowi* alone resemble this closely in the number of segments on the pygidium. *P. missouriensis* with its much larger size and strongly granulated surface is clearly distinct. *P. swallowi*, also much larger, appears to be without a smooth border surrounding the pygidium, the grooves that define the segments being continued to the margin.

As the generic arrangement of our Carboniferous trilobites is still more or less tentative, the present species, though referred to *Proetus*, needs to be compared also with species of *Phillipsia* and *Griffithides*. In general the species referred to *Phillipsia* have more numerous segments on the pygidium than *P. roundyi;* few have less than ten pleural segments. The Pennsylvanian species *P. cliftonensis* has but seven pleural segments, but it has thirteen or fourteen axial segments. *P. sampsoni* has but six pleural segments; its axial segments, on the other hand, number only seven, so that if all the other characters are disregarded the present species shows marked differences in this one.

The species of *Griffithides* are more comparable in the segmentation of the pygidium than those of *Phillipsia*, especially *G. ornatus* (which has seven pleural and eleven axial segments), *G. parvulus* (which has seven pleural and twelve axial segments), and *G. scitulus* (which has six pleural and eleven or twelve axial segments). The ornamentation of *G. ornatus* at once distinguishes it from *P. roundyi*. *G. parvulus* and *G. scitulus* (which may be the same species) are distinguished by the ornamentation, the abrupt flexure of the pleural lobes, and the absence upon them of any grooves such as in this species subdivide many of the pleural segments and connect with the stronger grooves that separate the axial segments.

Cranidium.—The glabella is rather convex, about half as wide as it is long, and almost parallel-sided. In most specimens an oblique curved furrow faintly defines on each side a basal lobe. This structure is ordinarily unmistakable but at the same time by no means conspicuous. The observer's eye, however, may follow this furrow so that the glabella appears to narrow posteriorly. I have been unable to make out any indication of lateral furrows. A rather broad border passes around the front of the glabella, strongly upturned at the anterior margin, where a thickened ridge is formed which is striated in the characteristic manner. The border consequently makes a troughlike depression between its own upraised margin and the steeply descending front of the glabella. In some specimens the border is more narrow, and in others less upturned. The fixed cheeks are fairly large and somewhat oblique. The occipital furrow is moderately strong and narrow, sharply defining the neck ring.

The surface of the glabella is finely granulated, more distinctly on the anterior and posterior parts than on the intermediate ones. I have distinguished as a separate variety a few cranidia that are rather strongly and coarsely granulated, the granules being elongated transversely so that the glabella has the appearance of being finely marked by irregular cross striae. These markings may cover the entire glabella and may extend also onto the free cheeks. It seems rather doubtful whether this difference in sculpture (which is the only one observed, though others may have escaped observation owing to the imperfection of my specimens) really marks a distinguishable type, but if so, no means have been found for assigning the two types of cranidia respectively to the different varieties that I have distinguished among the pygidia. It can hardly be, however, that among the cranidia here grouped together and cited under *Proetus? roundyi* some do not also represent the varieties *depressus* and *alternatus*.

Free cheeks.—As representing the free cheeks I have only three specimens, two of which are fragmentary and one very small. In the latter the only character that seems deserving of mention is the presence of a long, slender genal spine. This structure may have been present in the larger specimens as well, though they are too imperfect to show it.

Hypostoma.—This structure is poorly and in some instances doubtfully represented. It has the usual elongated pear-shaped outline, but further than this my specimens do not warrant me in going.

Locality: San Saba, Tex. (station 2623).

Proetus roundyi var. depressus Girty, n. var.

Plate VI, Figures 16a–17b

This form is distinguished from the principal one in a general way and in some respects by its lower "topography," or diminished superficial differentiation. The axial lobe is, indeed, high and sharply defined, but the pleural lobes are low and spreading. They are practically continuous with the border, which in typical *P. roundyi* is broad and well defined but which here is scarcely distinguished either by a bounding groove or by the abruptly terminated segments. Indeed, the segments die out gradually, and the more anterior ones may be continued well-nigh to the margin. The segments themselves are depressed, though distinct. They are not subdivided except in the outer part, where they have a bifurcated appearance. Many of them, however, are thus subdivided. The pleural lobes are not deflected in passing around the end of the pygidium, so that the prominent termination of the axial lobe is situated far from the posterior outline—much farther in appearance than in typical *P. roundyi*, in which these parts are steeply inclined.

Locality: San Saba, Tex. (station 2623).

Proetus roundyi var. alternatus Girty, n. var.

Plate VI, Figures 13a–15b

This variety is based on pygidia and is apparently a derivative from typical *P. roundyi*. It is primarily distinguished by being more strongly segmented and in addition, or as a consequence, by having all or nearly all the pleural segments subdivided and so arranged that every alternate semisegment is slightly depressed. At first appearance, then, the pygidium seems to be very numerously segmented.

The strong grooves that separate the axial segments are continued laterally onto the pleural segments, which they subdivide, the pleural segments themselves being defined by grooves leading up from the border to the axial furrows. If the pleural segments are regarded as defined in this manner, of each pair of semisegments the posterior one is depressed and the anterior one elevated. It might be added that in some lights the depressed semisegment appears to run out into the groove that separates the axial segments, but this is not the real arrangement.

Locality: San Saba, Tex. (station 2623).

PLATES V–VI

PLATE V

FIGURES 1a–3b. *Crania pertenuis* Girty, n. sp. (p. 25).

1a–1b. A brachial valve in large measure retaining the shell. 1a, Seen from above; 1b, side view in outline.

2a–2b. A brachial valve in large measure an internal mold. 2a, Seen from above; 2b, side view in outline.

3a–3b. A brachial valve in large measure an internal mold. 3a, Seen from above; 3b, side view in outline.

FIGURES 4a–6. *Rhipidomella perminuta* Girty, n. sp. (p. 25).

4a–4c. An average specimen. 4a, Ventral side; 4b, dorsal side; 4c, same in outline, natural size.

5a–5c. An unusually ovate specimen. 5a, Ventral side; 5b, dorsal side; 5c, same in outline, natural size.

6. A pedicle valve of the gibbous type; there are many such. Seen from above.

FIGURES 7–9. *Rhipidomella perminuta* var. (p. 26).

7. A brachial valve that probably belongs with this variety; it may belong with *R. perminuta* itself, however. Seen from above

8a–8d. A specimen representing a round form that may be a species distinct from *R. perminuta*. 8a, Dorsal side; 8b, same in outline, natural size; 8c, side view in outline; 8d, ventral side

9. A brachial valve referred to this variety, seen from above.

FIGURES 10a–16. *Chonetina subcarinata* Girty, n. sp. (p. 27).

10a–10c. A characteristic pedicle valve. 10a, Seen from above; 10b, posterior view; 10c, side view.

11a–11c. Another characteristic pedicle valve. 11a, Seen from above; 11b, side view in outline; 11c, posterior view in outline.

12a–12b. A pedicle valve having a different configuration. 12a, Seen from above; 12b, side view in outline.

13a–13c. A pedicle valve representing a broad variety which is abundant in the Moorefield fauna of Oklahoma. 13a, Seen from above; 13b, same in outline, natural size; 13c, anterior view in outline.

14. A brachial valve reduced almost to the condition of an external mold, seen from above.

15. A small pedicle valve, seen from above.

16. A larger pedicle valve, seen from above.

FIGURES 17–21b. *Pustula inconspicua* Girty, n. sp. (p. 28).

17. Mold of a strongly corrugated brachial valve, seen from above.

18. Exterior of a brachial valve, showing the corrugated and lamellose surface, seen from above.

19a–19b. A pedicle valve. 19a, Seen from above; 19b, side view in outline, natural size.

20. A feebly striated brachial valve, preserved as an external mold, seen from above.

21a–21b. A pedicle valve. The umbo is truncated, apparently not by fracture but as the result of fixation. A fragmentary crinoid segment has just the size and shape and position to have fitted into the indented umbo. 21a, Seen from above; 21b, same in outline, natural size.

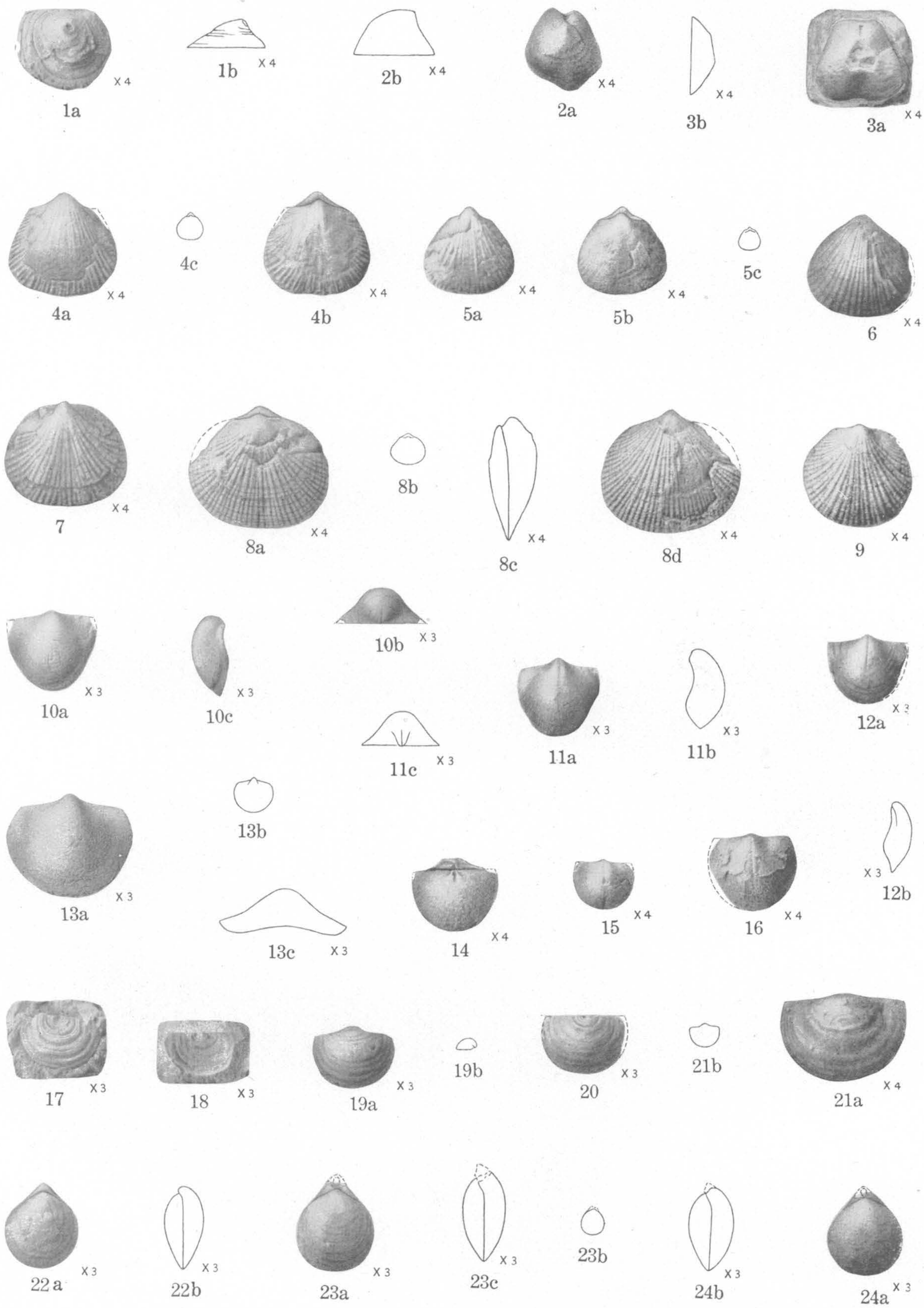
FIGURES 22a–24b. *Selenella? subcircularis* Girty, n. sp. (p. 30).

22a–22b. A specimen whose greatest width is somewhat above the middle. 22a, Dorsal side; 22b, side view in outline.

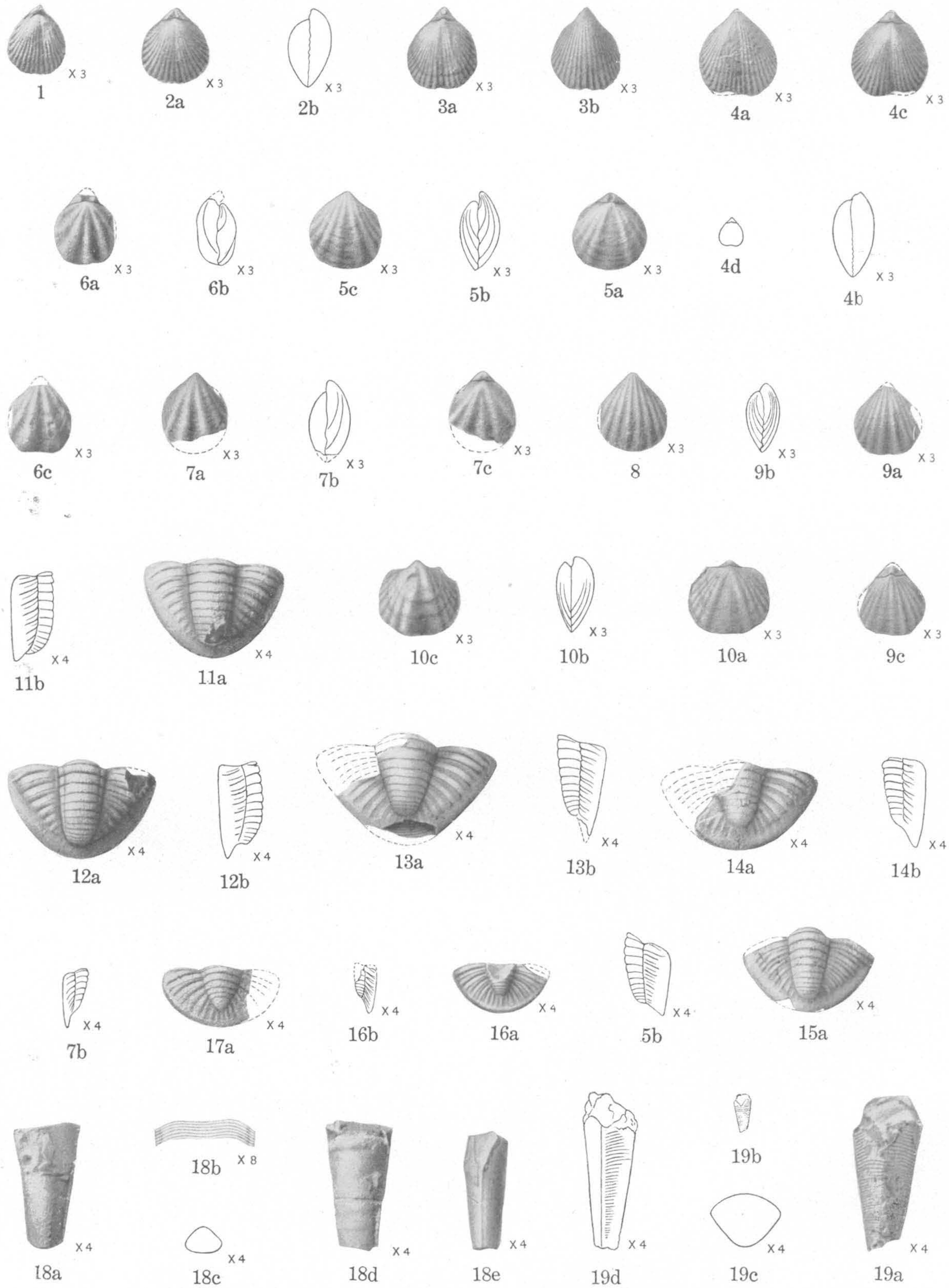
23a–23c. A specimen of somewhat different shape. 23a, Dorsal side; 23b, same in outline, natural size; 23c, side view in outline.

24a–24b. Another specimen. 24a, Dorsal side; 24b, side view in outline.

All the specimens figured on this plate were collected from the limestone of Boone age in San Saba County, Tex., except the originals of Figures 10, 11, and 12, which came from the Ridgetop shale, in the Waynesboro quadrangle, Tenn., and the original of Figures 13, which came from the "Mayes" formation, in the Muskogee quadrangle, Okla.



MACRO-FAUNA OF THE LIMESTONE OF BOONE AGE IN SAN SABA COUNTY, TEX.



MACRO-FAUNA OF THE LIMESTONE OF BOONE AGE IN SAN SABA COUNTY, TEX.

PLATE VI

FIGURES 1–4d. *Hustedia texana* Girty, n. sp. (p. 34).

1. A small specimen, dorsal side.

2a–2b. A larger specimen. 2a, Dorsal side; 2b, side view in outline.

3a–3b. A specimen which shows the circular foramen. 3a, Dorsal side; 3b, ventral side.

4a–4d. A rather large specimen conspicuously indented along the median line of the brachial valve. 4a, Ventral side; 4b, side view in outline; 4c, dorsal side; 4d, same in outline, natural size.

FIGURES 5a–5c. *Hustedia? parvicostata* Girty, n. sp. (p. 36). The typical specimen. 5a, Dorsal side; 5b, side view in outline; 5c, ventral side.

FIGURES 6a–7c. *Hustedia? problematica* Girty, n. sp. (p. 35).

6a–6c. The typical specimen. 6a, Dorsal side; 6b, side view in outline; 6c, ventral side.

7a–7c. Another specimen. 7a, Ventral side; 7b, side view in outline; 7c, dorsal side.

FIGURES 8–9c. *Hustedia subaequalis* Girty, n. sp. (p. 35).

8. The typical specimen, a pedicle valve, seen from above.

9a–9c. Another specimen. 9a, Ventral side; 9b, side view in outline; 9c, dorsal side.

FIGURES 10a–10c. *Brachythyris simulans* Girty, n. sp. (p. 33). The typical specimen, which surprisingly resembles the form described as *Hustedia? parvicostata*. 10a, Dorsal side; 10b, side view in outline; 10c, ventral side.

FIGURES 11a–12b. *Proetus roundyi* Girty, n. sp. (p. 39).

11a–11b. A characteristic pygidium. 11a, Seen from above; 11b, side view in outline.

12a–12b. Another broader pygidium. 12a, Seen from above; 12b, side view in outline.

FIGURES 13a–15b. *Proetus roundyi* var. *alternatus* Girty, n. var. (p. 40).

13a–13b. A typical pygidium. 13a, Seen from above; 13 b, side view in outline.

14a–14b. Another pygidium similar to the last. 14a, Seen from above; 14b, side view in outline.

15a–15b. A small but nearly perfect pygidium. 15a, Seen from above; 15b, side view in outline.

FIGURES 16a–17b. *Proetus roundyi* var. *depressus* Girty, n. var. (p. 40).

16a–16b. A pygidium which may be taken as the type. 16a, Seen from above; 16b, side view in outline.

17a–17b. A pygidium of somewhat different character referred to the same species. 17a, Seen from above; 17b, side view in outline.

FIGURES 18a–19d. *Hyolithes parvulus* Girty, n. sp. (p. 38).

18a–18e. A specimen preserved as a mold. 18a, Convex side; 18b, more or less schematic figure showing the course of the very fine transverse striae on the convex side; 18c, cross section in outline; 18d, flattened or depressed side; 18e, side view.

19a–19d. A specimen retaining the shell in part. 19a, Convex side, which is subangular down the middle; 19b, same in outline, natural size; 19c, cross section in outline; 19d, side view in outline.

All the specimens figured on this plate came from the limestone of Boone age, San Saba County, Tex.

Part IV. PETROLOGY OF THE CONTACT OF THE ORDOVICIAN ELLENBURGER LIMESTONE AND THE MISSISSIPPIAN LIMESTONE OF BOONE AGE IN SAN SABA COUNTY, TEXAS

By Marcus I. Goldman

INTRODUCTION

The contact of the Ellenburger limestone with the limestone of Boone age, whose fauna is described above, is represented in the collections of the Geological Survey by two specimens (Pls. VII, XIX, and XX). As the complexity of the problem presented by these specimens was not realized at the time they were collected, the problem did not receive the field study it requires. The following discussion, therefore, based purely on laboratory study, can not do it justice, and is offered, with accompanying illustrations, mainly to put on record the many interesting and peculiar features of the contact, the problems, they raise, and some of the interpretations they suggest.

SOURCE OF THE SPECIMENS

The specimens were obtained from a locality in San Saba County, Tex., about 3 miles south of the town of San Saba, on the south side of a fault that brings the bottom of the Smithwick shale on the north side several hundred feet below the bottom of the Mississippian on the south side.[1] Specimen G 105, illustrated in Plate VII, was in place probably not more than 200 to 300 feet south of the fault; and specimen G 114, illustrated in Plates XIX and XX, was probably only a few feet south of the fault.

SPECIMEN G 105: CONTACT OF THE ELLENBURGER LIMESTONE AND THE LIMESTONE OF BOONE AGE

GENERAL DESCRIPTION AND INTERPRETATION

Specimen G 105 will be considered first, because it shows the more normal relations of the two formations at their contact. As it is illustrated in Plate VII, the dark-gray rock full of undulating, parallel white markings in the upper part of the specimen above the line *Y–Y* is undoubted Mississippian. The lighter-colored rock below the line *X–X* is undoubted Ellenburger. The question that initiated this investigation was whether the intervening layer belongs to the Mississippian or the Ellenburger, or whether it includes a transition from one to the other. The fact that this layer is made up of pebbly limestone suggests that it is basal and therefore belongs to the Mississippian, and its apparent transition to the Mississippian fits this interpretation. On the other hand, it closely resembles, especially in its lower part, pebbly layers in the Ellenburger in the lower part of the specimen. The presence of these pebbles below unquestioned Mississippian may therefore be due merely to the chance that before the Mississippian was deposited the Ellenburger was eroded down to one of these pebble layers instead of to a more homogeneous layer in the Ellenburger.

Another possible interpretation suggested by the peculiarities of the pebble layers in the Ellenburger and of their relations to the more homogeneous layers and by the evident tectonic disturbance of the Ellenburger near by, as illustrated by specimen G 114 (Pls. XIX and XX), is that the pebble layers and some features of the contact may be due to tectonic crushing with shearing approximately parallel to the contact.

My conclusion is that the contact is a normal contact of the limestone of Boone age on a pebbly layer in the Ellenburger. On close examination with a hand lens the boundary as represented by the line *Y–Y* is found to be much sharper than it appears at first glance. I do not believe it lies more than 1 or 2 millimeters on either side of the line *Y–Y*. A principal cause of the apparent vagueness of the contact is the dark-gray color of the Ellenburger in the upper part of the zone between the line *X–X* and the line *Y–Y*. Undoubtedly this color is due to penetration of the coloring matter of the overlying Mississippian, a coloring matter which is presumably of organic origin.

A satisfactory interpretation of the contact requires an interpretation of the origin of the characteristic features of both formations near their contact. The features of the Ellenburger will be considered first.

[1] Plummer, F. B., and Moore, R. C., Stratigraphy of the Pennsylvanian formations of north-central Texas: Texas Univ. Bull. 2132, map pl. 8, p. 52, 1921. On this map the fault is shown running southwest from Barnett Spring, crossing the road that goes southeast from San Saba to Chapel at a sharp bend in the road. It is just west of the road and south of the fault at this point that the specimens here discussed were collected.

THE ELLENBURGER OF SPECIMEN G 105

GENERAL FEATURES

In general appearance in hand specimen the Ellenburger of specimen G 105 is a very fine grained light yellow-gray calcareous rock. It consists of an irregular alternation of more or less solid and continuous layers with layers made up of pellets or pebbles and angular fragments of material similar to the solid layers. Cross sections of thin shells or fragments of shells of mollusks, trilobites (*t*, Pl. VII), and perhaps brachiopods are characteristics of the solid layers. Some also occur in the pellet layers, as at *f* and *g*, Plate VII. Most of the shells are represented by clear calcite, and some have cavities filled with it. As this material absorbs much light, it appears dark on the polished face against the fine-grained opaque matrix of the solid layers. This contrast is emphasized by the photograph. The pellets are in a matrix that consists partly of clear, rather coarsely crystalline calcite and very largely of a light yellow granular calcite, which, on account of its color, appears very dark in the photograph. For this reason the general characteristics of the rock stand out much more clearly in the photograph than in the specimen itself.

ORIGIN OF THE PELLETS

Microscopic details of the Ellenburger are represented in Plates VIII, *B*, and IX, which illustrate parts of thin sections from about the areas marked *B* and *C* on Plate VII, but from a layer that was about 1 centimeter above the surface of the specimen shown in Plate VII.

It seems improbable that the pebbly portions of the Ellenburger and the rough and irregular boundaries of the homogeneous layers originated by crushing and shearing after consolidation. The boundaries of homogeneous layers are too irregular to have been sheared; the pebbles are too rounded and are oriented too much at random, without indications of a direction of flowage; the matrix of the pebbles, which is essentially rather coarse clear calcite, is too clear and free from rock meal such as would be expected to result from crushing and grinding of the rock.

Another mode of origin that suggests itself is submarine flow or solifluxion of the beds at the time of deposition, but most of the objections against tectonic origin hold against this origin also. Especially it seems that flowage of relatively soft beds could not produce the irregular sharp boundaries of the large homogeneous portions. Moreover, the approximate horizontality and parallelism of these portions seem to conform better with primary sedimentation. Probably in the field these bands, in spite of the irregularity of their boundaries and the variations in their composition, which in places in the hand specimen make them almost pinch out, would be found to be essentially continuous over so great a horizontal extent as to eliminate the possibility of origin by submarine flowage.

By what process, then, did these materials originate? The material of the homogeneous layers and of the pebbles is the same very fine grained calcareous matter (presumably of the type called drewite by Field and Kindle) [2] that makes up the homogeneous layers, so that the rock is presumably what Kindle [3] calls vaughanite and the British geologists call calcite-mudstone.[4] It diverges from the definition of both names, however, in containing many fossils, of which the sections show plainly in the homogeneous rock as illustrated in Plate VII. Some can also be seen among the pebbles. At *e* and *i*, Plate VII, there are the internal casts of two, and at *g* another. At *g* some of the original shell is represented. At *f* part of the cross section of a shell with the matrix adhering to it can be seen. A number can also be seen among the pellets in the thin section (Pl. VIII, *B*)—for instance, at *a*, *b*, *c*, and *d*. At *g* and *h*, Plate VIII, *B*, are groups of pellets as seen in cross section that plainly represent the internal casts of fossils (presumably gastropods) but appear to lack remnants of the shell in which they formed; and others, such as those at *e* and *f*, by their shape and their size clearly suggest the same origin. These evidences of the origin as shell casts of many of the pellets has led me to the conclusion that most of them originated in this way. Some others are perhaps the excrement of animals that passed the calcareous mud on which they lived through their intestines, and some are probably mechanically fragmented portions of the calcareous mud rock.

If this explanation of the origin of the pellets is accepted, the question still remains whether the absence of shells and of the fine-grained calcareous mud matrix is due to processes that were contemporaneous with the formation of the rock or to waters that circulated subsequently through the rock. The weight of evidence seems clearly in favor of the syngenetic origin of the essential features of the rock, though there are some features that can perhaps be better explained as the result of waters circulating in the rock after its formation and some that appear puzzling on either hypothesis. The interpretation proposed involves the assumption that this part of the Ellenburger was deposited at or near marine base-

[2] Field, R. M., Investigations regarding calcium carbonate oozes at Tortugas and the beach rocks at Loggerhead Key: Carnegie Inst. Washington Yearbook, 18, pp. 197–198, 1920. Kindle, E. M., Nomenclature and genetic relations of certain calcareous rocks: Pan-Am. Geologist, vol. 39, pp. 368–369, 1923.

[3] Op. cit., p. 370.

[4] Dixon, E. E. L., Carboniferous succession in Gower: Geol. Soc. London Quart. Jour., vol. 67, pp. 516–517, 1911.

level, where slight changes in conditions could cause a change from deposition to erosion and the reverse, so that these changes occurred frequently. The result was to erode and rework previously deposited calcareous mud, which on different occasions and in different localities was in different stages of solidification, from soft and incoherent mud to material hard enough to form angular fragments. When the matrix was soft enough, which it was usually, the inclosed shells, many of them filled with the same mud, were freed. A chemical change in the condition of the surrounding water by which it dissolved instead of precipitating calcium carbonate caused the solution of most of the shells, which were probably more soluble than the calcium carbonate of the mud that filled them. On account of the time required for solution of the shells, and perhaps also as a result of organic matter in them, the mud filling them was sometimes hardened by the time it was freed, and thus under favorable circumstances the internal cast was preserved to form a pellet. It is not to be understood that each pellet layer or accumulation of pellets represents a single interval of erosion and solution. The accumulation of many periods may be represented in one layer of pellets—some periods having left no trace, because the mud was not hard enough, and some having furnished angular fragments of the hardened mud matrix like that at *f*, Plate IX, *B*, or the angular fragment at *f*, Plate VII, in which the inclusion of part of a shell would seem to imply that hardening had gone so far that fracturing took place through matrix and shell alike instead of between matrix and shell.

Points in favor of such an origin may be briefly summarized as follows:

1. The sharpness and form of the bottom contact of the pellet layers. Surfaces like those shown in Plate VII might be expected to result by subaqueous erosion of a partly toughened mud containing shells, but not by shearing of the rock after induration, nor by solifluxion during deposition.

2. The approximate horizontality of this boundary, which corresponds to bedding.

3. The partial inclusion of some pellets, as at *a*, Plate IX, *A*, in the underlying continuous layer. This seems hard to explain except on the assumption that the underlying layer was soft and that the pellets were relatively hard at the time the pellets were inclosed by the mud. These pellets, from their form and size, might well be the excrement of small animals, and their greater hardness at the time they were buried in the mud might have been due to mechanical and chemical effects of their mode of origin.

4. The irregular and transitional character of the upper boundary as it appears especially in the top of zone *M—M*, Plate VII, indicating burial of the upper part of the pellet layer in subsequently precipitated calcareous mud.

5. The direct association with a predominance of rounded pellets of such angular pellets as that at *f*, Plate IX, *B*, and one still containing a remnant of a fossil like that at *f*, Plate VII, which seems explicable only by the assumption of syngenetic fragmentation.

6. The close crowding of shelless internal casts of fossils, as at *i*, Plate VII, shown enlarged on Plate VIII, *A*. If the shell had been dissolved after the formation of the rock the surrounding pellets should not be in direct contact with the cast, as some of them are. However, it is probable that some shells that survived solution before inclusion in the clear calcite matrix were replaced after inclusion in that matrix. Thus between the portions of a gastropod shell filling seen in cross section at *g*, Plate VIII, *B*, there is not shell structure but granular crystalline calcite like the clear calcite matrix. It seems improbable that without the shell this internal cast would have survived entire the reworking which it is assumed accompanied the accumulation of the pellets from their matrix of calcite mud, so that the shell layer between the whorls of this gastropod was probably recrystallized or replaced after the cast was embedded in the clear calcite matrix.

7. Perhaps the most conclusive evidence of contemporaneous origin is furnished by fragments such as those at *b*, and *k*, Plate VII (shown enlarged at *b*, Pl. X, *A*, and *k*, Pl. X, *B*) which themselves contain pellets in a clearer matrix. These fragments are particularly significant because they show that not only the pellets had been formed before the succeeding layer of continuous calcite mud rock which incloses them was deposited, but that the clearer coarser calcite matrix had also been formed around them. In fact, at *a*, Plate X, *B*, one of the contained pellets can be plainly seen cut off by the margin of the fragment, indicating abrasion or solution of the fragment as a whole before its inclusion in its present matrix. The pebble marked *b*, Plate X, *A*, is also significant because it appears to show in conjunction a body of pellets and a body of the continuous calcareous mud rock, indicating that they had been hardened into a single body before fragment *b* was formed.

That mechanical wear may have taken some part in rounding or otherwise modifying the form of some of the pellets is indicated by *k*, Plate X, *B*. But the very elongated and irregular form of many of them and their prevailing lack of sorting makes it seem probable that it was not an important factor in their origin. It appears rather, as might be expected under conditions of delicate balance between erosion and sedimentation, that wave or current action was intermittent and local. On the other hand, it seems likely, if the pellets originated as assumed, that syngenetic solution has somewhat modified their form, though no evidence on this point has been found.

It is worth noting that pellets of this type are an important constituent of many oolite rocks. Of some rocks called oolites they are the essential constituent, but they occur also in rocks of which the principal constituent is true concentrically banded oolites. The deduction that they are related to true oolites in origin is supported by the similarity of some of the processes indicated by this specimen to those under which, according to Cayeux [5] and others, some oolites appear to have originated, and by the similarity of many constituents of this rock to constituents described by him as occurring in oolitic rocks.

MATRIX OF THE PELLET LAYERS

The matrix of the pellet layers is of two kinds. One is a rather coarsely crystalline clear calcite, as illustrated in Plates VIII, *B*, and IX. Evidence has been adduced from the inclusions at *b* and *k*, Plates VII and X, to show that this material is syngenetic. The other is a finely granular, impure yellow carbonate material. This appears from the polished face to constitute a large part of the matrix in zone *M–M*, Plate VII. Its yellow color gives the strong contrast in the photograph between matrix and pellets in that band.

This material can be seen in thin section at *g*, Plate IX, *B*, and at points marked *a* in Plate XI, *A*, which illustrates part of thin section G 105–F. From these two illustrations it is clear that matrix of this type occurs characteristically not directly enveloping the pellets but rather in the midst of the coarse calcite matrix that does directly envelop them. This mode of occurrence, its association with a fissure at *l* and below *k*, Plates VII and X, *B*, and the fact that it cuts into the spheroidal boundary of the rounded fragment at *k* indicate that it is later than the clear calcite matrix and probably formed after the compacting of the rock. This material is limited to the Ellenburger in the specimen of Plate VII (G 105) and does not occur above the line *Y–Y* shown in that plate.

There is evidence that in places the clear crystalline matrix has grown at the expense of the material of the pellets and of the solid layers. This evidence may be found throughout the thin sections of Plates VIII, *B*, and IX, *B*; but it is particularly well illustrated at *d*, *e*, and *f*, Plate IX, *B*. Here the material of rounded pellets and of an angular fragment seems to be partly penetrated and replaced by the coarsely crystalline matrix, as if it had been dissolving in the matrix. Similar relations can perhaps be seen in the vague basal boundary at *k*, Plate VIII, *B*.

[5] Cayeux, L., Les minerais de fer oolithique de France: Soc. géol. France Bull., 4th ser., vol. 24, No. 5, pp. 263–277, 1924.

The association of the partly replaced pellets illustrated on Plate IX, *B*, with the fracturing of the calcite mud matrix at *a*, *b*, and *c*, Plate IX, *B*, which apparently preceded the formation of the coarsely crystalline matrix at these points, suggests that the penetration of the coarse calcite into the pellets at *d*, *e*, and *f* was also the result of syngenetic fracture of these pellets. But such a condition would be difficult to explain. For the fragments seen in cross section at *a*, *b*, and *c* may well have been supported somewhere along their length, in their displaced position. But that is not likely to have been the case with the pellets at *d*, *e*, and *f*, which were presumably approximately equidimensional. The disintegration of the pebbles at *d*, *e*, and *f* could have been syngenetic only if the coarsely crystalline matrix had been formed by some process of instantaneous precipitation from solution and if the disintegration of the pellets had coincided with this precipitation and perhaps been the result of it. In the absence of more conclusive evidence such a process can not reasonably be assumed, though the assumption of epigenetic origin of the penetration of the pellets by the coarser-grained calcite leaves the localization of this penetration in relatively few of the pellets unexplained. Perhaps they were less firmly indurated or contained some constituent like shell fragments which facilitated penetration by the coarser-grained calcite.

Sudden precipitation of the coarsely crystalline calcite matrix in the midst of pellets kept in suspension by agitated water might also explain the wide spacing of many of the pellets. But the great range in size of the pellets is opposed to the assumption that they were kept in suspension in agitated water, as such suspension would presumably result in better sorting, and the wide spacing can be satisfactorily accounted for by growth of calcite in the matrix.

SILICIFICATION IN THE ELLENBURGER LIMESTONE

The Ellenburger limestone of specimen G 105 contains silicified fragments. Just below the contact line *Y–Y*, Plate VII, they are fairly numerous, but below the line *X–X* only three, identified by their bluish-white color, could be found in the polished face. These three are shown at *o*, *p*, and *q*, Plate VII. They are not more than 1 millimeter in diameter. Two are also included in thin section G 105–F, and are illustrated in Plate XI, *A*, at *c* and *d*, and the one at *d* enlarged around *d*, Plate XII. There are also two occurrences illustrated at *v*, in the upper left corner of Plate VIII, *B*. As can be seen from the photomicrographs, these fragments are not detrital fragments of chert but are silicified elements of the limestone. The significance of silicification in these rocks is discussed on pages 56–58.

STYLOLITES IN THE ELLENBURGER LIMESTONE

The stylolites in specimen G 105 (Pl. VII, S–S and S′–S′) clearly illustrate solution along stylolite surfaces.[6] In Plate XIII, *A*, which is a detail of the stretch adjacent to *r*, Plate VII, a fossil at *a* and a large calcite mud pebble at *b* show truncation by a stylolite surface directly underlain by a mass of small pellets. On the other hand, Plate XIII, *B*, which is a detail along S′–S′, Plate VII, from a surface that was about 1 centimeter above the face of specimen G 105, shows almost no solution along the suture, fragments on opposite sides, as at *a* and *b*, apparently having continuous boundaries. This, together with the absence of pronounced columns and of any appreciable film of solution residue, indicates that these stylolites are young, though the extent to which these last two features are developed must evidently depend in great part on the original character of the rock involved.

An interesting effect of a stylolite can be seen at *b*, Plate X, *B*, where a piece of a shell has been displaced with respect to the rest of the shell on both sides of it.

THE BASAL MISSISSIPPIAN, AN "ECHINODERM BRECCIA"

GENERAL DESCRIPTION AND INTERPRETATION

The general features of the basal Mississippian, the limestone of Boone age, whose fauna is described on preceding pages by Messrs. Roundy and Girty, are well shown on Plate VII. It is necessary to add only that this rock is dark blackish gray, in contrast with the light yellow-gray of the underlying Ellenburger. Its more detailed characteristics are well illustrated by thin section G 105–D, Plate XIV, which shows typical Ellenburger pellet rock in the lower part. In distinction to the fine calcite mud of the Ellenburger the material of this basal part of the limestone of Boone age is a distinctly granular calcite containing (as at *a*, *b*, *c*, and *d*, Pl. XIV) many coarser fragments, each of which is a single crystal of calcite. In the finer-grained portion which forms the greater part of the rock in this basal inch or two and which may therefore be spoken of as a matrix, each grain, no matter how fine, appears distinct, surrounded by a thin dark film that is probably of organic origin. The grains are poorly sorted, passing by all gradations into the very coarse fragments. These characteristics are well illustrated by Plates XIV and XV. In most of the coarser fragments a nucleus of a cloudy granular nature can be more or less sharply distinguished from a very irregular envelope of clearer calcite, the whole grain forming a single crystal. These large grains at once suggest fossil fragments, and this interpretation is strongly supported by material from a highly fossiliferous layer of this same limestone from about 1 foot above the base, but not directly overlying the spot from which specimen G 105 was collected. It is illustrated in Plate XI, *B*. Most of the larger fragments in this thin section are single calcite crystals. It is well known that in the echinoderms each element of the skeleton is a single calcite crystal with a characteristic mesh structure in three dimensions, and that calcite which secondarily fills these meshes assumes the crystallographic orientation of the original framework.[7] At *a*, Plate XI, *B*, shown enlarged in Plate XVI, there is a fragment which shows this mesh structure in its inner part, passing outward into a granular specked structure which seems characteristically to take the place of the mesh structure as it alters with time. As this granularity and the crystallographic continuity are exhibited by the larger fragments shown in Plates XIV and XV the conclusion is indicated that these fragments also are echinodermal in origin.[8] The rock, then, may be regarded as an echinoderm limestone—by analogy with other rocks of the kind probably a crinoidal limestone or crinoid breccia, a common type of basal bed.

CAUSE OF THE FRAGMENTATION OF THE SKELETAL REMAINS AND GROWTH OF SECONDARY CALCITE

The principal problem regarding the origin of this basal portion of the rock is the cause of the fragmentation which apparently produced most of both the coarser fragments and the finer matrix from crinoidal and other skeletal material. The fragmented condition of this basal material compared with the material a foot or so higher, as shown in Plate XI, *B*, accords with the idea that the characteristics of the Ellenburger and Mississippian at their contact here might be due to shearing along that contact. From the study of the basal Mississippian of this specimen alone, in the absence of further field observation of this contact, I am not prepared to refute that interpretation. I reject it, mainly because the character of the top of the underlying Ellenburger, as brought out above, does not accord with it, and because the features of the basal Mississippian can be explained in other ways. The very jagged indented outlines of the coarse calcite fragments might seem to be opposed to the idea of origin by shearing, but these outlines, as will be shown, offer difficulties to the other interpretations offered. For instance, mere mechanical wear at the time of deposition would produce rounded fragments of the original skeletal elements; it would not produce angular fragments except of very delicate and fragile shells.

[6] Cf. Stockdale, P. B., Stylolites; their nature and origin: Indiana Univ. Studies, vol. 9, No. 55, 97 pp., 1922.

[7] Cf. Cayeux, L., Introduction à l'étude pétrographique des roches sédimentaires, p. 435, Paris, 1916; and Deecke, W., Die Fossilization, p. 63, Berlin, 1923.

[8] Cf. Cayeux, L., op. cit., pp. 436–437.

The very irregular outline of fragments like those at *a* and *b*, Plates XIV and XV, however, is probably not in the main due to the agents which originally fragmented them, but apparently to the addition of secondary calcite to the original organic fragments. That is to say, it is very probable that much if not all of the clear calcite that surrounds the granular nucleus of these fragments is calcite added in continuous crystallographic orientation with the nucleus. That such addition of calcite has taken place in the limestone of Boone age is proved by Plate XVII, *B*, which shows between crossed nicols an area in thin section G 105–E (Pl. XI, *B*), *b* and *c* in one plate corresponding to *b* and *c* in the other. Here the contacts between grains, which are all close and many of them very straight, prove secondary development of material around the original nucleus. The fragment *b*, of which the nucleus and added calcite can be differentiated in Plate XI, *B*, is shown at extinction in Plate XVII, *B*, to bring out the continuity of nucleus and envelope, and *c′* in both plates marks the large areas of clear calcite that between crossed nicols, though not in Plate XVII, *B*, are seen to belong crystallographically to the part of the nucleus immediately adjacent to *c*. In this grain the organic nucleus appears to be compound, and only the part immediately adjacent to *c* extinguishes simultaneously with the envelope *c′*. The same secondary growth of calcite around organic fragments has occurred in the Ellenburger, as shown at *i*, Plates VIII, *B*, IX, *A*, and XVII, *A*, where the nucleus is also distinctly an echinoderm fragment. There is no reason for supposing that this secondary calcite was added while the fragments of the limestone of Boone age lay on the bottom exposed to the fragmenting agents; therefore, if the clear calcite of irregular grains like those at *a*, *b*, *c*, and *d*, Plate XIV, and *a* and *b*, Plate XV, is secondary, it could not show the effect of these agents.

The irregular form of these grains is undoubtedly due mainly to the growth of the secondary calcite in the unhomogeneous medium that their matrix affords. This interpretation is made very probable by the fragment marked *k*, Plates XIV and XV. In Plate XV, *k* is the nucleus and *k′* added secondary calcite. The angular, nearly rectilinear outline of the upper part, *k′*, of this grain is evidently an attempt of the added calcite to develop its crystal form, and it is hard to escape the conclusion that the calcite has worked toward the same end at the left side but has been prevented by the unhomogeneity of the matrix there. Some irregularity in outline may be due to the original form of the fragment, as it is in fragments *g* and *h*, Plate XIV, which apparently have no added calcite.

What may have been the original outline of grains to which secondary calcite has been added is uncertain, as it may be obscured by blurring of the boundary between nucleus and added calcite, as in *a* and *b*, Plate XV, probably because recrystallization of the nucleus has destroyed its granular structure. This might and according to Cayeux[9] does happen by continuation of the process that converted the original mesh structure of echinoderm fragments into the granular structure. There is some evidence, in fragments which show a well-defined echinodermal nucleus, that that nucleus was not well rounded, but regardless of the original form of the nuclei the fact to be accounted for is the much greater comminution of skeletal fragments in this basal part compared with fragments of similar origin as they are found a foot or so above the base (as illustrated in Pl. XI, *B*), and according to Cayeux,[10] as they are found in most of their occurrences. It seems likely to me that fragmentation by shell-crushing animals, as described by Walther,[11] has produced this material. He finds that under modern conditions fishes with broad teeth, and crabs, are the main agents causing this fragmentation. Crabs are not known to have existed in Mississippian time, but among the fishes that existed then there are some with platy teeth that might have been used to crush shells.

RATE OF ACCUMULATION

Whatever the cause of the fragmentation of the skeletal material that makes up this basal Mississippian deposit, it seems clear that the material must have lain for some time on the bottom in order to have attained this state. That is to say, slow accumulation of this lower part of the limestone of Boone age is indicated. Here, as at so many basal contacts, submergence was apparently at first slow, so that the bottom remained for some time near base-level, exposed to frequent alternations of erosion and deposition; hence accumulation was slow, and time was available for agencies of destruction, alteration, or chemical precipitation to act on the accumulating deposit. As submergence progressed it probably became more rapid, hence organic fragments could accumulate faster, and because of this more rapid accumulation and because the depth in which they accumulated was beyond the influence of the agencies of extensive fragmentation that produced the lower part of the deposit, the more complete material of Plate XI, *B*, was accumulated.

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9 Cayeux, L., Introduction à l'étude pétrographique des roches sédimentaires, pp. 436–437, Paris, 1916.

10 Idem, pp. 319, 438.

11 Walther, Johannes, Die Sedimente der Taubenbank im Golfe von Neapel: K. preuss. Akad. Wiss. Abh., Anhang 1910, pp. 39–40, Berlin. 1910.

SILICIFICATION IN THE BASAL MISSISSIPPIAN

The silicified material in the Mississippian of specimen G 105 has the same general character as that in the Ellenburger of this specimen. In thin section G 105–D three fragments, marked *e* and *f* on Plate XIV and *x* on Plate XV, were found. The one marked *e* is shown more in detail in Plate XVIII. The silicified fragments appear to average slightly larger than those in the Ellenburger, are very much more numerous, and in the hand specimen, under a hand lens, appear to be more completely silicified.

CHARACTER OF THE ELLENBURGER DIRECTLY UNDERLYING THE CONTACT WITH THE MISSISSIPPIAN

The pellets in the Ellenburger directly underlying the Mississippian as they appear in thin section G 105–D, plate XIV, are of much coarser grain than most of those in the deeper part of the rock as they appear in Plates VIII, *B*, and IX. This gives them the more transparent, less sharply defined character that can be recognized in the lower left-hand part of Plate XIV. This character may be due to recrystallization during exposure of the upper part of the Ellenburger before and during the deposition of the limestone of Boone age, to more ready circulation of underground water along the contact of the two beds after the deposition of the limestone, or to reworking of these pellets from the top of the Ellenburger into the limestone of Boone age.

As noted on page 47, there has also apparently been more silicification in this upper part of the Ellenburger, which, as set forth in the general discussion of silification on pages 58, lends some support to the last interpretation.

SPECIMEN G 114: A FOLD AT THE CONTACT OF THE ELLENBURGER AND MISSISSIPPIAN

ANALYSIS OF THE FOLD

METHOD OF STUDY

Specimen G 114, which shows a fold at the contact of the two formations, is illustrated in Plates XIX and XX. The two polished faces illustrated are sawed parallel faces of the same original specimen. The surface illustrated in Plate XIX (G 114–I) lay about 2.5 centimeters above that illustrated in Plate XX (G 114–II). The numbered areas on Plate XIX represent areas taken for thin sections. With the knowledge of the more detailed structure of the rock that these sections afforded a careful study was made, with a hand lens, of the distribution of the Ellenburger and the limestone of Boone age on the polished surface of specimen G 114–II. The results are shown in Plate XXI.

It would not be possible to illustrate every detail of the evidence on which my interpretation is based. That evidence can be obtained only from a close examination of the polished face. Even such an examination leaves very much to personal judgment. Probably no two individuals, or even the same individual making two independent examinations, would delimit the areas of the different types of rock in just the same way; and on the mere basis of observation of the hand specimen, some might even question the entire interpretation offered. But the evidence of the thin sections, even as reproduced in the accompanying Plates XXII to XXVIII, seems very convincing.

That the results obtained from the study of the polished face probably agree pretty closely with the more trustworthy results that would be obtained by the study of thin sections is indicated by a comparison of the insert on Plate XIX with Plate XXVIII. The insert on Plate XIX shows diagrammatically the distribution of rock types as worked out from the polished area from which thin section G 114–8, illustrated in Plate XXVIII, was made. The relations worked out in the insert of Plate XIX agree well with those that can be recognized in Plate XXVIII and thus indicate the general trustworthiness of the results obtained from the study of the polished face.

CHARACTERISTICS OF THE ELLENBURGER AND THE LIMESTONE OF BOONE AGE USED IN WORKING OUT THE STRUCTURE OF SPECIMEN G 114

Most of the characteristic features on which the differentiation of the Ellenburger and the Mississippian is based are set forth above. For the sake of definiteness they are briefly summarized here.

The Ellenburger is fine grained and contains pellets of similar fine-grained material, and the fossils in it are predominantly shells which show as thin curved lines in cross section. In its original condition it is light yellowish gray. On silicification it turns white.

On Plates XIX and XX the areas lettered *C* and *E* are predominantly unsilicified Ellenburger, the areas *B* and *F* predominantly silicified Ellenburger.

The basal Mississippian limestone of Boone age characteristically shows much coarser grained calcite and large calcite crystals, most of which are probably echinodermal in origin. Similar large calcite crystals with the characters of echinodermal fragments occur also in the Ellenburger, as shown, for instance, at *i*, *l*, *m*, *n*, *o*, *p* (where several are associated), *q*, *s*, *t*, and *u*, Plate VIII, *B*; and it contains some coarse calcite crystals in small veins or pockets or filling the shells of organisms, most of them not more than a few millimeters across, as shown in the lower part of Plate IX, *B*. But grains of this kind form in the Ellenburger a small and inconspicuous proportion of the rock.

The limestone of Boone age is of a dark neutral gray color in its original condition and a somewhat lighter gray after partial silicification. Under the microscope this dark color appears to be due to a film, probably of organic origin, between the calcite grains. On Plates XIX and XX area *A* is limestone of Boone age, somewhat silicified adjacent to the silicified Ellenburger on the left. The letter *D* is placed near the bottom of an area consisting predominantly of limestone of Boone age, which is not much silicified in the darker portion adjacent to *D* but considerably silicified in the upper, lighter gray portion (cf. Plate XXI).

In general there seems to be a difference in the character of silicification of the two types of rock, which corresponds to their original difference in grain. In so far as the two rocks could be differentiated after silicification, silicification in the Ellenburger is more complete and the silica is finer grained. In the limestone of Boone age the original coarser calcite grains are intimately mixed with most of the silica.

REVIEW OF THE THIN SECTIONS OF SPECIMEN G 114-1 AND CONCLUSIONS

From its general appearance and relations (Pl. XIX) the area of thin section G 114-1 would be taken to be typical and pretty fine Ellenburger, silicified. The thin section (Pl. XXII) entirely confirms this interpretation. The apparently structureless groundmass is chert, and the darker and granular portions are calcite. A number of cross sections of thin shells can readily be recognized, as at *f*. The coarse-looking material at *c* appears to be the granular yellow carbonate material described above, mixed with coarser, purer calcite. At *b* this band runs into a single large calcite crystal with veinlike branches. Around *a*, especially as shown in Plate XXXII, *A*, Ellenburger pellet structure can be recognized, and under the microscope it can be found in other parts of this thin section.

The area of thin section G 114-5, Plate XIX, evidently shows the contact between normal limestone of Boone age and silicified Ellenburger limestone, and the thin section (Pl. XXIII) confirms this assumption.

The area of thin section G 114-4, Plate XIX, would appear to be representative unsilicified Ellenburger material, though even in the plate, and still more clearly in the hand specimen itself, thin curving bands of material of slightly different texture, suggesting flowage, can be recognized. These curving bands can be still more clearly recognized in the corresponding area on Plate XX. Thin section G 114-4 (Pl. XXIV) shows typical dense, fine-grained Ellenburger limestone with many thin cross sections of fossils, but many of these fossils appear to be broken. At the points marked *c*, in Plate XXIV, for instance, shells appear clearly to have been broken after inclusion in the rock. Some pellets of Ellenburger type can be seen at points marked *d* and elsewhere. At *a* and *b* are alternate curved bands such as could be seen on the polished face of this area. The lighter bands (*b*) consist of clearer, slightly coarse calcite intergrown with the dense fine-grained Ellenburger. This is, then, the first thin section in which evidences of flowage and fracturing can be seen. The compact condition of the rock, as indicated by the absence of scattered pellets in a clear calcite matrix, may be due to these processes.

The area of thin section G 114-2, Plate XIX, appears to be entirely dark-gray limestone of Boone age, but the upper part is lighter colored than the lower and suggests silicification. On account of a slight defect in illumination this contrast does not show as well on the photograph as in the specimen itself. It shows very clearly, however, in the thin section (Pl. XXV), in which the lower part is typical fresh-looking limestone of Boone age, but some of the larger fragments in the upper part (the areas marked *b* in Pl. XXV) are cloudy and poorly defined as a result of silicification. The whole slide, however, has distinctly the characters of the limestone of Boone age. The rock appears to be flow banded, but this appearance may be due mainly to bedding.[12]

The area of thin section G 114-3, Plate XIX, appears to be a contact between white silicified Ellenburger limestone and gray silicified limestone of Boone age, with fragmentation and mixing of the two types of rocks, fragments of the white silicified Ellenburger showing particularly clearly in the gray Mississippian. Although the relations here are evidently so complex that it would be impossible to determine from which of the two formations each integral part of the thin section is derived, still the general area occupied prevailingly by each formation is readily recognized in Plate XXVI. As right and left and hence the slopes of boundaries are reversed in the photomicrographs (see footnote 12), the right-hand part of the crack that formed in the thin section is seen to correspond about with the boundary between the two formations. Below the crack is fine-grained, largely silicified Ellenburger limestone; above it are coarse calcite fragments with some coarser matrix. Along most of the bottom of Plate XXVI the cross section of a single large gastropod or a group of mollusk shells can be

[12] It must be noted that the section is made with the polished face mounted on the object glass so that when bottom and top are seen in their correct relations under the microscope, through the cover glass, right and left are reversed. Hence the slope of the boundary between the unsilicified and more silicified bands, which in the polished face rises from left to right, is reversed in the photograph.

seen in the Ellenburger. At the left of Plate XXVI, which corresponds to the right-hand side of the area seen in Plate XIX, silicified cloudy Ellenburger material can be seen extending more or less in patches across the crack into an area consisting more dominantly of material of Boone age; and below the crack to the left there is some more coarsely granular calcite that looks like Mississippian in the midst of prevailing Ellenburger. The coarser yellow carbonate of Ellenburger type occurs in patches all through the rock, as at *a*, and, with the coarse calcite crystals of the type of the limestone of Boone age, brings out the intimate mingling that has taken place.

General appearances suggest that the area of thin section G 114–6, Plate XIX, covers merely a contact between silicified and unsilicified Ellenburger material, but there are two facts that might cast doubt on this supposition. One is the absence of any trace of a sharp contact between dark-gray limestone of Boone age and light yellow-gray Ellenburger limestone at the left-hand end of specimens G 114–I and G 114–II, Plates XIX and XX, below the area *D*. But for that it might be assumed that the Ellenburger had been merely thrust over the top of this body of limestone of Boone age and the limestone of Boone age slightly folded into it at its upper right-hand corner.

The other suggestive and puzzling fact is that the dark neutral-gray color of the Mississippian extends as a vague but recognizable band all along the upper part of the unsilicified Ellenburger just below the silicified part—that is, between areas *B* and *C* and even across the line *X—X* between the areas *E* and *F*, Plates XIX and XX.

Thin section G 114–6, Plate XXVII, is the crucial section in the entire problem of the relations in specimen G 114. It can leave no doubt, I think, that much shattered material of Boone age occurs here between and mingled with silicified and unsilicified Ellenburger material. Coarse calcite fossil fragments are abundant in the middle part of the area; below, especially to the left, fine-grained Ellenburger and Ellenburger pellets can be recognized; to the lower right fragments of thin Ellenburger shells; and in the upper part to the left probably silicified Ellenburger and more to the right an irregular band of what looks like dark coarse-grained material of Boone age running up from the large circular fossil fragment *a*, which is distinctly of the type of the limestone of Boone age.

With the information obtained from these thin sections as a basis the distribution of rock types and the flowage lines in the polished face of G 114–II were worked out bit by bit and without any conscious interpretation in mind, with the results shown in a generalized way in Plate XXI. As a final check on these surprising results, and especially on the peculiar spreading of the fold against the line *X–X*, thin section G 114–8 was made Before the thin section was cut a diagram was made of the distribution of rock types and of flow lines as they appeared in the polished face of the rock from which it was to be prepared. This diagram is shown in the insert on Plate XIX; Plate XXVIII is a photomicrograph of the thin section taken through the back of the object glass in order to show the parts in the same relations as in the polished surface. The photomicrograph leaves no doubt that Mississippian material represented by coarse calcite fragments like those at *m*, Plate XXVIII, is abundant along a roughly median strip, and the sharp upward flowage above the median line near *X–X* is clearly seen. In general the agreement with the insert on Plate XIX is very good, though the area of silicified limestone of Boone age may be a little too wide. Abundant Ellenburger material marked *e* on Plate XXVIII crowds Mississippian material closely in the upper left part of the plate and seems to predominate in all the more or less silicified area back of the distinctly flowed bands, but even in the thin section it would be difficult to decide to just which rock to assign certain areas. The intimate mixture of the two rock types in this thin section and the consequent difficulty of assigning some areas, even in thin section, to one or the other of them, makes it evident how great the difficulty must be of working out their distribution in the polished face. In doubtful areas identification may depend on a single coarse calcite crystal fragment or a single thin shell fragment that happens to be recognizable, and as such fragments may occur in either rock, isolated streaks and patches of one or the other might be wrongly identified. Thus there may be some doubt about the little streaks of Ellenburger material indicated in patch *D* of Mississippian at the left of Plate XXI. Otherwise, I believe the general features of Plate XXI are trustworthy. The streaks of Mississippian at the top center of Plate XXI are indicated both by the gray color, which can be recognized in Plate XX, and by the still darker and more characteristic extension of area *A* to the back of this part of the specimen about 2 centimeters back of the polished face.

INTERPRETATION OF THE ORIGIN OF THE FOLD

The assumed steps in the origin of the fold are shown qualitatively in the successive diagrams of Figure 1.

Two possible origins of the line *X–X*, which apparently remained practically unaffected by the folding, have been considered. One is that it is a pre-Mississippian fault plane, the other that it is the wall of a pocket in the Ellenburger formed while the

Ellenburger was exposed on the surface of the earth after its formation. Against this second assumption is the fact that the lower part especially is filled mainly with normal Ellenburger pellets. If it were a pocket formed under the conditions assumed it should presumably contain angular fragments of the rock as a whole, even more mixed in size than those in the upper silicified part. On the other hand, if it

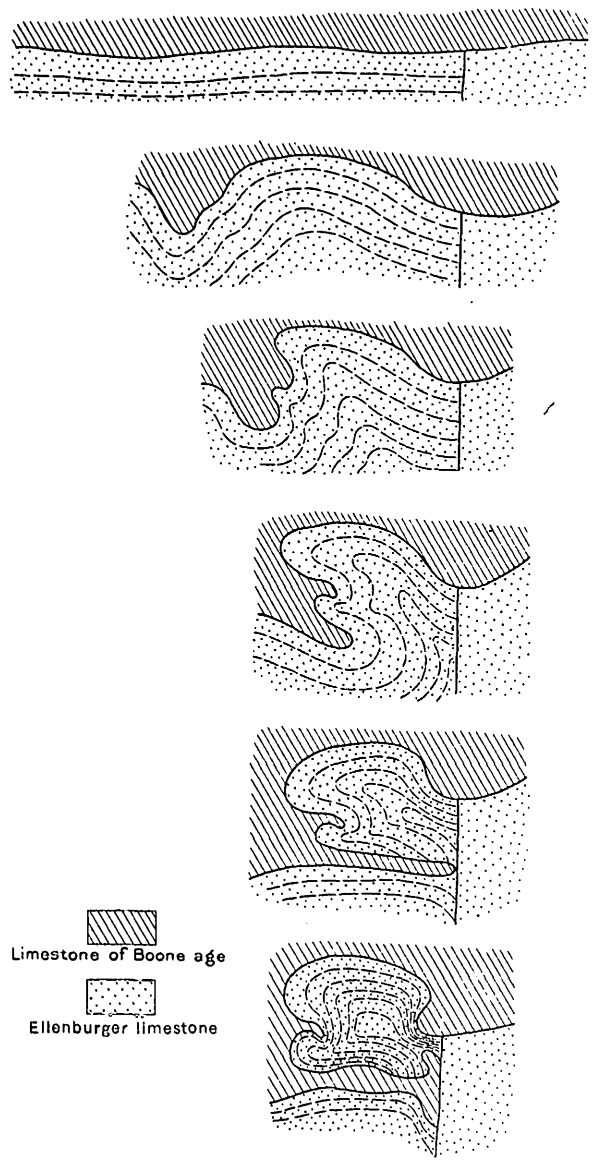


FIGURE 1.—Diagrams showing the supposed development of the fold in specimen G 114

were a fault, the material in area E should be more angular and look more fractured. That the boundary between silicified area F and unsilicified area E agrees so nearly with the boundary between a portion F consisting largely of angular fragments and a portion E consisting almost only of pellets is under any interpretation puzzling. However, the fact, recognizable on Plate XX, that the boundary does not quite agree—that the silicification boundary falls a little below the top of the more obvious pellet boundary—leads me to assume that the coincidence is accidental. My assumption is that the line X–X is a fault. The difference between the upper angular material and the lower pellet layer is assumed to be due to a primary difference. The angular upper part is assumed to have been one of the solid Ellenburger layers and to have been shattered somewhat when the faulting took place; the lower pellet part is assumed to have been originally a pellet layer, which was able to adjust itself to the faulting movement without appreciable shattering. The movement along the fault was in any case probably not great.

That the folding was nearly perpendicular to the plane of this fault which is roughly perpendicular to the polished face is confirmed by the evidence of the orientation of large calcite crystals in the folded rock, as brought out below. As this fault plane is practically undisturbed by the folding it must be assumed that the folding was due to an underthrust from the left.

As specimen G 114 was collected within a few feet of a fault which drops the bottom of the Smithwick shale (see stratigraphic table) several hundred feet below the top of the Ellenburger,[13] while specimen G 105, which is considered not to have been influenced by structural disturbances, was collected only 200 or 300 feet away from the fault, the fold is probably connected with the faulting. The plane X–X probably resulted from an earlier movement parallel to the post-Smithwick fault.

Stratigraphic section of formations from the Ellenburger limestone to the Strawn formation in San Saba County, Tex.

Age	Formation		Approximate thickness (feet)
	Strawn formation.		
Pennsylvanian	Smithwick shale.		275
	Marble Falls limestone.		440
	Barnett shale.	Limestone.	20
Mississippian		Shale.	90
		Glauconitic, phosphatic sand.	0. 5
	Limestone of Boone age.		0–2
Ordovician	Ellenburger limestone.		

[13] See footnote 1.

AGE OF THE FOLD AND LOAD UNDER WHICH FOLDING TOOK PLACE

The faulting that is assumed to have produced the fold may have occurred at any time after the deposition of the limestone of Boone age. In connection with the problem of its age the fissure fillings of glauconitic sand shown on Plate XXI, some of which are marked *a* in Plate XX, must be considered. Under the microscope (thin section G 114–10, Pl. XXIX) the filling of one of the largest of these fissures is found to consist mainly of coarse angular calcite grains, with round and angular quartz grains (*b*, Pl. XXIX), brown isotropic phosphate pellets (*c*), phosphatic or phosphatized fossil fragments (*d*), and chert fragments (*e*). Around *f* part of the rock itself has been partly chertified in place. In the polished face of specimen G 114–II green grains, undoubtedly glauconite, can be recognized. There is every reason for assuming that this material is derived from the directly overlying glauconite bed at the base of the Barnett shale (see stratigraphic table) and that it worked down into these cracks, which must have formed after the folding of the rock. The interpretation of this relation depends on whether the glauconite sand could have been present only a foot or two above the base of the limestone of Boone age, at the time that limestone was folded, without itself being involved. It does not seem probable, and yet on account of the slight coherence of the sand and the localization of the folding it must be regarded as possible.

If the glauconitic sand was present at the time of folding, a great but very indeterminate thickness of overlying beds may have overlain the Ellenburger here. H. D. Miser[14] says that as the source of the Pennsylvanian sediments probably lay to the east or northeast[15] it is quite possible that they formerly covered this region. As the latest uplift of the Llano region was post-Cretaceous, it is also quite possible that Comanche and Upper Cretaceous deposits once covered it. On the other hand, as the geologic map of Texas[16] plainly shows, the Comanche overlaps the Pennsylvanian and Permian with great unconformity, so that it may hardly be assumed that both Pennsylvanian and Comanche were fully represented. How the thicknesses of the different formations of these series would be related to their thicknesses at their nearest occurrences is all the more difficult to estimate in view of the uncertainties already enumerated. In general the Llano region was a positive geologic element[17] during Paleozoic, Triassic, and Jurassic times, so that there were probably during Pennsylvanian, Permian, and Mesozoic times many more intervals of nondeposition and erosion in that region than in the surrounding areas where the formations of these periods are now preserved, and the sediments deposited there were probably of a shallower-water facies. But many coarse near-shore sediments are thicker than their deeper-water equivalents, so that this factor tends to counterbalance the possible nondeposition or erosion. The best that can be done under the circumstances is to take rough figures for the nearest areas in which sediments of the periods involved are now present. Figures for the Pennsylvanian furnished by Mr. Roundy as derived from the areas to the north for the Permian from unpublished records of the United States Geological Survey and for the Cretaceous and lower Tertiary from the Austin folio give the following thicknesses:

	Feet
Lower Tertiary	500
Upper Cretaceous	1,500
Comanche	1,500
Permian	6,000
Pennsylvanian	6,000
Barnett shale (Mississippian)	100
	15,600

This total is probably much more than was ever present but probably may be safely taken as a maximum possible amount.

If the glauconitic sand of the Barnett shale was not present, however, then the greatest stratigraphic interval represented could not have been more than the larger part of Boone time and perhaps most or all of St. Louis time. The lower part of the Barnett shale, as explained in the preceding text, is believed by Messrs. Girty and Roundy to be correlatable with the Moorefield shale of Arkansas, which is very tentatively assigned by them[18] to St. Louis time, and may be as young as the later part of that epoch. The deposits overlying the Ellenburger could not have represented all of this interval, however, for the later part of it would have been taken up with the erosion of what was present before the glauconitic sand at the base of the Barnett shale was deposited. The thickness of such a column is also difficult to estimate, as no beds representing it occur in the neighborhood; but using figures from the nearest regions in which they are present Mr. Girty has roughly estimated a thickness of about 500 feet.

It is generally assumed that flowage of rock can take place only under great pressure, but as a matter

[14] Oral communication.

[15] Miser, H. D., Llanoria, the Paleozoic land area in Louisiana and eastern Texas: Am. Jour. Sci., 5th ser., vol. 2, pp. 74–75, 1921.

[16] Udden, J. A., Baker, C. L., and Böse, Emil, Review of the geology of Texas, 3d ed.: Texas Univ. Bull. 44, Aug. 5, 1916.

[17] Miser, H. D., op. cit.

[18] Oral communication.

of fact little seems to be known about the conditions of this kind of flowage, without fusion, in nature. In the field, too, most studies have been concerned with the more extreme types of flowage in regional metamorphism. Here, on the other hand, there has been flowage which has not even ground the flowed material very fine.[19] The preservation of large fossil cross sections in most of specimen G 114 is one of its striking features. Geophysicists of the Geophysical Laboratory of the Carnegie Institution [20] believe that folding such as occurred here could not occur under a column as short as the 500 feet or so that might have been present if the Barnett shale had not yet been deposited when folding took place. But no quantitative data appear to be available, and they recognize that other factors, especially the amount of water present in the rock, might have a big modifying influence. Moreover, the apparent extreme localization of the folding, directly adjacent to the faults, must be borne in mind.

ORIENTATION OF CALCITE FRAGMENTS IN THE FOLDED ROCK

A feature worth mentioning is the large proportion of large calcite fragments in specimen G 114, oriented with their bases nearly parallel to the plane of the section—that is, with their optic axes nearly at right angles to it. They stand out clearly between crossed nicols on account of their relatively low birefringence colors, bright green, red, blue, yellow, or even gray predominating in each crystal. Thin sections G 114–5 (Pl. XXIII) and G 114–7 show the phenomenon especially well. It is more conspicuous in the limestone of Boone age, because large calcite fragments are particularly abundant there; but it is also common in the Ellenburger limestone of thin section G 114–5, in large grains of calcite that fill fissures and are therefore clearly not of organic origin. This orientation is therefore apparently a result of flowage of the rock. The fact that the optic figures of all the calcite grains observed in specimen G 114 are slightly biaxial, indicating strain, would lead naturally to the conclusion that that condition is due to the unusual stresses to which the material of this specimen has been subjected. But the facts that a slightly biaxial figure was found also in a fossil crinoid stem from the Pennsylvanian Graham formation of Youngs County, Tex., where so far as known it has been involved in only the mildest folding, and that a recent crinoid stem and sea-urchin spine show normal uniaxial figures, indicate that the mere weight of overlying material or the slightest folding is able to produce enough stress to make the optic figure of these echinoderm fragments slightly biaxial.

[19] Cayeux has noted the striking absence of fragmentation of fossil fragments in many beds which have been subjected to considerable tectonic disturbance. (Introduction à l'étude pétrographique des roches sédimentaires, p. 319, Paris, 1916.)

[20] Oral communication.

FEATURES OF THE LIMESTONE OF BOONE AGE, ESPECIALLY OF ITS BASAL CONTACT, IN SPECIMEN G 114

POCKETS OF MATERIAL OF BOONE AGE IN THE ELLENBURGER LIMESTONE

Some features of the Mississippian in specimen G 114 that were not found in specimen G 105 deserve brief description. One is the presence of granular calcareous material, like the Mississippian, in pockets and fissures several millimeters below the contact in the underlying Ellenburger. Some of these pockets are indicated by *b* on Plate XXIII.

SULPHIDE ALONG THE CONTACT

Another peculiar feature of the contact here is the seam of yellow ocher along it. Because it photographs black it does not appear clearly in Plate XIX, but it stands out well in the thin section as the opaque matter at *e* in Plate XXIII. The inherent probability that this material was originally iron sulphide is supported by the groups of small more or less cubical grains (around 0.03 to 0.04 millimeter), which by reflected light can be distinguished in the thin section at some points. The transparent portions of this mass (*a*, Pl. XXIII) are silicified, and they are a much larger part of the mass than appears from the illustration.

Small accumulations of ocherous material of this same kind are not uncommon in the basal part of the limestone of Boone age of specimen G 105. Some of them are indicated at *v*, Plate VII. They are very common in the mass of skeletal fragments which makes up thin section G 105–E (Pl. XI *B*), which comes from the limestone of Boone age about 1 foot above the contact, and in this most of them are intimately associated with the skeletal fragments. In the Ellenburger of specimen G 105 they are very scarce, and most though not all of those that occur are associated with the few silicified portions or with the more coarsely granular ocherous calcite, which, as explained above (p. 47), is believed to be epigenetic. In the silicified Ellenburger material of specimen G 114, as for instance in thin section G 114–1, they appear to be slightly more common than in the Ellenburger of specimen G 105. In thin section G 114–5 some of the ocherous matter occurs in the very top of the Ellenburger, as along the line *f–f*, Plate XXIII. There is therefore some reason for thinking that the large amount of this material along the contact in thin section G 114–5 is epigenetic, especially as the association of epigenetic silica and sulphide is common.

I am nevertheless inclined to believe that the mass of original sulphide along this contact was syngenetic. The circulation of underground water might be more active along such a contact, and therefore, if the sulphide was epigenetic, it might be more abundant there, but it is hard to conceive of a factor that would lead to the formation by such a process of a single large mass such as the main mass at *e*, Plate XXIII. Moreover, masses that are not much smaller occur in the Mississippian of specimen G 105, where there has been no silicification, and concentrations of syngenetic sulphides at basal contacts are a particularly characteristic mode of occurrence of that type of mineral.[21] They are probably due to abundance of organic matter. The presence of the sulphides in the top of the underlying Ellenburger along line *f–f*, Plate XXIII, may well be due to a secondary redistribution of sulphide syngenetically formed at the base of the Mississippian.

ENVELOPES AROUND CALCITE FRAGMENTS

Another peculiar feature of thin section G 114–5 is the presence around many of the coarse calcite fragments in the limestone of Boone age of an irregular cloudy granular envelope in continuous crystallographic orientation with the crystal it surrounds. Some of the crystals which show it best in the photograph are marked *g*, *h*, *i*, *k*, *l*, on Plate XXIII, and in Plate XXX, *A*, *B*, *C*, *D*, and Plate XXXI, *A* and *B*, different types are shown enlarged. The way in which these envelopes merge with the granular matrix and inclose fragments of it independently oriented, as brought out between crossed nicols, indicates that the envelopes are the result of absorption and molecular rearrangement of the surrounding matrix by the large calcite crystal. This indication receives some support from a comparison of the boundaries of the inner part and of the cloudy envelope. In *a*, Plate XXX, *A* and *B*, which was chosen on account of the extreme irregularity of the outline of its inner clear part, that outline resembles the outline of the grains prevailing in this same limestone in its more normal condition, as illustrated in Plates XIV and XV. Plate XXX, *C* and *D*, illustrates at *a* a grain with less irregularly bounded inner clear part, but in both these grains the tendency of the outer envelope to assume a spherical form is plainly indicated between crossed nicols. This is opposed to the idea that the envelope is the result of marginal alteration of the original calcite and shows also that the conditions which produced it were different from those which produced the clear envelopes in the less disturbed limestone of Boone age of specimen G 105. Some doubt, however, is raised by Plates XXXI, *A* and *B*, in which three grains (*a*, *b*, and *c*) with cloudy borders are shown not only in contact but two of them (*b* and *c*) extinguishing together and the third (*a*) almost with these two. They have sharp contacts, as shown by the contact of *b* and *c* at *x*, Plate XXXI, *A*. The common orientation of these grains suggests some original relationship between them. If they were in contact before the border was formed, then the border must be due not to absorption of the matrix but to alteration of original clear calcite from the outside inward. However, the evidence from the other grains, discussed above, the lack of perfect common orientation between *a* and *b*, and the deep penetration of the matrix between *b* and *c*, as brought out in Plate XXXI, *B*, lead me to believe that the common orientation is merely a coincidence and that these grains have come into contact by taking into their crystal structure the calcite of their matrix.

[21] Goldman, M. I., Basal glauconite and phosphate beds: Science, new ser., vol. 56, pp. 171–173, 1922.

As these envelopes are peculiar to the limestone of Boone age in this specimen of strongly folded rock they are probably the result of pressure, perhaps with accompanying waters, acting on the rock.

STAINING OF THE ELLENBURGER LIMESTONE BY THE MISSISSIPPIAN

Now that the folding in specimen G 114 has been explained, a word of comment should be offered on the gray stain between the silicified and unsilicified Ellenburger, referred to above (p. 52). To the left of the line *X–X*, Plates XIX and XX, this stain is evidently due to actual inclusion of material of Boone age. To the right of that line, however, it must be due to spreading of the coloring matter, probably of organic origin, from the left side of the fault into the unsilicified Ellenburger limestone to the right of the fault. A similar spreading of the coloring matter of the Mississippian into the Ellenburger, as pointed out above (p. 44), occurs at their contact in specimen G 105, where it had the effect of obscuring the contact.

GENERAL OBSERVATIONS ON SILICIFICATION

THREE TYPES OF SILICIFICATION

The silicified portions of the Ellenburger limestone and the limestone of Boone age in the specimens under consideration are of three kinds—one very fine grained and the other two in coarse crystals but with different manners of occurrence, as will be explained. The fine-grained variety is in these specimens undoubtedly epigenetic. There is some evidence in favor of the belief that one of the coarsely crystalline varieties is syngenetic and that the other is probably not. Of the two coarsely crystalline varieties only one was found in specimen G 105. It is illustrated at *e* and *f*, Plate XIV, and at *a*, Plate XVIII, which shows *e* of Plate XIV, enlarged. These are in the limestone of Boone age. Plate XII, *A* and *B*, which are enlargements of *d*, Plate XI, *A*, illustrate an occurrence of this type in the Ellenburger material of specimen G 105. For convenience of reference this will be called coarse type A.

The other coarse-grained type was found only in specimen G 114. It is illustrated by *a*, Plate XXII, *a*, Plate XXXII, *A*, and by *b*, Plate XXXIII, *A* and *B*. For convenience of reference this will be called coarse type B.

The amorphous to fine-grained cryptocrystalline type is that which is characteristic of areas *B* and *F* and parts of *D* and *A*, plates XIX and XX. It is illustrated by Plate XXII, by Plate XXXII, *A* and *B*, which show it between crossed nicols, and by Plate XXXIII. That this type is epigenetic is obvious from the fact that it cuts at random across the boundaries of formations and across structural features formed long after the deposition of the rocks. The association of this fine-grained type with the coarse type *B*, the sharp boundaries between them, and the contrast between them is well brought out at *a* in Plate XXXII, *A*, where the granular inner part is a single calcite crystal, the coarse-grained rim is silica, and the matrix is the fine-grained silicified Ellenburger. The contrast between the three parts also shows well at *a* in Plate XXII. The large calcite crystal is undoubtedly a fossil fragment. It might be assumed that the difference in grain of silica between the matrix and the included calcite crystal is due to their original difference in grain—that is, that fine-grained calcite gives place to fine-grained silica, and coarse-grained calcite to coarse-grained silica. But Plate XXXII, *B*, which is a detail of an area around *d*, Plate XXII, shows at *a* a number of similar coarse calcite crystals whose edges are very irregularly corroded as a result of replacement by fine-grained silica. However, further search reveals the fact that in a great many other large calcite crystals in thin section G 114–1, which are replaced, especially around their margins, by coarse-grained silica, the border of the coarse silica against the fine-grained silica of the matrix is much more vague and irregular than in *a*, Plate XXXII, *A*, and parts of the same specimen are replaced by fine-grained silica. One of these is illustrated in plain light and between crossed nicols at *a* in Plate XXXIII, *A*, *B* (which is an enlargement of *e*, Pl. XXII), and another at *b* in Plate XXXII, *B*. In Plate XXXIII, *A*, the area of coarse silica (*b*) can be clearly recognized, and its grain appears somewhat in Plate XXXIII, *B*. But at *c*, in Plate XXXIII, *A*, the fine-grained cloudy siliceous matrix can be seen directly in contact with the large calcite grain *a*, and in Plate XXXIII, *B*, this contact can be seen to have the same corroded character as in the grains *a* of Plate XXXII, *B*. Here, then, the same grain has been silicified in both ways.

Equally significant is grain *b*, Plate XXXII, *B*, for it shows remnants of coarse calcite and complete transition from relatively clear and coarse silica to the very fine grained silica. The central darker part, *b*, is the fine-grained silica, *d* marks the coarser-grained silica, and *c* marks patches of relatively coarse calcite grains. This evidence, together with the scarcity of coarse silicified fragments in the Ellenburger of specimen G 105, as compared with their abundance in the silicified Ellenburger of Plate XXII, indicates that the coarse-grained secondary silica of type B is epigenetic and is connected with the silicification of the body of the rock.

The evidence from the silicified fragments in specimen G 105, which are all of type A, is different. These silicified areas in cross section are not bounded by the irregular outlines of the quartz crystals as in *a*, Plate XXXII, *A*, but by a scalloped line which in three dimensions would presumably have the botryoidal form characteristic of many concretionary growths. The individual grains of this type differ from those of type B in having serrate interlocking borders as compared with the much more regular, straighter borders of type B, and in showing pronounced wavy extinction, due probably to divergent fibrous structure and to overlapping of grains. They also do not attain as great size as those of type B. The mineralogy of the two types has not been determined. Most if not all of these silicified portions of type A occur entirely within the fossil fragments that contain them. In Plate XVIII, *A*, the chert areas, most of which are marked *a*, all seem to lie within the granular nuclei, which, as shown above, undoubtedly represent remains of organisms. There is no doubt that the main body at *d*, Plate XII, is within such a granular nucleus but a little doubt about the extension to the right. In *C* and *D*, Plate XXXI, two enlargements of *a*, thin section G 114–6, Plate XXVII, the chert areas, most of which are marked *b*, are clearly all within the organic fragment. If silicified rock of this type had been formed epigenetically by circulating waters it seems much more likely that the silica would spread inward from the outside, as in type B. Of the three examples shown that of Plate XXXI, *C* and *D*, is the only one that occurs in a partly silicified matrix, but there the silicification in the immediate neighborhood is slight, and the silicified rock does not come into direct contact with fragment *a*. If, as was indicated above, the calcite cement of the pellet layers in the Ellenburger is syngenetic, it is particularly difficult to conceive of silicifying waters reaching individual elements without affecting the surrounding rock. It seems probable, therefore, that coarse silicification of type A took place at the time of deposition. It is significant that all the fragments in which silicification of this type has been noted except *c*, Plate XI, *A*, have the characteristics of echinoderm fragments. It seems probable that to the open-mesh structure of this material is due the development of syngenetic silica in it. Within this meshwork conditions would be more stagnant than in the water surrounding the fragments, and decaying organic matter may have been present and been a factor in the precipitation of the silica. The circular outline of *c*, Plate XI, *A*, suggests that it fills a canal in some organism, where conditions would have been similar to those within the echinoderm fragments.[22]

It has been suggested above (p. 49) that the lower, more fragmented part of the limestone of Boone age, as illustrated in Plate XIV, may have been deposited more slowly and therefore been exposed longer to conditions on the ocean bottom than the fragments in the higher part as illustrated in Plate XI, *B*. This may account for the relative frequency of silicification of type A in the lower part and its absence, as far as I could find, in thin section G 105–E, Plate XI, *B*.

If this interpretation of the coarse silica of type A is accepted it has an important bearing on the history of the zone of material between *X–X* and *Y–Y*, Plate VII. I have concluded that this material is all of Ellenburger age, not Ellenburger reworked into the base of the Mississippian. As pointed out on pages 47 and 50, however, more or less chertified fragments are much more common in the upper part of this layer, above the stylolite S–S, than in the underlying part of the Ellenburger. This feature allies it with the overlying Mississippian. But if the chert of the overlying Mississippian is syngenetic this underlying layer of Ellenburger material would also have to be of Boone age to share that character. Perhaps, then, the pellets of the topmost part of the Ellenburger material of specimen G 105 were reworked into the basal part of the Mississippian. Perhaps there was even a recognizable boundary, which has been obliterated by the stylolite S–S.

METHOD OF SILICIFICATION

Plate XXXIII, *C*, a view taken by reflected light and showing an enlarged area of thin section G 114–1 around *h* and *i*, Plate XXII, illustrates fairly well a meshwork of lines of clearer silica in the midst of finely granular silica. This meshwork is believed to represent channels along which the silicifying waters penetrated the rock of specimen G 114. It is intersected in places by long straight lines, like those at *a–a* and *b–b*, Plate XXXIII, *C*, some of which can be traced a length of 6 millimeters. Plate XXXIII, *D*, which is a detail of thin section G 114–1 around *g*, Plate XXII, illustrates these straight lines particularly well but shows little of the meshwork. In plain light the straight lines and the meshwork of lines can be seen as clear veinlets between slightly granular cloudy-looking areas. The straight lines are probably joint planes, and the surrounding meshwork lateral channels along which the silicifying solution penetrated the rock. This penetration by a multitude of minute channels accounts for the even front of the silicified area as a whole in specimen G 114, Plates XIX and XX. In fine-grained material these channels are probably more closely crowded than in coarser-grained material; hence the apparently more complete and finer-grained silicification of the Ellenburger than of the limestone of Boone age in specimen G 114.

SUMMARY

This paper falls into three distinct parts. The first deals with the petrographic characteristics of the Ellenburger and the Mississippian as they bear on the origin of the contact of the two formations. The conclusion is reached that the contact is a normal sedimentary contact. Evidence is brought out to show that the Ellenburger is a fine calcareous mud rock, of the "vaughnite" type but full of fossils, and that it was formed near marine base-level under conditions of frequent alternation of accumulation and erosion, precipitation and solution, which resulted in alternation of solid layers full of shells and of accumulations of pellets and fragments of the rock. The formation of the coarser calcite matrix of the pellets was contemporaneous with the formation of the rock.

The limestone of Boone age is shown to be an "echinoderm breccia" or "crinoidal limestone." The material of the basal part is much more fragmented than that a foot or two above the bottom. This condition also is attributed to accumulation near marine base level, where the material was exposed for some time on the bottom and fragmented probably by shell-crushing fishes. After burial of the echinoderm and other fragments secondary calcite in continuous crystallographic orientation with the fragments of echinoderm skeletons developed very irregularly around the individual fragments. Silicification of individual fragments, believed to be syngenetic, is much more common in the base of the limestone of Boone age than in the higher parts or than in most of the Ellenburger. But abundance of silicified fragments in the topmost part of the rock of Ellenburger type may

[22] Cayeux states that silicification is rare in echinoderm fragments, but finds this surprising in view of the presumably favorable conditions that I have just enumerated. Cayeux, L., Introduction à l'étude pétrographique des roches sédimentaires, p. 438, Paris, 1916.

indicate reworking of some of the pellets of that rock into the limestone of Boone age.

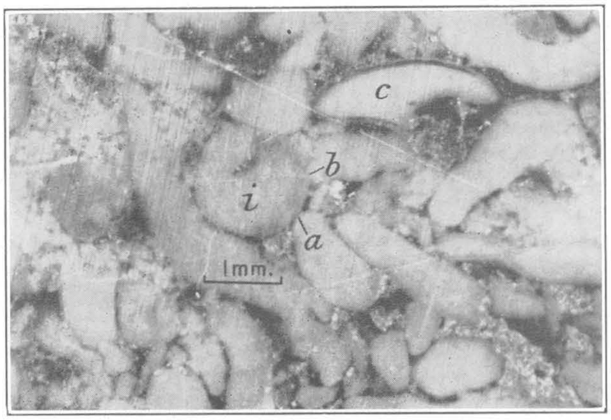
The second part of the paper deals with the details of folding, in a hand specimen, of the two types of rock at their contact. A complicated underthrust fold, which resulted in mixing of the two rocks in places but not in great shattering, is worked out by the study of polished faces and of thin sections. The fold is ascribed to a fault to which it is directly adjacent. On the basis of the presence of a sandstone of probable Barnett age in fissures in the folded rock the question of the age of the fold and the load under which it formed is discussed. Orientation of calcite crystals as a result of folding is pointed out. Special features of the limestone of Boone age in the folded rock are described.

In the third part of the paper three types of silicification are described and interpreted. A pervading fine-grained silicification which followed folding in specimen G 114 and a coarser-grained type invading the borders of large calcite crystals are considered epigenetic. A coarse-grained botryoidal type affecting the inside of organic fragments is considered probably syngenetic.

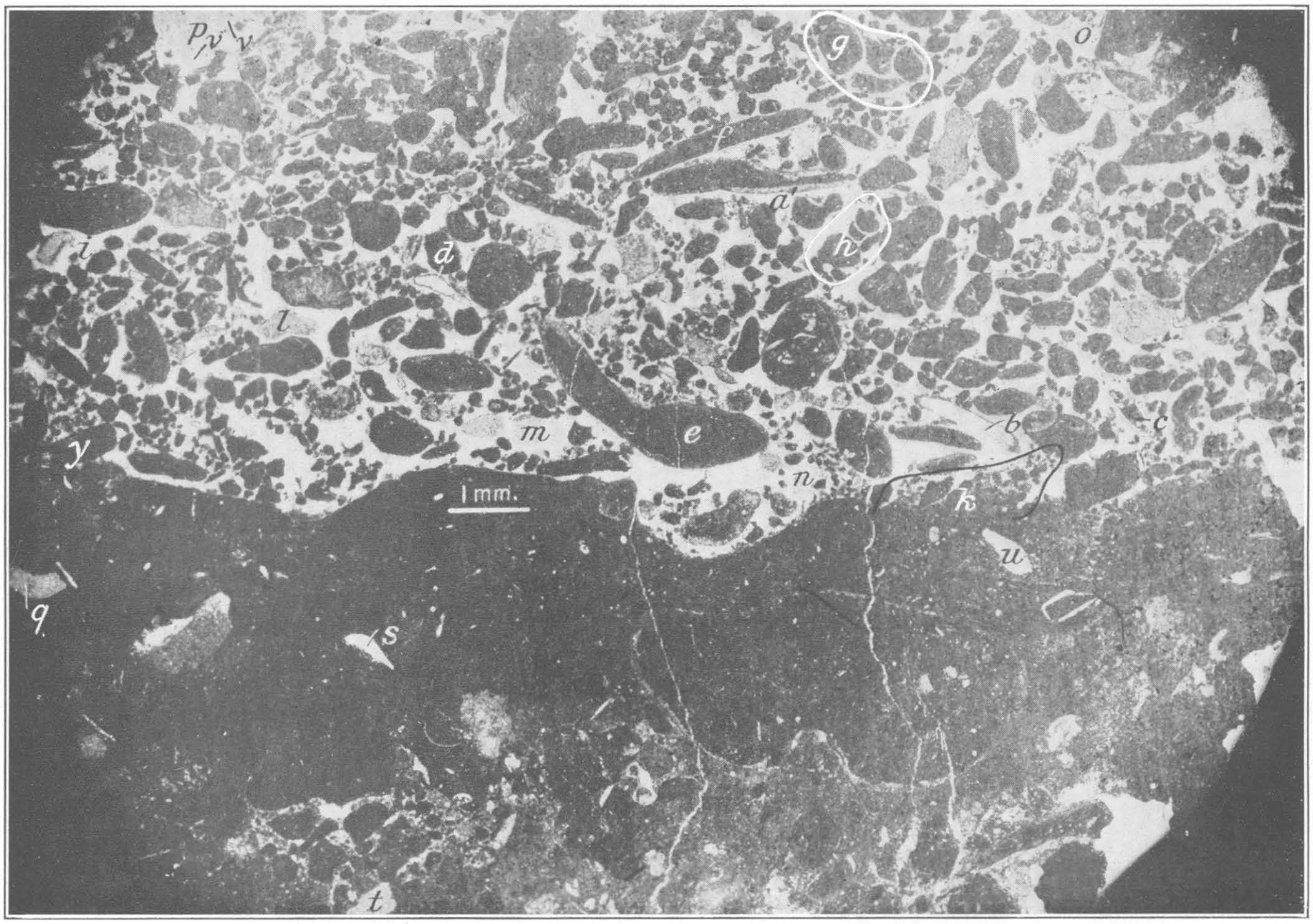
PLATES VII–XXXIII

SPECIMEN G 105: ELLENBURGER LIMESTONE AND LIMESTONE OF BOONE AGE IN CONTACT

Y-Y, Approximate base of Mississippian material. ***A, B, C, D,*** and ***F*** indicate approximate position of thin sections

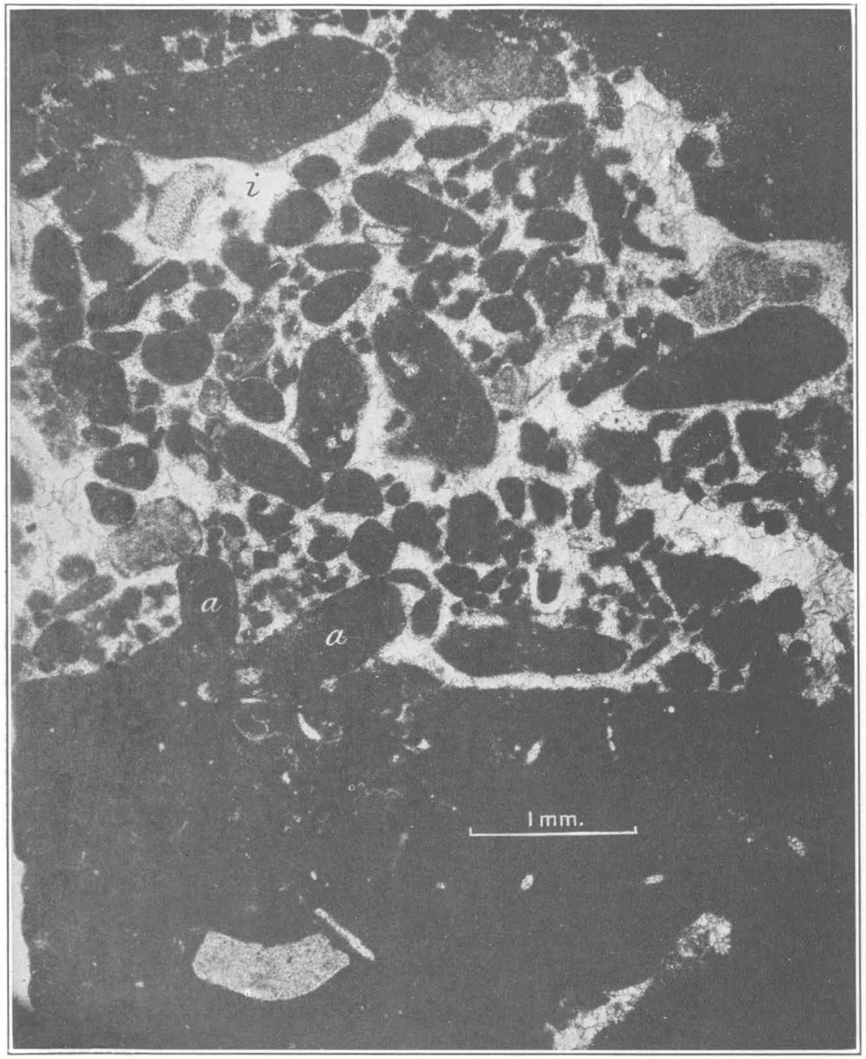


A. DETAIL OF *i*, PLATE VII, SHOWING INTERNAL CAST OF A FOSSIL IN DIRECT CONTACT WITH SURROUNDING PELLETS OF ELLENBURGER LIMESTONE

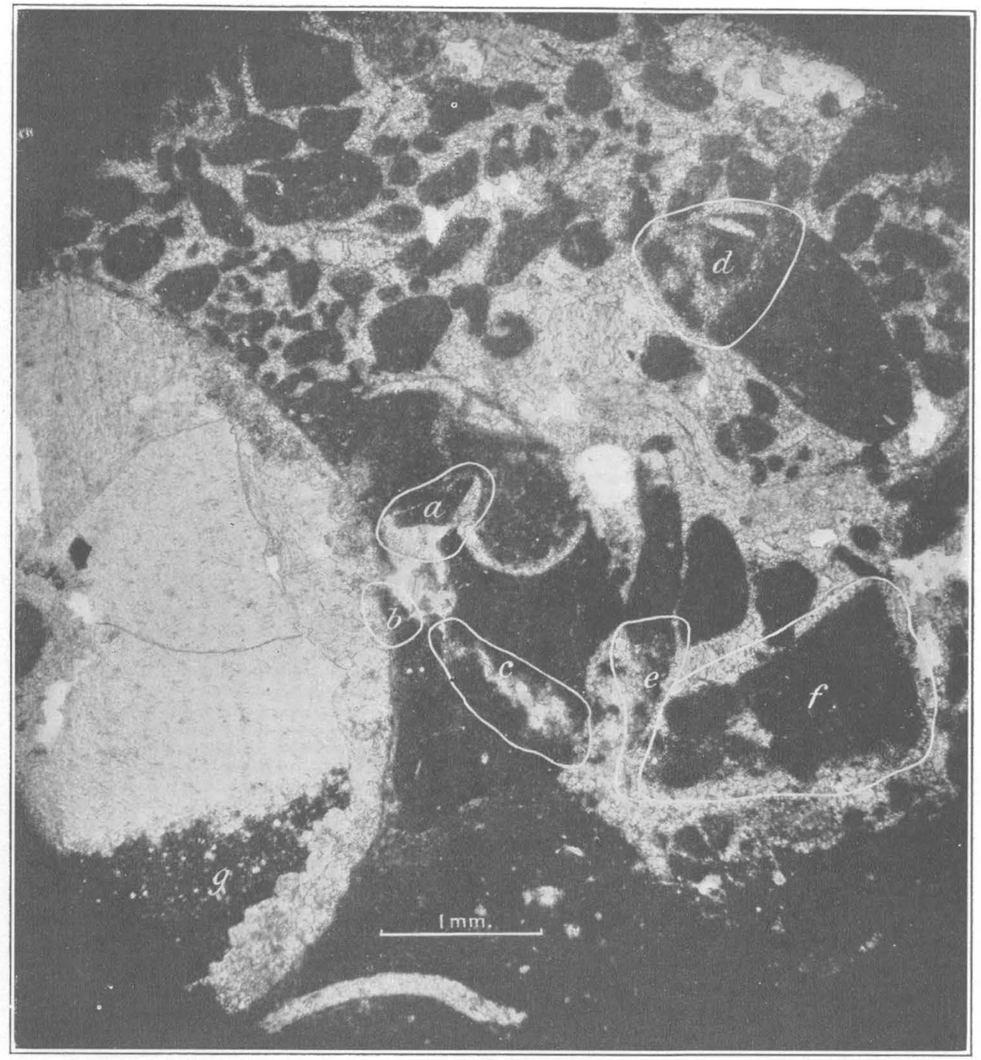


B. THIN SECTION OF THE UPPER PART OF THE ELLENBURGER LIMESTONE CORRESPONDING ABOUT TO THE POSITION OF *B*, PLATE VII

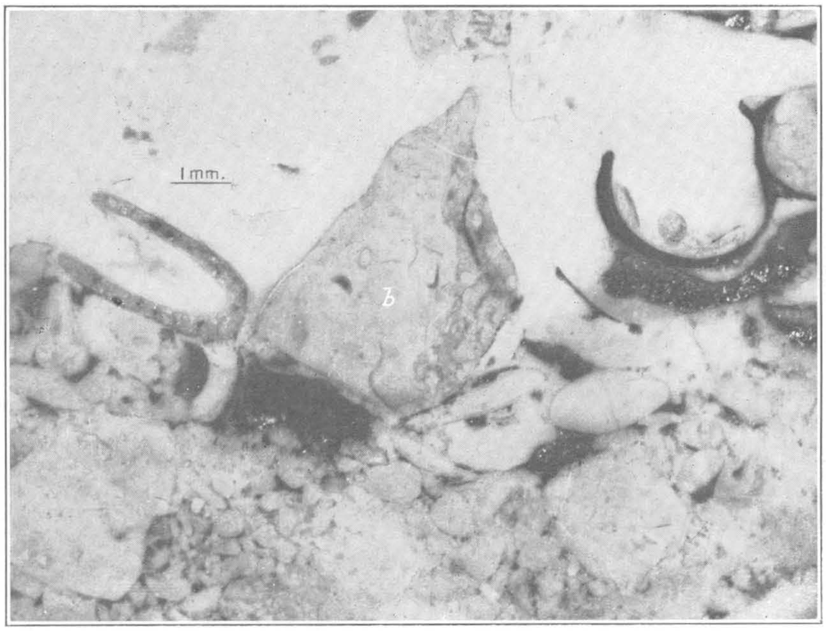
Shows a pellet layer and a solid layer



A. DETAIL OF *y*, PLATE VIII, *B*, SHOWING PELLETS PARTLY EMBEDDED IN THE UNDERLYING SOLID LAYER

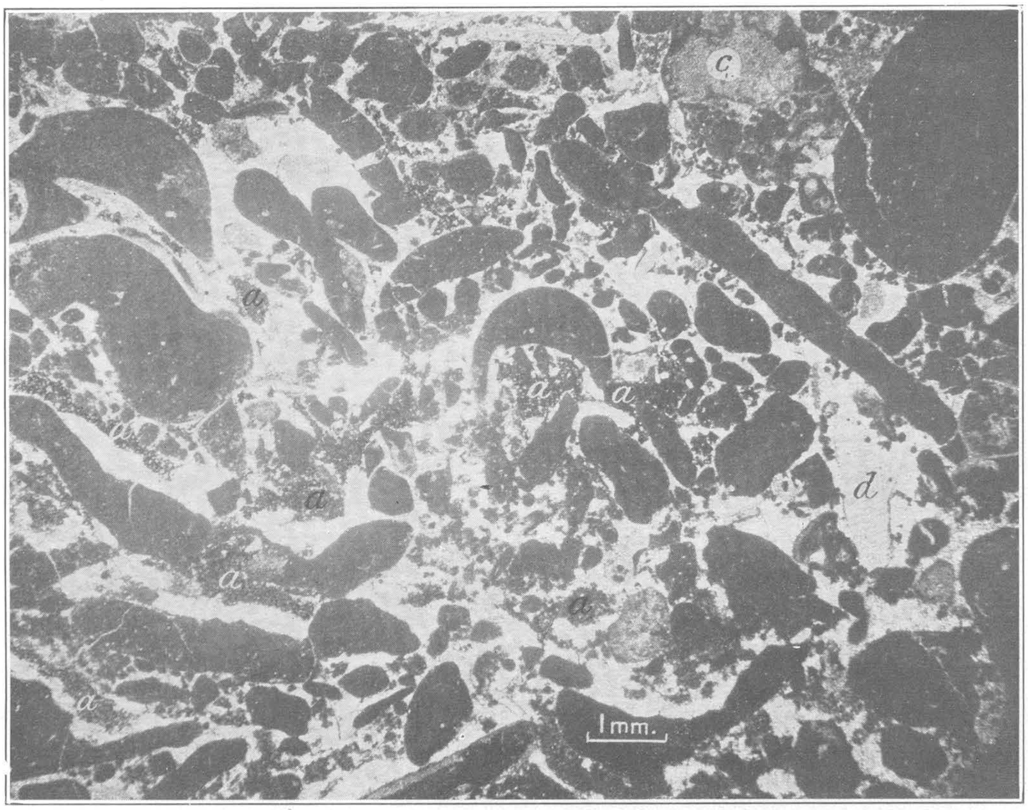


B. DETAIL OF THIN SECTION CORRESPONDING ABOUT TO AREA *C*, PLATE VII, SHOWING PARTIAL DISINTEGRATION OF ELLENBURGER PELLETS



A. DETAIL OF *b*, PLATE VII, SHOWING AN ANGULAR FRAGMENT OF ELLENBURGER LIMESTONE INCLOSED IN A LATER LAYER OF THE ELLENBURGER

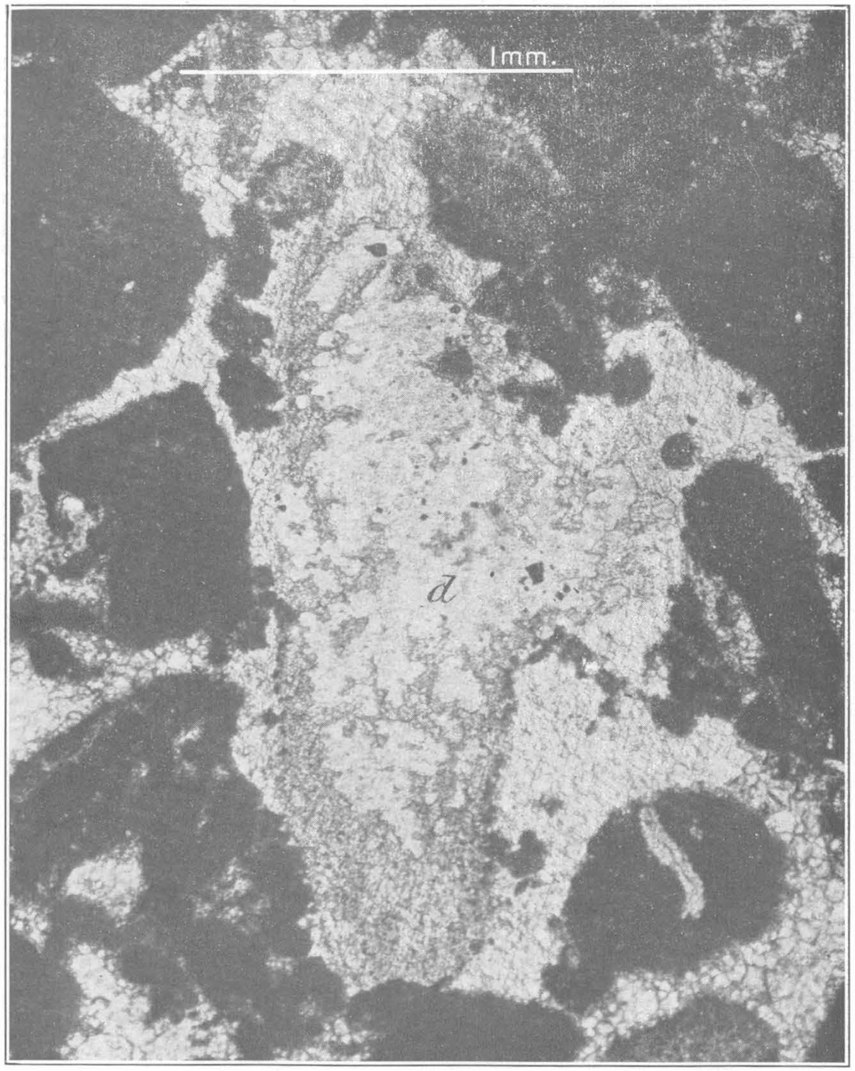
B. DETAIL OF *k* AND *l*, PLATE VII, SHOWING ROUNDED PEBBLE COMPOSED OF ELLENBURGER PELLETS INCLOSED IN A LATER LAYER OF THE ELLENBURGER AND FISSURE CONTAINING GRANULAR YELLOW CARBONATE



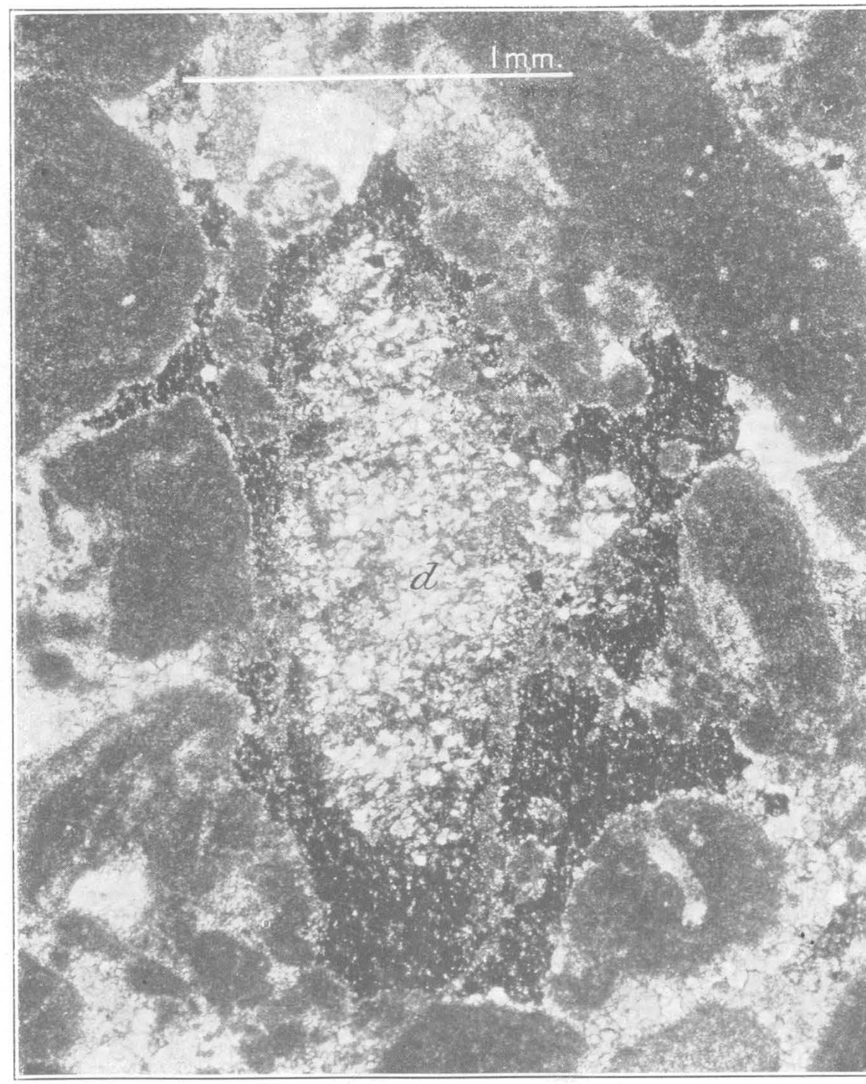
A. THIN SECTION OF ELLENBURGER LIMESTONE CORRESPONDING TO POSITION *F*, PLATE VII, SHOWING ESPECIALLY THE DISTRIBUTION OF YELLOW GRANULAR CALCITE AND PARTLY SILICIFIED FRAGMENTS OF ELLENBURGER

B. THIN SECTION OF TYPICAL LIMESTONE OF BOONE AGE, FULL OF LARGE FOSSIL FRAGMENTS

Specimen taken about 1 foot above the base



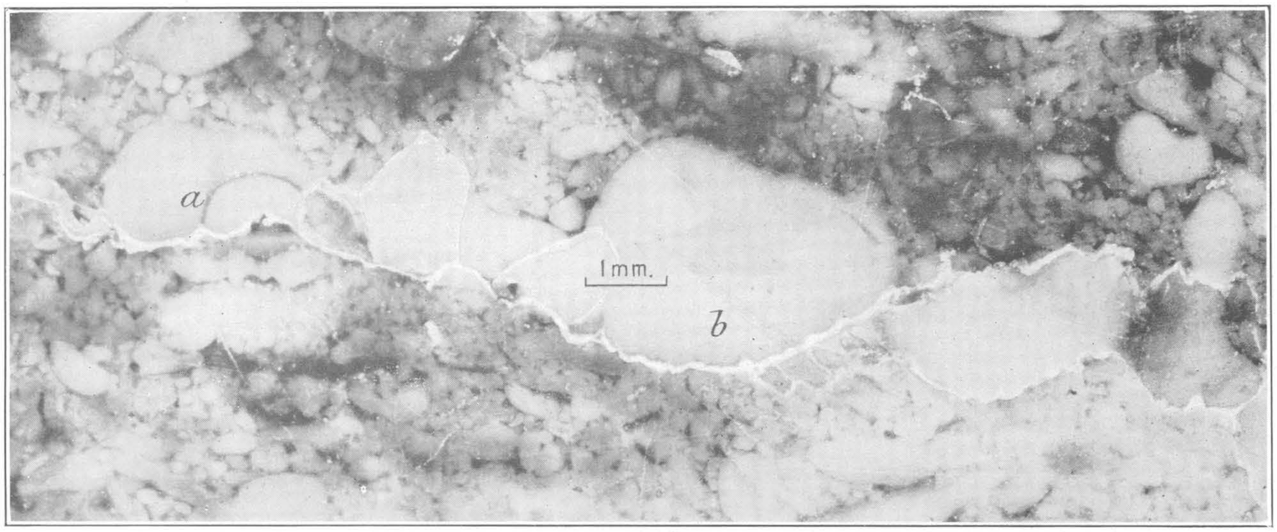
A



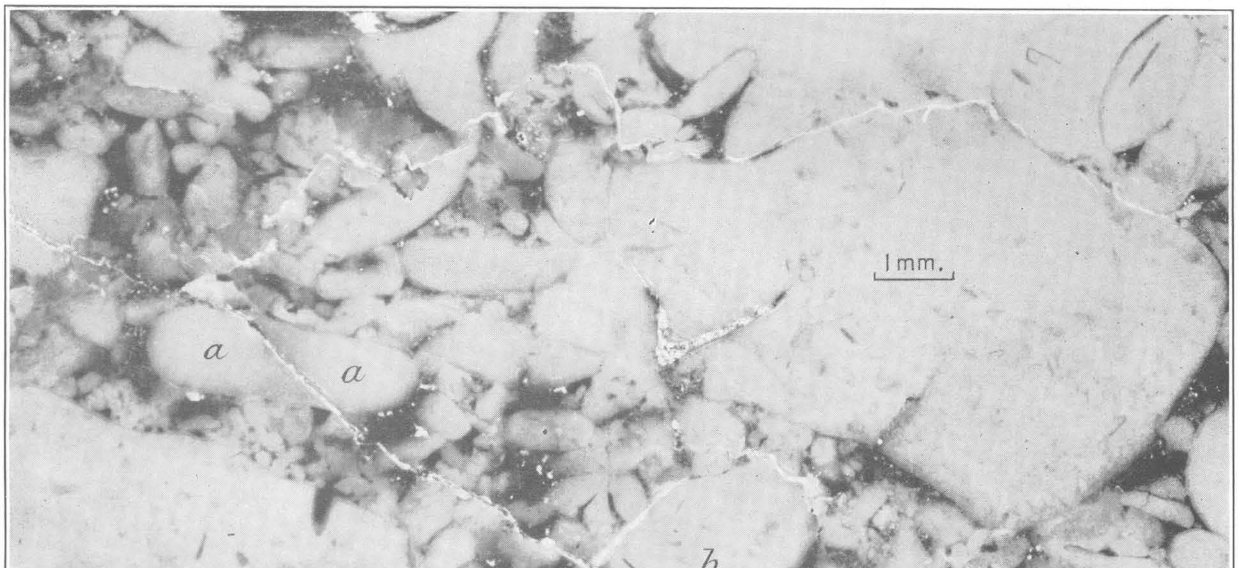
B

DETAIL OF PLATE XI, *A*, SHOWING A PARTLY SILICIFIED FRAGMENT IN THE ELLENBURGER LIMESTONE

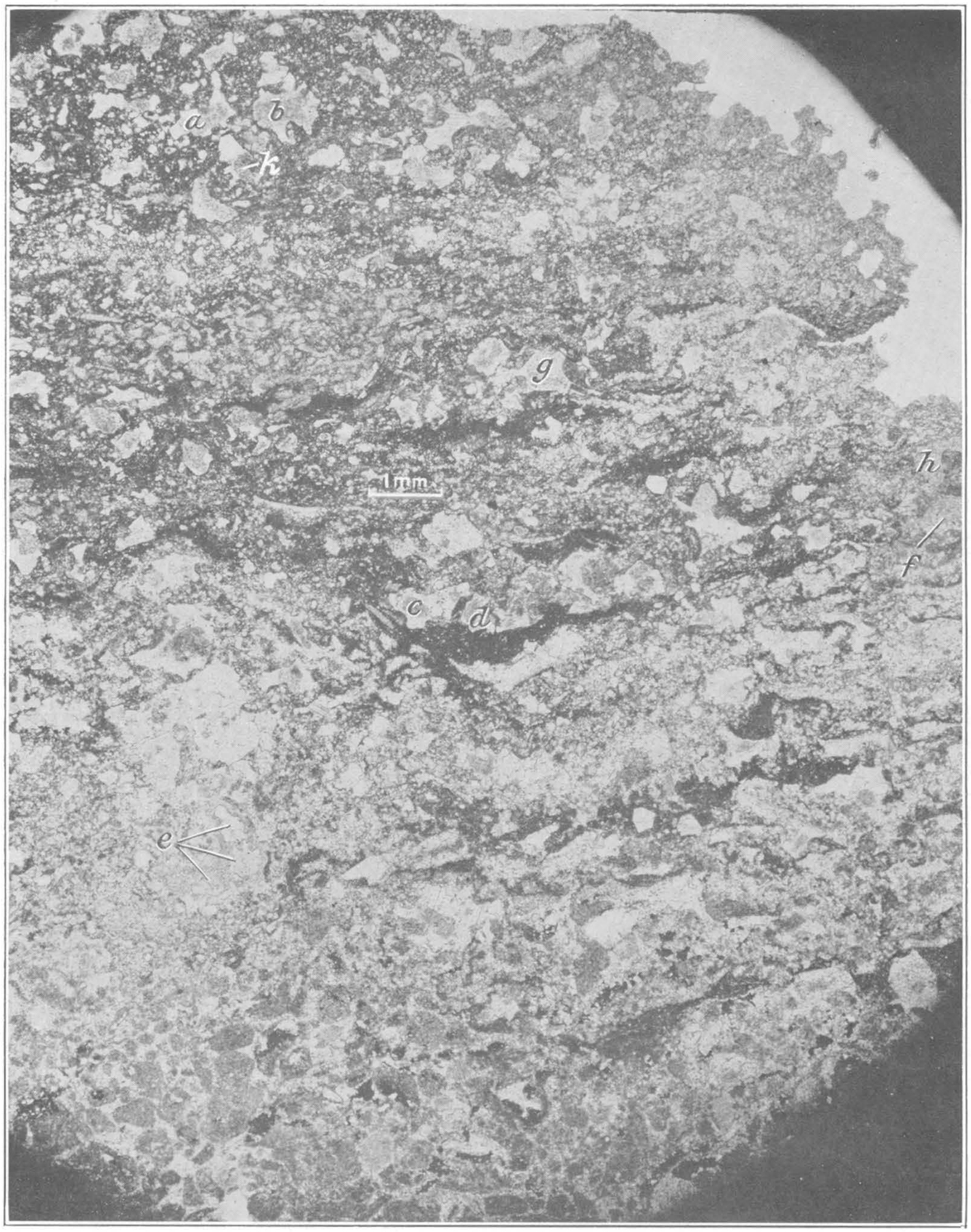
A, Plain light; *B*, between crossed nicols



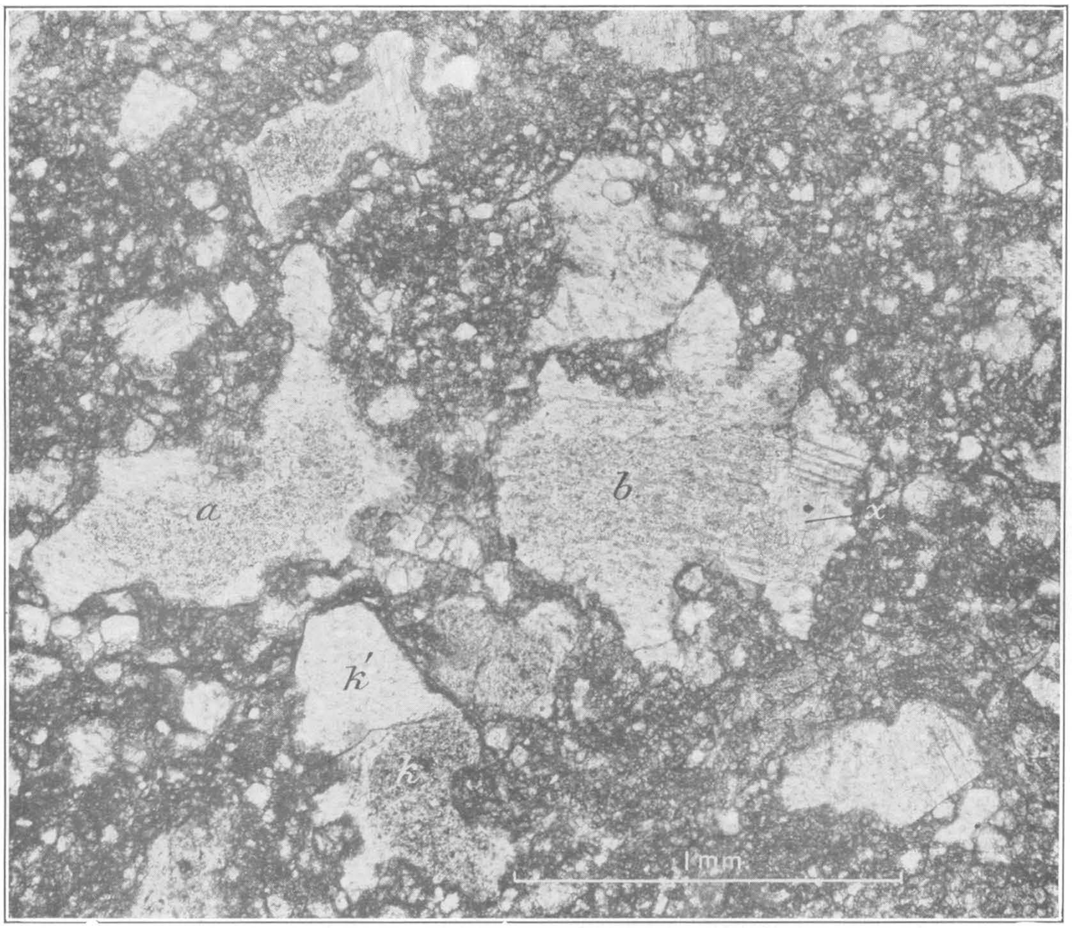
A. DETAIL AROUND *r*, PLATE VII, SHOWING APPRECIABLE MOVEMENT ALONG STYLOLITE *S–S*



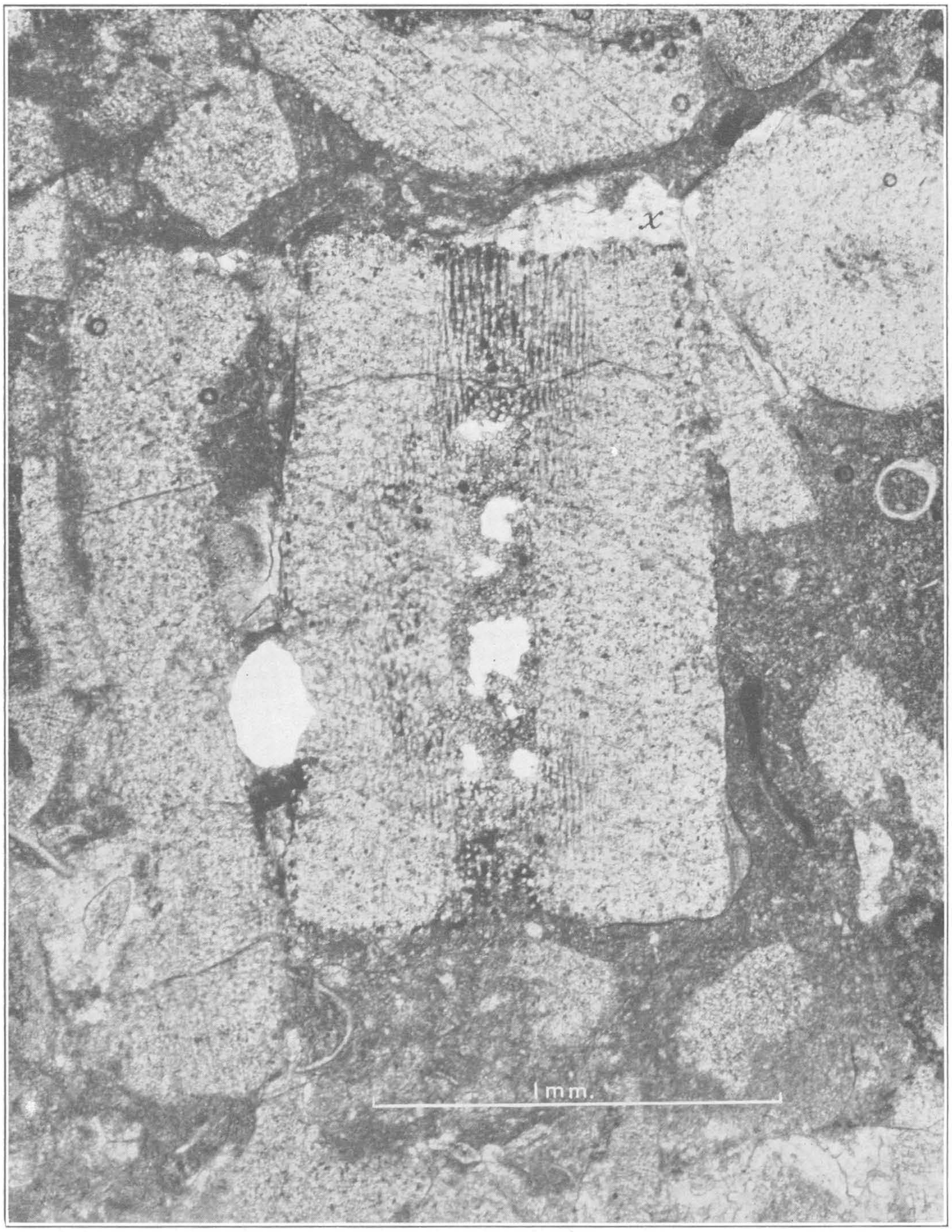
B. DETAIL ALONG STYLOLITE *S′–S′*, PLATE VII, SHOWING LITTLE MOVEMENT ALONG THE STYLOLITE



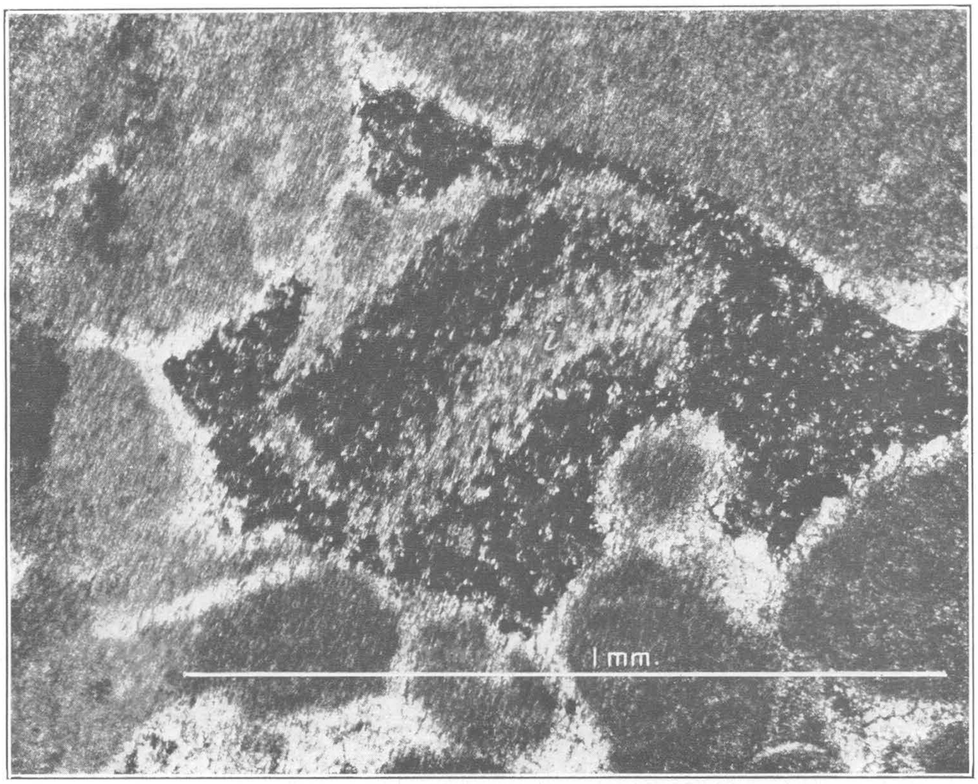
GENERAL VIEW OF THIN SECTION G 105-D, SHOWING CONTACT OF ELLENBURGER MATERIAL AND BASAL MATERIAL OF BOONE AGE



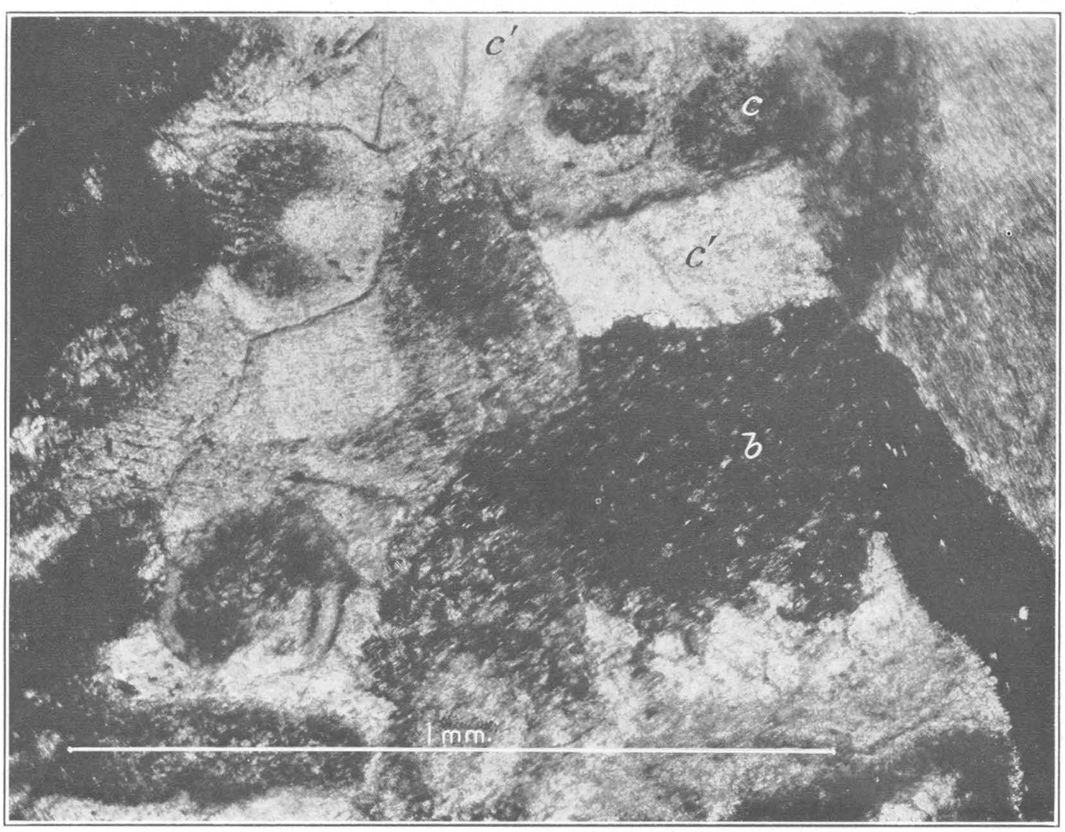
DETAIL OF IRREGULAR CALCITE FRAGMENTS IN PLATE XIV



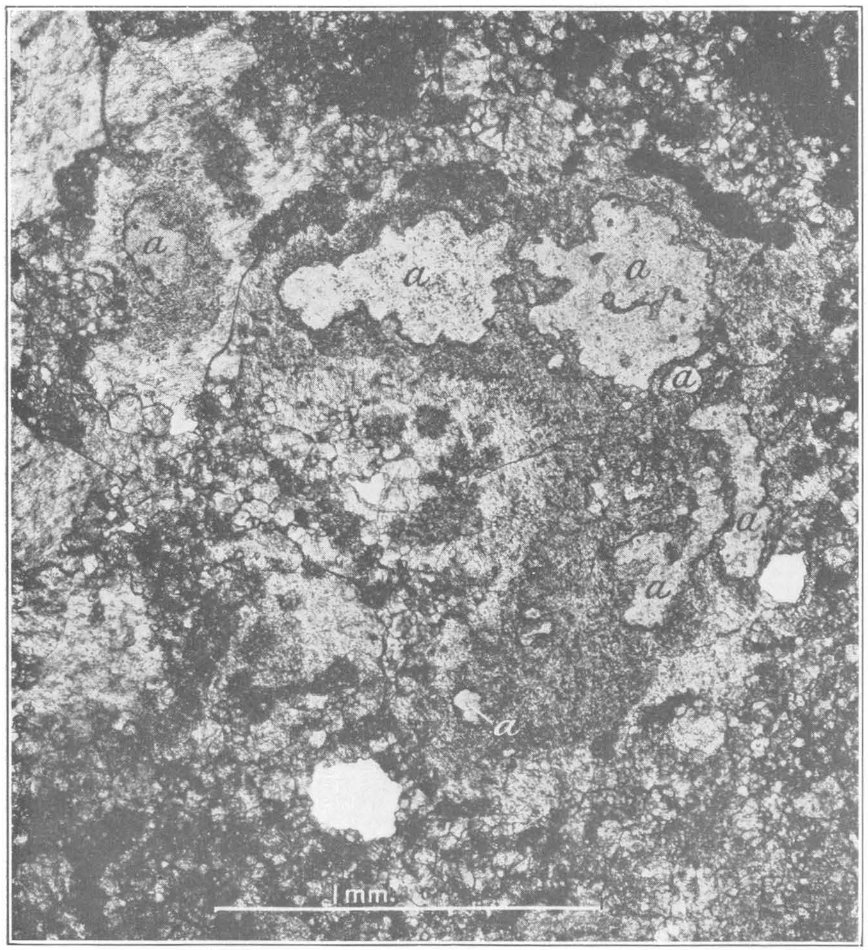
ENLARGEMENT OF ECHINODERM FRAGMENT FROM PLATE XI, *B*



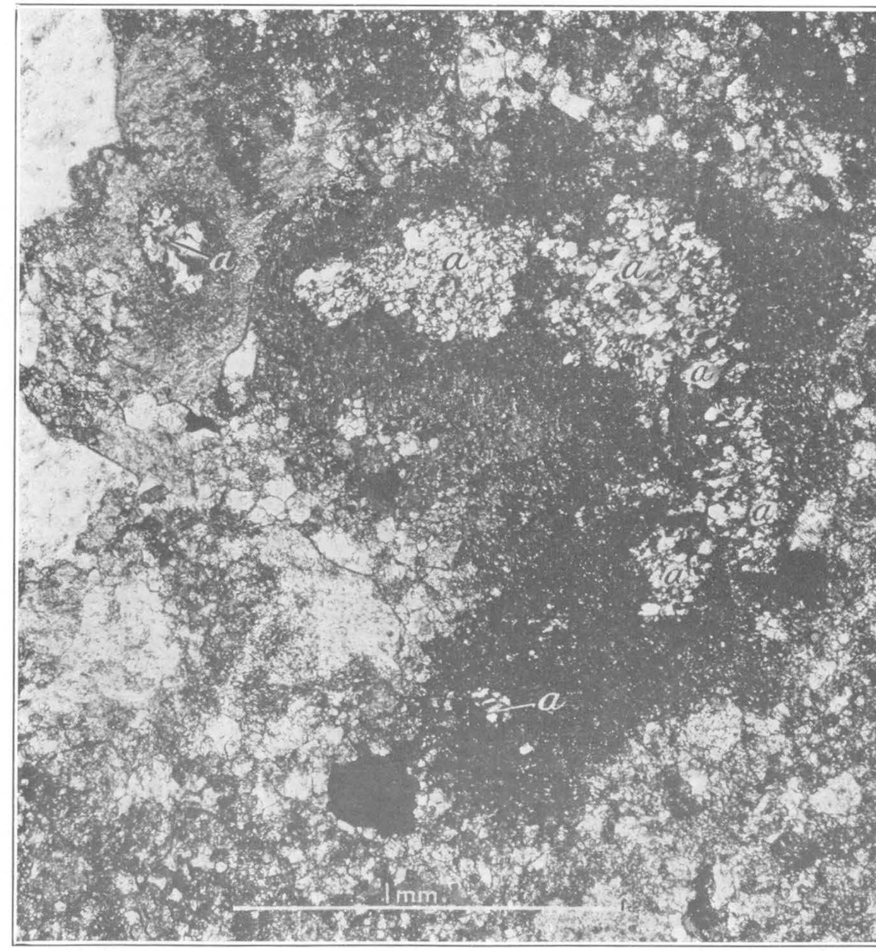
A. DETAIL OF PLATES VIII, *B*, AND IX, *A*, SHOWING SECONDARY GROWTH OF CALCITE AROUND A FOSSIL FRAGMENT IN THE ELLENBURGER



B. DETAIL OF PLATE XI, *B*, SHOWING SECONDARY GROWTH OF CALCITE AROUND FOSSIL FRAGMENTS IN THE LIMESTONE OF BOONE AGE



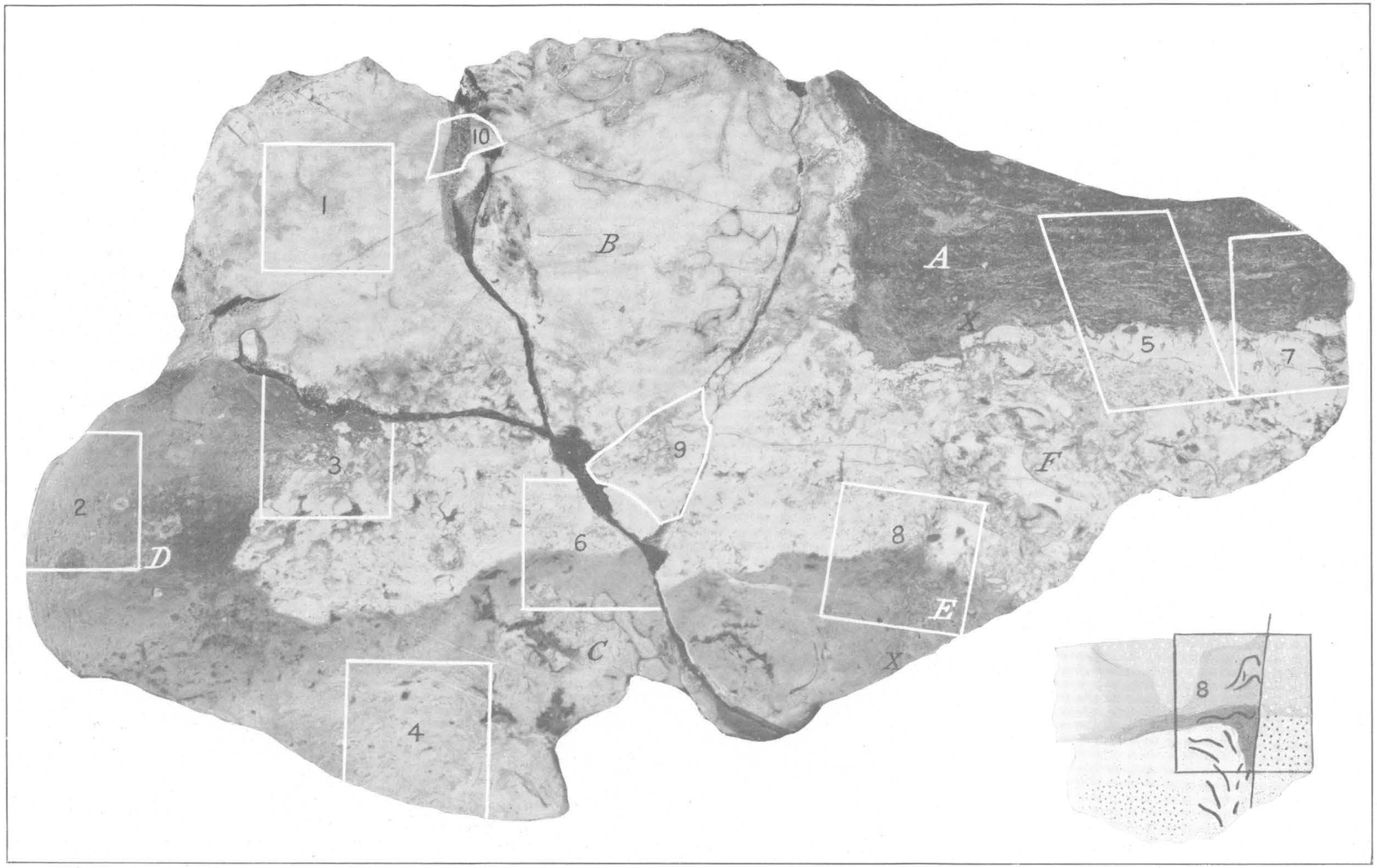
A



B

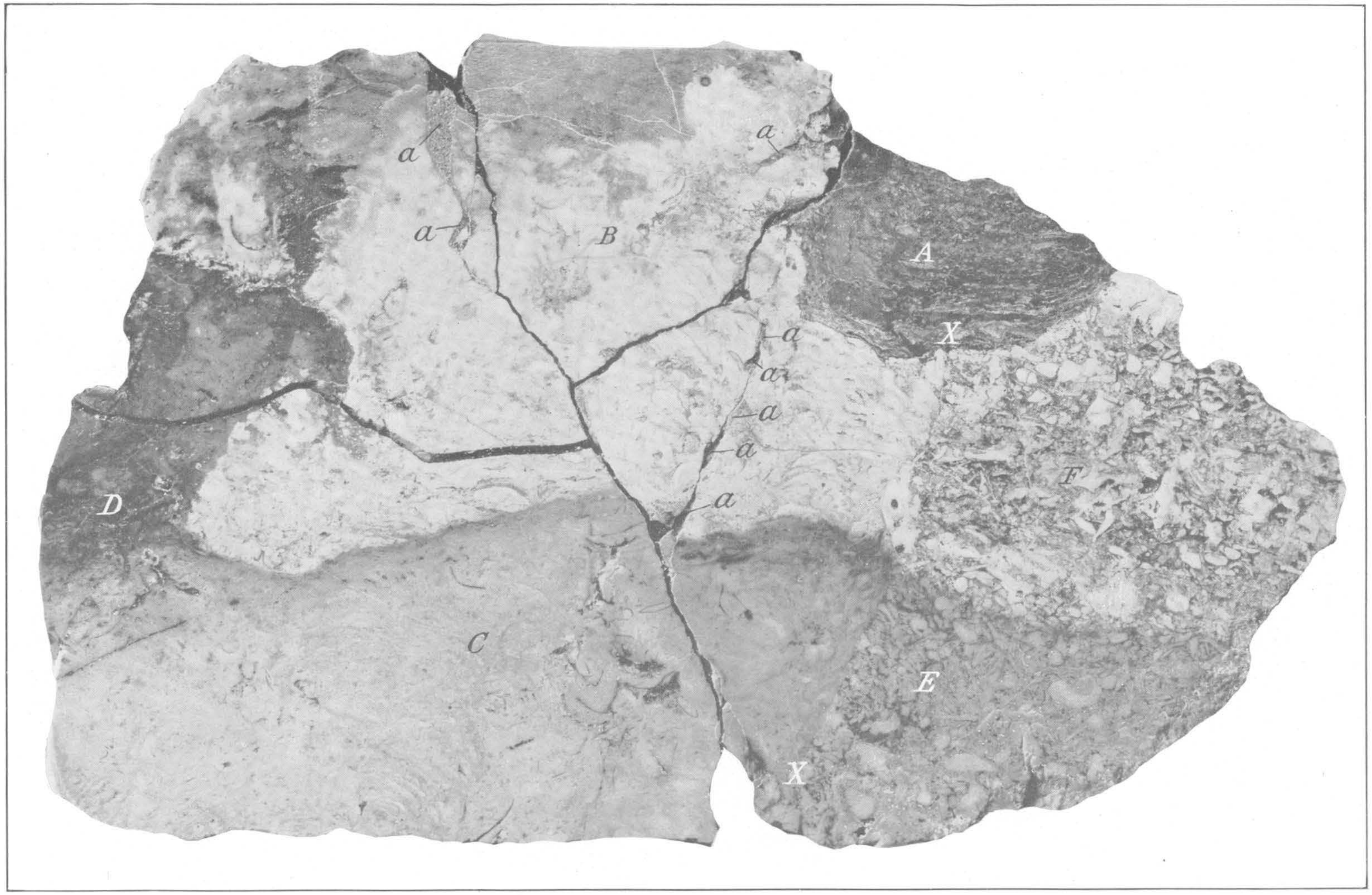
DETAIL OF PLATE XIV, SHOWING A SILICIFIED FOSSIL FRAGMENT FROM THE LIMESTONE OF BOONE AGE

A, Plain light; *B*, between crossed nicols

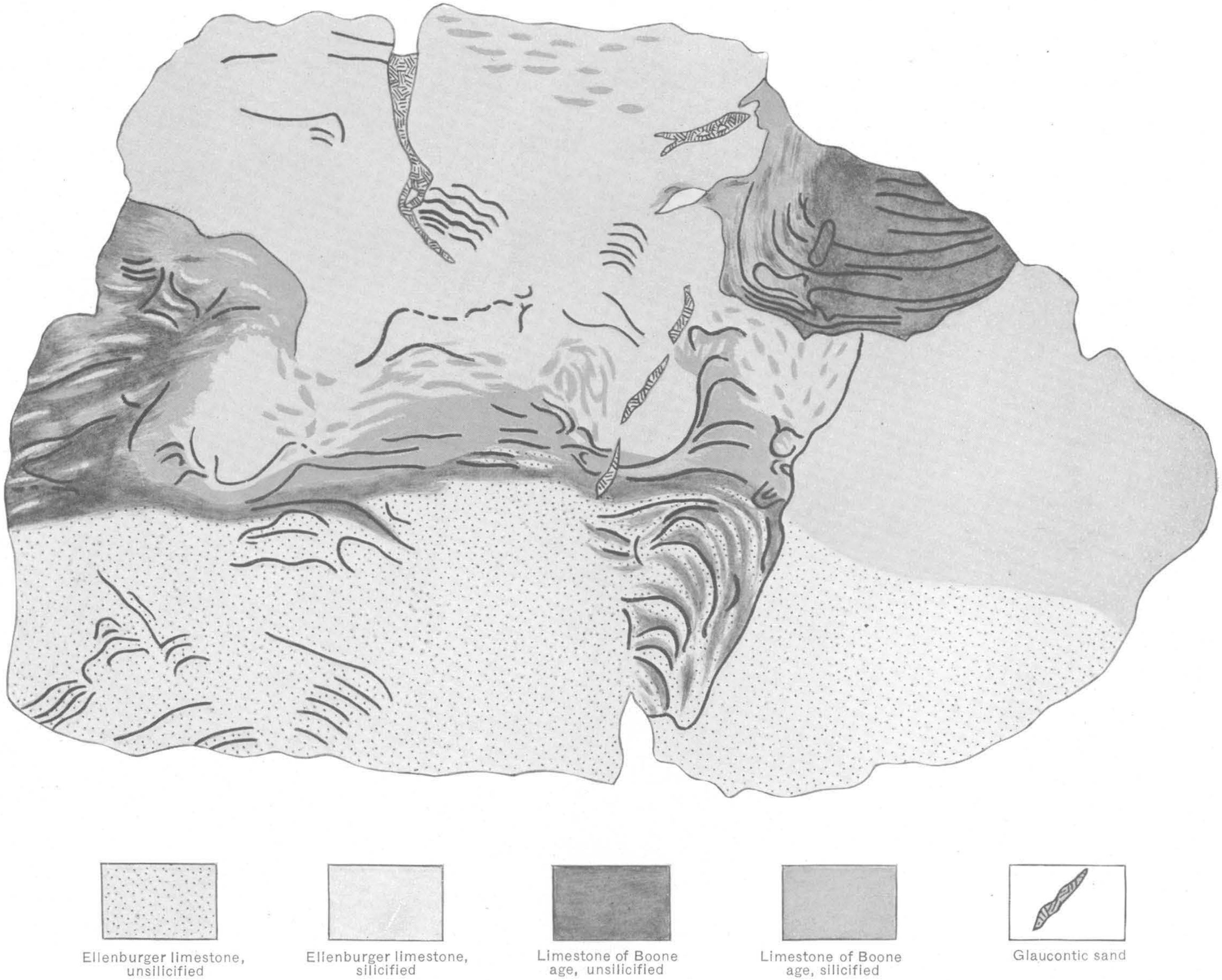


POLISHED FACE OF SPECIMEN G 114-I, SHOWING FOLDED AND SILICIFIED ELLENBURGER LIMESTONE AND LIMESTONE OF BOONE AGE, WITH GENERALIZED DIAGRAM OF THE DISTRIBUTION OF TYPES OF ROCK IN AREA 8 AND ADJACENT PARTS OF THE POLISHED FACE

For explanation see Plate XXI



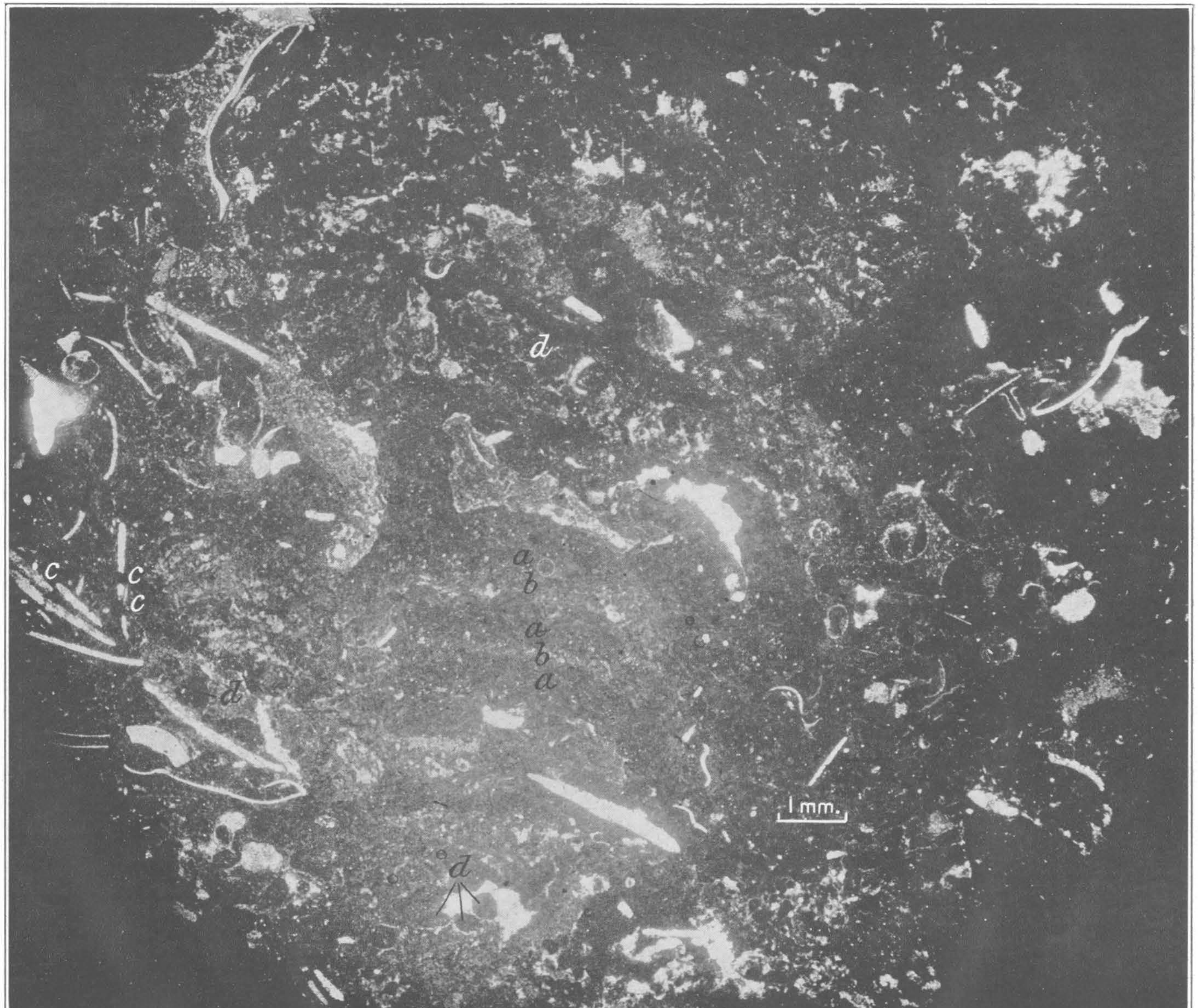
SPECIMEN G 114-II, SHOWING A POLISHED SURFACE ABOUT 2.5 CENTIMETERS BELOW THAT OF PLATE XIX



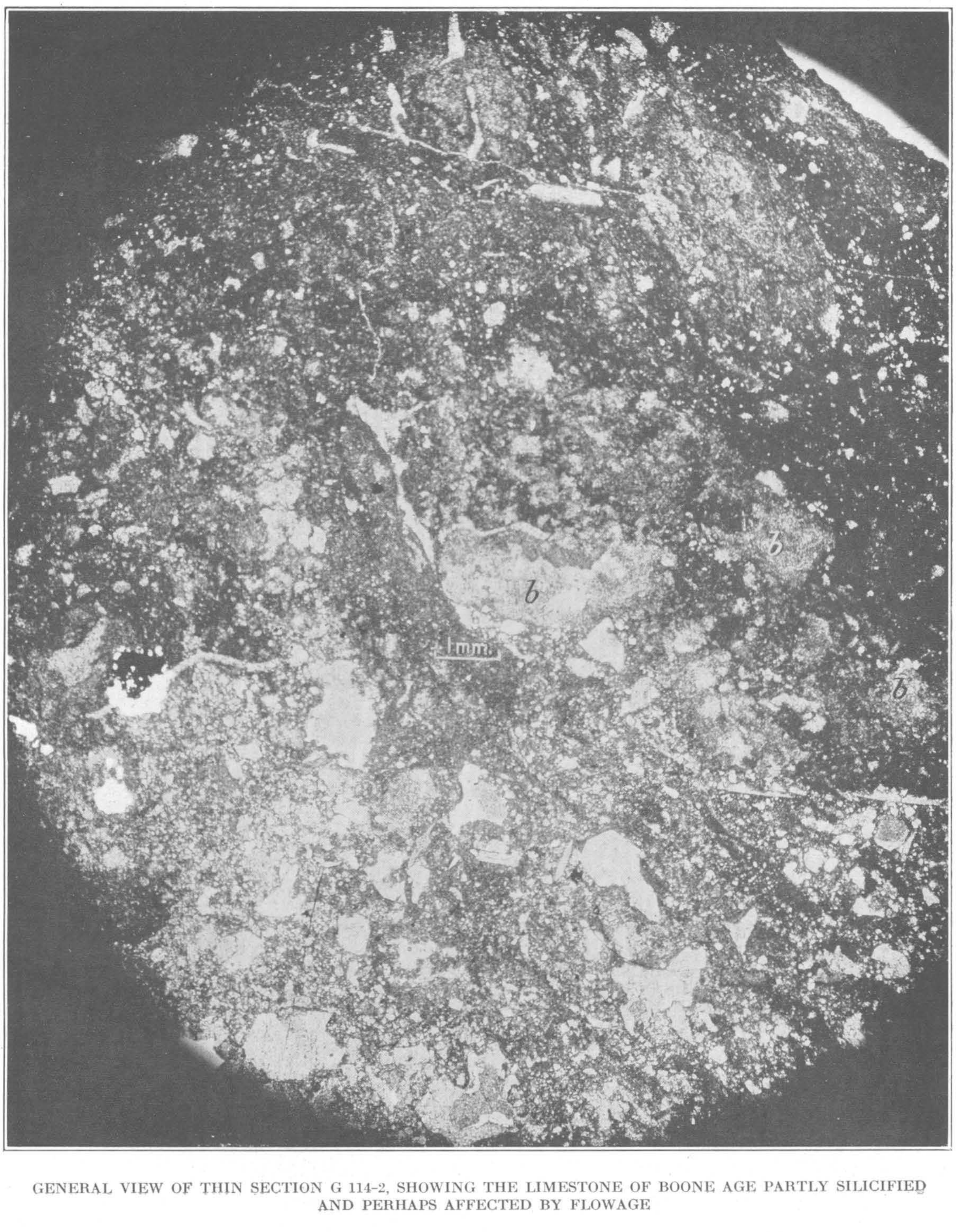
DIAGRAMMATIC ILLUSTRATION OF FLOW LINES AND OF THE DISTRIBUTION OF THE FIVE DIFFERENT KINDS OF ROCK IN SPECIMEN G 114-II, SHOWN IN PLATE XX

GENERAL VIEW OF THIN SECTION G 114-1, SHOWING SILICIFIED ELLENBURGER LIMESTONE

GENERAL VIEW OF THIN SECTION G 114-5, SHOWING LIMESTONE OF BOONE AGE NOT MUCH DISTURBED, RESTING ON SILICIFIED AND PROBABLY FAULT-FRACTURED ELLENBURGER LIMESTONE



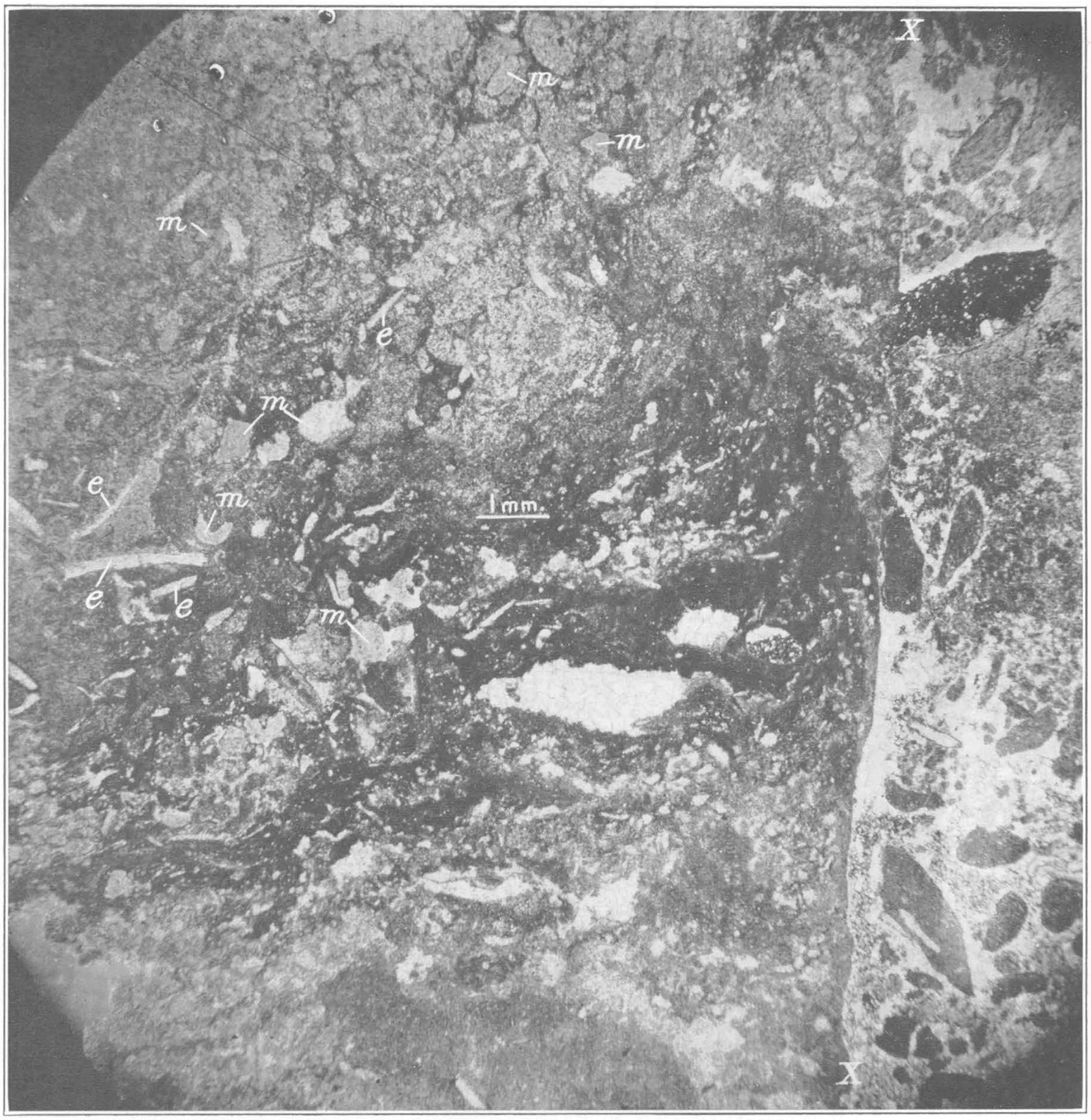
GENERAL VIEW OF THIN SECTION G 114-4, SHOWING UNSILICIFIED ELLENBURGER LIMESTONE SOMEWHAT SUBJECTED TO FLOWAGE AND TO FRACTURE



GENERAL VIEW OF THIN SECTION G 114-2, SHOWING THE LIMESTONE OF BOONE AGE PARTLY SILICIFIED AND PERHAPS AFFECTED BY FLOWAGE

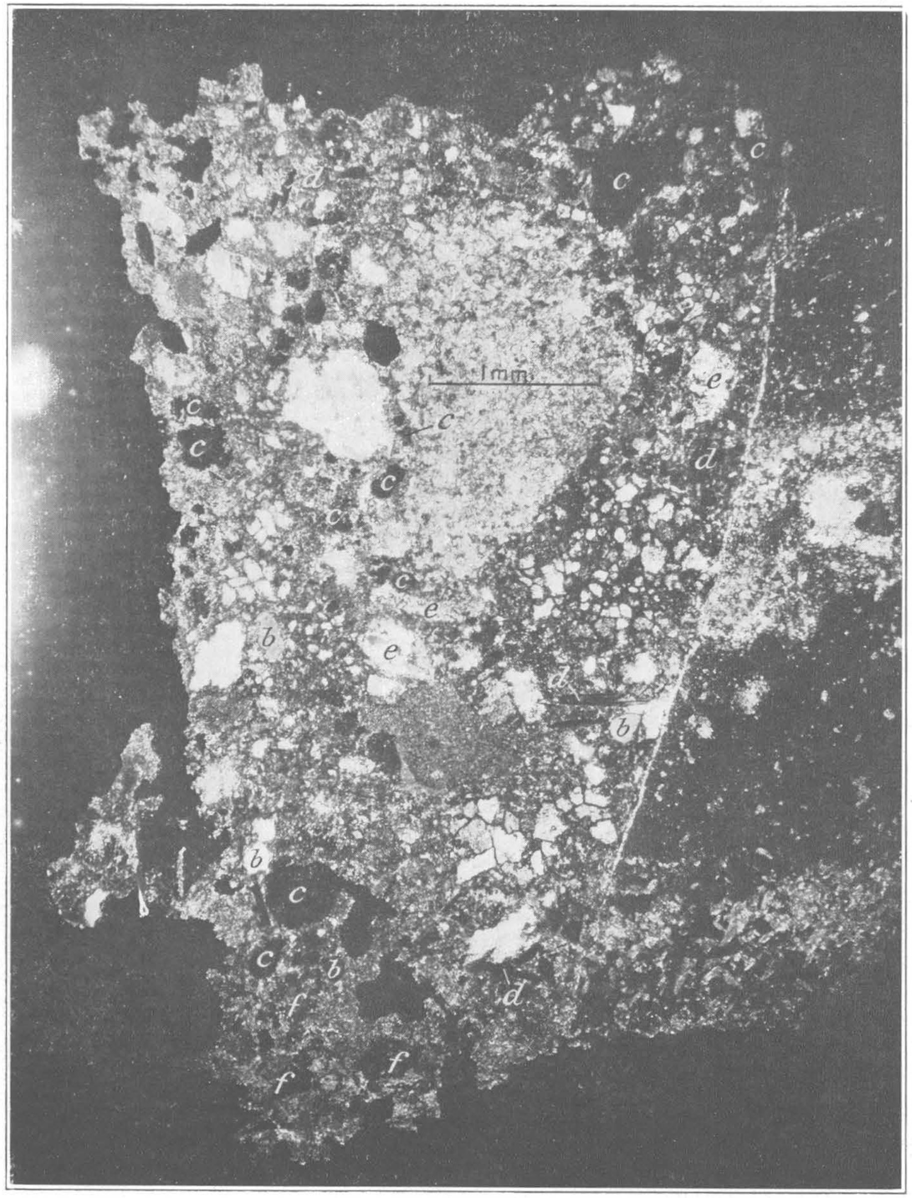
GENERAL VIEW OF THIN SECTION G 114-3, SHOWING A MIXTURE OF ELLENBURGER LIMESTONE AND LIMESTONE OF BOONE AGE PARTLY SILICIFIED

GENERAL VIEW OF THIN SECTION G 114-6, SHOWING ELLENBURGER LIMESTONE AND LIMESTONE OF BOONE AGE MIXED AND SHATTERED BY FLOWAGE AND PARTLY SILICIFIED



GENERAL VIEW OF THIN SECTION G 114-8, SHOWING ELLENBURGER LIMESTONE AND LIMESTONE OF BOONE AGE MIXED AND SHATTERED BY FLOWAGE AGAINST THE FAULT LINE *X-X*, PLATE XIX

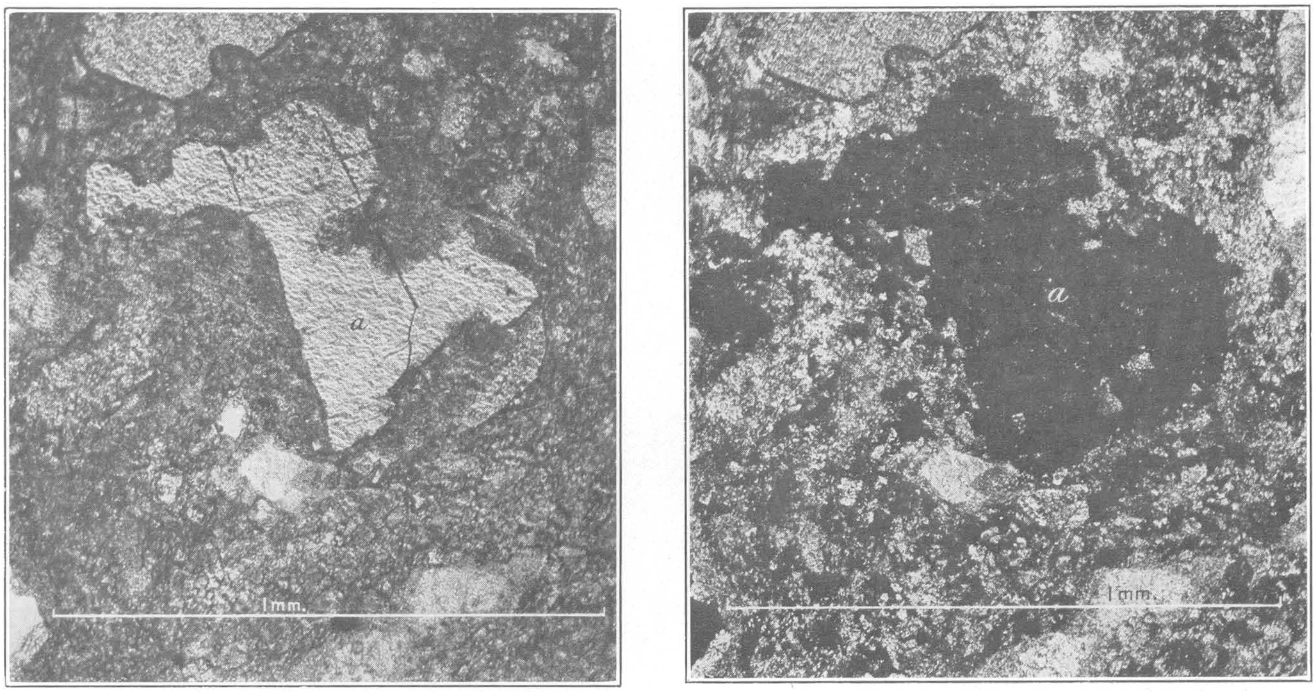
A



B

GENERAL VIEW OF THE GLAUCONITIC AND PHOSPHATIC SAND OF THIN SECTION G 114-10, WITH SOME OF THE WALL ROCK OF SILICIFIED ELLENBURGER LIMESTONE

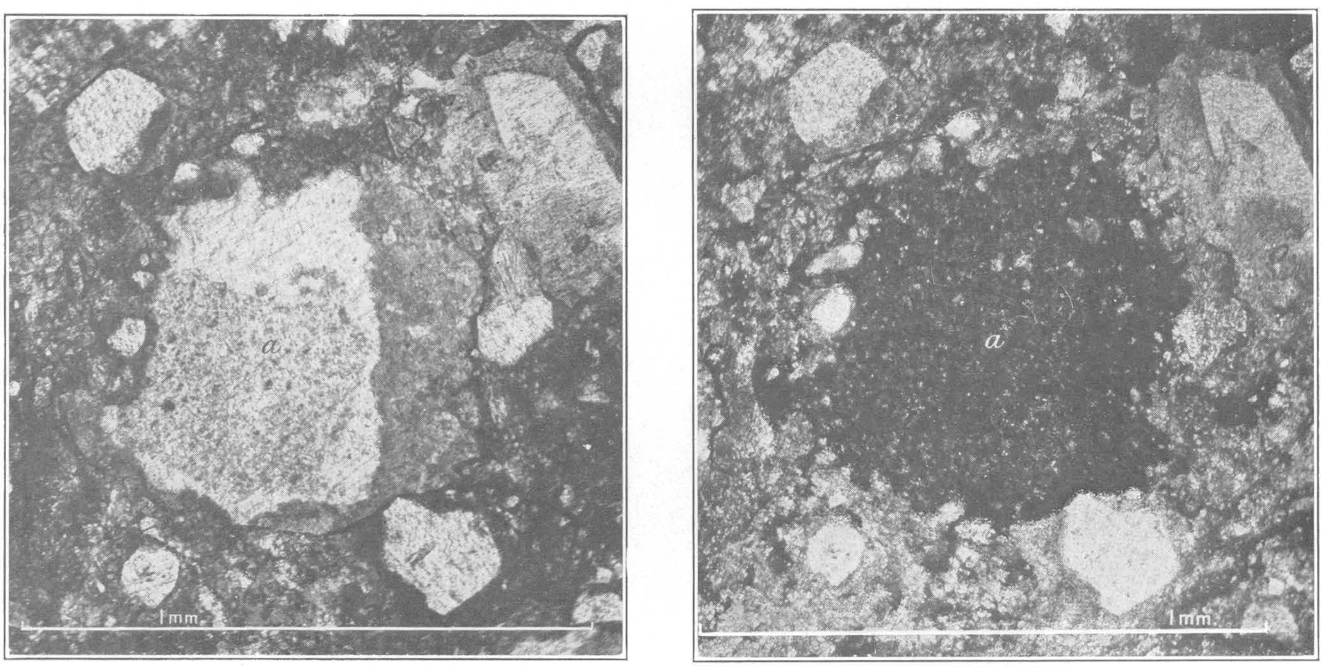
A. Plain light; *B*, between crossed nicols



A *B*

DETAIL OF PLATE XXIII, SHOWING CALCITE CRYSTAL WITH CLOUDY GRANULAR RIM AND VERY IRREGULAR CLEAR CENTER

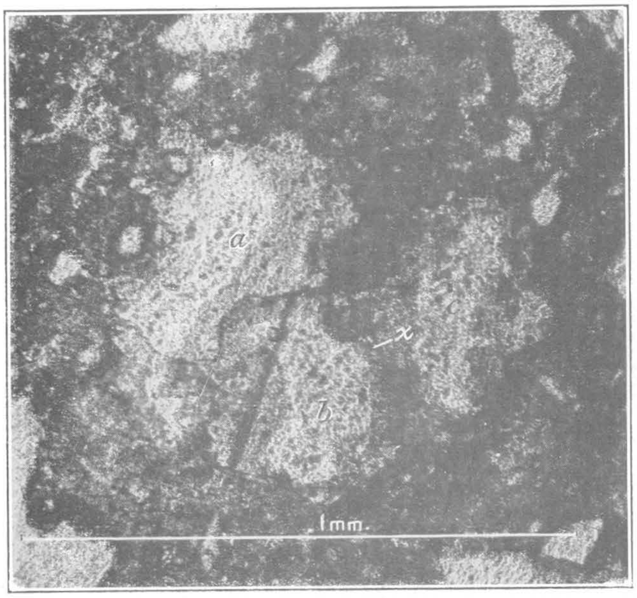
A, Plain light; *B*, between crossed nicols, showing the inclusion of the calcite matrix in the envelope of granular cloudy calcite



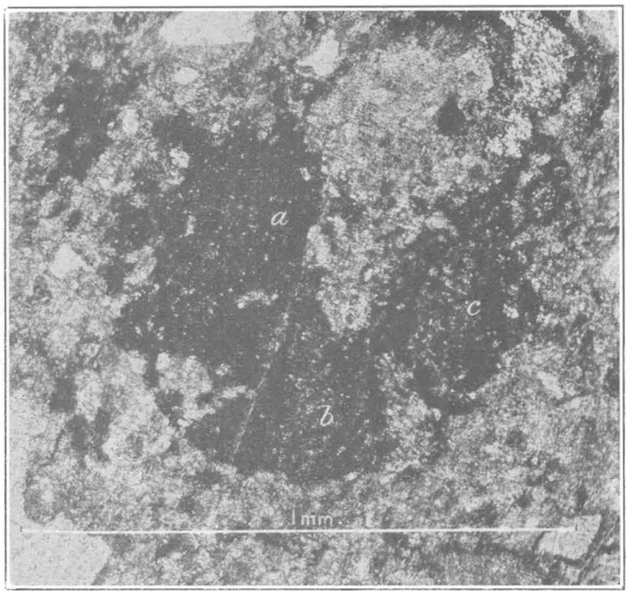
C *D*

DETAIL SIMILAR TO *A* BUT WITH A MORE REGULAR CLEAR NUCLEUS

C, Plain light; *D*, between crossed nicols



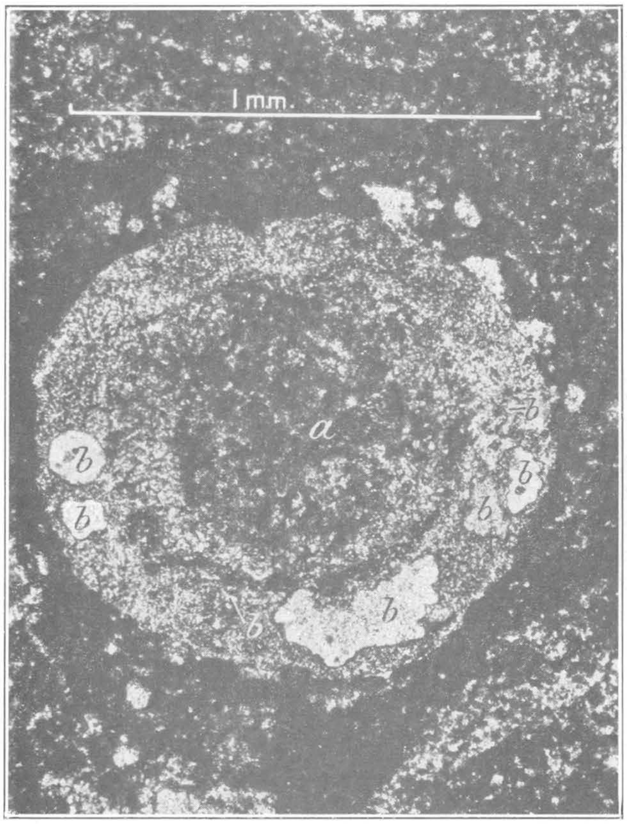
A



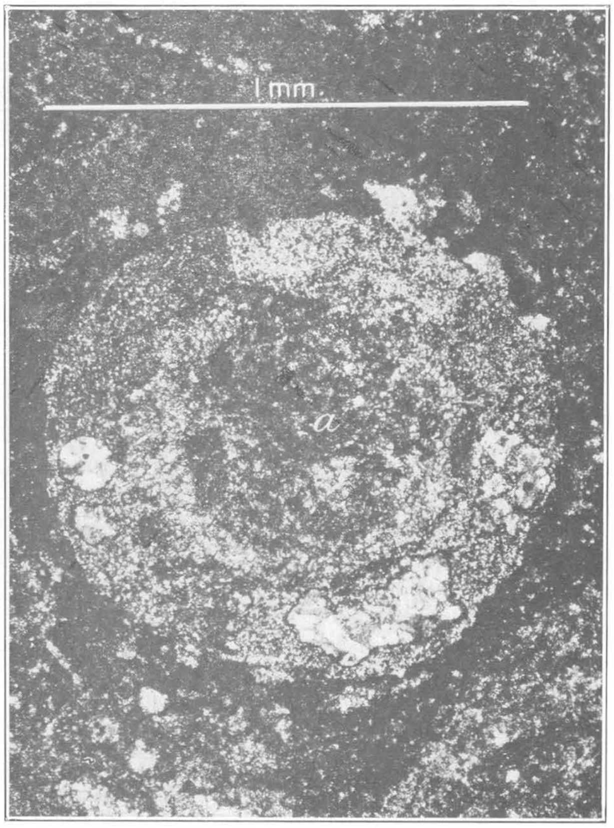
B

DETAIL OF PLATE XXIII, SIMILAR TO PLATE XXX BUT SHOWING THREE GRAINS IN CONTACT

A, Plain light; *B*, between crossed nicols



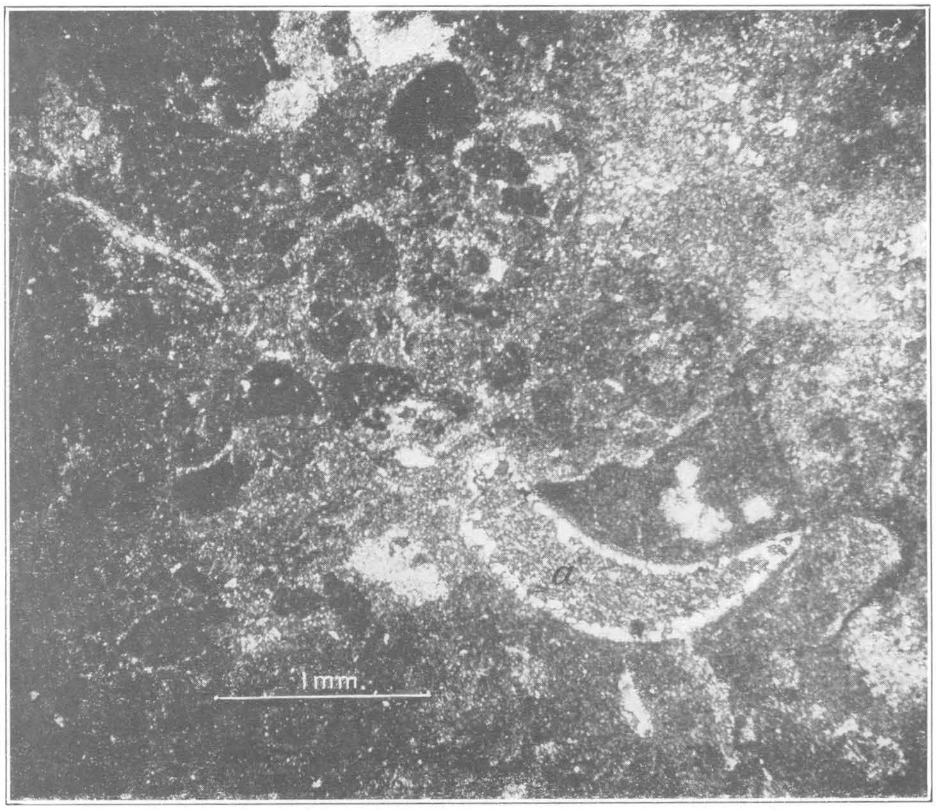
C



D

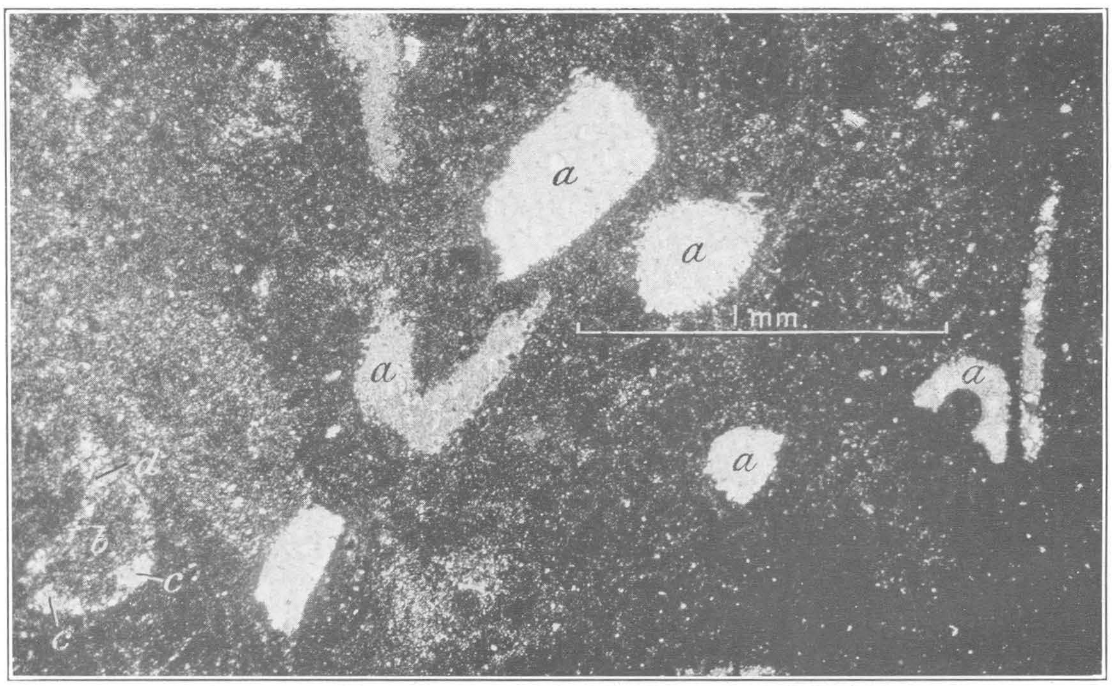
ENLARGEMENT OF *a*, PLATE XXVII, SHOWING AN ORGANIC FRAGMENT PARTLY SILICIFIED

C, Plain light; *D*, between crossed nicols, showing the coarse grain of the silica



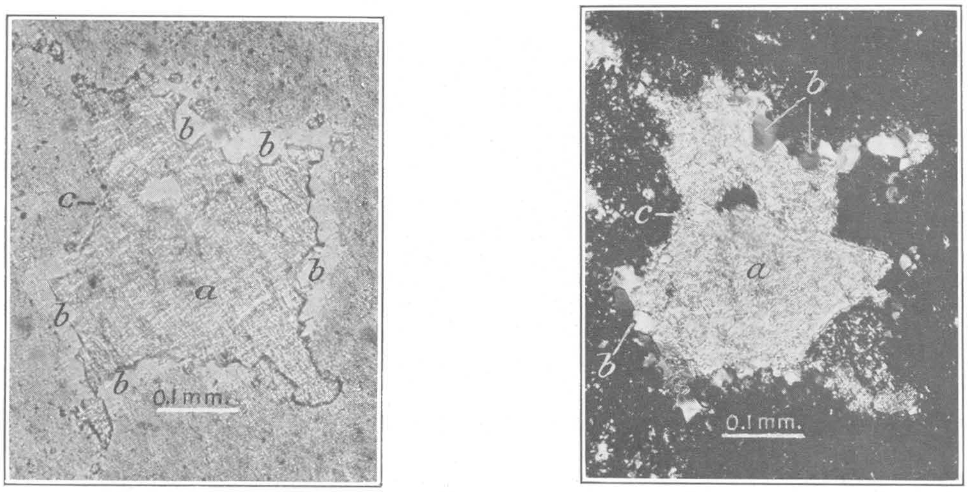
A. DETAIL OF ***a***, PLATE XXII, SHOWING PELLETS IN SILICIFIED ELLENBURGER LIMESTONE OF FINE GRAIN AND THE MARGINS OF A CALCITE CRYSTAL OF ORGANIC ORIGIN REPLACED BY COARSE-GRAINED SILICA

Between crossed nicols



B. DETAIL AROUND ***d***, PLATE XXII, SHOWING COARSE CALCITE CRYSTALS OF ORGANIC ORIGIN IN THE MIDST OF SILICIFIED ELLENBURGER LIMESTONE OF FINE GRAIN, THE LARGE CALCITE CRYSTALS PARTLY REPLACED BY FINE AND COARSE GRAINED SILICA

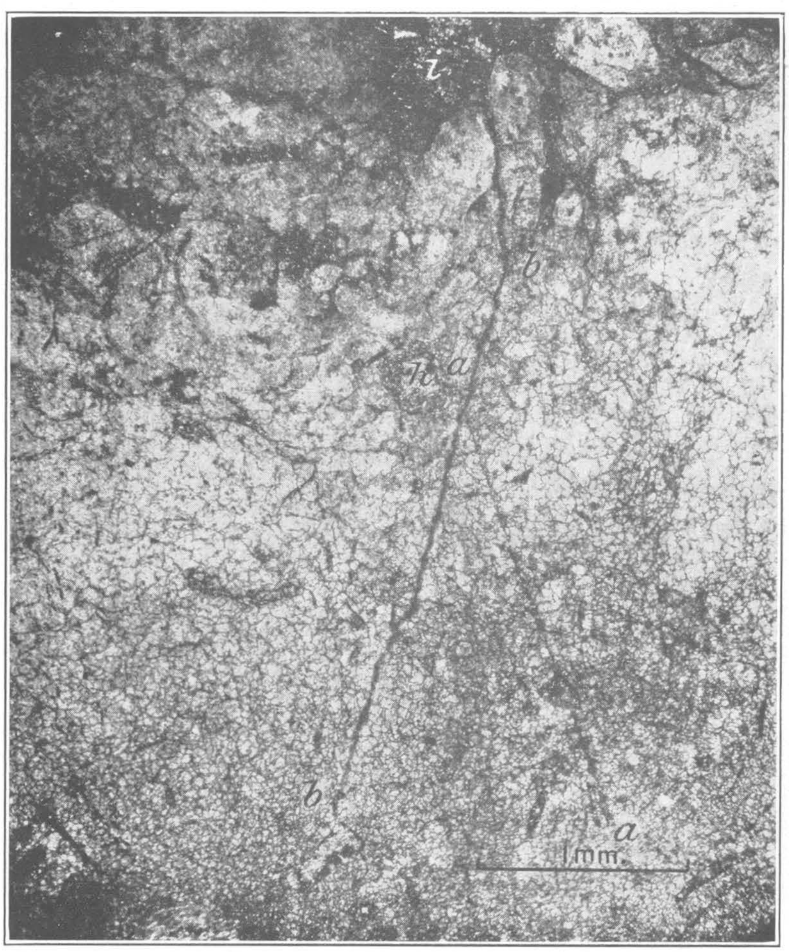
Between crossed nicols



A *B*

DETAIL OF *e*, PLATE XXII, SHOWING A LARGE CALCITE CRYSTAL IN THE MIDST OF SILICIFIED ELLENBURGER LIMESTONE OF FINE GRAIN REPLACED AROUND THE BORDER BY COARSE AND FINE GRAINED SILICA

A, Plain light; *B*, between crossed nicols



C. DETAIL NEAR *i*, PLATE XXII, SHOWING MESHWORK OF VEINS IN SILICIFIED ELLENBURGER LIMESTONE

D. DETAIL AROUND *g*, PLATE XXII, SHOWING INTERSECTING GROUP OF STRAIGHT VEINS IN SILICIFIED ELLENBURGER LIMESTONE

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