The Early Cambrian Fossil *Salterella conulata* Clark in Eastern North America

By ELLIS L. YOCHELSON

CONTRIBUTIONS TO PALEONTOLOGY

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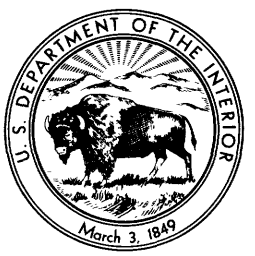
Redescription of a stratigraphically useful widespread Cambrian fossil



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CONTRIBUTIONS TO PALEONTOLOGY

THE EARLY CAMBRIAN FOSSIL *SALTERELLA CONULATA* CLARK IN EASTERN NORTH AMERICA

By Ellis L. Yochelson

ABSTRACT

Salterella conulata Clark from the Levis Conglomerate at Levis, Quebec, is redescribed from thin sections of topotype material and from additional specimens. This Early Cambrian form does not show septation and thus is not a cephalopod, contrary to an opinion that has been presented in the literature. The species is widespread in eastern North America. Only two occurrences of the species in place in a stratigraphic sequence can presently be demonstrated, but when local occurrences are more precisely documented, it is likely that this form will have considerable utility for correlation within rocks from the later part of the Lower Cambrian.

INTRODUCTION

The species *Salterella conulata* Clark has been described and interpreted as a primitive cephalopod (Clark, 1924, p. 9–10; 1925). Clark's work is part of a body of literature which supports the view that the Early Cambrian fossils *Salterella* and *Volborthella* are Cephalopoda. Although it is not germane to discuss the biologic placement of *Salterella*, thin sections demonstrate to my satisfaction that this form is not a cephalopod.

In spite of redescription of the species by Kobayashi (1937), additional features are to be noted in thin sections, and further study of this form is warranted. Reexamination of type material has convinced me, as it did Kobayashi (1937), that Clark had been misled by features of incomplete silicification. The original description inadvertently incorporated spurious characters. Perhaps that may be the reason that this species has not been recognized outside the type locality.

Salterella conulata is actually widespread in eastern North America. In the main, I have identified it in older collections that are not located stratigraphically with any high degree of precision. However, the species is so easily recognized because of its shape in cross section that notation of the various occurrences is presented with the hope of obtaining more accurate stratigraphic data from subsequent collectors. Limited fieldwork in southeastern Pennsylvania has led me to the sanguine conclusion that species of *Salterella* may have rather restricted vertical ranges and, accordingly, considerable stratigraphic utility in correlating strata of the later part of the Lower Cambrian in the Appalachian region.

Dr. John Price (retired) and Mr. Lyle Campbell, formerly of Franklin and Marshall College, Lancaster, Pa., have contributed significant specimens and accompanied me in the field in southeastern Pennsylvania, as did Mr. Michael E. Taylor. Dr. Ernst Cloos, Johns Hopkins University, Baltimore, Md., and Mr. James Balthazer, York, Pa., allowed me access to the working quarries of the Thomasville Stone and Lime Company in Thomasville, Pa. In particular, Dr. Cloos provided valuable stratigraphic data. Dr. Samuel Root, Pennsylvania Topographic and Geologic Survey, assisted in field checking a locality near Waynesboro, Pa. Dr. Claude Hubert, University of Montreal, kindly conducted me to several outcrops of the Bic Conglomerate in Quebec.

The types of *Salterella conulata* were lent for study by Dr. Bernhard Kummel, Museum of Comparative Zoology, Harvard University, Cambridge, Mass. Additional types were lent by Dr. Thomas Bolton, Geological Survey of Canada. This work would have been impossible without the meticulous thin sectioning performed by Messrs. William Pinckney and Keith Moore. Photomicrographs were taken by Messrs. David Massie and Jeffrey B. Yochelson.

THE CLARK *SALTERELLA* COLLECTION

The material studied by Clark (1924) is housed at the Museum of Comparative Zoology, Harvard University. It consists of some free specimens, none of which are singled out and marked as having been figured, and some rocks, both labeled and unlabeled. There is a real problem that rocks from several localities might have been inadvertently mixed among the unlabeled samples. Because all the material is from a breccia known to consist of rocks varying in age from Early Cambrian to Early Ordovician, such concern may be unnecessary. On the other hand, because the genus *Salterella* does contain a number of species, it is critical that future investigators be able to determine what is included and what is excluded from *S. conulata*.

Four plastic boxes contain loose specimens; one box has a single silicified fragment, and the remaining three contain from about 1 dozen to 1½ dozen silicified specimens in each. All these specimens are incomplete and some are also broken; they appear to have been dissolved from limestone by acid rather than weathered free. Two vials, one containing a single loose specimen and one containing six loose specimens, are in a tray labeled "Salterella conulata Clark, Lower Cambrian boulder. Near drydock, St. Joseph de Levis, P.Q. T. H. Clark, coll. & don."

The remainder of the collection consists of almost 3½ dozen pieces ranging from chips to pieces slightly larger than fist sized. Eleven chips and pieces are in the same tray with the vials and boxes, but not all these show isolated *Salterella* specimens protruding from the matrix of the breccia. Two of the other lots of rocks bear labels. One of these is labeled "Lower Cambrian, St. Joseph, Levis, P.Q." and consists of two rocks; the other is labeled "Dry Dock St. Joseph, P.Q." and consists of five rocks. Among other pieces with the last-mentioned lot is a scrap of paper bearing the notation "Salterella conulata T. H. Clark." None of these three notations is in the same penmanship as the label accompanying the vials.

One other piece is labeled "Limestone pebble, Sillery ls. cg. St. Joseph Shore, Que." Written over this in ink is "Salterella rugosa Bill." Finally, there is a box of 13 rock fragments, and on a scrap of newspaper with them is written "Bic cong." None of the writing on these matches any of the preceding labels.

The lots labeled as being from St. Joseph and those associated with the boxes and vials are all limestone breccia. In contrast, the rock from the Bic Conglomerate is principally a coarse-grained calcareous sandstone containing some oolites. Two rocks of similar lithology are in the same large package with the labeled material from St. Joseph. The specimen labeled "Sillery" is a limestone breccia, the matrix being oolitic in part.

One thin section each was cut from the Bic and the Sillery rocks. Both samples are relatively fossiliferous, and both showed slightly curved specimens very distinct from *S. conulata*. They are tentatively identified as *S. pulchella* Billings and are not figured here. Two thin sections were prepared from one of the rocks from the drydock (pl. 1, figs. 1, 7). The specimens are fragmentary and were recovered only after most of the rock had been sliced and polished; the limestone pieces in the breccia are unfossiliferous, and specimens were seen only in the matrix. They are not curved and show the same features illustrated by Kobayashi (1937, pl. 17, fig. 1) for *S. conulata*.

Finally, the largest unlabeled piece of limestone was sliced in an attempt to obtain additional fossiliferous thin sections. Both in hand sample and in thin section this rock is similar to that from the labeled collection at the St. Joseph drydock. After a number of rock slices were cut in a search for fossils, three fossiliferous thin sections were prepared (pl. 1, figs. 5, 6, and 8) from this piece. The specimens in these are fragmentary and also are within the matrix. It seems reasonable to conclude that further preparation would yield only a sparse number of specimens which are likely to be as incomplete as those obtained.

As unsatisfactory as the material is, I believe that the three thin sections are sufficient to bridge any morphologic gap between the even more unsatisfactory material labeled as being from the drydock at St. Joseph and the well-preserved material from Pennsylvania and Newfoundland.

I am unable to fully resolve the question of type material of *Salterella conulata*. Clark used line drawings in his 1924 paper and repeated the same illustrations in his 1925 paper; the 1924 paper has type numbers given in the figure captions to plate 2. The individual sketches cannot be conclusively matched up with any of the silicified fragments in the boxes, though it is reasonable to assume that these formed the basis for his sketches; Clark (written commun., 1969) does not specifically comment on this point. It is perfectly clear from these fragments how they could have been mistaken for septa attached to a siphuncle.

I assume that only the vials, boxes, and the rocks associated directly with them are the material studied by

Clark. The holotype cannot be identified, but it certainly is not the largest specimen isolated in one vial, for that is a very incomplete specimen showing the inner part of the apical cavity. The specimen illustrated by Kobayashi (1937, pl. 17, fig. 1) bears a resemblance in outline to the sketch of the holotype. The number of paratypes is a matter of conjecture, for in none of the boxes do the specimens match the fragments sketched by Clark (1924). Perhaps the etched material has fallen apart; perhaps the six specimens sketched were never separated out. I do not consider that a zoologically useful specimen is available from the presumed paratypes.

None of the rocks associated with the type material were sectioned because it is apparent that all specimens exposed on the surface of the matrix are incomplete and some at least are silicified. Neither of these factors is conducive to yielding meaningful thin sections.

The remaining rock samples do not show any *Salterella* on the exposed surfaces, except for the material of the second species labeled as being from Bic and from the St. Joseph shore. As the rocks were not sectioned by Clark, one could argue that they could not have played any part in his species concept. Accordingly, any fossils from the rocks labeled as being from St. Joseph could only have the status of topotypes. In spite of the slight doubt that may remain on the question of mixed collections, I am prepared to consider that all specimens from the unlabeled rock which has been sectioned at least have the status of topotypes. Indeed, all the limestone breccia not clearly of the oolitic Sillery type might be from St. Joseph, but there seems little point in preparing thin sections that may contain poor *S. conulata* at best, to examine rock types and gather evidence on this minor matter.

On the other hand one can argue that all the rocks probably were available to Clark, as there has been virtually no investigation of the species since the work of Kobayashi (1937), who presumably did not add to the collection. In that interpretation—which I follow here—the specimens in matrix would be considered as unfigured paratypes and therefore be available for selection of a neotype among them. Because none of the figured specimens can be conclusively identified and all the figures lead to a misinterpretation of the characters of the taxon, selection of a neotype is warranted. Accordingly, I designate the specimen figured here on plate 1, figure 1, as the neotype. Although it is not as well preserved as others in the Clark collection, it is from a rock labeled as being collected from the drydock and therefore is a topotype.

SYSTEMATIC PALEONTOLOGY

Genus SALTERELLA Billings, 1861

Salterella conulata Clark, 1924

Plates 1–6

Salterella conulata Clark, 1924, p. 8, pl. 2, figs. 1–6, 8–10.
Clark, 1925, p. 31, pl. 1, figs. 1–7, 9, 10.
Kobayashi, 1937, p. 177–179, pl. 17, figs. 1–4.

Description.—Relatively rapidly expanding calcareous cones. Shell composed of calcium carbonate in the shape of a cone; expanding at an angle from about 45° to 50° in the apical area, but with growth abruptly changing to an angle in the 10°–20° range so that in section the wall is abruptly geniculate. Outer shell wall thin at the apical area, gradually increasing in thickness, except for tapering at the growing apertural margin; rate of wall thickening seemingly decreasing with increasing size. Inner deposits filling apical part of cone, the amount of these deposits increasing with size of specimens, filling the cone to a maximum of near 50 percent of the total length in largest specimens. Upper part of inner deposits thin but extending along the inner walls of the cone to near the apertural margin. Shape of base of apertural cavity at juncture with inner deposits, hyperbolic in longitudinal section. Central tube extending from apical end of cone and opening into base of apertural cavity; tube maintaining an early constant diameter except just before the apex where it becomes extremely narrow.

Discussion.—The principal character distinguishing this species is considered to be a large apical angle giving a relatively rapid rate of expansion of the cone in the early stages. Even though the rate of expansion abruptly decreases after a short growth interval, *S. conulata* still expands at a high rate relative to other species. The shape of the surface of the inner deposits, extending far up the inner surface of the wall, also seems to be unique. Average size of specimens is somewhat larger than that of other *Salterella* species. Isolated free specimens commonly are bluntly rounded at the apical area, in part because the thickness of the wall seems to increase coordinate with the point of change of angle of expansion.

The shape of specimens from various areas seems to show a low degree of individual variation, though it should be apparent that thin sectioning may artificially suggest a high degree of variation. For example, the presence of a central tube is a generic feature, but because of the difficulty of precisely alining the rock, many illustrations of thin sections lack this feature.

Relatively few species of *Salterella* have been described, but even so, there is some confusion as to their characters. *S. pulchella* Billings is a gently curved, relatively slowly expanding species. *S. curvata* Shaler and Foerste and *S. acervulosa* Resser and Howell are both supposed to be strongly curved forms, but in *S. acervulosa*, the curvature is probably due to tectonic deformation. *S. maccullochi* (Salter) is known only from woodcut illustrations more than a century old; the only available material consists of very poor specimens from Scotland which actually may be hyolithids.

S. rugosa Billings is inadequately described; the rugose appearance of this form seems to be due entirely to loss of the outer shell layer and differential weathering of the edges of the laminated internal deposits. *S. expansa* Poulsen, from the Lower Cambrian of Greenland, is similar in rate of expansion to *S. rugosa* and thus slightly narrower than *S. conulata*. The apertural cavity is more V-shaped and relatively deeper than in *S. conulata*. There is also a suggestion that the inner deposits extend further toward the aperture. *S. mexicana* Lochman is very slowly expanding and needlelike, much like *S. rugosa;* additional material may demonstrate that these names are synonymous, or alternatively one or both of them may fall into the synonymy of *S. rugosa*.

Although it is not the aim of this paper to discuss the biology of *Salterella*, a few features should be commented upon. Kobayashi (1937, pl. 17, figs. 1a–1c) illustrated one of Clark's specimens and discussed this species in detail. He concluded, in part, that Clark was misled by secondary features in incompletely silicified specimens of his material and that the presumed septa and septal necks were spurious.

Kobayashi (1937, p. 179) further suggested that "The conch is originally composed of calcareous cones which are invaginated in the cone-in-cone structure." I am not entirely certain as to what is meant by this remark. The thin sections of shells at various sizes clearly indicate that there is an ontogenetic change in the interior of the fossil. Small shells contain virtually no inner deposits, but in large specimens as much as half the length of the tube is filled.

This inner deposit is clearly secondary in the sense that it was deposited during life but after the outer shell had grown to some extent. Thus, it is analogous to the cameral deposits of some cephalopods, rather than being part of the wall. However, this inner deposit bears no resemblance whatsoever to the septa of cephalopods, for the inner deposit is laid down layer upon layer with no intervening spaces or camerae.

Although Kobayashi reported several grooves in the specimens which he interpreted as cessation of growth, I believe that he was also misled by the nature of the material. The Newfoundland and Pennsylvania specimens illustrated are far superior in preservation to those from other areas, but even in these it is difficult to see any evidence of lamination within the inner deposits. I am confident that weathering or acid etching accentuates planes of weakness within the inner deposits but that it has some aspects of a random phenomenon, without any significance to be placed on the position of these secondarily formed discontinuities. The inner deposit is likely formed of thin, very closely spaced laminations, judging from what little can be seen and from the absence of relic structure in most recrystallized material, but it is not possible to demonstrate just how thick these laminae may have been originally.

The apical area of the shell is particularly susceptible to change after death. As noted, the earlier part of the shell expands rapidly, and both the outer wall and inner deposits are thin in the early stages of hard-part formation. Accordingly, the apex is commonly eroded or worn away. As a consequence, many free specimens have a bluntly rounded apical area from which the conch expands at a slow rate. Specimens of other species, having a slower rate of expansion and less ontogenetic change in the diameter, do not have the apex so obviously worn.

The apertural rim is another area of weakness because it is thin. In many specimens it may be broken back, masking the true shape. A worn specimen shows superficial similarity to the shape of a small-calibre bullet. Free specimens in a weathering regolith may even have a slightly larger diameter of the inner tube than that of specimens in matrix; presumably this is a result of solution.

The structure of the outer shell and its extension to the apertural rim are perplexing, in part, because of the recrystallization and tectonic forces that have affected the rocks. Many specimens show dark lines subparallel to the shell but inclined apically and outwardly. Probably these are tension joints, for they are too abundant to be saw marks formed during thin sectioning. Most specimens from Bic, Quebec, and a few from Lancaster, Pa., in longitudinal section have the apertural rim normal to the central tube except for a short tip extending abruptly forward. This feature is so distinctive that it was originally assumed to be a specific character. However, it does not appear in all specimens, and on some there is a difference between one side of the thin section and the other as though the limestone had flowed. This is particularly characteristic of the specimens from areas that have been strongly deformed, and it serves to emphasize the importance of examining a large number

of sections to differentiate primary and secondary features.

GEOLOGIC AND GEOGRAPHIC DISTRIBUTION OF *SALTERELLA CONULATA*

A number of collections of *S. conulata* Clark are available, all from rocks of Early Cambrian age. Many of the collections are old and do not provide stratigraphic data as accurate as might be desired for present-day work. During the current investigation, these fossils have been found in exposures at only two localities, one at Thomasville, the other near Waynesboro, Pa. In spite of the paucity of geologic data from other localities, representative specimens from a number of areas are illustrated in the hope that this may lead to their being found in outcrop and placed in a modern stratigraphic context.

The species has not been unequivocably identified in any of the Taconic Mountains area collections of New York and New England made by C. D. Walcott and his associates nearly a century ago. However, the occurrence of the species in Quebec and Newfoundland and in areas of the middle and southern Appalachians (fig. 1) indicates that it could be searched for in the Taconic region. In part, this may be a reflection of the observation that most Taconic *Salterella* specimens in the older collections are so poorly preserved as to be only generically determinate.

EASTERN CANADA

Pl. 2; pl. 3, figs. 5, 6

Salterella is well known in eastern Canada, the type species having been described from Labrador. However, it is appropriate to record two occurrences of *S. conulata*, in addition to the type locality.

Walcott, in 1899, made a large collection near Trois Pistoles, Temiscouata County, Quebec (USNM loc. 2–o; USNM 166230; pl. 2, figs. 5, 6). The species is in the Bic Conglomerate, though it is not possible to determine from the available locality data which conglomerate layer of the several conglomerates were sampled. Most of the material is a coarse-grained calcareous sandstone, and the contained specimens are the same slightly curved *S. pulchella* that occurs in the rock labeled "Sillery" in the Clark collection. Several pieces, however, are light-gray limestone, richly fossiliferous, which contains specimens that I assign to *S. conulata*. It is well known that the lower Paleozoic conglomerates of the St. Lawrence Valley contain an admixture of boulders of differing age, and it is no surprise that two species occur in rocks of different lithologies at the same locality. The fossiliferous pieces from the rock labeled "Bic" are relatively large so that specimens occur in host rock rather than in breccia matrix as at Levis, Quebec. The specimens are not broken like those in the Clark collection and are virtually unworn.

Newfoundland outcrops may eventually provide a detailed zonation of *Salterella*, but the necessary collections and stratigraphic data are not all available. Schuchert and Dunbar (1934, p. 19) mentioned the occurrence of *Salterella* at the type area along the Strait of Belle Isle in Labrador, just to the north of Newfoundland, where three species are reported to occur within a stratigraphic interval of 45 feet. They indicated that the genus ranges through a greater interval in the Highlands of St. John in western Newfoundland and a still greater thickness at Bonne Bay, Newfoundland. Although all the Cambrian material that was collected in 1910 and cited by them (Schuchert and Dunbar 1934, p. 3, 4) is supposed to be in the collections of the U.S. National Museum, I have been able to locate only two *Salterella*-bearing collections from the Bonne Bay area.

Both collections were made by Schuchert in 1910 from the "east shore of East Arm" (see Schuchert and Dunbar, 1934, p. 28). One (USNM loc. 41–f) is from "zone 23," and the second (USNM loc. 41–l; USNM 166227) is from "zone 24." There are no additional data with the specimens to indicate the relationship of one collection to the other, nor any notion of the thickness of each zone.

Dr. Copeland MacClintock, Yale Peabody Museum, kindly searched Charles Schuchert's field notes for 1910 and found additional data in a general section prepared at that time by W. H. Twenhofel. Pertinent details are: "Zone 23, Blue, black, and gray slate with yellow quartzites that are cross-bedded. Strike N. 34° E., dip 30° W., Thickness 30 feet. Equals Richardsons C 5. Has much fucoidal tracings. Zone 24. Nodular limestone 8 feet thick increasing northward to 25 feet, due perhaps to upper shales becoming more limey. Very fossiliferous. Equals Richardsons C 6." The notes indicate that the overlying unit of 70-foot thickness contains pyritized *Salterella* (C 7). The next overlying unit is 13 feet thick (C 8) and this in turn is overlain by "bluish black slate with *Salterella* casts. Richardsons C 9. Thickness 68 feet." This is locally the highest stratigraphic unit, and "The summit of this section is found at the east horn [sic] of Deer Brook Bay." It is to be noted that the zone numbers in the field notes do not match the bed numbers given by Schuchert and Dunbar (1934, p. 29–30) and that their report of two species of *Salterella* in the unit they consider to be the same as (C 6) cannot be confirmed from the available material.

Rocks from "zone 24" contain abundant specimens which I refer to *S. conulata* (pl. 2, figs. 1–4; pl. 3, figs. 5, 6). These specimens are particularly close to those

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FIGURE 1.—Index map showing principal localities mentioned in text, exclusive of Newfoundland. 1, Trois Pistoles, Quebec; 2, Quebec City, Quebec; 3, Lancaster, Pa.; 4, Thomasville, Pa.; 5, Waynesboro, Pa.; 6, Harpers Ferry, W. Va.; 7, Sugar Grove, Va.

from the Bic Conglomerate. Differences between these forms and topotypes seem due entirely to better preservation of the Newfoundland material. The specimens from the underlying "zone 23" are tentatively identified as *S. pulchella* Billings and are not illustrated.

LANCASTER, PA.

Pl. 4; pl. 5; pl. 6, figs. 1, 8

Near the city of Lancaster in southeastern Pennsylvania, two localities for *S. conulata* are known. At the first, part of the Vintage Dolomite is exposed in a small abandoned quarry east of the Landis Valley Farm Museum and 1,000 feet south of the intersection of Oregon Pike and Hunsecker Road in the northern quadrant of the Lancaster quadrangle (USGS loc. 6021–CO; USNM 166246; pls. 4, 5). The local structure is complex, but there is at least a suggestion that the upper part of the Vintage Dolomite is exposed at the crest of an anticline. Local mapping done for the last few years by students at Franklin and Marshall College suggests that the overlying shale of the Kinzers Formation might have been tectonically pinched out to the south. Approximately 20 feet of the Vintage has been excavated in the quarry, but the only specimens found are those that have weathered in relief from the blocks used to build the old kiln. The rock is a bluish-gray to white mottled carbonate that has some yellow mottled areas.

At the second locality, Walcott in 1909 obtained a limestone bearing this species from 1¼ miles east of Landis Valley (USNM loc. 12–y; USNM 166249; pl. 6, figs. 1, 8). This is less than a mile east of USGS locality 6021–CO and presumably is from the same limited stratigraphic interval and perhaps along the same structure. An abandoned quarry, now a dump, along Butter Road may have been the site of this collection. Limestone and dolomite as well as fragments of Kinzers shale were recovered. Shale blocks support the inference that this spot may have been near the top of the Vintage.

Even though the locality is no longer available and its location is uncertain, the available material is particularly useful, for it demonstrates the great variations in the number of specimens obtained; thin sections are much more fossiliferous than those from USGS locality 6021–CO. Further, rock type and preservation of fossils is very close to that in the two collections from eastern Canada mentioned previously.

THOMASVILLE, PA.

Pl. 6, figs. 2–5, 7

The Thomasville Stone and Lime Company quarries constitute a unique exposure in the southeastern Pennsylvania area. The principal commercial product is a chemical-grade high-calcium limestone that occurs near the top of the stratigraphic section and is informally designated the "Thomasville" limestone. Substantial operations have opened a large pit, and perhaps half a cubic mile has been excavated. The local faulting is exceedingly complex.

At Thomasville, specimens of *S. conulata* were first found in May 1969, by Lyle Campbell, near the upper part of the Vintage Dolomite, in a topographically higher, but stratigraphically lower part of the quarry pits (USGS loc. 6795–CO; USNM 166255). The mottled appearance of the rock is nearly identical with the matrix containing *S. conulata* at Lancaster, Pa., and successful search for the fossil was based on the premise of matching lithologic types.

Yochelson, Taylor, and Cloos (1968, p. 64) alluded to *S. conulata* as follows: "A third *Salterella* species is widespread throughout the Appalachian area in the lower part of the Vintage Dolomite equivalents, but quarrying operations have not exposed these beds at Thomasville." In point of fact, after this report appeared, scattered specimens of *S. conulata* were found from about 10 to 90 feet stratigraphically below a dark-gray limestone near the top of the section that has produced abundant specimens of *Salterella* sp. (Yochelson, Taylor, and Cloos, 1968). This overlying, atypical dark-gray limestone unit of about 100-foot thickness is also assigned to the Vintage Dolomite. It is overlain in turn by a tectonically thinned section of Kinzers "phyllite."

Although the dark-gray limestone is distinctive from the typical mottled lithology of the Vintage and begins above a 5-foot band of cream-colored limestone, it is convenient to use the formational name Vintage for all carbonate rocks below the Kinzers Formation (fig. 2). The dark-gray limestone is probably involved in a regional change in facies, but a separate designation for these upper beds is not appropriate. A detailed account of the stratigraphy at the Thomasville quarries is being prepared by Ernst Cloos (oral commun., Aug. 1969).

About 100 feet of limestone and dolomite, exposed in one of the Thomasville Stone and Lime Company quarries, below the lowest occurrence of *Salterella conulata* was examined without finding any indication of fossils. Much of this rock is dolomite. Cores taken from at least 187 feet below the quarry floor—a fault of presumed small throw complicates precise correlation between cores and quarry exposure—and above a lower highly graphitic dark limestone have yielded a few sparse specimens, possibly *S. pulchella* Billings. This occurrence substantiates the occurrence of *S. conulata* above *S. pulchella* in Newfoundland.

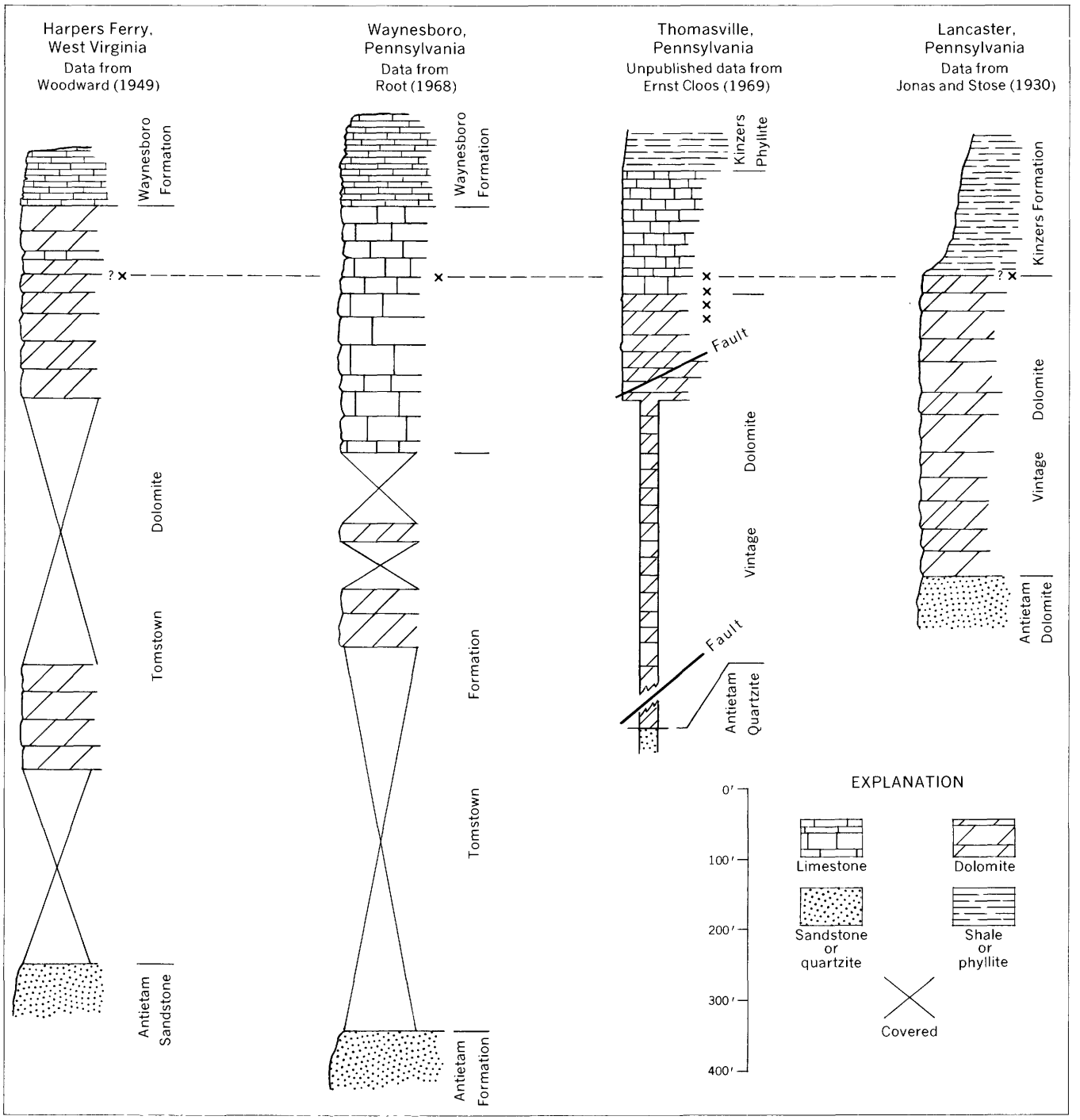

FIGURE 2.—Stratigraphic occurrence, indicated by X and dashed line, of *Salterella conulata* Clark in the central Appalachian area.

Much of the carbonate in the Vintage Dolomite is actually limestone, and local depositional history must have been complex. At Emigsville, Pa., about halfway between Thomasville and Lancaster, the middle part of the Vintage yields abundant poorly preserved echinoderm fragments. Some of these superficially resemble *Salterella* specimens, and a few conceivably could be generically indeterminate remnants of that genus.

No occurrences of *Salterella* low in the Vintage Dolomite are known, and in retrospect, the reasoning which led Yochelson, Taylor, and Cloos (1968) to suspect that *S. conulata* occurred in the lower part of the formation

seems to be in error. Several other occurrences mentioned herein inferentially support the suggestion that *S. conulata* occurs near the top of the Vintage or its equivalents, though the possibility of a longer range through this thick formation cannot be discounted at this stage of investigation.

For the sake of completeness, it is worth recording that *S. conulata* has also been found in an exposure within the city of York, Pa., about 7 miles east of Thomasville (pl. 3, fig. 3). The exposure is no longer accessible (USNM loc. 48–f; USNM 166235).

WAYNESBORO, PA.

Pl. 3, figs. 1, 2, 4, pl. 6, fig. 6

George W. Stose obtained *Salterella* from a limestone in the Tomstown Dolomite; the rock is labeled "south bank of creek at Roadside" (pl. 3, figs. 1, 2, 4; USNM 166233, 166237). In spite of the apparent vagueness of this locality, actually the hamlet of Roadside is a well-known spot about 2 miles east of Waynesboro. It is one of the few places in the area where the lower part of the overlying Waynesboro Formation may be observed (Root, 1968, p. 9). The gentle dip and absence of complex structure indicate that the *Salterella* occurrence is probably less than 100 feet below the base of the Waynesboro Formation. After three separate examinations of limited outcrops were made, *S. conulata* was found in the outcrop at stream level just below the parking lot of the Waynesboro Country Club, thus verifying Stose's collection.

So far as it is known, this occurrence and the Thomasville occurrence are the first paleontologic evidence of correlation between the Tomstown and Vintage Formations. Although a partial equivalence has been suggested by some authors in the past, it has been based on lithic similarity and similar stratigraphic position, both methods of correlation which are open to question.

If one uses the occurrence of *S. conulata* as a basis for correlation, one would infer that the Waynesboro Formation in the Waynesboro area, the dark-gray limestone and thin Kinzers Formation in the upper part of the Thomasville quarries, and the thicker Kinzers Formation in the Lancaster area are all approximately equivalent in time. The lowermost part of the Waynesboro Formation above the occurrence of *S. conulata* does show some lithic resemblance to the dark-gray limestone above the more typical Vintage Dolomite in the Thomasville section. Unfortunately, near Roadside, the Waynesboro is sparsely fossiliferous, and no younger *Salterella* species have been found; only a few poorly preserved trilobite fragments occur. It would be most helpful if this suggested tentative correlation could be substantiated by discovery of identifiable fossils in the Waynesboro.

WEST VIRGINIA

Pl. 1, fig. 4

In 1939, Charles Butts collected specimens of *Salterella* which are labeled in the collection as being from the "Shady Dolomite, 3 miles southwest of Harpers Ferry." The specimens were taken from the "top of east face at north end of quarry at Millville"; they are noted as being "fairly common, but ill preserved." More than a dozen specimens are present (USNM 166221), most of which presumably were broken from the weathered face of the rock. Woodward (1949, p. 136) noted that *Salterella* is common in the Tomstown Dolomite at Millville, referring to the same quarry.

The locality has been reinvestigated to no avail. Quarrying operations have removed a substantial part of the pit that was illustrated by Woodward. The east face of the quarry cannot be examined except perhaps by rope from above. The area is on the overturned limb of the South Mountain synclinorium, and a geologic map of the area by Nickelsen (1956) suggests that the east face of the quarry is close to the Antietam Sandstone and hence the top of the formation.

Two other quarries west of Millville were investigated without success. Presumably they are in rocks in the older part of the Tomstown. Tomstown and Waynesboro outcrops in Maryland were also examined in the hope of obtaining additional localities between those at Millville and that near Waynesboro, Pa., but no specimens were found.

SOUTHWESTERN VIRGINIA

Pl. 1, figs. 2, 3, and 9

Abundant *Salterella* were collected in 1942 by R. L. Miller and Josiah Bridge in the course of field investigations for strategic minerals; according to the label on their material, they obtained it from the "Shady [Dolomite], Umbarger Mine, Sugar Grove, Virginia." More than 500 specimens are available in the Geological Survey (loc. 1340–CO) and National Museum collections (USNM 166219); it is uncertain whether this is a single collection or the result of two trips to the same locality. This mine is in the Marion area of Smyth County, but I have been unable to find any detailed account of the local stratigraphy. Currier (1935) indicated that in this area the Shady is 1,600–2,000 feet thick.

These specimens are silicified and are stained a rich dark brown. Soil of the same color is associated and the fossils almost certainly occur in a residuum. Individual specimens are broken and incomplete, but collec-

tively they give a good idea of the variation that may be obtained as a result of silicification and natural etching. Many have the characteristic bullet-shaped apical area seen on worn specimens. This collection, together with the specimens from Millville, W. Va., duplicates the various shapes of all the loose specimens in the Clark collection from the Levis Conglomerate.

The specimens are significant in providing a paleontologic tie between the Shady and Tomstown Formations. Although the Early Cambrian age of each and their equivalence is generally accepted, fossil evidence of this presumed correlation is scant. In large measure, correlation again has been based on lithic similarity and stratigraphic position. This report of the occurrence of a specifically identified fossil common to both formations may be the first.

C. W. Cressler of the U.S. Geological Survey and I have unsuccessfully examined some outcrops of the Shady Dolomite in northwestern Georgia in the hopes of discovering *S. conulata.* Farther south, in Alabama, Butts (1926, p. 65) noted that McCalley in 1897 reported *Salterella* as being locally abundant in the unit then referred to as the Shady Limestone. However, the only Alabama specimens available in the collections are not of this species.

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PLATES 1–6

PLATE 1

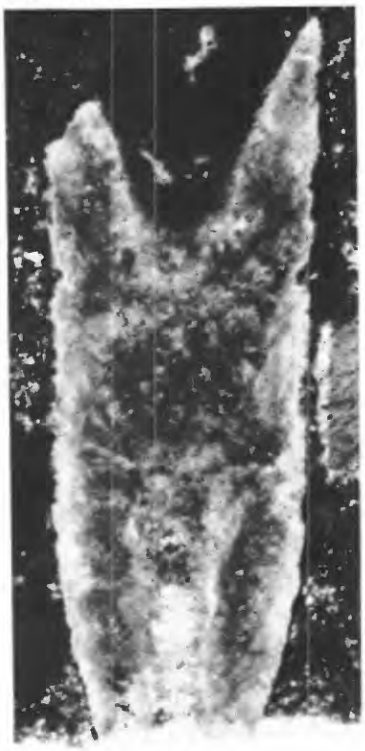
[Taken in plain transmitted light]

FIGURES 1–9. Thin sections of *Salterella conulata* Clark.

1, 5–8. Topotypes from the Clark type collection from rock dredged when the drydock at St. Joseph de Levis, Quebec, was enlarged. The original of figure 1 is designated as the neotype. × 15. Thin sections are in the collection of the Museum of Comparative Zoology, Harvard University, Cambridge, Mass.

2, 3, 9. Weathered specimens imbedded in plastic from "Umbarger Mine, Sugar Grove, Virginia" (collected by J. Bridge, December 1942). Figures 2 and 9, × 15; figure 3, × 10. USNM 166216, 166217, 166218.

4. Weathered specimen imbedded in plastic from "North end of quarry at Millville, W. Va." (collected by C. Butts, July 28, 1939). × 10. USNM 16622.



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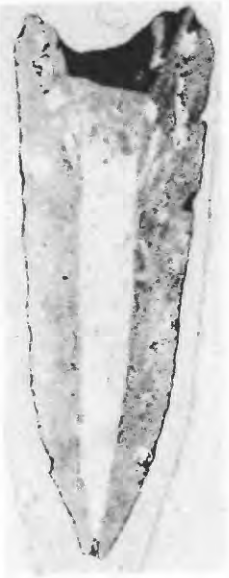

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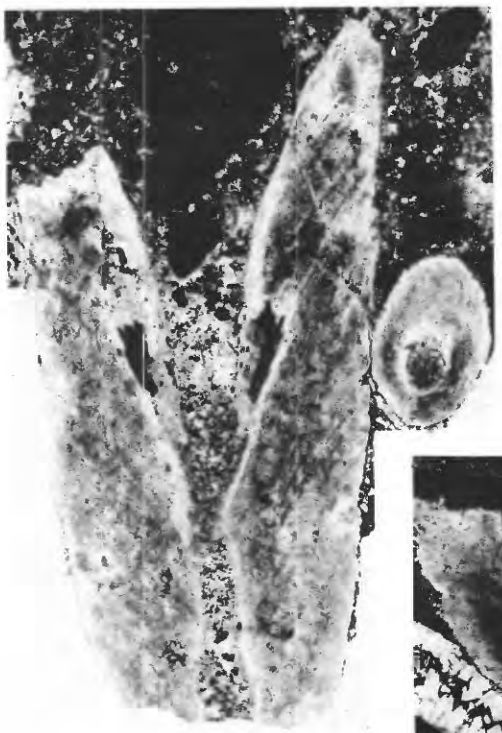

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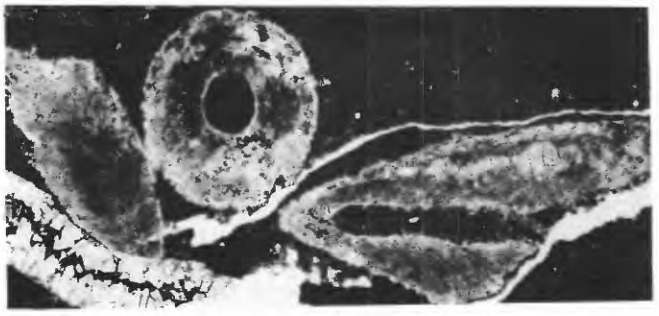

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THIN SECTIONS OF *SALTERELLA CONULATA* CLARK

PLATE 2

[Taken in plain transmitted light]

FIGURES 1–6. Thin sections of *Salterella conulata* Clark.

1–4. From "Bonne Bay, east shore of East Arm, west coast of Newfoundland, zone 24" (collected by C. Schuchert, Aug. 14–15, 1910) ; USNM locality 41–l. All four figures, × 15. USNM 166222, 166223, 166224, 166225. Figures 1 and 4 are from the same thin section.

5, 6. From "Limestone boulders in conglomerate along the shores of the St. Lawrence near Trois Pistoles, Temiscouata County, Quebec, Canada" (collected by C. D. Walcott, 1899) USNM locality 2–o. Figure 5, × 10, and figure 6, × 15. USNM 166229, 166230.

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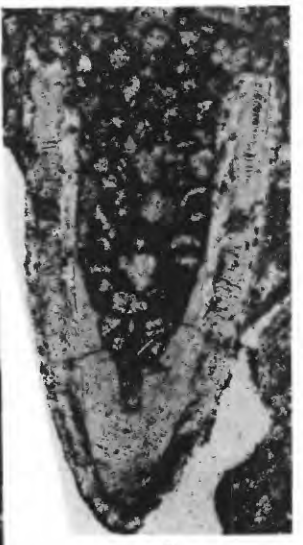

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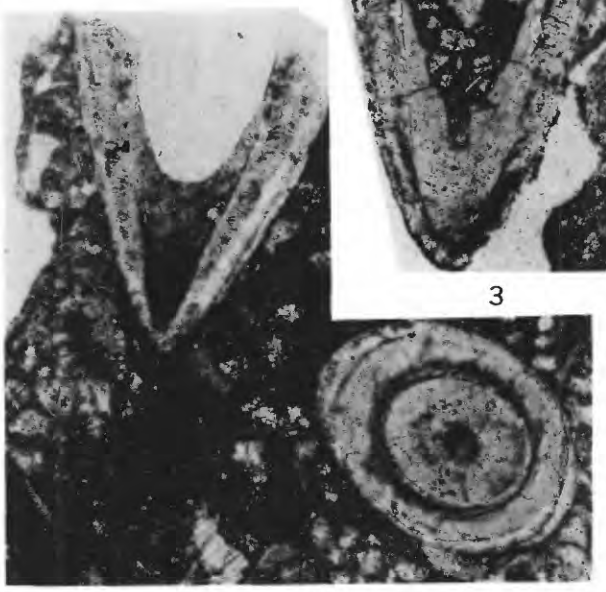

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THIN SECTIONS OF *SALTERELLA CONULATA* CLARK

PLATE 3

[Taken in plain transmitted light]

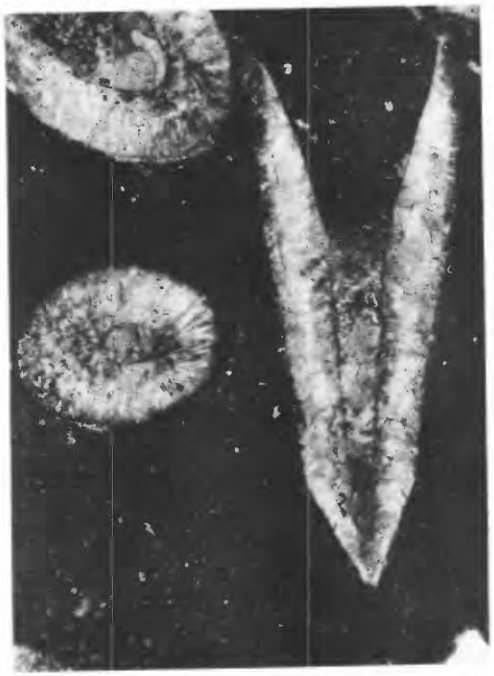
FIGURES 1–6. Thin sections of *Salterella conulata* Clark.

1, 2. From "Roadside, east of creek 2 miles east of Waynesboro, Chambersburg quadrangle, Pennsylvania" (collected by G. W. Stose); both figures, × 10. USNM 166231, 166232.

3. From "Edge of street running north and south in front of Smith's lime kiln and in back yard of first cottage north of Smith's lime kiln (excavation); city of York, York Co., Penn." (collected by H. E. Dickhaut, 1901); USNM locality 48f. × 10. USNM 166234.

4. From "South bank of creek at Roadside, Chambersburg quadrangle" (collected by G. W. Stose, June 21, 1901). × 10. USNM 166236.

5, 6. From Bonne Bay, east shore of East Arm, west coast of Newfoundland, zone 24 (collected by C. Schuchert, Aug. 14–15, 1910); USNM locality 41–l. Figure 5, × 10, and figure 6, × 15. USNM 166224, 166226. Figure 5 and plate 2, figure 3, are from the same thin section.



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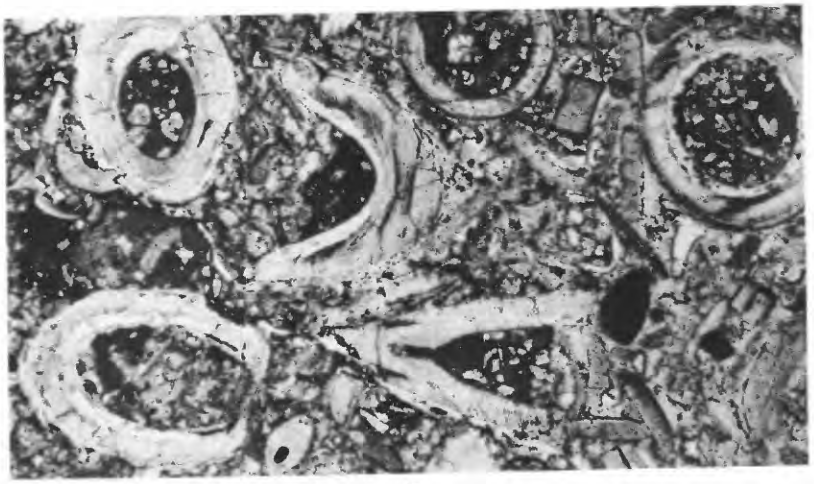

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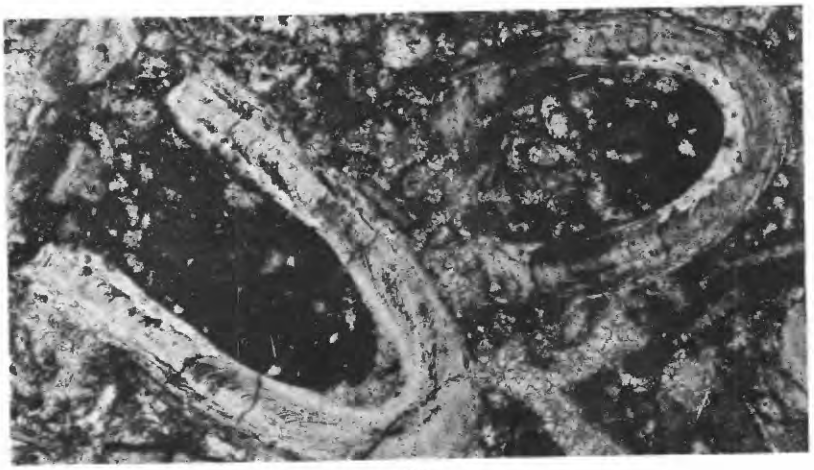

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THIN SECTIONS OF *SALTERELLA CONULATA* CLARK

PLATE 4

[Taken in plain transmitted light]

FIGURES 1–7. Thin sections of *Salterella conulata* Clark.

From the upper part of the Vintage Dolomite in the kiln of a small abandoned quarry, east of the Landis Valley Farm Museum and 1,000 feet south of the intersection of Oregon Pike and Hunsecker Road, Lancaster quadrangle, Pennsylvania; USGS locality 6021–CO. Figures 1 and 2, at × 25, and figures 3–7, × 15. USNM 166238, 166239, 166240, 166241, 166242, 166243, 166244. Figures 2 and 5 are from the same thin section. Figures 1 and 3 are from the same thin section as all figures on plate 5.

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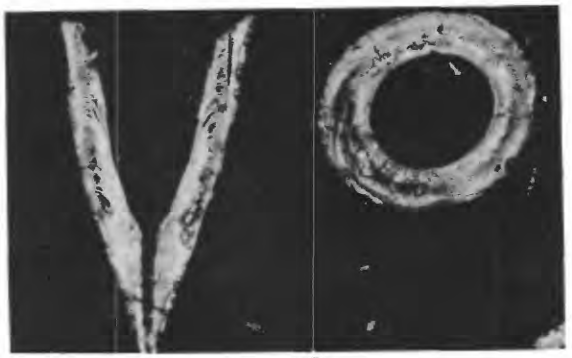

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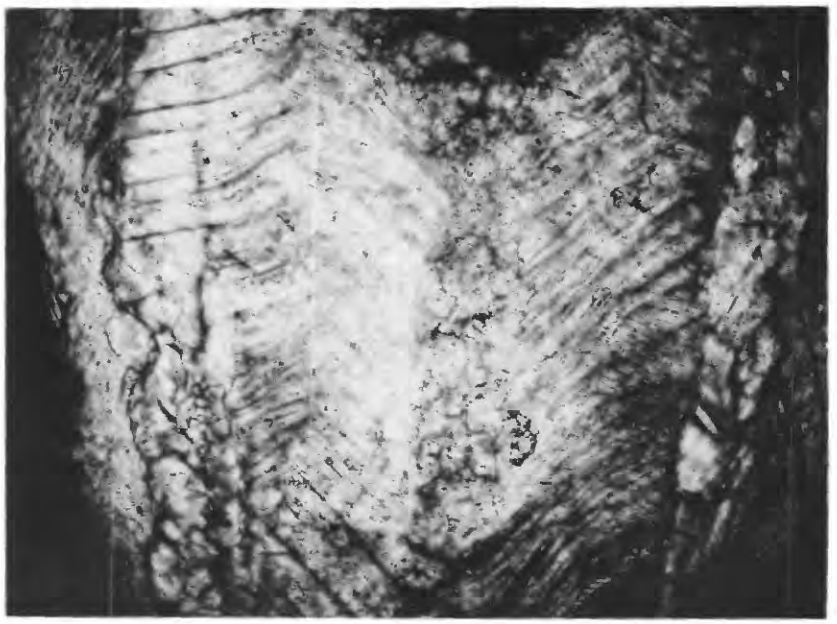
THIN SECTIONS OF *SALTERELLA CONULATA* CLARK

PLATE 5

[Taken in plain transmitted light. All four figures and pl. 4, figs. 1 and 3, are from the same thin section]

FIGURES 1–4. Thin sections of *Salterella conulata* Clark.

1. Part of thin section, a short distance below base of apertural cavity, showing central tube filled with recrystallized calcite, laminated inner deposits, and outer wall. × 100. From the upper part of the Vintage Dolomite in the kiln of a small abandoned quarry, east of the Landis Valley Farm Museum and 1,000 feet south of the intersection of Oregon Pike and Hunsecker Road, Lancaster quadrangle, Pennsylvania; USGS locality 6021–CO. USNM 166245.
2. Same specimen as figure 1, × 15.
3. Lower part of apertural cavity of same specimen, × 50.
4. Upper part of specimen shown to left on plate 4, figure 3, × 50 magnification.



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THIN SECTIONS OF *SALTERELLA CONULATA* CLARK

PLATE 6

[Taken in plain transmitted light]

FIGURES 1–8. Thin sections of *Salterella conulata* Clark.

1–8. From "1¼ miles east of Landis Valley, Manheim Township, Lancaster County, Penn." (collected by C. D. Walcott, May 1909), USNM locality 12–y. Figure 1, × 10, and figure 8, × 15. USNM 166247, 166248.

2–5, 7. From Lincoln Stone Company quarry within the grounds of Thomasville Stone and Lime Company, at Thomasville, Pa., USGS locality 6795–CO. Figures 2–4, × 15, figure 5, × 10, and figure 7, × 20. USNM 166250, 166251, 166252, 166253, 166254.

6. From "Just north of Roadside near Waynesboro, Pa. This specimen was found among Foerste's collection with no label. The above information supplied by E. O. U. [Irich] who says that he thinks that he collected it." Note by J. Bridge dated September 30, 1936. × 15. USNM 166256.

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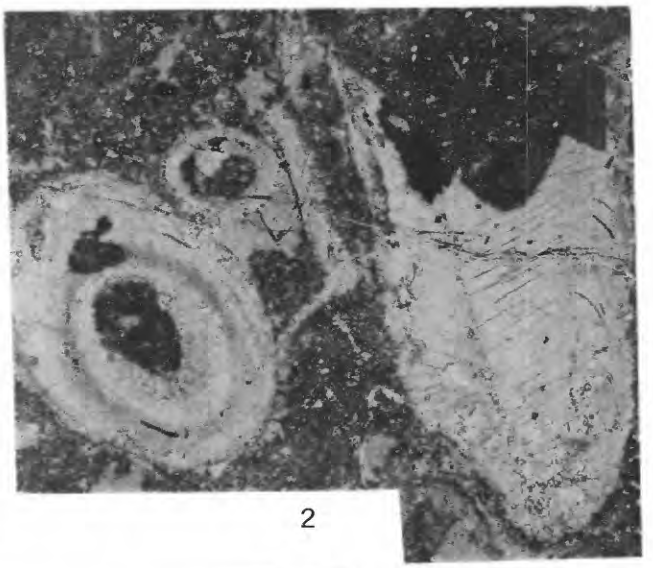

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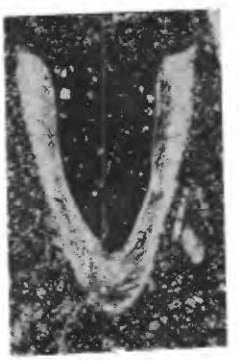

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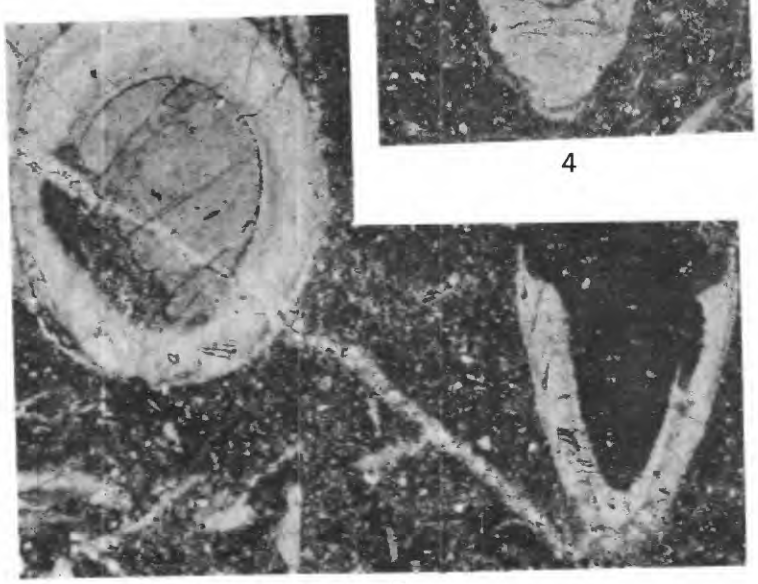

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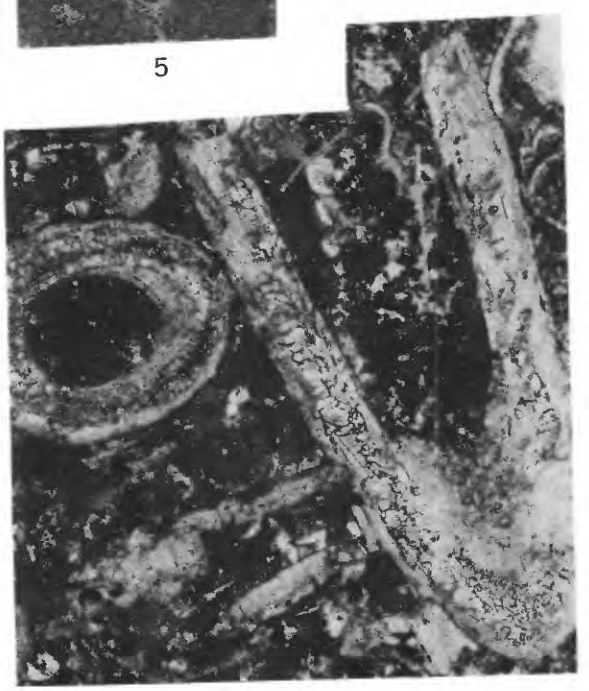

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THIN SECTIONS OF *SALTERELLA CONULATA* CLARK