Fossils in Ordovician Tuffs Northeastern Maine

By ROBERT B. NEUMAN

With a section on TRILOBITA

By HARRY B. WHITTINGTON

CONTRIBUTIONS TO GENERAL GEOLOGY

GEOLOGICAL SURVEY BULLETIN 1181-E

Description of a sequence of volcanic rocks in Maine and the brachiopods, trilobites, and other fossils in these rocks

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1964

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

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FOSSILS IN ORDOVICIAN TUFFS, NORTHEASTERN MAINE

By ROBERT B. NEUMAN

ABSTRACT

An Ordovician volcanic sequence in northeastern Maine consists of tuffs and related rocks, the Shin Brook Formation (new), and is overlain by metadiabase that is probably a sill.

Fossils collected from the Shin Brook Formation are largely brachiopods; trilobites, bryozoans, gastropods, and other phyla are present but considerably less abundant.

Brachiopods belonging to six genera, including three orthaceans and three clitambonaceans, are described. The three forms that are well-enough preserved and sufficiently abundant to be determined specifically are placed in new species, and for one of these a new monotypic genus is erected. Among the genera present, *Orthambonites*, *Productorthis*, and *Platystrophia* are long ranging, but *Tritoechia* has hitherto been recorded from rocks no younger than Early Ordovician. The assemblage compares most closely with the Early Ordovician (Arenig) of the eastern Baltic and with the early Middle Ordovician (Whiterock Stage of Cooper, 1956) of North America.

Trilobites are less abundant than brachiopods, but species belonging to nine different genera have been recognized. The assemblage is unusual in North America, the commonest species being a bathyurid tentatively referred to *Annamitella*. This genus, based on a species from North Vietnam, may be represented by other species in Lower and early Middle Ordovician rocks of Kazakhstan, Argentina, and Australia. *Geragnostus*, *Ampyx*, *Nileus*, *Illaenus* (s. l.), and *Raymondaspis* are present in the Shin Brook Formation and the middle Table Head Formation of western Newfoundland, the latter lying within the Whiterock Stage of Cooper, 1956. In rocks of this age in Newfoundland and Nevada, *Nileus*, *Illaenus* (s. l.), and *Raymondaspis* make their first appearances on this continent. The harpid and odontopleurid in the Maine rocks are rarities and are not helpful in correlation.

INTRODUCTION

A sequence of tuff, tuff-breccia, and volcanic sandstone containing fossils in some places has been traced through the Shin Pond and Island Falls quadrangles, Penobscot and Aroostook Counties, Maine; it is here named the Shin Brook Formation. The fossils, though imper-

fectly preserved, appear to constitute a unique assemblage, consisting dominantly of brachiopods but with sponges, corals, gastropods, bryozoans, trilobites, and cystoids. The principal purpose of this paper is to describe these brachiopods and trilobites. Notes on a few of the other fossils are also given, but their scarcity and poor preservation prohibit more detailed work on them at this time. The fossil assemblage indicates that the Shin Brook Formation is late Early Ordovician or early Middle Ordovician in age.

The Shin Brook Formation lies in a large steep-limbed, doubly plunging syncline and in two smaller synclines to the southeast (fig. 1). It is underlain by slate and quartzite of the Grand Pitch Formation (Grand Falls Formation of Ruedemann and Smith, 1935) containing *Oldhamia* of Cambrian(?) age (Neuman, 1962).

The geology of this area was little understood prior to the present work. Keith's (1933) geologic map of Maine shows a horseshoe-shaped body of "greenstone," whose northern arm is formed of the rocks considered in this paper. That these arms are not connected has been shown in an earlier paper (Neuman, 1960).

The Shin Brook is older and petrographically distinct from the other fossiliferous Ordovician units reported in Maine to this time. The most nearly comparable unit is the Kennebec Formation, 65 miles to the southwest, which consists of rhyolite tuffs and related rocks. Its small assemblage of fossils includes the brachiopod genus *Valcourea* (Boucot, 1961, p. 183) that suggests an age no greater than the Marmor Stage of Cooper (1956, p. 8). Even younger Middle Ordovician and probably Late Ordovician is represented by the calcareous slaty "ribbon rock" of eastern Aroostook County (Pavlides and others, 1961).

ACKNOWLEDGMENTS

John Allingham of the Geological Survey, and George Eaton, first discovered fossils on Sugarloaf Mountain (fig. 1) in the course of sampling igneous rocks for magnetic studies. My collections were made here and at other localities during geologic fieldwork in the Shin Pond quadrangle; in this work I was aided by John Duane in 1957, by R. H. Raymond in 1958 and by H. H. Roepke in 1959. Fossils along Townline Brook were discovered and collected by E. B. Ekren, of the Geological Survey, while mapping the geology of the Island Falls quadrangle.

Dr. G. A. Cooper of the U.S. National Museum and Dr. A. J. Boucot of the California Institute of Technology were generous in their help in the study of the brachiopods. I am also grateful to those paleontologists who contributed reports on fossils of other phyla discussed here and to Dr. Olcott Gates of the Johns Hopkins University, who

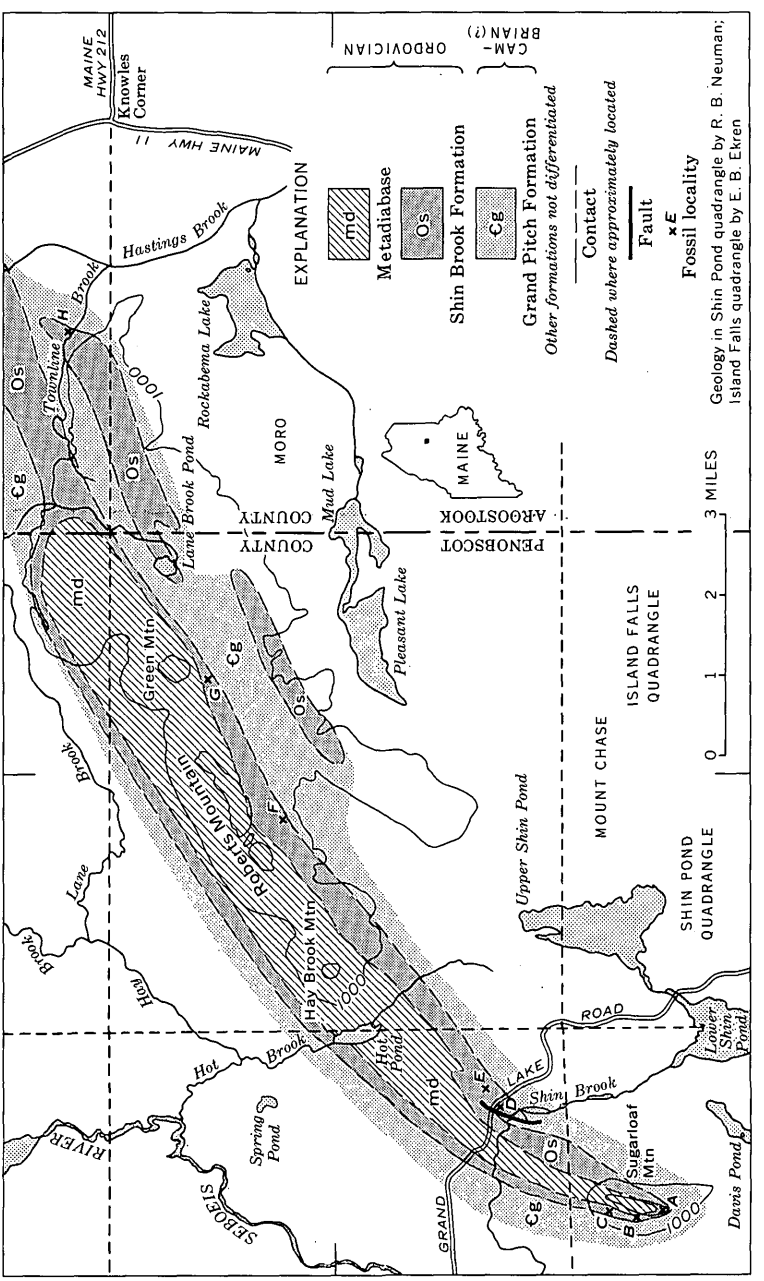

FIGURE 1.—Map showing distribution of Shin Brook Formation.

examined thin sections of the rocks and advised me on their petrography. Photographs of the brachiopods were made by R. P. Ulmer and R. H. McKinney; those of the trilobites were made by H. B. Whittington.

STRATIGRAPHY

SHIN BROOK FORMATION

The Shin Brook Formation is here named from exposures along Shin Brook, T. 6 N., R. 7 W., in the Shin Pond quadrangle, Penobscot County (figs. 1 and 2). The formation consists of bedded water-laid volcanic sandstone and conglomerate, massive porphyritic rocks that are probably crystal tuffs, and volcanic breccia.

The bedded rock ranges from fine-grained siltstone to coarse-grained conglomerate. In addition to volcanic constituents, the coarser grained layers contain fragments of fine-grained quartzite and chips of slate like that in the underlying formation, especially in the basal beds. Other than the quartzite fragments, quartz is rare except in some beds in the eastern part of the area.

The more massive porphyritic rock is probably crystal tuff with a mineral composition ranging from altered basaltic andesite to dacite. The saussuritized plagioclase crystals, which form about 15 percent of the rock, are about 2 mm in size, nearly equidimensional and commonly broken; there are a few large quartz grains as well. The felted groundmass is also largely saussuritized plagioclase, with abundant chlorite and calcite and more rarely epidote and clinozoisite.

Strong shearing prevails in both the crystal tuffs and the bedded rocks. Shapes of detrital particles have been modified, and in some places, bedding has been completely obliterated. In favorable places, however, details of flow structure, graded bedding, and fine laminations are preserved.

Exposures along Shin Brook (fig. 2) on the southeast flank of the main syncline are here designated the type section of the Shin Brook Formation. Although this section is faulted and much of the rock exposed is strongly deformed, part of it is suitable for stratigraphic measurement, and the remainder contains rock that is characteristic of the formation throughout the area.

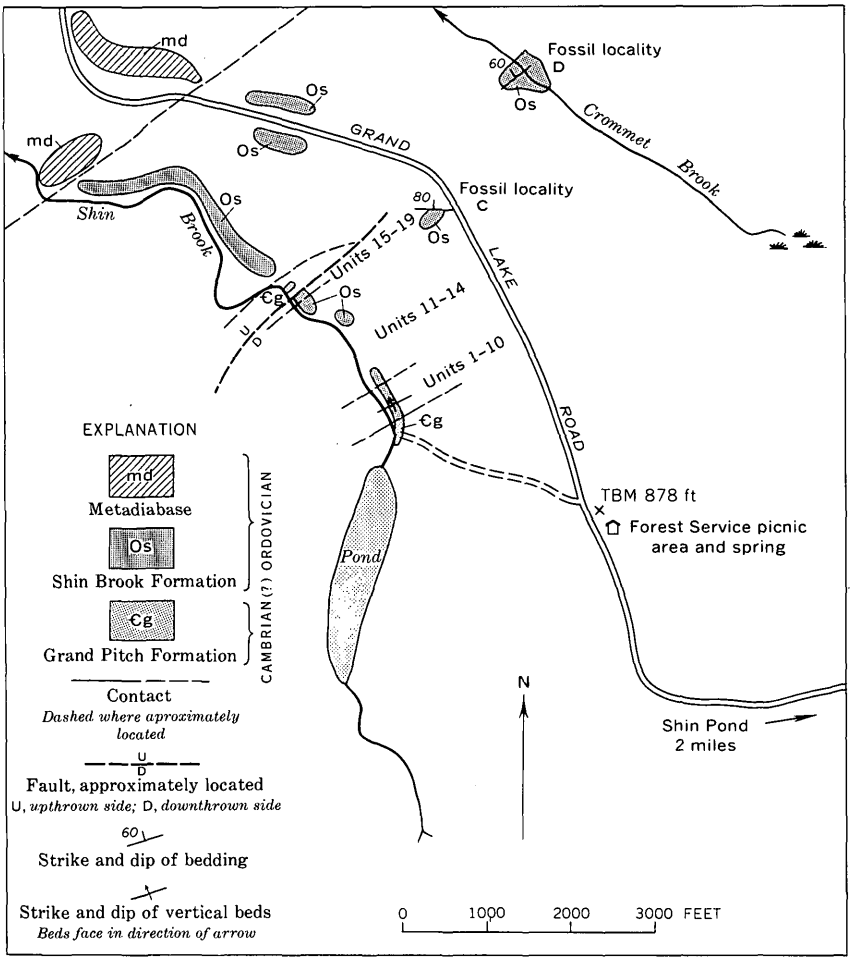

FIGURE 2.—Geologic sketch map of the vicinity of the type section of the Shin Brook Formation, showing location of stratigraphic units described in text. Patterned areas indicate location of outcrops.

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Type section of the Shin Brook Formation measured along Shin Brook in the SW¼ T. 6 N., R. 7 W., Penobscot County (Shin Pond quadrangle), Maine

[Section starts at an old bridge abutment at the foot of the old road leading west from temporary bench mark 878 feet, or 6,300 feet N. 62° W. from the SW. cor. of T. 6 N, R. 7 W. Measured with tape and compass by R. B. Neuman and H. H. Roepke, Aug. 13–15, 1959. Rocks northwest of measured section are intensely deformed gray slate and quartzite of the Grand Pitch Formation, in a faulted segment]

	Thickness (feet)
Shin Brook Formation: (907 ft measured of which 304 ft is exposed)	
19. Tuffaceous sandstone and siltstone in graded layers 3–12 in. thick; with coarse-grained sandstone in the basal part and finely laminated siltstone at the top; siltstone more abundant than sandstone; unit includes two layers of crystal tuff, 6 in. and 2 ft. thick, respectively	35
18. Crystal tuff, greenish-gray; crystals are green altered plagioclase	10
17. Covered	3
16. Tuffaceous sandstone, grit, and conglomerate; finer grained part is well laminated, coarser part not laminated and includes fragments of porphyritic and nonporphyritic fine-grained igneous rock; ledge in streambed has distorted bedding structures that suggest deformation prior to lithification; base concealed	7
15. Tuffaceous sandstone, fine- to medium-grained, calcareous; strongly sheared with weathered pits that may have been concentrations of fragmental fossils; fossils, largely brachiopods, too strongly deformed to be identified	18
14. Covered	70
13. Crystal tuff, greenish-gray; with scattered angular cognate rock fragments ½–6 in. in average diameter; crystals of both matrix and fragments are green altered plagioclase; no primary layering seen; quartz veins abundant	20
12. Covered	375
11. Crystal tuff; light-green altered plagioclase phenocrysts in a darker aphanitic matrix; fractured	45
10. Covered	95
9. Tuff, fine-grained, light-greenish-gray; abundant carbonate; strongly sheared, with no bedding structures preserved	30
8. Covered	30
7. Volcanic conglomerate, with granules of aphanitic volcanic rock and dark slate, strongly sheared; bedding obliterated	50
6. Tuffaceous sandstone, gray, medium- and fine-grained; abundant carbonate; bedding obliterated by strong shearing	20
5. Covered	30
4. Volcanic granule conglomerate and coarse-grained sandstone, light-gray, strongly sheared	25
3. Sandstone and conglomerate, interbedded, with conglomerate beds 10–20 in. thick, sandstone somewhat thinner; angular to subrounded fragments as much as 1½ in. in average diameter include volcanic rocks and fine-grained quartzite	35
2. Phyllite, light-gray, probably tuffaceous	2
1. Slate, dark-gray, with small (¼–½ mm) white grains (altered plagioclase?) with rhombic outline abundant	2

	Thickness (feet)
Grand Pitch Formation:	
Slate and quartzite, interbedded; slate is dark gray, silty; quartzite is medium gray, fine grained, in well-defined beds 1–6 in. thick	30
Covered	70
Slate and quartzite, interbedded; slate is dark gray, phyllitic; quartzite, which forms about 10 percent of unit, is fine grained, with thin cross-bedded sets, to base of measured section at old bridge abutment	50

The 900 feet of the measured section probably represents only a fraction of the total thickness of the Shin Brook Formation in this vicinity. Northwest of the segment of the Grand Pitch Formation brought up by faulting, the Shin Brook Formation crops out for 1,500 feet along the brook and on the adjacent bluffs. These exposures are almost entirely conglomerate, strongly deformed with flattened fragments of a variety of rocks, largely of volcanic origin but with some slate and a little quartzite. The original stratification has been largely obscured, but in the few places where it was seen it is vertical or dips steeply to the northwest.

On the west face of Sugarloaf Mountain, the Shin Brook Formation is only about 300 feet thick and consists of tuff and tuffaceous conglomerate with about 5 feet of fossiliferous tuffaceous sandstone near the middle (loc. *B* of fig. 1). To the east, however, southeast of Roberts Mountain, the Shin Brook Formation is about 2,500 feet thick, as measured along a small brook and on the adjacent slopes near the eastern edge of the Shin Pond quadrangle. The basal 10 feet of the section here is a conglomerate with rounded quartzite fragments ½–10 inches in diameter in a green tuff matrix. Above a sequence of tuffaceous sandstone and conglomerate, about 120 feet thick, tuffaceous sandstone is interbedded with slate, and one of these sandstone layers yielded gastropods (loc. *F* of fig. 1). About 2,000 feet of tuff conglomerate and tuff lies between this level and fine-grained tuffaceous sandstone with abundant but unidentifiable fragments of trilobites near the top of the formation.

Most of the outcrop area of the Shin Brook Formation on the northwest flank of the syncline is covered by glacial deposits. Between Sugarloaf Mountain and Townline Brook (fig. 1), only one small exposure was found, northwest of Hot Pond. This exposure and those at opposite ends of the syncline suggest that the Shin Brook Formation is continuous along the northwest flank as shown in figure 1.

The sharp contrast in lithology and style of deformation between the Shin Brook Formation and the Grand Pitch Formation that underlies it, together with the quartzite-bearing conglomerate in the basal layers of the Shin Brook, have been interpreted (Neuman, 1960) as evidence of an angular unconformity at this boundary. Inasmuch

as a late Precambrian or Early Cambrian age has been suggested for the Grand Pitch (Smith, 1928; Neuman, 1960), this unconformity may represent part of the Early Ordovician and most, if not all, of Cambrian time.

Metadiabase that was probably intruded as a sill lies at the top of the Shin Brook Formation in the trough of the large syncline of figure 1. Sedimentary rock younger than the Shin Brook or the metadiabase are not preserved here or in the shallower synclines to the south and east. Thus the full thickness of the Shin Brook Formation is not known.

METADIABASE

Dark-greenish-gray metadiabase crops out in the northeastward-trending belt from Sugarloaf Mountain through Hay Brook, Roberts, and Green Mountains to the Aroostook County line (fig. 1). Throughout the belt, this rock is nearly uniform and massive save for a network of joints some of which are filled by epidote-rich veinlets. The rock ranges from fine to medium grained, with parts that are porphyritic. About 60 percent of the rock is saussuritized plagioclase that forms a mat of elongate crystals typical of diabase. Augite, which forms about 30 percent of the rock, occurs as intersertal to subophitic small grains and locally as phenocrysts as large as a millimeter. The remaining 10 percent is largely interstitial chlorite and 2 or 3 percent opaque minerals, probably largely magnetite.

Evidence that the diabase was intruded into the Shin Brook Formation rather than extruded over it was found in exposures of the contact between them along the southwest face of Sugarloaf Mountain. Here the contact parallels bedding of the tuff at several places for short distances, but between these places the contact cuts across bedding abruptly, stepping up to the north, in places as much as 50 feet. Although no chilling or baking is visible along the contact, neither are there amygdules or fragments of tuff in the diabase as are common at the base of lava flows.

The age of the diabase is uncertain, but its close affinities with the Shin Brook suggest that it was intruded during the Ordovician.

COLLECTING AND PREPARATION

Fossils were obtained from almost a ton of fossiliferous rock that was shipped to the laboratory in Washington, D.C., a practice initiated by A. J. Boucot in his studies in this region (Boucot, 1961). Such quantities were needed because only a few percent of the specimens are sufficiently well preserved to permit identification.

Removal of the matrix from the shell proved impossible; the shells were therefore dissolved from the matrix. Each block was immersed in a weak solution of hydrochloric acid until effervescence ceased. Well-preserved specimens thus exposed were marked; the block was then marked with crisscrossing lines with colored pencils to facilitate reassembling and then broken into several pieces. Alternate breaking and leaching was repeated until individual specimens were surrounded by a minimum of matrix. Inevitably some good specimens are lost in breaking, adding strength to the argument for large collections.

The fossils thus obtained are all casts; the shells themselves formed the original molds which were removed by weathering or in the laboratory. For many specimens internal and external counterparts were obtained. Replicas of the fossils were made with latex with the aid of a wetting agent.

FOSSIL OCCURRENCES

Recognizable and identifiable fossils were found in the Shin Brook Formation in eight places (fig. 1). At these places, described in detail below, the fossils occur in conspicuously stratified water-laid tuffaceous sandstone and tuffs. Inasmuch as most of the carbonate of these rocks is of organic origin, including the fossils themselves, and is arranged along the bedding planes, the fossiliferous beds are readily distinguished in the field from the barren ones because the carbonate weathers more rapidly than any other constituent of the rock. Thus, fossiliferous beds are more deeply weathered and more porous than barren beds, and concentrations of shells are marked by recesses on the outcrop surface.

Deformation and regional alteration have had their effect upon the fossils. Thin sections through brachiopod shells show a coarse mosaic of calcite crystals and only small remnants of original fibrous structure. Chlorite or sericite has grown into calcite from the enclosing matrix, most abundantly in pressure shadows, forming drusy coatings on the casts of many fossils that are visible after laboratory solution of calcite with hydrochloric acid. A sample of this mineral coating from locality *A* was identified by X-ray (Mary Mrose, written communication, 1961) as ripidolite.

Recrystallization and deformation vary from specimen to specimen of the same species from the same locality, and there are greater differences in appearance of specimens taken from the different localities. Some features of a species are visible on one specimen but not on another, so that for most forms several carefully selected specimens chosen from among many are necessary. For these fossils, therefore,

variation in preservation tends to obscure the intraspecific variation inherent in the species.

Locality *A* at the southern tip of Sugarloaf Mountain (fig. 1) yielded the largest number and greatest variety of fossils of all the localities studied. Specimens of all but one of the forms found elsewhere were found there; some forms are known only from there, as were the best specimens of all but *Orthambonites robustus* n. sp.

Brachiopods are the most abundant fossils at seven fossil localities (table 1). Three forms are well-enough preserved and sufficiently abundant to permit observation in detail. A new genus and species is erected for one of these (*Platytoechia boucoti*), and the other two (*Orthambonites robustus* and *Productorthis mainensis*) are placed in new species. Specimens of *Tritoechia* sp. and *Platystrophia* sp. are fewer and less well preserved, and a distinctive shell showing affinities with *Polytoechia* is represented by two specimens. At least three other forms, represented by single valves or by poorly preserved or fragmental material, do not warrant description at this time.

TABLE 1.—*Chart showing occurrences of fossils in the Shin Brook Formation*

	Locality							
	A CO-3606	*B* 3605	*C* 3725	*D* 3607	*E* 3608	*F* 3726	*G* 3609	*H* 3610
Bryozoans:								
Batostoma sp.	×			×				
Nicholsonella sp.	×							
Brachiopods:								
Orthambonites robustus n. sp.	×	×	×	×	×			×
Productorthis mainensis n. sp.	×			×				
Platystrophia sp.	×			×				
Tritoechia sp.	×							
Platytoechia boucoti n. gen., n. sp.	×	×					×	×
Polytoechia? sp.	×							
Gastropod:								
Lesueurilla? sp.					×	×		
Trilobites:								
Geragnostus sp.	×							
Ampyx sp.	×							
Nileus sp.	×							
Annamitella? borealis n. sp.	×				×			
Illaenus (s. l.) sp.	×							
Raymondaspis sp.	×							
Hibbertia? sp.	×							
Miraspinid gen undet.	×							
Pygidium undet.	×							
Cystoid remains	×				×		×	×
Sponge spicules	×							

Relative abundance of fossils is different from bed to bed and from place to place. At locality *A* at the southern end of Sugarloaf Mountain, for example, *Platytoechia boucoti* occurs in great abundance, forming several shell beds through about 10 feet of fine-grained tuffaceous sandstone (fig. 3); virtually no other fossils were

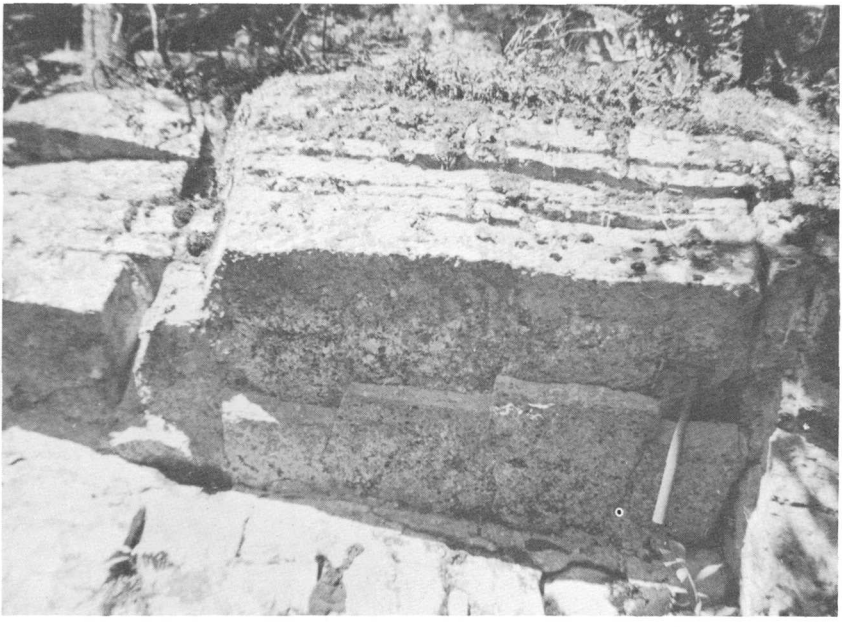

FIGURE 3.—Shell beds crowded with *Platytoechia boucoti* n. sp., southern end of Sugarloaf Mountain (loc. *A*, fig. 1). Beds dip 50° NW. Shells are concentrated on bedding surfaces of overhanging ledge and at intervals several inches apart through the succeeding 8 feet. Photograph by John Duane.

found in these beds. The overlying beds are somewhat coarser grained and contain very few *P. boucoti* but have a greater diversity of fossils, including *Orthambonites*, *Productorthis*, *Platystrophia*, bryozoans, sponge remains, and other forms. Similarly, one ledge several hundred feet along strike from those just mentioned contains the only significant numbers of identifiable trilobites discovered, and the same ledge is the only one that yielded *Tritoechia*.

A more detailed description of the fossil localities follows.

Locality A (*USGS CO–3606*).—T. 5 N., R. 7 W., Penobscot County (Shin Pond quadrangle), Sugarloaf Mountain, southern spur, altitude 1,500–1,520 ft. Fossils were obtained from the same beds in two places, one just east of the old trail, the other about 500 ft northwest of the trail. At the first the fossiliferous sequence is about 30 ft thick; the lower 10 ft consists of shell beds crowded with *Platytoechia boucoti* forming an overhanging ledge (fig. 3), overlain by beds with sponge root tufts with which are associated *Platystrophia* and other brachiopods and bryozoans. The fossiliferous sequence is overlain by thick-bedded coarse volcanic conglomerate and breccia; strike of beds here is N. 25° E., dip is 70° NW.; cleavage is not apparent. The fossiliferous beds and the overlying conglomerate lie in a syncline that can be traced around the sharp southern end of the mountain onto its western face with a change in strike to N. 80° W., and dip to 30° NE.; moderately strong vertical cleavage here strikes N. 25° E. Trilobites were found in greatest abundance, together with *Tritoechia*

and other brachiopods, on the western face at the top of the fossiliferous sequence, just beneath overhanging ledges of volcanic conglomerate. Beneath these are shell beds crowded with *Platytoechia* as on the eastern face of the ridge.

Locality B (*USGS CO–3605*).—T. 5 N., R. 7 W., Penobscot County (Shin Pond quadrangle), Sugarloaf Mountain, west face, altitude 1,460 ft, due west of the triangulation station at the summit of the mountain at its highest point. The fossiliferous beds are flinty tuffs about 5 ft thick in a sequence of tuff, sandstone, and granule conglomerate in about the middle of the Shin Brook Formation. Inasmuch as the locality is on the sheer face of the mountain where there are few landmarks, it is doubtful if it can be found again. Bedding strikes N. 25° E., cleavage is moderately strong, strikes north and is vertical.

Locality C (*USGS CO–3725*).—T. 5 N., R. 7 W., Penobscot County (Shin Pond quadrangle), Sugarloaf Mountain; gully on northwest face, altitude 1,250 ft. Greenish-gray fine-grained tuffaceous sandstone, 10 ft thick, about 300 ft beneath the top of the Shin Brook Formation contains widely scattered strongly deformed *Orthambonites robustus*.

Locality D (*USGS CO–3607*).—T. 6 N., R. 7 W., Penobscot County (Shin Pond quadrangle), roche mountonnée about 25 ft south of the Grand Lake road, 2.5 miles northwest of Shin Pond, just southwest of the point where the road curves from N. 40° to N. 80° W. About 18 ft of beds is exposed, consisting of fine- to coarse-grained conglomeratic tuff in graded beds, 6 in.–2 ft thick. Fossils scattered through the rock, are most abundant in the uppermost exposed layer. Bedding strikes east, dips 80° N.; cleavage strong, strikes N. 55° E., dips 75° NW.

Locality E (*USGS CO–3608*).—T. 6 N., R. 7 W., Penobscot County (Shin Pond quadrangle), falls in Crommett Brook at altitude 880 ft; 50 ft of fossiliferous tuff is coextensive with the cascades of the brook. Rock is fine- to coarse-grained tuffaceous sandstone in beds 8–15 in. thick; fossils are both scattered through the rock and concentrated in thin shelly layers. Beds strike N. 55° E. and dip 60° NW.; cleavage vertical, not pronounced, strikes N. 30° E.

Locality F (*USGS CO–3726*).—T. 6 N., R. 6 W., Penobscot County (Shin Pond quadrangle), small brook on southeast slope of Roberts Mountain (shown with waterline on topographic quadrangle map), altitude 1,050 ft, about 170 ft above the base of the Shin Brook Formation. A 6-in. sandstone bed about 50 ft above the base of a sequence of interbedded gray slate and greenish-gray tuffaceous sandstone contains *Lesueurilla*? sp. Strike and dip of bedding the same as those of cleavage; N. 55° E., 75° NW.

Locality G (*USGS CO–3609*).—T. 6 N., R. 6 W., Penobscot County (Island Falls quadrangle); E. B. Ekren supplied information as follows (letter of Nov. 17, 1960): "Draw, about 2,000 feet south of triangulation station 'Green' on Green Mountain. * * * The 'tuff' overlies a coarse volcanic conglomerate which in turn overlies the Grand Pitch Formation."

Locality H (*USGS CO–3610*).—T. 7 N., R. 5 W., Aroostook County (Island Falls quadrangle), ledges in bed of Townline Brook, altitude 840 ft. Fossils collected by E. B. Ekren. Rock is fine-grained tuff with scattered quartz grains. Fossils are concentrated in thin layers a few inches apart through about 10 ft of beds and are most abundant in the lower part of the exposed sequence. Fossils are strongly deformed, but detail of ornamentation is better preserved than in any of the other localities. Beds nearly flat, cleavage strong, strikes N. 60° E., dips nearly vertical. Base of Shin Brook Formation exposed about 150 ft southeast of fossiliferous beds.

PALEONTOLOGY

BRACHIOPODA

Suborder ORTHOIDEA Schuchert and Cooper, 1932
Superfamily ORTHACEA Walcott and Schuchert, 1928
Family ORTHIDAE Woodward, 1852
Subfamily ORTHINAE Schuchert and Cooper, 1931
Genus ORTHAMBONITES Pander, 1830

Orthambonites robustus Neuman n. sp.

Plate 1, figures 1–13

Description.—Shells large for the genus, unequally biconvex, the ventral valve considerably deeper than the dorsal. Length equal to or slightly less than the maximum width; hinge somewhat narrower than maximum width. Cardinal extremities obtuse, anterior margin broadly rounded. Anterior commissure straight. Shells stout, ornamentation costate, with 18–22 unbranching costae. Costae square in section, slightly narrower than similarly shaped interspaces. Interior of interspaces with shallow median grooves at the shell margin.

Ventral valve strongly convex in lateral profile, with maximum convexity near the middle. Anterior slope steeper than posterior slope. Break low; posterior margin forms an angle of about 130°. Interarea short, slightly curved, apsacline. Delthyrium open.

Ventral interior with stout teeth supported by advancing dental plates that rise vertically from the floor of the valve, thicken posteriorly, and merge with callus filling in the umbonal area. Musculature confined to delthyrial cavity. Diductor scars narrow, lanceolate, extending slightly beyond adductor track; adductor track wide, triangular, occupying about half the width of the delthyrial cavity, slightly elevated above diductor scars. Pallial sinuses lobate, divergent, extending from the margin of the diductor scars.

Dorsal valve gently convex in lateral profile, with maximum convexity near the middle. Sulcus shallow, containing three costae, confined to the umbonal region. Interarea short, anacline. Notothyrium open, unmodified.

Dorsal interior with short stout brachiophores supported by callus. Notothyrial cavity deep, with long, thin, delicate cardinal process. Median ridge low and wide, extending from margin of notothyrial cavity to midsection of shell. Posterior adductor scars deeply impressed; anterior adductor scars short, divided, heart shaped. Pallial sinuses narrow, divergent, extending from anterior adductor scars.

Immature forms.—In addition to the large shells that are presumably mature, described above, smaller shells that are probably conspecific with these but immature are abundant at locality *A* on Sugar-

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loaf Mountain. The maximum width of these shells is at their hinge line, and it exceeds the shell length. The dorsal sulcus, with three costae which in the adults is confined to the posterior part of the shell, extends to the anterior margin, so that the anterior margin of shells as much as 5 mm long is gently sulcate.

Measurements in millimeters.—

	USNM No.	Collection locality	Length (mm)	Width (mm)	
				Maximum	Hinge
Holotype (dorsal valve)	143668	*E*	12	15	12
Paratype (dorsal valve)	143672a	*E*	11	13	11
Do	143672b	*E*	13	16	------
Do	143672c	*E*	16	15	13
Do	143671	*E*	16	18	17
Paratype (ventral valve)	143667	*E*	16	17	14
Do	143672d	*E*	17	15	13
Do	143672e	*E*	18	18	16
Paratype (immature dorsal valve)	143670	*A*	4	--------	5
Paratype (immature ventral valve)	143672f	*A*	3	--------	4

Discussion.—The combination of its large size, deep convexity, and coarse paucicostate ornamentation, together with the details of musculature of both valves distinguish *O. robustus* from other North American species of *Orthambonites*. Of the previously described forms, *O. paucicostata* (Ulrich and Cooper) resembles it most closely, but this species is generally smaller than *O. robustus*, and its ventral valve is not as inflated as that of the present species.

Among European species, the ornamentation and shape of "*Orthis*" *kreklingensis* Öpik (1939) is much like that of *O. robustus*. Many features of the species cannot be directly compared with the published description and illustrations, but, among other things, the musculature of the two species seems to set them apart.

Exceptionally large shells provisionally referred to this species.—Very large but more deformed and incompletely preserved specimens of *Orthambonites* were taken from locality *D* and are provisionally assigned to *O. robustus*. The proportions as well as the size of these shells differ from those of the typical form, but a few of the largest shells associated with the type lot from locality *E* are as large as the smaller ones from locality *D*. The differences noted here, therefore, may be due more to tectonic deformation than to features of the undistorted shells.

These shells are unequally biconvex, with the ventral valve the deeper. They range from 25 to 40 mm in maximum width at the hinge; most are somewhat greater in width than in length. Shells are

ornamented with about 22 simple costae that are slightly narrower than the interspaces. A striking difference between these shells and typical *O. robustus* is their short straight strongly apsacline cardinal area; this could have resulted from deformation of the longer curved cardinal area of the typical form, but all the specimens from locality *C* display this characteristic feature. Teeth are indistinctly preserved; dental plates are parallel, short, and slightly advancing.

The exterior of the dorsal valve has a low sulcus with three costae that extends somewhat beyond the midlength of the shell. The dorsal interior has broad laterally expanded brachiophores bordering a deep notothyrial cavity which is bisected by a long thin cardinal process. A broad median ridge rises at the anterior margin of the notothyrial platform and extends to about the middle of the shell.

Subfamily PRODUCTORTHINAE Schuchert and Cooper, 1931
Genus PRODUCTORTHIS Kozlowski, 1927

Productorthis mainensis n. sp.

Plate 2, figures 1–11

Description.—Shell of average size for the genus, unequally biconvex, length about equal to width, with maximum width at the hinge line. Cardinal extremities slightly alate, sides subparallel, anterior margin rounded. Anterior commissure gently sulcate. Radial ornamentation of ventral valve more pronounced than concentric ornamentation, consisting of rounded costellae of unequal strength, about three per millimeter at the anterior margin, arising by implantation, with growth lamellae widely spaced except at anterior margin. Dorsal valve with strong concentric lamellation over entire shell surface, projecting as scalloped frills as much as a millimeter long, spaced at three to four per millimeter, closer at the anterior margin.

Ventral valve strongly convex, with maximum convexity in posterior half. Umbo swollen, beak incurved, extending to cardinal groove. Interarea a groove extending the full width of the shell, except where it is lacking in midpart of the shell, between the dental plates. Teeth delicate for the genus, bordered by well-defined crural fosettes, supported by short dental plates. Dental plates in younger shells slightly divergent, straight to slightly advancing covered by callus in older shells. Delthyrial cavity strongly elevated, occupied by wide adductor track bordered by a pair of narrow tracks interpreted by Cooper (1956, p. 334) as diductor muscle scars.

Dorsal valve smaller than ventral valve, gently convex, with maximum convexity in the posterior half. Sulcus shallow, expanding toward the front; lateral slopes gentle; interarea absent.

Dorsal interior with cardinalia confined to posterior margin. Brachiophores rodlike, merging at their bases with the base of the cardinal process to form a narrow buttresslike notothyrial platform. Sockets prominent grooves bordering platform. Cardinal process long, extended beyond the posterior margin of the shell. Myophore divided by shallow groove. A low sharp median ridge rises at the base of the notothyrial platform and extends to about midpoint of valve. Posterior adductor scars small, weakly impressed; anterior adductor scars considerably larger and more deeply impressed.

Measurements in millimeters.—

	USNM No.	Length (mm)	Width of hinge line (mm)
Paratype (dorsal valve)	143675	8	10
Do	143678a	7	8
Do	143678b	7	11
Holotype (ventral valve)	143674	8	8
Do	143678c	8	8
Do	143678d	7	7
Do	143678e	9	12

Length of ventral valves measured from posterior tip of umbo to anterior margin. All measured specimens from locality *A* of figure 1. In addition to the suite of specimens measured above, several specimens from locality *D*, either fragmentary or considerably deformed, are somewhat larger, with ventral valves about 12 mm long.

Discussion.—Williams (1956, p. 181) suggested that species of *Productorthis* described by Kozlowski (1927) fell into two groups, the *obtusa-parallela* group with poorly developed costellation and the *eminens* group in which the costellae are well developed. Like *P. mitchelli* Williams (1956), *P. mainensis* has well-developed costellae and might be assigned to the *eminens* group. Both species, however, lack the circular plate (chilidium) described by Schuchert and Cooper (1932, p. 82); whereas the cardinal process of *P. mitchelli* is supported by ridges, that of *P. mainensis* is free, like that of *P. agilera* (Willard) as shown in Cooper's illustrations (Cooper, 1956, pl. 56, especially fig. 7). *P. mainensis*, therefore, appears to be most closely allied to *P. agilera* (Willard), but the generally smaller size, less pronounced alation, and shallow fold and sulcus of *P. mainensis* clearly distinguishes it.

Family PLECTORTHIDAE Schuchert and Cooper, 1931
Subfamily PLATYSTROPHINAE Schuchert, 1920
Genus PLATYSTROPHIA King, 1850

Platystrophia sp.

Plate 2, figures 12–17

This genus is represented in the Shin Brook Formation by several poorly preserved specimens. Locality *A* yielded seven fragmentary specimens (five dorsal valves and two ventral valves) which are the best preserved of the lot. Locality *C* yielded about 25 specimens, all strongly deformed. None of these specimens are assigned to a species.

Description.—Shell small for the genus, biconvex. Ornamentation plicate with ventral sulcus shallow for the genus and comparable low dorsal fold. Shell surface imperfectly preserved, probably finely granulose.

Ventral valve convex, with prominent incurved beak. Cardinal area apsacline, approaching orthocline, short, triangular, longest in midparts and becoming very short toward the extremities. Delthyrium open. Valve highly arched in posterior third, sulcus developing in midparts, becoming prominent in the anterior third. Sulcus bears three plications; flanks with four or five plications.

Ventral interior with small teeth supported by stout dental plates converging slightly posteriorly and merging with callus deposit on the shell floor at the posterior margin of the delthyrial cavity. Muscle field a thickened platform that rises to a blunt point at the front; individual muscle scars not distinguishable.

Dorsal valve convex with low beak, cardinal area anacline, very short, reduced to a line at the extremities. Notothyrium open. Fold, rising in the midpart of the valve, becoming prominent at the anterior margin. Fold bears three plications, two of which rise from a point at the beak, the middle one intercalated a millimeter or two in front of the beak.

Dorsal interior with long wide bladelike brachiophores, indistinguishable from their supports, descending to shell floor to form shallow notothyrial platform. Shallow sockets defined by small fulcral plates. Cardinal process a thin blade. Myophore not seen.

Measurements.—All specimens are incomplete; measurements are of the preserved parts. The latter two probably most accurately reflect the dimensions of the shells. See table on page E18.

Discussion.—There is little question that these shells belong to the genus *Platystrophia*, but too little is known about them to assign them to a species. Their interareas, however, are shorter and narrower than most *Platystrophia* species. The order of origin of the plications

on the fold indicates their affinities with *P. precedens* McEwan (1919, p. 405).

	USNM No.	Collection locality	Length (mm)	Width (mm)
Dorsal valve	143682	*A*	13	13
Do	143681a	*A*	11	17
Do	143681b	*D*	10	16

B II beds of the Leningrad district, U.S.S.R., have yielded the oldest *Platystrophia* recorded to date (Rubel, 1961, p. 154–155). These shells, of probable Arenig age, and *P. precedens major* Williams, of upper Llandeilo age (Whittington and Williams, 1955, p. 402–404), are alike in having three plications on the fold, as do the Shin Brook specimens.

Suborder CLITAMBONOIDEA Öpik, 1934
Superfamily CLITAMBONACEA Schuchert, 1929
Family TRITOECHIIDAE Ulrich and Cooper, 1936
Subfamily TRITOECHIINAE Ulrich and Cooper, 1936
Genus TRITOECHIA Ulrich and Cooper, 1936

Tritoechia sp.

Plate 4, figures 1–12

Ten specimens of this distinctive genus were obtained from locality *A*. Because the specimens are few and fragmentary and the dorsal valve is not adequately represented, they are not assigned to a species.

Description.—Shell about average size for the genus. Width greater than length; hinge equal to maximum width. Cardinal extremities form right angle; anterior margin broadly rounded. Anterior and lateral commissures straight. Valves unequal in depth, with ventral valve hemipyramidal and dorsal valve gently convex. Ventral interarea long, catacline slightly concave, about one-third the length of the shell proper, with fine striations radiating from the beak. Pseudodeltidium strongly arched, with fine growth lines parallel to the hinge line. Foramen large, with thickened margin projecting posteriorly an unknown distance, probably forming a collar. Dorsal interarea short, strongly anacline, almost orthocline. Notothyrium partly closed by chilidial plates. Ornamentation multicostellate; costae rounded, slightly irregular. Costae increase by intercalation, numbering about four per millimeter at the anterior margin. Concentric ornamentation consists of fine filae, with more prominent growth lines toward the anterior third of the shell surface.

Teeth small, supported by short, thick dental plates that advance for a short distance at the floor of the valve to form the delthyrial cavity. Muscle field typical of *Tritoechia*, with tear-shaped diductor scars separated by a narrow linear adductor scar that stands as a ridge. A low ridge in front of the adductor scar extends about half the distance to the anterior margin. Pallial marks and ovarian impressions not seen.

Dorsal interior known from only two poorly preserved specimens. Cardinal process short and thin. Bladelike brachiophores typical of tritoechiids, supported by extensions from the posterior shell margin. Adductor scars deeply impressed for the genus, separated by a median ridge.

Measurements in millimeters.—

	USNM No.	Length (mm)	Width of hinge line (mm)	Interarea length
Ventral valve	143693	12. 0	14. 0	------
Do	143696	5. 0	9. 0	2. 5
Do	143692	7. 5	10. 0	2. 8

Discussion.—Three species of *Tritoechia* with concave ventral interareas have been described from North America, but they all differ from the Maine specimens in other details. *T. delicatula* Ulrich and Cooper (1938, p. 162–163) has a ventral sulcus, whereas the Maine specimens are broadly convex. *T. incurva* Ulrich and Cooper (1938, p. 164) is more coarsely ornamented, and its beak is incurved. *T. curvirostris* Sando (1957, p. 118–119) has a more curved interarea, and it is strongly apsacline rather than catacline. Thus, when enough is learned of its dorsal valve, a new species will probably be necessary for the Maine specimens.

Genus PLATYTOECHIA n. gen.

Diagnosis.—Convexi-concave or convexi-planar tritoechinids with costellate ornamentation, arched pseudodeltidium, and chilidial plates; ventral interarea radially striated, with small apical foramen; lacking a spondylium but with strong dental plates.

Description.—Convexi-concave to convexi-planar shells, strophomenoid in outline and profile. Ornamentation costellate, with stronger costellae separated by several finer ones, the radial ornamentation crossed by fine concentric growth lines. Anterior margins of both valves thickened.

Ventral valve gently convex in posterior part, becoming flat or concave in middle and anterior parts. Ventral interarea apsacline; pseudodeltidium convexly arched, with a very small foramen at its apex. Dental plates strong, supporting stout teeth. Muscle field confined to delthyrial cavity, like that of *Tritoechia*; diductor scars with thickened lanceolate margins bordering adductor field.

Dorsal valve strongly convex with anacline interarea. Notothyrium partly closed by chilidial plates. Cardinal process simple. Brachiophores unsupported except by lateral deposits of shell substance. Valve floor with thin platelike median ridge, and three to five pairs of lateral septa radially disposed.

Type species: *Platytoechia boucoti* n. sp.

No other species known.

Discussion.—The genus is here erected to contain the one species, *Platytoechia boucoti* n. sp. It shares features of each of the three genera now known in the subfamily Tritoechiinae. Its strongly convex dorsal valve with its long interarea is like that of *Eremotoechia*, whose ventral valve is also less deep than the dorsal valve. As defined (Cooper, 1956, p. 513), however, *Eremotoechia* has a hinge that is narrower than the greatest shell width, and its anterior commissure is uniplicate, whereas the maximum width of *Platytoechia* is at its hinge, and its anterior commissure is straight. No *Eremotoechia* is yet known with a prominent subperipheral border or radially striated interarea, both of which occur in *Tritoechia*, *Pomatotrema*, and *Platytoechia*. The ornamentation of *Platytoechia* is like *Pomatotrema* and is unlike that of the species of *Eremotoechia* described by Cooper (1956, p. 513–516), but this similarity is probably less important than the configuration of the dorsal valve in assessing generic relationships (Ulrich and Cooper, 1938, p. 6). Thus the nearest affinities of *Platytoechia* are considered to lie with *Eremotoechia*.

The strophomenoid outline and ornamentation of *Platytoechia* may be further evidence for convergence of the clitambonitid and strophomenoid stocks, earlier noted by Schuchert and Cooper (1932, p. 112).

Platytoechia boucoti n. sp.

Plate 3, figures 1–11

Description.—Large shells with dorsal valve deeply convex and reflexed ventral valve. Outline semicircular, with cardinal extremities slightly alate, the straight hinge line forming the greatest width of the shell. Lateral commissure slightly deflected ventrally; anterior commissure straight. Ornamentation strophomenoid, multicostellate, with stronger costellae at intervals of about 1 mm, with several weaker ones between them, the radial ornamentation crossed by concentric

ornament of fine filae and imbricate growth lamellae. Margins of both valves thickened by subperipheral borders.

Ventral valve reflexed in lateral profile with a low convex umbo flattening at about one-third the distance to the anterior margin, the middle and anterior parts with shallow concavity. Beak obscure; posterior margin forms an angle of about 175° at the apex. Pseudodeltidium, wide, moderately arched, with very small apical foramen.

Ventral interior with strong advancing dental plates, widely divergent towards the anterior. Teeth short, wide, and stout. Muscle field prominent, confined to the delthyrial cavity. V-shaped anterior margins of diductor scars sharply defined, adductor track narrow, faintly bilobed, slightly below diductor scars, with anterior margin indistinct. A pair of small blunt plates border the posterior point of the delthyrial cavity and connect the margins of the pedicle opening with the floor of the valve, defining two small chambers at either side. Inner margin of subperipheral border wrinkled; outer margin with fine grooves.

Dorsal valve moderately convex in lateral profile, with maximum convexity in the middle part of the valve. Hinge line straight, beak obscure, umbo low; cardinal extremities slightly reflexed. Lateral slopes gentle, but anterior part of the valve swollen, with steep anterior slope. Interarea anacline, about half the length of the ventral interarea. Notothyrium wide; chilidial plates prominent, each covering about one-fourth of the notothyrium.

Dorsal interior with broad brachiophores unsupported except for lateral deposits of shell that enclose wide sockets. Cardinal process large and bulbous, with stout shaft; myophore divided by shallow groove. Posterior part of cardinal process extends slightly beyond chilidial plates. Floor of valve anterior to cardinal process slightly raised to form low median ridge that is confined to posterior fourth of valve. Middle part of shell floor divided by thin median blade that rises from posterior of median ridge and persists nearly to the inner edge of the subperipheral border. Adductor scars deep, bordered by as many as five pairs of thin septa, radially arranged. Subperipheral border as in ventral valve.

Measurements.—Measurements of four of the common large-size specimens are tabulated on page E22. The collection also contains some that are half the size of these, and a few that are almost twice their size. All measured specimens from locality *A* of figure 1.

Discussion.—Collections from the Shin Brook Formation contain more than a hundred specimens of this species, largely from the shell beds at the southern end of Sugarloaf Mountains (loc. *A*, figs. 1 and 3) that are crammed with them to the exclusion of virtually any other form.

695-526 O—64——4

	USNM No.	Length (mm)	Hinge (mm)	Width 2 mm anterior from hinge (mm)
Holotype (ventral valve)	143683	16	19	18
Paratype (ventral valve)	143689	14	17	16
Paratype (dorsal valve)	143684	15	17	16
Do	143691	19	24	23

Although the main outlines of its architecture are visible on most specimens, a few important features are preserved in only a few. Shell structure and details of ornamentation are preserved in a few specimens from locality *H*, despite the fact that fossils at this locality are more strongly deformed; shell material from other localities is largely recrystallized, and details of ornamentation are masked by crystalline chlorite. The small apical foramen was preserved in only the few specimens that broke immediately anterior to the junction of the interarea and the shell proper, rather than along this line. The radial striations on the ventral interarea are also rarely preserved.

Genus POLYTOECHIA Hall and Clarke, 1892

Polytoechia? sp.

Plate 1, figures 14–17

Description.—Deep hemipyramidal ventral valve with long slightly curved apsacline interarea. Beak prominent, apical angle about 70°. Pseudodeltidium arched, with groove along its inner face; apical part not seen. Anterior part incompletely preserved. Ornamentation costellate, the costellae crossed by prominent growth lamellae. Costellae of unequal strength, two to four weaker ones lying between the stronger, the latter spaced at intervals of about 1 mm in the midpart of the shell. Growth lamellae elevated, three to four per millimeter.

Interior with spondylium triplex supported by receding dental plates and a longer median septum. Spondylium with median groove occupying about one-third of its width. Hinge teeth long.

Measurements in millimeters.—

Ventral valve, USNM 143673:	*Millimeters*
Length (incomplete)	10
Width (hinge)	14
Interarea length	7

Discussion.—The collection from Sugarloaf Mountain (loc. *A* of fig. 1) contains two ventral valves of this shell that although incomplete display the spondylium triplex and the pseudodeltidium characteristic of the genus *Polytoechia.* The strongly lamellose ornamentation and the configuration of the spondylium of these specimens are similar to those of *Kullervo* Öpik (1934), which, however, lacks a pseudodeltidium. With adequate material, therefore, a new genus will probably be necessary for this shell.

STRATIGRAPHIC IMPLICATIONS OF THE BRACHIOPODS

The brachiopods of the Shin Brook Formation are unquestionably Ordovician forms and most probably belong to the earlier half of the period, equivalent to the Arenig or Llanvirn Series of Great Britain. *Orthambonites*, *Productorthis*, and *Platystrophia* have been described from rocks of Arenig age in the eastern Baltic region (Rubel, 1961), and *Productorthis* and *Platystrophia* were listed from rocks of Llanvirn age in Argentina (Harrington and Leanza, 1957, p. 35). *Orthambonites* is a long-ranging genus of little aid in correlation, but earlier species, such as *O. paucicostata* of Whiterock age from Nevada and *O. robustus*, have fewer costae than later species. *Productorthis* is abundant and varied in rocks of Arenig age in the Baltic province (Kozlowski, 1927; Rubel, 1961, p. 166–168), but it occurs in North America and elsewhere in Middle Ordovician rocks (Cooper, 1956, p. 333–336; Williams, 1956). As already noted, the older species have a chilidium that is not seen in *P. mainensis* or in the younger species. *Platystrophia* has not heretofore been found in rocks older than Trenton in North America. Elsewhere older species have been found, the oldest having recently been described from rocks of Arenig age in the U.S.S.R. (Rubel, 1961, p. 154–155). Its occurrence, therefore, does not exclude an Early Ordovician age for the Shin Brook Formation.

Tritoechia has not previously been reported from above the Lower Ordovician, although the genus has been recognized in many Ordovician sequences throughout the world. The similarity of the new genus *Platytoechia* to Cooper's (1956, p. 513) *Eremotoechia* suggests a younger age, as do some features of the shell questionably assigned to *Polytoechia.*

Correlation of the Baltic and Argentine sequences in the British succession has been based on graptolites (Rõõmusoks, 1960, p. 59–60; Harrington and Leanza, 1957, p. 34–35). The Arenig is probably equivalent to the upper Canadian of North America (Twenhofel and others, 1954, p. 260) and the Llanvirn to the Whiterock Stage of Cooper (1956, p. 7–8; Kindle and Whittington, 1958, p. 338; Berry,

1960, p. 39–41). Accordingly, the brachiopods indicate that the Shin Brook Formation is either late Canadian or Whiterock in age.

Bryozoans, sponges, and gastropods

Bryozoans.—Fragments of bryozoan zoaria occur in small numbers, especially in some of the coarse-grained layers at locality *A* of figure 1. A few fragments were also obtained at localities *D* and *H*.

Specimens from locality *A* were studied by Dr. J. R. P. Ross of the Illinois State Geological Survey, who reported (written communication, 1961) that two genera were present. One is a branching form that she identified as a species of *Batostoma*; the other form, which is massive, she questionably refers to *Nicholsonella*. Both recrystallization of wall structures and the fragmentary nature of the specimens prohibited Dr. Ross from making specific determinations.

Sponges.—Sponge remains from locality *A* were examined by Dr. R. M. Finks of Queens College, New York, who advised me (written communication, 1962) in preparing the following notes.

The sponge spicules at locality *A* are all monaxons, largely fragmental. Although some are now calcite, it is likely that all were originally siliceous, because those that are calcite are ranged in the form of root tufts characteristic of siliceous sponges. These root tufts are bundles of monaxon spicules about 1 mm in diameter and as much as 5 cm long.

In addition, siliceous spicules are scattered through some of the rock, and four clusters of siliceous spicules occur in cavities 10–20 mm in diameter that were filled with calcite prior to acid etching. These clusters may represent the remains of individual sponges, for each cluster contains a consistent set of spicule types. Common to all the cavities are straight or somewhat sinuous spicules a few tenths of a millimeter in diameter and several millimeters long. Two of the cavities also contain spicules of the same size and shape that are covered with short slender spines, whereas some of the spicules in the remaining two are nearly straight columns of coaxial imbricate cones.

Age determinations cannot be made on this material. All but the imbricate cones are long-ranging forms, and the latter were not heretofore known to Dr. Finks.

Gastropods.—Gastropods probably related to *Lesueurilla* (Yochelson, written communications, 1961, 1962) were found at locality *F*. Although these shells are somewhat deformed, many features are preserved, and they are here briefly described and illustrated (pl. 4, figs. 13–17). Formal taxonomy and complete description are deferred to another place.

The gastropod is hyperstrophically coiled, discoidal, and phaneromphalous. The lower surface is nearly flat, with successive whorls standing slightly above one another. The upper surface has a deeply depressed spire, and the whorls are separated by a deeply incised suture. The whorl profile is subtriangular, with an inner face that is vertical to about the level of the top of the preceding whorl, then convexly arched to the base of a narrow angular keel. The outer face is steeply inclined and nearly straight except for a short distance above the basal angulation. The basal angulation at the periphery is acute. The ornament consists solely of growth lines that are strongly lamellose on the basal surface and are widely spaced on inner whorls but closely crowded on the outer whorl. On the inner whorl face the growth lines are prosocline from the suture to the keel, gradually flattening upward. On the outer face they are inclined near the keel and steepen downward. On the basal surface they are nearly radial, but curve backward from the angulation.

The collection consists of 10 specimens, including small parts and those that are nearly complete. These suggest that diameters range from 30 to 50 mm. Two somewhat larger but less well preserved specimens from locality *E* are probably conspecific with these.

TRILOBITA

By HARRY B. WHITTINGTON [1]

The numbers of specimens obtained from each locality are listed in table 2. Type and figured specimens are preserved in the U.S. National Museum.

Family AGNOSTIDAE M'Coy, 1849

Genus GERAGNOSTUS Howell, 1935

Geragnostus sp.

Plate 5, figures 2–5, 7, 8

Description.—Cephalon with well-defined glabella tapering forward, transverse furrow, shallow medially but deeper distally, situated at one-third the length from the anterior margin; lateral occipital lobe large, triangular. Cheeks and preglabellar field convex, border widest anterolaterally, posterior border narrow, convex. Pygidium with broad axis extending more than half the length, prominent median tubercle on second axial ring, border widest posterolaterally and bearing short border spine.

[1] Museum of Comparative Zoology at Harvard College, Cambridge, Mass.

TABLE 2.—*Numbers of specimens of trilobites from each locality* [1]

	Locality *A*		Locality *E*
	Cephalon	Pygidium	Pygidium
Geragnostus sp.	3	3	----
Ampyx sp.	1	13	----
Nileus sp.	18	10	----
Annamitella? *borealis* n. sp.	35	32	1
Illaenus (s.l.) sp.	3	2	----
Raymondaspis sp.	2	----	----
Hibbertia? sp.	13	----	----
Miraspinid gen. undet.	1	----	----
Pygidium undet.	----	3	----

[1] Numbers of specimens are given as an indication of relative abundance of the different species. Counts are of counterpart, internal or external molds of complete or incomplete specimens, and of fragments of the cephalic fringe in the case of *Hibbertia*? sp. undet. Twenty-nine specimens of the free cheek of *Annamitella*? *borealis* n. sp. have not been included, nor have eight specimens of the cephalic doublure of *Nileus* sp. undet., the numbers under cephalon being of cranidia or the complete cephalon.

Discussion.—Both cephalon and pygidium are like those of species of *Geragnostus* from the Lower and Middle Ordovician of Europe (Tjernvik, 1956, p. 188–194, text fig. 27, pl. 1, figs. 5–15; Whittard, 1955, p. 7–10, text fig. 2a, pl. 1, figs. 1–8). A similar species, questionably referred to *Trinodus*, has been described from the Lower Ordovician of Nevada (Ross, 1958, p. 562–564, pl. 83, figs. 1–8, 14–16), and another from limestone of Whiterock age in western Newfoundland (Whittington, 1963).

Family RAPHIOPHORIDAE Angelin, 1854
Genus AMPYX Dalman, 1827

Ampyx sp.

Plate 5, figures 1, 6, 9, 10, 13, 14, 16

Description.—The forwardly expanding glabella, the gently convex occipital ring and upwardly and forwardly directed glabellar spine, and the axial furrow in which is impressed a deep anterior pit are typical of this genus. The pygidium (pl. 5, figs. 9, 10) has the axis tapering back to reach the deep vertical border, across which it is extended by a narrow postaxial ridge. The pleural region is gently convex, the first pleural furrow deep and running outward in a curve which is convex posteriorly. In front of this pleural furrow the rib is strongly raised, and there is a facet. The border slopes vertically, is widest posterolaterally, narrowing as it approaches the axis; it is traversed by raised anastomosing lines. Distortion and flattening of the fossils in this deposit is such that in some specimens (pl. 5, figs. 13, 14, 16) the border appears to be gently sloping and not bent down vertically.

Ampyx has been recorded from Lower Ordovician strata in Newfoundland and Nevada (Kindle and Whittington, 1958, p. 324–328, 338) and occurs in beds of similar age in western Europe (Tjernvik, 1956, p. 270–272, pl. 11, figs. 13–18; Whittard, 1955, p. 15–18, pl. 1, figs. 15–21; Thoral, 1935, p. 305–307, pl. 28, figs. 7–10, pl. 30, fig. 6). In both continents it is well known in Middle Ordovician rocks.

Family NILEIDAE Angelin, 1854
Genus NILEUS Dalman, 1827

Nileus sp.

Plate 5, figures 11, 12, 15, 17–19

Description.—Cephalon subsemicircular in outline, gently convex, sloping most steeply anteriorly. Glabella not outlined by axial or preglabellar furrows and lacking occipital or lateral glabellar furrows. A narrow (sagittal and exsagittal) band along the posterior margin of the glabella, visible in the internal mold (pl. 5, fig. 12), is the mold of the doublure. Large semicircular eye lobe of length (exsagittal) two-thirds length (sagittal) of cephalon. In front of eye lobe anterior branch of suture runs outward and forward then curves around to run along the anterior margin of the cephalon, the two branches meeting in a smooth curve. Posterior branch of suture runs outward and backward to margin. Doublure (pl. 5, fig. 11) gently convex, of width anteriorly (sagittal) about one-quarter the length of cephalon, becoming progressively narrower laterally so that close to the genal angle the doublure is flexed up sharply and the ventral edge of the cephalon is a narrow ridge. Hypostomal suture runs in a curve gently convex forward, doublure immediately in front of this suture depressed by a shallow furrow. No median or connective sutures.

Pygidium subsemicircular in outline, gently convex, axis faintly indicated by slight additional convexity, extending back about two-thirds the length. Pleural regions slope gently outward and downward, doublure broad, posterolaterally reaching inward close to margin of axis.

Discussion.—In all respects except the lack of axial furrows this species is quite like typical *Nileus* (Tjernvik, 1956, p. 208–211, text fig. 33, pl. 2, figs. 12–23) from the Lower Ordovician of Sweden. I have recently (Whittington, 1963) redescribed *Nileus affinis* Billings, 1865, a species from beds of Whiterock age in western Newfoundland also characterized by lack of definition of the axial furrows. The species from Maine is particularly like *N. macrops* Billings (1865, p. 273, fig. 259) in the large size of the eye lobe. This latter species is

from beds of the middle part of the Table Head Formation at Table Point, western Newfoundland. A species of *Nileus* is also present in beds of the *Anomalorthis* zone of the Whiterock stage (=Zone N of Hintze, 1953) of Nevada. Studies of the species from Newfoundland and Nevada are in progress.

Family BATHYURIDAE Walcott, 1886
Genus ANNAMITELLA Mansuy, 1920

Annamitella? borealis n. sp.

Plate 6 and text figure 4

Holotype: USNM 143708, external mold of cranidium, loc. *A*.

Paratypes: USNM 143709, 143712, incomplete internal molds of cranidium; USNM 143710, 143711, counterpart molds of free cheeks; USNM 143713–143715, counterpart molds of pygidium, all from loc. *A*.

Description.—Characters of the cephalon are summarized in figure 4. Glabella subrectangular in outline, width (transverse) about twice length (sagittal), gently convex transversely, frontal lobe strongly convex and overhanging preglabellar furrow. Convex occipital ring defined by narrow, deep occipital furrow; lateral glabellar furrow 1p shallow, straight, directed inward and backward at about 45° from the axial furrow and not reaching the occipital furrow; outer end of 1p opposite about midpoint of eye lobe; lateral furrow 2p represented by faint, shallow depression extending inward and backward a short distance from the axial furrow, outer extremity situated opposite anterior part of eye lobe. Lateral glabellar lobe 1p slightly inflated, possibly median part of glabella between lobes 1p also slightly inflated. Deep axial furrow with shallow anterior pit, preglabellar furrow narrower and shallower than axial furrow. Large, curved eye lobe is situated close to glabella and extends back close to posterior border furrow. Palpebral lobe with strongly raised, convex rim and broad, deep palpebral furrow. Surface of eye lobe not preserved. A ridge and external furrow run immediately outside the outer margin of the eye surface. Cheek outside eye lobe curves steeply down to border furrows. Anterior border probably narrow (sagittal and exsagittal) and convex, lateral border becomes broader posteriorly, maximum width and depth at genal angle. Posterior border narrow, convex, clearly defined by border furrow, lateral and posterior borders merge at genal angle to form base of long, straight, slightly outwardly directed genal spine. Anterior branch of suture runs straight forward subparallel to the axial furrow and a short distance outside it, curving inward to run immediately outside the preglabellar furrow; two branches meet in an apparently smooth curve along the anterior margin. Free cheek suggests that connective suture crosses the border a short distance

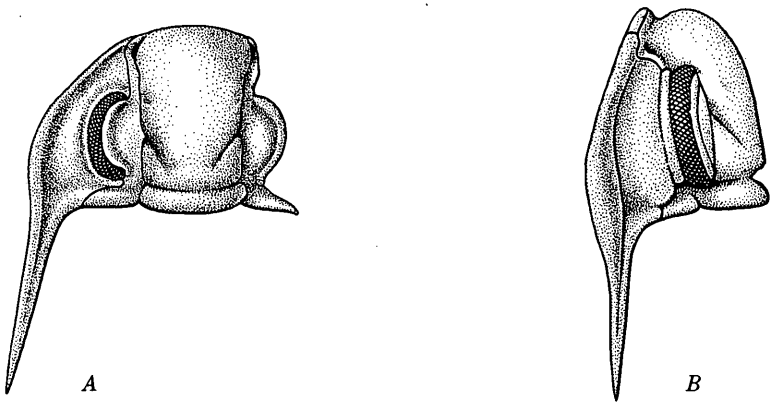

FIGURE 4.—*Annamitella? borealis* n. sp. Reconstruction of cranidium and left free cheek, based on originals of plate 6, figures 1–11. *A*, dorsal view; *B*, left lateral view, × 3. Drawing by N. Strekalovsky.

inside the point where anterior branch reaches the border. Posterior branch of suture runs outward and backward over posterior border to margin. Ridge outside eye surface, and outer slope of borders, traversed by raised lines; elsewhere external surface of cephalon apparently smooth, though sculpturing may be obscured by the coarseness of the matrix.

Pygidium has convex axis that tapers back to a prominent rounded tip, the first four axial rings successively more faintly defined; a succeeding ring may be discernible. The pleural regions are gently convex, a broad gently convex outward-sloping border defined at the inner margin by a shallow border furrow. Inside border the pleural region is crossed by deep first and second pleural furrows that extend out to the inner margin of the border; third, fourth, and fifth pleural furrows are successively shorter, shallower, and much more faintly defined. Convex ribs between the furrows, the fourth rib faint. Doublure convex ventrally and extending inward to inner margin of border (pl. 6, figs. 15, 18). Pygidia range between lengths (sagittal) of 2–12 mm; most are about the size of the original of plate 6, figures 13, 16, 17. All seem to belong to one species. In the three largest examples (for example pl. 6, fig. 14) the border appears to be relatively wider, but this appearance may be the result of distortion which has reduced the original length and increased the original width. No sculpture is preserved on external surface.

Discussion.—The cranidium is like that of such bathyurids as *Goniotelus*, *Goniotelina*, and *Bathyurina* (Whittington, 1953, p. 662–667, pl. 68, figs. 1–11, 13–21; Hintze, 1953, pl. 26, figs. 1–13; Poulsen, 1937, pl. 6, figs. 14, 15; pl. 7, fig. 1) from the high Canadian and Whiterock beds of North America and Greenland. It differs from

all of them in the presence of a deep lateral glabellar furrow 1p. This furrow and a deep short transversely-directed furrow 2p are present in the cranidium of *Annamitella asiatica* Mansuy, 1920 (p. 14–15, pl. 2, figs. 7a–f) from Ordovician sandstones in North Vietnam, of *Bathyuriscops granulatus* (Weber, 1948, p. 11, pl. 1, figs. 22–24, text fig. 2; Keller and Lisogor, 1954, p. 75–78, pl. 1, figs. 1–7; Chugaeva, 1958, p. 17–18, pl. 1, figs. 1–3) from strata of early Llandeilo age in Kazakhstan, and of *Proetillea tellecheai* Harrington and Leanza, 1957 (p. 139–141, fig. 59, [sub. figs.] 3–7) from beds of Llanvirn age in Argentina. The deeper and longer furrow 2p distinguishes the Asian and Argentine species, but in other features these cranidia are remarkably alike. A similar cranidium has been recognized in Lower Ordovician sandstones of central Australia by Miss F. Gilbert-Tomlinson (written communication from Dr. A. A. Öpik, 1962). As Miss Gilbert-Tomlinson pointed out, if these forms are congeneric, the senior name is *Annamitella*, and it is used here with question for the Maine species. Not only is uncertainty inherent in an identification based on comparisons between illustrations, but there are differences (notably in the nature of the border) between the isolated pygidia referred to the various species and between the accompanying faunas.

Family ILLAENIDAE Hawle and Corda, 1847
Genus ILLAENUS Dalman, 1827

Illaenus (s.l.) sp.

Plate 7, figures 1–7

Description.—Broad deep axial furrow runs inward and forward from posterior margin to about half the length (exsagittal) of the cephalon, dying out at the faintly defined "lunette" or crescentic muscle impression. In front of here, gently convex glabella not outlined. Small palpebral lobe in line with lunette, anterior branch of suture runs forward and slightly outward, then curves inward so that the two branches meet in a smooth arc. In profile view (pl. 7, fig. 2), it may be seen that the most anterior part of the cranidium adjacent to this arc is bent under at an oblique angle to the remainder of the cranidium. Posterior branch of suture runs outward and slightly backward. Part of fixed cheek inside and behind palpebral lobe gently convex, postero-lateral part curved to slope steeply outward. Internal mold (pl. 7, figs. 1, 5) shows narrow doublure beneath posterior margin of glabella and deep pit at posterior extremity of axial furrow. The latter is the mold of the articulating process.

Pygidium of width more than twice length (sagittal), axis gently convex, defined laterally by broad shallow axial furrows, not defined

posteriorly. Anterior margin of pleural region flexed sharply back at about half the width, outer part facetted. Pleural regions curve down to slope vertically posteriorly.

Discussion.—The form of this cranidium and pygidium are like those of *Illaenus* (s.l.) *utahensis* Hintze (1953, p. 169–171, pl. 28, figs. 8–12), from beds of late Whiterock age in Utah, and of *I. tumidifrons* Billings (1865, p. 278–279, fig. 264; Whittington, 1963), from limestones of similar age in western Newfoundland. Resemblances between the Maine material and species from younger rocks such as those of Chazy age are not readily apparent.

Family SCUTELLUIDAE Richter and Richter, 1955
Genus RAYMONDASPIS Pribyl, 1948

Raymondaspis sp.

Plate 7, figures 8–12

Description.—One internal mold (pl. 7, figs. 10, 11) shows the clearly defined occipital ring, the glabella narrowest a short distance in front of this ring and then expanding forward, the anterior margin not defined by a preglabellar furrow but by a change in slope to the narrow (sag. and exs.) anterior border. Beside the axial furrow the cheek is convex, most strongly so posteriorly opposite the narrowest part of the glabella.

The second cranidium (pl. 7, figs. 8, 9, 12) appears to belong to the same species but to have been considerably compressed in the longitudinal direction. This compression has steepened the slope of the anterior part of the glabella and adjacent cheeks and increased the angle of change in slope between these regions and the anterior border.

Discussion.—The outline of the glabella, the absence of lateral glabellar furrows, and the convexity of the cheek adjacent to the narrowest part of the glabella, is strongly reminiscent of species of *Raymondaspis* (Skjeseth, 1955, p. 20–24, pl. 4, figs. 1, 2, 5, 6, 8; Cooper, 1953, pl. 9, figs. 1, 3, 7–9, 11, 12), a genus that has been recorded from beds of Whiterock age (boulders in the Mystic Conglomerate and the Table Head Formation) and younger Middle Ordovician strata in the Appalachians (Raymond, 1925, p. 69–71, 165).

Family HARPIDAE Hawle and Corda, 1847
Genus HIBBERTIA Jones and Woodward, 1898

Hibbertia? sp.

Plate 7, figure 17

Description.—The cast shows the broad brim and strongly convex upper external rim, part of the cheek-roll laterally, and the complete prolongation. The smooth band on the upper lamella runs to the tip of the prolongation, and hence it is presumed that the deep girder also runs to the tip. On either side of the smooth band are slightly coarser pits, on the cheek-roll prolongation the pits are irregularly scattered, becoming finer toward the inner rim. On the brim and brim prolongation the pits are likewise irregularly disposed, closely spaced and small. Only on the prolongation does there appear to be larger pits adjacent to the external rim. The outline of the external rim in several fragments suggests that the cephalon may be subcircular in outline.

Because of the size and arrangement of the pits and because the girder extends to the tips of the prolongations, this fragment is referred with question to *Hibbertia* (=*Platyharpes* of Whittington, 1950, p. 10–11, text fig. 2, pl. 1, figs. 4–9). This genus is known from the Middle Ordovician of Scotland and Ireland.

Family ODONTOPLEURIDAE Burmeister, 1843
Miraspinid gen. undet.

Plate 7, figures 13, 14, 16, 18

Description.—The single incomplete cranidium is typical of this subfamily (Whittington, 1956, p. 235–236), having the long occipital ring (sagittal and exsagittal), bearing the prominent curved occipital spines, and the subparallel-sided median glabellar lobe defined by deep furrows. Outside these furrows the lateral glabellar lobes are fused, though the depression at the anterior end of the longitudinal furrow, and a similar depression at about the midlength of this furrow, suggest that lateral lobes 1p and 2p are present. The palpebral lobe is in a transverse line with the most anterior part of the occipital ring, is elongated, and slopes vertically inward. A prominent eye ridge runs inward and forward from the palpebral lobe parallel to the margin of the cranidium to merge with the frontal glabellar lobe. There is a prominent median occipital spine, and the occipital ring outside the base of the paired spine is inflated. Whether or not the typical depressed posterior band of the occipital ring is present cannot be observed.

Discussion.—The lack of definition of the lateral glabellar lobes suggests that this cranidium cannot be referred to *Miraspis* (a Lower Ordovician species of this genus has been described from Sweden by Whittington and Bohlin, 1958, p. 42–43, pl. 3, figs. 1–4). This feature, together with the posterior position of the palpebral lobe seems to preclude reference of it to either *Ceratocephala* or *Proceratocephala.* In the fusion of the lateral glabellar lobes this cranidium shows some resemblance to that of *Ceratocephala* (*Ceratocephalina*) (Whittington, 1956, p. 243–246, pl. 16), the type species of which is from the Middle Ordovician of Virginia. Odontopleurids are little known from Lower and early Middle Ordovician rocks in North America—a cranidium was figured by Hintze (1953, pl. 19, fig. 16), Raymond (1910, p. 234, pl. 38, fig. 5; pl. 39, fig. 15) described one from the middle Chazy of New York, and I have recently described a species of *Ceratocephala* from early Middle Ordovician limestones in western Newfoundland (Whittington, 1963). None of these specimens is particularly like the present cranidium.

Trilobite pygidium gen. undet.

Plate 7, figure 15

Discussion.—The largest fragment of three placed under this heading is illustrated to indicate that another type of trilobite occurs at locality *A*. The fragments appear to be of a pygidium, but even the family to which they may belong cannot be determined.

STRATIGRAPHIC IMPLICATIONS OF THE TRILOBITE FAUNA

In attempting to correlate the Shin Brook fauna, the presence of *Nileus*, *Illaenus* (s.l.), and *Raymondaspis* seems most significant. *Nileus* is only known in North America in the Antelope Valley Limestone of Nevada (Nolan and others, 1956) and the Table Head Formation (Whittington and Kindle, 1963). The Whiterock Stage (Cooper, 1956) of the early Middle Ordovician was proposed to include the strata now called the Antelope Valley Limestone, and the Table Head Formation belongs within this same stage. *Illaenus* and *Raymondaspis* appear for the first time in North America in rocks of this stage, and are found in younger strata. *Geragnostus* and *Ampyx* are longer ranging, appearing first in North America in Lower Ordovician rocks, and harpids and odontopleurids are too rare to be of value in correlation. The bathyurid *Annamitella? borealis* n. sp. is unlike any other species in North America but appears to resemble species from Lower and early Middle Ordovician rocks in Asia, Australia, and South America. *Geragnostus*, *Ampyx*, *Nileus*, *Illaenus*, and *Raymondaspis*, together with harpids, bathyurids, and odonto-

pleurids different from those in Maine, occur in Lower Ordovician rocks of the Baltic area of Europe (Tjernvik, 1956).

Thus, whereas the trilobite fauna of the Shin Brook Formation is unusual in North America, certain elements strongly indicate correlation with rocks of the Whiterock Stage. Outside North America similar species and genera to those from Maine occur in strata which are apparently older (Lower Ordovician), as well as in early Middle Ordovician rocks.

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INDEX

[Italic page numbers indicate major references]

PLATES 1–7

PLATE 1

[Figures × 2 unless otherwise indicated]

FIGURES 1–13. *Orthambonites robustus* n. sp. (p. E13).

1. Paratype; internal mold of ventral valve. Muscle scars and pallial sinuses well shown. USNM 143667, Crommet Brook, USGS loc. CO–3608, *E* of text and text fig. 1.
2. Latex replica prepared from specimen of fig. 1, × 1.
3. Same specimen, showing teeth and dental plates.
4. Same specimen, oblique posterior view to show teeth.
5. Paratype; internal mold of ventral valve. The proportions of this specimen are slightly different from those of the holotype. USNM 143669, Sugarloaf Mountain, USGS loc. CO–3606, *A* of text and text fig. 1.

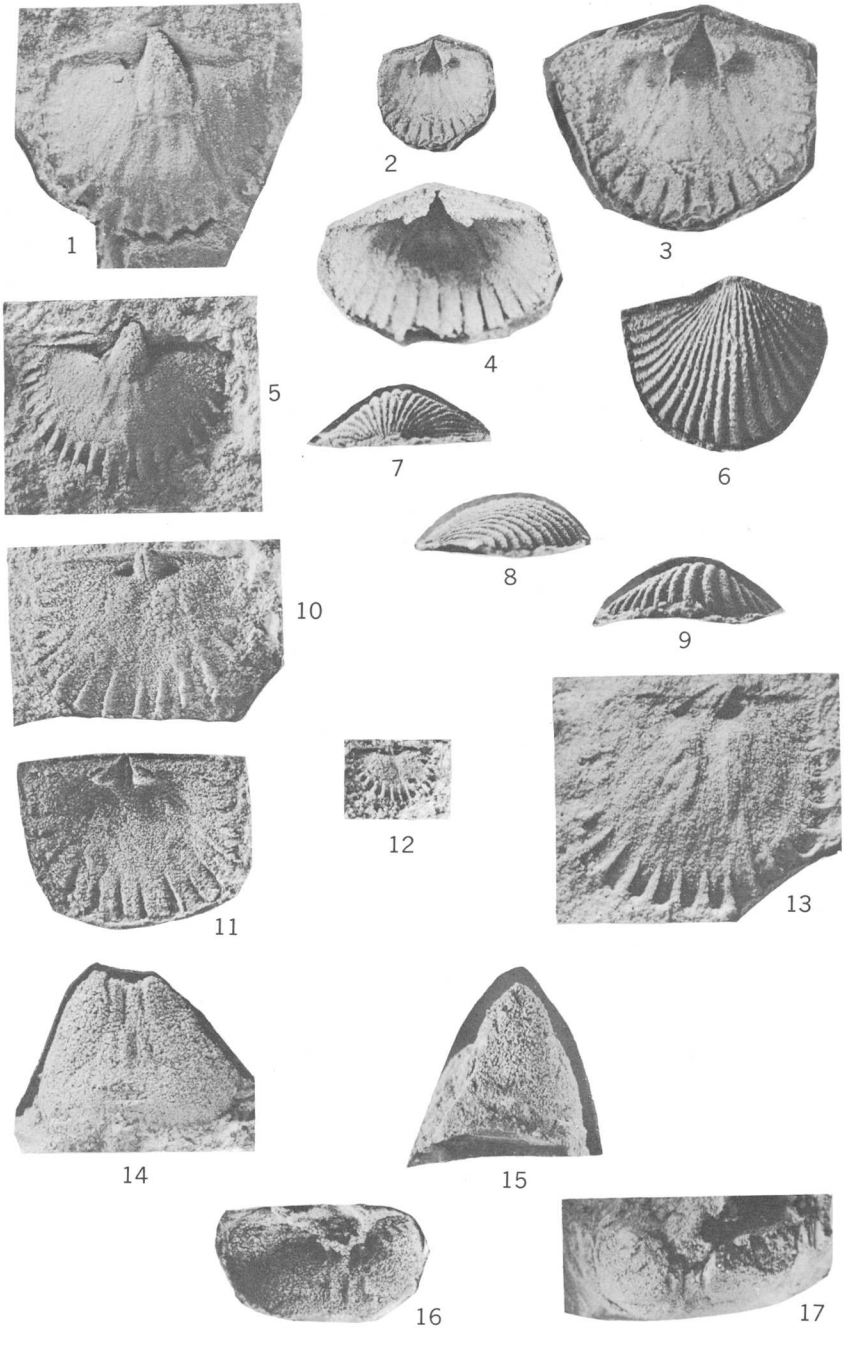
6–9. Latex replica of exterior of specimen of fig. 5. Fig. 6, ventral view; fig. 7, posterior view; fig. 8, side view; fig. 9, anterior view. Note the steep anterior slope.

10. Holotype; internal mold of dorsal valve, showing the impression of the delicate cardinal process. USNM 143668. Locality same as fig. 1.
11. Latex replica of holotype, showing the short, stout brachiophores.
12. Internal mold of immature dorsal valve, showing a shallow sulcus through its full length. USNM 143670. Locality same as fig. 5.
13. Paratype; internal mold of dorsal valve with cardinalia deformed but showing musculature and pallial sinuses. USNM 143671. Locality same as fig. 1.

14–17. *Polytoechia*? sp. (p. E22).

Incomplete ventral valve; USNM 143673. Locality same as fig. 5.

14. Ventral view, showing dental plates and median septum.
15. Side view; the interarea is on the left, the floor of the valve on the right.
16. Latex replica, showing the grooved spondylium.
17. Posterior view, showing the spondylium and its supporting plates and the arched and grooved pseudodeltidium.



ORTHAMBONITES ROBUSTUS N. SP. AND *POLYTOECHIA*? SP.

PLATE 2

[Figures × 2; all from Sugarloaf Mountain, USGS loc. CO-3606, *A* of text and text fig. 1]

FIGURES 1–11. *Productorthis mainensis* n. sp. (p. E15).

1. Holotype; internal mold of ventral valve showing characteristic alate outline. USNM 143674.
2. Latex replica of exterior of same specimen. The radial ornamentation is more pronounced on ventral valves, and concentric growth lamellae more pronounced on dorsal valves, shown on figs. 10 and 11.
3. Latex replica of interior of same specimen showing the teeth and their supports; note also the impression of the exterior of the incurved beak.

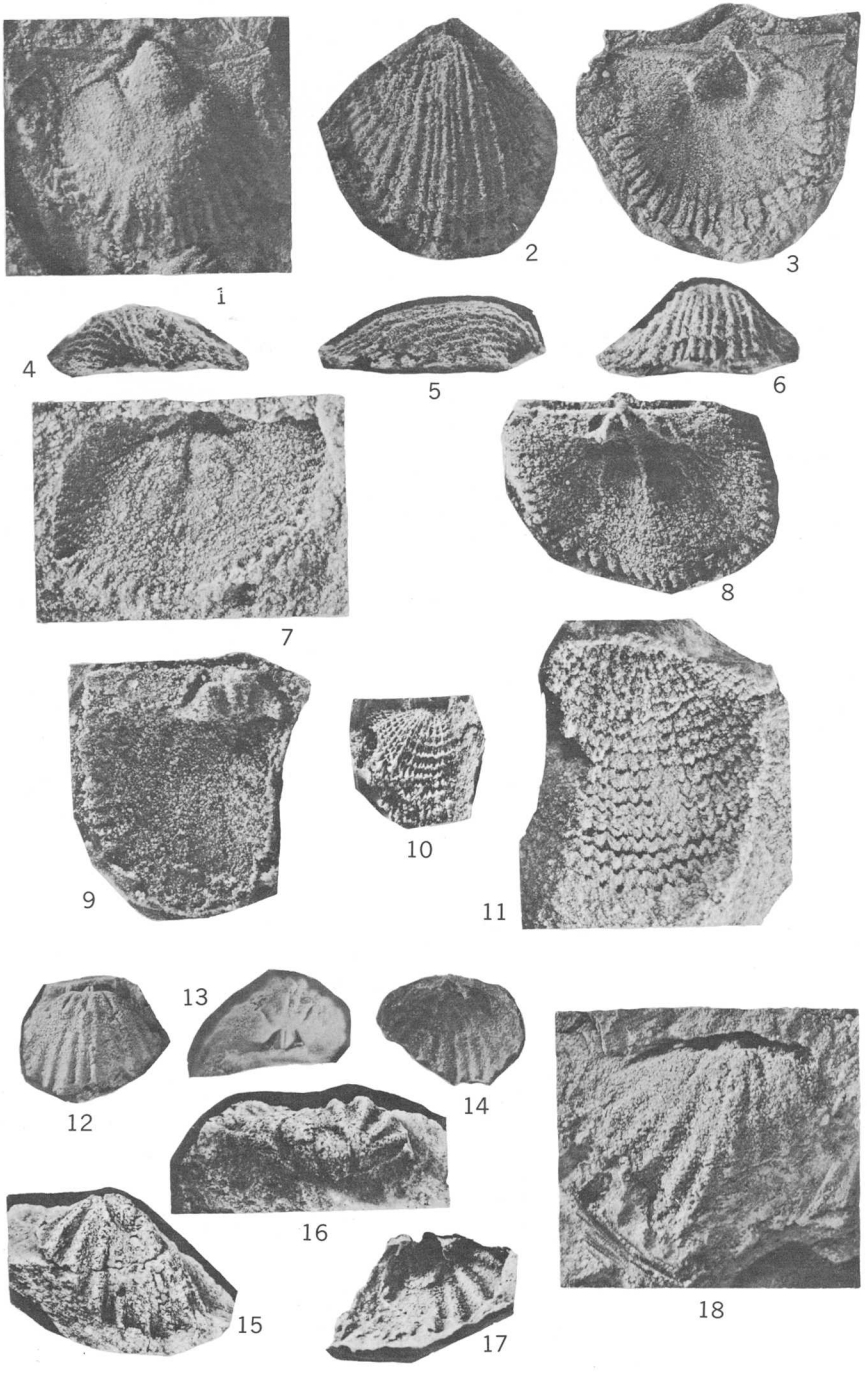
4, 5, 6. Posterior, side, and anterior views of latex replica of same specimen.

7. Paratype; internal mold of dorsal valve. USNM 143675.
8. Latex replica of same specimen showing cardinalia and musculature. Note the cardinal process extending beyond the hinge line.
9. Paratype; internal mold of dorsal valve, incomplete but less deformed than specimen of figs. 7, 8. USNM 143676.
10. Paratype; latex replica of exterior of an incomplete dorsal valve showing broad sulcus. USNM 143677.
11. External mold of same specimen as fig. 9 showing impressions of growth lamellae.

12–18. *Platystrophia* sp. (p. E17).

12–14. Dorsal valve; dorsal and posterior views of internal mold and latex replica, showing characteristic cardinalia and three plications on the fold. USNM 143679.

15–18. Ventral valve; ventral and posterior views of internal mold and oblique view of latex replica. USNM 143680.



PRODUCTORTHIS MAINENSIS N. SP. AND *PLATYSTROPHIA* SP.

PLATE 3

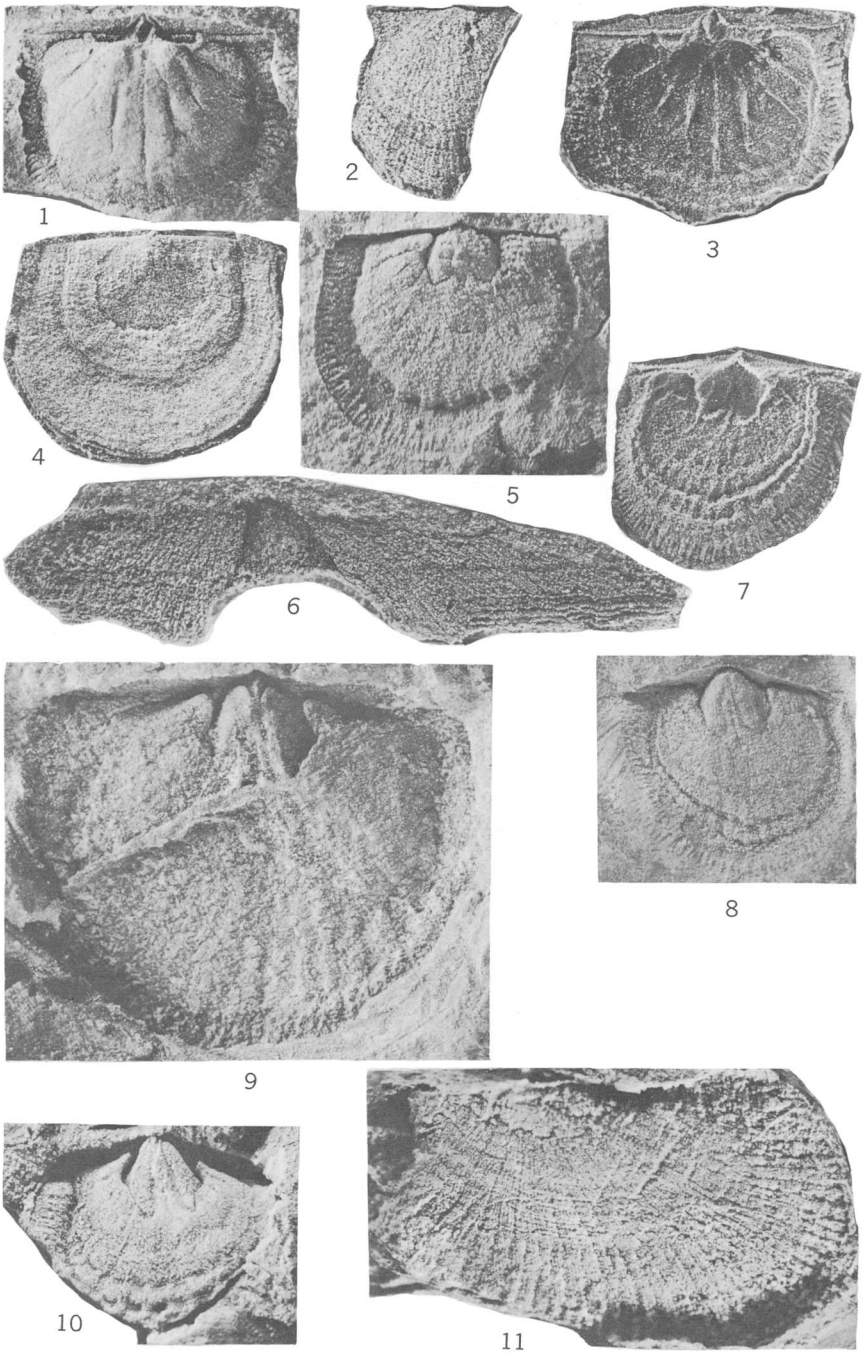
[Figures × 2 unless otherwise indicated; all but fig. 11 from Sugarloaf Mountain, USGS loc. CO-3606, *A* of text and text fig. 1]

FIGURES 1–11. *Platytoechia boucoti* n. gen. and n. sp. (p. E20).

1. Paratype; internal mold of a large well preserved dorsal valve. USNM 143684.
2. Latex replica of the exterior of a dorsal valve; paratype. USNM 143685.
3. Latex replica of paratype showing the unsupported brachiophores, chilidial plates, and bulbous cardinal process.
4. Latex replica of exterior of holotype, showing characteristic alate cardinal extremities, and reflexed profile.
5. Holotype; internal mold of ventral valve. USNM 143683.
6. Paratype: latex replica of interarea of a ventral valve, showing radial striations and convex pseudodeltidium. USNM 143686.

7, 8. Latex replica and internal mold of ventral valve, paratype. USNM 143678.

9. Paratype; internal mold of ventral valve showing the pair of small plates in the posterior part of the delthyrial cavity. USNM 143688, × 4.
10. Paratype; internal mold of ventral valve, tipped forward to show thin thread of matrix bridging apex of delthyrial cavity with shell exterior through apex of pseudodeltidium, evidence of a foramen at this point. USNM 143689.
11. Paratype; external mold of ventral valve showing multicostellate radial ornamentation and concentric filae. USNM 143690, × 4, USGS loc. CO–3610, Townline Brook, *H* of fig. 1 and text.



PLATYTOECHIA BOUCOTI N. GEN. AND N. SP.

PLATE 4

[Figures × 2]

FIGURES 1–12. *Tritoechia* sp. (p. E18).

Sugarloaf Mountain, USGS loc. CO–3606, *A* of text and text fig. 1.

1–4. Ventral valve; external mold and posterior, lateral, and ventral view of latex replica of exterior; note concave interarea in fig. 3. USNM 143692.

5–7. Ventral valve; interior of same specimen, ventral and posterior views of internal mold and ventral view of latex replica; note dental plates.

8. Ventral valve, internal mold showing muscle field. USNM 143693.

9, 10. Ventral valve, internal mold, ventral and oblique views; latter shows the thickened collar surrounding foramen through apex of strongly arched pseudodeltidium. USNM 143694.

11, 12. Dorsal valve, internal mold and latex replica, showing a part of the delicate cardinalia. USNM 143695.

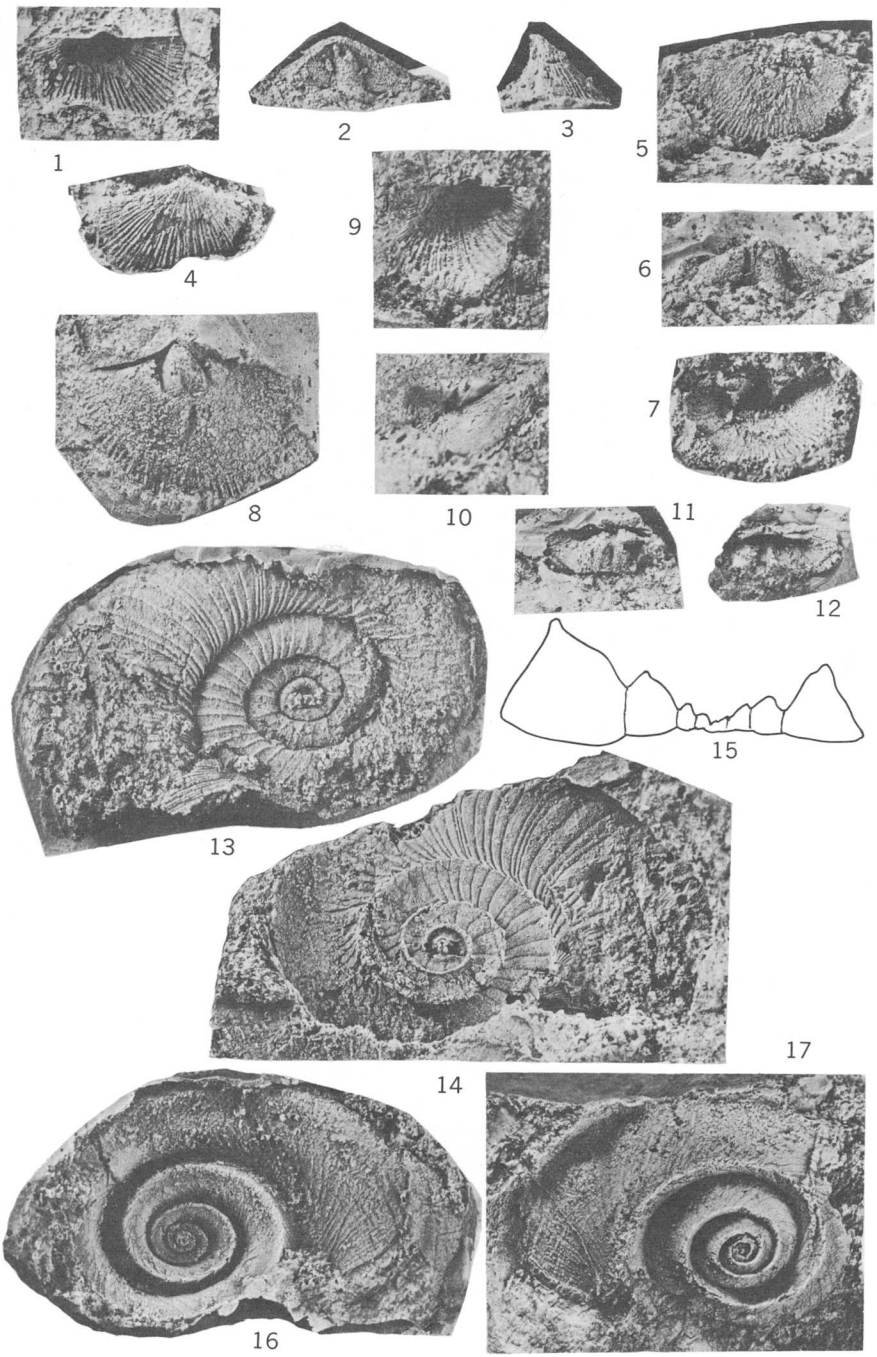
13–17. *Lesueurilla*? sp. (p. E24).

Southeastern slope of Roberts Mountain, USGS loc. CO–3726, *F* of text and text fig. 1. USNM 143697.

13, 14. Lower side; latex replica and external mold.

15. Cross section drawn from sectioned latex replica.

16, 17. Upper side; latex replica and external mold.



TRITOECHIA SP. AND *LESUEURILLA*? SP.

PLATE 5

[All from loc. *A*, USGS CO-3606.]

FIGURES 1, 6, 9, 10, 13, 14, 16. *Ampyx* sp. (p. E26).

1, 6. Internal mold of incomplete cranidium, right lateral, dorsal views, × 3. USNM 143698.

9, 10. Internal mold of pygidium, dorsal, posterior views, × 3. UNSM 143699.

13, 14, 16. Internal mold of distorted pygidium which is flattened so that border appears gently sloping; right lateral, dorsal, posterior views, × 3. USNM 143700.

2–5, 7, 8. *Geragnostus* sp. (p. E25).

2, 3, 7. Internal mold of cephalon, left lateral, anterior views × 6; dorsal view, × 9. Lateral occipital lobe and posterior border visible on left side. UNSM 143701.

4, 5. Latex cast from external mold of incomplete pygidium, dorsal, left lateral views, × 6. USNM 143702.

8. Latex cast from external mold of pygidium, dorsal view, × 6. On right side posterior border spine is visible. USNM 143703.

11, 12, 15, 17–19. *Nileus* sp. (p. E27).

11. Internal mold of cephalic doublure, incomplete on left side (right in the photograph), ventral view, × 3. USNM 143704.

12, 15. Internal mold of cranidium, dorsal, anterior views, × 3. USNM 143705.

17. Latex cast of external mold of incomplete and distorted cephalon, dorsal view, × 3. The subsemicircular outline is evident, and on the left side the large eye lobe and anterior branch of the suture are visible. USNM 143706.

18, 19. Internal mold of pygidium, right lateral, dorsal views, × 3. In the pleural regions much of the mold is stripped away to reveal the mold of the external surface of the doublure, which extends in close to the axis. USNM 143708.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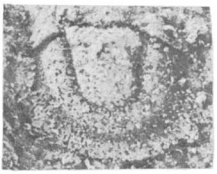
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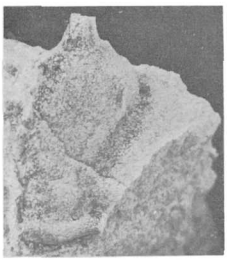
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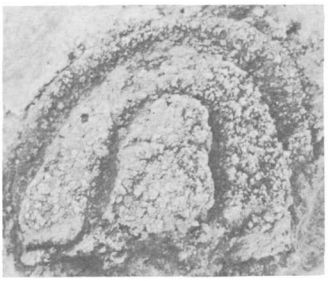
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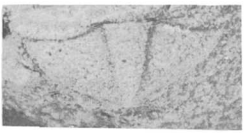
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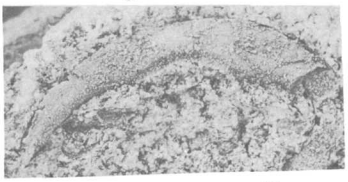
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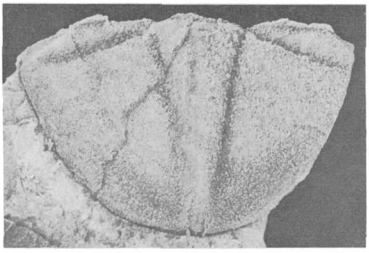
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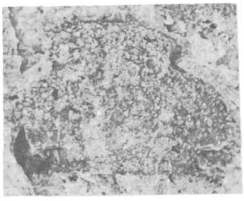
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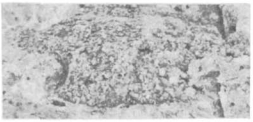
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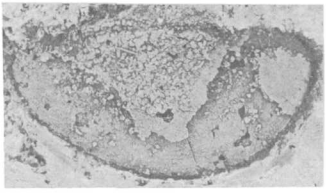
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AMPYX, *GERAGNOSTUS*, AND *NILEUS*

PLATE 6

[All from loc. *A*, USGS CO-3€06]

FIGURES 1–18. *Annamitella? borealis n. sp.* (*p.* E28).

1. Latex cast from holotype, USNM 143708, external mold of cranidium, dorsal view, × 4.5.
2, 5, 6. Paratype, USNM 143709, internal mold of incomplete cranidium, dorsal, anterior, right lateral views, × 4.5.
3, 7, 9, 11. Paratype, USNM 143710, internal mold of right free cheek, dorsal, right lateral, anterior, and exterior views, × 2.
4, 8, 10. Latex cast of paratypes, USNM 143711, external mold of left free cheek, dorsal, anterior, and left lateral views, × 3. Fig. 10 shows raised lines on outer slope of lateral border.
12. Paratype, USNM 143712, internal mold of cranidium, dorsal view, × 4.5. The original is apparently compressed longitudinally and relatively shortened, in contrast to the original of figs. 2, 5, 6, which may have been compressed in the transverse direction and relatively lengthened.
13, 16, 17. Latex cast from paratype, USNM 143713, external mold of pygidium, dorsal, posterior, and left lateral views, × 3.
14. Latex cast from paratype, USNM 143714, external mold of large pygidium, dorsal view, × 2.
15, 18. Internal mold of pygidium, paratype, USNM 143715, dorsal, posterior views, × 3.


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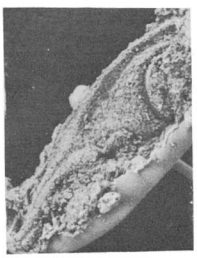
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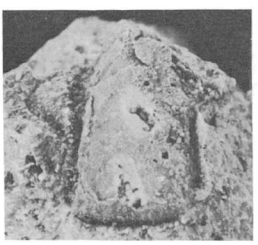
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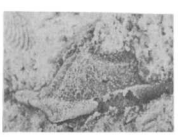
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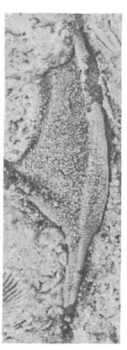
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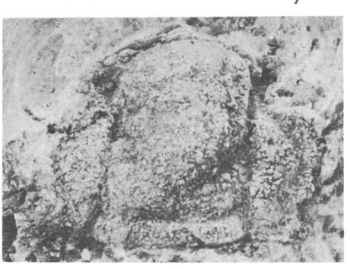
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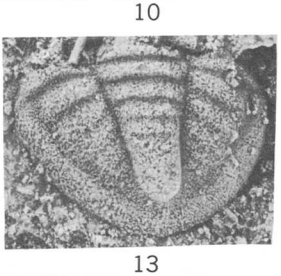
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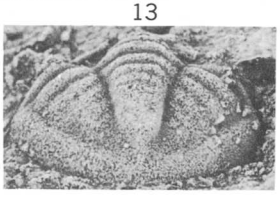
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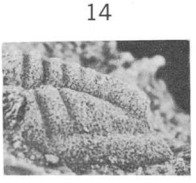
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18

ANNAMITELLA? BOREALIS N. SP.

PLATE 7

[All from loc. *A*, USGS CO-3606]

FIGURES 1–7. *Illaenus* (s. l.) sp. (p. E30).

1, 2, 4. Internal mold of cranidium, dorsal, left lateral, and anterior views, × 3. USNM 143716.

3, 6, 7. Internal mold of pygidium, left lateral, posterior, and dorsal views, × 3. USNM 143717.

5. Internal mold of cranidium, dorsal view, × 3. USNM 143718.

8–12. *Raymondaspis* sp. (p. E31).

8, 12. Latex cast from externl mold of distorted, incomplete cranidium, anterior and dorsal views, × 3. USNM 143719.

9. Internal mold, counterpart of original of figs. 8, 12, dorsal view, × 3.

10, 11. Internal mold of cranidium, dorsal view, left lateral view, × 3. USNM 143720.

13, 14, 16, 18. Miraspinid gen. undet. (p. E32).

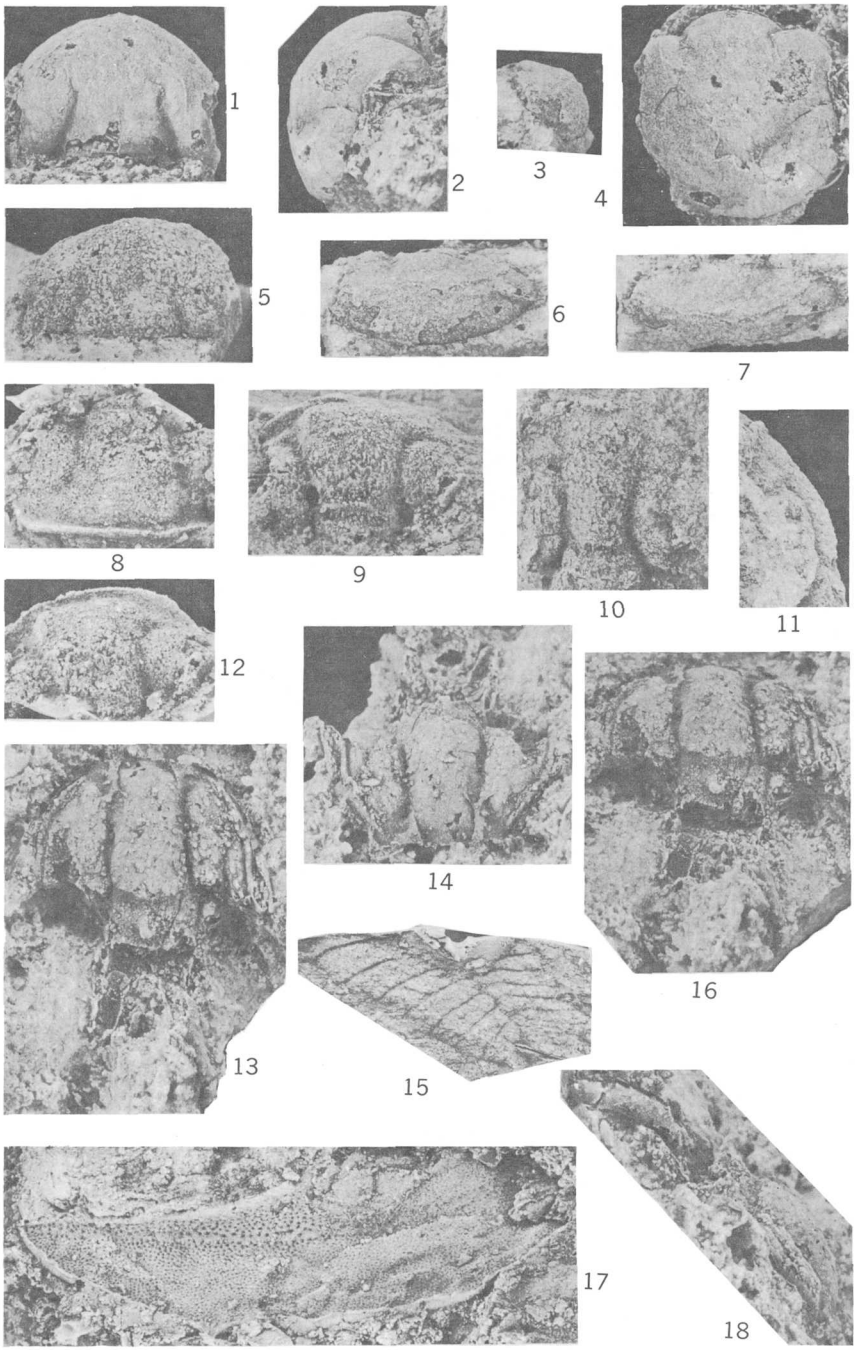
Internal mold of incomplete cranidium, exterior, anterior, dorsal, and right lateral views, × 4.5. USNM 143721.

15. Pygidium undet. (p. E32).

Internal mold of fragment, dorsal view, × 2. USNM 143722.

17. *Hibbertia*? sp. undet. (p. E32).

Latex cast from external mold of fringe on right side of cephalon, exterior view, showing cheek-roll, brim, and prolongation, × 2. The smooth band on the prolongation may be seen running out to the tip at the left, inside this band are the largest pits visible in this view.



ILLAENUS (s. l.), *RAYMONDASPIS, HIBBERTIA*?,
AND OTHER TRILOBITES