Brachiopods from the Upper Part of the Garden City Formation (Ordovician) North-Central Utah

GEOLOGICAL SURVEY PROFESSIONAL PAPER 593-H

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By REUBEN JAMES ROSS, JR.

CONTRIBUTIONS TO PALEONTOLOGY

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Brachiopods correlative with those of the Orthidiella *zone of the Whiterock Stage may also correlate with late Canadian fossils in the Appalachian region*

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CONTRIBUTIONS TO PALEONTOLOGY

BRACHIOPODS FROM THE UPPER PART OF THE GARDEN CITY FORMATION (ORDOVICIAN) NORTH-CENTRAL UTAH

By REUBEN JAMES ROSS, JR.

ABSTRACT

Brachiopods from the upper 250 feet of the Garden City Formation in the northern part of the Logan 30-minute quadrangle, Utah, indicate correlation of that part of the Garden City with the upper part of the Beekmantown Group of Maryland and Pennsylvania. The brachiopods of zone L of Ross, which is equivalent to the *Orthidiella* zone of the Whiterock Stage of Cooper, may be latest Canadian, rather than earliest Mohawkian, in age.

Species of *Orthambonites*, *Tritocchia* (one new species), *Hesperonomia*, *Diparelasma* (one new species), *Anomalorthis* (one new species), *Syntrophopsis*, and *Camerella* are described.

INTRODUCTION AND ACKNOWLEDGMENTS

Although brachiopods of the upper part of the Garden City Formation were included in lists of fossils and their stratigraphic significance was discussed by Ross (1951, p. 10–32), they were not described or illustrated. Comparisons and correlations between north-central Utah and areas farther west require a better knowledge of the brachiopod assemblages that occur with trilobites. In the East, Sando's studies (1957, 1958) of Lower and Middle Ordovician strata in Maryland and Pennsylvania provide data that permit a close correlation of parts of the Beekmantown Group with the upper part of the Garden City.

The Garden City brachiopods described in this report include species of *Orthambonites*, *Tritoechia*, *Hesperonomia*, *Diparelasma*, *Anomalorthis*, *Syntrophopsis*, and *Camerella*. They were obtained in 1949 and 1955 from two stratigraphic sections: at Blind Hollow and at Beaver Creek, Logan quadrangle, Utah. These two localities are within 25 miles north-northeast of Logan, Utah, and are not shown separately in figure 1.

C. G. Bowles and James Parkinson assisted in the field in 1949, as did F. B. Rowell, Jr., in 1955. In 1965, L. F. Hintze conducted the author and several other geologists in an examination of the Pogonip Group in the Ibex areas of western Utah; as a result of that examination, several conclusions are drawn concerning correlation of the fossil zones discussed here.

STRATIGRAPHIC SIGNIFICANCE OF THE BRACHIOPODS

The brachiopods and associated trilobites indicate an age equivalent to that of zones J and L of Ross (1949, 1951) and Hintze (1952). These zones are also found in the Wahwah and Juab Limestones of Hintze (1952, p. 15–19) in the Ibex area in west-central Utah and in the highest beds of the Ninemile Formation in Ninemile Canyon and the lower beds of the Antelope Valley Limestone on the west side of Antelope Valley in central Nevada (fig. 1).

Collections made along the ridge on the south side of Blind Hollow, SE¼ sec. 28 and SW¼ sec. 27, T. 13 N., R. 2 E., Logan quadrangle, Utah, yielded the following fossils:

USGS colln. D208c CO. Garden City Formation, 147 ft. below top. Zone J.
- Sponge:
  - *Calathium* sp.
- Brachiopods:
  - *Diparelasma* cf. *D. transversum* Ulrich and Cooper
  - *Diparelasma* sp.
  - *Tritoechia loganensis* Ross n. sp.
  - *Hesperonomia* cf. *H. dinorthoides* Ulrich and Cooper
  - *Hesperonomia fontinalis* (White)
  - *Syntrophopsis* sp.
- Gastropods, indet.

USGS colln. D208a CO. Garden City Formation, 250 ft. below top. Zone J.
- Brachiopods:
  - *Diparelasma rowelli* Ross n. sp.
  - *Diparelasma* sp.
  - *Tritoechia loganensis* Ross n. sp.
  - *Hesperonomia fontinalis* (White)
  - *Syntrophopsis* cf. *S. polita* Ulrich and Cooper
- Trilobites:
  - *Isoteloides* sp.
  - *Lachnostoma* sp.
  - *Goniotelina* cf. *G. brevis* Hintze

No well-preserved brachiopods were obtained higher in the section at the Blind Hollow locality, but an assemblage of zone L fossils was taken from the upper beds of the Garden City Formation above zone J on Beaver Creek.

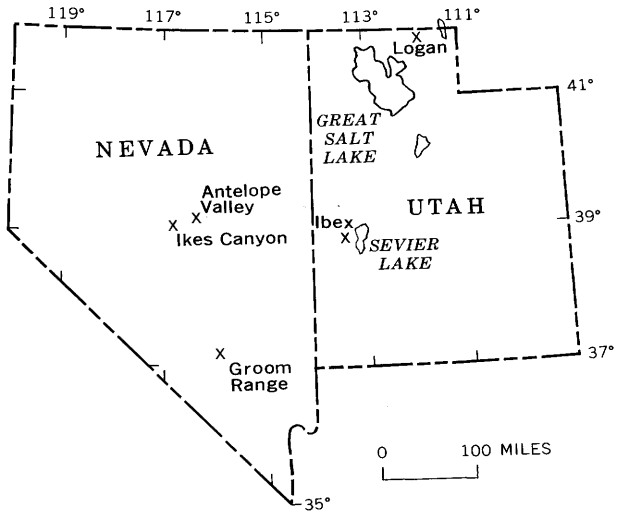

FIGURE 1.—Approximate locations of Ordovician sections, Utah and Nevada.

The collection locality at Beaver Creek is on the east side of the creek, just south of the Idaho-Utah State boundary, E½ sec. 35, T. 15 N., R. 4 E., Logan quadrangle, Utah (Ross, 1951, p. 13; 1964, p. C70–C71). Fossils include:

USGS colln. D190d CO, Garden City Formation, 105 ft below top. Zone L.
- Brachiopods:
  - *Anomalorthis lambda* Ross, n. sp.
  - *Orthambonites* cf. *O. cucharis* Ulrich and Cooper
  - *Syntrophopsis transversa* Ulrich and Cooper.
  - *Camerella* sp.
- Trilobites:
  - *Acidiphorus pseudobathyurus* Ross (Ross, 1967, pl. 6, figs. 16–23)
  - *Bathyurellus* sp. (Ross, 1967, pl. 6, fig. 9)
- Pelmatozoan:
  - *Blastoidocrinus* cf. B. *carchariaedens* Billings

USGS colln. D190c CO, Garden City Formation, 117 ft below top. Zone L.
- Brachiopod:
  - *Orthambonites* cf. *O. cucharis* Ulrich and Cooper

USGS colln. D190b CO, Garden City Formation, 150 ft below top. Zone J.
- Brachiopods:
  - *Diparelasma* cf. *D. pogonipense* (Hall and Whitfield)
  - *Hesperonomia* cf. H. *dinorthoides* Ulrich and Cooper

USGS colln. D190a CO, Garden City Formation, 153 ft below top. Zone J.
- Brachiopods:
  - *Hesperonomia* sp.
  - *Diparelasma* sp.
- Trilobite:
  - *Ptyocephalus declevita* (Ross) = *Kirkella* of previous reports

The two localities are 12 miles apart. As a result, the measurements below the highest bed of the Garden City Formation are not precisely comparable but are reasonably so.

In the general area of the Logan 30-minute quadrangle, the lower shale and limestone member of the Swan Peak Formation overlies the Garden City Formation. This member is lithically and faunally equivalent to much of the lower part of the Kanosh Shale of Hintze (1952, p. 20) and is overlain by the quartzite member (as in fig. 2) of the Swan Peak. A rich fossil assemblage occurs in the Swan Peak beds and includes:

Brachiopods:
- *Orthambonites michaelis* (Clark)
- *Orthambonites swanensis* Ulrich and Cooper (not Ulrich and Cooper, 1938, pl. 14, figs. 25–29)
- *Anomalorthis utahensis* Ulrich and Cooper

Trilobites:
- *Pseudoolenoides dilectus* Hintze
- *Eleutherocentrus petersoni* Clark
- *Pseudomera* sp.
- *Uromystrum* sp.

Abundant ostracodes

The assemblage from the lower member of the Swan Peak, zone M, is probably equivalent to that from the *Anomalorthis* zone of the Whiterock Stage in Nevada. The presence of *Uromystrum* is interesting; the genus is also represented in western Utah, where it has been included in *Bathyurellus pogonipensis* (Hintze, 1952, pl. 10, fig. 11a, b). According to Frederick C. Shaw (oral commun., 1966), *Uromystrum* is the only bathyurid trilobite found in the type Chazy Group of New York. Graptolites found in the lower shaly beds are referrable to *Didymograptus artus*.

CORRELATION OF ZONES L AND K

The zonal assemblage, zone L, next lower than zone M, is typified by USGS collns. D190d CO and D190c CO in the upper, but not topmost, Garden City beds. The combination of (1) a species of *Orthambonites* similar to *O. eucharis* Ulrich and Cooper, (2) an *Anomalorthis* with a low cardinal area, in this case *A. lambda* n. sp., (3) *Bathyurellus*, and (4) stratigraphic position is evidence for correlation with the *Orthidiella* zone, lowest zone of the Whiterock Stage in central Nevada. The Garden City assemblage of zone L includes *Blastoidocrinus* of which *B. carchariaedens* Billings is the only species ever described. This genus is known elsewhere only in rocks of Chazy (Marmor) or younger age (G. A. Cooper, written commun., 1967, informed me that it is present in the Edinburgh Formation in the Appalachians). Although its presence was noted previously (Ross, 1951, p. 27, 31), its significance in terms of Middle Ordovician correlations is not yet clear. *Blastoidocrinus* and *Uromystrum* are additions to the list of fossils giving a Chazy aspect to Whiterock faunas.

Anomalorthis occurs in the *Orthidiella* zone over a wide area. These early species of *Anomalorthis* are

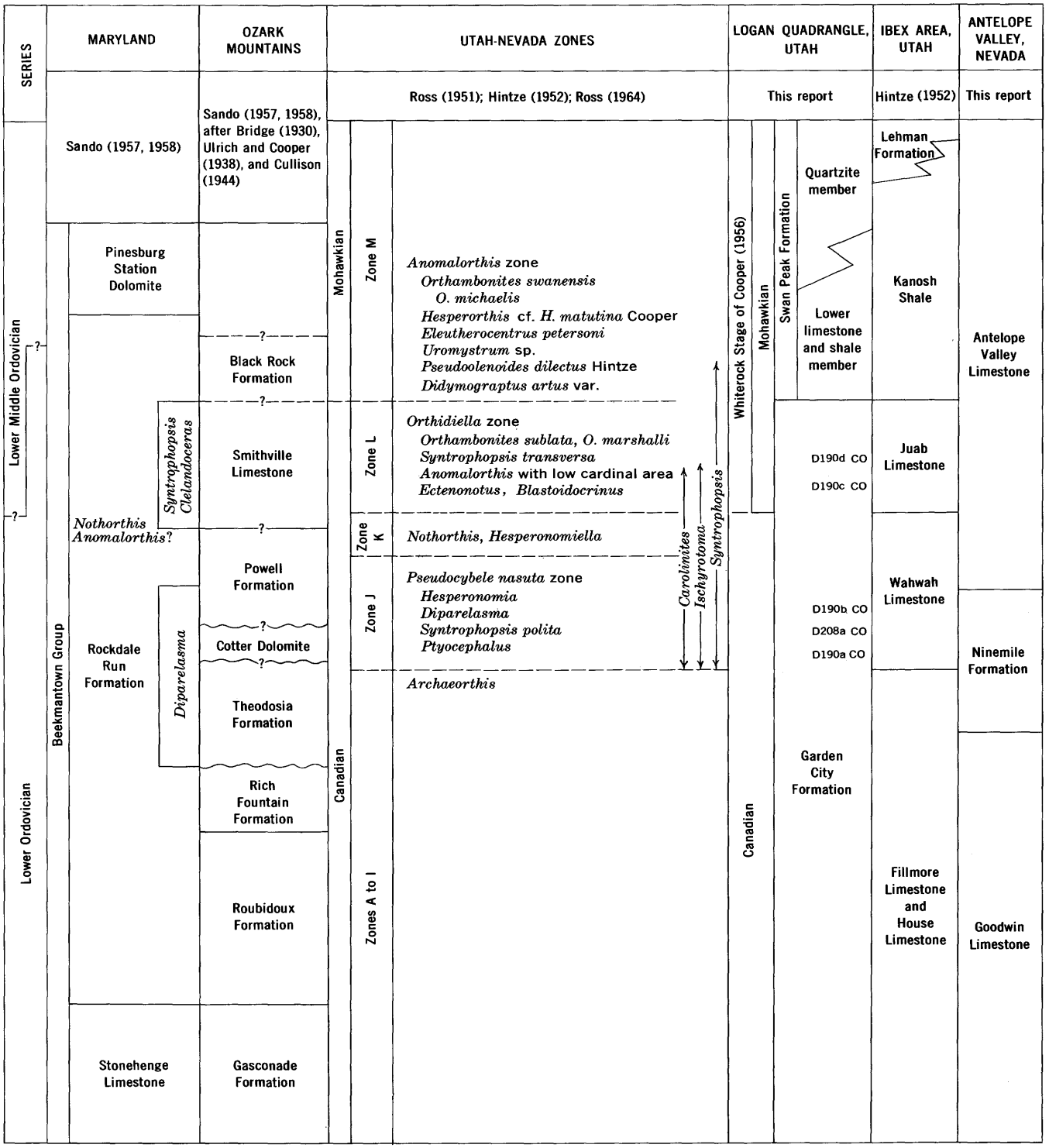

FIGURE 2.—Possible correlations of upper Lower and lower Middle Ordovician strata, Appalachian Mountains, Interior Highlands, and Utah.

characterized by a short, very obtusely pointed cardinal area compared with species of the *Anomalorthis* zone proper. In this respect *Anomalorthis lambda* n. sp. and other zone L (*Orthidiella* zone) species may be correlative with *Anomalorthis? vermontensis* Ulrich and Cooper (1938, pl. 22*B*; Sando, 1958, p. 850, pl. 2, figs. 11–14). Such a correlation would suggest that some part of the Providence Island Dolomite of the Lake Champlain area (Fisher, 1962; Ulrich and Cooper, 1938, p. 129–130) and of the Rockdale Run Formation of Pennsylvania (Sando, 1958, p. 844, 850) should be equivalent to the *Orthidiella* zone.

Below the fossils of zone L in the two sections discussed here, zone K has not been positively located, primarily because *Nothorthis* was not in any of the collections made. Previously (Ross, 1951, p. 27) *Nothorthis* was found with a mixture of species from zones J and L. Hintze (1952, p. 19) found no evidence of *Nothorthis* in western Utah and on the basis of stratigraphic position has used *Hesperonomiella minor* (Walcott) as a monospecific index for zone K. Sando (1958, p. 842, 843, 850, 851) found *Nothorthis pennsylvanica* associated with *Anomalorthis?* cf. *A.? vermontensis* near Chambersburg, Pa. Obviously, zone K is difficult to place in many stratigraphic sections and may not warrant designation as a separate zone. As modified by Hintze (1952, p. 19), however, often zone K serves as a very useful marker in the West.

In a constructive critique of probable correlations, Sando (1958, p. 843–844) noted that the K and L zones could be correlated with the Smithville and that the underlying J zone could surely be correlated with the Cotter and Powell Dolomites of the Ozarks. If Sando's correlation is correct, and if my correlation of zone L with the *Orthidiella* zone (Whiterock Stage) is correct, one is forced to conclude paradoxically that the [Canadian] Smithville and Black Rock Formations are both Early and Middle Ordovician in age.

The Garden City sections near and north of Logan, Utah, demonstrate that the Canadian fossils of zone J are succeeded without stratigraphic break by fossils of zone L, which is correlative with the earliest Whiterock *Orthidiella* zone. Zone K (Ross, 1951, p. 27) was erected to solve my own quandary concerning assemblages that could not be assigned with certainty to either zone J or zone L; there is a gradual change in faunal composition from one zone to the other. Those who seek to place a major interseries discontinuity between zone J and L are faced with a highly subjective ethereal problem. Sedimentation seems to have been continuous during the time span represented by these zones; as a result no faunal break is apparent between them. Furthermore, a similar situation exists in central Nevada, where the trilobite-brachiopod assemblage of zone J grades upward into the *Orthidiella* zone; both zones are within the lower strata of the Antelope Valley Limestone. There is no physical evidence for separating the fossils of zone L (*Orthidiella* zone) from the fossils of the Canadian zone J in Utah and much of Nevada.

In 1957 Sando (1957, p. 32) noted the probability of continuous sedimentation in Maryland from Lower to Middle Ordovician and (p. 30) commented on the absence of concrete evidence for disconformity between them. He concluded in 1958 (p. 844) that no meaningful correlations with the upper part of the standard Lower Ordovician section in the Ozark Mountains could be made until the faunal succession and physical relations of the Black Rock and Smithville Formation had been studied in detail.

The fossils of zone L (*Orthidiella* zone) are possibly correlative with parts of the Smithville and Black Rock. If so, the *Orthidiella* zone should probably be removed from the Whiterock Stage and assigned to the upper Canadian.

GEOGRAPHIC CHANGE WITHIN THE *ORTHIDIELLA* ZONE

Westward from the Logan area, Utah, the fossils assemblage of zone L changes. Near Logan and southward, *Orthambonites subalata* Ulrich and Cooper is characteristic; as noted above, *O.* cf. *O. eucharis* occurs in the zone north of Logan. Hintze (1952, p. 19) noted that a species similar to *O. subalata*, but more coarsely ribbed, is present at Ibex in western Utah; this is probably *Orthambonites marshalli* Wilson, a species found widely in Nevada as well as in British Columbia. *Orthidiella* is present at Ibex about 88 feet above the Juab Limestone (USGS colln. D1645 CO) but not to the east. *Anomalorthis*, represented by *A. lambda* n. sp. at Beaver Creek, is represented in the same zone by another new species with low cardinal area in the Groom Range and other Nevada localities.

The trilobites found within the *Orthidiella* zone also change westward, with *Ectenonotus* and other species typical of the Table Head Formation of Newfoundland becoming common. The *Orthidiella* zone at Ikes Canyon, Toquima Range, has nothing in common with the correlative zone L in Logan Canyon northeast of Logan, Utah. Out of context the two assemblages are so different that they seem to demand different age assignments. In the context of regional stratigraphy, however, the assemblages must differ for some other reason linked to geographic distribution.

SYSTEMATIC PALEONTOLOGY

Genus HESPERONOMIA Ulrich and Cooper, 1936

Hesperonomia Ulrich and Cooper, 1938, Geol. Soc. America Spec. Paper 13, p. 114.

Many silicified brachial valves of *Hesperonomia* appear to have been abraded along the inside of the hinge close to the cardinal extremities, and a system of fine tubules has thus been exposed. The phenomenon of exposed tubules is too common to be a freak of preservation.

This phenomenon has been illustrated in *H. louisensis* Ulrich and Cooper (1938, pl. 19*A*, figs. 9, 10), but never described. In two specimens of *H. fontinalis* shown in the present report (pl. 1, figs. 6, 7) the tubules are fully exposed on one extremity of the hinge and partly covered on the other. Because of the regular spacing of the tubules on many specimens it seems doubtful that they were caused by predator or parasite. Their purpose and cause remain puzzles.

In USGS colln. D208c CO, one of a dozen brachial valves (pl. 1, fig. 5) has a much thickened cardinal process which bears a resemblance to the cardinal process of some species of *Valcourea*. An evolutionary change producing cardinal processes of this type and a reversal in convexity of valves could lead to shells like those of *Valcourea*. The pedicle muscle field is much alike in *Hesperonomia* and *Valcourea*.

Hesperonomia fontinalis (White)

Hesperonomia fontinalis (White). Ulrich and Cooper, 1938, Geol. Soc. America Spec. Paper 13, p. 118, pl. 18*F*, figs. 27–29.

Plate 1, figures 1–9

The original description of this species was brought up to date by Ulrich and Cooper (1938, p. 118), who indicated that the original material was limited in quantity and quality, so limited that I cannot be completely confident that the Garden City specimens described here belong to *Hesperonomia fontinalis*. These specimens come from two collections, USGS collns. D208a CO and D208c CO, and are not perfectly preserved. The margins of all shells have been abraded or broken so that estimates of outlines must be made from growth lines where possible.

None of the original specimens shows interiors; therefore, comparisons of interior features are impossible to make from these specimens.

Outline semielliptical; hinge width not exceeding midwidth in mature shells. Costellae spaced 17–23 in 5 mm and almost uniform in size. Newly implanted costellae are finer than others so that there are commonly 4–6 relatively large costellae for each fine one.

Brachial valve gently concave, particularly in the proximal part of the median sulcus, which extends to the anterior margin. Area bordering sulcus flattened, in some specimens grading into another concave area near the cardinal extremities.

Pedicle valve most convex along median line in most specimens, evenly convex in others. Diductor scars extending forward almost as far as half-length in specimens from USGS colln. D208a CO; scars inaccessible in all specimens from D208c CO.

[Parentheses indicate estimated measurements]

USNM	Valve	Length (mm)	Width (mm)	Hinge width (mm)	L/W	L/HW	Costellae per 5 mm	Costellae per mm
Measurements of specimens from USGS colln. D208a CO								
158578	Brachial	(13.8)	18.3	19.8	0.75	0.70	18	3+
158579	do	11.5	15.3	--------	.75	--------	19	4–5
158580	Pedicle	13.0	15.9	14.0	.82	.93	23	4+
158581	do	15.5	19.7	17.2	.79	.90	17	3–4
Measurements of specimens from USGS colln. D208c CO								
158582	Brachial	12.5	17.0	17.0	0.74	0.74	19	4
158583	do	12+	(19.4)	(19.4)	----------	----------	19	4
158584	do	10.3	(13.7)	(13.5)	(.75)	(.75)	20	4
158585	do	10.3	(12.6)	(13.8)	(.82)	(.75)	18	3–4
158586	do	11.4	14.7	--------	.78	--------	19	4
158587	Pedicle	12.5	(16.7)	(17.8)	(.75)	(.70)	17	3+

Figured specimens: USNM 158578, 158581–3, 158586.

Occurrence: USGS colln. D208a CO, Garden City Formation, 250 ft below top; D208c CO, 147 ft below top. On ridge along south side of Blind Hollow, SE¼ sec. 28 and SW¼ sec. 27, T. 13 N., R. 2 E., Logan quadrangle, Utah.

Discussion.—The distinguishing of *Hesperononmia fontinalis* from *H. dinorthoides* depends almost entirely on one's interpreation of the difference between "nearly uniform costellae" (Ulrich and Cooper, 1938, p. 118) and "costellae, broadly rounded, and of unequal size" (Ulrich and Cooper, 1938, p. 117). Comparison of illustrations of the types of the two species does not assist much in making this distinction. Hintze (1951, p. 85) recorded *H. fontinalis* in the Fish Springs section north of Ibex from which the types came; there it is in the same zone as the fossils from USGS colln. D208a CO and possibly from D208c CO.

Hesperonomia cf. H. dinorthoides Ulrich and Cooper

Plate 1, figures 10–13

When describing *Hesperonomia dinorthoides*, Ulrich and Cooper (1938, p. 117–118, pl. 19c, figs. 18–22) relied almost entirely on comparisons with other species to establish features of this species. Costellae were stated to be low, broadly rounded, and of unequal size and to be spaced 17 in 5 mm. According to the illustrations of the types, inequality of size is not regular (Ulrich and Cooper, 1938, pl. 19c, figs. 18, 19), and on one specimen not

particularly obvious. Because of distortion it is almost impossible to establish the outline of any of the specimens.

The diductor scars in the pedicle valve clearly protrude well forward in the shell, a condition supposedly characteristic of the species but also shown by specimens assigned here to *Hesperonomia fontinalis* (pl. 1, fig. 2).

According to measurements on the types (Ulrich and Cooper, 1938, p. 117–118), the hinge forms the widest part of the shell in *H. dinorthoides*.

Shells from USGS colln. D190b CO (pl. 1, figs. 10, 11) and one from colln. D208c CO (pl. 1, figs. 12, 13) are included here in *H.* cf. *H. dinorthoides*. These specimens are characterized by acute cardinal extremities and costellae of two distinctly different sizes; there is a strong tendency toward alternation of one or two very fine costellae between coarser ones. Diductor scars extend forward a distance equal to ¼–⅓ the length of the pedicle valve. The associated brachial valves are essentially flat with a suggestion of a sulcus proximally only.

[Parentheses indicate estimated measurements]

USNM	Valve	Length (mm)	Width (mm)	Hinge width (mm)	L/W	L/HW	Costellae per 5 mm	Costellae per mm
Measurements of speciments from USGS colln. D190b CO								
158588	Brachial	14.4	(13–14)				17	3–4
158589	Pedicle	13.9	(19.2)	(22.2)	(0.72)	(0.63)	18	3
158590	do	13.2	15.7	(18.8)	.84	.70	18	4
Measurements of specimen from USGS colln. D208c CO								
158591	Pedicle	10.9	14.5	16.9	0.82	0.65	21	4

Figured specimens: USNM 158589, 158591.

Occurrence: USGS colln. D190b CO, Garden City Formation, 150 ft below top, Beaver Creek (Ross, 1951, p. 13). USGS colln. D208c CO, Garden City Formation, 147 ft below top, Blind Hollow.

Discussion.—The shells included here under *Hesperonomia* cf. *H. dinorthoides* from colln. D190b CO are large specimens, larger than original material on which *H. dinorthoides* was based (Ulrich and Cooper, 1938, p. 117–118).

H. dinorthoides bears finer costellation than *H. antelopensis* or *H. louisensis*, in which ribs are spaced 12 in 5 mm and 15 in 5 mm, respectively.

One or two specimens of *Hesperonomia* cf. *H. dinorthoides* from D208c CO exemplified by the pedicle valve shown in plate 1, figs. 12, 13 are wide hinged and have costellae of two sizes showing an imperfect alternation. This same ornamentation and outline is present in specimens from USGS colln. D190b CO, here assigned with trepidation tentatively to *Hesperonomia dinorthoides*.

Unfortunately, these two criteria are not always clear cut in separating specimens into lots. Another pedicle valve (USNM 158587) which on the basis of outline and convexity belongs with *H. fontinalis* has a well-developed alternation of fine and very fine costellae.

Genus ORTHAMBONITES Pander, 1830

Orthambonites cf. O. eucharis Ulrich and Cooper

Plate 3, figures 1–7

About 30 badly frayed silicified specimens from the upper beds of the Garden City along Beaver Creek (USGS collns. D190c CO and D190d CO) fall in this category. Poor preservation hampers comparison with known species.

Shells subcircular in outline; valves unequally biconvex. Surface costellate with two to three generations of intercalated ribs. Costellae total 34–39, spaced 5–7 in 5 mm at front of valves 10–11 mm long.

Pedicle valve the deeper, almost carinate in anterior profile; more strongly convex posteriorly in lateral profile.

Brachial valve sulcate; 7–9 costellae involved in sulcus. Valve only slightly convex in lateral profile. Cardinal process thin, not preserved in all specimens.

Measurements of specimens are as follows:

[Parentheses indicate estimated measurements]

USNM	Valve	Length (mm)	Width (mm)	Hinge width (mm)	Depth (mm)	Costellae Total	Costellae In 5 mm	Costellae In sulcus
158592	Brachial	10.1				34	4	7
158593	Pedicle	10.7	(10.9)	9.7	4.3	36	6	
158594	do	11.2	12.7		4.5	34	6	
158595	Brachial		11.0	10.2		31+	7	9
158596	do	10.3	(13.2)			36	5–6	8
158597	Pedicle	11.6		(10.0)	3.9	39	6–7	
158598	do	11.3	11.9	10.3	4.75	34	7	
158599	Brachial	5.6	5.7	6.0		40	11	9

Figured specimens: USNM 158592, 158598.

Occurrence: USGS colln. D190c CO, Garden City Formation, 117 ft below top; USGS colln. D190d CO Garden City Formation, 105 ft below top. Beaver Creek, east side, south of Utah-Idaho State line, E½ sec. 35, T. 15 N., R. 4 E., Logan quadrangle, Utah (Ross, R. J., Jr., 1964, p. C70–C71).

Discussion.—Poor preservation prevents assigning these specimens with certainty to *Orthambonites eucharis* Ulrich and Cooper. However, comparison with topotype material indicates that in size, outline, convexity, number of costellae, and spacing of costellae the Garden City form is virtually the same. The development of the cardinal process is a little more robust than in *O. eucharis* from USGS colln. D719 CO and D720 CO (Ross, 1964, p. C20) from the type locality; the Nevada specimens show three stages of costellar implantation a little more clearly, but the method of implantation varies between specimens.

This species was erroneously identified as *Orthambonites subalata* (Ross, 1964, C70–C71). The stratigraphic position in the Garden City Formation is nonetheless equivalent to zone L, correlative with the *Orthidiella* zone to the west.

Genus DIPARELASMA Ulrich and Cooper, 1936

In the upper beds of the Garden City Formation there are at least three, probably four, species of *Diparelasma*. Unfortunately, although preservation at one level (D208a CO) is excellent, collections somewhat higher stratigraphically (D208c CO, D190c CO, D190d CO) are coarsely silicified and not exactly comparable; thus, positive identifications are difficult to make. Although numbers of specimens are inadequate for thorough description of each species, they do show that a seemingly unstable and varying population must have represented the genus.

In his studies of the Beekmantown Group of Maryland, Sando (1957, p. 25, pls. 3, 4) established a *Diparelasma* zone in the Rockdale Run Formation. This zone undoubtedly can be correlated with *Diparelasma*-bearing strata in the upper part of the Garden City.

Diparelasma rowelli Ross, n. sp.

Plate 2, figures 3–10, 13

In outline and convexity, both valve shells are very similar to those of *Diparelasma elegantulum* (Butts) (Ulrich and Cooper, 1938, p. 149, pl. 28*A*). Costellae are very fine and regular in size, are hollow, and increase in number mainly by bifurcation so that a spacing of 24 in 5 mm is maintained along the front edge of the shell after it reaches a length of 2 mm.

Brachial valve subcircular in outline, of low even convexity; interior exhibits subequally quadripartite adductor scars. Rudimentary cardinal process present on wide nothothyrial platform. Brachiophores stout for the genus. Fulcral plates well developed.

Pedicle valve transversely subelliptical in outline; length equal to hinge width but less than width. Muscle field tripartite; the width of combined adductor scars equalling each of diductors. Front edge of scars not as clearly trilobed as in most species of genus. Very fine median ridge extends from front of adductor scars forward past middle of valve.

Measurements of type specimens are as follows:

[Parentheses indicate estimated measurements]

USNM	Valve	Length (mm)	Width (mm)	Hinge width (mm)	L/W	Costellae in 5 mm
158600	Brachial, paratype	6.3	(7.3)	(5.9)	(0.86)	24
158601	Pedicle, holotype	6.2	7.5	6.2	.83	24
158602	Brachial, paratype	6.0	7.0	6.1	.86	24
158603	Pedicle, paratype	6.7	8.0	6.7	.84	24

Figured specimens: USNM 158600–158603.

Occurrence: USGS colln. D208a CO, Garden City Formation, 250 ft below top, on ridge along south side of Blind Hollow, SE¼ sec. 28 and SW¼ sec. 27, T. 13 N., R. 2 E., Logan quadrangle, Utah.

Discussion.—This species is distinguished from *Diparelasma typicum* Ulrich and Cooper by its transverse rather than circular outline. The fineness of costellation is comparable to that of *D. typicum* but finer than that of *D. elegantulum* (Butts). From *D. subquadratum* Sando, it differs in its finer ornamentation and more transverse outline. Although its outline resembles that of *D. marylandicum* Sando, the eastern species has markedly coarse costellae.

The hollow costellae are like those of no other species of *Diparelasma* and resemble the ribbing of *Desmorthis nevadensis*. Ulrich and Cooper (1938, p. 147) discussed the probable relationship of *Diparelasma* to *Finkelnburgia*. The low narrow pseudospondylium of *D. rowelli* resembles that of *Finkelnburgia* to some extent. Except for the rudimentary nature of the cardinal process, the cardinalia of *D. rowelli* resemble those of *Desmorthis* more closely than those of *Finkelnburgia*. It therefore seems possible that *Diparelasma*, perhaps *D. rowelli*, was an intermediate between *Finkelnburgia* and *Desmorthis*.

Diparelasma cf. D. pogonipense (Hall and Whitfield)

Plate 2, figures 11, 12, 14, 15, 17, 18, 21, 22

Diparelasma pogonipense (Hall and Whitfield) is known only from a few specimens exposing no interiors (Ulrich and Cooper, 1938, p. 153). It is the only small species of the genus with costellae spaced as closely as 30 in 5 mm. Ten valves from USGS colln. D190b CO probably belong to this species.

Outline broadly elliptical to subcircular. Hinge width ¾–⅘ the total width. Costellae very fine, spaced 30 in 5 mm.

Pedicle valve evenly convex in lateral profile, narrowly rounded along midline in anterior profile. Posterolateral flanks flat to slightly concave. Brachial valve of low convexity in lateral and anterior profiles. Somewhat flattened along midline, not truly sulcate. Interiors of both valves as in *D. typicum* Ulrich and Cooper, the muscle field in the pedicle being distinctly trilobed.

Measurements of figured specimens are as follows:

[Parentheses indicate estimated measurements]

USNM	Valve	Length (mm)	Width (mm)	Hinge width (mm)	L/W	HW/W
158604	Brachial	6.4	(7.3)	(5.8)	0.83	0.80
158605	Pedicle	7.3	8.05	6.1	.90	.76

Occurrence: USGS colln. D190b CO, Garden City Formation, 150 ft below top. Beaver Creek, Utah (Ross, 1951, p. 13).

Discussion.—*Diparelasma* cf. *D. pogonipense* resembles *D. typicum* in size and outline but differs in fineness of costellation and in lacking any flattening or sulcation of the pedicle valve. Only *Diparelasma? magnum* Ulrich and Cooper (1938, p. 150, pl. 28*D*) possesses such fine ornamentation, but it is much larger and equally biconvex. In *D.* cf. *D. pogonipense* the brachial valve is markedly less convex than the pedicle.

Diparelasma cf. D. transversum Ulrich and Cooper

Plate 1, figures 14–17; plate 2, figures 1, 2

This species transversely elliptical in outline. Costellae spaced 16–17 in 5 mm at front of valve, showing a slight tendency toward bundling.

Measurements of specimens are as follows:

[Parentheses indicate estimated measurements]

USNM	Valve	Length (mm)	Width (mm)	Hinge width (mm)	L/W	Costellae in 5 mm
158606	Pedicle	9.7	12.4	10.1	0.78	17
158607	do	9.5	(11.0)	9.2	(.86)	16
158608	Brachial	8.6	12.3	9.5	.70	16

Figured specimens: USNM 158607, 158608.

Occurrence: USGS colln. D208c CO, Garden City Formation, 147 ft below top. On ridge along south side of Blind Hollow, SE¼ sec. 28 and SW¼ sec. 27, T. 13 N., R. 2 E., Logan quadrangle, Utah.

Discussion.—These specimens represent a species differing from *Diparelasma rowelli* in coarseness of costellae, in somewhat greater relative width, and in stratigraphic position. In the first two of these, it resembles *D. transversum* Ulrich and Cooper (1938, p. 154, pl. 27*B*). It is much more coarsely ornamented than *D. elegantulum* and *D. typicum* and is wider in outline than the latter. It appears to be a larger species than *D. marylandicus* Sando.

Diparelasma sp.

Plate 2, figures 16, 19, 20

A few specimens contribute variety to an already diverse assemblage of species of *Diparelasma* in the upper beds of the Garden City. Two pedicle valves, one of which is illustrated here, exemplify shells that seem to fit no previously described species and yet are too few in number to be the basis for a new species. These two valves are subcircular in outline and rotund in profile, and are ornamented with costellae spaced 20 in 5 mm. Costellae increase by implantation. Muscle scars are not as clearly tripartite as in other species.

Measurements of specimens are as follows:

[Parentheses indicate estimated measurements]

USNM	Length (mm)	Width (mm)	Hinge width (mm)	L/W	Costellae in 5 mm
158609	6.0	6.7	5.8	0.86	20
158610	9.8	10.5	9.3	.93	20

Figured specimen: USNM 158610.

Occurrence: USGS colln. D208a CO, Garden City Formation, 250 ft below top. D208c, CO, 147 ft below top. On ridge along south side of Blind Hollow, SE¼ sec. 28 and SW¼ sec. 27, T. 13 N., R. 2 E., Logan quadrangle, Utah.

Discussion—These shells differ from associated *Diparelasma rowelli* in having coarser costellae and more nearly circular outlines. From *D. typicum* they are differentiated by their coarser ornamentation and from *D. elegantulum* by their subcircular outline.

Genus TRITOECHIA Ulrich and Cooper, 1936

Tritoechia loganensis Ross, n. sp.

Plate 3, figures 8–18

Shell large, subquadrate in outline, hemipyramidal in profile. Cardinal area very long, its apical angle about 80°, steeply apsacline, inclined at 105°–110° from plane of commissure. Costellae very fine, increasing by implantation, numbering 20–24, most commonly 24, in 5 mm at front of valve.

In lateral profile outside of pedicle valve gently but evenly convex, forming an acute (close to 45°) angle with cardinal area.

Brachial valve strongly convex in lateral profile; moderately convex in anterior view. In some specimens very shallow wide sulcus present; in others, mere flattening of valve. Median septum narrow and well developed on interior. Cardinal process variously developed, ranging from tiny nub (pl. 3, fig. 17) to much-thickened prong (pl. 3, fig. 8).

Pedicle valve deep. Dental plates receding. Muscle field variably impressed. Linear adductor tracks bounded by low ridges. In one old specimen ridges enormously thickened. Diductor scars widen anteriorly, each a little wider than combined adductor scars. Adjustor scars a little narrower than diductors and located above them on dental plates. Pedicle foramen small.

Measurements of type specimens are as follows:

[Parentheses indicate estimated measurements]

USNM	Valve	Length (mm) (parallels commissure)	Width (mm)	Hinge width (mm)	Length cardinal area (mm)	Thickness (mm)	Apical angle (°)	Costellae in 5 mm
158611	Pedicle, holotype	14.0	(17.5)	(15.3)	8.2	----------	83	24
158612	Pedicle, paratype	(11.6+)	(17.7)	16.1	9.3	----------	77	24
158613	Brachial, paratype	11.7	16.8	14.5	----------	----------	----------	24
158614	----do	11.7	17.2	15.7	----------	6.6	----------	20
158615	Pedicle, paratype	Broken	Broken	(19.1)	10.3	----------	78	----------

Figured specimens: USNM 158611, 158613–158614.

Occurrence: USGS colln. D208a CO, Garden City Formation, 250 ft below top; USGS colln. D208c CO, 147 ft below top. On ridge along south side of Blind Hollow, SE¼ sec. 28 and SW¼ sec. 27, T. 13 N., R. 2 E., Logan quadrangle, Utah.

Discussion.—This species differs from most others in the length of its cardinal area and the resulting acute (80°) apical angle. Three species resemble it in this regard: *Tritoechia planodorsata* (Ulrich and Cooper), *T. hemipyramidata* Ulrich and Cooper, and *T. pennsylvanica* Ulrich and Cooper. The first of these possesses an alternation of coarse and fine costellae and is considerably smaller than *T. loganensis*. *T. hemipyramidata* resembles *T. loganensis* in costellar spacing but is much smaller and otherwise probably cannot be differentiated from it. Future collections in Alberta may show that the described specimens (Ulrich and Cooper, 1938, p. 163, pl. 32*A*) are merely immature.

In *T. pennsylvanica* there are about 15 costellae in 5 mm at the front of a valve, considerably fewer than in *T. loganensis*.

Tritoechia loganensis is probably the species to which should be referred specimens that Ulrich and Cooper (1938, p. 165) recorded as *T. occidentalis* from near Twin Bridges Dugway in Logan Canyon, possibly from the same location as *T. loganensis*. Although of comparable size and brachial outline, *T. occidentalis* is more coarsely ribbed and has a shorter cardinal area.

All three species of *Tritoechia* described by Sando (1957, p. 118–120, pl. 13, figs. 27, 30–36; pl. 14, figs. 1–12; pl. 13, figs. 37–52) from Maryland (*T. curvirostris*, *T. alticostellata*, and *T. tubulata*) have obtuse apical angles of the cardinal area and in this respect differ from *T. loganensis* with its long acutely pointed area. Compared with that of *T. loganensis*, the ornamentation of the shell is about twice as coarse in *T. alticostellata*, some coarser in *T. curvirostris*, and about the same in *T. tubulata*.

Genus ANOMALORTHIS Ulrich and Cooper, 1936

Anomalorthis lambda Ross, n. sp.

Plate 4, figures 1–12

Shell subquadrate in outline, hinge forming widest part of shell. Cardinal extremities acute or right angled. Lateral profile unequally biconvex, the pedicle valve having greater convexity. Surface finely costellate; 16 costellae in a space of 5 mm along front margin of valve 9 mm long.

Pedicle valve carinate in anterior profile with flat evenly sloping flanks. In lateral profile sloping evenly forward. Cardinal area strongly procline; its width more than four times its length. Dental plates greatly receding, little more than ridges along under side of cardinal area. Pseudospondylium with well-developed raised anterior edge.

Brachial valve gently convex in lateral profile; a very shallow median sulcus present in anterior and dorsal views.

Measurements of type specimens are as follows:

USNM	Valve	Length (mm)	Width (mm)	Hinge width (mm)	L/W	Costellae in 5 mm
158617	Brachial, paratype	9.13	13.3	14.6	0.69	16
158618	Pedicle, paratype	6.9	Broken	Broken	--------	18
158619	Brachial and pedicle, holotype.	7.3	10.0	10.8	.68	18
158620	Pedicle, paratype	2.8	----------	6.1	--------	23

Figured specimens: USNM 158617–158620.

Occurrence: USGS colln. D190d CO, Garden City Formation, 105 ft below top. On east side of Beaver Creek, south of Idaho-Utah State boundary, E½ sec. 35, T. 15, N., R. 4 E., Logan quadrangle, Utah.

Discussion.—The strongly procline cardinal area distinguishes this species from all but *Anomalorthis oklahomensis* and *A. nevadensis*. The latter lacks a brachial sulcus and both of those species have considerably finer costellae. The cardinal areas of *A. oklahomensis* and of *A. nevadensis* are about twice as wide as long whereas

that of *A. lambda* is four times as wide. This species was misidentified as *A. oklahomensis* in a previous publication (Ross, R. J., Jr., 1964, p. C71).

Genus SYNTROPHOPSIS Ulrich and Cooper, 1936

Syntrophopsis transversa Ulrich and Cooper

Syntrophopsis transversa Ulrich and Cooper, 1938, Geol. Soc. America Spec. Paper 13, p. 238, pl. 53*D*, *E*, figs. 22–25, 28.

Plate 4, figures 13–20

Syntrophopsis transversa is probably the most distinctive species in the genus and is therefore very useful stratigraphically. Its exact position within the Garden City Formation was not specified in the original description, but was subsequently indicated by Ross (1949, p. 480; 1951), p. 14, 20, 27).

Outline transversely subelliptical; length of brachial valves about two-thirds the width, and of pedicle valves about three-fourths. Surface smooth except for concentric growth lines. In anterior profile convexity of brachial valve pronounced along midline, flanks almost flat and sloping steeply to margin. Fold originated after first third of valve had developed; fold occupies more than half the width of valve. Hinge width about three-fourths greatest width.

Pedicle valve gently convex in anterior profile. Median sulcus shallow, increasing in depth forward. Tongue low, angular. Umbo swollen and markedly convex in lateral profile. In interior, spondylium confined to posterior $\frac{1}{3}$–$\frac{4}{10}$ of valve.

Measurements of figured specimens are as follows:

USNM	Valve	Length (mm)	Width (mm)	Hinge width (mm)	Thickness (mm)	L/W	HW/W
158621	Brachial	11.3	17.3	12.7	6.7	0.65	0.74
158622	Pedicle	11.8	15.7	11.5	4.5	.75	.73

Occurrence: USGS colln. D190d CO, Garden City Formation, 105 ft below top, Beaver Creek. (See also Ross, 1951, p. 13.)

Discussion.—*Syntrophopsis transversa* seems to have a fairly limited vertical stratigraphic range and is an important indicator of zone L in more easterly Utah sections. It is easily recognized because of its transverse outline. It has never been reported in western Utah or Nevada.

Genus CAMERELLA Billings, 1859

Rhynchocamara Schuchert and Cooper, 1932, Yale Univ., Peabody Mus. Nat. Hist. Mem., v. 4, pt. 1, p. 189.

Rhynchocamara Schuchert and Cooper. Ulrich and Cooper, 1938, Geol. Soc. America Spec. Paper 13, p. 250.

Camerella Billings. Amsden and Biernat, 1965, Treatise Invertebrate Paleontology, part H, p. H535. Geol. Soc. America and Kansas Univ. Press.

Camerella sp.

Plate 4, figures 21–23

A single fragmentary pedicle valve of a small camerellid was obtained in USGS colln. D190d CO.

Valve evenly convex in both lateral and anterior profiles. Outline subdeltoid. Smooth on the posterior half, and bears three, perhaps more, indistinct costae along the anterior part of the shell. Spondylium elevated on slender septum, restricted to posterior third of shell.

Measurements of the figured specimen are as follows:

USNM	Length (mm)	Width (mm)	Hinge width (mm)	L/W
158623	6.3	6.8	1.8	0.93

Occurrence: USGS colln. D190d CO, Garden City Formation, 105 ft below top, Beaver Creek (Ross, 1951, p. 13).

Discussion.—The poor condition of this single valve prevents all but a very cursory comparison with other species. In size it is similar to *Camerella* (*Rhynchocamara*) *sublaevis* (Ulrich and Cooper) except that its costae are less well developed and its outline is narrower. The deltoid outline is similar to that of *Camerella arkansasensis* (Ulrich and Cooper) from the Smithville Formation. A very similar species occurs in the Ibex area of western Utah 73 feet above the base of the Juab Limestone (USGS colln. D1644 CO) in association with *Ectenonotus* and other trilobites.

Genus BLASTOIDOCRINUS Billings, 1859

Blastoidocrinus Billings, 1859, Canadian Organic Remains, Decade IV, Canada Geol. Survey, p. 18–22.

Blastoidocrinus cf. B. carchariaedens Billings

Blastoidocrinus carchariaedens Billings, 1859, Canadian Organic Remains, Decade IV, Canada Geol. Survey, p. 18–22, pl. I, fig. 1a–n.

Blastoidocrinus carchariaedens Billings. Hudson, 1907, New York State Mus. Bull. 107, p. 97–119, pls. 1–7; 1911, New York State Mus. Bull. 149, p. 203–211, pls. 1–4.

Plate 4, figure 24

Blastoidocrinus is represented in the upper part of the Garden City Formation mainly by silicified plates, of which the deltoids are the most distinctive. Only one species of the genus has ever been described. Although it is probable that more than one species existed, the disarticulated nature of most discoveries has not encouraged serious studies of the genus.

For the purposes of this report, the significance of *Blastoidocrinus* is stratigraphic.

Occurrence: USGS colln. D190d CO, Garden City Formation, 105 ft below top, associated with brachiopods of zone L.

Discussion.—The original specimens described by Billings (1859, p. 18–22) and those studied by Hudson (1907, p. 97–119; 1911, p. 203–211) came from the Chazy rocks of easternmost Ontario, southwestern Quebec, and northeastern New York. Phleger (1933, p. 3) reported *Blastoidocrinus* in the Mazourka Formation (Badger Flat Formation of D. C. Ross, 1963) of the Northern Inyo Range, California. R. J. Ross (1949, p. 480; 1951, p. 27, 30, 31) called attention to its presence in zones K and L of the Garden City Formation. G. A. Cooper (written commun., 1967) informed me that *Blastoidocrinus* is also present in the Edinburgh Limestone of the Appalachians.

All occurrences of *Blastoidocrinus* outside the basin ranges of the Western United States are from rocks of Chazy (Marmor) or Black River (Porterfield) age. Those in the West are of Whiterock age. *Blastoidocrinus* therefore can be added to the growing list of genera and species occurring in Marmor or younger rocks in the Appalachian region and in supposedly older Whiterock strata in the Basin Ranges.

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[Italic page numbers indicate major references]

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PLATES 1-4

PLATE 1

[All figures are stereophotographs]

FIGURES 1–9. *Hesperonomia fontinalis* (White), × 2, Garden City Formation.

1, 2. Pedicle valve, exterior and interior views, USNM 158581, USGS colln. D208a CO.

3, 6. Brachial valve, exterior and interior views, USNM 158582, USGS colln. D208c CO.

4, 5. Brachial valve, exterior and interior views, USNM 158586, USGS colln. D208c CO; this valve shows unusual thickening and enlargement of cardinal process.

7. Brachial valve, interior view, USNM 158578, USGS colln. D208a CO; specimen shows tubules along hinge area partly covered on one side and exposed by abrasion on the other.

8, 9. Brachial valve, exterior and interior views, USNM 158583, USGS colln. D208c CO; specimen shows thickening parallel to hinge, probably caused by vascular trunk.

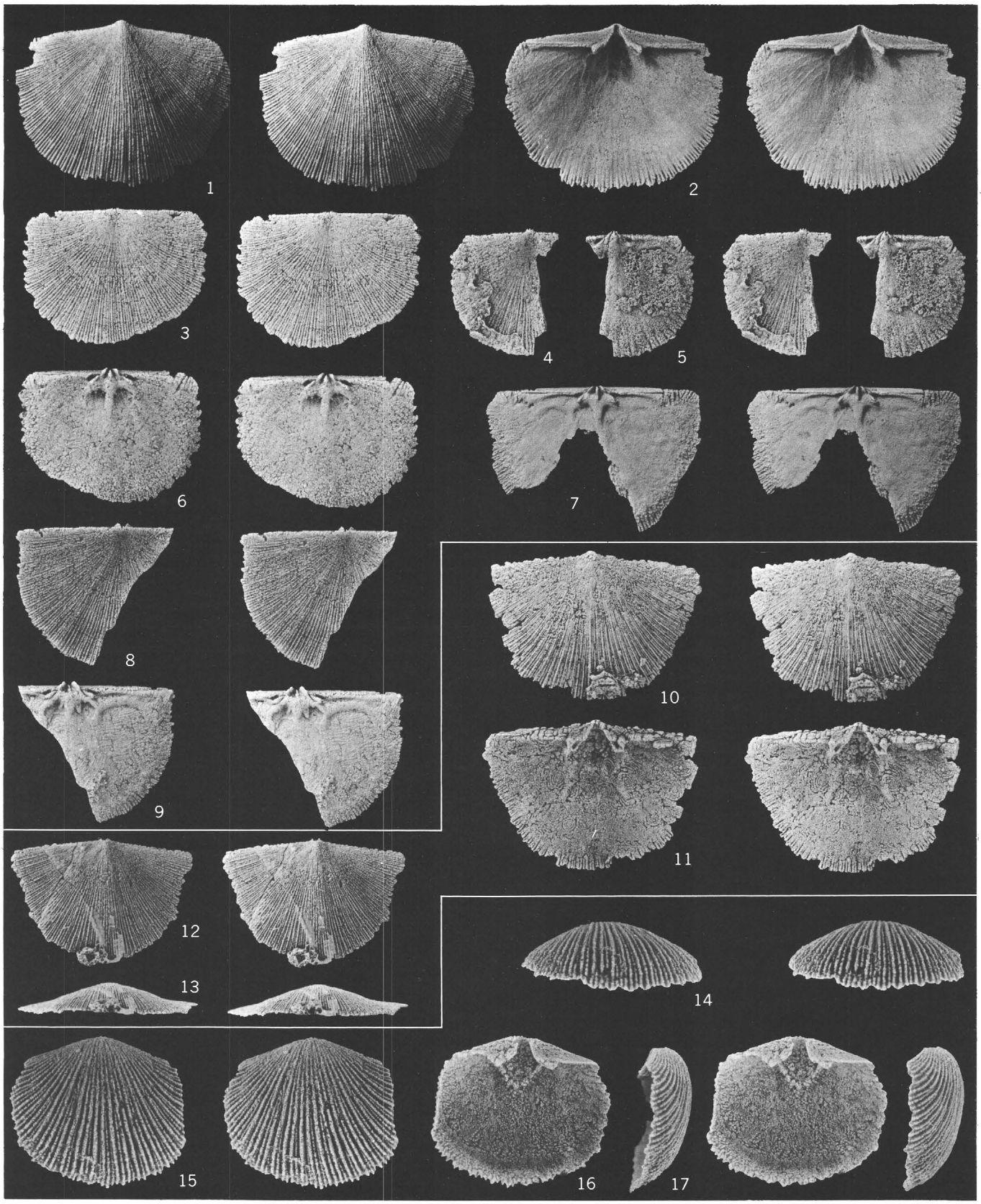
10–13. *Hesperonomia* cf. *H. dinorthoides* Ulrich and Cooper, × 2, Garden City Formation.

10, 11. Pedicle valve, exterior and interior views, USNM 158589, USGS colln. D190b CO.

12, 13. Pedicle valve, exterior and anterior views, USNM 158591, USGS colln. D208c CO.

14–17. *Diparelasma* cf. *D. transversum* Ulrich and Cooper, × 3, Garden City Formation, USGS colln. D208c CO.

14–17. Pedicle valve, anterior, exterior, interior, and lateral views, USNM 158607.



HESPERONOMIA AND *DIPARELASMA*

PLATE 2

[All figures are stereophotographs]

FIGURES 1, 2. *Diparelasma* cf. *D. transversum* Ulrich and Cooper, brachial valve, exterior and lateral views, × 3. USNM 158608 Garden City Formation, USGS colln. D208c CO.

3–10, 13. *Diparelasma rowelli* Ross, n. sp., × 4, Garden City Formation, USGS colln. D208a CO.

3. Paratype, pedicle valve, interior view, USNM 158603.

4–6. Paratype, brachial valve, exterior, interior, and lateral views, USNM 158600.

7–9. Holotype, pedicle valve, exterior, interior, and lateral views, USNM 158601.

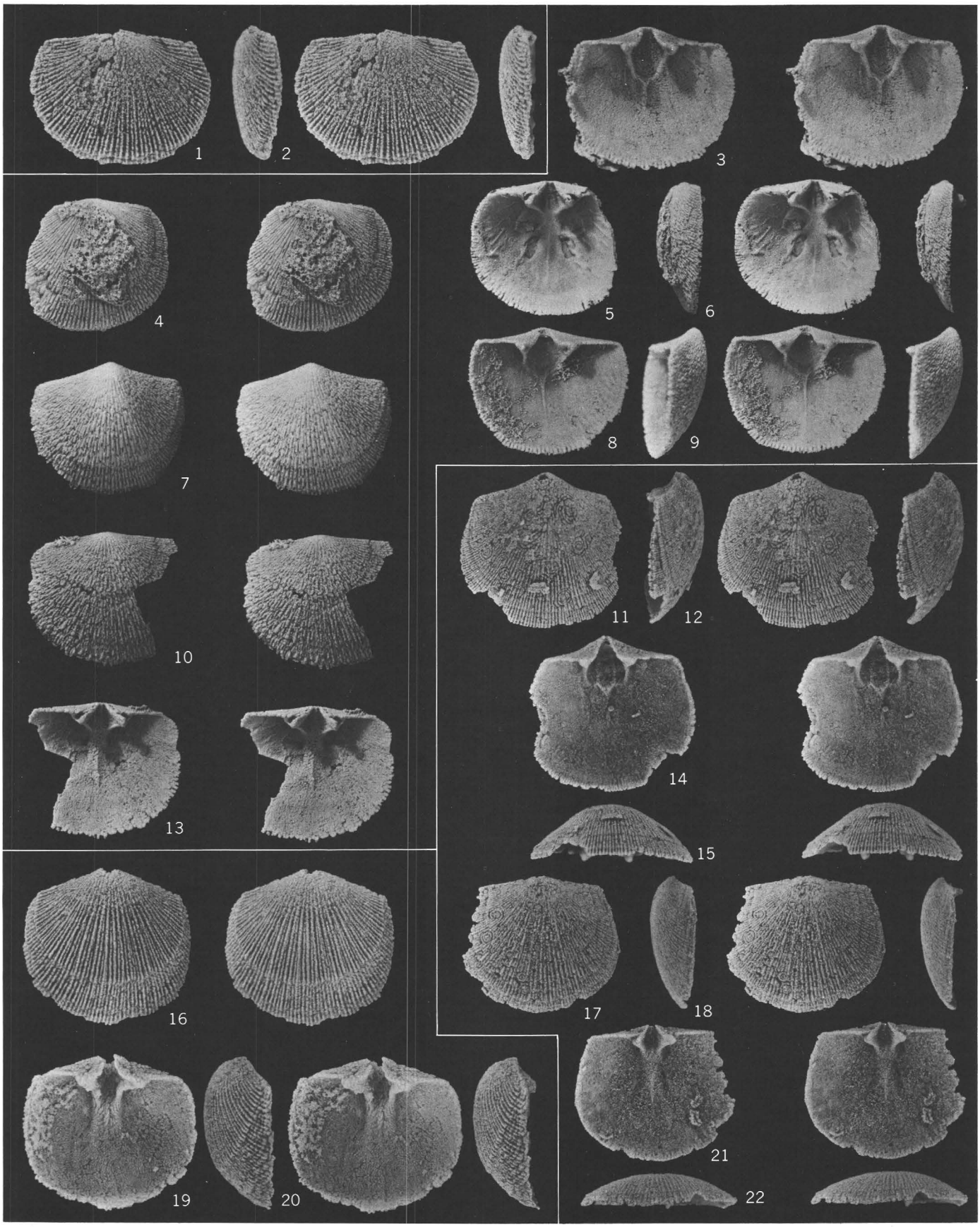
10, 13. Paratype, brachial valve, exterior and interior views, USNM 158602.

11, 12, 14, 15, 17, 18, 21, 22. *Diparelasma* cf. *D. pogonipense* (Hall and Whitfield), × 4, Garden City Formation, USGS colln. D190b CO.

11, 12, 14, 15. Pedicle valve, exterior, lateral, interior, and anterior views, USNM 158605.

17, 18, 21, 22. Brachial valve, exterior, lateral, interior, and anterior views, USNM 158604.

16, 19, 20. *Diparelasma* sp., pedicle valve, exterior, interior, and lateral views, × 3, USNM 158610, Garden City Formation, USGS colln. D208c CO.



DIPARELASMA

PLATE 3

[All figures except figure 16 are stereophotographs]

FIGURES 1-7. *Orthambonites* cf. *O. eucharis* Ulrich and Cooper, × 3, upper part, Garden City Formation.

1, 3, 5, 7. Pedicle valve, exterior, interior, anterior, and lateral views, USNM 158598, USGS colln. D190d CO.

2, 4. Brachial valve, exterior and interior views, USNM 15892, USGS colln. D190c CO.

6. Pedicle valve, exterior view, USNM 158593, USGS colln. D190c CO.

8-18. *Tritoechia loganensis* Ross, n. sp., × 2, Garden City Formation, USGS colln. D208a CO.

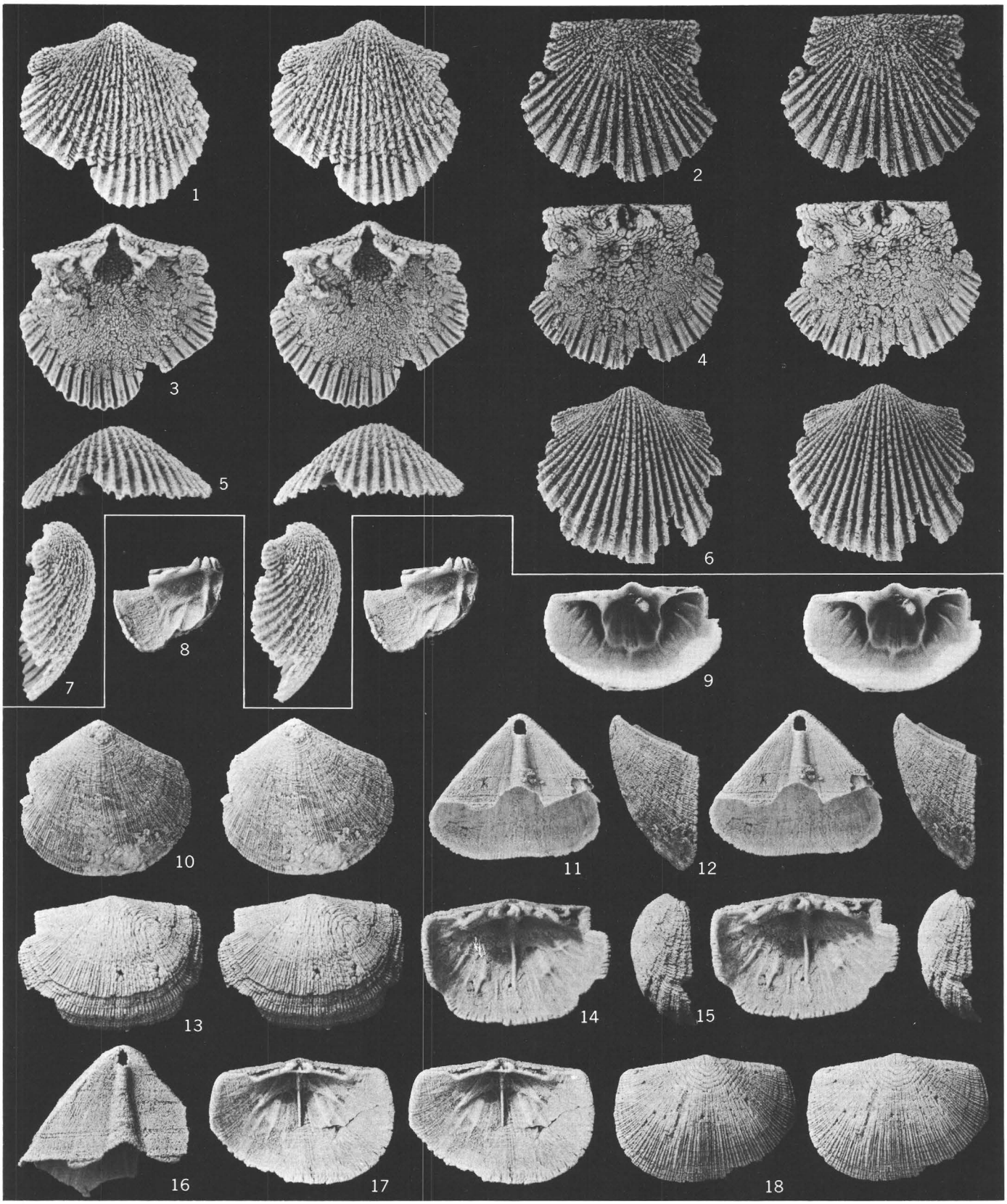
8. Paratype, brachial valve, fragmentary, interior view, showing enlarged cardinal process, USNM 158616.

9-12. Holotype, pedicle valve, interior, exterior, posterior, and lateral views, USNM 158611.

13-15. Paratype, brachial valve, exterior, interior, and lateral views; note large deformed cardinal process, USNM 158614.

16. Paratype, pedicle valve, posterior view, USNM 158615.

17, 18. Paratype, brachial valve, interior and exterior views, note minute cardinal process, USNM 158613.



ORTHAMBONITES AND *TRITOECHIA*

PLATE 4

[All figures are stereophotographs]

FIGURES 1-12. *Anomalorthis lambda* Ross, n. sp., Garden City Formation, USGS colln. D190d CO.

1, 2. Paratype, brachial valve, exterior and interior views, × 3, USNM 158617.

3-7. Holotype, damaged individual, both valves; pedicle exterior, brachial exterior, lateral, posterior, and anterior views, × 3, USNM 158619.

8-11. Paratype, immature pedicle valve, lateral, exterior, interior, and posterior views, × 5, USNM 158620.

12. Paratype, pedicle valve, interior view, × 3, USNM 158618.

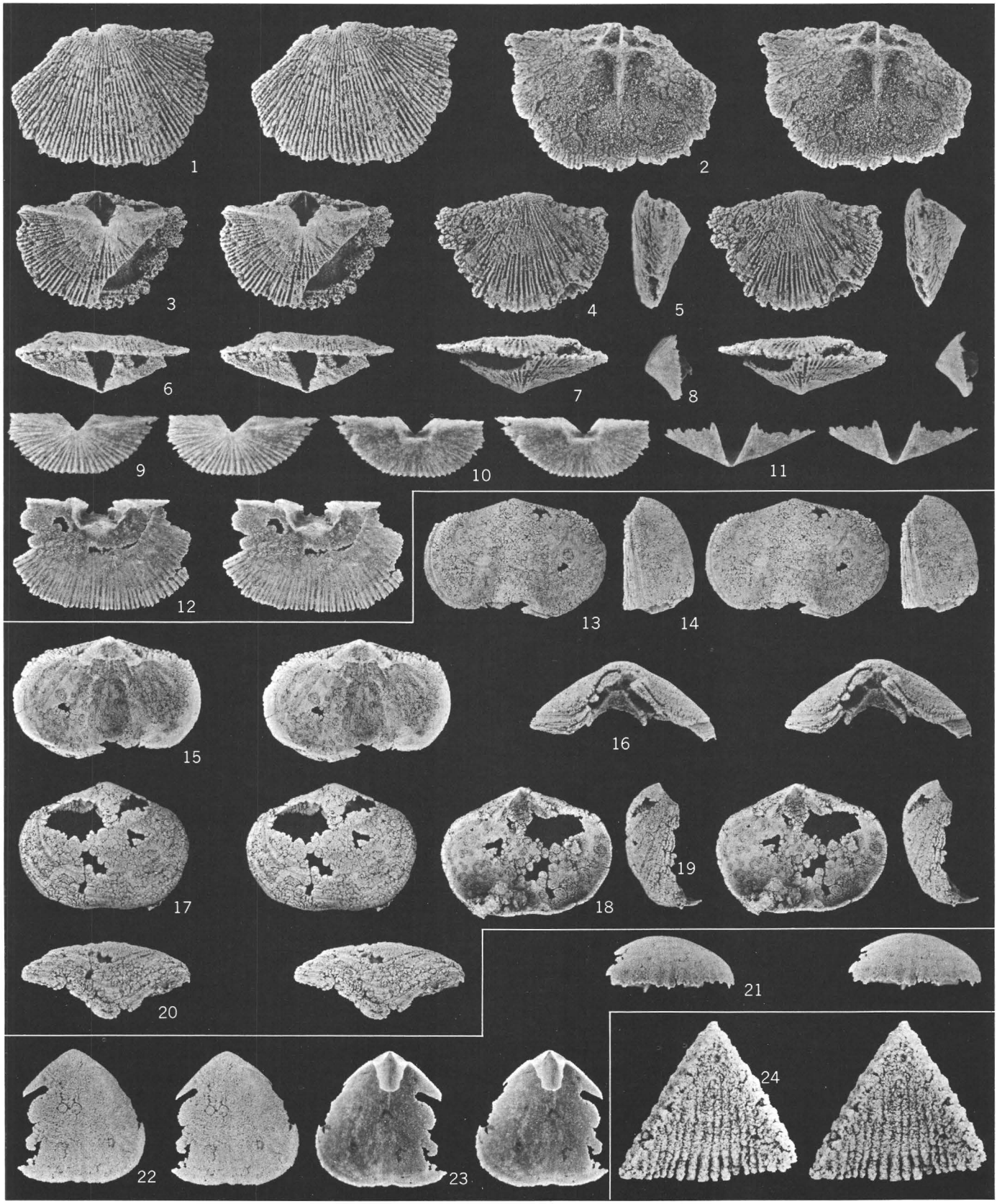
13-20. *Syntrophopsis transversa* Ulrich and Cooper, × 2, Garden City Formation, USGS colln. D190d CO.

13-16. Brachial valve, exterior, lateral, interior, and anterior views, USNM 158621.

17-20 Pedicle valve, exterior, interior, lateral and anterior views, USNM 158622.

21-23. *Camerella* sp., pedicle valve, anterior, exterior, and interior views, × 4, Garden City Formation, USNM 158623, USGS colln. D190d CO.

24. *Blastoidocrinus* cf. *B. carchariaedens* Billings, deltoid plate, exterior, × 5, Garden City Formation, USGS colln. D190d CO.



ANOMALORTHIS, SYNTROPHOPSIS, CAMERELLA, AND *BLASTOIDOCRINUS*