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New Silurian Heterostraci from Southeastern Yukon

ROBERT H. DENISON
CURATOR OF FOSSIL FISHES

INTRODUCTION

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During the 1959 and 1960 field seasons, California Standard Company field parties, under the direction of H. R. Hovdebo, collected ostracoderm remains in the Beaver River area of Yukon Territory. The locality at which these collections were made is approximately 60° 27′ N., 125° 47.5′ W., some 100 feet north of the Beaver River.

The east-dipping homocline (figs. 58, 59) of the area in which the ostracoderms were found is bounded to the east and to the west by faults on which substantial vertical displacement can be demonstrated, but which appear to diminish in magnitude in a southerly direction. Within this homocline the upper contact of map Unit 5, which is the top of a carbonate sequence, and the outcrop pattern of map Units 3 and 7, which are resistant sandstones, have been fairly closely defined; the other contacts are more loosely defined because of poor exposure. Ages of the map Units have been determined only for Unit 4 and the basal part of Unit 2; these are Silurian and Ordovician, respectively. Map Units 5 through 7 appear to encompass, on the basis of regional information, rocks of Middle and Late Devonian age.

The ostracoderms which are the subject of this paper were collected from a dolomite lens within the middle part of Unit 4 (fig. 59, Pt. C). Detailed relationships at the outcrop locality are shown in figure 59. The possible fault zone indicated on this figure (Pt. D) is not considered to have any significant magnitude in view of continuity of stratigraphically higher formations on the hillside above the exposure.

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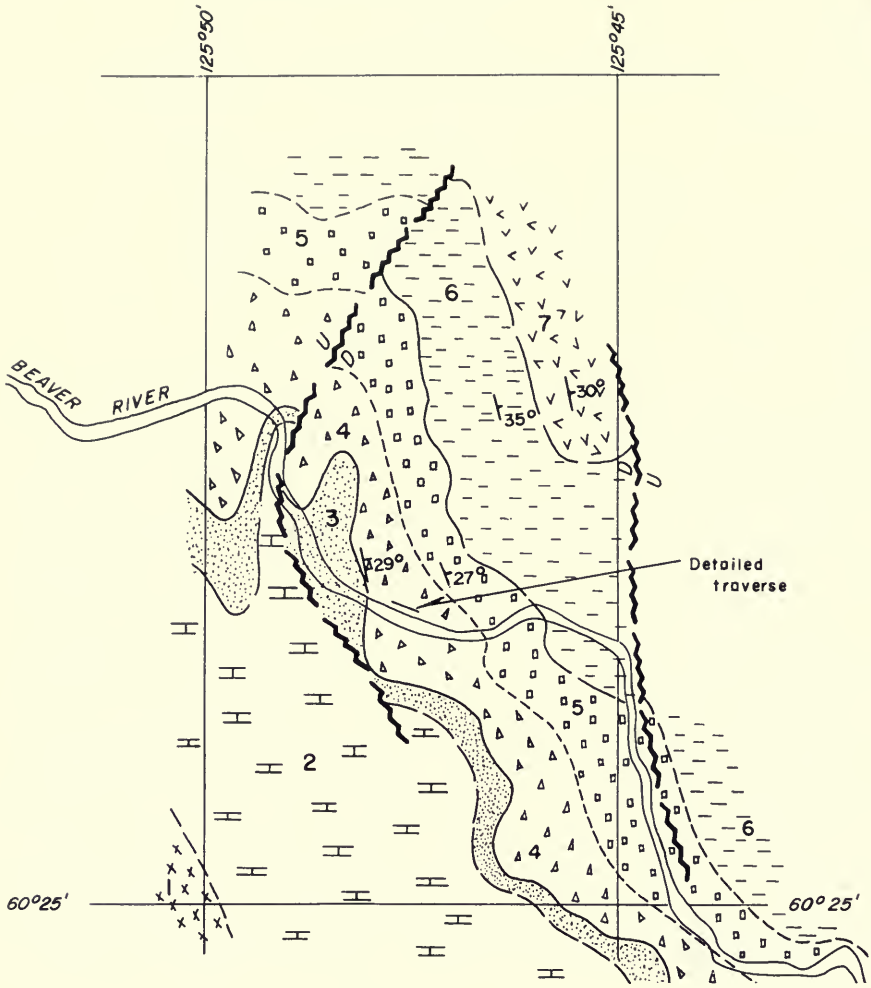

FIG. 58. Surface geology of Beaver River area, southeastern Yukon, by H. R. Hovdebo (scale: ¾ inch=1 mile). 1, Pre-Ordovician igneous complex; 2, Ordovician (and younger?) carbonates; 3, Silurian(?) sandstone; 4, Silurian limestones and graptolitic shale; 5, Lone Mountain formation (Middle Devonian?); 6, Fort Creek shale (Upper Devonian); 7, Sandstone (Upper Devonian?).

The following graptolites have been collected from the shale unit which is exposed some 250 feet below the ostracoderm occurrence (fig. 59, Pts. A to B): *Monograptus vomerinus* var. *gracilis*, *M. priodon*, *M. acus*, *M. "spiralis,"* *M.* ex grupo *dubius*, *Retiolites geinitzianus*, and *Cyrtograptus* cf. *murchisoni* var. *bohemicus*.

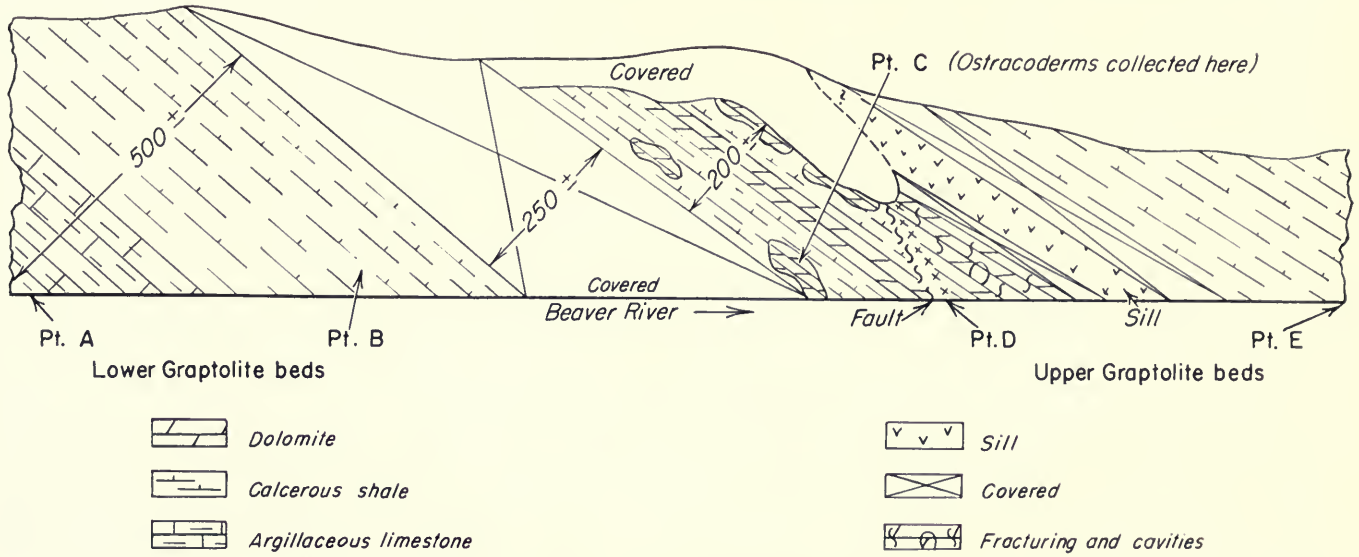

FIG. 59. Cross section along detailed traverse, located as indicated in figure 58. (By E. W. Bamber.) The thicknesses have been calculated approximately from an aerial photograph. The fault is based on the discontinuous massive dolomite bed and on numerous fractures and cavities filled with calcite; its displacement is probably very small (< 100 feet). It may be merely the slumping of a large dolomite lens into the shale below. The continuity of the Devonian? strata higher on the hillside above this cross section suggests that the fault is not very large.

This fauna appears to span the equivalents of zones 24 to 26 of the British graptolite succession, i.e., upper Llandovery and lowest Wenlock, or the upper Clinton of the New York section.

Occurring in the same beds as the ostracoderms (fig. 59, Pt. C) are: *Monograptus* sp. indet., *?Conchidium* sp., and *Atrypa* sp.

The presence of the brachiopod *?Conchidium* suggests a Late Silurian age for these beds.

Monograptus dubius is found in the shale beds above the ostracoderm occurrence (fig. 59, Pt. E). The European range of this species is Upper Wenlock through Middle Ludlow, i.e., late Middle to Late Silurian.

All ostracoderm specimens have been deposited in the Princeton University Geological Museum.

We wish to express our appreciation to The California Standard Company for permission to publish this introduction to Dr. Denison's paper.

VERTEBRATA: HETEROSTRACI

Family CYATHASPIDIDAE

Vernonaspis Flower and Wayland-Smith, 1952

The original description by Flower and Wayland-Smith (1952, pp. 373–374) does not adequately define this genus and in many respects is misleading. The shape of the dorsal shield of their specimens has been so modified by crushing that many of the features they describe have little significance. The anterior end is probably rounded rather than obscurely pointed. The posterior margin has a small, rounded, median lobe, rather than an obtuse point. The differentiation of the rostral epitegum is common in Cyathaspididae, rather than unique. There is almost certainly only a single pair of lateral epitega, rather than two pairs. The absence of a clear differentiation of lateral and central epitega is common in Cyathaspididae, not unique. The pustules that modify the dentine ridges are undoubtedly the result of some peculiarity of preservation, not a natural characteristic. But *Vernonaspis* is probably a valid genus, though it is similar to *Archegonaspis*. It is redefined as follows, incorporating characteristics shown only by the new species from the Yukon:

Vernonaspis is a member of the Cyathaspididae in which the dorsal shields are moderate to narrow in proportions (width/length= .54–.64), the orbits are far forward (orbital length/total length=.10–

.13), and the pineal macula has an anterior position (pineal length/total length=.20–.22). The postbranchial lobes are long. There is

FIG. 60. *Vernonaspis bamberi*, type, dorsal shield, PU 17081 (× 2).

a median lobe on the rostral edge of the dorsal shield, and the preorbital processes are strongly developed. The dentine ridges are of moderate width or fine (5–9 per mm.). The rostral epitegum usually has transverse ridges posteriorly, but its ornament is variable anteriorly. The pineal triangle is not distinct from the central epitegum. The ridges of the central epitegum are essentially longitudinal.

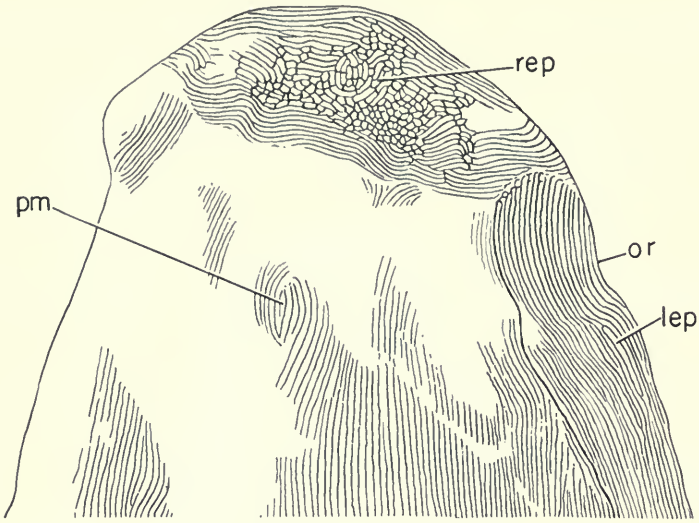

FIG. 61. *Vernonaspis bamberi*, anterior part of dorsal shield of type, PU 17081 (× 4). *lep*, lateral epitegum; *or*, orbital notch; *pm*, pineal region; *rep*, rostral epitegum.

Vernonaspis bamberi,[1] new species

Type.—PU 17081, a dorsal shield, nearly complete, though somewhat crushed and distorted (figs. 60, 61).

Referred specimens.—PU 17082, a dorsal shield, nearly complete though split in half near the midline; PU 17083–4, incomplete dorsal shields; PU 17375, the anterior part of a dorsal shield; PU 17086, a ventral shield, incomplete anteriorly and folded sharply near the midline; PU 17085, 17087, fragments of ventral shields.

Diagnosis.—The length of the dorsal shield is 43 to 46 mm. The dentine ridges are 5 to 6 per millimeter. The posterior edges of the shields are smoothly convex, without a median lobe.

Vernonaspis major, new species

Type.—PU 17104, a complete dorsal shield (figs. 62, 63).

Referred specimens.—PU 17105, a nearly complete dorsal shield; PU 17106, the anterior two-thirds of a dorsal shield; PU 17107, an incomplete and badly crushed dorsal shield; PU 17091, 17376, fragments of dorsal shields.

[1] After E. W. Bamber, collector of these specimens.

FIG. 62. *Vernonaspis major*, type, dorsal shield, PU 17104 (× 2).

Diagnosis.—The length of the dorsal shield is 57 mm. in the type. The dentine ridges are 5 to 6 per millimeter. The dorsal shield has a rounded median lobe on its posterior edge, and sharply marked postbranchial processes.

Discussion.—These new species are distinguished by their larger size and coarser dentine ridges from the previously described *Vernonaspis allenae* and *V. leonardi*. The species from the Yukon have a distinct median rostral process and strongly developed preorbital and postbranchial processes. None of these features is clearly shown

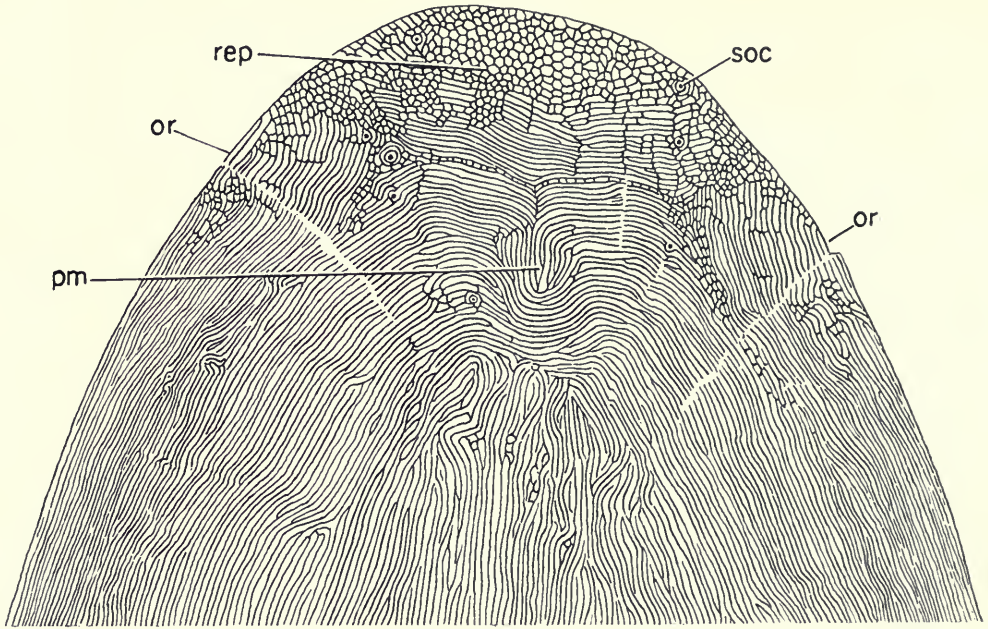

FIG. 63. *Vernonaspis major*, anterior part of dorsal shield of type, PU 17104 (× 4). *or*, orbital notch; *pm*, pineal region; *rep*, rostral epitegum; *soc*, pore of supraorbital sensory canal.

in the original material of *Vernonaspis*, although there is reason to believe that the preorbital and postbranchial processes, at least, are similarly developed.

The rostral epitegum shows considerable variability in its ridge pattern (figs. 61, 63, *rep*). Almost always there are transverse ridges on its posterior part. In front of this, *V. allenae* and *V. leonardi* show a fanlike arrangement of ridges directed anteriorly and antero-laterally. The ridges in the Yukon species show a tendency to be denticulate, coarse, and irregular anteriorly. There may be one or more ridges parallel to the anterior margin. Commonly, circular ridges surround the anterior pores of the supraorbital sensory canal (fig. 63, *soc*).

In *Vernonaspis major* (fig. 63) there is no differentiation of a pineal triangle, and this area, at least superficially, is incorporated into the central epitegum. In PU 17104 and 17105, ridges of the central epitegum curve medially, then postero-medially into the pineal region. In PU 17106, central ridges continue longitudinally through the pineal area. This region is not shown as well in the other species, but apparently in none is there a distinct pineal triangle. The type of *V. allenae* has an arrangement similar to PU 17104. In the type of *V. leonardi* the anterior ridges of the central epitegum curve antero-laterally to run parallel to the fanned lateral ridges of the pineal region.

The type dorsal shield of *Vernonaspis major* is relatively broader than in other *Vernonaspis*, the ratio of width/length being .63. The breadth in this specimen has undoubtedly been increased by flattening. The ratio of width/length is estimated to be .55 in PU 17106.

Vernonaspis is most closely similar to *Archegonaspis*. The latter differs in its broader shield, more posterior orbits and pineal macula, absence of median process on the rostrum, weak development of the postbranchial processes, and coarser dentine ridges (4.5–5 per mm.). The rostral epitegum usually has a more completely transverse ridge pattern, and the pineal triangle is distinct, with a fanned ridge pattern.

Ptomaspis,[1] new genus

Type species.—*P. canadensis.*

Diagnosis.—The dorsal shield is of moderate proportions; its orbital notches are shallow, its rostrum is smoothly rounded, and its

[1] From πτωμα, carcass, and ασπις, shield.

posterior margin is gently convex. The dentine ridges include some that are slightly higher between others that are lower and sometimes

FIG. 64. *Ptomaspis canadensis*, type, dorsal shield, PU 17090 (× 2).

slightly narrower; they are subdivided into short lengths or even into small denticles. Posteriorly the ridges are grouped into scale-like areas. The dorsal shield is divided by the pattern of ornamentation into epitega: the rostral epitegum has short transverse ridges anteriorly, and grades through a denticulate area into antero-posterior ridges in the pineal triangle; the central epitegum has a slightly elliptical pattern.

FIG. 65. *Ptomaspis canadensis*, type, dorsal shield, PU 17090 (× 3). *cd*, pores of transverse sensory commissure; *ldl*, pores of lateral dorsal sensory canal; *mdl*, pores of median dorsal sensory canal; *or*, orbital notch; *pm*, pineal macula; *rep*, rostral epitegum; *soc*, pores of supraorbital sensory canal.

Ptomaspis canadensis, new species

Type.—PU 17090, a nearly complete dorsal shield (figs. 64, 65).

Diagnosis.—The length of the dorsal shield is 61 mm.; the ratio of width to length is .58. Dentine ridges average about 5 per millimeter.

Discussion.—*Ptomaspis* belongs to the group of Cyathaspididae in which the dorsal shield is divided superficially into distinct epitega, though its lateral epitega are not very sharply differentiated. The postbranchial part of the shield is relatively long (the ratio of postbranchial length to total length is .46), and the postbranchial lobes are very slightly developed. The dentine ridge pattern, transverse on the rostrum and slightly elliptical on the central epitegum, is characteristic of this group of the Cyathaspididae. The subdivision of the ridges into short lengths or even into denticles, and their grouping into scale-like areas on the posterior part of the shield, distinguish *Ptomaspis* from other Cyathaspididae except *Tolypelepis.* In *Tolypelepis,* however, the scale-like areas are much more distinct and extend over the whole central epitegum and onto the pineal triangle. *Ptomaspis* approaches the ridge arrangement of *Archegonaspis* and retains only a vestige of what was presumably the original scale covering of the anterior part of the body. The pores of the lateral line canals (fig. 65) are easily distinguishable and show that the pattern of the sensory canals is similar to that of *Tolypelepis* (Stensiö, 1958, fig. 215) except that the lateral and medial dorsal lines appear to be continuous. Parts of four transverse commissures can be identified. *Ptomaspis canadensis* is one of the largest of the Cyathaspididae, and is exceeded in size only by *Allocryptaspis* and some species of *Poraspis.* The relative width of the type specimen may have been increased somewhat by flattening.

Dikenaspis,[1] new genus

Type species.—*D. yukonensis.*

Diagnosis.—The dorsal shield is moderately broad, the orbits are placed relatively far back, the rostrum has a strong median lobe on its anterior margin, and the postbranchial lobes are deep and truncated anteriorly. The dentine ridges are fine. The dorsal shield is divided by the ridge pattern into rostral, central, and paired lateral epitega. The ridges are mostly transverse on the rostral epitegum, and converge at the midline anteriorly on the central epitegum and

[1] From δικην, after the manner of; and ασπις, shield.

in the pineal area. The lateral line canals are branched in a complex fashion. There are two pairs of lateral lines on the rostrum.

Dikenaspis yukonensis, new species

Type.—PU 17088, a nearly complete dorsal shield, and the posterior part of a ventral shield (figs. 66, 67).

Referred specimens.—PU 17089, the anterior half of a dorsal shield; PU 17377, a ventral shield.

Diagnosis.—The length of the dorsal shield is about 30 mm.; its proportions are moderately broad, with width/length=.63. There are approximately 9 to 10 dentine ridges per millimeter.

Discussion.—*Dikenaspis* shows so many similarities to *Dinaspidella* and *Irregulareaspis* that a relationship is probable. In all three genera the dentine ridges are fine and the deep postbranchial lobes of the dorsal shield are abruptly truncated anteriorly. They all have the orbits placed relatively far posteriorly: orbital length/total length is .17 in *Dikenaspis* and *Irregulareaspis,* and .20 in *Dinaspidella;* it is less than .17 in other Cyathaspididae, except in some species of *Poraspis.* The branching of the lateral line system in *Dikenaspis* resembles that of *Irregulareaspis* (Kiaer and Heintz, 1932, fig. 9).

On the other hand, the presence of clearly distinct epitega in *Dikenaspis* is presumably a primitive cyathaspid characteristic that has disappeared in *Dinaspidella* and *Irregulareaspis.* On the rostral epitegum (fig. 67, *rep*) the dentine ridges are convex posteriorly at the sides and anteriorly in the middle; one or two ridges are parallel to the anterior edge. The central epitegum has the ridges arranged in a strongly elliptical fashion anteriorly. The pineal triangle is not distinct, and this area is included in the elliptical central pattern. The rostral region of the dorsal shield is narrow compared to its branchial region. The anterior edge of the rostrum has a distinctive shape, largely because of the strongly developed median lobe, which is even more pronounced than in *Vernonaspis.* On either side, the median lobe is separated by a deep notch from the powerfully developed preorbital processes. The orbital notches are quite deep.

The pores of the lateral line system are large and obvious. In the type dorsal shield some of the canals themselves can be seen because of the transparency or removal of the superficial layer of the shield (fig. 67, *cd, ldl, soc*). Where visible the canals have branched so as to form a network approaching that of *Irregulareaspis* in complexity. A striking feature of *Dikenaspis* is the presence of two pairs

FIG. 66. *Dikenaspis yukonensis*, type, dorsal shield and part of ventral shield, PU 17088 (× 2).

of sensory lines in the rostral region, instead of the single pair of supraorbital canals of other Cyathaspididae. A possible explanation,

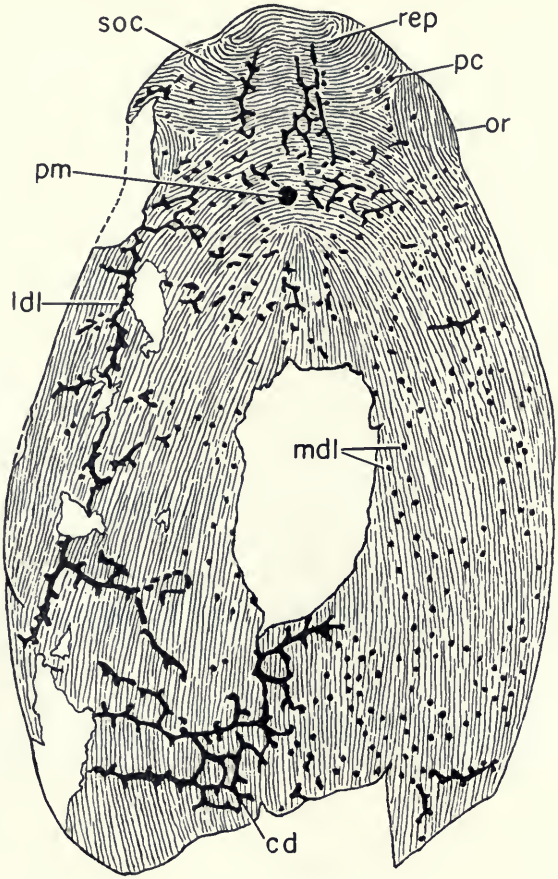

FIG. 67. *Dikenaspis yukonensis*, dorsal shield of type, PU 17088 (× 4). *cd*, branched transverse sensory commissure; *ldl*, lateral dorsal sensory line; *mdl*, pores of median dorsal sensory line; *or*, orbital notch; *pc*, pore of ?profundus sensory line; *pm*, pineal area; *rep*, rostral epitegum; *soc*, ?supraorbital sensory canal.

suggested by Stensiö (1958, p. 401), is that the medial pair (fig. 67, *soc*) represents the supraorbital canals of modern fishes, and that the lateral pair (fig. 67, *pc*), which passes immediately above the orbits, is innervated by the profundus nerves.

The ventral shield, PU 17377, agrees with *Dikenaspis yukonensis* in size (length=26.1 mm.), proportions (width/length=.67), and fine

dentine ridges (8 or more per mm.). The anterior border is concave, and the posterior border is convex with a rounded median point. The lateral borders do not show deep incisions for branchial plates, such as occur in *Dinaspidella* and *Irregulareaspis* (Kiaer and Heintz, 1932, p. 16). The shield is deeply arched posteriorly, but anteriorly it is nearly flat. Posteriorly the dentine ridges are arranged longitudinally, but in the anterior half they converge toward the midline. The most anterior and lateral ridges are, except for occasional irregularities, continuous around the anterior and lateral parts of the shield. They are concentric around the inner part of the shield, rather than conforming to the outer contour. This arrangement is reminiscent of that in Pteraspididae.

Ariaspis,[1] new genus

Type species.—*A. ornata.*

Diagnosis.—The dorsal shield is relatively broad and weakly vaulted. There is no median process on the rostral margin, but the preorbital processes are strongly developed. Narrow lateral laminae extend from the orbits to the branchial openings and are separated from the rest of the shield by sharp downward angulations. There are no postbranchial lobes, and the postero-lateral corners of the shield are small points. The posterior edge of the dorsal shield is nearly transverse except for the incorporation of a small, median, projecting scale. No separate epitega are distinguishable.

Ariaspis ornata, new species

Type.—PU 17103, a complete dorsal shield (figs. 68, 69).

Diagnosis.—This is a small species, with the length of the dorsal shield 21.5 mm. The ratio of width/length is .72. The dentine ridges are fine, 7.5 to 8 per millimeter, and have sharply or roundly convex crests.

Discussion.—The single but well-preserved specimen referred here represents a genus that is clearly distinct from other Cyathaspididae. Comparable lateral laminae are otherwise known only on the dorsal shields of *Allocryptaspis* and *Ctenaspis*. In *Ariaspis* these laminae form very narrow downwardly directed rims, and can hardly represent fused branchial plates, as appears to be the case in *Allocryptaspis*. As in *Ariaspis*, postbranchial lobes are also reduced or absent in *Anglaspis* and *Ctenaspis*. Because of the absence of

[1] From αρι, denoting excellence; and ασπις, shield.

these lobes and branchial notches, it is impossible to determine in *Ariaspis* the precise position of the branchial openings, but presum-

FIG. 68. *Ariaspis ornata*, type, dorsal shield, PU 17103 (× 4).

ably they were close behind the terminations of the lateral laminae. The median scale that is incorporated in the posterior edge of the shield is probably unique in Cyathaspididae; it is comparable to the dorsal spine of Pteraspididae.

In addition to these specializations, the absence of distinct epitega shows that this is an advanced genus. The ridge pattern is comparable to that in *Homalaspidella* and some *Poraspis*. A number of ridges are parallel to the anterior edge. Irregular ridges lie between these and the orbits. The pineal macula (fig. 69, *pm*) has a prominent, oval ridge pattern. The rest of the ridges are arranged antero-posteriorly near the midline, and pass into an elliptical pattern toward the lateral margins. These ridges are long and continuous except near

the posterior margin, where a distinct band appears to represent a separately formed part of the shield.

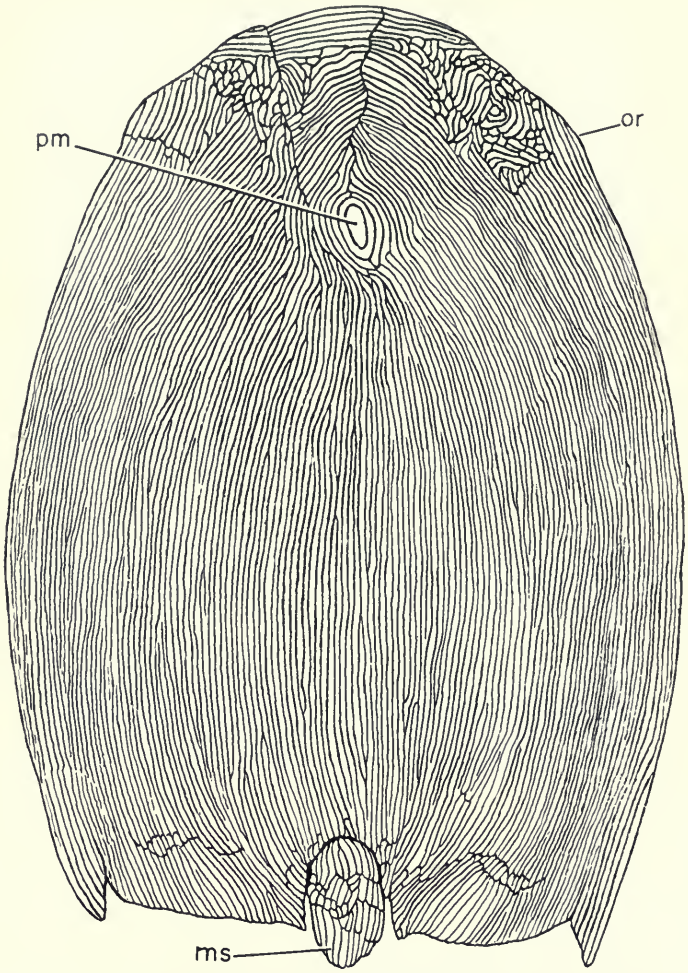

FIG. 69. *Ariaspis ornata*, type, dorsal shield, PU 17103 (× 6). *ms*, median dorsal scale; *or*, orbital notch; *pm*, pineal macula.

The pores of the lateral line system are small, and the pattern of the canals has been determined only so far as it has been made visible by immersion in alcohol and aniseed oil. The medial dorsal sensory lines are rather widely spaced and appear to be broken into short lengths. The anterior three transverse commissures are represented by short medial and lateral canals; the fourth was not visible.

Apparently there are no striking peculiarities of the lateral lines in *Ariaspis*.

Homalaspidella Strand 1934

This genus, originally described as *Homalaspis* by Kiaer and Heintz (1932, p. 14), has hitherto been known only from the Early Devonian, Red Bay series, of Spitsbergen. It includes small forms whose dorsal and ventral shields are moderately narrow, rather uniform in breadth, and arched relatively little. The rostral edge lacks a median process, the orbital notches are shallow, and the preorbital length is short. The dentine ridges are flat-topped, except perhaps near the lateral margins. Epitega and hypotega are hardly or not at all distinct. On the dorsal shield, there is a belt of nearly continuous ridges parallel to the anterior and lateral edges; central ridges are more or less longitudinal and may continue through the pineal area. Dorsal transverse commissures of the sensory canal system are poorly developed.

Homalaspidella borealis, new species

Type.—PU 17101, a dorsal shield, incomplete posteriorly (figs. 70–72).

Referred specimens.—PU 17102, an imperfect but articulated specimen, showing an incomplete dorsal shield, a branchial plate, and some scales of the tail; PU 17378–81, incomplete dorsal shields; PU 17092 (fig. 73), 17382, ventral shields, essentially complete; PU 17383, the posterior part of a ventral shield.

Diagnosis.—The dorsal shield has a length of 28 to 30 mm., and a ratio of width/length of .54. The rostral edge is nearly transverse. The preorbital processes and orbital notches are very slightly developed, and the orbits are far anterior. The ratio of postbranchial length to total length is .33–.37. The posterior edge of the dorsal shield is gently convex and lacks a median lobe. The dentine ridges are moderately coarse, 5.2–6.2 per millimeter on the dorsal shield, and 5.0–5.4 per millimeter on the ventral shield.

Discussion.—*Homalaspidella borealis* is presumably much older than the type and only other species, *H. nitida*. However, the differences, most of which are indicated in the diagnosis, hardly warrant a generic distinction. The ratio of pineal length to total length is .25–.26, about as in the type species. The ratio of orbital length to total length is .10–.12, slightly less than in the type species, where it is .14; this difference may be accounted for largely by the greater

convexity of the rostral margin in the type species. The preorbital processes and orbital notches are distinct though small in the type

FIG. 70. *Homalaspidella borealis*, type, incomplete dorsal shield, PU 17101 (× 4).

species, but are barely indicated in *H. borealis*. The posterior part of the dorsal shield is differently shaped in the two species: in *H. nitida* the postbranchial lobe is short, but the posterior edge is extended by a pronounced lobe; in *H. borealis* the postbranchial lobe is longer, but the postero-median edge is only slightly convex. No other cyathaspids, except *Allocryptaspis* and *Ctenaspis*, have gone as far in reducing all traces of distinct epitega. The dentine ridges of *H. borealis* (fig. 71) tend to be sinuous and discontinuous with many intercalations. PU 17379 (and to a less extent other specimens) has

FIG. 71. *Homalaspidella borealis*, type, incomplete dorsal shield, PU 17101 (× 6). *or*, position of orbit.

most lateral line pores set in very short ridges, one pore per ridge. These peculiarities of ridge arrangement occur to some extent in

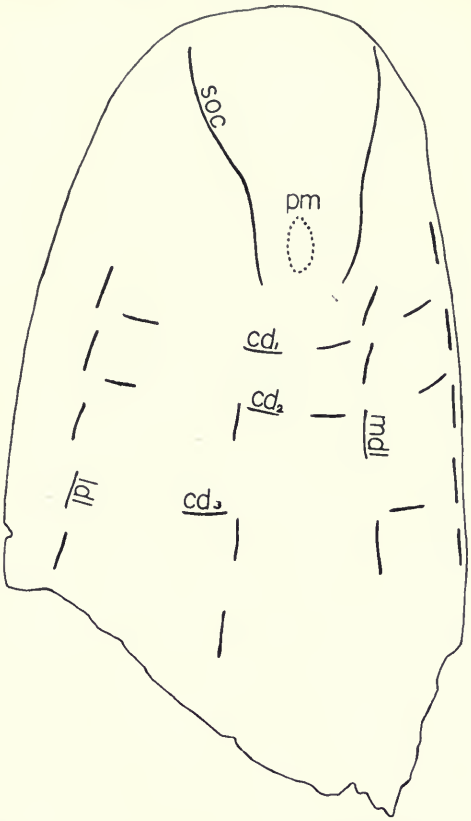

FIG. 72. *Homalaspidella borealis*, type, incomplete dorsal shield, PU 17101 (× 4). *cd* $_{\overline{1}-\overline{3}}$, transverse commissures of sensory system; *ldl*, *mdl*, lateral and medial dorsal sensory canals; *pm*, pineal area; *soc*, supraorbital sensory canal.

H. nitida. Of the dorsal sensory canals of *H. borealis* (fig. 72), not only the transverse commissures but also the median longitudinal canals are divided into short lengths.

The ventral shield of *H. borealis* (fig. 73) has a length of 25 to 29 mm. and a ratio of width/length of .58. The anterior edge is transverse or concave, and the posterior edge is convex with a rounded median point similar to that figured for *H. nitida* by Kiaer and Heintz (1935, fig. 55, C). The ridge pattern of the ventral shield is similar to the dorsal pattern, with a few anterior transverse ridges that continue around the lateral margins, and with longi-

tudinal central ridges that become irregular antero-medially behind the transverse ridges. Distinct hypotega are not indicated.

FIG. 73. *Homalaspidella borealis*, ventral shield, PU 17092 (× 4).

Undetermined Cyathaspididae

Two incomplete dorsal shields do not belong to the genera described above. PU 17384 (fig. 74) preserves the left side to or nearly to the midline, from the posterior edge anterior as far as the orbit. Its total length is estimated to be more than 60 mm., making this one of the largest Cyathaspididae. It has about six flat-topped dentine ridges per millimeter, arranged in an essentially longitudinal pattern, or somewhat diagonally on the lateral epitegum. The ridges tend to be short and slightly irregular, with many intercalations, especially posteriorly. The posterior edge is nearly transverse, probably with a slight median lobe. The postbranchial lobe is well developed and sharply demarked; its dentine ridges terminate against its anterior edge rather than running parallel to it. This specimen

is of interest in suggesting a subdivision of the shield, indicated by shallow grooves on the surface, and by breaks or irregularities in the dentine ridge pattern. The elements are: (*a*) a central disc (fig. 74,

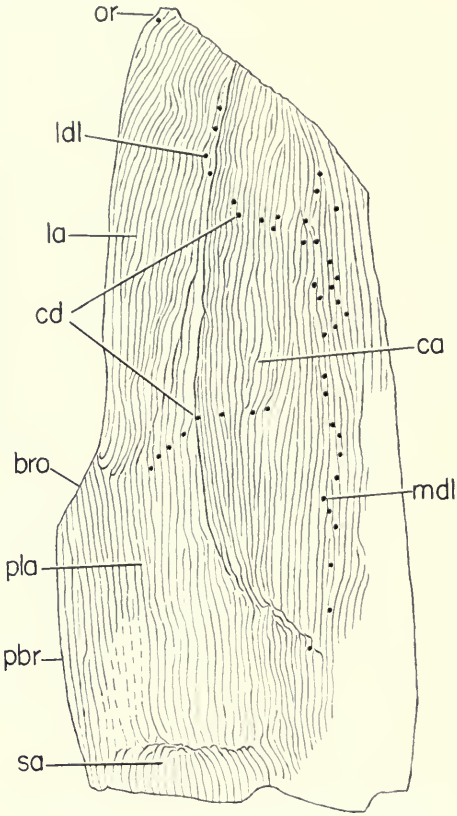

FIG. 74. Cyathaspid indet., part of dorsal shield, viewed dorso-laterally, PU 17384 (× 2); only enough ridges are shown to indicate the pattern. *bro*, branchial notch; *ca*, central area; *cd*, pores of transverse sensory commissures; *la*, lateral area; *ldl*, *mdl*, pores of lateral and medial dorsal sensory canals; *or*, posterior part of orbital notch; *pbr*, postbranchial lobe; *pla*, postero-lateral area; *sa*, scale-like posterior band.

ca); (*b*) a lateral area corresponding to the posterior part of the pteraspid orbital plate (fig. 74, *la*); (*c*) a postero-lateral area, extending between *a* and *b*, bounding *b* posteriorly, and forming the postbranchial lobe (fig. 74, *pla*); and (*d*) a scale-like band along the posterior border (fig. 74, *sa*).

PU 17385 is a dorsal shield lacking much of the central and right antero-lateral region. Its estimated total length is 39 mm. It is distinguished by its exceptional relative breadth; its ratio of width/length is about .77. It has 7½ to 8 dentine ridges per millimeter, and these are sinuously longitudinal postero-medially and denticulate on the rostral epitegum.

There are four undetermined cyathaspid ventral shields. An imperfectly preserved anterior end of a ventral shield, PU 17094, is highly arched and has a narrow concavity on its anterior margin.

FIG. 75. Cyathaspid indet., ventral shield, PU 17387 (× 2).

There are anterior and lateral marginal areas, separated from the central area both by their dentine ridge pattern and by a surface swelling that runs parallel to the edge at a distance of about 3.5 mm. On the anterior marginal area the dentine ridges are parallel to the concave margin anteriorly, but posteriorly they form rows of denticles that converge postero-medially. On the anterior ends of the lateral marginal areas the ridges are parallel to the margin of the shield. These ridges are very fine, about 8 per millimeter. On the central area the ridges are somewhat coarser, averaging about 6 per millimeter and are arranged elliptically. They are broken into short lengths or even into small denticles antero-medially, and include some slightly coarser and higher ridges among the others.

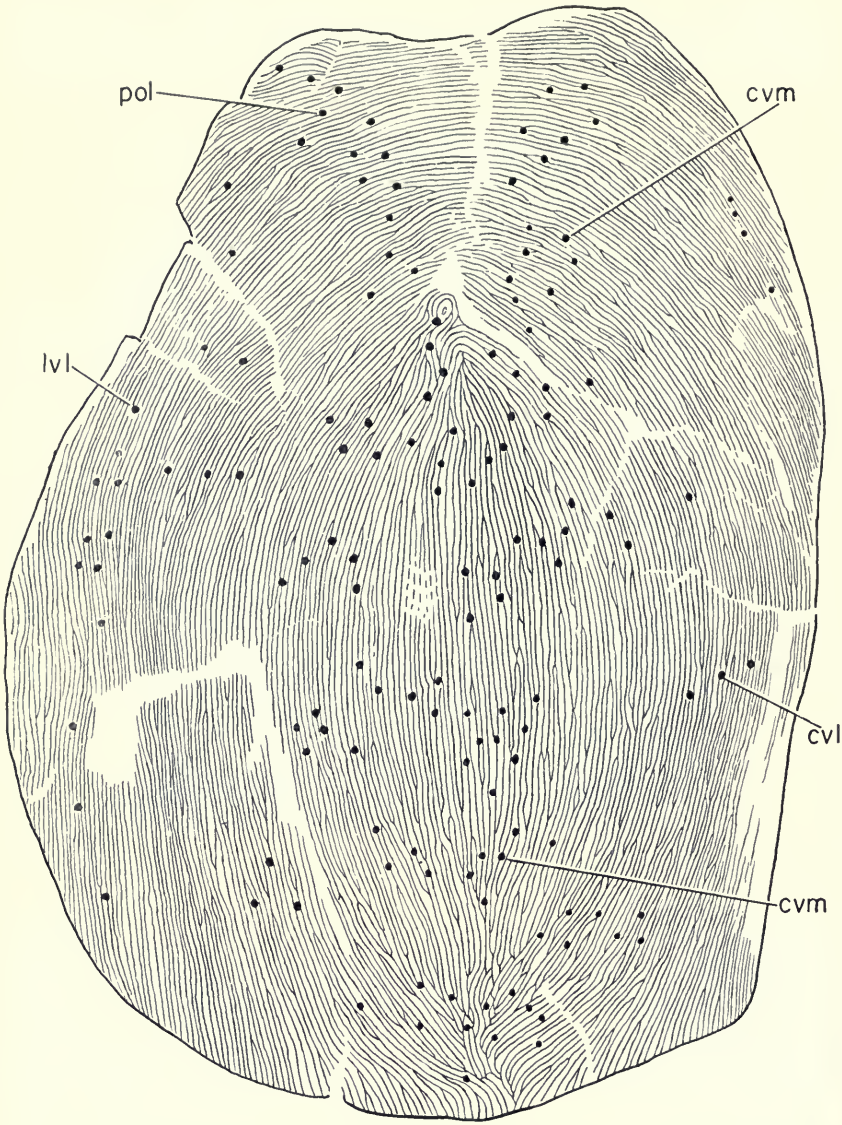

FIG. 76. Cyathaspid indet., ventral shield, PU 17387 (× 4). *cvl, cvm,* pores of lateral and medial ventral transverse commissures; *lvl,* pores of lateral ventral sensory canal; *pol,* pores of postoral canal.

PU 17093 is a ventral shield lacking the posterior edge and much of one side. It was associated with PU 17088, *Dikenaspis yukonensis*, but does not belong to *Dikenaspis*. Its estimated length is 34 mm. The dentine ridges, of which there are about 5 per millimeter, are arranged longitudinally with a slight flaring anteriorly.

PU 17387 (figs. 75, 76) is a ventral shield that is extremely interesting in having a ridge pattern similar to that of Pteraspididae. In the central part the arrangement is elliptical, with the ridges converging toward the midline at either end. The more anterior and lateral ridges are continuous around the central ellipse except at the posterior edge, which they meet at a steep angle. The course of these outer ridges is determined by the ridges medial to them, and the outer ridges are not necessarily parallel to the outer edge of the shield. Such a ridge pattern is typical of Pteraspididae, though it is approached in Cyathaspididae by *Dikenaspis* and *Cyathaspis*. The lateral line pattern, however, is typical of Cyathaspididae. It is indicated by the pores (fig. 76), which are arranged in a series of V's, pointed posteriorly in the midline. These may be identified as the paired postoral canals (fig. 76, *pol*), and six pairs of median ventral transverse commissures (fig. 76, *cvm*). The paired lateral ventral canals (fig. 76, *lvl*), and a few lateral segments of the ventral transverse commissures (fig. 76, *cvl*) are also indicated. Though somewhat crushed, this shield was originally highly vaulted posteriorly. Its dimensions are: length in midline=37.5 mm.; maximum width=26.5 mm. The anterior edge is concave; the posterior edge is gently convex. The dentine ridges are flat-topped, closely spaced, and 5–5½ per millimeter.

PU 17386 is a ventral shield lacking only the most anterior part. Its length is estimated to have been 30 mm. when complete. The posterior end is convex with a broadly rounded median lobe. The dentine ridges are 6–7 per millimeter, or still finer laterally. Their pattern is essentially longitudinal, and the ridges are broken into relatively longer lengths anteriorly and shorter lengths postero-medially. Many short ridges are intercalated. The pores of the lateral line system are relatively large and indicate a canal pattern similar to that of *Poraspis*. There is nothing to exclude this ventral shield from *Poraspis*, but a definite assignment does not seem warranted.

PU 17099 (fig. 77) is identified as a cyathaspid branchial plate. It is complete except for one corner and has a length of 25.0 mm. and a maximum depth of 6.3 mm. Its top and bottom edges are nearly parallel, though it tapers slightly toward each end from its

greatest depth near the middle. One end, probably anterior, is truncated slightly obliquely; the other end is bluntly pointed. The dentine ridges are about 5 per mm., and are arranged mostly longitudinally, although some are diagonal on the half with the truncated

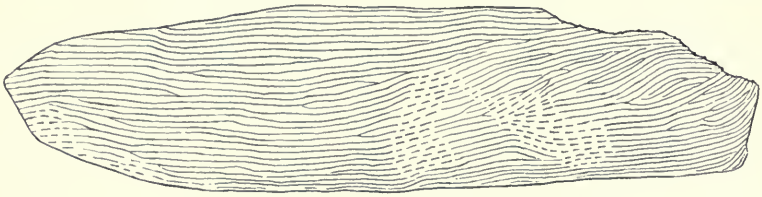

FIG. 77. Cyathaspid indet., branchial plate, PU 17099 (× 4).

end. This resembles the branchial plate of *Archegonaspis* cf. *lindstromi* figured by Heintz (1933, fig. 3), except that there is no branchial notch. It might be the branchial plate of *Vernonaspis bamberi*.

A number of isolated scales are referable to the Cyathaspididae but are not generically identifiable. Most of them are the long dorsolateral scales, and they agree in general with such scales in *Poraspis*, as described by Kiaer and Heintz (1935, pp. 112–116). In detail, however, they show many variations. A number of them have, as is usual in *Poraspis*, several long ridges arranged dorso-ventrally or parallel to the anterior border; commonly some of these ridges curve and pass into the longitudinal, or antero-posteriorly arranged ridges. In other cases the dorso-ventral ridges are separated from the longitudinal ridges by an area of short ridges. In other dorso-lateral scales, the dorso-ventral ridges are absent and the anterior border is denticulate; this condition is also known in *Poraspis*. One scale has an anterior finely denticulate band, then a band of short ridges; the longitudinal ridges are limited to the posterior third of this scale. A few ventro-lateral and caudal scales show nothing remarkable. Two specimens of *Homalaspidella borealis* (PU 17102, 17383), formerly attached to each other, show remains of two articulated tails. Unfortunately, the scales are incompletely and poorly preserved, and their arrangement and structure cannot be determined.

Family TRAQUAIRASPIDIDAE

?Traquairaspis Kiaer 1932

The traquairaspid from the Yukon possibly belongs to a new genus, but the one specimen is not adequate to distinguish it.

FIG. 78. *?Traquairaspis angusta*, type, ventral disc, PU 17388 (× 3/2).

?Traquairaspis angusta, new species

Type.—PU 17388, a ventral disc (figs. 78, 79). This specimen was obtained in two pieces without any contact. They surely belong together, and have been united with the spacing determined approximately by the contour of edges and surfaces.

Diagnosis.—The dimensions of the ventral disc are: estimated length=80–85 mm.; maximum width=35.5 mm. The disc is relatively narrow, with the estimated ratio of width/length=.42–.44.

The smooth central area covers nearly all of the ventral disc, and its ornamented margin is narrow.

Discussion.—The ventral disc of *?Traquairaspis angusta* is longer than those of *T. pococki* and *T. campbelli,* and somewhat shorter than that of *T. symondsi.* It is relatively much narrower than in the other species, in which the ratio of width/length ranges from .58 to .70. The ornamented margin covers only a minor part of the disc of *?T. angusta,* while it is broad in *T. pococki* and *T. symondsi; T. campbelli* is intermediate in this respect.

The anterior edge of the ventral disc is gently rounded. Its lateral edges are slightly concave anteriorly and then are convex, reaching the maximum width just in front of mid-length, and from there tapering gradually posteriorly. The posterior edge is biconvex with a median notch.

The central area is smooth except for pores of the lateral line system, which also occur in *T. campbelli,* and a number of grooves. One pair of irregular grooves (fig. 79, *gr*) extends from the posterior edge forward for two-thirds the length of the disc; these grooves have a number of short median and lateral branches. In the anterior part, a small circular area is marked by a groove, and small areas are separated from the main smooth area by grooves antero-laterally and postero-laterally. These grooves do not appear to be related to the lateral line canals. Their scalloped edges resemble the margins of the smooth area and of the tubercles of the brim. They may be considered as demarcations of separately formed areas of the superficial layer.

The ornamented brim is relatively narrow. Anteriorly it is 2.5–3.5 mm. wide and continues the plane of the adjacent smooth area. Laterally it is 5 mm. or less in width and is turned dorsally at a sharp angle from the smooth area. Posteriorly the brim is absent. On the anterior brim the tubercles are crowded and short, elongate parallel to the margin, and have many prominent side processes. There are no ridges between the tubercles here. Around each antero-lateral corner, these tubercles pass into a band marked by numerous low, fine, close ridges, elongated parallel to the edge; some, but not necessarily all of these ridges are crowned with dentine. A single row of high tubercles extends backward in this band from the antero-lateral corner parallel to the edge of the smooth area; the individual segments are short anteriorly and very long posteriorly; the side processes of these tubercles are relatively short. This combination of high tubercles and low ridges is reminiscent of the ornamentation of *T. pococki* and *T. campbelli.*

The lateral line system is indicated by a number of relatively large pores. A group of pores arranged in a V on the anterior part

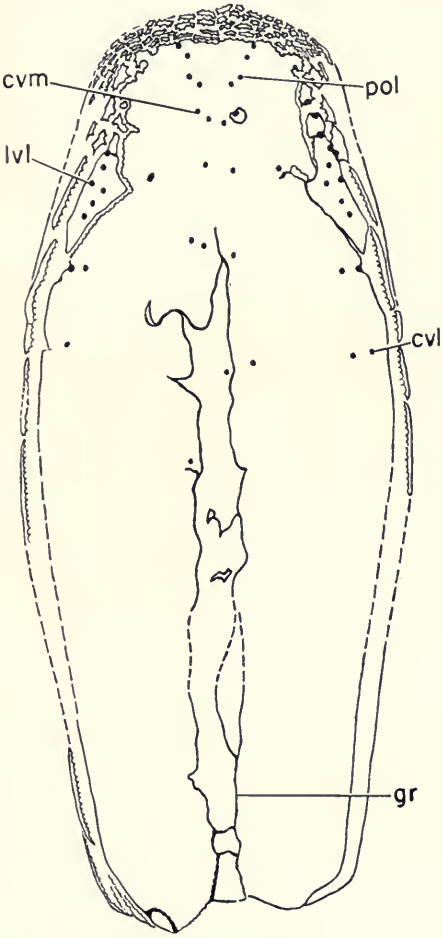

FIG. 79. *?Traquairaspis angusta*, type, ventral disc, PU 17388 (× 3/2). *cvl*, *cvm*, pores of lateral and medial parts of transverse sensory commissures; *gr*, groove in smooth central area of disc; *lvl*, pores of lateral ventral sensory canal; *pol*, pore of postoral canal.

of the smooth area represents the paired postoral canals (fig. 79, *pol*). Behind them are pores of the medial parts of three ventral transverse commissures (fig. 79, *cvm*), and three more posterior pores may indicate the fourth and fifth commissures. Lateral parts of three transverse commissures (fig. 79, *cvl*) are indicated by one or two pores each. Pores piercing the separated areas at the antero-lateral corners of the smooth area indicate the anterior parts of the lateral ventral canals (fig. 79, *lvl*). No pores are to be seen on the posterior part of the disc. The pattern is much as in *T. campbelli* (White, 1946, figs. 36–38).

HETEROSTRACI OF UNDETERMINED FAMILY

In addition to *?Traquairaspis*, there are a number of specimens with coarse ornament which are referred to Heterostraci, but which cannot be related with certainty to previously known families or genera. Based on the ornament, these may be grouped into four types.

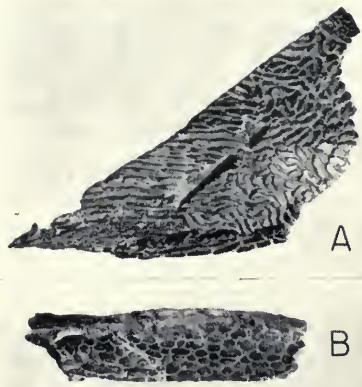

FIG. 80. Heterostraci indet. Type A, marginal plate, PU 17390 (× 1). A, probable dorsal face; B, probable ventral face.

Heterostraci indet., Type A, has tubercles whose margins are crenulated or provided with side processes. These tubercles may be long (to 21 mm.) and slender (.5 mm.), in which case they are widely spaced (figs. 80, A, 81, B); or they may be short and broad (to 1.5 mm.), in which case they are crowded closely together (figs. 80, B, 81, A). All intermediates occur between these tubercle types, and both types may occur on the same specimen (fig. 80). In the spaces between the narrower tubercles there are one to several fine, low ridges, arranged parallel to the tubercle margins (fig. 82, A). Only between the broadest, most closely packed tubercles are these interstitial ridges lacking; elsewhere there may be one to five of them. They are irregular, and adjacent to the tubercles they are usually zigzagged, with side processes at the angulations.

This type of ornament is comparable to that on the lateral brim of the ventral disc of *?Traquairaspis angusta*. It differs in having more closely spaced side processes on the tubercles, and perhaps in the character of the interstitial ridges, which are not well preserved in the type of *?T. angusta*. Three of the specimens (PU 17390–92) are fragments of plates of the lateral margin, and in one, PU 17390 (fig. 80), the plate has two laminae, representing parts of the dorsal

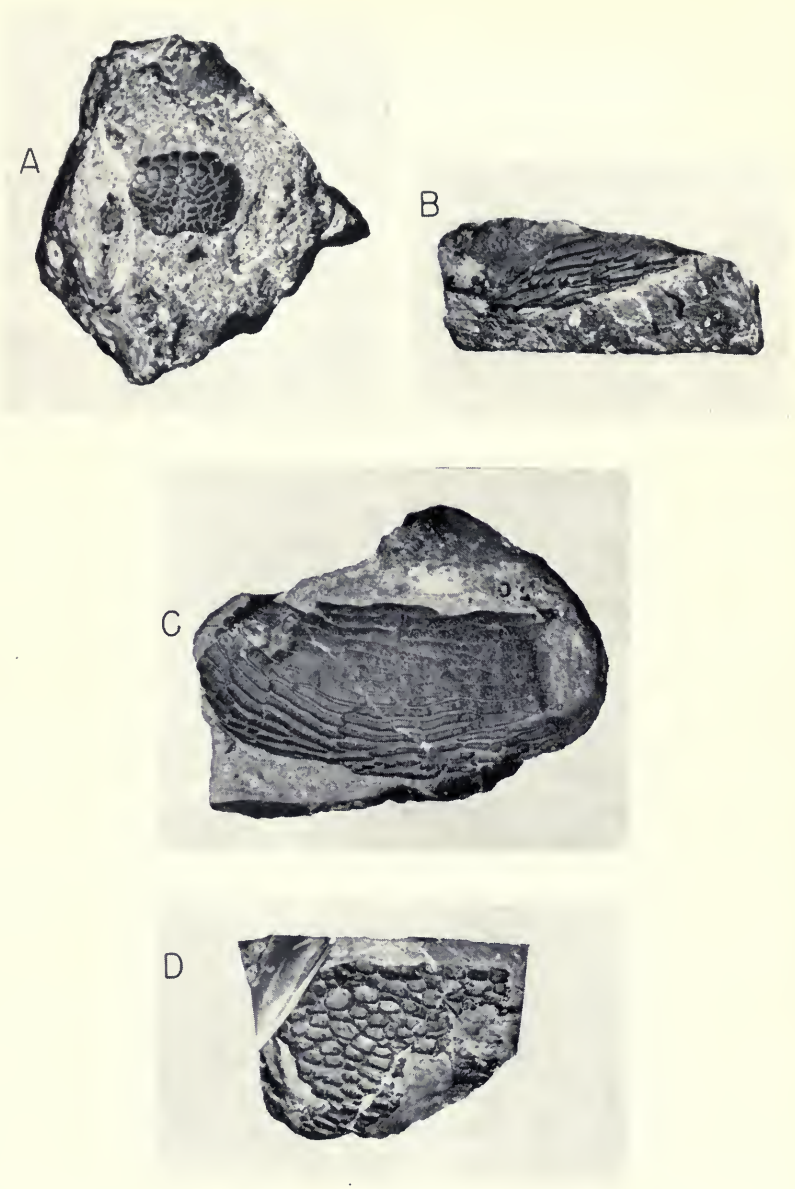

FIG. 81. Heterostraci indet. (× 1). A, Type A, PU 17095; B, Type A, PU 17098; C, Type B, PU 17097; D, Type D, PU 17096.

and ventral shields. The margins of PU 17391 and 17392, and the narrow lamina of PU 17390 have short, broad tubercles, while the rest of the plates have long, narrow, widely spaced tubercles. These plates cannot be identified with any plates of *Traquairaspis*, as restored by White (1946, figs. 40–44). PU 17098 (figs. 81, B, 82, A) is a fragment with long, slender tubercles, and with one row of short, forked tubercles; some of the latter are notched by pores of the lateral line system. PU 17095 (fig. 81, A) is a small, symmetrical, presumably median plate; its tubercles are short and broad, and usually there are interstitial ridges in the interspaces.

Heterostraci indet., Type B, represented by a shield fragment, PU 17097 (fig. 81, C), is possibly a variant of Type A. Near one edge it has long, narrow tubercles, as little as .5 mm. in width, and provided with small side processes. These tubercles are separated by interspaces as wide as 1.2 mm., in which there are as many as 9 fine, low ridges. Toward the other edge of the plate the tubercles become wider and the interspaces narrower, until finally the elongate, flat-topped tubercles are as much as 2 mm. wide, and the interspaces are very fine grooves. Except for its coarseness, the latter type of ornament resembles that of some Cyathaspididae. PU 17100, an incomplete, narrow ridge scale, may belong to this type.

Heterostraci indet., Type C, is represented by a single incomplete plate, PU 17389 (fig. 82, B). Its tubercles are elongate (to 9 mm.) and slender (.3–.7 mm.) and, in contrast to those of the other types, have smooth margins without crenulations or lateral processes. A few of the tubercles are short and forked. The tubercles are separated by interspaces of 1.0–2.5 mm. in which are numerous (4–10) low, simple, relatively straight ridges. Pores of two lateral line canals open between the fine ridges, and in some cases notch the tubercles.

Heterostraci indet., Type D, is typified by PU 17096 (figs. 81, D, 82, C). This fragment is covered for the most part with short, broad, ovoid tubercles, but these grade toward one edge into an ornament of narrow tubercles with very prominent side processes (fig. 82, C), similar to those of *Traquairaspis symondsi* or *T. plana* (Örvig, 1961, figs. 2–3). The spaces between the tubercles completely lack the fine ridges of the other types. Similar tubercles without interstitial ridges are found in the marginal plates of *Cardipeltis* and in the fragment from the Early Devonian of Podolia figured by Örvig (1961, fig. 4) as "gen. et sp., indet." A few scales (PU 17394–95), and a small plate (PU 17393) are also referable to this type.

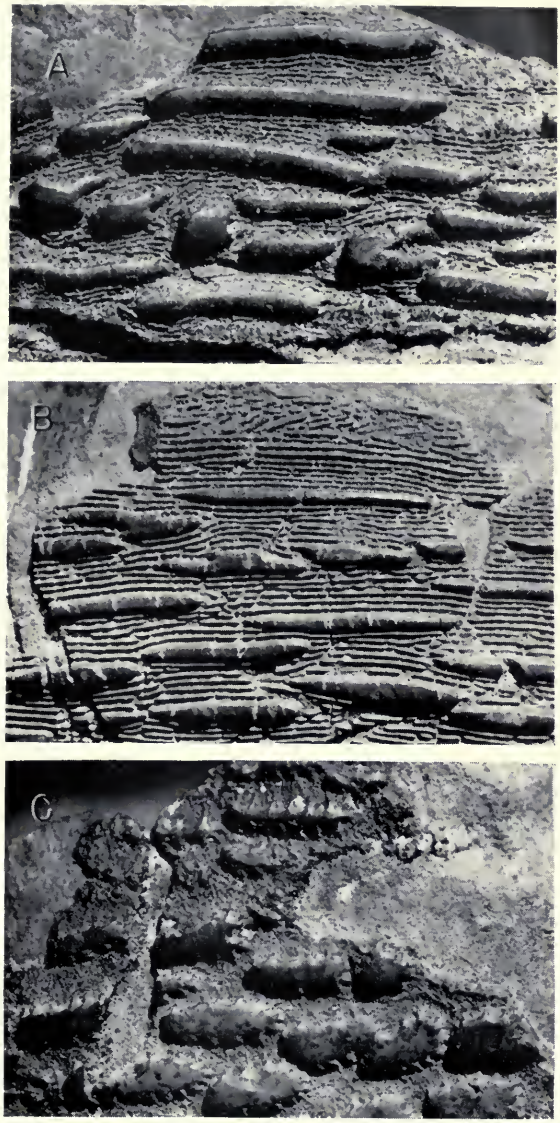

FIG. 82. Heterostraci indet., ornamentation (× 5). A, Type A, PU 17098; B, Type C, PU 17389; C, Type D, PU 17096.

GEOLOGIC AGE

Vernonaspis, the commonest form in the Yukon occurrence, is known otherwise only in the Vernon Shale of New York State, a formation of the Salina Group of the Late Silurian. A similar genus, *Archegonaspis*, occurs in the nearly equivalent Graptolithengestein and the Hemse Group of northern Europe, both belonging to the *Monograptus nilssoni* zone of the Early Ludlow. *Ptomaspis*, in regard to the specialization of its shield, is intermediate between *Tolypelepis* and *Archegonaspis*. The former occurs in the Late Silurian of the Baltic region, and in the Early Wenlockian of the Canadian arctic. *Dikenaspis* is most closely related to *Dinaspidella* and *Irregulareaspis*, both Early Devonian (Gedinnian) genera from Spitsbergen and Podolia. However, it is believed to be more primitive than the Devonian genera. *Ariaspis* is a specialized cyathaspid and, though not nearly related to other known genera, is suggestive of a Devonian rather than Silurian age. *Homalaspidella* is otherwise known only from the Ben Nevis Group of the Red Bay Series of Spitsbergen; the latter is correlated with the Gedinnian. Among the undetermined Cyathaspididae there is a dorsal shield that is clearly specialized in its large size, and a ventral shield specialized in its pteraspid-like ridge pattern; either is suggestive of Early Devonian rather than Silurian age. Traquairaspididae are otherwise known from Downtonian beds at the base of the Devonian in Great Britain, and from strata of equivalent age in Spitsbergen and Germany.

In summary, the vertebrates indicate either a Late Silurian or an Early Devonian age. The invertebrates identified by Lenz (p. 108) suggest an earlier dating. The most significant of them for correlation is the *Monograptus dubius* from beds overlying the vertebrate horizon. This species is a long-lived one in Europe, ranging from the Wenlock (zone 27 of the British section) into the Middle Ludlow (zone 35 or 36). The end of its known range overlaps the suggested vertebrate dating, and so Late Silurian, either Early or Middle Ludlow, may be taken tentatively as the probable age of this fauna, as estimated from the vertebrates. If this is correct it will extend downward the range of *Homalaspidella* and the Traquairaspididae, and suggest earlier specializations in certain Cyathaspididae.

ECOLOGY

Very little information is available upon which to base an ecological interpretation of this occurrence. The vertebrates are de-

scribed as occurring in dolomites that are interbedded with limestones and graptolitic shales. The graptolitic shales are marine, and the dolomites contain, in association with the vertebrates, articulate brachiopods, cryptostomatous bryozoans, crinoids, scolecodonts, and doubtless other invertebrates as yet undetermined. There can be no question as to the marine deposition of these dolomites. It is important to note that the vertebrates are not rare, but abundant and varied, at least in the few small samples from which the present collection was obtained. It seems to be an unavoidable conclusion that these Heterostraci were also marine forms. They are another example of the so-called "Cyathaspidinae–Acanthodii" assemblage which, during the Silurian, was largely or entirely restricted to marine deposits (Denison, 1956, pp. 376–387). The rarity of Heterostraci in most Silurian marine sediments is probably to be explained in large part by their special and restricted habitats at this time. What these habitats were cannot be determined now, but it is possible that, when better known, the present occurrence in the Yukon will give some clue.

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