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CYATHASPID FISHES FROM THE VERNON SHALE OF NEW YORK

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WITH EIGHT PLATES

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No. 6. — *Cyathaspid Fishes from the Vernon Shale of New York*

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Cyathaspid fishes are rare elements in Silurian faunas. Only three occurrences have been previously noted in North America, that of *Diplaspis acadica* Matthew from the Upper Silurian of New Brunswick, of *Palaeaspis americana* and *P. bitruncata* described by Claypole (1885) from the Upper Silurian of Pennsylvania, and of *Cyathaspis wardelli* (Ruedemann) and *C. van ingeni* Bryant from the Shawangunk formation of southeastern New York.

The present occurrence, in the Vernon shale in central New York, although it has yielded only eight identifiable specimens, compares very favorably in preservation and completeness of material with previous American finds. It is regrettable that the nature of the exposures makes it extremely improbable that more material can be obtained, particularly since the presence of several species in the association makes the matching of dorsal and ventral plates an extremely inferential matter.

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OCCURRENCE

The Vernon shale, of the Upper Silurian of New York, overlies the Pittsford shale, and underlies the Camillus shales, which are in turn succeeded by the Bertie waterlime. These formations constitute the Salina group, which is overlaid by higher Silurian limestones, the Waterlime group, consisting of the Cobleskill limestone, the Rondout and Manlius limestones. The Vernon shale, characterized by the presence of red and green beds, has yielded a few sparse faunas, but has come to be considered so proverbially barren that the suggestion has been made that it is, at least in a large part, composed of wind blown loess.

Two previous occurrences of fossils have been reported. The first was a recurrent Pittsford fauna, sparsely distributed in shales of the lower part of the Vernon near Pittsford, New York, from which Ruedemann (1920) reported a fauna of sixteen species. Later Eaton (1924) reported a fauna, from which he described several new species, from Elbridge township, fourteen and one-half miles northwest of Syracuse, New York.

The cyathaspid fish described in the following pages came from a layer of grey shale 1 ft. 9 in. thick, in the middle of the Vernon shale. This layer has been found exposed only in two small streams, tributaries of Oneida Creek, about two miles southeast of Kenwood, New York. The complete section, together with the invertebrate faunas, will be described upon another occasion. It will suffice here to mention that this thin layer has yielded several hundred specimens of invertebrate fossils, including abundant pelecypods (*Pterinea*, *Modiolopsis* and *Nuculites*), abundant but extremely fragmentary eurypterids of the genera *Hughmilleria* and *Pterygotus*, ostracods, several poorly preserved nautiloid cephalopods, including one brevicone and several orthoconic genera, brachiopods representing the genera *Lingula* and *Camarotoechia*, an annelid jaw, and a single large siphonophore (Flower and Wayland-Smith, 1947). The invertebrate elements are very closely allied to those of the underlying Pittsford shale and also to those of the younger Bertie waterlime.

The type specimens described in this paper are deposited in the collections of the Museum of Comparative Zoology at Harvard.

CLASSIFICATION OF CYATHASPID FISHES

The history of the study of the Cyathaspida has been summarized by Kiaer and Heintz (1935). In an earlier posthumous paper edited by Heintz, Kiaer (1932) presented a rather elaborate classification of the group. A generation ago, all dorsal plates of these rare and usually fragmentary fossils, were assigned to the genus *Cyathaspis*. After considerable controversy it came to be recognized that a second genus, *Scaphaspis*, was nothing more than the ventral plate of the same animal. It is a far cry from this to the classification of Kiaer, who recognizes the suborder Cyathaspida as divided into two tribes, the Poraspidei and Cyathaspidei, and further divided into seven families and fourteen genera. Unfortunately, problems of recognition and of the legal availability of some of the names used in Kiaer's work, are raised by the fact that some of the species which are new are only listed, while others also new, are listed and illustrated, but not described. This unfortunately applies to the type species of several of

the genera erected in this work and to the genus *Eoarchegonaspis* Kiaer and Heintz 1932. Under the present International Rules of Zoological Nomenclature, no species or genus described after 1930 shall be considered valid for the purposes of nomenclature and priority unless it is accompanied by either a description showing how it differs from other species or genera, or by a bibliographic reference to such a description, and in the case of a genus, is accompanied by a clear and unequivocal designation of a genotype.

Later work has resulted in the description of few additional genera and species, mainly those of Bryant and Woodward, but has produced marked and confusing changes in nomenclature. Many of the generic names used by Kiaer (1932) were found to be junior homonyms. New names were proposed by Strand (1934), by Whitley (1940), and by White and Moy-Thomas (1940–1941). Whitley, and White and Moy-Thomas unfortunately proposed new names for the same generic group at about the same time. The names of White and Moy-Thomas are more widely known, but those of Whitley clearly have priority and must therefore be used.

Recent trends in classification have been to employ as families the groups which Kiaer recognized as tribes, and to ignore the finer family divisions as employed by Kiaer. This more conservative treatment is a great improvement, for the much finer family groups which Kiaer used involve both serious problems of nomenclature, as well as serious morphological problems in their recognition. Further, critical analysis of the genera indicates that even the use of two families may imply a more distinct division within the Cyathaspida than actually exists-Moy-Thomas (1939) employed the families Palaeaspidae and Cyathaspidae. The use of *Palaeaspis* as the type of a family, is unfortunate as the genus is inadequately known. Romer (1945) used the families Poraspidae and Cyathaspidae, as employed in the present outline, again treating them as two of the five families of the Heterostraci.

The relationships of the Poraspidae and Cyathaspidae, as noted above, are much closer than a casual reading of Kiaer's paper would lead one to believe and, in fact, serious difficulties attend any attempt to draw a clear line between them. But there is no close connection between the cyathaspids on the one hand, and either the pteraspids or the drepanaspids on the other. It seems that it would be better to either recognize the two families as members of the suborder Cyathaspida, or else to suppress the family Poraspidae, and recognize only a single family, the Cyathaspidae.

In an attempt to determine the generic affinities of our material, it has been necessary to analyse the previous work rather closely. A short account of the results is presented here, partly to clarify the

rather intricate nomenclatorial problems, and partly to summarize the present additional morphological information. Particularly relevant to our present problem has been a comparison with the Silurian cyathaspids previously described from America. Of these, the genus *Diplaspis* Matthew proves to be still so poorly known that close comparison is not possible, and its exact position in the modern classification of cyathaspids is extremely dubious. *Palaeaspis* Claypole is still not adequately known, in spite of the work of Bryant (1926). In the same work, Bryant described additional cyathaspids from the Shawangunk formation of southeastern New York as *Cyathaspis wardelli* (Ruedemann) and *C. van ingeni* Bryant. Kiaer has reunited the two species, we think mistakenly, and erected for them the new genus *Eoarchegonaspis,* for which no description is vouchsafed. As shown below, under discussion of the genus, the original suite of specimens of *C. wardelli* consists of inadequate fragments of several cyathaspid plates, representing an indeterminate number of species and certainly including representatives of three different genera. What Bryant described as *C. wardelli* cannot be recognized among Ruedemann's suite of illustrated types. However, in that material there is at least one dorsal shield of *Cyathaspis van ingeni* Bryant. In any case, the genus *Eoarchegonaspis* is a *nomen nudum,* being without a description. None of the fish in the Vernon shale assemblage is conspecific with the Shawangunk materials.

Cyathaspida Kiaer

The Cyathaspida are Heterostraci characterized by single dorsal and ventral plates, and a pair of smaller branchial plates. Additional hard parts consist only of large scales which covered the posterior part of the body, and small lateral plates which are rarely found and are poorly known.

Kiaer divided the Cyathaspida into two "tribes", and the tribes into a number of families. This is unfortunate, as tribes are properly a category beneath families and subfamilies in rank. Romer (1945) in his summary of classification of fossil vertebrates, does not employ the families of Kiaer, which are too finely drawn, but instead employs the "tribes" Poraspidei and Cyathaspidei, as families Poraspidae and Cyathaspidae. These families are grouped with others in the Heterostraci without use of the term Cyathaspida to differentiate them from other members of the order. We are employing the term Cyathaspida here because these forms constitute an easily recognizable group, but appalling difficulties were encountered in trying to differentiate between the Poraspidae and Cyathaspidae. Indeed, our own material

and the present descriptions and illustrations, lead to the conclusion that these families intergrade to such an extent that their differentiation may have very little merit.

The Poraspidae are defined as having the dorsal plate undivided, and a lateral line system which is well developed, and consists usually of continuous series of canals within the dorsal and ventral plates.

The Cyathaspidae are defined as having the dorsal plate differentiated into a central disc, a rostrum, and two lateral plates, but the lateral line system is incomplete or wanting.

Actually, neither the differentiation of the dorsal plate into distinct areas nor the development of the lateral line system serve to divide the Cyathaspida into two distinct families. Impressions of the interior of the dorsal plate of some poraspids show branchial regions fairly well set off from a central disc. In the genera placed in the Cyathaspidae, the distinction is reported as complete in *Traquairaspis*, as poor in *Tolypelepis*, clear externally in *Cyathaspis*, and variable in *Archegonaspis*. It is apparently clear in the invalid genus *Eoarchegonaspis* Kiaer and *Diplaspis* Matthew. This may be more apparent than real, for these genera are to date represented in the literature only by extremely diagrammatic outline drawings. In the extant illustrations of the Cyathaspida there is no evidence of a clear separation of the dorsal plate into four discrete plates; rather the differentiation is produced mainly by the surface pattern. Indeed, one of our most vexing problems in the description of our new material has been the generic position of a specimen which resembled in some respects *Anglaspis* of the Poraspidae and in others *Archegonaspis* of the Cyathaspidae. So close are these two genera, that the decision was finally made on the basis of the texture of the surface pattern rather than on criteria mentioned in previous descriptions of the families and genera. On the other hand, differentiation of the two anterior lateral plates of the dorsal plate, in *Vernonaspis*, is clear on the interior but not on the exterior. Separation of rostral and lateral areas is not indicated in the suite of syntypes of *Cyathaspis wardelli* Ruedemann, the type species of *Eoarchegonaspis*. It is necessary to conclude that the differentiation of the dorsal plate is not a good basis for the recognition of two families in the Cyathaspida.

The lateral line system is no better as a family criterion. It is a feature difficult to demonstrate, frequently impossible to detect unless there is abundant and well preserved material. It can be seen best in specimens which have been exfoliated, or where the canals are so large that they have been accentuated as depressions on specimens which have been subjected to the slight crushing which accompanies compaction of the sediments. It must be remembered that the Poraspidae

from which the lateral lines have been described, are known from the only source of abundant and well preserved cyathaspids, the Spitzbergen material. Genera assigned to the Cyathaspidae, for which in general no lateral lines are reported at all, are known from associations yielding fewer individuals, and apparently, individuals in a much poorer state of preservation. There are certainly grounds for regarding with suspicion the assumption that the lateral line system is wanting in the majority of the genera of the Cyathaspidae simply because it has not been reported. Its value as a family character is therefore doubtful at the best. It is true that in some poraspids — those genera grouped currently under the Poraspidae — the lateral line system forms a complete and sometimes an elaborate series of canals. There are also others in which the canals in the inner layers of the plates form an incomplete and disconnected system of tubes. One such specimen (Pl. 3, fig. 6; Pl. 7; Pl. 8, fig. 3; text fig. 2), consists of a ventral plate. The interior is smooth, but shows a faint pattern of grooves. Upon removing the inner surface by etching (Pl. 7), a disconnected series of tubes of the lateral line system was found. It should be noted that this form, assigned tentatively to *Archegonaspis* of the Cyathaspidae, has the discontinuous canals which are said to characterize that family. However, in *Vernonaspis* (Pl. 1; Pl. 2, fig. 8), there is apparent a series of grooves similar in aspect to a lateral line system. Closer study shows that they are so askew in relation to the symmetry of the organism, that they are more probably wrinkles. Further, if this should prove to be a lateral line system, it would be one comparable with that of the Poraspidae, but this genus, with its distinct rostrum and two anterior lateral plates, is in other respects closer to the Cyathaspidae.

It is necessary to conclude that the boundary between the Poraspidae and Cyathaspidae is, in the present state of our knowledge, too tenuous to be recognized.

The problems of morphology, taxonomic recognition of genera, and their validity from a purely legalistic and nomenclatorial viewpoint, present such intricate problems, that they may be best summarized by a discussion of the individual generic groups. These are arranged, following the system of Kiaer (1932), with the addition of a few subsequently described genera.

Poraspis

Poraspis Kiaer 1932 (= *Holaspis* Lankester 1873, not Gray 1863) is based upon *Holaspis sericea* Lankester. Dorsal plate entire, surface with essentially longitudinal markings of dentin ridges. Lateral line

system represented externally by rows of pores, and well developed. Eye notches clear, branchial and postbranchial regions separated by a faint lateral constriction; posterior margin extended into a blunt median process. Ventral plate truncate in front, similar to dorsal plate in longitudinal markings. Lateral line system less well developed, with two main lateral branches. The genus is best known from the beautiful series of species from Spitzbergen described and admirably illustrated by Kiaer and Heintz (1935). Eleven species are listed by Kiaer (1932) including those later described by Kiaer and Heintz (1935).

Internal molds of the dorsal plate of *Poraspis* are quite similar to those of other genera, but *Poraspis* shows the following distinctive features: the first two pairs of branchial impressions are well anterior to the semicircular canals and prominent, instead of faint; lateral areas are distinct and bear lateral branchial impressions. In general, the semicircular canals are more prominent than the pineal body.

Homalaspidella

Homalaspidella Strand 1934 (= *Homalaspis* Kiaer 1932, not Reinhardt 1860; = *Homaspis* Kiaer and Heintz 1935, not Foerster 1868 or Skuse 1888) contains only the type species, *H. nitida* (Kiaer). It is differentiated from *Poraspis* by the polished surface and the very narrow grooves separating the dentin ridges. The lateral line system of the venter is more advanced, showing anterior median lateral commissures as well as the marginal lateral commissures.

These two genera are closely allied, but do not seem distinct enough from the following forms, particularly *Anglaspis*, to justify their separation into a family by themselves as was done by Kiaer (1932).

Americaspis

Whitley (1940) proposed the name *Americaspis* to replace *Palaeaspis* Claypole 1885, not Gray. Claypole proposed this generic name for two species from the Upper Silurian of Pennsylvania, *P. americana* and *P. bitruncata*, the former being the genotype. He later stated (1892) that he considered *P. bitruncata* to represent a ventral plate of *P. americana*. His descriptions are accompanied by drawings, giving for *P. americana* the shape of the plate and something of its surface pattern but only the outline of *P. bitruncata*.

Bryant (1926) restudied the species on the basis of material in the Princeton University collections, but without having access to the type specimens. He re-illustrated the species with exceptionally poor photographs, presented revised descriptions, and dismissed with little com-

ment Claypole's suggestion that *P. bitruncata* was the ventral plate of *P. americana*. It is unfortunately quite evident that what Bryant called *P. bitruncata* does not agree at all closely with Claypole's original description or outline drawing of that species, but was almost certainly the dorsal plate of quite another form. Indeed, Claypole's original drawing of *P. bitruncata* quite evidently does have the form of a ventral and not a dorsal plate, and is quite similar in shape to the specimen here described and illustrated as the ventral plate of *Vernonaspis leonardi* (Pl. 2, figs. 6–7).

Unfortunately, an effort to locate the Claypole types proved fruitless. This material was deposited in the collections of Buchtell College, Akron, Ohio, where Dr. Claypole taught from 1884 to 1897. The building which housed these collections was destroyed by fire in 1899, and there is little doubt that the types were destroyed at that time. Dr. Walter C. Kraatz assures me that the material is not in the collections of the University of Akron, which houses the extant records of Buchtell College; the collections were apparently completely destroyed.

Kiaer (1932) treats this genus under the name *Palaeaspis*, and apparently bases his conclusions upon Bryant's redescriptions of the two species. He considers that *P. americana* should be united with his genus *Dinaspis*, and *P. bitruncata* with the genus *Poraspis*, accepting both as dorsal shields. He then calmly proceeds to erect for it the family Palaeaspidae.

Actually, so little is known of the two species which constitute the genus *Americaspis* (= *Palaeaspis* Claypole) that restudy is necessary if the genus is to be considered in relation to the present classification of cyathaspid fishes. In view of the destruction of the type material, careful restudy of the problem is required to determine whether it will be possible to re-establish these species and the genus, on the basis of neotype material. Otherwise it will be necessary to admit that *P. americana* and *P. bitruncata* cannot be recognized with certainty. Therefore the genus *Americaspis* (= *Palaeaspis*) is regarded as valid from the nomenclatorial point of view, but one which is so inadequately known that no species can be referred to it. Even its type species cannot be recognized. Judging from the association of the Vernon shale, and also those in the Shawangunk and Longwood formations of southeastern New York, it will be remarkable if only one genus is present in the association of the Upper Silurian shales of Pennsylvania, which yielded the original material of *Palaeaspis*, as well as all subsequent specimens attributed to the genus and its two species.

Dinaspidella Strand

Dinaspidella Strand 1934 was proposed to replace *Dinaspis* Kiaer 1932, not Leonardi 1911. The generic group may be a valid one, and it is therefore discussed here. However, both of the species which Kiaer places in it are *nomina nuda*, since neither has been described. One is only listed; the other, the type species of the genus, is listed and illustrated but not described. In this and in the following genus the ventral plate is five-sided, broadly truncate in front, widest near the posterior margin, which is produced behind into a broad blunt point. In *Dinaspidella* two pairs of longitudinal commissures mark the lateral line system of the dorsal plate.

Irregularaspis Zych

Irregularaspis Zych was described only in Polish, which did not help in its general recognition in the least. White and Moy-Thomas (1940) state that it is the same genus as *Dictyaspis* Kiaer 1932. *Dictyaspis* is another genus which Kiaer described without any valid species. He refers to it three species, again illustrating but not describing the genotype. The genus is characterized by a ventral plate similar in form to that of the preceding genus. On both the dorsal and ventral plates the lateral line system is enlarged into a complex reticular network, quite unlike that of any other cyathaspid.

It should be noted that the family Dinaspidae of Kiaer 1932, erected for *Dinaspis* and *Dictyaspis*, is not legally available since *Dinaspis* rests upon a species which is a *nomen nudum*. In any case, since *Dinaspis* is a junior homonym, a new family name would have to be proposed if there is any point in doing so. While the striking similarity in the shape of the ventral plates suggests a close relationship between these genera, it does not seem that a group embracing them should have family rank.

Anglaspis Jaekel

This genus is defined for the first time by Kiaer, who also erects a family, Anglaspidae, for it. This does not seem necessary. *Anglaspis*, based upon *Cyathaspis mccullough*i Woodward, has been more extensively restudied and re-illustrated by Wills (1935). Kiaer considers as one of the significant features of this genus the fact that the dorsal plate is relatively flat, the ventral plate very strongly arched. The lateral line system is very similar to that of *Poraspis*, with two pairs of longitudinal commissures in the dorsal plate, two series of short

transverse pairs of lines on the venter, and a pair of longitudinal commissures at the extreme sides. Dentin ridges are well defined, prominent, in the main, forming a longitudinal pattern. An anterior triangular area is a conspicuous feature, embracing the rostral area and terminating in a point just behind the pineal body. The margins of this area correspond to a part of the lateral commissures of the lateral line system. In a part of this area a faint transverse line differentiates the rostrum on the exterior, and laterally the lateral line system is again responsible for differentiation of two lateral areas from a central disc. In this respect, the genus *Anglaspis* approaches the Cyathaspidae to such an extent that it might as well be considered a member of that family (= tribe Cyathaspidei as used by Kiaer) instead of the Poraspidae (= Poraspidei of Kiaer). The shape of the dorsal shield is somewhat varied, but the eye notches are developed, the sides are more convex than in *Poraspis*, and the branchial and postbranchial regions more poorly differentiated. The posterior margin is pointed at an angle sharp enough that the lateral angles at its sides are obtuse and sometimes obscure. Impressions of the interior of the dorsal plate resemble those of *Poraspis*, but the pineal body is more prominent, the mesocephalon more obscure; the anterior branchial grooves are more obscure, the anterior portion more transverse, and the nasal pits more pronounced. The ventral plate is quite similar to that of *Poraspis*; all species show much finer texture in the surface markings than does *Poraspis*. It should be added that the branchial plates are well known as are the posterior body scales, on the basis of which Kiaer (1932) has reconstructed the entire animal. In addition to the genotype, Kiaer lists four new species and one variety, which have not yet been described.

Ctenaspis Kiaer 1930

This genus is set apart by its striking form and ornament. Anterior part of dorsal shield transverse, sides rounded, widest near posterior margin, which is pointed behind, and joins the convex sides without a definite angle; main part of shield pustulose, sides with definite spines at the margins. Ventral shield more sharply transverse in front, posterior margin somewhat more distinct from sides. Lateral line system well developed, somewhat more advanced than in *Poraspis*. Two species from Spitzbergen, *C. dentata* and *C. cancellata* are all that are known. The former is the genotype. Kiaer (1930) erected a family for the reception of this genus alone.

Cyathaspis Lankester

The genus *Cyathaspis*, which formerly embraced all cyathaspid fish, is now considered to be confined to the type species, *C. banksi* Huxley and Salter. Dorsal shield a broad oval, longer than wide, narrowly rounded in front, and narrowing also behind; without a clear boundary between the lateral and posterior margins. Main part of plate with dentin ridges forming a concentric pattern, in which a prominent feature is a depression separating the rostral and lateral areas from the central disc; the separation of the rostrum from the lateral plates is more obscure. A low narrow raised ridge occurs on the posterior part of the dorsal shield. The ventral shield, originally described as *Scaphaspis truncatus* Lankester, was the center of some controversy before its identity with *C. banksi* was generally admitted (see Kiaer and Heintz, 1935, pp. 32–33); and as stated by Woodward (1891, p. 172), it is not at all certain that all of the ventral shields placed under this name belong to the same species. Kiaer (1932, pl. 8) has presented beautiful illustrations of dorsal and ventral shields. Differences in the character of the ornament are shown here that remind one of Woodward's statement, but may be due to different conditions of preservation, for the dorsal shield appears to have the internal features impressed on the exterior. Nothing is known of the lateral line system.

Archegonaspis Jaekel

This genus, proposed by Jaekel (1927) without any very clear diagnosis, is based upon *Cyathaspis integer* (Kunth, 1872). It is better known from Kiaer's (1932) definition. Dorsal plate with rostral and lateral areas well differentiated on the basis of the surface pattern; dentin ridges on rostrum transverse, arranged in two coalesced whorls, one centered near each side. As in *Anglaspis*, the rostrum forms part of a triangular area of the surface pattern which terminates in a point just behind the pineal body. Though nothing is stated concerning this area, its boundaries are in all probability a part of the lateral line system, which is not otherwise evident from extant descriptions or illustrations. Additional pores are present on the dorsal surface, suggesting a more extensive lateral line system. Ventral plate sharply truncate in front, broadest near posterior margin which is convex, apparently not greatly produced, and with only a short production of the center into a point, or else transverse. The posterior margin of the dorsal plate is faintly convex, but nearly transverse, and not pointed. Kiaer (1932) lists four species, all valid, except that he fails

to state on what basis he erects a species *A. lindstrømi* for the specimen which Lindstrøm (1895) assigned to *Cyathaspis? schmidti*. This is, however, probably the best known of the species, from the illustrations of Lindstrøm and Kiaer. This species is from the Upper Silurian of Skaane, Sweden. The other four are from erratic blocks in northern Germany.

The interior of the dorsal shield presents no features by which it can be separated with certainty from *Anglaspis*, other than the more transverse condition of the posterior margin. Indeed, the genera are quite similar. Kunth's (1872) illustrations of the type species indicate that, as in *Anglaspis*, the ventral shield is much more strongly arched than the dorsal shield; Kiaer states that the body scales are imperfectly known but also show a similarity with *Anglaspis* as far as can be told. These genera, then, appear to be separated mainly on matters of degree; in *Anglaspis* the ribbing of the surface is coarser; the posterior margin is more produced, the lateral line system is better developed, or perhaps only better observed, and the rostral and lateral areas are less distinctly set off from the central shield. One could wish for clearer differences.

Eoarchegonaspis Kiaer 1932

Original description:

"This new genus is established for the two forms known from America and described under the names of *Cyathaspis wardelli* Bryant and *Cyathaspis van ingeni* Bryant.

"The present writer regards these two forms as representatives of the *angusta* and *lata* forms, and therefore proposes to retain only the name *Eoarchegonaspis wardelli* Bryant. After the descriptions of Bryant it must be regarded as being closely related to the *Cyathaspis* and *Archegonaspis*, but it shows some features which make it necessary to establish a new genus for it. All the material of this form is known from the beds of Red shale in the part of the Yerguard Quarzit, Orange County, N. Y. These beds probably belong to the Medina formation."

This genus, happily, need not be recognized under the International Rules of Zoological Nomenclature. Kiaer states that in his opinion the genus is different, but does not say what the features are which impelled him to erect this new genus.

There are several minor errors in this description. The type species is to be attributed not to Bryant, but to Ruedemann, who described it as a species of *Anatifopsis* Barrande, a genus supposedly belonging to the cirripedes.

The material came from a formation proposed by Van Ingen, the Guymard quartzite, of Orange County, New York. Today this formation name is not generally used, and these beds are included in the Shawangunk conglomerate which grades upward into the Longwood shale.

These beds have been considered by many to be of Medina age, Lower Silurian, and therefore older than the other American Silurian cyathaspids. The supposedly greater age may have been at least a strong influencing factor in impelling Kiaer to erect a new genus for this material. The greater age of these beds is not, however, proved. The Medina age determination rests mainly upon the presence in the Shawangunk formation of the trail *Arthrophycus*, which is, to be sure, the abundant and conspicuous feature of the Medina sandstone in western New York, but is hardly an adequate or a reliable criterion for age determination. Overlying the Shawangunk and the almost equally barren Longwood shales, are fossiliferous beds of upper Cayugan age, the equivalent of the Cobleskill limestone, and it is therefore possible for these clastic beds to be as young as the Salina, lower Cayugan. It has been suggested that the Shawangunk may be Clinton rather than Medina in age, but there is no real evidence to oppose the view of Clarke (1907) or Hartnagel (1907) that the entire sequence may be no older than the base of the Salina group. If so, the Shawangunk fish are not materially older than those known from the Upper Silurian of Pennsylvania.

In the hope of clearing up the difficulties surrounding the recognition of *Eoarchegonaspis* and its two species, or two forms according to Kiaer, the original types of *Anatifopsis wardelli* Ruedemann and supplementary material from among which they were selected, were examined. It indicates, in brief, that these forms are cyathaspid fish, but too fragmentary for definite specific recognition. There are obviously several species and even several genera in the suite of type specimens. Further, among Ruedemann's type material there are some dorsal shields which are similar to what Bryant called *Cyathaspis van ingeni*, but not a single specimen which can be identified with what Bryant called *Cyathaspis wardelli*.

The type specimens are described briefly as follows:

1. New York State Museum, no. 9612. A strongly convex plate, sides subparallel, the whole rather strongly curved from one side to the other, surface with rather coarse longitudinal lineation, one end bluntly pointed, the other obviously incomplete. This is probably an incomplete ventral shield, but it might be also a part of a rather large branchial plate. Its generic position cannot be determined in relation to the present rather exacting classification.

2. N. Y. State Museum no. 9613. A small elongate plate, slightly curved and longitudinally striate. One end is drawn to a blunt oblique point; the other is broken. This is certainly a branchial plate.

3. N. Y. State Museum no. 9614. An incomplete plate, rounded at the complete end, and asymmetrical; ridges are mainly longitudinal, but concentric around the rounded border. This is obviously one end of a branchial plate.

4. N. Y. State Museum no. 9615. This is the anterior end of a plate, showing the ridges centering about two anterior lateral areas, the front transverse, truncate, but rather obscure. This is, by its shape and surface markings, a ventral plate similar to those known in *Anglaspis* and *Archegonaspis*. The test is remarkably thick on this specimen in comparison to its size.

5. N. Y. State Museum no. 9616 is the impression of the interior of a ventral plate, truncate in front, strongly produced behind, and suggestive of the (invalid) genus *Dinaspidella* and also to some extent, *Irregularaspis*. Unlike most of the other ventral plates, it is extremely flat.

6. N. Y. State Museum no. 9617 (Pl. 3, fig. 7). is a crushed dorsal plate, preserving the anterior end. The front is bluntly pointed; there are good eye notches. The extreme anterior part of the head has a remarkably thick shield, and shows a smooth surface. There is no clear separation of rostral and lateral plates. Ridges, which appear behind the anterior margin, are extremely fine and faint, and quite closely spaced. This appears to be quite similar to the *Cyathaspis van ingeni* of Bryant (1926).

7. N. Y. State Museum no. 9618. (Pl. 3, fig. 1.) A slender curved plate, with a definite ridge on one side, fractured transversely at several points, with longitudinal markings. This is quite plainly the narrow posterior end of a branchial plate.

8. N. Y. State Museum no. 9619 is a broader triangular plate, comparable in form, but not in surface marking to the unidentified triangular plate figured and described here from the Vernon shale.

9. N. Y. State Museum no. 9620. A plate, strongly curved from one side to the other, incompletely exposed, sides subparallel, very thin, with fine linear markings.

10. N. Y. State Museum no. 9621. A strongly convex plate incompletely exposed, of somewhat oval outline, suggesting the strongly convex ventral shields of *Archegonaspis* and *Anglaspis*. No. 9615 may be a smaller conspecific individual.

11. N. Y. State Museum no. 9622. A small piece of a ventral or dorsal plate, weathered, showing the dentin and cancellous layers

with typical cyathaspid structure. It is too poorly preserved for any attempt at generic or specific determination.

12. N. Y. State Museum no. 9623 is the fragmentary impression of the outer surface of a ventral or dorsal plate, showing in addition to the linear markings faint pustules, smaller than those of *Tolypelepis* and *Traquairaspis*, and not closely comparable to those of *Vernonaspis*.

A good drawerful of material has failed to yield any specimens from the original locality that are materially better, but does serve to indicate more strongly that several genera are present. There are, among such specimens, some with broad flat dentin ridges separated by narrow grooves, suggestive, some of *Poraspis* and *Homalaspidella*, others of *Anglaspis*.

None of this material contains anything at all similar to the form which Bryant called *Cyathaspis wardelli*. One such specimen was found (Pl. 2, fig. 4,), but it is from another collection, from the red Longwood shales which lie above the Shawangunk conglomerate. This is the anterior end of a broadly rounded plate, with very faint obscure eye notches. The surface bears dentin ridges which are irregularly arranged, tending to form small whorls over the anterior portion, and more linear, but still irregular and anastomosing, farther back. The pineal body is indistinct, there is no clear separation of the rostrum from the central disc, but there is some indication of a distinction of the lateral plates on the basis of surface irregularities, but this may be false because the whole surface pattern is so irregular, and quite probably variable from one specimen to another. The surface is folded into small wrinkles, a condition which was plainly not original.

This form poses quite another problem. It is quite similar to what Bryant figured as *Palaeaspis americana* (1926, Pl. 1, fig. 1) as well as to his *Cyathaspis wardelli* (his Pl. 4, fig. 1,) but quite unlike a somewhat narrower specimen with more prominent orbital notches, figured by him on Plate 2, figure 6, as *Cyathaspis wardelli*. Again, it appears similar in shape to the internal impressions of the dorsal plate which Bryant figured as *C. wardelli* on his Plate 2, figure 6, and Plate 3, figure 1.

It is essential that a lectotype be designated for *Archegonaspis wardelli*. If a recognizable dorsal plate is chosen from among the suite of type specimens it will have to be a specimen which is conspecific with *Cyathaspis van ingeni* of Bryant. In any case, at least one new name, and possibly two, will be needed for the *C. wardelli* of Bryant, 1926. A more radical step will at least reduce these name changes by one, and eliminate from all possible revival the undefined genus *Eoarchegonaspis*. This can be done by designating instead of a recognizable plate an unrecognizable fragment as the lectotype of

Anatifopsis wardelli Ruedemann. I therefore designate as the lectoholotype of this species New York State Museum no. 9613, which I have illustrated on Plate 2, figure 5. This will at least leave *C. van ingeni* Bryant as based upon much better type specimens than would be the case otherwise, and will require new names only for the material which Bryant called *Cyathaspis wardelli*. It is extremely dubious whether these forms are distinct generically from what has been called *Palaeaspis*, but as noted in the discussion of that genus, restudy of the original materials is impossible, and *Palaeaspis* and its two species may be completely unrecognizable. Any revision will at least require the re-establishing of the type species on neotype material. I propose no new name, specific or generic, for the form which was the *C. wardelli* of Bryant, being of the opinion that such proposals should rest upon better preserved and a larger suite of materials than are now available.

Tolypelepis Pander

Tolypelepis Pander has priority over *Tolypaspis* Schmidt; the former name was employed first for an isolated scale; *Tolypaspis* was proposed for an essentially complete dorsal shield. Kiaer employs Schmidt's generic name and erects the family Tolypaspidae. Dorsal shield oval in outline, very much as in *Cyathaspis*, posterior margin not adequately known. The separation of the rostral and lateral areas is reminiscent of that of *Archegonaspis*. The dorsal surface is given a distinctive appearance by elongate wart-like tubercles, or scale-like ridges. Kiaer states that these structures are marked by a broad median ridge and finer lateral ridges. Actually, from his photograph, each one of these protuberances is broad enough that its elevated portion consists of a central dentin ridge and two lateral ridges, which usually continue beyond these elevated areas, though the surface is quite irregular in this respect. The protuberances usually bear pores, frequently two or more pores to one protuberance. On this basis, something of the lateral line system can be reconstructed. One pair of commissures passes from the margin of the head in front of the eyes obliquely toward a point behind the pineal body, but does not join. The pattern of the remaining pores is less clear, but from what can be seen, there is a lateral line system here not strikingly different from that of *Poraspis*. The elongate wart-like ridges are quite evidently not all equipped with pores, and are not the direct result of the development of a lateral line system. Rather they are the effect produced by the breaking up of such longitudinal ridges, as are present in *Cyathaspis*, into individual elongate units. The only species known is the genotype, *T. undulata* Pander, from the upper Ludlow of Oesel, and possibly present also in the Ludlow of England.

Diplaspis Matthew

This genus is known only from the genotype, *Diplaspis acadica* Matthew, 1886. The description is accompanied by an outline drawing showing three plates in addition to a central disc. Although Matthew presents a rather detailed description, the exceedingly diagrammatic illustrations leave some doubt as to what the characters of this genus really are, particularly in view of the fact that diagrams of related forms have been found to exaggerate the distinctness of rostral and lateral plates. Kiaer (1932, p. 25) makes a new family for this form, on which, we gather, he is no better informed than we are: "It differs from all other previously known forms, and must therefore be regarded as a representative of a new family. As the author could not study the original specimen, he refers to Matthew's original description."

Traquairaspis Kiaer

Kiaer based this genus upon *Cyathaspis campbelli* Traquair, a species which had been described but not previously illustrated. Kiaer figures a ventral plate and two scales. Kiaer (1932, pp. 25–26) described the genus as follows: "Middle size *Cyathaspidei* with a complete clefting of the dorsal shield into the different parts (rostral, lateral, and the central disc). The anterior part of the lateral plates probably divided as a separate, small supra-orbital plate.

"The central disc roundish in the posterior part without any median keel or spine. Pineal area indistinctly limited. Traces of the pineal organ cannot be seen. The body scales small, probably in more rows than in *Poraspis*.

"The sculpture of the plates with fine, distinct *Psammosteus*-like ridges, which usually are sharply divided into short portions. On the central disc of the dorsal shield the ribs are more irregularly arranged than on the ventral shield. The latter has a well-marked median keel, and the ribs form an elliptical septum with very fine ribs between the gross ones.

"On the lateral and branchial plates a clear median keel with a strong ridge is developed. On both sides of the latter, fine ridges, regularly longitudinally arranged, are placed.

"This genus is represented only by one specimen, *Traquairaspis cambelli* [sic] Traq. The specimen was found by Professor Cambell [sic] in the Downtonian series in Stonehaven area, Scotland."

In the last paragraphs obviously, the word "specimen" is a misprint for "species." Traquair died shortly after publishing a short descrip-

tion of this species without illustrations. Kiaer (1932) has presented beautiful illustrations of a ventral plate and two scales, but the dorsal plate, which supplies the most crucial generic characters remains unillustrated. The longitudinal ridges on the surface are broken, and suggest the longitudinal ridges of a *Cyathaspis* more clearly than do the ridges in *Tolypelepis*. Pores have not been observed.

Corvaspis Woodward 1934

The genus *Corvaspis* is based upon a single species, *Corvaspis kingi* Woodward 1934, which is known only from a ventral plate. The plate is strongly concave in front, more deeply so than in any other known cyathaspid. The sides of the ventral shield are extremely tuberculate. Dentin ridges are linear except on the sides where they are broken up into tubercles, but are crossed by an irregular network of fine grooves, which is faintly reminiscent of the condition of the lateral line system portrayed by Kiaer (1932) for *Irregularaspis*, under the name of *Dictyaspis*. However, that these ridges are not the lateral linesystem, is shown clearly by the fact that they obviously have nothin g to do with the pores. A similar tuberculated border is unknown in other cyathaspids, although it is approached, though not closely, in the anterior margin of the ventral plate of *Archegonaspis lindstrømi* Kiaer, which was illustrated by Lindstrøm as *Cyathaspis schmidti*.

The emarginate anterior border of *Archegonaspis drummondi* approaches the form of *Corvaspis*, but does not attain it. This species lacks the complex network of *Corvaspis*. It should be noted that without the dorsal plate, it is manifestly impossible to tell whether *Corvaspis* should be assigned to the family Poraspidae or to the Cyathaspidae.

Two Devonian genera have been assigned to the Cyathaspida, which will only be mentioned. *Cyrtaspidicthys* Whitley (1940) antedates by a month *Eucyrtaspis* White and Moy-Thomas. The name replaces *Cyrtaspis* Bryant 1932, not Fischer 1853. Likewise, *Allocryptaspis* Whitley precedes *Bryantaspis* White and Moy-Thomas, proposed to replace *Cryptaspis* Bryant 1934.

DESCRIPTION OF THE VERNON SHALE CYATHASPIDS

As noted in the introduction, the cyathaspids of the Vernon shale consist of only eight good specimens. Considerable vexation has attended attempts to match dorsal and ventral plates, as well as plates showing the outer and inner surfaces. The species are, as a consequence, based upon dorsal shields showing the external features,

and the reference of ventral shields or dorsal interiors has been necessarily somewhat inferential. As a consequence, it has seemed wisest to discuss each of these plates separately, leaving as tentative the specific identification of the ventral shields as well as one beautiful dorsal interior. The material may be summarized as follows:

1. A fine dorsal shield, the holotype of *Vernonaspis allenae*.
2. A much smaller dorsal plate, incomplete, but showing a fine impression of the exterior of the crucial anterior end. This is the holotype of *Vernonaspis leonardi*.
3. A fine large dorsal plate, exposing only the inner surface and the impression of the interior. This is assigned tentatively to *V. leonardi*.
4. An essentially complete internal impression of a ventral shield, together with the impression of the exterior of the posterior portion. On the basis of form and surface this is assigned tentatively to the same species.
5. A fine internal impression of a dorsal plate, described as the holotype of *Archegonaspis drummondi*.
6. An impression of the exterior of a nearly complete ventral shield, clearly an *Archegonaspis*, tentatively assigned to the same species as the above.
7. A small triangular plate, possibly a branchial plate, but of uncertain affinities which is briefly described and illustrated, but not named.
8. A ventral plate exposing the interior, and etched to show the lateral line system. This is described as *Archegonaspis* sp.

Vernonaspis n. gen.

Genotype: *Vernonaspis allenae* n. sp.

This genus is known only from the dorsal shield, which is slender, the anterior end obscurely pointed, widened behind the eyes, slightly constricted before reaching the branchial region, branchial region gently expanded, sides subparallel in postbranchial region, prominent posterior lateral angles, the posterior margin obtusely pointed in the center, straight on either side; marginal band of posterior margin poorly developed. The surface shows an obscure division of the dorsal shield into a central disc, a rostral plate, and two small anterior lateral plates. The lateral plates proper are not distinguished from the central disc throughout most of their length; it is questionable as to whether the two anterior lateral plates are derived from the anterior end of the lateral plates, or from the rostrum. The surface of the rostrum is complexly whorled, centered about two points in the anterior lateral margin, pustulose in the center, transverse behind. Of the two lateral plates, the anterior one is smooth internally; the

posterior one bears coarse polygonal markings. On the exterior the ridges are slightly whorled in front, but become linear behind, blending with the pattern of the lateral plates and central disc. On the central disc the pineal body, itself not prominent or sharply elevated, is the center of radiating curved ridges which finally swing back joining the pattern of longitudinal ridges which occupy the greater part of the dorsal surface. They are modified at irregular intervals by pustules arranged in irregular groups. Some of these pustules bear minute pores, an expression of the lateral line system.

Discussion. This remarkable form is unique in the differentiation of the rostrum, in the two anterior lateral plates of small size, and the absence of any clear differentiation of the lateral plates from the central disc. In this respect, the genus is somewhat comparable to the extremely inadequately known genus *Diplaspis*, judging from the outline drawing of the one and only known specimen. Our form is very different in shape, and indeed, *Diplaspis acadica* is so inadequately known that close comparison is not possible. The pustules of the surface suggest a comparison with *Tolypelepis* and *Traquairaspis*, but the nodes of the surface are quite different in appearance in those genera. In *Tolypelepis* the nodes are larger and more wart-like; in *Traquairaspis* they are obviously isolated elements of broken up coarse longitudinal ridges such as are seen in a perfect state in the genus *Cyathaspis*. *Traquairaspis* according to the description of the genus, is said to have the rostral and lateral plates completely separated, and the anterior end of the lateral plate is possibly separated as a distinct plate. In this respect, *Traquairaspis* is closer to *Vernonaspis* than to any other described genus, but in *Vernonaspis* there is not one anterior lateral plate, but two, and the main parts of the lateral plates are not set off from the main part of the central disc.

Strangely, the form most similar superficially to *V. allenae* is not a cyathaspid, but a pteraspid, the form described as *Pteraspis lerichi* Zych (see Pauca, 1941, Pl. 2, fig. 2,) and *P. lerichi* var. *plana* Brontzen (see Pauca, 1941, Pl. 2, fig. 3.) This form is distinct in a number of features, having apparently distinct pineal and ocular plates and a posterior groove for the reception of a dorsal spine on the posterior part of the shield. Fine surface details are not well enough shown to permit a close comparison, but there is no indication of a pattern of linear ridges and pustules. *P. lerichi* is apparently a pteraspid and its resemblance to this cyathaspid is superficial, but it is not at all similar in aspect to *Pteraspis, sensu stricto*, as illustrated by White (1935).

Vernonaspis allenae n. sp.

Plate 1; Plate 2, figures 3, 8.

This species is known from a single dorsal plate, 31 mm. long, ocular width 11 mm., branchial width 16 mm., with the sides subparallel in the postbranchial region, no definite postbranchial expansion, 13 mm. wide at the posterior lateral angles. Pineal index 7.5 mm., rostrum 5 mm. long, rather bluntly pointed in front, the anterior part with the dentin ridges arranged in whorls about two anterior lateral centers, the central part pustulose, ridges broken and rather irregular, faintly radial in arrangement, transverse along posterior border. In the type, a slightly oblique break behind the rostrum is more conspicuous than the posterior boundary of the rostrum itself, but is clearly adventitous.

On the sides of the rostrum are two small anterior lateral plates, which are roughly rounded. The inner surface of the more anterior of these plates is smooth; the posterior one shows a surface of small polygonal facets, not closely similar to the usual pattern formed by the cancellous layer, but of a considerably coarser pattern. The external impression of this part of the type was available, and a portion of the test of this lateral region was broken away, and a rubber impression was then taken (Pl. 2, fig. 3,) which shows in part the surface pattern over these regions. Though whorled in front, the surface over the greater part of the area occupied by these two plates consists of longitudinal ridges which are very similar to the arrangement of the ridges over the lateral plates and the central disc. The lateral plates are not at all differentiated from the central disc on the basis of the surface features, and their margins are indicated only by broad shallow poorly defined grooves. The greater part of the central disc bears fine longitudinal ridges, modified at intervals by irregular groups of raised rounded pustules. In some of these pustules minute pores are seen, which evidently connect with the lateral line system. The pineal body is in itself poorly defined on the exterior and is not well elevated; in comparison to our other forms it is extremely small and inconspicuous. It is, however, a center from which the ridges of the surface radiate. Those ridges which extend obliquely forward or directly laterad are curved, eventually turning toward the posterior margin, and joining the general pattern of longitudinal ridges. There is no arrangement in the anterior-lateral portion of these ridges into whorls, as in *Vernonaspis leonardi*, and neither is there a strong V-shaped marking, pointing forward and terminating at the pineal body, as in *Anglaspis* and *Archegonaspis*, which, when present, represents a portion of the lateral line system.

The surface of the type shows several faint linear depressions, best shown in Plate 2, figure 8, which simulate the lateral line system, particularly in showing two prominent longitudinal grooves. These grooves are probably adventitious, as they are not centered at all. Indeed the one on the left passes forward from near the median posterior angle directly to the pineal body, which is a behavior shown by no normal part of the lateral line system in other cyathaspids where, instead, neither of the main commissures intersect the pineal body, but pass forward on either side of it.

There is indication of the thin posterior margin, which retains the dentin layer without the cancellous layer beneath, but it is not as well defined in this species as in our other forms.

Discussion. This specimen is remarkable for the very thin condition of the dorsal plate, which was evidently poorly calcified and quite flexible, for it has been flattened somewhat, but bent in the process without developing any of the cracks which are shown by other of our specimens. Although the test was broken in several places, it proved extremely thin, and no definite trace of the usual layers could be found. The cancellous layer was evidently very thin in comparison to that of *Vernonaspis* cf. *leonardi*. However, a similar condition was found in the small holotype of *V. leonardi*, where no cancellous layer could be detected, indicating that this layer was probably not well developed in small and probably immature individuals.

V. allenae is distinguished from *V. leonardi* by the quite different shape, particularly of the anterior end, the constriction of the lateral margins in front of the branchial region and behind the two anterior lateral plates, and by the much larger pustules of the surface. From other species, none of which it resembles closely, it can be distinguished by the characters of the genus.

Vernonaspis leonardi n. sp.

Plate 2, figures 6–7; Plate 3, figure 5; Plate 5, figure 2.

This species is represented by a small incomplete dorsal plate. There is an impression of the interior to which fragments of the plate adhere, the anterior end incomplete, the posterior end missing. The outline is gently rounded at the sides. The anterior end is shown clearly by an external impression, from which a rubber cast was made, which serves as the basis of our illustration (Pl. 3, fig. 5). This shows the anterior end to be slightly truncated, the sides very faintly notched for the reception of the eyes. The pineal body is large and strongly elevated. The rostrum is distinctly set off from the central disc, though the division between the central disc and the lateral plates is again obscure. At the anterior end, prominent depressions separate the anterior end of the lateral plate from the remainder, though both parts

bear essentially linear ridges. In front of this, and seemingly attached to the rostrum, is a similar small plate the surface of which shows the ridges developed into whorls, suggestive of the lateral plate figured by Kiaer and Heintz (1935, Pl. 33, fig. 1,) for *Homalaspidella nitida*, but with finer ornamentation.

The pustules of the ridges on the middle part of the plate are tiny, but well elevated. The markings on the posterior part are somewhat irregular, but essentially linear.

A ventral plate tentatively assigned to the same species, on the basis of form, is represented by an internal impression (Pl. 2, figs. 6–7) and an impression of the exterior from which a rubber mold was taken (Pl. 5, fig. 2.)

The internal impression, 26 mm. long, 16 mm. wide, is quite strongly convex and, in flattening, the margin on the right has been bent under the remainder of the specimen. The anterior end which is imperfect, appears to be strongly truncate in front, and scarcely emarginate if at all. The posterior outline is obtusely angled in the middle, the oblique sides straight and meeting the lateral margins at a prominent angle. Lateral margins curved, greatest width attained shortly behind the middle of the plate. The impression of the interior is relatively smooth but (Pl. 2, fig. 7,) shows a series of very faint ridges, which, however, it has proved impossible to distinguish with certainty from the cracks which are the result of slight crushing of the plate in flattening. In part, at least, these represent a portion of the lateral line system as in *Archegonaspis* sp., but no clear pattern can be made out (Fig. 1).

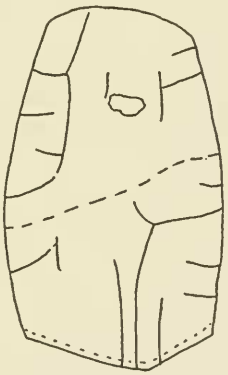

Fig. 1. Ventral shield attributed to *Vernonaspis leonardi*, showing observable pattern of fine ridges, and cracks of the surface, which cannot be properly differentiated. Part of this doubtless represents the lateral line system, which is here very imperfectly preserved.

The surface of the interior in natural color, shows the reticular pattern of the cancellous layer of the shell (Pl. 2, fig. 6.) A small piece of the plate, adhering just orad of the center, fails to show any of the surface features or structure.

The impression of the exterior of the same plate shows only the posterior portion (Pl. 5, fig. 2). The ridges are fine, closely spaced, linear, with irregularly scattered pustules, very tiny in relation to those of *V. allenae*, but suggesting affinities with that form, and comparable to the much smaller pustules of the dorsal plate which is the holotype of *Vernonaspis leonardi*. The internal mold shows a distinct and rather prominent posterior margin to the ventral plate, where, as usual, the cancellous layer is absent and only the dentin layer present.

This ventral plate bears a striking resemblance in outline to Claypole's original drawing of *Palaeaspis bitruncata*, and indicates that this is a true ventral plate as stated by Claypole (1892) and not a distinct species as stated by Bryant (1926). Strict comparison is impossible. Claypole's types have been destroyed, and the original illustration is only an outline drawing. *Palaeaspis bitruncata* cannot, under these circumstances, be recognized with certainty. The reference of this plate to *V. leonardi* rests upon similarity of form and the similarity of the tiny pustules to those of the dorsal plate and holotype.

Cf. *Vernonaspis leonardi*

Plate 3, figures 2–4; Plate 4; Plate 5, figure 1.

Ironically, the largest and finest dorsal plate in the entire collection of Vernon cyathaspids is known from an impression of the interior, and the plate itself, the dorsal surface of which is embedded in the matrix. Under these circumstances, nothing can be ascertained concerning the dorsal surface pattern, which supplies the generic criteria under our present rather finely divided classification. As a consequence, the generic and specific affinities of this form must remain uncertain. The plate has a maximum length of 32 mm., pineal index 6 mm., ocular width 10 mm., branchial width 18 mm., reduced to 17 mm. at the posterior lateral angles. The posterior margin is very thin, there being a well defined marginal band, and the shape of the posterior margin itself is somewhat obscure. There is clearly a blunt median point, as in *V. allenae*, the sides straight or very nearly so on either side of it. The lateral margins of the plate are slightly convex, with no clear differentiation of branchial and postbranchial regions, the anterior end rounded, the ocular impressions faint and very obscure.

There is no clear differentiation between the marginal branchial region and the remainder of the plate, which in most cyathaspids is

well marked by shallow grooves on the interior of thed orsal plate, even when no clear separation exists on the basis of the exterior alone.

The impression of the interior shows no clear indications of the nasal sacs. The pineal body is clearly defined and well elevated, behind which is the mesencephalon, represented by two faint vertical ridges, essentially in contact with the semicircular canals, and not distinct from them as in *Archegonaspis drummondi*. The tips of the anterior branches of the semicircular canals are bifid. The medullary ridge is long and well defined in contrast to *A. drummondi*, slightly depressed in the center of the most elevated portion. The branchail impressions are faint, poorly outlined, but the seven pairs can be distinguished. No marginal branchial impressions can be seen.

The interior of the dorsal plate (Pl. 4) shows with remarkable clarity the structure of the cancellous layer, in color. The broken edge, shown in further enlargement in Plate 5, figure 1, shows the usual cyathaspid structure, the thickest and most conspicuous element being the cancellous layer. The surface markings are indicated only in a few small areas where the plate has broken away from the shale, showing a small part of the impression of the exterior. The linear markings in the portion shown are not diagnostic, and agree closely with those of *A. drummondi* as known from the ventral plate, and also *V. leonardi*. The interior of the dorsal plate shows no traces of either a lateral line system, or the differentiation of anterior lateral plates. Slight flattening has caused the plate to be intersected by a series of cracks, widening toward the margin (Pl. 3, figs. 2–3). These have no significance, and fail to parallel any course of a probable lateral line system.

Discussion. The taxonomic position of this dorsal plate is uncertain without the dorsal surface. The transverse condition of the posterior margin is unlike that of most of the "Poraspidei," and is more closely approximated in *Archegonaspis* and in *Vernonaspis* than in any other of the known genera. The character of the interior of the dorsal shield is quite different in several particulars from that of *Archegonaspis drummondi*, particularly in the obscure distinction of the lateral areas, the lack of lateral expansion over the branchial area, and the straight lines which make up the posterior margin of the shield; in *Archegonaspis* these lines are sinuate. A striking feature of this specimen is the thickness of the cancellous layer. Either this is thickened through old age, which is possible, for none of our other specimens approximates this one in size, or else our form is strikingly distinct from any of the other dorsal plates in the present collection.

In shape, this plate agrees strongly with the much smaller holotype of *Vernonaspis leonardi*, and it is tentatively assigned to that species

mainly because of this strong resemblance. Two features oppose this determination. The first is the thickness of the cancellous layer which, as noted above, need not necessarily be a determining factor. The second is the absence of any discernible anterior lateral plates. Again, if old age has produced a thickening of the cancellous layer, it may well be accompanied by a secondary fusion of these plates.

As has been noted, the present species shows significant differences in proportions with the previously described genera. None of the Poraspidae is closely similar, and of the Cyathaspidae the only genus known to contain species at all similar in proportions is *Archegonaspis*, and the resemblance even here is not close. The original material of *Palaeaspis americana* was considerably different in outline, the greatest width of the plate being farther forward, and the sides approaching each other behind the middle. However, as pointed out, it is dubious whether this species or genus can be recognized in view of the loss of the type material.

ARCHEGONASPIS DRUMMONDI n. sp.

Plate 2, figures 1–2;

This species is based upon a beautifully preserved specimen, showing only the impression of the interior of a dorsal shield. This shield, 22 mm. in length, pineal index 5.5 mm., has an ocular width of 8 mm., increasing to a branchial width of 13.5 mm. There is no widening toward the posterior end to a definite postbranchial area. The branchial regions are depressed at the edges, and the elevated portion of the plate between them has margins which are essentially straight from the ocular region, diverging gently to the posterior lateral angles, which are 12 mm. across. The angles are rounded, in contrast to their sharp condition in *Vernonaspis*, the posterior margin sinuate, broadly convex in the center instead of coming to a blunt point. A clear narrow posterior border 1 mm. wide is sharply defined; the internal mold shows that here, as in other species, there is only the dentin layer, the cancellous layer being absent, as shown by faint longitudinal striations on the internal mold.

Pineal body large, round, well elevated; nasal sacs at anterior end relatively obscure, not prominently elevated on internal mold as in *Anglaspis*. Three short linear ridges behind the pineal body represent the mesencephalon; they lie between the anterior branches of the semicircular canals which are well elevated and clearly defined. The seven pairs of branchial impressions are broad, shallow, and about of equal clarity from the first to the last. Marginal branchial impressions are not at all evident. The surface over the lateral areas is faintly

pustulose, due in part to the presence of fragments of the plate, which as in our other material, was evidently more strongly calcified near the lateral margins. The medullary ridge is forked in front, and lies some distance behind the semicircular canals, between the posterior pair of branchial impressions. It is short, not penetrating into the postbranchial region.

Discussion. Reference of this form to any genus is somewhat hazardous, since the essential generic characters are drawn largely from the features of the exterior rather than the interior of the dorsal plate. However, the extant illustrations are adequate to show that our form is not closely comparable with any of the previously described genera except *Archegonaspis*. *Poraspis* differs in the somewhat more produced condition of the anterior end, the greater prominence of the nasal sacs, the more anterior position of the pineal body in relation to the branchial impressions, the lateral expansion of a postbranchial area, the obscurity of the posterior margin, and the presence of well defined marginal branchial impressions. The known forms of *Homalaspidella*, though more like the present species in the prominent posterior margin (Kiaer and Heintz, 1935, Pl. 30, fig. 2; see also text fig. 56), resemble *Poraspis* more closely in other features. Much closer to our form in proportions are the interiors of *Anglaspis* and *Archegonaspis*, both in general shape and the arrangement of the impressions of the branchial apparatus and brain. *Archegonaspis* is favored for several reasons. In *Anglaspis* the front of the head tends to be somewhat produced, and the nasal sacs are more prominent, the orbital notches more pronounced, and the posterior margin more strongly produced. Also, a ventral plate, tentatively assigned to this species on the basis of proportions, shows the relatively fine closely spaced striae of *Archegonaspis* instead of the much coarser and deeper markings of an *Anglaspis*. Our material does not show what is considered the crucial difference between the genera, namely whether the dorsal shield is entire as in *Anglapis*, or whether there is a separation of rostral and lateral plates on the basis of the surface marking, as in *Archegonaspis*. As noted in the discussion of these genera, this difference is relatively slight, and actually it is here that there is the closest link between the families Poraspidae and Cyathaspidae.

Archegonaspis cf. *drummondi*

Plate 6

This ventral plate is known only from an impression of the exterior. Our present illustration is taken from an artificial rubber cast. The plate is narrow in front, broadest in the posterior third, the posterior

margin bluntly pointed in the middle, the outline essentially straight on either side, and meeting the lateral margin at a well defined angle. The anterior end, obscure, was evidently considerably emarginate. Dentin ridges are longitudinal over the greater part of the length of the shield, but are centered about two whorls on the anterior lateral portions. The ridges are fine, closely spaced. No structures are seen which can be interpreted with certainty as pores of the lateral line system. The plate has a length of 21 mm., a width which increases from 6 mm. at the anterior end to a maximum of 11 mm.

Discussion. This plate in form and surface pattern is typical of *Archegonaspis*. Reference on the basis of such scant material s of course uncertain, but the general proportions suggest that this imay have well been the ventral plate of *Archegonaspis drummondi*. It is markedly different in proportions from *Archegonaspis* sp., described below, and differs considerably in texture as well as in outline from the more parallel-sided plate which is tentatively assigned to *Vernonaspis leonardi*.

Archegonaspis ? sp.

Plate 3, figure 6; Plate 7; Plate 8, figure 3; text figure 2.

Differing from all other forms in its considerable breadth, is a beautifully preserved ventral plate, remarkable for the sharp and slightly eccentric emargination of the anterior end, and the clarity with which the elements of the lateral line system are preserved. This form, we have been unable to identify with any of the other species described above, which is particularly unfortunate in view of the evidence it supplies as to the structure of the lateral line system. The reference to *Archegonaspis* is necessarily tentative, and is based upon the resemblance of its surface pattern to that of *A. drummondi* and also to *A. lindstrømi*. The plate is 24 mm. long, with a maximum width of 14 mm., with the dorsal surface embedded in matrix. The inner surface was essentially smooth, showing cracks due to flattening and a series of faint linear impressions. These are better seen on the impression of the inner surface (Pl. 8, fig. 3, Text fig. 2), than on the inner surface itself. The plate was subjected to gentle etching, which exposed the cancellous layer, the canals of the lateral line system and, in places, the surface pattern of the dentin layer of the exterior, as shown on Plate 7.

In shape, this plate is considerably broader in proportion to its length than other ventral plates encountered in the Vernon shale, showing a strong emargination of the anterior end, best shown in the specimen in its natural color (Pl. 3, fig. 6,) and which is clearly strongly

askew. The ventral shield was originally quite strongly curved. Flattening has tended to bend one side more than the other, but is apparently not entirely adequate in itself to account for the eccentric position of the anterior notch. The posterior border meets the lateral edges at sharp and definite angles; it is bluntly pointed in the middle, straight on either side. The posterior thin border of the plate is not as sharply set off from the remainder of the plate as in our other ventral shields, but, as in the other specimens, apparently represents an area in which the cancellous layer is lacking. The surface bears longitudinal dentin ridges as in most species of *Archegonaspis*. These ridges are fine, closely spaced, and probably appear shallower on the exterior than they do from the etched interior shown on Plate 7, for they are not nearly as sharply defined on the impression of the exterior which is shown in the lower left part of the plate as oriented in our figure.

Etching has revealed in addition to the normal features of the dentin and cancellous layers, a series of rather irregularly spaced short transverse canals which represent the lateral line system. Though more irregular and less complete, as series, than those shown for *Poraspis* (Kiaer and Heintz, 1935, fig. 3b, p. 45,) they are clearly analogous to the median portions of the ventral transverse commissures, and the lateral portions of the ventral transverse commissures, though only a very few individual canals of this last series can be detected, and it is not easy to distinguish them from the cracks in the ventral plate which are the result of slight flattening.

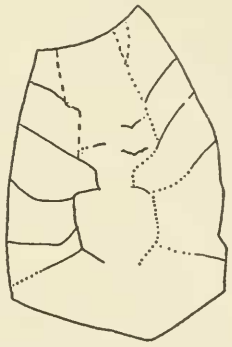

Fig. 2. Outline of *Archegonaspis*? sp., showing reconstruction of canal system from the grooves of the inner surface. Visible portions are indicated in solid lines; indistinct portions by broken lines, frankly inferred connections by dotted lines, where no trace of the canal system could be seen.

Though the matter does not seem to have been discussed in print, it stands to reason that the lateral line system, as a series of neural and sensory organs, must have had a direct connection with the brain and the central nervous system. If so, the incomplete series of canals which are embedded in the ventral plate must have been connected by nerve cords which lay within it, in the tissue of the animal. On the impression of the interior, such a system of canals is suggested by a series of faint ridges, representing, of course, grooves of the inner surface of the plate. They are obscure, low, poorly defined, and somewhat less prominent than the cracks of the ventral plate, in which we are not interested. Their appearance is shown in Plate 8, figure 3. Under favorable lighting, aided by turning the specimen, they can be reconstructed into a much more complete series, illustrated in text figure 2. This shows at least a reasonable series of canals which align with the portions which are embedded in the ventral plate. One possible objection to this explanation is that, prior to etching, no openings were found on the inner surface of the plate which would indicate a connection between the internal canal system, and that embedded in the ventral plate itself.

Discussion. This plate, the only one of our specimens showing clear evidence of the lateral line system, does not seem to match any of the species known from dorsal plates. This is particularly unfortunate because the lateral line system is so imperfectly known in the Cyathaspidae, to which apparently all of our forms belong. It is, however, evident that this form indicates that the differences in the lateral line systems of the Poraspidae and Cyathaspidae are not as marked as has been supposed, Indeed, it must be remembered that the Poraspidae, in which the lateral line system is fairly well known, have been studied on the basis of abundant and well preserved materials, which has not been true of any of the genera assigned to the Cyathaspidae. This fact, together with our present specimen, suggest that the differences are perhaps much more apparent than real and will decrease when more of the Cyathaspidae have been studied from better and more abundant materials.

Unidentified plate

Plate 8, figures 1–2.

This plate is roughly quadrangular, with one angle obtuse and rounded, or may be considered triangular, with one side convex and strongly curved in the middle. The upper side, as oriented in our figure, is perfectly straight; the under side strongly curved, the posterior side straight, forming an acute angle with the upper edge.

Most of the plate has been exfoliated, showing traces of the reticular structure of cancellous layer. Small portions indicate that the surface bore linear markings parallel to the long axis of the plate. As such, the most logical interpretation would be that of a branchial plate, but this form does not agree at all closely with any known branchial plate figured for cyathaspids, the best known being those of *Poraspis* (Kiaer and Heintz, 1935) and *Anglaspis* (Wills, 1935). The form is too blunt and too obtusely pointed to suggest any known spine or scale. Short of a specimen showing a plate similar to this in relation to dorsal and ventral plates, an extremely remote contingency, it will not be possible to refer the present specimen to any genus or species with certainty. Therefore all that is possible is to call attention to this plate and to illustrate it.

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