CONTRIBUTIONS FROM THE MUSEUM OF PALEONTOLOGY

THE UNIVERSITY OF MICHIGAN

VOL. 24, NO. 4, p. 23–30 (2 pls., 1 text-fig.) OCTOBER 4, 1973

ORDOVICIAN VERTEBRATES FROM ONTARIO

BY

KATHLEEN ANNE LEHTOLA
Michigan State University

PUBLISHED WITH GENEROUS SUPPORT OF
JOHN W. ARMSTRONG PALEONTOLOGY ASSISTANCE FUND

MUSEUM OF PALEONTOLOGY
THE UNIVERSITY OF MICHIGAN
ANN ARBOR

CONTRIBUTIONS FROM THE MUSEUM OF PALEONTOLOGY

Director: ROBERT V. KESLING

The series of contributions from the Museum of Paleontology is a medium for the publication of papers based chiefly upon the collection in the Museum. When the number of pages issued is sufficient to make a volume, a title page and a table of contents will be sent to libraries on the mailing list, and to individuals upon request. A list of the separate papers may also be obtained. Correspondence should be directed to the Museum of Paleontology, The University of Michigan, Ann Arbor, Michigan 48104.

VOLS. 2–23. Parts of volumes may be obtained if available. Price lists available upon inquiry.

VOLUME 24

1. A new species of *Porocrinus* from the Middle Ordovician Kimmswick Limestone of Missouri, by Robert V. Kesling. Pages 1–7, with 2 plates and 8 text-figures.
2. *Strataster devonicus*, a new brittle-star with unusual preservation from the Middle Devonian Silica Formation of Ohio, by Robert V. Kesling. Pages 9–15, with 2 plates and 3 text-figs.
3. Coccoliths and related calcareous nannofossils from the Upper Cretaceous Fencepost Limestone of northwestern Kansas, by John M. Huh and Charles I. Smith. Pages 17–22, with 2 plates.

ORDOVICIAN VERTEBRATES FROM ONTARIO

KATHLEEN ANNE LEHTOLA
Michigan State University

ABSTRACT—Vertebrate fossil fragments from the northeast part of St. Joseph Island, Ontario, Canada have been referred to *Astraspis desiderata* Walcott on the basis of their stellate tubercles. They occur in shallow marine limestones of Middle Ordovician age. This is the first record of an Ordovician vertebrate in limestone. This discovery considerably extends the geographic range of *Astraspis* and lends some additional support to the theory of the marine origin of the vertebrates.

INTRODUCTION

THE EARLIEST FOSSIL VERTEBRATES have perplexed several generations of workers. The remains are fragmentary and not at all abundant; some are poorly preserved. The earliest recorded occurrence of Ordovician vertebrates was made in Russia by J. V. Rohon (1889), who reported Ordovician fish remains from Russia's Baltic region. He established their vertebrate nature on the basis of the presence of pulp cavities, dentine and dentine tubules, and enamel. These fossils were not studied further and are now lost. Some doubt has recently been cast on their authenticity (Elga Kurik, TA Geoloogia Inst., Tallinn, Estonia, in. litt.). Dr. Walter Gross (Tübingen, Germany, in. litt.) thinks it possible that they may have been inadvertently mixed with younger fossils by Rohon.

Ordovician fish remains were next discovered in the Harding Sandstone of Colorado and described by C. D. Walcott (1892). He named two genera and species: *Astraspis desiderata* Walcott and *Eriptychius americanus* Walcott. The two genera are easily distinguished, *Eriptychius* having raised, elongate ridges, and *Astraspis* having stellate or mushroom-shaped tubercles. Cope (1893) suggested the fossils be placed in the Class Agnatha. In 1936, W. L. Bryant did the first thorough histological study of the two genera. He referred them to the Order Heterostraci on the basis of (1) a prominent medial dorsal plate, (2) ornamentation superficially similar to that of other heterostracans, and (3) aspidin (acellular bone).

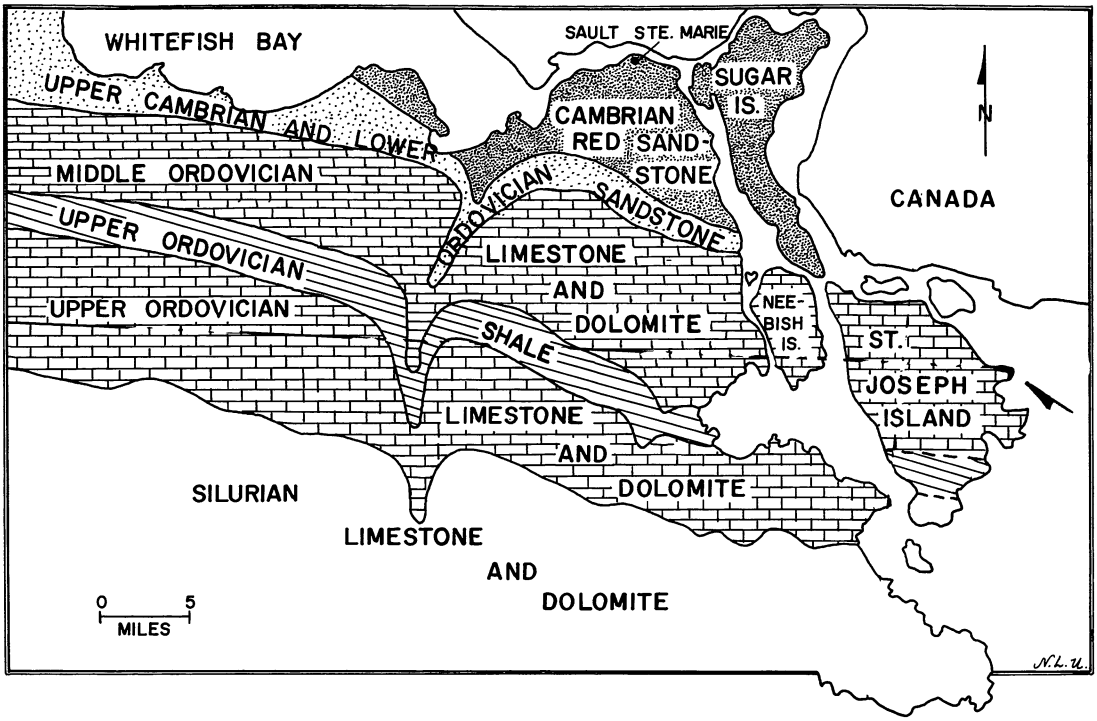
Darton (1906, 1909), Furnish *et al.* (1936), and Ross (1957) identified Ordovician ostracoderms in South Dakota, Wyoming, and Montana. Darton and Furnish both listed indeterminate vertebrate remains, and Ross reported *Eriptychius americanus* and *Astraspis desiderata* from well cores in Montana. Vertebrates of that area were first thoroughly studied by Ørvig (1958) who named a new genus and species, *Pycnaspis splendens* Ørvig, from near Sheridan, Wyoming. Denison (1967) later relegated *Pycnaspis* to the synonymy of *Astraspis*, as *A. splendens*.

In 1958, G. W. Sinclair reported two *Astraspis* plates from British Columbia and Quebec in Canada. Unfortunately, before these could be studied they were lost (T. E. Bolton, Geological Survey of Canada, in. litt.). Other Cambrian and Ordovician vertebrates have been recorded at various times (review in Ørvig, 1958; Denison, 1967), but all have been discredited or need considerable further study.

A reported Ordovician ostracoderm occurrence that was never discredited involved material from the Black River Group near Escanaba, Michigan. In his *Historical Geology*, R. C. Hussey (1947) figured a platelet of supposed vertebrate origin. The figured specimen has been lost. I microprobed and thin-sectioned an associated specimen (UMMP V43936) identified as an ostracoderm by Hussey. It has an outer covering of silica and a carbonate interior (R. H. Ehrlich, Michigan State University, pers. comm.), but it has been so diagenetically altered that the organic origin of the plate cannot be established.

In the course of my study of Hussey's Middle Ordovician collection from St. Joseph Island, Ontario, several samples were found to contain vertebrate plates with tubercles. These plates are here described and referred to *Astraspis desiderata*. They are deposited in the Museum of Paleontology collections at The University of Michigan under catalog number UMMP V57977.

This is the third major recorded occurrence



TEXT-FIG. *1*—Map of eastern tip of the Upper Peninsula of Michigan, including islands in the St. Mary's River. The outcrop area on St. Joseph Island, Ontario, is indicated by the arrow. (Modified from Vanlier & Deutsch, 1958.)

of Ordovician vertebrates. It is the first occurrence of *Astraspis* outside of the Cordilleran region of the western United States. It is also the first occurrence of an Ordovician vertebrate in limestone. The paleoecological significance of the limestone is that it was deposited in the open sea, thus lending support to a saltwater rather than a freshwater origin of vertebrates.

GEOLOGY

According to Hussey (1936), James Hall was the first person to report rocks of Middle Ordovician age in the Upper Peninsula of Michigan, publishing his observations in E. L. Foster & J. D. Whitney, 1851, On the age of the sandstone of Lake Superior, with a description of the phenomena of the association of igneous rocks: Proc. Amer. Assoc. Adv. Science, v. 5, p. 22–38. Hall correlated them with the Trenton Group in New York. Winchell (1861) and Rominger (1873) traced these in outcrops from Wisconsin across the Upper Peninsula and into Ontario.

The ostracoderm-bearing rocks are from St. Joseph Island, Ontario, which lies off the eastern tip of the Upper Peninsula of Michigan (text-fig. 1). On the basis of a description of fossils and lithology, Liberty (1968, 1969, and in. litt.) has confirmed the vertebrate-bearing rocks as the Gull River Formation. The outcrop area where Hussey collected fossils is on the northeastern side of the island. Hussey (1952) stated, "The top of the section begins at Quarry Point, on the northeast side of the Island, and continues northward to Gravel Point, and then westward for about two miles, along the north shore of Landspur." The outcrop area is solidly shaded in text-figure 1. Unfortunately, Hussey did not pinpoint his collecting site.

EXPLANATION OF PLATE 1
All figures × 50

Astraspis desiderata—UMMP V57977, from St. Joseph Island. *1–3*, stereo pairs of dermal armor plate with five tubercles; note dividing ray on lower left tubercle in figure 1. *4, 5*, single views of same plate. In figures 1–4, the specimen was coated with ammonium chloride to show the form of the tubercles; in figure 5, it is uncoated, showing the pearly luster. Photographed by Mr. Karl Kutasi, Museum of Paleontology, The University of Michigan.

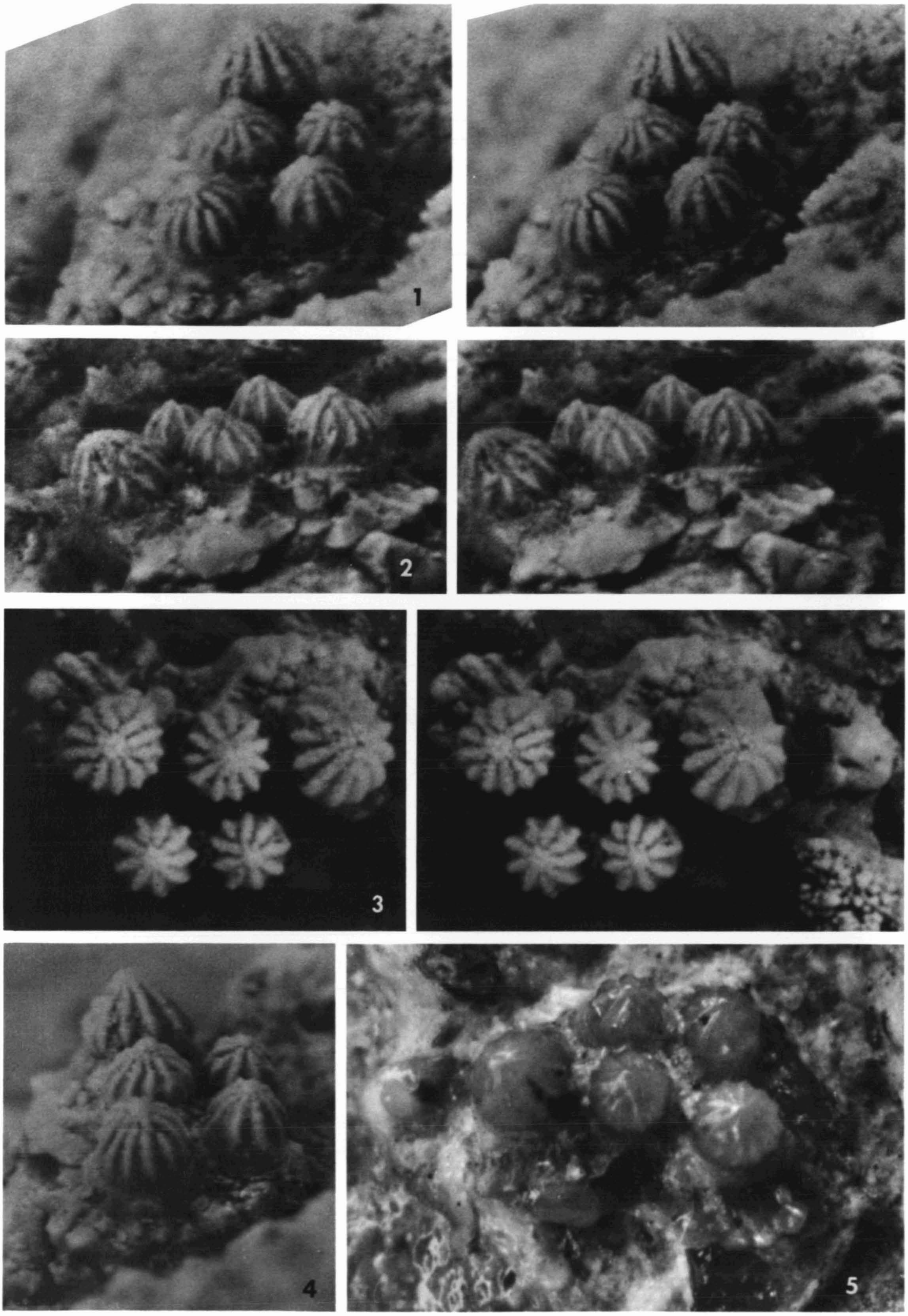
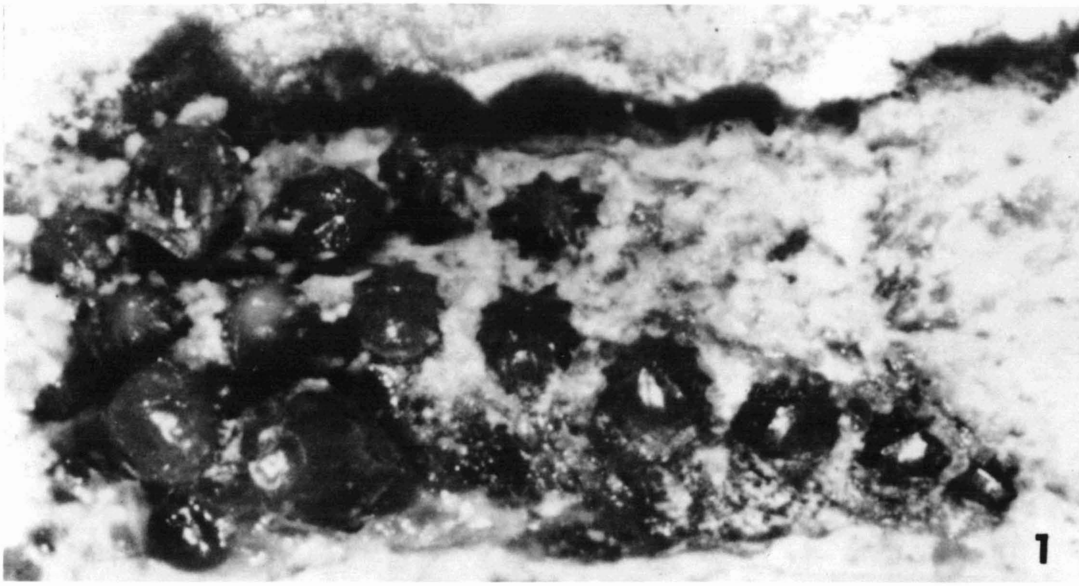


PLATE 1



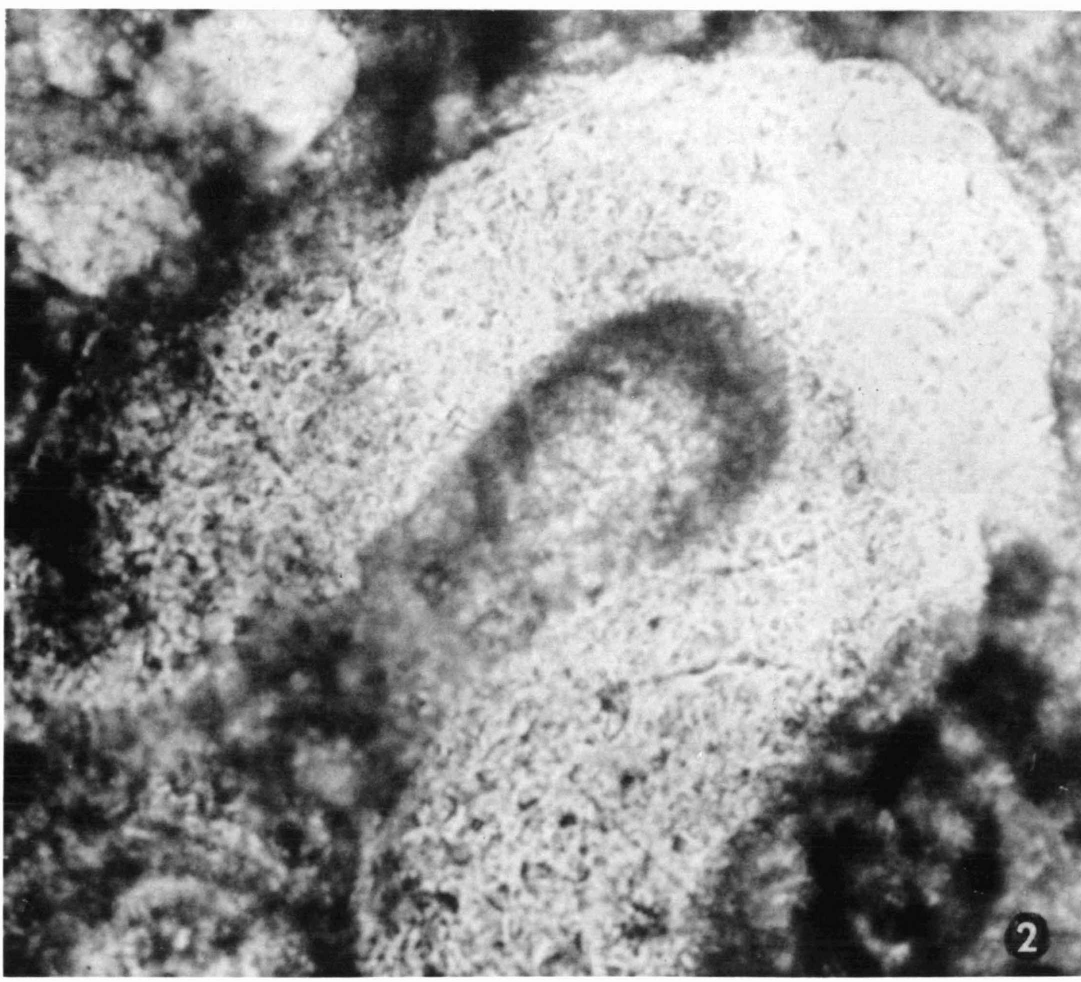


PLATE 2

TABLE 1—CORRELATION OF HARDING AND GULL RIVER FORMATIONS. From Twenhofel *et al.*, 1954.

Stage	Representative formations	Colorado	Central and southwestern Ontario
Trentonian	Cobourg		
	Sherman Fall		
	Kirkfield	Harding	
	Rockland		
Blackriveran	Chaumont		
	Lowville		Gull River
	Pamelia		

Limestones from this outcrop area are pure, fine-grained, gray, and very fossiliferous. A few brachiopods have been completely filled by calcite crystals; some invertebrate fossils have been partially replaced by pyrite.

The Gull River Formation (table 1) is middle Blackriveran (Twenhofel *et al.*, 1954; Liberty, 1968, 1969) and the Harding Sandstone of Colorado is middle Trentonian (Twenhofel *et al.*, 1954). The age of the Harding has been based on its invertebrate fauna, especially the conodonts. A comparison of Sweet's (1955) list of Harding conodonts with that of Schopf's (1966) for New York and surrounding areas demonstrates that the Harding may be nearly restricted to the Kirkfield part of Trentonian time (cf. Twenhofel *et al.*, 1954).

SYSTEMATIC PALEONTOLOGY

ASTRASPIS DESIDERATA Walcott, 1892

Pls. 1, 2

Material.—Disarticulated plates with stellate tubercles. UMMP V57977.

Age and locality.—Middle Ordovician (Black River Group, Middle Wilderness time). From fossiliferous marine limestone. "St. Joseph Island; West end of North Channel in Lake Huron" (UMMP Accession Card 1953/0-14).

Diagnosis.—The fossils are assigned to the genus *Astraspis* on the basis of tiny, discrete, disarticulated plates with tubercles attached; the tubercles have a central pulp cavity surrounded by laminated dentine. They are assigned to the species *A. desiderata* because the tubercles are small (0.25–0.40 mm in diameter) and stellate.

Remarks.—The ostracoderms occur in a nearly pure limestone, with some detrital quartz.

The tubercles are irregularly but closely spaced on the bony plates. They vary in size. The range of tubercles in the specimen shown in plate 1 is 0.25 to 0.40 mm. For Wyoming specimens, tubercles range from 0.19 to 1.39 mm, slightly less than Denison's (1967) maximum diameter of 1.45 mm. His minimum diameter for western *Astraspis* is 0.10 mm.

Externally, each tubercle is stellate with a tiny apical knob. No mushroom-shaped tubercles (cf. Ørvig, 1958) have been found among the specimens examined from Ontario. The number of rays on each star varies between eight and 13. The maximum variation on any one plate is between nine and 13. As tubercle size increases, the number of rays increases (Sawin, 1959). The tubercles may have grown by division of rays; figure 1 of plate 1 shows such a division on the lower tubercle. All tubercles have a definite pearly luster (pl. 1, fig. 5; pl. 2, fig. 1).

No very large fragments are found, the largest having 16 tubercles in three rows and measuring about 1 by 3 mm (pl. 2, fig. 1). A few single tubercles are found but most are in groups of three, four, or five.

The tubercles are soft and scratch very easily. A weak zone may be present along the tubercle base parallel to the bony plate beneath; many tubercles have fractures there that show air bubbles when dampened, and many tubercles have broken completely off at that place.

The primary sample contains about one surface tubercle per square cm, and saw cuts in any direction through the rock have usually revealed at least one tubercle.

The basal bony plate is extremely thin in the Ontario specimens. The western vertebrates are, in general, much thicker (Denison, 1967), but there is considerable variation in their thickness. Therefore, it is not known whether the thinness of the Ontario plates is a reflection of the area of the body from which they came, or whether the entire animal had thinner armor.

The tubercles have central, round pulp cavities (pl. 2, fig. 2). These cavities are surrounded by dentine. Fine laminations in the dentine parallel to the pulp cavity may be seen on a few specimens. On one specimen the laminations appear to extend to the outer edge of the tubercle, but this cannot be determined with certainty. No evidence of any amorphous

EXPLANATION OF PLATE 2

Astraspis desiderata—UMMP V57977, from St. Joseph Island. *1*, bony plate showing sixteen tubercles, approximately × 20; photographed by Mr. Karl Kutasi. *2*, thin section of tubercle showing pulp cavity, approximately × 180; photographed by Mr. Ralph Taggart, Michigan State University.

"enamel-like" layer as reported by Bryant (1936), Denison (1967), and others can be seen on the outer surface of the tubercle.

The exterior shape of the tubercles from Ontario is identical to that of western *Astraspis desiderata*. The only differences seem to be that the Ontario *Astraspis* have an extremely thin basal plate and a smaller average tubercle diameter than those of the Cordilleran region. Possibly the small average size indicates that we have so far only sampled a few plates from young individuals. The Ontario and western *Astraspis* may have lived in different epicontinental seas or on different coasts of a single sea. Until more information is available about *Astraspis* and its distribution, nomenclatural distinction of the Black River form is not warranted.

DISCUSSION

The occurrence of *Astraspis desiderata* from both the Cordilleran region of the United States and from Ontario, Canada, marine localities about 1500 miles apart, indicates they are much more widely distributed in North America than formerly thought.

In 1935, Romer & Grove published their classic paper on the environment of the early vertebrates. They discussed the paleontology of all vertebrate-bearing strata in North America from the Ordovician through the Devonian. Only their discussion of the Ordovician deposits will be reviewed here because the Silurian and Devonian localities have no bearing on the origin-of-vertebrates controversy.

The Ordovician Harding Sandstone of Colorado is considered to be a marine deposit because it contains marine invertebrates. Because the vertebrate material, though abundant, is always fragmentary and often waterworn, Romer & Grove (1935, p. 810, 811) concluded, "The littoral nature of the deposit combined with the fragmentary nature of the fossil material has led to the general acceptance of the theory that the Harding Sandstone vertebrates were in life inhabitants of fresh waters." They postulated the transporting of millions of fish fragments down rivers to the ocean.

Romer & Grove's conclusion as to the freshwater origin of the Harding vertebrates was based primarily on the fragmentary nature of the remains. Denison (1956) questioned their reasoning on several grounds: (1) some of the fragments are waterworn, but many others are very well preserved, (2) the fragments are found in equal abundance at all outcrops of the Harding, covering some 15,000 square miles, and at the Harding-equivalent outcrops in the Wyoming, South Dakota, and Montana area, and (3) the fragments are often quite large, up to about 4 cm, even though the sand is very well sorted. Currents that sorted sand grains so well would be expected to have sorted the vertebrates if they had been transported. Both Denison (1956, 1967) and Robertson (1957) disregarded the bulk of Romer & Grove's paper, which was a detailed summary of the North American Devonian deposits. In deposits of Late Silurian or Early Devonian age, evidence is found for the existence of both marine and freshwater vertebrates; thus, by that time they were adapted to both modes of life.

Errol White (1958) critically reviewed the literature based on geological, geographical, and zoological evidences and arrived at the same conclusions as did Denison and Robertson.

The most important zoological argument for a freshwater vertebrate origin is that of H. W. Smith (1953) in his work on the kidney. He concluded vertebrates must have originated in fresh water because of their glomerular kidney. But, as Robertson (1957) pointed out, if that type of kidney is so necessary for freshwater dwellers, how did the animals get into fresh water without it? Unfortunately, Smith (1932, p. 1) admitted to "an attempt to interpret the physiological phenomena in terms of evolutionary history," which is to say that because he thought the geological evidence supported a freshwater origin of vertebrates, he tried to interpret the physiological evidence in terms of geology.

Nils Spjeldnaes (1967) attributes the fragmentation of the vertebrates to the action of bacteria and other scavengers. Another explanation for the fragmentation might lie in their suturing. The anterior dermal armor of *Astraspis* and *Eriptychius* was composed of tiny, discrete plates. The plates abutted against one another with vertical sutures (Denison, 1967). Perhaps in life the armor was held together by some organic cementing agent. When decay set in after death, the plates became loose and were scattered by even slight water movement.

The new Ontario limestone locality is important as the first vertebrate occurrence in limestone from the Ordovician. Up to now, all Ordovician vertebrates have been reported from sandstones, shales, and siltstones. The Harding Sandstone in Colorado is a fairly fine grained, well-cemented, red sandstone and the Harding-equivalent in the Wyoming area is a coarser grained, poorly cemented sand. Darton (1909) reported some fish from the Black Hills of South Dakota occurring in the Whitewood Limestone. Furnish *et al.* (1936) figured the Black Hills vertebrate fragments, but placed them in the underlying Harding-equivalent Roughlock Siltstone. Ross (1957) reported fragments in the sandstones and shales of the Winnipeg Formation in the Williston Basin.

Sandstones, shales, and siltstones can occur in marine, brackish, or freshwater environments. In contrast, most widespread limestones are marine in origin; they imply a quiet environment, either shallow or deep (Pettijohn, 1957).

The Ontario ostracoderm-bearing limestone is considered to be a fairly shallow open-sea deposit (Hussey, 1936; Dr. R. V. Kesling, The University of Michigan, pers. comm.; Dr. C. E. Prouty, Michigan State University, pers. comm.). Paleogeographic maps indicate that Michigan was under an epicontinental sea in the Middle Ordovician.

Invertebrates identified from the limestone which bears the ostracoderms include *Liospira* cf. *eugenia* (a low-spired gastropod of the Ordovician), *Zygospira recurvirostris* (a brachiopod ranging from Middle to Upper Ordovician), *Rhynchotrema minnesotensis* (a brachiopod ranging from Middle to Upper Ordovician), *Rhynchotrema* sp., *Eoleperditia fabulites* (an ostracod from the Middle Ordovician), a ribbonlike cryptostome bryozoan, and a colonial coral. No trilobites are present. The fossils are well preserved generally; some are fragmented, many are not. *Rhynchotrema* is most abundant; *Liospira*, *Eoleperditia*, and the bryozoan are also common.

In the west, *Astraspis* has always been found in association with *Eriptychius*. *Eriptychius* has not yet been found in the Ontario rocks.

It is universally agreed that corals and nonlingulid brachiopods have always been marine and that bryozoans and gastropods are predominantly marine (Robertson, 1957, p. 158). Therefore, the limestone and its invertebrate fauna would suggest a marine environment—quiet, fairly shallow, with a muddy or calcareous bottom (Dr. H. Scott, Michigan State University, pers. comm.; Dr. R. V. Kesling, The University of Michigan, pers. comm.).

The occurrence of vertebrates in a normal marine, open-sea environment suggests that they lived there and were not introduced after death.

ACKNOWLEDGMENTS

Dr. J. Alan Holman (MS Committee Chairman), Dr. James H. Fisher, and Dr. Jane E. Smith, Michigan State University, and Dr. Gerald R. Smith, The University of Michigan, read and criticized the manuscript. Dr. R. H. Denison, Field Museum of Natural History, Chicago, kindly offered advice and encouragement during the course of this study. Dr. Robert V. Kesling, The University of Michigan, helped identify fossil invertebrates and edited the manuscript. Mr. Robert Kelley, Michigan Geological Survey, helped me locate certain reference materials. Dr. Bruce Liberty, Brock University, supplied information on the Gull River Formation; Elga Kurik, Tallinn, Estonia, and Professor W. Gross, Tübingen, Germany, wrote concerning the Russian locality. Mr. Karl Kutasi, The University of Michigan, and Mr. Ralph Taggart, Michigan State University, photographed the fossils. Miss Nancy Underwood made the map. All deserve my grateful thanks.

LITERATURE CITED

Bryant, W. L., 1936, A study of the oldest known vertebrates, *Astraspis* and *Eriptychius*: Proc. Am. Philos. Soc., v. 76, no. 4, p. 409–427.

Cope, E. D., 1893, The vertebrate fauna of the Ordovician of Colorado: Am. Naturalist, v. 27, p. 268, 269.

Darton, N. H., 1906, Fish remains in Ordovician rocks in Bighorn Mountains, Wyoming, with a résumé of Ordovician geology of the Northwest: Bull. Geol. Soc. America, v. 17, p. 541–566.

———, 1909, Discovery of fish remains in Ordovician of the Black Hills, South Dakota: *Ibid.*, v. 19, p. 567, 568.

Denison, R. H., 1956, A review of the habitat of the earliest vertebrates: Fieldiana, Geology, v. 11, no. 8, p. 361–457.

———, 1967, Ordovician vertebrates from western United States: *Ibid.*, v. 16, no. 6, p. 131–192.

Furnish, W. M., Barragy, E. J., & Miller, A. K., 1936, Ordovician fossils from upper part of type section of Deadwood Formation, South Dakota: Am. Assoc. Petrol. Geologists, Bull. 20, p. 1329–1341.

Hussey, R. C., 1936, The Trenton and Black River rocks of Michigan: Mich. Geol. Survey, publ. 40, ser. 34, pt. 3, p. 227–260, 8 figs.

———, 1947, Historical Geology: New York, McGraw-Hill Book Co.

———, 1952, The Middle and Upper Ordovician rocks of Michigan: Mich. Geol. Survey, publ. 46, ser. 39, 89 p., 10 pls.

Liberty, B. A., 1968, Ordovician and Silurian stratigraphy of Manitoulin, Ontario, *in* The Geology of Manitoulin Island: Mich. Basin Geol. Soc. Annual Field Excursion.

———, 1969, Paleozoic geology of the Lake Simcoe Area, Ontario: Geol. Survey Canada, mem. 355.

Ørvig, Tor, 1958, *Pycnaspis splendens*, new genus, new species, a new ostracoderm from the Upper Ordovician of North America: Proc. U.S. Natl. Mus., v. 108, p. 1–23.

Pettijohn, F. J., 1957, Sedimentary rocks: New York, Harper & Row.

Robertson, J. D., 1957, The habitat of the early vertebrates: Cambridge Philos. Soc. Biol. Rev., v. 32, p. 156–187.

Rohon, J. V., 1889, Über unter-silurische Fische: Bull. Acad. Imp. Sci., St. Petersburg, new ser., v. 1 (33), no. 2, p. 269–277.

Romer, A. S., & Grove, B. H., 1935, Environment of the early vertebrates: Am. Midl. Naturalist, v. 16, p. 805–856.

Rominger, Carl, 1873, Paleozoic rocks of the Upper

Peninsula: Mich. Geol. Survey, v. 1, pt. 3, p. 1–105.

ROSS, R. J., 1957, Ordovician fossils from wells in the Williston Basin, eastern Montana: U.S. Geol. Survey, Bull. 1021-M, p. 439–510.

SAWIN, H. J., 1959, Notes on the origin of bony armor: Rice Inst. Pamphlet, v. 46, p. 90–108.

SCHOPF, T. S. M., 1966, Conodonts of the Trenton Group (Ordovician) in New York, Southern Ontario, and Quebec: N.Y. State Mus. and Sci. Service, Bull. 405, p. 1–105.

SINCLAIR, G. W., 1958, Occurrence of fish in the Ordovician of Canada: Bull. Geol. Soc. America, v. 69, p. 1644.

SMITH, H. W., 1932, Water regulation and its evolution in the fishes: Quart. Rev. Biology, v. 7, no. 1, p. 1–26.

———, 1953, From fish to philosopher: Garden City, N.Y., Doubleday.

SPJELDNAES, NILS, 1967, The paleoecology of the Ordovician vertebrates of the Harding Formation (Colorado, U.S.A.), *in* Problèmes Actuels de Paléontologie (Évolution des Vertébrés): Colloques int. Cent. natl. Rech. Scient., v. 163, p. 11–20.

SWEET, W. C., 1955, Conodonts from the Harding Formation (Middle Ordovician) of Colorado: Jour. Paleontology, v. 29, no. 2, p. 226–262.

TWENHOFEL, W. H., *et al.*, 1954, Correlation of the Ordovician formations of North America: Bull. Geol. Soc. America, v. 65, p. 247–298.

VANLIER, K. E., & DEUTSCH, MORRIS, 1958, Reconnaissance of the ground water resources of Chippewa County, Michigan: Mich. Geol. Survey, Progress Rpt. 17.

WALCOTT, C. D., 1892, Preliminary notes on the discovery of a vertebrate fauna in Silurian (Ordovician) strata: Bull. Geol. Soc. America, v. 3, p. 153–172.

WHITE, ERROL, 1958, Original environment of the craniates, *in* T. S. Westoll, editor, Studies on fossil vertebrates: London, The Athlone Press.

WINCHELL, ALEXANDER, 1861, First biennial report of the progress of the geological survey of Michigan: 1859–1860: Mich. Geol. Survey, p. 1–210.