ORDOVICIAN VERTEBRATES FROM ONTARIO

Thesis for the Degree of M. S.

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KATHLEEN ANNE LEHTOLA

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ABSTRACT

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By

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Vertebrate fossil fragments found in the northeast part of St. Joseph Island, Ontario, Canada have been referred to *Astraspis desiderata* Walcott on the basis of their stellate tubercles. The fossils are found in shallow marine limestones of Middle Ordovician age. This is the first recorded occurrence of an Ordovician vertebrate in limestone. This find considerably widens the geographic range of *Astraspis* and lends some additional support to the theory of the marine origin of the vertebrates.

ORDOVICIAN VERTEBRATES FROM ONTARIO

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The earliest fossil vertebrates have perplexed several generations of workers. The remains are fragmentary, not at all abundant and, at times, poorly preserved. The earliest recorded occurrence of Ordovician vertebrates was made in Russia by J. V. Rohon (1889), who published a report of 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 have not been studied further but are currently placed in the Order Thelodontia by Russian paleontologists (Ørvig, 1958).

Ordovician fish remains were next discovered in 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 median 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. Furnish and Darton 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_, naming a second species _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 (Thomas E. Bolton, Geological Survey of Canada, pers. comm.). 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 another specimen (UMMP V43936) identified as an ostracoderm by Hussey. It has an outer covering of silica and a carbonate interior (Robert 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*.

Dr. Gerald R. Smith (Associate Curator of Lower Vertebrates, Museum of Paleontology, University of Michigan) granted me permission to study the fragments. They are now again in the Museum of Paleontology collections at the University of Michigan.

This is the third major recorded occurrence of Ordovician vertebrates. It is the first occurrence of *Astraspis* outside of the Cordilleran region of the western United States. It is the first occurrence of an Ordovician vertebrate in limestone. The paleoecological significance of the limestone is that it probably was deposited in the open sea, thus lending support to a salt-water rather than a fresh-water origin of vertebrates.

GEOLOGY

Hall (in Hussey, 1936) first reported rocks of Middle Ordovician age in the Upper Peninsula of Michigan. He 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 Canada (Figure 1).

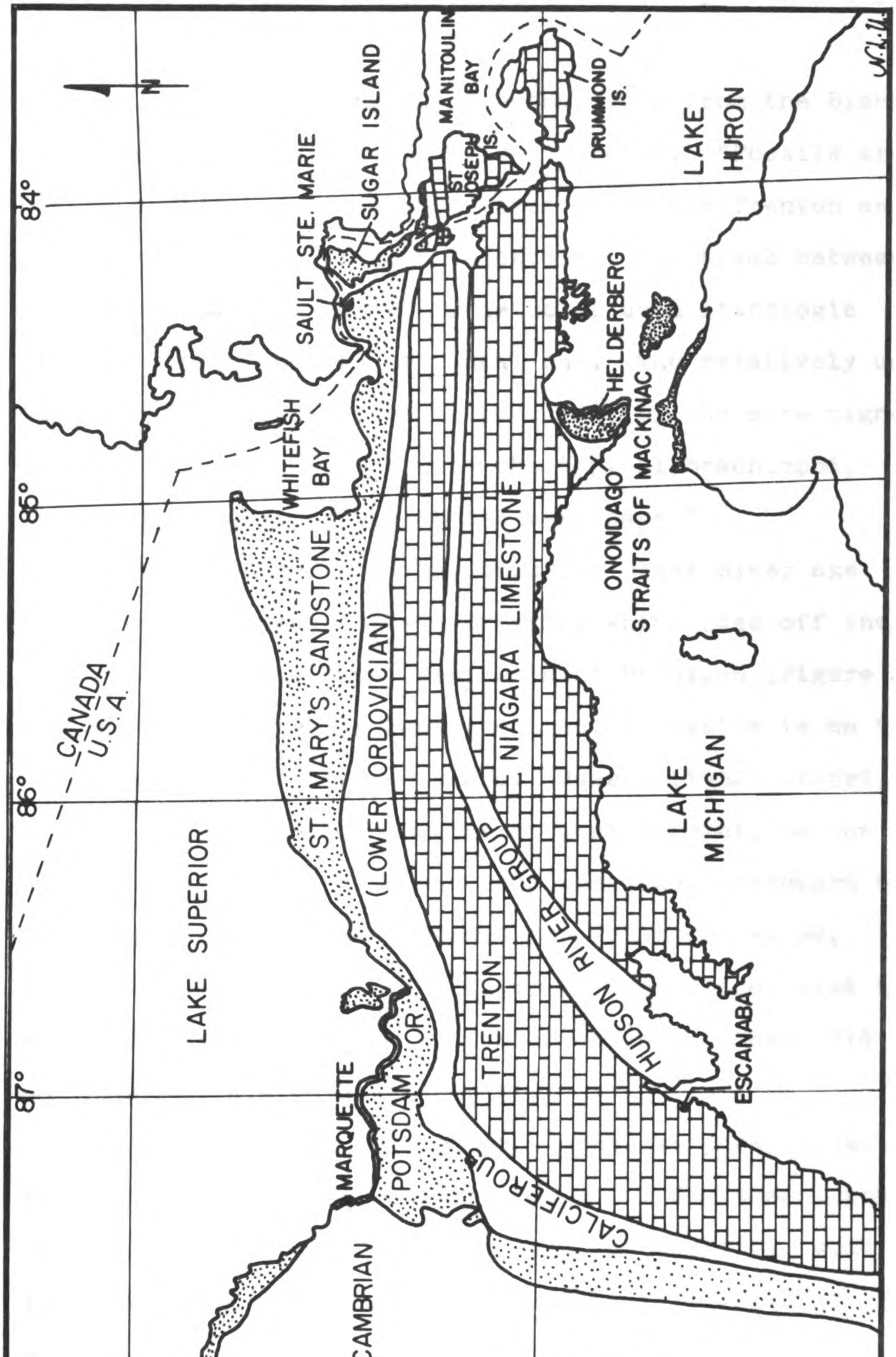
The rock terminology has changed considerably in the literature since Hall's report. Hussey (1936) broke the Trenton Group down to the Black River and Trenton Formations. Martin (1956) elevated the Trenton and Black River Formations to group status (Table 1).

TABLE 1. Stratigraphic relationships of Trenton and Black River rocks.

Series	Group	Formation
Mohawkian	Trenton	Groos Quarry
		Chandler Falls
	Black River	Bony Falls

The Trenton and Black River Groups are mainly limestones and dolomites. The best outcrops in the Upper Peninsula are around Escanaba, in Menominee, Delta, Marquette and Alger Counties. At each of his 86 localities, Hussey (1936, 1952) described the Trenton and Black River Groups, subdividing the outcrops into zones. Zones were differentiated on the basis of lamination, pureness or foreign

FIGURE 1. Paleozoic rocks in the Upper Peninsula of Michigan as mapped by Carl Rominger. (From Michigan Geological Survey, 1873).



N
LAKE SUPERIOR
CANADA
U.S.A.
PRECAMBRIAN
MARQUETTE
POTSDAM OR ST. MARY'S SANDSTONE
CALCIFEROUS (LOWER ORDOVICIAN)
TRENTON GROUP
HUDSON RIVER GROUP
NIAGARA LIMESTONE
WHITEFISH BAY
SAULT STE. MARIE
SUGAR ISLAND
ST. JOSEPH IS.
MANITOULIN BAY
DRUMMOND IS.
HELDERBERG
ONONDAGO
STRAITS OF MACKINAC
LAKE HURON
LAKE MICHIGAN
ESCANABA
47°
46°
88°
87°
86°
85°
84°

FIGURE 1

content of the limestone, color, weathering, faunas and contacts.

In differentiating the Trenton Group from the Black River Group, Hussey (1936, p. 243) stated, "Fossils are not as abundant in the Black River as in the Trenton and are usually more difficult to obtain. The break between the two formations cannot be detected upon lithologic grounds but is entirely a faunal one. The relatively unfossiliferous Black River is succeeded by the more highly fossiliferous Trenton with the typical brachiopod, _Zygospira recurvirostris_ at the very base."

The ostracoderm-bearing rocks of Black River age are from St. Joseph Island, Ontario, which lies off the eastern tip of the Upper Peninsula of Michigan (Figure 2). 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 Figure 2. Unfortunately, Hussey did not pinpoint his collecting site.

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.

FIGURE 2. Eastern tip of the Upper Peninsula of Michigan, including islands in the St. Mary's River. The outcrop area on St. Joseph Island is solidly shaded. (Modified from Vanlier and Deutsch, 1958).

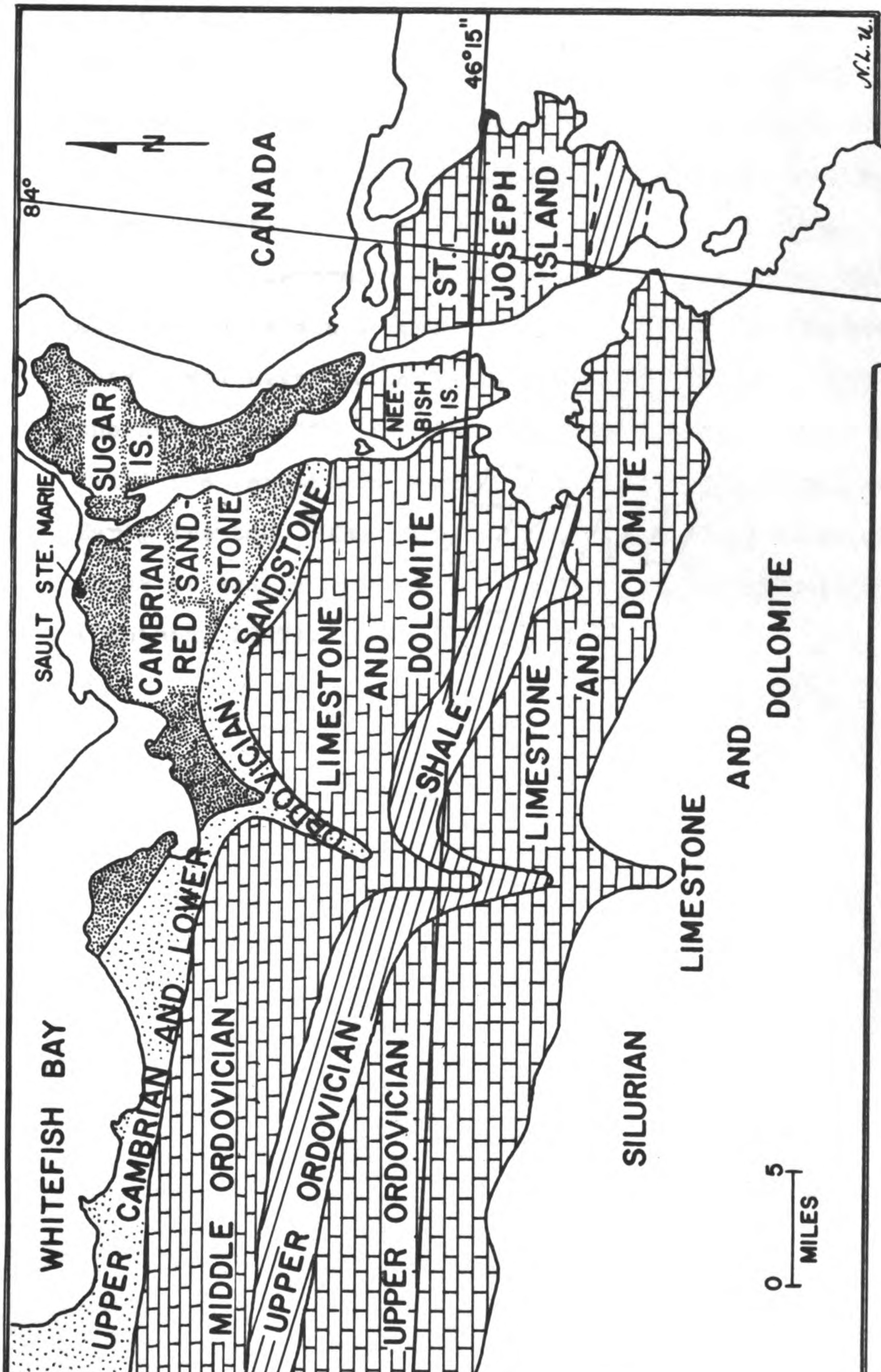

WHITEFISH BAY
UPPER CAMBRIAN AND LOWER ORDOVICIAN SANDSTONE
MIDDLE ORDOVICIAN LIMESTONE AND DOLOMITE
UPPER ORDOVICIAN SHALE
UPPER ORDOVICIAN LIMESTONE AND DOLOMITE
SILURIAN LIMESTONE AND DOLOMITE
CAMBRIAN RED SANDSTONE
SAULT STE. MARIE
SUGAR IS.
NEE-BISH IS.
ST. JOSEPH ISLAND
CANADA
N
84°
46°15"
0
5
MILES
N.L.U.

FIGURE 2

The age of the St. Joseph Island rocks is put at Lower Black River by Hussey (1936), making them slightly older than any of the western vertebrate-bearing rocks. The Harding sandstone of Colorado has been dated at Late Black River or Early Trenton (Walcott, 1892; Kirk, 1930). Furnish (1936) determined that the Black Hills were the same age as the Harding. Darton (1906) called the Bighorns Late Black River or Early Trenton, but Miller (1930) called the Harding-equivalent beds Richmond in age. Ross (1957) dated the vertebrate strata of the Williston Basin as Early Trenton. The oldest known vertebrates still remain those of Russia which are considered Lower Ordovician (Denison, 1967).

SYSTEMATIC PALEONTOLOGY

Astraspis desiderata Walcott, 1892
(Figures 3, 4, 5)

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

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

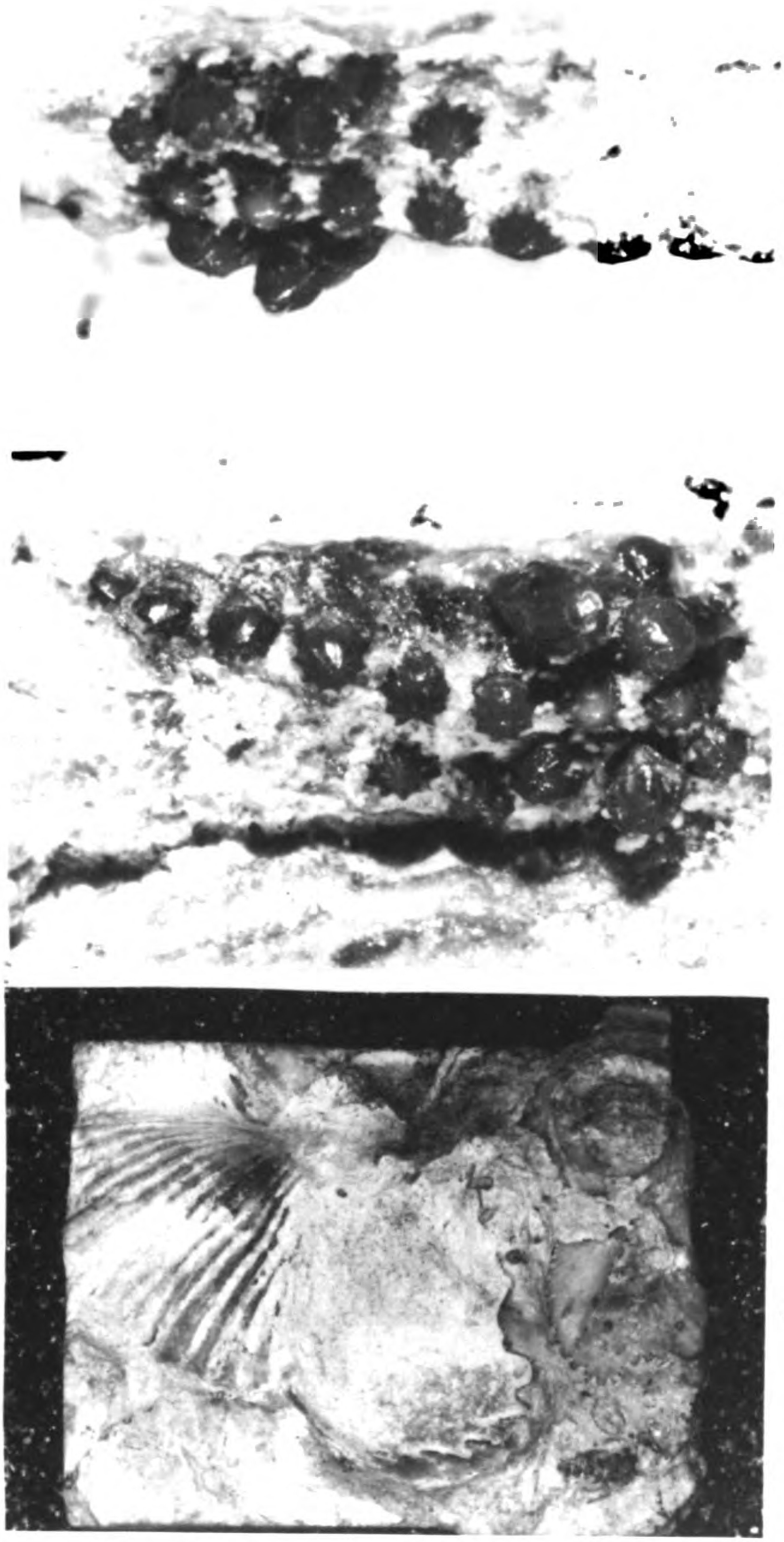
Diagnosis.--The fossils are assigned to the genus *Astraspis* on the basis of tiny, discrete, disarticulated plates with tubercles attached; the tubercles have a central pulp cavity surrounded by laminated dentine. They are assigned to the species *A. desiderata* because the tubercles are small (0.25-0.40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

Remarks.--The ostracoderms occur in a nearly pure limestone, with some detrital quartz. No very large fragments are found, the largest having 16 tubercles in three rows and measuring about 1 by 3 mm. (Figure 3). 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 horizontal to the bony plate beneath because 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 cm^2., and saw cuts in any direction through the plate

FIGURE 3. Three views of an Astraspis plate. Number 3:1 shows the plate in the matrix. Plate is in the upper left corner. Numbers 3:2 and 3:3 are close-ups of that plate in different aspects. 3:1 (x 4); 3:2, 3:3 (x 14.2). Photograph by Mr. Karl Kutasi, University of Michigan.



3

2

1

FIGURE 3

have usually revealed at least one tubercle.

Externally, each tubercle is stellate with a tiny apical knob, and all have a definite pearly lustre (Figures 3 and 4:5). 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 4:1 shows such a division on the front tubercle.

The tubercles are irregularly but closely spaced on the plates. Tubercle sizes are also variable. The size range of tubercles on the plate in Figure 4 is 0.25 to 0.40 mm. Tubercle size ranges for Wyoming specimens is 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.

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 (Figure 5:1). These cavities are surrounded by dentine. Fine laminations in the dentine parallel to the pulp cavity may

FIGURE 4. Five views of a group of tubercles from the dermal armor of an _Astraspis desiderata_ (UMMP V57977), from St. Joseph Island. Couplets 1-3 are stereo pairs; 4-5 are single views. Numbers 1-4 have been treated with silver nitrate. (x 20). Photograph by Mr. Karl Kutasi, University of Michigan.

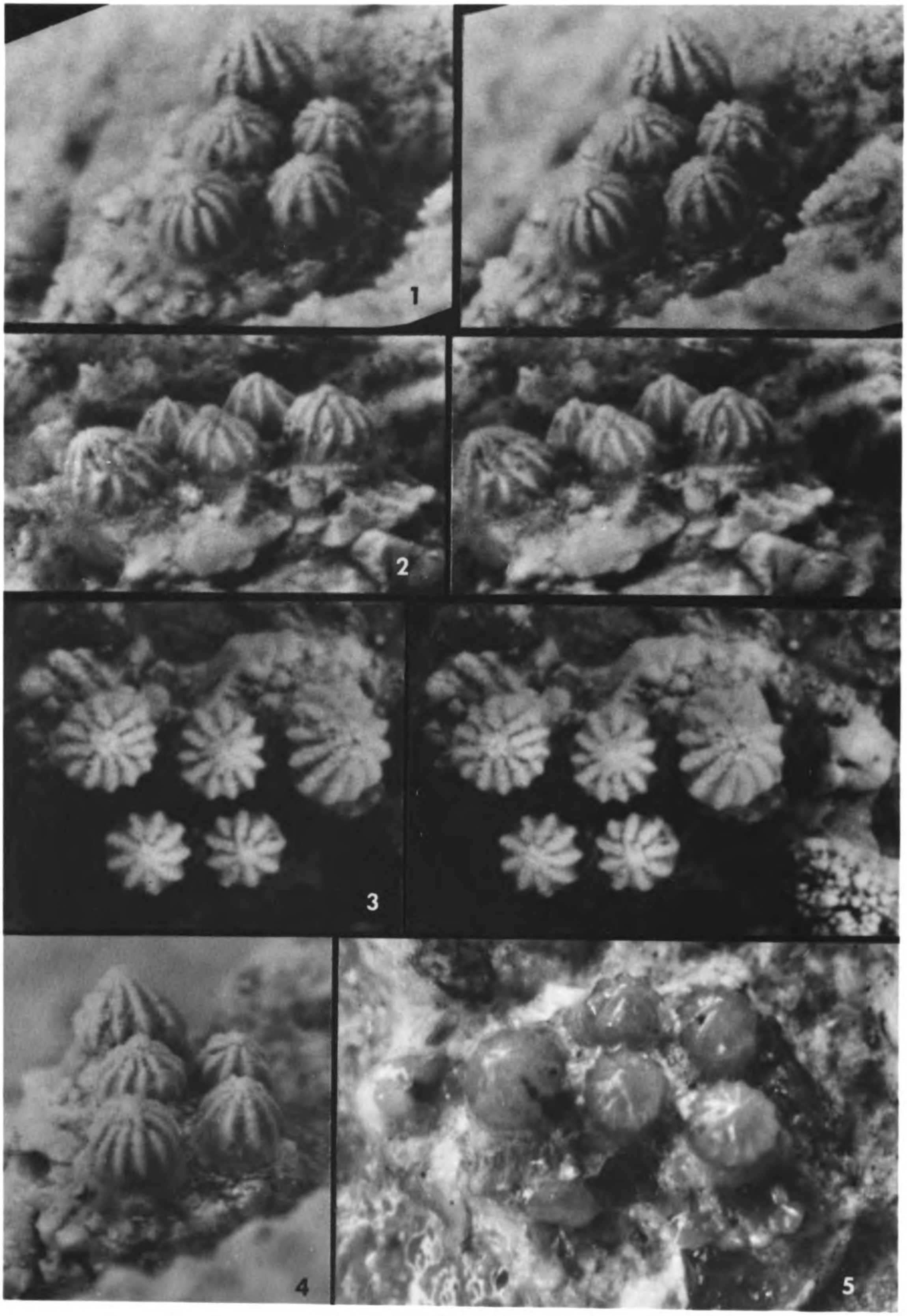
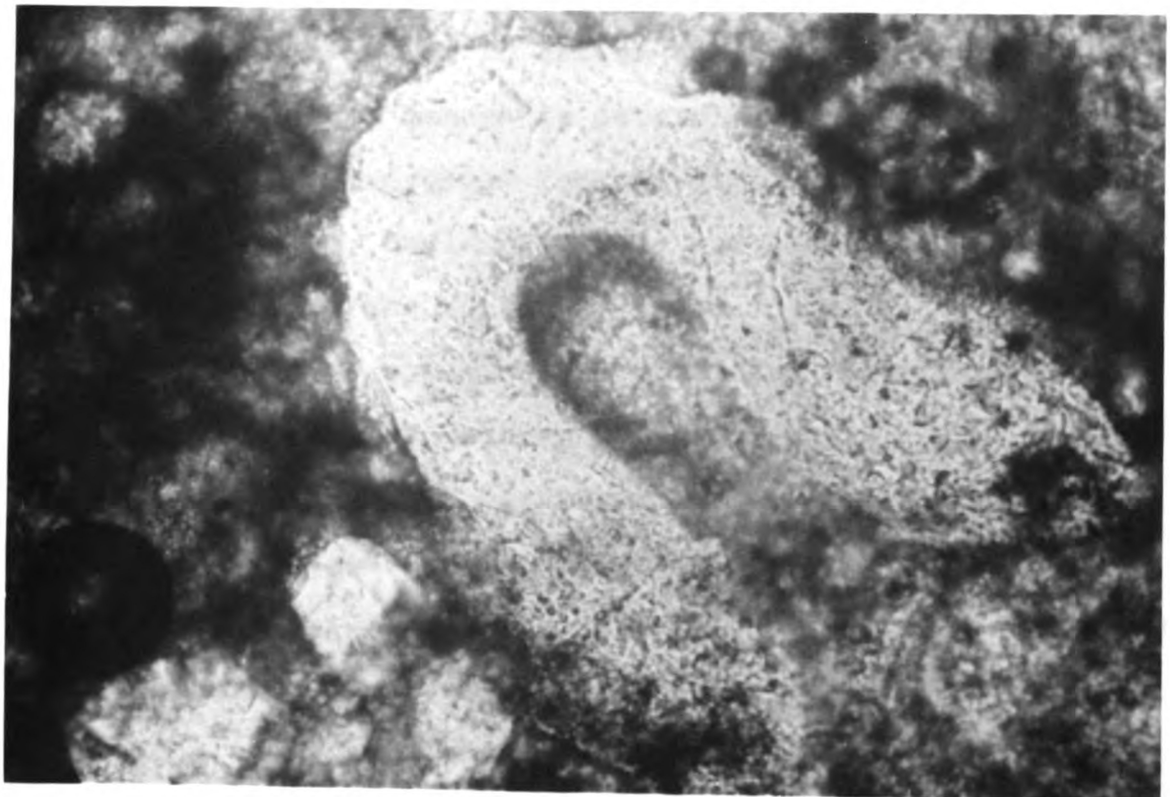


FIGURE 4

FIGURE 5. Astraspis desiderata; showing two views of tubercles: 5:1 in cross section, and 5:2 a horizontally sectioned tubercle. (x 165). Photograph by Mr. Ralph Taggart, Michigan State University.



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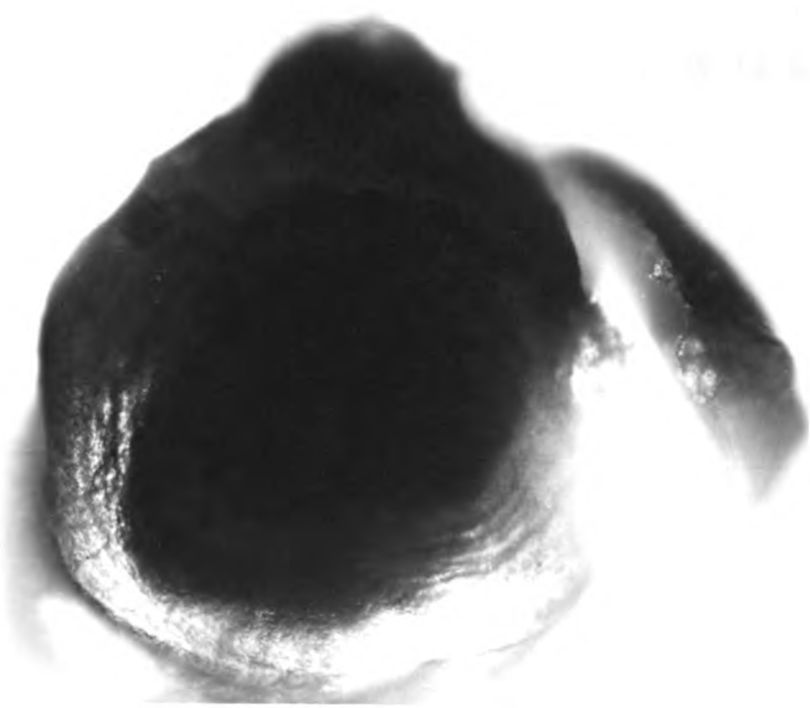

2

FIGURE 5

be seen on a few specimens (Figure 5:2). On one specimen the laminations appear to extend to the outer edge of the tubercle, but this cannot be determined absolutely. No evidence of any amorphous "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 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. But until more information is available about *Astraspis* and its distribution, nomenclatorial recognition of the Black River form is not warranted.

DISCUSSION

The fact that Ordovician vertebrates have been described from three such widely separated localities as Russia, Ontario and the western United States indicates they are much more widely distributed in North America than formerly thought and suggests the possibility of a world-wide distribution. It is interesting to note the occurrence of Astraspis desiderata from both the Cordilleran region of the United States and from Ontario, Canada, marine localities about 1500 miles apart.

The question of a fresh or salt water origin of vertebrates is an old but still controversial one. The first paper to deal specifically with the subject was that of T. C. Chamberlin (1900), who proposed a fluviatile origin for vertebrates based on the basic fusiform shape. He believed the fish developed their shape by living in swiftly flowing currents. In other words, the animal essentially was still and the medium moved past it.

In 1935, Romer and 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 water-worn, Romer and 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. The Russian occurrence of Ordovician vertebrates is mentioned only briefly by Romer and Grove. These fossils occur in the marine glauconitic sands of the Baltic.

In rebuttal to Chamberlin's arguments put forth favoring a fluviatile vertebrate origin, Berry (1925) stated that when fish move through quiet water the same stresses are put on the body as when the water moves past the fish. He also said that, while most existing fish are fusiform, that simply happens to be the shape which slips through the water with the least resistance. Thus fusiform shape cannot be considered as proof of fresh-water vertebrate origin.

Romer and Grove's conclusion as to the fresh-water 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 water-worn, 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., yet the sand is very well sorted. Currents that can sort sand grains so well could have sorted the vertebrates had they been transported. Both Denison and Robertson (1957) disregarded the bulk of Romer and Grove's paper which was a detailed summary of the North American Devonian deposits. By Late Silurian or Early Devonian, evidence is found for the existence of marine and fresh-water vertebrates; thus, by then they are adapted to both modes of life.

Nils Spjeldnaes (1967) would attribute the fragmentation of the vertebrates to bacteria and other scavangers living in the sediments. Another possible 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 would become loose and subject to any water movement. This might account for the fragmentary nature of the Ordovician vertebrates.

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 Formation 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. The Russian vertebrates are in marine glauconitic sands.

Sandstones, shales and siltstones can occur in marine, brackish or fresh-water. Limestones are nearly always 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. Kesling, University of Michigan, pers. comm.; Dr. C. E. Prouty, Michigan State University, pers. comm.). Paleogeographic maps (Figure 6) 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 ribbon-like cryptostome bryozoan, and a colonial coral. No

FIGURE 6. Paleogeographic map of North America. Solid black areas are Middle Ordovician outcrops; cross-hatching is thought to be the extent of the epicontinental seas. (From Chamberlin and Salisbury, 1930).

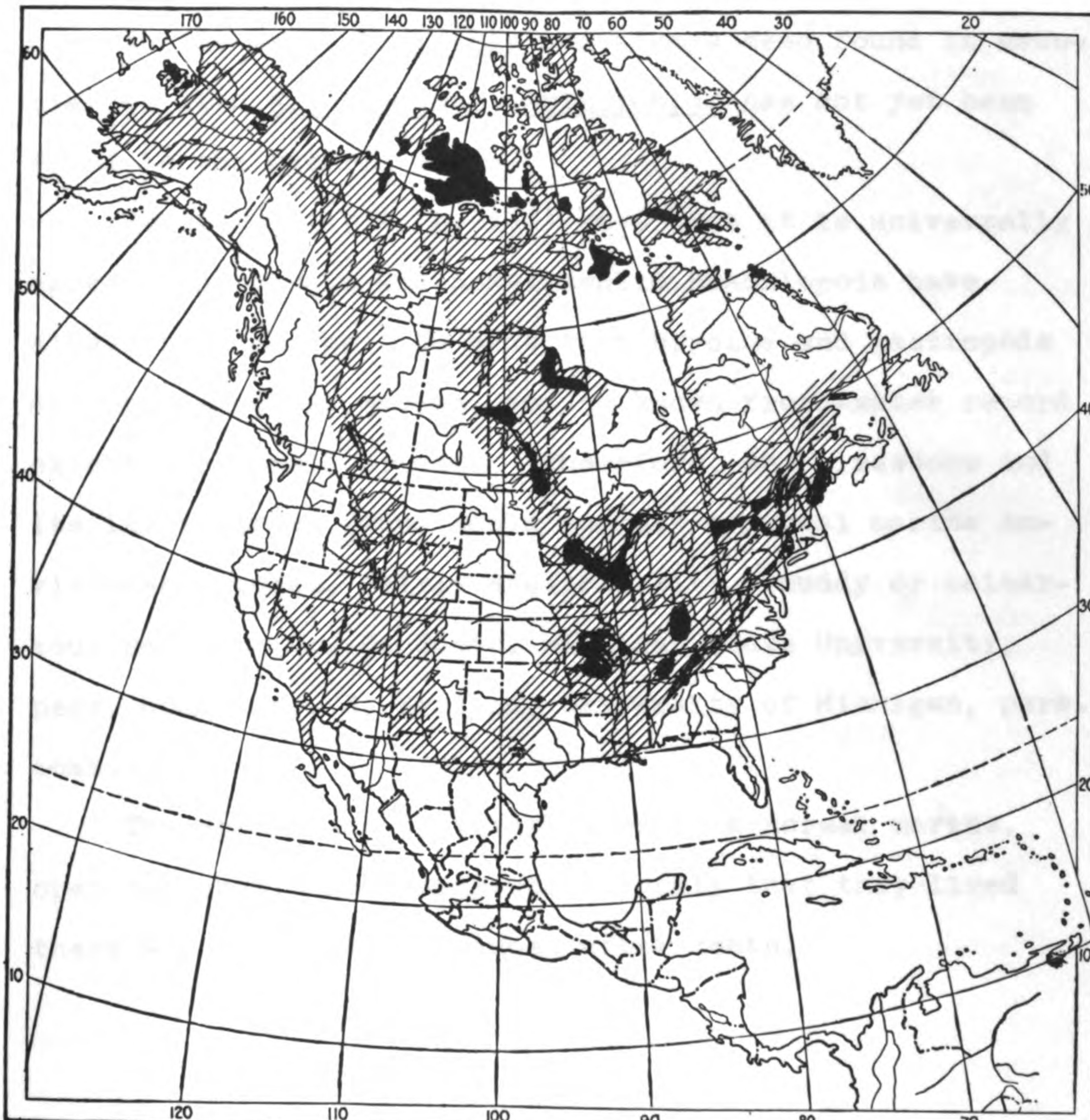
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FIGURE 6

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.

Robertson (1957, p. 158) says that it is universally agreed that corals and non-lingulid brachiopods have always been marine. He adds that bryozoa and gastropods are predominately marine, and no known fresh-water record exists for fossil bryozoa. Therefore, the limestone and its invertebrate fauna would suggest a normal marine environment, quiet, fairly shallow, with a muddy or calcareous bottom (Dr. H. Scott, Michigan State University, pers. comm.; Dr. R. Kesling, University of Michigan, pers. comm.).

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

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