ADDITIONAL LATE SILURIAN OSTRACODERMS FROM THE LEOPOLD FORMATION OF SOMERSET ISLAND NORTH WEST TERRITORIES, CANADA

by E. J. LOEFFLER *and* B. JONES

ABSTRACT. An ostracoderm fauna which includes *Tolypelepis leopoldensis* sp. nov., *Corvaspis* cf. *C. arctica* Loeffler and Dinely, and ?*Kallostrakon* sp. indet. occurs 30 m above the base of the Leopold Formation on Somerset Island in the Canadian Arctic Archipelago. Associated ostracods and conodonts indicate a Late Ludlovian or Pridolian age for the ostracoderm horizon. Although the lithology of the enclosing sediment suggests that it accumulated in intertidal conditions, the ostracoderms were not necessarily inhabitants of such an environment; some post-mortem transportation of the bony plates may have taken place.

THE ostracoderms described in this paper were collected 30 m above the base of the Leopold Formation, approximately 75 m above sea level, at Port Leopold (text-fig. 1) on Somerset Island. This locality was briefly described by Jones and Dixon (1975, p. 403) but, because of a typographical error, its position was given as 75 m above the base of the Leopold Formation. Vertebrates were first discovered here in 1971, by Dr. O. A. Dixon of the University of Ottawa, but a more extensive collection was made when the authors revisited the site in 1973.

The Leopold Formation comprises a complex succession of dolostone, limestone, and sandstone which probably accumulated in supratidal/intertidal conditions. It is becoming apparent that heterostracan ostracoderms were common and quite widespread during the period when these sediments were laid down. A fauna containing *Archegonaspis* cf. *A. schmidti* Geinitz, *Homalaspidella* cf. *H. borealis* Denison, Cyathaspididae indet. and Heterostraci indet. occurs at a higher stratigraphic level on the eastern side of the bay at Port Leopold (Loeffler and Jones 1976), and ostracoderms were found at four additional sites during the 1975 field season (text-fig. 1).

SUCCESSION AND DEPOSITIONAL ENVIRONMENTS

The section in which these ostracoderms were found (text-fig. 2) comprises rocks containing dolomite, calcite, quartz, shell debris, and minor quantities of muscovite. Petrographic analysis suggests that the original sediment was a lime mud, with which small quantities (generally less than 15%) of angular to subangular quartz grains (up to 0·15 mm longest axis, averaging 0·05–0·10 mm) and flakes of muscovite were intermixed. Dolomitization and the formation of evaporites occurred subsequently, probably at an early stage in the post-depositional history of the sediment, leading to the complex lithologic assemblage now found.

Dolomite is most common in the basal 30 m of the section (text-fig. 2, units 1–13),

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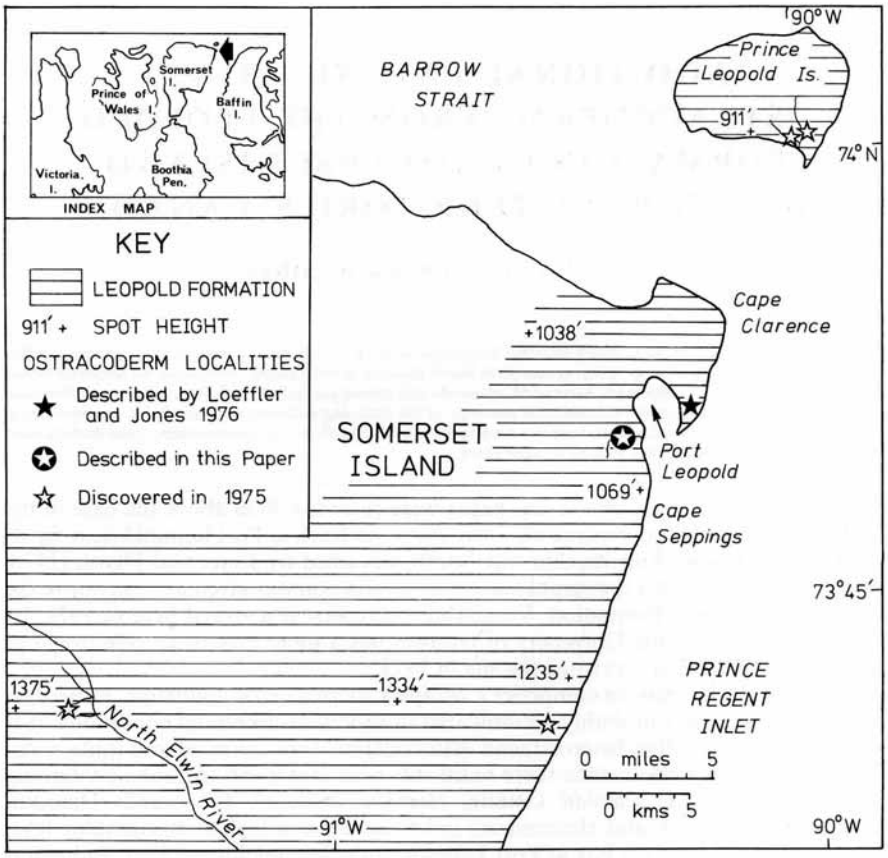
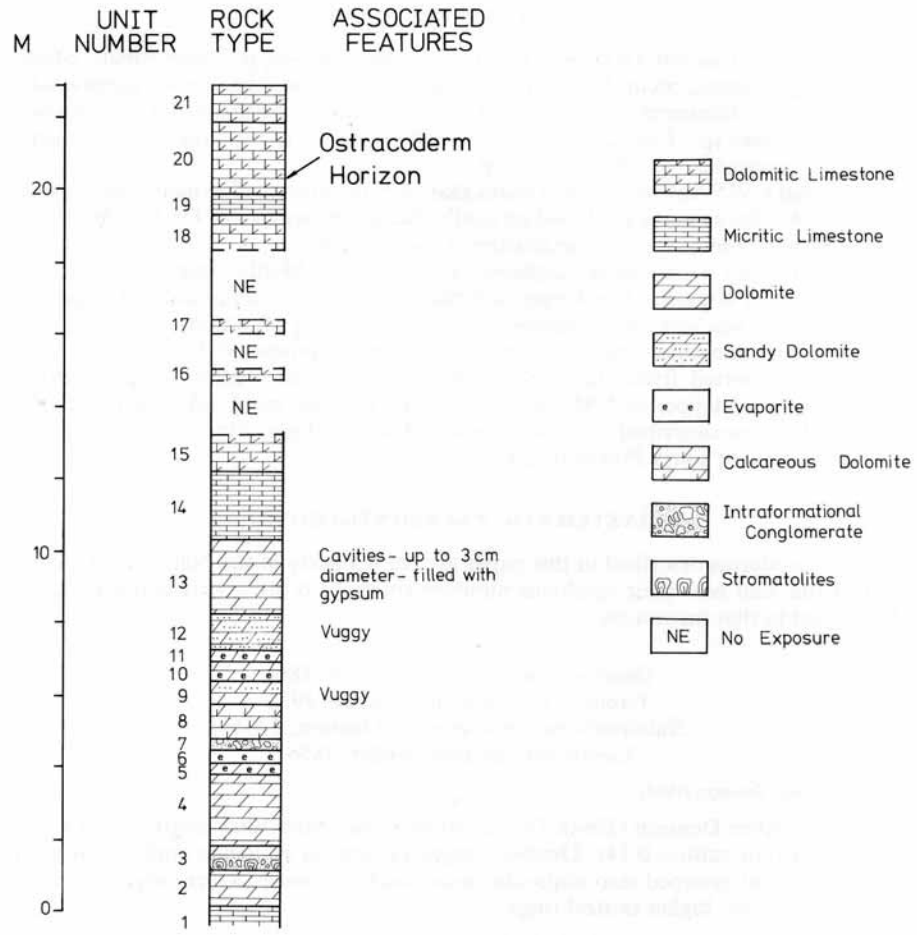


TEXT-FIG. 1. Map of north-eastern Somerset Island, showing ostracoderm localities in the Leopold Formation.

where it is closely associated with evaporites, the latter being restricted to this interval. At the present day, the synchronous formation of dolomite and evaporites is generally associated with sabkha-like environments, as exemplified by the Persian Gulf area (Bathurst 1971, pp. 205–211). The detrital quartz and muscovite may have been brought into the area from the near-by landmass (Jones and Dixon 1975) by intermittent currents or local winds.

Immediately above the evaporite–dolomite part of the sequence, there is a marked decrease in the amount of dolomite, and a complete absence of evaporites. Units 14–21 thus mark a change in depositional conditions, the sabkha-like environment



TEXT-FIG. 2. Measured section, commencing above second waterfall in gorge on the west side of the bay at Port Leopold, showing lithological divisions and the position of the ostracoderm horizon. The base of the section is approximately 10 m above the base of the Leopold Formation.

having been replaced by one in which dolomite formation was minimal and evaporite formation had ceased. The same part of the sequence also contains evidence of more favourable biotic conditions; pellets are present in some units (e.g. unit 17) and shell fragments (primarily ostracods) in others. Together these facts suggest that units 14–21 accumulated in the intertidal environment, possibly in a tidal flat zone.

ASSOCIATED FAUNA

In the measured section (text-fig. 2), unit 20 is the only unit in which fossils, other than shell fragments, occur. Dr. M. J. Copeland has identified the following ostracods (since they are steinkerns, specific identifications could not be made): *Dizygopleura?* sp., *Cytherellina* sp., *Eukloedenella* sp., *Kloedenia* sp. of '*K*'. *montaguensis* (Weller) type, *Zygobeyrichia?* sp., *Baschkirina* sp.

Copeland (1975, written comm.) states that 'A Late Silurian, Cayugan, age is most probable for this assemblage, based on similar faunas present in the Decker, Manlius, and Cobleskill limestones of northeastern United States'.

The conodont *Ozarkodina confluens* (Branson and Mehl), approaching the ϵ morphotype of Klapper (*in* Klapper and Murphy 1974) occurs in unit 20, together with the ostracods and ostracoderms. According to Dr. T. T. Uyeno (1975, written comm.), who identified the conodonts, 'the ϵ morphotype of *O. confluens* was previously reported from the level of the *Pelekysgnathus index* fauna, of early Pridolian age (Klapper and Murphy 1974). The Port Leopold individuals are not exactly like those described from the Roberts Mountain Formation, but may suggest a Late Ludlow or Early Pridolian age.'

SYSTEMATIC PALAEONTOLOGY

The ostracoderms described in this paper are the property of the National Museum of Canada, and bear their catalogue numbers (prefixed NMC); they will eventually be housed in that institution.

Order HETEROSTRACI Lankester, 1868
Family CYATHASPIDIDAE Kiaer, 1932
Subfamily TOLYPELEPIDINAE Denison, 1964
Genus TOLYPELEPIS Pander, 1856

Synonymy. See Denison (1964).

Diagnosis. After Denison (1964). Dorsal shield broad, preorbital length rather short (orbital length ratio = 0·14). Dentine ridges of central epitegum and postrostral field short and grouped into scale-like areas, with narrower, lower ridges grouped around a coarse, higher central ridge.

Type species. *Tolypelepis undulatus* Pander (1856).

Tolypelepis leopoldensis sp. nov.

Plate 80, figs. 3–6

Derivation of name. *Leopoldensis*, from Port Leopold.

Synonymy. *Ptomaspis* sp. nov. (Loeffler, *in* Jones and Dixon 1975).

Diagnosis. Dorsal shield 35 mm long, with width ratio of 0·77. Dentine ridges rather narrow (average 7 per mm) and of low relief over most of the dorsal shield, but wider (4/mm) on the rostrum; posterior scale-like units large and intricately ornamented.

Holotype. Dorsal shield, NMC 21635 (Pl. 80, fig. 5; text-fig. 3).

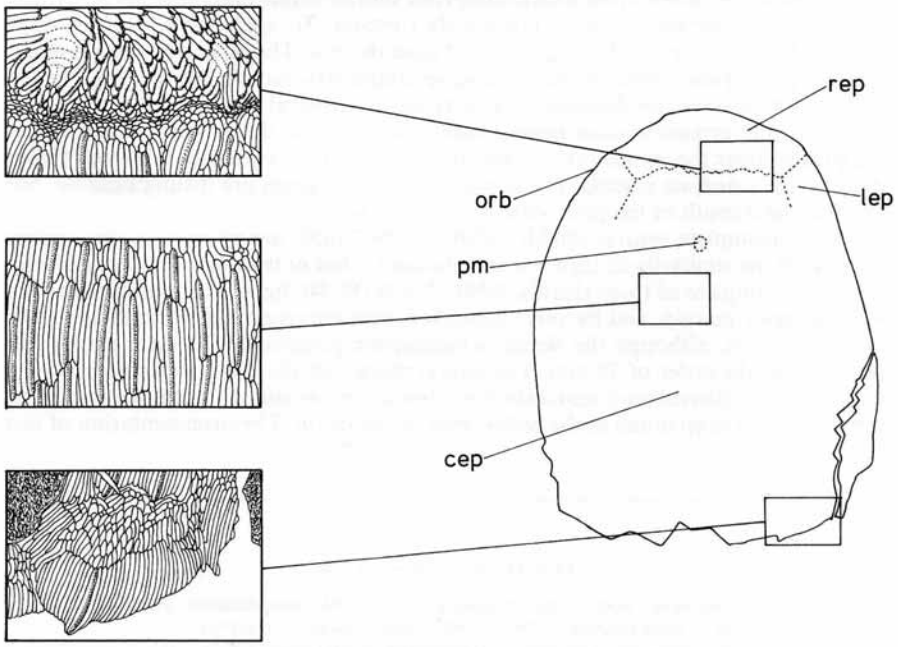
Other material. Three incomplete ventral shields, NMC 21636–21638; an isolated scale, NMC 21639.

Locality. Thirty metres above the base of the Leopold Formation, on the west side of the bay at Port Leopold, Somerset Island (text-fig. 1).

Description. Dimensions of holotype dorsal shield (parameters selected for measurement are the same as those used by Denison 1964):

Median length	35 mm		
Maximum width	27 mm	Width ratio	0·77
Orbital width	20 mm	Orbital width ratio	0·57
Orbital length	5 mm	Orbital length ratio	0·14
Pineal length	11 mm	Pineal length ratio	0·31

The dorsal shield is broad and flat, with a smoothly rounded rostral margin and shallow orbital notches. Its outline has undoubtedly been distorted somewhat by crushing, but maximum width was probably achieved at about mid-length. Although the boundary between the central and the lateral epitega is obscured by damage to the shield, other epitegal divisions are conspicuous; the opposing epitegal margins



TEXT-FIG. 3. *Tolypelepis leopoldensis* sp. nov. Holotype dorsal shield (NMC 21635), showing variation in ornamentation. Plan ×2, detail ×6. *cep*—central epitegum; *lep*—lateral epitegum; *orb*—position of orbital notch; *pm*—position of pineal body; *rep*—rostral epitegum.

are bordered by minute tubercles, particularly distinct along the boundary between the central and the rostral epitegum (text-fig. 3).

The ornamentation of the rostral epitegum comprises dentine ridges of uniform height, which are broad (4 per mm) and transverse anteriorly; posteriorly, they are narrower and divided into short lengths which have longitudinal and oblique orientations (text-fig. 3). On the lateral epitega, several continuous ridges are parallel to the margin of the shield; other ridges approach a longitudinal orientation and may be divided into short lengths. In the orbital region, broad (4 per mm) ridges curve around the orbital notch and small tubercles are present to its anterior and posterior. On the central epitegum, including the postrostral field, ridges are divided into short lengths, and grouped into areas which become more scale-like towards the posterior margin of the shield. Within these groupings, the median ridge is commonly wider, higher, and sharper crested than the peripheral ones, although the relief of all of the ridges is rather low. Immediately behind the pineal region, individual groups of ridges are longer and narrower than on the rest of the central epitegum, where 2–3 mm long and 1·5 mm wide is the typical size. Towards the posterior of the central epitegum, the groups of ridges take on an imbricated appearance closely resembling fused scales. These rhomb-shaped, scale-like areas are each approximately 5 mm in diameter, and have intricate ornamentation which comprises shorter ridges and tubercles anteriorly and longer, longitudinal ridges posteriorly (text-fig. 3); each has a median ridge which is higher, wider, and sharper crested than the rest. The posterior margin of the shield is incomplete, some of the fused scales apparently having become detached.

It is not possible to distinguish a separate postrostral field within the central epitegum, the ornamentation being gradational. Several short, longitudinal ridges are present over the pineal region, and the surrounding ridges curve around these; there is not a distinct macula. No lateral line sensory pores are distinguishable, but this may be a result of the poor state of preservation.

Three incomplete ventral shields, NMC 21636–21638, are referred to this species because of the similarity of their ornamentation to that of the holotype dorsal shield. The most complete of these shields, NMC 21636 (Pl. 80, fig. 6) has a deep concavity in its anterior margin, and its anterolateral corners are truncated. Its median length exceeds 28 mm, although the shield is incomplete posteriorly; its total length was probably in the order of 35 mm. The lateral margin of the shield comprises a long, straight, anterolateral part, and a shorter, straight, posterolateral part, the two being separated by a deep notch at the widest part of the shield. The ornamentation of this

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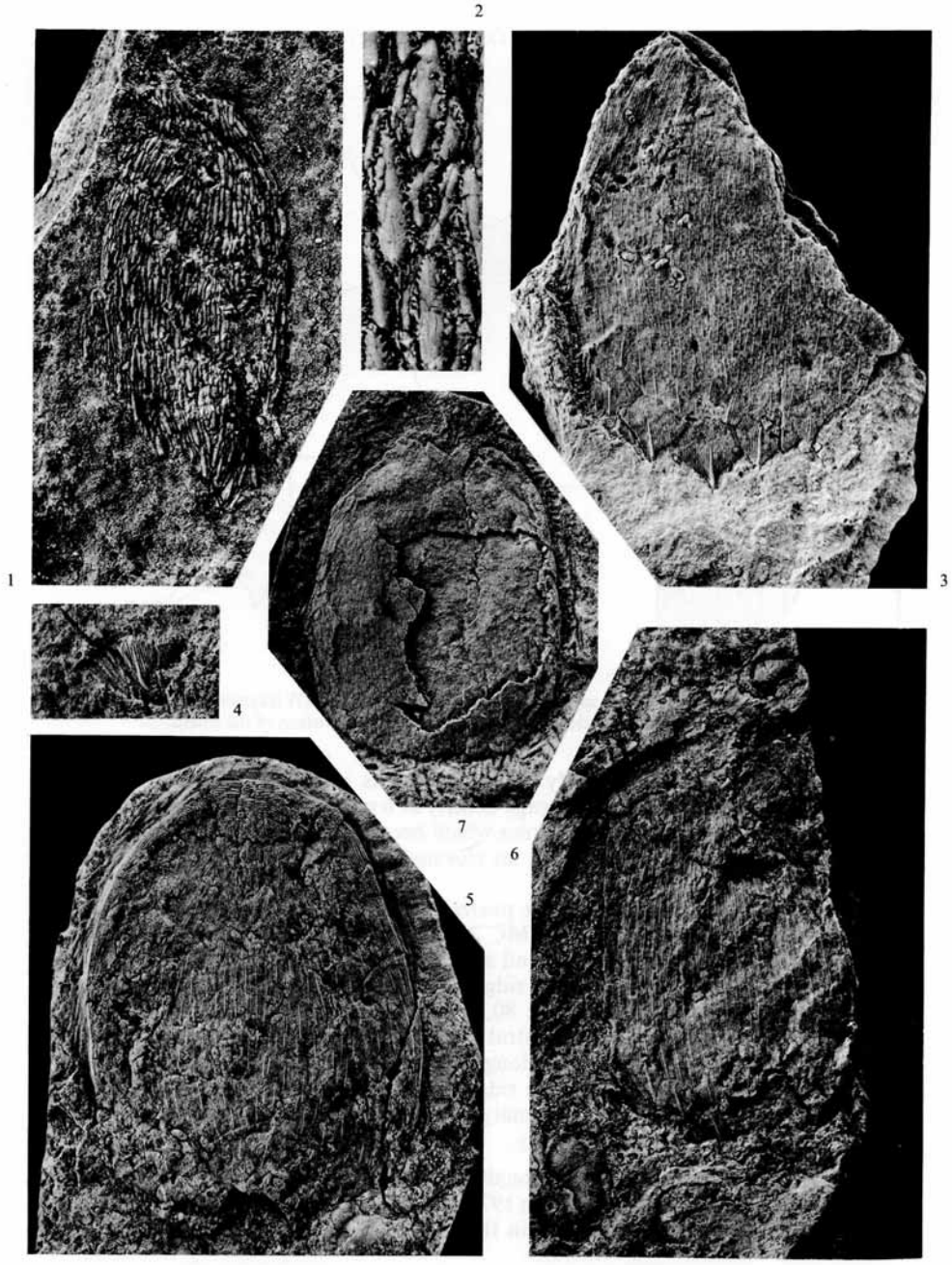
EXPLANATION OF PLATE 80

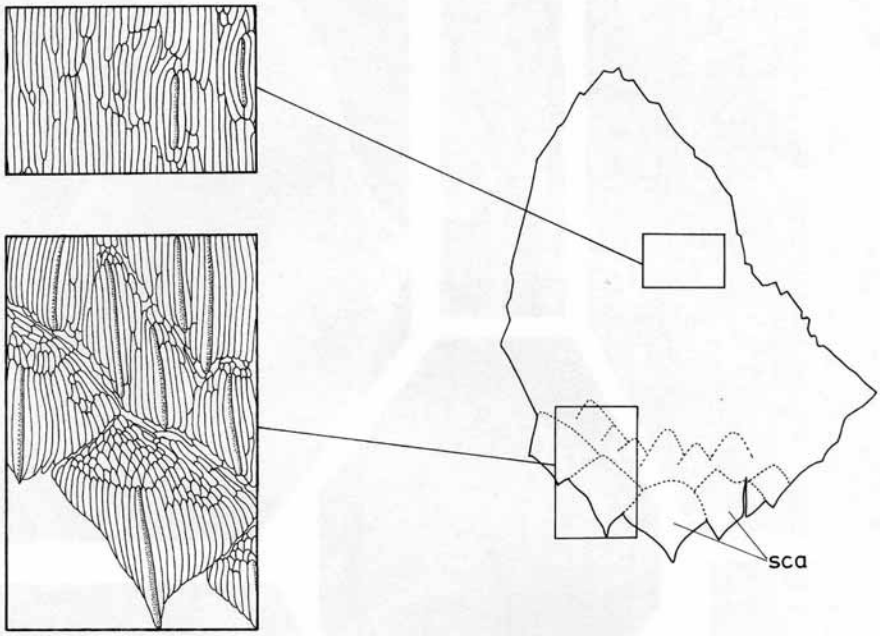
Figs. 1, 2. ?*Kallostrakon* sp. indet. 1, plate fragment (NMC 21648); magnification ×2 approx. 2, detail of ornamentation on plate fragment (NMC 21648); magnification ×12 approx.

Figs. 3–6. *Tolypelepis leopoldensis* sp. nov. 3, fragment of ventral shield (NMC 21637); magnification ×2 approx. 4, isolated scale (NMC 21639); magnification ×2 approx. 5, holotype dorsal shield (NMC 21635); magnification ×2 approx. 6, ventral shield (NMC 21636); magnification ×2 approx.

Fig. 7. *Corvaspis* cf. *C. arctica* Loeffler and Dineley. Median plate (NMC 21642); magnification ×1 approx.



LOEFFLER and JONES, Silurian ostracoderms



TEXT-FIG. 4. *Tolypelepis leopoldensis* sp. nov. Ventral shield (NMC 21637) fragment, showing scale-like subdivisions. Plan ×2, detail ×6. *sca*—scale-like subdivisions of the shield.

specimen (NMC 21636) is poorly preserved, but is seen to comprise short, non-uniform dentine ridges with an average density of 6 per mm. Over the greater part of the shield, these are grouped into areas which become progressively more scale-like towards the posterior of the shield; an elevated ridge occupies a median position within each group.

As on the dorsal shield, the most posterior scale-like areas have an imbricated appearance; this is best shown in NMC 21637, where the fused scales are approximately 5 mm long and 6 mm wide and are separated from an area of less scale-like ornamentation by a narrow band of ridges and tubercles (text-fig. 4).

An isolated scale, NMC 21639 (Pl. 80, fig. 4), which resembles the more posterior scale-like units of the dorsal and ventral shields, is also referred to this species. The scale, which is approximately 4 mm long and 6 mm wide, is asymmetrical. Its ornamentation is of longitudinal dentine ridges, one being more elevated than the rest and extending beyond the posterior margin as a spur. It is not possible to determine the position of this scale on the body.

Remarks. This material was provisionally identified as a new species of *Ptomaspis* Denison (Loeffler, *in* Jones and Dixon 1975), but more detailed examination indicates that it is better accommodated within the genus *Tolypelepis* Pander. Although the

ornamentation is finer and of lower relief, and the anterior scale-like groupings are less distinct than in the two established species (*T. undulata* Pander and *T. lenzi* Dineley and Loeffler), there are no features which exclude this species from *Tolypelepis*, as defined by Denison (1964).

cf. *Tolypelepis leopoldensis* sp. nov.

Material. Two incomplete ?ventral shields, NMC 21640–21641.

Locality. Thirty metres above the base of the Leopold Formation, on the west side of the bay at Port Leopold, Somerset Island (text-fig. 1).

Description. The two shields have very similar ornamentation to that developed in *T. leopoldensis* sp. nov., but they differ in shape, both from one another and from the three ventral shields which are referred to the latter species. NMC 21640 is a ?ventral shield approximately 29 mm long and 19 mm wide; its lateral margins are concave, such that the shield is narrowest some 7–8 mm behind the anterior margin, the latter being transverse but for a shallow median concavity. The poorly preserved ornamentation comprises short, relatively narrow (6/mm), dentine ridges which are not of uniform height; they are locally grouped into scale-like areas. The larger, but less complete, plate (NMC 21641) has the same sort of ornamentation, but its lateral margins are more deeply indented than those of NMC 21640, and its anterior margin is transverse with anterolateral notches. The plate is over 35 mm long and 29 mm wide, the border of short ridges and tubercles around the anterior and lateral margins suggesting that these are natural edges.

Remarks. This material was originally referred, along with the species with which it is compared, to the genus *Ptomaspis* (Loeffler, *in* Jones and Dixon 1975). In view of the differences in shape of the two shields, and the similarity in ornamentation to *T. leopoldensis* sp. nov., they are considered best accommodated by use of open nomenclature.

Family CORVASPIDIDAE Dineley, 1953
Genus CORVASPIS Woodward, 1934
Corvaspis cf. *C. arctica* Loeffler and Dineley

Plate 80, fig. 7

Material. Four incomplete median plates, NMC 21642–21645; an indeterminate fragment, NMC 21647; impression of plate fragment, NMC 21646.

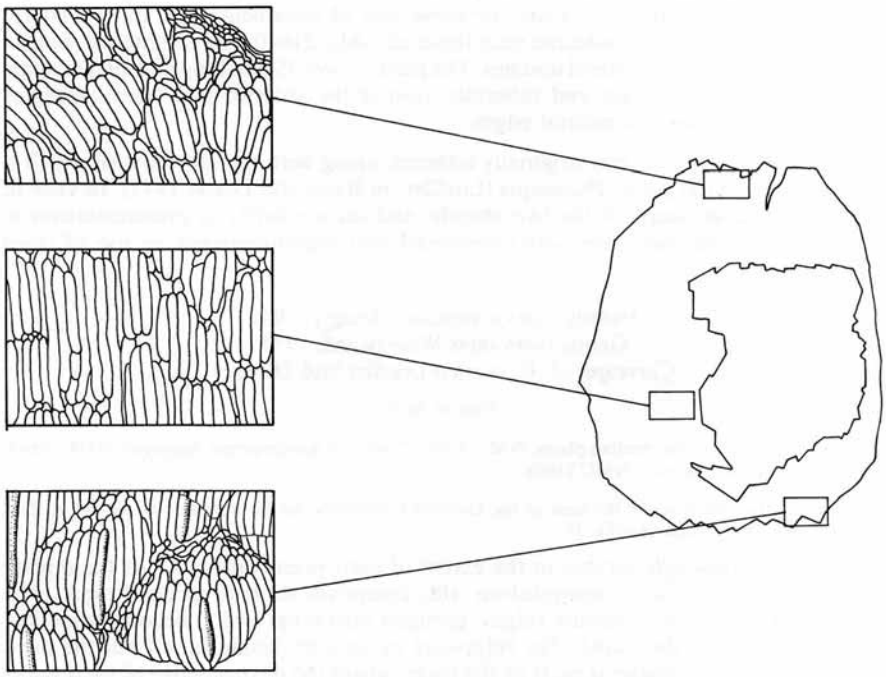
Locality. Thirty metres above the base of the Leopold Formation, on the west side of the bay at Port Leopold, Somerset Island (text-fig. 1).

Description. Although varying in the extent of their preservation, all of these plate fragments bear similar ornamentation; this comprises short (average 2 mm), relatively coarse (3–4/mm) dentine ridges, grouped into areas which become scale-like at the posterior of the shield. The ridges are of uniform height on all but the most posterior and posterolateral parts of the plate, where the median ridge of each scale-like area is sharper crested than are the peripheral ridges.

The best preserved of the plates, NMC 21642, is 48 mm long and 40 mm wide,

although the left side is apparently crushed. The anterior margin has a deep median notch, and the anterolateral corners are truncated. The over-all orientation of the dentine ridges on the plate is approximately longitudinal, with slight convergence on the mid-line towards the posterior, and stronger divergence around the median notch on the anterior margin. Over much of the area of the plate, ornamentation is of short (1·5–2·5 mm) straight dentine ridges which are grouped into areas or 'tesserae' approximately 2 mm wide and 4 mm long (text-fig. 5). Towards the posterior and posterolateral margins of the plate, the tesserae take on a more scale-like appearance and, within each, the median ridge is more sharply crested than the peripheral ridges. At the posterior margin of the plate, these scale-like units are up to 5 mm wide and have complex ornamentation, comprising short ridges anteriorly and longer ridges posteriorly. The anterior, anterolateral, and much of the lateral margin of the shield is bordered by a narrow band (0·5–1·0 mm) of tiny tubercles (text-fig. 5).

Other plate fragments, being less complete, show correspondingly less detail of the tuberculated border and of the scale-like areas. In NMC 21643, the scale-like areas are well developed at the posterolateral extremity of the plate, but are separated from areas of more typical ornamentation by an irregular band of short ridges. In NMC

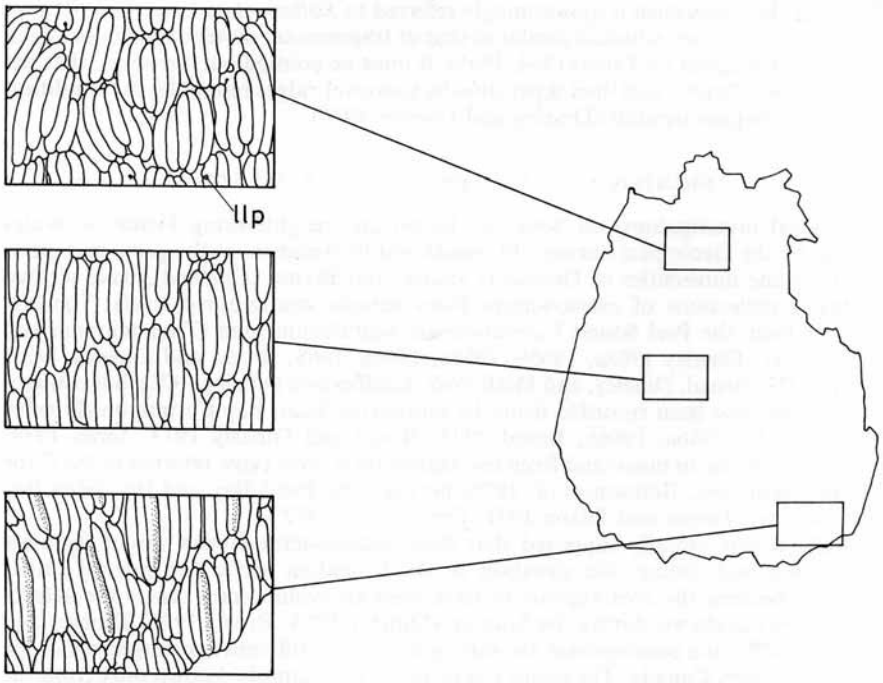


TEXT-FIG. 5. *Corvaspis* cf. *C. arctica* Loeffler and Dineley. Median plate (NMC 21642) showing variation in ornamentation. Plan ×1, detail ×6.

21644, the dentine ridges are commonly contorted in the region of the lateral line sensory pores (text-fig. 6). The more peripheral ridges of individual tesserae on the front of the shield in both NMC 21643 and 21644 are curved around the median ridge.

Remarks. This material is referred to *Corvaspis* Woodward because its ornamentation comprises short dentine ridges which are grouped into tesserae. Although originally (Loeffler, *in* Jones and Dixon 1975) compared with the type species, *C. kingi* Woodward, it is closer to the recently established *C. arctica* Loeffler and Dineley (1976) by virtue of the presence of scale-like areas towards the posterior of the shield. It does differ from *C. arctica*, however, in at least two respects: its dentine ridges are, on average, slightly coarser (3–4/mm as opposed to 4–5/mm) and its scale-like areas each have a sharp-crested median ridge. The importance of these differences is difficult to assess, as *C. arctica* is known only from dorsal shields.

There is also a marked similarity between this material and that which has been referred to *T. leopoldensis* sp. nov. The main differences are in the coarseness of the dentine ridges and in the distinctness of the tesserae in *Corvaspis*, also in the restriction of the sharper-crested ridges to within the most posterior scale-like areas.



TEXT-FIG. 6. *Corvaspis* cf. *C. arctica* Loeffler and Dineley. Median plate (NMC 21644) showing variation in ornamentation. Plan ×1·5, detail ×6. *llp*—lateral line sensory pore.

It has been suggested elsewhere (Loeffler and Dineley 1976) that *Corvaspis* is related to the primitive cyathaspidids; this may represent an intermediate form, but its exact status remains uncertain without knowledge of the morphology of the dorsal shield, particularly of the form of the orbital region.

Family TESSERASPIDIDAE Berg, 1955

?*Kallostrakon* sp. indet.

Plate 80, figs. 1, 2

Material. A plate fragment, NMC 21648.

Locality. Thirty metres above the base of the Leopold Formation, on the west side of the bay at Port Leopold, Somerset Island (text-fig. 1).

Description. The plate fragment, which is 34 mm long and 17 mm wide, has an ornamentation of rather irregular, bulbous, ridges with minutely serrated lateral margins; in some areas, these are closely spaced, but in others are interspersed with narrower ridges. The over-all pattern of ridges is longitudinal, with slight convergence both anteriorly and posteriorly.

Remarks. This specimen is questioningly referred to *Kallostrakon* Lankester because of its ornamentation, which is similar to that of fragmentary material which has been placed in that genus by Tarlo (1964, 1965). It must be pointed out, however, that the shape of the tubercles and their separation by narrower ridges resembles the condition in certain traquairaspidids (Dineley and Loeffler 1976).

SIGNIFICANCE OF THE VERTEBRATE FAUNA

Geological investigations on Somerset Island and neighbouring Prince of Wales Island, by the Geological Survey of Canada and by members of the geology departments of the universities of Ottawa (Canada) and Bristol (England), have yielded extensive collections of ostracoderms from various stratigraphic levels. The collections from the Peel Sound Formation are well documented (Thorsteinsson and Tozer 1963; Dineley 1965*a*, 1965*b*, 1966*a*, 1966*b*, 1968; Broad and Dineley 1973; Broad 1973; Broad, Dineley, and Miall 1968; Loeffler and Dineley 1976), but ostracoderms have also been recorded from the underlying Read Bay Formation (Dineley 1965*a*, 1965*b*, 1966*a*, 1966*b*; Broad 1973; Broad and Dineley 1973; Jones 1974; Jones and Dixon, in press) and from the 'transitional beds' (now referred to the Cape Storm Formation, Reinson *et al.* 1976) between the Read Bay and the Allen Bay Formations. (Turner and Dixon 1971; Dixon *et al.* 1972.)

While it was initially supposed that these ostracoderm faunas would facilitate correlation and dating, the situation in the Canadian arctic has proved rather complex because the area appears to have been an evolutionary centre for heterostracan ostracoderms during the Silurian (Dineley 1973; Broad 1973; Dineley and Loeffler 1976); as a consequence, the same genera have different age ranges in Europe and in northern Canada, The genus *Corvaspis* is, for example, known only from the latest Downtonian (*sensu* White 1950) and the Dittonian in Europe, but in arctic Canada it occurs in strata of pre- or early Downtonian age (the Pridolian Stage being

accepted as equivalent to the lower part of the Downtonian, below the *Traquairaspis* zones).

It is important, therefore, to establish the ranges of particular genera and species within the Canadian arctic, in order to permit their use for dating and correlation on a local basis and to appreciate the pattern of ostracoderm distribution in space and time. To these ends, an ostracoderm fauna which can be dated from the associated microfauna is of particular interest.

CONCLUSIONS

This ostracoderm fauna, comprising *Tolypelepis leopoldensis* sp. nov., cf. *T. leopoldensis*, *Corvaspis* cf. *C. arctica* Loeffler and Dineley, and ?*Kallostrakon* sp. indet., is dated as late Ludlovian or Pridolian on the basis of the associated ostracods and conodonts. Together with evidence outlined by Jones and Dixon (1975) this suggests a Late Ludlovian/Pridolian age for the Leopold Formation.

The lithology of the ostracoderm horizon suggests deposition in intertidal conditions, but this may not have been the environment in which the ostracoderms lived. The plates are dissociated and, although not appreciably abraded or broken, could have been transported over quite large distances while still attached to a buoyant corpse.

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The photographic illustrations are the work of R. Godwin of the University of Bristol, England.

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