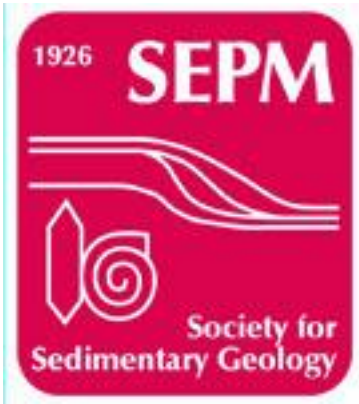

New Species of the Cyathaspidid Poraspis (Agnatha: Heterostraci) from the Late Silurian and Early Devonian of Northwest Territories, Canada

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Source: *Journal of Paleontology*, Vol. 72, No. 2 (Mar., 1998), pp. 360-370
Published by: Paleontological Society
Stable URL: http://www.jstor.org/stable/1306721
Accessed: 11-05-2016 05:10 UTC

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ACCEPTED 27 JULY 1997

J. Paleont., 72(2), 1998, pp. 360–370

0022-3360/98/0072-0360$03.00

NEW SPECIES OF THE CYATHASPIDID *PORASPIS* (AGNATHA: HETEROSTRACI) FROM THE LATE SILURIAN AND EARLY DEVONIAN OF NORTHWEST TERRITORIES, CANADA

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ABSTRACT—Four new species of cyathaspidid extend the range of the genus *Poraspis* back into the Late Silurian and indicate that the Canadian arctic was its center of origin. *Poraspis heintzae* n. sp., *P. cracens* n. sp., *P. thules* n. sp. and *P. parmula* n. sp. also increase the known geographic range of the genus which had previously been reported only from the District of Mackenzie (NWT, Canada), Spitsbergen, western and eastern Europe. The identification of *P. sericea* from the upper member of the Peel Sound Formation substantiates correlation of this interval with the *crouchi* zone of the Anglo-Welsh Borders, and provides another rare example of a species common to the Canadian arctic and European successions.

INTRODUCTION

VERTEBRATE FAUNAS were first discovered in the Late Silurian and Early Devonian rocks of the Canadian Arctic Archipelago, by the Geological Survey of Canada, in 1955 (Thorsteinsson, 1958). Since then many additional localities have been found and a stream of publications has described the new forms present, particularly the heterostracan agnathans (see Elliott and Dineley, 1985, 1991, and references therein). These papers have, however, tended to concentrate on the more unusual or well-preserved members of the fauna, whilst other taxa have been neglected. This has been particularly true for the cyathaspidids, of which only a few species have been described, although they are present in large numbers at some localities. In some instances, preliminary identifications were made (Broad, 1968), and used in biostratigraphic correlation (Elliott, 1984a) although detailed descriptions of these forms have never been published.

This paper is the first in a projected series describing the cyathaspidid faunas from the Canadian Arctic Archipelago, and deals with species of the genus *Poraspis,* a cyathaspidid which is particularly well known from the Early Devonian of Spitsbergen (Blieck and Heintz, 1983) and which has been used in biostratigraphic correlation with western Europe and arctic Canada (Elliott, 1984a). Although the Spitsbergen species *P. intermedia* and *P. polaris* have previously been reported from this area (Elliott, 1984a), it is now clear that these specimens represent distinct new species which occur somewhat earlier than those known from Spitsbergen. The new Canadian species extend the history of the genus back into the Pridoli and indicate that, as for some other heterostracan taxa (Thorsteinsson, 1967; Elliott, 1984a), arctic Canada may have been a center of origin and a locus of adaptive radiation for *Poraspis.*

In addition, the identification of *Poraspis sericea* in the fauna of the upper member of the Peel Sound Formation provides a rare example of a European species being found in the Canadian arctic, and helps to substantiate previous biostratigraphic correlations (Elliott, 1984a).

MATERIALS AND METHODS

The specimens were typically preserved in calcareous sandstones and responded well to preparation using a combination of dilute acetic acid and mechanical means. The measurements and ratios employed follow those used by Blieck and Heintz (1983). The specimens are the property of the Canadian Museum of Nature, Ottawa, and bear their catalogue numbers (prefixed NMC).

STRATIGRAPHY

The material was collected from the lower and upper members of the Peel Sound Formation (Prince of Wales Island) and the Somerset Island and Peel Sound Formations (Somerset Island) (Figure 1). The Peel Sound Formation occurs over much of Prince of Wales Island, and in the Cape Anne-Pressure Point and Creswell Bay areas of Somerset Island. It consists of silt-

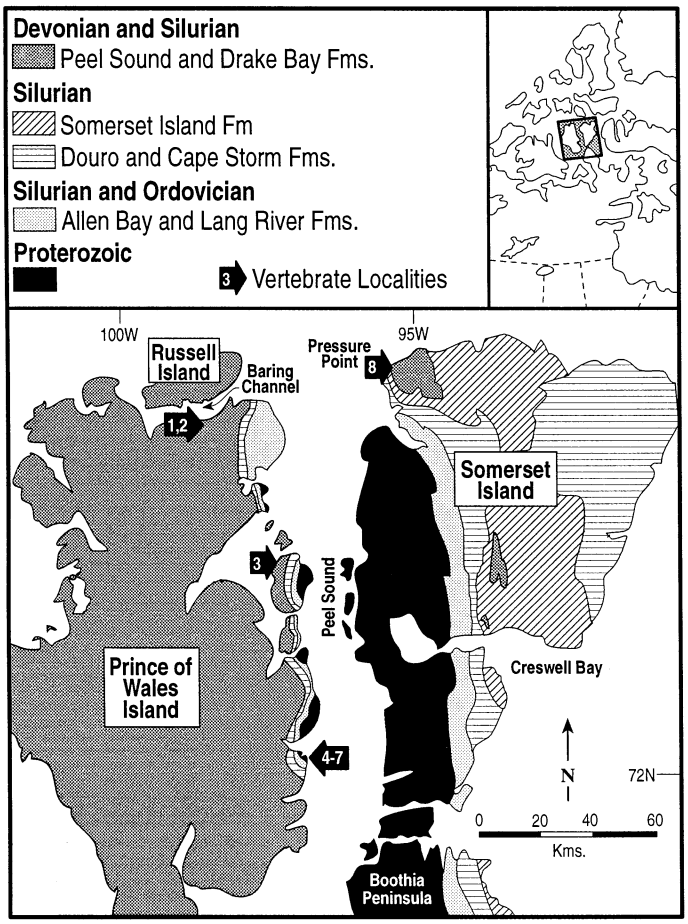


FIGURE 1—Locality map showing geology of Prince of Wales and Somerset islands and collecting localities for the *Poraspis* species.

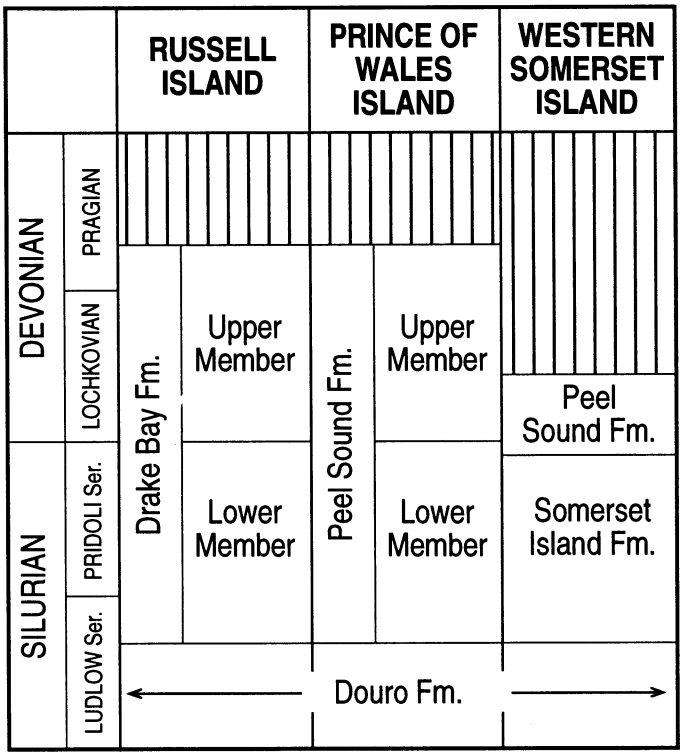


FIGURE 2—Correlation of Silurian and Devonian strata in the central Canadian arctic (from Elliott, 1984a).

stones, sandstones and conglomerates deposited over a large delta system as subaerial alluvial fans prograding from the rising Boothia Uplift (Thorsteinsson and Tozer, 1963).

On Prince of Wales Island the formation has been separated into upper and lower members (Miall, 1970) (Figure 2). The lower member is exposed only as a narrow band along the flank of the Boothia Uplift, where the succession is most completely documented in an unnamed gorge 22.5 km north of Transition Bay (Figure 1, localities 4–7). The upper member grades westwards through five distinct facies which crop out as north–south bands (Broad, Dineley and Miall, 1968; Miall, 1970). At Baring Channel (Figure 1, localities 1, 2), vertebrates occur in the sandstone-carbonate facies, which represents the interfingering of marine and continental deposits.

On Somerset Island, the Somerset Island Formation (Miall et al., 1978) (Figure 2) represents the transition between the Peel Sound Formation and the underlying Douro Formation (Thorsteinsson, 1980). The unit is considered to be the approximate age equivalent of the lower member of the Peel Sound Formation on Prince of Wales Island (Miall et al., 1978), although Thorsteinsson (1980) maintained that it was equivalent only to the lower part of the lower member.

AGE OF THE FAUNAS

Conodont dating of the Somerset Island Formation in the eastern part of the study area and the lower member of the Peel Sound Formation to the west suggests that both range from late Ludlow to Pridoli in age. On Somerset Island, the Somerset Island Formation has been dated as Pridoli at Cape Anne and Creswell Bay based on the presence of *Ozarkodina confluens* gamma morphotype and *Pelekysgnathus* sp. (Miall et al., 1978). On Boothia Peninsula, the base of the formation is considered to be latest Ludlow (*latialata* zone) as *Pedavis* sp. aff. *P. thorsteinssoni* is found there, and is known to occur with *Pedavis latialata* in the Douro Formation on Cornwallis Island (Thorsteinsson, 1980).

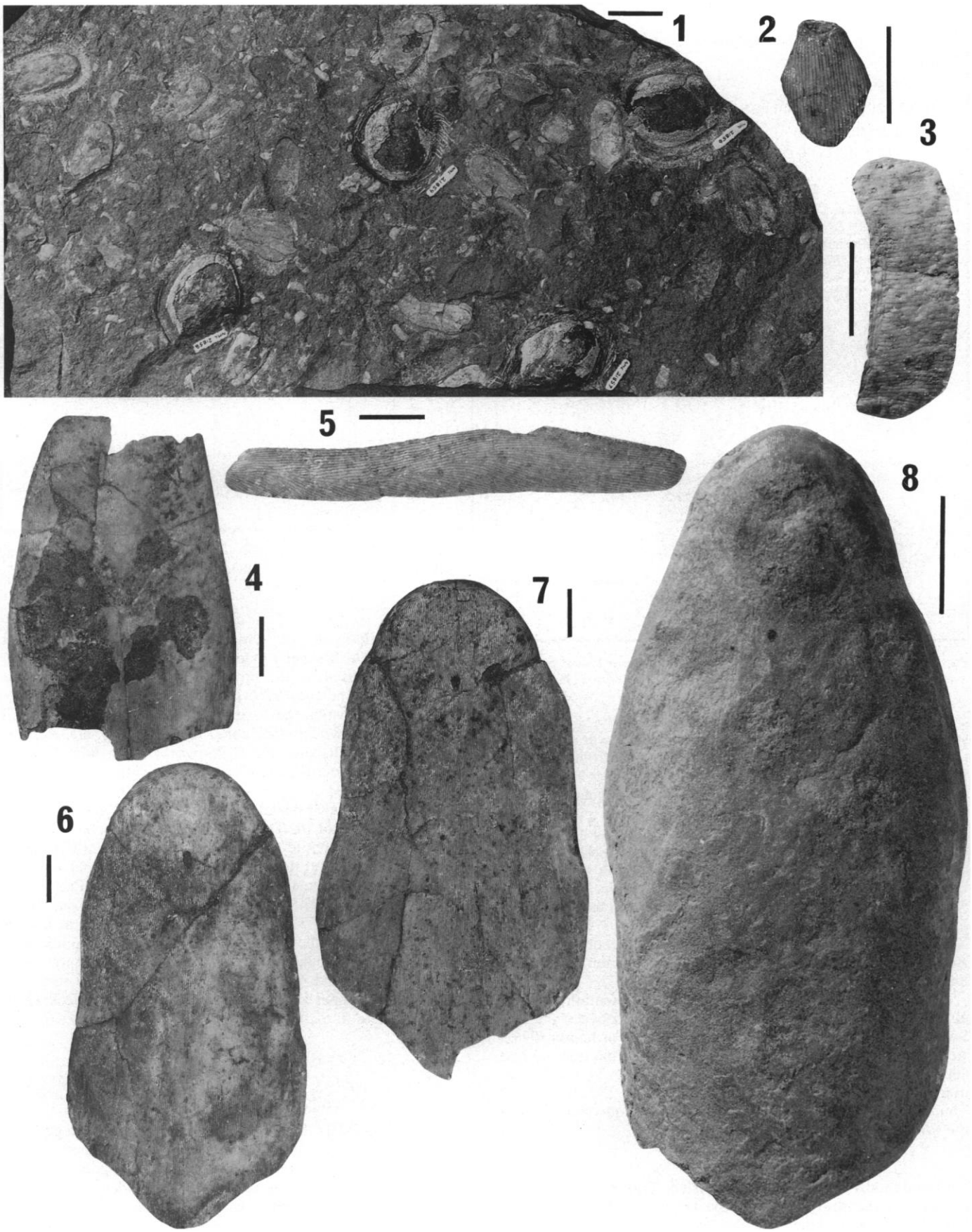
On Prince of Wales Island, *Pedavis* sp. aff. *P. thorsteinssoni* occurs in the base of the Drake Bay Formation, which is stratigraphically equivalent to the base of the Peel Sound Formation (Figure 2). In addition, the trilobite *Hemiarges bigener* is found towards the top of the lower member indicating a Pridoli age for this part of the Peel Sound Formation (Thorsteinsson, 1980).

The upper member of the Peel Sound Formation at Baring Channel has been dated as Lochkovian to early or middle Pragian (Elliott, 1984a), based on the presence of *Pelekysgnathus serratus serratus* and other conodonts which closely resemble forms found in upper Lochkovian and lower to middle Pragian strata elsewhere in the Canadian Arctic.

SYSTEMATIC PALEONTOLOGY

Family CYATHASPIDIDAE Kiaer, 1932
Subfamily PORASPIDINAE Kiaer, 1932

Diagnosis.—(After Elliott and Dineley, 1991) Epitega indicated faintly or not at all, scale components not evident; dentine ridges long and ridge pattern largely longitudinal, although commonly radiating on anterior parts of dorsal and ventral shields and diagonal on lateral parts of dorsal shield; orbits may be enclosed.



Genus PORASPIS Kiaer, 1930

Diagnosis.—(After Denison, 1964) Rostral region narrowing in front of orbits, anterior border with slight median convexity; maxillary brim broad and covered with ridges parallel to the anterior edge. Postbranchial lobes of dorsal shield long and strongly developed. Posterior margins of dorsal and ventral shields bear pronounced, rounded median lobes. Dentine ridges fine, 7–11 per mm; ridge pattern generally longitudinal but may be fanned or irregular on rostrum and anterior triangle of dorsal shield, and parallel to lateral and anterior margins of dorsal shield. Epitega indicated faintly, if at all. Pineal macula distinct. Lateral line pores and canals large.

Discussion.—The genus *Poraspis* is both distinctive and widespread, examples having been reported from Spitsbergen (see Blieck and Heintz, 1983 and refs. therein), western Europe (von Alth, 1874; Lankester, 1873; Leriche, 1906; Zych, 1927, 1931; Brotzen, 1933; White, 1950; Ball and Dineley, 1961; Bardenheuer and Otto, 1994) as well as from Canada's District of Mackenzie (Dineley and Loeffler, 1976) and arctic Archipelago (Broad, 1973; Broad and Dineley, 1973; Elliott, 1984a).

The type species, *Holaspis sericeus* Lankester (1873) was based on a specimen from the "Grey Cornstone" near Abergavenny, in South Wales; Woodward (1891) subsequently included this species in *Palaeaspis* Claypole, with *P. americana,* because *Holaspis* was preoccupied. In a paper published shortly before his untimely death, Kiaer (1930) outlined his proposal to separate the American and European species of *Palaeaspis,* and to group Lankester's *Holaspis sericeus* together with *Cyathaspis sturi* von Alth, *Cyathaspis barroisi* Leriche, and several new species from Spitsbergen in an "easily distinguishable group," a genus which he named *Poraspis.*

Although the names of eight new species from Spitsbergen were listed in a posthumously published paper (Kiaer, 1932), these were not fully described until 1935, under the authorship of Kiaer and his former pupil and collaborator, Anatol Heintz. In this more detailed account (Kiaer and Heintz, 1935), *angusta* and *lata* forms of *P. polaris* were recognised and interpreted as possible sexual dimorphs, and three more poorly characterised species from Podolia: *P. siemiradzkii* (Zych, 1931), *P. simplex* and *P. pompeckji* (Brotzen, 1933), were also added to the genus.

In an attempt to rationalise and more precisely define the various species of cyathaspidids from Spitsbergen, Blieck and Heintz (1983) were able to demonstrate considerable overlap in the morphology of previously described species of *Poraspis.* They reduced the Spitsbergen species of the genus from eight to three: *P. brevis, P. polaris,* and *P. rostrata*; they also showed that the *angusta* and *lata* forms of *P. polaris* were the result of tectonic deformation rather than sexual dimorphism.

In this paper, we adopt Blieck and Heintz's revised taxonomy in a re-evaluation of previously identified *Poraspis* material from Somerset and Prince of Wales Islands (Broad, 1973; Broad and Dineley, 1973; Elliott, 1984a), and description of new *Poraspis* material collected during expeditions to the area since 1973.

The members of the genus *Poraspis* show a considerable range in size, although the gross morphology of the shields in different species is very similar. Blieck and Heintz (1983) used a plot of pineal length against median length to separate their *Poraspis* species. Unfortunately, poor preservation of some of the specimens described in this paper precludes use of pineal length in this way; however, a plot of median length against maximum width (Figure 8) has proved equally effective in separating the species.

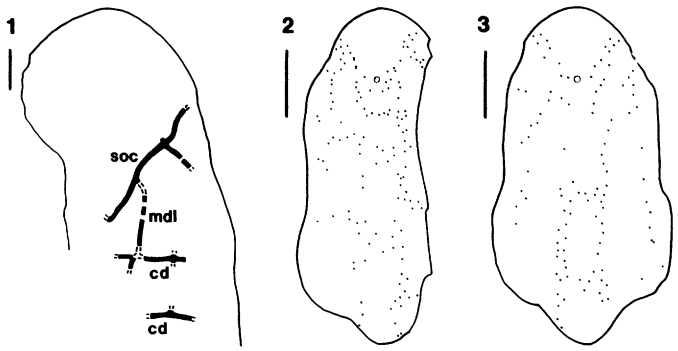


FIGURE *4—1, Poraspis sericea,* sensory canal system in anterior part of dorsal shield, NMC 40639. *2, 3, Poraspis heintzae,* pores of sensory canal system; *2,* NMC 40627; *3,* NMC 40624, holotype. Bar scales, 5 mm. Key; cd, dorsal transverse commissure; mdl, medial dorsal canal; soc, supraorbital canal.

PORASPIS SERICEA (Lankester, 1873)
Figures 3.8, 4.1

Holaspis sericeus LANKESTER, 1873, p. 241, 331–332, pl. 10.
Palaeaspis sericea (Lankester). WOODWARD, 1891, p. 169; STENSIÖ, 1926, p. 1, 7, fig. 6.
Palaeaspis (Poraspis) sericea (Lankester). ZYCH, 1931, fig. 18.
Poraspis sericea (Lankester). KIAER, 1930, p. 4; 1932, p. 13, 14; KIAER AND HEINTZ, 1935, p. 98–101, figs. 6, 33–35; HOLMGREN, 1942, p. 9, 10; WHITE, 1950, p. 56; BYSTROW, 1955, p. 488–491, figs. 16–18; BALL AND DINELEY, 1961, p. 202; DENISON, 1964, p. 408–409; BLIECK AND HEINTZ, 1983, p. 60, 62, fig. 11.
Poraspis (Palaeaspis) sericea (Lankester). WHITE, 1935, p. 179–180, figs. 3, 4.

Diagnosis.—(After Denison, 1964). Large *Poraspis* with broad dorsal shield, length 67–84.5 mm, width ratio 0.42–0.62, orbital ratio 0.19. Ridges flat-topped, 8 per mm; arranged longitudinally on the dorsal shield, fanning slightly on the rostrum. Lateral line system regular and complete with all branches united.

Description of referred specimens.—Large elongated *Poraspis* with broadly-curved shield, rather flattened in midline. Dorsal shield narrowing in front of rather posteriorly placed orbital notches; rostrum narrowly rounded, preorbital processes not strongly developed; maxillary brim broad (2.5 mm) and ornamented with dentine ridges parallel to anterior margin (6 per mm). Lateral margin indented by somewhat shallow branchial notches; post-branchial division of shield rather long, post-branchial lobe shallow. Posterior margin concave laterally and bearing a broad median lobe. Ornamentation consists of broadly-rounded ridges without crenulations, density 7–8 per mm. Pattern is broadly longitudinal over most of the dorsal shield; anteriorly and laterally, and particularly in the orbital area, there are 5–6 ridges running parallel to the shield margin; on the rostrum the ridges fan out and may form one or more loops or whorls against the marginal ridges anteriorly.

The pineal and preorbital areas of the sensory canal system are visible in one specimen (NMC 40639; Figure 4.1), and show

←

FIGURE *3—1–7, Poraspis heintzae*; *1,* view of slab containing all described specimens of *P. heintzae* and the type specimens of *Ctenaspis ornata*; *2,* ridge scale, NMC 40636; *3,* flank scale, NMC 40635; *4,* ventral shield, NMC 40632; *5,* branchial plate, NMC 40634; *6,* dorsal shield, NMC 40630; *7,* dorsal shield, NMC 40624, holotype. *8, Poraspis sericea,* NMC 34140. Bar scales; *1,* 2 cm; *2–7,* 3 mm; *8,* 1 cm.

TABLE 1—Measurements (in mm) of dorsal and ventral shields of arctic *Poraspis*.

Dimensions	*P. sericea*	*P. heintzae* n. sp.		*P. cracens* n. sp.	*P. thules* n. sp.	*P. parmula* n. sp.	
	Dorsal (n = 7)	Dorsal (n = 11)	Ventral (n = 2)	Dorsal (n = 5)	Dorsal (n = 4)	Dorsal (n = 2)	Ventral (n = 4)
Median length	67.0–84.5	28.1–30.8	22.6–23.0	18.0–20.9	12.0–14.1	10.1	9.0–10.0
Maximum width	30.0–43.0	12.7–14.6	14.7–15.7	9.0–11.9	6.0–9.0	6.5–6.9	5.9–6.7
Orbital width	21.0–26.0	9.8–10.8	—	6.0–8.0	4.3–6.5	4.5–5.0	—
Orbital length	12.0–17.0	3.7–4.5	—	2.6–3.6	2.0–2.3	1.3–1.7	—
Pineal length	11.1–19.6	5.6–6.3	—	3.5–5.0	2.8–3.6	1.9–2.1	—
Postbranchial length	21.0–35.0	10.6–13.0	—	6.7–7.7	3.7–5.3	3.7	—
Ratios							
Max. width / Med. length	0.42–0.62	0.41–0.49	0.65–0.68	0.45–0.56	0.50–0.63	0.68	0.62–0.67
Orb. length / Med. length	0.18–0.20	0.13–0.16	—	0.13–0.17	0.14–0.19	0.17	—
Pineal length / Med. length	0.16–0.26	0.19–0.21	—	0.18–0.23	0.20–0.25	0.19	—
Postbranch. length / Med. length	0.29–0.42	0.36–0.44	—	0.36–0.38	0.30–0.40	0.37	—
Orbital width / Orbital length	1.50–1.83	2.18–2.67	—	1.9–2.6	1.86–3.25	2.95–3.50	—
Ridges per mm	7–8	10–11		7–9	9–10	8–10	

the typical arrangement for *P. sericea* in which the posterior sections of the supra-orbital canals meet the median dorsal canals before uniting behind the pineal macula.

Discussion.—Although fragments of *Poraspis* occur throughout the *pococki* to *crouchi-rostrata* zones in the Welsh Borders (White, 1950), identifications of *Poraspis sericea* are rare. A fragmentary dorsal shield from Herefordshire was figured by Kiaer and Heintz (1935), and a further dorsal shield in the collections of the British Museum (Natural History) was figured by White (1935). More recently, an incomplete dorsal shield from the Lochkovian of Germany was tentatively assigned to the species by Bardenheuer and Otto (1994).

The specimens described here accord well with the size and proportions of the holotype and the additional dorsal shield (P. 16311) in the collections of the British Museum (Natural History). The new material from Canada extends the range of variation of length, in providing both longer and shorter shields (Table 1); the general proportions, the pattern and density of dentine ridges, and the distinctive pre-orbital elongation of the rostrum are, however, similar to that of previously described material. The course of the lateral line sensory system cannot be traced in many of the Canadian specimens, owing to poor preservation of the bone; NMC 40639, where the system is discernible in the orbital and pineal area (Figure 4.1), shows close similarity to the same area in the holotype (Lankester, 1873).

The presence of *Rhinopteraspis crouchi* and *Pteraspis rostrata* in the same bed (Lankester, 1873) indicates a "Dittonian" (now Lochkovian) age for the type locality. The Canadian material comes from the upper member of the Peel Sound Formation at Baring Channel (Figure 1, localities 1, 2), where it is associated with a fauna of pteraspids and placoderms (see Appendix). When Elliott (1984a) discussed the age of this fauna, he tentatively suggested stratigraphic equivalence with the *crouchi* zone of the Anglo–Welsh sequence and the *vogti* horizon of Spitsbergen. The recognition of *P. sericea* in the Peel Sound Formation substantially strengthens this correlation and provides only the second case of a vertebrate species common to both the Canadian Arctic and European successions during the Late Silurian to Early Devonian time interval, following the identification of *Hemicyclaspis murchisoni* in the upper member of the Somerset Island Formation at Pressure Point (Dineley, 1968).

Holotype.—*Holaspis sericeus* Lankester, BM(NH) P4117, dorsal shield.

Type locality.—"Grey Cornstone", near Abergavenny, S. Wales (Dittonian [now Lochkovian] in age).

Referred specimens.—NMC 34140–34141, 40637-3061, dorsal shields.

Locality for referred specimens.—Sandstone-carbonate facies of the upper member of the Peel Sound Formation, northern Prince of Wales Island, NWT, Canada (Lochkovian to early or middle Pragian). (Figure 1, localities 1, 2).

PORASPIS HEINTZAE new species
Figures 3.1–3.7, 4.2, 4.3

Diagnosis.—*Poraspis* with dorsal shield ranging from 28.1 to 30.8 mm in length; ornament of fine, flat-topped ridges, 10–11 per mm.

Description.—A slender cyathaspidid of typical *Poraspis* shape. Dorsal shield constricted in front of orbits, and rostrum broadly rounded; preorbital lobes moderately well developed; long post-branchial division of the shield, postbranchial lobes deep; posterior margin slightly concave laterally, with a broadly rounded median lobe.

Ornamentation consists of fine (10–11 per mm) flat-topped ridges; the overall pattern is longitudinal with one or two ridges parallel to the lateral margin in the branchial area and five or six in the orbital area. The pattern is more complex over the rostral area with much individual variation present; longitudinal ridges form whorls and loops against the short discontinuous ridges and large tubercles bordering the rostral margin.

Pores of the sensory canal system are distinct, particularly on the orbital and post-pineal branches (Figure 4.2, 4.3). The overall pattern is typically poraspid.

The ventral shield is narrowest anteriorly, at the transverse anterior margin. The lateral margins are gently convex, the maximum width of the shield being reached two-thirds of the distance back, and then narrowing slightly to the posterior margin which is drawn out to a median posterior lobe. Ornamentation

is longitudinal, fanning slightly anteriorly where two or three ridges run parallel to the margin. Sensory canal system visible in part, shows typical poraspid pattern of anterior 'V'-shaped commissure, lateral longitudinal canal and a number of medial commissures.

Branchial plate elongated, narrow anteriorly, with branchial notch in dorsal margin, 2.5 mm from posterior edge; ornamentation longitudinal in upper part of plate, transverse in lower half where ridges meet ventral margin at an acute angle (Figure 3.5).

Flank scales deep and regular, 8–10 mm in length, 3.4–4.5 mm in width; ridge scales trapezoidal in outline, 3.0–4.5 mm in length, 2.0–3.0 mm in width (Figure 3.2, 3.3).

Discussion.—The graph of median length against maximum width (Figure 8) shows that the members of this species plot within a cluster which overlaps that for *P. brevis* specimens from Spitsbergen. *Poraspis brevis* is used here sensu lato, as redefined by Blieck and Heintz (1983), and includes populations previously described as *P. brevis (s.s.), P. intermedia* and *P. subtilis.* In fact, *P. heintzae,* being a rather slender form with a gently rounded rostrum, is closest in overall morphology to forms originally designated as *P. intermedia.* However, *P. heintzae* differs significantly from this and all other forms now included in *P. brevis* (s.l.), in having much finer dentine ridges on the dorsal shield. Ridge density varies from 6 to 8 per mm in *P. brevis* (s.l.) but is in the range 10–11 per mm for *P. heintzae.*

The specimens of *P. heintzae* occur on a single slab which also bears the type specimens of *Ctenaspis ornata* Dineley (1976). Dineley mistakenly described this slab as coming from the sandstone facies of the upper member of the Peel Sound Formation at Mt. Matthias on northeast Prince of Wales Island; it was actually collected from the north coast of Prescott Island (Figure 1, locality 3) where it was found ex situ. Although this material appears to come from the upper member of the Peel Sound Formation, its stratigraphic relationship to the fauna at Baring Channel is unknown.

Etymology.—Named in honour of Dr. Natascha Heintz of the Paleontology Museum, Oslo.

Occurrence.—Peel Sound Formation, north coast of Prescott Island, NWT, Canada. Figure 1, locality 3.

Holotype.—NMC 40624, dorsal shield.

Additional material.—NMC 40620–40623, 40625–40631, dorsal shields; NMC 40632, 40633, ventral shields; NMC 40634, branchial plate; NMC 40635, flank scale; NMC 40636, ridge scale.

PORASPIS CRACENS new species
Figures 5.1, 5.2, 6.1, 7

Poraspis cf. *P. polaris* Kiaer. BROAD, 1973, p. 6; BROAD AND DINELEY, 1973, p. 57, 58; ELLIOTT, 1984b, p. 172; ELLIOTT AND DINELEY, 1985, p. 109; 1991, p. 313.

Poraspis polaris Kiaer. ELLIOTT, 1984a, p. 201, fig. 3.

Diagnosis.—Small, slender *Poraspis,* with length of dorsal shield ranging from 18.0 to 20.9 mm; ornament of fine flat-topped ridges, 7–9 per mm.

Description.—Dorsal shield small, slender and elongated, moderately arched transversely. Slight constriction in front of orbital notches, preorbital processes distinct. Long postbranchial division to the dorsal shield, postbranchial lobes well developed. Posterior margin of shield with strong median lobe.

Ornamentation of narrow, flat-topped ridges, 7–9 per mm; pattern longitudinal over much of the shield, fanning over the rostrum and abutting 3–4 transverse ridges anteriorly; laterally 4–5 ridges run parallel to the margin, increasing to 6–7 over the orbit (Figure 6.1).

Sensory canal system visible as large pores over the entire shield; pattern is typical of *Poraspis* with lateral and medial paired longitudinal canals joined by four pairs of transverse commissures; the medial canals do not appear to connect with the posterior branches of the supraorbital canals (Figure 7).

Discussion.—These are some of the specimens which Broad referred to as *Poraspis* cf. *P. polaris* (Broad, 1968; Broad 1973; Broad and Dineley, 1973). Whilst the overall shape of the dorsal shield is similar to *P. polaris,* the difference in size of these Canadian specimens places them well beyond the range of variation for that species. *Poraspis polaris,* as redefined by Blieck and Heinz (1983) includes dorsal shields with lengths of 32.0–44.0 mm, whereas shields here referred to *P. cracens* range from 18.0 to 0.9 mm in length. The plot of median length against maximum width for dorsal shields of *P. cracens* clearly separates this material from the other recognised species of *Poraspis,* and provides the basis for recognising the new species (Figure 8).

Poraspis cracens is known only from the lower member of the Peel Sound Formation on the southeast coast of Prince of Wales Island (Figure 1, locality 4). The faunas from this section have been dated as Pridoli (Elliott, 1984a), indicating that this new species occurs earlier than any of the *Poraspis* species recorded from Spitsbergen.

Etymology.—*Cracens* (Latin), slender, graceful.

Occurrence.—Lower member of the Peel Sound Formation, southeastern Prince of Wales Island, N.W.T. Figure 1, locality 4.

Holotype.—NMC 40648, dorsal shield, from the lower member of the Peel Sound Formation, southeastern Prince of Wales Island, N.W.T., Canada.

Additional material.—NMC 40649–40652, dorsal shields.

PORASPIS THULES new species
Figures 5.3, 6.2

Poraspis cf. *P. polaris* Kiaer. BROAD, 1973, p. 6; BROAD AND DINELEY, 1973, p. 58; ELLIOTT, 1984a, p. 172; ELLIOTT AND DINELEY, 1985, p. 109; 1991, p. 313.

Poraspis polaris Kiaer. ELLIOTT, 1984b, p. 201, fig. 3.

Diagnosis.—Very small, slender *Poraspis* with rather bluntly rounded rostrum, length of dorsal shield ranges from 12.0 to 14.1 mm; ornament of fine flat-topped ridges, 9–10 per mm. Broad transverse band of 7–9 ridges at anterior margin of rostrum.

Description.—Dorsal shield very small and slender, strongly arched transversely; with broadly rounded rostrum. Slight constriction anterior to orbits, preorbital lobe distinct. Postbranchial length relatively short and well developed. Posterior margin of shield with rounded median lobe on posterior margin.

Ornament consisting of fine flat-topped ridges, density 9–10 per mm. Pattern basically longitudinal but fanning over the rostrum to meet a deep band of 7 to 9 transverse ridges anteriorly; laterally a band of 4–5 ridges parallels the margin of the shield. The sensory canal system is not visible on any of the specimens.

Discussion.—This material was also compared with *Poraspis polaris,* using the conventions of open nomenclature (Broad 1968, 1973; Broad and Dineley, 1973). However, as with the other material (now referred to *P. cracens* n. sp.), it clearly falls beyond the range of variation in size of that species. Dorsal shields of *P. thules* have a maximum length of 14.1 mm (Table 1), in comparison with a range of 32.0–44.0 mm for *P. polaris* and 18.0–20.9 for *P. cracens.* In size, this species is closest to the tiny *P. parmula* n. sp., but distinguished from it by its more slender proportions.

Poraspis thules is further distinguished from all of these species by the presence of a broad band of 7–9 dentine ridges arranged parallel to the anterior margin of the rostrum, a feature which normally consists of only 4–5 ridges in other species of this genus.

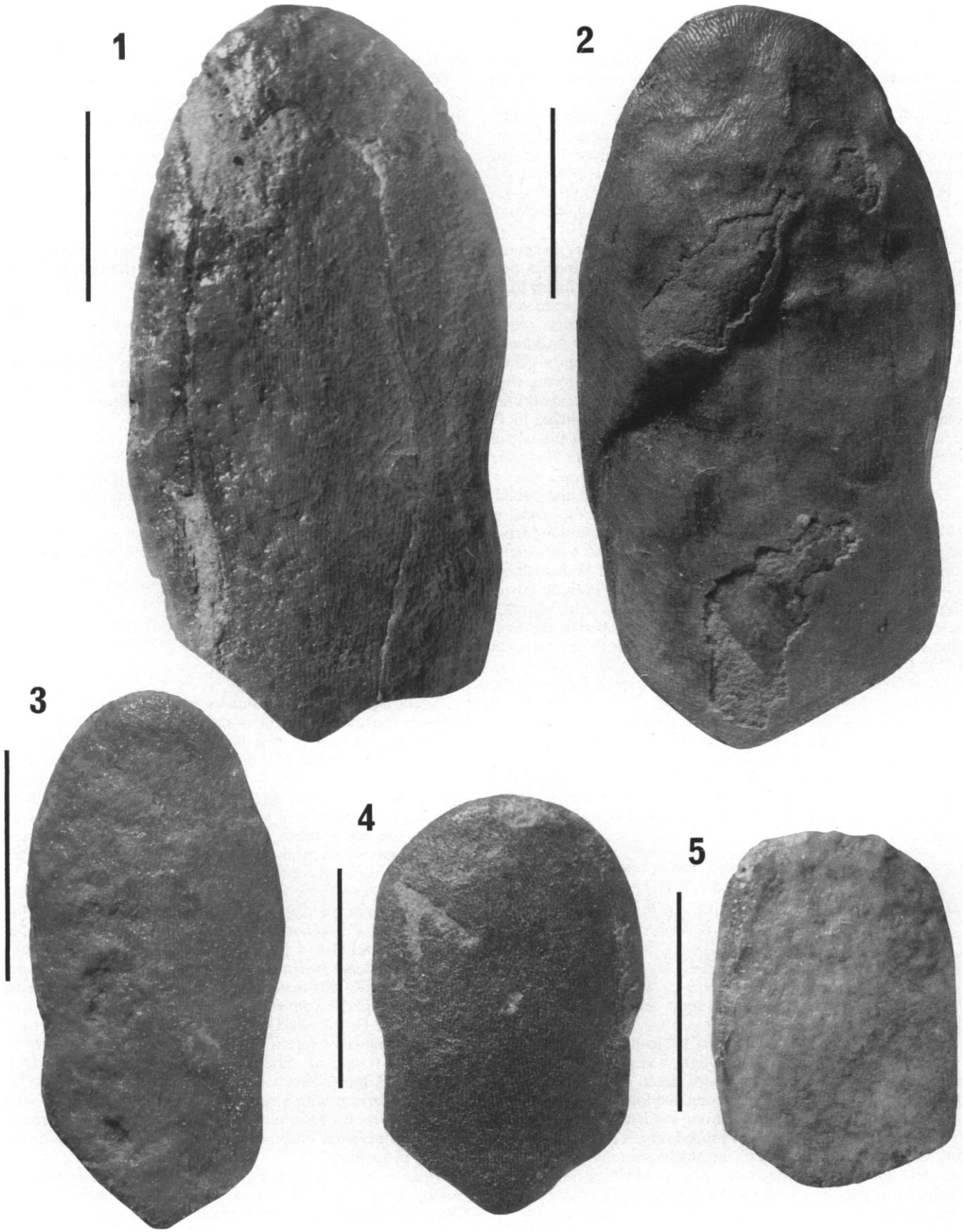


FIGURE 5—*1, 2, Poraspis cracens*; *1,* dorsal shield, NMC 40648, holotype; *2,* dorsal shield, NMC 40650. *3, Poraspis thules,* dorsal shield, NMC 40653, holotype. *4, 5, Poraspis parmula. 4,* dorsal shield, NMC 40642, holotype; *5,* ventral shield, NMC 40647. Scale bars 5 mm.

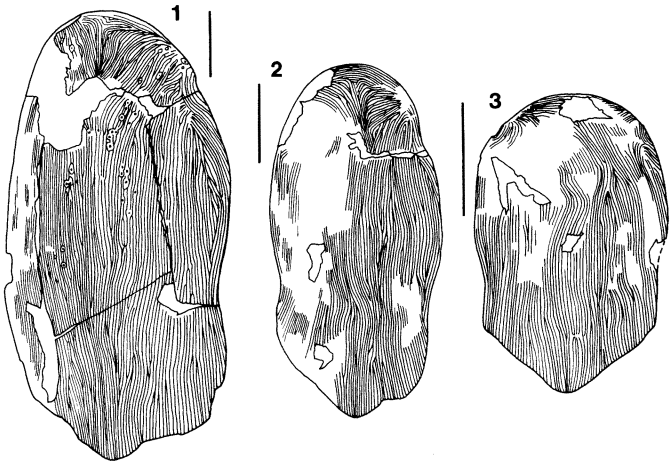


FIGURE 6—*1–3,* Line illustrations of holotypes of arctic *Poraspis* species showing pattern of surface ridges on dorsal shield. *1, Poraspis cracens,* NMC 40648. *2, Poraspis thules,* NMC 40653. *3, Poraspis parmula,* NMC 40642. Scale bars 3 mm.

Etymology.—From *thule* (L), north.

Occurrence.—Lower member of the Peel Sound Formation, southeastern Prince of Wales Island, N.W.T. Figure 1, localities 4–6.

Holotype.—NMC 40653, dorsal shield, lower member of Peel Sound Formation, southeastern Prince of Wales Island, N.W.T.

Additional material.—NMC 40654–40657, dorsal shields.

PORASPIS PARMULA new species
Figures 5.4, 5.5, 6.3

Poraspis cf. *P. intermedia* Kiaer and Heintz. BROAD AND DINELEY, 1973, p. 57.

Poraspis intermedia Kiaer and Heintz. ELLIOTT, 1984b, p. 201, fig. 3.

Diagnosis.—Extremely small, broad *Poraspis,* length 10.1 mm, width 6.5–6.9 mm; broadly rounded anteriorly with anteriorly placed orbits and slight preorbital constriction; ornamentation of fine, flat-topped ridges.

Description.—Dorsal shield very short and broad, moderately arched transversely, broadly rounded anteriorly. Orbits rather anteriorly placed with distinct preorbital lobe but only slight preorbital constriction. Branchial notches posteriorly placed, with strong postbranchial lobe; posterior margin of shield with well-developed median lobe.

Ornamentation of narrow, flat-topped ridges, 9–10 per mm; pattern longitudinal over most of the shield, fanned over the rostrum with 3–4 ridges running parallel to the shield margin. Sensory canal system visible as large pores on the pineal and rostral areas, otherwise incompletely known.

Ventral shield rectangular and moderately arched. Anterior margin transverse with slight median sulcus, posterior margin with slight median projection. Ornament of fine flat-topped ridges, pattern longitudinal with anterior fanning.

Discussion.—Although Broad (1968; Broad and Dineley 1973) compared these specimens to *Poraspis intermedia,* using the conventions of open nomenclature, identification with that species is clearly inappropriate; shields originally attributed to *P. intermedia* are two to three times as long, and much more coarsely ornamented. *Poraspis parmula* does resemble some examples of *Poraspis brevis* (as redefined by Blieck and Heintz, 1983), in having a bluntly rounded rostrum and anteriorly-placed orbits; however, the smallest specimens of *P. brevis* are still more than twice as long as the new species. In fact, *P. parmula* is closest in size to another of the new species from the Canadian arctic, the slightly larger but more slender *P. thules:* however, with a median length of slightly more than 10 mm, *P. parmula* is the smallest cyathaspidid yet described (Table 1; Figure 8).

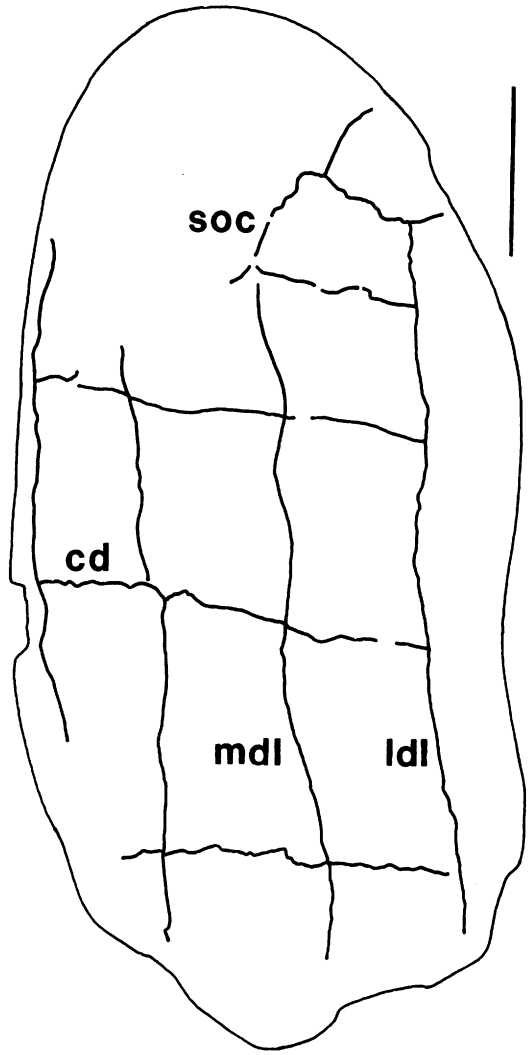


FIGURE 7—*Poraspis cracens,* dorsal shield showing pattern of sensory canal system, NMC 40648, holotype. Scale bar 3 mm. Key; cd, dorsal transverse commissure; Ldl, lateral dorsal canal; mdl, medial dorsal canal; soc, supraorbital canal.

Poraspis parmula is found in both the lower member of the Peel Sound Formation on Prince of Wales Island and in the upper member of the Somerset Island Formation, providing additional evidence for the stratigraphic equivalence of these two units. On Somerset Island the species occurs at a locality which has yielded *Hemicyclaspis murchisoni* (Dineley, 1968), the only other agnathan species besides *Poraspis sericea* which is common to both the Anglo-Welsh and Canadian arctic areas. *Hemicyclaspis murchisoni* is an index fossil for the lowest Downton Group of the Welsh Borders (White, 1950), which is early Pridoli in age (see discussion in Loeffler and Dineley, 1976 p. 199). Elliott (1984a) used the presence of *H. murchisoni* in the Somerset Island Formation to substantiate correlation with the Anglo-Welsh succession and to demonstrate that this part of the Canadian arctic vertebrate-bearing sequence was older than the lowest vertebrate horizons in Spitsbergen. The presence of small

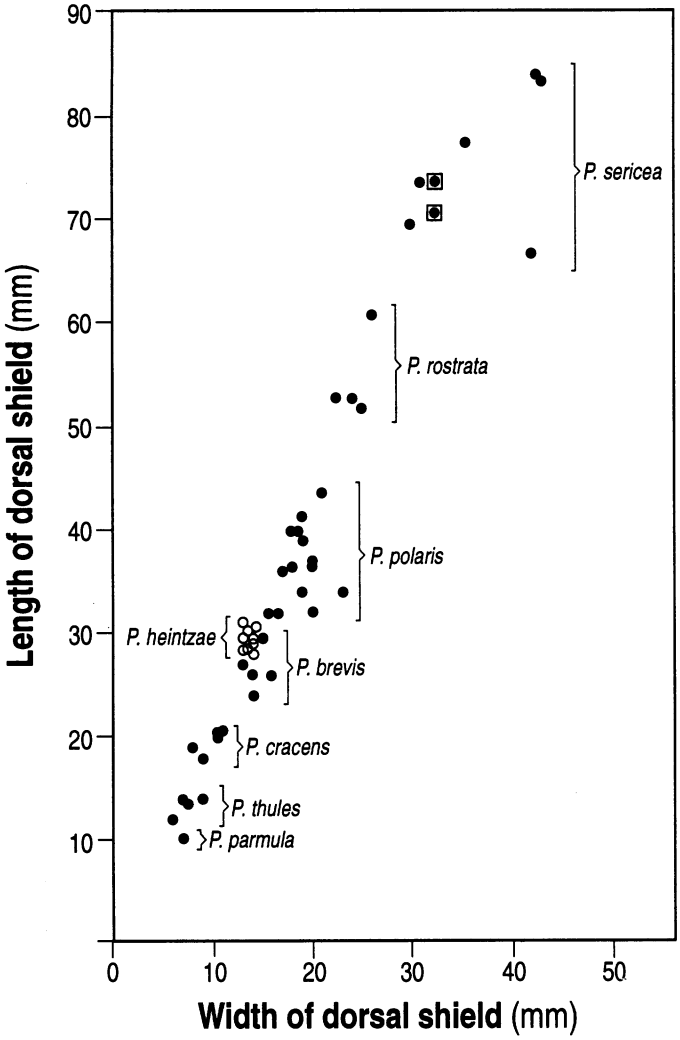


FIGURE 8—Plot of median length against maximum width of the dorsal shield for various species of *Poraspis*. The points for the two specimens of *P. sericea* from the Welsh Borders are enclosed within squares to distinguish them from the points for those from the Canadian arctic. The points for *P. heintzae* are plotted as open circles to separate them from the cluster for *P. brevis*. Data for Spitsbergen species from Blieck and Heintz (1983).

poraspids of primitive aspect in the Canadian succession is entirely consistent with this view.

Etymology.—*Parmula,* diminutive of *parma* (Latin), a small shield.

Occurence.—Lower member of the Peel Sound Formation, southeastern Prince of Wales Island, and upper member of the Somerset Island Formation, northwestern Somerset Island, N.W.T., Canada.

Holotype.—NMC 40642, dorsal shield, lower member of the Peel Sound Formation, southeastern Prince of Wales Island, N.W.T., Canada.

Additional material.—NMC 40643, dorsal shield; NMC 40644–40647, ventral shields.

DISCUSSION

Kiaer and Heintz (1935) recognized a number of consistent evolutionary trends amongst their Spitsbergen *Poraspis* species. The trend toward increased size is still apparent for the species as rationalised by Blieck and Heintz (1983). *Poraspis brevis,* the smallest of the Spitsbergen species is also the oldest; its stratigraphic range overlaps with that of the larger *P. polaris* in the upper part of the Fraenkelryggen Formation. *Poraspis rostrata,* the largest and youngest of the Spitsbergen species is found only in the succeeding Ben Nevis Formation, where the lower part of its stratigraphic range overlaps that of larger specimens of *P. polaris.* This same progression can be recognized amongst the species from arctic Canada. The Late Silurian species, from the lower member of the Peel Sound Formation and the Somerset Island Formation are very small, whereas the Early Devonian species, from the upper member of the Peel Sound Formation are larger; *P. sericea,* the youngest of the Canadian arctic species, is the largest known *Poraspis.*

Kiaer and Heintz (1935) also noted a trend toward greater organization of the longitudinal dentine ridge pattern through time, and a reduction in the number of transverse ridges on the anterior border of the rostrum. Again, this trend is confirmed in the newly described material from Canada. The three Late Silurian species exhibit a greater degree of flaring and sinuosity in the ridge pattern than any of the Devonian forms, and the Silurian *Poraspis thules* shows a particularly broad band of transverse rostral ridges.

The evolutionary trend towards a more completely united sensory canal network, and particularly towards the joining of the supraorbital and median dorsal canals has also been recognised amongst established species (Kiaer and Heintz, 1935; Denison, 1964). It is also apparent amongst the species described here. *Poraspis sericea* shows the post-pineal loop of the supraorbital canal and its connection with the median dorsal canals whilst *P. heintzae* and *P. cracens* lack these connections although there appears to be a completely united system of commissures and longitudinal canals. Unfortunately, the details of the canal system are not clear in *P. thules* or *P. parmula,* the smallest of the new species.

It is clear that the new species from arctic Canada conform to established trends within *Poraspis* and constitute part of a sequence which allows the origins of the genus to be extended back into the Late Silurian. It seems possible that arctic Canada formed a locus of development for *Poraspis,* followed by its primarily eastward radiation into Spitsbergen and western Europe. The presence of *P. polaris* in the Delorme Formation of the Mackenzie Mountains to the west (Dineley and Loeffler, 1976), and of *P. sericea* in the upper member of the Peel Sound Formation, suggests that later species had a rather wider geographical distribution. The Canadian arctic has been identified as the center of development for some other agnathan taxa during the Late Silurian, most notably the pteraspidids (Elliott and Dineley, 1985; Elliott, 1984b) and it is possible that this area exhibited a particular set of environmental conditions that contributed to a high rate of development of evolutionary novelties during the Late Silurian.

ACKNOWLEDGMENTS

This work was supported by NSF grant DPP 89-21819; field work was also supported by Polar Continental Shelf Project. Facilities were provided by the University of Bristol (DKE, YL), and University College London (DKE) during the course of this study and this help is gratefully acknowledged. Assistance with photography was provided by T. Melis (Flagstaff), S. Powell (Bristol) and M. Grey (University College, London); Figures 1, 2, and 8 were drafted by R. O'Reilly. The manuscript was substantially improved by the reviews of A. Blieck and P. Janvier.

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ACCEPTED 18 JUNE 1997

APPENDIX

Fossil Localities

Localities 1, 2, sandstone-carbonate facies of the upper member of the Peel Sound Formation, north coast of Prince of Wales Island.

Locality 1. Stream section 90°28′W, 73°46′N. (Locality K of Miles, 1973; Locality B of Dineley, 1976; Locality 9 of Elliott, 1983). Fauna: *Escharaspis alata, Stegobranchiaspis baringensis, Ctenaspis russelli, Poraspis sericea, Baringaspis dineleyi, Eskimaspis heintzi,* porolepid.

Locality 2. Stream section, 98°34′W, 73°46′N. (Locality D and H of Miles 1973; Localities 3 and 4 of Elliott, 1983; Locality A of Dineley and Liu, 1984). Fauna: *Stegobranchiaspis baringensis,* pteraspididae indet., *?Weigeltaspis* sp., *Poraspis sericea, Cephalaspis* sp., *Baringaspis dineleyi, Eskimaspis heintzi,* porolepid.

Locality 3. Upper member of the Peel Sound Formation, north west coast of Prescott Island. Ex situ from stream section, 96°57′W, 73°09′N. (*Ctenaspis ornata* locality of Dineley, 1976). Fauna: *Ctenaspis ornata, Poraspis heintzae, ?Pionaspis* sp., *?Cephalaspis* sp.

Localities 4–7, lower member of Peel Sound Formation, gorge 22.5 km north of Transition Bay, southeast Prince of Wales Island. 96°28′W, 72°10′N.

Locality 4. 5 m (18′) above the base of the Peel Sound Formation. (Locality 7 [part] of Broad, 1973; Broad and Dineley, 1973; Locality 2

of Elliott, 1984b; Locality 1 of Elliott and Dineley, 1985, 1991; GSC Locality C-10045.) Fauna: *Poraspis cracens, Poraspis thules,* ?*Ariaspis* sp., *Boothiaspis alata, B. ovata, Alainaspis*? sp., *Torpedaspis elongata, Corvaspis* sp., *Ulutitaspis truncata,* ?*Traquairaspis* sp.

Locality 5. 59.6 m (196′) above the base of the Peel Sound Formation. (Locality 7 [part] of Broad, 1973; Broad and Dineley, 1973: Locality 3 of Elliott, 1984b: Locality 2 of Elliott and Dineley, 1985, 1991; GSC Locality C-10046.) Fauna: *Poraspis thules, Poraspis parmula, Alainaspis platyrhina, Torpedaspis elongata, Ulutitaspis notidana,* ?*Traquairaspis* sp., acanthodian spines, lingulids.

Locality 6. 60.3 m (198′) above the base of the Peel Sound Formation. (Locality 4 of Elliott, 1984b.) Fauna: *Poraspis thules, Corvaspis* sp., ?*Traquairaspis* sp., lingulids.

Locality 7. 60.9 m (200′) above the base of the Peel Sound Formation. (Locality 7 [part] of Broad, 1973; Broad and Dineley, 1973; GSC Locality C-10047.) Fauna: *Poraspis parmula, Corvaspis* sp., *Torpedaspis elongata,* ?*Traquairaspis* sp., lingulids.

Locality 8. 15.2–31.4 m (50′–103′) above the base of the upper member of the Somerset Island Formation. Stream valley 1.6 km east of Pressure Point, Somerset Island. 95°14′W, 73°59′N. (Locality A of Dineley, 1968; Locality 5 [part] of Broad, 1973; Broad and Dineley, 1973; *Corvaspis* locality of Loeffler and Dineley, 1976; Locality 8 of Elliott, 1984b; GSC Locality C-10050.) Fauna: *Poraspis parmula, Torpedaspis elongata, Boothiaspis alata, Corvaspis arctica,* ?*Traquairaspis* sp., *Ulutitaspis aquilonia, Hemicyclaspis murchisoni,* acanthodian spines.