The brachymetopid trilobite *Radnoria* in the Silurian (Wenlock) of New York State and Arctic Canada

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Abstract: ***Radnoria bretti*** n. sp., from the Wenlock (Sheinwoodian) Rochester Formation of western New York State, is the best preserved and most completely known member of its genus. It provides the first definitive information on *Radnoria*'s hourglass-shaped rostral plate, the first known hypostome of a Silurian member of the genus, demonstrates that *Radnoria* engaged in sphaeroidal enrollment, and reveals that early holaspid individuals had tubercles on the posterior thoracic axes and pygidial axial rings that were effaced with maturity. Three new species from the Wenlock of the Cape Phillips Formation of Nunavut are known from sparse material and are reported in open nomenclature. Together, the species greatly increase knowledge of Laurentian Silurian brachymetopids, which have until now been known from a single cranidium from the Wenlock of Arkansas.

Résumé : ***Radnoria bretti*** n. sp., de la Formation de Rochester du Wenlock (Sheinwoodien) de l'Ouest de l'État de New York, est le membre le mieux préservé et dont la description est la plus complète de ce genre. Il fournit les premières données définitives sur la plaque rostrale en forme de sablier de *Radnoria*, le premier hypostome connu d'un membre d'âge silurien de ce genre, démontre que *Radnoria* était capable d'enroulement sphéroïdal, et révèle que les individus holaspides précoces présentaient des tubercules sur leurs axes thoraciques postérieurs et des anneaux axiaux pygidiaux qui s'effaçaient chez les individus à maturité. Trois nouvelles espèces provenant de matériel dispersé du Wenlock de la Formation de Cape Phillips, au Nunavut, sont connues et signalées en nomenclature ouverte. Ensemble, ces espèces accroissent considérablement les connaissances sur les brachymétopides siluriens de Laurentia qui, jusqu'à présent, étaient représentés par un unique cranidium du Wenlock de l'Arkansas.

[Traduit par la Rédaction]

Introduction

Prior to 1975, the family Brachymetopidae had not been recognized from rocks older than Early Devonian. Owens and Thomas (1975) erected *Radnoria* for three Wenlock species, two from the Anglo-Welsh basin and one from the Prague basin in the Czech Republic. Since then, two additional Silurian occurrences have been documented (Holloway 1980; Sun 1990) and several Upper Ordovician species have been assigned (reviewed by Owens and Hammann 1990; also Hammann and Leone 1997). To date the genus (and family) has been known from the Silurian of Laurentia only from a single cranidium, from the St. Clair Limestone of Arkansas (Sheinwoodian), figured in open nomenclature by Holloway (1980).

Herein, we describe what is to this point by far the best known species of *Radnoria*, based on multiple articulated specimens from the Sheinwoodian Rochester Formation of New York State. *Radnoria bretti* n. sp. provides new information on the course of the connective sutures and shape of the rostral plate, on the hypostome, on the style of enrollment, and on early holaspid ontogeny. We also figure three new but sparsely known species from the Sheinwoodian and Homerian of the Cape Phillips Formation of Nunavut, thus greatly extending the geographic range of the genus.

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Geological setting

New York State material

The Rochester Formation (Clinton Group) is a relatively homogenous dark gray shale (with subordinate limestone beds) developed during the Sheinwoodian across the northern half of the Appalachian Basin. The present-day Rochester Shale outcrop belt (see Fig. 1) roughly parallels the northern margin of the Appalachian Basin, with mid-basin at approximately the Rochester, New York region. Brett (1983) has given details of the sedimentology and lithostratigraphy. Tetreault (1994) has summarized the paleoecological and taphonomic character of the Rochester Shale, in the course of identifying several bathymetry-related brachiopod and trilobite biofacies within the unit. Tetreault (1990) also examined the autecology of the more common trilobites found within the unit. The Rochester Shale is interpreted as having been deposited during two transgressive–regressive cycles, with facies ranging from above storm wave base to distal shelf-slope. A wide variety of paleoenvironments is represented,

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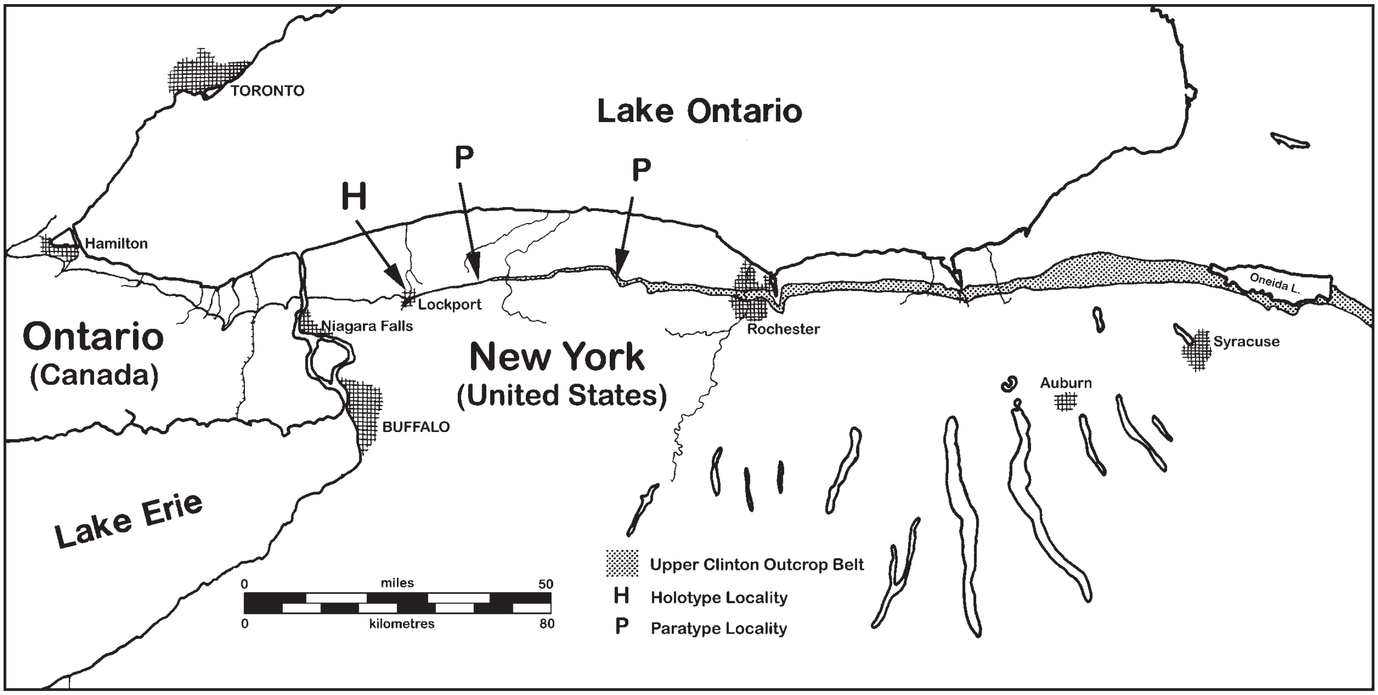
Fig. 1. Map showing outcrop belt of Upper Clinton Group (including the Rochester Formation) in northern New York State and eastern Ontario. **H** = Holoype locality near Lockport from which holotype of *Radnoria bretti* n. sp. was collected; P = paratyle localities. Grid-pattern represents metropolitan areas.



extending from shallow-water bryozoan patch reefs through brachiopod shell pavements, to sparsely fossiliferous deeper water muddy bottoms.

Tetreault (1994) has recognized four trilobite biofacies in the Rochester Shale, arranged in three bathymetric zones, and modified east–west by variations in clastic sediment supply. The phacopid *Dalmanites limulurus* (Green, 1832) is ubiquitous throughout the unit and therefore not useful in the definition of biofacies, hence it was not used in their naming. West of Rochester, the unit is divided into the *Bumastus*, *Arctinurus*, and *Trimerus* biofacies. East of Rochester, the unit is divided into the *Calymene* and *Trimerus* biofacies. *Radnoria bretti* occurs within the *Bumastus* and *Arctinurus* biofacies.

The *Bumastus* biofacies was developed above storm wave base in two separate horizons in the lower transgressive–regressive cycle. It is dominated by the small illaenid *Bumastus ioxus* (Hall, 1843), comprising 50%–90% of the trilobite fauna (mean of 65%). The *Bumastus* biofacies is of far higher diversity than the others recognized in the formation. Other trilobites occurring in this biofacies are, in decreasing order of species abundance, *Dalmanites limulurus*, *Calymene niagarensis* Hall, 1843, *Radnoria bretti*, *Dicranopeltis nereus* (Hall, 1863), an undescribed species of *Diacalymene*, *Trimerus delphinocephalus* (Green, 1832), *Arctinurus boltoni* (Bigsby, 1825), *Decoroproetus corycoeus* (Conrad, 1841), and *Deiphon pisum* Foerste, 1893. *Radnoria bretti* can make up 5% to 10% of the trilobite fauna and is most common in shaley interbeds between relatively barren dolostones (interpreted as tempestites by Brett (1983)) and bryozoan-rich bioclastic limestones.

The *Arctinurus* biofacies was developed at and just below storm wave base and is dominated by *Striispirifer* brachiopod shell pavements. It shares several trilobite species with the *Bumastus* biofacies, but displays a much different pattern of relative abundance. This biofacies is dominated by *Dalmanites limulurus*, composing approximately 75% of the trilobite fauna. Other trilobites occurring in this biofacies are, in decreasing order of abundance, *Calymene niagarensis*, *Arctinurus boltoni*, *Trimerus delphinocephalus*, *Decoroproetus corycoeus*, *Radnoria bretti*, *Bumastus ioxus* (Hall, 1843), and *Illaenoides* sp. *Radnoria bretti* is a rare component of the *Arctinurus* biofacies and typically makes up < 5% of the trilobite fauna.

The *Trimerus* biofacies was developed below storm wave base across the entire Rochester Shale outcrop belt and is the only biofacies in the Rochester Shale in which trilobite material is often the numerically dominant body fossil element (up to 75% of the fossil material). *Dalmanites limulurus* is the dominant trilobite, composing 60%–95% of the trilobite fauna (mean of 65%), *Trimerus delphinocephalus* constituting the remaining fraction.

East of Rochester, New York, the *Bumastus* and *Arctinurus* biofacies are both replaced by the *Calymene* biofacies. Dominated by *Dalmanites limulurus*, which makes up 20%–75% of the trilobite fauna (mean of 50%), this biofacies is characterized by the presence of an undescribed species of *Calymene* composing 10%–30% (mean of 20%) of the trilobite fauna. Other trilobites include, in decreasing order of abundance, *Maurotarion* sp., *Cheirurus* sp., *Trimerus delphinocephalus*, *Trochurus halli* (Foerste 1917), and *Bumastus* sp. Within the immediate Rochester, New York region, the Rochester Shale contains a mixed fauna.

Northern Canadian material

Locality information for new Arctic material follows Adrain and Edgecombe (1997*a*). Graptolite zones are cited following

Lenz and Melchin (1991) and Lenz (1995). In brief, the specimens are silicified and were deposited in debris flows shed from the (now dolomitized) Arctic Platform. These debris flows are interbedded with calcareous shales and argillaceous limestones of the Cape Phillips Formation. Rich graptolite faunas occur in the shales, permitting highly resolved dating of the shelly faunas. Trilobites from these Wenlock and lower Ludlow faunas have been described in a series of papers and monographs (Adrain 1994, 1997, 1998, 2003; Adrain and Edgecombe 1997*a*, 1997*b*; Adrain and MacDonald 1996; Adrain and Ramsköld 1996, 1997). Other fossils occurring in the debris flows include common and diverse articulate brachiopods, ostracods, bryozoans, corals, gastropods, disarticulated echinoderms, bivalves, polyplacophorans, nautiloids, machaeridians, conodonts, and radiolarians. Given the transported nature of the deposits, the original depositional environment is difficult to infer, but the high trilobite diversity and position relative to the platform indicates a relatively deep distal platform setting. This is supported by the fact that the trilobite faunas have much in common at the species level with those of the Selwyn Basin in the southern Mackenzie Mountains (e.g., Adrain and Edgecombe 1997*a*). The latter occur in autochthonous dark argillaceous limestones that were deposited in deep subtidal (i.e., below storm wave base) environments.

Systematic paleontology

Figured specimens are housed in the Department of Natural History (Palaeobiology), Royal Ontario Museum, Toronto, Ontario (with prefix ROM), the Paleontological Research Institution, Ithaca, New York (with prefix PRI), and the New York State Museum, Albany, New York (with prefix NYSM).

Superfamily Aulacopleuroidea Angelin, 1854
Family Brachymetopidae Prantl and Přibyl, 1951
Genus *Radnoria* Owens and Thomas, 1975

TYPE SPECIES: *Radnoria syrphetodes* Owens and Thomas, 1975, Wenlock (lower Sheinwoodian), Dolyhir Limestone, Wales.

OTHER SPECIES: *Radnoria bretti* n. sp.; *R. carlsi* Owens and Hammann, 1990; ?*Harpidella (Harpidella) dolianovensis* Hammann and Leone, 1997; *Harpidella* (s.l.) *dolicocephala* Ji, 1986; ?*R. elongata* Sun, 1990; *Cyphaspis humillima* Barrande, 1852; *Proetus loredensis* Delgado, 1908; *Otarion simplex* Kolobova, 1978; *Radnoria simplex* of Hammann and Leone (1997) (likely includes two distinct species, see the following remarks); *R. triquetra* Owens and Thomas, 1975.

REMARKS: *Radnoria simplex* (Kolobova, 1978), is presently the oldest known definite brachymetopid. The age of the species is not well constrained, as the Obikalon Member is dated on the basis of shelly fossils as broadly Caradoc (Kim et al. 1978; see also Nikitin et al. 1986). *Radnoria simplex* is relatively poorly known on the basis of distorted internal molds of a pygidium, an outstretched articulated specimen, a fragmentary cranidium, and a fragmentary cranidium with left librigena attached (Kolobova 1978, pl. 24, figs. 10–13).

Hammann and Leone (1997) assigned material from southern Sardinia to Kolobova's species. That some of the Sardinian material represents a taxon conspecific with the Uzbekistan species is not impossible, and indeed there is morphological evidence that the species are at least very similar. Most strikingly, they share pygidia with a doublure that is considerably longer medially than laterally. The respective overall faunas are similar at the generic level, and Hammann and Leone also considered their species of *Prionocheilus* conspecific with Kolobova's species. Nevertheless, the poor quality of preservation and small illustrations given by Kolobova do not permit confidence in the species identity and Hammann and Leone's material is better treated in open nomenclature as *Radnoria* cf. *R. simplex*. Hammann and Leone were equivocal about the assignment, observing (1997, pp. 109–110) that it is supported insofar as information is available from Kolobova's illustrations of poorly preserved specimens. In fact, they listed their Sardinian material on the explanation of their pl. 22, figs. 1–5, as *Radnoria* cf. *simplex*, whereas it was given as *Radnoria simplex* in the explanation of pl. 21 and in the text. No distinction between two Sardinian taxa was made in the text and the sets of material on pls. 21 and 22 each contain a mix of specimens from the same two horizons.

Hammann and Leone (1997) assigned to a single species specimens of *Radnoria* from two separate localities and horizons, one (their locality Gon 1, horizon TH2b) of approximate Streffordian (late Caradoc) age and a second (their locality Can 1c, horizon TH3a) of approximate Pusgillian (early Ashgill) age. They listed differences between the sets of specimens, but attributed them to varying preservation. However, there seem almost certainly to be two stratigraphically separate species of *Radnoria* involved. It is difficult to see how the much more inflated L1 of the older species (Hammann and Leone 1997, pl. 22, figs. 1, 2), fully isolated from the median glabellar lobe by a deep S1, could differ only through compaction from the weakly inflated L1 and shallow S1 of the younger occurrence (pl. 21, fig. 1). The older species resembles *Radnoria triquetra* in this morphology, whereas the younger is very like *R. syrphetodes* and *R. bretti*. In addition, the older species has very prominent caecal sculpture on its frontal area (pl. 22, fig. 2), and this is unmatched on either the well preserved internal or external mold of a cranidium of the younger species (pl. 21, figs. 1*a*–1*d*). Finally, the pygidium of the older species (pl. 22, fig. 3) bears as many as 9 axial rings, whereas that of the younger species (pl. 21, fig. 6, pl. 22, fig. 5) bears only 6 or 7.

Hammann and Leone (1997) named a new species, *Harpidella (Harpidella) dolianovensis*, and discussed it, as the name implies, as an aulacopleurid. The species bears little resemblance to those assigned to *Harpidella*, which was revised on the basis of the type and other species by Adrain and Chatterton (1995; not cited by Hammann and Leone, who may have finished their manuscript prior to the appearance of the paper). Further well-preserved Upper Ordovician species were described by Adrain (2005). The type material of *dolianovensis* is extremely poorly preserved as coarse-grained molds and comprises only two internal molds of cranidia, an internal mold and counterpart partial external mold of a cephalon, and an external mold of a librigena. To the extent they can be interpreted, however, they show little evidence of aulacopleurid affinity and the species probably represents a brachymetopid. In particular, the librigena has a

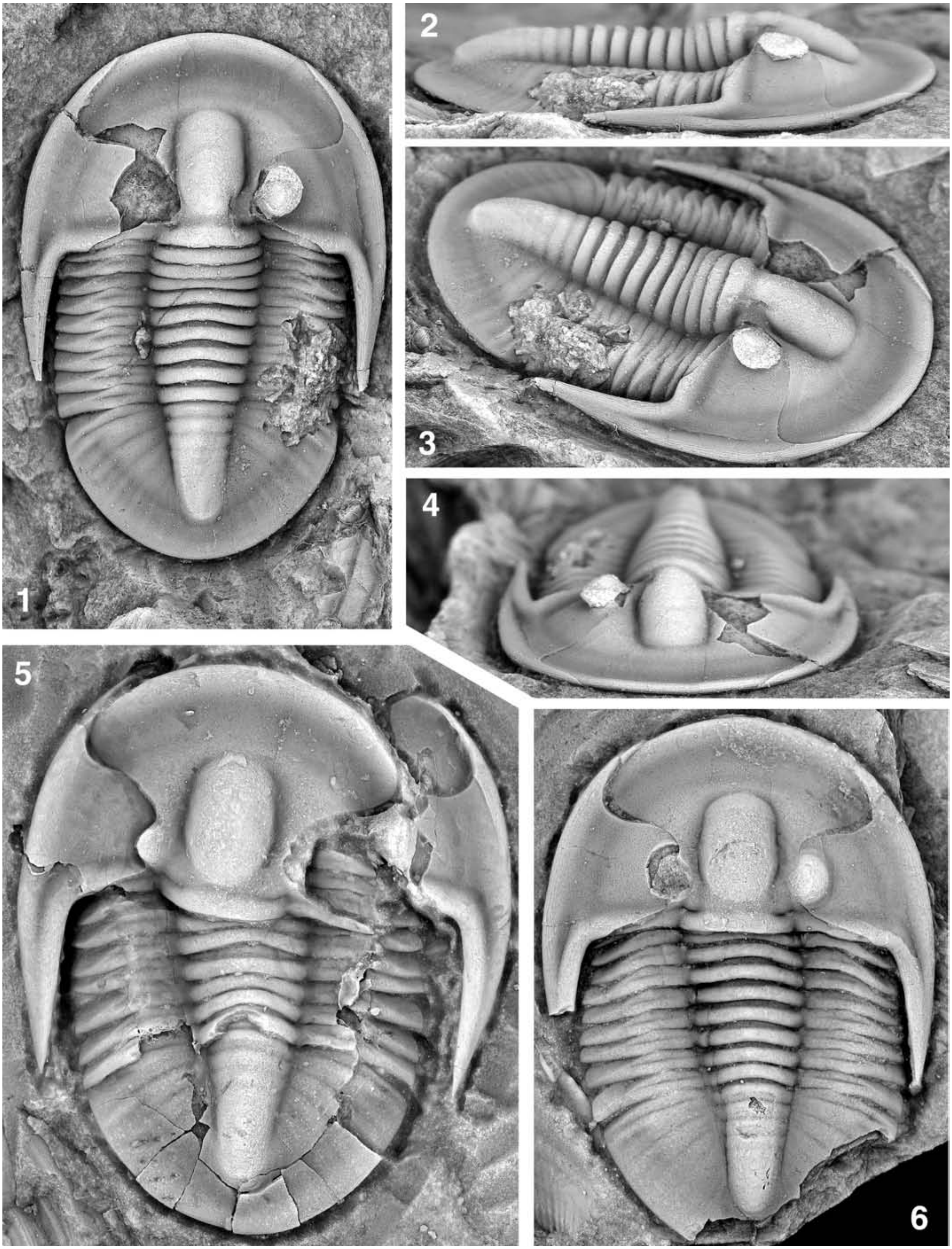

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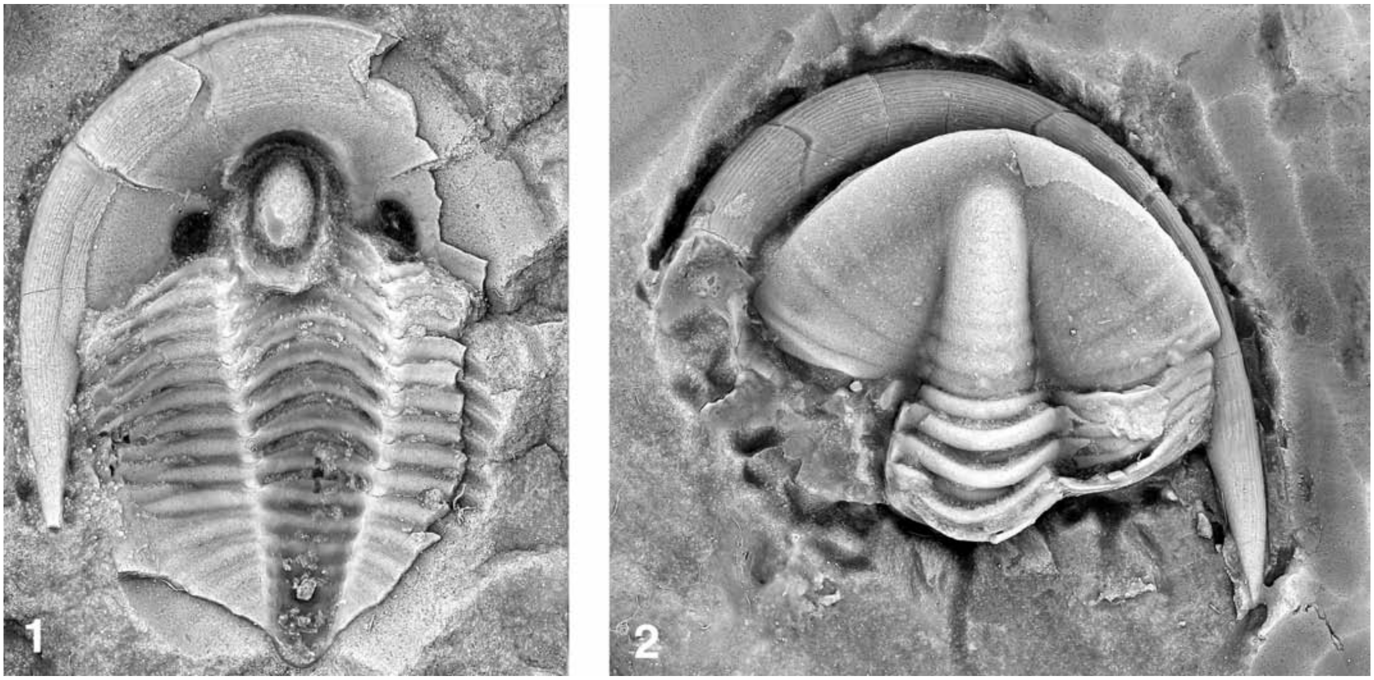
Fig. 2. *Radnoria bretti* n. sp., from the Rochester Formation, Wenlock (Sheinwoodian), western New York State. Magnification ×7.5. (**2.1–2.4**) exoskeleton, **holotype**, NYSM 16792, dorsal, right lateral, oblique, and anterodorsal views, Eighteen Mile Creek, near Lockport, Niagara County. (**2.5**) exoskeleton, PRI 41984, dorsal view, Caleb Quarry, near Middleport, Niagara County. (**2.6**) exoskeleton, PRI 44579, dorsal view, ×5, Caleb Quarry, near Middleport, Niagara County.

Fig. 3. *Radnoria bretti* n. sp., from the Rochester Formation, Wenlock (Sheinwoodian), western New York State. Magnification ×7.5. Specimens showing ventral morphology. (**3.1**) exoskeleton, PRI 42657, ventral view. (**3.2**) enrolled exoskeleton, PRI 41985, dorsal view of pygidium, Caleb Quarry, near Middleport, Niagara County.



very broad field, lacks a prominent eye socle, and the posterior and lateral borders are flattened, not tubular. The palpebral lobes (Hammann and Leone 1997, pl. 22, fig. 8*a*) nearly abut the glabella, and there is no development of independently inflated interocular fixigenae. These features are rare or unknown in aulacopleurids, but are commonly developed in *Radnoria*, to which the poorly known species is tentatively assigned. The only superficially aulacopleurid-like feature is the isolated L1, but a fully isolated L1 is developed in several species of *Radnoria*, including the older of the taxa assigned to *R. simplex* from the Portixeddu Formation by Hammann and Leone.

Radnoria elongata Sun, 1990, from the upper Ludlow (Ludfordian; Rickards and Wright 1999) Rainbow Hill Marl Member of the basal Rosebank Shale, near Yass, New South Wales, Australia, differs from all other species assigned to *Radnoria* in its broader, shorter glabella which occupies a much greater area of the cranidium and in its large and nearly fully isolated L1. The species may in fact be an early member of *Cordania*, as its glabellar morphology is close to that of such species as *C. buicki* Ebach and Edgecombe, 1999. Its 10 or 11 pygidial axial rings (Sun 1990, pl. 1, fig. 16) is the highest number known within *Radnoria* but is the same as in *C. buicki*. *Radnoria elongata* also has a distinct rim around the pygidial margin against which the prominently incised pleural and interpleural furrows terminate. This is the condition seen in *Cordania*, but in other species of *Radnoria* with strongly expressed pleural and interpleural furrows (e.g., *R. triquetra* — cf. Owens and Thomas 1975, pl. 96, fig. 5*a*), the furrows extend to the margin and no distinct rim is present. *Radnoria elongata* is retained with question in *Radnoria* for the time being, but further work and more complete knowledge of the species may indicate reassignment.

Radnoria bretti n. sp.
(Figs. 2–4)

1852 *Proetus? stokesii*; Hall, p. 316, pl. 67, figs. 13, 14.
1994 *Radnoria* sp.; Tetreault, p. 357, fig. 5.
2002 *Radnoria* species; Whiteley et al., p. 151, pl. 135.

DERIVATION OF NAME: After Carlton E. Brett of the University of Cincinnati, Cincinnati, Ohio.

TYPE SPECIMENS: Holotype dorsal exoskeleton NYSM 16792 (Figs. 2.1–2.4), from the Rochester Formation (Lewiston Member, *Homocrinus* bed), Wenlock (Sheinwoodian), exposures (now destroyed) along the west branch of Eighteen Mile Creek at Lockport Gulf, 0.8 km north of New York State (NYS) Route 31 and 0.3 km west of N.Y. Central railroad tracks, Lockport, Niagara County, New York (Lockport 7.5′ Quadrangle), locality 28a of Brett (1983); paratypes PRI 41984, PRI 41985, and PRI 44579, all from the Rochester Formation, Lewiston Member, contact between units B and C, borrow pit owned by Brent Caleb, ~300 m south of NYS Route 31, ~0.6 km west of Orleans County line, Middleport,

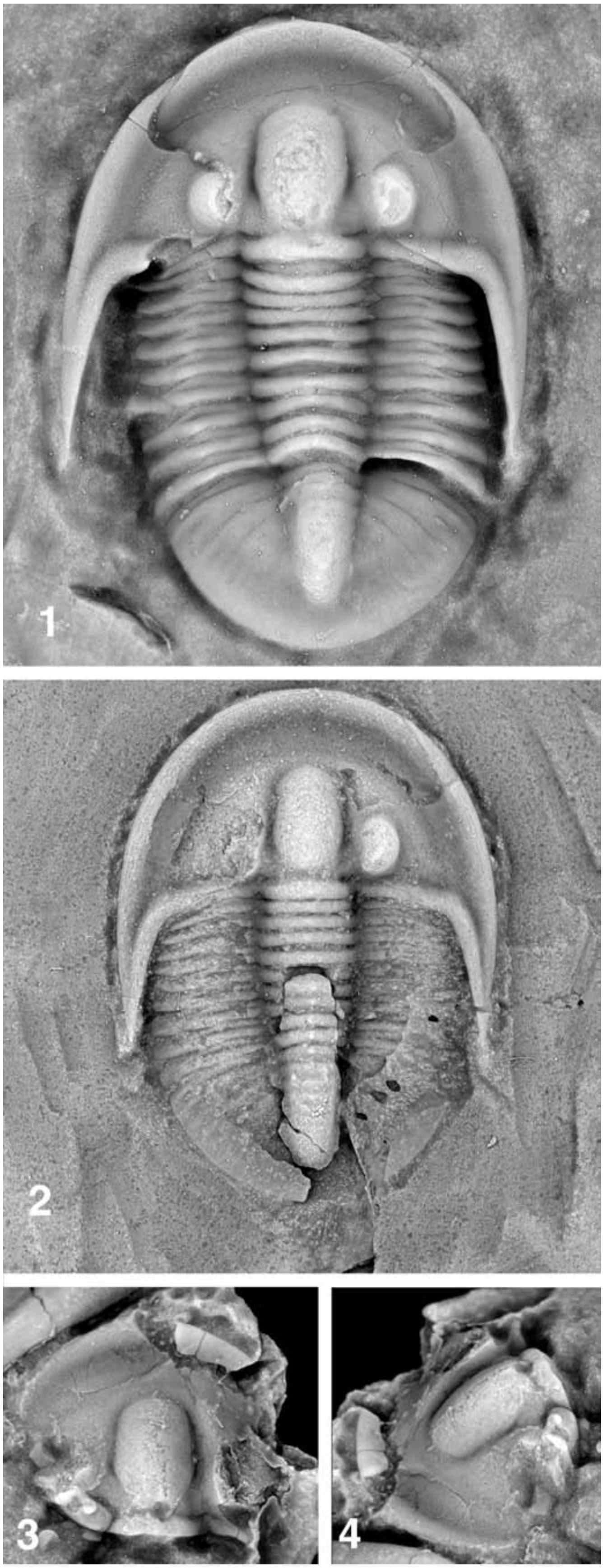


Fig. 4. *Radnoria bretti* n. sp., from the Rochester Formation, Wenlock (Sheinwoodian), western New York State. Small holaspid specimens. (**4.1**) exoskeleton, PRI 42656, dorsal view, ×10. (**4.2**) exoskeleton, PRI 42658, dorsal view, ×10. (**4.3, 4.4**) cranidium, NYSM 13232, dorsal and oblique views, ×7.5.

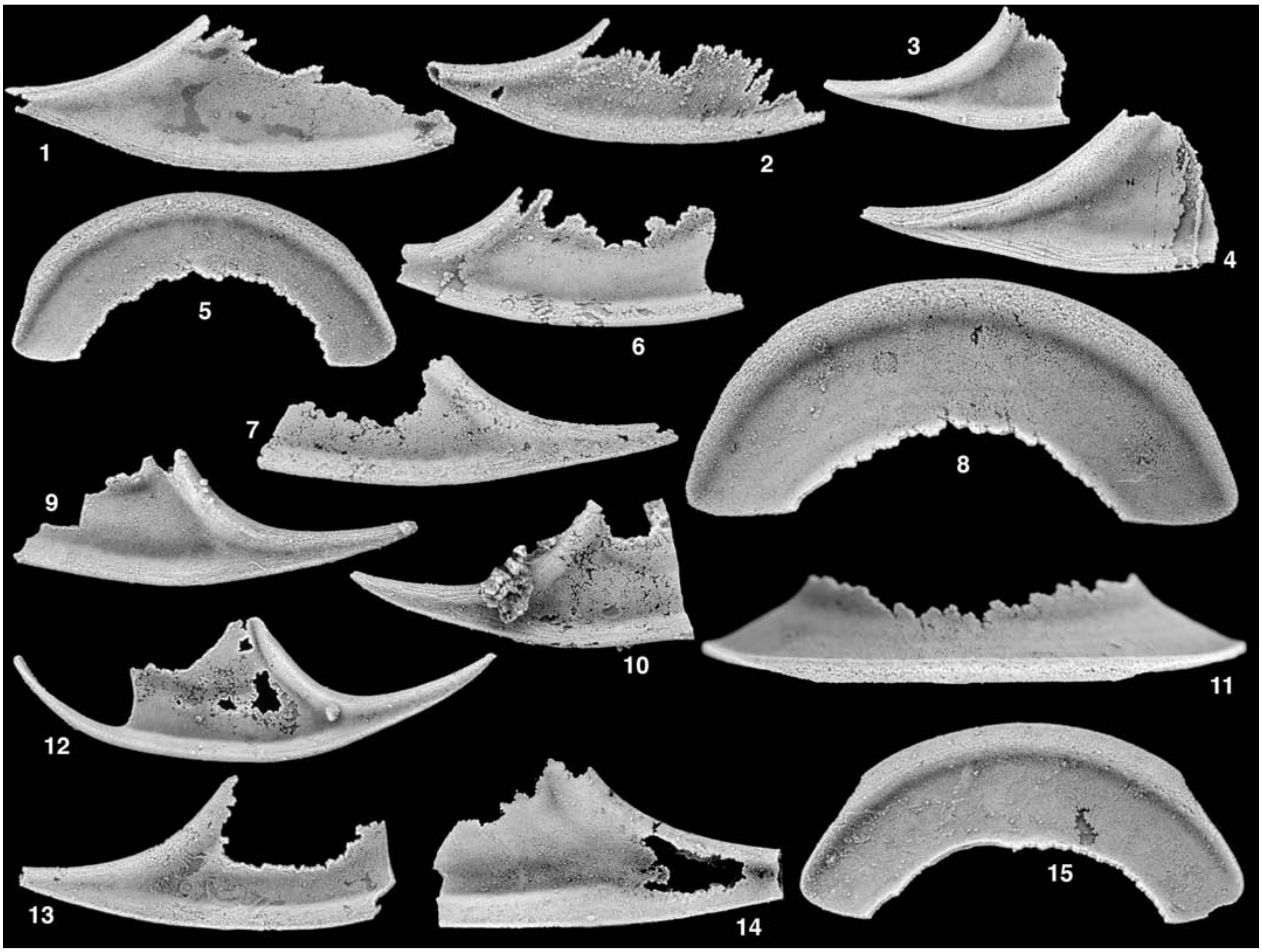
Niagara County, New York; paratypes PRI 42656 and NYSM 13232, from pond excavation in Rochester Formation, property of Howard Farm, south of Powerline Road and east of Hindsburg Road, ~4 km northwest of Clarendon, Orleans County, New York (Holly 7.5′ Quadrangle); paratypes PRI 42657 and PRI 42658, both from the Rochester Formation, higher construction excavating pond, ~300 m south of NYS Route 31 and at very west edge of Orleans county line, 1.5 km southeast of Middleport, Shelby Township, Orleans County (Medina 7.5′ Quadrangle), New York.

DIAGNOSIS: Entire dorsal exoskeleton with strong dorsal effacement; cranidium with relatively short length anterior to glabella; pygidium with only first five axial rings discernible in large specimens and only first pleural furrow well inscribed; pygidial border broad.

DESCRIPTION: Cephalon with maximum width opposite posterior border 175% sagittal length; cranidium with sagittal length 80% maximum width across β; width across γ 45% width across β; anterior border with sagittal length three times that of L0; border roll short (sagittal, sag.; exsagittal, exsag.), lengthening slightly abaxially, strongly convex, with sculpture of two or three fine terrace lines running along rim subparallel to and near to anterior margin; epiborder furrow broad and shallow, occupying one third sagittal length of border; anterior border furrow short (sag., exsag.), slightly deeper than epiborder furrow; preglabellar field very short; glabella with sagittal length (excluding L0) 160% width at distal end of S1, very weakly inflated, lacking dorsal sculpture; preglabellar furrow evenly arcuate, slightly deeper abaxially; axial furrows subparallel in front of L1, deep; axial furrow out-turned and much shallower opposite L1; L0 wide, widening posteriorly, lacking any dorsal sculpture; S0 long and shallow behind median glabellar lobe, forming shorter, deep, notch behind L1; L1 teardrop shaped, very weakly inflated; S0 deeper than axial furrow opposite L1, deepest near distal contact with axial furrow; glabellar lobes and furrows anterior to S1 obscure; interocular fixigena very narrow, weakly inflated, lacking sculpture; palpebral lobe large, long (exsag.), with faint median tubercle; posterior border long, slightly deeper than median part of S0.

Librigenal lateral border wide (transverse) anteriorly, narrowing significantly posteriorly; border roll broadening posteriorly, so that epiborder furrow is severely narrowed posteriorly; lateral border furrow similar in width and depth to cranidial anterior border furrow, shallowing slightly immediately in front of contact with posterior border furrow; posterior border furrow slightly longer (exsag.) than that of cranidium, interrupted by very fine sutural ridge; librigenal field weakly inflated, lacking sculpture; eye socle of single very weak band, of similar width anteriorly and posteriorly; eye large, length (exsag.) over twice width; genal spine long and subtriangular, reaching rear of eighth thoracic segment; genal spine base broad, spine tapering evenly to tip;

Fig. 5. *Radnoria* spp., from the Cape Phillips Formation, Wenlock, Nunavut. Magnifications are ×7.5 except where noted otherwise. (**5.1–5.4**) *Radnoria* n. sp. 1, from section BH 1 110 – BH 1 112 m (mid-Sheinwoodian; *Monograptus instrenuus – Cyrtograptus kolobus* Zone), southern Baillie-Hamilton Island. (5.1) right librigena, ROM 50693, external view, ×6 (BH 1 112 m). (5.2) right librigena, ROM 50694, external view, ×10 (BH 1 110 m). (5.3) right librigena, ROM 50695, external view (BH 1 110 m). (5.4) right librigena, ROM 51292, external view (BH 1 110 m). (**5.5–5.12**) *Radnoria* n. sp. 2, from sections BH 1 204 m, BHL 1 92 m, and locality BHH (upper Sheinwoodian; *Cyrtograptus perneri – Monograptus opimus* Zone), southern Baillie-Hamilton Island. (5.5) cranidium, ROM 52001, dorsal view (BHL 1 92 m) (5.6) right librigena, ROM 52002, external view (BHH-C); (5.7) left librigena, ROM 52005, external view (BHH-C). (5.8, 5.11) cranidium, ROM 52003, dorsal and anterior views (BHH-A). (5.9) left librigena, ROM 52004, external view (BHH-C). (5.10) right librigena, ROM 52006, external view, ×6 (BH 1 204). (5.12) left librigena, ROM 52007, external view (BHH-C). (**5.13–5.15**) *Radnoria* n. sp. 3, from sections ABR 1 22 m and ABR 3 24+ m (upper Homerian; *Pristiograptus ludensis* Zone), near Abbott River, northwestern Cornwallis Island. (5.13) right librigena, ROM 52008, external view (ABR 3 24+ m) (5.14) left librigena, ROM 52010, external view (ABR 1 22 m). (5.15) cranidium, ROM 52009, dorsal view, ×10 (ABR 3 24+ m).



posterior border similar in length (exsag.) to width of epiborder, both with sculpture of fine terrace lines similar to that of cranidial anterior border; epiborder furrow and posterior border furrow uniting to run as narrow furrow down dorsal aspect of genal spine; epiborder and posterior border continued posteriorly along abaxial and adaxial aspects of spine; doublure with sculpture of fine, closely spaced terrace lines running subparallel with margins.

Rostral plate shaped like laterally stretched hourglass; length (sag.) about 40% of maximum width across rostral suture; connective suture with adaxially directed “V” shape, anterior branch very slightly longer; ventral sculpture of fine subparallel terrace lines confluent, when articulated, with those of the librigenal doublure.

Hypostome poorly known; maximum width developed across shoulder, about 50% of sagittal length; anterior margin anteriorly convex, slightly downturned; lateral and posterior border furrows deep and convergent, defining swollen, ellipsoid middle body; middle furrow not evident; posterior border tab-shaped and elongate (sag., exsag.).

Thorax of nine segments, narrowest across first segment, reaching slightly broader maximum width across eighth segment; sagittal length slightly less than half maximum width; axial lobe broadest across fourth segment, width across first segment 95% that across fourth segment; width across narrowest ninth segment 70% that across fourth segment; axial rings lacking dorsal sculpture in mature individuals, bowed slightly anteriorly; axial furrow deep; fulcrum set about half distance distally on first five segments, distal part increasingly broader than proximal part on more posterior segments; pleural furrow finely incised, lengthening and deepening slightly at fulcrum, becoming effaced just distal to fulcrum; posterior pleural bands slightly longer (exsag.) than anterior bands; prominent articulating facet occupies much of anterior part of segment distal to fulcrum; segment tips subquadrate, with slight posterolateral point.

Pygidium with sagittal length (excluding articulating half ring) 57%–60% of maximum width; axis with sagittal length occupying about 77% sagittal length of pygidium and maximum anterior width about 27% the maximum pygidial width; axis with laterally concave margins, narrowing sharply opposite first two rings, then more gently posteriorly; axis dorsally inflated, raised in sagittal profile above pleurae to similar extent as thoracic axis; small specimen (Fig. 4.2) shows that probably eight or nine rings are present, but on larger specimens only the first five are discernible with the fifth nearly effaced and the posterior part of the axis entirely smooth; only the first two axial ring furrows are transversely complete, with the posterior ones progressively effaced; axial rings of similar length sagittally and exsagittally; axial furrows slightly deeper anteriorly, progressively shallowing posteriorly but meeting to fully circumscribe broad, rounded, rear of axis; first pleural furrow inscribed as well as that of ninth thoracic segment, posterior furrows progressively effaced, but up to seven remain discernible in some specimens; interpleural furrows very weak, break between segments is mostly obvious because of slight inflation of posterior pleural bands, which form faint raised ridges (Fig. 2.1); adaxial region of pleurae quite steeply sloping, slope changes abruptly at inner edge of broad border and becomes more nearly flat; border furrow marked as paradoublural line similar to that on cephalon; pleural and interpleural furrows run onto border with no change in expression; posterior margin of pygidium nearly semicircular, no marginal rim or obvious terrace lines present; ventral morphology poorly known.

REMARKS: Owens and Thomas (1975, p. 816, text-fig. 1) reconstructed the rostral plate of *Radnoria syrphetodes* as subtrapezoidal in shape, with the connective sutures diverging posteriorly. The basis for this was a librigena (Owens and Thomas 1975, pl. 95, fig. 4) upon which the excavated doublure appears to have this shape. The shape of the rostral plate in *R. bretti* is clear, as it is preserved intact on two specimens (Figs. 3.1, 3.2) and the connective suture is also well displayed by a slightly disarticulated librigena (Fig. 2.5). The rostral plate of this species has the connective sutures chevron-shaped, so that the whole plate resembles a laterally stretched hourglass. Based on the dimensions of the doublure revealed by the librigena in Fig. 2.5, it appears the specimen on which Owens and Thomas based their reconstruction may not be intact, and that the surface which appears to be the connective suture may in fact be a break.

One specimen (Fig. 3.2) is preserved in an enrolled position, the only evidence of enrollment style that we are aware of in the family. The specimen is somewhat crushed, but indicates that, as one might expect in a subisopygous animal, standard sphaeroidal enrollment was employed, with the cephalic and pygidial doublures flush.

Radnoria bretti is most similar among named species to the type species, *R. syrphetodes*. *Radnoria syrphetodes* is moderately well known, on the basis of one figured cranidium, three librigena, and three pygidia from the type locality in the Dolyhir Limestone of Powys, Wales. A second, larger, cranidium was assigned by Owens and Thomas (1975, pl. 95, fig. 1), but it is from a less securely dated unnamed limestone in Carmarthenshire. It seems doubtfully conspecific with the holotype cranidium, which has a much longer (sag., exsag.) shallow depression anterior to the paradoublural line and posterior to the raised anterior rim. It could be argued that this difference is ontogenetic, as the Carmarthenshire cranidium is larger. However, examination of specimens of *R. bretti* that are larger (Figs. 2.1, 2,2, 2.6) than the Carmarthenshire cranidium and smaller (Figs. 4.1, 4.2) than the holotype cranidium shows that in this species, the relative length of this depressed area changes very little if at all through ontogeny. Detailed comparison is hampered because of the fact that L1, the palpebral lobes, and the posterior fixigena are not preserved on the holotype of *R. syrphetodes*.

Radnoria bretti differs from *R. syrphetodes* in having a less abrupt break in slope separating the anterior rim of the cranidium from the depressed paradoublural area as well as a shorter frontal and preglabellar area (in the holotype of *R. syrphetodes*, the region in front of the glabella occupies 53% of the sagittal cranidial length; in the holotype of *R. bretti* this region occupies only 37% of the length). S2 and S3 are better expressed in *R. syrphetodes* though the holotype is exfoliated and direct comparison with cuticular specimens of *R. bretti* is difficult. Librigenae are very similar, with the main difference being an apparently deeper lateral border furrow in *R. syrphetodes*. Pygidia of *R. bretti* are conspicuously more dorsally effaced than those of *R. syrphetodes*, in which the more posterior pleural, interpleural, and axial ring furrows are much more clearly visible; 9–10 axial rings can be discerned on pygidia of *S. syrphetodes* versus only five on large specimens of *R. bretti*. Finally, the paradoublural line on pygidia of *R. bretti* encroaches further onto the pleural field than in *R. syrphetodes*, indicating that the pygidial doublure was broader.

Radnoria bretti differs from *Radnoria* sp. of Holloway (1980, p. 28, pl. 5, figs. 23, 24), from the Sheinwoodian St. Clair Limestone of Arkansas, in having a much smaller frontal and preglabellar area, less divergent anterior sections of the facial suture (they are nearly transverse in the Arkansas specimen) and slightly wider interocular fixigenae, at least opposite the anterior edge of the palpebral lobe.

Radnoria sp. 1
(Figs. 5.1–5.4)

MATERIAL: Assigned specimens ROM 50693 – ROM 50695, ROM 51412 from section BH 1 110 m/BHL 1 0 m and section BH 1 112 m, Cape Phillips Formation, Wenlock (mid-Sheinwoodian; *Monograptus instrenuus* – *Cyrtograptus kolobus* Zone), southern Baillie-Hamilton Island, central Canadian Arctic.

REMARKS: Material of *Radnoria* is rare in the Cape Phillips

Formation silicified faunas, with most sclerites comprising either the posterior portions of librigenae or the frontal area of cranidia. This is apparently due to the original cuticle being very thin over most of the exoskeleton. Thin-cuticled trilobites tend to be represented in the silicified samples only by particular sclerite types, in which the cuticle was thicker than over much of the rest of the exoskeleton. Styginids are represented mainly by hypostomes and rostral plates, and cheirurines by librigenae. Nevertheless, despite the paucity of material and its fragmentary nature, three morphologically distinct and stratigraphically separate species of *Radnoria* can be recognized, and some comparisons and contrasts are possible.

Radnoria sp. 1 is characterized by an extremely broad lateral border furrow that is very concave immediately in front of the genal spine base. This base is concomitantly broad, and the genal spine itself more subtriangular and less subcylindrical than in all other known species.

Radnoria sp. 2
(Figs. 5.5–5.12)

MATERIAL: Assigned specimens ROM 52001 – ROM 52007 from section BH 1 204 m, section BHL 1 92 m, and locality BHH, Cape Phillips Formation, Wenlock (upper Sheinwoodian; *Cyrtograptus perneri* – *Monograptus opimus* Zone), southern Baillie-Hamilton Island, central Canadian Arctic.

REMARKS: *Radnoria* sp. 2 is distinguished from the older *Radnoria* sp. 1 in the possession of a slightly narrower, much less posteriorly concave lateral border furrow, and a relatively longer, more tapering genal spine with a narrower base. Two cranidial fragments (Figs. 5.5, 5.8, 5.11) indicate that the anterior sections of the facial sutures were aligned almost exactly transversely. In what little is known, *Radnoria* species 2 is the Cape Phillips species most similar to *R. bretti*. The species are united in the transverse course of the anterior sections of the facial sutures, the length and taper of the genal spine, and the manner in which the posterior and lateral border furrows unite well in front of the base of the spine, then run along the dorsal aspect of the spine as a single incised furrow, versus the posterior projection of both furrows onto a subtriangular spine base seen in other species.

Radnoria sp. 3
(Figs. 5.13–5.15)

MATERIAL: Assigned specimens ROM 52008 – ROM 52010, from sections ABR 3 24+ m and ABR 1 22 m, Cape Phillips Formation, Wenlock (upper Homerian), northwestern Cornwallis Island, central Canadian Arctic. At the time of collection, these horizons were identified as within the *Pristiograptus ludensis* Zone sensu Lenz and Melchin 1991. This zone was subsequently (Lenz 1995) subdivided into three zones. The precise location of the trilobite collections within these refined graptolite zones is unknowable without further fieldwork, but they are from the upper part of the upper Homerian and belong to either the *Colonograptus? praedeubeli* – *C. ? deubeli* Zone or the *Colonograptus? ludensis* Zone sensu Lenz 1995.

REMARKS: *Radnoria* sp. 3 has the narrowest librigenal lateral border furrow of any of the Cape Phillips species and probably the narrowest of any Silurian *Radnoria*. It is further distinguished by the manner in which the connective sutures cut across the cranidial rim in dorsal view (Fig. 5.15), and the relative narrowness of the area of the rim between the sutures at the anterior margin. The anterior sections of the facial sutures are also less anteriorly divergent than in either *Radnoria* spp. 1 or 2.

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