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R. K. Pickerill

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Résumé de l'article

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*Bergaueria perata* Prantl, 1945 from the Silurian of Cape George, Nova Scotia

R. K. Pickerill

*Department of Geology, University of New Brunswick, Fredericton  
New Brunswick E3B 5A3, Canada*

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The ichnogenus *Bergaueria* is formally documented for only the second time from Silurian strata, from the Silurian (pre-late Ludlow) of Cape George, Nova Scotia, and for the first time from eastern Canada. Specimens are assigned to *B. perata*, thus representing the first recording of the ichnospecies in Silurian strata. The excellent preservation of several specimens, combined with a review of previously described examples, permits a revised diagnosis of *B. perata* to include the common, almost universal, presence of concentric ornamentation.

La présente documentation formelle de l'ichnogenre *Bergaueria*, dans le Silurien (avant le Ludlow tardif) de Cape George, en Nouvelle-Ecosse, est seulement la seconde dans des strates siluriennes et la toute première dans l'Est du Canada. Les spécimens sont rapportés à *B. perata*, dont la présence au sein de strates siluriennes est de ce fait notée pour la première fois. L'excellente conservation de plusieurs spécimens, combinée à une révision des exemples déjà décrits, permet d'inclure la présence répandue, quasi universelle, d'une ornementation concentrique dans une nouvelle diagnose de *B. perata*.

[Traduit par le journal]

## INTRODUCTION

The ichnotaxonomy of single-entrance, plug-shaped, soft-substrate trace fossils has recently been elegantly reviewed by Pemberton *et al.* (1988). These authors demonstrated that, following literally decades of confusion, all such trace fossils could be reasonably assigned to essentially five ichnogenera, namely *Bergaueria* Prantl, 1945, *Conichnus* Myannil, 1966, *Conostichus* Lesquereux, 1876, *Dolopichnus* Alpert and Moore, 1975 and *Astropolichnus* Crimes and Anderson, 1985, with minor forms encompassed within *Calycraterion* Karaszewski, 1971, *Margaritichnus* Bandel, 1973 or *Mammilichnis* Chamberlain, 1971. With respect to the ichnogenus *Bergaueria*, the subject of this contribution, Pemberton *et al.* (1988) recognized four distinctive ichnospecies, *B. perata* Prantl, 1945, *B. langi* (Hallam, 1960), *B. radiata* Alpert, 1973 and *B. hemispherica* Crimes *et al.*, 1977.

Somewhat surprisingly *Bergaueria*, although previously reported from strata of earliest Cambrian to Pleistocene age (see Crimes, 1987; Pemberton and Jones, 1988), has only once been formally documented from Silurian strata. This recording is by Narbonne (1984) from the Upper Silurian (Ludlow) Leopold Formation of arctic Canada. Because of their generally poor preservation, specimens recorded by Narbonne (1984) were only identified at the ichnogeneric level, though at an earlier date in his unpublished thesis (Narbonne, 1981) he did tentatively compare them to *B. radiata*.

In this paper, *Bergaueria* is formally recorded for only the second time from Silurian strata and certainly for the first time in any Phanerozoic sequence from eastern Canada. Specimens described herein can clearly be allocated to *B. perata* and therefore this recording also represents the first definitive occurrence of the ichnospecies in Silurian strata. Finally, the excellent preservation of several specimens permits a revised and expanded diagnosis of *B. perata* as recently proposed by Pemberton *et al.* (1988).

## GEOLOGIC SETTING

Material described here was collected in 1984 from School Brook Cove-East on the north coast of Cape George, the peninsula forming the prominent northeastern corner of mainland Nova Scotia between Northumberland Strait and St. Georges Bay (Figs. 1, 2). Cape George is underlain by Hadrynian metasedimentary and metavolcanic rocks and, predominantly, unmetamorphosed and lithologically variable Devonian to Carboniferous strata (Fig. 1). At the extreme northern end of the peninsula, at and between Cormorant Cliff and School Brook Cove-East, occurs a complex fault-bounded and, regionally, a stratigraphically enigmatic sequence of Ordovician to Lower Devonian strata. These strata are cut and bounded by major east-west striking normal, strike-slip and thrust faults and numerous and multidirectional minor faults. Boucot *et al.* (1974) referred to the entire sequence as the "Lower Palaeozoic Fault Complex,"

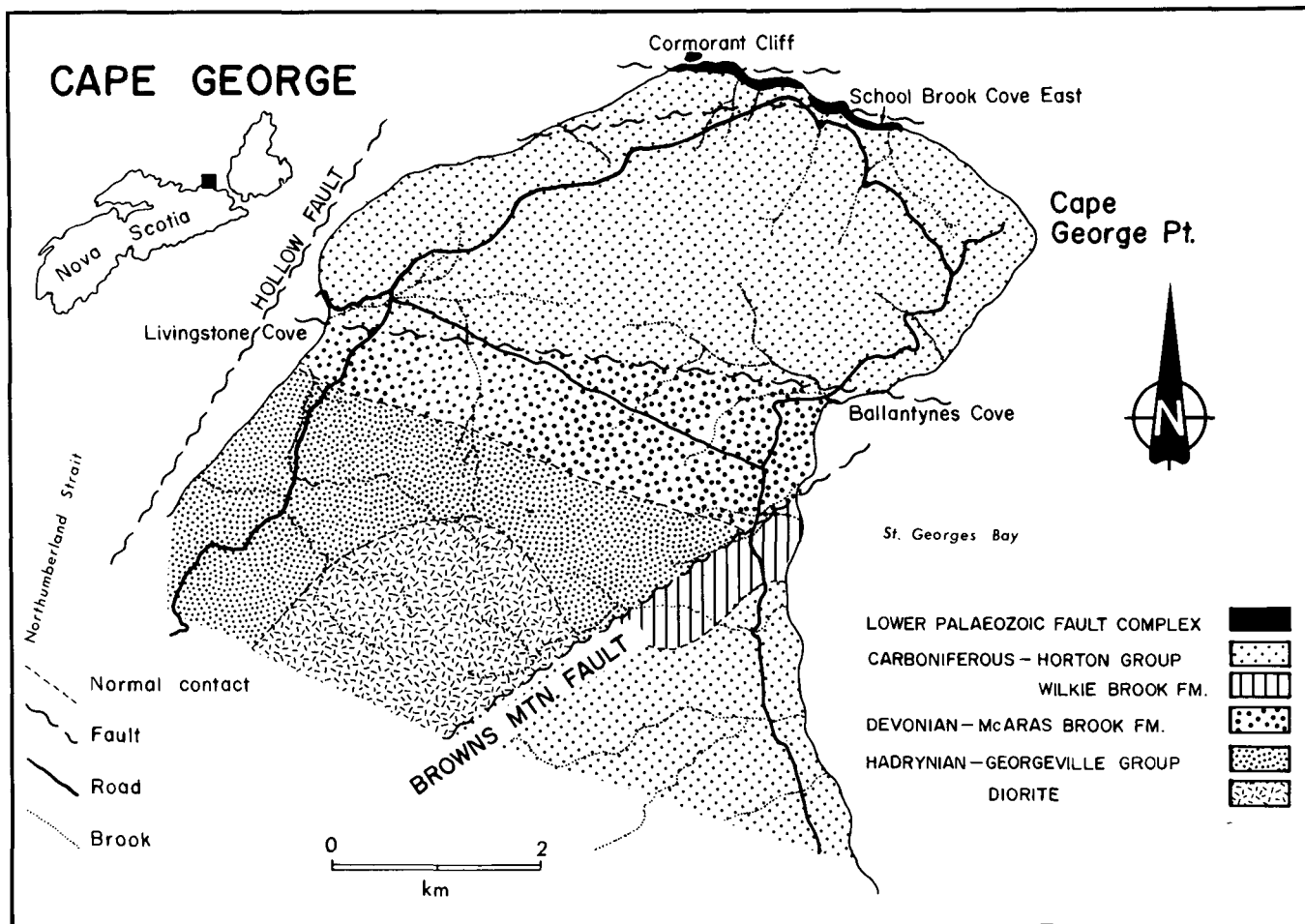


Fig. 1. Location map and generalized geology of Cape George, northeast mainland Nova Scotia. Specimens discussed herein are from School Brook Cove-East.

a terminology which is adopted herein (Fig. 1). These authors also provided detailed stratigraphic columns and structural maps of the complex.

The described material was collected from the *Scolithus* (Worm Tube) Quartzite (*sic.*) of Boucot *et al.* (1974 - their unit  $S_2$ ), estimated by these authors to be approximately 16 m in thickness. Brachiopods at the base of this unit indicate a Silurian age; however, its precise age cannot be ascertained. All that can be concluded is that it is one of the four units (in ascending stratigraphic order, units  $S_1$ - $S_4$  conclusive) that underlie upper Ludlow to lower Gedinnian strata and overlie Middle or Upper Ordovician brachiopod-bearing hornfelsed quartzites and associated intrusive hornblende diorites (Boucot *et al.*, 1974).

At School Brook Cove-East the *Scolithus* Quartzite of Boucot *et al.* (1974) is exposed as a series of typically discontinuous, small and low-lying outcrops (Fig. 2). The specimens were collected from one such outcrop located in the intertidal zone. The outcrop is currently covered by storm-derived gravels but may subsequently be re-exposed at some future date.

Lithologically, the *Scolithus* Quartzite consists of interbeds of massive or parallel-laminated, clean, white to pinkish-white, medium-grained, 0.5 to 0.8 m thick quartzites and greyish-white, parallel- and cross-laminated silty quartzites up to 0.5 m in thickness. These latter interbeds exhibit many examples of the

simple vertical to sub-vertical cylindrical trace fossil *Skolithos* Haldeman, 1840 in addition to the specimens of *Bergaueria perata* described herein.

## SYSTEMATIC PALICHOLOGY

### Ichnogenus *Bergaueria* Prantl, 1945

#### *Bergaueria perata* Prantl, 1945 (Fig. 3a-d)

#### Material

A single slab possessing ten variably preserved specimens (numbered 1 to 10 in Fig. 3a); housed in the Geology Department, University of New Brunswick.

#### Emended diagnosis

Unlined or thinly lined *Bergaueria*, diameter slightly less than, equal to, or more typically greater than height; rounded lower end rarely exhibits faint radial ridges emanating from a central depression and a peripheral ridge; surface may be smooth but concentric ornamentation typically present (after Prantl,

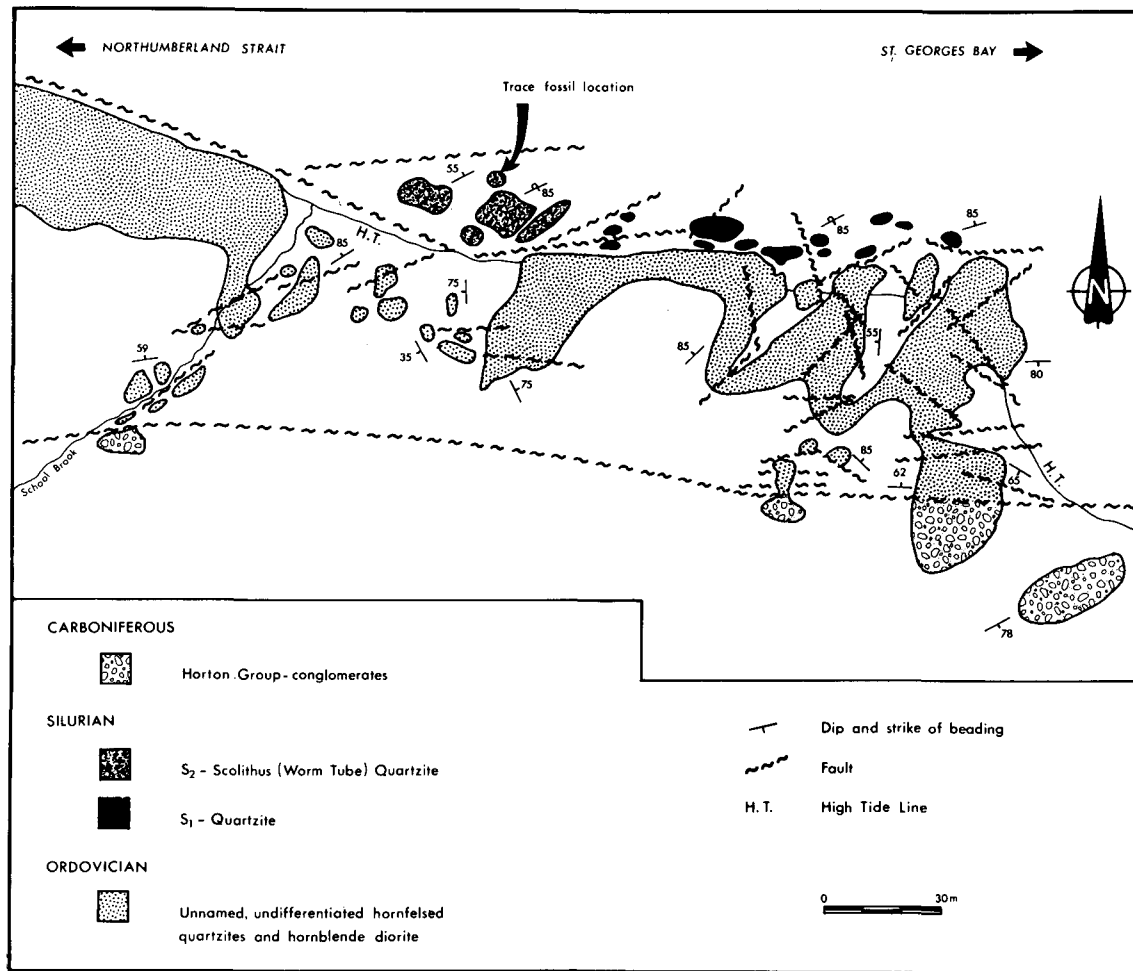


Fig. 2. Simplified geological map of School Brook Cove-East showing trace fossil location. Simplified greatly from Boucot *et al.* (1974, Plate 13).

1945; Crimes *et al.*, 1977; Pemberton *et al.*, 1988; Fillion and Pickerill, 1990).

### Description

Specimens are preserved in convex hyporelief as ventrally flattened inverted hemispheres on the sole of a 10 cm thick, massive to parallel-laminated passing into cross-laminated, greyish-white silty quartzite. Of the ten specimens (referred to as 1 through 10 - see Fig. 3) three are essentially completely preserved (1, 2, 3) and the remainder have been erosionally beheaded (9) or, because of the nature of the sample, are incomplete (4-8, 10).

In plan view, the complete specimens are circular to slightly sub-circular in shape with diameters of 3.7 x 2.9 (1), 4.1 x 4.1 (2) and 4.2 x 4.2 cm (3) and respective depths of 1.9, 1.8 and 1.8 cm. Specimen 9 (Fig. 2a) is 3.5 cm in diameter; assuming an essentially circular diameter for the incomplete examples, interpolated widths range from 3.9 (5) to 5.1 cm (7). Maximum depth, as noted, is 1.9 cm (1) but even in the incomplete specimens can confidently be ascertained to be considerably less, as little as 0.9 cm (4). Lower ends of the complete specimens are essentially flattened to gently rounded, symmetric (1) or asymmetric (2, 3) and possess a small, 3 to 5 mm wide depression (1, 2) or slightly elevated protuberance (3). These connect with smooth bases

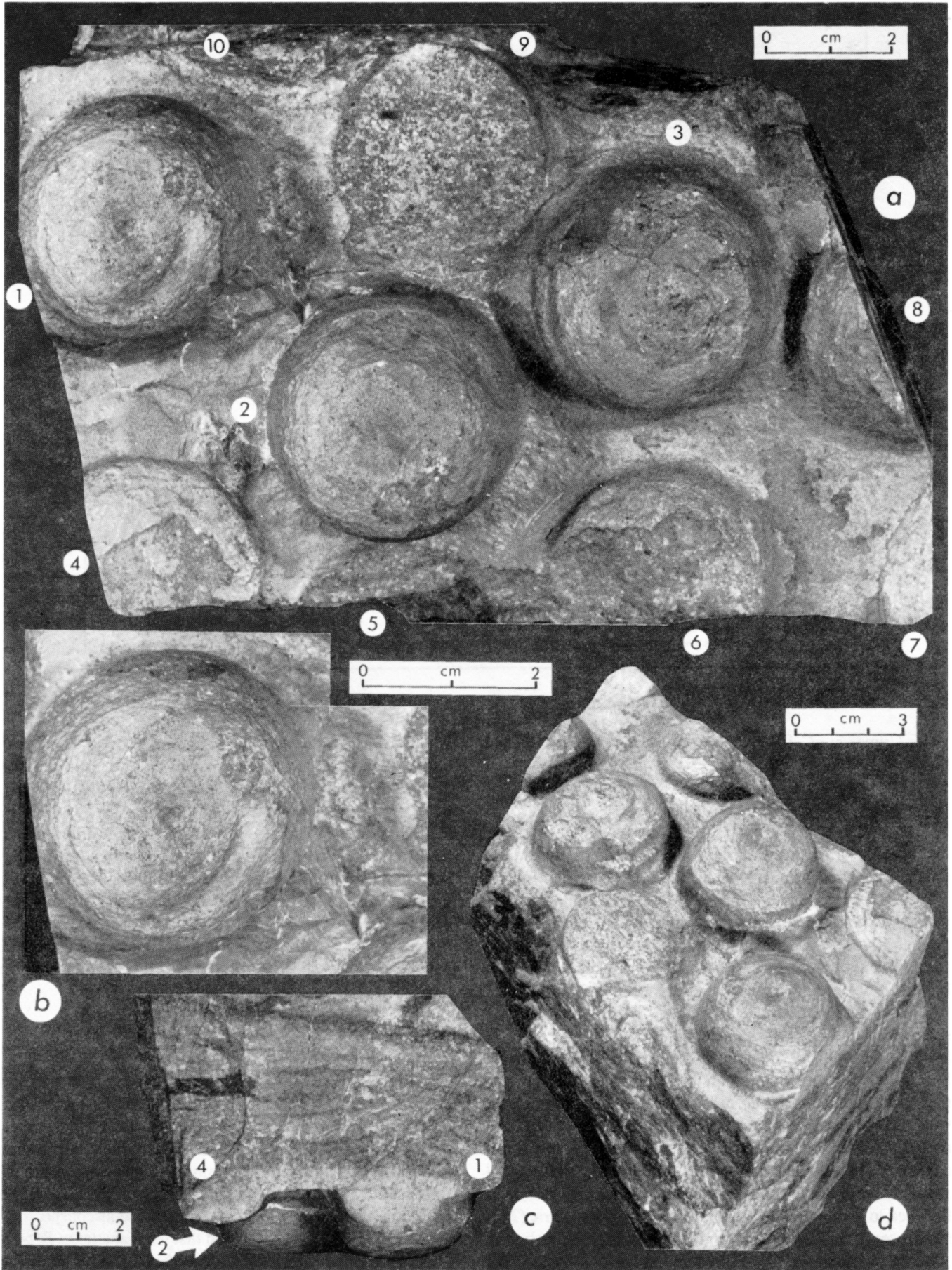
which are unornamented and extend outward to slightly elevated almost peripheral and concentric ridges (Fig. 3). From these peripheral ridges the structures extend convexly downwards as vertically or very steeply inclined margins.

All specimens possess an extremely thin lining (<1 mm thick) of pale brown mudstone which also veneers the basal bedding plane surface. From the basal peripheral ridge to the exposed uppermost portion of the specimens, the mudstone veneers exhibit variably but obviously developed concentric ornament (Fig. 3), which can also be recognized in the majority of the incomplete specimens. Burrow fill is massive and structureless.

### Remarks

As recognized by Pemberton *et al.* (1988), ichnospecies of *Bergaueria* are differentiated primarily on the characteristics of the wall linings and distal terminations. *Bergaueria langi* is thickly walled, *B. hemispherica* lacks a terminal central depression and *B. radiata* displays prominent radial ornament around a single central depression. Clearly, therefore, the material here conforms best with *B. perata* and is regarded as conspecific.

Prantl (1945, 1946) observed that the diameter of *B. perata* (35 to 45 mm) was about the same as the height, but subsequent



recordings have noted that it is typically greater than (e.g., Arai and McGugan, 1968; Crimes *et al.*, 1977; Pemberton *et al.*, 1988; Fillion and Pickerill, in press) or, in rare occurrences, slightly less than (e.g., Fürsich, 1974) the height. Specimens described here conform to the more typical case but this obvious variation is included in the emended diagnosis.

Most specimens described herein exhibit faint but well-defined concentric ornamentation; otherwise, walls are smooth. In their description and diagnosis of *B. perata*, Pemberton *et al.* (1988) do not indicate that the majority of previously described specimens of *B. perata* possess such ornament, even though it may be variably developed. Even the type material figured by Prantl (1945, 1946) possesses clearly defined concentric ornament in the majority of specimens, as does that figured and described by Radwanski and Roniewicz (1963), Arai and McGugan (1968), Alpert (1973), and Hakes (1976). Similarly, although not noted by Książkiewicz (1977), concentric ornament is clearly evident in his examples of *B. prantli*, subsequently questionably synonymized with *B. perata* by Pemberton *et al.* (1988). Even *B. perata* figured by Pemberton *et al.* (1988, p. 879, Fig. 5) displays concentric ornament. Thus, *B. perata* may be smooth, or, more typically, may possess concentric ornament externally to the ventral and peripheral external ridge; the diagnosis of the ichnospecies is also emended accordingly.

The origin of the concentric ornament is somewhat enigmatic but may possibly reflect the ability of the producing organism to bodily contract and dilate (cf. Radwanski and Roniewicz, 1963), may be a result of compaction (cf. Arai and McGugan, 1968; Boyd, 1974), or may reflect laminae in the presumed surrounding mud substrate (cf. Crimes *et al.*, 1977). In view of the morphologically variable previously described examples occurring on single stratification planes, a combination of the above could be equally as feasible. Nevertheless, irrespective of its origin, the concentric ornament appears to be particularly developed in *B. perata* in comparison to other ichnospecies. Crimes *et al.* (1977) did mention that faint concentric ornament could rarely occur in *B. hemispherica*, although the holotype does not indicate this (see Crimes *et al.*, 1977, p. 117, Plate 6c; Pemberton *et al.*, 1988, p. 883, Fig. 8). *Bergaueria radiata* and *B. langi* do not exhibit concentric ornament; clearly, therefore, the possible presence of such ornament in *B. perata* is significant and the diagnosis is emended accordingly.

Finally, although Pemberton *et al.* (1988) suggested that *B. perata* is thinly lined, this is clearly an oversimplification and is perhaps why these authors omitted the criterion of lining in their diagnosis of the ichnospecies. Material here is obviously thinly lined as is that reported by several previous authors (e.g., Arai and McGugan, 1968). Other reports, however, have emphasized the absence of linings (e.g., Fürsich, 1974; Fillion and Pickerill,

1990). Evidently, therefore, the ichnospecies may be lined or unlined and the emended diagnosis incorporates this observation.

## DISCUSSION AND CONCLUSIONS

Prantl (1945, 1946) remarked that the trace fossil *Bergaueria* represented the casts of burrows made by sea anenomes, which Alpert (1973) subsequently suggested, more specifically, to have been actinarians. Ethologically, two alternatives have been proposed. Seilacher (1956) and Alpert (1973) suggested they represent dwelling burrows (*Domichnia*) whereas Arai and McGugan (1969), Fürsich (1974) and Hakes (1976) interpreted them as resting traces (*Cubichnia*). As noted by Pemberton *et al.* (1988), however, both interpretations are probably correct, with lined specimens representing *Domichnia* and most unlined specimens *Cubichnia*. Burrow linings are an obvious requisite when mass sediment properties are such that in order for the producing organisms, in this case presumably actinarian anenomes, to maintain stability some reinforcement of the burrows are necessary. This, combined with the observation that specimens here are non-overlapping but all occur in close proximity, possibly a result of reproductive gregariousness, suggest they can best be interpreted as *Domichnia*.

*Bergaueria* and its various ichnospecies have been widely reported in strata of earliest Cambrian to Eocene age (Crimes, 1987; Pemberton and Jones, 1988) with most reports being from Cambrian rocks. Pemberton *et al.* (1988) list Precambrian recordings by Hofmann and Aitken (1979), Fedonkin (1981) and Crimes and Germs (1982); to this list must also be added Kumar *et al.* (1984) who recorded it from the Late Rhiphaean of the Himalayas. Of these recordings, however, the structures recorded by Hofmann and Aitken (1979, p. 164, Fig. 17c) only superficially resemble *Bergaueria* and were only questionably referred to the ichnogenus; indeed, even a nonbiologic origin was not ruled out by them. The specimens figured and described by Crimes and Germs (1982) are extremely small, only 1 to 5 mm in diameter, and more closely resemble *Intrites* Fedonkin, 1980, as subsequently noted by Crimes (1987) himself in his review of late Precambrian to early Cambrian trace fossils. Finally, the recordings by Fedonkin (1981) and Kumar *et al.* (1984) remain to be confirmed or otherwise, as they could equally represent the *Nemiana*-preservation of the body fossil *Beltanelliformis* (G.M. Narbonne, personal communication, see also Narbonne and Hofmann, 1987, who explain how to differentiate *Bergaueria* and *Beltanelliformis*). Thus, Precambrian recordings of *Bergaueria* are suspect and it is hardly surprising, therefore, that Crimes (1987) and Narbonne and Myrow (1988) regard it as a definitive Phanerozoic form.

Fig. 3. *Bergaueria perata* from the Silurian of Cape George, northeast mainland Nova Scotia. (a) View of basal surface of collected slab illustrating ventral surface of specimens (numbered 1 to 10) as described in main text. (b) More detailed view of specimen number 1 (upper left in (a)) illustrating a central dimple or depression which extends outwards across a smooth, unornamented area to a slightly elevated peripheral ridge and then downward into a concentrically ornamented steeply-convex margin. (c) Cross-sectional view of specimens 1 and 4 illustrating massive burrow infill. Note concentric ornament in specimen 2. (d) Oblique view of collected slab illustrating concentric ornament (1, 2, 3), ventral dimples (1, 2) and elevated protruberance (3) of complete specimens and general view of truncated and incomplete specimens.



Despite its obviously extensive stratigraphic range, *Bergaueria* has only previously been recorded once from Silurian strata, from the Upper Silurian (Ludlow) Leopold Formation of arctic Canada by Narbonne (1984). Because of poor preservation Narbonne (1984) only identified his material at the ichnogenetic level, though it is clear from his figure (Narbonne, 1984, p. 407, Fig. 6G) that the specimens possess concentric ornament and, because they are so unlike *B. hemispherica*, can perhaps be tentatively compared to *B. perata*. The recording herein, therefore, represents only the second report of *Bergaueria* and certainly the first of *B. perata* in Silurian strata. To my knowledge, no bergauerians of any age have previously been formally recorded from eastern Canada; the report by Arai and McGugan (1968) of *Bergaueria* in Lower Cambrian quartzites of the Labrador Group in western Newfoundland, and listed as such in Pemberton *et al.* (1988), remains to be confirmed as it was made in the form of a personal communication from Dr. S.J. Nelson.

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