

The trace fossil *Neonereites multiserialis* Pickerill and Harland, 1988 from the Devonian Wapske Formation, northwest New Brunswick

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The trace fossil *Neonereites multiserialis* Pickerill and Harland is recorded and described from the Lower Devonian Wapske Formation of northwest New Brunswick. Preserved typically in positive hyporelief on sandstone soles, the ichnospecies can potentially be confused with morphologically similar ichnotaxa, particularly *Granularia* Pomel, *Ophiomorpha* Lundgren, *Ardelia* Chamberlain and Baer and *Edaphichnium* Bown and Kraus, and is best differentiated by undertaking, whenever possible, vertical transverse and longitudinal sectioning of the structures. The records and included proposed synonymy suggest that *Neonereites multiserialis* is Silurian (Wenlock) to Tertiary (Eocene) in age and is indicative of deep-water flysch environments.

La Formation de Wapske (Dévonien inférieur, nord-ouest du Nouveau-Brunswick) a livré l'ichnite *Neonereites multiserialis* Pickerill et Harland, dont on fournit ici une description. Il est parfois délicat de distinguer cette ichnospèce, typiquement conservée en demi-relief convexe à la base des bancs de grès, de formes voisines (notamment *Granularia* Pomel, *Ophiomorpha* Lundgren, *Ardelia* Chamberlain et Baer, *Edaphichnium* Bown et Kraus). L'étude du matériel par coupes longitudinales et transversales constitue, le cas échéant, la meilleure approche afin de trancher la question. La documentation fossile et la synonymie que l'on propose suggèrent que *Neonereites multiserialis* s'échelonne du Silurien (Wenlock) au Tertiaire (Éocène) et fait foi de milieux d'eau profonde, sièges d'une sédimentation à caractère flyschéide.

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INTRODUCTION

The trace fossil ichnogenus *Neonereites* Seilacher, 1960 characteristically comprises straight, sinuous to irregularly curving, loose or interconnected chains of variably impressed dimples (when preserved on upper bedding plane surfaces in negative epirelief) or pustules, pills or knobs (when preserved on lower bedding plane surfaces in positive hyporelief—their more typical style of preservation) (Seilacher, 1960; Fillion and Pickerill, 1990a). To date, four ichnospecies have been described, namely *Neonereites uniserialis* Seilacher, 1960, *N. biserialis* Seilacher, 1960, *N. multiserialis* Pickerill and Harland, 1988 and *N. renarius* Fedonkin, 1980. As the etymology suggests, the first three are characterized, respectively, by single, double and multiple rows of dimples or, particularly, pustules, pills or knobs. *Neonereites renarius* is similar to *N. uniserialis* in that it comprises rows of uniserial pustules but is differentiated on the basis of its reniform—as distinct from hemispherical-shaped protruberances. *Neonereites uniserialis* and *N. biserialis* have each been commonly reported in the geological literature and range in age from late Proterozoic to Eocene (Häntzschel, 1975; Crimes, 1987; Narbonne *et al.*, 1987; Gibson, 1989). *Neonereites renarius* has, to my knowledge, only been documented from the Vendian of Russia and *N.*

multiserialis has, until now, only been formally recorded from a single location from Silurian strata of North Greenland.

Crimes and Crossley (1991) suggested that *Neonereites multiserialis* could be accommodated within *N. biserialis*, thereby indirectly suggesting that *N. multiserialis* is a subjective junior synonym of *N. biserialis*. However, better preserved examples of *N. multiserialis* recovered from Devonian strata of New Brunswick, demonstrate that the suggestion of Crimes and Crossley (1991) is speculative at best. In describing these Devonian examples, transverse and longitudinal thin sections of the structures have also been utilized in an attempt to better understand their 3-dimensional and internal geometry. Typically such an approach has, historically, been overlooked in the description of *Neonereites* but, as demonstrated later, is of critical importance in the differentiation of the trace fossil from several other ichnogenera.

The purpose of this contribution is therefore to (1) document and describe in detail *N. multiserialis* from Devonian strata of New Brunswick, thereby (2) reiterating its legitimacy as a distinctive ichnotaxon, and (3) extending its known stratigraphic range from the only previously documented recording from the Silurian of North Greenland to the Tertiary (Eocene).

GEOLOGICAL DETAILS

Specimens described here are from three locations within the Lower Devonian (Helderbergian) Wapske Formation of the Tobique Group of the Riley Brook area of northwestern New Brunswick, eastern Canada (Fig. 1). This formation comprises an essentially siliciclastic sedimentary sequence with lesser proportions of felsic and mafic volcanics, that was deposited in a relatively deep marine environment (Pickerill, 1986; Wilson, 1990). Sedimentary facies consist of thinly bedded (1-5 cm, rarely 5-10 cm thick), fine- to medium-grained, grey, green, brown or orange-brown sandstones interbedded with 1-3 cm thick shales. Although no detailed sedimentological analysis of this sequence has been undertaken, studies of coeval strata to the southwest (e.g., St. Peter, 1978, 1979; Pickerill, 1986) and northeast (e.g., Wilson, 1990) of the Riley Brook area suggest that the Wapske Formation represents a relatively deep water turbiditic sequence deposited below storm wave base, perhaps on an ancient slope. The thinly-bedded sandstones commonly exhibit partial Bouma sequences, particularly Tb, Tb-c, Tb-d and less commonly Ta-b sequences. Interbedded shales are difficult to sample, and internal structures are typically indiscernible.

Within the area depicted in Figure 1, *Neonereites multiserialis* was collected at three locations. These are: (i) East bank of the Tobique River, ca. 1 km northeast of the village of Riley Brook; (ii) Roadside section along Frasers Private Road along the Little Tobique River at Nictau; (iii) Roadside section along Route 385 parallel to the Mazarel River, ca. 1 km northeast of the Everett Brook/Mazarel River confluence.

Additional ichnotaxa at these and other locations are still under study but preliminary analysis has revealed the presence of *Chondrites* von Sternberg, *Cochlichnus* Hitchcock, cf. *Conostichus* Lesqueureux, *Cosmorhapha* Fuchs, *Cruziana* d'Orbigny, *Helminthopsis* Heer, *Neonereites uniserialis* Seilacher, *Neonereites biserialis* Seilacher, *Palaeophycus* Hall, *Phycodes* Richter, *Planolites* Nicholson, *Protovirgularia* McCoy, *Skolithos* Haldemann, *Taenidium* Heer and *Umfolozia* Savage.

SYSTEMATIC PALICHOLOGY

Ichnogenus *Neonereites* Seilacher, 1960

Type ichnospecies *Neonereites biserialis* Seilacher, 1960 by original designation

Diagnosis

Straight, irregularly or regularly winding chains of generally loose or interconnected pustules, pods or knobs when preserved in positive relief on lower bedding plane surfaces or corresponding dimples, more rarely pustules, pods or knobs, on upper bedding plane surfaces (modified after Seilacher, 1960; Hakes, 1976; Fillion and Pickerill, 1990a).

Remarks

Since Seilacher and Meischner (1965) first suggested that the ichnogenus *Neonereites* perhaps represented but one preservational variant of *Nereites* MacLeay, 1839 [others possibly including *Scalarituba*, Weller, 1899 and *Phyllodocites* Geinitz, 1867—see also Seilacher (1983)] *Neonereites* has proven to be a continual source of nomenclatural confusion. With exceptionally well-preserved material, Chamberlain (1971) demonstrated that his examples of *Neonereites* represented the convex hyporelief (or basal surface) view of internally complex burrows that possessed lateral lobes characteristic of *Nereites* and a meniscate median gallery characteristic of *Scalarituba* (see also Fillion and Pickerill, 1990a). He therefore proposed (Chamberlain, 1971) that *Neonereites* was a subjective junior synonym of *Scalarituba*, and expanded the definition of *Scalarituba* to include a '*Nereites* view' in convex hyporelief on lower surfaces and a '*Phyllodocites* view' in concave epirelief on upper surfaces. This approach, however, has only been adopted on occasion by authors such as Chaplin (1980), who did not observe the complete 3-dimensional variation of his material, and Seilacher (1983), who described material similar to, but not as ideally preserved as Chamberlain's (1971), as *Nereites*, though he still retained *Scalarituba* and *Neonereites* (see also D'Alessandro and Bromley, 1987). Indeed, most authors (e.g., Tanaka, 1971; Fedonkin, 1977, 1985; Crimes *et al.*, 1981; Benton, 1982; Crimes and Germs, 1982; Palij *et al.*, 1983; Paczesna, 1986; McCann and Pickerill, 1988; Powichrowski, 1989; Gibson, 1989; Narbonne and Aitken, 1990; Crimes and Crossley, 1991) have retained *Neonereites* and its ichnospecies as distinctive ichnotaxa. In all probability this more universal consensus reflects one or more of the following:

- (i) Preservational variants such as those described by Chamberlain (1971) and Seilacher (1983) are apparently extremely rare in the geological record.
- (ii) These preservational variants are all described as having a regular or irregular biserial arrangement of pustules (characteristic of *N. biserialis*). Thus, all additional ichnospecies of *Neonereites* cannot be accommodated within either *Nereites* or *Scalarituba*.
- (iii) The most common mode of preservation of *Neonereites* is in convex hyporelief. Because of sampling or preservational problems, it is typically difficult to ascertain the complete 3-dimensional form of the structures. In such cases assignment to *Scalarituba* or *Nereites* could be potentially misleading and even erroneous. This was demonstrated by Pickerill (1981), who vertically sectioned examples of *N. uniserialis* and *N. biserialis* and was unable to discern any *Nereites*-like or *Scalarituba*-like features, and by Benton (1982), who described *N. uniserialis* occurring in positive epirelief on upper surfaces and lacking any associated structures.
- (iv) As noted by Fillion and Pickerill (1990b), information in palaeontological studies must be unambiguous, accurate

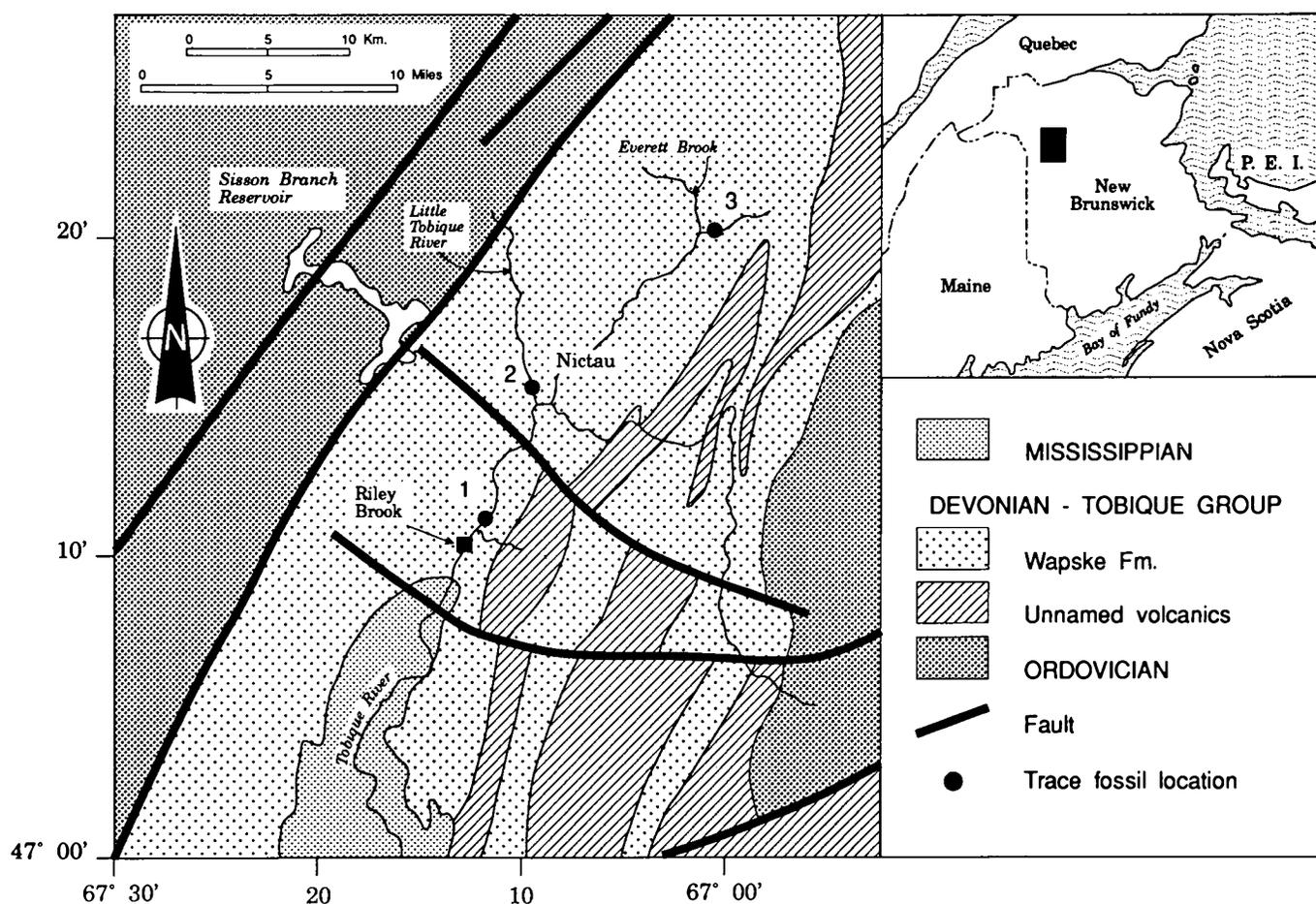


Fig. 1. Simplified geological map of the Riley Brook area of northwestern New Brunswick. *Neonereites multiserialis* described herein was collected from locations 1-3, details of which are given in the text.

and easily retrievable, otherwise the communicative function of taxonomy is greatly hampered, particularly by changes at the ichnogenic level at which most bibliographic surveys are undertaken. Inclusion of *Neonereites* within *Nereites* or *Scalarituba* would result in such ambiguities.

Therefore, following most authors I consider *Neonereites* to be a useful and valid ichnotaxon that should be retained. In ichnology it is not unusual to find combinations and intergradations of several ichnotaxa (see Bromley and Frey, 1974; Pickerill *et al.*, 1984), and in such cases most authors describe the variations accordingly. The nomenclature and concepts of *Nereites*, *Scalarituba* and *Neonereites* as separate and distinctive ichnogenera are so deeply implanted in palaeontological literature that their (rare) occurrence as separate parts of a single burrow system does not require that these forms represent a single ichnotaxon. A similar decision was made by Bromley and Frey (1974) to retain the ichnogenera *Gyrolithes* de Sapporta, 1884, *Thalassinoides* Ehrenberg, 1944 and *Ophiomorpha* Lundgren, 1891, which can similarly exhibit complex intergradations with each other, but which Bromley and Frey (1974) considered best retained as discrete ichnotaxa. Thus, if specimens similar to those described by

Chamberlain (1971) and Seilacher (1983) are discovered, nomenclatural assignment should be made with respect to the dominant morphological component. For example, in Seilacher (1983), the two specimens designated as *Nereites* spp. (fig. 13) should more appropriately be assigned to *Nereites* (fig. 13a) and *Neonereites biserialis* (fig. 13b).

As reviewed in Fillion and Pickerill (1990a), *Neonereites* is a facies-crossing ichnotaxon representing either the endogene burrow, or the trail of a benthic organism, most likely an annelid. It ranges in age from Late Proterozoic to Eocene.

***Neonereites multiserialis* Pickerill and Harland, 1988 (Fig. 2, 1-5)**

1971 *Scalarituba missouriensis*, *sensu* Chamberlain, pl. 31, fig. 2 (not paginated).

1980 *Scalarituba* (*Neonereites*-view), *sensu* Chaplin, p. 60, fig. 2.

1984 *Neonereites*, Ekdale, Bromley and Pemberton, p. 239, fig. 18-5.

1986 ?*Ophiomorpha* cf. *nodosa*, *sensu* Yang, Song and Liang, pl. I, fig. 6 (not paginated).

1988 *Neonereites multiserialis*, Pickerill and Harland, p. 127, figs. 5a,b.

1991 *Neonereites multiserialis*, Pickerill and Donovan, p. 21, fig. 2b.

Diagnosis

Neonereites composed of more than two rows of pustules or pods in positive hyporelief or dimples in negative epirelief (after Pickerill and Harland, 1988).

Description

All specimens are preserved on 1-3 cm thick, orange-brown, parallel laminated, fine-grained sandstone soles in positive hyporelief. They comprise horizontal, unbranched, longitudinally curved to irregularly sinuous chains of interconnected pustules or pods, individual chains being up to 15 cm in length, but typically less as most specimens are incomplete, being preserved on slabs with a relatively small total surface area. Single pustules are smooth and unornamented, variably impressed (<0.1 to 4 mm), variable in size (maximum diameter 4 mm, typically 1 to 2 mm) and spheroidal to ellipsoidal. Individual pustules may be discrete or composite in the sense that they comprise subtle amalgamations of up to an observed maximum of six mutually overlapping and smaller-scaled protruberances. Overall width of individual specimens is variable (e.g., Fig. 2.2), up to a maximum of 2 cm, and the number of pustules in cross-section varies from 4 to 7.

Vertical transverse and longitudinal sections of seven specimens indicate that the pustules are hemispheres and represent the basal surface expression of slightly compressed, broadly reniform-shaped burrows. Of these, five specimens possessed a massive and an apparently structureless fill of slightly different composition to the host rock. Vertical transverse sections of a sixth specimen (NBMG 8375) suggest the presence of a central circular burrow (Fig. 2.5) and indistinct laminae external to the central burrow and parallel to the margins of the entire structure (Fig. 2.3). A longitudinal section of the seventh specimen (Fig. 2.4) exhibits a generally massive lower burrow fill and an upper portion exhibiting relatively closely spaced, albeit poorly-preserved and not pervasively developed, crescentic menisci. Horizontal sections of several examples were constructed but failed to reveal details of the laminae or menisci as observed in vertical section.

Material

Twenty specimens from talus material at locations 1-3 of Figure 1. Two figured specimens and three thin sections repositied in the Division of Natural Sciences, New Brunswick Museum, Saint John, New Brunswick [NBMG 8375/1/2/3 (1 is the actual specimen, now incomplete, 2 and 3 are thin sections from the specimen), 8376 (not sectioned) and 8377 (thin section only; specimen destroyed during sectioning)].

Additional material housed in the Department of Geology, University of New Brunswick.

Remarks

As noted previously, *Neonereites* includes four ichno-species, namely *N. uniserialis*, *N. biserialis*, *N. multiserialis* and *N. renarius*. The multiserial arrangement of pustules in the New Brunswick specimens characterizes them as *N. multiserialis*. Vertical sectioning of seven specimens clearly revealed that, at least in these examples, *N. multiserialis* represents the basal surface expression of intergenic (*sensu* Chamberlain, 1971) burrows. Of the seven sectioned examples only two exhibited internal structures similar to those described by Seilacher and Meischner (1965), Chamberlain (1971, 1978) and Seilacher (1983) and, as previously discussed, assigned by these authors to either *Nereites* or *Scalari tuba*. The remaining five examples contained an apparently structureless fill, thereby obviously not conforming to the definitions of *Nereites* or *Scalari tuba*, but still possessed the multiserial pustules characteristic of *N. multiserialis*.

The included synonymy (see above) incorporates personally examined material previously assigned to *Neonereites multiserialis* (Pickerill and Harland, 1988; Pickerill and Donovan, 1991) and material considered as *N. multiserialis*. Thus, the multiserial convex hyporelief pustules figured by Chamberlain (1971), Chaplin (1980) and Ekdale *et al.* (1984) are regarded as conspecific. *Ophiomorpha cf. nodosa* figured by Yang *et al.* (1986) is identified by them as such on the presence of a single compressed burrow preserved in convex hyporelief. As this ichnogenus is more typically preserved as a vertical structure and knowledge of its 3-dimensional morphology was not determined, it is questionably included in the synonymy. Inclusion within *Neonereites multiserialis* is further suggested by its association with *N. uniserialis* and its co-occurrence with typical deep water ichnotaxa, as *N. multiserialis*, at least to date, has only been reported from flysch sequences.

When viewed as positive hyporeliefs small or isolated segments of *Neonereites multiserialis* could conceivably be confused with several additional ichnotaxa, namely *Granularia* Pomel, 1849, *Ophiomorpha* Lundgren, 1891, *Ardelia* Chamberlain and Baer, 1973 and *Edaphichnium* Bown and Kraus, 1983. These ichnotaxa are all characterized by burrows with walls that are distinctly pelleted to give an external surface appearance superficially similar to that of *N. multiserialis*, and each can potentially be preserved as positive hyporeliefs. The following outlines the essential characteristics of these ichnotaxa in order to establish important differences with respect to *N. multiserialis*.

As discussed by Crimes *et al.* (1981), the diagnosis of *Granularia* is unclear and a monographic treatment of the ichnogenus and related forms appears necessary. These authors utilized *Granularia* for twig-like, commonly branched, burrows with linings of small sand or mud pellets similar to an example figured in the Treatise on Invertebrate Paleontology by Häntzschel (1975, fig. 40, 3b, p. W66). The presence

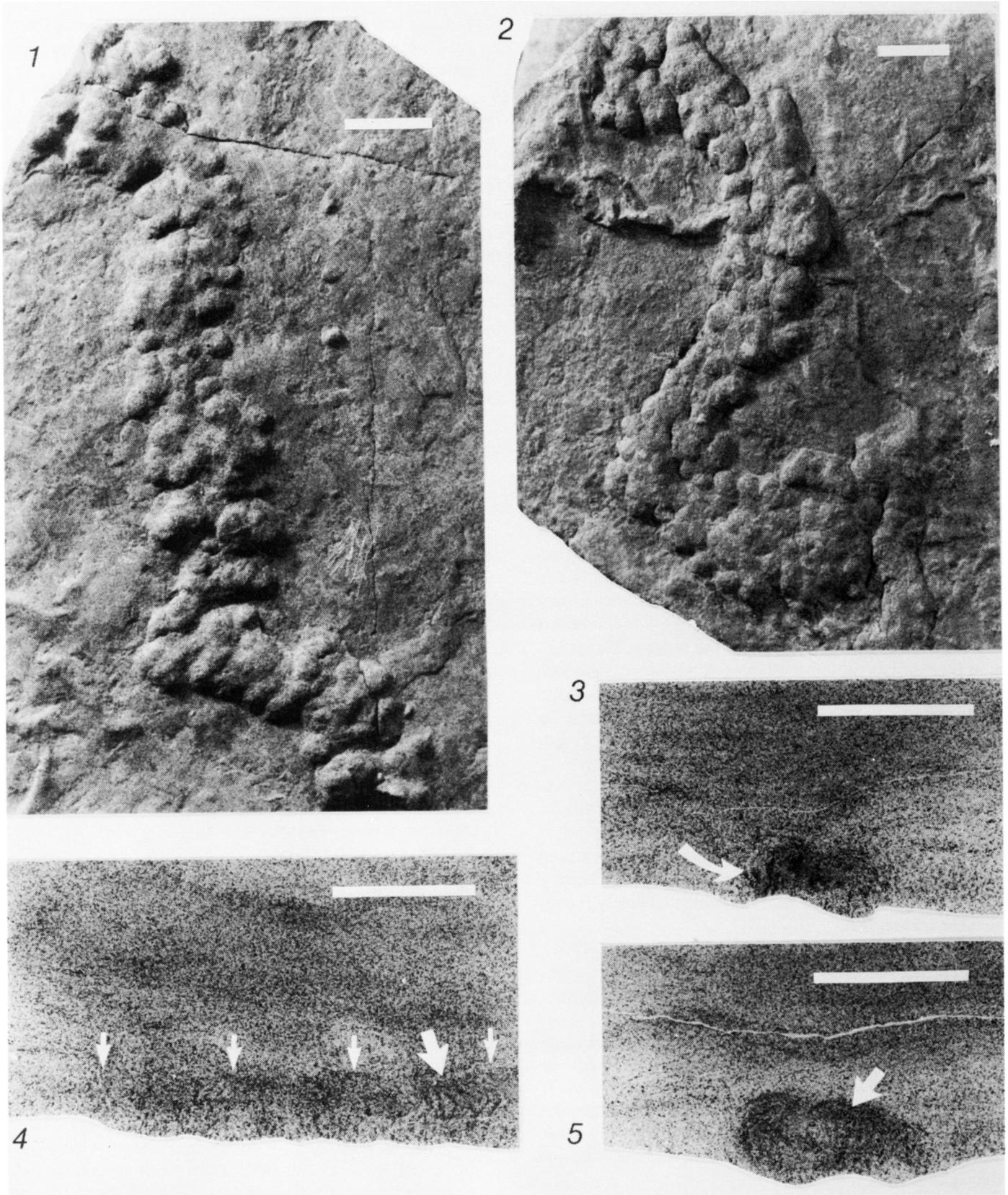


Fig. 2. (1) *Neonereites multiserialis* preserved in positive relief on a sandstone sole, NBMG 8375/1. (2) *N. multiserialis* preserved in positive relief on a sandstone sole, illustrating lateral variability of pustule development, NBMG 8376. (3) Vertical transverse thin section of NBMG 8375/2 exhibiting laminae paralleling the outer margin of the burrow wall (arrowed). (4) Vertical longitudinal thin section of NBMG 8377 illustrating massive lower fill and sparse development of crescentic menisci (large arrow); small arrows denote upper margin of burrow. (5) Vertical transverse section of NBMG 8375/3 exhibiting a more or less centrally located circular burrow (arrowed) Bar scales on all figures = 1 cm.

of a distinctive pellet lining prompted Frey *et al.* (1978) to suggest that *Granularia* may well be a synonym of *Ophiomorpha*. Indeed, *Ophiomorpha* and its several synonyms (see Frey *et al.*, 1978) are also characterized by burrows that possess distinctive knobby walls composed of agglutinated pelletoidal sediment. As with *Granularia*, *Ophiomorpha* is commonly branched, but in contrast, typically forms an integrated burrow system with regular or irregular horizontal and vertical mazes and boxworks (Frey *et al.*, 1978). *Ardelia* is very similar morphologically to *Ophiomorpha* except that it is considerably larger and possesses typically smooth horizontal burrows connected to moderately or highly irregular inclined or vertical mammilated sections (Chamberlain and Baer, 1973). Finally, *Edaphichnium* is an unbranched, horizontal, cylindrical burrow, commonly filled with fecal pellets that also form the periphery of the burrow, giving the ichnogenus a verrucose or nodose exterior (Bown and Kraus, 1983).

Thus, the essential difference between *Neonereites multiserialis* and these ichnotaxa is that in examples where *N. multiserialis* comprises the basal expression of horizontal burrows, the pustulose or nodose burrow wall is only developed on the base. *Granularia*, *Ophiomorpha*, *Edaphichnium* and, to a lesser extent, *Ardelia*, possess burrow walls that are completely pustulose or nodose. Additionally, in contrast to *Ardelia*, *Granularia* and *Ophiomorpha*, *Neonereites multiserialis* is consistently unbranched, and unlike *Edaphichnium* does not contain fecal pellets within the burrow. Nevertheless, in short or incomplete examples of pustulose or nodose burrows preserved in hyporelief, assignment or otherwise to *N. multiserialis* can be difficult and is best assessed by including analysis of transverse or longitudinal vertical sections.

CONCLUSIONS

- (1) *Neonereites* must be retained as a separate ichnogenus, in as much as it is an accurate, unambiguous and generally stable designation for an unmistakable and easily recognizable ichnotaxon.
- (2) Contrary to the suggestion by Crimes and Crossley (1991), *Neonereites multiserialis* is a distinctive ichnospecies that should not be considered synonymous with *N. biserialis*.
- (3) Recognition and distinction of *Neonereites multiserialis* from morphologically similar ichnogenera such as *Granularia*, *Ophiomorpha*, *Ardelia* and *Edaphichnium* is best undertaken by consideration of both its occurrence and general morphology but also by studying, whenever possible, vertical transverse and longitudinal sections through the structures.

Additionally, the recording and proposed synonymy of *Neonereites multiserialis* herein:

- (1) Represents the first record of *N. multiserialis* in Canada.
- (2) Suggest that the known stratigraphic range is Silurian (Wenlock) to Tertiary (Eocene) (Pickerill and Harland, 1988; Pickerill and Donovan, 1991).

- (3) Indicate that *N. multiserialis* has only been recorded from deep water flysch environments and therefore may well prove to be a useful palaeoenvironmental indicator.

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