LATE ORDOVICIAN-EARLY SILURIAN TRACE FOSSILS FROM THE MATAPEDIA GROUP, TOBIQUE RIVER, WESTERN NEW BRUNSWICK, CANADA

R.K. Pickerill
Department of Geology, University of New Brunswick
Fredericton, New Brunswick, E3B 5A3

L.R. Fyffe
Department of Forest, Mines and Energy, Mineral Resources Division
Fredericton, New Brunswick, E3B 5H1

W.H. Forbes
Department of Geology, University of Maine at Presque Isle
Maine 04769

Late Ordovician-Early Silurian flysch slope deposits of the Matapedia Group of the Matapedia Basin on the Tobique River, western New Brunswick, Canada, contain 13 ichnogenera (15 ichnospecies), namely:- *Chondrites* ichnospp., *Cochlichnus anguineus*, *Dictyodora scotica*, *Dictyodora tenuis*, *Dimorphichnus* ichnosp., *Glockerichnus* ichnosp., *Gordia marina*, *Helminthopsis* ichnosp., *Muensteria* ichnosp., *Neonereites uniserialis*, *Nereites jacksoni*, *Palaeophycus tubularis*, *Syncoprulus pharmaceus* and *Yakutatia emersoni*. Of these, *Dimorphichnus*, *Muensteria* and *Dictyodora* have never previously been recorded in the Matapedia Basin and *Dictyodora* is recorded for the first time in North America. The total assemblage represents the most diverse ichnocoenosis yet recorded from Paleozoic slope deposits.

Sur la rivière Tobique, dans l'ouest du Nouveau-Brunswick, au Canada, les flyschs du Groupe de Matapédia appartenant au Bassin de Matapédia, déposés en contexte de talus et d'âge tardiordovicien à éosilurien, ont livré 13 ichnogenres (15 ichnoespèces), savoir: *Chondrites* ichnospp., *Cochlichnus anguineus*, *Dictyodora scotica*, *Dictyodora tenuis*, *Dimorphichnus* ichnosp., *Glockerichnus* ichnosp., *Gordia marina*, *Helminthopsis* ichnosp., *Muensteria* ichnosp., *Neonereites uniserialis*, *Nereites jacksoni*, *Palaeophycus tubularis*, *Syncoprulus pharmaceus* and *Yakutatia emersoni*. Parmi ceux-ci, *Dimophichnus*, *Muensteria* et *Dictyodora* n'ont jamais été signalés dans le Bassin de Matapédia; il sagit, de plus, de la premier decouverte de *Dictyodora* en Amérique du Nord. Au total, l'assemblage représente l'ichnocénose la plus diverse jamais documentée dans les dépôts de talus de Paléozoique.

[Traduit par le journal]

INTRODUCTION

Detailed systematic ichnological studies of deep-water flysch strata of Mesozoic age have been undertaken in several parts of the world (e.g., Macsotay, 1967; Ksiazkiewicz, 1970, 1977; Tanaka, 1971; Kern and Warme, 1974; Crimes *et al.*, 1981; etc.). In contrast, Paleozoic, particularly lower Paleozoic studies remain poorly documented, with the notable exceptions of, for example, Crimes (1970), Aceñolaza (1978), Pickerill (1981), and Benton (1982a). The importance of detailed taxonomic studies of deep-water lower Paleozoic trace fossils cannot be overemphasized. For example, the paucity of such studies, as noted by Pickerill (1980), has resulted in Phanerozoic trace fossil diversity models (Seilacher, 1974, 1977; Frey and Seilacher, 1980) which are not in accord with the observed data. Over the last decade one of us (R.K.P.) has been involved with the collection and description of trace fossils from the middle Ordovician to lower Silurian flysch succession of the Matapedia Basin (see below) of New Brunswick and Quebec. Recent work in part of this basin in the Perth-Andover area of New Brunswick (Fig. 1, Pickerill, 1986) revealed an extremely important site with respect to trace fossils contained in these strata. Unfortunately, the site is situated

on the planned location of a trout and salmon aquaculture center, construction of which is imminent and will result in coverage of the exposed strata. In view of this, the purpose of this paper is therefore to document, particularly taxonomically, the trace fossils discovered at the site and to comment on their importance not only with respect to strata of the Matapedia Basin but also with respect to previous studies in coeval strata and trace fossil diversity models.

LOCATION AND GEOLOGICAL BACKGROUND

The Matapedia Basin of Fyffe *et al.* (1981), previously termed the Aroostook-Matapedia Carbonate Belt by Ayrton *et al.* (1969) and the Aroostook Anticlinorium by Pavlides (1968) and Rodgers (1970), is a narrow tectonostratigraphic zone extending from eastern Gaspe through New Brunswick and into northeastern Maine (Fig. 1) where it merges with the Merrimack Trough (Bradley, 1983). Strata in this basin are middle Ordovician-Early Silurian in age and have been assigned various group and, or, formational names at different locations along its length. In Gaspe, strata are referred to the late middle Ordovician-Early Silurian Honorat and Matapedia groups, the latter including the Late Ordovician-Early Silurian White

LEGEND

LOWER DEVONIAN - Wapske Formation

Interbedded medium grey siltstone and light grey, parallel, and cross-laminated quartzose sandstone

SILURIAN - Perham Group

Green and grey calcareous to non-calcareous siltstone and sandstone with thin argillites

UPPER ORDOVICIAN TO LOWER SILURIAN - Matapedia Group

Thinly interbedded grey calcareous slate, grey to black aphanitic lime-stone and fine-grained sandstone

Bedding, tops known (overturned)

Bedding, tops unknown (inclined, vertical)

Slaty cleavage (inclined, vertical)

Fault

Fossil locality

Route number

MAP LOCATION

Fig. 1. Location and simplified geological map of the Perth-Andover area, western New Brunswick. Note that in the small inset map, the Matapedia Basin is outlined by a stippled ornament.

Head and Pabos formations (Nowlan, 1983). In New Brunswick the strata include the late middle Ordovician-Early Silurian Grog Brook and Matapedia groups (St. Peter, 1977; Nowlan, 1983) while in Maine they are referred to as the Madawaska Lake Formation of at least middle Ordovician age (Roy and Mencher, 1976) and an overlying Carys Mills Formation of latest Ashgillian or earliest Silurian age (Rickards and Riva, 1981). Trace fossils described in this paper were located in western New Brunswick just north of the Perth-Andover area (Fig. 1) and were collected from the Matapedia Group whose equivalent to the west in eastern Maine is the Carys Mills Formation. The location of the site is on the eastern bank of the Tobique River approximately 1.5 km upstream from its confluence with the Saint John River (Fig. 1), though as noted in the introduction, this site will be unavailable in the near future as a consequence of construction of an acquaculture center. No fossils are present in the Matapedia Group at this location and therefore the assignment of a Late Ordovician (Ashgillian) to Early Silurian age is based on correlation with equivalent graptolite-bearing strata found elsewhere in the Matapedia Basin (e.g., Rickards and Riva, 1981).

The Matapedia Group consists of delicately laminated calcareous argillites, individual laminae typically being <1 mm in thickness, laterally persistent or (very rarely) impersistent, rarely lenticular, and separated by <2 cm-thick (typically <1 cm-thick) dark, relatively calcite- and ankerite-poor argillites. Interbedded with these parallel-laminated calcareous argillites are 1-2 cm

thick ankeritic limestones which are generally massive but rarely are parallel-laminated. On outcrop scale these interbeds are apparently laterally continuous though may be attenuated due to tectonism. They are sharp-based and exhibit sharp and clearly defined upper surfaces. Rare interbeds of slightly more coarser grained, less calcareous siltstones or fine-grained sandstones are also present and are parallel- or cross-laminated. The internal arrangement of laminae, parallel-laminated passing vertically into cross-laminated sets, indicates deposition of such units from decelerating flows. Some of these units are normally graded and several are composite. The units are planar based but with no obvious erosive features and exhibit sharply defined upper surfaces. The relative importance of the three lithotypes is difficult to estimate, even semi-quantitatively, because of structural, exposure and weathering problems; however, calcareous argillites and interbedded ankeritic limestones are very predominent with only rare interbeds of calcareous siltstones.

To date no systematic or detailed sedimentological studies of the Matapedia Group have been undertaken, although existing literature suggests deposition of the strata in a deep-water marine environment. St. Peter (1977) suggested deposition in a bathyal or abyssal environment whereas Stringer and Pickerill (1980) suggested deposition on a slope marginal to the northeast trending Miramichi Anticlinorium (see Fyffe et al., 1981) to the southeast. The more thickly bedded calcareous siltstones exhibit evidence of deposition from

decelerating flows, probably turbidite flows. The trace fossils indicate deposition in deep-water, but most have previously been reported from other sequences in both slope and basinal regimes. The interbedded calcareous argillites and ankeritic limestones are not indicative of any specific depositional environment, as they do not possess diagnostic environmental indicators. Nevertheless they do suggest deposition above the calcite compensation depth and therefore presumably of shallower origin than bathyal or abyssal conditions. Thus, the most realistic model appears to be that presented by Stringer and Pickerill (1980), who, based on studies of equivalent strata elsewhere in the Matapedia Group, suggested its deposition on a slope by hemipelagic and normal bottom-following contour currents with periodic introduction of ankeritic limestones and calcareous siltstones by turbidity currents.

THE TRACE FOSSIL ASSEMBLAGE

A total of 13 ichnogenera represented by 15 ichnospecies were collected from the site. These trace fossils, as described subsequently in more detail, are: *Chondrites* ichnospp., *Cochlichnus anguineus* Hitchock, 1858; *Dictyodora scotica* (M'Coy, 1851); *Dictyodora tenuis* (M'Coy, 1851); *Dimorphichnus* ichnosp.; *Glockerichnus* ichnosp.; *Gordia marina* Emmons, 1844; *Helminthopsis* ichnosp.;

Muensteria ichnosp.; *Neonereites uniseralis* Seilacher, 1960; *Nereites jacksoni* Emmons, 1844; *Palaeophycus tubularis* Hall, 1847; *Syncoprulus pharmaceus* Richter and Richter, 1939; *Yakutatia emersoni* (Ulrich, 1904). The trace fossils were collected from the extensive talus material at the site and therefore were not located *in situ*, though this is not an unusual situation in ichnological research (Fillion and Pickerill, in press). Because of extensive deformation and pressure solution activity (cf. Stringer and Pickerill, 1980) the trace fossils are, on the whole, poorly-preserved and difficult to observe. They occur on upper and lower bedding plane surfaces though because of the delicate and thinly laminated nature of most of the strata it is often difficult, if not impossible, to distinguish top from bottom surfaces.

Most specimens were discovered as isolated individual traces but some slabs (Fig. 2) exhibited numerous burrows. The most common traces, in decreasing order of abundance, were *Palaeophycus tubularis*, *Helminthopsis* ichnosp., *Chondrites* ichnospp. and *Dictyodora* ichnospp. The remainder were represented by only a few individual specimens and in the case of *Glockerichnus* ichnosp., *Neonereites uniserialis* and *Yakutatia emersoni* by only a single example of each. It must be emphasized that many hours of collecting were spent at this location and therefore we believe that the
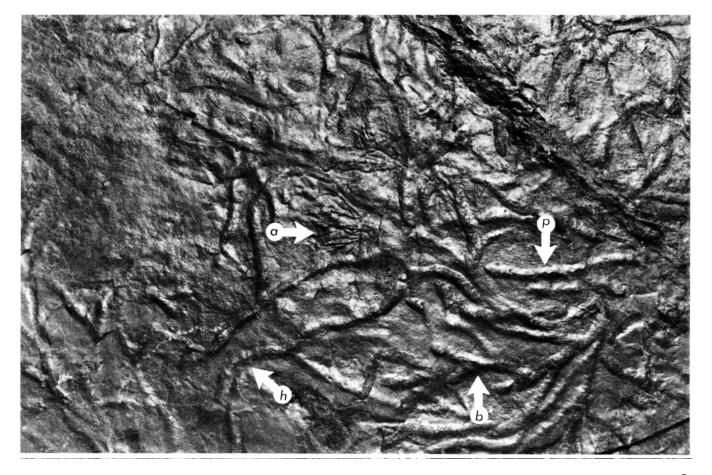

Fig. 2. Bottom surface of a siltstone slab from the Matapedia Group exhibiting numerous burrows. a – *Chondrites* ichnosp. type B. p – *Palaeophycus tubularis*, h – *Helminthopsis* ichnosp., b – *Chondrites* ichnosp. type A., x1.

trace fossils described herein are truly represen-
tative of the original assemblage.

DISCUSSION

With respect to the Matapedia Group elsewhere
within the Matapedia Basin of Maine, New Brunswick
and Quebec the trace fossils at the Tobique River
site are important in the following aspects:-
1. Personal observation of many additional sites
in the Matapedia Group has indicated that trace
fossils are generally rare in these strata and are
restricted to poorly-preserved simple burrow
systems, particularly *Chondrites*. The site is
therefore a unique locality within the Matapedia
Group.
2. As a corollary, the site has therefore pre-
served the most diverse and abundant collection of
trace fossils within the Matapedia Group. Previous
records of trace fossils in the Group (Pickerill,
1980, 1985, in press) have only listed *Chondrites*,
Helminthopsis, Planolites, Scalarituba, Syncoprulus
and *Yakutatia*. Thus, *Cochlichnus, Dictyodora,
Dimorphichnus, Glockerichnus, Gordia, Muensteria,
Neonereites* and *Palaeophycus* represent new record-
ings.
3. Of this latter list of new recordings only
Dimorphichus, Muensteria and *Dictyodora* represent
ichnogenera never previously documented from the
Matapedia Basin, the remainder having been
described from additional groups or formations
elsewhere in the Basin (Pickerill, 1980, 1981,
1985, in press). The detailed taxonomy of
Muensteria and other simple meniscate burrows such
as *Scalarituba, Laminites, Ancorichnus* etc., has
still to be resolved (Frey *et al.*, 1984) and there-
fore further comment on its presence is perhaps not
warranted at this time. Similarly *Dimorphichnus* is
a simple arthropod-produced trace morphologically
similar to *Diplichnites*, an ichnogenus previously
recorded from coeval strata of the Matapedia Basin
(Pickerill, 1980, 1981). However, the presence of
Dictyodora cannot be overemphasized. Not only has
this ichnogenus never previously been recorded from
the Matapedia Basin but also it is the first
recorded occurrence in North America despite being
common in Paleozoic flysch sequences in Europe (see
Benton and Trewin, 1980; Benton, 1982a, 1982b).
4. Until now, the trace fossil *Y. emersoni* has
only previously been recorded from the Matapedia
Basin in the Matapedia area of northern New
Brunswick and southern Gaspe (Pickerill, 1985).
This distinctive and unusual graphoglyptid trace
fossil is therefore more widely distributed geo-
graphically within the Basin than previous data
would suggest. *Y. emersoni* has only previously
been recorded from Kodiak Island, Alaska, and the
Matapedia Basin (Pickerill, 1985; McCann and
Pickerill, 1986).
The fact that 15 ichnospecies are recorded from
the Tobique River site together with *Planolites* and
Scalarituba noted elsewhere within the Matapedia
Group (Pickerill, in press) deserves additional
comment. As previously noted, the Matapedia Group
is interpreted to have been deposited in a slope
setting (Stringer and Pickerill, 1980). Paleozoic,
particularly lower Paleozoic, slope environments
(and herein we employ the descriptor slope to
exclude associated channelized features such as
canyons, channels, chutes and gulleys with their

associated fans and also continental rise environ-
ments (cf. Chamberlain, 1977) and utilize the term
in the sense of Buck and Bottjer (1985) as essen-
tially 'interchannel' slope environments) remain
poorly documented with respect to their
ichnocoenoses (Pickerill and Harland, in press).
Indeed, only two studies have to date been
published on ichnocoenoses of lower Paleozoic slope
sequences, those of Narbonne (1984) from upper
Silurian slope carbonates of Arctic Canada and
Pickerill and Harland (in press) from middle
Silurian slope clastics of North Greenland.
Narbonne (1984) records the ichnogenera *Chondrites,
?Neonereites, Margaratichnus?, Palaeophycus,
Phycodes, Skolithos* and *Teichnichnus*, and Pickerill
and Harland (in press) record the ichnogenera cf.
*Chondrites, Gordia, Helminthopsis, Megagrapton,
Muensteria, Neonereites, Nereites* and *Paleodictyon*.
The total of 15 ichnospecies recorded from the
Matapedia Group therefore represents the most
diverse trace fossil assemblage yet recorded from
lower Paleozoic slope deposits.
In a series of papers published in the 1970's,
Seilacher (summarized in Frey and Seilacher, 1980)
suggested a progressive increase in flysch (deep-
water) trace fossil diversity during the Paleozoic.
The three examples noted herein are broadly coeval
and contain 7-13 distinctive trace fossils
(ichnogenera) which do not numerically equate with
the 4-8 ichnospecies documented by Seilacher. This
is perhaps further reinforced when considering that
in toto the three slope sequences noted above con-
tain a combined total of at least 20 distinctive
ichnogenera and, if the unpublished studies of
Narbonne and Packard (1983) and Narbonne and James
(1984) are included, at least 28 separate
ichnogenera have to date been recorded from lower
Paleozoic slope sequences. Future trace fossil
analyses of Paleozoic flysch sequences should
therefore be directed to a more extensive and
taxonomic evaluation of the full range of trace
fossils because it is only with careful and
detailed analysis of such sequences that more
realistic and meaningful diversity models will
eventually be realised.

SYSTEMATIC ICHNOLOGY

In accordance with common ichnological procedure
the trace fossils described below are considered in
alphabetical order rather than any formal morpho-
logical or behavioural groupings (e.g., Osgood,
1970). Preservational terminology, where applica-
ble, follows Webby (1969) and Häntzschel (1975).
For brevity, descriptions and discussion of most
ichnospecies have been minimized and only relevant
literature is included. All figured specimens are
housed in the Geology Department, University of New
Brunswick.

Ichnogenus *Chondrites* von Sternberg, 1833
Chondrites ichnosp. type A
(Fig. 3a)

Description:

Small, acutely branched (typically less than
$30°$) burrow systems which initiate from a horizon-
tal mastershaft and then ramify to form a dendritic
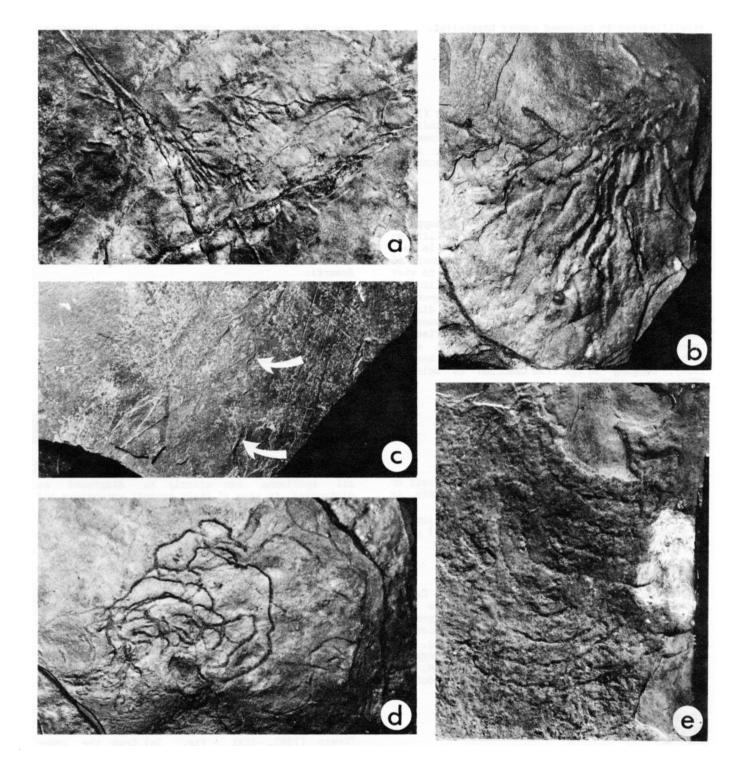network. Individual systems cover a maximum

Fig. 3. Trace fossils from the Matapedia Group, Tobique River. a — *Chondrites* ichnosp. type A, x1. b — *Chondrites* ichnosp. type B, x1.4. c — *Cochlichnus anguineus* (arrowed), x1. d — *Dictyodora tenuis*, x0.8. e — *Dictyodora scotica*, x0.8.

observed, area of 6 cm^2 but are typically smaller (2-3 cm^2). Individual burrows are straight and 1 mm or less in width; burrow fill is identical to host material. At least 3 orders of branching are commonly present. Preservation is parallel to stratification in presumed convex hyporelief.

Chondrites ichnosp. type B
(Fig. 3b)

Description:

As above except burrow diameter is larger (1-2.5 mm), branching is more irregular (20-90°), individual burrows may be straight or sinuous, commonly only 2 orders of branching are observed but individual systems cover a much larger surface area, up to a maximum observed of 30 cm^2.

Remarks:

Since first described in 1833, over 170 supposed ichnospecies of *Chondrites* now exist in the literature (Chamberlain, 1977) most of which are in all probability synonyms. Taxonomic re-assessment of these ichnospecies is clearly warranted and in view of this the present material is only identified at the ichnogeneric level. Equally as clear, however, is that 2 forms of *Chondrites* can be easily distinguished in the present material, and because of this taxonomic problem are herein identified as types A and B. *Chondrites* is a marine but eurybathic trace fossil (see Fillion and Pickerill, 1984), ranging in age from Cambrian to Holocene (Häntzschel, 1975).

Ichnogenus *Cochlichnus* Hitchcock, 1858
Cochlichnus anguineus Hitchcock, 1858
(Fig. 3c)

Description:

Regularly meandering, smooth, horizontal trail or burrow resembling a sine curve. Trace width is approximately 1 mm and wavelength is 5-6 mm. Fill is identical to host material and preservation is in positive convex (?epirelief or hyporelief) semi-relief parallel to stratification.

Remarks:

Although locally used as a distinctive facies indicator (e.g., Hakes, 1976) *Cochlichnus* is more typically a eurybathic trace fossil and ranges in age from Late Proterozoic to Holocene. Fillion and Pickerill (in press) regard *C. kochi* Ludwig, 1869 and *C. serpens* Webby, 1970 as junior synonyms of *C. anguineus,* a view which is held herein, and therefore the ichnogenus can best be regarded as monospecific.

Ichnogenus *Dictyodora* Weiss, 1884
Dictyodora scotica (M'Coy, 1851)
(Fig. 3e)

Description:

Burrow system essentially preserved parallel to stratification and consisting of 5-10 parallel meanders each approximately 60 mm long and

separated by 8-10 mm of undisturbed sediment. Individual segments of parallel meanders are gently curved. Burrow diameter varies from 2-3 mm. Rare examples, preserved at different stratification levels, demonstrate their 3-dimensionality; in such examples, burrow diameter slightly increases/decreases depending on whether such surfaces are below or above (respectively) the dominant stratification level.

Dictyodora tenuis (M'Coy, 1851)
(Fig. 3d)

Description:

Burrow system preserved parallel to stratification and consisting of irregularly meandering, typically cross-cutting but continuous trace. Primary meanders are typically broad and frequently develop secondary sinuosity. Burrow diameter varies from 0.5-1.0 mm, but as with *D. scotica,* preservation within a single specimen can be on different stratification levels and therefore vary accordingly.

Remarks:

Dictyodora is an extremely complex trace fossil consisting of a basal burrow, typically lenticular in cross-section and varying in width from 1.5-6 mm, from which extends a vertical or inclined upward tapering longitudinal wall from the dorsal line of the basal burrow which may be up to 25 mm in height (Benton and Trewin, 1980; Benton, 1982a). As such, individual specimens exhibit various preservational aspects depending on the level at which they are sectioned. We regard the specimens described herein as probably being preserved from near to the base of the wall (cf. Benton and Trewin, 1980, text – fig. 1c(b)), though there is no positive evidence to justify this as the basal burrows are conspicuously absent. Nevertheless, all specimens can clearly be diagnosed as *Dictyodora* in view of their overall morphology and the fact that slabs broken along different stratification levels illustrate their 3-dimensionality and slight morphological change with respect to this dimension.

D. scotica is differentiated from *D. tenuis* by the presence in the former of regular meanders and in the latter by irregular meanders and secondary sinuosity of the individual burrows. Additionally, although not apparent in the present material, the basal burrow in *D. scotica* is wider and the burrow height is greater (13 mm in *D. scotica,* 10 mm in *D. tenuis*). *D. zimmermanni* Hundt, 1913 possesses a less regular meandering pattern than *D. scotica* and lacks the regular secondary sinuosity characteristic of *D. tenuis* and *D. liebeana* (Geinitz, 1867) is a complex spiralled form of *Dictyodora* (Benton, 1982a). *D. scotica* as figured herein very closely resembles that figured by Benton (1982b, fig. 2d) and, particularly, Benton and Trewin (1980, text – fig. 3c) from the lower Silurian of Scotland and *D. tenuis* broadly resembles that figured by Benton and Trewin (1980, text – fig. 5), though the specimen figured herein exhibits more cross-cutting relationships.

Dictyodora has been widely reported from several European flysch sequences, as reviewed in Benton

and Trewin (1980) and Benton (1982a, 1982b). To our knowledge, however, it has never previously been documented in North America though some of Emmons' (1844) material from the Silurian of Maine may prove to be congeneric, particularly some of his 'Nereites' ichnospecies. This particular aspect is currently under investigation by two of us (R.K.P and W.H.F.). The ichnogenus ranges in age from Cambrian to Carboniferous and is an important member of the deep-water Nereites ichnofacies of Seilacher (1967).

Ichnogenus *Dimorphichnus* Seilacher, 1955
Dimorphichnus ichnosp.
(Fig. 4a)

Description:

Simple straight to gently curved trackways, parallel to stratification, up to 11 cm in length and composed of two types of impressions; thin straight to gently curved impressions, each 5 mm in length and 4-5 mm apart and oriented at an angle of 60° to the track axis, and short blunt impressions, each approximately 1 mm in length and located opposite to the main impressions, being separated from them by 1 cm of undisturbed sediment.

Remarks:

Seilacher (1955) erected *Dimorphichnus* for trackways produced by arthropods, particularly trilobites, in which the body was oriented nearly at right angles to the direction of movement. The resulting trace is a series of long raking imprints made by the appendages on the lee side of the body; the legs of the other side provided body support, thus these imprints resemble a series of small pits (Osgood and Drennen, 1975). It has previously been interpreted as both a feeding trail (Seilacher, 1955) or having been produced as a result of current activity (Osgood, 1975). Its reported age is from Cambrian to Silurian, though is probably present in strata of at least Paleozoic age.

Ichnogenus *Glockerichnus* Pickerill, 1982
Glockerichnus ichnosp.
(Fig. 4b)

Description:

Incomplete stellate trace preserved in negative ?epirelief, parallel to stratification. The trace consists of numerous straight to gently curved burrows which radiate out from a diffuse and poorly-preserved center. Individual burrows are unbranched, 3-4 mm in diameter and of unequal length. Maximum width of the trace is 17 cm.

Remarks:

Ichnospecies of *Glockerichnus* are based on the shape, dimensions and density of ribbing (Ksiazkiewicz, 1977). In all these respects the specimen described herein closely resembles the type ichnospecies *G. glockeri* but is only identified at the ichnogeneric level because of its generally poor and incomplete preservation. A more complete discussion of the trace fossil is given in Ksiazkiewicz (1977). It ranges in age from

Ordovician to Holocene and has only previously been recorded from deep-water flysch environments.

Ichnogenus *Gordia* Emmons, 1844
Gordia marina Emmons, 1844
(Fig. 4c)

Description:

Smooth, unbranched trails or burrows of uniform diameter (1-2 mm) which exhibit a tendency to wind, but not meander, and frequently cross-cut within a single burrow system. Preservation is in positive hyporelief.

Remarks:

More complete discussions and descriptions of *Gordia* and its ichnospecies are given in Ksiazkiewicz (1977) and Fillion and Pickerill (in press). The ichnogenus is distinguished from the morphologically similar ichnogenus *Helminthopsis* by the absence in the latter of true level-crossing. *Gordia* is a facies crossing form ranging in age from upper Proterozoic to Holocene.

Ichnogenus *Helminthopsis* Heer, 1877
Helminthopsis ichnosp.
(Fig. 4g)

Description:

Simple, irregularly meandering horizontal and unbranched smooth burrows preserved in convex hyporelief. Diameter varies from 2-4 mm but is constant in individual specimens. Length variable, up to a maximum observed of 15 cm. Burrow fill is identical to surrounding host material. Burrows never cross or touch themselves.

Remarks:

Many authors, too numerous to mention here, have reported the ichnogenus in strata of Late Precambrian to Holocene age (Fillion and Pickerill, in press). It is a eurybathic form, though more frequently reported from deep-water flysch successions (Pickerill, 1981). As with *Chondrites*, many ichnospecies of *Helminthopsis* exist in the literature, most of which are difficult to differentiate and some of which may be synonymous (Ksiazkiewicz, 1977). Detailed systematic study of the ichnogenus still, therefore, has to be undertaken and in view of this the present material is identified only at the ichnogeneric level.

Ichnogenus *Muensteria* Sternberg, 1833
Muensteria ichnosp.
(Fig. 4d)

Description:

Straight to gently curved unbranched horizontal burrows preserved in convex hyporelief and concave epirelief. Individual burrows are 7-10 mm in width, up to 11 cm in length and possess internal meniscate structures, typically 10-12 per centimetre. Burrow fill is identical to surrounding host material. Individual burrows retain a constant diameter and possess thinly lined (<1 mm) but extremely sharp walls.
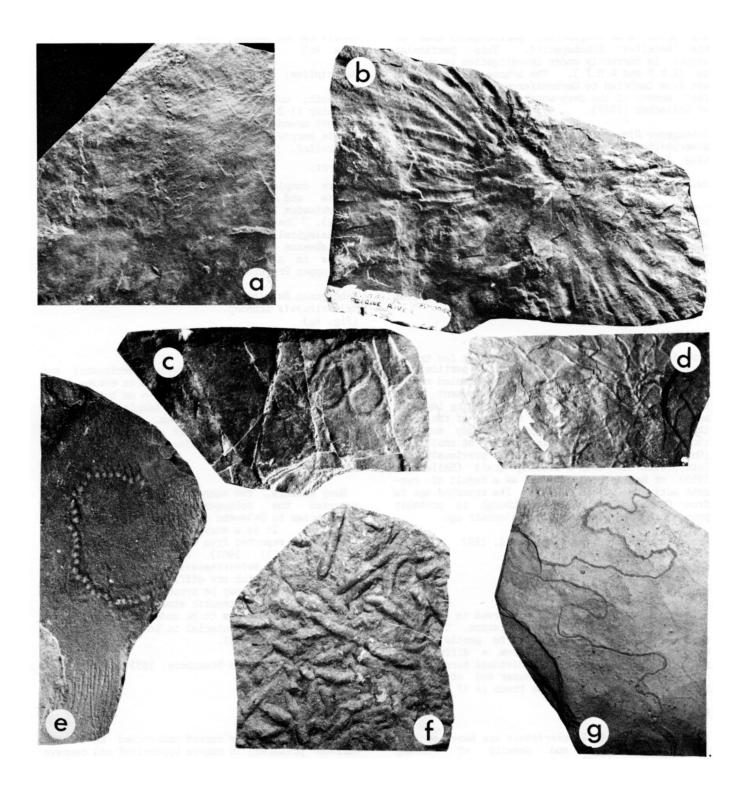
Fig. 4. Trace fossils from the Matapedia Group, Tobique River. a – *Diplichnites* ichnosp., x0.7. b – *Glockerichnus* ichnosp., x0.6. c – *Gordia marina*, x1. d – *Muensteria* ichnosp. x0.5. e – *Neonereites uniserialis*, x1.3. f – *Palaeophycus tubularis*, x1. g – *Helminthopsis* ichnosp., x0.5.

Remarks:

As noted by Frey *et al.* (1984), there is still considerable taxonomic confusion in the naming of both lined (e.g., *Ancorichnus*) and unlined (e.g., *Scalarituba, Beaconites, Taenidium*) meniscate burrows. Fürsich (1974) alluded to this difficulty and placed *Planolites montanus, Taenidium* and *Keckia* into synonymy with *Muensteria*. Although *Keckia* has not subsequently been utilized, both *P. montanus* and *Taenidium* are still commonly cited forms (see Pemberton and Frey, 1982; Hakes, 1985). Thus, *Muensteria* and its possible synonyms have been plagued by considerable taxonomic confusion and until re-evaluation is undertaken, as is supposedly underway by Squires and Advocate (1984), must be regarded, by rule of priority, as the available form for simple meniscate burrows. The material described herein most closely resembles, particularly with respect to width, length, non-branched nature and density of striations, the type ichnospecies, as denoted by Ksiazkiewicz (1977), *M. geniculata* Sternberg, but in view of the taxonomic confusion is only identified at ichnogeneric level. Though reportedly ranging in age from Jurassic to Cretaceous (Häntzschel, 1975), the ichnogenus has since been reported from the Holocene (Wetzel, 1983) and probably extends back to at least, as documented herein, the lower Paleozoic.

Ichnogenus *Neonereites* Seilacher, 1960
Neonereites uniserialis Seilacher, 1960
(Fig. 4e)

Description:

Curved, horseshoe-shaped chain of closely spaced uniserial subcircular pods preserved in convex hyporelief. The single specimen is 38 mm in total length, comprising 35 individual knobs, each of which is approximately 1 mm in diameter.

Remarks:

Ichnospecies of *Neonereites*, namely *N. unserialis* Seilacher, 1960, *N. biserialis* Seilacher, 1960 and *N. multiserialis* Pickerill and Harland, in press, are easily distinguished by the uniserial, biserial or multiserial arrangement of pods within an individual specimen even though transitional forms have previously been reported (e.g., Pickerill, 1981). The ichnogenus is a eurybathic but marine form and has been recorded from strata of Late Precambrian to Tertiary age (Häntzschel, 1975; Fedonkin, 1977).

Ichnogenus *Nereites* Macleay, 1839
Nereites jacksoni Emmons, 1844
(Fig. 5a)

Description:

Irregularly sinuous to meandering burrows of total and consistent width of 1 cm and variable length up to an observed maximum of 28 cm. Individual specimens consist of a smooth central portion, 2-3 mm in width, on each side of which are arranged poorly-preserved, dense (4-6 per cm), rounded and smooth lobes each up to 2.5-3 mm in
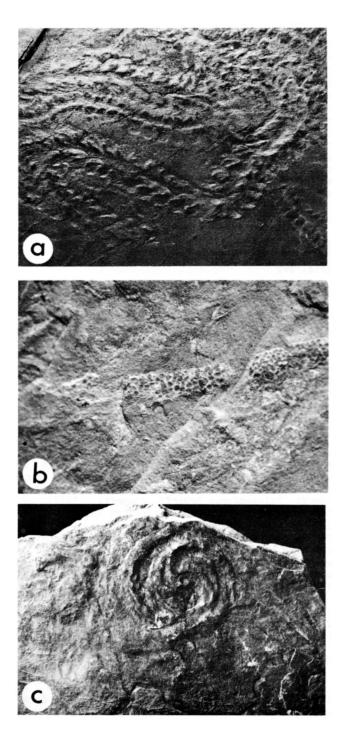

Fig. 5. Trace fossils from the Matapedia Group, Tobique River. a – *Nereites jacksoni*, x1. b – *Syncoprulus pharmaceus*, x1. c – *Yakutatia emersoni*, x1.2.

width. Preservation style is unknown but is probably in convex hyporelief.

Remarks:

A fairly comprehensive taxonomic re-assessment of the ichnogenus *Nereites* was recently undertaken by Benton (1982b). Of the four ichnospecies he recognized, namely *N. macleayi* (Murchison, 1839), *N. cambrensis* Murchison, 1939, *N. jacksoni* Emmons, 1844 and *N. pugnus* Emmons, 1844, the present material is remarkably similar to *N. jacksoni* with respect to shape and density of the lateral lobes and is diagnosed as such. Examination by one of us (R.K.P.) of topotype material of *N. jacksoni* from the Early Silurian Waterville Formation of Maine confirmed this identification. Although forming the type ichnogenus of the deep-water flysch *Nereites* ichnofacies of Seilacher (1967), the ichnogenus should be regarded as eurybathic (Hakes, 1976). It ranges in age from Late Precambrian to Holocene.

Ichnogenus *Palaeophycus* Hall, 1847
Palaeophycus tubularis Hall, 1847
(Fig. 5f)

Description:

Straight to slightly sinuous, but not meandering, smooth thinly lined horizontal burrows preserved in convex hyporelief. Diameter varies from 2-6 mm but is constant in individual specimens; length is variable, up to a maximum observed of 8 cm. Burrow fill is structureless and is identical to surrounding host material. No branching has been observed.

Remarks:

The detailed taxonomy of *Palaeophycus* was recently completed by Pemberton and Frey (1982) after several decades of confusion with respect to the ichnogenus and the closely related form *Planolites*. Of the ichnospecies they recognized, namely *Palaeophycus heberti* (Saporta, 1872), *P. tubularis* Hall, 1847, *P. striatus* Hall, 1852, *P. sulcatus* (Miller and Dyer, 1878) and *P. alternatus* Pemberton and Frey, 1982, the present material conforms best to *P. tubularis* and is diagnosed as such. *Palaeophycus* is a eurybathic form ranging in age from Proterozoic to Holocene (Häntzschel, 1975).

Ichnogenus *Syncoprulus* Richter and Richter, 1939
Syncoprulus pharmaceus Richter and Richter, 1939
(Fig. 5b)

Description:

Simple unbranched horizontal burrows, up to 5 mm in diameter and 15 cm in length filled with fecal pellets. Individual burrows may be straight or sinuous. Fecal pellets are subspherical to elliptical in shape, each approximately 1 mm in length and slightly less than 1 mm in width.

Remarks:

The oldest known pellet-filled burrows have been referred to as *Alcyonidiopsis* Massalongo, 1856, but

since this name was not utilized during 63 years preceding 1955 it should best be considered a *nomen oblitum* (International Code of Zoological Nomenclature, Article 23b). *Alcyonidiopsis* burrows from the Matapedia Basin previously noted by Pickerill (1980) should therefore now be regarded as *Syncoprulus*. Häntzschel (1975) placed *Syncoprulus* in synonymy with *Tomaculum* Groom, 1902, but as noted by Hofmann (1972) this name should only be applied to individual fecal pellets rather than pellet-filled burrows. Because of the sparse recordings of *Syncoprulus* its stratigraphic range is unknown. Nevertheless it does range from at least the lower Paleozoic (this study) to the Cretaceous (as *Alcyonidiopsis* – see Chamberlain, 1977) and is probably a eurybathic form.

Ichnogenus *Yakutatia* Häntzschel, 1962
Yakutatia emersoni (Ulrich, 1904)
(Fig. 5c)

Description:

Poorly-preserved specimen in positive hyporelief parallel to stratification. The specimen is a dextrally coiled burrow system of approximately circular outline and 2.4 cm in total diameter. A centrally positioned initial burrow branches at least twice, possibly three times, and these successive branches coil in the same manner and on the outside of the initial burrow. Individual burrows are 2-3 mm wide, smooth, and burrow fill is identical to surrounding host material.

Remarks:

The monospecific and enigmatic trace fossil *Y. emersoni* was recently reviewed and redescribed by McCann and Pickerill (1986) from its type location on Kodiak Island, Alaska. The only other presently known location of the trace is, in fact, from the Matapedia Basin (Pickerill, 1985). The trace fossil is restricted to deep-water flysch environments and ranges in age from Ordovician to Cretaceous.

ACKNOWLEDGEMENTS

ACEÑOLAZA, F.G. 1978. El paleozoico inferior de Argentina segun sus trazas fosiles. Ameghiniana, 15, pp. 15-64.

AYRTON, W.G., BERRY, W.B.M., BOUCTOT, A.J., LAJOIE, J., LESPÉRANCE, P.I., PAVLIDES, L. and SKIDMORE, W.B. 1969. Lower Llandovery of the northern Appalachians and adjacent regions. Bulletin of the Geological Society of America, 80, pp. 459-484.

BENTON, M.J. 1982a. *Dictyodora* and associated trace fossils from the Palaeozoic of Thuringia. Lethaia, 15, pp. 115-132.

BENTON, M.J. 1982b. Trace fossils from Lower Palaeozoic ocean-floor sediments of the Southern Uplands of Scotland. Transactions of the Royal Society of Edinburgh, Earth Sciences, 73, pp. 67-87.

BENTON, M.J. and TREWIN, N.H. 1980. *Dictyodora* from the Silurian of Peebleshire, Scotland. Palaeontology, 25, pp. 501-513.

BRADLEY, D.C. 1983. Tectonics of the Acadian orogeny in New England and adjacent Canada. Journal of Geology, 91, pp. 381-400.

BUCK, S.P. and BOTTJER, D.J. 1985. Continental slope deposits from a Late Cretaceous, tectonically active margin, southern California. Journal of Sedimentary Petrology, 55, pp. 843-855.

CHAMBERLAIN, C.K. 1977. Ordovician and Devonian trace fossils from Nevada: Bulletin Nevada Bureau Mines and Geology, 90, pp. 1-24.

CRIMES, T.P. 1970. The significance of trace fossils in sedimentology, stratigraphy and palaeoecology with examples from Lower Palaeozoic strata. In Trace fossils. Edited by T.P. Crimes and J.C. Harper. Geological Journal, Special Issue 3, Seel House Press, Liverpool, pp. 101-126.

CRIMES, T.P., GOLDRING, R., HOWEWOOD, P., STUIJVENBERG, J. VAN and WINKLER, W. 1981. Trace fossil assemblages of deep-sea fan deposits, Gurningel and Schlieren flysch (Cretaceous-Eocene), Switzerland. Geologicae Helvetiae, 74, pp. 953-99.

EMMONS, E. 1844. The Taconic System, Based on observations in New York, Massachusetts, Maine, Vermont and Rhode Island. Albany, Caroll and Cook, 68 p.

FEDONKIN, M.A. 1977. Precambrian-Cambrian ichnocoenoses of the east European platform. In Trace fossils 2. Edited by T.P. Crimes and J.C. Harper. Geological Journal, Special Issue 9, Seel House Press, Liverpool, pp. 183-194.

FILLION, D. and PICKERILL, R.K. 1984. Systematic ichnology of the Middle Ordovician Trenton Group, St. Lawrence Lowland, eastern Canada. Maritime Sediments and Atlantic Geology, 20, pp. 1-41.

FILLION, D. and PICKERILL, R.K. In press. Ichnology of the Lower Ordovician Bell Island and Wabana groups of eastern Newfoundland. Paleontographica Canadiana.

FREY, R.W. and SEILACHER, A. 1980. Uniformity in marine invertebrate ichnology. Lethaia, 13, pp. 183-207.

FREY, R.W., PEMBERTON, S.G. and FAGERSTROM, J.A. 1984. Morphological, ethological, and environmental significance of the ichnogenera Scoyenia and Ancorichnus. Journal of Paleontology, 58, pp. 511-528.

FÜRSICH, F.T. 1974. Corallian (Upper Jurassic) trace fossils from England and Normandy. Beitrage zur Naturkunde, Serie B (Geologie und Palaontologie), 13, pp. 1-52.

FYFFE, L.R., PAJARI, G.E. and CHERRY, M.E. 1981. The Acadian plutonic rocks of New Brunswick. Maritime Sediments and Atlantic Geology, 17, pp. 23-36.

HAKES, W.G. 1976. Trace fossils and depositional environment of four clastic units, Upper Pennsylvanian megacyclothens, northeast Kansas. University of Kansas Paleontological Contributions, 63, 46 p.

HAKES, W.G. 1985. Trace fossils from brackish-marine shales, Upper Pennsylvanian of Kansas, U.S.A.. In Biogenic structures: their use in interpreting depositional environments. Edited by H.A. Curran. Society of Economic Paleontologists and Mineralogists, Special Publication, 35, pp. 21-35.

HÄNTZSCHEL, W. 1975. Trace fossils and Problematica. In Treatise on Invertebrate Paleontology, Part W. Edited by C. Teichert. Geological Society of America and University of Kansas Press, Kansas Press, Boulder, Colorado, Lawrence, Kansas, 269 p.

HOFMANN, H.J. 1972. Systematically branching burrows from the Lower Ordovician (Quebec Group) near Quebec, Canada. Paläontologische Zeitschrift, 46, pp. 186-198.

KERN, J.P. and WARME, J.E. 1974. Trace fossils and Bathymetry of the Upper Cretaceous Point Loma Formation, San Diego, California. Geological Society of America Bulletin, 85, pp. 893-900.

KSIAZKIEWICZ, M. 1970. Observations on the ichnofauna of the Polish Carpathians. In Trace fossils. Edited by T.P. Crimes and J.C. Harper. Geological Journal, Special Issue 3, Seel House Press, Liverpool, pp. 288-322.

KSIAZKIEWICZ, M. 1977. Trace fossils in the flysch of the Polish Carpathians. Palaeontologica Polonica, 36, pp. 1-208.

MACSOTAY, O. 1967. Huellas problematicas y su valor paleoecologico en Venezuela. Geos (Venezuela), 16, pp. 7-79.

MCCANN, T. and PICKERILL, R.K. 1986. The trace fossil Yakutatia emersoni from the Cretaceous Kodiak Formation of Alaska. Canadian Journal of Earth Sciences, 23, pp. 262-269.

NARBONNE, G. 1984. Trace fossils in Upper Silurian tidal flat to basin slope carbonates of Arctic Canada. Journal of Paleontology, 58, pp. 398-415.

NARBONNE, G.M. and JAMES, N.P. 1984. Ichnology of the Cambro-Ordovician Cow Head Group, western Newfoundland. Society of Economic Paleontologists and Mineralogists, Annual Meeting, San Jose 1984, Abstracts, p. 58.

NARBONNE, G.M. and PACKARD, J.J. 1983. Trace fossils in Siluro-Devonian tidal flat to distal basin slope carbonates of Arctic Canada. American Association of Petroleum Geologists,

Annual Meeting, Dallas 1983, Abstracts, p. 136.

NOWLAN, G.S. 1983. Biostratigraphic, paleogeographic, and tectonic implications of Late Ordovician conodonts from the Grog Brook Group, northwestern New Brunswick. Canadian Journal of Earth Sciences, 20, pp. 651-671.

OSGOOD, R.G. 1970. Trace fossils of the Cincinnati area. Paleontographica Americana, 6, pp. 281-444.

OSGOOD, R.G. 1975. The paleontological significance of trace fossils. In The Study of Trace Fossils. Edited by R.W. Frey. Springer-Verlag, New York, pp. 87-108.

OSGOOD, R.G. and DRENNEN, W.T. 1975. Trilobite trace fossils from the Clinton Group (Silurian) of east-central New York State. Bulletin of American Paleontology, 287, pp. 299-348.

PAVLIDES, L. 1968. Stratigraphic and facies relationships of the Carys Mills Formation of Ordovician and Silurian age, northeastern Maine. Bulletin of the United States Geological Survey, 1264, 44 p.

PEMBERTON, S.G. and FREY, R.W. 1982. Trace fossil nomenclature and the Planolites - Palaeophycus dilemma. Journal of Paleontology, 56, pp. 843-881.

PICKERILL, R.K. 1980. Phanerozoic flysch trace fossil diversity - observations based on an Ordovician flysch ichnofauna from the Aroostook-Matapedia Carbonate Belt of northern New Brunswick. Canadian Journal of Earth Sciences, 17, pp. 1259-1270.

PICKERILL, R.K. 1981. Trace fossils in a Lower Palaeozoic submarine canyon sequence - the Siegas Formation of northwestern New Brunswick, Canada. Maritime Sediments and Atlantic Geology, 17, pp. 37-58.

PICKERILL, R.K. 1985. The trace fossil Yakutatia emersoni from the Matapedia Basin of New Brunswick and southeast Gaspe - its first reported occurrence outside of Alaska. Maritime Sediments and Atlantic Geology, 21, pp. 47-54.

PICKERILL, R.K. 1986. Stratigraphy, sedimentology and structural analysis of the geology of the Tobique Reserve Lands with an economic assessment of its geologic resources. Unpublished report to the Department of Indian and Northern Affairs, Ottawa, 61 p.

PICKERILL, R.K. In press. Late Ordovician sedimentary rocks and trace fossils of the Aroostook-Matapedia Carbonate Belt at Runnymede, Restigouche River, northern New Brunswick. Geological Society of America Centennial Field Guide - Northeast Section.

PICKERILL, R.K. and HARLAND, T.L. In press. Trace fossils from Silurian slope deposits, North Greenland. Grønlands Geologiske Undersøgelse, 113.

RICKARDS, R.B. and RIVA, J. 1981. Glyptograptus? persculptus (Salter), its tectonic deformation, and its stratigraphic significance for the Carys Mills Formation of Northeast Maine, U.S.A. Geological Journal, 16, pp. 219-235.

RODGERS, J. 1970. Tectonics of the Appalachians. New York, Interscience, 271 p.

ROY, D.C. and MENCHER, E. 1976. Ordovician and Silurian stratigraphy of northeastern Aroostook County, Maine. In Contributions to the Stratigraphy of New England. Edited by L.R. Page. Geological Society of America, Memoir 148, pp. 25-52.

SEILACHER, A. 1955. Spuren und Fazies in Unterkambrium. In Beitrage zur Kenntnis des Kambriums in der Salt Range (Pakistan). Edited by O.H. Schindewolf and A. Seilacher. Akademie der Wissenschaften und der Literatur zu Maintz, mathematische-naturwissenschoftliche Klasse, Abhandlunden, 10, pp. 22-27.

SEILACHER, A. 1967. Bathymetry of trace fossils. Marine Geology, 5, pp. 189-200.

SEILACHER, A. 1974. Flysch trace fossils: evolution of behavioural diversity in the deep-sea. Neues Jahrbuch fur Geologie und Palaontologie, Monatschefte, H-4, pp. 233-245.

SEILACHER, A. 1977. Evolution of trace fossil communities. In Patterns of evolution as illustrated by the fossil record. Edited by A. Hallam. Developments in Palaeontology and Stratigraphy, 5, Elsevier North Holland Incorporated, New York, New York, pp. 359-376.

ST. PETER, C. 1977. Geology of parts of Restigouche, Victoria, and Madawaska counties, northern New Brunswick. Mineral Resources Branch, Department of Natural Resources, New Brunswick. Report of Investigation, 17, 69 p.

STRINGER, P. and PICKERILL, R.K. 1980. Structure and sedimentology of the Siluro-Devonian between Edmundston and Grand Falls, New Brunswick. In The Geology of northeastern Maine and neighboring New Brunswick. Edited by D.C. Roy and N.S. Naylor. New England Intercollegiate Geological Conference, pp. 262-277.

SQUIRES, R.L. and ADVOCATE, D.M. 1984. Meniscate burrows from Miocene lacustrine-fluvial deposits, Diligencia Formation, Orocopia Mountains, southern California. Journal of Paleontology, 58, pp. 543-597.

TANAKA, K.   1971. Trace fossils from the Cretaceous flysch of
  the Irushumbetsu area, Hokkaido, Japan. Geological Survey of
  Japan, Hisamoto-cho, Kawasaki-shi, Japan, Report, 242, 31 p.
WEBBY, B.D. 1969. Trace fossils (Pasichnia) from the Silurian
  of New South Wales, Australia. Palaontologische Zeitschrift,
43, pp. 81-94.
WETZEL, A. 1983. Biogenic structures in modern slope to deep-
  sea sediments in the Sulu Sea Basin (Philippines). Palaeo-
  geography, Palaeoclimatology, Palaeoecology, 42, pp. 285-304.