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Paper 83-13

LITHOLOGY, TRACE FOSSILS, AND CORRELATION OF PRECAMBRIAN-CAMBRIAN BOUNDARY BEDS, CASSIAR MOUNTAINS, NORTH-CENTRAL BRITISH COLUMBIA

W.H. Fritz
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Canada

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Cover photo

View to west of Cassiar Mountains near Good Hope Lake. Light coloured ridges in fore- and middleground expose strata of Atan Group (Cambrian) and Ingenika Group (Upper Precambrian). GSC 204041-M

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Abstract

Trace fossils from the upper part of the Stelkuz Formation (609 m+) and from the overlying Boya Formation (400.5 m) permit a tentative definition of the Precambrian-Cambrian boundary in the Cassiar Mountains. The strata investigated are below the top of the Lower Cambrian *Fallotaspis* Zone, a level located 1.5 m above the upper contact of the Boya Formation. The Precambrian-Cambrian boundary is tentatively placed 592 m below this level at a disconformity within the Stelkuz Formation. Between the top of the *Fallotaspis* Zone and the boundary are *Arenicolites*?, *Cruziana, Diplocraterion, Monomorphichnus, Plagiogmus, Planolites, Phycodes, Rusophycus, Skolithos, Teichichnus,* and *Treptichnus*. In Precambrian(?) strata below the boundary are *Chondrites, Didymaulichnus, Gordia, Helminthopsis, Neonereites, Planolites, Skolithos,* and *Taphrhelminthopsis*. Correlations with other boundary strata in the Canadian Cordillera suggest the optimum area for further testing ichnofossil ranges is in the Mackenzie Mountains. Intercontinental correlations are also attempted.

Résumé

Des empreintes fossiles dans la partie supérieure de la formation de Stelkuz (606 m+) et dans la formation de Boya (400,5 m) sus-jacente permettent de définir provisoirement, la frontière précambrienne-cambrienne dans la chaîne des Cassiars. Les couches qui ont fait l'objet de recherche sont situées sous le sommet de la zone à *Fallotaspis* du Cambrien inférieur, à 1,5 m au-dessus du contact supérieur de la formation de Boya. La frontière précambrienne-cambrienne est fixée provisoirement à 592 m sous ce niveau à l'endroit d'une discordance stratigraphique à l'intérieur de la formation de Stelkuz. Entre le sommet de la zone à *Fallotaspis* et la frontière se trouvent les fossiles suivants: *Arenicolites, Cruziana, Diplocraterion, Monomorphichnus, Plagiogmus, Planolites, Phycodes, Rusophycus, Skolithos, Teichichnus* et *Treptichnus*. Dans les couches précambriennes situées sous la frontière se trouvent ces fossiles: *Chondrites, Didymaulichnus, Gordia, Helminthopsis, Neonereites, Planolites, Skolithos* et *Taphrhelminthopsis*. Des corrélations établies avec d'autres couches formant la frontière dans la région de la Cordillère canadienne suggèrent que la région la plus propice pour l'exécution d'autres essais de la répartition stratigraphique des empreintes fossiles se situe dans les monts Mackenzie. On a également essayé de faire des corrélations intercontinentales.

INTRODUCTION

At the present time, only a tentative level for the Precambrian-Cambrian boundary can be located in even the best of stratigraphic sections, as no standard level (point in a standard section) has yet been accepted by the Commission on Stratigraphy (I.U.G.S.). However, a group of geologists charged with the task of recommending a boundary position to the Commission has agreed to focus its attention on what it considers an optimum level, and has thereby narrowed the biostratigraphic interval under consideration. This group, the Precambrian-Cambrian Boundary Working Group, decided in Cambridge, England in February, 1978, that the boundary level should be at a horizon that is approximately equal to the base of the Tommotian Stage in Siberia. In North America this level is far below the lowest occurrence of archaeocyathids, trilobites, and brachiopods, and it passes through strata in which small shelly fossils, such as hyolithids and chancellorids, are exceedingly rare. Trace fossils, however, are common at this level, and may provide one of the best instruments for establishing a zonation across the Precambrian-Cambrian boundary in North America. At present there are not enough data available in North America or from other continents to erect such a zonation. During this early stage of research, and while awaiting a zonation, various trace fossil workers have tentatively used a boundary concept put forth by Fedonkin (1980). He has recommended placing the boundary at the change from simple surface traces (Precambrian) to complex traces that include evidence of active burrowing (Cambrian).

In 1979 a delegation of the Precambrian-Cambrian Boundary Working Group visited the Mackenzie Mountains in western Canada and was able to quickly agree on the tentative level for the boundary based on Fedonkin's trace fossil concept (Fritz, 1980a). During this visit plans for the present research were formulated, the objective being to duplicate the Mackenzie Mountains trace fossil results in a second region within the Canadian Cordillera. A site in the Cassiar Mountains (Fig. 1, location 1a) was chosen because it is suitably far from the Mackenzie Mountains and because the boundary horizon exists within similar strata.

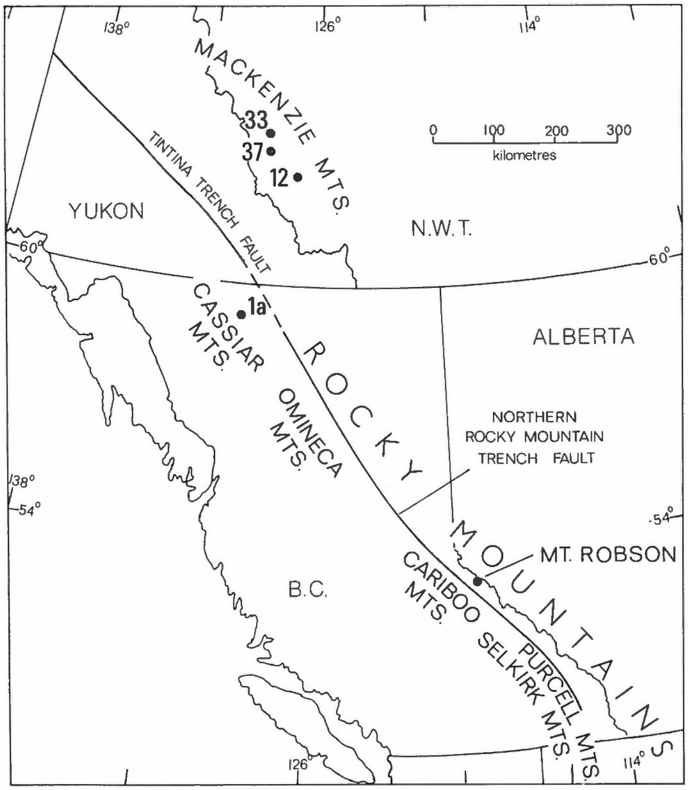


FIGURE 1. Locality map. Stratigraphic section and trace fossils described in present paper are from Section 1a in Cassiar Mountains. Mackenzie Mountains stratigraphic sections and trace fossils mentioned in text are from 12 (Gabrielse et al., 1973; Fritz, 1982), 33 (Fritz, 1979a, 1979b), and 37 (Fritz, 1979b; Hofmann, 1981).

ACKNOWLEDGMENTS

The writers wish to thank J.W. Cowie, who, as leader of the Precambrian-Cambrian Boundary Working Group, gave his support to the present study. Past field assistance by H. Gabrielse in the Cassiar Mountains enabled Fritz to select a suitable section in this structurally complex range where boundary strata are generally poorly exposed. The Canadian National Committee of the International Geological Correlation Programme paid the travel fare from England to Canada enabling Crimes to join Fritz in the field. Access to the collecting site was by helicopter from a staging area in Watson Lake, Yukon Territory. The fieldwork was accomplished in one week.

STRATIGRAPHY

General remarks

The stratigraphic data and trace fossils described in this report were obtained from the upper part of the Stelkuz Formation and the overlying Boya Formation. They are within Section 1a centred 3.4 km southeast of Good Hope Lake in the Cassiar Mountains (figs. 1, 2). Part of the section has been described in detail (Fritz, 1980b) as the type sections for the Boya Formation and lower part of the Rosella Formation. These two formations comprise the Atan Group. Only a general description is given herein for the previously described Boya Formation, and none is given for the Rosella Formation, as the latter is above the collecting horizons. Stelkuz strata are previously undescribed in Section 1a, and they are therefore recorded in detail.

The line of Section 1a is offset in the field in three places. These offsets are shown on the stratigraphic column in Figure 2 by dividing it into four segments (1a1, 1a2, etc.). Each segment represents strata measured at outcrops isolated by a surficial cover that prevented measurement along a continuous route. The stratigraphic horizon at the top of Segment 1a1 and the base of Segment 1a2, and at the top of Segment 1a3 and the base of Segment 1a4 have been matched using beds of distinctive lithology, and therefore the offsets along these two horizons have not affected true stratigraphic thickness. No distinctive beds are present at the top of Segment 1a2 and the base of Segment 1a3, and correlation between these points was made by sighting along the stratigraphic strike at the top of Segment 1a2 to the base of Segment 1a3. In making this correlation it was assumed that strata in segments 1a2 and 1a3 belong to an internally undeformed block as is implied by the similar strike and dip at the two outcrops, and the close agreement between these attitudes and those in the large (same?) block containing Segment 1a4 to the south. Irregular dips in strata intermittently exposed between segments 1a2 and 1a3 are attributed to a thin cover of strata emplaced by recent slumping from a higher position on the present slope, and therefore having no bearing on the relative position of strata in segments 1a2 and 1a3. Reasons for assigning the intermediate strata to "slumped beds" are: the configuration of the local topography (Pl. 1, fig. 1), their steeper dips (due to rotation?) toward the existing slope, and the existence of other, similarly slumped beds in the Cassiar Range.

Stratigraphic highlights

The oldest beds (Fig. 2, Unit 1S) in Section 1a probably belong to the "marker beds" described by Mansy and Gabrielse (1978, p. 13). They state: "Redbeds of the Stelkuz Formation constitute an excellent marker in the Cassiar Mountains. Near Dease River in McDame map area (Gabrielse, 1963), red, rose and green limestone, slate and laminated siltstone from 60 to 80 m thick contain chip breccias and mudcracks, and locally have a pseudonodular texture. The redbeds can be followed discontinuously to the southeast as far as Kechika River in Kechika map area (Gabrielse, 1962b)". The redbeds are reported (Gabrielse, oral communication) to be near the base of the Stelkuz Formation. If this report and the correlation between segments 2 and 3 mentioned above prove correct, the thickness of the Stelkuz in the present section is approximately the same as the 600 m thickness given by Mansy and Gabrielse (1978, Fig. 10a) for the formation in the Omineca Range to the southeast.

An abrupt change in the lithology within the Stelkuz Formation takes place at a level 190 m below the top. Below this level is light orange-brown to rust weathering very fine grained quartzite interbedded with siltstone. Above is light coloured, fine- to coarse-grained quartzite in medium to thick beds exhibiting high angle crossbedding. The first indication of this lithological change is 2 m of conglomerate (Pl. 2, fig. 2) that is in turn overlain by white, fine- to medium-grained quartzite

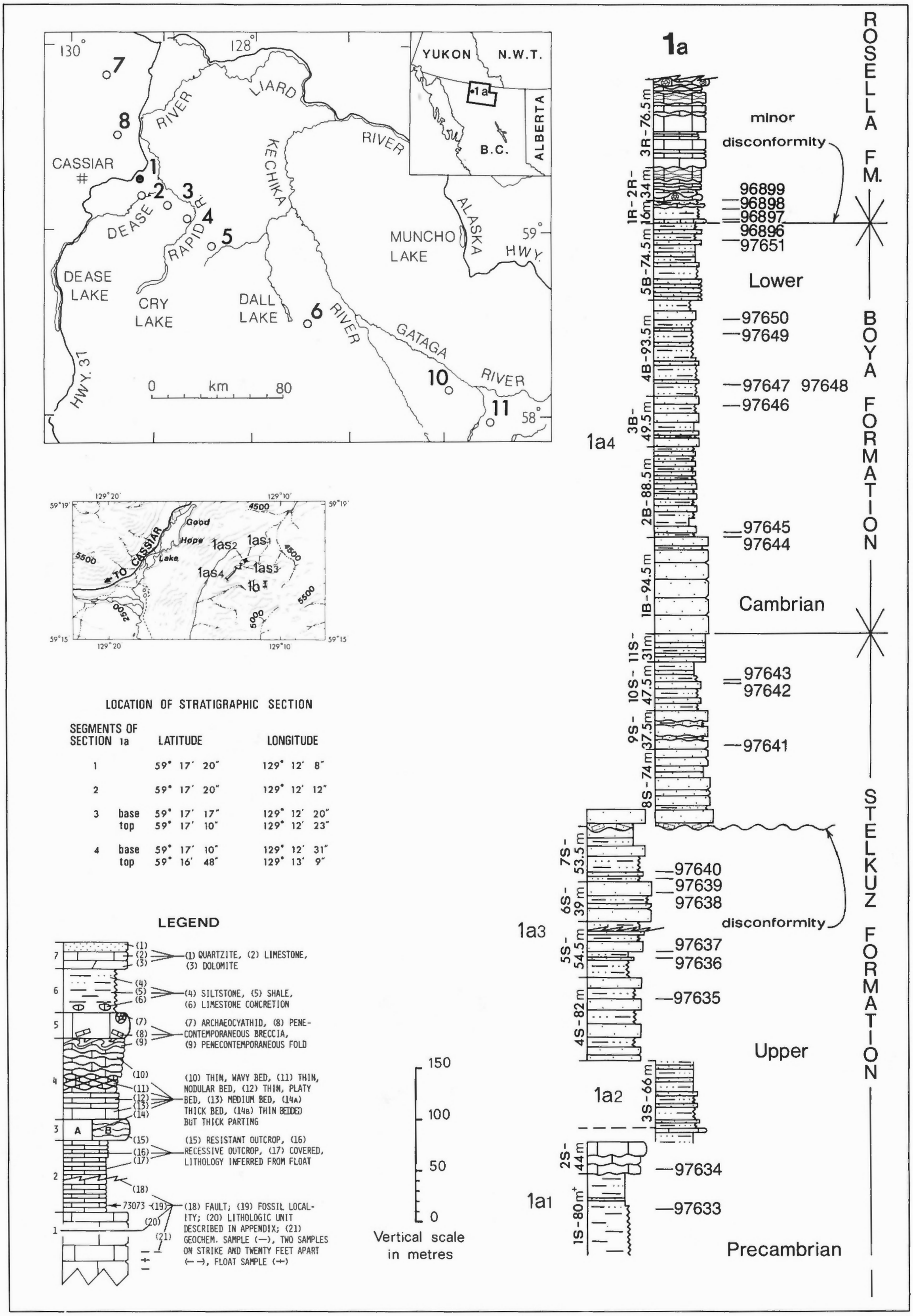
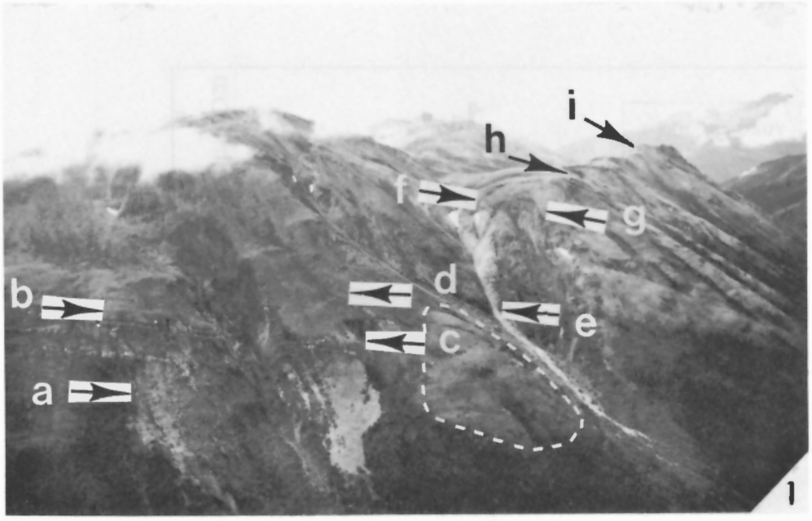


FIGURE 2. Stratigraphic section showing Upper Precambrian(?) and Lower Cambrian strata in the Cassiar Mountains. Trace fossils from GSC locs. 97633-97651 are studied in this paper. GSC localities 96896 to 96899 contain shelly fossils identified in a previous paper (Fritz, 1980b).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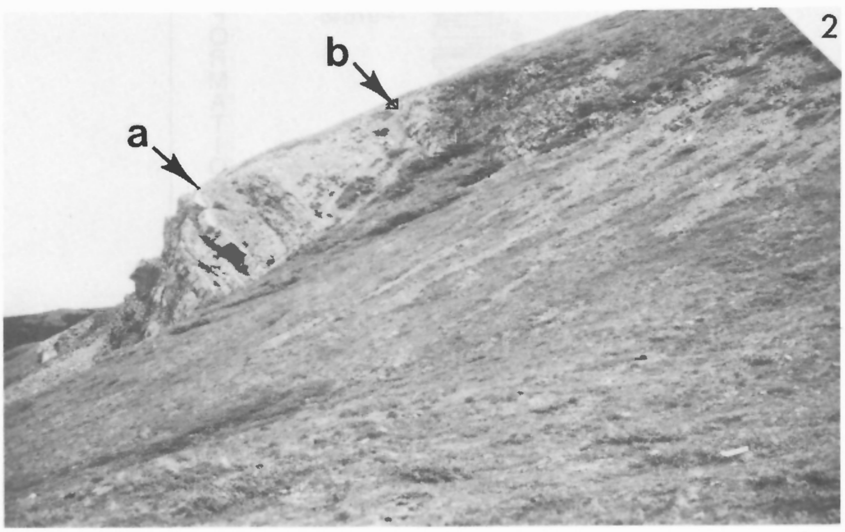

2
b
a


4


5
a

(2-14 m, Unit 8S) in beds that become thinner upwards in the section. These lithologies, plus their abrupt appearance above the darker quartzite and interbedded siltstone, suggest that the conglomerate and white quartzite represent channel fill deposits. No evidence of channeling or erosion of any type have been previously reported from the Stelkuz Formation, although Gabrielse (oral communication) has noted redbeds in this area that are a short distance below the Stelkuz-Boya formational contact. Until the significance of this lithological change is known, it is suggested that the boundary between the Stelkuz and Boya formations remain unchanged from the designated (Fritz, 1980b, p. 221) position at the base of the 94.5 m thick, white quartzite Unit 1B. This quartzite is more resistant than any of the previously mentioned quartzites and has served as an acceptable mapping horizon. The quartzites below the 1B level are not readily mappable because they are mainly covered throughout the map area.

A second abrupt lithological change occurs within Section 1a at the Boya-Rosella formational contact. This contact has been interpreted (Fritz, 1980b, p. 223) as possibly representing a disconformity resulting from minor erosion at the site of Section 1a, and as being related to a significant erosional surface below the Rosella Formation at Section 6 located (Fig. 2) 130 km to the southeast.

Lithology of Stelkuz Formation (609 m+)

The lowest measured unit (Unit 1S, 80 m+) in the formation begins above a covered base where a small, intermittent stream branches and strata is exposed for a short distance upsection along its two tributaries. Maroon (80 per cent) and light greenish grey (20 per cent) shale comprise the lowest visible strata (41.5 m) in the unit. In the overlying interval (41.5-48 m) the strata are composed of thin beds of light brown to orange-brown weathering limy siltstone. Minor amounts of thinly bedded, very fine grained sandstone and fine grained limestone are also present. The uppermost part of the unit (48-80 m) is covered, but its weak topographic expression suggests that it is underlain by siltstone and shale.

Prominent ribs of limestone (Pl. 1, figs. 1, 2) differentiate the next unit in the section (Unit 2S, 44 m) from others that have been assigned to the Stelkuz or Boya formations. The limestone is medium light grey on weathered surfaces and generally occurs in beds of medium thickness, although some thick to very thick beds are present. Fresh surfaces are medium dark grey and the limestone is fine- to medium-grained. Numerous beds exhibit laminae that parallel the parting surfaces and some display crossbeds 10 cm thick. A subunit (32-41.5 m) of reddish brown weathering, platy siltstone is present near the top of the unit.

The lower part (0-36 m) of Unit 3S (66 m) comprises siltstone (two-thirds), which weathers orange to reddish brown and is medium light brownish grey on fresh surfaces. Thin and medium interbeds of quartzite (one-third) weathering orange-brown and that are light brown on fresh surfaces are also present. The quartzite is planar laminated and is very fine grained. Float from the upper part of the unit (36-66 m) suggests that the lithology there is similar to that just described.

Approximately half of Unit 4S (82 m) is composed of medium and thick beds of medium light orange to rust weathering quartzite. Fresh surfaces are light brown and the quartzite is very fine grained except near the top of the unit where it is in part fine grained. The quartzite is interbedded with medium brownish grey siltstone that is medium grey on fresh surfaces.

Siltstone and shaly siltstone in thin, rust weathering plates predominate in the lower part (0-25 m) of Unit 5S (54.5 m). Fresh surfaces are dark grey. A thick (1 m) bed of quartzite 18 m above the base is the only resistant bed in this otherwise recessive subunit. The upper part (25-54.5 m) of Unit 5S is composed of siltstone similar to that below and orange-brown weathering quartzite in thin to thick beds. The quartzite is planar laminated, very fine grained, and light brown on fresh surfaces. A "bed" of white calcite 0.3 m thick and 49 m above the base of the unit is believed to mark the location of a small fault, because it cuts through younger strata to the south of the section.

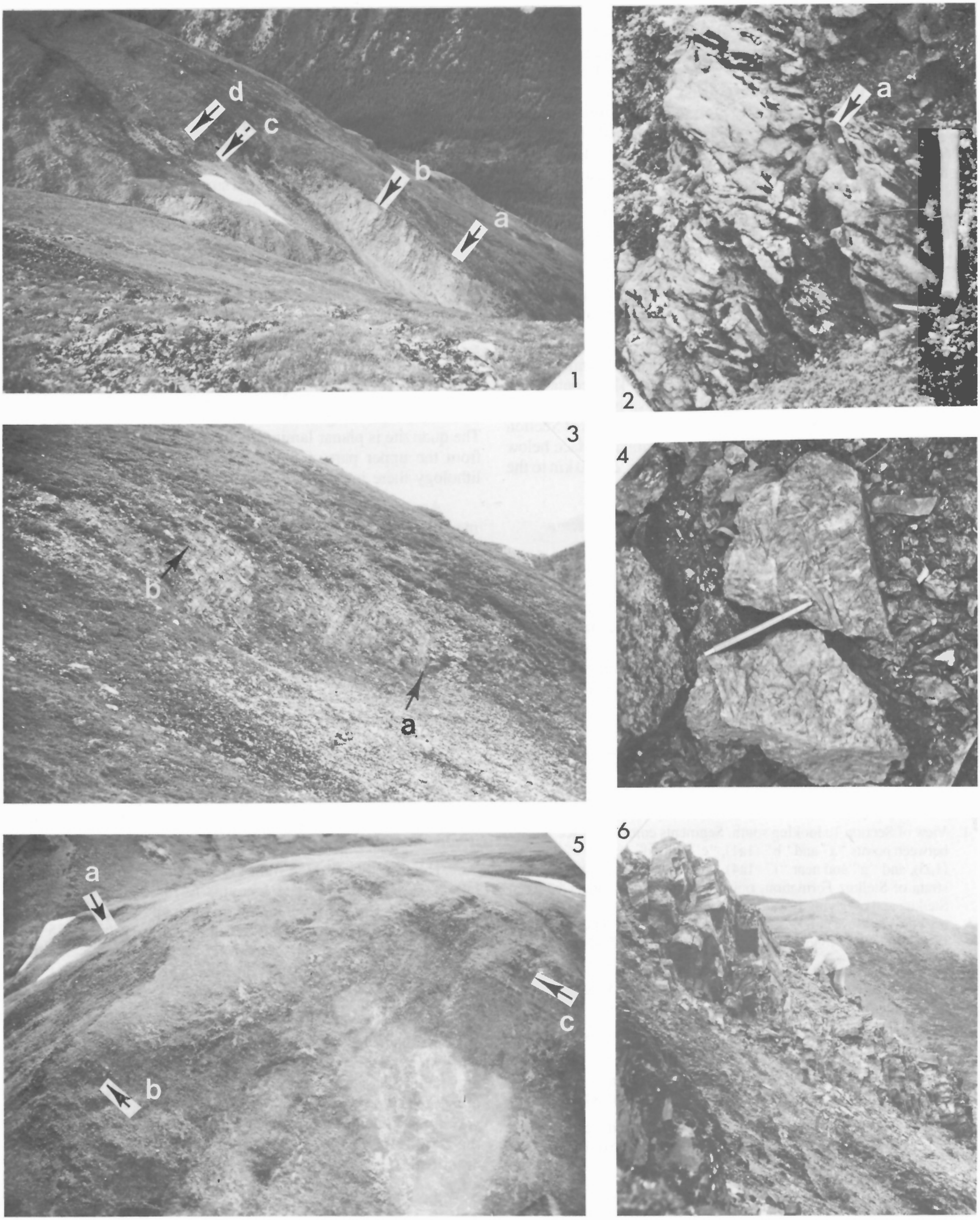
Thick to thin bedded light grey-brown to medium orange-brown weathering quartzite accounts for the resistance of this unit (Unit 6S, 39 m). The quartzite is fine and medium grained and exhibits some crossbeds, the thickest noted being 25 cm high. Interbedded with the quartzite is minor (25 per cent) orange-brown weathering siltstone that is greenish grey on fresh surfaces.

A lower (0-33.5 m) interval in Unit 7S (53.5 m) contains siltstone that is in part light orange weathering and medium grey on fresh surfaces and in part rust weathering and medium dark grey on unweathered surfaces. Present also is minor interbedded quartzite (20 per cent) resembling that below it except that it is very fine grained. An upper, covered interval (33.5-53.5 m) in the unit is believed to contain strata similar to those just described.

PLATE 1

Figures

1. View of Section 1a looking south. Segments comprising section are between points "a" and "b" (1a1), "c" and "d" (1a2), "e" and "f" (1a3), and "g" and near "i" (1a4). Point "a" marks lowest exposed strata of Stelkuz Formation, point "h" locates boundary between Stelkuz and overlying Boya Formation, and point "i" marks boundary between Boya and Rosella Formation. Section 1a ends on ridge a short distance beyond point "i". GSC photo 201853-N.
2. View of medium and thick bedded limestone of Unit 2S in Segment 1a2 looking east. Siltstone subinterval within Unit 2S (32-41.5 m) is between points "a" and "b". GSC photo 200875-E.
3. View of Segment 1a3 looking south. Base of Unit 6S is at "a" and top of segment is at "b". GSC photo 200875-G.
4. *Didymaulichnus* sp. on lower surface of beds excavated from horizon 61 m above base of Unit 4S (above). GSC photo 200875-C.
5. Typical outcrop of siltstone and interbedded quartzite in Stelkuz Formation. View of Segment 1a3 looking west. Top of Unit 6S is at "a". GSC photo 200875-L.


1
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c
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3
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a
4
5
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b
6

Some 2 to 14 m of Unit 8S (74 m) is exposed at the top of the third segment (1a3) in the stratigraphic section and all of the unit is exposed at the base of the fourth segment (1a4). The strata exposed at the top of the third segment are judged to represent channel deposits. These strata are composed of beds that range in thickness from medium to thin, (becoming thinner upsection), and consist of white, clean, medium and coarse grained quartzite that is in sharp contrast to the underlying siltstone and interbedded, generally very fine grained darker quartzite. At the base of the fourth segment, the white quartzite noted in the third segment is underlain by 2 m of conglomerate. The conglomerate (Pl. 2, fig. 2) comprises quartzite pebbles and siltstone plates in a matrix of fine- to coarse-grained quartz sand.

Overlying the white quartzite (2-16 m) in the fourth segment is quartzite that is red and maroon on weathered and fresh surfaces (16-42 m), and medium and fine grained except for sparse grit layers. It exhibits crossbeds up to 25 cm thick. The red and maroon quartzite is in turn overlain by light coloured quartzite (42-74 m), some of which is similar to the white quartzite near the base of the unit and the rest orange-brown weathering and light brown on fresh surfaces. In the uppermost interval the quartzite is medium and thickly bedded and is fine to medium grained.

Unit 9S (37.5 m) contains bioturbated (Pl. 2, fig. 4) orange to rust weathering thick beds of sandstone (75 per cent), which are light grey to light brown on fresh surfaces. Interbedded with the sandstone is orange weathering siltstone (20 per cent), and siltstone (5 per cent), which is dark grey on weathered and fresh surfaces.

Rust weathering siltstone (two-thirds) dominates Unit 10S (47.5 m). It is dark grey on fresh surfaces and interbedded with thin to thick beds of rust weathering, fine grained quartzite. The interval from 22.5 m to 26.5 m contains quartzite that exhibits bioturbation and mudcracks.

The highest unit (Unit 11S, 31 m) in the Stelkuz Formation contains thin to thick beds of orange to rust weathering quartzite (70 per cent). Covered intervals probably contain interbedded siltstone similar to that observed in the unit below.

Lithology of Boya Formation (400.5 m)

A detailed description of the Boya Formation has been given by Fritz (1980b, p. 217-222), and therefore only the main lithologies will be mentioned here. At the base of the formation (Unit 1B) is 94.5 m white quartzite that is predominantly medium grained. The remainder of the formation (units 2B-5B) comprises interbedded siltstone, which is rust weathering and dark grey on fresh surface, and rust to orange weathering quartzite that is light brown on unweathered surfaces. The quartzite is very fine grained, rarely bioturbated, and the lower surfaces are marked by rare to common trace fossils at various intervals. The white quartzite at the base of the Boya is in abrupt contact with the underlying Stelkuz Formation and the upper contact, also abrupt, is at the base of a thick (1.2 m), limy sandstone bed. It has been mentioned that this bed (the lowest in the Rosella Formation) may overlie a minor disconformity (Fritz, 1980b, p. 221, 223). No limy beds were noted below the Boya-Rosella formational contact, except for those in the Stelkuz Formation near the base of the section (Unit 2S), whereas above the contact the various units in the Rosella Formation are composed of limestone and limy siltstone (*op. cit.*, p. 222, 223).

TRACE FOSSILS

Fossil localities and deposition of material

The fossils described in this report are from field localities (GSC locs. 97633-97651) shown opposite the stratigraphic section illustrated in figures 2 and 3. All of the material has been marked with these locality numbers and is stored at the Geological Survey of Canada in Ottawa. The non-illustrated material is stored in an area used for general collections, and the illustrated material is stored in an area designated for the safekeeping of type fossils. The latter material has been assigned a second set of numbers, type numbers (GSC 69461, 69462, etc.), which are listed in the plate descriptions.

The localities are further located in Figure 3 by stratigraphic unit, distance above the base of the stratigraphic unit, and distance below the top of the *Fallotaspis* Zone (1.5 m above the top of the Boya Formation). If a collection was not made from outcrop, it has been designated as "float" or "local float" in the systematic description under "Material and occurrence".

PLATE 2

Figures

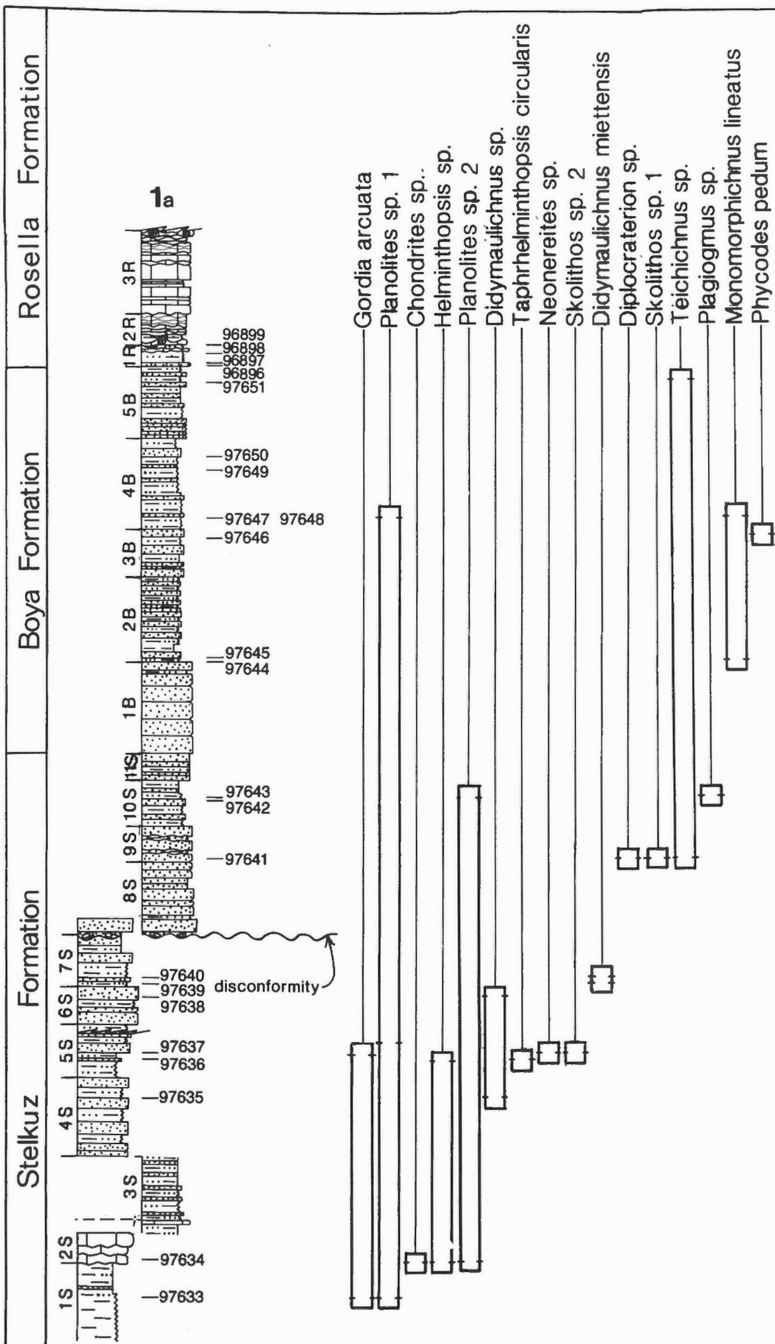
1. View of Segment 1a3 looking west. Fault near top of Unit 5S is at "a", top of Unit 6S is at "b", base of white quartzite (channel fill?) near base of Unit 8S is at "c", top of Segment 1a3 is at "d". GSC photo 200875-M.
2. Conglomerate (channel fill?) at base of Unit 8S, base of Segment 1a4 (see Fig. 5, point "b" for location). Dark siltstone clasts "a" are outlined by light coloured fine to coarse quartz sandstone and quartzite pebbles. GSC photo 200875-D.
3. White quartzite (channel fill?) in Unit 8S (2-14 m), top of Segment 1a3. Points "a" and "b" mark off 12 m of strata and are at same horizons as points "c" and "d" in Figure 1. GSC photo 200875-Z.
4. Bioturbated sandstone in Unit 9S. GSC photo 200875-B.
5. View from helicopter of Section 1a looking southeast. Top Segment 1a3 is at "a" and base of Segment 1a4 is at "b". Point "c" approximately locates bioturbated beds of Unit 9S and lowest collection of trace fossils assigned to the Lower Cambrian. Precambrian-Cambrian boundary is tentatively placed at base of channel deposits(?) at point "b". Anomalous light coloured area at lower right is reflection from helicopter window. GSC photo 200875-U.
6. View of siltstone (lower left) and interbedded quartzite (under geologist, T.P.C.) in Boya Formation looking southwest. Geologist's left hand is 5 m above base of Unit 2R and 2 m below strata containing fossil collection 97645. GSC photo 200875-A.

Distribution of taxa

All of the trace fossils are from below the lowest trilobite-bearing horizon (GSC loc. 96897), which is 1.5 m above the top of the Boya Formation. This horizon is also the top of the *Fallotaspis* Zone, and is the horizon from below which all distances are cited.

Trace fossils attributed to arthropod activity and assigned to *Cruziana* and *Rusophycus* occur in the 19.5 to 95 m interval, and a third arthropod ichnogenus, *Monomorphichnus*, ranges through the above interval and down to the 307 m level. Within these combined intervals are living and feeding burrows assigned to *Arenicolites*?, *Phycodes*, and *Treptichnus*. Also present here and extending into older strata are *Planolites* and *Teichichnus* sp.

Diplocraterion, Plagiogmus, Skolithos, and a second occurrence of *Teichichnus* are located in the interval from 450 to 520 m. This is considered the lowest Cambrian fossil-bearing interval, and the base of the interval lies 72 m above a disconformity that is tentatively selected as the Precambrian-Cambrian boundary. The lack of fossils between the disconformity and the first overlying locality is attributed to an adverse living environment.



GSC LOCALITY	DIST. BELOW TOP OF FALLOTASPIS Z.	DIST. ABOVE BASE OF STRAT. UNIT	STRAT. UNIT
97651	19.5 m	56.5 m	5 B
97650	95	75	4 B
97649	119	60	4 B
97647 97648	157.5	12	4 B
97646	179	40	3 B
97645	302.5	5	2 B
97644	307	0.5	2 B
Boya-Stelkuz Fm. contact	402	0	1 B
97643	450	30.5	10 S
97642	453.5	27	10 S
97641	520	4	9 S
Disconformity	592	0	8 S
97640	637	8.5	7 S
97639	643	2.5	7 S
97638	655.5	29	6 S
97637	714	25	5 S
97636	720	19	5 S
97635	760	61	4 S
97634	927	4	2 S
97633	964.5	46.5	1 S

FIGURE 3. Range chart for trace fossils from the Cassiar Mountains.

Below the disconformity are *Chondrites, Gordia, Helminthopsis,* and *Taphrhelminthopsis,* four ichnogenra known elsewhere only above the Precambrian-Cambrian boundary; and *Didymaulichnus, Neonereites, Planolites* and *Skolithos* known elsewhere to cross the boundary. *Gordia, Helminthopsis* and *Planolites* are unbranched, horizontal forms that are not unlike some other Precambrian ichnogenera. The low occurrence of *Chondrites,* a branched form, is puzzling, however, and serves as a warning that the temporary location of the Precambrian-Cambrian boundary may have been placed too high. The distribution of the trace fossils is discussed further under "International Correlations".

The material from GSC localities 97645 and 97649 could not be identified, and therefore no names are listed for these horizons on Figure 3.

Systematic descriptions

ICHNOGENUS ARENICOLITES Salter, 1857

Type ichnospecies. *Arenicola carbonaria* Binney, 1852

Arenicolites? sp.
Plate 4, figure 1

Material and occurrence. Single block with 10 specimens, local float, GSC loc. 97647.

Description. Paired circular outlines representing bedding plane intersection of U tubes. Burrow diameter is 1 to 2 mm and spacing between pairs is 5 to 10 mm. Burrows are filled with light coloured, fine grained sandstone and occur within a bed of similar lithology. They contrast with black mud laminae located along bedding planes.

Remarks. Arenicolites is common in the Lower Cambrian of North Spain (Crimes et al., 1977, p. 111) and has also been recorded from the Hartshill Formation in England of suggested Late Precambrian to Early Cambrian age (Brasier and Hewitt, 1979). It ranges from the Cambrian to the Eocene (Häntzschel, 1975; Crimes, 1977).

ICHNOGENUS CHONDRITES von Sternberg, 1833

Type ichnospecies. *Chondrites targionii* Brongniart, 1828

Chondrites sp.
Plate 3, figure a

Material and occurrence. One specimen from local float, GSC loc. 97634.

Description. Branching burrows, approximately 4 mm diameter, branches straight to slightly curved and making acute angle with main axis. Walls show faint lineations parallel to burrow length. Burrow system is crossed by another burrow which is probably not part of *Chondrites.* Burrows are found in brown weathering sandy limestone.

Remarks. Chondrites? sp. was found by Young (1972, p. 10) in rocks of the Yanks Peak Formation in the Fraser Valley, British Columbia and is considered by him to be Late Precambrian in age. Crimes and Germs (1982) record *Chondrites*? sp. from the Schwarzrand Subgroup, Nama Group, Namibia. These rocks probably belong to the Lower Cambrian (Tommotian).

The form and size of the present specimen is quite typical for Chondrites, which is a wide ichnogenus, but the parallel lineations on the burrow walls are unusual. The burrow system occurs on a bedding plane covered with other nondescript burrows of *Planolites* type.

ICHNOGENUS CRUZIANA d'Orbigny, 1842

Type ichnospecies. *Cruziana rugosa* d'Orbigny

Cruziana sp.
Not figured

Material and occurrence. Single specimen, local float, GSC loc. 97650. Unfigured type GSC 69479.

Description. Poorly preserved bilobed trace on sole of bed of medium grained sandstone. Trace is approximately 1 cm deep, 4 cm wide, 9 cm long and has coarse scratches making a V-angle (Crimes, 1970a, p. 51) of about 90°.

Remarks. This *Cruziana* has the same width as *Rusophycus bonnarensis* Crimes, Legg, Marcos and Arboleya, 1977, on the same block. This and the coarse scratch marks which are common to both suggest that they were made by the same animal. *Cruziana* occurs widely in Lower Cambrian strata (e.g. Banks, 1970; Cowie and Spencer, 1970; Seilacher, 1970; Alpert, 1977; Crimes et al., 1977) and does not become extinct until the end of the Carboniferous.

ICHNOGENUS DIDYMAULICHNUS Young, 1972

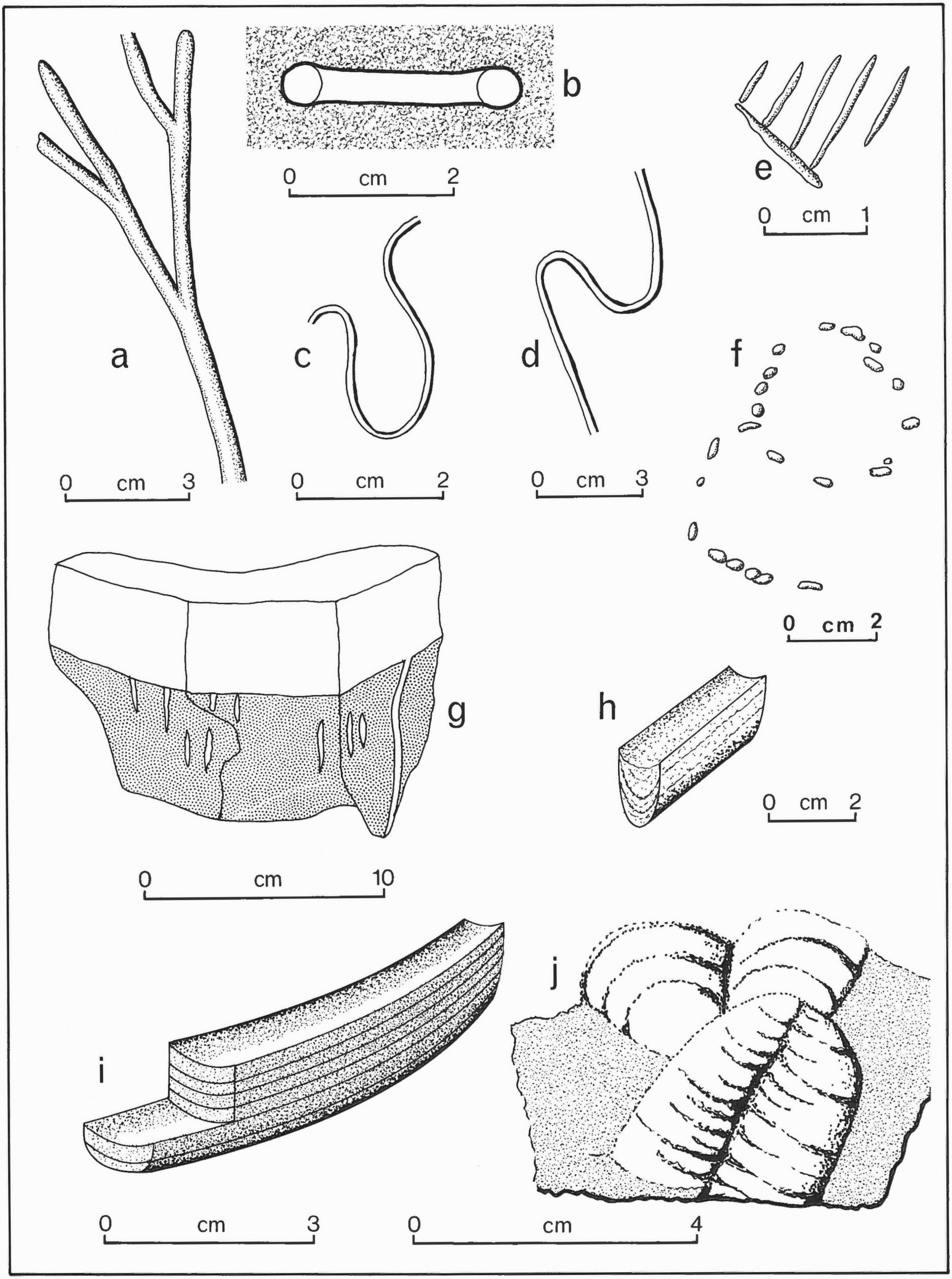
Type ichnospecies. *Fraena lyelli* Rouault, 1850

Didymaulichnus miettensis Young, 1972
Plate 4, figures 2, 3

"Molluscan trails" Glaessner, 1969, p. 389, Pl. 9B-C
Didymaulichnus miettensis Young, 1972, p. 10, figs. 8, 9, 10

Material and occurrence. Three specimens on one block, float, GSC loc. 97639, and numerous specimens on another block, GSC loc. 97640.

Description. Gently curving, deep, smooth trace fossils bisected longitudinally by narrow median ridge and oriented parallel to bedding. Some have gently sloping peripheral bevels. Where traces have preserved bevels they are 8 to 17 mm wide but the central section is only 4 to 8 mm wide. The trace fossils vary in depth from 2 to 8mm. Bevels sometimes occur only along part of trace. *D. miettensis* occurs in profusion on certain bedding planes and traces may overlap and truncate one another.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Remarks. D. miettensis was originally described by Young (1972) from material collected in the Upper Miette Group of the Rocky Mountains, Canada. He regarded the horizon (*op. cit.*, Fig. 2) as Upper Precambrian. Young also included in *D. miettensis* "molluscan trails" described by Glaessner (1969, Fig. 9 BC) from the Upper Precambrian/Lower Cambrian Arumbera Formation of central Australia. This designation seems reasonable to us, but has been questioned by Daily (1972, p. 24) without discussion. *Didymaulichnus tirasensis* Paliy, 1974 also occurs in the Upper Precambrian to Lower Cambrian of the East European Platform, Russia (Fedonkin, pers. comm., 1981; Paliy, Posti, and Fedonkin, 1979) and the ichnogenus ranges from the Vendian Redkino horizon of the Valdai Series at the White Sea to the *Holmia* zone Vergale horizon of the Baltic Series in Poland and the Dnestr River (Fedonkin, pers. comm., 1981).

Didymaulichnus sp.
Not figured

Material and occurrence. Numerous specimens on one block, GSC loc. 97635, and on one block of local float, GSC loc. 97638. Unfigured types GSC 69480, 69481, 69482.

Description. Gently curving partly bilobate traces that are deep and smooth. Trace fossils lack peripheral bevels and may be bilobed only along part of their length. Traces are 3 to 12 mm wide, several millimetres deep and occur in profusion at GSC loc. 97635. Specimen from GSC loc. 97638 shows only small, poorly preserved examples in negative relief on the upper surface of a ripple marked block.

Remarks. These examples lack bevels and so have not been included in *D. miettensis,* but this may only be a preservational variation. The ichnogenus has a much wider occurrence than *D. mittensis* and Häntzschel (1975, p. W61) quotes a range from Upper Precambrian to Silurian(?). It has recently also been reported from Devonian strata in northern Spain (Garcia-Ramos, 1976, Pl. 3f). Brasier et al. (1978) recorded the ichnogenus from the Upper Precambrian – Lower Cambrian Hartshill Formation of Warwickshire, U.K.

ICHNOGENUS DIPLOCRATERION Torell, 1870

Type ichnospecies. *Diplocraterion parallelum* Richter, 1926

Diplocraterion sp.
Plate 3, figure b

Material and occurrence. One *Diplocraterion* and other vertical burrows in single block of quartzite, GSC loc. 97641.

Description. Sand infilled U burrow in bed of quartzite, oriented perpendicular to bedding and containing spreite. Trace fossil intersects parting surface where it consists of paired circular openings of vertical burrows joined by a slit shaped area of disturbed sediment corresponding to the spreite. Overall shape is therefore that of a dumbbell. Vertical burrows are 4 mm in diameter and full length of trace is 2 cm.

Remarks. Diplocraterion occurs widely in Lower Cambrian strata and has been reported recently from the Cantabrian Mountains, Spain (Crimes et al., 1977); Cordillera of Canada (Young, 1972); Finnmark, Norway (Banks, 1970); southern Sweden (Bergström, 1970); and South Australia (Daily, 1972). Fedonkin (1977, p. 187; Pl. 3b) recorded an example of *Diplocraterion* sp. from Tommotian Stage rocks in eastern Poland almost identical in size and form to that described here. *Diplocraterion* ranges from (at least) Cambrian to Eocene (Häntzschel, 1975; Crimes, 1977).

ICHNOGENUS GORDIA Emmons, 1844

Type ichnospecies. *Gordia marina* Emmons, 1844

Gordia arcuata Ksiazkiewicz, 1977
Plate 4, figures 4, 5, 6

Gordia arcuata Ksiazkiewicz, 1977, p. 156, 157, Pl. 20, fig. 8, text-fig. 36y; Pickerill, 1981, p. 44, 45; fig. 3b

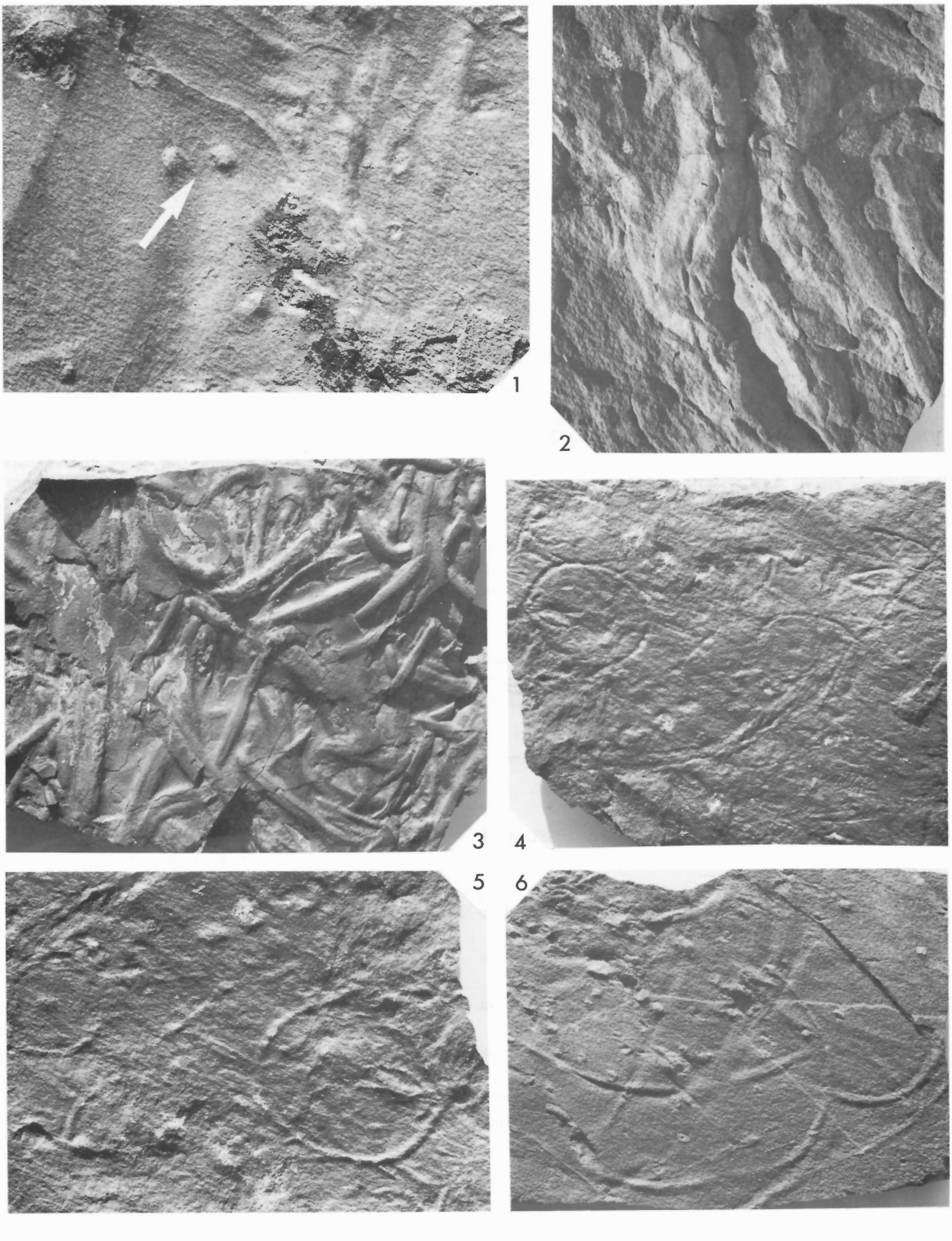
Material and occurrence. Two specimens in local float, GSC loc. 97633; third specimen and sketch of fourth, in float, GSC loc. 97637.

Description. Thin (1-3 mm), unbranched, unsculptured, unornamented burrows arranged in regular arcs or circles, some of which intersect. Circle diameters are 2 to 2.5 cm on specimens from GSC loc. 97633 (Pl. 4, figs. 4, 5) and 8 cm on example from GSC loc. 97637 (Pl. 4, fig. 6). Traces occur as sand infilled

PLATE 3

Figures

a. *Chondrites* sp., GSC loc. 97634, Stelkuz Formation, GSC 69461.
b. *Diplocraterion* sp., GSC loc. 97641, Stelkuz Formation, GSC 69462.
c. *Helminthopsis* sp., GSC loc. 97634, Stelkuz Formation, field drawing.
d. *Helminthopsis* sp., GSC loc. 97636, Stelkuz Formation, field drawing.
e. *Monomorphichnus lineatus* Crimes, Legg, Marcos and Arboleya, 1977, GSC loc. 97644, Boya Formation, GSC 69463.
f. *Neonereites* sp., 715 m below top of *Fallotaspis* Zone, Stelkuz Formation, field drawing.
g. *Skolithos* sp. 1, GSC loc. 97641, Stelkuz Formation, GSC 69464.
h. *Teichichnus* sp., GSC loc. 97641, Stelkuz Formation, GSC 69465.
i. *Teichichnus* sp., GSC loc. 97651, Boya Formation, GSC 69466.
j. *Rusophycus* cf. *R. bonnarensis* Crimes, Marcos, Legg and Arboleya, 1977, GSC loc. 97650, Boya Formation, GSC 69467.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on sole of thin bedded, parallel laminated, micaceous, maroon siltstone (GSC loc. 97633) and brown sandstone (GSC loc. 98737).

Remarks. This species was erected by Ksiazkiewicz (1977, p. 157) who recognized a relationship with the less regular *Gordia molassica* Heer, 1865. His material was from the Oligocene of the Carpathian flysch of Poland. Similar material has been seen in the Carboniferous flysch of the Cantabrian Mountains, Spain. On one slab of the material from GSC loc. 97633 described in this report, *Gordia* is intimately associated with *Planolites* of a similar diameter, and the same animal was probably responsible for both traces. Ksiazkiewicz (1977, p. 157) suggested the originator might be a small polychaete but the simplicity of the trace prevents any firm conclusion except that the animal was a Metazoan.

ICHNOGENUS HELMINTHOPSIS Heer, 1877

Type ichnospecies. *Helminthopsis magna* Ulrich, 1904

Helminthopsis sp.
Plate 3, figures c, d

Material and occurrence. Field drawings of material in local float, GSC loc. 97634 and float, GSC loc. 97636.

Description. Irregularly meandering burrows approximately 3 mm in diameter.

Remarks. *Helminthopsis* has previously been found in Lower Cambrian rocks in the White-Inyo mountains, California (Alpert, 1977, p. 5) and in Argentina (Aceñolaza and Durand, 1973). Younger strata containing this trace fossil are typically deep water deposits, but all the Cambrian occurrences are probably from shallow water sediments.

ICHNOGENUS MONOMORPHICHNUS Crimes, 1970

Type ichnospecies. *Monomorphichnus bilinearis* Crimes, 1970

Monomorphichnus lineatus Crimes, Legg,
Marcos and Arboleya, 1977
Plate 3, figure e

Monomorphichnus lineatus Crimes, Legg, Marcos and Arboleya, 1977, p. 103, Pl. 36, fig. 5a

Material and occurrence. Two specimens from GSC locs. 97644 and 97648, both local float.

Description. Sets of straight isolated ridges on sandstone soles. In specimen from GSC loc. 97644 there are at least 5 ridges about 1 cm long and 1 mm wide. Each ridge is deeply impressed (1 mm) and separated by about 2 mm from the next ridge. In specimen from GSC loc. 97648 preservation is poor. There are at least 4 ridges up to 1.5 cm long and separated by about 2 mm, but they are only a fraction of a millimetre deep.

Remarks. *Monomorphichnus* has been reported from the Lower Cambrian of the White-Inyo mountains, California (Alpert, 1977, p. 4) and examples described as "Arthropod scratch marks" occur in the Lower Cambrian Bastion Formation of eastern Greenland (Cowie and Spencer, 1970, Pl. 2a, b). *Monomorphichnus lineatus* was described from the Lower Cambrian of northern Spain (Crimes et al., 1977). Other examples referrable only to *Monomorphichnus* sp. and not meriting separate description occur at GSC locality 97651.

ICHNOGENUS NEONEREITES Seilacher, 1960

Type ichnospecies. *Neonereites biserialis* Seilacher, 1960

Neonereites sp.
Plate 3, figure f

Material and occurrence. Two specimens examined in local float from 715 m below top of *Fallotaspis* Zone.

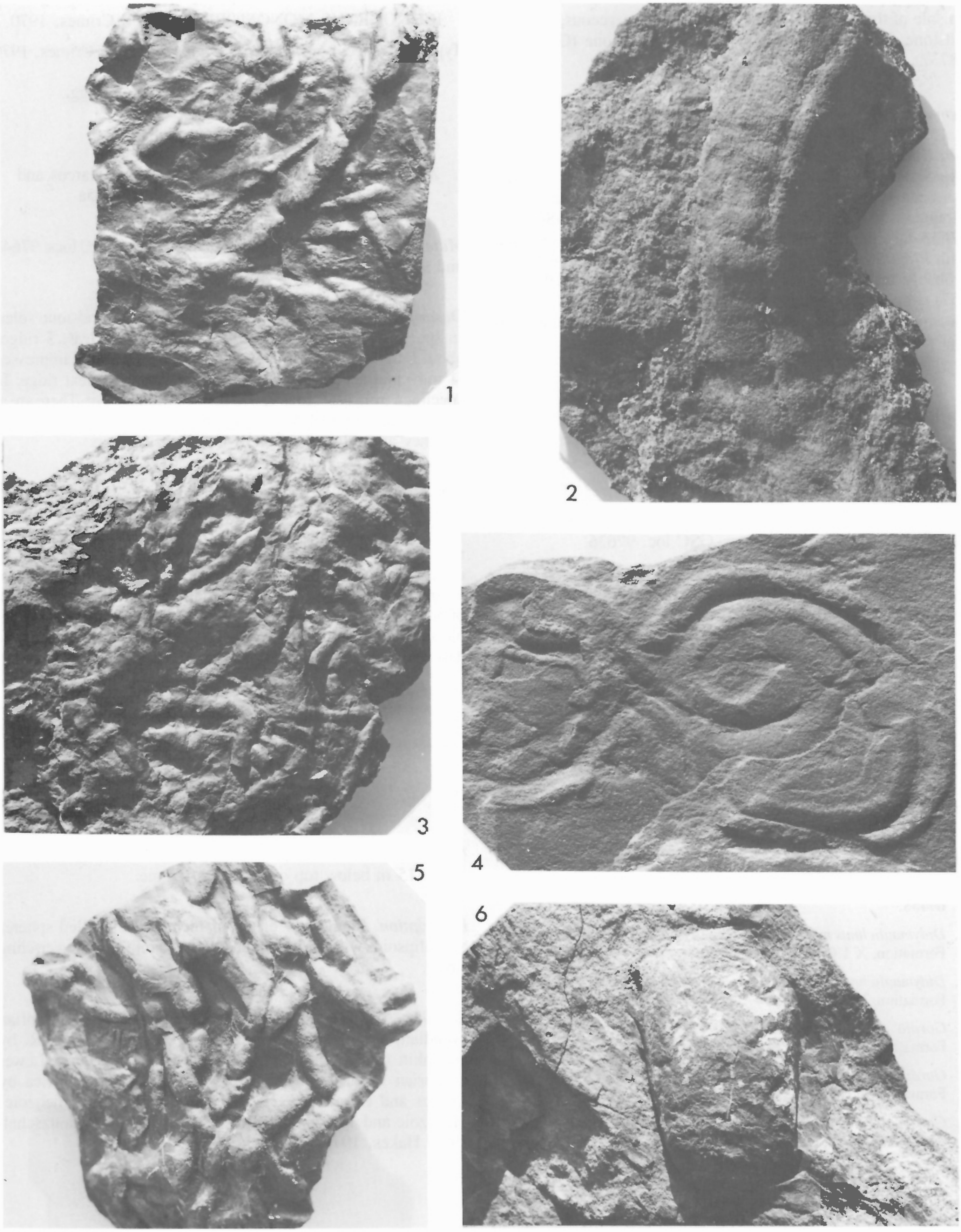
Description. Single row of unornamented, sand filled spheres and ellipsoids with larger dimension 1 to 4 mm, forming circling string.

Remarks. *Neonereites* has been recorded from the Precambrian (Vendian) Valdai Series of the Onega Peninsula, U.S.S.R. by Fedonkin (1977) and from the Upper Precambrian – Lower Cambrian Nama Group of Namibia, southwestern Africa by Crimes and Germs (1982), as well as from many Paleozoic, Mesozoic and Tertiary localities (Seilacher, 1962; Häntzschel, 1975; Hakes, 1976; Crimes, 1977).

PLATE 4

Figures

1. *Arenicolites*? sp., GSC loc. 97647, Boya Formation, X 2.0, GSC 69468.
2. *Didymaulichnus miettensis* Young, 1972, GSC loc. 97639, Stelkuz Formation, X 1.0, GSC 69469.
3. *Didymaulichnus miettensis* Young, 1972, GSC loc. 97640, Stelkuz Formation, X 0.5, GSC 69470.
4. *Gordia arcuata* Ksiazkiewicz, 1977, GSC loc. 97633, Stelkuz Formation, X 1.0, GSC 69471.
5. *Gordia arcuata* Ksiazkiewicz, 1977, GSC loc. 97633, Stelkuz Formation, close-up of Figure 4, X 1.5, GSC 69471.
6. *Gordia arcuata* Ksiazkiewicz, 1977, GSC loc. 97637, Stelkuz Formation, X 0.6, GSC 69472.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ICHNOGENUS PHYCODES Richter, 1850

Type ichnospecies. *Phycodes circinnatum* Richter, 1853

Phycodes pedum Seilacher, 1955
Plate 5, figure 1

Phycodes pedum Seilacher, 1955, p. 386, figs. 4a, b; Glaessner, 1969, p. 383, figs. 6c, d, e; Banks, 1970, p. 28, Pl. 2a; Germs, 1972, p. 869, Pl. 2, figs. 7, 8; Daily, 1972, p. 19; Crimes, Legg, Marcos, and Arboleya, 1977, p. 121-122, Pl. 7a, b; Palij, Posti, and Fedonkin, 1979, p. 73, Pl. 63, fig. 5

Material and occurrence. Three small blocks from local float, GSC loc. 97646. One block contains a well preserved example; the other two have a dense complex of burrows, some of which appear to be part of *P. pedum* systems.

Description. More or less straight burrow system composed of frequent upwardly directed sickle shaped branches on one side. Preserved as sandstone infilled burrows surrounded by black shale on base of sandstone bed.

Best preserved example is almost straight system 4 cm long, 4 mm wide and composed of 5 sickle shaped upwardly directed branches, all pointing in same direction.

Remarks. *Phycodes pedum* was first recorded by Seilacher (1955, p. 386) from the Lower Cambrian *Neobolus* Beds in Pakistan. It has since been found in Lower Cambrian strata in Australia (Glaessner, 1969; Daily, 1972; p. 19); Finnmark (Banks, 1970, p. 28); Spain (Crimes et al., 1977); and South Africa (Germs, 1972, p. 869). *Phycodes* aff. *pedum* has also been recorded in Upper Cambrian strata in Wales (Crimes, 1970a). *Treptichnus* occurs on the same block as *Phycodes pedum*, an association which also occurs in Finnmark (Banks, 1970). It is likely that the same animal made both burrow systems.

PLATE 5

Figures

1. *Phycodes pedum* Seilacher, 1955, GSC loc. 97646, Boya Formation, X 1.5, GSC 69473.
2. *Plagiogmus* sp., GSC loc. 97643, Stelkuz Formation, X 1.0, GSC 69474.
3. *Planolites* sp. 2, GSC loc. 97642, Stelkuz Formation, X 0.5, GSC 69475.
4. *Taphrhelminthopsis circularis* Crimes, Legg, Marcos and Arboleya, 1977, GSC loc. 97636, Stelkuz Formation, X 0.85, GSC 69476.
5. *Treptichnus* sp., GSC loc. 97646, Boya Formation, X 1.25, GSC 69477.
6. *Rusophycus* Form B. Crimes, 1979b, GSC loc. 97651, Boya Formation, X 1.25, GSC 69478.

ICHNOGENUS PLAGIOGMUS Roedel, 1929

Type ichnospecies. *Plagiogmus arcuatus* Roedel, 1929

Plagiogmus sp.
Plate 5, figure 2

Material and occurrence. One poorly preserved specimen, GSC loc. 97643.

Description. *Plagiogmus* occurs in positive relief on the sole of a bed of brown medium- to coarse-grained sandstone. It is curved and varies from 2.5 to 3.0 cm in width along its 11 cm length. It is several millimetres deep, trilobed, and consists of a central almost flat tape approximately 1 cm wide, cut by cross partitions into rectangles 7 × 10 mm. Side wall on convex side of the curve is about 7 mm wide and slopes away steeply to the bedding plane, whereas on the concave side, the wall is 13 mm wide, built up slightly against the tape, and then slopes away more gently. Subdivisions of the central tape seem to affect the side walls although poor preservation prevents this from being seen clearly.

Remarks. This trace fossil closely resembles an example described by Crimes et al. (1977) from the Lower Cambrian of northern Spain. These traces are also similar in size but differ in that the subdivision of the central tape is more closely spaced in the Spanish material, giving a series of more markedly rectangular areas.

The present material may compare more closely with Roedel's (1929) type material than with examples described from Cambrian strata in Australia (Glaessner, 1969), Finnmark (Banks, 1970), Greenland (Cowie and Spencer, 1970) and Wyoming (Cloud and Bever, 1973). The type description is, however, in need of amplification.

ICHNOGENUS PLANOLITES Nicholson, 1873

Type ichnospecies. *Planolites vulgaris* Nicholson and Hinde, 1875

Planolites sp. 1
Not figured

Material and occurrence. Two specimens, local float, GSC loc. 97633. Other specimens examined in the field only, 157 m and approximately 700 m below top of *Fallotaspis* Zone. Unfigured types GSC 69483, 69484.

Description. Unbranched, unsculptured, unornamented, straight or curving infilled burrows mostly 1 mm to 10 mm in diameter. Burrow spacing varies from isolated to dense and crossings are common.

Remarks. These well preserved burrows occur first as 1 mm diameter threads at the lowest trace fossil bearing locality (GSC loc. 97633). Where densely crowded they resemble *Planolites* *reticulatus* as described by Alpert (1975, Pl. 2, fig. 7) from the Upper Precambrian to Lower Cambrian upper Andrews Mountain Member, Campito Formation in the White-Inyo Mountains, California.

Planolites sp. 2
Plate 5, figure 3

Material and occurrence. Two specimens, GSC loc. 97642, and third specimen from local float at GSC loc. 97634. Other material was examined in situ at the latter locality.

Description. Unbranched, unsculptured, unornamented burrows, mostly straight, some crossing and 2 to 5 mm in diameter.

Remarks. These *Planolites* are of greater diameter and more closely spaced than the previously described example.

ICHNOGENUS SKOLITHOS Haldemann, 1840

Type ichnospecies. *Fucoides*? *linearis* Haldemann, 1840

Skolithos sp. 1
Plate 3, figure g

Material and occurrence. Specimen from GSC loc. 97641 with further material examined in field at same locality.

Description. Simple unbranched, unornamented, closely spaced, vertical burrows infilled with pure white quartz sand and set in bed of orange-brown stained impure quartzite. Burrows pass upwards into a pure quartzite of similar composition to that which fills them. Burrows are 2 to 4 mm in diameter and penetrate as much as 6 cm into the impure quartzite.

Remarks. These burrows have probably been passively filled by material from the overlying pure quartzite bed.

Skolithos occurs widely in the Lower Cambrian (e.g. Banks, 1970; Young, 1972; Alpert, 1977; Crimes, 1977; Fedonkin, 1977). It also has been found in the Kuibis Formation of the Nama Group (Germs, 1972) in rocks regarded by Crimes and Germs (in prep.) as probably Late Precambrian (Vendian) in age. As well, it has been found in the Late Precambrian Vendian Valdai Series of the White Sea region (Fedonkin, pers. comm., 1981). Alpert (1977, Fig. 2) assigns a Precambrian age to *Skolithos* recorded in the Kloftelv Formation of eastern Greenland by Cowie and Spencer (1970). This formation is, however, quite probably of Early Cambrian age (Cowie and Spencer, 1970, Fig. 2). Reports of *Skolithos* in earlier, Precambrian rocks have mostly been proven to be inaccurate (see Føyn and Glaessner, 1979, p. 44).

Skolithos sp. 2
Not figured

Material and occurrence. Specimen collected from float, GSC loc. 97637. Unfigured type GSC 69485.

Description. Closely spaced, sand-infilled, vertical burrows preserved as circular outlines on a bedding plane in micaceous sandstone. Most burrow diameters are approximately 2 mm.

Remarks. Similar structures have been described from two Upper Precambrian – Lower Cambrian sequences. The first is in Finnmark where they occur in the Innerelv Member of the Vestertana Group (Banks, 1970, p. 26, Pl. 1a). The second is in Namibia (southwestern Africa), where they occur in the Nasep Formation of the Schwarzrand Subgroup and the Rosenhof Member of the Fish River Subgroup (Crimes and Germs, in prep). Both of these occurrences have burrows of small diameter. Similar burrows have been observed in the Carboniferous Mam Tor Sandstones of Derbyshire, England and at other levels.

ICHNOGENUS TAPHRHELMINTHOPSIS Sacco, 1888

Type ichnospecies. *Taphrhelminthopsis auricularis* Sacco, 1888

Taphrhelminthopsis circularis Crimes, Legg, Marcos and Arboleya, 1977
Plate 5, figure 4

Taphrhelminthopsis circularis Crimes, Legg, Marcos and Arboleya, 1977, p. 125, 126, Pl. 8a, b, c, d, e.

Material and occurrence. Single specimen, float, GSC loc. 97636.

Description. Bilobate trace fossil with well defined central furrow, circling to form a figure 8. Trace varies from 1.0 to 1.5 cm wide and two circles forming figure 8 are approximately 7 cm and 5 cm in diameter. Trace is several millimetres deep and preserved in brown-green micaceous sandstone. There are faint, fine, cross-striations on part of trace.

Remarks. This trace fossil is remarkably similar in form, size and circling habit to the type material of *T. circularis* as described from the Cayetano Beds of the Candana Quartzite of northern Spain by Crimes et al. (1977, p. 125, 126, Pl. 8). The beds containing *T. circularis* lie over 200 m below the earliest body fossils, which are trilobites regarded by Sdzuy (in Crimes et al., *op. cit.*, p. 94) as probably lower Atdabanian.

A specimen found in the Fish River Formation, Nama Group, Namibia by Glaessner (1963) and described by Germs (1972, Pl. 2, fig. 9) as *Helminthoidichnites*? closely resembles *T. circularis*.

Examples of bilobed traces from the Vendian of the U.S.S.R. described by Fedonkin (1980, p. 45, Pl. 2, figs. 3-5) as *Aulichnites* are similar to those described above but show a less deep and prominent groove. Crimes has examined Fenton and Fenton's (1937) type material of *Aulichnites* and considers differences with *Taphrhelminthopsis* based mainly on the median groove as slightly and probably partly or wholly preservational. The figured material of Fedonkin does, however, appear to be adequately designated, pending more detailed work on bilobed traces.

T. circularis differs from *Didymaulichnus miettensis* by its lack of lateral bevels. *Taphrhelminthopsis* differs from *Didymaulichnus* only in having a wider median groove and in having less of a tendency for the burrows to cross and a greater tendency to meander.

ICHNOGENUS TEICHICHNUS Seilacher, 1955

Type ichnospecies. *Teichichnus rectus* Seilacher, 1955

Teichichnus sp.
Plate 3, figures h, i

Material and occurrence. One specimen, GSC loc. 97641, (Fig. 2h); and two specimens, GSC loc. 97651, (Fig. 2i).

Description. Spreite structure appearing as stacked series of flat, straight, U shaped roof gutters retrusively built and forming a wall-like structure. Specimen from locality 97641 is incomplete but part remaining is 3.5 cm long, approximately 1.2 cm wide and 1 cm deep. Other examples are respectively 6 and 8 cm long, 1.8 and 1.5 cm wide and 2.3 and 1.8 cm deep. They occur in white quartzite at GSC loc. 97641, and brown-grey fine sandstone at GSC loc. 97651.

Remarks. Teichichnus has been recorded from the Lower Cambrian of the Salt Range, Pakistan (Seilacher, 1955), the Cantabrian Mountains, Spain (Crimes et al., 1977), the White-Inyo Mountains, California (Alpert, 1977, p. 2) and East Poland (Fedonkin, 1977). It has also been found in younger rocks.

ICHNOGENUS TREPTICHNUS Miller, 1889

Type ichnospecies. *Treptichnus bifurcus* Miller, 1889

Treptichnus sp.
Plate 5, figure 5

Material and occurrence. One good example and several other specimens with a closely spaced, confused set of burrows, some of which are probably part of *Treptichnus* systems. All from local float, GSC loc. 97646.

Description. Straight set of short individual burrows arranged with regular alternations to right and left and thereby giving zig zag feather stitch pattern. Individual burrows are 7 to 15 mm long and 2 to 4 mm in diameter, and they form parts of systems 2.5 to 4 cm long. All examples occur in alternating fine sandstone and black shale with the burrows infilled with sandstone on sandstone sole.

Remarks. Treptichnus ranges from the Lower Cambrian to the Lower Cretaceous (Häntzschel, 1975, p. W117). It has been described as "feather stitch trail" from the probably Lower Cambrian Breivik Member in Finnmark (Banks, 1970, p. 28, Pl. 2b). Cowie and Spencer (1970, p. 94) also record a burrow "resembling a feather stitch trail" from the Lower Cambrian Bastion Formation of eastern Greenland.

ICHNOGENUS RUSOPHYCUS Hall, 1852

Type ichnospecies. *Fucoides biloba* Vanuxem, 1842

Rusophycus cf. *R. bonnarensis* Crimes, Legg, Marcos and Arboleya, 1977
Plate 3, figure j

Cruziana cantabrica Seilacher, 1970
p. 456, fig. 7-1, 7-2
Rusophycus bonnarensis Crimes, Legg, Marcos and Arboleya, 1977, p. 105, Pl. 3, d, e

Material and occurrence. Two examples on single block, local float, GSC loc. 97650; one specimen also examined *in situ* at GSC loc. 97651, block was fragmentary and could not be collected.

Description. Poorly preserved bilobed traces in positive relief on sole of thick bed of medium grained sandstone. Trace consists of pair of deeply excavated lobes showing more or less transversely directed coarse scratches meeting medially. Collected specimens are 4 cm wide and juxtaposed, suggesting they may have been made by same individual. Traces are approximately 2.5 cm deep and 3.5 cm long.

Remarks. R. bonnarensis was described from the Lower Cambrian of northern Spain by Seilacher (1970) and Crimes et al. (1977) where it occurs in thick bedded medium- to coarse-grained sandstone. Daily (1972, p. 27) also describes a form similar to *R. bonnarensis* (=*C. cantabrica*) from the Lower Cambrian Uratanna Formation of the Mount Scott area, Australia. The quality of illustration (*op. cit.*, Pl. 1B) does not, however, allow meaningful comparison.

Rusophycus Form B Crimes, 1970b
Plate 5, figure 6

Material and occurrence. Single specimen, GSC loc. 97651.

Description. Posteriorly tapering bilobate trace in which two lobes have fused along central line. Preserved as positive feature on sole of thin bed of fine grained sandstone. Trace is 4 cm long, 5 mm deep and has maximum width of 2.4 cm.

Remarks. This trace fossil conforms with examples described by Crimes (1970b, p. 114) from the Arenig of Shropshire, England and Wales where it occurs with a wide variety of rusophycids. An example has also been reported from the Tremadoc of Tortworth, England (Crimes, *op. cit.*, p. 114). The present specimen is, however, much smaller than most Arenig examples (e.g. Crimes, *op. cit.*, Pl. 4c).

CORRELATION IN CANADIAN CORDILLERA

Introduction

Strata measured in the Cassiar Mountains are correlated in Figure 4 with other map units in the eastern Canadian Cordillera. These strata lie between two regional carbonate units and are cut by a regional unconformity. The upper regional carbonate unit (Badshot, Mural, Rosella, and Sekwi formations) is replaced laterally by quartzites of the undifferentiated Gog Group in the northern and southern part of the Canadian Rocky Mountains. The lower regional carbonate unit (Byng Formation, "dolomite unit", Cunningham, Espee, and Keel formations) is locally present among the Miette Group clastics in and near the Mount Robson area, and is in part removed by a sub-Gog(?) Group unconformity in the northern Rocky Mountains. Correlation of the upper carbonate unit is reasonably firm, as the formations involved contain trilobites that have proven reliable for this purpose. The lower carbonate unit, however, is below the range of known index fossils, and therefore correlations at this level are far less reliable. Thinner, less widespread carbonate units occur between the regional carbonate units and may be of use for limited correlations. Some of these, such as Unit 2S in the present section, or carbonate units within the lower and middle members of the Backbone Ranges Formation, are within the range of abundant trace fossils.

Cassiar, Omineca, and Cariboo mountains

As a whole, the Hadrynian and Early Cambrian stratigraphic succession in the Cassiar Mountains correlates closely with strata in the Omineca and Cariboo mountains (Mansy and Gabrielse, 1978, Fig. 2), perhaps because the three areas lie along the depositional strike and are on the same side (west) of the Rocky Mountain Trench Fault. Correlation between the lower part of the Rosella Formation (upper Atan Group) and the Mural Formation in the Cariboo Mountains (no description available for Atan Group in the Omineca Mountains) is especially close. Both units have the same carbonate lithology, contain a thick medial shale that includes the boundary between the *Nevadella* Zone and the *Bonnia-Olenllus* Zone, and have their lower contacts close to the top of the *Fallotaspis* Zone.

The underlying Boya Formation (lower Atan Group) in the Cassiar Mountains, and the Midas Formation in the Cariboo Mountains are similar in that they are composed of fine clastics and have an abundance of trace fossils. The Midas contains more shale than the Boya as well as some thin bedded limestone. Figure 4 shows the base of the Atan Group in the Cassiar Mountains to be offset from the base of the Yanks Peak Formation in the Omineca and Cariboo mountains, rather than synchronous as shown by Mansy and Gabrielse (1978, Fig. 2). The offset reflects one concept applied to the quartzite in Stelkuz units 8S through 11S and Boya Unit 1B (Fig. 2) in the present Cassiar section, and another applied to equivalent but cleaner quartzite in the Cariboo Mountains (Campbell et al., 1973). In the Cassiar Mountains the tradition (Gabrielse, oral comm.) has been to draw the base of the Atan Group at the base of a relatively thin but resistant white quartzite that is Unit 1B in the present section, and therefore the base of Unit 1B became the base of the group when it was formally described (Fritz, 1980b, p. 221). The disconformity at the base of Unit 8S and within the underlying Stelkuz Formation was not suspected when the Atan-Stelkuz boundary was formally established, but even if known, the disconformity's lack of physical expression (Pl. 2, fig. 5) precludes its being used as a formational contact in the Cassiar Mountains.

In the Cariboo Mountains, the quartzite equivalent to units 8S though 11S and 1B is more resistant and uniform in composition, and therefore was placed in one map unit, the Yanks Peak Formation. At the principal reference section (Campbell et al., 1973, p. 46, 47), it is comprised of 360 m of white, light grey, and pink quartzite in medium to thick beds. In the Cariboo Mountains, the Yanks Peak Formation is reported (*op. cit.*, p. 46) to be in sharp to gradational contact with the overlying Midas Formation, and to intertongue with the underlying Yankee Belle Formation.

In the eastern Cariboo Mountains, a disconformity is present between the Yanks Peak and the Yankee Belle formations (Young et al., 1973, Table 1; Campbell et al., 1973, Fig. 3), and this disconformity is tentatively correlated with the disconformity at the base of Unit 8S in the Cassiar Mountains. Although the Atan Group has not been described in the Omineca Mountains, the same disconformity is suspected, because the top of the Stelkuz Formation is reported (Mansy and Gabrielse, 1978, p. 9) to be in "sharp contact with the basal sandstone of the overlying Atan Group".

Since only the upper part of the Stelkuz Formation is exposed in the present Cassiar section, the formation cannot be fully compared to the type section in the Omineca Mountains or to the equivalent Yankee Belle Formation in the Cariboo Mountains. In the Omineca Mountains the Stelkuz averages 600 m in thickness (Mansy and Gabrielse, 1978, Fig. 10a), and can be divided into three members that, together with their lithologies, are as follows:

1. Lower member, laterally variable, changing from varicoloured sandstone, siltstone, and limestone in the southwest to quartzite and dolomite in the northeast.

2. Middle member, shale and fine grained sandstone, in places capped by thick limestone unit.

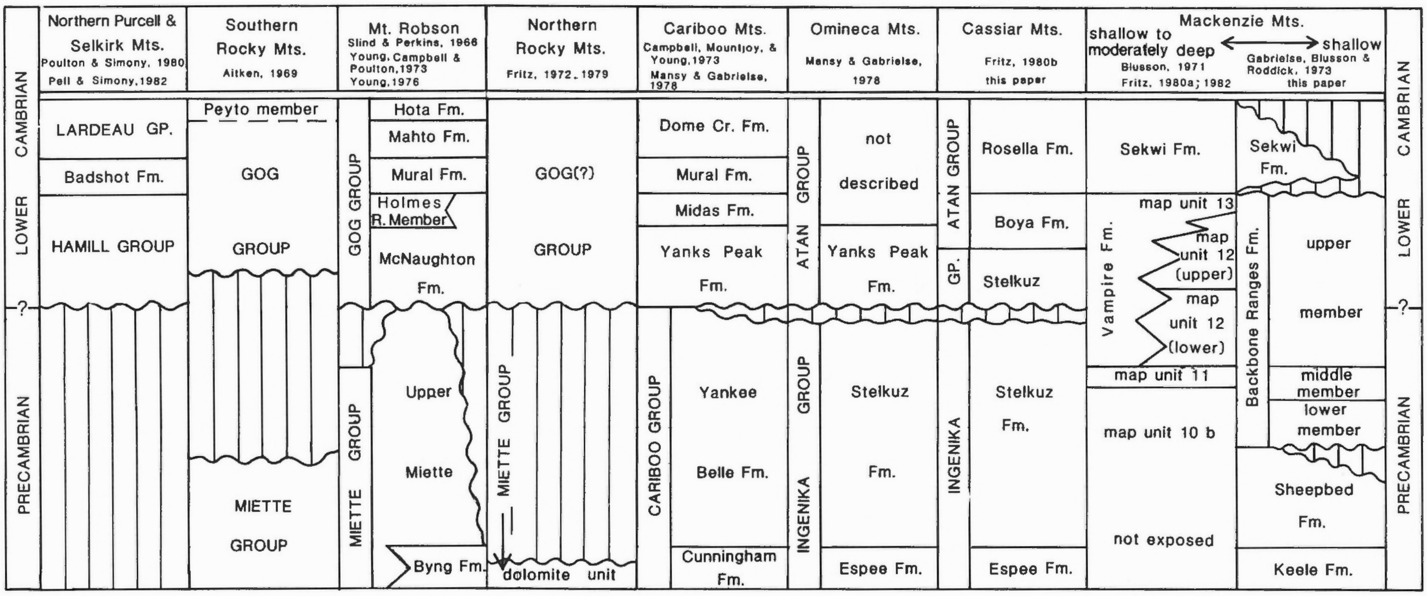

FIGURE 4. Correlation chart showing Upper Precambrian and Lower Cambrian map units in eastern Canadian Cordillera.

3. Upper member, shale and sandstone, the latter increasing upsection (*op. cit.*, p. 9, 16). Units 1S and 2S in the Cassiar section are tentatively correlated with the upper part of the middle member, and units 3S through 7S are tentatively correlated with the upper member. The top of Unit 1S is believed to be the top of the redbeds reported as an "excellent marker" in the Cassiar Mountains (Gabrielse, 1963, p. 22; Mansy and Gabrielse, 1978, p. 13).

In the Cariboo Mountains the Yankee Belle Formation (equivalent to lower and middle Stelkuz Formation) is between 395 to 910 m thick, and comprises alternating beds of shale, siltstone, fine grained quartzite, and limestone (Campbell et al., 1973, p. 38). The contact between the Yankee Belle and the underlying carbonates of the Cunningham Formation is locally disconformable in the eastern part of the mountains (*op. cit.*, Fig. 3). In the Omineca Mountains the contact between the equivalent Stelkuz and underlying Espee formations is gradational to locally abrupt (Mansy and Gabrielse, 1978, p. 9).

Young (1972) and Campbell et al. (1973) report *Planolites*(?), *Scolicia*(?), and an unnamed radiating burrow in the Midas Formation; *Chondrites*(?) and *Didymaulichnus*(?) in the Yanks Peak Formation; "rare organic traces" in the Yankee Belle Formation; and "worm" trails on a single bedding surface in the Isaac Formation which immediately underlies the Cunningham Formation.

Northern Purcell and Selkirk mountains

Southeast of the Cariboo Mountains, in the northern Purcell and Selkirk mountains, Hadrynian and Lower Cambrian strata have been subjected to a higher degree of tectonic and thermal alteration, but map units have nevertheless been traced with reasonable success (Poulton and Simony, 1980, Fig. 19). Here Lower Cambrian quartzites of the Hamill Group rest unconformably on the Hadrynian Horsethief Creek Group. Immediately below the unconformity is an "upper clastic" map unit which is in turn underlain by a "carbonate" map unit. The Hamill, "upper clastic", and "carbonate" map units were correlated by Young et al. (1973) with the Yanks Peak, Yankee Belle, and Cunningham formations, respectively, in the Cariboo Mountains. Poulton and Simony (1980, p. 1709) warned against placing too much confidence in this correlation, and it was later rejected by Pell and Simony (1982) who postulated a major unconformity below the Hamill in the Selkirk and northern Purcell mountains. They conclude that in that area, strata equivalent to the Yankee Belle, the Cunningham, and the underlying Isaac Formation are missing.

Northern Rocky Mountains

In the Northern Rocky Mountains and across the Rocky Mountain Trench Fault from the Cassiar Mountains, the Early Cambrian quartzites of the Gog(?) Group unconformably overlie a relatively thin Hadrynian succession consisting of diamictite (base), black shale (middle), and dolomite (top) that in turn unconformably overlies Helikian strata (Fritz, 1979a, Fig. 13.2). It has been suggested (Fritz, 1972, p. 211; Eisbacher, 1981, p. 38) that the diamictite in the Hadrynian succession may be a tillite (*sensu lato*). No trace fossils have been found in the Hadrynian strata, and this, together with their lithologies, suggests that they are older than the late Hadrynian strata in the Cassiar section. Lower Cambrian trilobites in the Gog(?) Group, plus abundant but unstudied Gog(?) trace fossils below the trilobite horizons, are the evidence used to correlate this group with the Atan Group.

Mount Robson Area

Farther south, in the Mount Robson area and nearby, the quartzites of the Lower Cambrian Gog Group unconformably overlie the Hadrynian Miette Group. Within the Gog is the Mural Formation that, as mentioned earlier, closely correlates with the lower part of the Rosella Formation in the Cassiar Mountains. The underlying and lowest formation in the group is the predominantly quartzitic McNaughton Formation. The McNaughton is reported (Campbell et al., 1973, p. 10, Fig. 3), to be between 260 to 2286 m thick and to in part bevel and in part (within Mount Robson Syncline) grade into the Miette Group. Within the upper McNaughton is a western facies of interbedded black shale and very fine grained sandstone that has been assigned to the Holmes River Member (*op. cit.*, p. 14). Burrows, some of which are assigned to *Planolites*, are common in the Holmes River (Young, 1972, p. 7; Campbell et al., 1973, p. 14), and in the laterally equivalent McNaughton Quartzite *Cruziana, Diplichnites, Rusophycus,* and *Skolithos* are present (Young, 1972, p. 5). In the correlation between the Mount Robson area and the Cassiar Mountains, the Holmes River is equated to the Boya Formation with the exception of Unit 1B, and the underlying part of the McNaughton Formation is correlated with Stelkuz units 8S and 11S plus Unit 1B.

Below the McNaughton Formation, the upper part of the Miette Group comprises a monotonous succession of green and grey shales, siltstones, interbedded sandstones, and some beds of conglomerate. Within this succession is the Byng Formation (Slind and Perkins, 1966), composed of dolomite attaining a thickness of 305 m. Because the Byng is not laterally persistent, it is of limited assistance in assessing the magnitude of the pre-McNaughton unconformity. The Byng can be traced, however, from Yellowhead Pass, where the McNaughton directly overlies the Byng Formation (Wheeler et al., 1972, p. 78), and into the Mount Robson map area, where Miette clastics intervene between the two formations (Mountjoy, 1980). Within the map area and farther northwest the Byng disappears by pinching out or by erosion, but it probably reappears beyond the map area and still farther northwest (near Cambrian Heights), as a thick dolomite overlain by an estimated 762 m of Miette clastics (Slind and Perkins, 1966, Fig. 2).

Near the Mount Robson map area, Young (1972, Fig. 2, p. 7) has reported *Didymaulichnus miettensis* from just below the top of the Miette Group and from approximately 320 m below the top. These occurrences are from young Miette that may have been removed from the northeast limb of the Robson Syncline where the Byng lies close to base of the McNaughton Formation.

The authors concur with Young et al. (1973, Table 1), in correlating the Byng and post-Byng Miette in the Mount Robson area with the Cunningham and Yankee Belle formations, respectively, in the Cariboo Mountains. As mentioned earlier, the Cunningham and Yankee Belle formations are correlated with the Espee and Stelkuz formations, respectively, in the Omineca and Cassiar mountains (excluding units 8S to 11S).

Southern Canadian Rocky Mountains

Hadrynian and Early Cambrian strata in the Rocky Mountains between the Mount Robson area and Mount Assiniboine 350 km to the southeast have been reviewed by Aitken (1969) in order to assess the unconformity between the Miette and Gog groups. In this region the Gog is mainly barren except for the Peyto Member at the top. A tongue of the Mural Formation extending 45 km southeast of the Mount Robson area suggests that the top of the *Fallotaspis* Zone there (Mount Kerkeslin) should be high in the Gog. In the southeastern part of the region, Rasetti (1951, p. 3) has reported olenellid trilobites at several horizons in the upper formation (St. Piran) in the Gog. Walcott (1910, Pl. 38, figs. 17-20, p. 301) has described trilobites belonging to the *Nevadella* Zone from "about" 610 m below the top of the Gog, and Young (1972, p. 5) reports Cambrian trace fossils "about halfway through" the Gog. In this paper, the Gog Group is correlated with the Atan Group and uppermost Stelkuz Formation in the Cassiar Mountains.

The underlying Miette Group is comprised of grey, green, purple and maroon slates and some interbedded sandstones and conglomerates. A regional marker unit of bright green and purple slates (Unit 1B) within the Miette has been used (Aitken, 1969, Fig. 3) to demonstrate an excess of 457 m of pre-Gog erosion in the northwestern part of the area and more than that amount in the southeastern part (*op. cit.*, p. 198). No shelly or trace fossils have been reported from the Miette in this area of the Rocky Mountains, and the youngest Miette is believed to be older than the oldest Stelkuz measured in the Cassiar Mountains.

Mackenzie Mountains

In the Mackenzie Mountains, Upper Precambrian and Lower Cambrian strata belong to two facies. To the northeast is a shallow water facies comprising mostly sandstone and some dolomite that have been assigned (Gabrielse et al., 1973) to the Backbone Ranges Formation (Fig. 1, locality 12). This formation is locally overlain (Fritz, 1981, p. 152) by the Lower Cambrian Sekwi Formation and elsewhere unconformably overlain by younger strata. The second facies lies to the southwest and was deposited in shallow to moderate depths. Like the first facies, it mainly comprises clastics, but they are finer and darker than in the first facies. These latter strata have been assigned to map units 10 through 13 (Blusson, 1971) and to the Sekwi Formation (Handfield, 1968). Within this facies, the basinward equivalent of map units 12 and 13 have been placed in the Vampire Formation (Fritz, 1982).

Fossils are generally lacking in the Backbone Ranges Formation, but *Planolites* sp. has been reported from the lower member of this formation (Fritz, 1982). Strata in the second facies are more productive, and the following taxa have been reported (Fritz, 1979b, 1980a; Hofmann, 1981) from sections 33 and 37 (see Fig. 1): Sekwi Formation, Lower Cambrian trilobites with top of *Fallotaspis* Zone just above the base of Sekwi Formation; Map unit 13, *Bergaueria* sp., *Scolicia* sp., *Rusophycus* sp., *Teichichnus* sp., with *Chancorella* sp. and *Volborthella*(?) sp. near the top; Map unit 12, upper part, *Didymaulichnus* sp., *Neonereites* sp., *Phycodes pedum, Planolites* sp., *Treptichnus* sp.; Map unit 12, lower part, *Didymaulichnus* sp., *Gyrolites polonicus, Phycodes* sp., *Treptichnus* sp.; Map unit 10b, *Gordia* sp., *Inkrylovia* sp. *Sekwia excentrica* Hofmann, *Torrowangea* sp. On the basis of trace fossils, the Precambrian-Cambrian boundary has been tentatively placed in the interval 350 to 370 above the base of the Map unit 12 (Fritz, 1980a).

An intra-Mackenzie correlation by Fritz (1982) appears in Figure 4. In this correlation the tentative horizon of the Precambrian-Cambrian boundary in Map unit 12 is correlated with a horizon low in the Vampire Formation and a low in the upper member of the Backbone Ranges Formation. The above correlations indicate that in the Mackenzie Mountains, the optimum strata for studying the boundary should be in the Vampire Formation, as it lies basinward of the coarser grained Backbone Ranges Formation and of Map unit 12, and landward of deeper water shales in which traces are likely to be sparse.

In Figure 4 the following Mackenzie-Cassiar correlations are shown: the Sekwi Formation is directly correlated with the Rosella Formation; the upper member of the Backbone Ranges Formation and the locally equivalent Vampire Formation is equated with the Boya Formation plus the Stelkuz Formation above Unit 2; the middle member of the Backbone Ranges Formation is tentatively correlated with stratigraphic Unit 2S in the Stelkuz Formation; Unit 10 and the Sheepbed Formation is correlated with the remaining (lower) part of the Stelkuz Formation; and the Keele Formation is correlated with the Espee Formation[1].

INTERNATIONAL CORRELATION

Norway

The succession in Finnmark described by Banks (1970) shows the occurrence of a varied ichnofauna below the lowest trilobite (*Holmia*). The most diverse and abundant ichnofaunas occur in the highest unit described, the Duolbasgaissa Formation, which yielded the trilobite traces *Cruziana, Rusophycus, Diplichnites* and *Dimorphichnus* as well as *Diplocraterion, Plagiogmus, Skolithos, Syringomorpha* and *Rhizocorallium*. The underlying Breivik Formation has *Phycodes palmatum* and *Teichichnus* in its Upper Member, whereas the Lower Member has *Phycodes pedum, Treptichnus, Cochlichnus, Planolites* and *Rusophycus*. The lowest level in which *Rusophycus* occurs is some 70 m above *Phycodes*.

According to Føyn and Glaessner (1979) the occurrence of *Platysolenites* 150 m above the base of the Breivik Formation suggests that the entire formation is Tommotian and that the underlying Manndraperelv Member is transitional between Precambrian and Cambrian. The Manndraperelv Member is underlain by the Innerelv Member which contains only simple vertical burrows and, according to Vidal (pers. comm., 1978), has undoubted Vendian microfossils. The Manndraperelv Member has yielded traces described by Banks (1970, p. 28) as vertical U tubes and designated as ?*Diplocraterion*. From the description they could equally well be *Arenicolites* but neither has yet been recorded below the Tommotian. The Vendian-Tommotian boundary might therefore be at or about the Innerelv-Manndraperelv contact.

East Greenland

In eastern Greenland, Cowie and Spencer (1970) also record a variety of trace fossils below the lowest olenellid trilobites. The trilobites occur in the Upper Bastion Formation while the Lower Bastion Formation, 50-55 m thick, contains *Scolicia, Skolithos, Planolites, Phycodes, Monomorphichnus* ('arthropod scratch marks') and *Treptichnus*. The top of the underlying Kloftelv Formation has *Skolithos* but no further diagnostic trace fossils are recorded in a section extending down to the late Precambrian tillites.

Northern Spain

In northern Spain (Crimes et al., 1977, p. 93) there is a 1600 m thick coastal section below the lowest Cambrian trilobites, which are probably of (?Lower) Atdabanian age. Trilobite traces (*Rusophycus* and *Monomorphichnus*) extend 700 m below the trilobites whereas *Arenicolites, Diplocraterion, Skolithos* and *Planolites* extend more than 1200 m down, in rocks presumably of Tommotian age. The lowest *Rusophycus* (*R. bonnarensis*) is comparable with that from the Cassiar Mountains.

California

Similarly, in the White-Inyo Mountains (Alpert, 1977) trilobite traces (*Rusophycus, Diplichnites, Monomorphichnus*) and other traces (e.g. *Skolithos, Scolicia, Monocraterion*) extend about 500 m below the lowest trilobite (*Fallotaspis*).

Eastern Poland

Fedonkin (1977) reported the following trace fossils from the Tommotian strata of eastern Poland: *Rusophycus, Teichichnus, Treptichnus, Skolithos, Diplocraterion* (=*Bifungites*), ?Gyrolithes, ?*Rhizocorallium* and ?*Curvolithus*. He found the following traces in Vendian strata: *Intrites, Planolites, Aulichnites, Neonereites, Vimerites, Paleopascichnus, Suzmites, Planolites* and *Nenoxites* (Fedonkin, 1977, 1980).

Namibia

Crimes and Germs (1982) have described trace fossils from the Precambrian/Cambrian Nama Group in Namibia. They found *Skolithos* and *Phycodes* cf. *P. pedum*, in the highest unit, the Fish River Subgroup. The top of the underlying Schwarzrand Subgroup has *Diplichnites, Neonereites biserialis, N. uniserialis* and *Phycodes pedum*, while *Diplocraterion, Nereites, Skolithos* and *Brooksella* occur lower down. The lowest unit, the Kuibis Subgroup, has *Bergaueria* sp. in its top few metres.

The occurrence of *Phycodes pedum* and *Diplichnites* sp. at the top of the Schwarzrand Subgroup indicates a Tommotian age for the upper part of the sequence. However, *Skolithos, Brooksella, Diplocraterion* and *Nereites* also occur in the lower half of the Schwarzrand Subgroup. These may also suggest a Tommotian age, although the very small size of most of these specimens recalls similarly small Vendian specimens described from Poland and the U.S.S.R. by Fedonkin (1977, 1980). In this context

[1]Recent work in and near the Mackenzie Mountains suggests an older age for the Sheepbed and Keele formations than is indicated here and in Figure 4.

it is interesting to note that the *Bergaueria* recorded from the top of the underlying Kuibis Subgroup, which has also yielded an ediacaran fauna, is similar to *Intrites punctatus*, a new genus and species described by Fedonkin (1980) from Upper Vendian rocks of the U.S.S.R., where it is also accompanied by an ediacaran fauna. It may be that the *Bergaueria* from the Nama Group and *Intrites* are synonymous.

Australia

Discussion concerning the upper Precambrian/Lower Cambrian trace fossils from Australia is hampered by an absence of published measured sections.

Glaessner (1969) described several ichnogenera from the Late Precambrian (Vendian) Pound Quartzite. Some are simple sediment infilled tubes which are probably referrable to *Planolites* (e.g. Glaessner, 1969, figs. 5E, F). There is also a trace fossil referred to *Cylindrichnus*, an invalid name for which Bandel (1973) substituted *Margaritichnus*. It appears, however, to have much in common with *Neonereites uniserialis*. There are also meandering trails (*op. cit.*, figs. 5C, D) which show a much closer thigmotactic pattern than is revealed by any other Vendian trace fossil yet described. Strata higher in the sequences, and referred by Glaessner to the Lower Cambrian, yield *Cruziana, Rusophycus, Diplichnites, Phycodes pedum, Plagiogmus* and *Didymaulichnus* [described as 'Molluscan trails' (*op. cit.*, figs. 9B, C)]

Daily (1972, 1973) has also drawn attention to the widespread occurrence of trace fossils such as *Diplocraterion, Phycodes pedum, Diplichnites, Plagiogmus* and *Rusophycus* in the lowest Cambrian strata below shelly faunas in south and central Australia.

CONCLUDING REMARKS

Dark weathering siltstone and quartzite of Late Precambrian and Early Cambrian age in the Cassiar Mountains are interrupted by three intervals containing light coloured quartzite or sandstone. The base of the lowest interval is a disconformity located 592 m below the top of the *Fallotaspis* Zone. Based upon physical and faunal evidence, the Precambrian-Cambrian boundary is tentatively placed at this disconformity. The base of the second interval is 402 m below the top of the *Fallotaspis* Zone and marks the contact between the Stelkuz and Boya formations. Although this contact is sharp, no evidence of erosion was seen. The base of the third interval is 1.5 m below the top of the *Fallotaspis* Zone and may be (Fritz, 1980b) a surface of shallow erosion.

Although widespread erosion of boundary strata has long been suspected in the Canadian Cordillera, it is nevertheless discouraging to note that erosion extends as far west as the Cassiar Mountains. The implication is that despite the vast size of the Canadian Cordillera, there are few areas of continuous deposition in which to test the evolution of trace fossils (or other fossils for that matter) across the boundary. The Rocky Mountain area near Mount Robson, and the Cariboo Mountains might contain adequate boundary sections, as has previously been suggested by P. Cloud (1973). However, known erosional surfaces or unfavorable strata within these areas restrict the sites for a boundary study. Stratigraphic work by F.G. Young (1976) has resulted in the location of several sections (*op. cit.*, secs. 6, 7, 9, 14, 16) that merit investigation.

An optimum area for boundary studies may be the Mackenzie Mountains in the basinward equivalent of the upper member of the Backbone Ranges Formation. The interval to be tested lies within the Vampire Formation located above a tongue of the middle member of the Backbone Ranges Formation (Map unit 11) and below the Sekwi Formation. Even in this succession there may be erosional gaps.

Twelve genera of trace fossils were noted above the Precambrian-Cambrian boundary and eight were noted below. No pronounced peak in the number of individuals or taxa was seen across the boundary except for the expected increase in individual abundance in the first favorable beds above the disconformity at the 592 m level. Since this pattern is repeated above unconformities throughout the Phanerozoic, no special significance is attributed to it here.

Range data from the Cassiar section and elsewhere suggest a gradual introduction of ichnogenera during Late Precambrian and Early Cambrian time. The isolated occurrence of *Chondrites* low in the Cassiar succession demonstrates an early trace fossil with a complex feeding pattern that is not closely followed by other genera with similar habits.

The present tentative placement of the Precambrian-Cambrian boundary in the Cassiar Mountains may be subject to change as more range data on ichnogenera are collected from the Canadian Cordillera and elsewhere. Finally, a second adjustment from even the most attractive trace fossil level may be necessary, as this level may not coincide with the boundary level soon to be formalized by the Commission on Stratigraphy.

REFERENCES

Aceñolaza, F.G. and Durand, F.
1973: Trazas fosiles de basamento cristalino del noroeste Argentino; Boletín de la Asociación Geológica de Córdoba, v. 2, no. 1-2, p. 45-55.

Aitken, J.D.
1969: Documentation of the sub-Cambrian unconformity, Rocky Mountains, Main Ranges Alberta; Canadian Journal of Earth Sciences, v. 6, no. 2, p. 193-200.

in press: Uppermost Proterozoic formations in central Mackenzie Mountains, Northwest Territories; Geological Survey of Canada, Paper 83-83.

Alpert, S.P.
1975: *Planolites* and *Skolithos* from the Upper Precambrian-Lower Cambrian, White-Inyo Mountains, California; Journal of Paleontology, v. 49, p. 508-521.

1977: Trace fossils and the basal Cambrian boundary; in Trace Fossils 2, T.P. Crimes and J.C. Harper, eds.; Geological Journal, Special Issue no. 9, Seel House Press, Liverpool, p. 1-8.

Bandel, K.
1973: A new name for the ichnogenus *Cylindrichnus Bandel*, 1967; Journal of Paleontology, v. 47, p. 1002.

Banks, N.L.
1970: Trace fossils from the late Precambrian and Lower Cambrian of Finnmark, Norway; in Trace Fossils, T.P. Crimes and J.C. Harper, eds.; Geological Journal, Special Issue no. 3, Seel House Press, Liverpool, p. 19-34.

Bergström, J.
1970: *Rusophycus* as an indication of early Cambrian age; in Trace Fossils, T.P. Crimes and J.C. Harper, eds.; Geological Journal, Special Issue no. 3, Seel House Press, Liverpool, p. 35-42.

Blusson, S.L.
1971: Sekwi Mountain map area, Yukon Territory and District of Mackenzie; Geological Survey of Canada, Paper 71-22; 17 p.

Brasier, M.D., Hewitt, R.A., and Brasier, C.J.
1978: On the Late Precambrian-Early Cambrian Hartshill Formation of Warwickshire; Geological Magazine, v. 115, no. 1, p. 21-36.

Brasier, M.D.and Hewitt, R.A.
1979: Environmental setting of fossiliferous rocks from the uppermost Proterozoic-Lower Cambrian of central England; Palaeogeography, Palaeoclimatology, Palaeoecology, v. 27, p. 35-57.

Campbell, R.B., Mountjoy, E.W. and Young, F.G.
1973: Geology of McBride map-area, British Columbia; Geological Survey of Canada, Paper 72-35, 104 p.

Cloud, P.
1973: Possible stratotype sequences for the basal Paleozoic in North America; American Journal of Science, v. 273, p. 193-206.

Cloud, P. and Bever, J.E.
1973: Trace fossils from the Flathead Sandstone, Fremont County, Wyoming, compared with Early Cambrian forms from California and Australia; Journal of Paleontology, v. 47, p. 883-885.

Cowie, J.W. and Spencer, A.M.
1970: Trace fossils from the late Precambrian/Lower Cambrian of East Greenland; in Trace Fossils, T.P. Crimes and J.C. Harper, eds.; Geological Journal, Special Issue no. 3, Seel House Press, Liverpool, p. 91-100.

Crimes, T.P.
1970a: Trilobite tracks and other trace fossils from the Upper Cambrian of North Wales; Geological Journal, v. 7, p. 47-68.

1970b: The significance of trace fossils in sedimentology, stratigraphy and palaeoecology with examples from Lower Palaeozoic strata; in Trace Fossils, T.P. Crimes and J.C. Harper, eds.; Geological Journal, Special Issue 3, Seel House Press, Liverpool, p. 101-126.

Crimes, T.P.
1977: Trace fossils of an Eocene deep-sea sand fan, northern Spain; in Trace Fossils 2, T.P. Crimes and J.C. Harper, eds.; Geological Journal, Special Issue, no. 9, Seel House Press, Liverpool, p. 71-90.

Crimes, T.P., Legg, I., Marcos, A., and Arboleya, M.
1977: ?Late Precambrian-low Lower Cambrian trace fossils from Spain; in Trace Fossils 2, T.P. Crimes and J.C. Harper, eds.; Geological Journal, Special Issue no. 9, Seel House Press, Liverpool, p. 91-138.

Crimes, T.P. and Germs, G.J.B.
1982: Trace fossils from the Nama Group (Precambrian-Cambrian) of South-West Africa; Journal of Paleontology, v. 56, p. 890-907.

Daily, B.
1972: The base of the Cambrian and the first Cambrian faunas; in Stratigraphic problems of the Late Precambrian and Early Cambrian; J.B. Jones and B. McGowran, eds.; University of Adelaide, Special Paper 1, p. 13-37.

1973: Discovery and significance of basal Cambrian Uratanna Formation, Mt. Scott Range, Flinders Range, South Australia; Search, v. 4, no. 6, p. 202-205.

Eisbacher, G.H.
1981: Sedimentary tectonics and glacial record in the Windermere Supergroup, Mackenzie Mountains, northwestern Canada; Geological Survey of Canada, Paper 80-27, 40 p.

Fedonkin, M.A.
1977: Precambrian-Cambrian ichnocoenoses of the east European platform; in Trace Fossils 2, T.P. Crimes and J.C. Harper, eds.; Geological Journal, Special Issue no. 9, Seel House Press, Liverpool, p. 183-194.

1980: Fossil traces of Precambrian Metazoa (in Russian); Izvestija Akademii nauk SSSR, Geology Series, no. 1, p. 39-46.

Fenton, C.L. and Fenton, M.A.
1937: Burrows and trails from Pennsylvanian rocks of Texas; American Midland Naturalist, v. 18, no. 6, p. 1079-1984.

Føyn, S. and Glaessner, M.F.
1979: *Platysolenites*, other animal fossils, and the Precambrian-Cambrian transition in Norway; Norske Geologisk Tidsskrift, v. 59, p. 25-46.

Fritz, W.H.
1972: Cambrian biostratigraphy, western Rocky Mountains, British Columbia (83E, 94C, 94F); in Report of Activities, Part A, Geological Survey of Canada, Paper 72-1, p. 209-211.

1979a: Cambrian stratigraphy in the Northern Rocky Mountains, British Columbia; in Current Research, Part B, Geological Survey of Canada, Paper 79-1B, p. 99-109.

1979b: Eleven stratigraphic sections from the Lower Cambrian of the Mackenzie Mountains, northwestern Canada; Geological Survey of Canada, Paper 78-23.

1980a: International Precambrian-Cambrian Boundary Working Group's 1979 field study to Mackenzie Mountains, Northwest Territories, Canada; in Current Research, Part A, Geological Survey of Canada, Paper 80-1A, p. 41-45.

1980b: Two new formations in the Lower Cambrian Atan Group, Cassiar Mountains, north-central British Columbia; in Current Research, Part B, Geological Survey of Canada, Paper 80-1B, p. 217-225.

1981: Two Cambrian stratigraphic sections, eastern Nahanni map area, Mackenzie Mountains, District of Mackenzie; in Current Research, Part A, Geological Survey of Canada, Paper 81-1A, p. 145-156.

1982: Vampire Formation, a new Upper Precambrian(?)/Lower Cambrian formation, Mackenzie Mountains, Yukon and N.W.T.; in Current Research, Part B, Geological Survey of Canada, Paper 82-1B, p. 83-92.

Gabrielse, H.
1962b: Geology, Kechika, British Columbia; Geological Survey of Canada map 42-1962.

Gabrielse, H.
1963: McDame map-area, Cassiar District, British Columbia; Geological Survey of Canada, Memoir 319, 138 p.

Gabrielse, H., Blusson, S.L., and Roddick, J.A.
1973: Geology of Flat River, Glacier Lake, and Wrigley Lake map areas, District of Mackenzie and Yukon Territory; Geological Survey of Canada, Memoir 366.

Garcia-Ramos, J.C.M.
1976: Morfologia de trazas fosiles en dos afloramientos de "Arenisca de Naracos" (Devonico medio) de Asturias (N.W. de Espana); Trabajos de Geologia, no. 8, p. 131-171.

Germs, Gerard J.B.
1972: Trace fossils from the Nama Group, southwest Africa; Journal of Paleontology, v. 46, p. 864-870.

Glaessner, M.F.
1963: Major trends in the evolution of the Foraminifera; in Evolutionary trends in Foraminifera, G.H.R. von Koenigswald, et al., eds.; Elsevier, Amsterdam, p. 9-24.

1969: Trace fossils from the Precambrian and basal Cambrian; Lethaia, v. 2, p. 369-393.

Hakes, W.G.
1976: Trace fossils and depositional environment of four clastic units, Upper Pennsylvanian megacyclothems, northeast Kansas; University of Kansas Paleontological Contributions, Article 63.

Handfield, R.C.
1968: Sekwi Formation, a new Lower Cambrian formation in the southern Mackenzie Mountains, District of Mackenzie (95L, 105I, 105P); Geological Survey of Canada, Paper 68-47, 23 p.

Häntzschel, W.
1975: Trace fossils and problematica; in Treatise on Invertebrate Paleontology, Part W, Miscellaneous, Supplement 1; Geological Society of America and University of Kansas Press, 269 p.

Heer, O.
1965: Die Urewelt der Schweiz; F. Schulthess, Zurich, 622 p.

Ksiazkiewicz, M.
1977: Trace fossils in the flysch of the Polish Carpathians; Palaeontologia Polonica, n. 36, 208 p.

Mansy, J.L. and Gabrielse, H.
1978: Stratigraphy, terminology and correlation of upper Proterozoic rocks in Omineca and Cassiar mountains, north-central British Columbia; Geological Survey of Canada, Paper 77-19, 17 p.

Mountjoy, E.W.
1980: Geology of Mount Robson, west sixth meridian, Alberta-British Columbia; Geological Survey of Canada, map 1499A.

Paliy, V.M.
1974: Double traces (bilobites) in the deposits of the Baltic Series in the Dniester area (in Ukranian); Reports, Academy of Science of the Ukranian Socialist Republic, Series B, no. 6, p. 499-503.

Paliy, V.M., Posti, E., and Fedonkin, M.A.
1979: Soft-bodied Metazoa and trace fossils of the Vendian and Lower Cambrian; in Upper Precambrian and Cambrian paleontology of East- European Platform, B.M. Keller and A. Yu Rozanov, eds.; USSR Academy of Sciences, p. 49-82.

Pell, J. and Simony, P.S.
1982: Hadrynian Horsethief Creek Group/Kaza Group correlations in the southern Cariboo Mountains, British Columbia; in Current Research, Part A, Geological Survey of Canada, Paper 82-A, p. 305-308.

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, v. 17, p. 36-58.

Poulton, T.P. and Simony, P.S.
1980: Stratigraphy, sedimentology, and regional correlation of the Horsethief Creek Group (Hadrynian, Late Precambrian) in the northern Purcell and Selkirk Mountains, British Columbia; Canadian Journal of Earth Sciences, v. 17, no. 12, p. 1708-1724.

Rasetti, F.
1951: Middle Cambrian stratigraphy and faunas of the Canadian Rocky Mountains; Smithsonian Miscellaneous Collections, v. 116, no. 5, 270 p.

Roedel, H.
1929: Ergänzung zu meiner Mitteilung über ein kambrisches Geschiebe mit problematischen Spuren; Zeitschrift für Geschiebe forschung, v. 5, p. 48-52.

Seilacher, A.
1955: Spuren and Fazies im Unterkambrium; in Beiträge zur Kenntnis des Kambriums in der Salt Range (Pakistan), by O.H. Schindewolf and A. Seilacher; Akademie der Wissenschaften und der Literatur, Abhandlungen de Mathematisch-Naturwissenschaftlichen Klasse, Jahrgang 1955, no. 10, p. 373-399.

1962: Form and Funktion des Trilobiten-Daktylus; Paläontologishen Zeitschrift (H. Schmidt Festband) p. 218-227.

1970: *Cruziana* stratigraphy of "non-fossiliferous" Palaeozoic sandstones; in Trace Fossils, T.P. Crimes and J.C. Harper, eds.; Geological Journal, Special Issue 3, Seel House Press, Liverpool, p. 447-476.

Slind, O.L. and Perkins, G.D.
1966: Lower Paleozoic and Proterozoic sediments of the Rocky Mountains between Jasper, Alberta and Pine River, British Columbia; Bulletin of Canadian Petroleum Geology, v. 14, no. 4, p. 442-468.

Walcott, C.D.
1910: *Olenellus* and other genera of the Mesonacidae; Smithsonian Miscellaneous Collections, v. 53, no. 6, 422 p.

Wheeler, J.O., Campbell, R.B., and Reesor, J.E.
1972: Structural style of the southern Canadian Cordillera; 24th International Geological Congress Field Excursion XO1-AO1, John D. McAra Ltd., Calgary, 118 p.

Young, F.G.
1972: Early Cambrian and older trace fossils from the southern Cordillera of Canada; Canadian Journal of Earth Sciences, v. 9, no. 1, p. 1-17.

Young, F.G.
1976: The Lowermost Paleozoic McNaughton Formation and equivalent Cariboo Group of eastern British Columbia; piedmont and tidal complex; Geological Survey of Canada, Bulletin 288, 60 p.

Young, F.G., Campbell, R.B., and Poulton, T.P.
1973: The Windermere Supergroup of the southern Cordillera; in Belt Symposium, v. 1; Department of Geology, University of Idaho and Idaho Bureau of Mines and Geology, Moscow, Idaho, p. 181-203.