REPORT No. 242

GEOLOGICAL SURVEY OF JAPAN

TRACE FOSSILS FROM THE CRETACEOUS FLYSCH OF THE IKUSHUMBETSU AREA, HOKKAIDO, JAPAN

By

Keisaku TANAKA

GEOLOGICAL SURVEY OF JAPAN

Hisamoto-cho, Kawasaki-shi, Japan

1971

562/569 : 551.763 (524)

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Trace Fossils from the Cretaceous Flysch of the Ikushumbetsu Area, Hokkaido, Japan

By

Keisaku TANAKA*

Abstract

This paper contains the systematic descriptions of the trace fossils from the Lower Cretaceous flysch sequence, constituting the main part of the Middle Yezo Group, of the Ikushumbetsu area, central Hokkaido. The described trace fossils are assigned to *Chondrites, Glockeria, Helminthoida, Helminthopsis, Lorenzinia* (?), *Megagrapton, Neonereites, Paleodictyon, Protopaleodictyon, Scolicia, Spirorhaphe* (?) and *Zoophycos*, including four unnamed peculiar forms. Among them two species are new. Brief comments are given on the character of the ichnofauna and the stratigraphical variation of the ichnofacies.

I. Introduction

The Ikushumbetsu area, central Hokkaido (Fig. 1), is known as one of the classical and typical fields of the Cretaceous System in Hokkaido. The Cretaceous deposits of this area yield a large variety of molluscan fossils such as ammonites and inocerami abundantly, and have therefore furnished much of our knowledge about the Cretaceous biostratigraphy of Japan. However, trace fossils which are important for interpretation of palaeoenvironments have received little attention in the Cretaceous sequence of the Ikushumbetsu area.

I had an opportunity to study the Lower Cretaceous flysch of the present area to make clear its sedimentary features. As a result, it has been revealed that many different kinds of animal trails and burrows occur abundantly throughout the flysch sequence constituting the main part of the Middle Yezo Group. Thus, in my previous paper (TANAKA, 1970) the identified trace fossils were provisionally listed and illustrated without palaeontological descriptions, and then the mode of occurrence and the character of the trace-fossil fauna were described in connection with the sedimentary features of the flysch sequence.

In Japan few systematic descriptions have been made as yet of trace fossils from Cretaceous flysch-type or geosynclinal deposits. Actually, pioneer studies of such trace fossils have been limited to the Cretaco-Palaeogene in the Shimanto terrane of Shikoku (FUKADA, 1951; KATTO, 1952, 1960a, 1960b, 1964).

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On the other hand, some of the trace fossils from the Ikushumbetsu area are new to science and others are not known from any other parts of Japan even generically. Moreover, it would be interesting to compare the trace-fossil fauna of the studied area with that of the Shimanto terrane. For these reasons, the trace fossils from the Ikushumbetsu Cretaceous flysch among which twelve genera and sixteen species have been identified are to be described in this paper.

All the described specimens were collected by myself. They are deposited at the Geological Survey of Japan, Kawasaki City, Kanagawa Prefecture, which is denoted as GSJ in the text.

Acknowledgements.—I wish to thank Professor Kotora HATAI, Tohoku University, for many helpful suggestions, and Professor Walter HÄNTZSCHEL, Hamburg, West Germany, for his valuable advice on some of the trace fossils. I am also indebted to Mr. Yoshio MASAI, Geological Survey of Japan, for photographing the specimens.

II. Stratigraphical Notes

The details of the stratigraphy of the Cretaceous deposits in the Ikushumbetsu area have been described elsewhere (MATSUNO and others, 1964; TANAKA, 1970). What follows is a brief summary of the stratigraphic context of the main part of the Middle Yezo Group from which the described trace fossils came.

The main part of the Middle Yezo Group is conformably overlain by the neritic Mikasa Formation (Cenomanian—Turonian), the uppermost part of the group, and consists predominantly of flysch deposits. The sandstones of this sequence are mostly of turbidity current origin. The sequence is Middle Albian? to Upper Albian in age.

The main part of the Middle Yezo Group along the Ikushumbetsu Valley is stratigraphically divisible into five members as follows.

From the top downwards

Member Me: Massive or thick-bedded, medium- to coarse-grained sandstone, with *Mortoniceras* (*Durnovarites*) sp. in the lower part, and laminated sandy mudstone in the upper part; about 110 m thick.

Member Md: Laminated sandy mudstone and laminated mudstone, with *Mortoniceras* (*Cantabrigites*) *imaii*; about 300 m thick.

Member Mc: Medium- to thick-bedded, medium- to coarse-grained sandstone; about 120 m thick.

Member Mb: Thin-bedded alternation of sandstone and mudstone in the lower part (Mb_1), and sandstone and mudstone in alternation and laminated sandy mudstone in the upper part (Mb_2); about 220 m thick.

Member Ma: Laminated sandy mudstone and laminated mudstone; more than 300 m thick.

Unlike the case of the Ikushumbetsu Valley, Member Me along the Pombetsu Valley northeast of Ikushumbetsu consists exclusively of thinly alternating sandstone and mudstone, and the middle part of Member Md (Md_2) also is dominated by such deposits. Member Me is stratigraphically subdivisible into seven units, named A to G.

III. Fossil Localities

A large variety of trace fossils occur abundantly throughout the main part of the Middle Yezo Group. The localities where the described trace fossils were collected are as follows (Fig. 1).

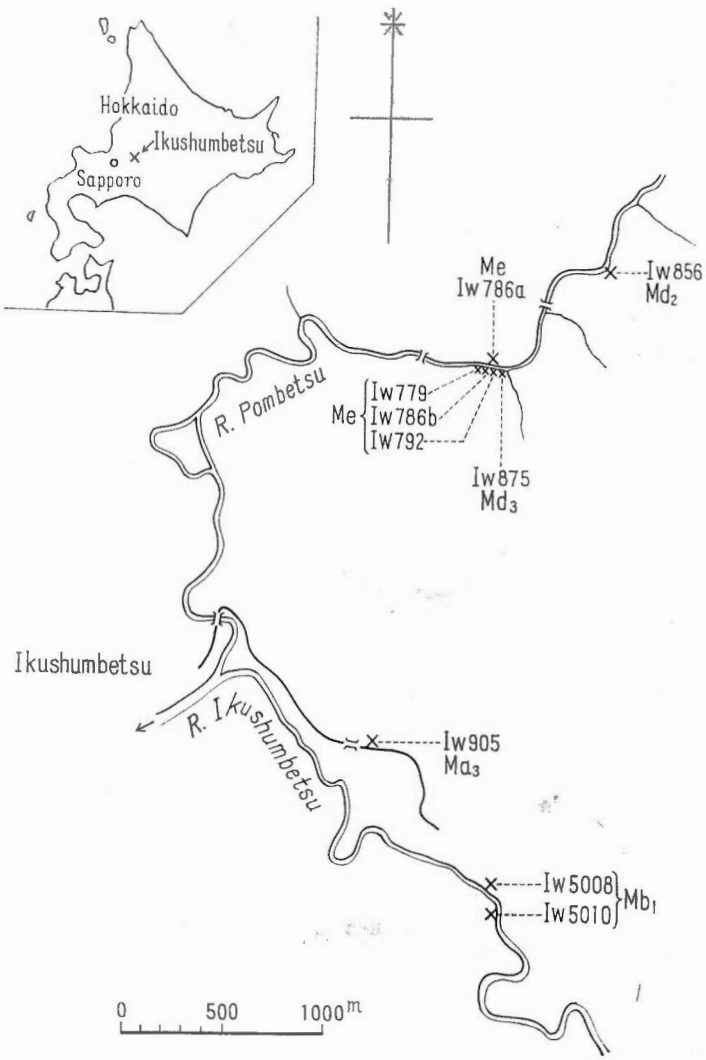

Fig. 1. Index map showing the fossil localities. For Ma_3, Mb_1, Md_2, Md_3 and Me see text.

Loc. Iw779: About 2.5 km northeast of Ikushumbetsu, Mikasa City; left bank of the Pombetsu; uppermost part (subdivision F) of Member Me, Middle Yezo Group.

Loc. Iw786a: About 2.5 km northeast of Ikushumbetsu, Mikasa City;

right bank of the Pombetsu; lower to middle parts (subdivisions B to D) of Member Me, Middle Yezo Group.

Loc. Iw786b: About 2.5 km northeast of Ikushumbetsu, Mikasa City; left bank of the Pombetsu; middle part (subdivisions D and E) of Member Me, Middle Yezo Group.

Loc. Iw792: About 2.5 km northeast of Ikushumbetsu, Mikasa City; left bank of the Pombetsu; lowermost part (subdivision A) of Member Me, Middle Yezo Group.

Loc. Iw856: About 3.3 km northeast of Ikushumbetsu, Mikasa City; left bank of the Pombetsu; middle part of Member Md (Md_2), Middle Yezo Group.

Loc. Iw875: About 2.5 km northeast of Ikushumbetsu, Mikasa City; left bank of the Pombetsu; upper part of Member Md (Md_3), Middle Yezo Group.

Loc. Iw905: About 1.5 km east-southeast of Ikushumbetsu, Mikasa City; roadcut up the right bank of the Ikushumbetsu; upper part of Member Ma (Ma_3), Middle Yezo Group.

Loc. Iw5008: About 2.3 km southeast of Ikushumbetsu, Mikasa City; right bank of the Ikushumbetsu; lower part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group.

Loc. Iw5010: About 2.3 km southeast of Ikushumbetsu, Mikasa City; left bank of the Ikushumbetsu; upper part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group.

IV. Systematic Descriptions

Conforming to HÄNTZSCHEL's practice (1962), the trace-fossil genera are to be described in alphabetical order.

Ichnogenus *Chondrites* STERNBERG, 1833

Chondrites sp.
Pl. II, Fig. 3

Material.—A single specimen, GSJ6904, from loc. Iw5010, Ikushumbetsu Valley.

Description.—The structure is composed of a mass of regularly branching grooves, in part radially arranged. The grooves branch off many times at angles of 35 to 45 degrees, being not dichotomous. The ramifying grooves neither intersect nor anastomose. The grooves are smooth-walled, and are usually straight or nearly so, but rarely curved gracefully.

The diameter of the grooves is constant along any part of the tunnel system, generally less than 1 mm, being about 0.7 to 0.8 mm.

Comparison.—The described form impressed on the top surface of a sandstone layer is regarded as representing the distal portion of a tunnel system. The branching grooves are often filled with pelitic material. Although it cannot be confirmed whether the branches (or tunnels) are continuous from the overlying layer (in this case mudstone layer), the present form can be surely identified with Chondrites on the basis of the general features described above.

The specimen at hand is similar in the diameter of the branches as well as in the general features of the burrow system to *Chondrites* sp. from the Upper Cretaceous flysch of Austria, figured by HÄNTZSCHEL (1955, text-fig. 7), to a smaller form of *Chondrites* from the Maastrichtian flysch of Spain (GÓMEZ DE LLARENA, 1946, pl. 4, fig. 20), and also to a certain specimen of *Chondrites* from the Upper Aptian of the Antarctic (TAYLOR, 1967, text-fig. 8, h).

Further comparisons of the specimen with any other species so far reported are suspended, because the available material is single and imperfectly preserved.

Remarks.—*Chondrites* has been interpreted by SIMPSON (1957) as a feeding burrow of a siphunculoid worm, and by HÄNTZSCHEL (1962) as a dwelling burrow or a feeding burrow of a marine worm. To sum up, the described form is regarded as a feeding burrow made by a semisessile, sediment-eating worm-like animal, i.e. Fodinichnia (SEILACHER, 1953).

Occurrence.—Ikushumbetsu Valley, Mikasa City, central Hokkaido; upper part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group; Albian.

The fossil is preserved as endogene concave epireliefs (SEILACHER, 1964a), i.e. epichnial grooves (MARTINSSON, 1965, 1970) on the top surface of a sandstone layer. It is found associated with *Neonereites uniserialis* SEILACHER (to be described below) on the same sandstone layer.

Ichnogenus *Glockeria* KSIAZKIEWICZ, 1968

Glockeria parvula KSIAZKIEWICZ
Pl. X, Fig. 3

1960. Rosetted trail, KSIAZKIEWICZ, *Kwart. Geol.*, vol. 4, p. 746, pl. 3, fig. 10.
1970. *Glockeria parvula* KSIAZKIEWICZ, *Trace Fossils*, p. 312, text-fig. 7c.

Material.—A single specimen, GSJ6972, from loc. Iw786a, Pombetsu Valley.

Description.—The trail is represented by a starlike structure consisting of nearly straight and tapering primary ridges regularly radiating from a small raised mid-field. The mid-field is provided with a small crater-like pit at its top. The primary ridges are nearly equal in length and thickness. The number of the primary ridges is nine. One smaller, less distinct secondary ridge is intercalated between the primary ridges without connecting with the mid-field. The secondary ridges are pointed towards their distal end. At least three secondary ridges are observed.

The trail is about 3 cm in diameter.

Comparison.—A variety of starlike sole trails have been reported by various authors (e.g. NOWAK, 1956; SEILACHER, 1958, 1963a; KSIAZKIEWICZ, 1960, 1968, 1970; LUCAS and RECH-FROLLO, 1964; HÄNTZSCHEL, 1970). The described specimen is most close to and identified with *Glockeria parvula* KSIAZKIEWICZ from the Upper Cretaceous flysch of the Polish Carpathians.

Glockeria parvula distinctly differs from *G. glockeri* KSIAZKIEWICZ, the type species of the genus (KSIAZKIEWICZ, 1968, p. 15, 1970, p. 312, text-fig. 7a; SEILACHER, 1958, p. 1070, text-fig. 22, 1963a, p. 139, text-fig. 89) and *G. sparsicostata* KSIAZKIEWICZ (1968, p. 15, pl. 5, fig. 4; 1970, p. 312, text-fig. 7b) from the Polish Carpathians, in having a raised mid-field with a small pit at

its top. Nevertheless, this species, in accordance with KSIAZKIEWICZ's (1970) opinion, is provisionally assigned to *Glockeria*.

Remarks.—The origin of various types of starlike trace fossils has been discussed by various authors (e.g. LUCAS and RECH-FROLLO, 1964; GRUBIĆ, 1970; HÄNTZSCHEL, 1970). The present specimen may have been formed in the same fashion as KSIAZKIEWICZ (1960) has envisaged about the Polish rosetted trail (=*Glockeria parvula*). It represents a radiating groove pattern in the sediment around the aperture produced by the feeding action of the marine organism living in a hole on the sea-floor. The described form is, therefore, considered to be a feeding trail, i.e. Pascichnia (SEILACHER, 1953) combined with a dwelling burrow pertaining to the Domichnia (SEILACHER, 1953), as suggested by HÄNTZSCHEL (1970).

Occurrence.—Pombetsu Valley, Mikasa City, central Hokkaido; subdivision B of Member Me, Middle Yezo Group; Albian.

The preservation is in convex hyporelief (SEILACHER, 1964a), i.e. hypichnial ridge (MARTINSSON, 1970) on the sole of a sandstone layer.

Ichnogenus *Helminthoida* SCHAFHÄUTL, 1851

Helminthoida japonica ichnosp. nov.
Pl. I, Figs. 1–2; Pl. II, Fig. 1; Pl. III, Figs. 1–2

Material.—Holotype: GSJ6971, from loc. Iw786b, Pombetsu Valley. Paratypes: GSJ6905 and GSJ6906, from loc. Iw786a, and GSJ6921, from loc. Iw786b, Pombetsu Valley. There are some more specimens from loc. Iw786b and loc. Iw792, Pombetsu Valley.

Description.—The trail is represented by extremely long, slender strings with numerous, parallel, tightly developed sigmoidal structures which are equidistant almost throughout. The sigmoidal structures are mostly curved, and tend to be arranged in a concentric fashion. They are wider and have a more uniform shape in the distal part of the concentric trail system than in the proximal. The surface and sides of the strings are smooth. The thickness of the strings is almost constant throughout the length of the trail.

The trail meanders generally 3 to 5 cm, about 7 cm in maximum, between turns in the distal part of the concentric trail system and 1.5 to 2 cm between turns in the proximal part. The strings are about 1 mm thick. The intervals between the strings are nearly constant and are somewhat greater than the thickness of the strings. They are 1 to 2 mm except near the corners of the meanders where the intervals become wider.

Comparison.—The described species closely resembles *Helminthoida labyrinthica* HEER from the Upper Cretaceous flysch of Italy (SEILACHER, 1954, text-fig. 2, 17), from the Upper Cretaceous flysch of Austria (HÄNTZSCHEL, 1962, text-fig. 122, 5; ABEL, 1935, text-figs. 334, 335, 336*), from the Eocene flysch of Austria (GÓMEZ DE LLARENA, 1946, pl. 3, fig. 14, text-fig. 3) and from the Upper Cretaceous and Palaeocene flysches of the Polish Carpathians (forma *typica*, KSIAZKIEWICZ, 1970, p. 296, text-fig. 2g), in the general features of the trail. However, *H. japonica* differs from *H. labyrinthica* (forma *typica*) in

* These three specimens figured by ABEL have been referred by GÓMEZ DE LLARENA (1946) to *Helminthoida **labyrinthica***.

having less concentric trails and less numerous sigmoidal structures. The former occurs on sandstone soles, whereas the latter is found in marls and shales.

The described species is similar also to *H. crassa* SCHAFHÄUTL (sole trail) from the Upper Cretaceous flysch of Marnia (SEILACHER, 1954, pl. 8, fig. 3, text-fig. 2, 10), from the Cretaceous flysch of Spain (SEILACHER, 1967a, pl. 2, fig. d) and from the Cretaceous and Eocene flysches of Poland (KSIAZKIEWICZ, 1970, p. 296, text-figs. 2 d–f). But *H. japonica* is clearly distinguished from *H. crassa* by its uniform, tight meanders and narrower intervals between the strings. *Helminthoida* type A from the probable Lower Cretaceous of Okinawa, the Ryukyu Islands (KONISHI, 1963, text-figs. 6, 7, A-1, 3, S-1a, 3), though imperfectly preserved, is close to *H. crassa* in the general features of the trail.

Remarks.—The described forms are interpreted as feeding trails made by mud-eating vagile organisms, i.e. Pascichnia.

Occurrence.—Pombetsu Valley (including the type locality), Mikasa City, central Hokkaido; Member Me, Middle Yezo Group. Ikushumbetsu Valley, Mikasa City; lower part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. Albian. In addition to the specimens mentioned above, trails similar to but not identical with the present species and those classified as the genus *Helminthoida* occur abundantly, particularly at loc. Iw786b (subdivision E of Member Me), Pombetsu Valley.

The trails are preserved as convex hyporeliefs, i.e. hypichnial ridges on the lower surface of sandstone layers.

Ichnogenus *Helminthopsis* HEER, 1877

Helminthopsis akkesiensis (MINATO and SUYAMA)

Pl. II, Fig. 2; Pl. III, Fig. 4

1949. *Magarikune akkesiensis* MINATO and SUYAMA, *Jap. Jour. Geol. Geogr.*, vol. 21, p. 277–279, pl. 11, figs. 1–2.

Material.—GSJ6923 and GSJ6924, from loc. Iw792, Pombetsu Valley, and GSJ6967, from loc. Iw5010, Ikushumbetsu Valley.

Description.—The trail is composed of slender, free meandering strings. It meanders occasionally 1.5 to 2 cm between turns. The strings are not entirely smooth, and tend to be more or less wrinkled, thus being occasionally provided with minute marginal ridges. The thickness of the strings is nearly constant throughout the length of the trail, being 2.5 to 3 mm.

Comparison.—The present species was described and figured under the genus *Magarikune* by the original authors. *Magarikune* is now considered by HÄNTZSCHEL (1962) as a synonym of *Helminthopsis*. More or less winkled surface and sides of the strings and occasional minute marginal ridges have not been pointed out in the original specific diagnosis. However, the trails illustrated by MINATO and SUYAMA, as can be seen from the photograph, are not entirely smooth.

This species is closely allied to *Helminthopsis magna* ULRICH from the Upper Cretaceous flysch of Austria (HÄNTZSCHEL, 1962, p. 200, text-fig. 122, 4a; ABEL, 1935, text-fig. 261B), in the general features of the trail, but is distinguished from that species by its thinner strings.

The species described here is distinctly separated from *H. curvata* (KATTO)* (1960a, p. 333, pl. 35, fig. 1) from the Eocene of southern Shikoku, in many respects. In *H. curvata* the trail comprises several parallel, somewhat tight meanders, while in *H. akkesiensis* the trail consists of free meandering strings.

Remarks.—The described forms are interpreted as feeding trails made by vagile sediment-eaters, i.e. Pascichnia. MINATO and SUYAMA (1949) have suggested that the animal producing the *H. akkesiensis* trails was an *Arenicola*-like annelid.

Occurrence.—Ikushumbetsu Valley, Mikasa City, central Hokkaido; upper part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. Pombetsu Valley, Mikasa City; Member Me, Middle Yezo Group. Albian. The specimens described and figured by MINATO and SUYAMA (1949, indicated above) came from the Upper Cretaceous at Akkeshi, eastern Hokkaido.

The preservation is in convex hyporelief, i.e. hypichnial ridge on the bottom surface of sandstone layers.

Ichnogenus *Lorenzinia* GABELL, 1900

Lorenzinia (?) sp.
Pl. III, Fig. 3

Material.—A single, imperfectly preserved specimen, GSJ6931, from loc. Iw786b, Pombetsu Valley.

Description.—The structure is discoidal and convex, being about 21 mm in diameter. The mid-field of the structure is represented by a circular, smooth depression. It is about 9 mm across. The mid-field is encircled by prominent, elongated, radiating lobes. The lobes are sharply separated from each other, equidistant, smooth, and raised at the proximal end, tapering distally. The lobes are about 6 mm long, and are 1.2 to 1.5 mm thick in their proximal part. The interspaces of the lobes are narrower than the lobes. Lobes are about nine or ten in the preserved nearly semicircular portion of the structure.

Comparison.—The specimen at hand is fragmentary and imperfectly preserved. However, it is most close to *Lorenzinia* in the general features of the structure.

The described form resembles *Lorenzinia apenninica* GABELL from the Eocene of southern Europe (HARRINGTON and MOORE, 1956, text-fig. 32, 1a–e), from the Maastrichtian flysch of Spain (FRANCISCO FARRÉS, 1963, p. 125–127, pl. 7, fig. 2) and from the Upper Cretaceous flysch of the Polish Carpathians (KSIAZKIEWICZ, 1970, p. 312–313, text-fig. 7m) in that the lobes are sharp at their outer end.

This specimen is similar also to *Lorenzinia carpathica* (ZUBER) from the Upper Cretaceous and Palaeogene flysches of Europe (HARRINGTON and MOORE, 1956, text-fig. 32, 2a–d; NOWAK, 1956, text-figs. 2, 3; KSIAZKIEWICZ, 1968, pl. 5, fig. 3, 1970, p. 312, text-fig. 7g–i). However, it is distinguished from that species by its tapering lobes.

Be that as it may, the fragmentary and imperfect preservation of the specimen makes difficult further comparisons of the present form with other

* The genus *Tosahelminthes* KATTO, 1960, established based on this species is now considered by HÄNTZSCHEL (1962) as a synonym of *Helminthopsis*.

hitherto reported foreign species.

Remarks.—*Lorenzinia* has commonly been regarded as a medusoid (see LUCAS and RECH-FROLLO, 1964, GRUBIĆ, 1970). On the other hand, NOWAK (1956) has stated that *Lorenzinia*-type forms from the Upper Cretaceous of Poland are extremely similar to feeding traces of recent crabs, and SEILACHER (1954, 1963a) has considered *Lorenzinia* as a feeding burrow. At any rate, the described form, in accordance with HÄNTZSCHEL's (1970) opinion, is interpreted as a feeding trail (Pascichnia).

Occurrence.—Pombetsu Valley, Mikasa City, central Hokkaido; subdivision E of Member Me, Middle Yezo Group; Albian.

The specimen is preserved as convex hyporeliefs, i.e. hypichnial ridges on the lower bedding surface of a sandstone layer.

Ichnogenus *Megagrapton* KSIAZKIEWICZ, 1961

Megagrapton sp.
Pl. V, Fig. 1

Material.—A single specimen, GSJ6983, from loc. Iw786a, Pombetsu Valley.

Description.—The trail is represented by straight or slightly curved strings, branching at nearly right angles. The strings ramify at irregular intervals. The branching strings occasionally end abruptly, with a tubiform extremity. The strings are cylindrical and somewhat variable in thickness. The surface and sides of the strings are not entirely smooth, and tend to be more or less wrinkled.

The strings are 2.5 to 3 mm thick.

Comparison.—The described specimen is similar to *M. irregulare* KSIAZKIEWICZ (1961, p. 882, 888, pl. 1, figs. 1–2; 1968, p. 5, 14, text-fig. 3; 1970, p. 305, text-fig. 6b) from the Eocene of the Polish Carpathians, in the general features of the trail. But the former is separated from the latter by its narrower strings.

Remarks.—The described form is interpreted as a feeding trail made by a vagile deposit-eating animal, i.e. Pascichnia.

This trace fossil cuts across longitudinal furrows and ridges. From this fact combined with the cylindrical sole trail, the fossil is considered to be of post-depositional origin.

Occurrence.—Pombetsu Valley, Mikasa City, central Hokkaido; Member Me, Middle Yezo Group; Albian.

The trail is in convex hyporelief or hypichnial ridge preservation on the sole of a sandstone layer.

Ichnogenus *Neonereites* SEILACHER, 1960

Neonereites uniserialis SEILACHER
Pl. IV, Figs. 1–5; Pl. V, Fig. 3; Pl. VI, Figs. 4–7

1960. *Neonereites uniserialis* SEILACHER, *Geol. Rundschau*, vol. 49, p. 48, pl. 2, fig. 1, text-fig. 3.

1968. *Neonereites uniserialis*, KEMPER, *Geol. Jahrb.*, vol. 86, p. 69–71, pl. 6,

figs. 3–4, text-fig. 6.

1968. *Neonereites uniserialis*, HÄNTZSCHEL and REINECK, *Mitt. Geol. Staatsinst. Hamburg*, no. 37, p. 21–22, pl. 9, figs. 1–2.

Material.—GSJ6900*, from loc. Iw779, Pombetsu Valley; GSJ6901*, GSJ-6902, GSJ6903*, GSJ6910*, GSJ6932*, GSJ6933* and GSJ6949, from loc. Iw5010, Ikushumbetsu Valley; GSJ6934, from loc. Iw856, Pombetsu Valley; GSJ6936, GSJ6979 and GSJ6980, from loc. Iw786a, Pombetsu Valley. There are many other specimens from loc. Iw786a, loc. Iw856 and loc. Iw5010.

Description.—The trail is represented by an irregularly curved chain of rather rounded, deep, smooth-walled depressions. It is curved in all directions and occasionally strongly curved in a sigmoidal pattern. The segmental depressions are of uniform size throughout the length of the trail. They are separated from each other by a marked, thin transverse ridge which is commonly slightly arched in a plan view. The width of the segmental depressions is nearly equal to or slightly greater than the length of the segmental depressions. The lateral sides of the trail are occasionally fringed with flabby structures caused by burrowing.

The trails are commonly 4 to 5 mm wide and between 9 and 12 cm long. The smaller (or narrower) forms are 1.5 to 2 mm wide and about 4 cm long.

Observation.—In general, the trails are found on the top surface of sandstone layers and consist of chains of empty segmental depressions (Pl. IV, Figs. 2, 3, 5). The specific characters described above are based on observations of such top trails. However, there is a certain extent of variation between individuals. In some top trails (e.g. GSJ6903 and GSJ6910), especially those from loc. Iw5010, the segmental depressions are shallow and nearly rectangle-shaped, being wider than long (Pl. IV, Figs. 1, 4); in others (e.g. GSJ6949) the transverse ridges are more or less thicker than in the normal forms (Pl. VI, Fig. 5). Of course there are intermediate forms between the former case and the normal forms. The latter case occurs on the top surface of sandstone coarser gained than normal. At any rate, all the above-mentioned differences between individuals are considered to have been due largely to the properties (e.g. consolidation and humidity) of the sand and mud material which, in turn, may have been influenced partly by their grain sizes.

Where the trails are met with at the boundary between sandstone and overlying shale or at the base of shale layers, they are represented by tubes, looking like a string of pearls, stuffed with finer pelitic material than that constituting the shale layers (Pl. VI, Fig. 6), or by mud-filled tubes, with somewhat wrinkled sides, segmentation of which is very indistinct or imperceptible (Pl. VI, Fig. 4). The trails imprinted inside sandstone layers are represented by the necklace-like, mud-filled tubes or somewhat wrinkled-sided, non-segmented, mud-filled tubes, which are almost parallel to bedding. Furthermore, the trails are impressed as an irregularly curved series of pustules (Pl. V, Fig. 3; Pl. VI, Fig. 7) or as irregularly curved grooves fringed with flabby structures (Pl. V, Fig. 3) on the underside of sandstone layers, though rarely. In the latter case, some grooves are distinctly segmented by comparatively arched, thick transverse ridges, while others are indistinctly segmented and partly stuffed with pelitic material derived from the underlying shale layer.

* The specimens marked with an asterisk contain several or more trails.

Comparison.—The specimens at hand closely resemble *Neonereites uniserialis* SEILACHER from the Lower Jurassic of Germany (SEILACHER, 1960, p. 48, pl. 2, fig. 1; HÄNTZSCHEL and REINECK, 1968, p. 21–22, pl. 9, figs. 1–2) and from the Valanginian of Germany (KEMPER, 1968, p. 69–71, pl. 6, figs. 3–4, text-fig. 6), in the general features of the trail.

Particularly, the usual width of the described trails approximates to the width of the trail figured by SEILACHER (1960, pl. 2, fig. 1). But the specimens described here have more rounded segmental depressions and thinner, less arched transverse ridges in between than does SEILACHER's specimen. In the trail illustrated by SEILACHER the curved portion consists of longer, more rounded segmental depressions bordered by thinner, less arched transverse ridges than does the nearly straight portion (see the upper left of SEILACHER's figure mentioned above). Such features observed in the curved portion of the trail in question are extremely similar to the case of the Ikushumbetsu trails in which similarly the segmental depressions occasionally become longer in the curved portion than in the nearly straight portion of the trail. Furthermore, flabby structures bordering the trail are more distinct in the trail figured by SEILACHER than in the specimens at hand.

The smaller forms of the Ikushumbetsu trails are most close to the *N. uniserialis* trails figured by HÄNTZSCHEL and REINECK (1968, pl. 9, figs. 1–2) in the size as well as in the general features of the trail.

There are some differences between the Ikushumbetsu trails and the Valanginian trails illustrated by KEMPER (1968, pl. 6, figs. 3–4). The segmental depressions are rather semilunar-shaped in the Valanginian trails, while in the Ikushumbetsu trails they are rounded. The transverse ridges bordering the segmental depressions are thicker and more arched in the former than in the latter trails.

Be that as it may, all the above-mentioned differences may be due largely to the conditions of formation and preservation and within the extent of variation in the same ichnospecies. As mentioned before, considerable variation in features of segmental depressions is recognized also in the Ikushumbetsu specimens themselves. Therefore, the described specimens can be identified with *N. uniserialis*.

Remarks.—*Neonereites uniserialis* has been interpreted by SEILACHER (1960) as an endogene burrow and by HÄNTZSCHEL and REINECK (1968) as a crawling trail made by a vagile benthic animal, i.e. Repichnia (SEILACHER, 1953).

Occurrence.—Ikushumbetsu Valley, Mikasa City, central Hokkaido; lower and upper parts of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. Pombetsu Valley, Mikasa City; middle part of Member Md (Md_2) and subdivisions B and F of Member Me, Middle Yezo Group. Albian.

The trails usually occur as concave epireliefs, i.e. epichnial grooves on the top surface of sandstone layers. On rare occasions, they are preserved as convex hyporeliefs, i.e. hypichnial ridges, or as concave hyporeliefs (SEILACHER, 1964a), i.e. *hypichnial grooves* (a new term introduced here by myself) on the sole of sandstone layers. Moreover, the trails are imprinted as mud-filled tubes, i.e. full reliefs (SEILACHER, 1964a) or endichnial burrows (MARTINSSON, 1965, 1970) inside sandstone layers. In some cases the trails are exclusively widespread on the upper bedding surface of sandstone layers.

N. uniserialis is found also in the lower part of the Middle Yezo Group (probably Albian in age) along the Sounnai Valley west of Soeushinai, Horo-

kanai-machi, Uryu-gun, Teshio province, northern Hokkaido.

Ichnogenus *Paleodictyon* MENEGHINI, 1850

Remarks.—The genus *Paleodictyon* has been classified by VIALOV and GOLEV (1960, 1964, 1966a) into two subgenera, *Paleodictyon* and *Glenodictyum*, according to the thickness of mesh sides. However, approving of HÄNTZSCHEL's opinion (1964), I do not support the framework of classification proposed by VIALOV and GOLEV, because in the Ikushumbetsu specimens the thickness of mesh sides occasionally varies with individuals of one and the same species and also with parts of a single individual.

Following VIALOV and GOLEV's (1964, 1966a) and KSIAZKIEWICZ's (1970) framework of classification, the division into species is based on the diameter of meshes* and the thickness of mesh sides (or strings). In this way, the *Paleodictyon* structures from the Ikushumbetsu flysch comprise at least five species: *P.* aff. *strozzi*, *P. latum*, *P. miocenicum*, *P.* cf. *regulare* and *P. hokkaidoense* sp. nov.

The origin of *Paleodictyon* has been interpreted in a number of ways, as reviewed by, for example, LESSERTISSEUR (1955) and VIALOV (1964). An overwhelming opinion now is that *Paleodictyon* represents feeding trails, i.e. Pascichnia (e.g. ABEL, 1935; SEILACHER, 1954; NOWAK, 1959; SIMPSON, 1967; WEBBY, 1969a; CHAMBERLAIN, 1971). In some of the Ikushumbetsu specimens the strings occasionally overlap at the corners of the meshes. This may give some support to the origin of *Paleodictyon* networks that has been considered by WEBBY (1969a) and CHAMBERLAIN (1971).

The *Paleodictyon* trails from the Ikushumbetsu area are all preserved as convex hyporeliefs, i.e. hypichnial ridges on the sole of sandstone layers. The trails occasionally occupy the small-scale elevations of sandstone soles.

Paleodictyon sp. aff. *P. strozzi* MENEGHINI

Pl. VII, Fig. 1; Pl. VIII, Fig. 2

Compare.—

1964. *Paleodictyon strozzi*, VIALOV, *Jour. Sed. Petrology*, vol. 34, text-fig. 1.
1970. *Paleodictyon strozzi*, KSIAZKIEWICZ, *Trace Fossils*, p. 308, pl. 4, fig. h.

Material.—GSJ6961, GSJ6962 and GSJ6977, from loc. Iw786a, Pombetsu Valley, and GSJ6963 and GSJ6968, from loc. Iw786b, Pombetsu Valley.

Description.—The impression is represented by a reticulate structure consisting of polygonal meshes. The polygonal meshes are variable in shape and size, being occasionally deformed and elongated. They are commonly arranged chaotically. The meshes are usually hexagonal, occasionally pentagonal or heptagonal, but are sometimes indistinct (more or less rounded) polygons. The sides of the polygonal meshes are thin and often unequal in length, and are occasionally somewhat flexuous.

The meshes vary in diameter from 2.5 mm to 7 mm, averaging about 4 mm (GSJ6963 and GSJ6968) to about 4.5 mm (GSJ6961). The strings are 0.5 to 0.7 mm thick.

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* The diameter of meshes in this paper means the longest diagonal of a mesh polygon.

Observation.—Considerable variation in size of meshes is recognized in one of the specimens, GSJ6968. In this specimen the meshes tend to vary in diameter also in a definite direction (see Pl. VII, Fig. 1). In GSJ6963 and GSJ6968 the strings occasionally overlap at the corners of the meshes.

Comparison.—According to VIALOV and GOLEV's (1964) and KSIAZKIEWICZ's (1970) frameworks of classification, the described specimens could be referred to *P. strozzi* MENEGHINI (mesh diameter: 2.5–5.5 mm or 3–5 mm). But they differ from the *P. strozzi* trails from the Palaeogene flysch of the Carpathians, figured by VIALOV (1964, text-fig. 1) and KSIAZKIEWICZ (1970, pl. 4, fig. h), in having less regular networks. In *P. strozzi* the corners of the polygons in the networks are blunt (GÓMEZ DE LLARENA, 1946); such is the case with a part of the networks of the described trails.

The present forms are apparently similar in mesh size to *P. miocenicum* SACCO to be described below, but are easily distinguishable from that species by their less uniform networks and thinner strings.

Occurrence.—Pombetsu Valley, Mikasa City, central Hokkaido; Member Me, Middle Yezo Group; Albian.

In addition to the specimens described here, *Paleodictyon* with thin, polygonal meshes are found abundantly in the Ikushumbetsu flysch.

Paleodictyon latum VIALOV and GOLEV
Pl. VI, Figs. 1–2

1964. *Paleodictyon* (*Glenodictyum*) *latum* VIALOV and GOLEV, *Izvest. vysshih uchebnyh zavedenii, Geol. i razvedka*, vol. 7, p. 30, pl. 2, fig. 1.
1966. *Paleodictyon* (*Glenodictyum*) *latum* VIALOV and GOLEV, *Review Bulgarian Geol. Soc.*, vol. 27, p. 176–177, text-figs. 2–3.
1970. *Paleodictyon latum*, KSIAZKIEWICZ, *Trace Fossils*, p. 306, pl. 4, figs. d–f.

Material.—GSJ6952 and GSJ6955, from loc. Iw786a, Pombetsu Valley; GSJ6954, from loc. Iw786b, Pombetsu Valley; GSJ6953, from loc. Iw905, Ikushumbetsu Valley; GSJ6907, from loc. Iw5008, Ikushumbetsu Valley.

Description.—The structure is represented by honeycomb-like networks consisting of regular-polygon meshes. The meshes are uniform in shape and size, being regularly arranged. They are usually distinct regular polygons. The meshes are usually hexagonal, but very rarely pentagonal. The strings are thick.

The meshes are between 1.5 and 2 mm in diameter. The strings are between 0.5 and 0.7 mm in thickness.

Comparison.—Following VIALOV and GOLEV's framework of classification (1964, 1966a), the specimens at hand are assigned to *P. latum* VIALOV and GOLEV (mesh size, 1–2 mm; string thickness, 0.6 mm). However, *P. latum*, according to KSIAZKIEWICZ (1970), is 1 to 1.2 mm in mesh size. On the other hand, the described specimens, as far as the size of meshes is concerned, are could be referred to *P. intermedium* KSIAZKIEWICZ, with mesh sizes of 1.5 to 2.5 mm (1970, p. 306, pl. 4, fig. g). They are more similar in string thickness to *P. latum* of VIALOV and GOLEV and of KSIAZKIEWICZ than to *P. intermedium*. At any rate, there is no need to separate *P. intermedium* from *P. latum* of VIALOV and GOLEV as a distinct species.

The described species is distinguished from *P. miocenicum* SACCO and *P.* sp. cf. *P. regulare* SACCO to be described below by its smaller size of meshes.

Some smaller forms of *P. majus* MENEGHINI from the Palaeogene of the Kii Peninsula, figured by KORIBA and MIKI (1939, pl. 4, figs. a–e) can be identified with *P. latum* in the general features and size of the meshes.

Occurrence.—Ikushumbetsu Valley, Mikasa City, central Hokkaido; upper part of Member Ma (Ma_3) and lower part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. Pombetsu Valley, Mikasa City; Member Me, Middle Yezo Group. Albian. *P. latum* trails occur abundantly at loc. Iw905, Pombetsu Valley.

P. latum has been reported from the Cretaceous and Palaeogene flysches of the Carpathians (VIALOV and GOLEV, 1964; KSIAZKIEWICZ, 1970), and from the Maastrichtian flysch of eastern Bulgaria (VIALOV and GOLEV, 1966b).

Paleodictyon miocenicum SACCO
Pl. V, Fig. 2; Pl. VI, Fig. 3

1964. *Paleodictyon (Glenodictyum) miocenicum*, VIALOV and GOLEV, *Izvest. vysshih uchebnyh zavedenii, Geol. i razvedka*, vol. 7, p. 30, pl. 1, figs. 1–3.
1970. *Paleodictyon miocenicum*, KSIAZKIEWICZ, *Trace Fossils*, p. 308, pl. 4, figs. i–k.

Material.—GSJ6956 and GSJ6957, from loc. Iw786a, Pombetsu Valley; GSJ6976, from loc. Iw786b, Pombetsu Valley; GSJ6961, from loc. Iw792, Pombetsu Valley.

Description.—The impression is represented by a reticulate structure consisting of regular-polygon meshes. The meshes are of uniform shape and size, being arranged generally regularly, but in part irregularly. They are usually regular polygons, but occasionally (or commonly) deformed or elongated polygons. The meshes are usually hexagonal, but very rarely pentagonal. The strings are thick.

The meshes are between 2.5 and 5 mm in diameter and the strings are between 0.7 and 1.3 mm in thickness.

Comparison.—The meshes of *P. miocenicum* are 3 to 5 mm across and 1 to 1.5 mm thick (VIALOV and GOLEV, 1964), or 2.5 to 5 mm across and 1 to 1.2 mm thick (KSIAZKIEWICZ, 1970). The described specimens can be identified with *P. miocenicum* on the basis of the mesh size and string thickness.

This species is distinct from *P. latum* VIALOV and GOLEV described in the preceding paragraph and *P.* cf. *regulare* SACCO to be described below, in some respects. The meshes of *P. miocenicum* are larger than those of *P. latum*, while they are smaller than those of *P. regulare*.

The present specimens are apparently similar in mesh size to *P.* sp. aff. *P. strozzi* MENEGHINI described in the preceding paragraph, but are easily distinguishable from that species by their more uniform networks and thicker strings.

Some smaller forms of *P. majus* MENEGHINI from the Palaeogene of the Kii Peninsula, illustrated by KORIBA and MIKI (1939, pl. 4, figs. f–g) are identified as *P. miocenicum* on the basis of the general features and size of the meshes.

Occurrence.—Pombetsu Valley, Mikasa City, central Hokkaido; Member Me, Middle Yezo Group; Albian.

The occurrence of *P. miocenicum* is known from Crimea (VIALOV and GOLEV,

1964) and from the Cretaceous and Eocene flysches of the Polish Carpathians (KSIAZKIEWICZ, 1970).

Paleodictyon sp. cf. *P. regulare* SACCO
Pl. VII, Fig. 2

Compare.—

1962. *Paleodictyon regulare*, HÄNTZSCHEL, *Treatise on Invertebrate Paleontology*, part W, text-fig. 128, 5.
1964. *Paleodictyon (Glenodictyum) regulare*, VIALOV and GOLEV, *Izvest. vysshih uchebnyh zavedenii, Geol. i razvedka*, vol. 7, p. 30–31, pl. 2, fig. 2.
1970. *Paleodictyon regulare*, KSIAZKIEWICZ, *Trace Fossils*, p. 310, pl. 4, fig. r.

Material.—A single specimen, GSJ6958, from loc. Iw786b, Pombetsu Valley.

Description.—The structure is represented by regular networks consisting of regular-polygon meshes. The meshes are of equal shape and size, being regularly arranged. They are usually hexagonal. The strings are thick.

The meshes are 6.5 to 7 mm in diameter and the strings are 1.2 to 1.8 mm in thickness.

Comparison.—The meshes of *P. regulare* are 6 to 9 mm across and 1.5 to 2 mm thick (VIALOV and GOLEV, 1964, 1966a), or they are 5 to 9 mm across and 1 to 2 mm (mostly more than 1.5 mm) thick (KSIAZKIEWICZ, 1970). *P. regulare* is known to occur in the Lower Tertiary flysch of Italy (HÄNTZSCHEL, 1962) and in the Eocene flysch of the Polish Carpathians (KSIAZKIEWICZ, 1970).

Although the specimen at hand is represented by only a small area of network system, it is probably classified as *P. regulare* on the basis of the above descriptions.

The described form is separated from *P. latum* and *P. miocenicum* described in the preceding paragraphs by their larger size of meshes.

The present specimen is apparently similar in general size of meshes to *P. hokkaidoense* to be described below. But the networks of the former are regular in comparison with those of the latter.

Occurrence.—Pombetsu Valley, Mikasa City, central Hokkaido; Member Me, Middle Yezo Group; Albian.

Paleodictyon hokkaidoense ichnosp. nov.
Pl. VIII, Fig. 1; Pl. X, Fig. 1

Material.—Holotype: GSJ6964, from loc. Iw786a, Pombetsu Valley. Paratype: GSJ6965, from loc. Iw5008, Ikushumbetsu Valley.

Description.—The structure is represented by networks consisting of meshes which are greatly variable in size as well as in shape. The meshes are deformed or elongated polygons (commonly hexagon) or indistinct (more or less rounded) polygons (commonly hexagon) in some parts of the networks, but in others they are of irregular shape and flexuous side. The meshes are generally arranged chaotically. The strings are thick.

The mesh diameter is 6 to 15 mm and the string thickness is 1 to 1.8 mm in the holotype, and the former is 7 to 15 mm and the latter is 1.2 to 2 mm in the paratype.

Observation.—In the holotype, GSJ6964 (Pl. VIII, Fig. 1), the meshes are

variable in thickness, being thinner (generally about 1 mm) in the marginal part of the network system than in the central part where the meshes are constantly thick (1.3 to 1.8 mm). The paratype (Pl. X, Fig. 1), on the other hand, is represented by a small area of network system in comparison with the holotype. The meshes of the paratype are as thick as those in the central part of the network system of the holotype, being usually between 1.5 and 1.8 mm. In the holotype, GSJ6964, the strings occasionally overlap at the corners of the meshes.

Comparison.—This new species is entirely distinct from *P. latum*, *P. miocenicum* and *P.* cf. *regulare* described in the preceding paragraphs, in having larger and less regular-shaped meshes.

The described forms are to some extent similar to *Paleodictyon* sp., with thick meshes, from the Maastrichtian flysch of Spain (GÓMEZ DE LLARENA, 1946, pl. 3, fig. 10), in the general features and size of the meshes. But the meshes of the former are irregular in comparison with those of the latter.

Occurrence.—Pombetsu Valley (type locality), Mikasa City, central Hokkaido; Member Me, Middle Yezo Group. Ikushumbetsu Valley, Mikasa City; lower part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. Albian.

Ichnogenus *Protopaleodictyon* KSIAZKIEWICZ, 1970

Protopaleodictyon sp.
Pl. IX, Figs. 1–4

Material.—GSJ6912, GSJ6914 and GSJ6928, from loc. Iw786a, Pombetsu Valley; GSJ6927, from loc. Iw786b, Pombetsu Valley; GSJ6913, from loc. Iw875, Pombetsu Valley. There are some more specimens from loc. Iw786a.

Description.—The trail is represented by slender, free meandering strings. The length of the meanders is nearly equal to the height. One protrusion ramifies at the corners of the meanders. Many of the protrusions are short and stubby; some others are longer, flexuous and tapering, their length being nearly equal to the height of the meanders. The trail tends to exhibit some network pattern. The surface of the strings is smooth.

The strings are about 2 mm in thickness. The length or height of the meanders is between 1.3 and 1.8 cm.

Observation.—Considerable variations in shape of meanders and length of protrusions are recognized in the specimens at hand. In all the examined specimens one short, stubby protrusion branches off at many of the corners of the meanders. Longer, flexuous, tapering protrusions, on the other hand, are observed in GSJ6913 (Pl. IX, Fig. 1), GSJ6914 (Pl. IX, Fig. 4) and an imperfect specimen, GSJ6928. In GSJ6913 and GSJ6914 one long, meandering subsidiary trail ramifies at a certain corner of meander in the main trail, exhibiting some network pattern. Furthermore, GSJ6927 (Pl. IX, Fig. 3) forms a distinct, irregular network.

Comparison.—The described trails closely resemble *Protopaleodictyon incompositum* KSIAZKIEWICZ (1958, pl. 2, fig. 1; 1960, p. 737–738, 745–746, pl. 1, fig. 5, text-fig. 1; 1970, p. 303, text-fig. 4e) from the Eocene flysch of Poland, in the general size of the trail, the common ramification of one short protrusion at the corners of the meanders and the tendency towards forming irregular networks.

Protopaleodictyon is found also in the Cretaceous flysch of Spain and the Tertiary flysch of Austria and Spain (SEILACHER, 1958, table 1, 11).

Remarks.—The described forms are interpreted as feeding trails made by a vagile deposit-eating animal, i.e. Pascichnia.

Occurrence.—Pombetsu Valley, Mikasa City, central Hokkaido; upper part of Member Md (Md_3) and Member Me, Middle Yezo Group. Albian.

The trails are impressed as convex hyporeliefs or hypichnial ridges on the sole of sandstone layers.

Ichnogenus *Scolicia* DE QUATREFAGES, 1849

Scolicia sp.
Pl. XI, Fig. 2

Material.—A single specimen, GSJ6973, from loc. Iw786a, Pombetsu Valley.

Description.—The trail is represented by an irregularly curved, shallow groove of flattened ribbon-like shape. It is trilobate; the median lobe and the lateral lobes are bordered by a fairly distinct, narrow furrow. The median lobe is somewhat more depressed than the lateral lobes, and is of nearly the same breadth as the latter. The lateral lobes are inclined gently towards the median lobe. The median lobe is flat and is margined on both sides with a narrow, low, round-topped ridge. Both the median lobe (including the marginal ridges) and the lateral lobes are ornamented with numerous delicate transverse ribs produced by repeated displacement of sediment. The transverse ribs are broarder than the interspaces of them. In the lateral lobes the transverse ribs are oblique to the trend of the trail. The trail is fringed with flabby structures caused by burrowing.

The trail (excluding the marginal flabby structures) is about 1.5 to 1.8 cm wide, and about 2 mm in maximum depth. The median lobe is 5 to 6 mm in width.

Observation.—The marginal ridge of the median lobe is distinct throughout one side of the median lobe, but on the other side it is imprinted only in a limited portion of the length of the trail. In the former case the lateral lobe is markedly striped transversely. In this way, the trail is more distinctly imprinted on one side than on the other. The median lobe, though nearly smooth owing probably to the ill-preservation of the trail, is ornamented with transverse ribs only in its limited part where both marginal ridges also become stronger. Furthermore, the transverse ribs of the lateral lobe become thicker and more widely spaced in a certain outward curved part of the trail.

Comparison.—The described trail occurs on the top surface of a sandstone layer, thus being referred to "*Palaeobullia*," GÖTZINGER and BECKER, 1932, which has been regarded by various authors (e.g. HÄNTZSCHEL, 1962; SEILACHER, 1962, 1963a; FRANCISCO FARRÉS, 1963) as a synonym of *Scolicia*.

The specimen at hand most closely resembles one of the trails of *Scolicia* (type 6) from the Eocene flysch of Austria, figured by GÖTZINGER and BECKER (1934, text-fig. 4, 6), in that the median lobe is as wide as the lateral lobes and flat and is margined on both sides with a narrow, low, round-topped ridge and that the transverse ribs are delicate and dense.

The described form is similar also to *Scolicia plana* KSIAZKIEWICZ (1970, p. 289, pl. 1, fig. c) from the Cretaceous-Palaeogene flysch of the Polish Carpathians,

in the general features of the trail. However, in *S. plana* the median lobe has no marginal ridges and the ribbing is stronger in the median lobe than in the lateral lobes.

The present specimen resembles *S. prisca* DE QUATREFAGES from the Eocene flysch of Austria (ABEL, 1935, text-fig. 202; HÄNTZSCHEL, 1962, text-fig. 132, 4a), from the Maastrichtian flysch of Spain (GÓMEZ DE LLARENA, 1946, pl. 2, fig. 4) and from the Eocene flysch of the Polish Carpathians (KSIAZKIEWICZ, 1970, p. 289, pl. 1, fig. d), in the general features of the trail. However, there are some distinct differences between the Ikushumbetsu specimen and *S. prisca*. The median lobe is as wide as the lateral lobes and flat in the Ikushumbetsu specimen, while in *S. prisca* it is narrow and convex. Moreover, as compared with the case of *S. prisca,* the transverse ribs on both the median and the lateral lobes are thinner in the Ikushumbetsu trail.

The *Scolicia* trails figured by FRANCISCO FARRÉS (1963, text-fig. 6a–e) include various types. Among them, three types, with marginal ridges in the median lobe, from the Maastrichtian flysch of Spain (text-fig. 6c–e) are easily distinguishable from the described specimen, by its narrow axial furrow in the median lobe.

Remarks.—*Scolicia* trails have been interpreted by various authors (e.g. GÖTZINGER and BECKER, 1932; ABEL, 1935; SEILACHER, 1953) as crawling trails made by gastropods, i.e. Repichnia.

Occurrence.—Pombetsu Valley, Mikasa City, central Hokkaido; subdivision B of Member Me, Middle Yezo Group; Albian.

The preservation is in concave epirelief, i.e. epichnial groove on the upper bedding surface of a sandstone layer.

Ichnogenus *Spirorhaphe* FUCHS, 1895

Spirorhaphe (?) sp.
Pl. VIII, Fig. 3

Material.—A single specimen, GSJ6911, from loc. Iw786a, Pombetsu Valley.

Description.—The trail is composed of very slender, spirally coiled strings, with a rather wide loop in the centre. The strings are smooth and about 1 mm in thickness. The intervals between the strings are nearly equal to or slightly broader than the strings. The impression is about 2 cm across.

Comparison.—Although it cannot be confirmed whether the trail turning in the centre with a loop runs backwards between the primary coils, the described form is to be provisionally referred to *Spirorhaphe* on the basis of the general features of the trail. Judging from the size (diameter) of the impression, the imperfect U-turn in the centre and the small number of spirals, the described trail is regarded as representing the spiral portion at the comparatively high level of a multifloored, three dimentional burrow as inferred by SEILACHER (1967b, lower left-hand illustration on page 76).

The described specimen resembles *Spirorhaphe concentrica* KATTO (non AZPEITIA, 1932; FRANCISCO FARRÉS, 1963) (KATTO, 1964, p. 54, pl. 6, fig. 5, pl. 7, fig. 2) from the Eocene of eastern Shikoku, in some respects, but differs from that species by its slender strings.

The present form is to some extent similar to a form of *Spirorhaphe* from the Upper Cretaceous of Alaska, figured by HÄNTZSCHEL (1962, text-fig. 134,

3a). However, the distinction between the two forms is that the strings are more widely spaced in the former than in the latter.

Remarks.—The described form is interpreted as a feeding burrow made by a vagile mud-eater, i.e. Pascichnia.

Occurrence.—Pombetsu Valley, Mikasa City, central Hokkaido; Member Me, Middle Yezo Group; Albian.

The trail is in convex hyporelief or hypichnial ridge preservation on the sole of a sandstone layer.

Spiral sole trails (e.g. GSJ6982, Pl. X, Fig. 2) similar to the simple type without a central loop of *Spirorhaphe* (LESSERTISSEUR, 1955, p. 50, text-fig. 29, H1) or to *Spirophycus*, HÄNTZSCHEL, 1962, are occasionally found at loc. Iw786a and loc. Iw786b, Pombetsu Valley.

Ichnogenus *Zoophycos* MASSALONGO, 1855

Zoophycos sp.
Pl. X, Fig. 4

Material.—A single specimen, GSJ6975, from loc. Iw786a, Pombetsu Valley.

Description.—The impression is represented by a "Spreiten" structure consisting of a series of thin concentric laminae (corresponding to SIMPSON's (1970) lamellae) of varied outline and one thin marginal tube bordering them. The outline of the structure is not lobate but smooth. The concentric laminae are composed of alternating dark- and light-coloured sediments at irregular intervals, and have large but variable radius of curvature. The concentric laminae approach and join the marginal tube at acute angles. The laminae commonly show dichotomous branching.

The Spreiten structure is more than 13 cm in maximum length and about 9.5 cm in width. The concentric laminae are between 2 and 4 mm thick and about 15 cm in maximal length. The marginal tube is more than 1.5 mm and may reach 3 mm across.

Comparison.—Unfortunately, in the specimen at hand the proximal part of the Spreiten structure is missing and the marginal tube also is imprinted only in a limited part of the length. The present specimen, however, can be identified as *Zoophycos* on the basis of the characters described above.

Judging from the general features of the structure and the mode of occurrence, the described form is probably classified as the flat, nonspiral variety of *Zoophycos* as figured by SEILACHER (1964a, text-fig. 7, 13, table 1; 1967a, text-fig. 3, 1).

The specimen described here resembles a planar type of *Z. circinnatus* (BRONGNIART) from the Eocene flysch of Czechoslovakia (PLIČKA, 1968, pl. 108, fig. 4), but differs from that form by the less curved concentric laminae of the Spreiten structure.

Remarks.—*Zoophycos* has been interpreted as a feeding burrow by a polychaete annelid (BISCHOFF, 1968), i.e. Fodinichnia. On the other hand, PLIČKA's (1968, 1969) interpretation that *Zoophycos* represents the imprints of gill organs of sabellid worms is questionable, as pointed out by WEBBY (1969b). Sabellids including *Zoophycos* indicate a shallow-water marine environment with very rapid sedimentation (PLIČKA, 1968, 1970). SIMPSON (1970) also has stated that *Zoophycos* occurs in sediments of shelf-sea environment. According

to SEILACHER (1964a, 1967a), the flat, nonspiral form of *Zoophycos* is characteristic of the *Zoophycos* facies which is intermediate between the *Nereites* facies indicating bathyal environments and the *Cruziana* facies indicating littoral to sublittoral environments.

Occurrence.—Pombetsu Valley, Mikasa City, central Hokkaido; subdivision B of Member Me, Middle Yezo Group; Albian.

The structure is impressed on or just below the upper bedding surface of a poorly sorted, fine-grained sandstone layer.

In addition to the trace fossils described above, there are many other undeterminable forms including trails and burrows of worms or wormlike animals and excrements of unknown animals. Among them, some unnamed peculiar forms are described in the succeeding paragraphs.

Meandering trail
Pl. V, Fig. 4

Material.—GSJ6984, from loc. Iw786b, Pombetsu Valley.

Description.—The trail is represented by thin, meandering strings. The meanders are irregular, in part sigmoidal, being often cut one another on the same level. The strings are smooth and nearly constant in thickness.

The strings are 0.8 to 1 mm in thickness.

Remarks.—The described specimen is closely allied to *Helminthoida* (?) aff. *molassica* HEER (sole trail; KSIAZKIEWICZ, 1970, p. 298, text-fig. 2j) from the Oligocene of the Polish Carpathians, in the general features of the trail and the thickness of the strings. However, the meanders of the trail are much smaller in the former than in the latter. "*Helminthoida molassica*" has been reported from the Miocene molasse of Switzerland (SEILACHER, 1954, text-fig. 2, 6; 1963a, text-fig. 96). This form is considered as an endogene full relief, while the described trail as well as the Polish trail mentioned above is a sole trail.

The specimen at hand apparently resembles the reticulate trail to be described below, but differs from the latter in that the meanders are often cut one another on the same level.

The meandering trail described here is interpreted as a feeding trail made by a vagile animal, i.e. Pascichnia.

Occurrence.—Pombetsu Valley, Mikasa City, central Hokkaido; Member Me, Middle Yezo Group; Albian.

The trail is preserved as convex hyporeliefs, i.e. hypichnial ridges on the underside of a sandstone layer.

Reticulate trail
Pl. VII, Figs. 3–4

Material.—Two specimens, GSJ6909 and GSJ6966, from loc. Iw786a, Pombetsu Valley.

Description—The impression is represented by irregular networks consisting of variously flexuous-sided meshes. The meshes are greatly variable in size as well as in shape. They are generally of irregular shape, but occasionally deformed or irregular polygons and rectangles. The strings are thin and smooth.

The meshes are 3 to 12 mm across and 0.7 to 1.2 mm, averaging about 1 mm thick in GSJ6909, and 12 mm in maximum diameter and about 0.7 mm in thickness in another specimen, GSJ6966.

Remarks.—The described forms are most close to and probably identical with *Paleodictyon tenue* KORIBA and MIKI (1939, p. 61–62, pl. 5, fig. 4) from the Palaeogene of the Kii Peninsula, in the general features of the structure. However, it is doubtful whether the trail described and figured by KORIBA and MIKI belongs to the ichnogenus *Paleodictyon*, because the networks of the trail are extremely irregular. In the described specimens the strings occasionally overlap at the corners of the meshes.

Particularly, one of the specimens at hand, GSJ6966, closely resembles "irregular *Paleodictyon*" from the Middle Eocene flysch of Poland, figured by SIMPSON (1969, pl. 93, fig. 1), in the general features and size of the networks.

The specimens described here are apparently similar to the meandering trail described in the preceding paragraph. In the former the trail forms a reticulate pattern without intersecting on the same level, while in the latter it is often cut one another on the same level.

The present forms are interpreted as feeding trails made by vagile organisms, i.e. Pascichnia.

Occurrence.—Pombetsu Valley, Mikasa City, central Hokkaido; Member Me, Middle Yezo Group; Albian. The impressions are preserved as convex hyporeliefs, i.e. hypichnial ridges on the underside of sandstone layers.

Ribbon-shaped trail
Pl. XI, Fig. 3

Material.—A single specimen, GSJ6974, from loc. Iw786a, Pombetsu Valley.

Description.—The trail is represented by an irregularly curved, shallow groove. The groove consists of two rows of narrow, low, flat-topped axial ridges bordering two lateral lobes. The width of the axial ridges is nearly equal to or somewhat wider than the interspace of the axial ridges. The axial ridges are finely striped transversely. The lateral lobes are almost smooth but partly somewhat uneven. They are in some parts stuffed with pelitic material. The trail is fringed with flabby structures caused by burrowing.

The trail (excluding the marginal flabby structures) is between 1.5 and 2 cm in width and about 2 mm in maximum depth. The axial part consisting of two rows of ridges is about 2.5 to 3 mm wide.

Remarks.—The described form impressed on the sole of a sandstone layer is similar to the concave hyporelief of *"Subphyllochorda,"* GÖTZINGER and BECKER, 1932 which has been regarded by HÄNTZSCHEL (1962) and SEILACHER (1962, 1963a) as the lower side form of *Scolicia* DE QUATREFAGES, 1849.

The fossil in question is interpreted as a burrow made by a vagile bethonic animal during locomotion, i.e. Repichnia.

Occurrence.—Pombetsu Valley, Mikasa City, central Hokkaido; subdivision B of Member Me, Middle Yezo Group; Albian.

The trail is in concave hyporelief, i.e. *hypichnial groove* (a new term introduced here by myself) preservation on the sole of a sandstone layer.

U-shaped trace
Pl. IX, Fig. 5; Pl. XI, Fig. 1

Material.—GSJ6945, GSJ6946, GSJ6947 and GSJ6948, from loc. Iw5010, Ikushumbetsu Valley, and GSJ6951, from loc. Iw856, Pombetsu Valley. The specimens are all composed of numerous impressions.

Description.—The structure is represented by a narrow, strongly curved groove, which tends to exhibit a U-shaped pattern. The surface and sides of the groove are smooth. The groove (or burrow) is almost parallel to bedding and is sometimes filled with pelitic material. The groove is about 0.5 to 0.6 mm thick.

Remarks.—The burrows occur in common association with small circular pits representing the transverse section of the burrows on the top surface of sandstone layers. The described forms are considered as feeding burrows made by a *Polydora*-like annelid, i.e. Fodinichnia. It cannot be confirmed whether the specimens at hand have a "Spreiten" structure, consisting of a series of transverse laminae caused by burrowing, which is characteristic of *Polydora* burrows as noticed by LESSERTISSEUR (1955). In general, *Polydora* burrows occur on the surface of calcareous rocks and shells.

Similar structures have been reported from the Upper Cretaceous of Austria (ABEL, 1935, text-fig. 261A) and from the Maastrichtian flysch of Spain (GÓMEZ DE LLARENA, 1946, p. 153, pl. 5, fig. 22).

Occurrence.—Ikushumbetsu Valley, Mikasa City, central Hokkaido; upper part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. Pombetsu Valley, Mikasa City; middle part of Member Md (Md_2), Middle Yezo Group. Albian.

The described forms are preserved as endogene concave epireliefs, i.e. epichnial grooves on the top surface of sandstone layers. They occur gregariously, accompanied by a few trails of *Neonereites uniserialis* SEILACHER.

V. Concluding Remarks

In the Lower Cretaceous (Albian) flysch sequence, constituting the main part of the Middle Yezo Group of the Ikushumbetsu area, central Hokkaido, various types of animal trails and burrows are found on many sandstone soles and less commonly on the top surface and in the interior of sandstone layers. On the basis of the above descriptions the following remarks can be given as a conclusion.

Taxonomic results.—Sixteen identified species and four unnamed peculiar forms are listed below which have been described in this paper, indicating the ethological category in parentheses.

Chondrites sp. (Fodinichnia)
Glockeria parvula KSIAZKIEWICZ (Pascichnia combined with Domichnia)
Helminthoida japonica ichnosp. nov. (Pascichnia)
Helminthopsis akkesiensis (MINATO and SUYAMA) (Pascichnia)
Lorenzinia (?) sp. (Pascichnia)
Megagrapton sp. (Pascichnia)
Neonereites uniserialis SEILACHER (Repichnia)
Paleodictyon sp. aff. *P. strozzi* MENEGHINI (Pascichnia)
Paleodictyon latum VIALOV and GOLEV (Pascichnia)

Paleodictyon miocenicum SACCO (Pascichnia)
Paleodictyon sp. cf. *P. regulare* SACCO (Pascichnia)
Paleodictyon hokkaidoense ichnosp. nov. (Pascichnia)
Protopaleodictyon sp. (Pascichnia)
Scolicia sp. (Repichnia)
Spirorhaphe (?) sp. (Pascichnia)
Zoophycos sp. (Fodinichnia)
Meandering trail (resembling *"Helminthoida*? aff. *molassica* HEER" KSIAZKIEWICZ) (Pascichnia)
Reticulate trail (resembling *"Paleodictyon" tenue* KORIBA and MIKI) (Pascichnia)
Ribbon-shaped trail (resembling *Subphyllochorda*) (Repichnia)
U-shaped trace (resembling *Polydora* burrows) (Fodinichnia)

There are many other undeterminable forms including trails and burrows of worms or wormlike animals and excrements of unknown animals.

Character of the trace-fossil fauna.—Of the trace-fossil species listed above, two species are new to science and eight genera, *Chondrites, Glockeria, Lorenzinia* (?), *Megagrapton, Neonereites**, *Protopaleodictyon, Scolicia* and *Zoophycos*, have not hitherto been reported from Japan. Among the commonest trace fossils are *Helminthoida japonica, Neonereites uniserialis* and *Paleodictyon* with regular meshes. The occasional occurrence of *Spirorhaphe* (?) sp. and allied spiral forms also is worthy of mention.

Most of the trace-fossil genera from the Ikushumbetsu area are common to those from the Cretaceous to Palaeogene flysches of Europe (ABEL, 1935; SEILACHER, 1954, 1958, 1963a, 1963b, 1964a; KSIAZKIEWICZ, 1970). They are *Chondrites, Glockeria, Helminthoida, Helminthopsis, Lorenzinia, Megagrapton, Paleodictyon, Protopaleodictyon, Scolicia, Spirorhaphe* and *Zoophycos*. Moreover, trace fossils comparable with *Neonereites* are found in the Eocene flysch of northern Spain (SEILACHER, 1960). It follows from these facts that the Ikushumbetsu fauna closely resembles the European fauna, although not so many genera have been identified in the former.

The trace-fossil genera from the Ikushumbetsu Cretaceous flysch are referred to Pascichnia, i.e. feeding trails or burrows produced by vagile, mud-eating animals and subsidiary Fodinichnia, i.e. feeding burrows made by semisessile deposit-eaters and Repichnia, i.e. crawling trails or burrows made by vagile benthonic animals. On the other hand, entirely absent from the trace-fossil fauna are Cubichnia (SEILACHER, 1953), i.e. resting tracks or trails left by vagile animals and Domichnia (SEILACHER, 1953), i.e. dwelling burrows made by vagile or semisessile animals (excluding Pascichnia combined with Domichnia).

Judging from the above-mentioned ethological aspects of the fauna and the common occurrence of characteristic forms such as *Helminthoida* and *Paleodictyon*, it may well be said that the trace-fossil fauna, roughly speaking, belongs to the *Nereites* facies (SEILACHER, 1963c, 1964a) characteristic of geosynclinal areas or flysch facies.

It should be noticed here, however, that a flat, nonspiral form of *Zoophycos* is found in the flysch sequence, though very rarely. According to SEILACHER (1964a, 1967a), *Zoophycos* of planar type is characteristic of the *Zoophycos*

* *Nereites murotoensis* KATTO from the Eocene of Shikoku has been assigned by SEILACHER to *Neonereites* (ARITA, 1971).

facies which is intermediate between the deeper *Nereites* facies and the shallower *Cruziana* facies. Noteworthy is the abundant occurrence of *Neonereites* (Repichnia) at several levels, too. It has been stated by SEILACHER (1964a) that *Neonereites* occurs not only in the *Nereites* facies but also in shallower facies, i.e. the *Zoophycos* and the *Cruziana* facies. The ecological setting of *Neonereites* from the Ikushumbetsu flysch will be discussed below in some detail.

In short, part of the sediments of the Ikushumbetsu flysch somewhat indicate the *Zoophycos* facies.

Stratigraphical variation of the trace-fossil assemblages.—In the flysch formation of the Ikushumbetsu area trace fossils are most abundant in Member Me along the Pombetsu Valley. This member, though its upper limit is not observable in the field, is about 100 m thick, and is composed exclusively of thinnly alternating sandstone (mostly less than 15 cm thick) and mudstone (mostly less than 5 cm thick). It attracts one's attention that in spite of the lithological consistency the palaeocurrent pattern varies with subdivision (Table 1). Subdivisions B and F are characterized exclusively by transverse current directions intersecting at large angles the roughly N-S trending axis of the flysch basin, the source areas of which may have been situated to the west of the Ikushumbetsu area. Subdivision E is much dominated by longitudinal current directions which are nearly parallel to the axis of the flysch basin. Thus subdivisions B and F should be naturally interpreted as being of shallower, nearer-shore deposition on the whole than subdivision E.

From Table 1 it can be seen that the most characteristic trace fossils from Member Me are *Helminthoida* and *Paleodictyon* which are representatives of the communities of the *Nereites* facies. However, going into detail, minor but distinct vertical variations in trace-fossil content are noticed in the sequence. Of particular interest is the occurrence of a planar form of *Zoophycos* in subdivision B where the current directions are consistently transverse. The abundant occurrence of *Neonereites uniserialis* also is limited to the transverse current-deposited sequences, i.e. subdivisions B and F; such is the case with the middle part of Member Md (Md_2) along the Pombetsu Valley*. *Neonereites uniserialis*, however, is ubiquitous even in the longitudinal current-deposited sequence, as evidenced by the case of the upper part of the lower subdivision (Mb_1) of Member Mb along the Ikushumbetsu Valley. The implication of this will be explained below. *Neonereites uniserialis*, moreover, occurs in the sequences containing *Helminthoida japonica* and *Paleodictyon*, i.e. the lower part of the lower subdivision (Mb_1) of Member Mb, Ikushumbetsu Valley, deposited from longitudinal currents and subdivision B of Member Me deposited from transverse currents. Neither *Helminthoida japonica* nor *Paleodictyon* is found in subdivision F and Md_2. On the other hand, *Helminthoida japonica*, together with allied meandering trails, is most predominant in subdivision E which characteristically shows a longitudinal current pattern in contrast with subdivisions B and F.

It seems probable, therefore, that *Neonereites uniserialis* has a wider depth-range towards shallower environments than do *Helminthoida japonica* and *Paleodictyon*. In other words, this ichnofossil occurs not only in the *Nereites* facies but also in shallower facies, probably the *Zoophycos* facies. Moreover, the plentiful occurrence of *Neonereites uniserialis* is indicative of shallower environ-

* The sandstone layers on which *Neonereites uniserialis* occurs in groups in the Soeushinai area (see p. 11 of this paper) also show eastward, transverse current directions.

Table 1. Vertical variations of the trace-fossil assemblages and palaeocurrent pattern in Member Me of the Middle Yezo Group along the Pombetsu Valley Arabic figures indicate the approximate thickness in metres.

Locality	Member Subdivision	Characteristic trace fossils (*: dominant)		Ichnofacies	Palaeocurrent pattern
	Member Me G 8				Transverse (SE)
Iw779	F 19.5	*Neonereites uniserialis** (*Helminthoida* and *Paleodictyon* not yet found)		*Nereites* facies? to *Zoophycos* facies	Transverse (SE)
Iw786b	E 15	*Helminthoida japonica** *Helminthoida*-like meandering trails*	*Paleodictyon* spp.* *Spirorhaphe* (?) sp. Spiral trails	*Nereites* facies	Longitudinal (NNE)
Iw786a	D 12	*Helminthoida japonica*			Transverse (SE) and longitudinal (NNE)
Iw786a	C 17.5	*Helminthoida japonica*			Transverse (SE,E) and longitudinal (NNE)
Iw786a	B 14	*Neonereites uniserialis** *Zoophycos* (planar type)		*Nereites* facies to *Zoophycos* facies	Transverse (E)
Iw792	A 13.5	*Helminthoida japonica* *Paleodictyon* spp.		*Nereites* facies	Transverse (E,SE) and longitudinal (NNE)

ments than is that of *Helminthoida japonica* and *Paleodictyon*. Subdivision F represents an ichnofacies similar to that of subdivision B, although the available data are not sufficient for the ichnofacies interpretation. However, we had better regard subdivision F as being of shallower deposition than subdivision B, because neither *Helminthoida japonica* nor *Paleodictyon* is found in former. Thus the ichnofacies of the individual subdivisions of Member Me are interpreted as shown in Table 1.

It may be remarked here that crawling trails or burrows (Repichnia) other than *Neonereites uniserialis*, e.g. *Scolicia* sp. and the described ribbon-shaped trail are found only in the laterally derived sediments, i.e. subdivision B. *Glockeria parvula*, a stellate feeding trail (Pascichnia) combined with a dwelling burrow (Domichnia), also occurs in subdivision B. On the other hand, another starlike trail, *Lorenzinia* (?) sp., is found in subdivision E which may have been of deeper deposition than subdivision B.

To sum up, the sediments of Member Me along the Pombetsu Valley are mostly referred to the *Nereites* facies but partly to a shallower, nearer-shore facies, e.g. the *Zoophycos* facies (Table 1). In this manner, it is clear that the vertical variation of the ichnofacies in this sequence bears an initimate relation to that of the depositional environments of the strata.

In connection with the above, the ichnofacies of various horizons lower than Member Me, too, are interpreted as follows, indicating the characteristic trace fossils (asterisk, dominant) in parentheses.

Locality	Horizon	Ichnofacies	Palaeocurrents
Iw875	Upper part of Member Md (Md_3)	Undetermined (Spiral trail)	Transverse (E)
Iw856	Middle part of Member Md (Md_2)	*Nereites* facies? to *Zoophycos* facies (*Neonereites uniserialis**)	Transverse (E, SE)
Iw5010	Upper part of the lower subdivision (Mb_1) of Member Mb	*Nereites* facies to *Zoophycos* facies? (*Neonereites uniserialis**)	Longitudinal (NNE)
Iw5008	Lower part of the lower subdivision (Mb_1) of Member Mb	*Nereites* facies (*Helminthoida japonica*, *Paleodictyon* spp. and *Neonereites uniserialis*)	Longitudinal (NNE)
Iw905	Upper part of Member Ma (Ma_3)	*Nereites* facies (*Paleodictyon* spp.*)	Longitudinal (NNE)

In the longitudinally deposited sequences (Ma_3, lower Mb_1 and upper Mb_1 in ascending order), *Neonereites uniserialis* increases upwards in number in quite contrast with *Paleodictyon*. The longitudinal current-deposited sequence abounding in *Neonereites uniserialis*, i.e. the upper part of Mb_1 is interpreted as showing shallower environments on the whole than the sediments of the typical *Nereites* facies. If this be true, it will be inferred that the depositional environment became shallower as the time lapsed from Ma_3 through lower Mb_1 to upper Mb_1.

Furthermore, it must be noted that the neritic Mikasa Formation overlying the flysch series contains a number of trace fossils characterized by a "Spreiten" structure.

Comparison with the trace-fossil fauna of the Shimanto terrane.—The trace-fossil fauna of the Ikushumbetsu area is compared with that of the Cretaceous to Palaeogene, dominated by flysch deposits, in the Shimanto terrane of Southwest Japan (e.g. the Kii Peninsula and Shikoku) including Okinawa. The Shimanto fauna of Shikoku (FUKADA, 1951; KATTO, 1952, 1960a, 1960b, 1964; ARITA, 1971) is composed mostly of trace fossils from the Palaeogene. The Palaeogene fauna comprises a large variety of trace fossils such as *Helminthoida, Paleodictyon, Spirorhaphe* and *Ulohelminthoida*. However, in Shikoku *Helminthoida* and *Paleodictyon* which are characteristic of and predominant in the Ikushumbetsu fauna are not found from the Cretaceous strata.

The Palaeogene ichnofauna of the Kii Peninsula (KORIBA and MIKI, 1939; MIZUNO and IMAI, 1964; HARATA, 1965; HARATA and others, 1967; KISHU SHIMANTO RESEARCH GROUP, 1970) is very similar to that of Shikoku, comprising *Paleodictyon* in addition to *Helminthopsis* and others. But the occurrence of *Helminthoida* and *Spirorhaphe*, representatives of the *Nereites* facies, has not been reported from the Kii Peninsula.

The trace-fossil fauna from the probable Lower Cretaceous of Okinawa (KONISHI, 1963), like the Ikushumbetsu fauna, comprises *Helminthoida, Helminthopsis*? (=KONISHI's *Helminthoida* type B) and *Paleodictyon*.

From the facts described above it is concluded that the Cretaco-Palaeogene trace-fossil faunas of the Shimanto terrane have some resemblance to the Ikushumbetsu fauna, and therefore show the *Nereites* facies on the whole.

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(Written in June 1971)

北海道幾春別地域白亜紀フリッシュ層産の生痕化石

田 中 啓 策

要 旨

北海道幾春別地域の白亜系のうち，三笠層の下位の中部蝦夷層群主部を構成するフリッシュ層においては，種々の生痕化石が砂岩層の下底面や頂上面に多数みられ，さらに砂岩層の内部にも含まれている。これらの生痕化石について，12属16種と同定不能の４タイプの化石（第22頁参照）を記載した。２種は新種，８属は本邦に未知である。

生痕化石のうち，*Helminthoida japonica*，*Neonereites uniserialis* および *Paleodictyon*（網目構造が規則的なタイプ）が代表的であり，さらに *Spirorhaphe*（？）sp. や類似の渦巻状のものも目立っている。幾春別地域の白亜紀フリッシュ層の生痕化石群集は，ヨーロッパの白亜紀～古第三紀フリッシュに普遍的な属と共通のものを多く含み，また西南日本四万十帯の白亜紀～古第三紀生痕化石群集とも比較的類似している。

生痕化石群集における属に関しては，生態的にみてPascichnia(クイアルキアト)が優勢，Fodinichnia(スミクイアト)が従属的で，さらに Repichnia（ハイアルキアト）も存在するが，Cubichnia（ヤスミアト）や Domichnia(スマイアト)は全くみられない。このような生態的特徴と，*Helminthcida*，*Paleodictyon* や *Spirorhaphe* 型のものが優勢なことから，問題の生痕化石群集は全体として地向斜地域，またはフリッシュ相の地層を特徴づける *Nereites* 相を示す。しかし，平面型の *Zoophycos* がごくまれながら産出するので，幾春別地域のフリッシュ層の一部には，*Nereites* 相よりも浅い環境を示す *Zoophyccs* 相が認められる。

生痕化石は，このフリッシュ層のうち，奔別川流域の Me 部層中において最も多くみられる。この地層では，上下を通じての均一な岩相(砂岩泥岩細互層)にもかかわらず，古流系からみた堆積環境の違いに応じて，生痕化石相も変化している。最も浅い環境と推定される部分には平面型の *Zoophycos* がみいだされ，あるいは *Neonereites uniserialis* が多産している。いっぽう，*Helminthoida japonica* は最も深いと推定される部分に最も優勢である。*Neonereites uniserialis* は，産状，*Helminthoida*，*Paleodictyon* との産出関係，産出地層の堆積環境などからみると，*Nereites* 相のみならず，より浅い相（おそらく*Zoophycos*相）にも分布するといえる。しかも，*Neonereites uniserialis* は典型的な *Nereites*相よりも浅い相を示す地層中に多産する。

PLATES
AND
EXPLANATIONS

(With 11 Plates)

PLATE I

Figs. 1–2. *Helminthoida japonica* ichnosp. nov.

1. Paratype, GSJ6905, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.1.
2. Paratype, GSJ6921, on sole of sandstone, from loc. Iw786b, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.

Y. Masai photos

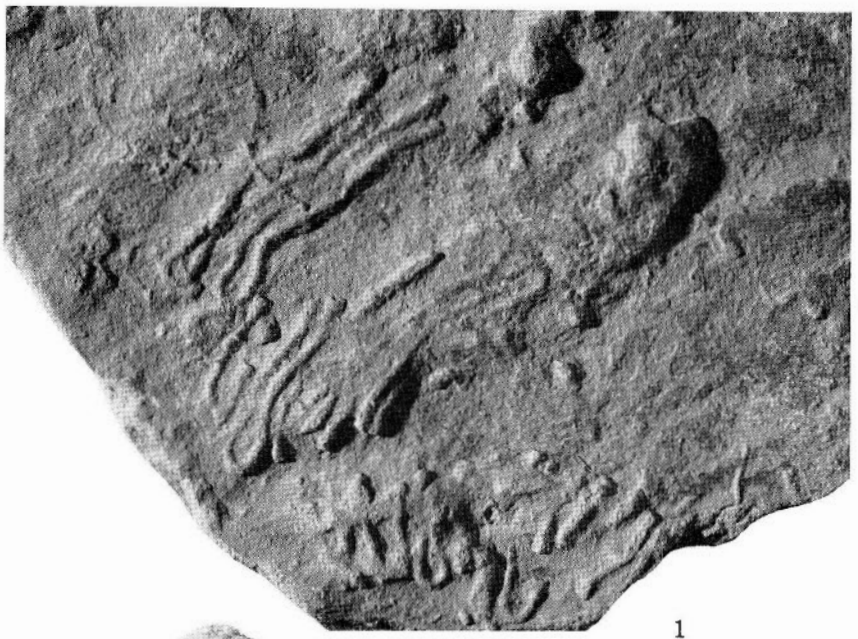

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PLATE II

Fig. 1. *Helminthoida japonica* ichnosp. nov.
Holotype, GSJ6971, on sole of sandstone, from loc. Iw786b, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×0.8.

Fig. 2. *Helminthopsis akkesiensis* (MINATO and SUYAMA)
GSJ6923, on sole of sandstone, from loc. Iw792, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.

Fig. 3. *Chondrites* sp.
GSJ6904, on top surface of sandstone, from loc. Iw5010, Ikushumbetsu Valley, Mikasa City, central Hokkaido, upper part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. ×1.

Y. MASAI photos

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PLATE III

Figs. 1–2. *Helminthoida japonica* ichnosp. nov.

1. Paratype, GSJ6906, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.
2. GSJ6919, on sole of sandstone, from loc. Iw786b, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.

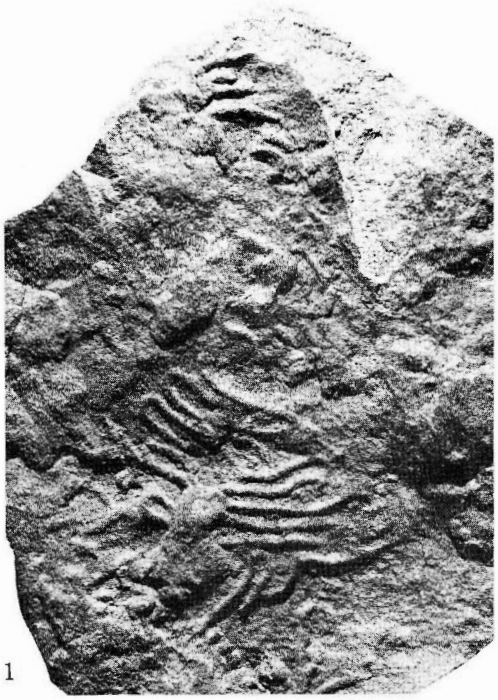
Fig. 3. *Lorenzinia* (?) sp.

GSJ6931, on sole of sandstone, from loc. Iw786b, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.5.

Fig. 4. *Helminthopsis akkesiensis* (MINATO and SUYAMA)

GSJ6924, on sole of sandstone, from loc. Iw792, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.

Y. MASAI photos



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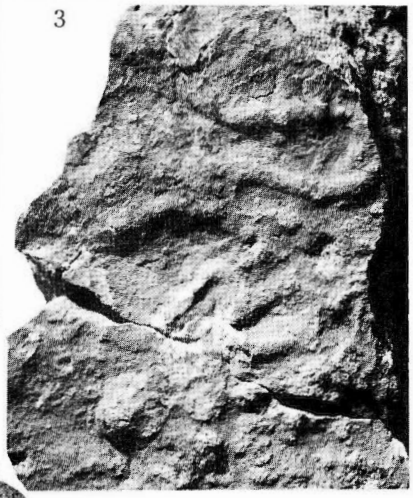

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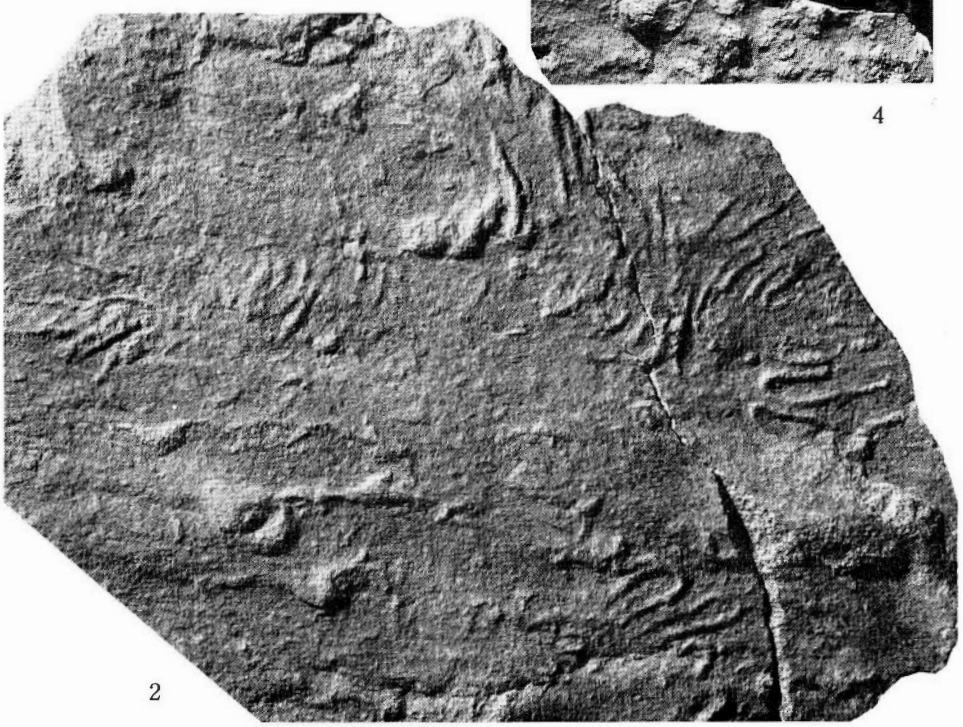

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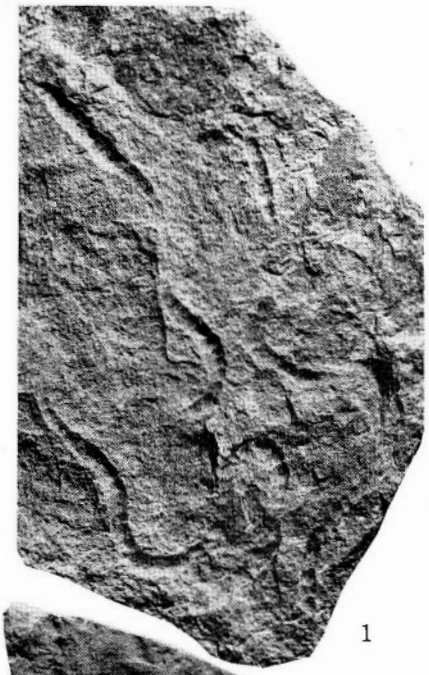
PLATE IV

Figs. 1–5. *Neonereites uniserialis* SEILACHER

1. GSJ6910, on top surface of sandstone, from loc. Iw5010, Ikushumbetsu Valley, Mikasa City, central Hokkaido, upper part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. ×1.
2. GSJ6902, on top surface of sandstone, from loc. Iw5010, Ikushumbetsu Valley, Mikasa City, central Hokkaido, upper part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. ×1.
3. GSJ6900, on top surface of sandstone, from loc. Iw779, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×0.6.
4. GSJ6903, on top surface of sandstone, from loc. Iw5010, Ikushumbetsu Valley, Mikasa City, Central Hokkaido, upper part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. ×1.
5. GSJ6932, on top surface of sandstone, from loc. Iw5010, Ikushumbetsu Valley, Mikasa City, central Hokkaido, upper part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. ×1.2.

Y. MASAI photos



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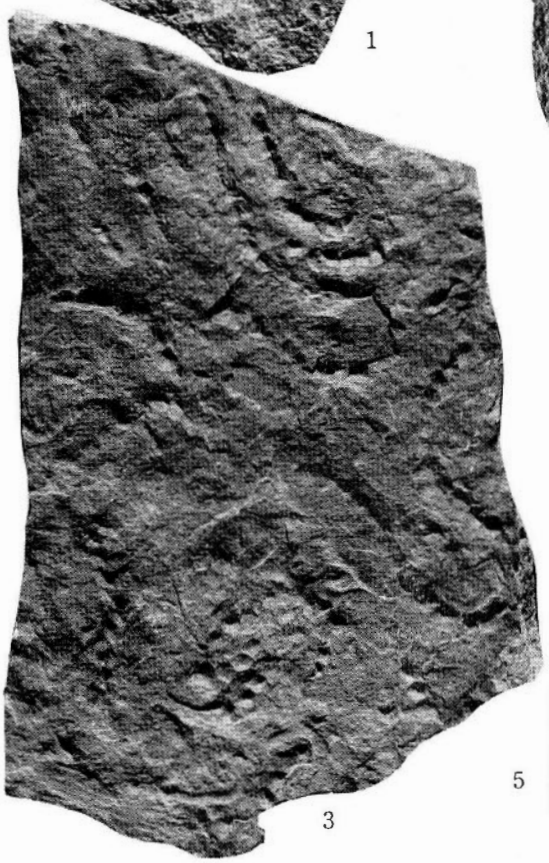

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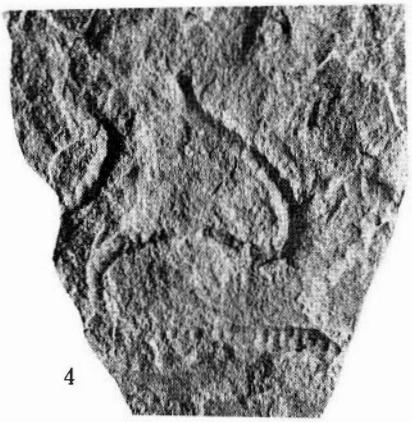

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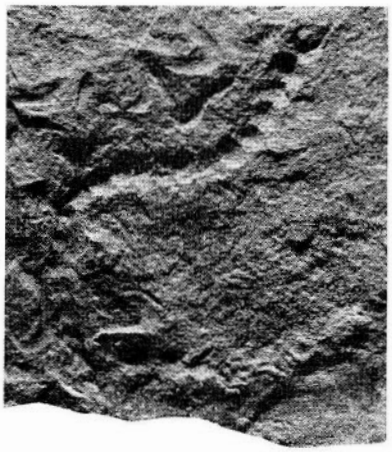

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PLATE V

Fig. 1. *Megagrapton* sp.
GSJ6983, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×0.5.

Fig. 2. *Paleodictyon miocenicum* SACCO
GSJ6956, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.5.

Fig. 3. *Neonereites uniserialis* SEILACHER
GSJ6980, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×0.6.

Fig. 4. Meandering trail
GSJ6984, on sole of sandstone, from loc. Iw786b, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.3.

Y. MASAI photos

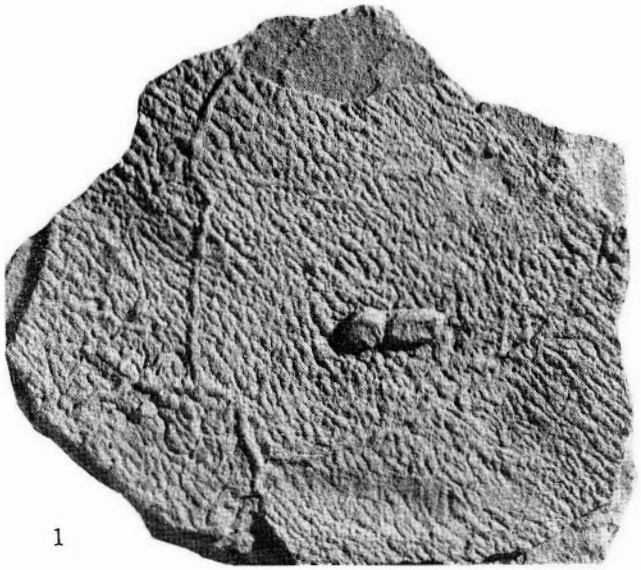

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PLATE VI

Figs. 1–2. *Paleodictyon latum* VIALOV and GOLEV

1. GSJ6952, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×2.
2. GSJ6907, on sole of sandstone, from loc. Iw5008, Ikushumbetsu Valley, Mikasa City, central Hokkaido, lower part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. ×2.

Fig. 3. *Paleodictyon miocenicum* SACCO

GSJ6976, on sole of sandstone, from loc. Iw786b, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.5.

Figs. 4–7. *Neonereites uniserialis* SEILACHER

4. GSJ6901, at boundary between sandstone and overlying shale or near base of shale, from loc. Iw5010, Ikushumbetsu Valley, Mikasa City, central Hokkaido, upper part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. ×1.
5. GSJ6949, on top surface of sandstone, from loc. Iw5010, Ikushumbetsu Valley, Mikasa City, central Hokkaido, upper part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. ×1.
6. GSJ6936, at boundary between sandstone and overlying shale, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.2.
7. GSJ6933, on sole of sandstone, from loc. Iw5010, Ikushumbetsu Valley, Mikasa City, central Hokkaido, upper part of the lower subdivision (Mb_1) of Member Me, Middle Yezo Group. ×1.

Y. MASAI photos

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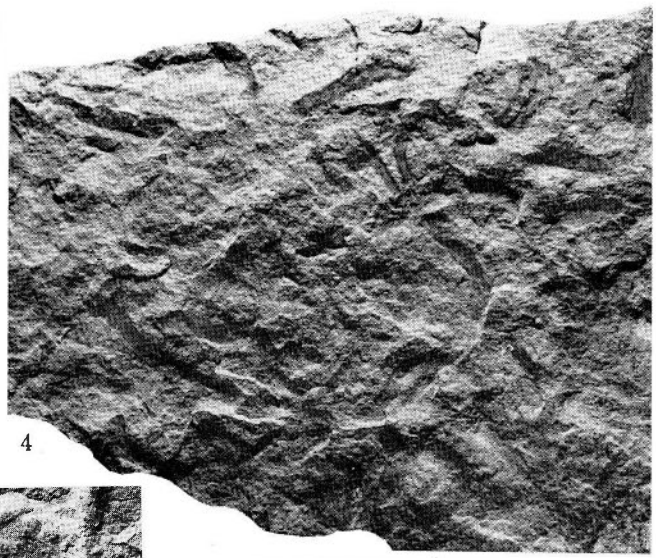

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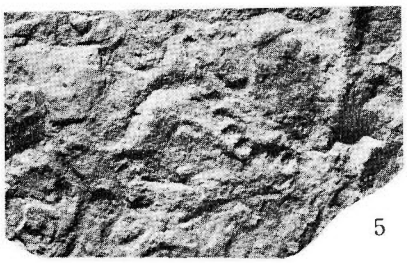

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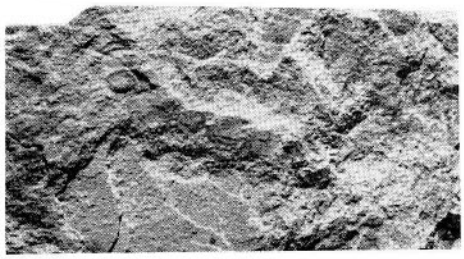

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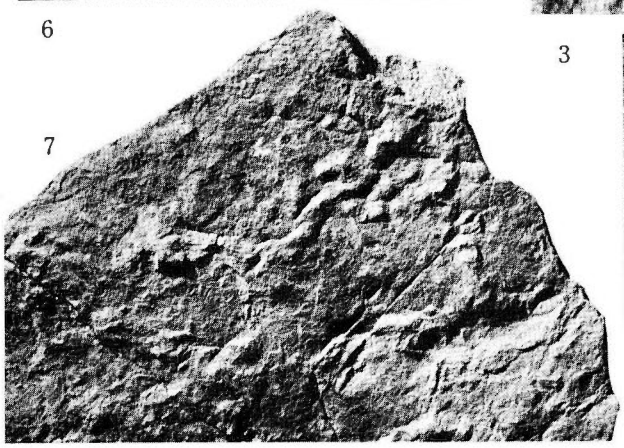

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PLATE VII

Fig. 1. *Paleodictyon* sp. aff. *P. strozzi* MENEGHINI
GSJ6968, on sole of sandstone, from loc. Iw786b, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.5.

Fig. 2. *Paleodictyon* sp. cf. *P. regulare* SACCO
GSJ6858, on sole of sandstone, from loc. Iw786b, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×2.

Figs. 3–4. Reticulate trail

3. GSJ6966, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×2.
4. GSJ6909, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.

Y. MASAI photos

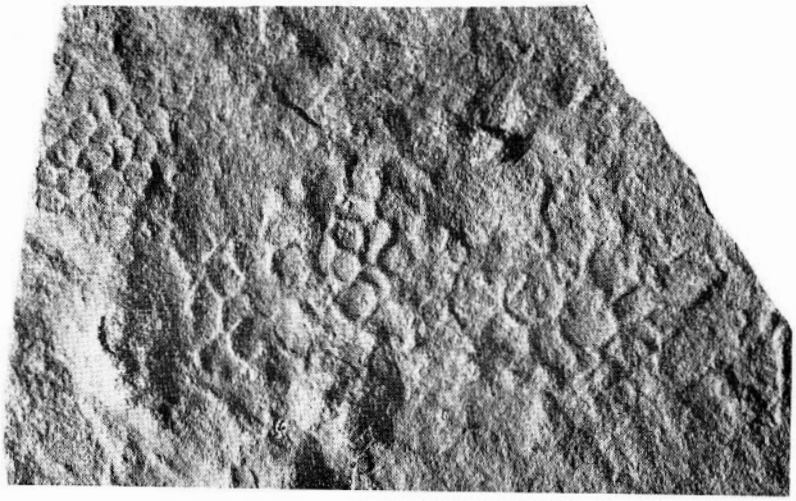

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PLATE VIII

Fig. 1. *Paleodictyon hokkaidoense* ichnosp. nov.
Holotype, GSJ6964, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.

Fig. 2. *Paleodictyon* sp. aff. *P. strozzi* MENEGHINI
GSJ6963, on sole of sandstone, from loc. Iw786b, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.5.

Fig. 3. *Spirorhaphe* (?) sp.
GSJ6911, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.5.

Y. MASAI photos

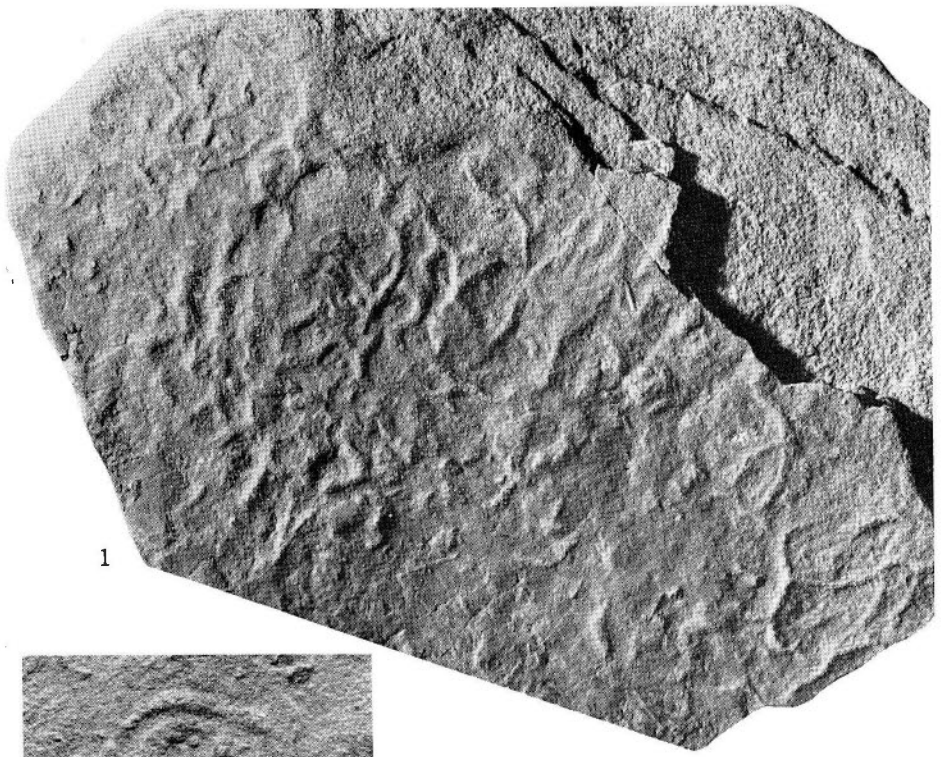

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PLATE IX

Figs. 1–4. *Protopaleodictyon* sp.

1. GSJ6913, on sole of sandstone, from loc. Iw875, Pombetsu Valley, Mikasa City, central Hokkaido, upper part of Member Md (Md_3), Middle Yezo Group. ×1.
2. GSJ6912, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.2.
3. GSJ6927, on sole of sandstone, from loc. Iw786b, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.
4. GSJ6914, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.

Fig. 5. U-shaped trace

GSJ6948, on top surface of sandstone, from loc. Iw5010, Ikushumbetsu Valley, Mikasa City, central Hokkaido, upper part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. ×1.

Y. Masai photos

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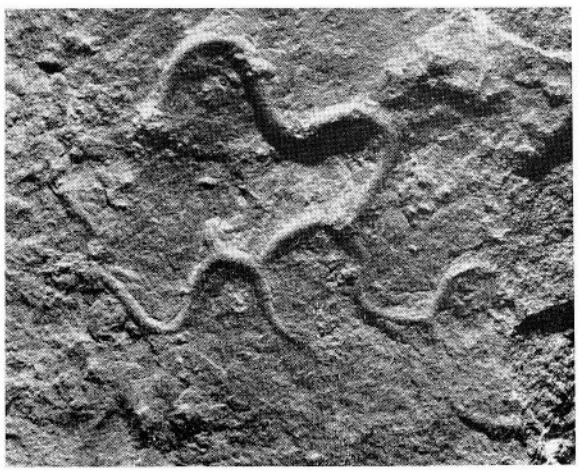

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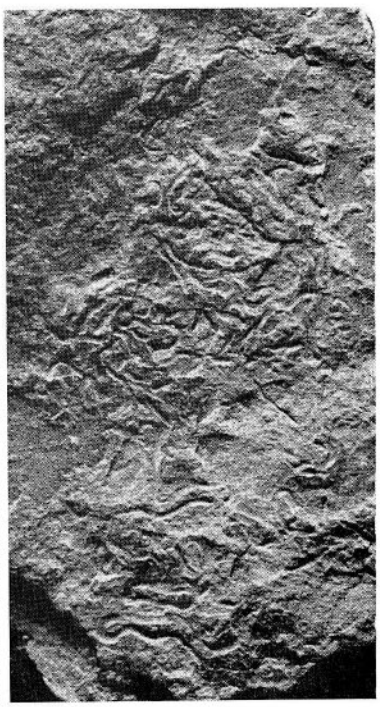

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PLATE X

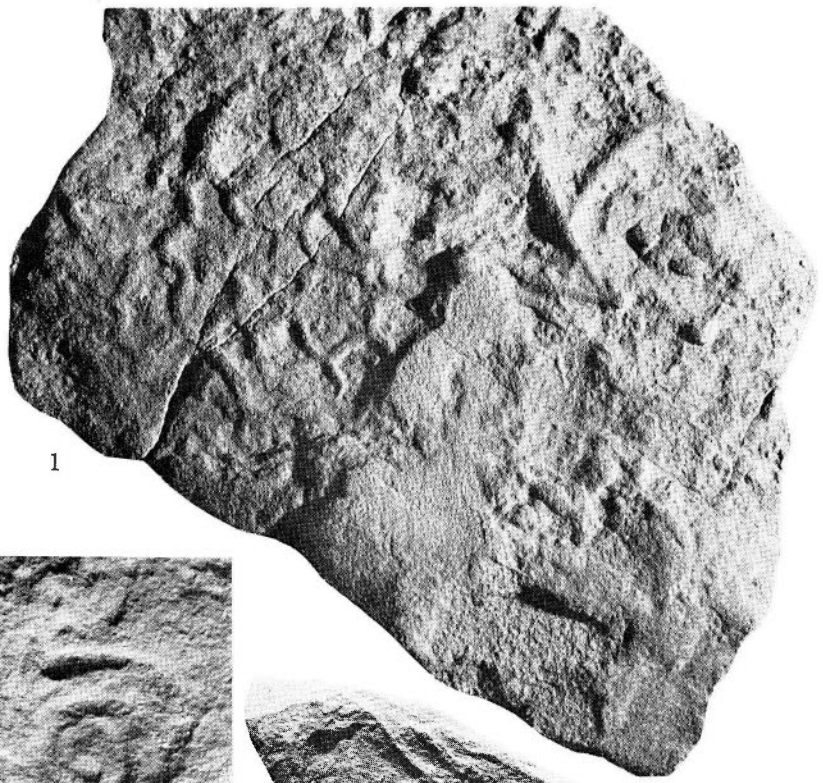
Fig. 1. *Paleodictyon hokkaidoense* ichnosp. nov.
Paratype, GSJ6965, on sole of sandstone, from loc. Iw5008, Ikushumbetsu Valley, Mikasa City, central Hokkaido, lower part of the lower subdivision (Mb_1) of Member Mb, Middle Yezo Group. ×1.

Fig. 2. Spiral trail
GSJ6982, on sole of sandstone, from loc. Iw786b, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.6.

Fig. 3. *Glockeria parvula* KSIAZKIEWICZ
GSJ6972, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×1.

Fig. 4. *Zoophycos* sp.
GSJ6975, on top surface of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×0.7.

Y. MASAI photos



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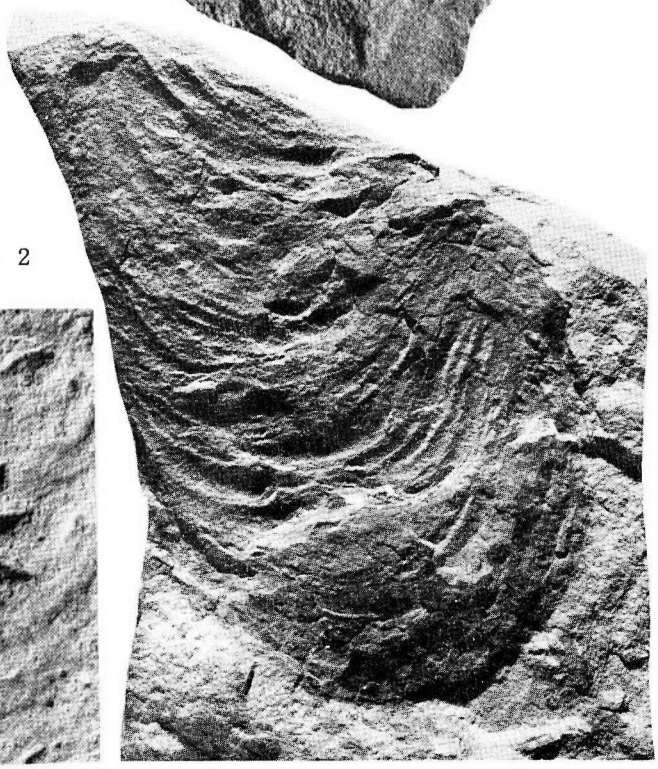

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PLATE XI

Fig. 1. U-shaped trace

GSJ6946, on top surface of sandstone, from loc. Iw5010, Ikushumbetsu Valley, Mikasa City, central Hokkaido, upper part of the lower subdivision (Mb_1) of Member Me, Middle Yezo Group. ×1.5.

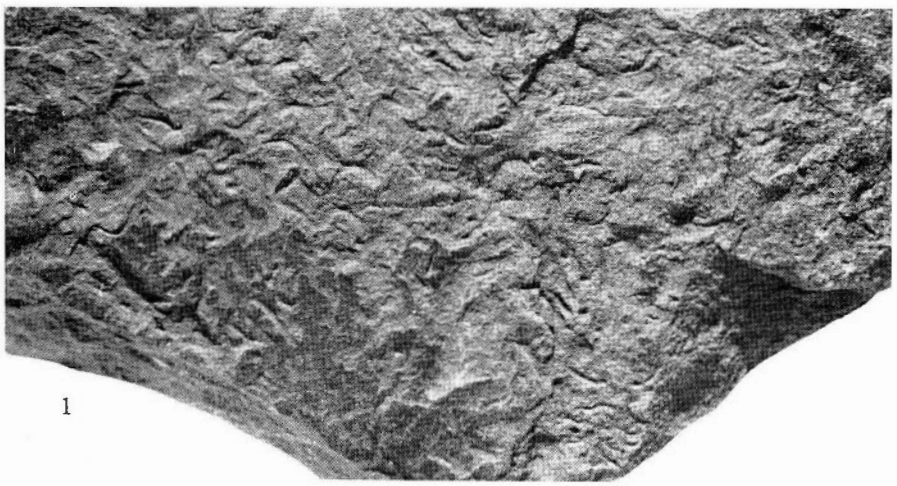
Fig. 2. *Scolicia* sp.

GSJ6973, on top surface of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×0.9.

Fig. 3. Ribbon-shaped trail

GSJ6974, on sole of sandstone, from loc. Iw786a, Pombetsu Valley, Mikasa City, central Hokkaido, Member Me, Middle Yezo Group. ×0.7.

Y. MASAI photos



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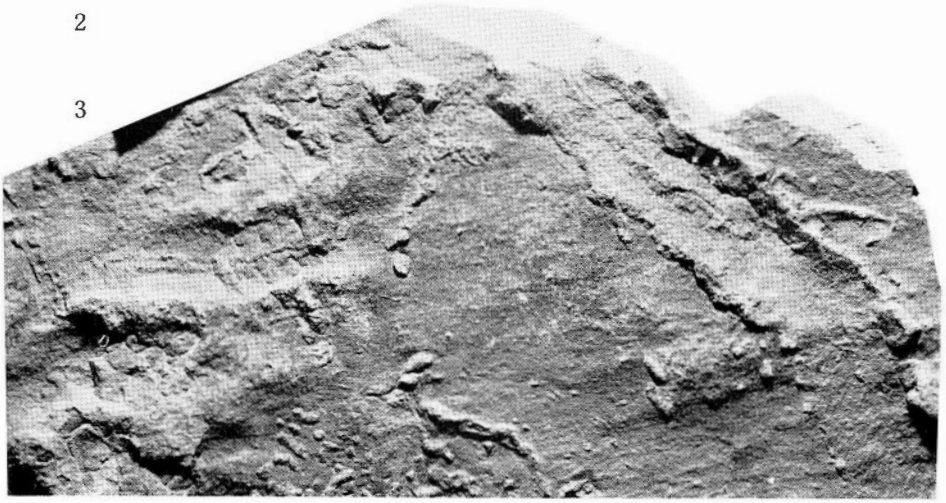

地質調査所報告は1報文について報告1冊を原則とし，その分類の便宜のために，次のようにアルファベットによる略号をつける。

A. 地質およびその基礎科学に関するもの
- a. 地　質
- b. 岩石・鉱物
- c. 古生物
- d. 火山・温泉
- e. 地球物理
- f. 地球化学

B. 応用地質に関するもの
- a. 鉱　床
- b. 石　炭
- c. 石油・天然ガス
- d. 地下水
- e. 農林地質・土木地質
- f. 物理探鉱・化学探鉱および試錐

C. そ の 他

D. 事業報告

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A. Geological & allied sciences
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- b. Petrology and Mineralogy
- c. Paleontology
- d. Volcanology and Hot spring
- e. Geophysics
- f. Geochemistry

B. Applied geology
- a. Ore deposits
- b. Coal
- c. Petroleum and Natural gas
- d. Underground water
- e. Agricultural geology and Engineering geology
- f. Physical prospecting, Chemical prospecting and Boring

C. Miscellaneous

D. Annual Report of Progress

地 質 調 査 所 報 告

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Trace Fossils from the Cretaceous Flysch of the Ikushumbetsu Area, Hokkaido, Japan

Keisaku TANAKA

Report, Geological Survey of Japan, no. 242, p. 1~32, 1971
1 illus., 11 pl., 1 tab.

Animal trails and burrows from the Cretaceous flysch, constituting the main part of the Middle Yezo Group of the Ikushumbetsu area, Hokkaido, are described. Some of them are recorded in literature; others are new. Brief remarks are given on the character of the ichnofauna and the stratigraphical variation of the ichnofacies.

562/569 : 551.763 (524)

昭和 46 年 10 月 16 日　印　刷
昭和 46 年 10 月 21 日　発　行

工業技術院地質調査所

印刷者　小 林 銀 二
印刷所　泰成印刷株式会社
東京都墨田区両国 3 — 1 —12

地 質 調 報
Rept. Geol. Surv. J.
No. 242, 1971