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# TRACE FOSSILS IN THE FLYSCH OF THE POLISH CARPATHIANS

(ICHNOSKAMIENIAŁOŚCI Z OSADÓW FLISZOWYCH KARPAT POLSKICH)

BY

MARIAN KSIĄŻKIEWICZ

(WITH 45 TEXT-FIGURES AND 29 PLATES)

WARSZAWA — KRAKÓW 1977

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# ABSTRACT

The ichnofauna of the flysch in the Polish Carpathians described herein consists of 56 ichnogenera and 151 ichnospecies. In this assemblage 6 new ichnogenera and 40 new ichnospecies have been described. The ichnofossils are divided into ten informal morphological groups. Ethologically most of the Carpathian trace fossils belong to *Pascichnia*, some to *Repichnia* and presumably to *Fodinichnia*, and very few to other ecological groups. The ichnofauna occurs in beds of uppermost Jurassic, Cretaceous and Palaeogene age. It attains the maximum development in the Senonian and in the early Palaeogene. The vertical and lateral distribution of the ichnofauna seems to support the assumption that the Carpathian flysch was mostly deposited at bathyal depths.

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Fig. 1

Map of the Carpathian flysch zone with localities in which an effective search for trace fossils was made, *A—A* northern border of the flysch zone; *B—B* southern border of the flysch zone

# INTRODUCTION

Many geologists working in the Carpathian flysch zone noted biogenic structures, currently termed "trace fossils". Some of these structures were considered to be remains of plants. PUSCH (1837), GLOCKER (1841) and ETTINGHAUSEN (1863) described several "fucoids" and fucoid-like traces as plants. ROTHPLETZ (1896) also mentioned a few occurrences of "fucoids" in the Polish Carpathians. Other biogenic structures were simply called "hieroglyphs", and the early workers made no accurate distinction between hieroglyphs of mechanical and of biogenic origin. Some traces were regarded as imprints of medusae (ZUBER, 1910 & KUŹNIAR, 1911). Certain traces, named but not described or illustrated, were included in the lists of fossils given in the classic paper of HOHENEGGER (1861). In many papers on the stratigraphy and regional geology of the Carpathian flysch zone trace fossils, usually treated as "problematica", were mentioned and in some cases illustrated (ZUBER, 1918). Until recently no special papers were devoted to the problems of the Carpathian ichnofauna. During last twenty years a few papers appeared presenting results of more detailed research. NOWAK published papers on stellate traces (1956), on paleodictyonids (1959, partly based on the material collected by the present author) and *Belorhaphe* (1970), and the present author (KSIĄŻKIEWICZ, 1958, 1960, 1961, 1968) reported on a number of trace fossils, little known or unknown from the Carpathian flysch. In 1970, on the occasion of the International Symposium on Trace Fossils in Liverpool, he presented a general review on his research on the ichnofauna in the Polish Carpathians. In this paper some forty ichnogenera were reported.

The author's research on the Carpathian ichnofauna dates from the beginning of his studies in the Carpathians in 1926. While mapping, trace fossils were collected or noted, but only in more recent years was he able to concentrate on this subject. At first the search for trace fossils was limited only to the mapped areas in the western part of the flysch zone, but in a last few years "tracking" might have been extended over the whole area of the Polish Carpathians (text-fig. 1). This vast region was studied as uniformly as possible. Each stratigraphic horizon of the flysch was examined in several localities and the best exposed sections were chosen for this purpose. The localities in which trace fossils were found are indicated on the map (text-fig. 1). As seen on it, the localities are much more numerous in the west than in the east. This is caused mainly by the difference in structure: in the western part of the range the tectonics is more complex and, consequently, formations exposed on the surface are much more numerous than in the east, where the tectonics is much simpler, and fewer horizons occur on the surface. In addition, in the east Oligocene beds occupy vast areas. They are barren in most places; many of the localities visited afforded no trace fossils. These places are not marked on the map.

About 3000 specimens have been collected by the author, and more than 2000 have been specifically determined. They are housed in the Department of Geology of the Jagellonian University of Cracow (abbreviated as UJ), registered in the division marked TF (trace fossils). In this Department there are also deposited some specimens collected by W. SZAJNOCHA, K. WÓJCIK and H. ZAPAŁOWICZ before 1914. A few specimens described in this paper were lent to the author from other collections in Poland: Geological Survey of Poland (abbreviated

IG Warsaw) and its Cracow Branch (abbreviated IG Cracow), Geological Institute of the Academy of Mines in Cracow (abbreviated as AGH) and the Museum of the Geological Institute of the Polish Academy of Science, Cracow branch (abbreviated ZNG).

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To all the persons and institutions mentioned above the author expresses his warmest thanks.

# GENERAL PART

## GEOLOGICAL SETTING

Within the Polish territory the Carpathian Mountains form a zone about 300 km long and up to 100 km broad. Their northern part is known as the "Flysch Carpathians", since it is composed mostly of flysch type deposits, approximately 6000 m thick. Their sedimentation began towards the end of the Upper Jurassic, and lasted without interruption until the end of the Lower Miocene.

The stratigraphy of the flysch deposits is rather well known on the basis of the microfauna and fairly common large fossils. It is presented in table 1 in a somewhat simplified manner, according to the results presented in the papers of BIEDA *et al.* (1963) and GEROCH *et al.* (1967), with some minor alterations. The Middle Miocene folding produced several thrusts directed northward which divided the flysch zone into several nappes. South of the folded outer zone is situated the Pieniny "Klippen" zone, in which certain stratigraphic members are also developed in flysch facies. From the south the Pieniny zone is bordered by the Podhale flysch of Late Palaeogene age. This was deposited on the inner Carpathian zone (the Tatra Mts within the Polish territory) which was folded before the Palaeogene. In spite of the complex tectonics of the Carpathian range, the flysch rocks were not markedly tectonized, a feature promoting the preservation of trace fossils. This favourable feature if often offset by severe jointing.

## TOPONOMY OF TRACE FOSSILS

(table 2; text-fig. 3)

The trace fossils in flysch deposits occupy various positions in relation to bedding. Flysch, as is well known, consists of coarser beds (sandstones, limestones, siltstones) alternating with fine-grained layers (mudstones, marlstones, argillites, clay). Following F. SIMPSON (1970) the former are called element I, and the latter — element II. According to current views element I was produced by currents which more or less instantaneously introduced material into the basin. Therefore the interface between element II and I is sharp. Element II may represent an indigenous sediment. But in many instances the contact between element I and II is not sharp but intergradational (KSIĄŻKIEWICZ, 1954). This implies that a part or the whole of element II may be a product of selection of the material brought in by the current (RADOMSKI, 1960). Probably in most cases only a thin layer of a very fine-grained sediment (clay) of the uppermost part of element II represents a true pelagic deposit. In some instances it may be missing, washed away by the current, in others the material in the current did not undergo selection before deposition, and the lower current-borne part of element II was not formed. Accordingly, the following types of flysch sequences may exist: 1. element II is allochthonous in the lower part, and autochthonous (pelagic) in the upper part; 2. element II is wholly autochthonous; 3. element II is wholly allochthonous (text-fig. 2).

Table 1

STRATIGRAPHY OF THE CARPATHIAN FLYSCH

| | | SKOLE NAPPE | SUBSILESIAN NAPPE | SILESIAN NAPPE | DUKLA SCALES | MAGURA NAPPE | PIENINY ZONE |
|---|---|---|---|---|---|---|---|
| OLIGOCENE | | Krosno Beds<br>Menilitic Shales | Krosno Beds<br>Menilitic Shales | Krosno Beds<br>Menilitic Shales | Krosno Beds<br>Menilitic Shales | Magura Sandstone | |
| EOCENE | Upper | Globigerina Marls | Globigerina Marls | Globigerina Marls | Globigerina Marls | | Magura Type Sandstone |
| | Middle | Hieroglyphic Beds | Hieroglyphic Beds | Hieroglyphic Beds | Hieroglyphic Beds and Variegated Shales | Variegated Shales; Hieroglyphic Beds; Pasierbiec Sd.; Łącko B. | |
| | Lower | Variegated Shales | Variegated Shales and Marls | Ciężkowice Sandstone | | Ciężkowice Sd.; Bełoweża B. | |
| PALAEOCENE | | Babica Clays | | Upper Istebna Beds | Cisna Beds | Variegated Shales | Szczawnica Beds; Babiarze B. |
| SENONIAN | | Węgierka Marls<br>Inoceramian Beds | Frydek Marls; Szydłowiec and Gorzeń Beds<br>Węglówka Marls; Skrzydlna Beds | Lower Istebna Beds<br>Upper Godula B. | Łupków Beds | Ropianka Beds | Jarmuta Beds; Sromowce Beds |
| TURONIAN | | Siliceous Marls | Jasienica Marls | Middle Godula Beds; Variegated Shales | | Variegated Marls | Globotruncana Marls |
| CENOMANIAN | | Variegated Shales | Variegated Shales | Lower Godula B. | | | |
| ALBIAN | | Black Shales | Gaize Beds | Lgota Beds | | | Trawne Beds |
| APTIAN | | | Grodziszcze Beds | Verowice Shales | | | |
| BARREMIAN | | | | | | | |
| HAUTERIVIAN | | Marls | | Grodziszcze Beds | | | |
| VALANGINIAN | | | Upper Cieszyn Shales | Upper Cieszyn Shales | | | |
| BERRIASIAN | | | | Cieszyn Limestone | | | |
| TITHONIAN | | | | Lower Cieszyn Shales | | | |

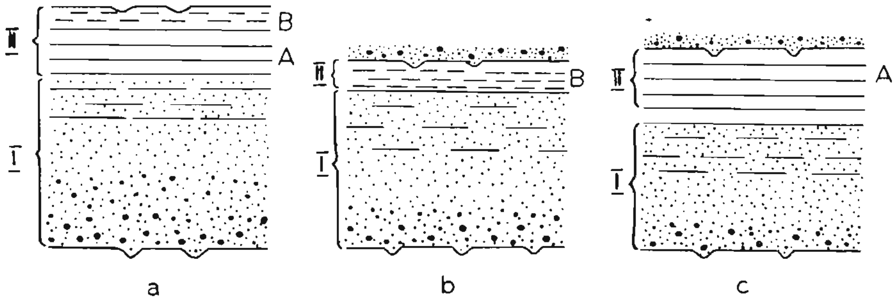



Fig. 2
The relation of the current-borne and pelagic sediments in the flysch, *I* — element I; *II* — element II; *A* — current-borne shale; *B* — pelagic clay or ooze

This type of stratification has much bearing on the distribution of traces with regard to bedding and preservation. In flysch deposits most traces were produced by the animals which lived and burrowed in the sediment. Many trace-making animals burrowed preferentially along stratification planes, and in most cases followed sedimentary interfaces, most commonly between II and I, less frequently between I and II. Some burrowed in both elements, others were restricted either to element I or element II. Others presumably lived on the sea-bottom or just beneath it and made traces on the surface of element I or, more commonly, element II. The traces made on the sea-bottom might be preserved if they were covered with current-born material. These traces are pre-depositional with regard to the time of deposition of element I, which covered them. Other trace-makers burrowed after element I had been deposited. They are post-depositional with regard to the time of deposition of element I. Very likely, some animals were able to live either way, and the traces they made are both pre- and post-depositional (table 3).

Practically, the traces formed at the II/I interface and within element I are post-depositional, and the traces occurring at the I/II interface are also post-depositional. The traces formed in element II or on its surface, before the next element I was formed, are pre-depositional.

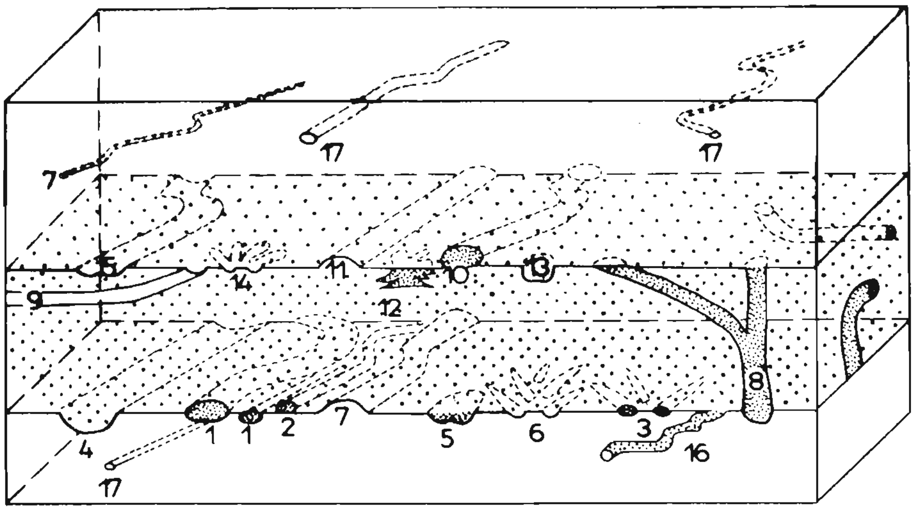



Fig. 3
Toponomy of flysch trace fossils, *1, 2* — hypichnial full burrows; 3 — hypichnial stellate full burrow; *4* — hypichnial groove cast; *5* — hypichnial mound; *6* — hypichnial stellate cast; *7* — hypichnial furrow; *8* — endichnial full burrow; *9* — endichnial void burrow; *10* — epichnial full burrow; *11* — epichnial ridge; *12* — epichnial spiro-helicoidal burrow; *13* — epichnial void hole; *14* — epichnial stellate grooves; *15* — epichnial furrow; *16* — exichnial full burrow; 17 — exichnial full or void burrows

The classification of the position of a trace fossil in relation to a bed (layer) used in this paper approximately follows that proposed by MARTINSSON (1965, 1970), with certain changes required by the Carpathian material. The terms are used in such a way as to denote the manner of development and preservation of biogenic structures.

The position of all biogenic structures occurring on lower surfaces (soles) of element I is described as hypichnial (= hyporelief, SEILACHER, 1964*a*, 1964*b*; intergenic, CHAMBERLAIN, 1971*a*). These structures were formed in two ways: either by animals burrowing parallel to bedding at the clay/sand interface, or by the filling by sand of voids and furrows produced by animals living on the sea-floor before the arrival of the current which covered them with sand. In either case the structures may be approximately horizontal, linear or planar.

Table 2

TOPONOMICAL CLASSIFICATION OF TRACE FOSSILS

| Hypichnial | Endichnial | Epichnial | Exichnial |
|---|---|---|---|
| burrows: full {linear, stellate}; void {tubes, furrows, stellate} | burrows {full, void} | burrows: full; ridges; void {furrows, holes, stellate} | burrows {full, void?} |
| casts {furrows, mounds, stellate} | spiro-helicoidal spreiten | | |
| planar spreiten | | planar spreiten | planar spreiten |

When the animal burrowed and at the same time filled the excavation it had made with the processed material (= "active fill", WEBBY, 1969*b*), the trace is termed a hypichnial full burrow. If the burrow was left empty, the trace is called hypichnial void burrow. The hypichnial full burrows are cylindrical (thread-, string- or rope-sized), more rarely spherical or ellipsoidal (mound-like). A stellate full burrow is a special case, when full burrows are arranged in a star-like form. The hypichnial void linear burrows are termed hypichnial furrows (actually, these furrows are inverted, i.e. the concave or negative hyporelief, SEILACHER, 1964*b*).

All structures produced by the filling of any hollows made by animals before the deposition of element I, on the sole of which they occur, are termed hypichnial casts. If the hollow is linear, the structure is termed a hypichnial groove cast; if circular a hypichnial hole cast. The grooves or holes may be arranged in a rosette pattern; this is a hypichnial stellate cast. Hypichnial groove casts are sub-cylindrical, their filling material is post-genetic ("passive fill", WEBBY, 1969*b*) in contrast to the syn-genetic material of full burrows. In SEILACHER's classification these structures are termed convex (or positive) hyporeliefs (= epigenetic hyporeliefs of CHAMBERLAIN, 1971*a*).

The recognition of the post-genetic origin is easy when the filling material displays any depositional sedimentary structures, such as grading or lamination, horizontal or oblique. The last-named structure is particularly helpful, as it is easy to recognize, although usually only in larger casts. In many cases the grooves are filled with coarser material than that occurring on the sole in the neighbourhood of the cast. It may be supposed that the groove acted as a trap for coarser grain falling from a suspension carried by a turbidity current, or from the material dragged along the bottom by any current. It should, however, be pointed out that full burrows are also often filled with coarser grains than those constituting the basal part of the bed (element I). This difference is probably due to the processing of the material by the sediment-ingesting animal.

In many cases there are difficulties in distinguishing between hypichnial groove casts and hypichnial full burrows. The burrowing animals usually secrete mucus which percolates and hardens the wall of the excavation they have made. Owing to this the filling is sharply demarkated from the surrounding sediment and the burrow filling preserves the shape of the excavation or the hole. When the mucus is secreted in insufficient amount or not at all, the filling of the burrow may fuse with the overlying sediment and the boundary between them is obliterated. The filling loses its cylindrical shape and becomes subcylindrical. Also, the animal might have not filled its excavation when burrowing, but have left it or certain sectors of it void. This possibility is indicated by the presence of inverted furrows on underfaces. In this case the animal removed the material not by ingesting and subsequent excreting, but by pushing it away. If sufficient mucus was secreted, the shape of the excavation in the form of an inverted furrow might be preserved. But if the percolation with mucus was not adequate, or the overburden too heavy or too fluid, the roof of the excavation might collapse and the excavation has been filled by the overlying material. In this case the burrow assumes a subcylindrical form and does not differ from the cast structures. Naturally, this structure is also a cast, but its origin is different from the cast formed when a pre-existing furrow is filled by sedimentation. Thus the terms "sedimentation casts" and "collapse casts" may be used, but their distinction, particularly in structures of small size, is difficult and indeed often impossible.

The distinction between the syngenetic full burrow and post-genetic casts is of importance for the question whether the structure was formed before or after the deposition of the trace-bearing bed. Obviously full burrows were formed after, and sedimentary casts during the deposition of the bed. In the latter case the current-borne material might have filled a pre-existing furrow or hole made by creeping, crawling or sheltering on the sea-bottom. In fact, on the present-day sea-floors there are plenty of all sorts of concave traces (NORTHROP, 1951, HEEZEN & HOLLISTER, 1971). On the other hand, many burrowing animals live in sediment a few centimeters below the sea-bottom filling the galleries they make with excretory material. On this account SEILACHER (1962) believes that the majority of sole traces were formed by scouring and sand casting.

The position of the biogenic structures that occur within element I is described as endichnial (= endogenic p. pt. *sensu* CHAMBERLAIN, 1971*a*). They are either parallel to stratification, subhorizontal, oblique or at right angles to the bedding. Most of them are endichnial full burrows, in the form of cylinders filled with sand or any other material, commonly not differing much from the material of the host rock. Some are tubiform endichnial void burrows, often with lined walls. To this group belong also spiro-helicoidal burrows ("spreiten").

The epichnial position is occupied by structures developed and preserved on the upper surfaces of element I. They occur as epichnial full burrows, cylindrical in shape, or as epichnial ridges, if the burrow filling has fused with the underlying sediment. Linear epichnial furrows are more common, while circular epichnial holes and epichnial stellate holes are less frequent. Some of the epichnial structures are tracks or trails produced by creeping or crawling animals on the upper surface of element I when this surface was sediment/water interface, but most of them have been produced by animals working along the I/II interface, when element I was separated from the sea-water by mud, forming element II. The animal either moved along this interface leaving no excretory material behind, or more commonly, ingested the sediment and filled the excavation with the processed material.

The position of biogenic structures occurring within element II is described as exichnial. Because this element underwent compaction to a much higher degree than element I, the structures are usually flattened, and it is often hardly possible to distinguish between void and filled traces. The excavations are either filled with the same material as the enclosing sediment, or the filling was brought in from outside. In most cases the structures are horizontal or subparallel to the stratification, but most commonly the actual relation of the structur to the original stratification is obliterated by compaction.

Certain types of traces occur in both the exichnial and epichnial positions. It appears that the animals burrowed within the current-borne part of element II more commonly than in its pelagic portion (text-fig. 2).

There are instances, on the whole rare, of a full burrow abandoning its hypichnial position, crossing the interface II/I and either entering the overlying element I, thus becoming an endichnial full burrow, or even going farther up and becoming epichnial. Conversely, it may enter the underlying element II and assume an exichnial situation. In either case the burrow filling for some distance consists of material of element I. By this means cylindrical burrows filled with sand may occur in clay or clayey shales. Most of the Carpathian flysch trace fossils, however, tend to occupy a steady position in relation to bedding.

## CLASSIFICATION OF TRACE FOSSILS

The only rational classification of trace fossils should be linked with the current taxonomic zoological classification. This would be possible if we were able to determine with certainty the producers of traces. Unfortunately, this is not the case, and only in a few instances can be this done. In other cases we may tentatively presume that such-and-such an animal was the potential producer.

The systems of classification so far proposed are based on ecological, ethological, morphological and genetic criteria. According to SEILACHER'S (1953*a*, 1964*a*) ecological and ethological classification most of the Carpathian trace fossils belong to *Pascichnia*, several presumably to *Fodinichnia*, and a small number may be regarded as representing *Repichnia* and other groups. In very many cases the distinction between *Pascichnia* and *Repichnia* is hardly possible (MARTINSSON, 1970, p. 325). There are also difficulties in distinguishing between some *Fodinichnia* and *Pascichnia*, as the manner of burrowing and filling of the former is still uncertain.

In the classification proposed by LESSERTISSEUR (1955), which is partly morphological, partly ecological, most of the Carpathian traces belong to the group of exogenic traces, made on the surfaces of the beds by nutrition or locomotion. The endogenic traces are less numerous (chondritids, *Zoophycos*, some stellate traces). A large group of traces, abundantly represented in the Carpathian material, in LESSERTISSEUR'S classification is treated as "incertae sedis". To this group he assigns: *Vermiglyphes* (e.g. *Cosmorhaphe*), *Graphoglyptes* (*Paleodictyon*, *Paleomeandron*, *Belorhaphe* etc.) and *Rhabdoglyphes*. Stellate traces are regarded by LESSERTISSEUR as endogene, but in the Carpathian material most of them belong to surface traces. In addition, several types occur both on surfaces and inside the layers.

VIALOV (1972*b*), similarly as LESSERTISSEUR, tried to combine morphological and ecological criteria in his classification. The Carpathian material may be placed in his two classes: *Fossiglyphia* (burrows in sediment) and *Excrelithia* (burrows filled with excrements). To the first group he assigns, among the others, *Zoophycos* and chondritids. *Zoophycos*, has, however, marginal cylindrical tubes, which in all appearance, are filled with the materal processed by the burrower. The manner of filling in *Chondrites* is uncertain, and in *Taenidium* most probably by the processed material. Most of the Carpathian types may be assigned to *Excrelithia* — *Farcimindii*. But in adopting the classification of this class we meet further difficulties. *Farcimindii* (strings of sand- and clay-ingesting animals) are divided into *Infarcia* (= endichnial) and *Exterafarcia* (occurring on surfaces, toponomically hypichnial and epichnial). There are, however, some types which occur both on the surface and inside the layer, e.g. *Buthotrephis*, *Subphyllochorda* (text-fig. 25), some *Helminthoida*. Thus in this classification one and the same ichnogenus belongs both to *Infarcia* and *Exterafarcia*. Spiral types are grouped as Spirolitidae and assigned to *Exterafarcia*, but one type of *Spirorhaphe* — *S. involuta* — occurs on the surface, and another, *S. zumayensis*, inside the layer. The same must be said about Helmintholitidae assigned by VIALOV to *Exterafarcia*. Actually several ichnospecies of *Helminthoida* are surface traces, but the most characteristic of this group, *Helminthoida labyrinthica*, occurs most commonly within the sediment.

It is little doubt that because of varied origin and nature of trace fossils and many uncertainties in their genetic interpretation, there are difficulties in establishing a satisfactory formal classification into meaningful groups at suprageneric levels (SARJEANT & KENNEDY, 1973). In view of difficulties in the application of the discussed classifications, similarly as in the previous paper (KSIĄŻKIEWICZ, 1970), an informal classification based on purely morphological features has been adopted. The traces are divided into ten groups. To a certain extent each of these reflects both the morphology of the trace and the behaviour of the producer. The following groups are distinguished: 1. Circular; 2. Simple; 3. Branched; 4. Rosetted; 5. Spreiten; 6. Winding; 7. Spiral; 8. Meandering; 9. Winding and meandering with branches; 10. Networks.

This is a purely auxiliary classification used in order to group together similar types and to avoid their description in an alphabetic order. In no sense does this grouping imply that the groups form any taxonomic or parataxonomic classes. The boundaries between them, with few exceptions, are sharp. For a few types only it may be debatable whether they should be included in one group or another. For example, some simple forms have only one or two branches; they may be included either in the second or the third group, the latter being characterized by numerous branches, the former by no branching. Certain types, like *Gyrochorte*, have an intermediate position between simple and winding traces, or like *Helminthopsis*, between winding and meandering traces. There are also some intermediate types between branched and spreiten types, like *Lophoctenium*. These few instances do not invalidate the classification adopted.

In the ethologic interpretation the following terms are used in this paper: feeding burrows denote galleries or furrows made by the animal during its locomotion and immediately filled with egested materials; feeding and habitation burrows are galleries excavated presumably by the animal during the feeding process and serving as probably temporary dwelling holes; as feeding trails are termed the traces produced by the animal when in order to get food by means of the proboscis or tentacles it made galleries in the sediment or grooves on its surface. Locomotion trails are furrows or galleries made by animals crawling on the surface or in the sediment, but not filled with excrements. If the locomotion of the animal is marked not by a continuous trace (trail), but as a series of imprints, as if made not by crawling but by walking, the trace is termed track. Shelter burrows are holes made by animals for a presumably temporary protection.

Most of the Carpathian traces belong to the first category (table 3). In several types these categories may combine. Certain types presumably consist of feeding burrows and lateral feeding trails.

Several types described here can formally be treated as "genera" and "species", since according to the rules of the International Commission of Zoological Nomenclature the names of trace fossils (tracks, burrows etc.) introduced before 1931 are recognized as valid, while the names used after 1931 are invalid. It follows that a trace named before 1931 is included in the binominal system of the zoological nomenclature, but the trace described after that date is not. This is, certainly, an absurd situation, and many workers have demanded a uniform system of trace fossils nomenclature. HÄNTZSCHEL and KRAUS (1972) use the abundance of types of trace fossils in the Polish Carpathians as an argument for this. On this account throughout the paper the terms "ichnogenus" and "ichnospecies" (proposed first by SEILACHER, 1953*a*) have been used for all trace fossils named both before and after 1931, as in many of the articles in "Trace Fossils" edited by CRIMES and HARPER (1970).

There are many new ichnogenera and ichnospecies proposed in this paper, although the author has tried to limit their number as much as possible. In this respect the view of OSGOOD (1970) that "trace fossils must be named to survive" was, however, also kept in mind. The introduction of new names is due to the wealth of the Carpathian material collected in beds of considerable age range and thickness, and to great lateral variation in the facies and lithology.

The spelling of the names used in this paper follows that employed by HÄNTZSCHEL (1962, 1965), although the author in some previous papers followed LESSERTISSEUR'S (1955) simplified spelling ((*Beloraphe* instead of *Belorhaphe*, *Hercoraphe* instead of *Hercorhaphe*, etc., see also ABEL; 1936, *Spiroraphe* instead of *Spirorhaphe*).

## TRACE FOSSILS AND LITHOLOGY

There is little doubt that lithology to a considerable extent influences the preservation and distribution of trace fossils, as has already been pointed out by several authors, more recently by FREY (1970), and in relation to the Carpathian flysch, by the present author (1970). The most important controlling factors are the nature of the sediment and the thickness of the layers on the base of which the traces occur.

In the Carpathian flysch the complexes rich in trace fossils display the following features:

1. Sandy layers are thin-bedded (table 3), alternating with shales of similar thickness.
2. Sandy layers are fine-grained, horizontally or ripple-current laminated.
3. Both indigenous clays and current-borne sands and silts are light in colour.
4. Soles of sandy layers are flat with no or poorly developed flute casts.

Although it is beyond doubt that the influence of lithology on the development and abundance of trace fossils is considerable, other factors might play an important role, such as depth of water, amount of food, distance from the shore and evolutionary trends of the infauna. There are many instances in which we are not able to say with certainty which factor was the most decisive.

Most of the Carpathian trace fossils are post-depositional in origin (table 3). Since they were produced most commonly at the base of element I, its thickness and coarseness were the limiting factors. It leaves no doubt that it was easier for the burrower to work below a thin cover, where its oxygen requirements were more easily satisfied. Actually, in the Carpathian flysch trace fossils are much more numerous and better developed in the thin than in the thicker elements I. Most of the burrowers preferred fine-grained sediment. In the flysch the grain size is linked with grading, the bedding may be graded, composite (graded passing upward into laminated, KSIĄŻKIEWICZ, 1954), horizontally or obliquely laminated. In the first instance the basal portion is more or less coarse, in the second fairly coarse, while in the third, and, especially in the fourth, the basal portion is fine-grained. Post-depositional traces are infrequent in the first type of bedding, more frequent in the second and third types and most frequent in the fourth type.

The type of bedding has also some influence on the preservation of pre-depositional traces, since the deposition of sandy layers is connected with some erosion of the sea-floor. The thicker layers were admittedly laid down by stronger currents that to some degree eroded the floor. It seems that the erosion caused by the current that deposited very thick layers was small. Very likely these currents were either overloaded or a traction carpet (DŻULYŃSKI & SANDERS, 1962) preventing scouring of the underlying mud was formed. These may be the reasons why very thick sandstone layers have many pre-depositional traces on their soles. The sandstones of moderate thickness often display abundant flute casts on their soles which indicates some scouring of the floor. On these soles pre-depositional traces only rarely occur. This leads to the inference that the sand-bearing current obliterated the surface traces on the floor, and also destroyed the burrows below it more or less entirely. The middle part of the Krosno Beds and the Godula Beds may serve as examples. Horizontally laminated layers were deposited in all likelihood by weak currents, with small or hardly any erosion of the floor, as evidenced by small flute casts or their absence. In these beds pre-depositional traces are fairly common (most of the *Taphrhelminthopsis* and *Spirophycus* specimens occur in these beds). The layers with ripple-current lamination were presumably deposited with no scouring of the floor. In these layers pre-depositional traces abound. This is in agreement with the observation of OSGOOD (1970) who noted the great abundance of traces in cross-laminated beds.

The composition of elements I is another factor to be reckoned with. The burrowers (deposit feeders) extracted their nourishment mainly from argillaceous matter, although they possibly made use of bacterial film covering sand grains. They could find more abundant food in layers with a greater amount of clayey substance. This is another reason for the abundance of post-depositional trace fossils in laminated layers, as these are richer in clay than the graded, coarser layers. In addition, most burrowers preferred finer grains for their diet.

It is striking that elements I with glauconite are on the whole poorer in post-depositional trace fossils. This is the case with the Godula Beds, the Hieroglyphic Beds and with all interbeds of glauconitic sandstones in other horizons. Certainly, other factors, e.g. depth of water, might have caused this, but it may be surmised that the trace producers tended to avoid layers with aboundant glauconite.

Whether the presence of undecomposed vegetable matter was attractive for trace-makers, is debatable. Most workers believe that the infauna makes use of decomposed products, and not of primary matter, but it is noteworthy that *Zoophycos* often occurs in the upper part of element I which has been enriched in plant-remains.

Several types of trace fossils are connected with calcareous rocks. *Chondrites* and *Taenidium* occur in marls, limestones and marly siltstones, and as often as not are absent in purely argillaceous sediments. They were probably made by specialized kinds of animals which were able to burrow and extract food in limy sediments.

Since the flysch trace-makers worked chiefly along the underface, its character might have influenced the development of biogenic structures. It appears that the beds with numerous flute casts (most of the Godula Beds, the Hieroglyphic Beds, the middle part of the Krosno Beds) are poor not only in pre-depositional traces, the reason of which has already been explained, but also in post-depositional burrows. The layers in these complexes with flat or only feebly fluted underfaces may contain post-depositional traces. The inference is that the uneven surface presented obstacles to burrowing animals which tended to avoid it.

The ratio of sandstones (or limestones) to shales has also a marked influence on the abundance of the ichnofauna. In the complexes composed of alternating sandstones and shales of similar thickness with a ratio of 1:1 or 1:2 the trace fossils are more abundant than in the complexes in which the ratio is below that value. The sandy interbeds in such complexes, although they have all the features favourable for the presence of trace fossils, are almost always devoid of them. The probable reason of this is that the flysch ichnofauna was of a specialized kind, consisting mostly of animals preferably burrowing along the clay/sand interface. A prolonged stretch of only clay sedimentation might have been prohibitive for their development, and those regions of the sea-floor on which for a longer time span only clay particles accumulated were abandoned by most of the trace-making animals. An occasional inflow of sand created better conditions for their activity, but trace producers were absent in the region.

A prolonged sedimentation of complexes with predominant sandy interbeds, with a ratio of 4:1 or more, had a similar effect. It led to the extermination of the lower interface burrowers, and even after it ceased, and complexes with features favourable for the development of the interface trace-makers were deposited again, a longer period was required until the ichnofauna appeared in some strength.

It is known that poor aeration of the bottom and interstitial waters of surface sediments is a prohibitive, or at any rate obstructive factor for the development of fauna whether living on the sea-floor or burrowing in the substratum. EMERY and HÜLSEMANN (1962) showed how small differences in the content of oxygen in bottom waters control the presence or absence of benthonic fauna. The example of black shales with traces described by RICHTER (1931) indicates that the black colour in sediments alone does not necessarily mean a total absence of oxygen. Nevertheless, in the Carpathian flysch the complexes in which dark shales predominate, particularly when disseminated pyrite is also present, are markedly poor in trace fossils. The Upper Cieszyn Shales, the Lgota Beds, the Istebna Beds and the Menilitic Shales may serve as examples, although the presence of impoverished foraminiferal assemblages in them indicates that their environment did not reach a truly euxinic stage.

## PRODUCERS OF TRACE FOSSILS

(table 3)

In most cases, if not in all, what the producer was can only be guessed. In no instance have any body fossils, remains or imprints associated with biogenic structures been found. The situation is similar to that of the traces on the present-day sea-floor: there are many tracks, trails and burrows seen on numerous submarine photographs (HEEZEN & HOLLISTER, 1971, HERRING & CLARKE, 1971), but only in a few instances the animals which made them have been photographed, or has it been possible to assign the trace to a particular animal.

Since biogenic structures reflect both the morphology and behaviour of the producers, certain conclusions may be drawn from the morphology of the structures. The animal when burrowing through the sediment may impress its sculptural features on the walls of the excavation. Transversal annulations (as in annelids) or longitudinal musculature (as in priapulids) may be imprinted on the wall of the gallery, especially when the wall is hardened with secreted mucus. When the animal is moving in the sediment, transversal or longitudinal elements of the surface sculpture of its body (spines, warts, muscles) may be impressed or made scratches or pits on the wall of the burrow gallery. Their counterparts may be preserved on the surface of the burrow filling. These features compared with those of the present-day inhabitants of the sea-floor, particularly those which are known to burrow in sediments, may give a clue to the determination of the trace producers. Certain fossil traces may also be compared with the marks left by crawling animals on a soft substratum known mainly from intertidal flats (ABEL, 1936; SCHÄFER, 1972 and numerous other authors). It should, however, be kept in mind that the movement of the animal body may obliterate or deform the structure impressed on the wall of the burrow or on the trail, change it partly or entirely and impress rather the manner of its locomotion than the outline and sculpture of the body. For the most part the burrows are filled with excretory material. If the animal squirted its excrement intermittently, an annulated "coprolithic sausage" may be formed imitating the annulated morphology of the producer's body. There are many reasons why no much reliance can be placed on the morphology of biogenic structures, but in the present state of our knowledge this is one of the main line of approach.

The problem is particularly difficult with respect to the material described. More than half the ichnospecies were produced by marine animals living in the sediment below the sea-floor, and very few made by sessile animals or by animals crawling on the sediment. If the biology and behaviour of the latter are known in a very rudimentary way, the habits of the former are practically unknown, except for a few shallow-water types which seem to be absent in the flysch.

In brief, any determinations of the producers can only be matters for conjecture, and the attempts at interpretation given in this paper, summarized in table 3 and substantiated in the descriptive part, should be treated with caution.

It follows from table 3 that at least 60% of the ichnospecies are ascribed (tentatively, of

Table 3

ORIGIN OF TRACE FOSSILS

| Name of trace fossil | Relation to element I | Usual thickness of element I (in cm) | Maximum thickness of element I (in cm) | Toponomy | Ethology | Presumed producer |
|---|---|---|---|---|---|---|
| *Mammillichnis aggeris* CHAMBERLAIN | pre | 3 | 4 | H | sh | crustacean |
| *Bergaueria prantli* n. ichnosp. | pre | 4—5 | 75 | H | sh | anthozoan |
| *Pararusophycus oblongus* n. ichnosp. | pre | 4—5 | 75 | H | sh | crustacean |
| *Traucumichnis glaber* n. ichnosp. | post | | | E | fd | echinoid |
| *Arthrophycus annulatus* n. ichnosp. | post | 3—4 | 4 | En | f | polychaete or echinoid |
| *Arthrophycus strictus* n. ichnosp. | post | 3—4 | 9 | H | f | polychaete |
| *Arthrophycus dzułyńskii* n. ichnosp. | post | | 1·5 | H | f | polychaete |
| *Fucusopsis angulata* PALIBIN | post | 3—5 | 6 | H | f | priapulid |
| *Fucusopsis annulata* KSIĄŻKIEWICZ | post | 3—4 | 5 | H | f | priapulid |
| *Fucusopsis striata* (HALL) | post | | 3 | H | f | priapulid |
| *Halymenidium sublumbricoides* (AZPEITIA) | post | 3—4 | 5 | H, En | f | ochiuroid or sipunculid |
| *Halymenidium oraviense* (KSIĄŻKIEWICZ) | post | 2—4 | 4 | H, En | f | ochiuroid or sipunculid |
| *Keckia annulata* GLOCKER | post | | 4 | H, E | f | polychaete |
| *Keckia hoessii* (STERNB.) | post | 2—3 | 3 | E, En | f | polychaete |
| *Planolites reinecki* n. ichnosp. | post | | 4 | H | f | priapulid |
| *Rhabdoglyphus grossheimi* VASSOEVICH | post | | 5 | H | f | polychaete |
| *Rhabdoglyphus spinosus* n. ichnosp. | post | 3 | 7 | H | f | polychaete |
| *Rhabdoglyphus caliciformis* n. ichnosp. | post | | 7·5 | H | f | polychaete |
| *Rhabdoglyphus* aff. *caliciformis* n. ichnosp. | post | | | E | f | polychaete |
| *Rhabdoglyphus sulcatus* n. ichnosp. | post | | 4 | H | f | polychaete |
| *Rhabdoglyphus compositus* n. ichnosp. | post | 1—2 | 3 | H | f | polychaete |
| *Sabularia simplex* n. ichnosp. | post | 10 | 20 | H, En E, Ex | f | polychaete |
| *Sabularia rudis* n. ichnosp. | post | 10—15 | 50 | En, H, Ep, Ex | f | polychaete |
| *Sabularia tenuis* n. ichnosp. | post | 10 | 20 | H | f | polychaete |
| *Sabularia ramosa* n. ichnosp. | post | 2—3 | 5 | H, Ex | f | polychaete |
| *Buthotrephis* aff. *palmata* HALL | post | | 4 | H | fd | polychaete |
| *Buthotrephis* aff. *succulens* HALL | post | | 25 | H | fd | polychaete |
| *Buthotrephis bifurcata* n. ichnosp. | post | 3—4 | 4 | H | fd | polychaete |
| *Buthotrephis bilix* n. ichnosp. | post | 2—4 | 4 | H | fd | polychaete |
| *Chondrites aequalis* STERNBERG | pre | | | Ex | fd | sipunculoid |
| *Chondrites affinis* (BRONGNIART) | pre | | | Ex | fd | sipunculoid |
| *Chondrites arbuscula* FISCHER OOSTER | pre | | | Ex | fd | sipunculoid |
| *Chondrites expansus* FISCHER OOSTER | pre | | | Ex | fd | sipunculoid |
| *Chondrites filiformis* FISCHER OOSTER | pre | | | Ex | fd | sipunculoid |
| *Chondrites flexilis* FISCHER OOSTER | pre | | | Ex | fd | sipunculoid |
| *Chondrites furcatus* (BRONGNIART) | pre | | | Ex | fd | sipunculoid |
| *Chondrites intricatus* (BRONGNIART) | pre | | | Ex | fd | sipunculoid |
| *Chondrites patulus* FISCHER OOSTER | pre | | | Ex | fd | sipunculoid |
| *Granularia* indet. | post | | | En, Ex | fd | polychaete |
| *Lophoctenium ramosum* (TOULA) | post | 1—2 | 13 | H, E | f | polychaete |
| *Lophoctenium* aff. *comosum* REINH. RICHTER | post | | 3 | H, E | f | polychaete |

cont.

| Name of trace fossil | Relation to element I | Usual thickness of element I (in cm) | Maximum thickness of element I (in cm) | Toponomy | Ethology | Presumed producer |
|---|---|---|---|---|---|---|
| *Phycodes* aff. *harlani* Hall | post | | 5 | En | f | polychaete |
| *Strobilorhaphe clavata* Książkiewicz | post | 3—4 | 5 | H | fd | polychaete |
| *Strobilorhaphe pusilla* Książkiewicz | post | 2—3 | 3 | H | fd | polychaete |
| *Strobilorhaphe glandifer* n. ichnosp. | post | 4—5 | 5 | H | fd | polychaete |
| *Taenidium annulatum* (Schafhäutl) | pre | | | Ex | fd | polychaete |
| *Taenidium isseli* (Squinabol) | pre | | | Ex | fd | polychaete |
| *Bostricophyton pantenellii* Squinabol | pre | | | Ex | fd | polychaete |
| *Lorenzinia* aff. *apenninica* Gabelli | pre | | 4 | H | ft | hydromedusa |
| *Lorenzinia carpathica* (Zuber) | pre | 6 | 12 | H | ft | hydromedusa |
| *Lorenzinia kuźniari* n. ichnosp. | pre | ? | | H | ft | hydromedusa |
| *Lorenzinia curticostata* n. ichnosp. | pre | | 6 | H | ft | hydromedusa |
| *Lorenzinia kulczyńskii* Kuźniar | pre | ? | | H | ft | hydromedusa |
| *Lorenzinia perlata* Książkiewicz | pre | | 6 | H | ft | hydromedusa |
| *Lorenzinia moreae* Renz | pre | | 6 | H | ft | hydromedusa |
| *Lorenzinia* aff. *moreae* Renz | pre | | 6 | H | ft | hydromedusa |
| *Sublorenzinia plana* Książkiewicz | pre | 3—5 | 35 | H | ft | polychaete |
| *Sublorenzinia nowaki* (Książkiewicz) | post | 10 | 35 | H | f | polychaete |
| *Sublorenzinia pustulosa* n. ichnosp. | post | | 6 | H | f | polychaete |
| *Sublorenzinia pusilla* n. ichnosp. | post? | 4—5 | 7 | H | f | polychaete |
| *Capodistria vettersi* Vialov | post | 4—6 | 12 | H | f | polychaete |
| *Glockeria glockeri* Książkiewicz | post | | 15 | H | f | polychaete |
| *Glockeria sparsicostata* Książkiewicz | post | | 15 | H | f | priapulid |
| *Glockeria disordinata* n. ichnosp. | post | 4 | | H | f | polychaete |
| *Glockeria parvula* Książkiewicz | pre | | 3 | H | ft | polychaete |
| *Fascisichnium extentum* Książkiewicz | post | 8—10 | 15 | H | ft | lamellibranch or hydromedusa |
| *Asterichnus* aff. *lawrencensis* Bandel | post | | | E | ft | crustacean |
| *Gyrophyllites kwassizensis* Glocker | post | | | E | f | polychaete |
| *Phycosiphon incertum* Fischer-Ooster | post | | | En, E | f | polychaete |
| ?*Rhizocorallium* indet. | post | | | H, E | f | crustacean? |
| *Zoophycos brianteus* Massalongo | post | | | En | f | polychaete |
| *Zoophycos insignis* Squinabol | post | | | En | f | polychaete |
| *Anemonichnus concentricus* Chamberlain | post | | | En | f | anemone? |
| *Gyrochorte burtani* n. ichnosp. | post | 1—5 | 10 | H | f | amphipod |
| *Gyrochorte imbricata* n. ichnosp. | post | | 3 | H | f | amphipod |
| *Gyrochorte obliterata* n. ichnosp. | post | | 10 | H | f | amphipod |
| *Helicorhaphe tortilis* Książkiewicz | post | | 4 | H | f | polychaete |
| *Helminthopsis abeli* n. ichnosp. | post | 2—3 | 30 | H | f | polychaete |
| *Helminthopsis hieroglyphica* Heer | post | | 6·5 | H | f | polychaete |
| *Helminthopsis irregularis* (Schafhäutl) | post | | | En, E | f | polychaete |
| *Helminthopsis tenuis* Książkiewicz | post | 2—5 | 75 | H | f | polychaete |
| *Helminthopsis granulata* Książkiewicz | post | | 5 | H | f | priapulid |
| *Muensteria geniculata* Sternberg | post | | | En | f | gastropod |
| *Muensteria hamata* Fischer-Ooster | post | | | En | f | gastropod |
| *Muensteria planicostata* n. ichnosp. | pre | | 4 | H | lt | gastropod |
| *Naviculichnium marginatum* n. ichnosp. | post | | | E | f | polychaete |
| *Oniscoidichnus carpathicus* n. ichnosp. | post | | | E | tr | isopod |
| *Scolicia prisca* de Quatrefages | post | | | E | lt, f | polychaete |
| *Scolicia plana* Książkiewicz | post | | | E | lt, f | polychaete |

cont.

| Name of trace fossil | Relation to element I | Usual thickness of element I (in cm) | Maximum thickness of element I (in cm) | Toponomy | Ethology | Presumed producer |
|---|---|---|---|---|---|---|
| *Scolicia vertebralis* n. ichnosp. | post | | | E | lt, f | polychaete |
| *Subphyllochorda granulata* KSIĄŻKIEWICZ | post | 2—4 | 4 | H, En | f | holothurian |
| *Subphyllochorda striata* KSIĄŻKIEWICZ | post | 3 | 3 | H | f | holothurian |
| *Subphyllochorda rudis* KSIĄŻKIEWICZ | post | 3 | 3·5 | H, En | f | holothurian |
| *Subphyllochorda laevis* KSIĄŻKIEWICZ | pre | 4—6 | 15 | H | lt | ? |
| *Taphrhelminthopsis auricularis* SACCO | pre | | | H | lt | solenogastre |
| *Taphrhelminthopsis vagans* KSIĄŻKIEWICZ | pre | | | H | lt | solenogastre |
| *Taphrhelminthopsis recta* SACCO | pre | | | H | lt | solenogastre |
| *Tuberculichnus vagans* n. ichnosp. | post | | 8 | H | f | nematode? |
| *Tuberculichnus meandrinus* n. ichnosp. | post | 8—10 | 45 | H | ft? lt? | nematode? |
| *Tuberculichnus bulbosus* n. ichnosp. | pre | 6—7 | | H | ft? lt? | nematode? |
| *Tubulichnium incertum* n. ichnosp. | post | | | En | fd | crustacean |
| *Spirorhaphe involuta* (DE STEFANI) | post | 4—10 | 40 | H | f | polychaete |
| *Spirorhaphe zumayensis* LLARENA | post | | | Ex | f | polychaete |
| *Spirophycus bicornis* (HEER) | pre, post | 4—6 | 8 | H | lt, f | polychaete |
| *Spirophycus caprinus* (HEER) | pre, post | | 6 | H | lt, f | polychaete |
| *Spirophycus involutissimus* (SACCO) | pre | | 4 | H | lt | polychaete |
| *Cochlichnus* aff. *anguineus* HITCHCOK | post | | 15 | H | f | polychaete |
| *Cosmorhaphe gracilis* n. ichnosp. | post, pre | | 5·5 | H | lt, f | polychaete or gastropod |
| *Cosmorhaphe sinuosa* (AZPEITIA) | post, pre | 4—5 | 25 | H | lt, f | ,, |
| *Cosmorhaphe helminthopsoidea* n. ichnosp. | pre, post | | 5 | H | lt, f | ,, |
| *Cosmorhaphe fuchsi* KSIĄŻKIEWICZ | pre, post | 2—4 | | H | lt, f | ,, |
| *Cosmorhaphe*(?) *tortuosa* KSIĄŻKIEWICZ | ? | | 4 | H | ? | ? |
| *Gordia molassica* (HEER) | post | | 12 | H | f, lt | polychaete |
| *Gordia arcuata* n. ichnosp. | pre | 1—4 | 5 | H | lt? | polychaete |
| *Helicolithus sampelayoi* AZPEITIA | post | 4—6 | 14 | H | f | polychaete |
| *Helminthoida labyrinthica* HEER | pre | | | Ex, E | f | polychaete |
| *Helminthoida serrata* n. ichnosp. | pre | | | En, Ex | f | polychaete |
| *Helminthoida crassa* SCHAFHÄUTL | post | 3—5 | 5 | H | f | polychaete |
| *Helminthoida miocenica* SACCO | post, pre | 2—4 | | H | f, lt | polychaete |
| *Helminthoida alterna* n. ichnosp. | post | 4—5 | 7 | H | f | polychaete |
| *Helminthoida helminthopsoidea* SACCO | post? | 2—3 | 3 | H | f? | polychaete |
| *Helminthoida aculeata* n. ichnosp. | post | | 20 | H | f | polychaete |
| *Paleomeandron elegans* PERUZZI | post | 4 | 12 | H | f | polychaete |
| *Paleomeandron rude* PERUZZI | post | | 5 | H | f | polychaete |
| *Paleomeandron robustum* KSIĄŻKIEWICZ | post | | 4 | H | f | polychaete |
| *Taphrhelminthoida convoluta* n. ichnosp. | pre, post | | 10 | H | lt, f | solenogastre |
| *Taphrhelminthoida plana* (KSIĄŻKIEWICZ) | pre, post | | 10 | H | lt, f | solenogastre |
| *Acanthorhaphe delicatula* n. ichnosp. | post | 3—5 | 6 | H | f | polychaete |
| *Acanthorhaphe incerta* KSIĄŻKIEWICZ | post | 3—4 | 4 | H | f | polychaete |
| *Belorhaphe zickzack* (HEER) | post, pre | | 6 | H | f | polychaete |
| *Belorhaphe fabregae* (AZPEITIA) | post, pre | 6 | 8 | H | f | polychaete |
| *Protopaleodictyon incompositum* KSIĄŻKIEWICZ | post | | 15 | H | f | polychaete |
| *Protopaleodictyon minutum* n. ichnosp. | pre? | | 75 | H | f | polychaete |
| *Protopaleodictyon submontanum* (AZPEITIA) | post | 5—12 | 50 | H | f | polychaete |
| *Urohelminthoida appendiculata* (HEER) | post | 3—4 | 6 | H | f | polychaete |
| *Urohelminthoida dertonensis* SACCO | post | 5—8 | 20 | H | f | polychaete |

cont.

| Name of trace fossil | Relation to element I | Usual thickness of element I (in cm) | Maximum thickness of element I (in cm) | Toponomy | Ethology | Presumed producer |
|---|---|---|---|---|---|---|
| *Desmograpton fuchsi* n. ichnosp. | post | 3—5 | 15 | H | f | polychaete |
| *Megagrapton irregulare* KSIĄŻKIEWICZ | post | 3—6 | 12 | H | f | polychaete |
| *Megagrapton tenue* KSIĄŻKIEWICZ | post | | 3 | H | f | polychaete |
| *Paleodictyon minutissimum* KSIĄŻKIEWICZ | post pre? | 2·5 | 10 | H | f | polychaete |
| *Paleodictyon minimum* SACCO | post | 3 | 9 | H | f | polychaete |
| *Paleodictyon latum* VIALOV & GOLEV | post | 2—5 | 5 | H | f | polychaete |
| *Paleodictyon intermedium* KSIĄŻKIEWICZ | post | 2—5 | 7 | H | f | polychaete |
| *Paleodictyon intermedium* f. *punctata* | post | | 3 | H | f | polychaete |
| *Paleodictyon strozzii* MENEGHINI | post | 3—5 | 10 | H | f | polychaete |
| *Paleodictyon miocenicum* SACCO | post | 1—3 | 6 | H | f | polychaete |
| *Paleodictyon miocenicum* f. *punctata* | post | | 6 | H | f | polychaete |
| *Paleodictyon miocenicum* f. *pleurodictyonoides* | post? | | 2 | H | f | polychaete |
| *Paleodictyon carpathicum* MATYASOVSZKY | post, pre | 2—3 | 6 | H | f | polychaete |
| *Paleodictyon regulare* SACCO | post | | 5·5 | H | f | polychaete |
| *Paleodictyon regulare* f. *pleurodictyonoides* | post | | 10 | H | f | polychaete |
| *Paleodictyon majus* MENEGHINI | post? | | 15 | H | f | polychaete |
| *Paleodictyon tellinii* SACCO | ? | | 7 | H | f | polychaete |
| *Paleodictyon* aff. *gomezi* AZPEITIA | post | | 4 | H | f | polychaete |

Abbreviations: *pre* — pre-depositional; *post* — post-depositional; *f* — feeding burrow; *ft* — feeding trail; *sh* — shelter burrow; *lt* — locomotion burrow; *fd* — feeding and habitation burrow; *tr* — track; *H* — hypichnial, *E* — epichnial, *En* — endichnial, *Ex* — exichnial structure.

course) to polychaete worms, and the rest to solenogasters, sipunculids, priapulids and other worm-shaped animals (enteropneusts?) with some assigned to gastropods and lamellibranchs and very few to echinoderms and crustaceans.

## VERTICAL DISTRIBUTION OF TRACE FOSSILS

(tables 4–6)

The oldest beds of the outer Carpathian range which occur at the surface do not display any features of the flysch facies. They are marly Tithonian **Lower Cieszyn Shales**. They contain few trace fossils: *Sabularia*, *Granularia*? and *Zoophycos*.

Gradually those beds pass upward into **Cieszyn Limestone** (Upper Tithonian — Berriasian). This unit consists of graded and laminated calcarenites alternating with marly shales. The calcarenites are thin-bedded and the shaly interbeds are of the same thickness, except for the upper part, where calcarenites occur in thick layers. With the outset of the flysch régime typical flysch assemblages of trace fossils appear in some strength. Nearly all characteristic ichnogenera such as chondritids, *Belorhaphe*, stellate forms, helminthoids and paleodictyonids appear, though represented by a small number of ichnospecies (30) and specimens (table 4). The fauna is not varied in spite of favourable stratinomic conditions. In all likelihood in this case the time factor played a role: an appreciable time is required to evolve a highly diverse fauna (SANDERS, 1968), and the conditions favouring the appearance and development of the flysch type ichnofauna only commenced with the deposition of the Cieszyn Limestone.

With the deposition of the **Upper Cieszyn Shales** (Valanginian) conditions for the bottom fauna deteriorated. These beds consist of thin-bedded sandstones and usually predominant black shales. The dark colours of the sediments and occurrences of argillaceous siderites point to poor aeration of the bottom waters. This was probably the main cause of the impoverishment of the ichnofauna. The number of ichnospecies is almost halved (17) and their individual abundance is also very low. Poor oxygenation was not quite prohibitive for trace-makers, as even in black shales chondritids occur, but probably other factors, namely a greater amount of shales also played a role. In essence the character of the ichnofauna was maintained: stellate

Table 4

TRACE FOSSILS OF THE NEOCOMIAN

| | Lower Cieszyn Sh. | Cieszyn Limestone | Upper Cieszyn Sh. | Grodziszcze Beds | Verovice Shales |
|---|---|---|---|---|---|
| *Sabularia simplex* | x | x | x | x | |
| *Sabularia rudis* | x | x | x | F | |
| *Sabularia tenuis* | | | x | x | |
| *Sabularia ramosa* | | | x | x | |
| *Fuscusopsis striata* | | x | | | |
| *Halymenidium oraviense* | | x | | | |
| *Keckia hoessii* | | x | x | F | x |
| *Rhabdoglyphus caliciformis* | | x | | | |
| *Rhabdoglyphus sulcatus* | | x | | | |
| *Buthotrephis bilix* | | | | x | |
| *Buthotrephis* aff. *succulens* | | ? | x | | |
| *Chondrites aequalis* | | | x | | |
| *Chondrites affinis* | | x | | x | |
| *Chondrites arbuscula* | | x | | | |
| *Chondrites furcatus* | | F | | x | |
| *Chondrites intricatus* | | x | | x | |
| *Chondrites* indet. | | | | x | x |
| *Lophoctenium* aff. *comosum* | | x | | | |
| *Glockeria glockeri* | | x | x | x | |
| *Sublorenzinia plana* | | x | x | x | |
| *Sublorenzinia nowaki* | | x | x | | |
| *Asterichnus* aff. *lawrencensis* | | | x | | |
| *Gyrophyllites* indet. | | | | | ? |

| | Lower Cieszyn Sh. | Cieszyn Limestone | Upper Cieszyn Sh. | Grodziszcze Beds | Verovice Shales |
|---|---|---|---|---|---|
| *Phycosiphon incertum* | | x | | x | |
| *Zoophycos* indet. | x | x | | | |
| *Gyrochorte burtani* | | | | F | x |
| *Gyrochorte obliterata* | | | | | x |
| *Helminthopsis abeli* | | x | | x | |
| *Helminthopsis granulata* | | x | | x | |
| *Helminthopsis hieroglyphica* | | x | x | x | |
| *Helminthopsis tenuis* | | x | x | x | |
| *Naviculichnium* indet. | | x | | | |
| *Tuberculichnus meandrinus* | | x | | x | |
| *Gordia molassica* | | x | | ? | |
| *Helminthoida crassa* | | x | x | | |
| *Acanthorhaphe incerta* | | x | | x | |
| *Belorhaphe zickzack* | | x | x | F | |
| *Urohelminthoida dertonensis* | | | | x | |
| *Megagrapton tenue* | | x | | | |
| *Paleodictyon carpathicum* | | | | x | |
| *Paleodictyon intermedium* | | | | x | |
| *Paleodictyon miocenicum* | | x | | | |
| *Paleodictyon strozzii* | | | x | | |
| *Paleodictyon tellinii* | | x | | | |

cont.

types, *Belorhaphe*, paleodictyonids, but chondritids, abundant in the Cieszyn Limestone, almost disappeared. No new types appeared.

The **Grodziszcze Beds** (Hauterivian) consist of thin-bedded sandstones alternating with marly shales which predominate in some sections. Light-coloured sediments returned and this is probably the reason for a marked increase in the diversity of species (25). Chondritids reappear in some strength, individually less abundant than in the Cieszyn Limestone; stellate traces are less frequent but of the same type. New types that will play a considerable role in later stages appear: *Keckia*, *Gyrochorte*, *Urohelminthoida*.

The sedimentation of the next horizon, **Verovice Shales** (Barremian — Aptian) brought an almost complete extinction of the relatively rich and diversified ichnofauna of the preceding

Table 5

TRACE FOSSILS OF THE ALBIAN — SENONIAN

| | Lgota Beds | Godula Beds | Siliceous Marls | Inoceramian Beds | Skrzydlna Beds | Gorzeń Beds | Lower Istebna Beds | Cisna Beds | Ropianka Beds | Sromowce Beds |
|---|---|---|---|---|---|---|---|---|---|---|
| *Mammillichnis aggeris* | | | | x | | | | | x | |
| *Bergaueria prantli* | | x | | | x | | | | x | |
| *Traucumichnis glaber* | | | | x | | | x | | | |
| *Sabularia simplex* | x | x | x | x | x | x | x | x | x | F |
| *Sabularia rudis* | | | F | | x | | F | | x | |
| *Sabularia tenuis* | | F | x | x | | | | | x | |
| *Sabularia ramosa* | x | F | | x | | x | | | x | x |
| *Arthrophycus annulatus* | | x | | x | | | x | | x | |
| *Arthrophycus strictus* | x | x | | x | | | | | x | |
| *Fucusopsis angulata* | | x | | x | x | x | | | x | x |
| *Keckia annulata* | x | x | | x | | | | | x | |
| *Keckia hoessii* | | | | x | | | x | | x | |
| *Planolites reinecki* | | | | | x | | | | x | |
| *Rhabdoglyphus compositus* | | x | | | | | | | x | |
| *Rhabdoglyphus grossheimi* | | x | | | | | | | | |
| *Rhabdoglyphus spinosus* | | x | | | x | | | | x | |
| *Rhabdoglyphus sulcatus* | | | | | | | | | x | |
| *Bostricophyton pantenellii* | | | | | | | | | x | |
| *Buthotrephis bifurcata* | | | | | x | | | | | |
| *Buthotrephis* aff. *palmata* | | x | | | | | | | | |
| *Buthotrephis* aff. *succulens* | | x | | | | | | | x | |
| *Buthotrephis* indet. | x | x | x | | x | | | | x | |
| *Chondrites aequalis* | x | x | x | F | | | x | x | x | |
| *Chondrites affinis* | | | x | F | | | x | | F | |
| *Chondrites arbuscula* | | | F | F | | | x | | F | |
| *Chondrites expansus* | | | | | | | | | x | |
| *Chondrites filiformis* | | | | | | | | | x | |
| *Chondrites flexilis* | | | x | x | | | | | x | |
| *Chondrites furcatus* | x | | x | F | | | x | | F | |
| *Chondrites intricatus* | | | x | x | | | x | x | x | |
| *Chondrites* indet. | | | x | | | | | x | | x |
| *Granularia* indet. | | | | | | | | | x | |
| *Lophoctenium ramosum* | | | | x | x | | | | x | |
| *Lophoctenium* aff. *comosum* | | | | | x | | | | | |
| *Strobilorhaphe clavata* | | | | | | x | | | x | |
| *Strobilorhaphe pusilla* | | | | | | | | | x | |
| *Taenidium annulatum* | | | | | | | | | x | |
| *Taenidium isseli* | | | | x | | | | | x | |
| *Lorenzinia* aff. *apenninica* | | | | | | | | | x | |
| *Lorenzinia carpathica* | | | | | | | | | x | |
| *Lorenzinia kuźniari* | | | | | | | x | | | |
| *Lorenzinia kulczyńskii* | | | | | | | | | x | |
| *Lorenizinia moreae* | | | | | | | | | x | |
| *Sublorenzinia plana* | | x | | x | | | | | | |
| *Sublorenzinia nowaki* | | x | | x | x | | | | x | |
| *Sublorenzinia pustulosa* | | x | | x | x | | | | | |
| *Sublorenzinia pusilla* | | | | | | | | | x | x |

cont.

| | Lgota Beds | Godula Beds | Siliceous Marls | Inoceramian Beds | Skrzydlna Beds | Gorzeń Beds | Lower Istebna Beds | Cisna Beds | Ropianka Beds | Sromowce Beds |
|---|---|---|---|---|---|---|---|---|---|---|
| *Glockeria sparsicostata* | | | | | | | | | x | |
| *Glockeria parvula* | | | | | x | | | | | |
| *Capodistria vettersi* | | x | | | x | | | | x | |
| *Fascisichnium extentum* | | | | x | | | | | | |
| *Gyrophyllites kwassizensis* | | | | | | | x | | | |
| *Phycosiphon incertum* | | | | F | | | | x | F | |
| *Zoophycos brianteus* | | | | x | | | | | x | x |
| *Zoophycos insignis* | | x | x | x | x | x | | | x | x |
| *Zoophycos* indet. | | x | x | x | | | | x | x | |
| *Gyrochorte burtani* | | | | | x | | | | | |
| *Helminthopsis abeli* | | x | x | F | x | x | x | | F | |
| *Helminthopsis hieroglyphica* | | x | x | x | | | x | | x | |
| *Helminthopsis irregularis* | | | | x | | | | | x | F |
| *Helminthopsis tenuis* | | x | | x | | x | | | x | |
| *Muensteria geniculata* | | | x | | | | | | | |
| *Muensteria hamata* | | | | x | | | | | x | |
| *Muensteria planicostata* | | | | | | | | | x | |
| *Naviculichnium marginatum* | | | | | | | | | x | |
| *Scolicia plana* | x | F | | F | F | x | | ? | F | F |
| *Scolicia prisca* | | | | | | | | | x | |
| *Scolicia vertebralis* | | x | | x | | | x | | x | x |
| *Subphyllochorda granulata* | | x | x | | | | | | x | F |
| *Subphyllochorda laevis* | x | x | x | x | | | | | x | x |
| *Subphyllochorda rudis* | | | | | x | x | | | | |
| *Subphyllochorda striata* | | | | | | x | | | | x |
| *Taphrhelminthopsis auricularis* | | x | | x | | | x | x | F | |
| *Taphrhelminthopsis vagans* | x | x | | x | x | | | x | x | x |
| *Tuberculichnus meandrinus* | | | | x | x | | | | x | |
| *Tuberculichnus vagans* | | x | | | | | | | x | |
| *Tubulichnium incertum* | | | | F | | | x | | x | x |
| *Spirorhaphe involuta* | | | | x | | | x | | x | |
| *Spirorhaphe zumayensis* | | | | | | | | | x | |
| *Spirophycus bicornis* | | x | | x | | | x | | x | |
| *Spirophycus caprinus* | | | | | | | | | x | |
| *Spirophycus involutissimus* | | | | | | x | x | | x | |
| *Cosmorhaphe gracilis* | | | | x | x | x | | | x | |
| *Cosmorhaphe sinuosa* | | | | x | | | | | x | |
| *Cosmorhaphe helminthopsoidea* | | | | | | | | | x | |
| *Cosmorhaphe fuchsi* | | | | | | | | | x | |
| *Gordia molassica* | | | x | x | | | | | | |
| *Helicolithus sampelayoi* | | | | x | x | | | | x | |
| *Helminthoida crassa* | x | x | x | x | x | x | x | | F | x |
| *Helminthoida helminthopsoidea* | | x | | | | | | | x | |
| *Helminthoida labyrinthica* | | | x | x | x | | | | F | |
| *Helminthoida miocenica* | | | | | x | x | | | x | |
| *Helminthoida serrata* | | | | x | | | | | x | |
| *Paleomeandron elegans* | | | | | x | | | | x | |
| *Taphrhelminthoida convoluta* | | ? | | x | | | | | x | |
| *Acanthorhaphe delicatula* | | | | x | | | x | | x | x |
| *Belorhaphe fabregae* | | | | | | | | | x | |
| *Belorhaphe zickzack* | | | | | | | | | x | ? |

cont.

| | Lgota Beds | Godula Beds | Siliceous Marls | Inoceramian Beds | Skrzydlna Beds | Gorzeń Beds | Lower Istebna Beds | Cisna Beds | Ropianka Beds | Sromowce Beds |
|---|---|---|---|---|---|---|---|---|---|---|
| *Protopaleodictyon incompositum* | | | | x | | | | | x | |
| *Protopaleodictyon submontanum* | | x | | | | | | | x | |
| *Urohelminthoida appendiculata* | | | | | x | | | | x | |
| *Urohelminthoida dertonensis* | | | | x | x | | | | x | |
| *Desmograpton fuchsi* | | x | | x | | | | | x | x |
| *Megagrapton* indet. | | | | | | | | | x | |
| *Paleodictyon minimum* | | | | | | | | | | x |
| *Paleodictyon latum* | | | | x | | x | | | x | x |
| *Paleodictyon intermedium* | | | | x | | x | | | x | F |
| *Paleodictyon miocenicum* | | x | | x | | | x | | x | |
| *Paleodictyon miocenicum* f. *pleurodictyonoides* | | | | | x | | | | | |
| *Paleodictyon strozzii* | | x | | x | | x | | x | F | |
| *Paleodictyon carpathicum* | | x | | | | | | | | |
| *Paleodictyon regulare* f. *pleurodictyonoides* | | | | | | | | | | x |
| *Paleodictyon majus* | | | | | ? | | | | | |
| *Paleodictyon tellinii* | | | | x | | x | x | | x | |

unit. These are black shales with argillaceous siderites and very few intercalations of sandstones. Both factors, poor oxygenation of bottom waters and lack of sandstones, were unfavourable for the ichnofauna and only few trace producers survived. The only traces are *Keckia*, *Gyrochorte* and *Gyrophyllites* (?).

During the deposition of the **Lgota Beds** the conditions improved only slightly. At first in many regions thick-bedded sandstones were deposited, also an unfavourable factor, followed by thin-bedded sandstones alternating with shales in various proportions. Dark-coloured shales still prevailed, but green shales were also present indicating an improvement in the bottom conditions. The ichnofauna only slowly recovered. It is poor in the number of ichnospecies (11) and specimens. Several types characteristic of Neocomian beds disappear *(Glockeria, Gyrochorte)* and new ichnogenera, although very scarce, appear for the first time *(Scolicia, Subphyllochorda, Taphrhelminthopsis)*. These types will play a considerable role in the higher formations of the Carpathian flysch.

During the Late Cretaceous (table 5) considerable changes took place in the palaeogeography of the Carpathian flysch basin. The previously single basin was divided into two troughs, a northern and a southern. At the same time the bottom conditions improved considerably as evidenced by the light colours of the sediments, appearance of red shales and the abundant benthonic foraminiferal assemblages.

In the **Godula Beds** (Cenomanian — Lower Senonian) lithologic conditions for the development of the ichnofauna were not too favourable. These beds were laid down in the northern through. In the western part the formation consists of alternating sandstones and shales, but in many sections thick-bedded sandstones predominate and glauconite is present. In the eastern part the Godula flysch is replaced by variegated shales, mostly red, with few intercalations of sandstones. In spite of this further development of the ichnofauna is noticeable, although it is not exuberant. The total number of ichnospecies known from this very thick formation is only 35; in some parts of the formation much smaller, and the number of specimens is also low. Nevertheless, new elements, although sparingly, appear: *Fucusopsis angulata*, *Strobilorhaphe*, *Spirophycus* and *Desmograpton*, and the number of types of *Subphyllochorda* and *Taphrhelminthopsis* increases. Meandering and reticulated types are present but are very rare and of small specific diversity. *Scolicia* seems to be more abundant than any other type.

In the eastern part of the trough partly coeval with the Godula Beds "Siliceous Marls" (Turonian — Lower Senonian) are developed. This carbonate flysch has a particular kind of ichnofauna, consisting mostly of numerous chondritids, while other types are poorly represented. The Jasienica Marls, partly of the same age (Cenomanian — Turonian), developed in the axial zone of the northern trough and with no flysch features, are devoid of trace fossils, except for small *Zoophycos*.

The Senonian times bring a great increase in the specific and numerical abundance of trace fossils. The Carpathian ichnofauna attains the climax of its development in this period. Several ichnogenera appear for the first time in the basin: *Spirorhaphe*, *Cosmorhaphe*, *Lorenzinia*, and helminthoids and paleodictyonids together with *Taphrhelminthopsis* occur in a variety of types. Across the range from the north southwards the Senonian is successively represented by the Inoceramian, Węglówka, Istebna, Ropianka and Sromowce Beds. All with the exception of the Węglówka Beds (pelagic marls) are developed in flysch facies.

The **Inoceramian Beds** (Turonian — Senonian) developed gradually upward from the Siliceous Marls. They consist of a variety of sandstones, but medium- and thin-bedded sandstones predominate alternating with clayey or marly shales, usually in various proportions. In many sections the proportion sandstone to shale is over 2 : 1 or even 3 : 1, in others shales predominate. Considerable interbeds of thick-bedded sandstones with few shales are also developed. In the north-eastern part of the area occupied by these beds, they pass laterally and intermingle with Węgierka Marls, which are a non-flysch deposit.

The ichnofauna is specifically much more diverse and richer in specimens than in the partly coeval Godula Beds. The number of chondritids greatly increases, the number of winding types is almost the same, but that of patterned traces (spirals, meandering, networks) is doubled. None of the latter, with the exception of *Helminthoida labyrinthica*, is common. The most common are *Arthrophycus annulatus* (particularly in somewhat coarser layers), *Tubulichnium incertum*, *Helminthopsis abeli* and *Helminthoida labyrinthica*. The total number of ichnospecies is over 50. This is numerous for a complex whose thickness is less than half of that of the Godula Beds, but still, except for some sections with marls in which chondritids and *Helminthoida labyrinthica* are plentiful, the frequency of well-developed traces is relatively small.

The **Węglówka Marls** (Turonian — Senonian) were laid down in the axial zone of the northern trough. In these green and red marls no trace fossils occur except for some rare underdeveloped chondritids, but in some parts the marls are replaced by intercalated complexes of flysch character. To these belong the Skrzydlna, and Gorzeń and Szydłowiec Beds.

The **Skrzydlna Beds** occur in the lower part of the Węglówka Beds. They unite features of the Inoceramian and Godula Beds (Burtan, 1974). The sandstones are thin-bedded and in most sections predominate over the shales. In spite of their small thickness (c. 300 m) and the small area they occupy these beds are relatively rich in trace fossils. The proportion of patterned types (almost a third of the total number of ichnospecies) to other types is high. *Scolicia plana*, as in the Godula and Inoceramian Beds, is the most common trace. Branched forms are very rare; this is probably due to the almost total absence of marls.

The **Gorzeń Beds** replace the uppermost part of the Węglówka Beds. They are formed of a thin-bedded glauconitic flysch, laterally passing into the **Szydłowiec Sandstone**, which is coarse and less glauconitic. These beds, not very thick (c. 200 m), are poorly exposed and occur only in small patches. This may be one of the reasons of their poor content of trace fossils. The number of patterned types, in proportion to the total number (18) of ichnospecies, is fairly high.

The **Lower Istebna Beds** (Upper Senonian) consist of thick-bedded, conglomeratic and coarse sandstones which predominate over shales, although here and there they contain interbeds of thick shales, pebble-clays and, in the eastern part, a thick intercalation of beds consisting of thin-bedded sandstones, marls and shales, known as "Fucoidal marls" and resembling Inoceramian Beds. The Lower Istebna Beds are one of the horizons poorest in trace fossils (24 types, most of which occur in "Fucoidal marls"). The coarseness of the sandstones and the

Table 6

TRACE FOSSILS OF THE PALAEOGENE

| | Palaeocene | | Eocene | | | | | | Oligocene |
|---|---|---|---|---|---|---|---|---|---|
| | Upper Istebna Beds | Szczawnica Beds | Variegated Shales | Ciężkowice Sandstone | Beloveza Beda | Hieroglyphic Beds | Łącko Beds | Magura Sandstone | Krosno Beds |
| *Mammillichnis aggeris* | | x | x | | x | | | | F |
| *Bergaueria prantli* | | | x | | | x | | x | |
| *Pararusophycus oblongus* | | | | | | x | | x | |
| *Traucumichnis glaber* | | | | x | | | | | |
| *Sabularia simplex* | x | x | x | x | F | F | x | x | x |
| *Sabularia rudis* | x | | | F | | x | x | x | |
| *Sabularia tenuis* | | | | | | x | | | F |
| *Sabularia ramosa* | | | x | x | x | x | | ? | F |
| *Arthrophycus annulatus* | x | x | | F | x | x | | x | |
| *Arthrophycus* aff. *harlani* | | | | x | | | | | |
| *Arthrophycus dzulyńskii* | | | | | | | | | x |
| *Fucusopsis angulata* | x | | | | | | | | |
| *Fucusopsis annulata* | | | F | x | F | x | x | x | |
| *Halymenidium sublumbricoides* | | | | | x | x | x | | |
| *Halymenidium oraviense* | | | x | | F | | | | |
| *Keckia annulata* | x | x | | | | x | | | |
| *Keckia hoessii* | | | | | | x | | | |
| *Buthotrephis bifurcata* | | | | | x | x | | | |
| *Buthotrephis* aff. *palmata* | | x | | | | | | | |
| *Buthotrephis* aff. *succulens* | | | | | x | | | | |
| *Buthotrephis* indet. | | | | | x | x | | | |
| *Chondrites aequalis* | | x | x | | x | x | x | | x |
| *Chondrites affinis* | | x | x | | x | x | x | | x |
| *Chondrites arbuscula* | | | x | x | x | | x | | |
| *Chondrites flexilis* | | x | | | | | | | |
| *Chondrites furcatus* | | | x | | x | x | x | x | |
| *Chondrites intricatus* | | | | | | x | | | |
| *Chondrites patulus* | | | | | | | | | x |
| *Chondrites* indet. | | x | | | | | | | |
| *Granularia* indet. | | x | | | | ? | | | |
| *Lophoctenium ramosum* | | | F | x | x | x | | | x |
| *Lophoctenium* aff. *comosum* | | | x | | | | | | |
| *Strobilorhaphe clavata* | | | x | | F | x | | x | |
| *Strobilorhaphe pusilla* | | | x | | x | x | | | |
| *Strobilorhaphe glandifer* | | | | | x | x | | | |
| *Lorenzinia carpathica* | ? | | x | | | | | | |
| *Lorenzinia curticostata* | | | x | | | | | | |
| *Lorenzinia perlata* | | | x | | | | | | |
| *Lorenzinia moreae* | | | x | | | | | | |
| *Lorenzinia* aff. *moreae* | | | x | | | | | | |
| *Sublorenzinia plana* | | | | | x | x | | x | |
| *Sublorenzinia nowaki* | | | | | x | | | ? | |

cont.

| | Palaeocene | | Eocene | | | | | | Oligocene |
|---|---|---|---|---|---|---|---|---|---|
| | Upper Istebna Beds | Szczawnica Beds | Variegated Shales | Ciężkowice Sandstone | Beloveza Beds | Hieroglyphic Beds | Łącko Beds | Magura Sandstone | Krosno Beds |
| *Sublorenzinia pusilla* | | x | | | | x | | | |
| *Capodistria vettersi* | | | x | | | | | | |
| *Glockeria disordinata* | x | | | | | | | | |
| *Fascisichnium extentum* | | | x | | | x | | | |
| *Phycosiphon incertum* | x | x | x | x | x | x | x | | x |
| *Rhizocorallium*(?) indet. | | | | x | | | | x | |
| *Zoophycos brianteus* | | | | x | x | | | | x |
| *Zoophycos insignis* | | | x | | x | x | x | x | x |
| *Zoophycos* indet. | | | | x | x | x | | | x |
| *Anemonichnus concentricus* | | | | | | | | x | |
| *Gyrochorte burtani* | | | | | | | | | x |
| *Gyrochorte imbricata* | | | | x | | | | | |
| *Helicorhaphe tortilis* | | ? | | | x | | | | |
| *Helminthopsis abeli* | | x | x | x | x | x | x | x | x |
| *Helminthopsis hieroglyphica* | | x | x | x | x | | | | x |
| *Helminthopsis irregularis* | | x | x | | x | x | | | |
| *Helminthopsis tenuis* | | x | x | | x | x | x | x | x |
| *Muensteria hamata* | | | x | | | | | | |
| *Naviculichnium marginatum* | | | x | | x | x | | | |
| *Oniscoidichnus carpathicus* | | | | | | | | | x |
| *Scolicia plana* | | x | | | | | | | |
| *Scolicia prisca* | x | | x | | F | F | x | x | x |
| *Subphyllochorda granulata* | | x | F | ? | F | x | x | | |
| *Subphyllochorda laevis* | | | | | x | x | | | x |
| *Subphyllochorda striata* | | | | | x | x | | | |
| *Taphrhelminthopsis auricularis* | | x | x | | F | x | | x | x |
| *Taphrhelminthopsis recta* | | | | | | | | x | |
| *Taphrhelmithopsis vagans* | x | | x | x | F | x | x | F | x |
| *Tuberculichnus bulbosus* | | | x | | x | x | | | |
| *Tuberculichnus meandrinus* | | | | | x | | | | ? |
| *Tuberculichnus vagans* | | x | | | x | | | | |
| *Tubulichnium incertum* | | x | x | | x | x | | | |
| *Spirorhaphe involuta* | x | | | F | x | | | x | |
| *Spirorhaphe zumayensis* | | F | x | | x | | | | |
| *Spirophycus bicornis* | x | x | x | | F | F | x | x | |
| *Spirophycus caprinus* | x | | | | | x | | | |
| *Spirophycus involutissimus* | | x | x | x | x | x | | | |
| *Cochlichnus* aff. *anguineus* | | | x | | x | x | | | |
| *Cosmorhaphe gracilis* | | | | x | | | | | ? |
| *Cosmorhaphe sinuosa* | | | x | | x | x | | | |
| *Cosmorhaphe helminthopsoidea* | | | x | | x | | | | |
| *Cosmorhaphe fuchsi* | | | x | | F | x | x | | |
| *Gordia arcuata* | | | | | | | | | x |
| *Gordia molassica* | | | | x | | x | | x | x |
| *Helicolithus sampelayoi* | | | x | | x | x | | x | |
| *Helminthoida aculeata* | | | | | x | | | | |
| *Helminthoida alterna* | | | x | | F | | x | | |

cont.

| | Palaeocene | Eocene | | | | | | Oligocene | |
|---|---|---|---|---|---|---|---|---|---|
| | Upper Istebna Beds | Szczawnica Beds | Variegated Shales | Ciężkowice Sandstone | Beloveza Beds | Hieroglyphic Beds | Łącko Beds | Magura Sandstone | Krosno Beds |
| *Helminthoida crassa* | | x | x | x | F | x | | | x |
| *Helminthoida helminthopsoidea* | x | | | | x | | | | |
| *Helminthoida labyrinthica* | | x | F | | x | x | x | | |
| *Helminthoida miocenica* | | | x | | | x | | | x |
| *Helminthoida serrata* | | x | x | | x | x | | | |
| *Paleomeandron robustum* | | | | | x | x | x | | |
| *Paleomeandron rude* | | | | | x | x | x | | ? |
| *Taphrhelminthoida convoluta* | | x | x | | x | x | x | x | |
| *Taphrhelminthoida plana* | | | | | x | | | | |
| *Acanthorhaphe delicatula* | x | | | | x | x | | | |
| *Belorhaphe fabregae* | | x | x | | x | x | x | | |
| *Belorhaphe zickzack* | | | | | x | x | x | | |
| *Protopaleodictyon incompositum* | | | x | x | x | F | x | x | |
| *Protopaleodictyon submontanum* | | | x | | x | F | x | | |
| *Protopaleodictyon minutum* | | | | | | | | x | |
| *Urohelminthoida appendiculata* | | x | x | | | | | | |
| *Urohelminthoida dertonensis* | x | x | x | x | F | x | x | x | |
| *Desmograpton fuchsi* | | | | | ? | | | | |
| *Megagrapton irregulare* | | | | x | x | | x | | |
| *Paleodictyon minutissimum* | | | | | x | x | | | |
| *Paleodictyon minimum* | | | x | | x | | | | x |
| *Paleodictyon latum* | | | x | | F | x | | | x |
| *Paleodictyon intermedium* | | x | | | | x | | | |
| *Paleodictyon intermedium* f. *punctata* | | | | x | | | | | |
| *Paleodictyon miocenicum* | | | | | x | x | | | x |
| *Paleodictyon miocenicum* f. *punctata* | | | | | | x | | | |
| *Paleodictyon strozzii* | | x | x | | F | x | | | |
| *Paleodictyon carpathicum* | x | | F | | F | x | | x | |
| *Paleodictyon majus* | | | x | | x | | | | |
| *Paleodictyon regulare* | | | x | x | x | | | | |
| *Paleodictyon tellinii* | | | | ? | | | | | |
| *Paleodictyon* aff. *gomezi* | | | | | x | | | | |

presence of dark shales are, no doubt, the main cause. In sandstones *Arthrophycus annulatus* and coarse types of *Sabularia* may occur in greater abundance. The "Fucoidal marls" are rich in chondritids and contain fairly common patterned types.

In the southern trough the **Ropianka Beds** (called also "Inoceramian Beds") were deposited during the Senonian. In the eastern part they are replaced by the Cisna Beds which do not differ much from the Ropianka Beds. The latter consist of predominantly medium- and thin-bedded sandstones, on the whole thicker than the intervening shales. Marls are also present, but not so common as in the coeval Inoceramian Beds of the northern trough, and thick-bedded sandstones also occur. The thickness is not very great (c. 500 m). The Ropianka Beds are the formation richest in the number of ichnospecies (92), although not so much in fully developed traces. All morphological groups are well represented, and branched, spreiten, winding and patterned groups include types which may be qualified as frequent. Chondritids, *Phycosiphon* *incertum*, *Zoophycos insignis*, *Scolicia plana*, *Taphrhelminthopsis auricularis*, *Helminthoida labyrinthica* and *Paleodictyon strozzii* are particularly frequent. Lorenzinias appear for the first time. Nearly a third of the ichnospecies are of the meandering and net-like types.

In the southern region close to the Pieniny Klippen zone the Ropianka Beds are laterally and partly replaced by the **Jarmuta Beds,** in which *Fucusopsis angulata* is particularly abundant in some layers.

The **Cisna Beds** are characterized by the predominance of thick- and medium-bedded sandstones. This is probably the main reason for the paucity of their trace fossils whose assemblage in essence does not differ much from the ichnofauna of the Ropianka Beds.

The **Sromowce Beds** (Lower Senonian and the lower part of the Upper Senonian) do not differ much from the Ropianka Beds in their lithology and stratinomy. The ichnofauna is much poorer in the total number of types. This may be partly due to the much smaller area of the occurrence of the Sromowce Beds and their lesser thickness. The trace fossil assemblage consists of many winding and patterned types; of the former *Scolicia plana* and of the latter *Paleodictyon intermedium* occur in substantial numbers. The most common trace fossil is *Sabularia simplex*, present in very many sandstone layers. The scarcity of chondritids and other branched types is a marked difference as compared with the Ropianka Beds.

With the beginning of the Palaeogene times (table 6) the lateral variation of the sediments is somewhat smaller than in the Upper Cretaceous, but on the whole still maintained. In the Palaeocene near the northern border of the basin the Babica Clays occur, farther south replaced by the Variegated Shales which also represent the Lower Eocene. Near the southern border of the northern trough the Upper Istebna Beds were laid down. In the southern trough the Variegated Shales are the main Palaeocene and Lower Eocene formation, but the uppermost Ropianka Beds also belong to the Palaeocene. In the southern part, close to the Pieniny Klippen zone, both the upper part of the Ropianka Beds and the Variegated Shales are replaced by the Szczawnica Beds.

The **Babica Clays** consist mainly of olistostromal deposits, with few intercalations of packets composed of alternating shales and sandstones. It is no wonder that such a character of sediments causes the ichnofauna to be extremely poor and confined to few types such as *Sabularia*, *Arthrophycus*, *Zoophycos* and some chondritids. In the variegated shales (green and red) of the northern trough there are very few sandstones and, consequently, there is an almost complete absence of ichnofauna.

The **Upper Istebna Beds**, by the nature of their sediments, are not a trace-bearing horizon. They consist for the most part of coarse sandstones, conglomerates, pebble-clays and dark, often black shales. The coarse layers are devoid of traces. In less coarse and thin-bedded sandstones *Arthrophycus annulatus* and *Sabularia simplex* are not uncommon, *Glockeria disordinata* occurs widely and patterned types are not very rare. In fact, on the specific level they apparently predominate with 10 ichnospecies, more than one-half of the composition, but they have all been found only in single specimens.

In contrast with the northern trough the sediments of the southern trough are abundant in trace fossils.

The **Variegated Shales** (Palaeocene — Lower Eocene) with 61 ichnospecies are fairly close behind the underlying Ropianka Beds. The smaller number may be caused only by the lithology, as the Variegated Shales have relatively few sandy intercalations. Their thickness is also smaller (c. 200 m). In the specific composition the patterned types dominate, represented by 25 ichnospecies, but only a few may be regarded as frequent. The second place is taken by winding types (12). Branched types are few, with the exception of the widely distributed *Lophoctenium ramosum*. A few new types appear for the first time: *Fucusopsis annulata*, *Halymenidium*; they are going to play a considerable role higher up in the succession. *Scolicia prisca* now entirely replaces its older predecessors. In brief, the ichnofauna of the Variegated Shales is characterized by great specific diversity, but is rather poor in the number of specimens.

The **Szczawnica Beds** (Palaeocene) resemble the thin-bedded parts of the Ropianka Beds, but are much darker in colour, and this is presumably the reason for the great difference in number of ichnospecies (34) as compared with the latter. A third of ichnospecies belongs to patterned types, another third to the winding group and the rest to other groups. Only *Urohelminthoida dertonensis* and in some shaly layers *Spirorhaphe zumayensis* are represented by any greater numbers of specimens.

The Lower Eocene is represented by red and green shales in the northern trough, except for its inner zone where the **Ciężkowice Sandstone** is developed. It consists of thick-bedded, coarse-grained sandstones, often with large-scale stratification, but also contains interbeds of thick-bedded, graded sandstones and substantial intercalations mostly composed of variegated shales with thin-bedded sandstones. Most of this member was deposited by traction currents, sandflows and dense turbidity currents (KSIĄŻKIEWICZ, 1975). The ichnofauna is very scarce. There is a marked difference between the assemblages of thick and coarse layers and those occurring in more finely grained interbeds. In the former sabularias, *Arthrophycus annulatus* and *Traucumichnis glaber* are fairly common, although apparently absent in very coarse and cross-stratified layers. Several forms such as *Fucusopsis annulata*, *Lophoctenium ramosum*, *Megagrapton irregulare*, *Subphyllochorda* or *Helminthoida crassa* seem to be restricted to packets with thin-bedded sandstones. In some medium-grained layers rare *Paleodictyon* (with a tendency to occur in aberrant varieties), *Cosmorhaphe*, *Gyrochorte* and quite frequently *Spirorhaphe involuta* may occur. The total number of ichnospecies is low (28), but half of them belong to patterned types. *Zoophycos* is not very common. As to the number of specimens, simple burrows markedly predominate.

The **Beloveza Beds** represent the upper part of the Lower Eocene in the southern trough. They consist of alternating thin-bedded sandstones and shales, the latter slightly predominating: the proportion of sandstones to shales varies between 1:1 and 1:3. The sediments are light in colour, the shales mostly green or green-grey. The ichnofauna is very rich and rivals that of the Ropianka Beds in the number of ichnospecies (77 against 92 in the Ropianka Beds), but surpasses them in the average number of specimens of almost every ichnospecies. Half the ichnospecies belong to patterned types, particularly to *Cosmorhaphe*, *Helminthoida* and *Paleodictyon* (9 types of *Paleodictyon*, 6 types of *Helminthoida*). Many ichnospecies such as *Halymenidium oraviense*, *Spirophycus bicornis*, *Taphrhelminthopsis auricularis*, *Helminthoida crassa* or *Paleodictyon carpathicum* and *latum*, attain the peak of their frequency in these beds. New types of *Paleomeandron* and *Helminthoida* appear, but some types frequent in older beds now become very rare *(Helminthoida labyrinthica, Desmograpton)* or apparently extinct. Rosetted types are extremely rare, and so is *Zoophycos*, represented by a type with very thin lamellae.

In the Middle Eocene a considerable facies unification took place in the basin, in which the **Hieroglyphic Beds** are the main deposit, though in some regions replaced by variegated shales or marls. The Hieroglyphic Beds consist mostly of thin-bedded sandstones alternating with argillaceous shales, usually in equal proportions. In some regions shales may predominate. Specifically, the assemblage of trace fossils is of considerable diversity (67). The number of specimens, except for a few ichnospecies, is not great, and on the whole the Hieroglyphic Beds give the impression of being rather poor in trace fossils. Certain types, like *Protopaleodictyon submontanum* and particularly *Protopaleodictyon incompositum* here attain their maximum frequency. *Scolicia prisca* is also abundant probably more so than in the Beloveza Beds. Most other ichnospecies, with the exception of the very common *Sabularia simplex* and the fairly common *Fucusopsis annulata*, are found only in single specimens. The number of patterned types is high (27), almost one-half of the total number of ichnospecies, but with the two exceptions already mentioned, they are extremely rare. *Cosmorhaphe*, *Helminthoida* and *Paleodictyon* are very infrequently met with. The distribution of the ichnofauna within the Hieroglyphic Beds is far from uniform. The beds occurring in the northern trough are much poorer in ichnofauna in comparison with the southern trough. Most probably this is mainly due to the differences in lithology, as the Hieroglyphic Beds of the northern trough have a greater proportion of shales.

In the south-western part of the southern trough the Hieroglyphic Beds are partly replaced by the **Pasierbiec Sandstone** and **Łącko Beds.** The former consists of coarse-grained sandstones and conglomerates with thin intercalations of thin-bedded sandstones, marls and shales. The latter is composed of alternating sandstones, marls and shales; in many sections marls strongly predominate. The Pasierbiec Sandstone, because of its lithology, is very poor in trace fossils. In the Łącko Beds, laterally replacing the Pasierbiec Sandstone, the ichnofauna is not so poor (26 ichnospecies) but much poorer than in the equivalent Hieroglyphic Beds. No type is particularly frequent in these beds, and, in spite of the presence of marls, chondritids are rather uncommon.

At the end of the Eocene the flysch type of sedimentation ceased for some time, and pelagic **Globigerina Marls** were deposited on large areas in the northern trough. In the southern trough, on the contrary, the flysch régime was maintained. Here the Upper Eocene and probably the lowest part of the Oligocene are represented by the thick **Magura Sandstone** (c. 2000 m). Locally, a subdivision of **Sub-Magura Beds** is separated. The Magura Sandstone consists mostly of thick-bedded sandstones alternating with marly shales, which may predominate in the lowest part of the horizon. It includes packets of thin-bedded sandstones alternating with shales, a type of sediment not unlike the underlying Hieroglyphic Beds. To a certain degree the presence of these interbeds somewhat weakens conditions on the whole unfavourable for the development and preservation of trace fossils. The ichnofauna is poor, with a low specific diversity (31) and rather small number of specimens. *Sabularia* and *Zoophycos* are fairly frequent and with *Taphrhelminthopsis vagans* are the only types widely distributed. *Scolicia prisca* may be abundant locally. Patterned types are rare and limited to thin-bedded intercalations.

Generally it may be said that the end of the Eocene times brought a marked decline in the number of ichnospecies and their frequency.

In the northern trough the sedimentation of the Globigerina Marls was followed by the deposition of dark oil shales, usually with silicites ("menilites") near the base, with some interbeds of fairly coarse, often glauconitic sandstones in marginal zones. These beds were deposited under semi-euxinic conditions which were anything but favourable for the development of bottom fauna. Trace fossils are extremely rare, and in most sections virtually absent. The **Menilite Shales,** laid down at the Upper Eocene — Lower Oligocene boundary, are covered by the Krosno Beds (Oligocene — Lower Miocene). This is a very thick complex (up to 3000 m) consisting mostly of medium- and thin-bedded sandstones alternating with marly shales in variable proportions. In the lower part thick-bedded sandstones tend to predominate. Towards the top the amount of shales increases, and the complex often ends with only shaly beds.

In spite of the apparently propitious conditions for the occurrence of ichnofauna, the **Krosno Beds** are very poor in trace fossils. In this very thick and widely distributed complex (the Krosno Beds cover almost one-third of the area of the Polish Carpathians) only 32 ichnospecies have been found, and the number of specimens is also very low. Very many well exposed cross-sections (e.g. the stream Janoska in the Silesian Beskid, the area of Krzeszów, cross-sections along the Biała, Wisłoka, and Wisłok rivers) turned out to be entirely barren or with very few occurrences of trace fossils. Even underdeveloped traces, with no distinct morphological features which could be determined at least on the generic level, are in the Krosno Beds very rare and for the most part, absent. Very few sandstone layers are trace-bearing. The shales, though marly, contain chondritids in only a few cases. *Sabularia* and *Subphyllochorda laevis* occur here and there in greater abundance, but *Zoophycos* is extremely rare. Most of the types are the same as in older beds, few new types appear *(Gordia arcuata, Oniscoidichnus)* and patterned ichnospecies are very rare (9). The re-appearance of *Gyrochorte*, absent since the Lower Eocene, is noteworthy.

The paucity of trace fossils in the Krosno Beds was presumably conditioned by various factors. First of all, the semi-euxinic environment which reigned in the northern trough at the outset of the Oligocene during the deposition of the Menilite Shales caused an almost total extermination of the ichnofauna, already depleted in the Upper Eocene. Not only the trace-making animals were extirpated. The benthonic agglutinate foraminifers, which dominated in the microfauna of older horizons, almost completely disappeared and were replaced in the Krosno Beds by calcareous types. It is probable that the manner of deposition of the Krosno Beds was not favourable for the preservation and development of the ichnofauna. The abundance of flute casts in these beds points to a fairly strong erosion of the sea-bottom by currents which might have scoured the uppermost layer of sediments where the "pre-depositional" infauna and bottom dwellers lived. The shallowing of the basin, a problem which will be discussed in one of the following chapters, and the gradual dwindling of the flysch régime towards the end of the deposition of the Krosno Beds may be yet other causes.

## LATERAL DISTRIBUTION OF TRACE FOSSILS

(tables 7–9)

In individual members of the Carpathian flysch the trace fossils assemblages are fairly uniform. Nevertheless, in the horizontal direction there are some differences in the generic and specific composition of the assemblages and variations in the frequency of particular ichnospecies.

The uniformity of the composition seems to imply rather a deep-water environment in which the abiotic factors controlling life conditions do not change much from place to place, but tend to be uniform and constant over broader areas (CHAMBERLAIN, 1971 *b*). In all likelihood, however, in the Carpathian basin there existed some transversal elements of the floor which divided the basin and its troughs into second-order depressions. A variable topography of the sea-floor is implied by the palaeocurrent analysis in several members of the Carpathian flysch (KSIĄŻKIEWICZ, 1975). In these depressions there might have existed somewhat different conditions in bottom sediments, bathymetry, deep-water circulation, nutrient and oxygen content, which probably influenced the development of the infauna and epifauna and could produce differences in trace fossil assemblages even in neighbouring parts of the basin.

The palaeocurrent analysis shows that the bottom of the Carpathian flysch troughs sloped along longitudinal axes, approximately parallel to the general trend of the basin, in one direction or another. The sediment-carrying currents descended along the axes of the troughs. There are some changes in lithology along the main current direction, and no doubt, the depth of the basin increased in the direction of the currents. Both factors, the lithology and the water depth, controlled the distribution of trace producers.

It is no easy matter to assess which was the dominant factor causing the lateral changes in the distribution of trace fossils: the topography of the sea-floor, the character of the sediments or the depth of water. The last-named factor will be discussed at length in the next chapter. Meanwhile, a few examples of lateral changes in the distribution of trace fossils taken from such units as have a larger areal extent will now be presented.

The *Godula Beds* are exposed in a belt almost 200 km long. In the western sector, in which the beds often display a proximal character, the ichnofauna is comparatively poorer in the number of ichnospecies and less abundant than in the east, where the majority of beds have an intermediate or even distal character. Since the main current direction is eastward, it may be inferred that the diversity of types increases downcurrent. There are no notable differences in the assemblages of trace fossils, but *Taphrhelminthopsis*, *Scolicia* and *Zoophycos* seem to be more frequent in the east.

The *Inoceramian Beds* (table 7) furnish a more clear picture of downcurrent variations. They occur in a zone 150 km in length, with the principal current direction towards south-east.

The beds on the whole exhibit an intermediate character, but in the north-west marly intercalations and thick-bedded sandstones are more frequent. For comparison the middle course of the San River has been taken as the dividing line: east of it the total number of ichnospecies is slightly greater and so is the number of occurrences of some types. There is no appreciable difference in the number of meandering and net-like traces.

Table 7

LATERAL DISTRIBUTION OF THE ICHNOFAUNA IN THE INOCERAMIAN BEDS

| | western reg. | eastern reg. |
|---|---|---|
| *Mammillichnis aggeris* | | x |
| *Traucumichnis glaber* | x | |
| *Sabularia simplex* | x | x |
| *Sabularia tenuis* | x | x |
| *Sabularia ramosa* | x | x |
| *Arthrophycus annulatus* | x | x |
| *Arthrophycus strictus* | | x |
| *Fucusopsis angulata* | x | x |
| *Keckia annulata* | x | x |
| *Keckia hoessii* | | x |
| *Chondrites aequalis* | x | x |
| *Chondrites affinis* | x | x |
| *Chondrites arbuscula* | x | x |
| *Chondrites flexilis* | | x |
| *Chondrites furcatus* | x | |
| *Chondrites intricatus* | | x |
| *Lophoctenium ramosum* | x | x |
| *Taenidium isseli* | | x |
| *Sublorenzinia nowaki* | x | |
| *Sublorenzinia plana* | | x |
| *Sublorenzinia pustulosa* | | x |
| *Fascisichnium extentum* | | x |
| *Phycosiphon incertum* | x | x |
| *Zoophycos brianteus* | x | F |
| *Zoophycos insignis* | x | F |
| *Helminthopsis abeli* | x | x |
| *Helminthopsis hieroglyphica* | | x |
| *Helminthopsis irregularis* | | x |

cont.

| | western reg. | eastern reg. |
|---|---|---|
| *Helminthopsis tenuis* | x | x |
| *Muensteria hamata* | | x |
| *Scolicia plana* | x | x |
| *Scolicia vertebralis* | x | x |
| *Subphyllochorda laevis* | x | |
| *Taphrhelminthopsis auricularis* | x | x |
| *Taphrhelminthopsis vagans* | x | x |
| *Tuberculichnus meandrinus* | | x |
| *Tubulichnium incertum* | x | F |
| *Spirorhaphe involuta* | x | |
| *Spirophycus bicornis* | x | x |
| *Cosmorhaphe gracilis* | x | |
| *Cosmorhaphe sinuosa* | x | |
| *Gordia molassica* | | x |
| *Helicolithus sampelayoi* | | x |
| *Helminthoida crassa* | | x |
| *Helminthoida labyrinthica* | x | x |
| *Helminthoida serrata* | x | x |
| *Taphrhelminthoida convoluta* | x | |
| *Acanthorhaphe delicatula* | | x |
| *Belorhaphe zickzack* | | x |
| *Protopaleodictyon incompositum* | x | x |
| *Urohelminthoida dertonensis* | x | x |
| *Desmograpton fuchsi* | x | x |
| *Paleodictyon latum* | x | |
| *Paleodictyon intermedium* | | x |
| *Paleodictyon miocenicum* | x | x |
| *Paleodictyon strozzii* | x | x |
| *Paleodictyon tellinii* | x | |

The *Ropianka Beds* (table 8), together with the coeval and lithologically very similar *Cisna Beds*, crop out along a belt almost 300 km long. Both members were deposited in one trough, which was being filled by material brought in principally from two opposite directions, from the east and west. In addition some lateral inflow is also marked (see Geological Atlas of Poland, Fasc. 13, collective work, M. KSIĄŻKIEWICZ, ed., Geol. Survey of Poland, Warsaw, 1962). For these reasons the westernmost and eastern parts of the zone occupied by the Ropianka and Cisna Beds display features rather of a proximal character, with a considerable amount

Table 8

LATERAL DISTRIBUTION OF TRACE FOSSILS IN THE ROPIANKA AND CISNA BEDS

| | western reg. | central reg. | eastern reg. |
|---|---|---|---|
| *Mammillichnis aggeris* | | x | |
| *Bergaueria prantli* | | x | |
| *Sabularia simplex* | x | x | x |
| *Sabularia rudis* | x | x | |
| *Sabularia tenuis* | x | x | |
| *Sabularia ramosa* | x | x | |
| *Arthrophycus annulatus* | | x | |
| *Arthrophycus strictus* | | x | |
| *Fucusopsis angulata* | x | x | |
| *Fucusopsis striata* | | x | |
| *Keckia annulata* | x | x | |
| *Keckia hoessii* | | x | |
| *Rhabdoglyphus compositus* | x | | |
| *Rhabdoglyphus spinosus* | | x | |
| *Rhabdoglyphus sulcatus* | | x | |
| *Bostricophyton pantenellii* | | x | |
| *Buthotrephis* aff. *succulens* | | x | |
| *Buthotrephis* indet. | | x | |
| *Chondrites aequalis* | x | x | x |
| *Chondrites affinis* | x | x | |
| *Chondrites arbuscula* | x | x | |
| *Chondrites expansus* | | x | |
| *Chondrites filiformis* | | x | |
| *Chondrites flexilis* | | x | |
| *Chondrites furcatus* | x | x | |
| *Chondrites intricatus* | x | x | x |
| *Lophoctenium ramosum* | | x | |
| *Strobilorhaphe clavata* | | x | |
| *Strobilorhaphe pusilla* | | x | |
| *Taenidium annulatum* | | x | |
| *Taenidium isseli* | | x | |
| *Lorenzinia* aff. *apenninica* | | x | |
| *Lorenzinia carpathica* | | x | x |
| *Lorenzinia moreae* | | x | |
| *Sublorenzinia nowaki* | | x | |
| *Sublorenzinia pusilla* | | x | |
| *Capodistria vettersi* | | x | |
| *Glockeria sparsicostata* | x | | |
| *Fascisichnium extentum* | | x | |
| *Phycosiphon incertum* | x | x | x |
| *Zoophycos brianteus* | x | x | |
| *Zoophycos insignis* | x | x | |
| *Zoophycos* indet. | | | x |
| *Helminthopsis abeli* | | x | |

cont.

| | western reg. | central reg. | eastern reg. |
|---|---|---|---|
| *Helminthopsis hieroglyphica* | | x | |
| *Helminthopsis irregularis* | | x | |
| *Helminthopsis tenuis* | | x | x |
| *Muensteria hamata* | | x | |
| *Muensteria planicostata* | | x | |
| *Naviculichnium marginatum* | x | x | |
| *Scolicia plana* | x | x | ? |
| *Scolicia prisca* | | x | |
| *Scolicia vertebralis* | x | x | |
| *Subphyllochorda granulata* | | x | |
| *Subphyllochorda laevis* | | x | |
| *Taphrhelminthopsis auricularis* | | x | x |
| *Taphrhelminthopsis vagans* | x | | x |
| *Tuberculichnus meandrinus* | | x | |
| *Tuberculichnus vagans* | x | | |
| *Tubulichnium incertum* | x | x | |
| *Spirorhaphe involuta* | x | x | |
| *Spirorhaphe zumayensis* | | x | |
| *Spirophycus bicornis* | | x | |
| *Spirophycus caprinus* | | x | |
| *Spirophycus involutissimus* | | x | |
| *Cosmorhaphe gracilis* | | x | |
| *Cosmorhaphe helminthopsoidea* | x | x | |
| *Cosmorhaphe sinuosa* | x | x | |
| *Cosmorhaphe fuchsi* | x | x | |
| *Helicolithus sampelayoi* | x | x | |
| *Helminthoida crassa* | x | x | |
| *Helminthoida helminthopsoidea* | x | x | |
| *Helminthoida labyrinthica* | x | x | x |
| *Helminthoida miocenica* | x | x | |
| *Helminthoida serrata* | x | | |
| *Paleomeandron elegans* | x | x | |
| *Taphrhelminthoida convoluta* | x | x | |
| *Acanthorhaphe delicatula* | | x | |
| *Belorhaphe fabregae* | | x | |
| *Belorhaphe zickzack* | | x | |
| *Protopaleodictyon incompositum* | | x | |
| *Protopaleodictyon submontanum* | x | x | |
| *Urohelminthoida appendiculata* | x | x | |
| *Urohelminthoida dertonensis* | x | x | |
| *Desmograpton fuchsi* | x | x | |
| *Paleodictyon latum* | | x | |
| *Paleodictyon intermedium* | | x | |
| *Paleodictyon miocenicum* | x | x | |
| *Paleodictyon strozzii* | x | x | |
| *Paleodictyon tellinii* | | x | |

of thick- and medium-bedded sandstones, while the central part of the zone may be classified as of an intermediate character, with intercalations of marly layers and many packets of a thin-bedded flysch. The differences in trace fossil diversity are well marked. In the most western part (west of the river Skawa) and in the eastern part (east of the river Wisłok, including the Cisna Beds in its most eastern sector) the number of ichnospecies is much lower (38 in the west, 11 in the east) than in the central region, particularly the area of Nowy Sącz — Grybów — Gorlice, with 84 ichnospecies. The difference is largely due to chondritids, abundantly occurring in the marls of the central region, but the number of winding and patterned types is also greater. It should, however, be stressed that the numerical difference may be due partly to adverse sampling conditions, particularly in the eastern area, caused by the state and paucity of good outcrops.

The *Beloveza Beds* (table 9) crop out in a belt about 200 km long. The sub-axial transport direction is from the east and south-east (see Geological Atlas of Poland, Fasc. 13). There are small changes in the lithology and stratinomy of the beds along the current direction, but in the east medium-bedded layers are more numerous and interbeds of marls present, while in the west the thin-bedded, horizontally or single-current laminated sandstones predominate. The eastern part is rather of an intermediate character, while the western is typically distal, the line of the river Skawa being taken as the divide. The difference in specific diversity is small, the western region surpassing the eastern only by 10 ichnospecies, but other differences are substantial: in the east chondritids are more abundant both as to the number of types and of specimens. Large and coarsely ribbed *Zoophycos*, although very rare, are present as well as *Spirorhaphe*, which are absent in the western sector, where the meandering types *(Cosmorhaphe, Helminthoida, Helicolithus)* and paleodictyonids are better represented.

The *Hieroglyphic Beds* are much more widely distributed than any other formation so far discussed, as they occur in all tectonic units and the length of the area within which they crop out is almost 300 km. The transport direction is longitudinal, almost parallel to the axis of the basin and, generally speaking, westward. It might be thought that because it covers so great an area this formation should be particularly instructive in deciphering the lateral variation in the assemblages of trace fossils. This is not the case, because of the predominantly shaly development of these beds in the northern and central parts of the range, and consequently very poor ichnofauna. Only in the southern zone, where the proportion of sandstones to shales averages 1:1, is the ichnofauna fairly abundant. In this zone the number of ichnospecies increases westward (downcurrent), *Zoophycos*, *Keckia* and coarse sabularias are more frequent in the eastern part, while *Scolicia* and *Subphyllochorda* are more common in the western sector.

The *Krosno Beds* also cover a very large area. The scarcity of trace fossils is here again a great obstacle for tracing lateral changes in the composition of assemblages. Few data are available for the lower part of this very thick formation, but the middle part has supplied a relatively fair number of traces. These have been collected mainly in the eastern part, where the beds have an intermediate or distal character. Some helminthoids and paleodictyonids have been found in that part, in addition to *Scolicia* and other winding traces, very rare or apparently absent in the western part. Since in the middle part of the Krosno Beds eastward current directions predominate, the inference is that the diversity of species increases downcurrent.

The changes in the lateral distribution of trace fossils may be a function of two main factors: the distribution of trace-making animals on the sea-floor and the preservation of traces (Crimes, 1973). The latter factor, no doubt, plays a considerable role, particularly in areas where the currents invading the sea-bottom were able to scour it and destroy more or less completely the pre-depositional traces made prior to the advent of the current on the surface or within the substratum. There are indications that the preservational factor was of minor importance. In the Beloveza Beds the pre-depositional *Taphrhelminthopsis* occurs abundantly in both intermediate and distal regions. In the Krosno Beds pre-depositional *Taphrhelminthopsis* and *Subphyllochorda laevis* occur in regions situated more distally, and are even more abundant than in the west, in the more proximal area. It may therefore be assumed that the increasing frequency of trace fossil types in more distal deposits only partly depends on preservational factors, and is more indicative of the influence of the depth of deposition. The water depth

Table 9

LATERAL DISTRIBUTION OF THE ICHNOFAUNA IN THE BELOVEZA BEDS

| | western reg. | eastern reg. |
|---|---|---|
| *Mammillichnis aggeris* | x | x |
| *Sabularia simplex* | x | x |
| *Sabularia ramosa* | x | |
| *Arthrophycus annulatus* | x | x |
| *Fucusopsis annulata* | F | x |
| *Halymenidium sublumbricoides* | x | x |
| *Halymenidium oraviense* | x | |
| *Buthotrephis bifurcata* | x | |
| *Buthotrephis* aff. *succulens* | | x |
| *Buthotrephis* indet. | x | |
| *Chondrites arbuscula* | | x |
| *Chondrites furcatus* | | x |
| *Chondrites affinis* | x | F |
| *Chondrites aequalis* | x | x |
| *Lophoctenium ramosum* | x | x |
| *Strobilorhaphe clavata* | F | x |
| *Strobilorhaphe pusilla* | x | x |
| *Strobilorhaphe glandifer* | | x |
| *Sublorenzinia plana* | x | |
| *Sublorenzinia nowaki* | x | |
| *Phycosiphon incertum* | x | x |
| *Zoophycos brianteus* | | x |
| *Zoophycos insignis* | | x |
| *Zoophycos* indet. | x | x |
| *Helicorhaphe tortilis* | x | |
| *Helminthopsis abeli* | x | x |
| *Helminthopsis hieroglyphica* | x | x |
| *Helminthopsis irregularis* | x | |
| *Helminthopsis tenuis* | x | x |
| *Naviculichnium marginatum* | x | x |
| *Scolicia prisca* | x | x |
| *Subphyllochorda granulata* | x | x |
| *Subphyllochorda striata* | x | x |
| *Subphyllochorda laevis* | | x |
| *Taphrhelminthopsis auricularis* | x | x |
| *Taphrhelminthopsis vagans* | x | x |
| *Tuberculichnus meandrinus* | | x |

cont.

| | western reg. | eastern reg. |
|---|---|---|
| *Tuberculichnus vagans* | x | |
| *Tuberculichnus bulbosus* | x | |
| *Tubulichnium incertum* | x | |
| *Spirorhaphe involuta* | | x |
| *Spirorhaphe zumayensis* | | x |
| *Spirophycus bicornis* | F | x |
| *Spirophycus involutissimus* | x | x |
| *Cochlichnus* aff. *anguineus* | x | x |
| *Cosmorhaphe sinuosa* | x | x |
| *Cosmorhaphe helminthopsoidea* | x | |
| *Cosmorhaphe fuchsi* | F | x |
| *Helicolithus sampelayoi* | F | x |
| *Helminthoida aculeata* | | x |
| *Helminthoida alterna* | x | x |
| *Helminthoida crassa* | x | x |
| *Helminthoida helminthopsoidea* | x | x |
| *Helminthoida labyrinthica* | x | x |
| *Helminthoida serrata* | x | x |
| *Paleomeandron rude* | x | |
| *Paleomeandron robustum* | x | |
| *Taphrhelminthoida convoluta* | F | x |
| *Taphrhelminthoida plana* | x | |
| *Acanthorhaphe delicatula* | F | x |
| *Belorhaphe zickzack* | x | |
| *Belorhaphe fabregae* | x | |
| *Protopaleodictyon incompositum* | x | x |
| *Protopaleodictyon submontanum* | F | x |
| *Urohelminthoida dertonensis* | F | x |
| *Desmograpton fuchsi* | x | |
| *Megagrapton irregulare* | x | x |
| *Paleodictyon minutissimum* | x | |
| *Paleodictyon minimum* | x | x |
| *Paleodictyon latum* | F | x |
| *Paleodictyon miocenicum* | x | |
| *Paleodictyon strozzii* | x | x |
| *Paleodictyon carpathicum* | x | x |
| *Paleodictyon regulare* | x | |
| *Paleodictyon majus* | x | x |
| *Paleodictyon* aff. *gomezi* | x | |

might exert this influence either directly (some animals were better adapted to certain depths) or indirectly (the sediments brought in and deposited by currents underwent lateral changes in thickness, composition and stratification depending on the distance from the source and the depth of water). On the whole, the more distal sedimentation induced a greater diversity of species.

## TRACE FOSSILS AND DEPTH OF WATER
(tables 10–11)

The application of trace fossils in palaeobathymetric determinations has already been attempted by several authors, beginning with SEILACHER (1954, 1959, 1967*b*). More recently CHAMBERLAIN (1971*b*), CHAMBERLAIN and CLARKE (1973), CRIMES (1973) and KERN and WARME (1974) have tackled this problem. It is generally recognized that, although other factors such as the type of the sediment, aeration of bottom waters and conditions of preservation may interfere or interact, trace fossils may give clues for the interpretation of ancient environmental conditions (TEICHERT *in* HÄNTZSCHEL & KRAUS, 1972, discussion) and the depth of water. According to SEILACHER (1967*b*) organisms respond by their behaviour to the amount of food available in the substratum. Since trace fossil morphology is to a great extent controlled by the feeding behaviour of the trace-making organism, the behavioural pattern reflects the manner of the organism's search for food. As water deepens the amount of food decreases, and the animal has to search for it and process the nutrient-bearing sediment effectively by a more elaborate manner of locomotion. Therefore according to SEILACHER (1967*b*) the presence of trace fossils of more complex patterns, guided meanders and networks may be expected in the sediments that were deposited at greater depths. In the flysch the problem is more complicated, since there is little doubt that by transferring sediments from shallow into deeper parts of the basin turbidity currents could increase the amount of organic material and nutrients in the basin (KSIĄŻKIEWICZ, 1961*b*, GRIGGS *et al.*, 1969).

In the Carpathian flysch its stratigraphic units have well-defined sedimentary features and their fauna, particularly microfauna, is fairly well known (BIEDA *et al.*, 1963, GEROCH *et al.*, 1967). On these grounds an attempt was made to determine the depth of the basin in successive stages of its evolution (KSIĄŻKIEWICZ, 1975). The depth of deposition of each stratigraphic unit has approximately been determined on the basis of the microfaunal content and the sedimentary character (text-fig. 4). The microfaunal assemblages in the Carpathian flysch contain many species that still live in the present-day seas. They also include a number of fossil species which are homeomorphs or closely related to recent species. Presumably their environmental adaptations were similar to those of the related recent species, and so they may be used for bathymetric interpretations (BANDY & ARNAL, 1960). The sedimentary features of particular stratigraphic units enable it to be decided whether they were deposited near the source or further away from it, in other words, whether they are of a proximal, intermediate or distal character. This to some extent enabled the depth differences to be estimated for particular lithostratigraphic units or their parts. The grounds for this kind of argumentation are presented elsewhere (KSIĄŻKIEWICZ, 1975). In the present context we intend to compare the bathymetrical interpretation based on sedimentological features and microfaunal data with the vertical and lateral distribution of trace fossils (table 10).

In the first line the bathymetric distribution of the most frequent groups (simple, branched, winding and patterned, i.e. spirals, meandering and networks) is taken into consideration.

It follows from table 10 that beds presumably deposited at the greatest depth of the basin, i.e. the Ropianka, Sromowce, Beloveza, Łącko and Hieroglyphic Beds and the Variegated Shales, laid down in the mesobathyal zone or deeper, contain a very high proportion of patterned ichnospecies, all above 30%. At the same time they have a relatively low proportion of simple types, on the whole below 16%. The beds deposited presumably at epibathyal depths have a smaller proportion of patterned ichnospecies (the Cieszyn Limestone, the Lgota, the Godula and the Krosno Beds and the Magura Sandstone), generally less than 30%. Concurrently, most of them show a greater proportion of simple forms. On the strength of these data it may be concluded that virtually the number of patterned ichnospecies is greater in beds deposited at greater depths, and the number of simple traces is greater in beds laid down at smaller depths.

Table 10

FACIES, DEPTH AND TRACE FOSSIL ASSEMBLAGES IN THE CARPATHIAN FLYSCH
(in brackets the number of ichnospecies classified as „frequent")

| | Formation or member | Facies | Depth | Number of ichnospecies | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | total | simple | bran-ched | winding | pat-terned |
| Oligocene | Krosno Beds | intermediate partly distal | epibathyal | 33 | 4 (2)<br>12·1% | 5<br>15·1% | 10<br>30·2% | 9<br>27·2% |
| Oligocene | Magura Sandstone | proximal partly intermediate | lower epibathyal partly upper mesobathyal | 31 | 5<br>16·1% | 3<br>9·6% | 6 (1)<br>19·2% | 9<br>28·8% |
| Eocene | Łącko Beds | intermediate partly distal | mesobathyal | 26 | 4<br>15·3% | 4<br>15·3% | 6<br>23·0% | 12<br>46·0% |
| Eocene | Hieroglyphic Beds | intermediate | upper mesobathyal | 67 | 9 (1)<br>13·4% | 9<br>13·4% | 12 (1)<br>17·9% | 27 (4)<br>40·3% |
| Eocene | Beloveza Beds | distal | middle mesobathyal | 79 | 6 (3)<br>7·5% | 9 (1)<br>11·2% | 16 (4)<br>20·2% | 37 (9)<br>46·8% |
| Eocene | Ciężkowice Sandstone | proximal | neritic, partly upper epibathyal | 29 | 7 (2)<br>24·1% | 2<br>6·9% | 5<br>17·2% | 11<br>37·9% |
| Eocene | Variegated Shales | distal | lower mesobathyal or/and infrabathyal | 61 | 6 (1)<br>9·5% | 8 (1)<br>13·2% | 6 (1)<br>9·5% | 25 (2)<br>41·0% |
| Palaeocene | Szczawnica Beds | intermediate | middle mesobathyal | 34 | 4 (1)<br>11·7% | 5<br>14·7% | 5<br>14·7% | 13 (1)<br>38·2% |
| Palaeocene | Upper Istebna Beds | proximal | upper epibathyal | 18 | 5<br>27·7% | —<br>— | 3<br>16·6% | 7<br>38·8 % |
| Upper Cretaceous | Sromowce Beds | intermediate | lower epibathyal or/and upper mesobathyal | 25 | 4 (1)<br>16·0% | 1<br>4·0% | 8 (3)<br>32·0% | 9 (1)<br>36·0% |
| Upper Cretaceous | Ropianka Beds | intermediate | upper and middle mesobathyal | 92 | 12<br>13·0% | 16 (3)<br>17·6% | 16 (2)<br>17·6% | 30 (3)<br>32·7% |
| Upper Cretaceous | Lower Istebna Beds "fucoidal marls" interbeds | intermediate or distal | upper mesobathyal | 14 | 1<br>7·1% | 6<br>42·9% | 2<br>14·2% | 5<br>35·7% |
| Upper Cretaceous | Lower Istebna Beds (whole unit) | proximal | epibathyal | 24 | 4 (1)<br>16·6% | 6<br>25·0% | 4<br>16·6% | 7<br>29·1% |
| Upper Cretaceous | Inoceramian Beds | intermediate | lower epibathyal | 57 | 4<br>7·0% | 8 (4)<br>14·0% | 12 (3)<br>21·0% | 18<br>31·5% |
| Upper Cretaceous | Godula Beds | intermediate locally proximal | lower epibathyal | 41 | 10 (2)<br>24·3% | 4<br>9·7 % | 10 (1)<br>24·3% | 10<br>24·3% |

cont.

| | Formation or member | Facies | Depth | Number of ichnospecies | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | total | simple | bran-ched | winding | pat-terned |
| Albian | Lgota Beds | intermediate locally proximal | epibathyal, locally neritic | 11 | 4 | 3 | 3 | 1 |
| | | | | | 36·3% | 27·2% | 27·2% | 9·0% |
| Neocomian | Grodziszcze Beds | proximal | lower epibathyal | 25 | 5 (2) | 5 | 7 (1) | 5 (1) |
| | | | | | 20·0% | 20·0% | 28·0% | 20·0% |
| | Upper Cieszyn Shales | intermediate? | epibathyal | 16 | 5 | 2 | 2 | 3 |
| | | | | | 31·2% | 12·5% | 12·5% | 18·7% |
| | Cieszyn Limestone | proximal | epibathyal | 31 | 7 | 6 (1) | 7 | 6 |
| | | | | | 22·2% | 19·3% | 22·2% | 19·3% |

Apparently there are some exceptions to this rule. The Upper Istebna Beds, interpreted as deposited at an upper epibathyal depth, show a very high proportion of patterned ichnospecies (38·8 %). In these beds the ichnofauna is very scarce, but numerically the simple types are relatively abundant, while patterned ichnospecies are extremely rare and are almost all found in single specimens. Another exception is represented by the Lower Istebna Beds. Although believed to have been deposited in the epibathyal zone, they have a high proportion of patterned ichnospecies (29 %). This figure relates to the whole unit, which in the east contains a thick interbed of "fucoidal marls". If the ichnospecies occurring solely in these marls are deduced from the total number of ichnospecies, it appears that the predominant sedimentary type of the Lower Istebna Beds, with evident proximal features, includes only 18 % of patterned ichnospecies. The Ciężkowice Sandstone presents a similar example. The proportion of patterned ichnospecies in this member, taken as whole, is high. The Ciężkowice Sandstone is thought to be deposited on the edge of a shallow coastal fringe, partly deposited in the neritic zone, partly in the uppermost part of the epibathyal zone. If the traces found in the sandstone layers that were certainly deposited at shallow depths (with large-scale cross-stratification) are taken into account, it appears that they belong solely to simple types *(Sabularia, Arthrophycus)*. The patterned ichnospecies seem to be limited to rather thin-bedded sandstones, very likely laid down below the edge at somewhat greater depths. In addition, although numerous on the specific level, the patterned ichnospecies are mostly found in single specimens.

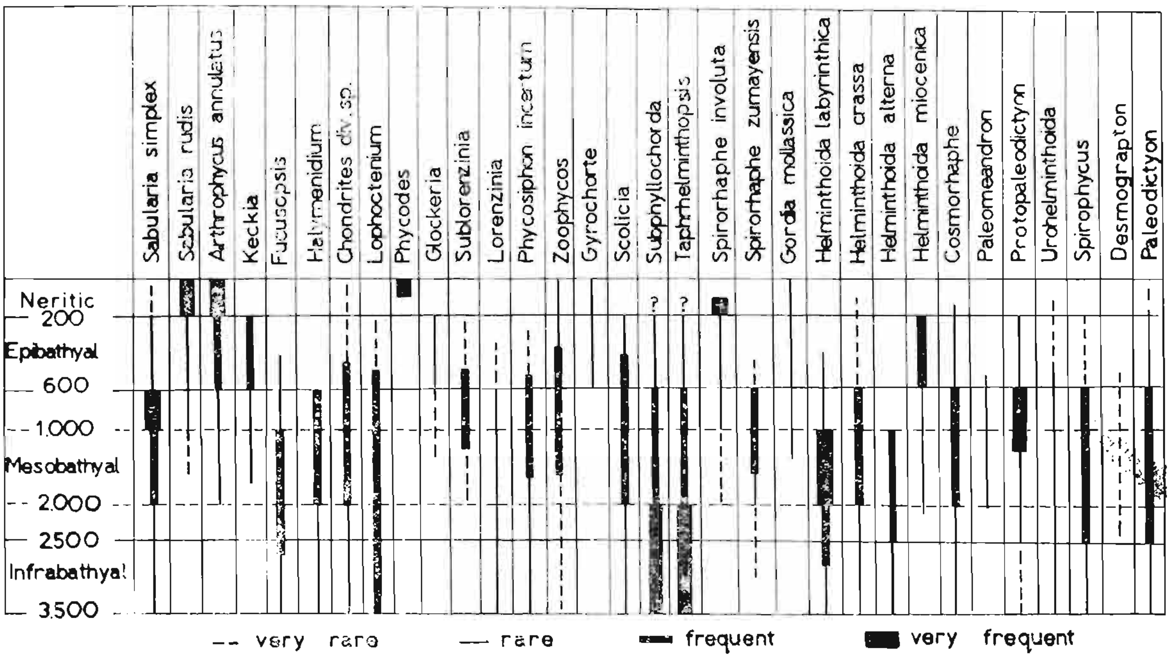
It appears then that not only the total number of ichnospecies, but also their frequency is of significance in the bathymetric distribution of trace fossils. Another inference should also be drawn from the instances discussed: it cannot be assumed that the patterned types are restricted to greater depths. They do occur in relatively shallow water deposits, though much less abundantly.

The significance of differences in the frequency of patterned ichnospecies is also shown when the beds presumably deposited at greater depth are compared. The Inoceramian and Ropianka Beds were deposited in the same period (Senonian). The depth of deposition of the former was determined as the lower epibathyal zone, and the latter are believed to be laid down at mesobathyal depths. The proportion of patterned ichnospecies to the total number of ichnospecies in either unit is almost the same, but the number of patterned types is much greater in the Ropianka Beds, and several of them occur in a considerable number, while in the Inoceramian Beds the number of occurrences of particular patterned ichnospecies is small. The Beloveza Beds (Lower Eocene) as compared with the stratinomically similar Hieroglyphic Beds (Middle Eocene) may serve as another example. There is a small difference in the total number of patterned ichnospecies in these beds, but in the Beloveza Beds 9 patterned ichnospecies may be classified as frequent against 4 in the Hieroglyphic Beds. This particularly refers to highly intricate patterned types: in the Beloveza Beds 2 helminthoids and 3 paleodictyonids are represented by numerous specimens; in the Hieroglyphic Beds none of these types could be classified as frequent, as all ichnospecies of these two groups are represented by few if not single specimens.

Now the bathymetric range of particular patterned ichnospecies is tentatively presented (table 11).

Table 11

DEPTH DISTRIBUTION OF THE CARPATHIAN TRACE FOSSILS




*Gordia molassica* occurs in a variety of beds, but does not occur in the beds presumably deposited at the greatest depth. *Helminthoida* are represented in practically all types of beds, but clearly attains the greatest frequency in the beds deposited in the mesobathyal zone: *Helminthoida labyrinthica* in the Ropianka Beds and in the Variegated Shales, *H. crassa* in the Ropianka and Beloveza Beds, *H. alterna* in the Beloveza Beds. Of all helminthoids *H. miocenica* seems to have the widest bathymetric range and even to be more common in the beds laid down at a relatively moderate depth.

*Cosmorhaphe* is present in all kinds of beds, including the Ciężkowice Sandstone, but beyond any doubt is much more frequent in the beds deposited in the mesobathyal zone.

All types of *Paleomeandron* are restricted to beds deposited at greater depths.

*Protopaleodictyon incompositum* and *P. submontanum* may occur sparingly at smaller depths, but are most frequent in the beds presumably deposited in the upper part of the mesobathyal zone (Hieroglyphic Beds).

*Urohelminthoida*, nowhere very frequent, is present in all types of beds, even as aberrant varieties in the shallow-water Ciężkowice Sandstone, but is more common in the beds of the mesobathyal zone.

*Paleodictyon* occurs in all beds (except for the Lgota Beds, where bottom conditions were prohibitive for many types of burrowers), but the diversity of its types and the number of its occurrences markedly increase with depth and attain a maximum in the beds of the mesobathyal zone (Beloveza and Ropianka Beds, and also the presumably infrabathyal or abyssal Variegated Shales). Paleodictyonids occurring in the Ciężkowice Sandstone tend to be represented by aberrant varieties, of the *Pleurodictyon*-like types.

Of the spirals, *Spirorhaphe involuta* is more frequent in the Ciężkowice Sandstone than anywhere else, and only paringly occurs in beds of epi- and mesobathyal depths. Thus it seems to represent a notable exception with regard to other patterned types. In contrast, *Spirorhaphe zumayensis* is restricted to the presumably mesobathyal Ropianka and Szczawnica Beds. All three ichnospecies of *Spirophycus* appear to have a wide bathymetric range, but are most frequent in the mesobathyal Hieroglyphic and Beloveza Beds and apparently absent in the Ciężkowice Sandstone.

Simple traces are present in all beds, and this implies that they are not restricted to beds deposited at smaller depths. Their number, however, generally diminishes in the beds laid down at greater depths, although the difference is not very substantial (table 10). In respect to their bathymetric distribution the simple traces seem to fall into two groups: one consisting of traces with smooth or transversely ribbed surface *(Sabularia, Arthrophycus, Keckia)* occurs mainly in the beds of epibathyal origin, although *Sabularia simplex* may be very common in mesobathyal beds; the second group includes structures with surface ornamentation like *Fucusopsis* and *Halymenidium* which are most frequent in beds whose depth of deposition may be defined as mesobathyal. In particular, coarse *Sabularia rudis* is rather more frequent in beds deposited at shallower depths, but *S. simplex* is common in the Sromowce and Beloveza Beds and still present in the possibly infrabathyal Variegated Shales. *Arthrophycus annulatus* is very common in the Ciężkowice Sandstone and still abundant in the epibathyal Inoceramian Beds. *Keckia* is frequent in the epibathyal Godula Beds and also present in the mesobathyal Hieroglyphic Beds. *Fucusopsis angulata* and *F. annulata* have a wide depth range, as they occur both in the epi- and mesobathyal beds, but are certainly much more common in deeper-water deposits. Both kinds of *Halymenidium* appear to be limited to mesobathyal beds (Beloveza and Hieroglyphic Beds).

Branched traces are represented mostly by chondritids, the occurrence of which is obviously linked with marly sediments. In the Carpathian flysch these beds, commonly termed "fucoidal marls", occur in a number of units, mainly in the Inoceramian Beds and as thick interbeds in the Lower Istebna Beds; they are less frequent in the Ropianka Beds. The first-named beds were presumably deposited in the lower part of the epibathyal zone, as were most probably the "fucoidal marls" intercalated in the Lower Istebna Beds, while the Ropianka Beds were laid down in the mesobathyal zone. All these three units contain a wealth of chondritids and related types *(Taenidium, Bostricophyton, Buthotrephis)*. This would mean that *Chondrites* has its maximum frequency in the lower epibathyal and the mesobathyal zone, an assertion in fair agreement with the view of CHAMBERLAIN (1971*b*). The related *Strobilorhaphe* seems to have a similar depth range, and *Lophoctenium* is also very frequent in the beds of the same bathymetric assignment, although it is not uncommon in still deeper deposited beds (Variegated Shales).

The winding types are the most common group in the Carpathian flysch, both in the number of ichnospecies and occurrences. On the basis of their distribution in beds of different origin, it may be said that the number of types increases with the depth as exemplified by 12 ichnospecies in the Inoceramian Beds (lower epibathyal zone), against 16 ichnospecies in the Ropianka Beds (mesobathyal zone) and the same number in the Beloveza Beds (also mesobathyal), while the upper epibathyal Lower Istebna Beds have merely 4 and the Ciężkowice Sandstone 5 winding ichnospecies. Very likely this increase with depth takes place only to a certain limit: the Variegated Shales of the Palaeocene — Lower Eocene age, presumably the deepest sediment of the Carpathian flysch, have a small number (6) of winding ichnospecies, but the number of their occurrences is not small. *Subphyllochorda granulata* is here particularly frequent.

Among the winding types *Gyrochorte* seems to have a fairly limited depth range. *Gyrochorte burtani* occurs in the beds assumed to have been laid down in the epibathyal zone (Grodziszcze Beds, Verovice Shales), but afterwards disappears to reappear in the also epibathyal Krosno Beds. It is absent in the intervening beds of Upper Senonian — Palaeocene — Eocene age believed to be deposited mostly at greater depths than the epibathyal zone. One specimen was found in the Senonian Skrzydlna Beds. These form an interbed in the Węglówka Marls which probably, according to their microfauna, could not have been deposited much deeper than the lower epibathyal zone.

All types of *Helminthopsis* seem to be indifferent to depth, but are few and rare in the supposedly neritic beds.

*Scolicia* appears to be absent in the presumably neritic beds, but is otherwise ubiquitous, with the greatest frequency in the lower part of the epibathyal (Inoceramian Beds) and the upper part of the mesobathyal zone (the Ropianka, Sromowce, Beloveza and Hieroglyphic Beds). It seems to be much less frequent in the Variegated Shales deposited at greater depths than the beds enumerated above.

*Subphyllochorda* occurs in the beds assigned to both epi- and mesobathyal depths. Probably absent in the neritic beds, it attains its maximum frequency in the beds deposited at the greatest depths of the Carpathian flysch basin (Variegated Shales).

*Taphrhelminthopsis*, absent in the beds laid down at small depths, occurs abundantly in the beds assigned to the mesobathyal depths (the Ropianka and Beloveza Beds).

The depth distribution of the much discussed *Zoophycos* seems to be at variance with the views restricting this trace fossil to shallow-water deposits. Actually, it is present in the neritic Lower Cieszyn Shales, and almost disappears in the epibathyal Cieszyn Limestone. But later it is frequent in beds attributed to epi- and even mesobathyal depths: it is numerous in the Godula, Inoceramian, Ropianka and Hieroglyphic Beds. On the contrary, *Zoophycos* is very rare in the beds deposited at shallower depths than the beds enumerated above. It is practically absent in the epibathyal Istebna Beds, and very rare in the Ciężkowice Sandstone and the Krosno Beds. This would mean that *Zoophycos* producers developed better at greater depths, say in the neighbourhood of 1000 m. Such an assertion must be weighed against the possibility that not the depth but the character of sediments played a role in the distribution of this trace. On the other hand, in some beds, deposited at the greatest depths of the basin (Variegated Shales, the Beloveza and Łącko Beds) *Zoophycos* is extremely rare, and if present, usually developed as a very thin-ribbed type, most probably produced by an organism different from those that formed *Zoophycos* structures in other beds.

Another spreite *Phycosiphon incertum* is present in almost all flysch beds in various amounts, but abounds in the Inoceramian and particularly in the Ropianka Beds. This would mean that this ichnospecies was frequent in the beds deposited in the lower part of the epibathyal and in the mesobathyal zone.

A single occurrence of *Anemonichnus* does not say much. It is present in the Magura Sandstone which might have been deposited locally near the wave base. At any rate this trace is indicative of depths not greater than the epibathyal zone.

The rosetted traces are represented by a variety of types produced by various organisms in different manners and probably living in different environments. *Glockeria* occurs in epibathyal beds and seems to be absent in deposits laid down at greater depths, except for the very rare *G. sparsicostata*. On the other hand, *G. disordinata* is, so far as one can judge, limited to the epibathyal Upper Istebna Beds. *Sublorenzinia* and *Capodistria* have a wider depth range, being fairly common both in epi- (the Cieszyn Limestone, Grodziszcze, Godula and Inoceramian Beds) and mesobathyal beds (Ropianka Beds), but very rare or absent in the beds that were deposited deeper (Variegated Shales, the Beloveza Beds). Lorenzinias appear to occur more abundantly in deep-water sediments (the Ropianka Beds, Variegated Shales). No rosetted traces have been found in the Ciężkowice Sandstone, no doubt the shallowest deposit of the Carpathian flysch.

The circular traces show few types and specimens, and therefore little can be said abouth their depth range. *Mammillichnis* occurs in beds to which differing depths have been assigned. *M. aggeris* is present both in the presumably deepest-water Variegated Shales and in the epibathyal Krosno Beds. Only *Traucumichnis glaber* seems to be limited to beds deposited not deeper than the epibathyal zone, and is particularly frequent in the shallow water layers of the Ciężkowice Sandstone.

To end this review of the presumed depth range of the groups of trace fossils and particular types, it should be stressed that the results presented should be treated with reserve. Analysis of the distribution of trace fossils in relation to the presumed depth of the flysch sediments in particular stages of their deposition shows that it is not an easy matter to assess the usefulness of trace fossils for bathymetric zonation. Nevertheless some results have been obtained. Certainly, they should not be generalized. They refer to the Carpathian flysch basin and its conditions. There is also little doubt that individual types should not be used alone as environmental indicators (KERN & WARME, 1974).

One result of the analysis of the depth range of trace fossils in the Carpathian basin is that simple burrows occur in all beds of the Carpathian flysch. This may indicate that the Carpathian flysch was not deposited at great depths. Such a conclusion is in agreement with sedimentological and microfaunal data (text-fig. 4). A supporting argument seems to be found in the presumed composition of the flysch infauna (table 3), in which polychaete worms seem to prevail. In the bottom fauna of the present-day seas the polychaetes form the main element down to 1000 m of water depth, and are still very numerous to a depth of 2000 m. Below that depth the percentage of their species falls to 3·7 (in the Pacific Ocean to·5, according to ZENKEVICH, 1963), although farther down including hadal depths they still exist (MOORE, 1958). The presence of structures tentatively assigned to other groups is not of much avail, as these groups have a very large range of depth distribution. The sipunculids are for the most part littoral, but several species descend to great depths. Significantly, some species such as *Goldfingia flagifera* occur in cold Artic seas at small depths, but in oceans live at infrabathyal depths (TETRY, 1959). The priapulids prefer cold waters and are frequent down to 400 m, but some species, identical to shallow-water types have been found at very great depths (DAWYDOFF, 1959). The holothurians are most frequent down to 3600 m (CUENOT, 1948, MOORE, 1958), but were photographed at greater depths (HEEZEN & HOLLISTER, 1971). Solenogastres have a large range of depth distribution. Finally, if the assignment of the *Lorenzinia* traces to the sessile hydromedusae similar to *Corymorpha* is right, this would indicate depths of about 1000 m, as these animals can attach themselves to suitable soft bottom in deeper waters (HYMAN, 1940).

In any case the composition of the fauna of the presumed trace-producers does not contradict the assumption that the Carpathian flysch was deposited for the most part at moderate bathyal depths.

Some light on the problem of water depth in the basin is shed by analysing the specific diversity of trace fossils. SANDERS and HESSLER (1969) showed that species diversity on the con-

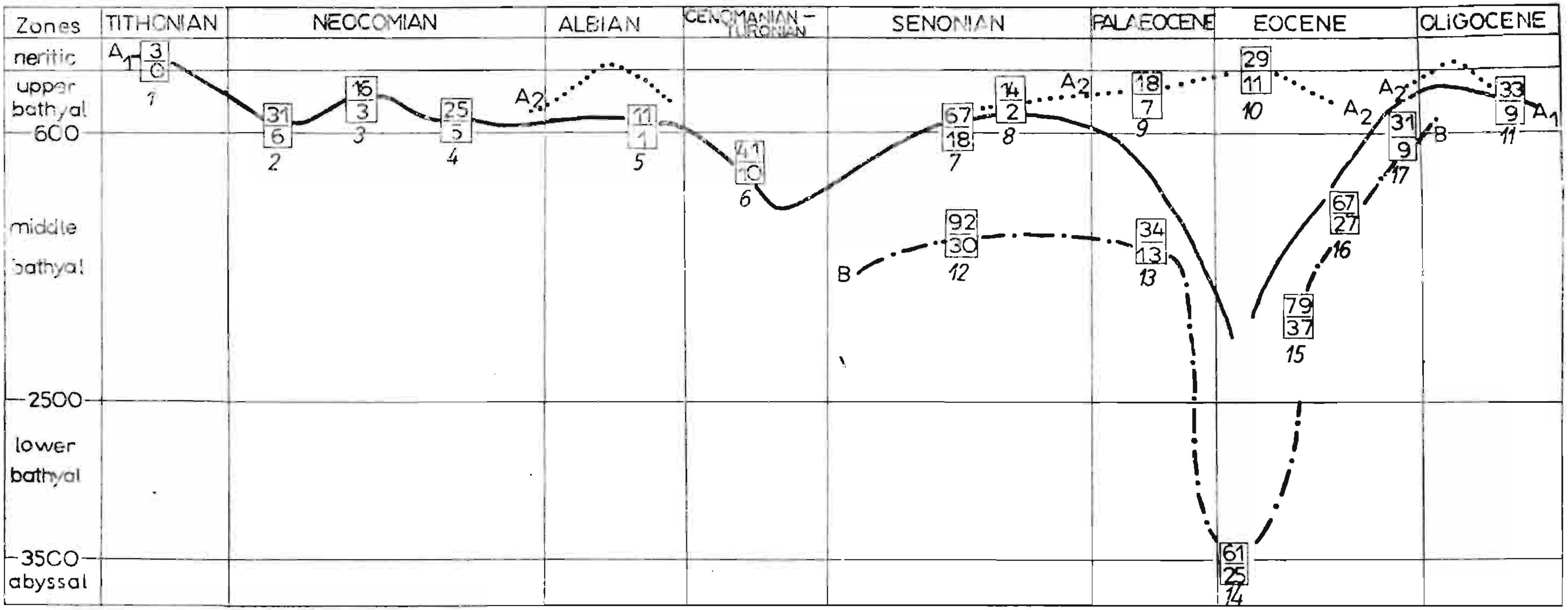



Fig. 4

Depth changes and trace fossils in the Carpathian flysch basin, *A1* — Depth changes in the main trough, intermediate and distal zones; *A2* — depth changes in the main trough, proximal zones; *B* — depth changes in the southern trough. In the rectangles the total number of ichnospecies and the number of patterned types are given for particular horizons; *1* — Lower Cieszyn Shales; *2* — Cieszyn Limestone; *3* — Upper Cieszyn Shales; *4* — Grodziszcze Beds; *5* — Lgota Beds; *6* — Godula Beds; *7* — Inoceramian Beds; *8* — Lower Istebna Beds; *9* — Upper Istebna Beds; *10* — Ciężkowice Sandstone; *11* — Krosno Beds; *12* — Ropianka Beds; *13* — Szczawnica Beds; *14* — Variegated Shales; *15* — Beloveza Beds; *16* — Hieroglyphic Beds; *17* — Magura Sandstone. The length of the particular periods is based on the "Geological Society Phanerozoic time-scale 1964" (Quart. Journ. Geol. Soc. London, 120 S, p. 260–262) tinental slope is higher than on the shelf. It is also known that species diversity lessens below 2000 m (VINOGRADOVA, 1962). The number of trace types may not be identical with that of trace-making species, as it is possible that one species may produce two or more traces, but at any rate the number of trace types should be proportional to the number of trace-making species. The highest diversity in ichnospecies (table 10) is shown by the Ropianka (92) and Beloveza Beds (79), followed closely by the Hieroglyphic Beds (67) and the Variegated Shales (61). All these beds on the strength of the sedimentological evidence and their microfaunal assemblages have been classified as deposited below the epibathyal zone. Close to them follow the Inoceramian (57) and Godula (41) Beds whose deposition has been assigned to lower epibathyal depths. Other formations lie behind, not attaining or scarcely surpassing 30 ichnospecies in number. Some of them, like the Łącko or Szczawnica Beds are regarded as mesobathyal, but their low ichnospecies diversity is easily explained by few sandy intercalations in the Łącko Beds, and by unfavourable bottom conditions (dark sediments) in the Szczawnica Beds. Others, like the Krosno and Istebna Beds, most of the Magura Sandstone, and especially the Ciężkowice Sandstone, were deposited well above the mesobathyal depth.

In this way the conclusion that the specific diversity of the flysch ichnofauna increased with depth appears to be justified. Possibly the smaller number of types in the Palaeocene — Lower Eocene Variegated Shales in comparison with other formations assigned to the mesobathyal zone also suggests that these beds, in all probability the deepest sediment of the Carpathian flysch, were laid down at a depth at which the diversity of species begins to dwindle.

It also should be recalled that, as shown in the preceding chapter, in several formations (the Inoceramian, the Ropianka, the Beloveza and the Krosno Beds) the number of ichnospecies tends to increase downcurrent, i.e. with the depth of water.

Certain general results obtained by means of various lines of approach may be summarized as follows.

There is too good an agreement between the inferences based on ichnological analysis on the one hand, and on sedimentological and microfaunal determinations of the water depth in the basin on the other, to presume that it was not water depth but other factors, such as the type of sediments, evolutionary trends, time and bottom conditions, which mainly controlled the development and composition of the ichnofauna. Nevertheless, these factors cannot be discounted and their intervention has often obscured the significance of the water depth.

The number of patterned (meandering and network structures) types, in accordance with the hypothesis of SEILACHER (1967*b*), increases in the beds presumably deposited at greater depths, although these types may be present in the deposits assigned to fairly shallow-water conditions. The increased diversity of patterned ichnospecies in the downcurrent direction was noted in the analysis of the lateral distribution of trace fossils (tables 7—9).

Simple ichnospecies are highest in number and frequency in shallower deposits, but they are also present, sometimes in considerable strength, in deep-water deposits. Some types show preference for deeper-water environments (*Fucusopsis*, *Halymenidium*, table 11).

Branched traces show a preference for intermediate depths, although the type of sediment is influential in their distribution.

The number of winding types increases markedly with the depth.

There are no vertical burrows which could be ascribed to suspension feeders. The burrows of this kind occasionally occurring in the Carpathian flysch were most probably, like other traces, made by deposit feeders. Although the abundance of burrows and their distribution are most difficult to document quantitively, it may be stated that the frequency of a few types (guided meanders, networks, some of the winding types) increases with depth. The diversity of species also increases markedly with the depth at which the sediment were deposited.

The presumed composition of the trace-producing fauna does not discard the assumption that the Carpathian flysch was mostly deposited at bathyal depths.

## COLONIZATION OF THE SEA-FLOOR BY TRACE PRODUCERS

(table 12)

In most cases the toponomic situation permits the determination of whether the trace had been made before the sea-floor was covered by current-brought sand or silt, or whether it was produced after the sand layer had been deposited. Obviously, pre-depositional traces are due to older dwellers of the sea-bottom living either on the surface of the sediment or within the substratum, most probably at a small depth beneath the bottom.

All traces occurring on the underface of sandy or silty layers (element I) are, if preserved as sedimentary casts, older than the full burrows occurring on the same underface or within element I. Traces clearly cut across by current marks (flute casts, drag marks etc.) are also evidently older than the deposition of the sandy layer. From the mutual relations of traces occurring on the same interface it may also be estimated which traces were made earlier, as in many instances traces of different kinds intersect or interpenetrate one another. The relationship between traces is not haphazard: certain types are consistently cut across by other types (details given in the descriptive part).

Table 12

SUCCESSION OF THE SEA-FLOOR COLONIZATION IN THE CARPATHIAN FLYSCH BASIN

| | | |
|---|---|---|
| Sand dwellers | *Sabularia*<br>*Fucusopsis, Halymenidium*<br>*Zoophycos, Tubulichnium*<br>*Subphyllochorda, Scolicia, Buthotrephis, Spirorhaphe involuta* | *Strobilorhaphe*, *Megagrapton*, *Helminthopsis* |
| Fine-sand dwellers | *Lophoctenium*<br>*Protopaleodictyon*<br>*Cosmorhaphe, Urohelminthoida, Belorhaphe* | *Helminthopsis*, *Paleodictyon*, *Spirophycus* |
| Mud- and fine-sand dwellers | *Desmograpton, Paleomeandron, Helicolithus, Phycosiphon,* | *Paleodictyon*, *Spirophycus*, *Helminthoida* |
| Bottom- and mud dwellers | *Taphrhelminthopsis, Taphrhelminthoida, Lorenzinia, Sublorenzinia plana, circular traces* | *Paleodictyon*, *Spirophycus* |

The traces from the network group only rarely intersect other traces but are often cut across by traces of other groups. Paleodictyonids of various kinds are not uncommonly intersected by simple traces such as *Sabularia* (most often by *S. simplex*), *Fucusopsis annulata* or *Halymenidium oraviense*. It may also be intersected by *Subphyllochorda granulata* or, in rare instances, by *Helminthopsis, Cosmorhaphe* or *Urohelminthoida dertonensis*. In one or two cases a *Paleodictyon* net is laid down over a *Taphrhelminthopsis* furrow. This indicates that *Paleodictyon* is later than the pre-depositional trail of *Taphrhelminthopsis,* but earlier than many meandering, winding or simple traces. In one case, however, its net overlaps a *Helminthopsis* full burrow (KSIĄŻKIEWICZ, 1970, pl. 4*q*). *Desmograpton* is intersected by *Sabularia. Megagrapton* may be intersected by *Sabularia*, but it cuts across *Strobilorhaphe* and in one case seems to intersect *Sabularia. Urohelminthoida* is cut through by *Subphyllochorda granulata*, *Buthotrephis* and *Spirophycus. Protopaleodictyon incompositum* is intersected by *Spirophycus* and *Strobilorhaphe pusilla. Protopaleodictyon submontanum* may be intersected by *Fucusopsis annulata. Belorhaphe* is intersected by a *Helminthopsis (hieroglyphica)* and in another case, by *Megagrapton irregulare.* Meandering traces are intersected by a variety of traces: *Helminthoida crassa* has been found penetrated by *Spirophycus* and *Sabularia, H. alterna* by *Cosmorhaphe* or *Halymenidium oraviense*; *H. labyrinthica* is quite commonly intersected by *Scolicia* and *Chondrites*; *H. aculeata* is cut across by *Sabularia simplex. Cosmorhaphe sinuosa* may be intersected by *Sabularia. Helicolithus sampelayoi* is intersected by *Halymenidium oraviense. Paleomeandron elegans* may be intersected by *Helminthoida crassa*, or by *Sabularia*.

Spiral types are only rarely affected by other traces. *Spirophycus* is cut across by *Sabularia*, and *Spirorhaphe involuta* in one case by a *Helminthopsis*, but it may itself intersect this trace.

Winding traces often intersect meandering types and networks, and are commonly intersected by simple traces. *Scolicia vertebralis* is cut across by *Tubulichnium incertum*, *Subphyllochorda* is quite commonly intersected or penetrated by *Sabularia simplex*, and in one or two instances by a *Zoophycos*. *Helminthopsis* in one case is overlapped by bordering riblets of a *Paleodictyon carpathicum* net, but otherwise cuts across other complex types, itself being intersected by *Sabularia*.

Spreiten types only rarely interfere with other traces, and *Zoophycos*, which may penetrate other structures, is only seldom intersected. In one case it seems that some chondritids penetrate this structure and possibly a *Sabularia*. Another spreite, *Phycosiphon incertum*, covers an epichnial furrow of *Taphrhelminthopsis*, obviously posterior to that trace, but may be intersected by *Scolicia plana*, *S. prisca*, *Tubulichnium incertum* or *Zoophycos*.

Branched types, particularly chondritids, are in rare instances intersected by other traces. *Chondrites* may be cut through by *Zoophycos* and *Sabularia*, *Buthotrephis* by *Scolicia* and *Sabularia*, and *Lophoctenium ramosum* by *Scolicia*. *Strobilorhapte* in some instances is cut across by *Megagrapton*, *Fucusopsis annulata* and various types of *Sabularia*. It may, however, penetrate both *Fucusopsis* and *Sabularia*.

Simple burrows are cut across by other simple burrows: *Halymenidium* by *Sabularia*, also *Fucusopsis* may be intersected by *Sabularia*. In some very rare instances, simple types are ntersected by more complex types: *Fucusopsis* and *Sabularia* may be penetrated by *Strobilorhaphe clavata* or *Rhizocorallium*. In most instances simple forms are posterior to other types. *Sabularia* burrows in particular commonly intersect other traces.

On the ground of the data presented above an attempt may be made to reconstruct the succession of trace-making animals in a basin repeatedly invaded by sand-bringing turbidity currents (table 12).

The indigenous clayey sediments were inhabited by the animals to which pre-depositional traces may be assigned: lorenzinias, some *Sublorenzinia*, most of *Taphrhelminthopsis* and almost all *Spirophycus* and *Subphyllochorda laevis*.

When sand layers had been deposited, they were colonized first by more complex patterned types: netlayers *(Paleodictyon, Desmograpton)* and obligatorily meandering animals producing *Helminthoida*-type traces. The evidence on which the succession of complex patterned types could be established is very scarce, but it seems that the producers of *Paleodictyon* and *Paleomeandron*, and possibly also of *Helicolithus*, appeared earlier, while *Helminthoida*, *Cosmorhaphe*, *Urohelminthoida*, probably also *Protopaleodictyon* partly at the same time or slightly later. Approximately at the same time the planar spreite *Phycosiphon* colonized the introduced sand layers. At a later stage some *Spirophycus* (most of them are pre-depositional) and several winding types invaded sandy layers, followed by branched types, which, however, may also have appeared earlier or at the same time as branched traces. Simple straight burrowers, producing *Fucusopsis*, *Halymenidium*, *Sabularia* and perhaps *Keckia*, were the last invaders of sandy layers, although in some probably rare cases, branched *Strobilorhaphe* may be posterior to them. *Sabularia* appears to be particularly indiscriminate in intersecting and penetrating other traces, both of complex and simple. Its producer was no doubt the last animal burrowing in sand layers.

Generally, it may be concluded that the patterned types are intersected by winding and simple straight types, the branched and winding traces by straight simple traces. The latter were produced by the last colonists of the current-brought sandy layers, the former by the animals which most likely had an easier access to the sand layers.

It is striking that late burrowers in sandy layers are without any doubt post-depositional, while the early ones include types for which the evidence is not always clear whether they are post- or pre-depositional. Indeed, some of them may be suspected of being both pre- and post-depositional (*Cosmorhaphe*, some *Helminthoida*, *Taphrhelminthoida*, *Belorhaphe*, *Paleodictyon*, see table 3). It is possible that these types might have been made by the animals that lived in the argillaceous substratum or on its surface, but when the sand or silt was introduced, they were able to burrow in it, always close to the underlying mud, at the mud/sand interface, provided that the sand was very fine-grained, or that silt instead of sand was introduced by the current. On the other hand, the traces formed in the sand later, including most of the spreiten and winding types and all simple burrows, were produced by animals that were adapted to live and burrow essentially in sand.

The question seems to be linked with the problem of the manner in which biogenic structures were made on the interfaces, particularly on the lower interface of elements I. From the number of types described (almost 150 are classified as ichnospecies) an impression may be given that the Carpathian flysch is very rich in trace fossils, though this is not so. Although certainly more than half of the elements I may be regarded as trace-bearing, there are comparatively few underfaces with well-developed biogenic structures. Most trace-bearing layers contain on their underface innumerable irregular small ridges, knobs and tubercules, but few structures have such distinct morphological features that they can be classified as determinable ichnotaxa. The abundance of traces indicates that the life on the sea-floor was plentiful, but that the animals formed fully developed structures rather exceptionally.

If all traces were pre-depositional, their rudimentary development would be easy to explain: the trace made on the sea-floor or just beneath it was scoured by the current, and only certain parts, more or less fortuitously preserved and cast with sand remained. Most of the sole structures are, however, clearly post-depositional (table 3). A tentative interpretation is that many apparently post-depositional structures were made by animals which principally lived in the mud or on its surface, and occasionally for some reason, probably for a change or supplement of diet, or to get more oxygen, the amount of which might be depleted when the bottom was covered by sand, entered the lowest part of the current-brought sediment and constructed their traces there. These animals only exceptionally produced distinctive sole traces, now scattered here and there on the sole. More often, possibly probing the new sediment or looking for a way to escape from below the suddenly introduced sandy cover, they entered it for a little while, leaving only shapeless ridges or tubercules. The producers of *Helminthoida*, *Paleodictyon*, *Cosmorhaphe* and of some rosetted traces probably had this way of life. The traces of their activities in the mud might have been obliterated by compaction.

Apart from this type of animal, there must have been many true sand-dwellers, living or at least mainly living in sand. There are never any doubts as to the time of construction of their burrows: they are always post-depositional. In most cases their traces may be called "endless", with hardly any beginning or end. Usually they occur in serried masses, densely covering the interfaces or traversing the sand layers. *Sabularia*, *Fucusopsis* and *Keckia* are the main representatives of this group.

It may therefore be presumed that the trace-making animals belonged to three categories: 1. mud-dwellers that were unable to live in sand and never entered it; 2. mud-dwellers able to enter sand transiently and to process it; 3. sand-dwellers, never entering mud.

Since mud was the main deposit, whose sedimentation was from time to time interrupted by the sudden deposition of sand or silt, the animals living in mud may be regarded as the indigenous inhabitants of the basin floor. This might have been the reason why they appeared in sand layers earlier than the exclusive sand-dwellers. These were better off in the areas more frequently invaded by sand inflows, situated nearer the shore and at shallower depths than the areas of the sea-floor where clayey deposition prevailed. The mud-dwellers to a great extent consisted of patterned types. We shall not be far wrong if we conclude that these meandering and net-laying animals were the main inhabitants of the deeper part of the bottom and were therefore the first to colonize the sand and silt layers brought by turbidity currents into the deeper part of the basin. Simple burrows appeared in sand layers at later stages. This suggests that their producers following the sandy layers descended to greater depths from a shallower habitat. Evidently they found enough food in the sand brought from shallower zones. For these reasons we find a considerable admixture of simple types in beds deposited at great depths. In this context it is worth while to recall that many benthonic animals display considerable tolerance with respect to pressure, and that it is rather the amount of food than the pressure which controls their depth distribution.

The composition of the ichnofauna in particular stratigraphic units is fairly uniform (except for the Ciężkowice Sandstone). This suggests that the colonization of the sea-floor by the trace-making fauna embraced large areas and that the ecological conditions did not change much from one place to another. In each unit the assemblages consist of many types and in most cases the trace fossils in successive layers are not identical. There are, however, quite numerous instances of an ichnospecies persistently appearing in several layers close to one another in the succession. A few example illustrate the case. In the Albian Lgota Beds at Rzyki *Scolicia plana* occurs in several adjacent layers. In the Senonian Ropianka Beds on the slope of Mt. Lubogoszcz *Subphyllochorda laevis* occurs on the soles of at least six sandy layers situated closely one above the other, separated, naturally, by shaly interbeds, each 10 to 15 cm thick. At Złatna in the Lower Eocene Variegated Beds in each silty layer *Subphyllochorda granulata* abounds over a distance of several metres, to the exclusion of other types. In the same beds at Lipowe *Fucusopsis annulata* is numerous in several adjacent layers. *Subphyllochorda granulata* occurs in very many layers one above the other in the cross-sections cutting across the Variegated Shales and the Beloveza Beds at Lubomierz. In the Królów stream at Dźwiniacz Dolny *Subphyllochorda laevis* occurs in a few layers situated near one another. At Zalesie two adjacent sandstone layers display *Paleodictyon carpathicum* on their underfaces. These and other facts indicate that some burrowers occupied certain areas of the sea-floor to the exclusion of others and maintained their preponderance for a long time, perhaps hundreds of years, colonizing one layer after another in turn.

## TRACE FOSSILS AND STRATIGRAPHY

(tables 13–14)

The possibility of using trace fossils for stratigraphy was discussed by SEILACHER (1960), HÄNTZSCHEL (1962), VIALOV (1966), CRIMES (1968). The present author expressed opinion (KSIĄŻKIEWICZ, 1970) that several trace fossils may be of stratigraphical value for the Carpathian flysch.

The problem is not an easy one, as the conclusion are in part based on negative evidence. Further research may bring new findings which might enlarge the vertical range of individual ichnogenera and ichnospecies. On the other hand, all stratigraphic units have been thoroughly searched for trace fossils, and the collected and observed material is abundant (several hundred specimens or occurrences noted for each unit). This may justify a tentative drawing of certain conclusions, summarized in tables 13 and 14. These conclusions largely confirm the data given earlier by the author (KSIĄŻKIEWICZ, 1970).

It appears that only a few genera have a confined stratigraphic range, and very few ichnospecies appear to be limited to one stratigraphic stage. To these belong: *Glockeria glockeri* (Neocomian), *G. sparsicostata* (Senonian), *Lorenzinia* (seemingly limited to the Senonian and Palaeocene), *Scolicia plana* (Albian — Senonian, later replaced by *S. prisca*), *Paleomeandron*

Table 13

STRATIGRAPHIC DISTRIBUTION OF ICHNOGENERA IN THE CARPATHIAN FLYSCH

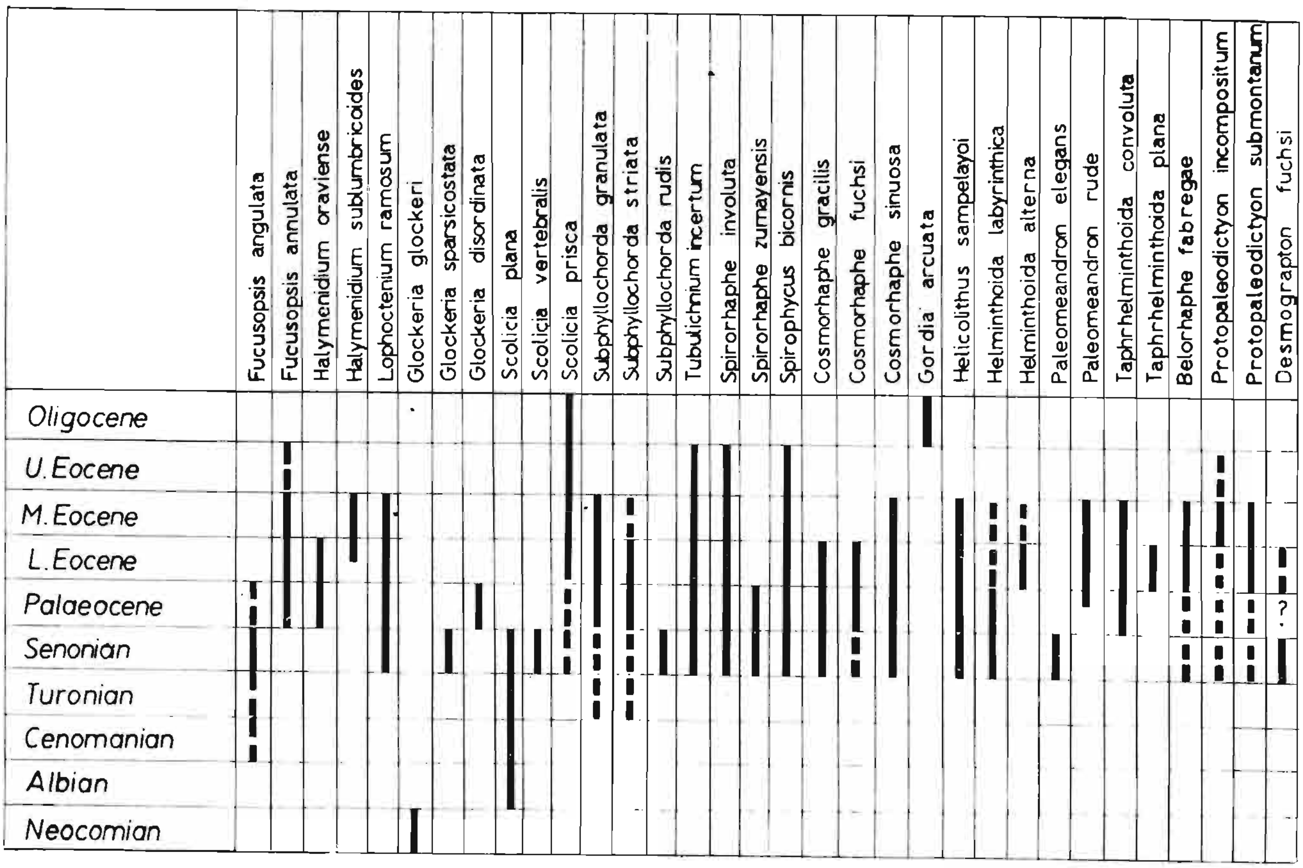
| | Tithonian | Berriasian | Valanginian | Hauterivian | Barremian — Aptian | Albian | Cenomanian | Turonian | Senonian | Palaeocene | Lower Eocene | Middle Eocene | Upper Eocene | Oligocene |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Mammillichnis* | | | | | | | | | x | x | x | x | | x |
| *Bergaueria* | | | | | | | x | | x | x | x | x | x | |
| *Pararusophycus* | | | | | | | | | | | | x | x | |
| *Traucumichnis* | | | | | | | | | x | x | x | | | |
| *Arthrophycus* | | | | | | x | x | x | x | x | x | x | x | x |
| *Keckia* | | x | x | x | x | x | x | x | x | x | x | x | | |
| *Fucusopsis* | | x | | | | | x | x | x | x | x | x | x | |
| *Halymenidium* | | ? | | | | | | | | x | x | x | | |
| *Rhabdoglyphus* | | | | | | | x | x | x | | | | | |
| *Sabularia* | x | x | x | x | | x | x | x | x | x | x | x | x | x |
| *Buthotrephis* | | | | x | | | x | x | x | x | x | x | | ? |
| *Bostricophyton* | | | | | | | | | x | | | | | |
| *Chondrites* | x | x | x | x | | x | x | x | x | x | x | x | x | x |
| *Granularia* | x | | | | | | | | x | x | | | | |
| *Lophoctenium* | | | | | | | | | x | x | x | x | | |
| *Strobilorhaphe* | | | | | | | | | x | x | x | x | x | x |
| *Taenidium* | | | | | | | | | x | | | | | |
| *Asterichnus* | | | x | | | | | | | | | | | |
| *Capodistria* | | | | | | | x | | x | x | | | | |
| *Fascisichnium* | | | | | | | | | | x | | x | | |
| *Glockeria* | x | x | x | x | | | | | x | x | | | | |
| *Gyrophyllites* | | | | | | | | | x | ? | ? | x | x | |
| *Lorenzinia* | | | | | | | | | x | x | | | | |
| *Sublorenzinia* | | x | x | x | | | x | x | x | | x | x | | |
| *Anemonichnus* | | | | | | | | | | | | | x | |
| *Phycosiphon* | | x | | x | | | | | x | x | x | x | x | x |
| *Zoophycos* | x | x | | | | | x | x | x | x | x | x | x | x |
| *Gyrochorte* | | | | x | x | | | | x | | x | | | x |
| *Helicorhaphe* | | | | | | | | | | x | x | | | |
| *Helminthopsis* | | x | x | x | | | x | x | x | x | x | x | x | x |
| *Muensteria* | | | | | | | | | x | x | | | | |
| *Oniscoidichnus* | | | | | | | | | | | | | | x |
| *Scolicia* | | | | | | | x | x | x | x | x | x | x | x |
| *Subphyllochorda* | | | | | | | x | x | x | x | x | x | x | x |
| *Naviculichnium* | | | | | | | | | x | x | x | x | | |
| *Taphrhelminthopsis* | | | | | | | x | x | x | x | x | x | x | x |
| *Tuberculichnus* | | x | | x | | x | x | x | x | x | x | | | ? |
| *Tubulichnium* | | | | | | | | | x | x | x | x | | |

cont.

| | Tithonian | Berriasian | Valanginian | Hauterivian | Barremian — Aptian | Albian | Cenomanian | Turonian | Senonian | Palaeocene | Lower Eocene | Middle Eocene | Upper Eocene | Oligocene |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Spirorhaphe* | | | | | | | | | x | x | x | x | x | |
| *Spirophycus* | | | | | | | | | x | x | x | x | x | |
| *Cochlichnus* | | | | | | | | | | x | x | x | | |
| *Cosmorhaphe* | | | | | | | | | x | x | x | x | | ? |
| *Gordia* | | | | | | | | x | x | | | x | x | x |
| *Helicolithus* | | | | | | | | | x | x | x | x | x | |
| *Helminthoida* | | x | x | | | x | x | x | x | x | x | x | x | x |
| *Paleomeandron* | | | | | | | | | x | x | x | x | | |
| *Taphrhelminthoida* | | | | | | | | | x | x | x | x | x | |
| *Acanthorhaphe* | | x | | x | | | | | x | x | x | x | | |
| *Belorhaphe* | | x | x | x | | x | x | x | x | x | x | x | | |
| *Protopaleodictyon* | | | | | | x | | | x | x | x | x | x | |
| *Urohelminthoida* | | | | x | | | | | x | x | x | x | x | |
| *Desmograpton* | | | | | | | | | x | | x | | | |
| *Megagrapton* | | | | | | | | | x | x | x | | | |
| *Paleodictyon* | | x | x | x | | | x | x | x | x | x | x | x | |

Table 14

STRATIGRAPHIC DISTRIBUTION OF SOME TRACE FOSSILS IN THE CARPATHIAN FLYSCH



*elegans* (Senonian, in Palaeogene replaced by *P. rude*) and *Desmograpton*, in typical forms limited to the Senonian. In contrast with other regions of the Tethys (SEILACHER, 1974) it seems that some ichnospecies may be used to distinguish the Cretaceous from the Palaeogene beds.

The factors controlling the vertical distribution of the trace fossils in the Carpathian basin may have been multifarious. There is little doubt that the changes in sedimentation were the main factor. For example, the ranges of *Fucusopsis annulata* and *Lophoctenium ramosum* end with the lower boundary of the thick-bedded Magura Sandstone. Depth changes may also have influenced the appearance or disappearance of many types. It can never be said for certain that a trace disappeared because the producer became extinct, nor that other factors, changes in sedimentation, bottom conditions or depth caused its temporary removal from the basin.

# DESCRIPTIVE PART

## I. CIRCULAR AND ELLIPTICAL STRUCTURES

This group includes traces with round or elliptical outline, hypichnial or epichnial. It is scantily represented in the Carpathian flysch, both in the number of types and in specimens. It consists of four ichnogenera: *Mammillichnis* CHAMBERLAIN, *Bergaueria* PRANTL, *Pararusophycus* n. ichnogen., *Traucumichnis* n. ichnogen. Perhaps some unnamed round traces (loose tubercules, text-fig. 28 and presumed scribing traces, text-fig. 32) should also be assigned to this group.

### Ichnogenus *Mammillichnis* CHAMBERLAIN, 1971

*Type ichnospecies*: *Mammillichnis aggeris* CHAMBERLAIN.

#### *Mammillichnis aggeris* CHAMBERLAIN, 1971 *a*
(pl. 1, figs 1, 2; text-fig. 5*a*, *b*)

1971*a*. *Mammillichnis aggeris* n. ichnogen. and sp. CHAMBERLAIN, p. 238, pl. 30, figs 6, 7, text-fig. 7*G–J*.
*Material*: 9 specimens and a similar number of occurrences noted in the field.

**Description.** — The specimens range from 8 to 10 mm in diameter and 3 to 4 mm in height. The apical depression is 4 mm wide and the teat-like tubercule it contains in the middle is 1 mm wide. In some specimens the central tubercule is encircled by a low ring-like wall (text-fig. 5*a*).

This trace never occurs gregariously, but occasionally a few mounds occur scattered near one another on the sole.

**Remarks.** — The resemblance to the CHAMBERLAIN's type, in spite of regional and stratigraphic differences, is striking. The difference is small: some Ouachita specimens are slightly lobed and have no central ring, also absent in our specimens. There seems to be no ground for classifying the Carpathian material as another ichnospecies.

**Sediment.** — Thin-bedded (the thickest 4 cm), fine-grained sandstones, horizontally or single-current laminated.

**Association.** — Small *Sabularia*, little tubercules and ridges.

**Origin.** — CHAMBERLAIN (1971 *a*) gives three interpretations, of which the concept of a hiding or resting trace seems to be the most probable. He does not say anything about the presumed producer, but the shape of the trace and its radial symmetry (particularly as seen in his fig. 7J) would suggest an anthozoan (actinian?).

**Occurrence.**[1] — Nowhere is this type frequent. Senonian—Inoceramian Beds: Makowa; Ropianka Beds: Chyżówki. Palaeocene—Szczawnica Beds: Hałuszowa, Grywałd. Palaeocene

[1] Localities in the text are given from the west eastwards (text-fig. 1).

to Lower Eocene—Variegated Shales: Lipnica Mała. Lower Eocene—Beloveza Beds: Lipnica Mała, Myślec. Oligocene—Krosno Beds: Wujskie (here fairly frequent).

### Ichnogenus *Bergaueria* PRANTL, 1945

*Type ichnospecies: Bergaueria perata* PRANTL (HÄNTZSCHEL, 1962).

### *Bergaueria prantli* n. ichnosp.

(pl. 1, figs 3–5; text-fig. 5*c, d, e*)

*Holotype*: UJ TF 115 (pl. 1. fig. 3).
*Type locality*: Grzechynia near Sucha Beskidzka.
*Type horizon*: Hieroglyphic Beds, Middle Eocene.
*Derivation of the name*: in honour of F. PRANTL, eminent Czech geologist and palaeontologist.
*Material*: 11 specimens.

**Diagnosis.** — Hypichnial hemispherical mound-like cast, with a depression in the apical part of the mound.

**Description.** — The holotype has a completely circular outline. Its diameter is 13 mm long, its height 3 mm. The mound slopes slightly in one direction. There are two interconnected shallow pits in the top of the mound.

The largest specimen is elliptical in outline. Its greater diameter is 60 mm and the lesser 35 mm in length. The apical depression is oval and also consists of two holes. Smaller specimens are more common, they are nearly circular, 10 to 15 cm wide. They almost always slope in one direction. Some of them have only one apical hole.

Most of the occurrences seem to be solitary, but in one case the traces occur near one another or even overlap (pl. 1, fig. 5).

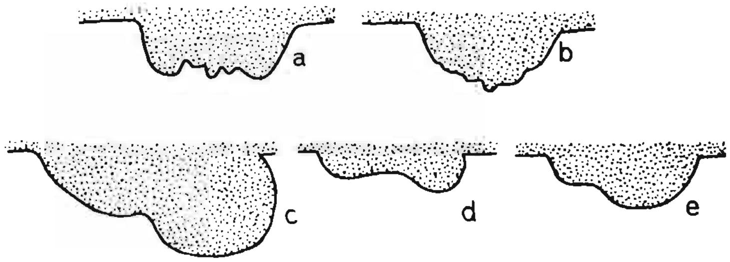



Fig. 5

a *Mammillichnis aggeris* CHAMBERLAIN, Wujskie, Krosno Beds, UJ TF 118; b *Mammillichnis aggeris* CHAMBERLAIN, Lipnica Mała, the stream Linorka, Variegated Shales, UJ TF 1117; c *Bergaueria prantli* n. ichnosp., Kąclowa, Ropianka Beds, UJ TF 907; d Id., Wierzbanowa, Ropianka Beds, UJ TF 1178; e Id., Limanowa, Ropianka Beds, UJ TF 824. All figures × 1

**Remarks.** — At first sight the trace seems to be identical with *Bergaueria perata* PRANTL which occurs as "bag-like" protuberances on the lower surfaces of some sandstones in the Bohemian Ordovician flysch (PRANTL, 1945). In our material the dimensions are more variable (in *B. perata* the diameter is 35–45 mm, the height almost the same) and the apical hole tends to be doubled, a feature absent in the Ordovician form. In addition, *B. perata*, if well preserved, shows radially arranged protuberances around the central depression. No traces of such protuberances are seen in our material. No declivity is noted in *B. perata*, and its flanks are steeper.

There is little doubt that *Bergaueria* is related to *Mammillichnis aggeris* CHAMBERLAIN, which is smaller and has a teat-like tubercule in the apical depression. It is open to argument whether *Bergaueria* and *Mammillichnis* should not be united under one generic name, the more so since *M. aggeris*, according to CHAMBERLAIN, (1971*a*) may be slightly lobed. These lobes, seen on the better preserved specimens in the Ouachita material, may correspond with the radial protuberances of *B. perata*.

**Sediment.** — Thin-bedded (up to 6 cm), fine-grained, horizontally laminated sandstones. In one specimen (pl. 1, fig. 4) the filling material is coarser than the host rock.

**Association.** — In one instance associated with *Capodistria vettersi* (pl. 7, fig. 12).

**Origin.** — Probably a pre-depositional shelter burrow. According to PRANTL (1945) *Bergaueria perata* may be a protective burrow of some anthozoans allied to Recent *Cerianthus* or *Edwardsia*.

**Occurrence.** — Cenomanian—Lower Godula Beds: Jaroszowice. Turonian—Middle Godula Beds: Ponikiew. Senonian—Skrzydlna Beds: Wierzbanowa; Upper Godula Beds: Rudnik; Ropianka Beds (here fairly frequent): Wierzbanowa, Kasina Wielka, Limanowa (the hamlet Marciszów), Chyżówki, Stara Wieś, Kąclowa, Kwiatoń. Palaeocene to Lower Eocene—Variegated Shales: Pawel Wielka. Middle Eocene—Hieroglyphic Beds: Grzechynia. Upper Eocene—Magura Sandstone: Rzyki near Limanowa.

## Ichnogenus *Pararusophycus* n. ichnogen.

*Type ichnospecies: Pararusophycus oblongus* n. ichnosp.
*Derivation of the name*: a certain similarity to *Rusophycus*.

**Diagnosis.** — Hemi-ellipsoidal mound with a medium furrow.

### *Pararusophycus oblongus* n. ichnosp.
(pl. 1, fig. 6)

*Holotype*: UJ TF 114 (pl. 1, fig. 6).
*Type locality*: Liszna in the Bieszczady Mts.
*Type horizon*: Hieroglyphic Beds, Middle Eocene.
*Derivation of the name*: Lat. *oblongus* — oblong.
*Material*: 4 specimens and several occurrences noted in the field.

**Diagnosis.** — Hypichnial mound of elliptical outline, sloping along its axis in one direction, with a longitudinal shallow furrow along the crest and two knobs on the elevated sides of the mound.

**Description.** — The holotype is 45 mm long, 35 mm wide and 15 mm high in the elevated part of the mound. The median furrow is 2–3 mm deep, 10–12 mm broad. The elevated part of the mound is clearly delineated, with re-entrants on all sides, while the lower part has rather diffuse borders. The knobs, situated on the very border of the furrow, are 4–5 mm wide and about 1·5 mm high.

Other specimens are smaller and their sculpture, i.e. the median furrow and the knobs, is not so distinct as in the holotype. In particular, the knobs may be hardly developed. The specimens found so far seem to occur solitarily, but in one slab from the Hieroglyphic Beds at Komańcza two oblong mounds seem to be aligned.

**Remarks.** — There is an external resemblance to *Rusophycus*: the outline is similar and the median furrow present, but there is no transversal wrinkling or ribbing. The dimensions are larger in our material. The trace in question differs from *Sagittichnus* SEILACHER (1953*b*) in outline (in *Sagittichnus* it is triangular), in its greater dimensions and solitary manner of occurrence.

F. SIMPSON (1970, p. 261, pl. 10, fig. 1) described similar but not identical traces, smaller than our typical specimen, with a narrower median furrow disappearing in one direction, and with no knobs. Some of our specimens which are not fully developed or preserved are similar to SIMPSON'S material, which he has placed in the affinity of *Sagittichnus*.

**Sediment.** — Thin-bedded (4–5 cm), fine-grained, horizontally laminated sandstones, but in one case (Magura Sandstone, Zawoja, the hamlet Mosorne) on the sole of a sandstone 75 cm thick.

**Origin.** — This trace may be interpreted as a pre-depositional hollow made prior to sand-casting. Its shape suggests that the producer was a crustacean. The knobs may be imprints of its eyes when the animal was overturned by the current and was trying to shelter in the mud. F. SIMPSON (1970) presumes that his type was a syn-depositional burrow formed by an animal to avoid being swept away be the current.

**Occurrence.** — Middle Eocene—Hieroglyphic Beds: Zawoja (if SIMPSON's material belongs here), Osielec, Komańcza, Liszna. Upper Eocene—Magura Sandstone: Zawoja, the hamlet Mosorne.

### Ichnogenus *Traucumichnis* n. ichnogen.

*Type ichnospecies: Traucumichnis glaber* n. ichnosp.
*Derivation of the name*: Lat.: *traucum* — hole, pit, (French — le trou).

**Diagnosis.** — Hemispherical smooth-walled cavities, void or filled with sediment.

### *Traucumichnis glaber* n. ichnosp.
(pl. 1, fig. 7)

*Holotype*: UJ TF 125 (pl. 1, fig. 7).
*Type locality*: Wara in the San valley.
*Type horizon*: Inoceramian Beds, Senonian.
*Derivation of the name*: Lat. *glaber* — bald; the walls of the hole are smooth.
*Material*: 4 slabs, each with numerous traces, and very many occurrences observed in the field.

**Diagnosis.** — Epichnial small hemispherical cavities, in some specimens filled with ring-like deposited sand. The trace occurs gregariously.

**Description.** — In the specimen taken for the holotype the cavities are perfectly circular, 1·0 to 2·5 cm wide and 4 to 15 mm deep. On the average, the larger cavities are deeper. Their walls are quite smooth, except for some horizontal striation reflecting the lamination of the host rock. Some cavities are filled with sand. In this instance there is a circular furrow along the rim of the cavity.

In the Ciężkowice Sandstone, in which this kind of trace is not uncommon, the cavities attain 4 cm in diameter. Many of them are filled with sand and the bordering furrow is developed in most cases. One or two cavities have a rather elliptical outline. Some fillings display a ring-like structure.

**Remarks.** — The ring-like filling of the cavities, seen in some instances, recalls the structures described as *Laevicyclus* QUENSTEDT. This, however, is a cylindrical vertical body (WURM, 1911, KEMPER, 1968). The central canal existing in *Laevicyclus* is not visible in the discussed traces. Their assignment to *Mammillichnis* or *Bergaueria* could be based only on the circular outline. It therefore seems justifiable to create a new ichnogenus for this type of trace.

**Sediment.** — The trace occurs on the upper surface of thin-bedded (4–5 cm) sandstones which are graded and frequently coarse-grained at the base, but the cavities are confined to the fine-grained portions.

**Association.** — *Arthrophycus*, *Sabularia*.

**Origin.** — The round cavities are somewhat similar in shape and size to the holes produced by certain sea-urchins, like *Echinocardium cordatum* or *E. flavescens* (see HYMAN, 1955, SCHÄFER, 1972). These spatangoids dig in the sand with their underside spines and make circular shafts ending in a cavity. As the walls of the burrow are plastered with mucus, they retain their shape in loose sand. According to SCHÄFER (1972) *E. cordatum*, when moving from one place to another, also produces structures in the form of segmented cut-and-fill burrow. The occurrence of *Traucumichnis glaber* is often accompanied in the same slab by segmented burrows described here as *Arthrophycus annulatus* (pl. 1, fig. 7, the left upper corner and centre right of the photo). This association may suggest that these were also made by spatangoids. In no occurrence of *Traucumichnis* have remains of echinoids been found, but in associated beds of the Cretaceous age (Inoceramian Beds), in which this trace occurs, such remains are not uncommon. In Eocene beds with *Traucumichnis*, echinoids have not been found.

**Occurrence.** — Senonian—Inoceramian Beds: Wara (common in thin-bedded layers): Lower Istebna Beds: Rożnów. Lower Eocene—Ciężkowice Sandstone (fairly frequent): Znamirowice, Gródek, Ciężkowice.

## II. SIMPLE STRUCTURES

This group is well represented in the Carpathian flysch. It consists of cylindrical, mostly straight, more rarely feebly curved burrows, with no or few lateral branches. The surface is either sculptured or smooth. Sculptural elements, such as ribbing or striations, may be purely superficial, or reflecting an internal segmentation of the burrow. Most of the types are long burrow, with no detectable terminations, but some are short with one end well defined. There are types quite continuous without any transversal articulation, but many consist of clearly defined segments. The classification into ichnogenera is based on the external sculpture: *Arthrophycus* HALL, *Keckia* GLOCKER and *Rhabdoglyphus* VASSOEVICH are transversally striated or ribbed, *Fucusopsis* PALIBIN is longitudinally striated, *Halymenidium* SCHIMPER is obliquely ribbed or wrinkled, *Planolites* NICHOLSON both longitudinally and transversally striated, and *Sabularia* n. ichnogen. is smooth.

### Ichnogenus *Arthrophycus* HALL, 1852

*Type ichnospecies: Arthrophycus alleghaniensis* HARLEN (HÄNTZSCHEL, 1962).

### *Arthrophycus annulatus* n. ichnosp.
(pl. 1, figs 8–10)

*Holotype*: UJ TF122 (full burrow: pl. 1, fig. 10) and TF 123 (void burrow, pl. 1, fig. 8).
*Type locality*: Znamirowice on the river Dunajec.
*Type horizon*: Ciężkowice Sandstone, Lower Eocene.
*Derivation of the name*: Lat. *annulatus* — ring-like; the burrow consists of ring-like segments.
*Material*: 12 specimens, including some slabs with numerous traces, also about a dozen occurrences noted in the field.

**Diagnosis.** — Mostly endichnial, cylindrical, rope-sized segmented, void or full burrow, also epichnial full burrow or furrow, more rarely hypichnial void or full burrow.

**Description.** — A fragment of a sand-filled cylinder, 10 cm long and about 1 cm wide, very slightly curved, has been taken for the holotype. The cross-section of the cylinder is circular or oval. Its surface is transversally carved by narrow grooves which divide the surface of the burrow into segments 2.0–2.5 mm wide. Since the trace more often occurs as void tubes, the description of the holotype is supplemented with that of a void cylinder. Its wall shows transverse hollows left by segments of the burrow.

Most of the burrows are straight, some are feebly bent. Branching is rare and probably due more to intersection or interpenetration than to actual branching. The burrow is apparently very long, as in most specimens no endings have been found. In one instance or two the tube ends in a larger hole. This type of trace occurs either singly or close to one another along the stratification plane (pl. 1, fig. 8). Usually the traces occur parallel to internal horizontal partings in the sandstone, but they may also traverse the bed obliquely.

The traces occurring in beds of the Upper Cretaceous age are somewhat thinner and most often occur as epichnial horizontal shallow furrows, or as subhorizontal tubes near the upper surface. In some specimens small oblong hollows are arranged in two rows occurring alternately in the walls of the tube. The Cretaceous traces seem to occur rather solitarily in contrast with more gregarious Palaeogene traces.

In one specimen (UJ TF 1689) there are rather indistinct short grooves on either side of the endichnial tube. These may be traces made by parapodial appendages.

**Remarks.** — Our material resembles the trace described by Howard (1966, p. 41, fig. 6) as *Arthrophycus* with no specific name. The dimensions and ornamentation are identical. The difference is that in our traces no bulge is visible at the branching points. This is probably due to the fact that no true branching has been found in the Carpathian material.

As noted by Howard, there are difficulties in distinguishing *Arthrophycus* from *Ophiomorpha*. The separation of these two types may be based on differences in the structure of the tube walls. In *Arthrophycus* the sculpture of the wall consists of elongate hollows corresponding to the segments of the burrow, while in *Ophiomorpha* the wall is either lined with grains or irregularly pitted (see below, *Tubulichnium*).

**Sediment.** — Medium- to fine-grained, thin-bedded (up to 4 cm) sandstones.

**Association.** — The only company is *Sabularia*-type burrows, which, however, may also be *Arthrophycus* with obliterated outer sculpture. In some cases *Arthrophycus*-like traces are associated with *Traucumichnis* holes (pl. 1, fig. 7).

**Origin.** — Post-depositional feeding burrow made either by a polychaete worm or by echinoids.

**Occurrence.** — Turonian—Middle Godula Beds: Kocierz, the hamlet Zakocierz. Senonian—Inoceramian Beds: (frequent): Rzegocin, Kąkolówka, Dubiecko, Kuźmina, Krzywcza, Bachów, Kalwaria Pacławska, Wola Romanowa, Makowa, Brzegi Dolne; Upper Godula Beds: Kocierz; Lower Istebna Beds: Izdebnik, Czarnorzeki; Ropianka Beds: Sękowa, Owczary. Palaeocene — Babica Clays: Łodzinka, Chmielnik; Upper Istebna Beds: Krzeszów, Kamesznica, stream Janoska; Szczawnica Beds: Hałuszowa. Lower Eocene — Ciężkowice Sandstone (locally frequent): Znamirowice, Gródek, Dąbrówka, Korczyna; Beloveza Beds: Lipnica Mała, Popowice, Berest. Middle Eocene — Łącko Beds: Naszacowice, Myślec; Hieroglyphic Beds: Osielec, Wola Krzywecka, Bircza, Zawadka.

### *Arthrophycus strictus* n. ichnosp.

(pl. 1, figs. 11, 12)

*Holotype*: UJ TF 131 (pl. 1, fig. 11).
*Type locality*: Rzyki near Wadowice.
*Type horizon*: Albian.
*Derivation of the name*: Lat. *strictus* — narrow, drawn together; the burrow is very narrow.
*Material*: 4 slabs, each with numerous traces.

**Diagnosis.** — Hypichnial string-sized short straight full burrow with dense transverse striation.

**Description.** — As the holotype a slab with at least twenty burrows has been taken. The burrows are cylindrical or hemicylindrical, 5 to 6 cm long, 1.5 to 2.0 mm wide, straight or only feebly curved, slightly protruding above the sole. The burrow described are associated with short lenticular cylindrical bodies, 3–4 mm wide and only 14 mm long, also transversally striated in the same manner as the longer burrows. The transversal striations are very dense, with about 20 striae to each centimetre of the length. Some of the longer burrows branch at an acute angle. The burrows densely cover the sole, crossing one another in a few places.

It is not clear whether the striation of the surface is superficial or related to an inner segmentation of the burrow.

Other specimens are similar to those described above. A somewhat different kind occurs in the Ropianka Beds (pl. 1, fig. 12). These are cylindrical burrows, pointed at one end and round at the other, about 2 cm long and 2·5 mm wide. Their striation is more pronounced than in the holotype. They tend to be radially arranged in a manner similar to that in *Fascisichnium*.

**Remarks.** — Our specimens are similar to *Arthrophycus alleghaniensis* (HARLAN), cf. HÄNTZSCHEL, 1962, p. W 184, fig. 111, 3, but are about three times thinner and do not show the median groove seen in places in the American material.

**Sediment.** — Thin-bedded, fine-grained, horizontally laminated sandstones, 3–9 cm thick.

**Origin.** — The cylindrical shape indicates a post-depositional origin. It is open to question whether the superficial sculpture is due to peristaltic movements or to the segmentation of the producing animal. Most probably this is the feeding burrow of a polychaete worm.

**Occurrence.** — This is a rare ichnospecies. Albian — Lgota Beds: Rzyki near Wadowice. Cenomanian — Lower Godula Beds: Tymowa. Senonian — Inoceramian Beds: Huwniki; Ropianka Beds: Mszana Dolna (the hamlet Glisne).

### *Arthrophycus(?) dzulynskii* n. ichnosp.
(pl. 1, figs 13, 14)

*Holotype*: UJ TF 177 (pl. 1, fig. 13).
*Type locality*: Dębna near Sanok.
*Type horizon*: Krosno Beds, Oligocene.
*Derivation of the name*: in honour of Professor S. DŻUŁYŃSKI, who supplied the author with this trace.
*Material*. 1 slab with a few specimens.

**Diagnosis.** — Hypichnial cylindrical rope-sized full burrow, or hypichnial furrow. The sculpture of full burrow consists of tuberculated transversal narrow ribs slightly bent in one direction. The furrows are transversally grooved.

**Description.** — The holotype is 8 cm long. One end is broken off, the other is provided with an elliptical knob, 1 cm long, with a round depression in the middle. The burrow is 10–11 mm wide. The ribs, about 1 mm wide on the crest of the cylinder, become thinner towards the borders. The ribs consist of elongated tubercules, 4 to 6 in each riblets. The grooves between the riblets are fairly deep.

The furrow form occurs on the sole of the same slab. The largest furrow is 5 cm long (one end is broken off) and only 7 mm wide. The median part of the furrow consists of shallow oblong depressions separated from one another by low subdued ridges. The borders of the furrow are slightly elevated above the sole. One end of the furrow terminates in a round knob, depressed in the centre, very similar in shape to the knob of the full burrow form.

**Remarks.** — The assignment of this type to *Arthrophycus* may be questionable. The straight course of the burrow and its external sculpure are characteristic of this ichnogenus. If both the forms of the burrow are put together for reconstruction, it appears that the sculpture produced by the burrowing animal on the ventral side was somewhat different to that on the dorsal side. Differences between the ventral and dorsal sides are not apparent in other representatives of *Arthrophycus*. The curving of the riblets in the full burrow is absent in other arthrophycids. The terminal knobs of either form are similar to those of *Climactichnites*.

**Sediment.** — Thin-bedded (1.5 cm), fine-grained, single-current laminated sandstones.

**Origin.** — This is clearly a post-depositional feeding burrow. It might have been produced by an annelid, but the differences between the dorsal and ventral sides seem to suggest another producer. The curving of the riblets (on the ventral side) may reflect the backfill action by the expanding foot of a gastropod (SEILACHER, 1955, GLAESSNER, 1969) while the structure of the dorsal side of the burrow may be due to undulatory movements of animal's body as it burrowed along the clay/sand interface. The animal burrowed partly in the sand close to the interface, partly in the mud below the interface. In the former case it produced the full burrow form on its ventral side, and in the latter the furrow form on its dorsal side.

**Occurrence.** — Oligocene — Krosno Beds: Dębna.

### Ichnogenus *Fucusopsis* Palibin, 1932

*Type ichnospecies: Fucusopsis angulata* Palibin (Häntzschel, 1962).

**Remarks.** — Here are grouped cylindrical straight full burrows longitudinally striated.

**Origin.** — The cylindrical shape indicates that the traces of this group are post-depositional. The cylinders often adhere to the sole. In some specimens these burrows clearly cut across drag marks, in others they traverse a delicate ridge-and-furrow lineation (pl. 2, fig. 6). These facts corroborate the view of post-depositional origin. It is difficult to say what kind of animal produced this trace. It may be considered that the sculpture of the burrow is an impression of the external surface of the tunnelling animal. This might have been a worm of the priapulids group, whose introvert is provided with longitudinal retractory muscles and whose mouth is encirled by an armour of strong cuticular protuberances. Both the muscles and protuberances during the motion of the animal may scratch the walls of the tunnel, and the counterparts of the scratches may be formed on the surface of the burrow in the form of riblets and wrinkles, more or less irregular and longitudinally arranged. The animal worked its way along the clay/sand interface either almost continuously as in the case of *Fucusopsis angulata* and *F. striata*, or by bolting as in *F. annulata*, changing its course slightly after each bolt. Actually, priapulids move by bolting (Schäfer, 1972). Recent priapulids live in excavations in mud and are common in the shallow, cold waters of polar seas, but also occur at depths of 300–400 m, and even at a depth of 4000 m the expedition of „Vitiaz'" found a form morphologically identical with the common *Priapulus caudatus* (Fauvel, 1959, Zenkevich, 1963).

The interpretation presented meets with one difficulty. The mud-burrowing priapulids keep their caudal termination outside the sediment for respiration. Therefore some burrows traversing the sand layer should be connected with their occurrences, but in no case have they been found. It is possible, however, that the water-logged sediment freshly brought from the shallow-water zone by the turbidity current contained enough oxygen.

### *Fucusopsis angulata* Palibin, 1932
(pl. 2, fig. 5)

1932. *Fucusopsis angulatus* Palibin, *in* Vassoevich, p. 51, pl. 2, figs 2, 6.

*Material*: 8 slabs, most of them with gregarious traces, and a dozen of field observations.

**Description.** These are hypichnial cylindrical full burrows, with hardly any terminations, long, straight, 5–10 mm wide, covered with wrinkles irregularly arranged lengthwise. The wrinkles are thin; there are 3–5 wrinkles in one half of the cross-section of a burrow. They are not continuous but break off at a short distance and are replaced by other wrinkles, not necessarily prolongations. In addition to longitudinal wrinkles there are transversal step-like breaks on the surface of the burrow. Bifurcations of the burrows are very rare, and when they occur branch off at an acute angle (10–20°). The burrows normally cover the sole densely, but may also be solitary. Level crossing and interpenetrations at various angles are common.

**Remarks.** — This form was reported by Birkenmajer (1959) from the variegated shales associated with the Jarmuta Beds (Senonian) in the Pieniny zone. This determination was called in doubt by Vialov (1966, p. 18, footnote) and Osgood (1970, p. 380). What was shown by Birkenmajer in pl. 22 may, however, actually be *Fucusopsis angulata*, although poorly preserved. It comes from beds in which this ichnospecies is plentiful. On the other hand the specimen shown by BIRKENMAJER in fig. 1, p. 229 is certainly not a *Fucusopsis*. In the synonymy BIRKENMAJER wrongly assigns the specimen illustrated by VASSOEVICH (1953, fig. 14) to *Fucusopsis*.

**Sediment.** — Thin-bedded (the thickest 6 cm), fine-grained, graded or horizontally laminated sandstones.

**Association.** — In one case *Paleodictyon miocenicum*; in most cases the burrows cover the sole so densely that there is no room for other traces.

**Occurrence.** — Cenomanian — Lower Godula Beds: Rzyki near Wadowice. Turonian — Middle Godula Beds: Wiśniowa. Senonian — Inoceramian Beds (fairly frequent, but tends to occur singly): Kąkolówka, Łodyna, Krasice, Huwniki, Romanowa Wola; Skrzydlna Beds: Wierzbanowa, Skrzydlna; Szydłowiec Beds: Kobielnik (here very abundant and gregarious in some layers); Ropianka Beds: Krzeszów, Wierzbanowa, Półrzeczki, Wola Krogulecka; Jarmuta Beds: Jaworki, Szczawnica (numerous and gregarious in sandstone intercalations in the red shales of the lower part of the Jarmuta Beds); Sromowce Beds (rare and single): Sromowce Wyżne. Palaeocene — Upper Istebna Beds: Kamesznica, the stream Janoska.

### *Fucusopsis annulata* KSIĄŻKIEWICZ, 1970
(pl. 2, figs 6, 7)

1970. *Fucusopsis annulata* ichnosp. n., KSIĄŻKIEWICZ, p. 286, fig. 1r.

*Holotype*. UJ TF 1263 (pl. 2, fig. 6).

*Type locality*: Kamionka Wielka near Nowy Sącz.

*Type horizon*: uppermost part of the Hieroglyphic Beds (transition to the Magura Sandstone), Middle Eocene or possibly lower Upper Eocene.

*Derivation of the name*: Lat. — *annulatus* — ring-like; the burrow is transversally divided into segments.

*Material*: 9 specimens and no less than 10 localities in which this ichnospecies has been noted.

**Diagnosis.** — Hypichnial cylindrical straight or feebly curved string-sized full burrow, longitudinally densely striated with numerous transverse breaks. Only in rare cases branched, at a wide angle.

**Description.** — In the holotype the string, broken at either end, is 18 cm long. Its width is 5 mm, but towards one end it becomes thinner. The height is 3 mm. The surface is densely covered with longitudinal striations. There are 5 to 7 very thin riblets on the visible side of the burrow, separated by shallow grooves. The riblets are irregular in shape. In some parts of the burrow a very weak transversal striation is also visible. The string is divided by transverse narrow grooves into segments of unequal length. Some are only 2–3 mm long, others 10 mm or even more. At the point of contact with the transverse grooves the segments are somewhat swollen. At these transversal breaks the segments slightly change their direction. The string ramifies at a fairly wide angle (70° or 45°). The lateral branches are short (1.5 cm, 3.0 cm).

The length of this burrow must be considerable, as only in a few cases have natural endings been found. The thickness of the string ranges from 0.5 to 6 mm. Ramifications are uncommon, and numerous specimens are unbranched. Lateral branches as a rule are short. This type occurs singly only in rare cases. This is a gregarious burrow, but never covers the sole so densely as *Fucusopsis angulata*. In some instances the strings transect one another on the same level (pl. 2, fig. 7).

**Remarks.** — The delicate striation and the transversal segmentation distinctly differentiate this ichnospecies from *F. angulata*.

**Sediment.** — Fine-grained, thin-bedded (the thickest 5 cm), usually horizontally laminated sandstones, also marly siltstones,

**Association.** — In one instance with *Paleodictyon carpathicum*, in another with *Paleodictyon minutissimum*. Cuts across a *Protopaleodictyon submontanum* network.

**Occurrence.** — Palaeocene-Lower Eocene — Variegated Shales: Lipowe (in a few neighbouring layers very frequent), Stara Wieś. Lower Eocene — Ciężkowice Sandstone: Korczyna; Beloveza Beds (fairly frequent): Złatna, Zubrzyca Górna, Sidzina, Tokarnia, Zbludza, Myślec, Berest. Middle Eocene — Hieroglyphic Beds (frequent): Zawoja (the stream Końskie), Osielec, Juszczyn (the hamlet Kozłownik), Jordanów (the hamlet Munkacz), Tokarnia, Kamionka Wielka, Polany, Hańczowa, Wysowa, Łosie; Łącko Beds: Kamienica near Nowy Sącz (in marlstone). Upper Eocene — Magura Sandstone: Orawka (in thin-bedded intercalations), Grzechynia, Berest, Polany, Klimkówka, Smrekowiec.

### *Fucusopsis striata* (HALL, 1852)
(pl. 2, fig. 8)

1852. *Palaeophycus*? *striatus* (n. sp.), HALL, p. 22, pl. 10, fig. 1*a*.
*Material*: 2 specimens.

**Description.** — The better preserved specimen is hemicylindrical, straight, long (19 cm, no endings), 12 mm wide and 3–4 mm high. The surface is densely covered with longitudinal, continuous delicate striae, spaced 0.5–1.0 mm from one another.

**Remarks.** — Our material seems to be identical to that illustrated by HALL (1852) who tentatively assigned it to *Palaeophycus*, and also to the specimens of OSGOOD (1970, pl. 76, figs 6–7) determined as *Palaeophycus striatum* HALL. The ichnogenus *Palaeophycus* is not clearly defined and various types have been dumped together under this term. If the original definition of HALL (1847, p. 7) were taken as the basis, the striated types should be excluded, for HALL defines *Palaeophycus* as stems with "surface nearly smooth". In the present paper all simple, straight burrows with longitudinal striae are assigned to *Fucusopsis*.

**Sediment.** — Thin-bedded limestone.

**Occurrence.** — Berriasian. Cieszyn Limestone: Goleszów (main quarry).

## Ichnogenus *Halymenidium* SCHIMPER, 1879

*Type ichnospecies: Halymenidium flexuosum* (FISCHER-OOSTER) (HÄNTZSCHEL, 1965).

**Remarks.** — As noted by HÄNTZSCHEL (1965), there is a morphological resemblance between *Halymenidium* and *Granularia*. This resemblance, however, relates to the outward ornamentation and not to the inner texture: the cylinders of *Granularia* consist of pellets and grains (REIS, 1909) and their surface ornamentation reflects the arrangement of the constituents. In *Halymenidium* the surface ornamentation is independent of the inner filling, and, most probably, is due to the surface ornamentation of the producing animal.

**Origin.** — FUCHS (1895, p. 408) presumed that traces of this kind are fillings of tubes inhabited by annelids, like *Terebella*. The two Carpathian ichnospecies are obviously post-depositional, as shown by their cylindrical form and relation to sedimentary structures, e.g. they transect lineation. They might have been formed by worm-shaped animals whose bodies were covered with tubercules or spines. When the animal drew its body forward in the sediment by alternate contraction and extension, the tubercules or spines could have produced little holes and streaks on the wall of the tunnel, which was subsequently filled with the material processed by the animal. In this way the filling might receive an ornamentation consisting of little ridges and tubercules. What the animal was is open to question; perhaps it was one of the holothurians or, more probably, of those ophiuroids and sipunculids which have bodies covered with protuberances of various sorts.

### *Halymenidium sublumbricoides* (AZPEITIA, 1933)
(pl. 3, figs 1, 2)

1933. *Halymenites sublumbricoides* n. sp., AZPEITIA, p. 56, pl. 18, fig. 32.
*Material*: 9 specimens.

**Description.** — For the most part hypichnial full burrows, seldom endichnial or epichnial. The cylinders, usually long, are 10–13 mm thick. They are covered with short riblets, near the borders of the string oblique to the axis of the cylinder and more distinct. Elsewhere the string is covered by tiny tubercules scattered with no consistent orientation, or with tiny ridges forming an irregular criss-cross pattern. In some parts of the surface even these elements are lacking and the cylinder is almost smooth. Only in one specimen is there an almost right-angled dichotomous branching. The lateral branch is devoid of any sculpture. The burrow projects of a few mm in relation to the underface, but may also be almost hidden above it. It is a solitary trace.

**Remarks.** — The original type of AZPEITIA is thinner (5.5 to 7.8 mm) and its sculpture is even less developed than in our material (AZPEITIA writes that the sculpture is visible under a magnifying glass, but at any rate it is noticeable in his figure). In those parts of the burrow in which the ornamentation merely consists of irregularly scattered tubercules the trace is similar to *Halymenites rectus* FISCHER-OOSTER (1858, pl. 13). It seems that the affinity of these two types is very close.

**Sediment.** — Fine-grained, thin-bedded (up to 5 cm) sandstones.

**Association.** — *Fucusopsis annulata*, *Halymenidium oraviense*, small *Sabularia* (probably posterior).

**Occurrence.** — Lower Eocene — Beloveza Beds: Lipnica Wielka, Lipnica Mała, Zubrzyca Górna, Zbludza. Middle Eocene — Hieroglyphic Beds: Daliowa, Komańcza; Łącko Beds: Kamienica near Nowy Sącz.

### *Halymenidium oraviense* (KSIĄŻKIEWICZ, 1961)
(pl. 3, figs 3–4)

1961*a*. *Halymenites oraviensis* (n. f.), KSIĄŻKIEWICZ, p. 884, pl. 2, fig. 1
*Holotype*: UJ TF 61 (pl. 3, fig. 4).
*Type locality*: Lipnica Mała near Nowy Targ (Orawa region).
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: found in the Orawa region.
*Material*: 23 specimens and a number of occurrences noted in the field.

**Diagnosis.** — Hypichnial, more rarely endichnial or epichnial string-sized full burrow, long, straight, seldom branching. Surface covered with distinct oblique riblets arranged in a plaited design.

**Description.** — The holotype runs straight, it is 10 cm long (broken off at either end). Its cylindrical form is somewhat dorso-ventrally flattened. The width of the cylinder is 1 cm. The ornamentation consists of riblets, 0.5 to 0.7 mm thick, separated by slightly wider grooves. The riblets may be somewhat wavy or straight, their width and height are variable. They run obliquely to the axis of the burrow, and in the median zone of the cylinder they transect one another, or without a break pass to the other side of the cylinder, most commonly changing their direction, but some riblets pass to the other flank undeflected.

Other specimen are very much the same. The cylinders range up to 12 mm in width, which on the average is about 8–10 mm. Some, presumably juvenile forms, are very thin. On the specimens that could be disengaged from the host rock it may be seen that the sculpture on the dorsal side of the burrow is the same as on the lower (ventral) side, but less distinctly developed or preserved. Branching is rare. The lateral branches are short (a few cm), thinner and at right angles to the main stem. They exhibit a different pattern of sculpture (pl. 3, fig. 3). The riblets are oblique in respect to the axis of the burrow at a smaller angle, so that they are almost longitudinal. The origin of the lateral branches is not clear. The animal, as many "worms" do, might burrow laterally and afterwards withdraw (NATHORST, 1889), and when proceeding in the previous, main direction, fill the lateral as well as the main gallery with the material excreted. But in this case the difference in sculpture is inexplicable. It may well be that in the filling left behind in the main gallery the animal also left some eggs, and the young animals burrowed laterally.

Essentially, this is a hypichnial burrow, but there are specimens in which the sole burrow enters the sandstone layer, traverses it obliquely and eventually follows the sandstone/argillite interface. In this way it penetrates very thin (3–4 cm) sandstone layers.

This burrow is rather solitary, the soles are never crowded with it. In very rare instances one burrow intersects another.

**Remarks.** — This type is differentiated from *H. sublumbricoides* by its much more distinct and more regular sculpture.

**Sediment.** — Thin-bedded (up to 4 cm), fine-grained sandstones, mostly horizontally laminated. May also occur in coarser sandstones (grain diameter up to 0·4 mm).

**Association.** — *Cosmorhaphe fuchsi.* Intersected by *Sabularia simplex.*

**Occurrence.** — Berriasian — Cieszyn Limestone: Godziszów, Mt. Chełm (a thin, not very typical burrow). Palaeocene-Lower Eocene — Variegated Shales: Półrzeczki, Mordarka. Lower Eocene — Beloveza Beds (locally fairly frequent): Złatna, Lipnica Wielka, Lipnica Mała, Zubrzyca Górna, Zubrzyca Dolna, Sidzina, Łętownia Górna.

### Ichnogenus *Keckia* GLOCKER, 1841

*Type ichnospecies: Keckia annulata* GLOCKER (HÄNTZSCHEL, 1962)

**Remarks.** — To this ichnogenus, not very clearly defined, are assigned cylindrical full burrows with chevron-like surface sculpture. According to HÄNTZSCHEL (1965) tunnels packed by backward pressing ("Stopfung") of reworked material are included here. This sort of filling may be due to the contraction and expansion of the animal's body during peristaltic movements. This seems to suggest that the polychaete worms were the most probable producers.

### *Keckia annulata* GLOCKER, 1841

(pl. 3, fig. 14)

1841. *Keckia annulata,* GLOCKER, p. 319, pl. 4.
*Material*: 5 specimens.

**Description.** — Here are assigned hypichnial cylindrical straight full burrows with chevron-like surface sculpture. The specimen illustrated is a long burrow 4 to 5 mm wide and 3–4 mm high. It consists of arcuate, uniformly bent segments, each 1.0–1.5 mm long, separated by very narrow and shallow grooves.

In the specimens from the Lower Cretaceous the segments are on the whole smaller, similar to those collected from the Godula Beds, which are 3 mm wide. In one specimen (Komańcza, UJ TF 1198) the surface of the cylinder is smooth, but the inside shows crescentic segmentation.

**Remarks.** — In contrast to the figure of GLOCKER no branching has been observed, although level crossing exists. This trace is similar to that described by HOWARD (1966, p. 41, fig. 4) as a "chevron trail". HOWARD's form is three times larger than our specimens, and it occurs as an epichnial ridge. A similar type was described by SCHAFHÄUTL (1851) as *Muensteria annulata,* considered by HÄNTZSCHEL (1938) to be synonymous with GLOCKER's ichnospecies.

**Sediment.** — Thin-bedded (up to 4 cm), fine-grained sandstones with composite or horizontally laminated bedding.

**Occurrence.** — Hauterivian — Grodziszcze Beds: Raciechowice. Barremian — Verovice Shales: Lipnik near Myślenice, Wiśniowa. Cenomanian — Lower Godula Beds: Ponikiew.

Turonian — Middle Godula Beds: Targoszów, Bieśnik (*Keckia* was reported from the Godula Beds by HOHENEGGER, 1861). Senonian — Inoceramian Beds: Dubiecko (here horizontal endichnial burrow), Rzegocin, Makowa; Upper Godula Beds: Mucharz, the stream Jamnicki; Ropianka Beds: Ślemień, Skwirtne. Palaeocene — Upper Istebna Beds: Targoszów, Tabaszowa; Szczawnica Beds: Krościenko on the river Dunajec. Middle Eocene — Hieroglyphic Beds: Istebna, Rajcza, Daliowa, Komańcza.

### *Keckia hoessii* (STERNBERG, 1833)

(pl. 3, figs 15, 16)

1858. *Münsteria Hoessii* STERNB., FISCHER-OOSTER, p. 38, pl. 7, fig. 3, pl. 6, fig. 4.
*Material*: 7 specimens.

**Description.** — Long, more or less straight cylinders, elliptical in cross-section, about 10 mm wide, 5 mm thick. They usually occur in the epichnial position, in some instances just below the upper surface. Very often gregarious. Specimen illustrated on pl. 3, fig. 15 represents a somewhat different type, hypichnial, of smaller size, consisting of bent lamellae, 0.3–0.4 mm thick, alternating in colour, grey and black, the former of fine-grained sandstone, the latter of carbonaceous matter.

**Remarks.** — FISCHER-OOSTER assigned this type to *Münsteria*, in which he distinguished the "subgenus" *Keckia*.

**Sediment.** — Pelletal limestones, fine-grained or medium-grained sandstones.

**Occurrence.** — Berriasian — Cieszyn Limestone: Jaworze. Valanginian — Upper Cieszyn Shales: Gorzeń Górny. Hauterivian — Grodziszcze Beds: Poznachowice (here very frequent), Żegocina. Barremian — Verovice Shales: Lipnik near Myślenice. Senonian — Inoceramian Beds: Kalwaria Pacławska; Lower Istebna Beds (fucoidal marls interbed): Czarnorzeki. Ropianka Beds: Lubomierz; Limanowa, the hamlet Marciszów. Middle Eocene — Hieroglyphic Beds: Darów, Daliowa (endichnial), Dobra.

### Ichnogenus *Planolites* NICHOLSON, 1873

*Type ichnospecies*: ?*Planolites vulgaris* NICHOLSON & HINDE (HÄNTZSCHEL, 1965).

**Remarks.** — This is a very poorly defined ichnogenus, as noted by CHAMBERLAIN (1971*a*), and its type "species" has not been illustrated. Its separation from *Palaeophycus*, another vaguely defined ichnogenus, also presents difficulties (OSGOOD, 1970). According to the last named author the morphology of *Planolites* and *Palaeophycus* is very similar; both are "cylindrical, irregular, unbranched, and penetrate obliquely through the strata".

The most detailed description of a trace assigned to *Planolites* is given by REINECK (1955). His *P. rugulosus* is a cylindrical body, about 1 cm in diameter, with its surface marked by annulations and longitudinal striae. This type of external sculpture gives a corrugated ("feinrunzelig") appearance to the surface. There is no branching in this type. As one type assigned to *Planolites* was named "corrugatus" (WALCOTT, 1899), it seems that unbranched cylindrical burrows with a corrugated surface may be taken as the type of *Planolites* and *P. rugulosus* REINECK as the type ichnospecies for this ichnogenus.

### *Planolites reinecki* n. ichnosp.

(pl. 2, fig. 9)

*Holotype*: UJ TF 1015 (pl. 2, fig. 9).
*Type locality*: Wola Brzezińska near Nowy Sącz.
*Type horizon*: Ropianka Beds, Senonian.
*Derivation of the name*: in honour of Professor H. E. REINECK (Wilhelmshaven, W Germany).
*Material*: 5 specimens.

**Diagnosis.** — Hypichnial cylindrical rope-sized full burrow, with the surface covered by densely spaced transversal striae and longitudinal, irregular wrinkles, also densely spaced.

**Description.** — The holotype is represented by a cylinder 5.5 cm long and 11 mm in diameter. One end is broken off. The burrow is slightly curved, but this is due mainly to a fracture in the host rock. It lies somewhat obliquely to the underface, so that at one end it stands high 6 mm in relation to the sole, and at the other end it is apparently pointed, because it enters the sandstone above the sole. The transverse striation is very dense: there are 12–14 delicate transverse grooves per 1 cm of the length. The longitudinal wrinkles are also densely spaced. They are somewhat wavy and not strictly parallel to the axis of the burrow.

On the same sole of the slab as the holotype there is another cylinder of identical shape, dimensions and sculpture. In other specimens the transversal striation is feebly marked. In one specimen two burrows of this type adhere to the sole; they overlap, but do not penetrate one another.

**Sediment.** — Fine-grained, thin-bedded sandstone (up to 4 cm) with composite bedding.

**Origin.** — Evidently a post-depositional feeding burrow. The nature of the sculpture suggests a priapulid rather than a polychaete worm.

**Occurrence.** — This is a very rare type. Senonian — Skrzydlna Beds: Przenosza; Ropianka Beds: Wola Brzezińska, Skwirtne.

## Ichnogenus *Rhabdoglyphus* VASSOEVICH, 1951

*Type ichnospecies: Rhabdoglyphus grossheimi* VASSOEVICH (HÄNTZSCHEL, 1962).

**Remarks.** — FUCHS (1895, p. 391) used the term "*Rhabdoglyphus*" for segmented biogenic structures. It follows from his description that he had different types in mind. Taking as the model *Rhabdoglyphus grossheimi* VASSOEVICH (illustrated but not described by him) all short articulated rods consisting of uniformly shaped and relatively large limbs may be grouped as *Rhabdoglyphus*. Their classification is based on the shape of the limbs. In the Carpathian flysch the representatives of this ichnogenus, although diversified, are very rare.

**Origin.** — All types are post-depositional, as evidenced by the commonly preserved cylindrical shape and the relation to the sedimentary structures. They may intersect sole lineation (pl. 3, fig. 12) or drag marks (pl. 3, fig. 10). It is particularly difficult to assign an originator to this type of trace. According to BOUČEK and ELIAŠ (1962), the trace they assigned to *Rh. grossheimi* (in all likelihood wrongly, see KSIĄŻKIEWICZ, 1970 and VIALOV, 1971, but at any rate to a related kind) may be due to the activity of a gastropod, amphipod or to a holothurian. According to OSGOOD (1970) the swellings represent periodic (peristaltic) anal constrictions and expansions. This might have been a polychaete worm, advancing by bolting.

### *Rhabdoglyphus grossheimi* VASSOEVICH, 1951
(pl. 3, fig. 5; text-fig. 6*a*)

1951. *Rhabdoglyphus grossheimi*, n. sp., VASSOEVICH, p. 61, pl. 5, fig. 4 (no description).
*Material*: 1 specimen.

**Description.** — Hypichnial short (5 cm) rod, straight, consisting of seven limbs, 5–7 mm long. Each limb is spicate in shape: at one end it is 8–11 mm wide but tapers toward the base, where it is only 2 mm wide; the larger part bifurcates into two lateral, thorn-like appendages, slightly curved towards the base of the limb.

**Remarks.** — Our specimen corresponds well with the figure given by VASSOEVICH, only the lateral thorns are larger and more markedly bent.

**Sediment.** — Fine-grained, thin-bedded sandstone (5 cm).

**Occurrence.** — Cenomanian — Lower Godula Beds: Jaroszowice.

### *Rhabdoglyphus spinosus* n. ichnosp.
(pl. 3, figs 7, 8, 13; text-fig. 6*b*)

*Holotype*: UJ TF 1175 (pl. 3, fig. 7).
*Type locality*: Wierzbanowa near Myślenice.
*Type horizon*: Skrzydlna Beds, Senonian.
*Derivation of the name*: Lat. *spinosus* — provided with spines; the rod has thorn-like appendages.
*Material*: 4 specimens.

**Diagnosis.** — Hypichnial full burrow. The rod is short, straight and swollen at regular intervals into round protuberances provided with thorn-like appendages.

The specimen taken for the holotype is 6 cm long (one end broken off) and 3 mm wide between the protuberances, which are 4–5 mm wide. They have an elliptical or almost circular outline. Some of them are flattened at one end. The appendages are of variable length; the longest is 10 mm. Each protuberance has one appendix. The appendages occur alternately on one side or the other. They are slightly curved.

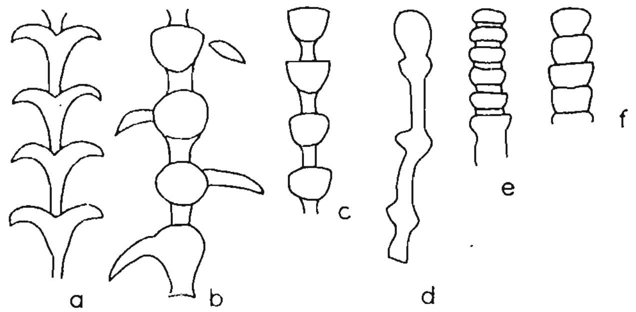



Fig. 6
Types of articulation in *Rhabdoglyphus* (diagrammatically); a *Rhabdoglyphus grossheimi* Vassoevich (cf. pl. 3, fig. 5); b *Rh. spinosus* n. ichnosp. (cf. pl. 3, fig. 7); c *Rh. caliciformis* n. ichnosp. (cf. pl. 3, fig. 11); d *Rh.* aff. *caliciformis* n. ichnosp. (cf. pl. 3, fig. 17); e *Rh. compositus* n. ichnosp. (cf. pl. 3, fig. 10); f *Rh. sulcatus* n. ichnosp. (cf. pl. 3, fig. 9). All figures × 1

Another specimen (pl. 3, fig. 8) is complete. The rod is 5 cm long and only 1.0–1.5 mm wide. The protuberances are less pronounced, but also arranged at regular intervals and provided with short spines, also arranged alternately on either side. Some of the lateral spines are not directly linked with the protuberances. In the specimen in pl. 3, fig. 13 the protuberances are elongated, the lateral thorns long and markedly curved. It is possible that this specimen represents another, although closely related, ichnospecies.

**Sediment.** — The holotype occurs on the sole of a sandstone 7 cm thick, others on very fine-grained and thin-bedded sandstones.

**Occurrence.** — Cenomanian — Lower Godula Beds: Wisła. Senonian — Skrzydlna Beds: Wierzbanowa; Ropianka Beds: Mszana Dolna, Limanowa.

### *Rhabdoglyphus caliciformis* n. ichnosp.
(pl. 3, figs 6, 11; text-fig. 6*c*, *d*)

1970. *Rhabdoglyphus* ichnosp. a *(pro parte)*, Książkiewicz, p. 385, figs 1*h*, *i*.
*Holotype*: UJ 182 TF (pl. 3, fig. 11).
*Type locality*: Godziszów near Cieszyn.
*Type horizon*: Cieszyn Limestone, Berriasian.
*Derivation of the name*: Lat. *calix* — calix; the cup-shaped limbs of which the rod consists.
*Material*: 5 specimens.

**Diagnosis.** — Hypichnial cylindrical short straight rod consisting of uniformly shaped calicular limbs.

For the holotype has been chosen the largest (although broken) trace, about 30 mm long. It consists of four calicular limbs, each 5 mm long, 3 mm wide at the base of the limb and 5 mm at the upper rim. These limbs are connected by narrow links, each 2–3 mm long, less protuberant in relation to the sole than the calicular limbs.

Another specimen (pl. 3, fig. 12) is 20 mm long and only 2–3 mm wide. The links between the calix-shaped limbs are longer than in the holotype. The terminal limb is bulbous in shape. A small specimen in pl. 3, fig. 6 may also be assigned here. The upper rim is more concave and the rod is slightly bent.

The specimen illustrated in pl. 3, fig. 17 is considered to have affinity with this ichnospecies. It is much bigger, the calicular elements are less regular and the intervening links longer. The terminating limb has also a bulbous shape. On the contrary to other specimens this is an epichnial full burrow. The elongated intermediate links between the swollen limbs are similar to those in *Fustiglyphus annulatus* VIALOV (1971, p. 90, fig. 3 = *Rhabdoglyphus grossheimi* BOUČEK & ELIAS, 1962). It is possible that our specimen represents an intermediate type between *Rhabdoglyphus* and *Fustiglyphus*. The trace determined by F. SIMPSON (1970, pl. 10, fig. 5) as *Rhabdoglyphus* VASSOEVICH probably should be assigned to *Fustiglyphus* VIALOV.

**Remarks.** — *Rh. caliciformis* differs from *Rh. grossheimi* and *Rh. spinosus* in the different shape of the limbs and the absence of lateral appendages.

**Sediment.** — Horizontally laminated limestones, 7·5 cm thick, or sandstones of similar thickness. In one specimen the filling material is somewhat coarser than the host rock.

**Occurrence.** — Berriasian — Cieszyn Limestone: Goleszów, main quarry, Godziszów, Mt. Chełm. Senonian Ropianka Beds: Wola Krogulecka. Middle Eocene — Hieroglyphic Beds: Dobra.

*Rhabdoglyphus sulcatus* n. ichnosp.
(pl. 3, fig. 9; text-fig. 6*e*)

1970. *Rhabdoglyphus* ichnosp. a *(pro parte)*, KSIĄŻKIEWICZ, p. 285, fig. 1*k*.
*Holotype*: UJ TF 180 (pl. 3, fig. 9).
*Type locality*: Mszana Dolna.
*Type horizon*: Ropianka Beds, Senonian.
*Derivation of the name*: Lat. *sulcus* — groove; sulcated rod.
*Material*: 3 specimens.

**Diagnosis.** — Hypichnial cylindrical rod-shaped full burrow, divided by transverse grooves into segments with round edges.

**Description.** — The holotype is represented by a hemicylindrical rod, 45 mm long, 7–9 mm wide, 3 mm high. One end of the rod is broken. The rod is divided by fairly deep transverse grooves into segments 3–4 mm long. Towards the preserved end the segments become narrower, while near the other the furrows are only slightly marked and the burrow seems to pass into a cylindrical smooth stem.

**Remarks.** — This form is to a certain extent similar to the "*Rhabdoglyphus*" figured by FUCHS (1895, pl. 4, fig. 4, the upper part of the figure).

**Sediment.** — Fine-grained, thin-bedded limestones or sandstones.

**Occurrence.** — Berriasian — Cieszyn Limestone: Godziszów, Mt. Chełm. Senonian — Ropianka Beds: Mszana Dolna, the hamlet Glisne.

*Rhabdoglyphus compositus* n. ichnosp.
(pl. 3, fig. 10; text-fig. 6*f*)

1970. *Rhabdoglyphus* ichnosp. a *(pro parte)*, KSIĄŻKIEWICZ, p. 285, fig. 1*j*.
*Holotype*: UJ TF 179 (pl. 3, fig. 10).

*Type locality*: Tabaszowa near Nowy Sącz.
*Type horizon*: Upper Istebna Beds, Palaeocene.
*Derivation of the name*: Lat. *compositus* — composite; the rod is composed of annular limbs.
*Material*: 3 specimens.

**Diagnosis.** — Hypichnial rod-like burrow composed of roundish segments with no intervening elements.

**Description.** — The holotype is 3 cm long, 2 mm wide and 0·5 mm high. It is feebly curved. The rod is divided by transversal shallow constrictions into swollen segments of identical calicular shape, each 2 mm long. The segments, nine in number, touch one another, with no links between them. The terminations of the rod are different: at one end there is a straight supporting stem, at the other the last segment is longer (4 mm) and somewhat rounded.

**Remarks.** — This type differs from other Rhabdoglyphs in the absence of lateral spines and absence of links between the swollen elements; from *Rh. sulcatus* in shape of the limbs.

**Sediment.** — Thin-bedded, fine-grained, horizontally laminated sandstone.

**Occurrence.** — Senonian — Upper Godula Beds: Mucharz, the Jamnicki stream; Ropianka Beds: Lipnica Mała, the Zosiak clearing. Palaeocene — Upper Istebna Beds: Tabaszowa.

### Ichnogenus *Sabularia* n. ichnogen.

*Type ichnospecies: Sabularia simplex* n. ichnosp.
*Derivation of the name*: Lat. *sabulum* — sand; the burrows filled with sand.

**Diagnosis.** — Horizontal, oblique or vertical, cylindrical full burrows, straight or feebly curved, only rarely ramified.

**Remarks.** — Outwardly the burrows assigned here are similar to *Granularia* POMEL, which also includes straight, sometimes curved cylinders (HÄNTZSCHEL, 1962), but these are filled with clay particles and pellets, while the cylinders now assigned to *Sabularia* are sand-filled. The clay pellets in *Granularia* are arranged, according to REIS (1909) at right angles to the axis of the burrow. The similarity in morphology and the not very clear definition of *Granularia* caused the straight sand-filled tubes, without surface ornamentation, to be also assigned to *Granularia* (KSIĄŻKIEWICZ, 1970). It should also be added that none of the two specimens taken by HÄNTZSCHEL (1962, fig. 123, 1, 5) corresponds with the discussed trace. The differences in the filling material and the manner of occurrence (*Granularia* occurs in limestones and marls, *Sabularia* in sandstones), and also some differences (as shown below) in the manner of packing, justify the grouping of the types discussed in a separate ichnogenus.

The types assigned here have often been determined as *Cylindrites*. Since various materials have been treated under this term, used originally for some algae and not clearly defined, it seems that it should be dropped altogether.

**Origin.** — All sabularias, as indicated by their cylindrical shape, are post-depositional, presumably produced by a worm-shaped animal. The filling material is often coarser than the host rock. The animal must have been indiscriminate in using material for food. Polychaetes are known for this peculiarity, unselectively ingesting the whole sediment. In some specimens cut along the axis of the burrow some traces of backfilling are discernible (text-fig. 9*e*). The backfilling, unlike that in *Keckia*, did not influence the surface morphology of the burrow. In most cases the filling consists of disorderly packed grains; if the burrow intersects a sole with grain lineation, there is a marked contrast between the fabric of the burrow filling and the host rock.

### *Sabularia simplex* n. ichnosp.

(pl. 2, fig. 2; text-fig. 9*e*)

*Holotype*: UJ TF 1477 (pl. 2, fig. 2).
*Type locality*: Berest near Grybów.

*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *simplex* — simple; simple nature of the trace.
*Material*: 16 slabs and at least 50 occurrences noted in the field.

**Diagnosis.** — Hypichnial, more rarely endichnial, epichnial or exichnial, string-sized cylindrical full burrow, long, more or less straight, with smooth surface.

**Description.** — The holotype is represented by horizontal, cylindrical, long, with neither beginning nor end, burrow, 4 mm wide, 1 mm high, slightly curved. There is no ramification, but the cylinders cross one another.

There is little variability in this ichnospecies. The largest specimen is 10 mm wide, the smallest 2 mm. Branching, extremely rare, occurs at an acute angle if at all. In some specimens there occur some knob-like swellings, spaced at irregular intervals (text-fig. 9*f*). Usually the burrows keep their direct course for long distances (some metres), but in some instances they change it abruptly (text-fig. 26*j*). This is essentially a horizontal burrow, but in a few cases vertical cylinders of the same size and shape traverse vertically a sandstone bed a few centimetres thick. In one case (Znamirowice, Ciężkowice Sandstone) a horizontal burrow penetrates vertically a sandstone bed 6 cm thick. Such behaviour seems to be exceptional. This trace tends to occur gregariously, with much intersection and interpenetration, but may also occur singly.

**Remarks.** — There is a resemblance to "*Palaeophycus*" *simplex* HALL (1847, p. 63, pl. 22, fig. 1), to which belong cylindrical stems, somewhat wider than the type discussed, also with a smooth surface but often provided with a longitudinal groove on one side. This feature is entirely lacking in our material. HALL's type was assigned to *Cylindrites*? by WILCKENS (1947). Traces of this type from the Carpathian flysch were casually reported as *Cylindrites* (KSIĄŻKIEWICZ, 1966, F. SIMPSON, 1967).

**Sediment.** — Thin-bedded (up to 25 cm), fine-grained sandstones, graded or laminated, also on top surfaces of sandstones of various thickness.

**Association.** — If occurs with other traces, intersects them (*Desmograpton*, *Paleodictyon*, *Chondrites*, *Subphyllochorda* etc.).

**Occurrence.** — Occurs in almost all stratigraphic units, but is particularly abundant in Senonian Sromowce Beds and in the Middle Eocene Hieroglyphic Beds.

Berriasian — Cieszyn Limestone: Kamienica near Bielsko. Valanginian — Upper Cieszyn Shales: Trzemeśnia. Hauterivian — Grodziszcze Beds: Wiśniowa, Żegocina (also epichnial), Brzyska. Albien — Lgota Beds: Kaczyna, Bystre. Cenomanian — Lower Godula Beds: Ustroń (the hamlet Poniwiec), Rzyki near Wadowice, Bieśnik. Turonian — Middle Godula Beds: Kocierz, Rzyki near Wadowice, Ponikiew, Czchów, Bieśnik, the stream Paleśnica; Siliceous Marls: Szczepanowice, Rybotycze, Huwniki (horizontal and vertical burrows). Senonian — Inoceramian Beds: Rzegocin, Kąkolówka, Krasice, Dubiecko (the hamlet Utrata), Romanowa Wola; Gorzeń Beds: Gorzeń Dolny, Gorzeń Górny, Wierzbanowa; Lower Istebna Beds: Czarnorzeki; Ropianka Beds: Lipnica Mała, Zaryte, Lubomierz, Szczawa, Wola Krogulecka, Siary, Skwirtne; Sromowce Beds (very frequent): Szaflary, Sromowce Wyżne, Sromowce Niżne, Niedzica, Jaworki (the stream Biała Woda, and the stream Skalski). Palaeocene — Upper Istebna Beds: Krzeszów, Czarnorzeki. Palaeocene-Lower Eocene — Variegated Shales: Brzeźna (also epichnial); Szczawnica Beds: Krościenko on the river Dunajec, Grywałd (also endichnial), Hałuszowa. Lower Eocene — Ciężkowice Sandstone: Ciężkowice (horizontal and vertical); Beloveza Beds: Złatna; Lipnica Wielka, Zubrzyca Górna, Sidzina, Tokarnia, Lubomierz, Zbludza, Nawojowa, Popowice, Myślec, Berest. Middle Eocene — Hieroglyphic Beds (very frequent): Istebna, Kamesznica (the stream Janoska), Milówka, Rajcza, Dąbrówka, Zawoja (the stream Końskie and other places), Sidzina, Łętownia Górna, Jordanów (the hamlet Munkacz), Stara Wieś, Zalesie, Brzeźna, Polany, Hańczowa, Wysowa, Daliowa, Darów, Żubracze, Liszna, Wola Krzywecka, Dobra; Łącko Beds: Kamienica near Nowy Sącz, Naszacowice

Myślec. Upper Eocene — Magura Sandstone: Ujsoły, Zawoja, Kamionka Wielka, Tylmanowa, Żegiestów (on the lower and on the upper surface, also endichnial but close to the upper surface), Berest, Bednarka, Smrekowiec. Oligocene — Krosno Beds: Ślemień, Kąty, Dębna, Wetlina.

### *Sabularia rudis* n. ichnosp.

(pl., 2 fig. 4; text-fig. 7)

*Holotype*: UJ TF 128 (text-fig. 7).
*Type locality*: Gródek near Nowy Sącz.
*Type horizon*: Ciężkowice Sandstone, Lower Eocene.
*Derivation of the name*: Lat. *rudis* — rough; usually rough surface of the burrow.
*Material*: 16 specimens and many field observations.

**Diagnosis.** — Endichnial, more rarely hypichnial, exichnial and epichnial, rope-sized cylindrical full burrow. Horizontal, also transverse.

Fig. 7
A fragment of *Sabularia rudis* n. ichnosp. Gródek, Ciężkowice Sandstone. UJ TF 128. × 0.5

**Description.** — The specimen taken for the holotype presents a long, without beginning or end, thick (2.5 cm) cylinder, almost straight, circular in cross-section, filled with coarse sand (grains up to 5 mm). It is hypichnial, parallel to the bedding. The filling material is of the same grain-size as that of the host rock.

A great variety of types has been lumped together under the proposed term. Thick cylinders, vertical, oblique or subhorizontal, are not uncommon in coarse-grained sandstones. They may traverse layers 1.2 m thick. The filling material is of the same grade as the enclosing rock, but frequently is much coarser. In a few cases (Pasierbiec Sandstone, Osielec) the grains are arranged with their longer axes parallel to each other and at right angles to the axis of the burrow. No obvious distortion of the fabric in the enclosing rock in the proximity of the burrows has been noted.

To this ichnospecies have been assigned heaps of thick (2–3 cm) and usually short cylindrical burrows, penetrating and overlapping each other (pl. 2, fig. 4). The heaps adhere to the sole of sandstones; they may be several centimetres high, and built of coarser material than the adhering sandstone. Many of the cylinder endings are obtuse.

**Sediment.** — Sandstones, mainly coarse and thick-bedded.

**Association.** — *Arthrophycus*.

**Occurrence.** — Tithonian — Lower Cieszyn Shales: Bażanowice, Gumna. Berriasian — Cieszyn Limestone: Kamienna near Bielsko. Valanginian — Upper Cieszyn Shales: Trzemeśnia. Hauterivian — Grodziszcze Beds: Raciechowice, Poznachowice (on either surface, some layers are full of this trace), Brzyska. Turonian — Siliceous Marls: Huwniki. Senonian — Inoceramian Beds: Wołodź; Lower Istebna Beds: Istebna, Będzieszyna, Kobyle near Jasło, Czarnorzeki; Skrzydlna Beds: Przenosza; Ropianka Beds: Jaworzynka, Limanowa, the hamlet Marciszów (heap form common). Lower Eocene — Ciężkowice Sandstone (locally frequent): Znamirowice, Gródek, Ostrusza. Middle Eocene — Pasierbiec Sandstone: Osielec; Hieroglyphic Beds: Darów, Komańcza (heap form frequent); Łącko Beds: Naszacowice. Upper Eocene — Magura Sandstone: Rzyki near Limanowa, Piwniczna, Żegiestów.

### *Sabularia tenuis* n. ichnosp.
(pl. 2, fig. 3)

*Holotype*: UJ TF 1687 (pl. 2, fig. 3).
*Type locality*: Wujskie near Lesko.
*Type horizon*: Krosno Beds Oligocene.
*Derivation of the name*: Lat. *tenuis* — thin.
*Material*: 7 slabs and many occurrences noted in the field.

**Diagnosis.** — Hypichnial, more rarely endichnial thread-sized short, straight full burrow.

**Description.** — In the holotype the burrows are 0.5–0.7 mm wide, 10–40 mm long and about 0.5 mm high. The surface is smooth, but on some burrows a very delicate transverse striation may be seen. One end of the burrows, which for the most part are hemicylindrical, is usually pointed, the other obtuse, but some have both ends pointed. There are not true ramifications, but level crossing is common. This is a gregarious trace.

In some specimens the burrows are slightly thicker (up to 1 mm). They are always straight, but occasionally they change course at an angle.

**Sediment.** — Fine-grained, thin-bedded (a few cm) sandstones, usually horizontally or single-current laminated.

**Association.** — As the trace occurs gregariously there is no room for other traces. In one case it is posterior to a *Buthotrephis*.

**Occurrence.** — This trace occurs in most of the members of the Carpathian flysch, but abounds in a few sandstones while most other sandstone layers are devoid of it. It is particularly frequent in the following horizons:

Valanginian — Upper Cieszyn Shales: e.g. Jaroszowice. Hauterivian — Grodziszcze Beds: Wiśniowa, Poznachowice (endichnial). Cenomanian — Lower Godula Beds: Ponikiew, Jaroszowice, Rzyki near Wadowice. Turonian — Siliceous Marls, Rybotycze, Huwniki; Middle Godula Beds: Czchów. Senonian — Inoceramian Beds: Rzegocin, Kąkolówka, Łodzinka, Kuźmina, Krasice, Kalwaria Pacławska; Upper Godula Beds: Okrajnik, Łąkta; Ropianka Beds: Lipnica Mała (the stream Linorka), Wierzbanowa, Siary. Middle Eocene — Hieroglyphic Beds: Wysowa, Darów. Oligocene — Krosno Beds (here seems to be locally particularly frequent): Brzyska, Mymoń, Wujskie, Brzozowiec, Szczawne, Zwierzyń (coll. W. Szajnocha), Wetlina, Dźwiniacz Dolny, also Serednie Wielkie near Sanok, a good illustration in Zuber, 1918, fig. 3.

### *Sabularia ramosa* n. ichnosp.
(text-figs 8, 9*a–d*)

*Holotype*: UJ TF 842 (text-fig. 8).
*Type locality*: Besko near Krosno.
*Type horizon*: Krosno Beds, Oligocene.
*Derivation of the name*: Lat. *ramosus* — ramified.
*Material*: 11 slabs, some with numerous specimens and many occurrences noted in the field.

**Diagnosis.** — Hypichnial, more rarely exichnial, cylindrical full burrows of somewhat irregular course, with few ramifications at obtuse angles.

For the holotype a slab densely covered by this burrow was taken, as this type commonly occurs in this form. The strings are cylindrical, slightly flattened (by compaction?), about 6 mm wide and 4–5 mm high. If the terminations are seen, they are obtuse. Most of the burrows do not enter the rock but are affixed to the sole. Their course is somewhat irregular, but certain sectors are straight. There are very few ramifications, but many level crossings and interpenetrations.

Other specimens do not differ much from that described. The crowded covering of soles is not always displayed. The burrows with one or two ramifications often occur singly (text-fig.

Fig. 8
*Sabularia ramosa* n. ichnosp., Besko, Krosno Beds, UJ TF 842. × 0.5

9*a–c*) or are scattered loosely on the sole. In some specimens the width of the cylinder attains 12 mm. Quite often the burrow assumes an exichnial position, penetrating the clay a few millimetres below the underface.

**Remarks.** — There is some resemblance to *Imbrichnus* HALLAM (1970), which is of similar size, shape and congested manner of occurrence, but differs in the imbrication of the fill.

**Sediment.** — Fine-grained, thin-bedded (a few cm) sandstones, with composite or horizontally laminated bedding.

**Occurrence.** — Valanginian — Upper Cieszyn Shales: Skrzydlna. Hauterivian — Grodziszcze Beds: Raciechowice, Bieśnik. Albian — Lgota Beds: Czchów. Cenomanian — Lower

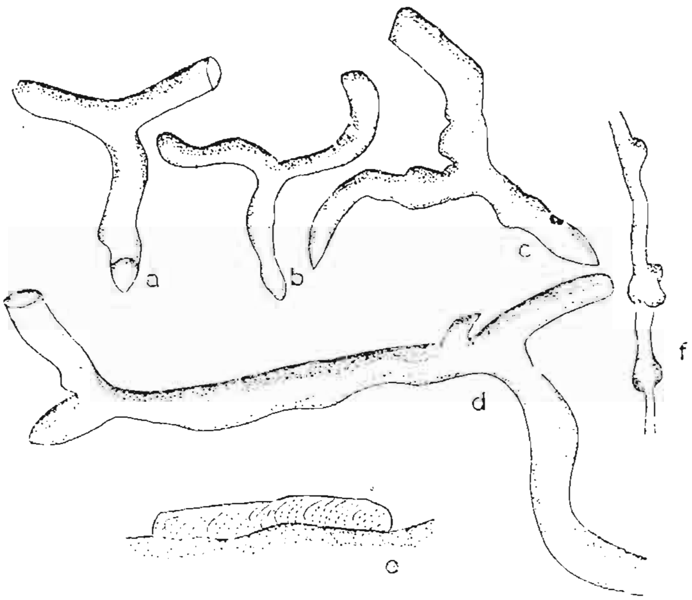



Fig. 9
[a] *Sabularia ramosa* n. ichnosp. Grybów, Ropianka Beds. UJ TF 384; [b] Id., Wola Kroguleska, Ropianka Beds. UJ TF 1845; [c] Id., Sowina, Krosno Beds. UJ TF 1752; [d] Id., Wujskie, Krosno Beds. UJ TF 1802; [e] *Sabularia simplex*. Dobra, Hieroglyphic Beds. UJ TF 2019; [f] Id., Dąbrówka, Hieroglyphic Beds. UJ TF 375. All figures ×0.5

Godula Beds (frequent): Ponikiew, Jaroszowice, Czchów. Turonian — Siliceous Marls: Krasiczyn; Middle Godula Beds (frequent): Kocierz, Ponikiew, Jaroszowice, Czchów, Bieśnik. Senonian — Inoceramian Beds (fairly frequent): Rzegocin, Krzywcza, Wołodź, Krasice, Bachów; Gorzeń Beds: Gorzeń Górny, Wierzbanowa; Ropianka Beds: Sopotnia Mała, Tokarnia, Zaryte, Mszana Dolna, Limanowa, Młynne, Wola Brzezińska, Wola Krogulecka, Grybów, Smrekowiec, Kwiatoń, Siary; Cisna Beds: Cisna; Sromowce Beds: Niedzica. Palaeocene — Lower Eocene — Variegated Shales: Zaryte. Lower Eocene — Ciężkowice Sandstone: Korczyna; Beloveza Beds: Lipnica Wielka, Sidzina, Lubomierz. Middle Eocene — Hieroglyphic Beds: Skomielna Czarna, Daliowa, Darów (in a few adjacent layers), Liszna. Upper Eocene — Magura Sandstone: Klimkówka. Oligocene — Krosno Beds (frequent): Besko, Wujskie, Sowina, Godowa.

## III. BRANCHED STRUCTURES

Here are grouped traces with a main, cylindrical or tubiform stem which in a twig-like or bundle-like manner ramifies into numerous lateral branches. These may be rectilinear or feebly curved, or developed in a tuberculate form. All types branch horizontally or subhorizontally; no vertical branching has been found. Probably all types grouped here are the *Fodinichnia* of SEILACHER (1953, "Fressbauten", SEILACHER, 1955). They include *Buthotrephis* HALL, *Chondrites* STERNBERG, *Granularia* POMEL, *Lophoctenium* REINH. RICHTER, *Phycodes* REINH. RICHTER, *Strobilorhaphe* KSIĄŻKIEWICZ, *Taenidium* HEER, *Bostricophyton* SQUINABOL.

### Ichnogenus *Buthotrephis* HALL, 1847

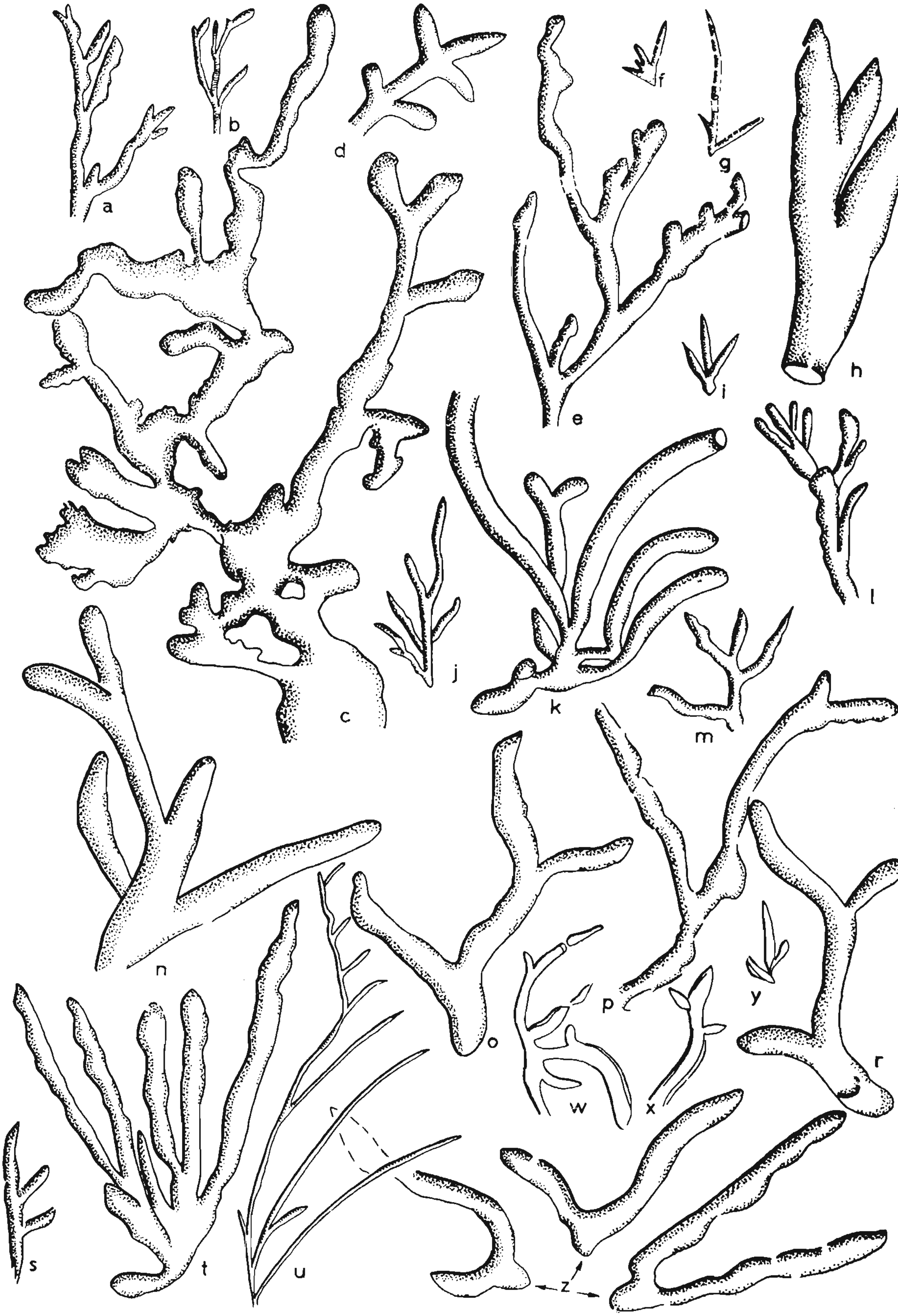
*Type ichnospecies: Buthotrephis palmata* HALL

**Remarks.** — HALL (1847, p. 8) assigned here "stems subcylindric or compressed, branched; branches are numerous, divaricating, lead-like". It follows from his description and illustration of particular types that the stems are smooth. HÄNTZSCHEL (1965) regards *Buthotrephis* as a synonymy of *Chondrites*. Actually, most of the types described by HALL are chondritids, including *B. gracilis*, given by ANDREWS (1955) as the type species. There are, however, two distinct groups in HALL's material, "compressed", which are evidently chondritids, and "subcylindrical" or cylindrical, represented by *B. palmata* and *B. succulens*. They also display another manner of branching.

Branched cylindrical and subcylindrical types of similar shape have often been described as *Palaeophycus* HALL (e.g. LUDWIG, 1869). This is not a clearly defined ichnogenus. According to HALL (1847) it includes stems cylindrical or subcylindrical, apparently hollow, simple or branched. The type species of *Palaeophycus* (*P. tubularis*, according to ANDREWS, 1955) is a straight unbranched burrow, and OSGOOD (1970) tends to assign to *Palaeophycus* only cylindrical, irregular, unbranched tunnel fillings. He emphasizes that *Palaeophycus* contains too wide a range of characteristics and requires a restudy (see also PACHECO, 1908, p. 84). In view of this it seems justifiable to keep the name of *Buthotrephis* (or *Bythotrephis*, as corrected by SCHIMPER, 1869), but limit it to cylindrical and subcylindrical branched forms.

In the Carpathian material the types that may be assigned to *Buthotrephis* understood in this manner are comparatively rare, but occur in a variety of shapes. None of them corresponds strictly to known types. As they occur in single, often incomplete specimens, some are left undetermined, some grouped in the affinity of the two species of HALL, and two new ichnospecies are proposed.

**Origin.** — The cylindrical shape of the stem and branches indicate a post-depositional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origin. Probably large polychaete worms might have produced these feeding burrows. The manner of filling is obscure. Possibly it was retrusive, as supposed by SEILACHER (1955, p. 386) for *Chondrites*.

### *Buthotrephis* aff. *palmata* HALL, 1852
(text-fig. 10*h*, *n*)

1852. *Buthotrephis palmata* (n. sp.), HALL, p. 20, pl. 3, fig. 1, pl. 7, fig. 1.
*Material*: 2 specimens and a few occurrences noted in the field.

**Description.** — Hypichnial, cylindrical, flattened full burrow, branches short but wide, ramification angle small.

In contrast with the obtuse ends of branches in *B. palmata* in our one specimen (text-fig. 10*h*) they are rather pointed, but in another (text-fig. 10*n*) rounder with less palmate branching.

SEILACHER (1955) assigns *B. palmata* to *Phycodes*, but OSGOOD (1970) keeps HALL's generic term for this type.

**Sediment.** — Fine-grained, graded or graded-laminated sandstones, a few cm thick.

**Occurrence.** — Senonian — Upper Godula Beds: Mucharz (the stream Jamnicki). Palaeocene — Szczawnica Beds: Grywałd.

### *Buthotrephis* aff. *succulens* HALL, 1847
(text-fig. 10*a*, *e*, *k*, *l*, *t*)

1847. *Buthotrephis succulens* (n. sp.), HALL, p. 62, pl. 22, fig. 2.
*Material*: 5 specimens and three occurrences noted in the field.

**Description.** — Hypichnial, but in one case epichnial, or endichnial (just below the uppe, surface). From the common large basal stem ramify branches, bifurcating near the base ar small angles. In the largest specimen the branches are 8–10 mm wide, cylindrical, gently flexuous, up to 15 cm long.

The resemblance of some specimens (text-fig. 10*k*, *t*) to *B. succulens* HALL pictured in his fig. 2*a* is considerable. Others have a greater resemblance to his fig. 2*b*, with ramifications situated well above the base. Less similar is the large specimen in text-fig. 10*c*.

**Sediment.** — Fine-grained sandstones, up to 25 cm thick.

**Occurrence.** — Valanginian — Upper Cieszyn Shales: Przenosza. Turonian — Middle Godula Beds: Ponikiew. Senonian — Ropianka Beds: Smrekowiec, Sękowa (sub-epichnial void tubes). Palaocene — Variegated Shales: Półrzeczki. Lower Eocene — Beloveza Beds: Lubomierz.

Fig. 10
*Buthotrephis* HALL

[a] *B.* aff. *succulens* HALL, Półrzeczki, Variegated Shales, UJ TF 761; [b] *B.* indet., Tymowa, Lower Godula Beds, UJ TF 1318; [c] *B.* aff. *succulens* HALL, Huwniki, Inoceramian Beds (field drawing); [d] *B.* indet., Krzeszów, Upper Istebna Beds (field drawing); [e] *B.* aff. *succulens* HALL, Lubomierz, Beloveza Beds, UJ TF 382; [f] *B.* indet., Ropianka Beds, Lipnica Mała, UJ TF 1402; [g] *B.* indet., Lipnica Mała, Ropianka Beds, UJ TF 1402; [h] *B.* aff. *palmata* HALL, Mucharz, Upper Godula Beds, UJ TF 368; [i] *B.* indet., Goleszów, Cieszyn Limestone, UJ TF 376; [j] *B.* indet., Osielec, Hieroglyphic Beds, UJ TF 2016; [k] *B.* aff. *succulens* HALL, Ponikiew, Middle Godula Beds, UJ TF 1726; [l] *B.* aff. *succulens* HALL, Przenosza, Upper Cieszyn Shales, UJ TF 1173; [m] *B.* indet., Wola Brzezińska, Ropianka Beds, UJ TF 1023 (× 0·25); [n] *B.* aff. *palmata*, Grywałd, Szczawnica Beds (field drawing); [o] *B.* indet., Kąclowa, Ropianka Beds, UJ TF 703; [p] *B.* indet., Tylmanowa, Magura Sandstone, UJ TF 1356; [r] *B.* indet., Kąclowa, Ropianka Beds, UJ TF 902; [s] *B.* indet., Dźwiniacz Dolny, Krosno Beds, UJ TF 709; [t] *B.* aff. *succulens* HALL. Smrekowiec, Ropianka Beds (field drawing); [u] *B.* indet., Krościenko, Szczawnica Beds, UJ TF 350; [w] *B.*(?) indet., Wujskie, Krosno Beds, UJ TF 1820; [x] *B.* indet., Wujskie, Krosno Beds, UJ TF 1820; [y] *B.*(?) indet., Wujskie, Krosno Beds, UJ TF 1814; [z] *B. bifurcata* n. ichnosp. Komańcza, Hieroglyphic Beds (field drawing). All figures (except for fig. *m*) × 0.5

### *Buthotrephis bifurcata* n. ichnosp.

(pl. 5, fig. 14; text-fig. 10*z*)

*Holotype*: UJ TF 1383 (pl. 5, fig. 14).
*Type locality*: Sidzina near Jordanów.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *bifurcatus* — dichotomous.
*Material*: 3 specimens and 2 occurrences noted in the field.

**Diagnosis.** — Hypichnial cylindrical full burrow. Short stem bifurcates at a small angle into two long branches. There is a tendency toward a radial arrangement of the double branches.

**Description.** — In the holotype the basal stem is a few millimetres long and the lateral branches are 5–6 mm wide, 10 mm high and about 12 cm long. The bifurcate burrows are radially arranged in a semi-circle.

There is a much smaller, similar type with branches up to 8 cm long, in which the radial arrangement is also marked. In one specimen the forked burrows are linked with one another (KSIĄŻKIEWICZ, 1970, fig. 6*g2*). Similar bifurcate burrows may also occur singly.

**Sediment.** — The holotype occurs on the sole of a sandstone bed 7 cm thick; other specimens occur in thinner beds, horizontally or obliquely laminated.

**Occurrence.** — Senonian — Skrzydlna Beds: Przenosza. Lower Eocene — Beloveza Beds: Sidzina, Podwilk. Middle Eocene — Hieroglyphic Beds: Komańcza.

### *Buthotrephis bilix* n. ichnosp.

(pl. 5, fig. 13)

*Holotype*: UJ TF 1311 (pl. 5, fig. 13).
*Type locality*: Poznachowice near Myślenice.
*Type horizon*: Grodziszcze Beds, Hauterivian.
*Derivation of the name*: Lat. *bilix* — made of double strings; the branches of the burrow are bilobed.
*Material*: 3 slabs.

**Diagnosis.** — Hypichnial full burrow, composed of several branches, each consisting of two rows of irregular tubercules separated by a furrows of the same width as the rows. Branching at acute angles.

**Description.** — In the holotype the stem is 6–7 mm wide, short, and ramifies into 4 branches of various lengths; the longest is about 10 cm. The branches are somewhat wavy. Each branch is divided by a medium furrow, 1–2 mm deep, into two strings, which are 1–3 mm high and about 3 mm wide, but on the whole the height and width of the branches vary. The filling material is substantially coarser than that of the sole. In other specimens the branches are slightly thicker. The trace is gregarious and densely covers the sole, without interpenetration or overlapping.

**Sediment.** — Thin-bedded (2–4 cm), fine-grained, single-current bedded sandstones.

**Association.** — The burrow transects a *Helminthopsis*.

**Occurrence.** — Hauterivian — Grodziszcze Beds: Koźmice Wielkie, Poznachowice.

### *Buthotrephis* sp. indet.

(text-fig. 10)

A few characteristic types are described here without specific determination.

(1) Text-fig. 10*m*. Branching at fairly large angles. Branches slightly curved, their endings sharp. This specimen resembles "*Palaeophycus*" *fruticosus* LUDWIG (1869), but the branching angles are smaller in that type. Of similar type are specimens in text-fig. 10*d*, *o*, *r*, all hypichnial, and 10*p*, which is endichnial.

(2) Text-fig. 10*u*. This differs from the others, as it is thin (1·0–1·5 mm), unilaterally branching at various angles. It cuts across a *Urohelminthoida*. Similar types, somewhat thicker and also branching mainly on one side, are represented in text-fig. 10*f, g, i, j, s*.

(3) Text-fig. 10*b*. Ramifies at an acute angle, branches clavate. In contrast to other types, its surface here and there shows some delicate transverse striations.

(4) Text-fig. 10*w, x, y*. In contrast to all the types described above, which are hypichnial (one endichnial), these are epichnial branching furrows, 2–5 mm wide. Some of them are rimmed on one or both sides by narrow levee-like rims, as in *Naviculichnium*. Their assignment to *Buthotrephis* may be open to argument.

## Ichnogenus *Chondrites* STERNBERG

*Type ichnospecies: Chondrites targionii* (BRONGNIART) (ANDREWS, 1955).

**Remarks.** — Classification is based on branch width and the mode and angle of branching. The distinction of many described "species" is obscure, and many types seem to occupy an intermediate position between the others. In this paper only 9 types have been determined, those which have more distinct morphological features and more widely accepted by several authors. There are many which can be placed in their affinity, and others that are so preserved that their specific determination is not possible. Whether the distinguished types are actually separate ichnospecies, it is difficult to say, as in some cases the difference may be due to the stages in the ontogenic growth of the producers. S. SIMPSON (1957) doubts the validity and usefulness of specific recognition in *Chondrites*. He presumes that the differences may be attributed to the animal's behaviour controlled by the distribution of food in the sediment.

**Sediment.** — Almost all chondritids occur in marls or limestones. The limestones are graded and laminated, and evidently represent element I. Also most of the marls may be considered as redeposited, since they are either closely connected with underlying sandstones or, with sharp soles, rest on shales (KSIĄŻKIEWICZ, 1975). Thus most chondritids are endichnial, some are exichnial, few occur in truly pelagic shales, some on the upper surfaces of sandstones and marls. In very rare cases they occur on soles, either affixed or incised. In some hypichnial occurrences the traces might have been formed in the underlying mud, and later excavated and cast with current-brought sand in conformity with the mechanism envisaged by SEILACHER (1962).

**Origin.** — It is not clear whether chondritids are feeding or dwelling burrows or both. ABEL (1935) defines them as "Fressrohren" and SEILACHER (1954, 1955) as "Fressbauten". According to TAUBER (1949) they are "Wohnrohren" of some sessile filter-feeding Annelida, and S. SIMPSON (1957) believes that they are tunnels made by an animal living on the bottom and digging downwards and laterally in the sediment with the help of its retractible proboscis. The problem of filling has not been solved either. Some authors think that the filling material was introduced into the void tunnels from the overlying sediment (REIS, 1909, S. SIMPSON, 1957, FERGUSON, 1965, OSGOOD, 1970), while SEILACHER (1955) supposes that the tunnels were filled retrusively by the animal, and FREY (1970), having found faecal pellets in the tunnels, regards *Chondrites* as feeding burrows. According to TAUBER (1949) the tubes are lined with quartz grains selected from the sediment. In the Carpathian material no coarse material was found inside to admit a filling mechanism similar to that supposed by FERGUSON, but occasionally very fine grains of quartz have been found. As *Chondrites* occur in marls which contain a certain amount of quartz, it may be that the quartz in tunnels is residual after the animal has removed most of the calcium carbonate and clayey substance. The clayey material of the fill may also be a residual product, and not necessarily sieved in from above. In some specimens the argillaceous filling consists of very thin transversal lamellae. This seems to suggest packing by the animal. In light-coloured rocks chondritids are dark (iron sulphides?), but in darker rocks (e.g. Cieszyn Limestone) light (iron content too low for the formation of sulphides?).

The change in colour of the processed material may be due to the action of body excretions (GRIGGS *et al.*, 1969) or enzymes (OSGOOD, 1970).

S. SIMPSON (1957) presumes that unsegmented "worms" like sipunculids might have been the producers, but according to SCHÄFER (1972) recent Polychaeta form structures similar to *Chondrites*.

### *Chondrites aequalis* (BRONGNIART, 1828)
(pl. 4, fig. 6)

1828. *Fucoides aequalis*, BRONGNIART, p. 58, pl. 5, figs 3, 4.
*Material*: 10 specimens and numerous occurrences noted in the field.

**Remarks.** — Reported from the Carpathian flysch by ETTINGHAUSEN (1863) as *Chondrites vindobonensis* var. *aequalis*.

**Occurrence.** — In almost all horizons of the flysch. Valanginian — Upper Cieszyn Shales: Żywiec. Barremian — Verovice Shales: Wiśniowa. Albian — Lgota Beds: Rzyki near Wadowice. Turonian — Siliceous Marls: Szczepanowice, Huwniki; Middle Godula Beds: Łąkta. Senonian — Inoceramian Beds (frequent): Rzegocin, Wołodź, Kuźmina, Łodzinka, Kalwaria Pacławska, Romanowa Wola, Dźwiniacz Dolny; Węgierka Marls: Węgierka (very rare); Upper Godula Beds: Kocierz; Lower Istebna Beds: Czarnorzeki (in "fucoid" marls); Ropianka Beds (fairly frequent): Jaworzynka, Złatna, Lipnica Wielka, Zawoja (the hamlet Zalesie), Raba Wyżna, Grybów, Biała Wyżna, Skwirtne, Kwiatoń; Cisna Beds: Cisna. Palaeocene — Szczawnica Beds: Krościenko on the river Dunajec. Palaeocene — Lower Eocene — Variegated Shales: Lipnica Mała (the stream Linorka), Lipcwe, Półrzeczki. Lower Eocene — Beloveza Beds: Lipnica Mała, Tokarnia, Myślec, Hańczowa. Middle Eocene — Hieroglyphic Beds: Brzeźna, Komańcza; Łącko Beds: Zubrzyca Górna. Oligocene — Krosno Beds: Wujskie, Słonne Mts., Brzozowiec.

### *Chondrites affinis* (BRONGNIART, 1849)
(pl. 4, fig. 11)

1858. *Chondrites affinis* BRONGN., FISCHER-OOSTER, p. 53, pl. 11, fig. 1, 2.
*Material*: 14 specimens and many occurrences noted in the field.

**Remarks.** — The largest specimen is 9 cm long and 6 mm wide. Small-sized specimens also have rounded endings.

**Association.** — Rarely associated with other chondritids (*Ch. arbuscula*, *Ch. furcatus*, etc.).

**Occurrence.** — In almost all horizons containing marly interbeds. Berriasian — Cieszyn Limestone: Goleszów, Kamienica near Bielsko. Hauterivian — Grodziszcze Beds: Koźmice Wielkie. Turonian — Siliceous Marls: Szczepanowice, Braciejowa, Huwniki; Inoceramian Beds (frequent): Rzegocin, Huwniki, Makowa; Lower Istebna Beds: Czarnorzeki (in "fucoid" marls); Ropianka Beds (frequent): Jaworzynka, Złatna, Ślemień, Raba Wyżna, Mszana Dolna, Mordarka, Wola Brzezińska, Wola Krogulecka, Szczawa, Kąclowa, Uście Gorlickie, Sękowa, Kwiatoń, Skwirtne. Palaeocene — Szczawnica Beds: Krościenko on the river Dunajec, Hałuszowa. Palaeocene-Lower Eocene — Variegated Shales: Lipnica Mała (the stream Linorka), Zaryte, Lubomierz. Lower Eocene — Beloveza Beds: Lipnica Mała, Szczawa, the stream Głębieniec. Middle Eocene — Łącko Beds: Zubrzyca Górna, Myślec; Hieroglyphic Beds: Kamesznica, Rajcza, Brzeźna, Darów, Żubracze. Oligocene — Krosno Beds: Sanok.

### *Chondrites arbuscula* FISCHER-OOSTER, 1858
(pl. 4, fig. 7)

1858. *Chondrites arbuscula* F. O., FISCHER-OOSTER, p. 47, pl. 8, figs 4, 5.
*Material*: 20 slabs, each with many specimens, and many field occurrences.

**Occurrence.** — Reported from the Carpathians by ETTINGHAUSEN (1863). Berriasian—Cieszyn Limestone: Goleszów, Kamienica near Bielsko. Turonian — Siliceous Marls (frequent): Szczepanowice, Rybotycze, Huwniki. Senonian — Inoceramian Beds (frequent): Łączki Kucharskie, Rzegocin, Łodzinka, Kuźmina, Huwniki; Lower Istebna Beds: Czarnorzeki (in "fucoid" marls); Ropianka Beds (frequent): Złatna, Osielec, Zawoja (the hamlet Zalas), Poręba Wielka, Lubomierz, Wola KroguIecka, Florynka, Kąclowa, Siary. Palaeocene-Lower Eocene — Variegated Shales: Lipnica Mała (the stream Linorka), Zaryte, Półrzeczki. Lower Eocene — Ciężkowice Sandstone: Znamirowice (incised in sandstone); Beloveza Beds: Szczawa (the stream Głębieniec), Zbludza, Zalesie, Berest. Middle Eocene — Łącko Beds: Zubrzyca Górna.

### *Chondrites expansus* FISCHER-OOSTER, 1858
(pl. 4, fig. 3)

1858. *Chondrites expansus* F. O., FISCHER-OOSTER, p. 47, pl. 9, figs 1–3.
*Material*: 3 specimens (2 in marls, 1 on the upper surface of a sandstone). In one slab in addition to large form there occur small radial forms of the same type.

**Occurrence.** — Senonian — Ropianka Beds: Lubomierz, Limanowa, Biała Wyżna, Kąclowa, Florynka.

### *Chondrites filiformis* FISCHER-OOSTER, 1858
(pl. 4, fig. 8)

1858. *Chondrites filiformis* F. O., FISCHER-OOSTER, p. 46, pl. 12, fig. 1.
*Material*: 2 specimens.

**Occurrence.** — Senonian — Ropianka Beds: Grybów.

### *Chondrites flexilis* FISCHER-OOSTER, 1858
(pl. 4, figs 4, 10)

1858. *Chondrites flexilis* F. O., FISCHER-OOSTER, p. 45, pl. 8, fig. 3.
*Material*: 3 specimens (2 endichnial, 1 hypichnial).

**Remarks.** — In one specimen (pl. 4, fig. 10) the hypichnial branched burrows are radially arranged. Theoretically each of the *Chondrites* types may develop a radial pattern (S. SIMPSON, 1957). In our specimens there are no indications that the radial form has a vertical shaft (or shafts) leading across the bed to its upper surface.

**Occurrence.** — Turonian — Siliceous Marls: Huwniki. Senonian — Inoceramian Beds: Łodzinka. Ropianka Beds: Wola Brzezińska. Palaeocene — Szczawnica Beds: Hałuszowa.

### *Chondrites furcatus* (BRONGNIART, 1828)
(pl. 4, figs 1, 2)

1828. *Fucoides furcatus*, BRONGNIART. p. 62 pl. 5, fig. 1.
*Material*: 10 specimens and many observations in the field.

**Remarks.** — This type was reported from the Carpathians by ETTINGHAUSEN (1863) and VASSOEVICH (1953, p. 42, fig. 9*w*).

**Association.** — On the same parting plane may occur together with *Ch. intricatus* and *Ch. arbuscula.*

**Occurrence.** — Berriasian — Cieszyn Limestone (frequent): Goleszów, Godziszów, Kamienica near Bielsko. Hauterivian — Grodziszcze Beds: Wiśniowa, the stream Marków. Albian — Lgota Beds: Brody (in the horizon with spongiolites). Turonian — Jasienica Marls: Jastrzębia, Jasienica. Senonian — Inoceramian Beds (frequent): Rzegocin, Wołodź, Makowa, Kalwaria Pacławska, Romanowa Wola; Lower Istebna Beds (in "fucoid" marls): Czarnorzeki; Ropianka Beds (frequent): Złatna, Zawoja (the hamlet Zalas), Trzebunia, Mszana Dolna, Wola Krogulecka, Kąclowa, Siary. Palaeocene — Variegated Shales: Zaryte, Szczawa, the stream Głębieniec (in dark shales intercalated in green and red shales). Lower Eocene — Beloveza Beds: Szczawa (the stream Głębieniec), Zbludza. Middle Eocene — Hieroglyphic Beds: Nahurczany, Komańcza; Łącko Beds: Zubrzyca Górna, Naszacowice. Upper Eocene — Magura Sandstone: Rzyki near Limanowa.

### *Chondrites intricatus* (BRONGNIART, 1828)
(pl. 4, fig. 5)

1828. *Fucoides intricatus*, BRONGNIART, p. 59, pl. 5, figs 6–8.
*Material*: 20 slabs and many field observations.

**Remarks.** — Most of the bush-like traces are no more than 1 cm long. Reported by ETTINGHAUSEN (1863) as *Ch. vindobonensis* var. *intricatus.*

**Association.** — Together with *Ch. arbuscula* and *Ch. furcatus.*

**Occurrence.** — Berriasian — Cieszyn Limestone: Goleszów, Jaworze. Hauterivian — Koźmice Wielkie, Lipnik near Myślenice, Poznachowice, Bieśnik. Turonian — Siliceous Marls: Rybotycze, Huwniki. Senonian — Inoceramian Beds: Łodzinka, Makowa; Lower Istebna Beds ("fucoid" marls): Czarnorzeki; Cisna Beds: Liszna; Ropianka Beds: Jaworzynka, Ślemień, Uście Gorlickie, Siary, Owczary, Skwirtne. Middle Eocene — Hieroglyphic Beds: Rajcza, Wysowa, Żubracze.

### *Chondrites patulus* FISCHER-OOSTER, 1858
(pl. 4, fig. 9)

1858. *Chondrites patulus* F. O., FISCHER-OOSTER, p. 48, pl. 8, figs 6, 7.
*Material*: 1 slab.

**Remarks.** — This very rare type differs from other chondritids by the approximately right angle of branching.

**Occurrence.** — Oligocene — Krosno Beds: Brzozowiec.

## Ichnogenus ?*Granularia* POMEL, 1849

**Remarks.** — Some traces are assigned here with reservation. These are flattened cylinders, a few cm long, up to 1 cm wide, ramifying at variable angles. They are filled with irregularly packed dark, almost black clay particles cemented with grey fine-grained material almost identical with the material of the host rock. The particles are round or elongated. The borders of the cylinders are not sharp but somewhat diffuse. The particles of the fill are either closely packed or loosely scattered. Possibly they are faecal pellets.

These structures are not uncommon in the Palaeocene Szczawnica Beds (Krościenko on the river Dunajec and other places). They occur in the fine-grained uppermost part of sandstones, in association with undeterminable chondritids.

Similar traces, as a rule poorly preserved, occur in the Grodziszcze Beds, in which the cylinders in addition to clay pellets contain quartz grains.

### Ichnogenus *Lophoctenium* REINHARD RICHTER, 1850

*Type ichnospecies: Lophoctenium comosum* REINH. RICHTER (HÄNTZSCHEL, 1962).

### *Lophoctenium ramosum* (TOULA, 1900)
(pl. 5, figs 6–8)

1900. *Criophycus ramosus,* TOULA, p. 159, fig. 159 (no description; assigned to *Lophoctenium* by SEILACHER, 1954, p. 225).

*Material*: 14 specimens.

**Description.** — Hypichnial full burrow. The main stem is 1–2 mm wide, lateral branches up to 10 mm long.

In the affinity of this type is placed a bunch-like trace consisting of incisions on the upper surface; from the main furrow branch lateral grooves, 1–2 mm wide, curved in one direction (pl. 5, fig. 8). Usually the ramifications occur on one side of the main furrow. In contrast with the typical *L. ramosum,* the endings of lateral branches are pointed. The trace covers the surface densely.

**Sediment.** — Hypichnial forms occur in thin-bedded sandstones, in one case 13 cm thick.

**Association.** — May be intersected by *Scolicia* and *Tubulichnium.*

**Origin.** — According to SEILACHER (1959, p. 1070) it is a feeding trace. CHAMBERLAIN (1971*a*) relates the manner of formation of this trace to a spreite builder. In one specimen the trace covers a lineated sole which indicates a post-depositional origin.

**Occurrence.** — Senonian — Inoceramian Beds: Rzeki, Krasice (in both localities in the epichnial form); Skrzydlna Beds: Przenosza (endichnial); Ropianka Beds: Wola Kroguleeka. Palaeocene-Lower Eocene — Variegated Shales: Złatna, Lipnica Wielka, Zaryte, Limanowa. Lower Eocene — Ciężkowice Sandstone: Korczyna (in variegated shales interbed); Beloveza Beds: Lipnica Wielka, Lubomierz, Hańczowa. Middle Eocene — Hieroglyphic Beds: Daliowa, Oligocene — Krosno Beds: Wujskie.

### *Lophoctenium* aff. *comosum* REINH. RICHTER, 1850
(pl. 5, fig. 9)

1954. *Lophoctenium comosum* RICHTER, SEILACHER, p. 225, pl. 8, fig. 6.

*Material*: 5 slabs.

**Description.** — In the affinity of this ichnospecies are placed, with caution, hypichnial or epichnial, in either case full burrows. They consist of rows of swollen short (2–3 mm) ridges, parallel to one another, branching from a common narrow shallow furrow. In some parts the furrow may be replaced by a narrow low ridge-like stem. The lateral ridges are runiformly slightly bent in one direction. Some lateral ridges are delicately striated. They are ar tanged in parallel rows separated by strips not affected by burrowing (pl. 5, fig. 9, left side), but the rows may occur close to one another, and even overlap or overcross one another.

**Remarks.** — From comparison with the picture of RICHTER (1850, p. 8, figs 1–5) it may be presumed that the rows of ridges in our material are longer, and less curved and more spaced. When the spacing is closer the picture of the trace is more like that illustrated by SEILACHER (1954) or DELGADO (1910, pl. 5a).

**Sediment.** — Very thin-bedded (3 cm), fine-grained, horizontally laminated sandstone.

**Occurrence.** — Berriasian — Cieszyn Limestone: Goleszów (quarry). Senonian — Skrzydlna Beds: Przenosza (epichnial, with a *Chondrites*-like appearance); Ropianka Beds: Uście Gorlickie (epichnial). Palaeocene-Lower Eocene — Variegated Shales: Lipnica Mała, the stream Linorka (hypichnial full burrow).

### Ichnogenus *Phycodes* Reinh. Richter, 1850

*Type ichnospecies: Phycodes circinatum* Richter (Häntzschel, 1962).

#### *Phycodes* aff. *harlani* (Hall, 1843)
(pl. 2, fig. 1)

1843. *Fucoides Harlani*, Hall, p. 46, figs 1–2.
*Material*: 1 specimen and a few observations.

**Description.** — An endichnial bundle consisting of seven cylinders or void tubes, each 3–4 mm wide, with dense transversal segmentation. The segments are 1.0–1.5 mm wide. The cylinders branch from a common stem at small angles and almost touch one another. The bundle occurs subhorizontally near the base of a sandstone bed.

This trace occurs in a very flimsy sandstone, therefore it is difficult to collect better preserved specimens.

**Remarks.** — There is considerable similarity to the trace described first by Hall (1843) as fucoid and later assigned to *Arthrophycus* (1852, p. 5, pl. 2, fig. 1). Hall's type is more densely segmented than our specimen. This type of bundle is assigned by Seilacher (1955) to *Phycodes*. In contradistinction to other types of *Phycodes* that are affixed from below to the sole, our burrow occurs just above the sole.

**Sediment.** — Medium-grained sandstone, 5 cm thick.

**Occurrence.** — Lower Eocene — Ciężkowice Sandstone: Znamirowice.

### Ichnogenus *Strobilorhaphe* Książkiewicz, 1968

*Type ichnospecies: Strobilorhaphe clavata* Książkiewicz

**Diagnosis.** — Hypichnial horizontal full burrow consisting of a central stem which laterally ramifies into knobs arranged in a cone-like form.

**Origin.** — Most probably post-depositional feeding burrow. The animal (a polychaete?) burrowed along a central tunnel and laterally excavated (with the proboscis?) small oblong holes, subsequently filling them with the reworked material. The manner of the filling is not easy to explain.

#### *Strobilorhaphe clavata* Książkiewicz, 1968
(pl. 5, figs 10, 11; text-fig. 11*a–r*)

1968. *Strobilorhaphe clavata* n. "sp.", Książkiewicz, pp. 8, 15, pl. 1, figs 4, 5.
*Holotype*: UJ TF 188 (pl. 5, fig. 10).
*Type locality*: Lipnica Mała near Nowy Targ.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *clava* — club; the clavate shape of lateral knobs.
*Material*: 25 specimens and many occurrences noted in the field.

**Diagnosis.** — Hypichnial full burrow consisting of a thin stem passing into a cone composed of round or subelliptical knobs which vary in size, arranged obliquely in relation to the axis of the burrow.

**Description.** — The holotype is 5 cm long and its maximum width is 1·5 cm. The supporting stem is 2 mm wide. It ramifies into short oblong knobs, most of which are narrow at the base. They are 6–8 mm long and 1–3 mm high.

There is considerable variety in the shape and size of this kind (text-fig. 11), but the essential features are the same. The basal stem may not be developed and the trace may consist of two rows of knobs, lying more or less close to one another, and even overlapping. The club-like shape of the knobs is predominant, but sometimes they are more thorn-like. The knobs lie mostly in the plane of the sole, but may also be oblique or perpendicular to the sole. The length of the burrow varies between 3 and 8 cm; its width is more constant. This type often occurs in close proximity on the sole, but never gregariously.

**Sediment.** — Fine-grained, thin-bedded (up to 6 cm) sandstones, horizontally or single-current laminated.

**Association.** — Often together with *Sabularia, Fucusopsis*; it is sometimes intersected by

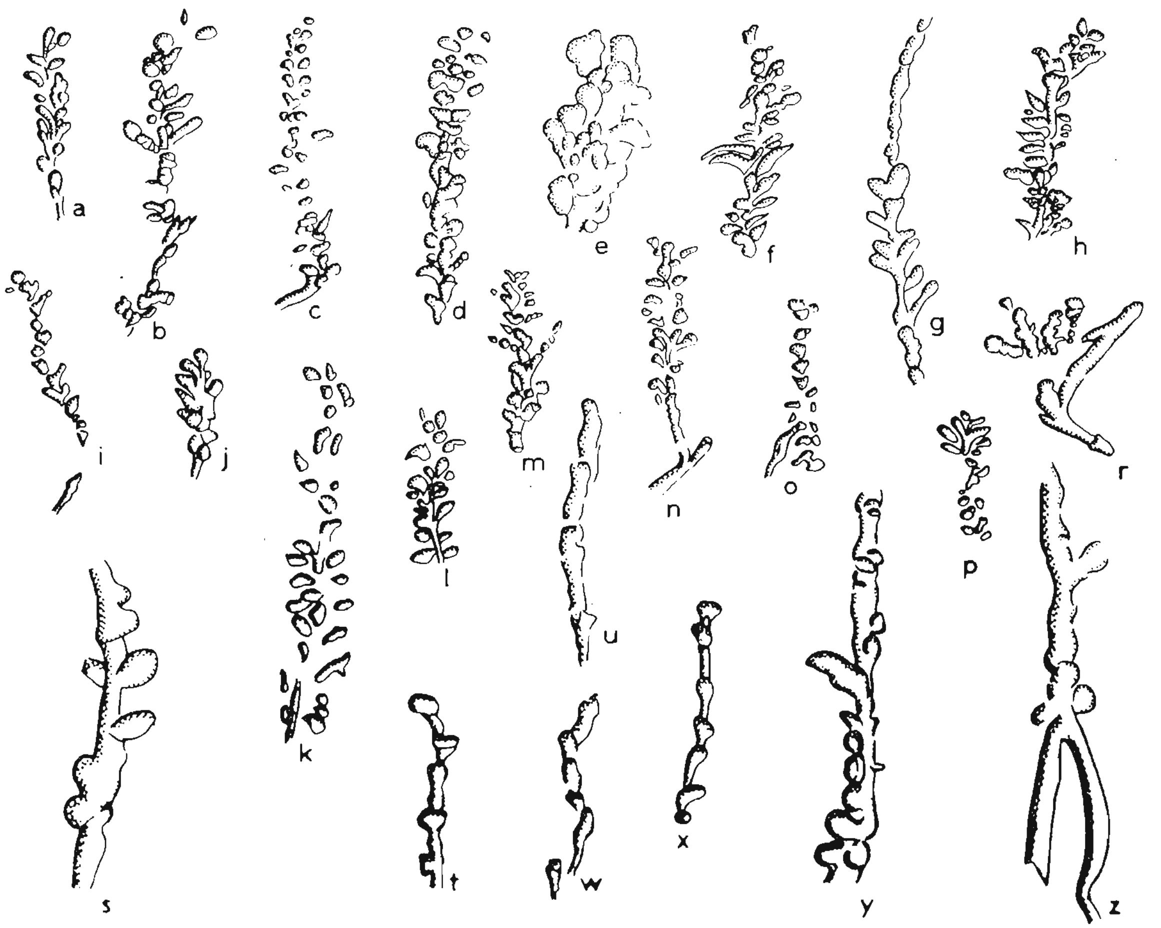



Fig. 11

*Strobilorhaphe* KSIĄŻKIEWICZ

a–r *Strobilorhaphe clavata* KSIĄŻKIEWICZ; a Lipnica Mała, Beloveza Beds, UJ TF 381; b Sidzina, Beloveza Beds, UJ TF 2020; c Lipnica Mała, Beloveza Beds, UJ TF 1274; d Lipnica Mała, Beloveza Beds, UJ TF 1280; e Lipnica Mała, Beloveza Beds, UJ TF 386; f Zubrzyca Górna, Beloveza Beds, UJ TF 1275; g Sidzina, Beloveza Beds, UJ TF 863; h Lipnica Mała, Beloveza Beds, UJ TF 1286; i Lipnica Mała, Beloveza Beds, UJ TF 1269; j Lipnica Mała, Beloveza Beds, UJ TF 1266; k Zubrzyca Górna, Beloveza Beds, UJ TF 1287; l Wysowa ,Beloveza Beds, UJ TF 1841; m Sidzina, Beloveza Beds, UJ TF 1281; n Lipnica Mała, Beloveza Beds, UJ TF 1270; o Grybów, Ropianka Beds, UJ TF 1335; p Sidzina, Beloveza Beds, UJ TF 1283; r Lipnica Mała, Beloveza Beds, UJ TF 1282; s–z *Strobilorhaphe glandifer* n. ichnosp.: s Jordanów, the hamlet Munkacz, Hieroglyphic Beds, UJ TF 764; t Skomielna Czarna, Hieroglyphic Beds, UJ TF 934; u Huwniki, Inoceramian Beds, UJ TF 920; w Huwniki, Inoceramian Beds, UJ TF 920; x Zawoja, Hieroglyphic Beds, UJ TF 1272; y Łętownia Górna, Hieroglyphic Beds, UJ TF 1317; z Komańcza, Hieroglyphic Beds (field drawing). All figures × 0.5

these traces, in one case by *Megagrapton irregulare*, but on the contrary may penetrate these cylindrical traces.

**Occurrence.** — Cenomanian — Lower Godula Beds: Czchów. Senonian — Gorzeń Beds: Gorzeń Górny; Ropianka Beds: Grybów. Palaeocene-Lower Eocene — Variegated Shales: Złatna, Sopotnia Mała, Półrzeczki; Beloveza Beds (frequent): Złatna, Lipnica Wielka, Lipnica

Mała, Zubrzyca Górna, Sidzina, Tokarnia, Zbludza, Myślec, Wysowa. Middle Eocene — Hieroglyphic Beds: Zawoja (the stream Końskie), Osielec, Kamionka Wielka, Wysowa. Upper Eocene — Magura Sandstone: Pątna.

### *Strobilorhaphe pusilla* Książkiewicz, 1968
(pl. 5, fig. 12)

1968. *Strobilorhaphe pusilla* n. "sp.", Książkiewicz, pp. 8, 15, pl. 1, fig. 6.
*Holotype*: UJ TF 90 (pl. 5, fig. 12).
*Type locality*: Zubrzyca Górna near Nowy Targ.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *pusillus* — very small.
*Material*: 12 specimens.

**Diagnosis.** — Hypichnial full burrow, consisting of a short thin stem crowned with a narrow cone composed of subcircular knobs of uniform size and shape.

The holotype is 15 mm long, and its greatest width is 3·5 mm. The stem is short (5 mm) and narrow (1·5 mm). The tapering cone consists of two ranges of alternately arranged small protuberances. In one specimen the stem bifurcates, and each branch is terminated by a cone. The largest specimen is 20 mm long.

**Remarks.** — The structural plan is identical with *S. clavata*, but the trace is much smaller and the knobs are more circular.

**Sediment.** — Fine-grained, very thin-bedded (2–3 cm), horizontally laminated sandstones.

**Occurrence.** — Senonian — Ropianka Beds: Wola Brzezińska. Palaeocene-Lower Eocene — Variegated Shales: Złatna. Lower Eocene — Beloveza Beds (fairly frequent): Lipnica Mała, Zubrzyca Górna, Osielec, Sidzina, Tokarnia, Rabka, Lubomierz. Middle Eocene — Hieroglyphic Beds: Kamesznica, Grzechynia, Jordanów (the hamlet Munkacz), Tokarnia, Polany.

### *Strobilorhaphe glandifer* n. ichnosp.
(pl. 11, fig. 16; text-fig. 11*s–z*)

*Holotype*: UJ TF 764 (pl. 11, fig. 16).
*Type locality*: Jordanów, the hamlet Munkacz.
*Type horizon*: Hieroglyphic Beds, Middle Eocene.
*Derivation of the name*: Lat. *glandifer* — bearing acorns; the trace is provided with acorn-like protuberances.
*Material*: 4 specimens and several occurrences noted in the field.

**Diagnosis.** — Hypichnial full burrow, more or less straight, with lateral knob-like lobate side-shoots branching from the thick stem.

**Description.** — In the holotype the stem is cylindrical, 5–6 mm wide, feebly curved. At short intervals oblong knobs, about 1 cm long, branch laterally. Four branch on one side of the stem, and only one on the other. They are oblique in relation to the stem.

Other specimens are somewhat smaller. In most instances the knobs are more numerous on one side of the stem than on the other. The knobs lie normally in the plane of the sole, but may also be perpendicular to it. In some kinds (text-fig. 11*u*, *w*, *x*) the trace consists of aligned elongated knobs. This form is never gregarious.

**Remarks.** — The assignment of this type to *Strobilorhaphe* may be debatable, as the stem is thick and long, and the knobs are not assembled in conical form. It may be related to *Sabularia simplex*, which often has some swellings on the stem, though never in a lateral position. Moreover, this trace occurs singly, and *Sabularia simplex* tends to occur gregariously.

**Sediment.** — Thin-bedded (up to 5 cm), fine-grained sandstones with gradational or ordinary horizontal lamination.

**Occurrence.** — Lower Eocene — Beloveza Beds: Trzetrzewina. Middle Eocene — Hieroglyphic Beds: Jordanów (the hamlet Munkacz), Skomielna Czarna, Łętownia Górna, Zawoja (the stream Końskie), Juszczyn (the hamlet Kozłownik).

### Ichnogenus *Taenidium* HEER, 1876

*Type ichnospecies: Taenidium serpentinum* HEER (ANDREWS, 1955).

**Origin.** — Endichnial or exichnial feeding burrows. According to CHAMBERLAIN (1971*a*) the animal made a gallery and back-filled it without turning around. The distinctive and regular annulation seen in some ichnospecies *(T. annulatum, T. fischeri)* seems to suggest that the tunnel mirrors the annulation of the animal's body (a polychaete worm?).

#### *Taenidium annulatum* (SCHAFHÄUTL, 1851)
(pl. 5, fig. 4)

1851. *Münsteria annulata* SCHAFHÄUTL, pp. 22, 140, pl. 8, fig. 9 (no description).
*Material*: 1 specimen.

**Description.** — A fragment, 2.5 cm long and 6–7 mm wide, consists of seven oval segments 3–4 mm long. Probably this is a fragment of the end of a branch.

**Remarks.** — WILCKENS (1947) assigned *Muensteria annulata* to *Taenidium*. HÄNTZSCHEL (1965) also notes the resemblance to *Taenidium*. Our fragment corresponds better with the figure of SQUINABOL (1887, p. 554, pl. 17, fig. 3) than with the drawing of SCHAFHÄUTL.

**Sediment.** — Laminated siltstone.

**Occurrence.** — Senonian — Ropianka Beds: Grybów.

#### *Taenidium isseli* (SQUINABOL, 1887)
(pl. 5, figs 1, 2)

1887. *Münsteria Isseli* sp. n., SQUINABOL, p. 555, pl. 17, figs 4, 5.
*Material*: 6 specimens, including 2 slabs with numerous traces.

**Description.** — Flat segmented galleries, reaching a length of 5 cm, 4–5 mm wide, so flattened by compaction that they are only a fraction of a millimetre thick. They ramify at various angles, mostly acute, apparently radiating from a centre. No specimens with a perfect radiating design, as seen in the material pictured by LIBURNAU (1900, pl. 3) have been found. For comparison with this kind of *Taenidium* the related *T. fischeri* HEER, collected by the author in the Caucasus flysch, is presented in pl. 5, fig. 3.

**Remarks.** — The Carpathian material corresponds well with the form of SQUINABOL. It is also identical with the *Taenidium* of PAPP (1941) reproduced by HÄNTZSCHEL (1962) as typical of this ichnogenus.

**Sediment.** — All specimens, with the exception of one found in a siltstone, have been collected from marls.

**Association.** — *Chondrites arbuscula* and unidentified chondritids.

**Occurrence.** — Senonian — Inoceramian Beds: Łodzinka, Kalwaria Pacławska, the stream Sopotnik; Lower Istebna Beds ("fucoid marls"): Czarnorzeki; Ropianka Beds: Zaryte, Mszana Dolna (the stream Szarków), Grybów, Florynka.

### Ichnogenus *Bostricophyton* SQUINABOL, 1890

*Type ichnospecies: Bostricophyton pantenellii* SQUINABOL (ANDREWS, 1955).

#### *Bostricophyton pantenellii* SQUINABOL, 1890
(pl. 5, fig. 5)

1890. *Bostricophyton Pantenellii* n. sp., SQUINABOL, p. 183, pl. 7, fig. 7.
*Material*: 2 specimens.

**Description.** — The trace consists of small aligned dark streaks, 0.2–0.4 mm wide. Between the streaks, which are round, oval or shapeless, there are short intervals. The apparent separation is caused by the intersection of the spirally wound strings by the parting plane parallel to the bedding.

**Remarks.** — SQUINABOL regarded this trace as a spirally wound algue stalk, but FUCHS (1895, p. 406) interpreted it as a *Chondrites*-like burrow.

**Sediment.** — Finely laminated sandy marl in the top of a sandstone bed.

**Occurrence.** — Senonian — Ropianka Beds: Osielec, Biała Wyżna.

## IV. ROSETTED STRUCTURES

Star-shaped traces occur either on the lower or upper surface. For the classification of hypichnial traces on the ichnogeneric level the following features have been taken into consideration: the shape and length of the ribs and the presence or absence of the central field devoid of ribbing (areola). On this basis hypichnial stellate traces are grouped in four ichnogenera:

1. Areola present and well delineated, ribs of uniform length and shape — *Lorenzinia* GABELLI.
2. Areola present, poorly delineated, ribs of variable length and shape — *Sublorenzinia* KSIĄŻKIEWICZ.
3. Areola present, poorly delineated, with a tubercule in the centre — *Capodistria* VIALOV.
4. Areola absent, ribs of variable length and shape — *Glockeria* KSIĄŻKIEWICZ.
5. Riblets of variable shape disposed around oblong open areola — *Fascisichnium* KSIĄŻKIEWICZ. This is not a fully developed stellate trace.

Epichnial types are represented by two ichnogenera: *Asterichnus* BANDEL and *Gyrophyllites* GLOCKER. They may also occupy an exichnial position.

In the classification of SEILACHER (1964*a*) all stellate traces belong to feeding burrows *(Fodinichnia)*.

### Ichnogenus *Lorenzinia* GABELLI, 1900

*Type ichnospecies: Lorenzinia apenninica* GABELLI (HÄNTZSCHEL, 1962).

**Remarks.** — Several types treated on the specific level were described by GABELLI (1900), ZUBER (1910), KUŹNIAR (1911), GORTANI (1920), DESIO (1923), SANDLER (1951), VIALOV (1968) and KSIĄŻKIEWICZ (1970). As the basis for the specific separation the following features were taken: the diameter of the rosette, the diameter of the areola, and the number and shape of the riblets. It seems that least attention has been paid to the shape of the riblets.

GORTANI (1920) was the first who made an attempt to define the differences between the two kinds then known, *L. apenninica* and *L. carpathica*. He used two features: the number of the riblets and the relation of the diameter of the areola to the diameter of the whole rosette. According to his data, *L. apenninica* is characterized by a smaller number of riblets (in his specimen 16) and the diameter of its areola is equal to 1/3 to 2/5 of the diameter of the whole star. In *L. carpathica* the number of the riblets is greater (20–24) and the diameter of the areola equal to half that of the whole star.

SANDLER (1951) took into consideration the size of the star and the number of the riblets. On this ground he created a new species "*Atollites*" *bucovinicus*, with a diameter of 44 mm and 22 riblets.

VIALOV (1968) based his classification on the relation of the diameter of the star (D) and the diameter of the areola (d). On this ground he regards the specimens with D:d = 1.70 to 2.00 as belonging to *L. carpathica*, and those with D:d > 2.90 as *L. apenninica*. Accordingly, he considers SANDLER'S *L. bucovinica* as belonging to *L. carpathica*. Using arbitrarily the difference 0.30 in the relation D:d, VIALOV created three new "species": *L. nowaki* with D:d = 1.40 to 1.70, *L. gabellii* with D:d = 2.30 to 2.60 and *L. zuberi* with D:d = 2.60 to 2.90. No other features were used in this classification. However, the same author created two other new "species", *L. prutensis* on the basis of the number of riblets (14) and *L. desioi* on the ground of the shape of the riblets (based on the figure in DESIO'S paper, 1923).

The great variability both in the dimensions and the shape of lorenzinias causes a danger of creating too many ichnospecies with no clearly defined differences.

**Origin.** — These rosetted forms were for a long time regarded as imprints of medusae and, accordingly, assigned to *Atollites*. SEILACHER (1954, fig. 2) was the first to classify them as feeding burrows (Fressbauten). Now the interpretation of these forms as body fossils seems to have been abandoned (HÄNTZSCHEL, 1970) and other possible explanations are envisaged.

In the author's material there are no indications that the riblets of lorenzinias are full burrows. On the contrary, in one specimen (UJ TF 1801 from Jaśliska) the riblets are slightly effaced by fluting and in another (pl. 6, fig. 13) the star seems to be cut across by a flute cast. This suggests that lorenzinias are pre-depositional grooves cast with sand.

NOWAK (1956) presumes that *Lorenzinia*-type traces are made by crabs, accumulating their processed material in a star-shaped trace. In this respect he refers to the paper of MORIN (1907) who described the star-like arrangement of excretory pellets produced on the shores of the Indian Ocean by certain crabs. To support his view, NOWAK claims that *Lorenzinia* occurs on the upper surface of sandstone layers. This assertion, however, bears no relation to the truth. All Carpathian specimens known to the present autor occur on soles. GRUBIĆ (1961) noted the same position in the Yougoslav material. The appearance of the picture of "*Atollites*" in ZUBER'S paper (1910) is also that of the sole. It should be recalled that FUCHS (1910) had already called attention to MORIN'S paper and suggested that certain rosetted traces might have been made by crustaceans, but stressed that only the traces occurring on upper surfaces might be ascribed to the activity of crabs. FARRES (1963) stresses that the smooth surface of the riblets does not suggest a coprolithic origin.

SIMONELLI (1905) envisaged the possibility that the *Lorenzinia* may be an impression of the tentacles of holothurians, and FARRES (1963) thinks of tentacled "worms". It seems that the view ascribing these traces to a tentacled animal may be endorsed by several features. Lorenzinias in all probability are groove casts and not full burrows. Their shape is too regular to be produced by an animal digging around or accumulating excrements in a more or less random manner, neither does the even number of riblets favour this presumption (if the number of riblets is odd, there is always room for an additional riblet). These features are easier to explain on the presumption that the stellate grooves were formed by the simultaneous scratching of the sea-bottom by the tentacles of an animal. The pattern of the trace produced in this manner would depend on the structure of the feeding animal and not on the rather fortuitous way of burrowing. HÄNTZSCHEL (1970) remarked that the problem could be solved by a better knowledge of the biology of the sessile medusae. Although little is yet known about the habits of these animals, certain facts seem to illuminate the question. The hydrozoan medusa *Corymorpha* and similar types can attach themselves to soft bottoms in deeper waters. They catch small animals with their tentacles. According to HYMAN (1940) and COLIN NICOL (1967), when feeding the stalk bends over, its distal tentacles touch the mud, then the stalk straightens and the food material adhering to the tentacles is conveyed to the mouth. It may be presumed that during this procedure the tentacles scratch the bottom from outside inward and make short grooves arranged circularly. The number of tentacles in Hydromedusae is even (*Corymorpha* has 18 tentacles), and this would explain the even number of riblets in *Lorenzinia*. It is also possible that when touching the bottom the animal contracts its tentacled crown intermittently, producing the outer ring of grooves or pits first, and subsequently the inner ring. This would explain the origin of the double rings in some types of *Lorenzinia*. If this interpretation is right, ethologically lorenzinias should be interpreted as feeding trails.

Other groups of medusoid animals may also be taken into consideration. From the hydrozoans some aberrant forms belonging to the order *Trachylina* walk on the sea-bottom *(Polypodium)*. When catching small organisms they also may scratch the bottom. Certain *Trachylina* occur at depths as great as 3000 m. Scyphozoans are less probable producers of the traces under discussion, although some Coronatae, e.g. *Periphyllum*, also inhabit deeper waters, and, if they hunt near the bottom, may also make a regular pattern of scratches with their rhopalia and tentacles.

*Lorenzinia* rosettes are very often accompanied by numerous little tubercules and straight or sinuous tiny ridges. Very likely these traces formed by tentacles when the animal was probing the bottom. If so, their presence would be a concurrent evidence.

If lorenzinias are produced by scratching the bottom by tentacles, the shape of the riblets should depend on the morphology of the tentacle endings, and their spatial arrangement of the riblets on the structural body differences of particular species of hydrozoan. Generally, in the Carpathian material four kinds of riblets may be distinguished: (1) riblets with either end more or less round (as in *L. carpathica*), (2) riblets with pointed outer ends (as in *L. apenninica*), (3) riblets with larger outer endings *(L. kuźniari)*, and (4) riblets replaced partly or totally by tubercules *(L. perlata, L. moreae)*. It is possible that the different shape of the riblets indicates a different kind of producer, and if so, it is justifiable to use this feature in the division of lorenzinias on the specific level. The size of the animal and the different habits of contracting the tentacles and scratching the bottom might also influence the shape and arrangement of the grooves.

On the other hand, if the proposed interpretation is right, one and the same animal could have produced different patterns depending on the manner of the movements of its tentacles. In one case the touching and scratching of the sea-bottom around a central field was necessary to catch enough food, in another the animal could make a smaller circle to catch its prey. The length of the riblets and the size of the areola would have been different in either case, although produced by the same animal. Also, in order to catch food, under certain circumstances the animal must have touched the bottom not once but twice or more, and several rings of grooves and pits were made. If so, this must have some bearing on the specific classification and may invalidate the separation of different ichnospecies on the ground of the dimensional relations of the star to the size of the areola. This suspicion seems to be strengthened by the fact that in one case several types of *Lorenzinia*, although different morphologically, have been found near one another on the underface within a small area (1–2 sq.m) at Lipnica Mała. It seems not unreasonable to suspect that one kind of producer made all these traces (unless there was some sort of an assemblage composed of different species of hydromedusoids). On this occasion it may be recalled that SIMONELLI (1905) found two considerably different lorenzinias, one near the other, on one slab.

Although the possibility discussed should be kept in mind, in the present state of our knowledge there is no sure ground for uniting all the types under one specific name, but on the basis of their morphological differences they should be assigned to different ichnospecies, according to the accepted view in ichnology that although one organism may produce different traces, each of them if morphologically distinctive should be classified as a different species (VIALOV, 1972, p. 21).

*Lorenzinia* aff. *apenninica* GABELLI, 1900
(pl. 6, fig. 1)

1900. *Lorenzinia apenninica*, GABELLI, p. 1. pl. 1, fig. 1.
*Material*: 1 specimen (found by S. KWIATKOWSKI Sen., housed in ZNG Cracow).

**Description.** — The dimensions of the star are 30×24 mm and of the areola 12×9 mm. The riblets ("rays"), 16 in number, are 8–10 mm long and 2 mm wide, all pointed outward. Its D:d = 2·5 is not quite comparable with that of *L. apenninica*, but is much higher than in *L. carpathica*. It differs from all the lorenzinias collected in the low number of the riblets, identical with that in *L. apenninica*. The shape of the riblets is also identical with that in this ichnospecies. Some of the riblets have a small tubercule at their outer ends, a feature absent in *L. apenninica* and other lorenzinias, including *L. gabellii* VIALOV, which the specimen would approach by its D:d relation.

**Occurrence.** — Senonian — Ropianka Beds: Limanowa.

*Lorenzinia carpathica* (ZUBER, 1910)
(pl. 6, figs 2–7)

1910. *Atollites carpathicus* n. sp., ZUBER, p. 57.
*Material*: 18 slabs, some with more than one star, and a small number of specimens in other collections (IG Warsaw, IG Cracow, AGH).

Table 15
*Lorenzinia carpathica* (ZUBER)

| | | D | d | n | l | w | D : d |
|---|---|---|---|---|---|---|---|
| 1 | Holotype of ZUBER | 35 | 20 | 20 | 5—10 | 2—3·5 | 1·7 |
| 2 | Lipnica Mała UJ TF 134 | 36 | 20 | 18 | 7—10 | 2·5—3 | 1·8 |
| 3 | Limanowa * IG Warsaw | 45 | 25 | 15 | 8—10 | 2—3 | 1·8 |
| 4 | Lipnica Mala UJ TF 871 | 36 | 18 | 18 | 7—9 | 2—3 | 2·0 |
| 5 | Wola Brzezińska UJ TF 1030 | 47 | 23 | 22 | 7—12 | 1·5—3 | 2·0 |
| 6 | Jaśliska UJ TF 1801 | 40 | 20 | 22 | 8 | 1·5—2 | 2·0 |
| 7 | Majdan IG Cracow | 35 | 16 | 22 | 10 | 3·5 | 2·1 |
| 8 | Poręba Wielka UJ TF 2043 | 30 | 14 | 18 | 3—9 | 2 | 2·1 |
| 9 | Lipnica Mała UJ TF 1156 | 33 | 15 | 19 | 4—10 | 1—2·5 | 2·2 |
| 10 | Lipnica Mała UJ TF 1111 | 40 | 18 | 20 | 4—11 | 0·5—2 | 2·2 |

*D* maximum diameter of the star (mm); *d* maximum diameter of the areola (mm); *n* number of riblets; *l* length of riblets (mm); *w* width of riblets (mm)

* Damaged specimen.

The dimensions of the best preserved specimens are given in table 15.

The specimen in pl. 6, fig. 2 is the most similar to the specimen illustrated by ZUBER. It has the relation D:d = 1.80 (in ZUBER's holotype, 1.75) and 18 riblets (20 in the holotype). Most of the riblets have round outer ends. In numerous specimens collected from the same bed at Lipnica Mała the relation D:d varies between 1.70 and 2.20, and the number of riblets in complete specimens is 18 or 20. The riblets in all specimens are low and flat, some pointed outward. In one incomplete specimen three riblets are jointed together similarly as in *L. kulczyńskii*. One specimen (pl. 6, fig. 5) is somewhat different: its riblets are comparatively high and narrow, its D:d = 2.0, and the number of riblets is 22.

A specimen termed "star-shaped hieroglyph" in the paper of KOSZARSKI *et al.*, 1961, pl. 1, fig. 6) has 22 ribs, which are wide and round at the outer end, and D:d = 2.1 probably also belongs here (according to VIALOV's scheme it should be a *L.* aff. *kulczyńskii*).

**Sediment.** — Fine-grained, thin-bedded (the thickest 12 cm), horizontally laminated sandstones.

**Association.** — At Lipnica Mała, where it occurs gregariously on one sole, it is accompanied by other lorenzinias *(L. perlata, L. curticostata, L. moreae)*, *Helminthoida miocenica* and numerous little tubercules and irregular strings.

**Occurrence.** — Senonian — Cisna Beds: Jaśliska, Majdan; Ropianka Beds: Poręba Wielka (coll. J. BURTAN), Limanowa (coll. W. SZAJNOCHA), Wola Brzezińska, Siary. Palaeocene-Lower Eocene — Variegated Shales: Lipnica Mała (KSIĄŻKIEWICZ, 1968, pl. 5, fig. 3). Upper(?) Istebna Beds: Polichty (coll. F. BIEDA, see NOWAK, 1956, pl. 18, fig. M).

### *Lorenzinia kuzniari* n. ichnosp.

(pl. 6, fig. 8)

1911. *Atollites carpathicus* ZUB., KUŹNIAR, p. 518, fig. E.
*Holotype*: coll. ZNG Cracow A-1-53/1. (pl. 6, fig. 8).
*Lectotype*: fig. E in KUŹNIAR, 1911 (somewhat reduced in scale).
*Type locality*: Wiśnicz near Bochnia.
*Type horizon*: Lower Istebna Beds, Senonian.
*Derivation of the name*: in honour of WIKTOR KUŹNIAR.
*Material*: 1 specimen.

**Diagnosis.** — Hypichnial rosette. Small areola encircled by outwardly enlarged riblets with rounded outer ends.

**Descriptions.** — The greatest diameter of the star is 35 mm, the smallest 32 mm, D:d = 2·7. The areola is perfectly circular, its diameter is 13 mm long. The riblets, 18 in number, are 10 to 12 mm long, 2.5 to 4 mm wide and 2–4 mm high. Many of them are widest near the outer end. They are densely spaced.

**Remarks.** — In the shape of the riblets, the relation D:d and its well-pronounced relief this kind differs from *L. carpathica*.

VIALOV (1968) created a new ichnospecies *L. gabellii* for the stars with D:d = 2.30 to 2.60. He did not give any description, but two photographs. In his pl. 1, fig. 5 the holotype is represented and fig 6 illustrates another specimen. There is a considerable difference between these two specimens in the sculpture. In VIALOV's fig. 5 the areola is larger, the ribs are thinner and much less densely spaced. In fig. 6 the riblets are thicker, high and clavate with well rounded outer ends, very much of the same shape as in the specimen of KUŹNIAR. The number of the riblets is identical. Therefore it is proposed to assign this specimen to *L. kuzniari*.

**Sediment.** — The specimen collected by KUŹNIAR (1911) occurs clearly on the lower surface of a fine-grained sandstone. The surface is covered with other small traces.

**Occurrence.** — Senonian — Lower Istebna Beds: Wiśnicz; Ropianka Beds: Zaryte (coll. by S. WEIGNER, the specimen in the collection of Lwów University, see VIALOV, pl. 1, fig. 6).

*Lorenzinia curticostata* n. ichnosp.
(pl. 6, fig. 11)

*Holotype*: UJ TF 1365 (pl. 6, fig. 11).
*Type locality*: Lipnica Mała, the stream Linorka, near Nowy Targ.
*Type horizon*: Variegated Shales, Palaeocene.
*Derivation of the name*: Lat. *curticostatus* — with short riblets.
*Material*: 2 specimens.

**Diagnosis.** — Hypichnial rosette with a very large areola surrounded by numerous short riblets.

**Description.** — The holotype is elliptical in outline, with a maximum diameter of 55 mm, and minimum diameter of 40 mm. The greatest diameter of the areola is 40 mm, the relation D:d = 1·37. The riblets are short and oval; the longest is 8 mm, the shortest 5 mm. They are 1–2 mm high. The number of riblets is 22, but there is room for about four more.

In the other specimen, which is damaged, only half the star is preserved. There are 17 riblets in the circumference, slightly longer than half the ellipse. The length of the longest riblet is 7 mm.

**Remarks.** — According to the classification of VIALOV (1968) this kind with D:d = 1·37 is very near *L. nowaki* VIALOV, characterized by D:d = 1·40 to 1·70. VIALOV does not present any original material, but creates this ichnospecies on the basis of fig. N, pl. 18 of NOWAK (1956), in which three specimens are represented. In the best specimen the greatest diameter of the star is 43 mm and of the areola 33 mm. This gives the relation D:d = 1·30 and does not fall within the interval chosen by VIALOV for *L. nowaki*. The riblets are short, probably 21 in number (the picture is not very clear). This specimen seems to be very similar to *L. curticostata*.

**Sediment.** — Fine-grained, thin-bedded (6 cm) sandstone, horizontally laminated.

**Association.** — Other lorenzinias *(L. carpathica, L. perlata, L. moreae)* and numerous small tubercules and ridges.

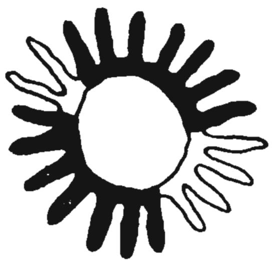
**Occurrence.** — Palaeocene-Variegated Shales: Lipnica Mała, the stream Linorka.

*Lorenzinia kulczynskii* KUŹNIAR, 1911
(text-fig. 12)

1911. *Atollites Kulczyński* n. sp., KUŹNIAR, p. 519, fig. F.
*Material*: None (original specimen lost?).

KUŹNIAR (1911) created this "species" on the basis of an incomplete and damaged specimen. As he emphasized, this kind is similar to *Atollites carpathicus*. Its riblets are of the same length but narrower. The main difference is that on the inward side the riblets are connected with a ring.

Fig. 12
*Lorenzinia kulczynskii* KUŹNIAR (1911, Fig. F). × 1?



Its D:d = 2.06; the difference with *L. carpathica* is very small. Possibly this type should be treated only as a "varietas" of *L. carpathica*. Text-fig. 12 reproduced after KUŹNIAR gives a probable reconstruction of the specimen. The photograph in KUŹNIAR's paper is unfortunately of a very low quality.

**Occurrence.** — Senonian — Ropianka Beds: Mordarka.

### *Lorenzinia perlata* KSIĄŻKIEWICZ, 1970
(pl. 6, figs 9, 10)

1970. *Lorenzinia perlata* ichnosp. nov., KSIĄŻKIEWICZ, p. 313, fig. 7*p*.
*Holotype*: UJ TF 1103 (pl. 6, fig. 9).
*Type locality*: Lipnica Mała, the stream Linorka, near Nowy Targ.
*Type horizon*: Variegated Shales, Palaeocene.
*Derivation of the name*: Lat. *perla* — pearl; the areola is encircled by pearl-like tubercules.
*Material*: 3 specimens.

**Diagnosis.** — Hypichnial form consisting of subcircular or elliptical areola surrounded by a wreath of tiny tubercules, almost identical in shape and size.

In the holotype the areola is well delineated and elliptical, with the maximum diameter of 25 mm and the minimum diameter of 17 mm. The wreath consists of 22 tubercules. They are of the same shape, round, up to 2 mm wide and no more than 1 mm high, equally spaced. There is one tubercule inside the areola, excentrically situated. Similar isolated tubercules occur outside the wreath of tubercules scattered randomly on the sole.

In the second specimen the areola is also elliptical (25×20 mm), surrounded by 22 tubercules, slightly larger than in the holotype. In the third specimen the areola is irregularly circular and the tubercules are not so densely packed. Two of them pass into rib-like knobs.

**Remarks.** — This type seems to be related to *Lorenzinia moreae* RENZ, from which it differs by the absence of an outer ring of ribs.

The specimen from Polichty illustrated by NOWAK (1956, pl. 18, fig. M, upper right corner) probably also belongs here. The areola is 20×28 mm large, encircled by only 15 tubercules, but there are breaks in the ring with room for at least three more tubercules.

**Sediment.** — Fine-grained, thin-bedded, horizontally laminated sandstone 6 cm thick.

**Association.** — In one bed together with *L. carpatica*, *L. curticostata* and *L. moreae*.

**Occurrence.** — Palaeocene — Variegated Shales: Lipnica Mała, the stream Linorka; Upper(?) Istebna Beds: Polichty (coll. F. BIEDA).

### *Lorenzinia moreae* RENZ, 1925
(pl. 6, figs 12, 13)

1925. *Lorenzinia (Bassaenia) Moreae*, RENZ, p. 220, fig. 1.
*Material*: 2 specimens.

**Description.** — One specimen (pl. 6, fig. 12) is elliptical, 50×60 mm large, with an areola 22 mm wide. The inner circle consists of 26 tubercules; five of these are doubled. Some of the tubercules are tiny and round (0.5 mm wide), others are larger, 5 mm long and 1 mm wide, elliptical or doubled. In the outer ring there are 21 tubercules, but judging from their spacing at least four or five are missing. They are less variable in shape than the tubercules of the inner ring, predominantly riblet-like, up to 6 mm in length.

Another specimen (pl. 6, fig. 13) is also elliptical (35×30 mm large) with an areola 18×10 mm broad. The inner ring consists of 19 tubercules (there is room for at least one more), not uniform in size and shape. Some are round, other elliptical or doubled. The smallest tubercules are below 1 mm, the largest 3 mm in diameter. Some tubercules are slightly narrowed in the middle. The outer ring is composed of 22 tubercules, slightly elongated. The largest tubercule is 4.5 mm long and 1.0 mm wide.

**Remarks.** — The specimen in pl. 6, fig. 13 resembles the type of RENZ (1925) in its size and sculpture. The doubling of some tubercules in the inner ring is the only difference. A greater difference exists between the other specimen, pl. 6, fig. 12, mainly in the shape of some inner tubercules which are formed by the fusing of two tubercules.

RENZ (o. c.) treated his type as belonging to a subgenus of *Lorenzinia*, called by him *Bassaenia* which is characterized by a double ring of tubercules instead of a single ring of riblets, as occurs in *Lorenzinia* proper. In the Carpathian material there exist types with one ring of tubercules *(L. perlata)* and types with both tubercules in the inner ring and riblets in the outer ring, described below as *L.* aff. *moreae*. This suggests close affinities between the single-ringed *Lorenzinia* and the double-ringed *Bassaenia*. It seems that either group may be joined together under the name *Lorenzinia*.

**Sediment.** — Fine-grained, thin-bedded sandstones.

**Association.** — At Lipnica Mała together with *L. carpathica*, *curticostata* and *perlata*.

**Occurrence.** — Senonian — Ropianka Beds: Siekierczyna near Limanowa. Palaeocene — Variegated Shales: Lipnica Mała, the stream Linorka.

### *Lorenzinia* aff. *moreae* RENZ
(pl. 6, figs 14–16)

*Material*: 3 specimens.

**Description.** — The specimen in pl. 6, fig. 16 is almost circular, with a diameter of 45 mm. The outline of the areola is more elliptical, $22 \times 16$ mm. The almost complete inner ring consists of 22 tubercules, of which the largest is 3 mm wide. Some of the tubercules are doubled. The outer ring consists partly of tubercules, partly of riblets, which are 10–11 mm long. Their shape is not very regular. The riblets of the outer ring are higher (1.0–1.5 mm) than the inner tubercules (less than 1 mm).

The specimen in pl. 6, fig. 14 is partly eroded (cut across by a flute). The areola is encircled by round tubercules to which closely adhere the riblets of the outer ring. Some of them end with a tubercule on the outward side. In the third specimen (pl. 6, fig. 15) some of the tubercules of the inner ring are joined into a short wall. The outer riblets are marked by scarcely visible swellings. They do not touch the tubercules of the inner circle.

It follows from this description that there are considerable differences between these three specimens, but in all there are two rings, the inner tuberculate, the outer consisting of tubercules and/or riblets. They are related both to *L. perlata* and *L. moreae*. The third specimen, with a poorly developed outer ring, may be regarded as a link with the former, and the first and second as links with the latter. The specimen in pl. 6, fig. 4, on the whole similar to *L. carpathica*, may be a link between this ichnospecies and the types described, as its riblets end with tubercules on the inner side.

**Sediment.** — Fine-grained, thin-bedded (6 cm) horizontally laminated sandstone.

**Association.** — *L. carpathica*, *L. curticostata*, *L. perlata* and *L. moreae*. Numerous small tubercules and thread-sized, often zigzag features.

**Occurrence.** — Palaeocene — Variegated Shales: Lipnica Mała, the stream Linorka.

### Ichnogenus *Sublorenzinia* KSIĄŻKIEWICZ, 1968

*Type ichnospecies: Sublorenzinia plana* KSIĄŻKIEWICZ.

**Diagnosis.** — Hypichnial star-shaped form. The irregularly delineated areola is encircled by a wreath of ribs, irregularly spaced and variable in size and shape.

**Remarks.** — *Sublorenzinia* differs from lorenzinias in the unequal length and variable shape of the ribs. The size of the star is also much more variable than in *Lorenzinia*. The diameter of the star ranges from 2–3 to 10 cm and even more. In some ichnospecies, now assigned to *Sublorenzinia*, the ribbing is similar to that in *Glockeria*, i.e. the ribs are long and pointed outwards. For this group the present author (KSIĄŻKIEWICZ, 1970) proposed the term *Asterichnus* used by NOWAK (1961), who gave neither description nor illustration, apparently using this name for the stellate traces he had described earlier (1956, pls 13–16). The same name, however, was used by BANDEL (1967) for epichnial rosetted traces, and since this author duly described and illustrated the type ichnospecies, the term *Asterichnus* in NOWAK'S sense cannot be used for the group in question. The teim *Subglockeria* has therefore been proposed for stellate traces with an areola and long, pointed ribs, to distinguish them from *Sublorenzinia*, in which the areola is surrounded by short irregularly oval ribs. This term has been proposed for the second edition of the "Treatise on Invertebrate Paleontology". At the time when this term was proposed it seemed that there was a considerable difference between *Subglockeria* (= *Asterichnus* NOWAK *in* KSIĄŻKIEWICZ, 1970) and *Sublorenzinia*, as seen by a comparison of the type ichnospecies *Asterichnus* (= *Subglockeria*) *nowaki* KSIĄŻKIEWICZ (1970, fig. 7*d*) and *Sublorenzinia plana* KSIĄŻKIEWICZ (1968, p. 9, pl. 5, figs 1–2; 1970, fig. 7*e,f*). Further research, however, has discovered several intermediate types between the type ichnospecies of either ichnogenus. This implies that rib shape is not a sufficient features to be used for a generic distinction, and therefore *Subglockeria* has now been united with *Sublorenzinia.*

### *Sublorenzinia plana* KSIĄŻKIEWICZ, 1968
(pl. 7, figs 4–8, text-fig. 13*q, r*)

1968. *Sublorenzinia plana* n. "sp,". KSIĄŻKIEWICZ, p. 10, pl. 5, figs 1, 2.
*Holotype*: UJ TF 72 (pl. 7, fig. 4, see KSIĄŻKIEWICZ, 1968, pl. 5, fig. 1).
*Type locality*: Porąbka near Bielsko.
*Type horizon*: Lower Godula Beds, Cenomanian.
*Derivation of the name*: Lat. *planus* — flat; depressed ribbing.
*Material*: 16 specimens and 3 noted in the field.

**Diagnosis.** — Hypichnial rosetted groove-cast. The areola is surrounded by a wreath of short ribs of variable shape and size, disorderly although fairly densely arranged around the central field.

**Description.** — In the holotype the areola is elliptical, 35×20 mm large. There are 26 oblong ribs and knobs, densely spaced. The largest rib is 14 mm long and 5 mm wide. Both ends of the ribs are round or feebly pointed. The ribs are very low (1 mm) and smooth.

On the sole of the same slab there occur similar traces but smaller in diameter (text-fig. 13*q1*) also with densely arranged ribs, but some of them have fewer and more scattered and rounder ribs (text-fig. 13*q2*). This shows the diversity of this trace, as there is little doubt that they all were produced by the same organism.

There is considerable variety in the size of the star and of the shape, size and spacing of the ribs in other specimens. The outline of the star is circular or irregularly elliptical. Most frequently the diameter of the star is 5 cm, but in very small specimens it is about 22 mm.

This traces occurs singly. Gregarious occurrence on a single sole has been noted only in one case.

**Sediment.** — Fine-grained, graded, gradationally and horizontally laminated sandstones, generally of small thickness (exceptionally 35 cm). The soles are usually devoid of mechanical marks, but the holotype specimen occurs on a sole with numerous small flute casts and drag marks.

**Association.** — Tiny strings and small tubercules similar to those occurring in the star. *Taphrhelminthopsis* cf. *auricularis, Protopaleodictyon.*

**Origin.** — In the holotype the star is intersected by drag marks. This points to a pre-depositional origin, in such circumstances that the sand-laden current hardly scoured the bottom, and so the grooves made on the sea-bottom could have been preserved. In one specimen (pl. 7, fig. 7, right side) small flute casts start from the tubercules of the star. This means that the depressions on the sea-bottom, made by the producer, initiated the formation of the erosive furrows. This also indicates a pre-depositional origin. In most specimens there are no re-entrants on the flanks of the ribs which pass almost imperceptibly into the sole. This does not repudiate the presumption of a pre-depositional origin. The trace is then a feeding trail (= grooves made in the process of feeding).

Star-shaped traces with many radiating "rays" from the centre have been photographed on the sea-bottom in the Indian and Pacific Oceans. They are ascribed to polychaetes with many tentacles (HÄNTZSCHEL, 1970) or to sipunculids (HEEZEN & HOLLISTER, 1971).

**Occurrence.** — This is a comparatively rare type. It seems to be more common in the Godula Beds than in any other unit.

Berriasian — Cieszyn Limestone: Goleszów, Jaworze, Jasienica. Valanginian — Upper Cieszyn Shales: Poznachowice. Hauterivian — Grodziszcze Beds: Wiśniowa (the stream Marków), Poznachowice. Cenomanian-Lower Godula Beds: Porąbka, Ponikiew. Turonian — Middle Godula Beds: Ponikiew, Jaroszowice, Wiśniowa (slope of Mt. Ciecień), Czchów. Senonian — Inoceramian Beds: Huwniki. Lower Eocene — Beloveza Beds: Sidzina (the hamlet Drabowa). Middle Eocene — Hieroglyphic Beds: Osielec (Mt. Przykrzec), Tokarnia. Upper Eocene — Magura Sandstone: the star illustrated by F. SIMPSON (1970, pl. 11, fig. 1 may belong here).

### *Sublorenzinia nowaki* (KSIĄŻKIEWICZ, 1970)
(pl. 7, figs 1–3, text-fig. 13*f–p*)

1970. *Asterichnus nowaki* n. ichnosp., KSIĄŻKIEWICZ, p. 310, fig. 7*d*.

*Holotype*: UJ TF 650 (pl. 7, fig. 1).

*Type locality*: Mordarka near Limanowa.

*Type horizon*: Ropianka Beds, Senonian.

*Derivation of the name*: in honour of WIESŁAW NOWAK, who first reported large star-shaped traces from the Carpathian flysch.

*Material*: 18 specimens.

**Diagnosis.** — Hypichnial stellate full burrow. The areola is irregularly circular or elliptical surrounded with a wreath of string-sized long ribs of unequal length, with pointed outer ends, irregularly spaced.

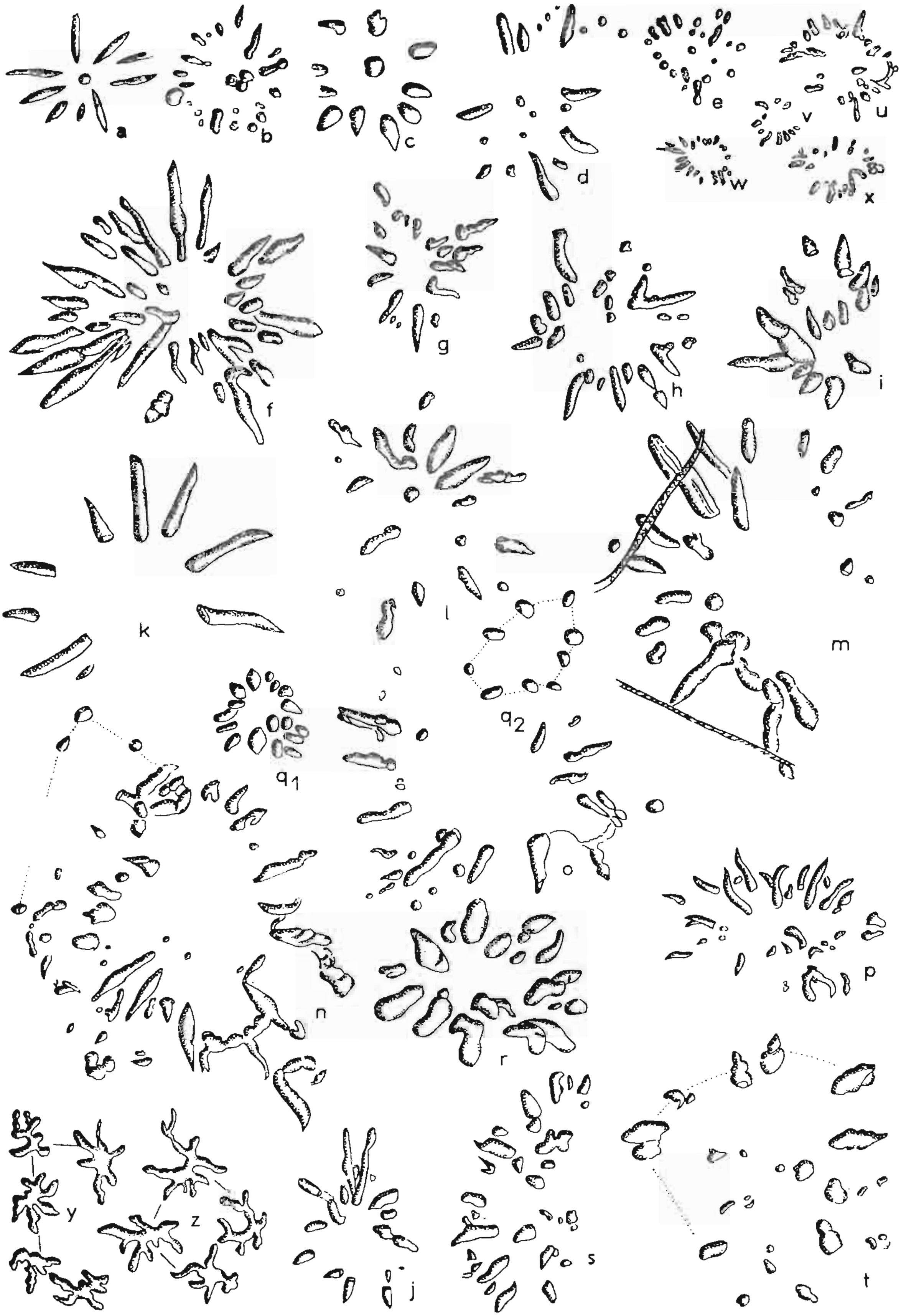
**Description.** — In the holotype the diameter of the star is 50 mm and the areola is 28 × 10 mm. The ribs are 17 to 25 mm long. Some of them have the shape of elongated knobs. The ribs are about 5 mm wide at the inner end and 2–3 mm high. The number of ribs is 10. On some there is a delicate transverse striation.

There is great diversity in the size of the star and in the number and shape of the ribs. Some specimens are considerably larger than the holotype, like that in text-fig. 13*f*, which is 11 cm wide with ribs, 37 in number, reaching a length of 40 mm. Some of the ribs are dichotomous and overlapping. The smallest specimen has an areola 25 × 10 mm large; its ribs, 20 in number, are short, at maximum 15 mm long (text-fig. 13*g*). In some specimens one side of the star is better developed than the other (text-fig. 13*m, o, p*). In all specimens the ribs are high, in some cases reaching a height of 8 mm. Many ribs are more or less clearly cylindrical, some are subcylindrical, but often with re-entrants on their flanks. The surface of the ribs is usually smooth. In some specimens one or two ribs are delicately transversally striated. In all occurrences the trace occurs singly.

**Sediment.** — Fine-grained, thin-bedded sandstones, but the holotype occurs on the sole of a sandstone 35 cm thick. There is no relation between the size of the star and the thickness of the sandstone. Some specimens were collected from limestones. In one specimen the material of the ribs is slightly coarser than that of the host rock.

**Association.** — In many specimens the sole is covered with riblets and knobs of very much the same shape and size as those of which the star consists, but they are scattered in disorder. No overlapping of two stars has been observed.

**Origin.** — The presence of cylindrical ribs indicates that the star is a post-depositional full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burrow. Many ribs, as already pointed out, are subcylindrical, and in some specimens full cylindrical ribs occur side by side with subcylindrical ones. Probably, if the walls of the excavation made by the producer were well hardened with mucus, the cylindrical shape of the fill was preserved, otherwise the filling fused with the covering sand. Unlike the producer of *Sublorenzinia plana*, the originator of *S. nowaki* lived not on the bottom nor in the mud just below the sea-bottom, but below the sand.

**Occurrence.** — This type occurs in many members of the Carpathian flysch, but in none of them is it frequent. It seems to be more common in beds of Cretaceous age.

Berriasian — Cieszyn Limestone: Goleszów (quarry), Kamienica near Bielsko. Valanginian — Upper Cieszyn Shales: Jaworze, Raciechowice. Cenomanian — Lower Godula Beds: Rzyki near Wadowice. Turonian — Middle Godula Beds: Rzyki near Wadowice, Wiśniowa (a stream on the slope of Mt. Ciecień). Senonian — Inoceramian Beds: Rzeki; Skrzydlna Beds: Wierzbanowa; Upper Godula Beds: Mucharz (the stream Jamnicki); Ropianka Beds: Szczawa, Półrzeczki, Mordarka, Kąclowa. Lower Eocene — Beloveza Beds: Sidzina (the stream Głaza). Upper Eocene — Magura Sandstone: Klimkówka.

### *Sublorenzinia pustulosa* n. ichnosp.

(pl. 7, fig. 9; text-fig. 13*s*, *t*)

*Holotype*: UJ TF 129 (pl. 7, fig. 9; the specimen was collected by K. Wójcik in 1903).
*Type locality*: Krasiczyn, near Przemyśl.
*Type horizon*: Inoceramian Beds, Senonian.
*Derivation of the name*: Lat. *pustulosus* — pimply; the blister-like shape of the ribs.
*Material*: 6 specimens.

**Diagnosis.** — Hypichnial star-shaped full burrow. Areola of vague outline surrounded by a wreath of short wide loosely spaced ribs.

**Description.** — In the holotype the greater diameter of the areola is 14·5 cm. Its outline is irregular, rather oblong. The ribs do not begin from a better defined curve, as is the case in other ichnospecies of *Sublorenzinia*. They are short, of unequal size: the largest is 25 mm long and 10 mm wide, the smallest 5 mm long and only 3 mm wide. The ribs have a rather elliptical outline; either both their ends are rounded, or the outer end is feebly pointed. These ribs apparently occur in two circles. In the inner circle there are four small knobs, in the outer nine ribs. The spacing of the ribs is irregular, but their longer axes are disposed radially. The outer circle is not complete; in one part of the ring there are no ribs at all. The surface of several ribs show distinct transverse striations feebly curved in an outward direction.

The largest specimen is of elliptical outline, 26 cm long and 18 cm wide. Its areola is 11 × 7 cm, encircled irregularly by numerous but loosely spread oblong knob-like ribs, in an approximately

Fig. 13
Stellate traces

a–e *Capodistria vettersi* Vialov; a Vetters, 1910, fig. a; b Przenosza, Skrzydlna Beds. UJ TF 1137; c Zaryte, Variegated Shales. UJ TF 1436; d Kąclowa, Ropianka Beds. UJ TF 958; e Chyżówki, Ropianka Beds, UJ TF 671. f–p *Sublorenzinia nowaki* (Książkiewicz); f Goleszów, Cieszyn Limestone. UJ TF 1157; g Raciechowice, Upper Cieszyn Shales. UJ TF 216; h Wierzbanowa, Skrzydlna Beds. UJ TF 1705; i Rzyki near Wadowice, Lower Godula Beds. UJ TF 256; k Limanowa, Ropianka Beds. UJ TF 655; l Rzeki, Inoceramian Beds. UJ TF 215; m Kąclowa, Ropianka Beds. UJ TF 1126; n Półrzeczki, Ropianka Beds. UJ TF 1155; o Szczawa, Ropianka Beds. UJ TF 1154; p (aff.) Sidzina, Beloveza Beds, UJ TF 201; q–r *Sublorenzinia plana* Książkiewicz; *q1* Porąbka, Lower Godula Beds. UJ TF 72. *q2* Porąbka, Lower Godula Beds, UJ TF 446. r Huwniki, Inoceramian Beds. UJ TF 939; s–t *Sublorenzinia pustulosa* n. ichnosp.; s Huwniki, Inoceramian Beds. UJ TF 943; t Wierzbanowa, Skrzydlna Beds, UJ TF 1177; u–x *Sublorenzinia pusilla* n. ichnosp.: u Kąclowa, Ropianka Beds (field drawing); w Grzechynia, Hieroglyphic Beds, UJ TF 136; v Skomielna Czarna, Hieroglyphic Beds, UJ TF 931; x Kąclowa, Ropianka Beds, UJ TF 971; y–z *Glockeria disordinata* n. ichnosp.: y Kamesznica, Upper Istebna Beds, UJ TF 1840; z Tabaszowa, Upper Istebna Beds, UJ TF 1524. All figures × 0.5

radial arrangement. On one side of the areola there is only one row of knobs, and on the other the ribs occur in disorder. Several ribs are transversally striated.

In the smallest specimen (text-fig. 13*s*) the areola is only 9×9·5 cm large. On one side it is bordered by a single row of knobs, whereas on the other the knobs are irregularly placed in more than one row. On the ribs, very irregular in shape, no transverse striation is discernible.

The specimen pictured in text-fig. 13*t* is assigned here with caution. Only half of the star is developed, with the ribs apparently arranged in two semi-circlets. The ribs are short, without sculpture, and several are pointed outward.

**Remarks.** — The shape of the ribs is not unlike that of *Sublorenzinia plana*, but their loose arrangement is different. The distinction of this type from *S. plana* is obvious when the holotypes are compared: the mostly pointed ribs and their dense spacing in *S. plana* contrast with round loosely scattered ribs of *S. pustulosa*. In addition, *S. plana* is a cast form, and *S. pustulosa* a full burrow. Nevertheless, there are some doubtful cases, exemplified by the specimen in text-fig. 13*q2*, collected from the samé sole on which the holotype of *S. plana* occurs.

**Sediment.** — Thin-bedded (up to 6 cm), fine-grained, horizontally laminated sandstones.

**Association.** — Usually numerous thread-sized ridges and knobs similar to those occurring in the star.

**Origin.** — In all specimens the ribs are full burrows; this indicates a post-depositional origin, similar to that of *S. nowaki*. The producer was an animal, presumably a polychaete worm, living in mud below the sand cover and foraging in it radially.

**Occurrence.** — Cenomanian — Lower Godula Beds: Ponikiew. Turonian — Middle Godula Beds: Wiśniowa. Senonian — Inoceramian Beds: Krasiczyn, Huwniki; Skrzydlna Beds: Wierzbanowa.

### *Sublorenzinia pusilla* n. ichnosp.

(pl. 7, figs 10, 11; text-fig. 13*u*, *w*, *v*, *x*)

*Holotype*: UJ TF 97 (pl. 7, fig. 10).
*Type locality*: Sromowce Wyżne, Pieniny.
*Type horizon*: Sromowce Beds, Lower Senonian.
*Derivation of the name*: Lat. *pusillus* — very small.
*Material*: 11 specimens.

**Diagnosis.** — Hypichnial full (?) burrow. The areola, relatively large, is surrounded by a circlet of short radiating tiny riblets and tubercules, variable in shape and dimensions.

**Description.** — In the holotype the areola is nearly circular, 13 mm in diameter. The circlet consists of 22 riblets which are short (the longest is 5 mm), thickened at/or near the inner end and more or less distinctly pointed at the outer end. Some riblets are elongated little tubercules.

On the same slab on which occurs the specimen described there is also one half of another identically shaped rosetted trace.

The specimen in text-fig. 13*x* shows a more irregular shape, its areola is rather elliptical, the riblets short, narrow, and irregularly spaced. The specimen in pl. 7, fig. 11 has a feebly elliptical areola surrounded by 17 riblets of unequal length (the longest is 5 mm), replaced on one side by small tubercules.

**Remarks.** — *S. pusilla* may be regarded as a miniature of *S. nowaki*. Except for the Senonian Ropianka Beds (where *S. pusilla* is very rare) these two types do not occur together. Therefore it is not presumed that *S. pusilla* is a structure made by a juvenile individual belonging to the same species which produced *S. nowaki*.

**Sediment.** — Fine-grained, thin-bedded (the thickest 7 cm), horizontally laminated sandstones.

**Association.** — Usually threads, riblets and tubercules of similar shape as in the rosette. Also *Acanthorhaphe delicatula*, *Helminthopsis tenuis*, and *Sabularia*, which may intersect the star.

**Origin.** — The very small dimensions do not allow it to be said for certain whether the riblets are groove casts or full strings. The presence of re-entrants argues rather for a post-depositional origin.

**Occurrence.** — Senonian — Sromowce Beds: Sromowce Wyżne; Ropianka Beds: Kąclowa. Palaeocene — Szczawnica Beds: Krościenko on the river Dunajec (cf.). Lower Eocene — Beloveza Beds: Łętownia Górna. Middle Eocene — Hieroglyphic Beds: Grzechynia, Skomielna Czarna.

### Ichnogenus *Capodistria* VIALOV, 1968

*Type ichnospecies: Capodistria vettersi* VIALOV.

**Remarks.** — The creation of this ichnogenus, with only one ichnospecies, is based on an incomplete specimen illustrated by VETTERS (1910, p. 131, fig. *a*). It is a stellate trace with a poorly delineated areola encircled by a few ribs variable in shape and size. There is a knob in the centre of the areola. VIALOV does not mention the existence of any co-types or other lectotypes.

The present author (KSIĄŻKIEWICZ, 1968, p. 9) noted the presence of rosetted traces with long ribs and a central field with a tubercule in the centre. These types were joined together with other similar stellate forms, but without the central knob, under the name *Asterichnus* NOWAK (now assigned to *Sublorenzinia*, see above).

It may be debatable whether the distinction of these two ichnogenera is actually justified. The shape of the ribs and their arrangement are very much the same. The only difference is the presence of the central knob. In some cases its presence may be fortuitous, as the soles with stellate traces are usually spotted with tubercules scattered in disorder. The central knob might have been formed not when the animal was producing its radiate gallery system, but before or after the formation of the rosette. On the other hand, the central knob may represent the filling of the outlet of the habitation hole of the producer. Presumably the producers of similar stellate forms also dug around from a hole which served them as a temporary shelter. The filling of the outlet might have also been accidental.

With these reservations the term *Capodistria* is used here for traces of close affinity with *Sublorenzinia*.

### *Capodistria vettersi* VIALOV, 1968

(pl. 7, figs 12, 13; text-fig. 13*a–e*)

1968. *Capodistria vettersi* VIALOV, VIALOV, p. 337, fig. 4.
*Material*: 6 specimens.

**Description.**—The specimen in pl. 7, fig. 12 is the most similar to that of VETTERS, but like the latter, it is also incomplete. The star is more unilaterally formed. It has 7 longer ribs (in Vetter's specimen there are 9) and a few small knobs. The length of the ribs ranges from 5 to 20 mm, their width is up to 4 mm, their height is 2–3 mm. The surface of the ribs is smooth. The areola is oval, and the longer diameter is 25 mm (in VETTERS' specimen about 20 mm). The ribs are slightly pointed outwards, not so sharply as in VETTERS' illustration. The central knob is 4 mm in diameter. There are distinct re-entrants on the flanks of the knob and on some ribs.

The specimen in pl. 7, fig. 13 is much longer. Its areola is 50 mm wide encircled with a wreath of 11 ribs, most of them long. On one side of the star the ribs are markedly longer than on the other. The length of the ribs varies between 5 and 45 mm, some of them are clearly cylindrical. The central knob is small (3 mm) and low.

One specimen (text-fig. 13*b*) has three tubercules in the central field.

**Remarks.** — The variability in the size and ribbing in the collected material is considerable, as in all sublorenzinias. Some are very much like *Sublorenzinia nowaki*, practically differing from it only by the presence of the central knob.

The star-like trace with a small aieola and a distinct central tubercule described by GROSSHEIM (1961) may also be assigned to the type described.

**Sediment.** — Fine-grained, thin-bedded (up to 12 cm), graded or horizontally laminated sandstones. In one specimen the ribs consist of coarser grains than the host rock.

**Association.** — *Bergaueria prantli* (pl. 7, fig. 12), isolated riblets, tubercules, winding strings.

**Origin.** — The cylindrical shape of the ribs in some specimens and the re-entrants on the flanks of the ribs argue for a post-depositional burrowing. The central knob may mark the outlet of the habitation hole of the animal (polychaete?) working below the sand.

**Occurrence.** — This is a very rare trace fossil.

Cenomanian — Lower Godula Beds: Jaroszowice. Turonian — Middle Godula Beds: Rzyki near Wadowice (the stream Doliny). Senonian — Skrzydlna Beds: Przenosza; Ropianka Beds: Grybów, Kąclowa. Palaeocene-Lower Eocene — Variegated Shales: Zaryte, (a stream on the slope of Mt. Luboń).

## Ichnogenus *Glockeria* KSIĄŻKIEWICZ, 1968

*Type ichnospecies: Glockeria glockeri* KSIĄŻKIEWICZ.

**Diagnosis.** — Hypichnial star-shaped form consisting of ribs radiating from a centre, to which all or some of the ribs are joined. Small ribs may intercalate between the main ribs. Outline of the star is irregularly circular.

**Remarks.** — This ichnogenus is established on the basis of a star-like unnamed and undescribed trace fossil collected by GLOCKER in the Moravian Carpathians and illustrated by SEILACHER (1955, text-plate, fig. 89). The manner of the central junction of the ribs is variable: either all ribs join at the centre and may form a central knob, or only a few are joined and the others are intercalated between them. The ribs are of variable length and may be dichotomous.

In the same year in which creation of the ichnogenus *Glockeria* was proposed, VIALOV introduced a new "genus" *Stelloglyphus* (VIALOV, 1968, p. 335). It is apparently comparable with *Glockeria*. There are some differences: the ribs are more clearly joined in the centre, the centre seems to be elevated although there is no central knob, the ribs are larger and shorter. These features may indicate differences at a specific and not generic level.

The division of *Glockeria* into ichnospecies is based on the shape, dimensions and density of the ribbing.

### *Glockeria glockeri* KSIĄŻKIEWICZ, 1968
(pl. 8, fig. 1, pl. 9, fig. 1)

1968. *Glockeria glockeri* n. "sp.", KSIĄŻKIEWICZ, pp. 9 and 15.
*Holotype*: UJ TF 95 (pl. 9, fig. 1).
*Lectotype*: SEILACHER, 1955, fig. 89.
*Type locality*: Goleszów, main quarry, near Cieszyn.
*Type horizon*: Cieszyn Limestone, Berriasian.
*Derivation of the name*: in honour of E. F. GLOCKER who first collected this type of traces in the Carpathians.
*Material*: 3 specimens and a few occurrences noted in the field.

**Diagnosis.** — Hypichnial large stellate full burrow composed of numerous string-sized ribs pointed at the outward ends. The ribs are almost straight, of unequal length and for the most part unbranched. Only a few ribs join one another in the centre; most of them begin at some distance from it.

**Description.** — In the holotype the outline of the star is nearly circular, with a diameter of 17 cm. From the centre there radiate 12 ribs. Some of the ribs are joined two or three together, others begin singly close to the centre. There are small knobs at the jonction of the ribs. There are already 40 ribs midway from the centre, since several begin at some distance from it. The maximum width of the ribs is 5 mm. The inner part of the star is vaulted. This vault, oval in outline, is 6 to 7 cm in diameter. Many ribs begin at the edge of the vault.

The largest specimen (pl. 8, fig. 1) is elliptical in outline, with a greater diameter of 20 cm and a smaller of 12 cm. The star consists of more than 40 ribs counted at its periphery. Several ribs begin at a good distance from the centre. Near the centre two or three ribs join together, but most of them end singly. In one place one rib overlaps another. The transversal striation seen on the surface of some ribs is very delicate and densely spaced. Many of the ribs are clearly cylindrical. They are affixed to the underface. In some the material is slightly coarser than in the host rock.

**Remarks.** — Large star-shaped traces from the Polish Carpathians were first described by NOWAK (1956).

**Sediment.** — Fine-grained, graded and horizontally laminated limestones. The thickness of beds with this type does not exceed 15 cm.

**Origin.** — Large rosetted traces of similar shape were described by CLARKE (1924). He ascribed their origin to "worms", which protruded radially in all directions around their habitation hole or tube, and looped back their bodies, thus creating a radiating system of grooves on the sea-bottom. He interpreted these traces as moulds of the grooves when the grooved sea-bottom was covered by sand. CLARKE also presumed that similar types might have been produced by some many-tentacled annelids; the animal might have moved along the bottom and stopped to flap its armed head back and forth. The dichotomy of the ribs according to TRUSHEIM (1930) indicates "worms" as producers. NOWAK (1956) also ascribed the origin of the star-like forms he described to the action of "worms".

*Glockeria glockeri* represents a radiating system of full burrows, and not a radiating system of groove casts, as in the case described by CLARKE. The trace is then a post-depositional feeding burrow, and was formed not on the sea-bottom as a feeding trail, but by an animal working along the clay/sand interface, as is shown by the cylindrical shape of the ribs. It might have been a polychaete which by means of its extensible proboscis burrowed horizontal excavations and subsequently filled them by "waste stowing" (SCHÄFER, 1972). The striae on the ribs are probably peristaltic. Some of the ribs are subcylindrical. It is possible that, if the walls of the excavations were not sufficiently hardened with mucus, the filling material fused with the covering sand, or the roof of the excavation collapsed. It is also possible that during the process of digging and stowing the animal removed a good portion of the sandy material above its habitation hole and formed the vaulted cave seen in some specimens (pl. 9, fig. 1). When this cave was formed the animal started to excavate from the edge of the vault.

Single occurrence of this trace suggest that the producer was solitary in habit.

**Occurrence.** — Berriasian — Cieszyn Limestone: Goleszów (main quarry), Godziszów. Valanginian — Upper Cieszyn Shales: Wilamowice. Hauterivian — Grodziszcze Beds: Rudzica (NOWAK, 1956).

### *Glockeria sparsicostata* KSIĄŻKIEWICZ, 1968
(pl. 9, fig. 3)

1968. *Glockeria sparsicostata* n. "sp.", KSIĄŻKIEWICZ, pp. 10, 15, pl. 5, fig. 4.
*Holotype*: UJ TF 210 (pl. 9, fig. 3).
*Type locality*: Zawoja, the stream Końskie.
*Type horizon*: Ropianka Beds, Senonian.
*Derivation of the name*: Lat. *sparsicostatus* — with few ribs.
*Material*: 1 slab with 2 specimens, taken from a sole on which this trace occurs gregariously.

**Diagnosis.** — Hypichnial star with ribs radiating from the centre. The ribs, few in number, are straight and pointed towards the periphery of the star. A few short ribs are intercalated between the main ribs.

**Description.** — In the holotype the star consists of 9 larger ribs, some of which are joined in the centre. The diameter of the star is 8.5 cm. Its central part is nearly 2 cm high. The length of the ribs ranges from 3 to 4 cm, their greatest width is 4 mm. The intercalated ribs are few, short and low. The ribs are subcylindrical and some are somewhat longitudinally striated.

The holotype is the largest specimen, others are smaller and have a smaller number of ribs.

In the holotype and in some other specimens the ribs are filled with somewhat coarser grains than the host rock.

**Sediment.** — Medium-grained, graded sandstone, 15 cm thick.

**Origin.** — Post-depositional feeding burrow, probably formed in the same way as *G. glockeri*, but the animal must have had some sort of longitudinal ornamentation, warts or spines on its body, or was provided with a longitudinal musculature (priapulid ?) and was probably gregarious in habit.

**Occurrence.** — Senonian — Ropianka Beds: Zawoja (the stream Końskie).

### *Glockeria disordinata* n. ichnosp.

(pl. 9, fig. 2; text-fig. 13*y*, *z*)

*Holotype*: UJ TF 1735 (pl. 9, fig. 2).
*Type locality*: Krzeszów, Mt. Harańczykowa, near Sucha Beskidzka.
*Type horizon*: Upper Istebna Beds, Palaeocene.
*Derivation of the name*: Lat. *disordinatus* — not orderly; the irregular shape of the trace and ribbing.
*Material*: 3 slabs, each with numerous traces. A few occurrences noted in the field.

**Diagnosis.** — Hypichnial small stellate full burrow composed of a few winding and branching riblets, joined in the centre and pointed outwards. Gregarious.

**Description.** — The diameter of the star taken for the holotype is 25 mm. The star consists of 7 riblets of various length (10–15 mm), 2–3 mm thick. They join in the centre, which is slightly depressed. The riblets are somewhat curved. The relief of the star is relatively marked, it is about 3 mm high in the centre. The star occurs on a sole crowded with other similar traces.

The outline of this stellate form always tends to be elongated. The ribbing is irregular, some ribs are much longer than others which may be reduced to small knobs. A rough transverse striation may be noticeable on some ribs. This trace always occurs gregariously, the star are close to one another, so that the ribs of one star may touch those of the neighbouring star, but there are no clear cases of overlapping.

**Sediment.** — Fine-grained, horizontally or current-ripple laminated sandstone, up to 4 cm thick.

**Occurrence.** — This trace seems to be limited to the Upper Istebna Beds (Palaeocene): Kamesznica, Krzeszów, Targoszów, Tabaszowa.

### *Glockeria parvula* Książkiewicz, 1970

(pl. 8, fig. 3)

1970. *Glockeria parvula* ichnosp. nov., Książkiewicz, p. 312, fig. 7*c*.
*Holotype*: UJ TF 108 (pl. 8, fig. 3).
*Type locality*: Lipnik near Myślenice.
*Type horizon*: Skrzydlna Beds, Senonian.
*Derivation of the name*: Lat. *parvulus* — small.
*Material*: 2 specimens.

**Diagnosis.** — Hypichnial small stellate cast, consisting of a central cone from which radiate a few short straight thin ribs. A tiny crater-like pit is situated at the top of the cone.

**Description.** — In the holotype the central knob is 6 mm high and the diameter of the star is 4.5 cm. The ribs, 8 in number, are up to 18 mm long and only 2 mm wide. There are tiny knob-shaped riblets intercalated between the main ribs. One side of the star is better developed than the other, but this is most probably due to posterior scouring. The pit in the top of the central knob is 1.5 mm wide and 1 mm deep.

The other specimen is almost identical but much smaller (8 mm in diameter) and also has one side better developed.

**Remarks.** — This form was described by the present author (KSIĄŻKIEWICZ, 1960, p. 746, pl. 3, fig. 10) as a "rosetted trail". A similar trace is reported by TANAKA (1971) from the Albian flysch of Japan. It differs in its smaller size (3 cm) and the number of ribs (9).

**Sediment.** — The holotype specimen occurs on the sole of a fine-grained, single-current bedded sandstones, 3 cm thick.

**Association.** — With *Urohelminthoida dertonensis.*

**Origin.** — The trace seems to be pre-depositional, as implied by the ribs, which are not cylindrical and have no re-entrants. The current covering the trace with sand might have partly eroded and obliterated the grooves, so that one side of the star is worse preserved. The interpretation previously advanced (KSIĄŻKIEWICZ, 1960, p. 746) may be repeated: the trace might have been formed by an animal (polychaete?) living in a hole on the sea-floor. It grazed around in all directions, producing grooves (now ribs). The little pit on the top of the cone may represent the termination of a tube in which the animal lived, and, when the hole was being filled with sand, the animal was still in the shaft, slightly protruding above the bottom of the hole.

According to the ethological terminology used in this paper, this trace represents a feeding trail.

**Occurrence.** — Senonian — Skrzydlna Beds: Lipnik near Myślenice, Skrzydlna.

### Ichnogenus *Fascisichnium* KSIĄŻKIEWICZ, 1968

*Type ichnospecies: Fascisichnium extentum* KSIĄŻKIEWICZ, 1968.

**Diagnosis.** — Ribs arranged semi-radially in a bundle ("fascis") around an empty central field.

### *Fascisichnium extentum* KSIĄŻKIEWICZ, 1968
(pl. 8, fig. 4)

1968. *Fascisichnium extendum* n. "sp.", KSIĄŻKIEWICZ, p. 10, pl. 6, fig. 1.
*Holotype*: UJ TF 1567 (pl. 8, fig. 4).
*Type locality*: Lipnica Mała near Nowy Targ.
*Type horizon*: Variegated Shales, Palaeocene.
*Derivation of the name*: Lat. *extentum* — extended; the spread arrangement of the ribs.
*Material*: 3 specimens and a few occurrences noted in the field.

**Diagnosis.** — Hypichnial semi-rosetted cast consisting of arrow-like ribs spread on three sides of a large oblong central field.

The holotype is about 10 cm long and up to 4.5 cm wide. The central field is 1 cm wide, narrowing towards one end. The slightly curved ribs, 22 in number, are 0.5 to 1.5 cm, some even 2 cm long. They are 4 mm wide at the base and sharply pointed at the outer end. Like their length, their spacing is also irregular. The arrangement of the ribs is similar to a bundle (fascis) of scattered rods, as if they were branching off from a point situated outside the central area. Other specimens are similar, although there is some diversity in the shape of the bundle and the number of the ribs.

**Sediment.** — Fine-grained, thin bedded (up to 15 cm) sandstones, horizontally laminated.

**Association.** — In one instance *Helicolithus sampelayoi.*

**Origin.** — In all specimens the ribs seem to be casts, and therefore a pre-depositional origin may be presumed. The semi-radiate ribbing resembles the arrangement of scrape marks made by the inhalant siphon of some lamellibranchs, e.g. *Macoma baltica*, on the sediment surface (SCHÄFER, 1972). Another possible explanation would be the assignment of this trace to the activity of some sessile hydromedusae scraping the sea-bottom unilaterally with their tentacles when searching for food.

**Occurrence.** — Senonian — Inoceramian Beds: Wola Romanowa; Ropianka Beds: Mszana Dolna; Jarmuta Beds: Jaworki, the stream Sztolnia. Palaeocene-Lower Eocene — Variegated Shales: Lipnica Mała. Middle Eocene — Hieroglyphic Beds: Komańcza.

Ichnogenus: *Asterichnus* BANDEL, 1967

*Asterichnus* aff. *lawrencensis* BANDEL, 1967

(pl. 9, fig. 4)

1967. *Asterichnus lawrencensis* n. sp., BANDEL, p. 2, pls 1, 2, figs 4, 6, text-figs 2, 3.
*Material*: 1 slab (UJ TF 79) with 2 specimens.

**Description.** — The better developed specimen, roughly circular in outline, is 5 cm wide and consists of 15 grooves. This is an epichnial structure. In the centre of the star there is a round shallow hole, 1 cm wide, from which radiate grooves of variable length (12–20 mm), up to 4 mm wide. All are of somewhat petaloid shape, becoming larger towards the periphery of the star. Near the centre the grooves overlap one another, but there is no branching. The grooves are lined with a black silty substance.

Outside the star there are round or oblong shallow depressions. The axes of the oblong holes are concordant with the direction of the grooves in the rosette.

On the same surface there is a similar star-shaped trace, less distinctly developed.

**Remarks.** — The specimens are very similar to the trace described by BANDEL, but are smaller (BANDEL's specimens are 4 to 12 cm wide). The width of the grooves is almost the same and their number is within the range he gives (10–30). The grooves in BANDEL's trace are filled with cylindrical strings; no such strings have been found in our material, but this may be due to the state of preservation.

**Sediment.** — Fine-grained sandstone, 3 cm thick.

**Origin.** — According to BANDEL the trace was produced by an animal living in the mud covering the sandstone and foraging along the sand/clay interface. The round holes beyond the star are also probaly traces of the activity of the same animal. The trace is not unlike the rosette of *Gyrophyllites*. It is possible that the animal worked down in a manner similar to that which produced the *Gyrophyllites* structures, and the rosette may be the lowest whorl of the helicoidal vertical burrow. If it is only a surface trace, its origin may be due to various potential makers, as not only certain types of "worms" but also crabs may produce stellate traces. According to TRUSHEIM (1930) the lack of branching rather suggests crabs.

**Occurrence.** — Valanginian — Upper Cieszyn Shales: Raciechowice.

Ichnogenus *Gyrophyllites* GLOCKER, 1841

*Type ichnospecies: Gyrophyllites kwassizensis* GLOCKER (HÄNTZSCHEL, 1962).

*Gyrophyllites kwassizensis* GLOCKER, 1841

(pl. 8, fig. 2)

1841. *Gyrophyllites kwassizensis*, GLOCKER, p. 322.
*Material*: 18 specimens and many occurrences noted in the field.

**Description.** — The rosettes are 3–5 cm in diameter. The leaf-shaped furrows are up to

20 mm long in the lowest whorls. They are lined with an argillaceous substance, usually darker in colour than the surrounding rock. In some specimens there are some rough transverse striations on the furrows. The number of furrows varies on the same level and becomes smaller towards the top of the cone. In most cases the stellate furrows occur on one level only. In these specimens the upper whorls have evidently been removed and only the lowest storey of the conical burrow has been preserved.

This trace commonly occurs on the upper surfaces of fine-grained silty layers in the form of round depressione 2–3 mm deep (KSIĄŻKIEWICZ, 1968, figs 5, 6). In some instances these depressions may be 1–2 cm deep.

The upper surfaces of sandstones or siltstones are crowded with this trace. The rosettes occur near one another, occasionally in close contact, but only rarely overlap one another.

**Remarks.** — The material corresponds well with the description and the figure given by GLOCKER. The "stem" of GLOCKER's figure is also seen in the form of a cylindrical burrow. It may mark the path of the animal when it left one rosette-like burrow for another place to dig out another rosette.

Not uncommon are cross-sections of *Gyrophyllites* structures occurring in siltstones or marls, corresponding well to those illustrated by FUCHS (1894).

**Sediment.** — Siltstones overlying sandstones, also upper surface of sandstones.

**Origin.** — Traces of this kind have often been described as imprints of scyphozoans, although FUCHS (1901) showed that the medusa-like form *Medusina geryonoides* von HUENE may belong to *Gyrophyllites*. ZAHALKA (1927) determined a form similar if not identical to *Gyrophyllites* as *Palaeosemaestoma geryonoides* von HUENE. More recently ŚLĄCZKA (1971) described very similar traces under name *Dactylodiscus beskidensis* n. sp., considering them to be imprints of medusae. The finds both of ZAHALKA and of ŚLĄCZKA were made in beds of the same age and type in which the material described was collected, namely in the Senonian Lower Istebna Beds.

The traces described cannot be imprints of medusae. This is indicated by: (1) the depressions on the upper surface of sandstone beds; it is hardly possible that the soft body of a medusa when sunk on the sea-bottom could make a hole 1–2 cm deep, (2) the spiral arrangement of furrows in several whorls one above another, (3) the spacing of the rosettes with no overlapping; it is hardly imaginable that if the medusae sank to the bottom or were brought by a current, they would settle and rest on the bottom with no overlapping. The absence of overlapping is easily explainable on the assumption that the rosettes are burrows: burrowers generally avoid burrowing in places affected by previous burrowing. The occurrence of the trace on the top of a current-bedded sandstone is no proof that the medusae were brought by the current. This position only implies that the animal stopped its downward burrowing when it reached the sand.

According to SCHÄFER (1972, p. 187) medusae of all kinds are heavy enough to form moulds only when their bodies are dry, so that the imprints of medusae may be expected only on the beaches and tidal flats. When dead medusae sink to the sea-bottom they have much buoyancy that they can made only insignificant imprints which cannot be identified. According to SCHÄFER this particularly refers to Semaeostomeae.

It is probable that the animal (polychaete?) burrowed downward in a vertical shaft from which by means of the proboscis dug sideways, gradually descending until it reached a firmer or coarser sand layer, presumably also poorer in food.

**Occurrence.** — Senonian — Lower Istebna Beds: Istebna, the river Olza (here occurs in profusion on the upper surfaces of several adjacent sandstones), Łazy, Łapanów.

Undeterminable vertical cross-sections of *Gyrophyllites* or poorly developed rosettes have been noted in a number of localities in the Lower Istebna Beds, Hieroglyphic Beds and in the Magura sandstone.

## V. SPREITEN STRUCTURES

This group consists of two types of burrow: one produced by planar feeders working along the interfaces or any other discontinuity (now parting) planes; the other is essentially endichnial, but the spreiten may occur also on boundary planes, preferably on the upper surfaces. The former group is represented by *Phycosiphon* FISCHER-OOSTER and *Rhizocorallium* ZENKER, the latter by *Zoophycos* MASSALONGO and presumably by *Anemonichnus* CHAMBERLAIN.

### Ichnogenus *Phycosiphon* FISCHER-OOSTER, 1858

*Type ichnospecies: Phycosiphon incertum* FISCHER-OOSTER, 1858 (HÄNTZSCHEL, 1962).

#### *Phycosiphon incertum* FISCHER-OOSTER, 1858
(text-fig. 14)

1858. *Phycosiphon incertum* F. O., FISCHER-OOSTER, p. 59, pl. 15, fig. 4.
*Material*: 11 slabs.

In most cases this is an endichnial, often epichnial, rarely hypichnial burrow. Usually it densely covers the upper surface or the parting planes of the upper part of a sandstone bed. In some cases it consists of thread-sized strings which form loops. In the space between the arms of the loop there is dense oblique striation. More often there are narrow furrows instead of the strings.

**Sediment.** — The trace commonly occurs in the silty portion of sandstone beds, particularly if this portion is marly (in sandstone-marl-clay sequences). It more rarely occurs in the top part of very fined-grained sandstones seen on parting planes when the sandstone is split.

**Association.** — Because it covers the surface densely, other traces are eliminated. It may be cut through by *Lophoctenium* (Variegated Shales, Lipnica Mała), by *Scolicia plana* (Inoceramian beds, Kuźmina, Wołodź), by *Scolicia prisca* (Beloveza Beds, Zbludza), or by *Zoophycos* (often in the Ropianka Beds). It is posterior to *Taphrhelminthopsis*, as it covers the trail of the latter (Inoceramian Beds, Wołodź).

**Origin.** — Evidently a post-depositional feeding burrow probably produced by a polychaete.

**Occurrence.** — Common in many units, particularly of the Cretaceous age.

Berriasian. — Cieszyn Limestones: Goleszów (main quarry), Godziszów, Jaworze. Hauterivian — Grodziszcze Beds: Lipnik near Myślenice, Wiśniowa, Senonian — Inoceramian Beds (frequent): Kąkolówka, Wara, Wołodź, Kuźmina, Huwniki, Kalwaria Pacławska; Cisna Beds: Jaśliska, Cisna; Ropianka Beds (frequent): Jaworzynka, Lipnica Mała (the stream Linorka), Zaryte, Raba Wyżna, Mszana Dolna, Chyżówki, Limanowa, Mordarka, Kanina, Grybów, Biała Wyżna, Kąclowa, Florynka, Wola Brzezińska, Owczary, Siary, Smrekowiec, Skwirtne. Palaeocene — Upper Istebna Beds: Kamesznica; Szczawnica Beds: Hałuszowa. Palaeocene-Lower Eocene — Variegated Shales: Lipnica Wielka (the hamlet Kiczora), Lipnica Mała, (the stream Linorka), Trzetrzewina. Lower Eocene — Ciężkowice Sandstone: Znamirowice; Beloveza Beds: Złatna, Lipnica Mała, Sidzina, Zbludza, Zalesie, Trzetrzewina. Middle Eocene — Hieroglyphic Beds: Daliowa. Upper Eocene — Magura Sandstone: Młynne.

#### ?*Rhizocorallium* sp. indet.
(text-fig. 15)

*Material*: 2 poorly preserved specimens.

**Description.** — One specimen is 15 cm long and only 2 cm wide at its broadest part. The marginal cylinder is 2–3 cm wide. The spreite between the marginal rims shows curved grooves and irregular ridges. The specimen may be taken for an extremely elongated narrow lobe of

Fig. 14
*Phycosiphon incertum* FISCHER-OOSTER, Mordarka, Ropianka Beds, UJ TF 646. × 1

*Zoophycos insignis.* This is, however, a hypichnial trace. It occurs on the sole of a sandstone bed 5 cm thick.

Another specimen occurs on the upper surface. It is not complete. The length of the fragment

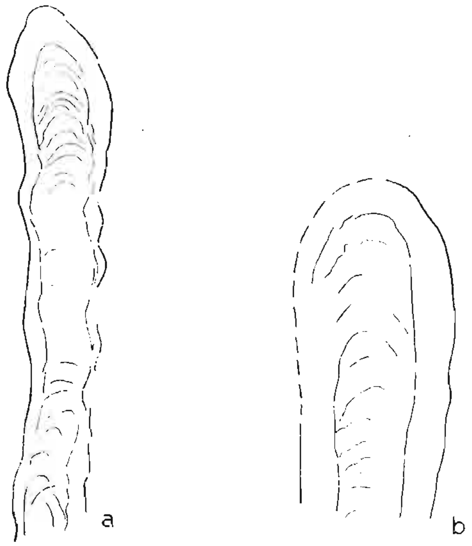


Fig. 15
?*Rhizocorallium*
[a] Blądzonka, Variegated Shales. Lower surface, UJ TF 1610. × 0.5; [b] Klimkówka, Magura Sandstone. Upper surface, UJ TF 1556. × 0.5

is 9 cm, its width 3,5 cm. The marginal rim is nearly 10 mm wide. The ratio of the width of the marginal rim to that of the spreite approaches 1:3·5. This is very near the values given by HÄNTZSCHEL (1960) as characteristic of *Rhizocorallium*.

### Ichnogenus *Zoophycos* MASSALONGO, 1855

*Type ichnospecies: Zoophycos brianteus* (VILLA, 1844) (HÄNTZSCHEL, 1962).

**Remarks.** — The classification of *Zoophycos* on the specific level is not an easy task. Several authors have created many species, based on the shape of the whorls, and the width and the manner of branching of the rays (BARSANTI, 1902). On the other hand BISCHOFF (1968) restricted *Zoophycos* to *Z. brianteus* MASSALONGO, while PLIČKA (1968) grouped several "species" in the synonymy of *Z. circinatus* (BRONGNIART).

In the Carpathian material there is considerable diversity in *Zoophycos*. If the outline of the whorl (= lamina *sensu* SIMPSON 1970) is taken as the main distinctive feature, most of the material falls into two groups: one with an approximately circular outline, another with a lobed, antler-like outline. Following the approach taken by VENGO (1951) the first group may be assigned to *Zoophycos brianteus* MASSALONGO and the second to *Z. insignis* SQUINABOL. SEILACHER (1967*b*), however, showed that the outline changes with the growth of the burrow: in early stages it is antler-like, in advanced stages more circular. But there are numerous small and so "early" specimens with a round and not lobed outline of the whorl. Thus distinction is easier in the early stages of *Zoophycos* structures and difficult or hardly possible in adult specimens that must be left as *Zoophycos* indet.

It seems that there is yet another feature that may be helpful in the distinction of these two main types of *Zoophycos*. The antler-shaped types are as a rule provided with a well-developed marginal cylindrical rim which is absent or poorly developed in the specimens with a circular outline. All the specimens illustrated by PLIČKA (1968) are without the marginal rim. Although BISCHOFF (1968) believes that this is due to the state of preservation, in the Carpathian material there are very many specimens, both small and large, without any trace of the lateral rim. There are no indications that the marginal rim has been filled by sediment introduced into the tube. It is of the same material as the host rock and most probably consists of sediment (sand) reworked by the producer.

In addition, there are specimens with very delicate riblets (= lamellae, S. SIMPSON, 1970), and others with very rough ribbing. Possibly these differences might also be taken as the basis for a specific distinction.

**Origin.** — FUCHS (1895) and SARLE (1906) followed by ABEL (1935), LESSERTISSEUR (1955) and BISCHOFF (1968) consider *Zoophycos* as feeding burrows of polychaete annelids. Another view is advanced by PLIČKA (1968), who considers that *Zoophycos* represents the abandoned prostomial parts of sedentary marine annelids from the family Sabellidae. This view is not supported by other authors. BOUČEK (1964) stresses that the *Zoophycos* structures may have much greater dimensions than the sabellid worms, and WEBBY (1969) stresses the fact that the lobes seen in many specimens of *Zoophycos* have no counterpart in sabellid gill-organs, while the septa may be biodeformational structures. It should also be added that the presence of the marginal rim is not accounted for in the interpretation of PLIČKA. The sculptural features of the whorls are easily explained by the supposition that the "ribs" were formed by scooping the sediment by means of the extensible proboscis: they are nothing else but ridges of unprocessed material. When the scooping was continuous, the grooves between the ribs are not interrupted by transverse riblets. If the animal shovelled intermittently, oblong depressions might have been formed between the riblets (pl. 10, fig. 3).

### *Zoophycos brianteus* MASSALONGO, 1855

(pl. 10, figs 2–3)

1855. *Zoophycos brianteus*, MASSALONGO, p. 51, pl. 3, figs 1, 2.
*Material*: 13 specimens and many occurrences noted in the field.

**Description.** — The radius of the whorl may attain 25 cm. The whorls occur in cross-section in stairs, one above the other at intervals of 1 to 3 cm. The rays (lamellae) are about 1 mm wide near the centre. Dichotomy of rays is common. In some specimens there are elongated oval hollows between the rays. Both small and large specimens have a circular outline.

**Remarks.** — The specimens assigned here correspond excellently with the description of PLIČKA (1968) and his pictures pl. 107, figs 1, 2, pl. 108, fig. 5 (except that no "pinnulae" are visible on our specimens), and also PLIČKA, 1969, particularly fig. 2. PLIČKA assigned these kinds of *Zoophycos* to the *Z. circinnatus* (correctly *circinatus*) of BRONGNIART, 1828. BRONGNIART'S specimen (1828, pl. 3, fig. 8, p. 83), not seen by PLIČKA, is a fragment of a lobed whorl, 8 cm long, with a fairly distinct marginal rim, and may rather be assigned to *Z. insignis* SQUINABOL. The specimens collected in Lower Cieszyn Shales owing to their ring-like alternation of ribbed bands, resemble *Zoophycos scoparius* HEER, 1865, p. 141, fig. 92 and the very similar *Z. ferrum equium* of the same author, p. 141, fig. 93. Both kinds are included by PLIČKA (1968) in the synonymy of *Z. circinatus*, but it is possible that they should be treated as distinct ichnospecies.

**Sediment.** — Fine to medium grained sandstones. Mostly developed near the top surface and easily visible on it, but in some cases also on the sole.

**Association.** — Small *Sabularia, Helminthoida labyrinthica, Phycosiphon incertum.*

**Occurrence.** — Tithonian — Lower Cieszyn Shales: Gumna. Senonian — Inoceramian Beds (frequent): Wara, Dubiecko (the hamlet Utrata), Huwniki; Ropianka Beds (frequent): Ślemień, Lipnica Wielka, the hamlet Kiczora (KSIĄŻKIEWICZ, 1960, p. 741, pl. 4, fig. 16), Bieńkówka, Poręba Wielka, Szczawa, Kasina Wielka, Limanowa, Wola Brzezińska, Kąclowa, Florynka; Sromowce Beds: Jaworki (the stream Skalski), Sromowce Wyżne. Palaeocene-Lower Eocene — Variegated Shales: Lipnica Wielka, Lipowe. Lower Eocene — Ciężkowice Sandstone: Znamirowice, Gródek; Beloveza Beds: Szczawa (stream Głębieniec), Półrzeczki, Zalesie. Oligocene — Krosno Beds: Sanok.

*Zoophycos insignis* SQUINABOL, 1890
(pl. 10, figs 1, 7, text-figs 16, 17)

1890. *Zoophycos insignis* n. sp., SQUINABOL, p. 195, pl. 5, fig. 2, pl. 6, fig. 1.
*Material*: 22 specimens and numerous occurrences noted in the field.

**Description.** — In small specimens the outline is antler-like, in larger it is more or less lobed. The lobes are elongated, up to 20 cm long, usually rimmed. The cylindrical rim attains a thickness of 5 mm. Often it is not continuous. The ribbing seems to be on the whole more delicate

Fig. 16
*Zoophycos insignis* SQUINABOL, Komańcza, Hieroglyphic Beds, Upper surface (field drawing) × 0.5

than in *Z. brianteus*. In small specimens the spreite pass into *Chondrites*-like densely branching traces (text-fig. 17). It also happens that the outer rim leaves the contour of the whorl and goes in another direction, as if the animal had abandoned its burrow to look for another, still marking its path by leaving digested material behind.

**Sediment and association.** — Like *Z. brianteus*.

**Occurrence.** — Cenomanian — Lower Godula Beds: Ustroń, the hamlet Poniwiec. Turonian — Middle Godula Beds: Rudnik, streams on the slope of Mts. Bukowiec and Barnasiówka (KSIĄŻKIEWICZ, 1960, pl. 4, fig. 15), Brzączowice. Senonian — Inoceramian Beds (frequent): Kąkolówka, Bachów, Huwniki, Kalwaria Pacławska (the stream Sopotnik), Wola Romanowa; Skrzydlna Beds: Wierzbanowa; Gorzeń Beds: Gorzeń Dolny; Ropianka Beds (frequent): Jeleśna, Lipnica Wielka (the hamlet Kiczora), Lipnica Mała (the clearing Zosiak), Wola Brzezińska, Biczyce, Kąclowa; Sromowce Beds: Jaworki (the stream Skalski), Hałuszowa. Palaeocene-Lower Eocene — Variegated Shales: Gilowice, Biczyce, Lower Eocene — Beloveza Beds: Szczawa (the stream Głębieniec). Middle Eocene — Hieroglyphic Beds: Stryszawa (the hamlet Roztoki), Juszczyn (the hamlet Kozłownik), Tokarnia, Komańcza (frequent); Łącko Beds:

Fig. 17
?*Zoophycos insignis* SQUINABOL, Lower surface, Komańcza, Hieroglyphic Beds, UJ TF 1229. × 0.5

Kamienica near Nowy Sącz. Upper Eocene — Magura Sandstone (frequent in some horizons): Zawoja, hamlet Mosorne (very large whorls, KSIĄŻKIEWICZ, 1958, pl. 5), Osielec, Sidzina, Młynne, Klimkówka. Oligocene — Krosno Beds: Kąty (?), Dębna.

*Zoophycos* sp. indet.

There are a number of specimens, either collected or noted, that are not completely developed or preserved. Probably most of them belong to *Z. brianteus* or *insignis*. They occur in many members of the Carpathian flysch: Berriasian — Cieszyn Limestone: Żywiec. Turonian — Siliceous Marls: Huwniki. Senonian — Inoceramian Beds: Kuźmina, Kalwaria Pacławska; Ropianka Beds: Mszana Dolna, Wola Krogulecka, Skwirtne, Uście Gorlickie, Siary; Cisna Beds: Jaśliska. Palaeocene — Upper Istebna Beds: Kamesznica, the stream Janoska; Szczawnica Beds: Hałuszowa, Krościenko on the river Dunajec. Lower Eocene — Beloveza Beds: Zalesie, Trzetrzewina. Middle Eocene — Hieroglyphic Beds: Rajcza, Stryszawa, Zalesie, Darów. Oligocene — Krosno Beds: Wisłok Górny.

Apart from these there are some types with characteristic features differentiating them from both *Z. insignis* and *Z. brianteus*. They probably deserve to be classified as distinctive ichnospecies.

Plate 10, fig. 4 shows a specimen with very thin and densely spaced riblets, with no obvious branching. The dense ribbing resembles that in *Z. massalongi* PLIČKA, but the dichotomy is not so obvious as in that type. In all the specimens collected the margin is broken, but the outline seems to be at any rate circular. This kind occurs in the Palaeocene-Lower Eocene Variegated Shales (Lipowe, Zbludza) and in the Lower Eocene Beloveza Beds (Zubrzyca Górna, the hamlet Ochlipów).

Plate 10, fig. 5 represents a fragmented whorl with particularly well-developed transverse riblets, spaced 1.5 mm from one another, and forming a network consisting of almost quadrate meshes. Palaeocene Babica Clays (Babica).

Plate 10, fig. 6 shows a fragment displaying a very coarse ribbing: the ribs are 2–4 mm wide and divided by deep furrows up to 8 mm wide. The radius of the whorl is about 25 cm long. Such "*Inoceramus*-like" coarsely ribbed zoophycids have been found in a number of localities: the Senonian Ropianka Beds (Uście Gorlickie), the Lower Eocene Beloveza Beds (Szczawa, the stream Głębieniec) and the Middle Eocene Hieroglyphic Beds (Juszczyn, the hamlet Kozłownik).

Ichnogenus *Anemonichnus* CHAMBERLAIN, 1973

*Type ichnospecies: Anemonichnus concentricus* CHAMBERLAIN

*Anemonichnus concentricus* CHAMBERLAIN, 1973
(text-fig. 18)

1973. *Anemonichnus concentricus*, CHAMBERLAIN, p. 677, pl. 3, fig. 8, text-fig. 2.
*Material*: No depository. One field observation.

**Description.** — Almost vertical funnel-shaped burrow consisting of concentric layers. The burrow is about 1 m high and 25 cm wide at the upper end of the funnel, gradually tapering downward. The sides of the burrow are rough and uneven. The filling consists of concentric lamelae 1.0–1.5 cm thick, composed of quartz and plant detritus.

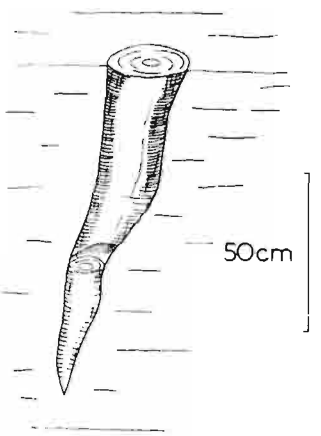



Fig. 18
*Anemonichnus concentricus* CHAMBERLAIN. Grzechynia, Magura Sandstone (field drawing)

**Remarks.** — This trace, noted but not named by the author (KSIĄŻKIEWICZ, 1958, fig. 3), was ascribed to *Cylindrichnus* HOWARD (KSIĄŻKIEWICZ, 1970, p. 314, fig. 8). As this name was formally used by BANDEL (1967) for another material, CHAMBERLAIN (1973) proposed the generic name *Anemonichnus*, assuming on the ground of SHINN's (1968) observations that such structures may have been made by anemones. Our specimen is twice as large as that described by CHAMBERLAIN. The assignment to *Asterosoma* OTTO (FREY, 1970) should also be taken into account. *Asterosoma* was presumably made be a polychaete.

**Occurrence.** — Upper Eocene — Magura Sandstone: Grzechynia.

## VI. WINDING STRUCTURES

The manner and degree of winding is variable. Some types are almost straight and feebly curved, others assume a more sinuous but still irregular course or are loosely meandering. Some types may assume both straight and winding course *(Gyrochorte, Scolicia)*, others are winding and meandering *(Subphyllochorda, Scolicia)*, or only meandering *(Helminthopsis)*. In meandering types the shape and size of each meander are different. This feature is at variance with the traces grouped in "meandering structures", in which the meanders are of the same style and similar size. On the whole, the group of "winding" structures may be treated as intermediate between the simple and meandering structures.

This is the largest group of the Carpathian flysch trace fossils as to the number of ichnogenera (11), most of which are represented by several ichnospecies. In the ethological classification most of the winding types belong to *Pascichnia* and *Repichnia*. The following ichnogenera are grouped here: *Gyrochorte* HEER, *Helicorhaphe* KSIĄŻKIEWICZ, *Helminthopsis* HEER, *Muensteria* STERNBERG, *Naviculichnium* n. ichnogen, *Oniscoidichnus* BRADY, *Scolicia* de QUATREFAGES, *Subphyllochorda* GÖTZINGER & BECKER, *Taphrhelminthopsis* SACCO, *Tuberculichnus* n. ichnogen., *Tubulichnium* n. ichnogen.

## Ichnogenus *Gyrochorte* HEER, 1965

*Type ichnospecies: Gyrochorte comosa* HEER (HÄNTZSCHEL, 1962)

**Origin.** — All three ichnospecies occurring in the Carpathian material are cylindrical full burrows, and this indicates their post-depositional origin. FUCHS (1895) and HALLAM (1970) presumed that the *Gyrochorte* traces were produced by tunnelling amphipods, while SEILACHER (1955) thought of a worm-like (wurmformig) animal, and WEISS (1941) of a polychaete.

### *Gyrochorte burtani* n. ichnosp.

(pl. 11, figs 1–5; text-fig. 19)

*Holotype*: UJ TF 1475 (pl. 11, fig. 1).
*Type locality*: Poznachowice near Myślenice.
*Type horizon*: Grodziszcze Beds, Hauterivian.
*Derivation of the name*: in honour of Dr. JADWIGA BURTAN, Carpathian geologist, who found the specimen taken for the holotype.
*Material*: 16 slabs, some of them with several specimens.

**Diagnosis.** — Mostly hypichnial bilobate full burrow with transverse oblique incisions bi-serially arranged and joined in a medium apical groove. It may occur also as a hypichnial furrow.

**Description.** — The holotype is 20 cm long and 18–20 mm wide, protruding a few mm from the underface. The specimen is almost straight. At one end it terminates in an oblong conical extremity. The shallow lateral incisions are spaced 3 to 4 mm from one another, disposed obliquely to the axis of the trace and inclined towards the coniform end. The riblets between

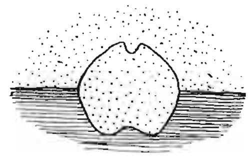


Fig. 19
Reconstruction of the cross-section of *Gyrochorte burtani* n. ichnosp. Based partly on specimen UJ TF 1169, Wiśniowa, Verovice Shales, which represents an hypichnial furrow. × 1

the incisions are thick, flat and, like the incisions, slightly curved. The median groove is about 1 mm deep. In the cross-section the burrow is oval (text-fig. 19), becoming more circular near the coniform end.

The specimen taken for the holotype is exceptionally large. With one exception the other specimens are 5–6 mm wide and a few cm long. The riblets are less flat and the ribbing is on the whole more dense than in the holotype specimen. Some of the small specimens are devoid of the median groove; instead, the riblets join in a sharp apical ridge (pl. 11, fig. 4), resembling the "razorback" structures called *Sustergichnus* by CHAMBERLAIN (1971 *a*). On the same underface there occur specimens with an apical groove.

This trace never densely covers the sole but is scattered over it in such a manner that usually several traces occur within a restricted area. Often they occur as relatively short traces aligned in a curved line, one following the other at short intervals. There is some level-crossing.

This trace may also occur in the form a hypichnial furrow. In this case, in the middle of the furrow there is a low apical ridge bordered on either side by shallow grooves. The ribbing of the flanks is like that of hypichnial ridges. The presence of hypichnial furrows helps in reconstructing the cross-section of this trace (text-fig. 19).

**Remarks.** — The assignment or this trace to *Gyrochorte* is based on the presence of the plaited ornamentation. In comparison with *Gyrochorte comosa* there are considerable differences: *G. comosa* is a long trace while our specimens are relatively short. Since our plaited ridges are often aligned, this difference may be apparent: possibly we have those parts of a long trace in which the animal worked in sand along a mud/sand interface, dipping below it in certain sections of its path. The ornamentation and the size of our specimens are also different as compared with *G. comosa* (the specimens described by HALLAM, 1970, are 3–4 mm wide). Many *Gyrochorte* occur as epichnial ridges, absent in our material. From the description of HEER (1865, p. 142) it is not clear whether his traces occurred on the upper or the lower surface. WINCIERZ (1973) showed that in Lower Jurassic beds *Gyrochorte* may occur both on the lower and upper surfaces.

**Sediment.** — The Lower Cretaceous specimens occur in very thin-bedded (1–2 cm), fine-grained, single-current laminated sandstones.

In Oligocene beds the sandstones are somewhat thicker (5–10 cm). The burrow may sub-horizontally penetrate flute casts (pl. 11, fig. 2).

**Occurrence.** — Hauterivian — Grodziszcze Beds: Lipnik near Myślenice, Poznachowice Bieśnik. Barremian — Verovice Shales: Wiśniowa, the stream Marków (here fairly frequent) Senonian — Skrzydlna Beds: Wierzbanowa (1 specimen). Oligocene — Krosno Beds: Dębna.

### *Gyrochorte imbricata* n. ichnosp.

(pl. 11, figs 6–8)

*Holotype*: UJ TF 176 (pl. 11, fig. 8).
*Type locality*: Gródek near Nowy Sącz.
*Type horizon*: Ciężkowice Sandstone, Lower Eocene.
*Derivation of the name*: Lat. *imbricatus* — imbricate; the imbricate arrangement of the lateral riblets.
*Material*: 3 specimens.

**Diagnosis.** — Hypichnial cylindrical full burrow, straight or feebly curved, with biserial oblique incisions joining in the median very shallow groove. Asymmetrical riblets between the incisions, with one steeper side, giving an imbricate appearance.

**Description.** — The holotype is 3.5 cm long. This specimen has been taken for the holotype as it shows the termination of the burrow. The median groove is very shallow, the lateral incisions much deeper, very narrow near the median groove but wider towards the sides, and are almost 1 mm wide at the contact with the sole. The incisions occur at regular intervals of 2–4 mm. The riblets between the incisions are 2–3 mm wide in the median zone of the trace, but towards the margins they thin out as spine-like appendages. In some riblets there is an additional incision which hardly reaches the median groove. One end of the trail is obtuse and coniform, the other is broken off. The burrow is not quite horizontal, but seems to penetrate the sandstone obliquely.

**Sediment.** — Thin-bedded (up to 3 cm) single-current laminated fine-grained sandstones.

**Occurrence.** — Lower Eocene — Ciężkowice Sandstone: Gródek.

### *Gyrochorte obliterata* n. ichnosp.

(pl. 11, fig. 9; text-fig. 20)

*Holotype*: UJ TF 127 (pl. 11, fig. 9).
*Type locality*: Lipnik near Myślenice.
*Type horizon*: Verovice Shales, Barremian.
*Derivation of the name*: Lab. *obliterata* — effacted; because the sculpture is not distinctly marked.
*Material*: 3 slabs, each with numerous specimens. A few occurrences noted in the field.

**Diagnosis.** — Hypichnial cylindrical bilobate full burrow with a shallow median groove and oblique densely spaced irregular incisions.

**Description.** — In the slab taken for the holotype the trace occurs densely in the form of long (several cm) rope-sized (1 cm wide) cylindrical burrows, markedly protruding from the sole or affixed to it. The median groove is very shallow, often discontinuous, or even disappearing completely. The lateral incisions are also very shallow, often indistinct, densely spaced. In some parts of the burrow the sculpture is entirely effaced and the surface of the cylinder

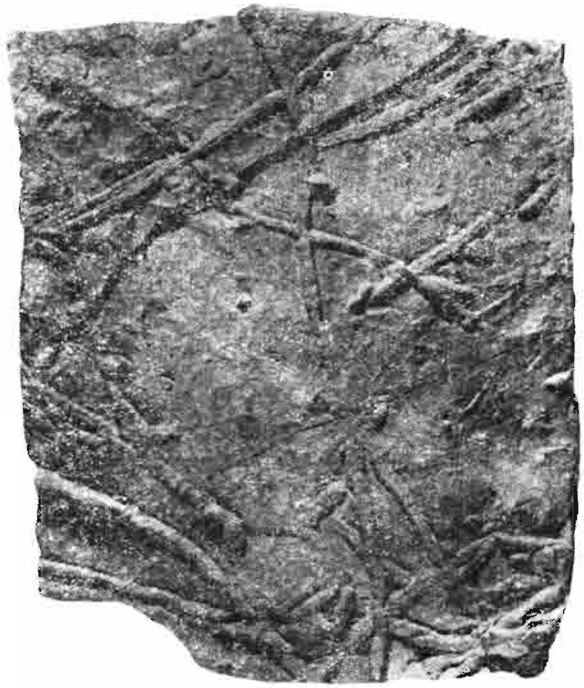


Fig. 20
*Gyrochorte obliterata* n. ichnosp., Lipnik near Myślenice, Verovice Shales, UJ TF 127. × 0.5

is nearly smooth. This trace occurs gregariously, there is a good deal of overcrossing and overlapping. The burrow is filled with somewhat coarser material than the host rock.

**Remarks.** — To a certain extent this trace is similar to *Crossopodia scotica* McCoy (Häntzschel, 1962, fig. 118, 2), but the sculpture is rougher and less distinct in our specimens. Our material resembles the "*Gyrochorte* Bänder", with a median groove and feeble ribbing, of Kemper (1968, pl. 7).

**Sediment.** — Medium-grained, thin bedded (10 cm), graded sandstones.

**Occurrence.** — Barremian — Verovice Shales: Grabie, Lipnik near Myślenice (here are several intercalations of sandstones with this trace).

### Ichnogenus *Helicorhaphe* Książkiewicz, 1961 *a*

*Type ichnospecies: Helicorhaphe tortilis* Książkiewicz.

**Diagnosis.** — Strings helicoidally twisted along a horizontal axis

### *Helicorhaphe tortilis* KSIĄŻKIEWICZ, 1970
(pl. 11, fig. 10)

1970. *Helicorhaphe tortilis* ichnosp. nov., KSIĄŻKIEWICZ, p. 286, fig. 1*t* (cf. also KSIĄŻKIEWICZ, 1961*a*, p. 885, pl. 2 fig. 3).
*Holotype*: UJ TF 277 (pl. 11, fig. 10).
*Type locality*: Lipnica Mała near Nowy Targ.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *tortilis* — twisted.
*Material*: 5 specimens.

**Diagnosis.** — Hypichnial string-sized full burrow tightly twisted along a horizontal axis.

**Description.** — The holotype is 5 cm long and 0.8 to 1.2 mm wide. It consists of a row of tiny elliptical beads arranged obliquely to the axis of the trace, which is feebly curved. This arrangement suggests that the lower parts of cylindrical whorls whose upper parts are situated above the underface are visible on the sole. In some parts of the trace the beads occur in a double row. The doubling probably indicates that the surface of the string is uneven. In the two specimens from Palaeocene beds the "beads" are longer and more elliptical.

**Remarks.** — Twisted traces were noted by FUCHS (1895, fig. 7). Twisting is present in *Helicolithus* AZPEITIA and in *Bostricophyton* SQUINABOL. In the former the trace is meandering, in the latter branching, while the trace now described is freely winding.

**Sediment.** — The holotype has been found in a very fine-grained, single-current laminated sandstone, 2·5 cm thick. Other specimens in sandstones about 4 cm thick.

**Association.** — Fragment of a *Cosmorhaphe*.

**Origin.** — To all appearance a post-depositional feeding burrow. Holothurians cast out helicoidally knotted strings of egested material (HEEZEN & HOLLISTER, 1971), but more probably the trace was formed by a polychaete burrowing a helicoidal tunnel just above the clay/sand interface and filling it with excrements.

**Occurrence.** — Palaeocene — Szczawnica Beds(?): Krościenko on the river Dunajec. Lower Eocene — Beloveza Beds: Lipnica Mała, Zbludza.

## Ichnogenus *Helminthopsis* HEER, 1877

*Type ichnospecies: Helminthopsis abeli* n. ichnosp. (*in* HÄNTZSCHEL, 1962, p. W 197, fig. 4*a*)

**Remarks.** — ANDREWS (1955) and HÄNTZSCHEL (1962, 1965) proposed *H. magna* HEER as the type species. This is, however a bilobate trace (HEER *in* MAILLARD, 1887, pl. 1, fig. 1) resembling a *Taphrhelminthopsis*. It is therefore proposed to take the type illustrated by ABEL (1935, p. 290, fig. 261*B*) but unnamed, and re-illustrated by HÄNTZSCHEL (1962, p. W 197, fig. 4*a*), as the type ichnospecies under the name *Helminthopsis abeli* n. ichnosp. This type best represents the features of this ichnogenus in the sense given to it by SACCO (1888).

**Origin.** — Most specimens of *Helminthopsis* are cylindrical burrows and not uncommonly intersect the sedimentary structures of underfaces (in pl. 12, fig. 1 the trace cuts across an arcuate ridge-and-furrow structure = Schrägschichtunsbogen; in pl. 12, fig. 6 the burrow traverses flute and other linear structures). This indicates that *Helminthopsis* are post-depositional feeding burrows. There are, however, some exceptions. In one or two cases the trace is intersected by flute casts. This would mean that most of the *Helminthopsis* producers burrowed in sand, but some were able to live in mud. Polychaete annelids were the most probable animals responsible for *Helminthopsis*, except for *H. granulata*, the burrow of which has a surface ornamentation. It may suggest that the burrow was produced by a priapulid, as the representatives of this group have the introvert armoured with spines. It is not known, however, whether priapulids are able to follow a sinuous path.

*Helminthopsis abeli* n. ichnosp.
(pl. 12, fig. 5; text-fig. 21 *a–h*)

1888. *Helminthopsis hieroglyphica* HEER, SACCO, p. 175, pl. 2, figs 2, 11.
1935. *Helminthopsis*, ABEL, p. 290, fig. 261B.
*Lectotype*: fig. 261B in ABEL, 1935.
*Cotype*: UJ TF 1321 (pl. 12, fig. 5).
*Type locality*: Poznachowice, near Myślenice.
*Type horizon*: Grodziszcze Beds, Hauterivian.
*Derivation of the name*: in honour of Professor OTHENIO ABEL, Austrian palaeobiologist.
*Material*: 21 specimens and a number of occurrences observed in the field.

**Diagnosis.** — Hypichnial string- or rope-sized full burrow, or in some cases cast, loosely winding with a tendency to meandering. Meanders irregular and variable in shape.

**Description.** — In the specimen chosen for the co-type the burrow is 6 mm wide and 2–3 mm high. The meanders are of variable height (10, 20, 26 mm), either low and broad at the base, or high and narrow, with some tendency to assume a loop-like shape. In some parts the burrow assumes an almost straight course.

There is considerable diversity in the shape and size of the traces assigned here. The width of the burrow ranges from 2 to 15 mm, but is most commonly 4 to 6 mm. The windings are irregular, and variable in shape. Some may be meander-like, fairly narrow and somewhat constricted. There are nearly always some parts of the trace that are almost straight. The surface of the burrow is smooth, but in one specimen (UJ TF 1082) there is some delicate transversal striation.

**Remarks.** — This ichnospecies differs from other species of *Helminthopsis* by a tendency to meandering. In this way it approaches the meandering traces of the meandering group, but its meanders are never so regular as in that group.

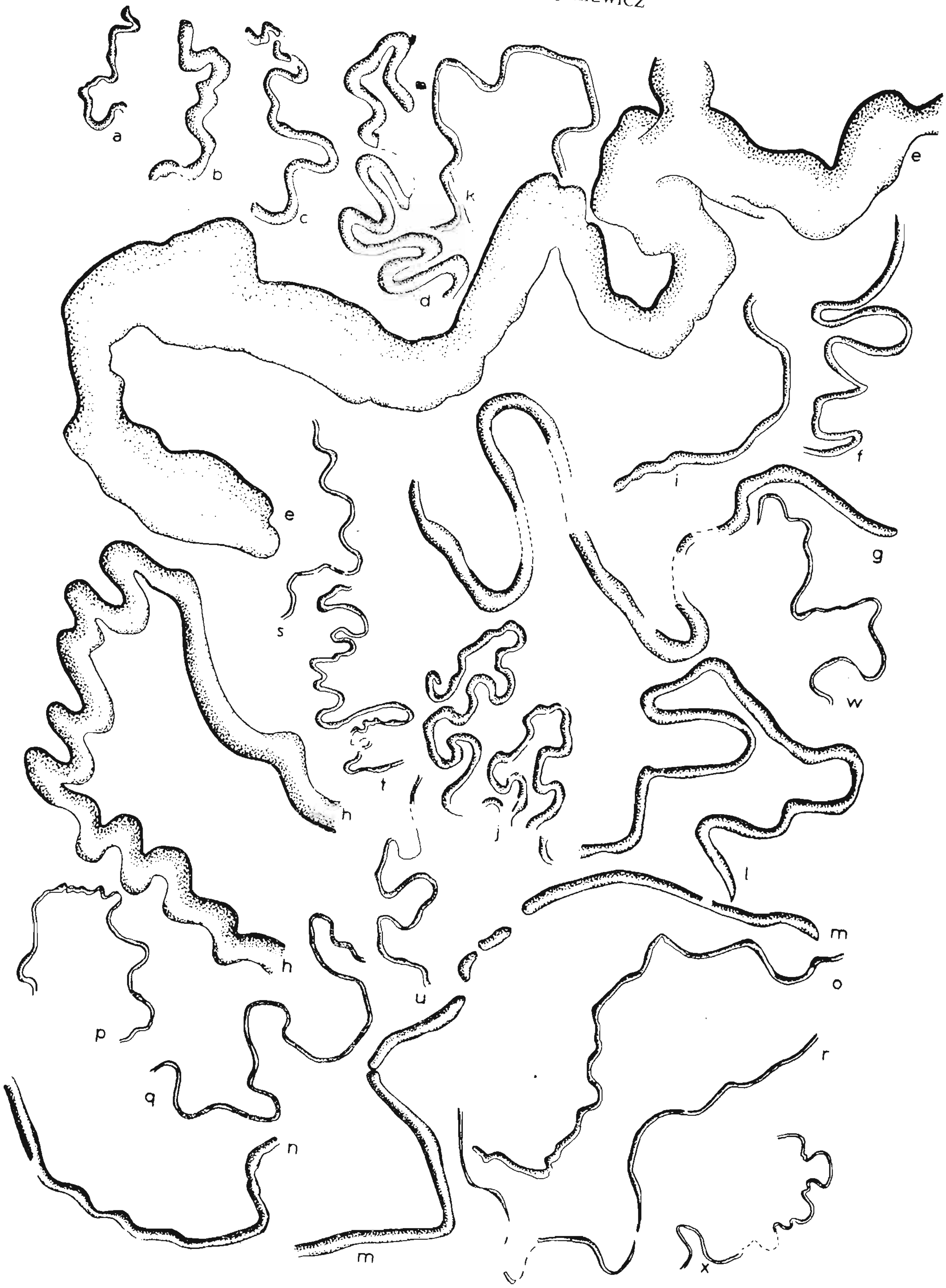
In the affinity of this ichnospecies have been placed some very thick burrows occurring in the shape of a horse-shoe. They often occur near one another but are not joined. Sometimes they are associated with thick *Helminthopsis*, as in text-fig. 21*e*. This horse-shoe type seems to be common in the Sub-Magura Beds and in the lower part of the Magura Sandstone (KSIĄŻKIEWICZ, 1935, p. 108, 1958).

**Sediment.** — Fine- or fairly fine-grained sandstones or limestones on the average 2–3 cm thick, in some cases 8 cm, and in one 30 cm. On the whole the thicker burrows are associated with more thick-bedded sandstones. The large horse-shoe type occurs at the base of sandstones 50 cm thick.

In the marls of the Lower Istebna Beds there occur ribbon-like flat irregularly winding traces, of the same style as *H. abeli*. This is probably a pre-depositional form of this ichnospecies.

**Occurrence.** — Seems to be fairly common in all members of the Carpathian flysch.

Berriasian — Cieszyn Limestone: Goleszów, Godziszów, Jaworze, Żywiec. Hauterivian — Grodziszcze Beds: Woźniki, Lipnik near Myślenice, Poznachowice, Brzyska. Cenomanian — Lower Godula Beds: Czchów. Turonian — Siliceous Marls: Krasiczyn; Middle Godula Beds: Targoszów. Senonian — Inoceramian Beds: Łączki Kucharskie, Krzywcza, Bachów, Łodzinka, Huwniki, Kalwaria Pacławska (the stream Sopotnik); Skrzydlna Beds: Przenosza; Gorzeń Beds: Gorzeń Dolny, Wierzbanowa; Ropianka Beds: Młynne, Biczyce, Biała Wyżna, Kąclowa, Skwirtne, Smrekowiec. Palaeocene — Szczawnica Beds: Łomnica. Palaeocene-Lower Eocene — Variegated Shales: Lipowe. Lower Eocene — Ciężkowice Sandstone: Znamirowice; Beloveza Beds: Lipnica Mała, Sidzina, Szczawa, Zbludza, Półrzeczki, Myślec. Middle Eocene — Hieroglyphic Beds: Jeleśna, Juszczyn, Zalesie, Stara Wieś; Łącko Beds: Kamienica near Nowy Sącz. Upper Eocene — Magura Sandstone: Sidzina (the hamlet Jarominy) Zembrzyce, Juszczyn, Krzczonów, Kamionka Wielka; Piwniczna. Oligocene—Krosno Beds: Kąty; Wujskie, Słonne Mt., Łodyna.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### *Helminthopsis hieroglyphica* HEER, 1887

(pl. 12, fig. 3; text-fig. 21 *i*, *k–o*)

1887. *Helminthopsis hieroglyphica* HR., HEER *in* MAILLARD, pl. 2, fig. 4 (non pl. 1, fig. 2).
*Material*: 11 specimens and many occurrences observed in the field.

**Description.** — The strings are most frequently a few mm thick, the thinnest 1·5 mm, the thickest 1·5 cm. The windings are irregular, low, and the course of the trace is often alternately winding and straight. This is hypichnial burrow, probably in most cases a full burrow.

**Remarks.** — This is a not very well defined ichnospecies. There is no description in MAILLARD'S paper and the figures (pl. 1, fig. 2, pl. 2, fig. 4) represent two quite different kinds. Fig. 2 in plate 1, as far as can be seen from a not very good photograph, shows two fairly high and narrow meanders with tortuous limbs and parallel axes (see text-fig. 21 *j*). This would, according to current definitions, be a *Helminthoida* (*helminthopsoidea* SACCO?) rather than a *Helminthopsis*. The second specimen shown in pl. 2, fig. 4 presents quite a different type: this is a large, irregularly winding trace, and this specimen may be taken as the type of *Helminthopsis hieroglyphica*. SACCO (1888, p. 175, pl. 2, figs 2 and 11) gives no description and illustrates only two fragments, stating that his specimens are identical with the form of HEER. He stresses that the mode of meandering approaches "alquanto alla *Helminthoida crassa*". This feature seems to indicate that his material would rather fit into *Helminthopsis abeli*.

**Sediment.** — Thin-bedded (the thickest 6.5 cm), fine-grained sandstones or limestones, graded, composite or horizontally laminated.

**Association.** — Occurs usually on flat soles with no associated traces. Occasionally with *Sabularia tenuis*.

**Occurrence.** — Berriasian — Cieszyn Limestone: Goleszów. Valanginian — Upper Cieszyn Shales: Trzemeśnia (a full burrow passing into a hypichnial furrow). Hauterivian — Grodziszcze Beds: Lipnik near Myślenice. Cenomanian — Lower Godula Beds: Rzyki near Wadowice. Turonian — Siliceous Marls: Krasiczyn. Senonian — Inoceramian Beds: Bachów, Łodzinka, Wołodź, Huwniki; Ropianka Beds: Mszana Dolna (a stream on the slope of Mt Lubogoszcz), Wierzbanowa, Półrzeczki, Biała Wyżna. Palaeocene — Szczawnica Beds: Łomnica. Palaeocene-Lower Eocene — Variegated Shales: Lipnica Mała, the stream Linorka. Lower Eocene — Ciężkowice Sandstone: Gródek; Beloveza Beds: Lipnica Mała, Sidzina, Lubomierz, Zbludza, Myślec. Oligocene — Krosno Beds: Kąty, Dębna, Radoszyce, Dźwiniacz Dolny.

### *Helminthopsis irregularis* (SCHAFHÄUTL, 1851)

(pl. 12, fig. 2; text-fig. 22)

1851. *Helminthoida irregularis* m., SCHAFHÄUTL, p. 142, pl. 9, fig. 10 (no description).
*Material*: 13 slabs, each with numerous specimens.

**Description.** — These are endichnial and epichnial irregularly meandering narrow-gauged, void or sometimes filled tubes with traces of transversal segmentation. This type is easiest to study on the upper surfaces of sandstone layers. In this case the trace occurs in the form of

Fig. 21
*Helminthopsis* HEER, emend. SACCO

a–h *H. abeli* n. ichnosp.: a Krzywcza, Inoceramian Beds, UJ TF 1290; b Przenosza, Skrzydlna Beds, UJ TF 1302; c Poznachowice, Grodziszcze Beds, UJ TF 1321; d based on fig. 261B of ABEL, 1935, Wienerwald flysch; e Krzczonów, Magura Sandstone (field drawing); f Znamirowice, Ciężkowice Sandstone, UJ TF 100; g Łodzinka, Inoceramian Beds, UJ TF 234; h Sidzina, Magura Sandstone (field drawing); i–p *H. hieroglyphica* HEER: i MAITLAND, 1887, pl. 2, fig. 4; j MAITLAND, 1887, pl. 1, fig. 2 = ?*Helminthoida helminthopsoidea* SACCO; k Lipnica Mała, Beloveza Beds, UJ TF 252; l Goleszów, Cieszyn Limestone, UJ TF 233; m Kąty, Krosno Beds, UJ TF 1587; n Huwniki, Inoceramian Beds, UJ TF 920; o Radoszyce, Krosno Beds, UJ TF 1320; p(?) Zbludza, Beloveza Beds, UJ TF 1888; q–x *H. tenuis* KSIĄŻKIEWICZ: p Kwiatoń, Ropianka Beds (field drawing); r Sidzina, the stream Głaza, Beloveza Beds, UJ TF 1661; s Gródek, Ciężkowice Sandstone, UJ TF 1631; t Sopotnia Mała, Hieroglyphic Beds (field drawing), u Wujskie, Krosno Beds, UJ TF 1615, w Zubrzyca Górna, Beloveza Beds, UJ TF 33; x Ponikiew, Lower Godula Beds (field drawing). All figures × 0.5

furrows 1–3 mm wide, incised about 1.0 to 1.5 mm in the rock. The furrows are here and there filled with flattened cylinders. On the bottom of some furrows a delicate transverse striation is visible. The meanders are highly variable in shape: some are elongated and narrow with their arms close to one another, and even touching; others are short and broad at the base. The height of the meanders varies within large limits: some are only 1–2 cm, others 3–5 cm high. When the rock is split parallel to the bedding, it appears that the void tubes occur at several levels near the upper surface, though they are not limited to one parting plane but descend from one level to the other, evidently developed subhorizontally.

Fig. 22
*Helminthopsis irregularis* (SCHAFHÄUTL). Upper surface. Tokarnia, Hieroglyphic Beds, UJ TF 797. × 0.5

This form tends to occur densely in the uppermost part of sandstone layers.

**Remarks.** — This type well resembles the trace illustrated but not described by SCHAFHÄUTL (1851). The shape and dimensions are very much the same, only it is not clear whether SCHAFHÄUTL's figure represents a concave trace. Some transverse striations are also visible on his drawing. SCHAFHÄUTL assigned his type to helminthoids. Although some of the meanders are narrow, their course is highly irregular and the axes of the meanders are not parallel to one another, so this ichnospecies should be assigned to *Helminthopsis*, according to the current definitions of either type.

**Sediment.** — Very fine-grained sandstone or marly siltstone.

**Association.** — In one case *Tubulichnium incertum*.

**Occurrence.** — Senonian — Inoceramian Beds: Romanowa Wola; Ropianka Beds: Limanowa; Sromowce Beds (frequent): Maruszyna, Sromowce Wyżne, Sromowce Niżne, Jaworki. Palaeocene — Szczawnica Beds: Krościenko on the river Dunajec. Lower Eocene — Beloveza Beds: Zubrzyca Górna. Middle Eocene — Hieroglyphic Beds: Tokarnia.

### *Helminthopsis tenuis* KSIĄŻKIEWICZ, 1968
(pl. 12, fig. 1; text-fig. 21*q–x*)

1968. *Helminthopsis tenuis* n. "sp.", KSIĄŻKIEWICZ, p. 7 and 14, pl. 4, fig. 1.
*Holotype*: UJ TF 1465 (pl. 12, fig. 1).
*Type locality*: Goleszów near Cieszyn.
*Type horizon*: Cieszyn Limestone, Berriasian.
*Derivation of the name*: Lat. *tenuis* — slight, slender.
*Material*: 12 specimens and numerous field observations.

**Diagnosis.** — Hypichnial thread-sized full burrow, irregularly meandering, some meanders high and narrow, others low and broad.

**Description.** — In the holotype the string is about 1 mm wide and less than 0·5 mm high. The shape and dimensions of the irregular meanders vary. They tend to be alternately high (up to 4 cm) and narrow on one side, and low (about 1 cm) and broad on the other. The surface of the string is smooth.

There is considerable diversity in the manner of winding in this trace, but the general pattern is maintained. The width of the string may reach 1.5 mm. The trace occurs solitarily.

Alternation of the shape of the windings which on one side are high, on the other low, may point to a physiological asymmetry displayed by some organisms, chiefly by crustaceans (LESSERTISSEUR, 1955, fig. 15).

**Remarks.** — Not well developed or fragmentary specimens are difficult to distinguish from young specimens of *H. abeli*. The style of winding is different in these two types. The absence of straight courses and more strongly marked winding differentiate this ichnospecies from *H. hieroglyphica*.

**Sediment.** — The holotype occurs on the sole of a thin-bedded, current-laminated limestone. Other specimens occur in thin-bedded, a few cm thick sandstones, but in one instance the sandstone is 75 cm thick.

**Association.** — *Paleodictyon*, *Protopaleodictyon*, *Taphrhelminthopsis auricularis*. Seems to be posterior to *Paleodictyon*.

**Occurrence.** — Fairly numerous in all horizons, but only rarely well developed.

Berriasian — Cieszyn Limestone: Goleszów. Valanginian — Upper Cieszyn Shales: Trzemeśnia. Hauterivian — Grodziszcze Beds: Wiśniowa, Brzyska. Cenomanian — Lower Godula Beds: Ponikiew, Czchów. Turonian — Middle Godula Beds: Targoszów, Wiśniowa, Bieśnik. Senonian — Inoceramian Beds: Rzegocin, Kąkolówka, Romanowa Wola, Dźwiniacz Dolny; Upper Godula Beds: Czchów; Gorzeń Beds: Gorzeń Dolny, Wierzbanowa; Ropianka Beds: Półrzeczki, Uście Gorlickie, Kwiatoń, Skwirtne; Cisna Beds: Cisna. Palaeocene — Szczawnica Beds: Haluszowa. Palaeocene-Lower Eocene — Variegated Shales: Lipowe. Lower Eocene — Beloveza Beds: Złatna, Zubrzyca Górna, Sidzina, Tokarnia, Szczawa, Myślec, Łosie. Middle Eocene — Hieroglyphic Beds: Koszarawa, Żarnówka, Juszczyn, Żubracze, Liszna; Łącko Beds: Kamienica near Nowy Sącz. Upper Eocene — Magura Sandstone: Zachełmna, Rzyki near Limanowa, Kamionka Wielka. Oligocene — Krosno Beds: Dźwinacz Dolny.

### *Helminthopsis granulata* KSIĄŻKIEWICZ, 1968
(pl. 12, fig. 6)

1968. *Helminthopsis granulata* n. "sp.", KSIĄŻKIEWICZ, pp. 7 and 15, pl. 4, fig. 2 and text-fig. 4.
*Holotype*: UJ TF 224 (pl. 12, fig. 6).
*Type locality*: Goleszów near Cieszyn.
*Type horizon*: Cieszyn Limestone, Berriasian.
*Derivation of the name*: Lat. *granulatus* — granular; the surface of the burrow is covered with tiny tubercules.
*Material*: 10 specimens and a similar number noted in the field.

**Diagnosis.** — Hypichnial string-sized full burrow, irregularly and loosely meandering. Surface covered with warts and ridges arranged parallel to the axis of the burrow.

In the holotype the string is 5 to 7 mm wide and no more than 2–3 mm high. The meanders are loose and large, 6 to 7 cm high and a few cm broad at the base. Some meanders are somewhat constricted but no loop-like form is developed. The ornamentation consists of little warts and ridges arranged in 3 to 4 rows on the visible (ventral) side of the cylindrical burrow. In some parts of the burrow this ornamentation is effaced. The slab is fairly densely covered with this trace.

There is little diversity in the size, manner of winding and surface ornamentation in other specimens. The ornamentation may be more or less obliterated or feebly developed. The soles are crowded with this burrow.

**Sediment.** — Current-ripple or horizontally laminated limestones no more than 5 cm thick; also thin-bedded sandstones.

**Association.** — In the Grodziszcze Beds together with *Gyrochorte burtani.*

**Occurrence.** — Berriasian — Cieszyn Limestone: Goleszów (main quarry), Kamienica near Bielsko. Hauterivian — Grodziszcze Beds: Lipnik near Myślenice, Brzyska (a stream on the slope of Mt Liwocz).

### Ichnogenus *Muensteria* STERNBERG, 1833

*Type ichnospecies: ?Münsteria geniculata* STERNBERG, 1853

**Remarks.** — *Muensteria* is not clearly defined (HÄNTZSCHEL, 1965). This name has been used in various meanings. Its relation to *Keckia* on the one hand and to *Hydrancylus* on the other are vague. Perhaps this term should be dropped and for the types grouped here a new generic name introduced. Here are grouped ribbon-like winding traces, comparatively wide and short, with more or less dense arcuate striation.

**Origin.** — Apparently these forms are similar to spreite structures. The arcuate striations may represent a backfill fabric produced by a gastropod moving in the sediment or on its surface, and pushing the sediment backward by its expanded foot (see GLAESSNER, 1969, explanation of rather similar traces).

### *Muensteria geniculata* STERNBERG, 1833
(pl. 13, fig. 2)

1833. *Münsteria geniculata*, STERNBERG, p. 32, pl. 5, fig. 4.
*Material*: 10 specimens.

**Description.** — Endichnial, horizontal or subhorizontal traces. Most of the specimens are 10 to 12 mm wide, with very dense striation (5–8 striae per 1 cm). The terminations, if preserved, are obtuse. No branching has been noted.

**Sediment.** — Limestones and marls.

**Occurrence.** — Turonian — Siliceous Marls: Huwniki (here fairly numerous).

### *Muensteria hamata* FISCHER-OOSTER, 1858
(pl. 13, fig. 3)

1858. *Münsteria hamata*, FISCHER–OOSTER, p. 41, pl. 5.
*Material*: 7 specimens and a few occurrences noted in the field.

**Description.**—Endichnial, in some specimens with one branch. Most of the specimens are 3–4 cm wide, filled with darker material than the enclosing rock. Occurs horizontally or sub-horizontally on parting planes.

**Sediment.** — Marls. If they are layered, the trace occurs near the upper surface.

**Occurrence.** — Senonian — Inoceramian Beds: Kąkolówka, Wołodź; Ropianka Beds: Szczawa (the Kamienica valley), Wola Brzezińska, Grybów, Biała Wyżna, Kąclowa, Florynka. Palaeocene-Lower Eocene — Variegated Shales: Lipnica Mała (the stream Linorka).

### *Muensteria planicostata* n. ichnosp.
(pl. 13, fig. 1)

*Holotype*: UJ TF 133 (pl. 13, fig. 1).
*Type locality*: Poręba Wielka.
*Type horizon*: Ropianka Beds, Senonian.

*Derivation of the name*: Lat. *planicostatus* — with flat riblets.
*Material*: 1 specimen.

**Diagnosis.** — Hypichnial narrow ribbon-like burrow, winding, consisting of crescent narrow flat riblets.

The trace is 2 cm wide, about 20 cm long, but both its ends are broken. It winds freely. The crescent riblets are low, hardly projecting with respect to the sole. They are 0.1 to 0.5 mm, occasionally 1.5 mm wide, and attain their greatest width in the median part of the ribbon. The distances between the riblets are of a similar width.

**Remarks.** — The trace is probably a cast. A creeping animal (gastropod?) left on the mud crescent grooves produced by the contraction of its foot, later cast in sand. In the Ropianka Beds similar traces occur in marls. The crescents are somewhat larger, and the form is endichnial.

**Sediment.** — Thin-bedded, fine-grained sandstone, horizontally laminated, 4 cm thick.

**Occurrence.** — Senonian — Ropianka Beds: Poręba Wielka.

### Ichnogenus *Naviculichnium* n. ichnogen.

*Type ichnospecies: Naviculichnium marginatum* n. ichnosp.
*Derivation of the name*: Lat. *naviculum* — small boat.

**Diagnosis.** — Epichnial elongated trough shallowing towards either end.

### *Naviculichnium marginatum* n. ichnosp.
(pl. 11, fig. 13)

*Holotype*: UJ TF 760 (pl. 11, fig. 13).
*Type locality*: Półrzeczki near Limanowa.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *marginatus* — marginal; the trace is bordered with marginal rims.
*Material*: 9 specimens (slabs) and several occurrences noted in the field.

**Diagnosis.** — Epichnial shallow trough-like furrows, bordered with levee-like marginal rims. Furrows filled with reworked shaly material in the form of imbricate flakes.

**Description.** — For the holotype a slab with four partly overlapping troughs has been taken. The troughs are partly filled with clayey material, though in many other finds they are usually empty. The longest trough reaches a length of 7 cm; others are 4.5, 4.0 and 3.0 cm long. The width of the largest furrow is 6 mm, other furrows are somewhat narrower. The depth, after the filling has been removed, is 5 cm in the central part of the trough, which becomes shallower towards either end. The edges of the longest trough are bordered near one ending with a thin elevated levee-like fringe, 1.0 to 1.5 mm wide. A similar fringe occurs in one of the other furrows, while in the remaining two it is not developed. The filling consists of clay flakes obliquely arranged.

In other specimens the troughs may reach a length of 7 cm, and a width of 12 mm. The greatest depth is 6 mm. Bordering fringes are as a rule developed near one end of the trough and absent at the other. In some troughs there is rather indistinct longitudinal striation: The troughs are rectilinear or, more frequently curved.

This trace rarely occurs alone. Usually there are several troughs near one another. Not uncommonly one trough intersects another.

**Remarks.** — The trace is identical with those described by Dżułyński and Kinle (1957).

**Sediment.** — Fine-grained, thin-bedded sandstones.

**Association.** — Together with *Scolicia* and *Subphyllochorda*.

**Origin.** — The filling of the troughs suggests that the trace was formed by an animal (polychaete?) which burrowed along the sand/clay interface, ingested mainly clay and when moving along ploughed the underlying sand and formed the trough which was subsequently filled with excretory clayey material. If so, the part of the trough with the marginal fringes indicates the direction of the burrowing. DŻUŁYŃSKI and KINLE (1957) ascribe the origin of the troughs to the brushing of the bottom by free swimming animals, probably fishes.

**Occurrence.** — Senonian — Ropianka Beds: Ślemień, Wola Brzezińska. Palaeocene-Lower Eocene — Variegated Shales: Uście Gorlickie. Lower Eocene — Beloveza Beds (locally fairly frequent): Zubrzyca Górna, Lubomierz, Półrzeczki, Popowice, Trzetrzewina, Nawojowa, Berest, Uście Gorlickie. Middle Eocene — Hieroglyphic Beds: Skomielna Czarna.

### Ichnogenus *Oniscoidichnus* BRADY, 1949

*Type ichnospecies: Oniscoidichnus filiciformis* (BRADY) (HÄNTZSCHEL, 1962).

#### *Oniscoidichnus carpathicus* n. ichnosp.

(pl. 11, fig. 11)

*Holotype*: UJ TF 1471 (pl. 11, fig. 11).
*Type locality*: Lubomierz near Mszana Dolna.
*Type horizon*: Krosno Beds, Oligocene.
*Material*: 2 slabs, one with a single trace, the other with seven traces.

**Diagnosis.** — Epichnial track, feebly curved, with a low median ridge bordered on either side with tiny round incisions.

**Description.** — In the holotype the median ridge is 1.5 mm wide. It is bordered by grooves of similar width. In places, the ridge is incised by transversal delicate grooves, otherwise it is smooth. In the lateral grooves on either side of the median ridge there are rows of small roundish incisions, about 1 mm wide and 0·8–1 mm long, spaced at fairly regular intervals. These incisions are slightly oblique to the axis of the trace. The course of the trace is only weakly bent.

On the other slab, collected in the same cross-section, there are several similar traces, but much smaller. Some of them are straight, others curved.

**Remarks.** — The trace resembles that described by BRADY (1949), which is twice as wide as our specimen and shows a more pronounced relief.

**Sediment.** — Marly siltstone.

**Association.** — Some round or elliptical depressions occur in the proximity of the trace.

**Origin.** — BRADY regards *Oniscoidichnus* as the track of an isopod (*Oniscus* — recent isopod). The incisions might have been made by the half-walking, half-swimming animal.

**Occurrence.** — Oligocene — Krosno Beds: Lubomierz.

### Ichnogenus *Scolicia* de QUATREFAGES, 1849

*Type ichnospecies: Scolicia prisca* de QUATREFAGES (HÄNTZSCHEL, 1962).

**Remarks.** — GÖTZINGER and BECKER (1932, 1934) described three-lobed traces under the name *Palaeobullia*, regarding them as tracks ("Fährten"). They distinguished several types, not giving any specific names to them, although they believed that "offenbar wurden manche dieser Fährten von verschiedenartigen Gastropoden erzeugt" (1934, p. 83). All the kinds they illustrated have been found in the Carpathian flysch. All three ichnospecies assigned here occur essentially as crawling trails, but full burrow forms also exist.

**Origin.** — GÖTZINGER and BECKER (1932) ascribed the *Scolicia* traces to crawling gastropods. If in fact the producer were a prosobranch, the median lobe may represent its median crawl-way and its sculpture is due to the undulatory movements of the foot of the animal, while the side-to-side pendulating movements of the forward part of the body sculptured the lateral fringes (SCHÄFER, 1972). CHAMBERLAIN (1971*a*), however, who noticed certain pits and lobes at the base of the burrow, presumes that this type of burrow may be made by a crustacean. The presence of narrow rims or cylindrical strings bordering the median lobe on either side is also difficult to account for, if the trace were produced by a crawling gastropod. It may be assumed that a large polychaete was the producer of this trace. Some errant polychaete worms have developed relatively wide and long parapodia. In some kinds, as in the recent *Nereis (Neanthes)*

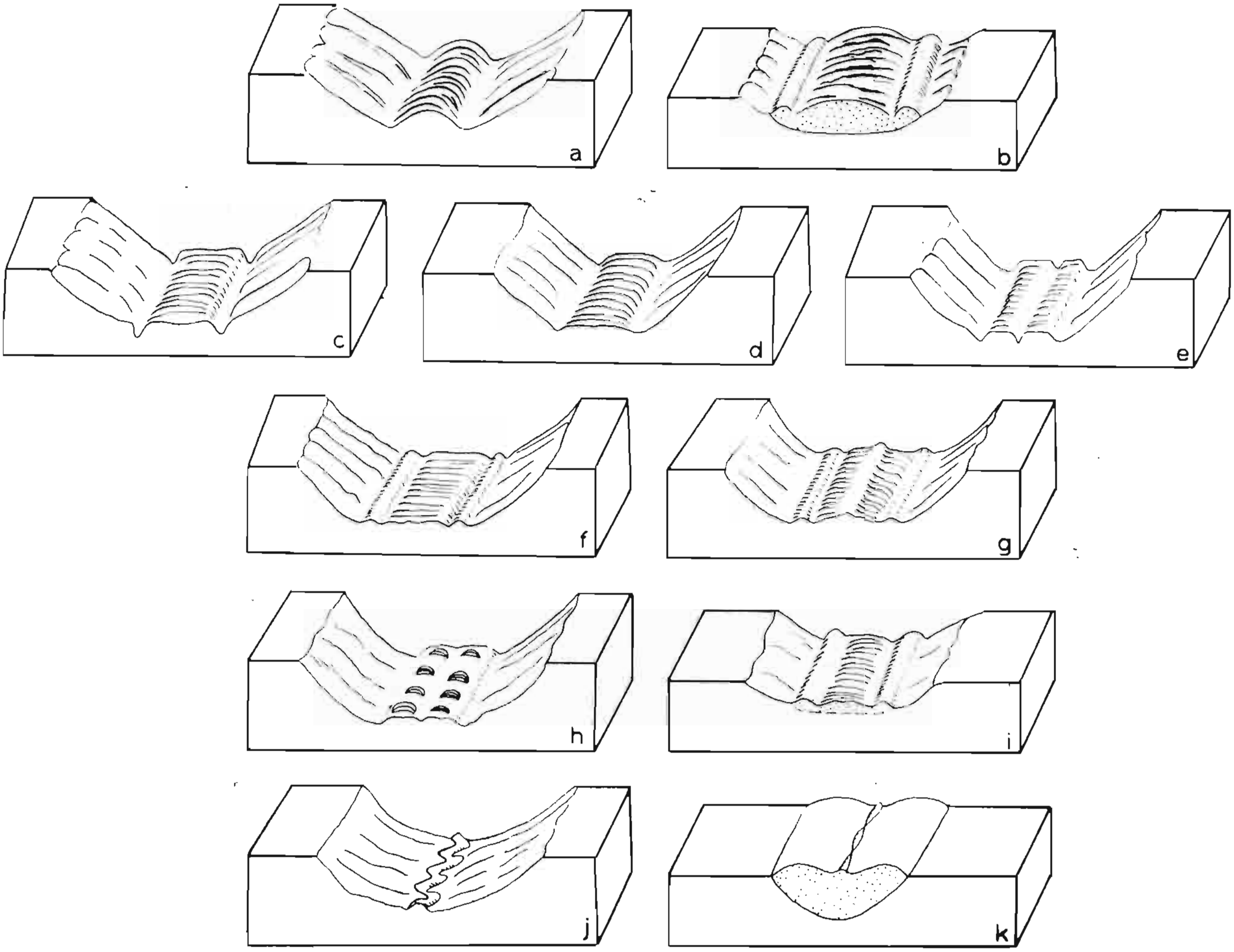



Fig. 23
*Scolicia* DE QUATREFAGES (diagrammatically)
[a] *S. prisca*, locomotion trail; [b] *A. prisca*, feeding burrow; [c]–[h] *S. plana*: [c] the type with deep marginal grooves; [d] the type with shallow marginal grooves; [e] the type with a median trench; [f] the type with lateral rims; [g] the type with a median ridge; [h] the type with bundle-like riblets in the median lobe; [i] *S. plana*, feeding burrow; [j] *S. vertebralis*, locomotion trail; [k] *S. vertebralis*, feeding burrow

*virens*, the parapodia overlap on bends (FAUVEL *in* GRASSE, 1959, pl. 1) and when the animal crawls they may impress an imbricate track similar to the lateral fringe in *Scolicia*, and the annulated trunk of the animal imprints the segmented median lobe of the trail. In some kinds of *Scolicia* the median lobe is bordered by narrow rims (pl. 14, fig. 2). Some polychaetes have short narrow rims at the base of the parapodia (*Hesione splendida*, FAUVEL, o. c., p. 171, fig. 141A) which may form the bordering rims during locomotion. The winding course of the *Scolicia* traces is also in conformity with the manner of locomotion proper to most of the errant polychaete annelids, which tend to follow a sinuous course. It is also possible that the pits and lobes noticed by CHAMBERLAIN at the base of the burrow are imprints of the parapodial protuberances, by means of which the animal finds points of support on the substratum during its motion.

The trails of *Scolicia* occur for the most part on the upper surface of sandstone layers, so that it may be supposed that they might have been formed by animals crawling on the sea-bottom, along the sediment/water interface. In many instances, however, the covering mudstone or shale is so gradually linked with the underlying sandstone that it must be supposed that the mud was deposited immediately after the sand had been laid down, so that the latter never formed the sea-bottom, but was separated from the water by a mud layer a few centimeters thick. For this reason it may be presumed that many *Scolicia* were formed by animals moving in mud, below the sea-bottom. In same instances *Scolicia* occurs just below the upper surface of the sandstone. It should be added that KERN and WARME (1974), who observed backfill structures within the *Scolicia* trace, presume that *Scolicia* is a burrow rather than a surface trace. The presence of full burrow forms at the sandstone/shale interface may also serve as concurrent evidence that *Scolicia* is not only a surface trail.

In this way the conclusion is reached that the traces of *Scolicia* are of three kinds: (1) actual surface crawling trails, (2) subsurface crawling trails made when the animal moved in mud but did not fill its gallery with excretory material, (3) full burrows when the animal filled its gallery with the processed material. In the first and second cases the trace reflects only the movements of the ventral side of the animal; in the third instance the movements of the whole body of the animal are impressed to a certain extent on the walls of the burrowing gallery.

### *Scolicia prisca* de QUATREFAGES, 1849

(pl. 11, fig. 12; pl. 14, fig. 8; pl. 15, fig. 6)

1849. *Scolicia prisca* (A. de Q.), de QUATREFAGES, p. 265 (no illustration).

1934. *Palaeobullia* (p. pt.), GÖTZINGER & BECKER, p. 83, fig. 2, 3.

*Material*: The trace is developed in two forms: A — an epichnial or sub-epichnial trail; B — as an epichnial full burrow.

**Description.** — *Form A:* 20 specimens and at least one hundred occurrences noted in the field.

In most specimens the median ridge is 5–7 mm wide and 4–6 mm high; the lateral lobes are each up to 10 mm wide. The height of the median ridge is always smaller than that attained by the lateral lobes. The ribs on the median lobe are either straight, or slightly crescent, bent in one direction. In some specimens there is a shallow longitudinal incision along the crest of the median lobe. The sculpture of the fringing lobes consists of asymmetric riblets, oblique to the axis of the trail, with one side steep and the other almost flat. This gives an imbricate appearance to the fringes.

The trails wind loosely and often densely cover the upper surface, transecting or overlapping one another. Only in rare instances does this form occur singly.

*Form B:* 8 specimens, all epichnial except for one hypichnial.

The median lobe of the trace is a cylindrical body (text-fig. 23) with an arched dorsal side but an almost flat bottom. Its diameter ranges from 5 to 10 mm; its height is about 8 mm. On either side the central cylinder is bordered by full strings 3–5 mm wide. The lateral fringes are usually only feebly developed, and in one or two specimens are entirely lacking. The trace is long, loosely winding, but may be quite short, 5–6 cm long.

If the median cylinder is removed, an epichnial furrow is left (pl. 15, fig. 6). It shows a rather indistinct transverse ribbing, similar to that in form A, three-lobed or bilobate. In the latter case there is no median lobe. This may lead to the inference that when the animal was excreting, its body (the foot if it were a gastropod) executed somewhat different movements than when it moved leaving only its trail. Since a trail is often combined with a full burrow it may be presumed that the animal egested intermittently.

Form B also winds freely. On the contrary to form A, it never profusely covers the upper surface.

**Sediment.** — Very fine-grained sandstones and siltstones.

**Association.** — Form A occurs to the exclusion of other traces. In a few instances it is accompanied by *Naviculichnium*.

**Occurrence.** — Senonian — Ropianka Beds: Limanowa, the hamlet Marciszów (1 specimen). Palaeocene — Upper Istebna Beds: Tabaszowa. Lower Eocene — Variegated Shales: Zaryte, Lipowe; Beloveza Beds (frequent): Złatna, Zubrzyca Górna, Lipnica Mała, Sidzina, Osielec, Łętownia Górna, Tokarnia, Zbludza, Myślec, Popowice, Berest (here particularly frequent). Middle Eocene — Hieroglyphic Beds (frequent): Istebna, Milówka, Zawoja (the stream Końskie), Grzechynia, Juszczyn, the hamlet Kozłownik (full burrow form reported as aff. *Climactichnites*, KSIĄŻKIEWICZ, 1960), Osielec, Jordanów (the hamlet Munkacz), Kojszówka, Tokarnia, Więcierza, Polany, Wysowa, Daliowa; Pasierbiec Sandstone: Tokarnia; Łącko Beds: Sidzina, Kamienica near Nowy Sącz, Myślec. Upper Eocene — Magura Sandstone: Grzechynia, Rzyki near Limanowa, Ochotnica, Kamionka Wielka, Florynka, Berest. Oligocene — Krosno Beds: Dębna (in some layers frequent), Wujskie (the Słonne Mts.), Dźwinacz Dolny (full burrow on the lower surface!).

### *Scolicia plana* KSIĄŻKIEWICZ, 1970

(pl. 14, figs 2–5, 7; text-fig. 23)

1932. *Palaeobullia* (p. pt.), GÖTZINGER & BECKER, p. 379, figs 2–4.
1970. *Scolicia plana* ichnosp. nov., KSIĄŻKIEWICZ, p. 289, pl. 1*c*.
*Holotype*: UJ TF 585 (pl. 14, fig. 3)
*Type locality*: Sromowce Wyżne, Pieniny zone.
*Type horizon*: Sromowce Beds, Lower Senonian.
*Derivation of the name*: Lat. *planus* — flat; flat median lobe.
*Material*: 35 specimens of form A and 2 specimens of form B.

**Diagnosis.** — The trace is developed in two forms:

*Form A.* Epichnial trilobate furrow with low flat median lobe, densely striated and bordered by lateral less densely ribbed fringes. The median lobe may be bordered by narrow rims and longitudinally transected by a very narrow trench.

*Form B.* Epichnial trilobate full burrow, almost rectangular in cross-section bordered on either side by full cylindrical strings and feebly developed lateral fringes.

**Description.** — In the holotype the median lobe is 10–12 mm wide, and the lateral fringes attain no more than 10 mm in width. The median lobe is flat and rimmed with narrow deep grooves. The transverse ribbing of the median lobe is dense (8 to 12 riblets per 1 cm), the riblets are nearly straight and at right angles to the axis of the trail. The sculpture of the lateral fringes consists of irregular riblets and striations oblique to the axis of the trail.

This trace is variable in the details of its sculpture. (text-fig. 23*c–i*). There are specimens in which the grooves bordering the median lobe are not so deep as in the holotype and gently pass into the slope of the lateral lobes (text-fig. 23*d*). These two modes of lateral grooves may occur in one and the same specimen, but more frequently the grooves maintain the same character along the whole length of the trail. In some specimens the median lobe is bordered not by grooves but by very narrow ridges (text-fig. 23*f*). Their crests may be round or flat. They are either lower than the median lobe, or project slightly above it. Their presence was noted by GÖTZINGER and BECKER (1934, figs 4 and 6). In some specimens they occur along the whole length of the trail, but more frequently are developed only in some parts of the trail, and disappear in others. This indicates that the presence or absence of lateral grooves and ridges cannot be taken as a basis for specific division of the trails grouped as *Scolicia plana*. Probably these features are due to the producer's complex type of crawling.

The riblets on the median lobe are either straight or uniformly bent in one direction. In some instances the riblets join into two or three at the edge of the median lobe.

The median lobe may have a longitudinal narrow incisions in the middle (text-fig. 23*e*). This trench seems to be devoid of any transversal striations, but it interrupts the riblets of the median lobe which are weakly bent at the contact with the trench. Again, in some specimens the trench is seen along the whole length of the trail, but usually it occurs in some parts and disappears in others, so that this feature, also noted by GÖTZINGER and BECKER (1934, figs 7, 8), cannot be taken as a specific distinction. Conversely, in one specimen (pl. 14, fig. 5; text-fig. 23*g*), instead of the median trench there is a narrow ridge, on which the transverse riblets are either slightly elevated or interrupted.

In one specimen the median incision is relatively large (1·0 to 1·5 mm) and divides the ribbing of the median lobe into two parts. The riblets are not so delicate as in other specimens; they are thicker and joined in bundles (pl. 14, fig. 4). This specimen corresponds to types 7 and 9 in fig. 4 of GÖTZINGER and BECKER (1934). It seems that this type deserves specific distinction.

The lateral fringes are not always well developed. Usually they slope towards the median lobe at a more or less low angle, but in some cases they are almost horizontal. The sculpture of the fringe is, on the whole, feebly marked or even absent. The spacing of the riblets is much less dense than in the median lobe. In contrast with *S. prisca*, the imbrication of the fringes is hardly developed.

*Scolicia plana*, like *S. prisca*, occurs gregariously: upper surfaces are crowded with these traces, loosely winding and commonly crossing through one another.

*Form B.* Specimen UJ TF 498 (pl. 14, fig. 2; text-fig. 23*h*) represents a full burrow form. The median striated lobe is bordered by two narrow rims which are cylindrical. The median lobe is also cylindrical, but flattened and not so well separated from its base as the lateral strings. The central lobe is 10 and the lateral strings are 3–5 mm wide. The lateral fringes are weakly developed, marked as shallow depressions with no sculpture at all.

The full form is not so common as the locomotion trail, and never occurs so gregariously.

**Remarks.** — Some types figured by KINDELAN (1919, pl. 5*a*) and FARRÈS (1963, fig. 6, with a trench in the median lobe) represent the locomotion trail of this ichnospecies.

**Sediment.** — Very fine-grained sandstones and siltstones. Exceptionally in one case the trail is developed in coarse material, with grains up to 1 mm in diameter.

**Association.** — Usually other traces are absent. In the Sromowce Beds posterior to *Helminthopsis irregularis.* In the Inoceramian Beds intersects *Phycosiphon.*

**Occurrence.** — Albian — Lgota Beds (frequent): Rzyki near Wadowice (in several layers), Kaczyna, Bystre. Cenomanian — Lower Godula Beds: Ustroń (the hamlet Poniwiec), Rzyki near Wadowice, Czchów. Turonian — Middle Godula Beds: Kocierz, Targoszów, Ponikiew, Jaroszowice (the hamlet Gołębiówka); Globotruncana Variegated Marls: Szaflary. Senonian — Inoceramian Beds: Łączki Kucharskie, Rzegocin, Kąkolówka, Wołodź, Nienadowa (the stream Świnka), Huwniki, Makowa, Kalwaria Pacławska, Romanowa Wola; Skrzydlna Beds: Wierzbanowa, Przenosza; Gorzeń Beds: Wierzbanowa; Upper Godula Beds: Rudnik, Czchów; Ropianka Beds: Jaworzynka, Lipnica Wielka (the hamlet Kiczora), Bieńkówka, Trzebunia, Tokarnia, Raba Wyżna, Limanowa, Wola Krogulecka, Biczyce, Biała Wyżna, Owczary, Siary (form B), Sękowa, Skwirtne. Palaeocene — Szczawnica Beds: Krościenko on the Dunajec.

*Scolicia vertebralis* n. ichnosp.

(pl. 14, fig. 1,6 text-figs 23*j*, *k*, 29)

*Holotype*: UJ TF 1478 (pl. 14, fig. 1).
*Type locality*: Bachów near Przemyśl.
*Type horizon*: Inoceramian Beds, Senonian.

*Derivation of the name*: Lat. *vertebralis* — composed of vertebrae; the median lobe consists of vertebra-shaped segments.

*Material*: 8 specimens and a similar number of occurrences noted in the field.

**Diagnosis.** — The trace is developed either as a locomotion trail (form A), or as a full burrow (form B).

*Form A*. Epichnial trilobe furrow. The very narrow median lobe consists of small transverse knobby ridges, irregular in shape, bent like a crescent in one direction, opposite to the inclination of the riblets in large lateral fringes.

*Form B*. Trilobate full burrow, median lobe very narrow and thin, with a knobby median ridge.

In the holotype the median lobe is 5 mm wide, low, while the lateral fringes are 20 mm wide. The ridges of the median lobe are closely spaced; there are 5 to 6 per centimetre of length. The lateral fringes are distinctly, although irregularly, ribbed, with an imbricated appearance, as in *S. prisca*.

The shahpe of the median lobe and the difference in the width of the median and lateral lobes are ceraracteristic of this trace. In some specimens the median lobe is only 3 mm wide and the laeral lobes 20 mm each; in a very large specimen the corresponding figures are 5 and 25 mm.

This type does not so profusely cover the upper surfaces as *S. plana* or *S. prisca*. Generally is is loosely winding, but some specimens display a guided manner of meandering.

*Form B*. Only one specimen has been found (text-fig. 23*k*). It is 35 cm wide, the median lobe very narrow (10 cm) with a slender interrupted ridge in the middle. In cross-section it has swollen lateral lobes and a comparatively depressed median lobe.

**Sediment.** — Fine-grained sandstones.

**Association.** — In some layers *Phycosiphon incertum*, *Lophoctenium ramosum*, *Helminthoida labyrinthica*. In all cases *S. vertebralis* intersects these traces. It may be cut across by *Tubulichnium incertum* (text-fig. 29).

**Occurrence.** — This is a much less common trace than *S. plana* and *S. prisca*.

Cenomanian — Lower Godula Beds: Jaroszowice (the hamlet Gołębiówka). Senonian — Inoceramian Beds: Łączki Kucharskie (either form), Kąkolówka, Bachów, Huwniki; Lower Istebna Beds: Czchów (in the interbed of "Inoceramian Beds type"); Ropianka Beds: Lipnica Wielka (the hamlet Kiczora), Grybów; Sromowce Beds: Sromowce Wyżne.

### Ichnogenus *Subphyllochorda* GÖTZINGER & BECKER, 1932

*Type ichnospecies: Subphyllochorda granulata* KSIĄŻKIEWICZ, 1970.

**Remarks.** — The name, introduced by GÖTZINGER and BECKER (1932), is regarded by HÄNTZSCHEL (1965) as a synonym of *Scolicia*. The traces grouped here, however, exhibit several distinct features (KSIĄŻKIEWICZ, 1970, p. 289). The sculpture of the ventral side is quite different from that of *Scolicia*. The dorsal side is also unlike the upper side of the *Scolicia* full burrow (cf. fig. 8 in pl. 14 and fig. 6 in pl. 15 with fig. 3 in pl. 15). The dorsal side of *Subphyllochorda* is seldom to be seen, as this trace is mostly developed as a hypichnial full burrow form well welded with the sole. If the *Subphyllochorda* cylinder is detached from the sole, one gets a convex furrow on the sole, with a median sculptureless narrow ridge bordered by two featureless depressions (this was known to GÖTZINGER and BECKER, 1932, p. 382, pl. 9*a*), while on the detached cylinder any sculpture is obliterated by welding and compaction. In some instances, however, both on the counterpart of the dorsal side in the furrow and on the back of the cylinder certain features may be seen. The ornamentation of the hypichnial furrow (pl. 15, fig. 3) consists of a median narrow zigzag winding slender ridge with delicate lateral riblets oblique to the axis of the trace, forming a plaited design (see also ABEL, 1935, fig. 205).

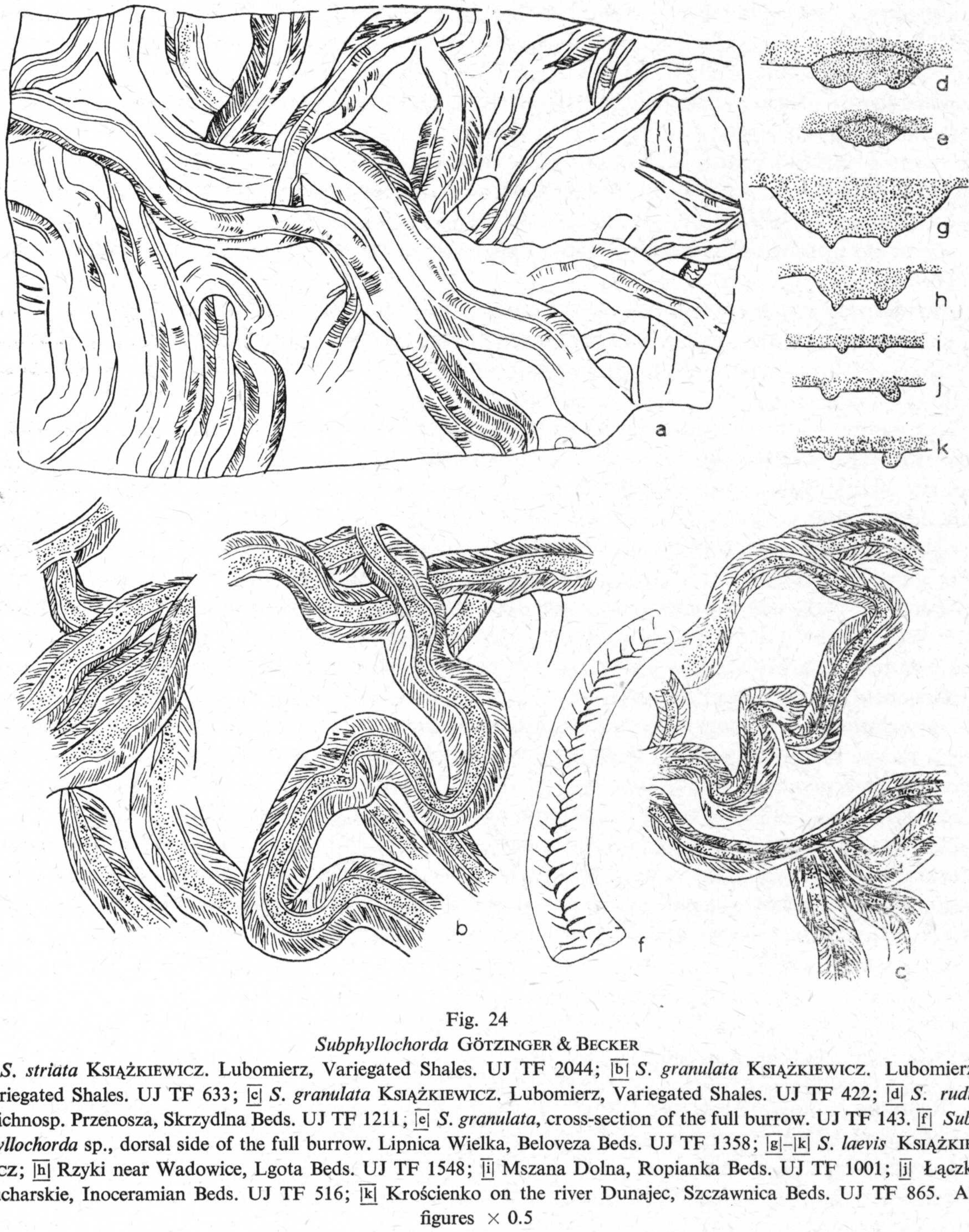



Fig. 24
*Subphyllochorda* GÖTZINGER & BECKER
a *S. striata* KSIĄŻKIEWICZ. Lubomierz, Variegated Shales. UJ TF 2044; b *S. granulata* KSIĄŻKIEWICZ. Lubomierz, Variegated Shales. UJ TF 633; c *S. granulata* KSIĄŻKIEWICZ. Lubomierz, Variegated Shales. UJ TF 422; d *S. rudis* n. ichnosp. Przenosza, Skrzydlna Beds. UJ TF 1211; e *S. granulata*, cross-section of the full burrow. UJ TF 143. f *Subphyllochorda* sp., dorsal side of the full burrow. Lipnica Wielka, Beloveza Beds. UJ TF 1358; g–k *S. laevis* KSIĄŻKIEWICZ; h Rzyki near Wadowice, Lgota Beds. UJ TF 1548; i Mszana Dolna, Ropianka Beds. UJ TF 1001; j Łączki Kucharskie, Inoceramian Beds. UJ TF 516; k Krościenko on the river Dunajec, Szczawnica Beds. UJ TF 865. All figures × 0.5

This indicates that along the crest of the *Subphyllochorda* cylinder there runs a zigzag depression with lateral grooves (text fig. 24*f*). *Subphyllochorda* is essentially a hypichnial full burrow, but in some instances assumes an endichnial (text-fig. 25) or even epichnial position. In the latter case it is a full burrow, occurring just above the upper surface of the sandstone, but so flattened by compaction that is looks like an epichnial trace similar to the *Gyrochorte* type (ex aff. *Gyrochorte*, KSIĄŻKIEWICZ, 1960, p. 742, 747, pl. 3, fig. 11; 1970, p. 288, pl. 1*b*, see pl. 15, fig. 4 in this paper). The plaited design in this case is developed as grooves. No similar features have been detected in *Scolicia*.

**Origin.** — GÖTZINGER and BECKER (1932, 1934) ascribed *Subphyllochorda* to the activity of gastropods, but the ornamentation on the ventral side of these traces can hardly be related to the sculpture that can be produced by the gastropod foot. The trilobate design on the ventral side, together with the trilobate zoning of the dorsal side, may suggest holothurians as the producers. The size and shape of the cylindrical full burrows of *Subphyllochorda*, dorso-ventrally flattened, may correspond to an excavation made by the elongated cylindroid body of a sea cucumber. Several holothurians have a three-lobed ventral side, like *Leptosynapta*, *Cucumaia* and others. The median lobe of the ventral side may correspond to the midventral zone, and the median dorsal zone may be compared to the mid-dorsal zone, which in holothurians is always developed differently from the midventral zone. The lower surface of the burrow may thus correspond with the ventral creeping surface of the animal. The midventral zone is provided with numerous, densely spaced locomotory podia. Their creeping may form the ornamentation of the median lobe, which in *S. granulata* consists of numerous tiny tubercules, also irregularly spaced. The transversal riblets seen in the median zone of *S. striata* and less distinctly in *S. rudis* may be due to the body contractions by means of which the animal advances. On the arched dorsal side of holothurians the podia are rudimentary and converted into warts and papillae. The sideways movement caused by lateral undulation during the animal's motion could form the quasi-plaited ornamentation of the dorsal side. In some holothurians the flat creeping surface is often sharply marked off from the arched dorsal surface by a projecting rim. It is possible that the lateral narrow ridges bordering the median lobe of *Subphyllochorda* reflect this feature .The body surface of most holothurians is thick, leathery and slimy. When the animal slowly pushed forward in the sediment it could form a gallery with well-impressed details of its superficies. Many holothurians are surface creepers and leave traces in the form of pits arranged in rows (HEEZEN & HOLLISTER, 1971), but many live wholly or partly buried in muddy or sandy sediments. Some of them, like *Leptosynapta*, spend their entire lives buried in the sediment. Their sluggish habits and slow movements may facilitate the impression of their superficies on the wall of the galleries they make.

The burrowing holothurians ingest the sediment as they advance (HYMAN, 1955). Their intestines are full of mud and sand. As seen in longitudinal cross-sections, the gallery is filled with a material which consists of concentrically curved laminae (text-fig. 25). This backfill could be produced by contractions of the animal's body proceeding from the anal region forward and compressing the excretory material. It should be added that similar crescent-shaped structures were described by REINECK, 1963 (pl. 5, fig. 19, pl. 7, fig. 30) as burrows of sea urchins.

### *Subphyllochorda granulata* KSIĄŻKIEWICZ, 1970
(pl. 15, figs 3, 5; text-fig. 24*b*, *c*, *e*)

1970. *Subphyllochorda granulata* ichnosp. nov., KSIĄŻKIEWICZ, p. 289, pl. 1*g*.
*Holotype*: UJ TF 1542 (pl. 15, fig. 5).
*Type locality*: Lipnica Wielka near Nowy Targ.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *granulatus* — granulated; the median lobe is covered with tiny tubercules.
*Material*: 13 specimens and about 50 occurrences noted in the field.

**Diagnosis.** — Hypichnial trilobed, rope-sized full burrow, in some cases like a hypichnial furrow. Median lobe densely and irregularly covered with tubercules.

**Description.** — The holotype forms a long ridge nearly 10 mm high and 18 to 25 mm wide. It is divided longitudinally into three zones. The median lobe is slightly convex, almost flat, about 8 mm wide, covered with small tubercules, irregularly spaced, some of the tubercules are elongated. The median lobe on either side is bordered by rims 1.0 to 1.5 mm wide. The surface of the rims is rough, as if consisting of small granules or transversally ribbed. The lateral lobes are 5 to 10 mm wide. They are densely covered with oblique delicate striation and some irregular tubercules are also present. The trace is subcylindrical, but the re-entrants on its flank seem to indicate that the burrow is actually cylindrical. The winding is irregular.

This ichnospecies is variable in size but the pattern of its sculpture is always the same. The width ranges from 2 to 3 cm. Small forms occur together with the large ones (text-fig. 24*b*). The rims bordering the median lobe may be thicker than in the holotype (up to 3 mm), but may be thinner and in some specimens are scarcely developed. They may be more distinctly ribbed than in the holotype. The winding is very irregular (text-fig. 24*b*, *c*), but never assumes the pattern of guided meanders. Intersections and interpenetrations are common. Usually this trace densely covers the soles, but may occur alone. In one specimen (UJ TF 1626, Sromowce Niżne, Sromowce Beds) the lateral lobes are granulated, while the median lobe is smooth. Perhaps this poorly preserved specimen should be treated as belonging to another ichnospecies.

**Sediment.** — Very fine-grained sandstones and siltstones, thin-bedded (the thickest 4 cm).

**Association.** — *Desmograpton.* May be intersected by *Sabularia*, but distorts *Paleodictyon* nets.

**Occurrence.** — Turonian — Siliceous Marls: Krasiczyn; Middle Godula Beds: Ponikiew; Globotruncana Marls: Sromowce Niżne. Senonian — Ropianka Beds: Wola Kroguleckа; Sromowce Beds (frequent): Maruszyna, Szaflary, Sromowce Wyżne, Sromowce Niżne, Niedzica. Palaeocene — Szczawnica Beds: Krościenko of the Dunajec. Palaeocene-Lower Eocene — Variegated Shales (frequent): Złatna (in several adjacent layers), Zubrzyca Górna, Zaryte, Lubomierz (numerous in several layers), Szczawa (the stream Głębieniec), Półrzeczki, Zbludza, Stara Wieś, Popowice, Kąclowa. Lower Eocene — Beloveza Beds (frequent): Złatna, Zubrzyca Górna, Lipnica Wielka, Lipnica Mała, Podwilk, Sidzina, Koninka, Lubomierz (here particularly frequent), Zbludza, Trzetrzewina, Popowice, Berest; Ciężkowice Sandstone: Ciężkowice (cf., in shaly interbed). Middle Eocene — Hieroglyphic Beds: Istebna, Rajcza, Orawka, Kojszówka, Tokarnia, Koninka, Hańczowa, Żubracze, Liszna (cf.); Łącko Beds: Kamienica near Nowy Sącz. Eo-oligocene — Menilitic Shales: Dołżyca.

### *Subphyllochorda striata* KSIĄŻKIEWICZ, 1970

(pl. 15, fig. 1; text-fig. 24*a*)

1970. *Subphyllochorda striata*, KSIĄŻKIEWICZ, p. 290, pl. 1*f*.
*Holotype*: UJ TF 135 (pl. 15, fig. 1).
*Type locality*: Lubomierz near Mszana Dolna.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *striatus* — striated; the median lobe of the trace is striated.
*Material*: 6 slabs, each with numerous traces, and a few occurrences noted in the field.

**Diagnosis.** — Hypichnial trilobed, rope-sized full burrow. Median lobe transversally striated.

**Description.** — The holotype is subcylindrical, 20 mm wide. The median lobe, 8 mm wide, is bordered by lateral rims, 1–1·5 mm wide. Their surface is smooth. The striation of the median lobe is fairly coarse, there are 12–15 tiny riblets to the centimetre, and the striation of the marginal lobes is very delicate (18–20 striations per centimeter). The trace is loosely winding.

The dimensions and shape of this ichnospecies are similar to *S. granulata*, and the style of winding, with many level-crossings and overlaps, is identical (text-fig. 24a). This is less common than *S. granulata.*

**Sediment.** — Fine-grained sandstones and siltstones, thin-bedded (up to 3 cm).

**Association.** — Sometimes together with *S. granulata.*

**Occurrence.** — Turonian — Globotruncana Marls: Sromowce Niżne; Middle Godula Beds: Wiśniowa (a stream on the slope of Mt. Ciecień). Senonian — Gorzeń Beds: Gorzeń Dolny. Palaeocene-Lower Eocene — Variegated Shales: Zubrzyca Górna, Trzebunia, Lubomierz, Kąclowa. Lower Eocene — Beloveza Beds: Lipnica Mała, Zubrzyca Górna (the hamlet Moniaków), Lubomierz (here rather common). Middle Eocene — Hieroglyphic Beds: Jachówka (the hamlet Worownikówka).

*Subphyllochorda rudis* n. ichnosp.
(pl. 15, fig. 2; text-figs 24*d*, 25)

*Holotype*: UJ TF 1211 (pl. 15, fig. 2).
*Type locality*: Przenosza near Myślenice.
*Type horizon*: Skrzydlna Beds, Senonian.
*Derivation of the name*: Lat. *rudis* — rough; unornamented type of surface.
*Material*: 20 specimens.

**Diagnosis.** — Hypichnial, also endichnial, trilobed rope-sized full burrow. Median lobe separated from the lateral lobes by furrows. No ornamentation of the surface.

**Description.** — In the holotype the width of the trace is 30 to 40 mm. All the three lobes are of equal height and almost of the same width, the median lobe being slightly narrower. On the turns of the winding trace the lobe situated on the outer (convex) side of the curve becomes larger. The lobes are smooth, the median lobe is transversally ribbed here and there,

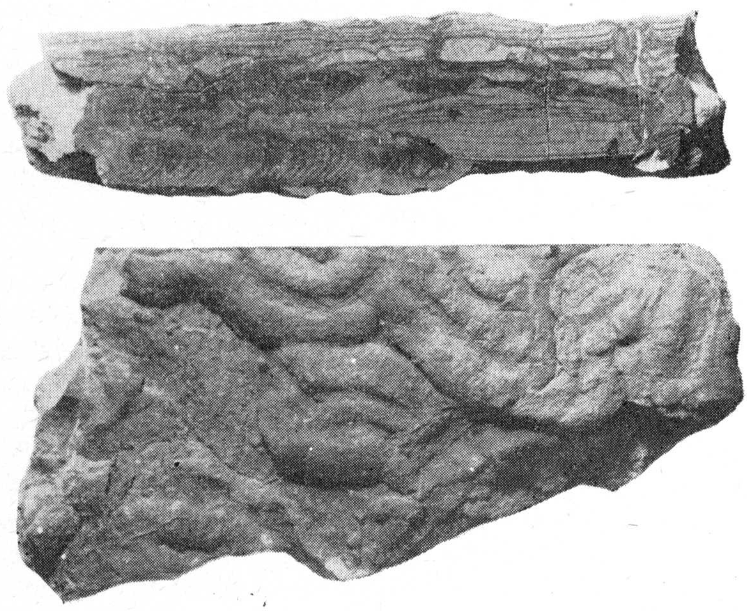


Fig. 25
*Subphyllochorda rudis* n. ichnosp. Sole full burrow (below) and its longitudinal cross-section (above). Przenosza, Skrzydlna Beds, UJ TF 1233. × 0.5

but the ribbing is indistinct. The furrows separating the median lobe from the lateral lobes is concave, 2–4 mm wide and 2–4 mm deep. The burrow is thick (about 15 mm) dorso-ventrally flattened (text-fig. 24*d*), with the lower side consisting of three convex arches, and the upper side flatly domed. The trace is irregularly winding, with some tendency to irregular meandering. It covers the sole densely, with plenty of level crossings and some overlapping. There is not much variability in this type.

**Remarks.** — The absence of ornamentation and the presence of furrows along the median lobe, instead of rims, differentiate this type from other *Subphyllochorda*. The assignment to this ichnogenus is based on its longitudinal trilobed zoning.

**Sediment.** — Thin-bedded (3–3.5 cm), fine-grained, horizontally laminated sandstones. The filling material is somewhat coarser than in the host rock.

**Association.** — Intersects *Helminthoida crassa*, *Paleomeandron elegans*.

**Occurrence.** — Senonian — Skrzydlna Beds: Przenosza (here frequent); Gorzeń Beds: Gorzeń Dolny.

### *Subphyllochorda laevis* Książkiewicz, 1970
(pl. 16, figs 1–3; text-fig. 24*g–k*)

1970. *Subphyllochorda laevis*, Książkiewicz, p. 290, pl. 1*e*.
*Holotype*: UJ TF 1548 (pl. 16, fig. 1).
*Type locality*: Rzyki near Wadowice.
*Type horizon*: Lgota Beds, Albian.
*Derivation of the name*: Lat. *laevis* — smooth; the trace has no ornamentation.
*Material*: 9 specimens (slabs) and about 20 occurrences noted in the field.

**Diagnosis.** — Hypichnial trilobed ridge-like cast, with two narrow longitudinal ridges on the ventral side, loosely winding.

**Description.** — A fragment of a loosely winding trail, 30 mm wide and 10 mm high has been taken for the holotype. The median lobe, 7–8 mm wide is flat or even concave, bordered by two strongly marked ridges, 1 mm wide. The trace occurs singly, but in the close vicinity there are paired winding parallel ridges, in all likelihood belonging to the same ichnospecies. There is no boundary whatsoever between the filling material and the material of the host rock.

Similar traces occur in many beds, but their development is variable. Most commonly they occur as paired narrow parallel ridges up to 2 mm high and 1 to 3 mm wide, resting directly on the sole, with the median lobe, 4 to 8 mm in width, lying between them on the same level as the sole. In some parts of its course the trace is elevated above the surface and the paired ridges rest on a pedestal, as in the holotype (text-fig. 24*g–k*). The pedestal may be 1 to 4 mm high. The winding is irregular with no guided meandering and hardly any straight courses. The trace usually covers the sole densely over large areas: surfaces of several square metres covered with this trace have been observed in the Senonian Ropianka Beds and in the Oligocene Krosno Beds. In many occurrences the covering is so dense that hardly any part of the sole is left unaffected by trailing. Level crossing is promiscuous. There are, however, some cases in which the trace occurs singly.

**Remarks.** — The assignment of this trace to *Subphyllochorda* is based mainly on the existence of the median lobe which, as in *S. granulata* and *S. striata*, is bordered by narrow rims. The flanks of the pedestal may correspond to the lateral lobes in other *Subphyllochorda*. If the pedestal form is not developed and the ridges bordering the median lobe are thick, the form resembles *Taphrhelminthopsis*, but in this case the flat median lobe differentiates the type discussed from *Taphrhelminthopsis*, in which the corresponding part of the trace assumes the form of a large concave trough.

**Sediment.** — Fine-grained sandstones, up 15 cm thick.

**Association.** — In one case (Dębna, Krosno Beds) penetrated by *Zoophycos*.

**Origin.** — No full burrow form has been found. The holotype is a cast, but there are no indications whether the cast is a sedimentation or a collapse cast. In some instances (Dźwiniacz Dolny, Krosno Beds) the trace occurs on the sole of a current-laminated sandstone. These features suggest that the trace is a pre-depositional locomotion trail. The variable height of the structure may be due to the varying amount of truncation by the current, which might remove the upper part of the pre-depositional furrow down to a level at which only the bordering ridges were preserved.

**Occurrence.** — Albian — Lgota Beds: Rzyki near Wadowice, Kaczyna. Turonian — Siliceous Marls: Krasiczyn; Middle Godula Beds: Targoszów; Globotruncana Marls: Sromowce

Wyżne (the hamlet Kąty). Senonian — Inoceramian Beds: Łączki Kucharskie, Kąkolówka; Ropianka Beds: Mszana Dolna (a stream on the slope of Mt. Lubogoszcz — several adjacent beds with numerous trails), Limanowa; Sromowce Beds: Krempachy. Lower Eocene — Beloveza Beds: Popowice, Berest. Middle Eocene — Hieroglyphic Beds: Juszczyn (the hamlet Kozłownik). Oligocene — Krosno Beds: Dębna, Dźwiniacz Dolny (the stream Królów — a few sandstones with soles densely covered by this trail); Krościenko on the river Strwiąż (coll. K. Wójcik).

Ichnogenus *Taphrhelminthopsis* Sacco, 1888

*Type ichnospecies: Taphrhelminthopsis auricularis* Sacco (Häntzschel, 1962).

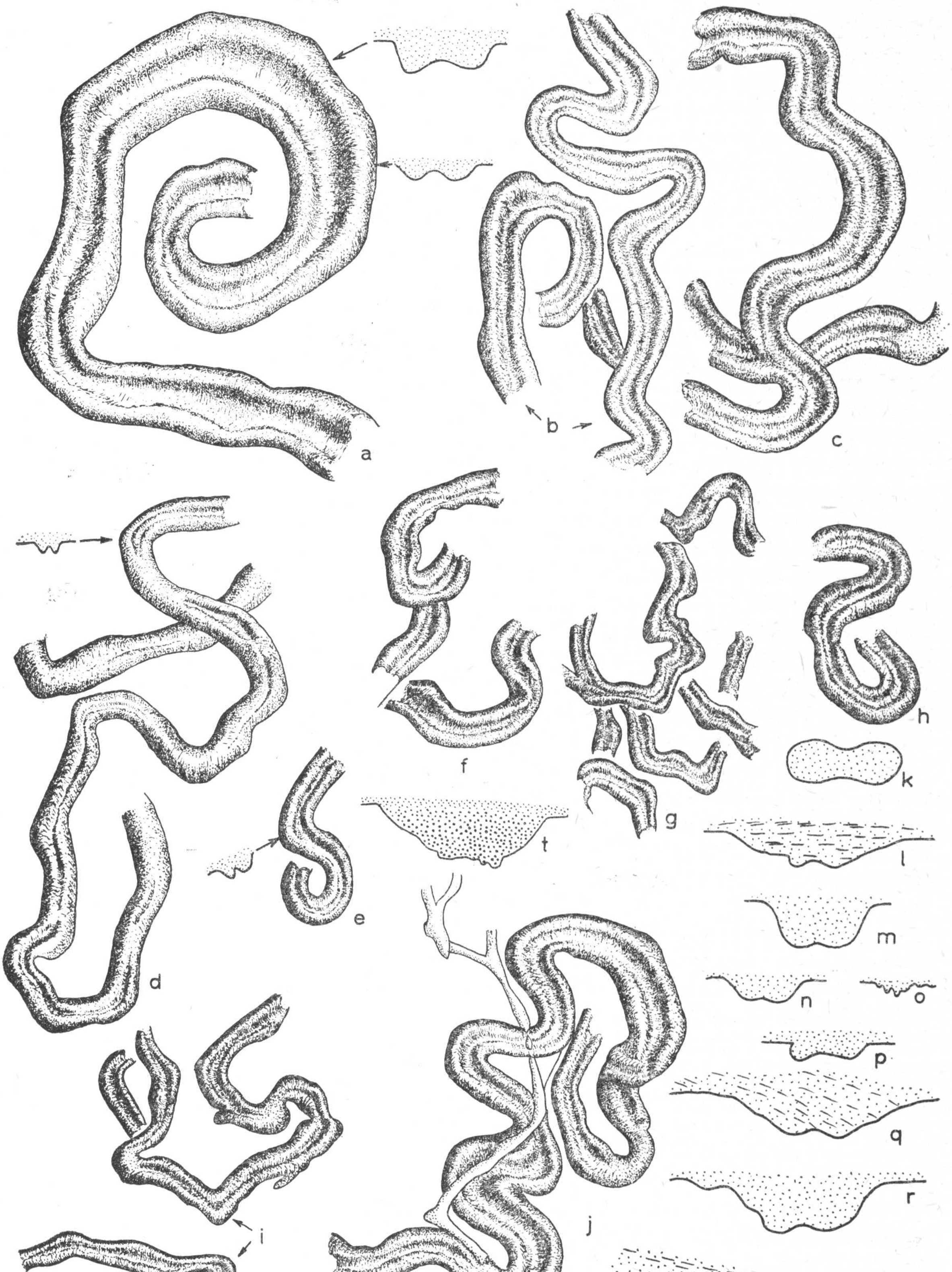
**Remarks.** — Sacco (1888) grouped here bilobate, irregularly winding ("gyro-flexuous" traces with a distinct median trough (Greek — tafrós). None of his six "species" shows a guided type of meandering. The form chosen by Häntzschel (1962, 1965, p. 91) as the type species *(T. auricularis)* is also irregularly winding. Theoretically, it may be presumed that a freely winding trace may pass into a obligatorily meandering form. Although the present author has collected more than 50 specimens which may be assigned to *Taphrhelminthopsis* and observed dozens of this type in the field, nowhere have intermediate types been found. Since double guided meanders were also assigned to *Taphrhelminthopsis* (Häntzschel, 1962), the range of this genus has been enlarged, not in accordance with the meaning given to it by Sacco. It is therefore proposed to classify all types with guided meanders under the term *Taphrhelminthoida* (by analogy with *Helminthoida*, which is characterized by guided meanders), and freely winding forms group under the term *Taphrhelminthopsis* in Sacco's sense.

Most of the specimens assigned here are hypichnial, occasionally epichnial (1 specimen). In addition there are two endichnial full burrows which may be suspected of belonging to this ichnogenus.

**Origin.** — Most of the traces are casts. This is indicated by the filling with much coarser material than the host rock (text-fig. 26*t*, see also Książkiewicz, 1960, pl. 2, fig. 8; 1970, pl. 2*d*), or with obliquely laminated sand, as seen in many specimens (text-fig. 26*q*, *s*). It may be presumed that these traces were formed either as surface locomotion trails by animals crawling on the sea-bottom, or, in conformity with the hypothesis of Seilacher (1962), they are excavated burrows: the current removed the soft muddy filling of the full burrow made in the mud and filled the excavated furrow with sand. Since the traces on the whole do not show any traces of erosion, the first interpretation seems to be more plausible, but the second presumption should also be kept in mind, as some full burrow forms that may be related to this ichnogenus have also been found, as already mentioned, in the Carpathian flysch.

The presence of the median trough bordered by lateral ridges indicates that the creeping animal had a longitudinal furrow on its ventral side. When it crept on a soft substratum it could form moulds with a central ridge (the trough in the trace) bordered by furrows (the lateral ridges in the trace). Solenogaster is an animal with a longitudinal furrow on its ventral side. Some solenogasters descend to deep bathyal depths and live on the muddy bottom.

However, if the full burrow form (pl. 17, fig. 7; text-fig. 26*k*) is rightly assigned to this ichnospecies, the trough in the upper side of the burrow is difficult to account for if the burrow were made by a solenogaster. Therefore other interpretations should be examined. The producer must have been a fairly large long animal with a cylindrical body, perhaps an acorn worm. Enteropneusts are provided on the trunk of the body with mid-dorsal and midventral longitudinal ridges. These ridges are often sunk into longitudinal depressions (Hyman, 1959, p. 87). In such a situation the crawling animal may produce a trail with a medium ridge, bordered on either side by furrows. Its mould would correspond to the *Taphrhelminthopsis* trail. Moreover, if an enteropneust with sunken ridges burrowed in sediment and filled its excavation with



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processed material, a burrow oval in cross-section with slight lateral depressions might be formed, as in the case of the presumed full burrow form of *Taphrhelminthopsis vagans* (text-fig. 26*k*). BOURNE and HEEZEN (1965) have already compared some meandering traces photographed on the sea-bottom made by giant acorn worm with the meandering traces of *Taphrhelminthopsis*. But there is another difficulty. The manner of locomotion of enteropneusts, particularly of those living at great depths is not well known, but certain facts are known about the shallow-water types. According to HYMAN (1959) and BARRINGTON (1965) the proboscis and its anchoring action are the main locomotory agents, while the trunk is passively pulled along. In several specimens of *Taphrhelminthopsis* some transverse riblets or striations are marked on the ridges. This points rather to an animal creeping by means of peristaltic movements of its body. This might by expected if the animal were a solenogaster.

### *Taphrhelminthopsis auricularis* SACCO, 1888

(pl. 17, figs 1–3; text-fig. 26*a–j*)

1888. *Taphrhelminthopsis auricularis* SACC., p. 172, pl. 2, fig. 3.
*Material*: 32 specimens and about 50 occurrences noted in the field.

**Description.** — There is a great diversity in the size, form and the manner of winding. It is so great that it may be suspected that different ichnospecies have been lumped here under one name. There are, on the other hand, so many intermediate forms between extremal types that it is not possible to find a basis for the separation of actually distinct ichnospecies.

The type specimen of SACCO is 10 mm wide, with the median trough 3 mm wide and the ridges 2 mm high. In our material the width of the trace ranges from 8 to 40 mm, most commonly being 15 to 20 mm. The width of the median furrow varies from 4 to 12 mm and in most cases is about 6–7 mm. The height of the ridge may attain 20 mm; in most cases it is about 10 mm, in some specimens being as low as 3–4 mm. The median trough is usually deep, but never so deep as to reach the level of the underface. The lateral ridges slope gently toward the trough. In most specimens the ridges and the trough are smooth, but in some delicate oblique striations are visible. The manner of winding is very variable. There are specimens with large meander-like "sweeps", the meanders are of different shape in one and the same specimen, some are low and broad, while others are higher, narrow or constricted. Auricular winding is not uncommon (pl. 17, fig. 1). In some specimens the trail ends spirally (text-fig. 26*a*, *e*).

**Sediment.** — Fine- or medium-grained sandstones, graded, laminated or small-scale current laminated.

**Association.** — *Paleodictyon strozzii*, *Desmograpton fuchsi*, *Helminthoida crassa*.

**Occurrence.** — Cenomanian — Lower Godula Beds: Ustroń (the hamlet Poniwiec), Rzyki near Wadowice (the stream Doliny), Czchów, Bieśnik. Turonian — Middle Godula Beds: Kocierz, Targoszów, Bieśnik (the stream Palenica). Senonian — Inoceramian Beds: Łączki Kucharskie, Łodzinka, Huwniki, Romanowa Wola; Upper Godula Beds: Jawornik, Kocierz,

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Fig. 26
*Taphrhelminthopsis* SACCO

a–j *T. auricularis* SACCO; a Mszana Dolna, Ropianka Beds (after field photography), b Berest, Beloveza Beds (field drawing), c Sidzina, Beloveza Beds, UJ TF 550, d Lipnica Mała, Beloveza Beds, UJ TF 543; e Lubomierz, Beloveza Beds, UJ TF 517, f Mordarka, Variegated Shales, UJ TF 659, g Lipnica Mała, Beloveza Beds, UJ TF 511; h Limanowa, Variegated Shales, UJ TF 649; i Zubrzyca Górna, Beloveza Beds, UJ TF 812; j Zubrzyca Górna, Beloveza Beds, UJ TF 703; k cross-section of an ?*Taphrhelminthopsis* (endichnial), Grzechynia, Magura Sandstone, UJ TF 1207; l–o *T. vagans* n. ichnosp.: l Sidzina, Beloveza Beds. UJ TF 869; m Szaflary, Sromowce Beds, UJ TF 531; n Dźwiniacz Dolny, Krosno Beds, UJ TF 748; o Sromowce Wyżne, Sromowce Beds, UJ TF 580; p Sidzina, Beloveza Beds, UJ TF 520; q Kaczyna, Lgota Beds, UJ TF 868; r Łączki Kucharskie, Inoceramian Beds, UJ TF 533; s Lipnica Mała, Beloveza Beds, UJ TF 867; t *T. recta* SACCO; Zubrzyca Górna, Magura Sandstone, UJTF 870.
All figures × 0.5

Czchów; Lower Istebna Beds: Czarnorzeki (in "fucoid" marls); Cisna Beds: Jaśliska; Ropianka Beds: Sopotnia, Lipnica Wielka (the hamlet Kiczora), Mszana Dolna (a stream on the slope of Mt. Strzebel), Mszana Dolna (the stream Szarków), Szczawa, Mordarka, Limanowa (the hamlet Marciszów) Gıybów, Kąclowa, Brzeźna, Kwiatoń. Palaeocene — Babica Clays: Chmielnik; Szczawnica Beds: Krościenko on the river Dunajec. Palaeocene-Lower Eocene — Variegated Shales: Limanowa, Mordarka. Lower Eocene — Beloveza Beds (frequent): Lipnica Mała, Zubrzyca Górna, Sidzina, Szczawa (the stream Głębieniec) Zalesie, Porąbka Wielka, Półrzeczki, Popowice, Berest. Middle Eocene — Hieroglyphic Beds: Istebna (Olza valley), Pewel Wielka, Osielec, Przybradz (coll. W. SZAJNOCHA); Wola Krogulecka. Upper Eocene — Magura Sandstone: Ujsoły (the stream Złatna). Oligocene — Krosno Beds: Dębna, Dźwiniacz Dolny (the stream Królów).

*Taphrhelminthopsis vagans* n. ichnosp.
(pl. 17, figs 4, 5; text-fig. 26*l–s*)

1970. *Taphrhelminthopsis* aff. *recta* SACCO, KSIĄŻKIEWICZ, p. 290, pl. 2*a–d*.
*Holotype*: UJ TF 869 (pl. 17, fig. 5; text-fig. 26*l*).
*Type locality*: Sidzina near Jordanów.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *vagans* — wandering; the irregular windings of the trail.
*Material*: 20 specimens and at least a similar number of occurrences noted in the field.

**Diagnosis.** — Hypichnial ridge-like cast, bilobate, almost straight or feebly winding, with median concave trough bordered by round ridges.

**Description.** — In the holotype the width of the ridge is 5 cm, its height about 13 mm, and the median trough is 5 mm wide. The trace is very long (neither end not beginning), gently winding. The surface of the trail is smooth. It occurs on the sole in company of another almost identical trail; they do not intersect one another.

There are many similar specimens whose width ranges from 1 to 5 cm. The median furrow is never so deep as to attain the level of the sole. The width of the median trough is approximately the same as that of the ridges which slope gently toward the trough. In some specimens (text-fig. 26*l*) there is a break in the outer slope of the ridges, as if they were resting on a pedestal, in somewhat similar fashion to the bordering rims in *Subphyllochorda laevis*. The height of the trail is variable, but this may be due to scouring, which might remove part of the pre-depositional furrow. The trails may be very long: in some cases gently winding trails 50 cm long were observed. This ichnospecies tends to occur singly and never covers the sole densely. In rare instances the trails cross one another (KSIĄŻKIEWICZ, 1970, pl. 2*d*).

To this ichnospecies is cautiously assigned an endichnial full burrow (pl. 17, fig. 7; text-fig. 26*k*). This is a cylindrical body constricted in the middle. Its ventral side corresponds well with the profile of *Taphrhelminthopsis* trails, and its course, gently winding, is like that of *T. vagans*. It occurs near the upper surface of a sandstone layer. If eroded, excavated and re-filled it would form a *Taphrhelminthopsis* trail. Only two specimens of this kind have been found.

**Remarks.** — *Taphrhelminthopsis* with an almost straight course was termed *T. recta* by SACCO. The specimen of SACCO (1888, pl. 1, fig. 20) is small. It is characterized by the presence of longitudinal striations in the median trough. This feature is absent in the material described, and so it has been classified as a distinct ichnospecies. Although the range of diversity in size and shape is similar to that of *T. auricularis*, no intermediate types have been noted. It should be stressed that the small fragments of *Taphrhelminthopsis*, unless clearly winding, cannot be identified and have been left as *Taphrhelminthopsis* indet.

**Sediment.** — Sandstones varying in thickness and coarseness, in many instances up to 1.5 m thick and coarse or conglomeratic at the base. The furrows acted as traps for coarse material (KSIĄŻKIEWICZ, 1970, pl. 2*d*).

**Association.** — *Paleodictyon* network and *Phycosiphon* spreite may line the trail, evidently posterior to it.

**Occurrence.** — Albian — Lgota Beds: Kaczyna. Cenomanian — Lower Godula Beds: Rzyki near Wadowice (the stream Doliny). Senonian — Inoceramian Beds: Łączki Kucharskie, Łodzinka, Huwniki; Skrzydlna Beds: Skrzydlna; Cisna Beds: Jaśliska; Ropianka Beds (frequent): Sopotnia Mała, Mszana Dolna (the stream Szarków), Raba Wyżna, Lubomierz, Wola Krogulecka (endichnial), Grybów, Uście Gorlickie; Sromowce Beds: Szaflary, Jaworki (the stream Skalski). Palaeocene — Babica Clays: Babica; Upper Istebna Beds: Czarnorzeki. Palaeocene-Lower Eocene — Variegated Shales: Złatna, Zaryte; Ciężkowice Sandstone: Ciężkowice. Lower Eocene — Beloveza Beds (frequent): Złatna, Zubrzyca Górna, Lipnica Mała, Sidzina, Zbludza, Popowice, Myślec, Berest. Middle Eocene — Hieroglyphic Beds: Zawoja (the hamlets Policzne and Podpolice), Osielec, Żubracze, Liszna; Łącko Beds: Kamienica near Nowy Sącz, Naszacowice. Upper Eocene — Magura Sandstone: Grzechynia (endichnial), Sidzina (the hamlet Zacylin), Tylmanowa, Kamionka Wielka, Zbludza, Ochotnica, Klimkówka, Wysowa. Oligocene. — Krosno Beds: Krzeszów, Sowina, Kąty, Dębna, Dźwiniacz Dolny.

### *Taphrhelminthopsis recta* SACCO, 1888

(pl. 17, fig. 6; text-fig. 26*t*)

1888. *Taphrhelminthopsis recta* SACC., SACCO, p. 172, pl. 1, fig. 20.
*Material*: 1 specimen.

**Description.** — It is a fragment of a long trail, 18 cm long, 5 cm wide and 2 cm high, with a large (1.5 cm) median shallow trough bordered by two flat ridges. The ridges are delicately striated, and in the median trough tiny longitudinal ridges are seen.

**Remarks.** — This specimen is twice as large as the specimen described by SACCO. It differs from other types of *Taphrhelminthopsis* in the presence of longitudinal striations.

**Sediment.** — Medium-grained, graded sandstone, 2 cm thick. The filling material is coarser than the host rock.

**Association.** — The trace is penetrated by a *Sabularia* burrow.

**Occurrence.** — Upper Eocene — Magura Sandstone: Zubrzyca Górna.

### Ichnogenus *Tuberculichnus* n. ichnogen.

*Type ichnospecies: Tuberculichnus meandrinus* n. ichnosp.

**Diagnosis.** — Hypichnial burrows or casts composed of knobs and tubercules arranged in freely winding rows.

**Remarks.** — Isolated or scattered tubercules of various shapes are frequent on the soles of Carpathian sandstones (text-fig. 28). They occur in almost all horizons. The diameter of these tubercules varies from 1 to a few mm. Many of them seem to be independent of fluting, as they occur both on flute casts and between them. Apart from these presumably post-depositional traces there are many which are casts. These might have been formed by the filling up of pre-existing holes. Present sea-bottoms in many regions show innumerable holes associated with conical structures (HEEZEN & HOLLISTER, 1971, fig. 6, 24). According to HEEZEN and HOLLISTER these holes are entrances to U-shaped galleries ending in excretory mounds. It may be supposed that the entrance is hardened with mucus and may be preserved as a cast when the sea-bottom is covered by sand brought by a current, but the excretory loose material of the mounds is easily washed away by the current. Therefore the soles of sandstones are covered only by tuberculoid casts, with no structures corresponding to mounds.

Apart from these irregularly scattered tubercules, aligned tubercules are met with. Aligned tubercules have been noted by LLARENA (1946), PAPP (1955) and SEILACHER (1959).

According to the shape and the manner of alignment of tubercules three types may be distinguished in the Carpathian material.

### *Tuberculichnus vagans* n. ichnosp.

(pl. 13, figs 4; text-fig. 27*c–g*)

*Holotype*: UJ TF 1036 (pl. 13, fig. 4).
*Type locality*: Sidzina near Jordanów.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *vagans* — wandering; an irregularly winding trace.
*Material*: 4 specimens and a few examples photographed or drawn in the field.

**Description.** — The holotype has an almost spirally arranged course. It consists of elongated ridge-like knobs, of various length (10 to 20 mm), which are either separated from one another by intervals up to 10 mm long, or are almost contiguous. These ridges are 3–4 mm wide and

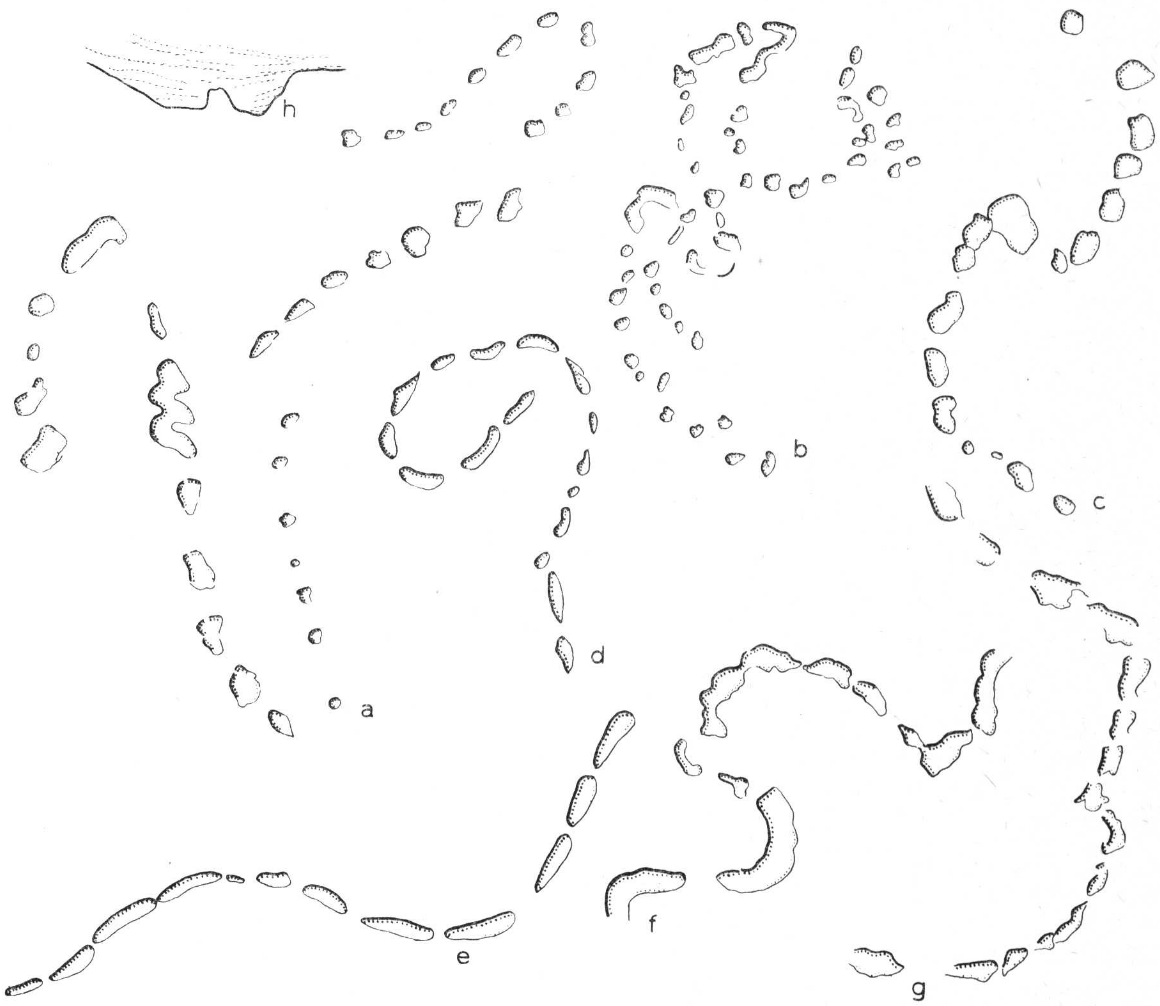


Fig. 27
*Tuberculichnus* n. ichnogen.

a–b *Tuberculichnus meandrinus* n. ichnosp.: a Mszana Dolna, Ropianka Beds (field drawing); b Berest, Beloveza Beds (field drawing), c–g *T. vagans* n. ichnosp.: c Kamienica near Bielsko, Cieszyn Limestone (field drawing); d Krościenko on the river Dunajec, Szczawnica Beds, UJ TF 773; e Lipnica Mała, Ropianka Beds, UJ TF 255; f Czchów, Upper Godula Beds (field drawing); g Krościenko on the Dunajec river, Szczawnica Beds (field drawing); h *T. bulbosus* n. ichnosp. Berest, Variegated Shales, UJ TF 855. All figures × 0·5

3–5 mm high, sharply delineated from the sole. There are re-entrants at the base of some knobs.

Another specimen from the same horizon and locality has identical knobs, but its course is more regular and broadly meandering. In other specimens the course is similar to that in the holotype, but the knobs are usually ıower.

**Sediment.** — The holotype occurs on the sole of a sandstone 8 cm thick. The sandstone is fine-grained and single-current laminated. Other specimens occur on soles of thin-bedded sandstones horizontally laminated.

Fig. 28
Tubercules on the underface, Lipnica Mała, Beloveza Beds, UJ TF 2045, × 1

**Association.** — In one instance (Beloveza Beds) together with *Helicolithus sampelayoi.*

**Origin.** — The presence of re-entrants, sharp delineation and traversing flute casts and ridge-and-furrow lineation suggest a post-depositional formation. If it is actually a full burrow, it may be presumed that the animal when working its way along the clay/sand interface ingested sand and egested it intermittently, or that it moved in bends on a vertical plane (like the caterpillars of Geometridae), partly tunneling in sand, partly in clay. Nematoda move by bending their body ventro-dorsally.

**Occurrence.** — Turonian — Middle Godula Beds: Czchów. Senonian. — Upper Godula Beds: Czchów; Ropianka Beds: Lipnica Wielka (the hamlet Kiczora). Palaeocene — Szczawnica Beds: Krościenko on the river Dunajec. Lower Eocene — Beloveza Beds: Sidzina.

### *Tuberculichnus meandrinus* n. ichnosp.

(pl. 13, fig. 5, 6; text-fig. 27*a*, *b*)

*Holotype*: UJ TF 917 (pl. 13, fig. 5).
*Type locality*: Huwniki near Przemyśl.
*Type horizon*: Inoceramian Beds, Senonian.
*Derivation of the name*: Lat. *meandrinus* — meander-like; tubercules aligned in a quasi-meandering course.
*Material*: 6 specimens and a few occurrences noted in the field.

**Diagnosis.** — Hypichnial tubercular casts arranged in irregular meanders.

**Description.** — The holotype consists of two rows of tubercules which in all probability are two limbs of an irregular meanders, about 15 cm high and 7 to 8 cm wide near its base. The tubercules are irregular in shape, circular or slightly elongated transversally to the direction of the limb. They are 7 to 15 mm wide and up to 5 mm high. They occur at intervals of different length (4 to 20 mm).

In the specimen shown in text-fig. 27*a* the meanders are narrower and the tubercules smaller than in the holotype. Still smaller are the tubercules in the specimen in text-fig. 27*b*.

**Remarks.** — The tendency to meandering differentiates this type from *T. vagans*, which is a full burrow, while the trace described is a cast.

**Sediment.** — The holotype occurs on the sole of a sandstone 12 cm thick, with composite bedding and a smooth surface, on which there is only a weakly marked graining. The same can be said of the other specimens, except for that in text-fig. 27*a* which occurs on the sole of a sandstone bed 45 cm thick.

**Association.** — *Helminthopsis*-like traces.

**Origin.** — The tubercules are not clearly demarcated on the sole and seem to be produced by the filling up of irregular holes. Two ways of producing these holes may be envisaged. Either the animal moving ventro-dorsally (like Nematoda) touched the bottom at short intervals with its tentacle or proboscis, or the holes were produced by its movement on the bottom, similar to that of the leech. In the first instance the trace would be a feeding trail, in the other a locomotion trail.

**Occurrence.** — Berriasian — Cieszyn Limestone: Kamienica near Bielsko. Hauterivian — Grodziszcze Beds: Żegocina (1 specimen with small round tubercules). Senonian — Inoceramian Beds: Huwniki; Skrzydlna Beds: Przenosza; Ropianka Beds: Mszana Dolna, Florynka. Lower Eocene — Beloveza Beds: Sidzina, Berest. Oligocene — Krosno Beds: Wujskie (Mt. Słonne).

### *Tuberculichnus bulbosus* n. ichnosp.

(pl. 13, fig. 7; text-fig. 27*h*)

*Holotype*: UJ TF 851 (pl. 13, fig. 7).
*Type locality*: Berest near Grybów.
*Type horizon*: Variegated Shales, Lower Eocene.
*Derivation of the name*: Lat. *bulbosus* — bulbous; the form of the tubercules.
*Material*: 4 specimens and a few occurrences noted in the field.

**Diagnosis.** — Hypichnial casts forming high and thick knobs, arranged in meandering(?) rows.

**Description.** — In the holotype there are 16 knobs (some with the tops broken off) arranged in two almost parallel rows which seem to be joined by the apical bend in a meander. The knobs are coniform; their basis may be 50 mm wide while the top part, smoothly rounded, is only about 10 mm wide. Their height is up to 20 mm.

In another specimen (from Tokarnia) the bulbs are 3 cm high and 4 cm wide at the base.

**Sediment.** — Fine-grained, thin-bedded (6–7 cm) sandstones with composite bedding. In one case the knobs occur on a striated surface.

**Origin.** — In the cross-section the bulbs are filled with obliquely stratified sand. This suggests a pre-depositional origin. The trace might have been produced in the same way as *T. meandrinus*.

**Occurrence.** — Lower Eocene — Variegated Shales: Berest; Beloveza Beds: Tokarnia. Middle Eocene — Hieroglyphic Beds: Żubracze.

### Ichnogenus *Tubulichnium* n. ichnogen.

*Type species: Tubulichnium incertum* n. ichnosp.

**Diagnosis.** — Void subhorizontal and horizontal tubes with lined walls.

*Tubulichnium incertum* n. ichnosp.
(pl. 11, figs 14, 15; text-fig. 29)

*Holotype*: UJ TF 938 (pl. 11, fig. 15).
*Type locality*: Bachów near Przemyśl.
*Type horizon*: Inoceramian Beds, Senonian.
*Derivation of the name*: Lat. *incertum* — uncertain; the uncertain position of this trace in relation to other traces.
*Material*: 9 specimens and many noted occurrences.

**Diagnosis.** — Endichnial (sub-epichnial) horizontal and subhorizontal long void tubes, irregularly winding with the walls lined with argillaceous substance in the form of an irregular network.

**Description.** — In the holotype the tubes are 7 to 10 mm wide. They are long; on the surface of the slab from which the holotype specimen has been taken, the tubes are about 30 cm long

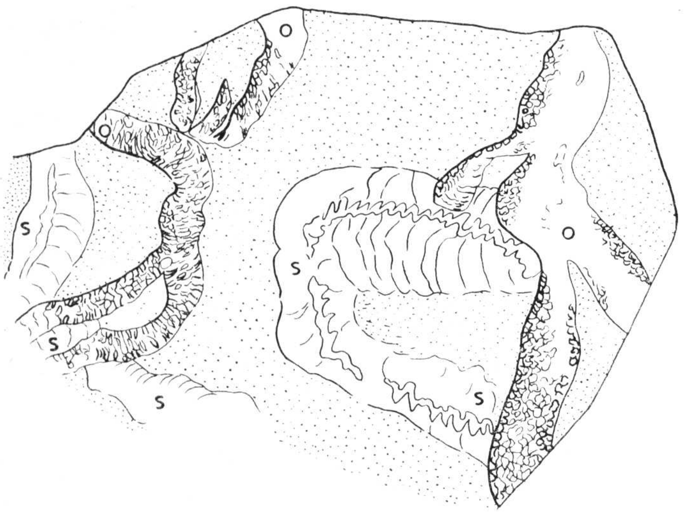


Fig. 29
*Tubulichnium incertum* n. ichnosp. (*o*) intersecting *Scolicia vertebralis* n. ichnosp. (*s*). Bachów, Inoceramian Beds, UJ TF 938

and no terminations have been found. The lining of the walls consists of clay particles with a small admixture of tiny quartz grains and muscovite flakes. The slight depressions between the spongy network are irregular, but in some parts of the tube they may be elongated and aligned at right angles to the axis of the tube. The tubes are slightly oblique to the stratification of the host rock. The branching seen in the specimen seems to be due to interpenetration and not to a true dichotomy.

In other specimens the width varies between 4 mm and 2 cm. It is also variable in one and the same specimen. The cross-section of the tubes is circular, very weakly affected by compaction. This trace always occurs near the upper surface or on it. Because it is often subhorizontal, the surface may be full of oblong holes. Occasionally the tubes are filled with clay, probably sieved in from the overlying layer. The tubes may occur gregariously, but more often they occur singly.

**Sediment.** — Fine-grained, laminated sandstone.

**Association.** — It may intersect *Scolicia* trace (text-fig. 29) and *Phycosiphon incertum*.

**Origin.** — This type may be related to *Ophiomorpha* in which the walls of the tube are lined with a coarse material. *Ophiomorpha*-like traces are commonly ascribed to the activity of thalassinid decapods. The lining might have been produced in the manner described by LUTZE (fide SCHÄFER, 1972, p. 314): the animal presses mud lumps against the tube walls to reinforce them. ABEL (1936), who illustrated a fairly similar tube (1936, p. 473, fig. 396), ascribes its origin to tubicole worms. This trace may be regarded as a feeding burrow which could serve as a temporary or permanent shelter (*Fodinichnia* of SEILACHER, 1953*a*).

**Occurrence.** — Turonian — Globotruncana Marls: Sromowce Wyżne. Senonian — Inoceramian Beds (frequent): Wara, Wołodź, Kuźmina, Bachów; Huwniki, Kalwaria Pacławska (the stream Sopotnik), Wola Romanowa; Sromowce Beds: Sromowce Wyżne; Ropianka Beds: Złatna, Mordarka, Biczyce, Wola Brzezińska, Wola Krogulecka, Siary, Uście Gorlickie. Palaeocene — Upper Istebna Beds: Kamesznica (the stream Janoska); Variegated Shales: Wola Brzezińska; Szczawnica Beds: Hałuszowa. Lower Eocene — Beloveza Beds: Sidzina. Middle Eocene — Hieroglyphic Beds: Rajcza (?), Daliowa.

## VII. SPIRAL STRUCTURES

In this small group are included two ichnogenera: *Spirorhaphe* FUCHS and *Spirophycus* HÄNTZSCHEL. They are characterized by planispiral coiling.

### Ichnogenus *Spirorhaphe* FUCHS, 1895

*Type ichnospecies*: *Spirorhaphe involuta* (DE STEFANI)

#### *Spirorhaphe involuta* (DE STEFANI, 1895)

(pl. 18, fig. 1, 2; text-fig. 30)

1895. *Helminthopsis involuta* n., DE STEFANI, p. 16, pl. 14, fig. 1.
1895. *Spirorhaphe*, FUCHS, p. 395, pl. 6, fig. 3.
*Material*: 10 specimens of small size and 3 large specimens. A few occurrences noted in the field.

**Description.** — The Carpathian material falls into two groups differing in size. In one group the strings are 0.5 to 1.5 mm wide and the diameter of the spiral does not exceed 8 cm. The spacing of the strings is comparatively dense, with a distance of 4–6 mm between the adjacent strings. In another group the strings are 2–4 mm wide, their spacing is not so close (with a distance of 3–15 mm between the strings). The diameter of the spirals may reach 40 cm. The central return loop is visible in specimens of either group.

**Remarks.** — DE STEFANI (1895) gave a somewhat vague description of this type, but he noted the existence of the return loop. His specimen, here illustrated in text-fig. 30*a*, has strings 2 to 2.5 mm wide and may be included in the second size group. The spacing in his specimen is also far from close. The question arises whether these two groups should be treated as one ichnospecies, or specifically separated. In the latter case the first group might be determined as *Spirorhaphe concentrica* (AZPEITIA, 1933, p. 46, pl. 12), and the second as *S. involuta* (DE STEFANI). It may, however, be surmised that the larger forms were made by mature animals and the small ones represent the work of juvenile individuals. Characteristically, the specimens of the small-size group have never been found together with large forms, and it seems that these two groups occur in different horizons. This would endorse their specific separation. But differences in size are certainly not a sufficient argument for specific distinction.

**Sediment.** — The small-size specimens occur in thin-bedded (up to 5 cm), single-current laminated fine-grained sandstones, whereas the large specimens have been found in fine-grained, graded sandstones, 10 to 40 cm thick.

**Association.** — Irregular thin strings of *Helminthopsis* type. May be intersected by *Sabularia*.

**Origin.** — The occasionally well developed cylindrical shape of the strings in this hypichnial

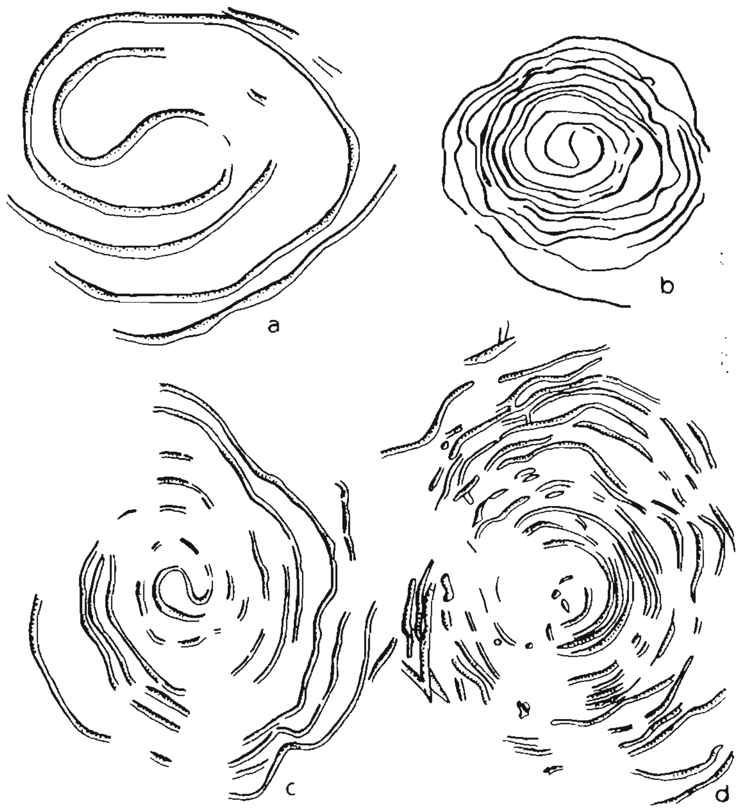


Fig. 30
*Spirorhaphe involuta* DE STEFANI
a DE STEFANI, 1895, pl. 14, fig. 1. × 0.5; b Gródek, Ciężkowice Sandstone, UJ TF 211. × 0.5; c Wola KroguIecka, Ropianka Beds, UJ TF 1850. × 0.5; d Lipnica Mała, near the Zosiak clearing, Ropianka Beds, UJ TF 210. × 0.25

trace, which may even by detached from the sole, point to a post-depositional origin. This means that the trace is a feeding burrow of the *Pascichnia sensu* SEILACHER type.

The worm *Paraonis fulgens* makes similar spirals which pass outwards into meanders (GRIPP, 1927). This has not been observed in the Carpathian material. Neither have spirals been found occurring at different levels one above the other with vertical links between them, as is described in the contemporary traces on the Baltic shore.

This trace sometimes occurs in a not wholly completed form as interrupted circular rings. In some cases, if no fragments of spirals are developed, doubts arise whether these traces actually belong to *Spirorhaphe*. There are traces like that illustrated in text-fig. 32 in the form of a circular or elliptical ring. They are hypichnial forms, in all likelihood casts. The outermost ring is the highest (in the illustrated specimen 2.5 mm) the inner rings are much lower and the inner part of the circle is smooth. The outer ring, and to all appearance also the inner rings, are interrupted in one place. It may be presumed that these traces were made by "circle scribers" which live in mud and by means of their bristles, tentacles or proboscis, grazing the mud, make circles on the sea-bottom, as described by HEEZEN and HOLLISTER (1971).

**Occurrence.** — Senonian — Inoceramian Beds: Kąkolówka (small form); Lower Istebna Beds: Tabaszowa (KSIĄŻKIEWICZ, 1960, p. 738, pl. 2, fig. 6). Ropianka Beds; Lipnica Mała (the clearing Zosiak — spirals up to 25 cm in diameter), Wola Kroguleck a (large type). Palaeocene — Upper Istebna Beds: Tabaszowa (small form), Czarnorzeki (small form). Lower Eocene — Ciężkowice Sandstone: Znamirowice, Gródek (small form, here very frequent in some layers); Beloveza Beds: Nawojowa (1 specimen, 20 cm in diameter). Upper Eocene — Magura Sandstone: Maszkowice (spiral 40 cm in diameter).


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### *Spirorhaphe zumayensis* (LLARENA), 1946
(pl. 18, fig. 3)

1946. *Helminthoida zumayensis* n. sp.?, LLARENA, p. 37, pl. 1, fig. 12, pl. 3, fig. 11.
*Material*: 9 slabs, some with a few spirals.

**Description.** — This is an exichnial form with very narrow-gauged furrows (0.1–1 mm), closely spaced. The bottom of the furrows is inclined towards the centre of the spiral. In some specimens very delicate dense transverse striations (10–12 per 1 cm) of the furrows are visible. The trace occurs on the upper surfaces of sandstones, and more frequently on the parting planes of shales. When the rock is split parallel to the bedding, almost every plane is densely covered with spirals. The size of the spirals ranges from 10 to 40 cm, and some spirals are even greater, but to extract a complete specimen from fissile shales is imposible. No return loop has been noted.

**Remarks.** — LLARENA (1946) rather doubtfully assigned this trace to *Helminthoida* and regarded it as related to *Helminthoida labyrinthica*. SEILACHER (1959) included it to *Spirorhaphe*. Identical spirals with minute furrows were previously regarded (KSIĄŻKIEWICZ, 1970, p. 305, pl. 3*e*) as a new ichnospecies named *S. minuta*. On collecting more material it appeared that there are no appreciable differences, except for the size, from the type of LLARENA.

**Sediment.** — In most cases this traces occurs in dark, almost black shales, also in marly interbeds. In very rare instances this in an interface trace at a sandstone-shale juncture.

**Association.** — Often together with *Helminthoida labyrinthica*.

**Origin.** — Probably similar to that of *S. involuta*, but produced by an animal burrowing not along the interface but inside the clay. The striae may be peristaltic in origin. Their presence seems to suggest a polychaete worm.

**Occurrence.** — Senonian — Ropianka Beds: Sopotnia Mała, Mszana Dolna (the stream on the slope of Mt. Strzebel), Wola Krogulecka. Palaeocene — Szczawnica Beds (frequent): Krościenko on the river Dunajec; Variegated Shales: Szczawa (the stream Głębieniec — here frequent in dark shales developed in the lowest part of the horizon, which is possibly equivalent to the Szczawnica Beds). Lower Eocene — Beloveza Beds: Szczawa (the stream Głębieniec).

## Ichnogenus *Spirophycus* HÄNTZSCHEL, 1962

*Type ichnospecies: Spirophycus bicornis* (HEER).

**Remarks.** — This name has been introduced by HÄNTZSCHEL (1962) to replace the term *Ceratophycus* of SCHIMPER (1879) and later authors (FUCHS, 1895). Here are included thick traces spirally coiled at one or both ends.

**Origin.** — All the three ichnospecies recognized in the Carpathian material are subcylindrical casts filled with small scale current laminated sand. There are few exceptions to this rule, like the specimen of *S. bicornis* UJ TF 567 which is a full burrow. SEILACHER (1955, fig. 5,

←

Fig. 31
*Spirophycus* HÄNTZSCHEL

a–o *S. bicornis* (HEER): a Szczawa, the stream Głębieniec, Beloveza Beds (field drawing); b Smrekowiec, Ropianka Beds (field drawing); c Zubrzyca Górna, Beloveza Beds, UJ TF 575; d Łętownia Górna, Beloveza Beds, UJ TF 208; e Zubrzyca Górna, Beloveza Beds, UJ TF 565; f Osielec, Hieroglyphic Beds, UJ TF 555; g Skomielna Czarna, Hieroglyphic Beds. UJ TF 932; h Grzechynia, Hieroglyphic Beds, UJ TF 570; i Tabaszowa, Upper Istebna Beds, UJ TF 203; j Kąclowa, Ropianka Beds (field drawing); k Ujsoły, Magura Sandstone, UJ TF 2004; l Budzów, the stream Droździna, Hieroglyphic Beds, UJ TF 206; m Harbutowice, Sub-Magura Beds, UJ TF 557; n Łętownia Górna, Hieroglyphic Beds, UJ TF 2046; o Brzeźna, Ropianka Beds (field drawing); p–r *S. caprinus* (HEER): p Tokarnia, Hieroglyphic Beds, UJ TF 796; q Łętownia Górna, Beloveza Beds, UJ TF 81; r Osielec, Hieroglyphic Beds, UJ TF 194; s–w *S. involutissimus* (SACCO): s Myślec. Hieroglyphic Beds. UJ TF 2047; t Lipnica Wielka, Beloveza Beds. UJ TF 566; u Lipowe, Variegated Shales (field drawing); w Sidzina, Beloveza Beds, UJ TF 569. All figures × 0.5

74) regarded this form as a cast, as implied by his drawing, but later (1967, fig. 4) the same form was interpreted by him as a full burrow. According to KERN and WARME (1974) *Spirophycus* is a burrow rather than a surface trace. It follows from the abundant Carpathian material that the producer most frequently lived on the sea-bottom, or just below it, but was also able to burrow below thin sand layers. *Spirophycus* is then either a locomotion trail (in most cases), or a feeding burrow. The producer might have been a polychaete, but acorn worms may also be taken into account (HEEZEN & HOLLISTER, 1971).

### *Spirophycus bicornis* (HEER, 1876)
(pl. 18, figs 4, 5; text-fig. 31 *a–o*)

1876. *Münsteria bicornis* HR., HEER, p. 165, pl. 66, figs 1*b*, 2.
*Material*: 30 specimens and numerous occurrences noted in the field.

**Description.** — This hypichnial, rope-sized trace has a smooth surface. It is most frequently curved like a crozier at one end, more rarely at both ends. There is considerable variability in the manner of coiling and the shape beyond the coiled part. The width of the trace is 10 to 15 mm, its height may be as much as 15 mm. The specimens occurring in Cretaceous beds are for the most part smaller than those in Palaeogene beds. The trace often occurs singly, but may also be gregarious. In this case two strings may touch or intersect one another, but usually they are set far enough apart not to overlap.

**Sediment.** — Mostly horizontally or current laminated sandstones fine-grained and thin-bedded (the thickest 8 cm).

**Association.** — Usually with no company. In one case posterior (full burrow) to *Helminthoida crassa*.

**Occurrence.** — Common in the lower part of the Palaeogene. Senonian — Inoceramian Beds: Łączki Kucharskie, Huwniki; Upper Godula Beds: Jawornik; Lower Istebna Beds: Istebna (the Olza valley); Ropianka Beds: Limanowa (the hamlet Marciszów), Mordarka, Brzeźna, Uście Gorlickie, Kąclowa, Smrekowiec. Palaeocene — Upper Istebna Beds: Tabaszowa. Lower Eocene — Beloveza Beds (frequent): Lipnica Wielka (KSIĄŻKIEWICZ, 1960, p. 738, pl. 2, fig. 7, reported as *Ceratophycus*), Lipnica Mała, Sidzina, Tokarnia, Szczawa (the stream Głębieniec), Trzetrzewina, Uście Gorlickie. Middle Eocene — Hieroglyphic Beds (frequent): Koszarawa, Zawoja, Osielec, Łętownia Górna, Sidzina, Grzechynia, Skomielna Czarna, Więcierza, Budzów (the stream Droździna), Tokarnia, Stara Wieś, Żubracze; Łącko Beds: Naszacowice, Myślec. Upper Eocene — Sub-Magura Beds: Harbutowice; Magura Sandstone: Ujsoły.

### *Spirophycus caprinus* (HEER, 1876)
(pl. 18, figs 6, 7; text-fig. 31 *p*, *q*, *r*)

1876. *Münsteria caprina*. HR., HEER, p. 163, pl. 65, fig. 1.
*Material*: 8 specimens.

**Description.** — This trace is similar in shape and dimensions to *S. bicornis*. The only difference is the presence of small knobs, round or feebly elongated, developed mainly on the coiled part. Some parts of the surface may be devoid of any ornamentation. The Cretaceous specimens like those of *S. bicornis*, are usually smaller than the specimens occurring in Palaeogene beds. It occurs singly, but in one or two places is gregarious.

**Remarks.** — The ornamentation in the specimen illustrated by HEER is more regular than in our material. His type is also larger than our specimens.

**Sediment.** — Fine-grained, graded or horizontally laminated sandstones up to 6 cm thi

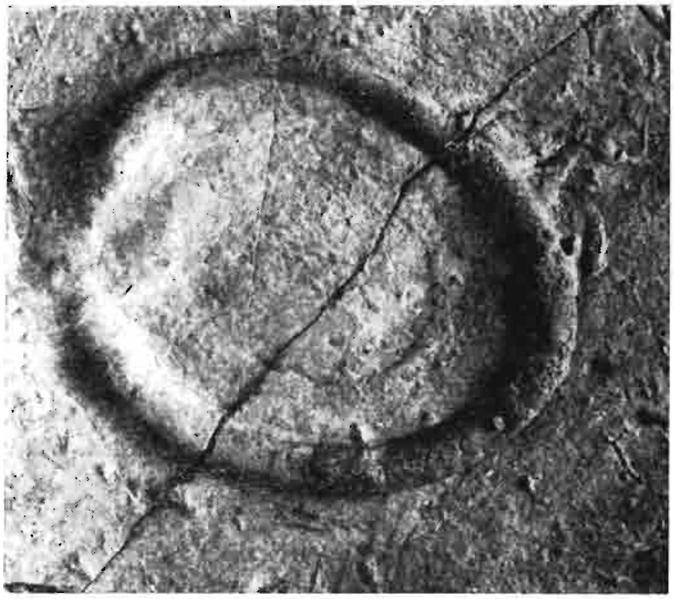


Fig. 32
Scribing trace? Przenosza, Skrzydlna Beds, UJ TF 1140. × 1

**Association.** — *Sublorenzinia pusilla*, *Protopaleodictyon submontanum*, intersected by *Sabularia*.

**Occurrence.** — Much rarer than *S. bicornis*. Senonian — Ropianka Beds: Limanowa, Wola Brzezińska, Florynka. Palaeocene — Upper Istebna Beds: Nawsie Kołaczyckie. Lower Eocene — Beloveza Beds: Zubrzyca Górna, Łętownia Górna. Middle Eocene — Hieroglyphic Beds: Milówka, Zawoja (the stream Końskie), Osielec (Przykrzec Mt.), Tokarnia, Łętownia Górna, Juszczyn, Hańczowa (one layer with this trace profusely covering the sole). Łącko Beds: Zubrzyca Górna (the hamlet Moniaków).

### *Spirophycus involutissimus* (SACCO, 1888)
(pl. 18, fig. 8; text-fig. 31*s–w*)

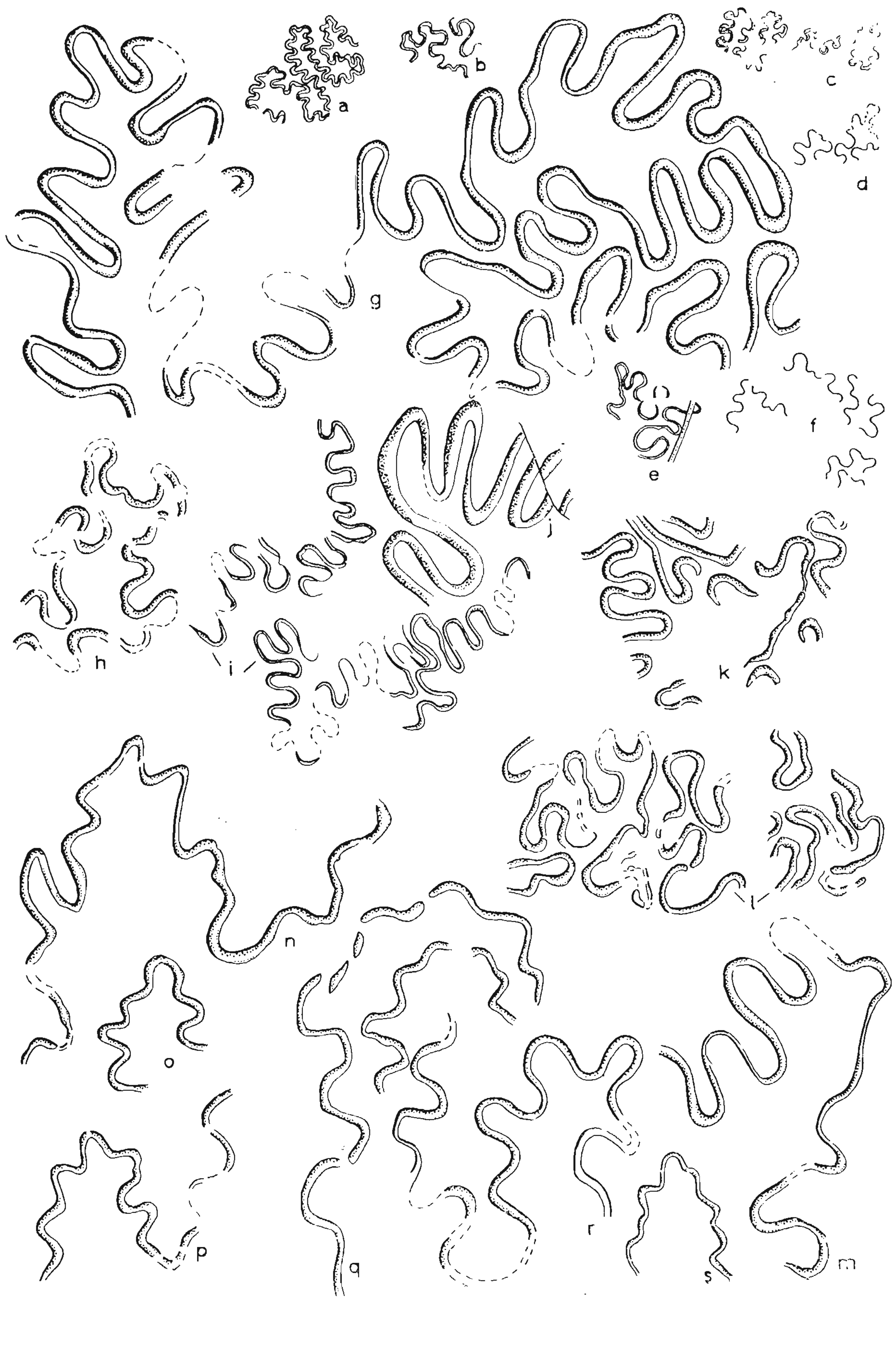
1888. *Münsteria involutissima*, SACCO, p. 168, pl. 2, fig. 14.
*Material*: 4 specimens and a few occurrences noted in the field.

**Description.** — The few specimens collected from various horizons have the following features in common: the spiral is composed of not very thick strings (6–8 mm, on the whole thinner than in *S. bicornis*), it is rather low, and there are usually three rings. This corresponds well with SACCO's description and illustration.

**Remarks.** — It may be open to argument whether *Cylindrites convolutus* FISCHER–OOSTER (1858, p. 58, pl. 15, fig. 1) is not the same form. It is somewhat larger. The specimen is broken and therefore a comparison with the material of SACCO is not possible. If it is identical, the name used by FISCHER–OOSTER should have priority.

**Sediment.** — Fine-grained, thin-bedded (up to 4 cm).

**Occurrence.** — Senonian — Gorzeń Beds: Wierzbanowa; Ropianka Beds: Brzeźna, Kąclowa. Palaeocene-Lower Eocene — Variegated Shales: Lipowe. Lower Eocene — Beloveza Beds: Lipnica Wielka, Berest; Ciężkowice Sandstone: Znamirowice. Middle Eocene — Hieroglyphic Beds: Zawoja (the stream Końskie — a trail filled with tests of *Sphaerammina*, another proof of pre-depositional origin), Lipowe, Wola Krogulecka, Myślec.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## VIII. MEANDERING STRUCTURES

Here are assigned all regularly meandering traces not provided with lateral appendages or branches. The meanders in particular ichnospecies are of approximately uniform shape. In some ichnogenera the meanders are composite: they consist of larger first-order meanders composed of smaller second-order meanders. The meanders may be either free, when the width of the meander at its base is not much smaller than its height and the arms of meander are not parallel, or forced ("guided" meanders, "geführte Meander"), when the meanders are narrow with more or less parallel arms. Finally, the path of the meander may lie in one plane, or be helicoidally wound.

The following ichnogenera are included in this group: *Cochlichnus* HITCHCOCK, *Cosmorhaphe* FUCHS, *Gordia* EMMONS, *Helicolithus* AZPEITIA, *Helminthoida* SCHAFHÄUTL, *Paleomeandron* PERUZZI, *Taphrhelminthoida* n. ichnogen.

Most types of this group may be assigned to *Pascichnia* (feeding trails of SEILACHER, 1964*a*) and some to *Repichnia*, but for several the interpretation is ambiguous.

### Ichnogenus *Cochlichnus* HITCHCOCK, 1858

*Type ichnospecies: Cochlichnus anguineus* HITCHCOCK (HÄNTZSCHEL, 1962).

### *Cochlichnus* aff. *anguineus* HITCHCOCK, 1858

(pl. 20, fig. 1; text-fig. 36*p*, *q*)

1858. *Cochlichnus anguineus* (Nov. Sp.), HITCHCOCK, p. 161, pl. 26, fig. 6.
*Material*: 3 specimens and a few occurrences noted in the field.

**Description.** — The string in the best specimen is 0·8 to 1·0 mm wide, thickened at the apices of the meanders. The meanders, which are low and broad at the base, but short, are on the whole of similar shape. The relation of the length to the height of the meanders varies within narrow limits: 8:4, 6:3, 5:3. The course of the meandering trace is almost straight or feebly winding.

**Remarks.** — There is hardly any difference from the Triassic trace described by HITCHCOCK. Some of the specimens illustrated by him are thinner and less regularly meandering, but one (left side of his fig. 6) seems to be identical.

A very similar form was described by NOWAK (1970) from the Podhale Flysch under the name ex aff. *Sinusites* RENIER, a term regarded by HÄNTZSCHEL (1965) as synonymous with *Cochlichnus*.

**Sediment.** — Thin-bedded, but in one case 15 cm thick, sandstones, fine-grained, horizontally laminated.

**Association.** — *Cosmorhaphe*, *Fucusopsis annulata*.

**Origin.** — Re-entrants on the sides of the string and its cylindrical form indicate a post-depositional origin, but Hitchcock described this trace as a "trackway".

Fig. 33
*Cosmorhaphe* FUCHS

a–f *C. gracilis* n. ichnosp.: a FUCHS, 1895, pl. 6, fig. 1. Wienerwald flysch; b Kobielnik, Szydłowiec Beds, UJ TF 1162; c Przenosza, Skrzydlna Beds, UJ TF 1138; d Wola Krogulecka, Ropianka Beds, UJ TF 1853; e Rzegocin, Inoceramian Beds, UJ TF 1755; f Gródek, Ciężkowice Sandstone, UJ TF 91; g–j *C. sinuosa* (AZPEITIA): g Grybów, Ropianka Beds, UJ TF 1872; h Chyżówki, Ropianka Beds, UJ TF 672; i Lipnica Wielka, the hamlet Kiczory, UJ TF 1118; j Lipnica Wielka, Variegated Shales, UJ TF 1107; k–m *C. helminthopsoidea* n. ichnosp.: k Limanowa, Ropianka Beds, UJ TF 829; l Limanowa, Ropianka Beds, UJ TF 828; m Osielec, Ropianka Beds, UJ TF 249; n–s *C. fuchsi* KSIĄŻKIEWICZ: n Berest, Beloveza Beds (field drawing); o Lipnica Mała, Beloveza Beds, UJ TF 2048; p Łętownia Górna, Beloveza Beds, UJ TF 2049; q Sidzina, Beloveza Beds, UJ TF 7; r Lipnica Wielka, Beloveza Beds, UJ TF 11; s Lipnica Wielka, Beloveza Beds, UJ TF 2050. All figures × 0.5

**Occurrence.** — Palaeocene-Lower Eocene — Variegated Shales: Lipowe, Uście Gorlickie. Lower Eocene — Beloveza Beds: Lipnica Mała, Zubrzyca Górna, Sidzina, Berest. Middle Eocene — Hieroglyphic Beds: Wysowa, Komańcza.

### Ichnogenus *Cosmorhaphe* FUCHS, 1895

*Type ichnospecies: Helminthopsis sinuosa* AZPEITIA (*in* HÄNTZSCHEL, 1962).

**Remarks.** — Here are included composite meanders consisting of first-order meanders with numerous second-order meanders which are guided. The surface of the string is smooth.

Neither diagnosis nor species name was given by FUCHS, who illustrated a fine specimen in pl. 6, fig. 1.

**Origin.** — There are difficulties in determining whether the representatives of this ichnogenus are pre- or post-depositional. The strings are almost always subcylindrical which does not give a clue to the answer. In one ichnospecies, *C. fuchsi*, the trace is intersected in two specimens by drag marks, but in other specimens full cylindrical forms are almost certain. It is then possible that the traces of *Cosmorhaphe* may be either pre- or post-depositional, produced by animals which could live both on the sea-bottom or close to it, but when the sea-floor was covered with a thin layer of very fine-grained sand, they were able to burrow in it along the clay/sand interface. This view seems to be corroborated by the fact that all representatives of this ichnogenus occur only on soles of very fine-grained and thin-bedded sandstones. It is also possible that some specimens are locomotion trails, and others feeding burrows of the *Pascichnia* type. The absence of any segmentation does not necessarily invalidate the presumption that the animal was a polychaete. Any worm-shaped animal or gastropod without external ornamentation could produce this trace.

### *Cosmorhaphe gracilis* n. ichnosp.

(pl. 19, figs 1, 2; text-fig. 33*a–f*)

*Lectotype*: FUCHS, 1895, pl. 6, fig. 1.
*Neotype*: UJ TF 1162 (pl. 19, fig. 1).
*Type locality* (for the neotype): Kobielnik near Myślenice.
*Type horizon* (for the neotype): Szydłowiec Beds, Senonian.
*Derivation of the name*: Lat. *gracilis* — graceful; because of the style of the pattern.
*Material*: 8 specimens.

**Diagnosis.** — Hypichnial thread-sized subcylindrical full burrow (?) gently meandering. The height of the second-order meanders is equal to their width.

**Description.** — In the specimen chosen for the neotype the string is 0.5 mm wide and a fraction of a millimetre high. The first-order meanders are up to 15 mm high and about 5 mm broad at the base. The second-order meanders are about 2 mm high and 2 mm wide. They show a slight tendency to become loop-like. The string is composed of somewhat coarser material than the enclosing rock.

In another specimen (pl. 19, fig. 2, text-fig. 33*f*) the strings are even thinner (0·3 mm); the first-order meanders are about 7 mm high and 10 mm broad at the base. The very regular second-order meanders are 2·5 to 3 mm high and almost equally wide at the base. There is no loop-like form in the second-order meanders.

Other fragmentarily developed specimens resemble more or less closely the specimens described. In the specimens from the Krosno Beds, poorly developed, the strings are thicker (almost 1 mm).

**Remarks.** — The pattern of meandering and the dimensions do not differ much from the form pictured by FUCHS. The trace is to a certain extent a miniature of *Cosmorhaphe sinuosa*, and the possibility that *Cosmorhaphe gracilis* may be a juvenile form of that ichnospecies should be kept in mind. The loop-like form of the meanders of the second-order is more accentuated in *C. sinuosa*, which is a much larger type. It should be added that *C. gracilis* never occurs together with other *Cosmorhaphe*, either on the same sole or in the same stratigraphic position.

**Sediment.** — Fine-grained laminated sandstones, a few cm thick (the thickest 5.5 cm).

**Occurrence.** — Senonian — Inoceramian Beds: Rzegocin; Skrzydlna Beds: Przenosza; Szydłowiec Beds: Kobielnik; Ropianka Beds: Wola Krogulecka, Wola Brzezińska (cf.). Lower Eocene — Ciężkowice Sandstone: Gródek (cf.) Oligocene — Krosno Beds: Wujskie, Mts. Słonne (cf.).

### *Cosmorhaphe sinuosa* (AZPEITIA, 1933)

(pl. 19, figs 3–5; text-fig. 33*g–j*)

1933. *Helminthopsis sinuosa* n. sp., AZPEITIA, p. 45, pl. 14, fig. 24*B*.
*Material*: 17 specimens and 3 occurrences noted in the field.

**Description.** — The largest specimen (text-fig. 33*g*) has a string 3.5 mm wide and 1–1.5 mm high. It consists of two first-order meanders, one of which is 21 and the other 14.5 cm in height. Their width at the base is 3 and 2.5 cm respectively. The second-order meanders are high and for the most part narrow with loop-like constrictions at the base. Their height ranges from 17 to 43 mm, the width at the base from 8 to 17 mm, and the width of the loop constriction from 2.5 to 9 mm. These figures show a certain variability in the size, but not so much in the shape, of the second-order meanders.

Another well-developed specimen (pl. 19, fig. 3) has a string 2.0 to 2.5 mm wide. The first-order meanders are not so high (11 to 15 cm) but are closely spaced. The height of the second-order meanders is 17 to 26 mm, the width at the base 5 to 12 mm, and the width of the loop constrictions is only 0.5 to 2 mm. This shows that in this specimen the second-order meanders are strongly constricted. Other specimens are smaller than the two described.

In all specimens the strings are well welded with the rock and are apparently subcylindrical, but in some specimens the string is missing in some parts of the trace and replaced by a furrow. This suggests a cylindrical form.

**Sediment.** — Thin bedded, fine-grained sandstones (the thickest bed is 25 cm).

**Association.** — May be cut by *Sabularia*.

**Occurrence.** — Senonian — Inoceramian Beds: Szczepanowice (found in the cross-section in which the present author found *Inoceramus zitteli* KOCIUBIŃSKI determ. by F. MITURA; this indicates the Upper Campanian — Lower Maastrichtian age). Ropianka Beds: Lipnica Wielka, (the hamlet Kiczora), Zaryte, Półrzeczki, Chyżówki, Limanowa, Grybów (a few specimens), Kąclowa. Palaeocene-Lower Eocene — Variegated Shales: Lipnica Wielka (the hamlet Kiczora — KSIĄŻKIEWICZ, 1970). Lower Eocene — Beloveza Beds: Lipnica Mała, Sidzina (the hamlet Drabowa) Myślec, Berest. Middle Eocene — Hieroglyphic Beds: Daliowa.

### *Cosmorhaphe helminthopsoidea* n. ichnosp.

(pl. 19, fig. 6; text-fig. 33*k–m*)

1898. *Helminthoida helminthopsoidea* SACCO, PAUL, pl. 3, fig. 1 (no description).
*Holotype*: UJ TF 77 (pl. 19, fig. 6; HÄNTZSCHEL, 1962, fig. 118, 3).
*Type locality*: *Łętownia Górna*.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: the course of the trace bears some resemblance to the course of *Helminthopsis*.
*Material*: 5 specimens.

**Diagnosis.** — Hypichnial subcylindrical string-sized full burrow (?). Arms of the first-order meanders tightly compressed, the second-order meanders also compressed, often of a loop-like form, but with intervening meanders variable in shape.

The classification of this ichnospecies is based on a specimen whose strings are 1·5 to 2 mm wide and low (0·1 mm). The first-order meanders are up to 10 cm high and very narrow at the base (less than 1 cm). The second-order meanders are fairly variable in size and shape. Their height does not exceed 20 mm. Most of them have loop-like constrictions. This type of meander is developed in one arm of the first-order meander while in the other the string winds freely or even assumes a straight course. Other specimens may be somewhat thinner. In all of them one arm of the first-order meander tends to be straight, while the other resolves into loop-like second-order meanders.

**Remarks.** — This type is related to *C. sinuosa* AZPEITIA, but the course of meandering is looser. It strongly resembles the specimen illustrated by PAUL (1898), compared by that author with *Helminthoida helminthopsoidea* SACCO (1888, p. 180, pl. 2, fig. 7). The resemblance to SACCO's type is, however, small. The type of SACCO actually represents a trace of the *Helminthoida* type (elongated, parallel meanders) with secondary meanders of irregular type, more irregular than those of the type described. The feature common to both forms is the *Helminthopsis*-like irregularity in some sectors of the trace. In this respect our type unites the features proper to *Cosmorhaphe* and to *Helminthopsis*, and SACCO'S type, as he stresses, may represent a link between *Helminthoida* and *Helminthopsis*. Therefore I abandon the previous assignment of the type discussed to the ichnospecies of SACCO (KSIĄŻKIEWICZ, 1970, p. 294, fig. 2*c*) and consider it to be a new ichnospecies.

It is open to question whether the difference in the style of meandering may be taken as sufficient ground for distinguishing this type from the similar *C. sinuosa*, other differences being small. The momentary change of the course from meandering to almost straight may be due to a phobotaxic reflex. There is however, no obvious reason which caused this abandoning of the meandering style. The animal followed its path under the influence of thigmotaxis, since it kept close to the proximity of the path already passed. Both thigmotactic and phobotactic behaviour are not observed in the same type (LESSERTISSEUR, 1955, p. 51). If the meandering was caused by thigmotactic behaviour, the abandoning of meandering might have been caused by an innate difference in the manner of locomotion of the producing animal. This reasoning may endorse the distinction of *C. helminthopsoidea* from *C. sinuosa*. The problem still remains whether this distinction should be made on the specific level, or whether this type should be treated as a "varietas", a procedure permissible in the code proposed by SARGEANT and KENNEDY (1973) for the nomenclature of trace fossils.

**Sediment.** — Thin-bedded (up to 5 cm), fine-grained sandstones with composite bedding.

**Occurrence.** — Senonian — Ropianka Beds: Osielec, Limanowa. Palaeocene-Lower Eocene — Variegated Shales: Lipnica Mała (the stream Linorka). Lower Eocene — Beloveza Beds: Łętownia Górna.

### *Cosmorhaphe fuchsi* KSIĄŻKIEWICZ, 1970
(pl. 19, fig. 7; text-fig. 33*n–s*)

1970. *Cosmorhaphe fuchsi* ichnosp. nov., KSIĄŻKIEWICZ, p. 294, fig. 2*b*, pl. 3*b*.
*Holotype*: UJ TF 243 (pl. 19, fig. 7).
*Type locality*: Zubrzyca Górna near Nowy Targ.
*Type horizon*: Łącko Beds, Middle Eocene.
*Derivation of the name*: in honour of THEODOR FUCHS.
*Material*: 25 specimens and 6 occurrences in the field.

**Diagnosis.** — Hypichnial string-sized subcylindrical cast or full burrow. First-order meanders high and broad at the base, second-order meanders also not compressed, low and wide at the base.

In the holotype the string is 1.5 mm wide and 0.5 mm high. The first-order meanders are 110 mm high and 25 mm broad at the base. The second-order meanders are rather variable, but always wide at the base and low, never compressed or constricted. Their width at the base ranges from 8 to 15 mm and the height from 3 to 15 mm. The string is not continuous: in some parts it consists of short segments 1–2 mm long. The trace is intersected by a drag mark. Other specimens do not differ much from that described. The string may be slightly thicker and the first-order meanders higher.

**Remarks.** — The absence of compression and constriction of both first- and second-order meanders differentiates *C. fuchsi* from other *Cosmorhaphe.*

**Sediment.** — Fine-grained, laminated or single-current bedded sandstones of small thickness (2–4 cm).

**Association.** — *Helicolithus sampelayoi, Paleodictyon strozzii, P. carpathicum, Halymenidium oraviense.* It intersects *Helminthoida alterna* and *Paleodictyon carpathicum.*

**Occurrence.** — Senonian — Ropianka Beds: Sidzina (the hamlet Jarominy), Szczawa (?), Limanowa (the hamlet Marciszów). Palaeocene-Lower Eocene — Variegated Shales: Zubrzyca Górna (the hamlet Ochlipów), Osielec, Brzeźna. Lower Eocene — Beloveza Beds (frequent): Lipnica Wielka, Lipnica Mała, Zubrzyca Górna, Sidzina, Jordanów (the hamlet Munkacz), Łętownia Górna, Lubomierz, Szczawa (the stream Głębieniec), Trzetrzewina, Popowice, Myślec, Berest. Middle Eocene — Hieroglyphic Beds: Leśna, Osielec, Skomielna Czarna, Żubracze; Łącko Beds: Zubrzyca Górna (the hamlet Moniaków).

### *Cosmorhaphe* (?) *tortuosa* KSIĄŻKIEWICZ, 1970

(pl. 19, fig. 9)

1970. *Cosmorhaphe*(?) *tortuosa* ichnosp. nov., KSIĄŻKIEWICZ, p. 294, pl. 3*c*.
*Holotype*: AGH (pl. 19, fig. 9).
*Type locality and type horizon*: unknown, probably Ropianka Beds in the Gorlice area (coll. J. GRZYBOWSKI?).
*Material*: 1 specimen.

**Diagnosis.** — Hypichnial string-sized meandering cast (?). Meanders of the first-order narrow, apparently consisting of numerous very tightly compressed second-order meanders.

**Description.** — Very thin strings, almost equal in length, parallel, slightly curved, are so arranged that the line joining their centres describes narrow meanders. In a few places it can be seen that the parallel strings join at their ends forming narrow arcuate bends. This may indicate that the strings are actually arms of second-order meanders set at right angles to the axis of the first-order meanders. The height of the latter is about 5 cm, their width 2.5 cm, while the length of the arms of the second-order meanders is 15 mm.

**Remarks.** — The arrangement into first- and second-order meanders would indicate that the trace may be assigned to *Cosmorhaphe*, as this kind of meandering is a typical feature of this ichnogenus.

### Ichnogenus *Gordia* EMMONS, 1844

*Type ichnospecies: Gordia marina* EMMONS (HÄNTZSCHEL, 1962).

**Remarks.** — Here are assigned slender, smooth, loosely meandering traces with numerous level-crossings. This assignment is based on the figure of *Gordia marina* EMMONS (1844, pl. 14, fig. 24, redrawn in this paper, text-fig. 36*r*) rather than on EMMONS's scanty description, to a certain extent supplemented by HALL (1847, p. 264, pl. 71) who described this trace as a meandering "slightly elevated ridge". This description is not in agreement with that given by HÄNTZSCHEL (1962) who defines this form as "mostly bent but not meandering" and does not mention the level-crossing seen in the figures of both EMMONS and HALL. Neither does the schematic drawing given by HÄNTZSCHEL correspond to the figures given by EMMONS and HALL. It represents a trace of a *Helminthopsis* type.

*Gordia molassica* (HEER, 1865)
(pl. 20, figs 4–7; text-fig. 36*s–x*)

1865. *Helminthoida molassica* HEER, p. 439, fig. 327.
*Material*: 8 specimens.

**Description.** — Here have been grouped traces of various sizes and shapes having two features in common: a tendency to guided meandering and level crossing. Most of them are hypichnial, most probably full burrows, but some are hypichnial furrows and in one case an epichnial furrow. In the hypichnial burrows the width of the string varies from 1 to 4 mm. The meandering is rather irregular: some meanders are narrow and compressed, even of loop-like form, others are looser in one and the same specimen. In some specimens (pl. 20, fig. 5) the meanders occur at three levels, one above the other, the lowest occurring on the very sole. In some specimens the meandering is rather chaotic (text-fig. 36*x*). The specimen in pl. 20, fig. 4 is a hypichnial furrow, but the style of meandering is very much the same as in other hypichnial structures. They are narrow, compressed, slightly coiled, and intersect one another on the same level. The furrows are 3–4 mm wide and 1 mm deep, fringed, with narrow levees. Evidently the animal, when working its way along the clay/sand interface, ploughed the sand away.

**Remarks.** — HEER'S type is not well defined (no description). The course of the meanders seen on his figure (reproduced here, text-fig. 36*u*) resembles rather *Helminthopsis* than *Helminthoida*, although some tendency to form loops is also seen. HEER'S figure recalls the types pictured by McCOY (1851–55, pl. 1A, figs 1–3), which he named *Palaeochorda* (= *Gordia* EMMONS 1844). The mutual intersecting of the meanders is characteristic of the material presented in papers of EMMONS, HALL and HEER (o. c.).

**Sediment.** — Fine-grained sandstones, also marls.

**Origin.** — All kinds are post-depositional. Hypichnial strings may be classified as feeding burrows or feeding trails, the hypichnial furrow as a locomotion trail. The producer was probably a polychaete worm.

**Occurrence.** — Berriasian — Cieszyn Limestone. Kamienica near Bielsko (epichnial). Hauterivian — Grodziszcze Beds (?): Wiśniowa (the stream Marków). Turonian — Siliceous Marls: Huwniki. Senonian — Inoceramian Beds: Kuźmina. Lower Eocene — Ciężkowice Sandstone: Gródek. Middle Eocene — Hieroglyphic Beds: Juszczyn (the hamlet Kozłownik), Komańcza. Upper Eocene — Magura Sandstone: Klimkówka (epichnial). Oligocene — Krosno Beds: Skrzydlna (KSIĄŻKIEWICZ, 1960, p. 739, pl. 4, fig. 14).

*Gordia arcuata* n. ichnosp.
(pl. 20, fig. 8; text-fig. 36*y*)

*Holotype*: UJ TF 1219 (pl. 20, fig. 8).
*Type locality*: Wetlina near Lesko.
*Type horizon*: Krosno Beds, Oligocene.
*Derivation of the name*: Lat. *arcuatus* — arched; arcuate bends in the apical parts of the meandering trace.
*Material*: 5 specimens and several occurrences noted in the field.

**Diagnosis.** — Hypichnial thread-sized meandering groove casts in which only apical arcuate bends are developed.

The string is very thin (0.3–0.4 mm) in the holotype (and in all specimens). The trace consists of regular arcs, intersecting one another and densely covering the sole. In some specimens the sinuous course of the trace is seen as well as a tendency to assume a loop-like form. This trace almost always occurs gregariously.

**Remarks.** — The assignment of this species to *Gordia* may be open to question, since the actual shape of the meanders, never wholly developed, is unknown. The trace may be treated as fragments of *Helminthoida* or *Helminthopsis*, but in both these ichnogenera level-crossing is absent. Its presence indicates a relationship to *G. molassica*.

**Sediment.** — Thin-bedded (1–5 cm), fine-grained sandstones, horizontally or single-current laminated, with flat soles.

**Origin.** — The level-crossing combined with partial preservation of the meanders may indicate a pre-depositional origin. The animal, presumably a small polychaete, probably incised its path more strongly in the bends of the meanders (this is suggested by the often thickened bends of other meandering traces). When the current feebly scoured the bottom, it might eliminate the shallower grooves situated between the bends.

**Occurrence.** — Oligocene — Krosno Beds: Kąty, Dydnia, Wetlina, Dźwiniacz Dolny.

## Ichnogenus *Helicolithus* Azpeitia, 1933

*Type ichnospecies: Helicolithus sampelayoi* Azpeitia (Häntzschel, 1962).

### *Helicolithus sampelayoi* Azpeitia, 1933
(pl. 23, fig. 4)

1933. *Helicolithus sampelayoi* n. sp., Azpeitia, p. 48, pl. 4, fig. 11, pl. 13, fig. 24A.
*Material*: 11 specimens and a few observations in the field.

**Description.** — In the best specimen the meanders are 30–40 mm high and 10–15 mm broad at the base. They are "guided" and in some parts their arms come close to one another, with some tendency to form loops. The string is 0.8–1.0 mm wide and in some parts 0.3 mm high. Helicoidal winding is seen along almost the whole course of the trace. This trace may cover large areas of the sole.

**Sediment.** — Fine-grained, thin-bedded (the thickest bed 14 cm) sandstones with gradational lamination or single-current bedding.

**Association.** — *Cosmorhaphe fuchsi*, *Fascisichnium extentum*, *Halymenidium*.

**Origin.** — Intersects lineation and small flute casts (pl. 23, fig. 4) in one case. This points to a post-depositional origin. The producer might have been a polychaete, as some worms of this group move helicoidally (Kükenthal and Krumbach, 1934, p. 128).

**Occurrence.** — Senonian — Inoceramian Beds: Huwniki (string 1.2 mm thick); Skrzydlna Beds: Przenosza; Ropianka Beds: Wola Krogulecka, Skwirtne (reported by Węcławik, 1969). Palaeocene-Lower Eocene — Variegated Shales: Lipowe, Wola Brzezińska. Lower Eocene — Beloveza Beds: Lipnica Mała (Książkiewicz, 1961*a*, p. 885, pl. 2, fig. 2), Zubrzyca Górna, Sidzina (the stream Głaza), Półrzeczki, Berest. Middle Eocene — Hieroglyphic Beds: Osielec, Tokarnia, Komańcza. Upper Eocene — Magura Sandstone (interbed of thin bedded sandstones and shales): Homrzyska, Rzyki near Limanowa. Oligocene — Krosno Beds: Dębna.

## Ichnogenus *Helminthoida* Schafhäutl, 1851

*Type ichnospecies: Helminthoida labyrinthica* Heer (Häntzschel, 1962).

**Origin.** — Most kinds of *Helminthoida* appear to be post-depositional, as evidenced by the cylindrical shape of the hypichnial burrows noted in many instances and by their epichnial and exichnial position of some ichnospecies. In a few cases, however, the meanders are cut across by flute casts (e. g. in text fig. 36*c*). This implies that some of the types are pre-depositional. In many specimens the meandering strings are subcylindrical, and it is not possible to say whether the excremental string was so fused with the covering sand that the contact between the fill and the covering sand was obliterated, or that the strings are casts of pre-existing surface furrows. It is possible that in some ichnospecies of *Helminthoida* some specimens are post-depositional feeding burrows, and others pre-depositional trails. At any rate *Helminthoida* are typical *Pascichnia sensu* Seilacher (1953*a*).

According to RICHTER (1928) the traces of this type might have been made by gastropods, the view supported by RECH FROLLO (1962). However, the objections of LESSERTISSEUR (1955, p. 51) seem to be justified, and it may be presumed that *Helminthoida*-like traces could have been produced by worm-like animals, presumably polychaetes.

### *Helminthoida labyrinthica* HEER, 1865
(pl. 21, fig. 1)

1865. *Helminthoida labyrinthica*, HEER, p. 246, pl. 10, figs 12, 13.
*Material*: 28 slabs and very many occurrences noted in the field.

**Description.** — This trace, in most cases occurring in an exichnial or apparently epichnial position, always covers large surfaces. When the rock is split in very thin sheets (about 1 mm thick) each sheet is densely covered by this trace. The meanders are on the average 2–3 cm, rarely 4–5 cm high, very narrow and so closely packed that the distance between two neighbouring meanders is less than 1 mm, and only exceptionally 2–3 mm. The width of the furrows is 0.7 to 1.0 mm. The meanders are often coiled, and even arranged in spirals. The furrows, apparently empty, are often filled with the same material of which the rock consists, in some cases by infiltrations of limonite or calcite. The narrow-gauged meanders never cross one another in one plane, but are sometimes intersected by larger meanders which are higher and differ in style; they are not so tightly spaced. In some instances the closely spaced narrow-gauged meanders are intersected or superposed by the looser meanders of large-gauged furrows, as pictured by GÖTZINGER (1951, p. 244, fig. 3).

There are numerous occurrences of a similar but much larger kind with the furrows 2.0 to 2.5 mm wide, arranged in elongated meanders (5–10 mm). As in the small form, these meanders densely cover the parting planes. Not only the dimensions but also the manner of meandering is different from that of the typical *H. labyrinthica*. The meanders, although forced, are not so tightly compressed and coiling is practically absent. This trace occurs much less frequently than the narrow-gauged type. It was noted as *Helminthoida labyrinthica forma lata* (KSIĄŻKIEWICZ, 1970, p. 296, fig. 2*i*). It is an open question whether this form should be distinguished as a variety of the typical form, or whether it is only a kind within the diversity range of the ichnospecies.

**Sediment.** — Marls, marly argillites, very often in marls directly resting on sandstones, more rarely on the upper surface of very fine-grained sandstones.

**Association.** — *Chondrites*, *Scolicia*, both posterior to the trace.

**Occurrence.** — Particularly frequent in beds of the Senonian age.

Turonian — Siliceous Marls (frequent): Krasiczyn, Huwniki. Senonian — Inoceramian Beds (in some horizons very frequent): Łączki Kucharskie, Rzegocin, Kąkolówka, Wołodź, Krasice, Łodzinka, Huwniki, Kalwaria Pacławska, Romanowa Wola; Skrzydlna Beds: Skrzydlna; Cisna Beds: Jaśliska; Ropianka Beds (frequent): Sopotnia Mała, Lipnica Wielka, Lipnica Mała (the stream Linorka), Bieńkówka, Tokarnia, Raba Wyżna, Poręba Wielka, Lubomierz (the hamlet Przysłop), Szczawa (the stream Kamienica), Wierzbanowa, Mszana Dolna, Limanowa, Kanina, Mordarka, Wola Brzezińska, Grybów, Biała Wyżna, Kąclowa, Biczyce, Wola Krogulecka, Uście Gorlickie, Siary, Kwiatoń, Skwirtne; Sromowce Beds: Niedzica. Palaeocene — Szczawnica Beds: Krościenko on the river Dunajec, Grywałd, Hałuszowa. Palaeocene-Lower Eocene — Variegated Shales: Lipnica Mała (the stream Linorka), Szczawa (the stream Głębieniec), Zbludza, Lipowe, Stara Wieś, Biczyce, Kąclowa. Lower Eocene — Beloveza Beds: Zubrzyca Górna, Sidzina, Szczawa (the stream Głębieniec), Zbludza, Trzetrzewina, Myślec, Brzeźna, Popowice, Berest. Middle Eocene — Variegated Beds: Jachówka; Hieroglyphic Beds: Rajcza, Stryszawa, Skomielna Czarna, Łętownia Górna, Osielec, Tokarnia, Stara Wieś, Brzeźna, Komańcza. Łącko Beds: Kamienica near Nowy Sącz.

### *Helminthoida serrata* n. ichnosp.
(pl. 21, fig. 2)

1970. *Helminthoida labyrinthica forma serrata*, KSIĄŻKIEWICZ, p. 298, fig. 2*h*.
*Holotype*: UJ TF 105 (pl. 21, fig. 2).
*Type locality*: Bieńkówka near Sucha Beskidzka.
*Type horizon*: Ropianka Beds, Senonian.
*Derivation of the name*: Lat. *serratus* — serrate; the shape of the longitudinal cross-section of the furrow.
*Material*: 10 specimens (slabs).

**Diagnosis.** — Exichnial and epichnial furrows, with forced meanders, transversally ribbed.

**Description.** — In the holotype the furrows are 2 mm wide, fairly deep (1–2 mm), partly filled. The height of the meanders is about 10 cm, their spacing dense. Transverse riblets are very thin. They divide the furrow into narrow transverse depressions, each 1 mm long. In the parts in which the furrow is filled, there is no segmentation in the burrow fill.

Other specimens are similar, but the trace may be narrower than in the holotype. All are exichnial or epichnial, except for one specimen (UJ TF 1488) in which a furrow of identical shape occurs on the lower surface with raised edges. Evidently the burrower worked below the sand and ploughed the sand sideways.

**Remarks.** — The style of guided meandering and the width of the furrow is the same as in larger kinds of *H. labyrinthica*. It is differentiated from that type by transverse segmentation and deeper incised furrows. The furrows in the specimens from Palaeogene beds are slightly narrower than in those occurring in Cretaceous strata.

**Sediment.** — Marly siltstones in the uppermost part of laminated sandstones.

**Association.** — *H. labyrinthica* may occur together in the same slab.

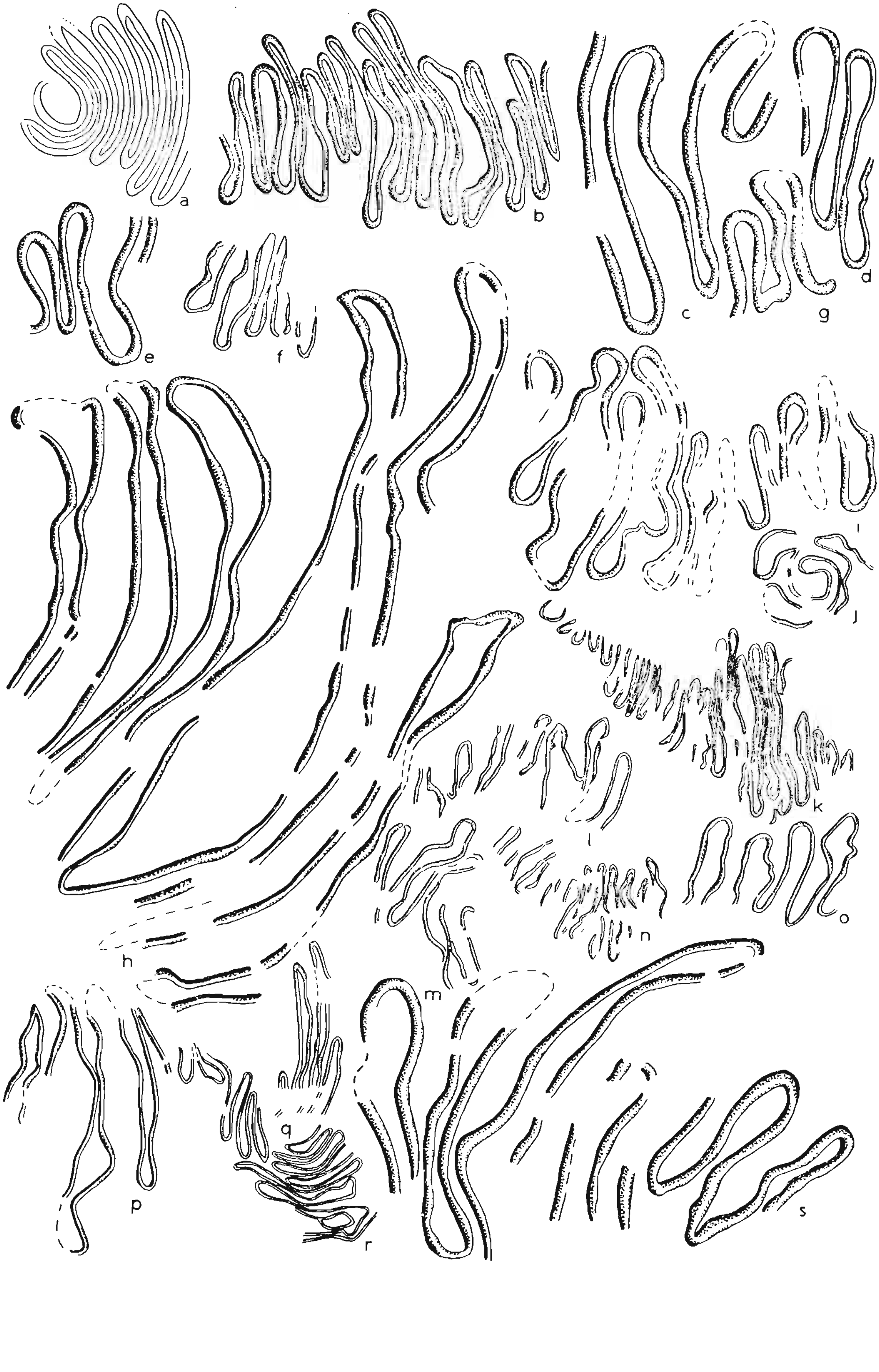
**Occurrence.** — Senonian — Inoceramian Beds: Łączki Kucharskie, Huwniki, Kalwaria Pacławska (hypichnial form); Ropianka Beds: Bieńkówka. Palaeocene — Szczawnica Beds: Krościenko on the river Dunajec. Palaeocene-Lower Eocene — Variegated Shales: Zalesie, Wola Brzezińska, Binczarowa. Lower Eocene — Beloveza Beds: Zubrzyca Górna, Tokarnia, Binczarowa. Middle Eocene — Hieroglyphic Beds: Osielec, Daliowa.

### *Helminthoida crassa* SCHAFHÄUTL, 1851
(pl. 21, figs 3–8; text-fig. 34)

1851. *Helminthoida crassa*, SCHAFHÄUTL, p. 142, pl. 9, fig. 11.
*Material*: 51 specimens and many occurrences noted in the field.

**Description.** — This is a hypichnial form characterized by very compressed forced meanders. There is considerable diversity in this ichnospecies both in dimensions and in the manner of meandering. The width of the strings ranges from a fraction of a millimetre to 5 mm. It may vary to about 50% in one specimen. The height of the string is 0.5 mm in thinner types, and up to 2 mm in thicker ones. The height of the meanders often varies in one and the same specimen. The relation of the maximum height to the maximum width of the meanders varies between 5:1 and 20:1. The tendency to coiling is often very strong and in some cases the meanders may be arranged in a spiral (text-fig. 34*j*). The surface of the string is smooth, but in one specimen there is some delicate longitudinal striation in the median part of the string, and in another tiny transversal riblets are seen.

**Remarks.** — SCHAFHÄUTL (1851) gave no description, and from his figure it is not clear whether this type occurs on the lower or upper surface. The specimens referred to SCHAFHÄUTL'S type clearly represent hypichnial structures (DE STEFANI, 1895, pl. 14, fig. 4; SACCO, 1888, figs 5, 18; SEILACHER, 1954, pl. 8, fig. 3). There are some differences between the Carpathian specimens and the picture given by SCHAFHÄUTL. The meanders of his specimens are more regular and more compressed; the relation of height to width is 23:1, higher than in any of the Carpathian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specimens. Our material rather resembles the specimens illustrated by DE STEFANI and SEILACHER (o. c.).

**Sediment.** — Thin-bedded (the thickest 5 cm), fine-grained, graded or horizontally laminated sandstones. In several cases the strings are filled with coarser grains than those constituting the host rock.

**Association.** — *Helminthopsis*, *Paleodictyon*. In one instance intersected by *Spirophycus*.

**Occurrence.** — Berriasian. Cieszyn Limestone: Goleszów (the main quarry), Kamienica near Bielsko. Valanginian — Upper Cieszyn Shales: Żywiec. Albian — Lgota Beds: Rzyki near Wadowice. Cenomanian — Lower Godula Beds: Czchów. Turonian — Middle Godula Beds: Ponikiew. Senonian — Inoceramian Beds: Krasiczyn (coll. W. SZAJNOCHA), Huwniki, Krzywcza, Kalwaria Pacławska, Wola Romanowa; Skrzydlna Beds: Wierzbanowa, Przenosza; Gorzeń Beds: Gorzeń Górny; Szydłowiec Beds: Kobielnik; Lower Istebna Beds: Czarnorzeki (in marly interbeds); Ropianka Beds (frequent): Lipnica Mała (the hamlet Zosiak), Tokarnia, Zaryte, Wierzbanowa, Kasina Wielka, Poręba Wielka, Limanowa, Mordarka, Brzeźna, Wola Brzezińska, Wola Krogulecka, Biała Wyżna, Uście Gorlickie, Kwiatoń; Sromowce Beds: Sromowce Wyżne. Palaeocene — Upper Istebna Beds: Czarnorzeki; Szczawnica Beds: Krościenko on the river Dunajec, Grywałd (the stream Tylka), Haluszowa; Babiarze Beds: Maruszyna (the hamlet Babiarze). Palaeocene-Lower Eocene — Variegated Shales (frequent): Lipnica Mała (the stream Linorka), Zubrzyca Górna, Zaryte, Raba Wyżna, Stara Wieś, Lipowe. Lower Eocene. — Ciężkowice Sandstone: Znamirowice, Gródek; Beloveza Beds: Lipnica Wielka (KSIĄŻKIEWICZ, 1960, p. 939, pl. 2, fig. 9); Sidzina, Szczawa, (the stream Głębieniec), Zbludza, Półrzeczki, Uście Gorlickie. Middle Eocene — Hieroglyphic Beds: Kamesznica (the stream Janoska), Grzechynia, Skomielna Czarna, Tokarnia, Półrzeczki, Brzeźna, Żubracze. Oligocene — Krosno Beds: Wujskie (the Słonne Mts.), Dźwiniacz Dolny (the stream Królów).

### *Helminthoida miocenica* SACCO, 1886

(pl. 21, figs 10, 11; text-fig. 36*a-j*)

1886. *Helminthoida miocenica* SACC., SACCO, p. 16, fig. 2.
*Material*: 9 specimens and several occurrences noted in the field.

The specimen most closely approximating the type of SACCO (text-fig. 36*j*) consists of meanders up to 20 mm in height while the distance between the arms of the meanders is 3–4 mm. This gives a height: width relation of 5:1. In other specimens this relation varies between 2:1 and 4:1. The meanders are roughly parallel to one another, but in one specimen they are flabellate (pl. 21, fig. 11; text-fig. 36*c*). The width of the string varies between 0·6 and 2 mm, but is commonly 1 mm. The surface of the string is smooth.

**Remarks.** — One may judge from the description and figure given by SACCO that his type is related to *H. crassa*, from which it differs in lower and less compressed meanders and a total absence of coiling. In the Carpathian material, apart from the specimens that fit this type well, there are some with larger and looser meanders (pl. 21, fig. 10, text-fig. 36*a*, *b*, *d*, *e*, *h*). They have also been assigned here, as their style of meandering is more or less similar. Perhaps

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Fig. 34
*Helminthoida crassa* (SCHAFHÄUTL)
[a] SCHAFHÄUTL, 1851, pl. 9, fig. 11; [b] Sromowce Wyżne, Sromowce Beds, UJ TF 103; [c] Lipnica Wielka, Beloveza Beds, UJ TF 238; [d] Sidzina, Beloveza Beds (field drawing); [e] Tabaszowa, Upper Istebna Beds, UJ TF 38; [f] Dźwiniacz Dolny, Krosno Beds, UJ TF 1361; [g] Goleszów, Cieszyn Limestone, UJ TF 1244; [h] Szczawa, the stream Głębieniec, UJ TF 722; [i] Żubracze, Hieroglyphic Beds, UJ TF 1812; [j] Tokarnia, Hieroglyphic Beds, UJ TF 788; [k] Biała Wyżna, Ropianka Beds. UJ TF 99; [l] Wujskie, Krosno Beds (field drawing); [m] Gródek, Ciężkowice Sandstone, UJ TF 42; [n] Kobielnik, Szydłowiec Beds, UJ TF 1160; [o] Dźwiniacz Dolny, Krosno Beds, UJ TF 1495; [p] Rzyki near Wadowice (coll. Dept. of Geology, University of Groningen, Nederland); [q] Limanowa, Ropianka Beds, UJ TF 825; [r] Poręba Wielka, Ropianka Beds, UJ TF 49; [s] Lipnica Mała, Ropianka Beds (field drawing). All figures × 0.5

they should be treated as *H.* aff. *miocenica* or as a variety of this ichnospecies, but more probably they may be placed within the range of diversity of *H. miocenica.*

**Sediment.** — Thin-bedded (2–4 cm), fine-grained, horizontally or single-current laminated sandstones.

**Occurrence.** — Senonian — Ropianka Beds: Złatna, Wola Brzezińska; Skrzydlna Beds: Przenosza; Gorzeń Beds: Gorzeń Górny. Middle Eocene. — Hieroglyphic Beds: Kamesznica (the stream Janoska), Brzeźna. Oligocene — Krosno Beds: Wujskie (the Słonne Mts.), Dźwiniacz Dolny (the stream Królów).

### *Helminthoida alterna* n. ichnosp.

(pl. 20, fig. 2; text-fig. 35)

*Holotype*: UJ TF 843 (pl. 20, fig. 2).
*Type locality*: Berest near Grybów.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *alternus* — alternate; the alternate arrangement of the apical bends of the meanders.
*Material*: 13 specimens.

**Diagnosis.** — Hypichnial string-sized full burrow. Narrow and high meanders arranged in opposite sets. The apical bends of one set alternately face the space between the apical bends of the opposite set. Away from the apex the strings become thinner and eventually wane away.

**Description.** — In the holotype the strings are 2 mm wide and up to 1 mm high in the apical part of the meanders; away from the apex the strings flatten and eventually disappear for a short distance to reappear again on the other side of the set. The meanders are comparatively narrow, about 8 cm high and 4–8 mm wide. The arms of the meanders are roughly parallel. The apices of the opposite sets of the meanders are situated as if along an almost straight line.

In many specimens only one side of the set exists, the median part is slightly, and the other side not or only very feebly developed. In all specimens the apical bends of two opposite sets never face one another, but are placed in alternate succession. The arms of the meanders are parallel, but occasional overlapping or overcrossing is seen. Short strings may traverse the space between the two opposite rows of apical bends. Most probably they belong to another set formed in the same place earlier. In several specimens this type is reduced to two sets of short crescents (text-fig. 35*d–l*). The crescents of one set face the space between the crescents of the opposite set.

**Remarks.** — This form differs from other helminthoids by the parallel meanders which are not compressed and do not show any tendency to coil, and by the arrangement of the meanders ending along a straight or weakly curved line.

To a certain extent this type recalls the *Baroccoichnites* of VIALOV (1971, p. 88, pl. 1, figs 2, 3) from the Trias of the Pamir. That type consists of crescents arranged alternately ("chess-like") in two opposite rows. The crescents, as in our form, are open outward, but, unlike *H. alterna*, they are closely contiguous (text-fig. 35*m–o*). The crescents of *B. pamiricus* VIALOV are much larger and thicker (3–4 mm wide, 10–12 mm large at the outward end). The resemblance seems to suggest that *Baroccoichnites* belongs to meandering forms developed in rudimentary fashion, with only the apical bends preserved.

**Sediment.** — Thin-bedded sandstones, the thickest 7 cm, fine-grained, horizontally or obliquely laminated. Usually occurs on flat, even soles.

**Association.** — In one case *Cosmorhaphe fuchsi*, in others *Halymenidium* and *Sabularia*, all clearly posterior. Also *Helminthopsis tenuis.*

**Occurrence.** — Palaeocene-Lower Eocene — Variegated Shales: Limanowa. Lower Eocene — Beloweza Beds: Lipnica Mała, Zubrzyca Górna, Sidzina (the hamlet Drabowa), Łętownia Górna, Berest (here particularly frequent).

### *Helminthoida helminthopsoidea* SACCO, 1888
(pl. 20, fig. 3; pl. 21, fig. 9; text-fig. 36 *k–n*)

1888. *Helminthoida helminthopsoidea* SACC., SACCO, p. 180, pl. 2, fig. 7.
*Material*: 9 specimens, few of them well preserved.

**Description.** — The meanders are 5 to 6 cm high and only 8 mm broad at the base. The arms of the meanders are more or less twisted into quasi second-order meanders. The width of the string varies from 0.2 to 2 mm.

**Remarks.** — The style of meandering, i.e. the narrow, roughly parallel meanders, is similar to that of *H. crassa*. In the last-named type the strings in the arms of the meanders are straight or uniformly curved. As there are hardly any intermediate types, it seems that the ichnospecies of SACCO should be maintained as a distinct type.

**Sediment.** — Very fine-grained, thin-bedded (up to 3 cm), horizontally laminated sandstones.

**Occurrence.** — Turonian — Middle Godula Beds: Wiśniowa (the stream on the slope of Mt. Ciecień). Senonian — Ropianka Beds: Lipnica Wielka (the hamlet Kiczora), Wola Brzezińska, Kąclowa; Upper Istebna Beds: Krzeszów. Lower Eocene; Beloveza Beds: Lipnica Mała, Sidzina, Łętownia Górna, Myślec.

### *Helminthoida aculeata* n. ichnosp.
(pl. 19, fig. 8; text-fig. 36*o*)

*Holotype*: UJ TF 1360 (pl. 19, fig. 8).
*Type locality*: Szczawa, the stream Głębieniec.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *aculeata* — spiny.
*Material*: 2 specimens.

**Diagnosis.** — Hypichnial string-sized full burrow, closely meandering. Meanders, high and narrow, provided with lateral short spine-like protuberances.

In the holotype the string is 3–5 mm wide and about 1 mm high. The meanders are 6 to 7 cm high. Their style is similar to that of other helminthoids. The spines are short (0.7 to 1.2 mm) and triangular, but some of them have rounded tips. They are better developed on the outer convex side of the bends.

The other specimen, found in the same locality as the holotype, is somewhat thinner.

**Remarks.** — This type is assigned to *Helminthoida* according to the style of meandering, but no other helminthoid has lateral protuberances. They are so short that they cannot be regarded as branches. Probably they were formed when the animal probed the sediment sideways.

**Sediment.** — Fine-grained, horizontally laminated sandstone, in one case 20 cm, in another 9 cm thick. In the larger specimen the trace intersects a distinct grain lineation. There is some increase of muscovite in the strings.

**Occurrence.** — Lower Eocene — Beloveza Beds: Szczawa (the stream Głębieniec).

## Ichnogenus *Paleomeandron* PERUZZI, 1880

*Type ichnospecies: Paleomeandron rude* PERUZZI (ANDREWS, 1955).

### *Paleomendron elegans* PERUZZI, 1880
(pl. 23, fig. 1)

1880. *Paleomeandron elegans*, PERUZZI, p. 8, pl. 1, figs 2, 5.
*Material*: 6 specimens.

**Description.** — The best preserved specimen consists of three full first-order meanders, which are 20–25 mm high and relatively narrow at the base (6–10 mm). Their axes are roughly parallel. The second-order quadratic ("Greek") meanders are very regular, 1 mm wide. On


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their corners occur tiny thorn-like tubercules. The string is low and very thin (0.5 mm). In some specimens the meanders are slightly constricted.

There are no differences whatsoever between our material and that pictured by PERUZZI. The trace is hypichnial. The string is well welded to the sole, but in one specimen (Lipnica Mała) the cross-section of the string is round. This indicates that the trace is post-depositional.

**Sediment.** — Thin-bedded (maximum 12 cm), fine-grained, horizontally or obliquely laminated sandstones.

**Association.** — In a specimen from Przenosza accompanied by *Helminthoida crassa* and *Subphyllochorda rudis*, both posterior.

**Occurrence.** — Senonian — Ropianka Beds: Złatna, Lipnica (the stream Linorka — KSIĄŻKIEWICZ, 1968, pl. 1, fig. 1), Raba Wyżna, Szczawa (the Kamienica valley — the specimen found by G. L. Shideler during a joint excursion), Skwirtne; Skrzydlna Beds: Wierzbanowa, Przenosza.

### *Paleomeandron rude* PERUZZI, 1880

(pl. 22, fig. 4; pl. 23, fig. 2)

1880. *Paleomeandron rude*, PERUZZI, p. 8, pl. 1, fig. 4.
*Material*: 6 specimens.

**Description.** — The specimen illustrated in pl. 23, fig. 2 is well developed, much better than the fragmentary specimen of PERUZZI. The meanders of the first-order are 3–4 cm high and 1 cm broad at the base, with parallel axes. The quadratic meanders are of equal size, 2 mm wide, with thorny protuberances on the corners. The string is 1 mm wide.

Other specimen do not differ much from that described. In some the string is thicker, approximates more closely the thickness of PERUZZI's specimen.

**Sediment.** — Fine-grained, thin-bedded (up to 5 cm), horizontally laminated sandstones.

**Association.** — *Spirophycus bicornis.*

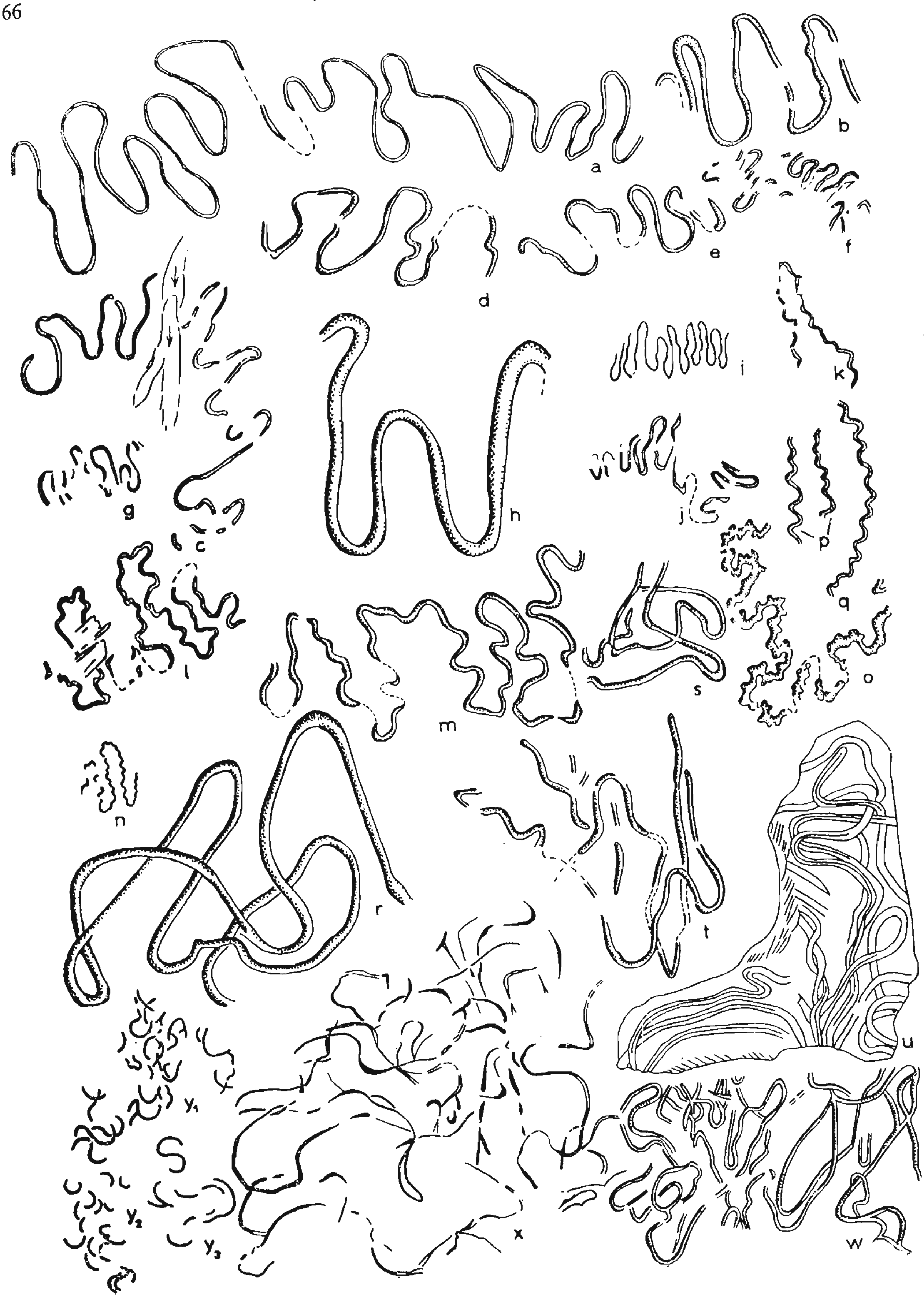
**Occurrence.** — Senonian — Ropianka Beds: Złatna. Lower Eocene — Beloveza Beds: Sidzina (the stream Głaza — KSIĄŻKIEWICZ, 1970, fig. 3*e*). Middle Eocene — Hieroglyphic Beds: Grzechynia, Zawoja (the stream Końskie — F. SIMPSON, 1970, pl. 10, fig. 4) found in the uppermost part of the Hieroglyphic Beds (= "Sub-Magura Beds"), Budzów (the stream Droździna — KSIĄŻKIEWICZ, 1968, pl. 1, fig. 2); Pasierbiec Sandstone: Sułkowice (the stream Gościbia); Łącko Beds: Kamienica near Nowy Sącz. Oligocene — Krosno Beds: Wujskie (the Słonne Mts.).

### *Paleomeandron robustum* KSIĄŻKIEWICZ, 1968

(pl. 23, fig. 3; text-fig. 37)

1968. *Paleomeandron robustum* n. "sp.", KSIĄŻKIEWICZ, p. 4, 14, pl. 1, fig. 3.
*Holotype*: UJ TF 231 (pl. 23, fig. 3).
*Type locality*: Lipnica Mała, the main stream, near Nowy Targ.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *robustum* — robust; the form is much thicker than other types of *Paleomeandron*.
*Material*: 9 specimens.

Fig. 35
*Helminthoida alterna* n. ichnosp.
a Berest, Beloveza Beds, UJ TF 816; b Berest, Beloveza Beds, UJ TF 815; c Berest, Beloveza Beds, UJ TF 806; d Myślec, Łącko Beds, UJ TF 975; e Berest, Beloveza Beds, UJ TF 790; f Lipnica Mała, Beloveza Beds, UJ TF 246; g Zubrzyca Górna, the hamlet Moniaków, Beloveza Beds, UJ TF 247; h Sidzina, the hamlet Drabowa, Beloveza Beds, UJ TF 248; i Sidzina, the hamlet Drabowa, Beloveza Beds, UJ TF 248; j Limanowa, Variegated Shales, UJ TF 656; k Łętownia Górna, Beloveza Beds, UJ TF 1232; l Zubrzyca Górna, the hamlet Ochlipów, UJ TF 1432; m Sidzina, Beloveza Beds, UJ TF 1081; n–p *Baroccoichnites pamiricus* VIALOV, 1971, pl. 1, fig. 2, 3. All figures. × 0.5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**Diagnosis.** — Hypichnial rope-sized full burrow, with quadratic or trapezoidal second-order meanders.

**Description.** — In the holotype the width of the string is 4–5 mm, its height 2–3 mm, the second-order meanders almost quadratic, are $12\times14$ mm wide. The outer (convex) side of these meanders is slightly rounded, the inner side is straight. On the corner of the meanders there are tubercules, usually stronger on one corner than on the other. The string, about 14 mm long, is strongly curved, and probably represents a fragment of a large (not forced) meander.

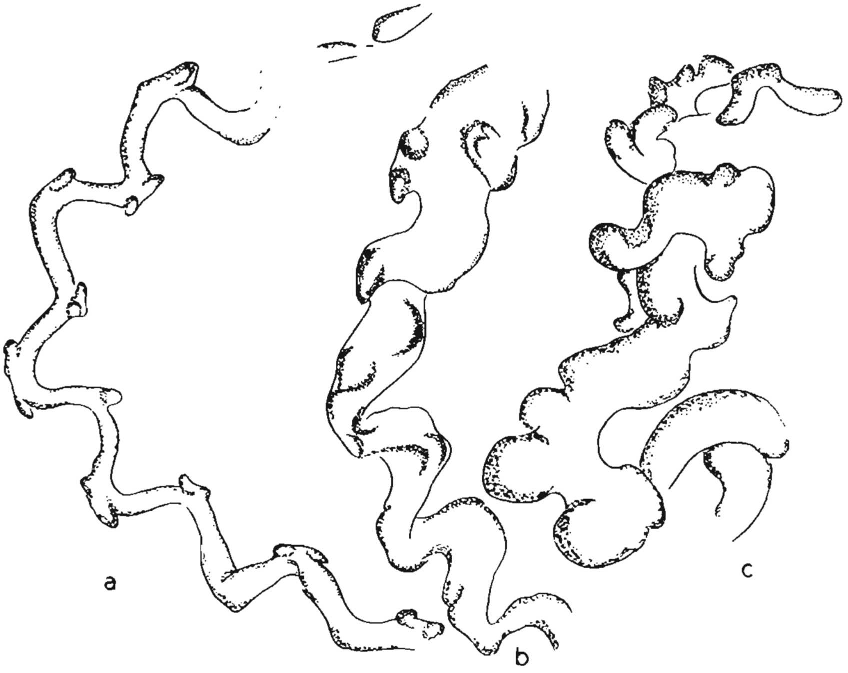



Fig. 37
*Paleomeandron* aff. *robustum* KSIĄŻKIEWICZ
[a] Lipnica Mała, Beloveza Beds, UJ TF 228; [b] Podwilk, Łącko Beds, UJ TF 229; [c] Berest, Beloveza Beds. UJ TF 834. All figures $\times$ 0.5

There is considerable variability in the dimensions and shape of this type. Unfortunately, only not fully developed or fragmented specimens have been found, consisting of a few second-order meanders aligned along a curved line. In some specimens the second-order meanders are much wider ($25\times30$ mm) than in the holotype, but the string may be relatively thin -4–5 mm), and the shape of these meanders is rather trapezoidal or even triangular. In other

Fig. 36
[a]-[j] *Helminthoida miocenica* SACCO: [a] Brzeźna, Hieroglyphic Beds (field drawing); [b] Limanowa, Ropianka Beds, UJ TF 652; [c] Dźwiniacz Dolny, Krosno Beds (the trace intersected by a flute cast), UJ TF 714; [d] (?), Złatna, Ropianka Beds (field drawing); [e] Gorzeń Górny, Gorzeń Beds, UJ TF 1403; [f] Przenosza, Skrzydlna Beds, UJ TF 1174; [g] Wola Brzezińska, Ropianka Beds, UJ TF 1022; [h] Przenosza, Skrzydlna Beds, UJ TF 1127; [i] SACCO, 1886, fig. 2; [j] Przenosza, Skrzydlna Beds, UJ TF 1133; [k]-[n] *Helminthoida helminthopsoidea* SACCO: [k] Wola Brzezińska, Ropianka Beds, UJ TF 1013; [l] Lipnica Mała, Beloveza Beds, UJ TF 339; [m] Łętownia Górna, Beloveza Beds, UJ TF 2; [n] Krzeszów, Upper Istebna Beds, UJ TF 2030; [o] *Helminthoida aculeata* n. ichnosp., Szczawa, the stream Głębieniec, UJ TF 716; [p]-[q] *Cochlichnus* aff. *anguineus* HITCHCOCK: [p] Lipnica Mała, Beloveza Beds, UJ TF 1635; [q] Komańcza, Hieroglyphic Beds, UJ TF 1203; [r] *Gordia marina* EMMONS, EMMONS, 1844, pl. 14, fig. 24; [s]-[x] *Gordia molassica* (HEER): [s] Juszczyn, Hieroglyphic Beds, UJ TF 1249; [t] Juszczyn, Hieroglyphic Beds, UJ TF 1253; [u] *Helminthoida molassica* HEER, HEER, 1865, fig. 327; [w] Skrzydlna, Krosno Beds, UJ TF 245; [x] Gródek, Ciężkowice Sandstone, UJ TF 1520; [y] *Gordia arcuata* n. ichnosp; [y1] Wetlina, Krosno Beds, UJ TF 1219; [y2] Wetlina, Krosno Beds, UJ TF 1225; [y3] Wetlina, Krosno Beds, UJ TF 1222. All figures $\times$ 0.5

specimens the string is wide (10 mm) and high. The tubercules are not developed on all corners, (text-fig. 37).

In one specimen the string intersects a flute cast, in another a clearly pre-depositional cast (filled with obliquely laminated sand). This points to post-depositional origin.

**Remarks.** — The assignment of this type to *Paleomeandron* is based on the existence of the secondary, mostly "Greek" type meanders. No full meander has been found and this may open this assignment to argument.

**Sediment.** — Thin-bedded (up to 4 cm) horizontally or obliquely rippled current laminated sandstones.

**Association.** — In one instance it is posterior to *Taphrhelminthopsis*, but is intersected by *Sabularia*.

**Occurrence.** — Lower Eocene — Beloveza Beds: Lipnica Mała (the main stream), Sidzina. Lubomierz. Middle Eocene — Hieroglyphic Beds: Daliowa (cf.); Łącko Beds: Podwilk (aff.),

## Ichnogenus *Taphrhelminthoida* n. ichnogen.

*Type ichnospecies: Taphrhelminthoida convoluta* n. ichnosp.

**Diagnosis.** — Bilobate guided meandering trace, with a tendency to coiling.

**Remarks.** — As pointed out before (p. 135) all types of *Taphrhelminthopsis* distinguished by Sacco (1888) are freely winding, and none shows guided meandering. Since in the quite abundant Carpathian material no intermediate types between these two classes, freely meandering and guided meanders, have been found, it seems to be advisable to classify the bilobate guided meanders as a distinct ichnogenus, joining the features of *Taphrhelminthopsis* (the median furrow, "tafrós") and of *Helminthoida* (elongated, guided meanders).

**Origin.** — In most cases the specimens are pre-depositional, as evidenced by the filling with obliquely laminated sand (casts). But in one or two cases the trace intersects flute casts. This would mean that *Taphrhelminthoida* in some instances is a pre-depositional locomotion trail, but in others may be a post-depositional feeding burrow of the *Pascichnia* type. The producer was probably a solenogaster (see discussion on the origin of *Taphrhelminthopsis*, p. 135).

### *Taphrhelminthoida convoluta* n. ichnosp.

(pl. 22, fig. 1; pl. 23, fig. 5)

1932. *Cylindrites convolutus* Heer, Palibin *in* Vassoevich, p. 53, pl. 2, fig. 5.
*Holotype*: UJ TF 813 (pl. 22, fig. 1).
*Type locality*: Berest near Grybów.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *convolutus* — convolute.
*Material*: 23 specimens and a number of field observations.

**Diagnosis.** — Hypichnial rope-sized groove cast; bilobate meanders closely spaced, often coiled. Median groove concave, fairly deep, the marginal ridges large and rounded.

**Description.** — In the holotype the meanders are 10 to 16 cm high and 2 to 4 cm broad near the base. The width of the string varies between 12 and 20 mm, the height attains 5 mm. The median groove, on the average 4 mm wide, is 2 to 3 mm deep. The meanders densely cover the sole. Their axes only are partly parallel to one another.

The dimensions of other specimens assigned here are variable. There are specimens in which the height of the meanders is 20 cm, and others in which the largest meander is only 6 cm high. The width of the trace ranges from 6 to 20 mm. The degree of "guiding" of the meanders also varies, even in one and the same specimen. There are specimens with more obligatorily developed meanders, and some with looser meandering. In some specimens coiling may be conspicuous (pl. 23, fig. 5).

**Remarks.** — So far as I have been able to find, the first mention and figure of a similar type were given by VASSOEVICH (1932) and his specimen was determined as *Cylindrites convolutus* HEER. Following this I determined my specimens as *Taphrhelminthopsis convoluta* (HEER) (KSIĄŻKIEWICZ, 1970, p. 300), since the figure of VASSOEVICH clearly shows two ridges separated by a median groove. However, in no paper of HEER could I find a double meandering form under the name indicated by PALIBIN, and HEER'S *Cylindrites convolutus* (1876, p. 159, pl. 65, fig. 4) represents a unilobate cylindrical form, probably belonging to a *Helminthopsis*. The form discussed is similar to the "Mäanderfährte" of GÖTZINGER and BECKER (1934).

**Sediment.** — Graded or horizontally laminated sandstones, up to 10 cm thick.

**Occurrence.** — Senonian — Inoceramian Beds: Kąkolówka; Ropianka Beds: Lipnica Mała, Raba Wyżna, Mszana Dolna (the stream on the slope of Mt. Strzebel), Szczawa, Wierzbanowa, Poręba Wielka, Limanowa, Wola Brzezińska, Wola Krogulecka, Skwirtne; Sromowce Beds: Krempachy, Sromowce Wyżne (the hamlet Kąty). Palaeocene — Szczawnica Beds: Krościenko on the river Dunajec. Palaeocene-Lower Eocene — Variegated Shales: Sopotnia Mała, Zbludza, Mordarka, Lipowe, Stara Wieś, Uście Gorlickie. Lower Eocene — Beloveza Beds (fairly frequent): Złatna, Lipnica Wielka, Lipnica Mała, Zubrzyca Górna, Sidzina, Łętownia Górna, Trzetrzewina, Popowice, Berest. Middle Eocene — Hieroglyphic Beds: Daliowa; Majdan; Łącko Beds: Kamienica near Nowy Sącz. Upper Eocene — Magura Sandstone: Ochotnica.

### *Taphrhelminthoida plana* (KSIĄŻKIEWICZ, 1970)

(pl. 22, figs 2, 3)

1970. *Taphrhelminthopsis plana* ichnosp. nov., KSIĄŻKIEWICZ, p. 300, pl. 3, figs *g*, *h*.
*Holotype*: UJ TF 1367 (pl. 22, fig. 2).
*Type locality*: Zubrzyca Górna, the hamlet Ochlipów.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *planus* — flat; the low relief of the trace.
*Material*: 4 specimens, one of them a slab with numerous traces. Few occurrences noted in the field.

**Diagnosis.** — Hypichnial groove cast or full burrow (?). Double guided meanders, often coiled, the median groove wide and flat, the marginal ridges narrow and low.

**Description.** — The holotype represents a double trace, 12 to 30 mm wide and a few mm high. The meanders are guided, coiled, about 14 cm high and 3–4 cm wide at the base. The distance between the arms of the meander is 2 cm. The median groove is 6 mm and the ridges 3–4 mm wide. The ridges are delicately and densely covered with striations.

Other specimens are similar though in some the height of the meanders is less and in some it may be almost twice as high as in the holotype. The meanders may be spaced less closely than in the holotype.

**Remarks.** — This type differs from *H. convoluta* by its subdued relief.

**Sediment.** — Fine-grained sandstones, up to 10 cm thick.

**Occurrence.** — Lower Eocene — Beloveza Beds: Lipnica Wielka, Zubrzyca Górna (the hamlets Ochlipów and Moniaków).

## IX. BRANCHED WINDING AND MEANDERING STRUCTURES

Here are grouped freely winding and meandering strings provided with more or less long lateral branches or appendages. In some types the meandering is fairly close and the lateral branches approach or reach the neighbouring main string, thus forming an incomplete network. In this way some types grouped here form an intermediate link between the winding and meandering structures and the true networks.

All types of this group are hypichnial structures. In very many cases the structures are cylindrical and intersect sedimentary structures of the soles (lineation, flute casts). In many cases, however, the evidence is not clear and the structures seem to be casts, but it is not possible to determine with certainty whether they are full burrows welded with the material of the sole, or collapse or sedimentation casts. The suggestion should be kept in mind that some structures might have been formed as feeding burrows along the clay/sand interface, and others as surface trails prior to the deposition of the sand. For the most part they were made by animals densely processing the substratum and should be treated as *Pascichnia*.

If the structures discussed are pre-depositional, the problem of the filling does not present any difficulties. Either they are branching grooves on the sea-bottom cast by the current-borne sand, or they are subsurface burrows excavated and recast (SEILACHER, 1962). If they are full burrows, the manner of the filling is more difficult to explain. The worms form a branched trail, as observed by NATHORST (1889). The lateral branch may be made by means of the proboscis laterally probing the sediment, or by the animal itself: polychaete worms living in tubes are able to move forward and backward (KÜKENTHAL & KRUMBACH, 1934, pp. 130–131). When the animal moves forward in its main burrow it fills it as fast as it moves with the material which has passed through its alimentary canal. This manner of filling is impossible in the lateral branch, from which the animal has to retire. It is possible that the lateral branches were not filled with egested material but by the collapsing material of the roof. This view seems to be endorsed by the observation that the lateral branches are often lower and of no clear cylindrical shape. Thus the main burrow would be a full feeding burrow and the lateral branches collapse casts. But it is also possible that the animal produces so much excreted material that, under pressure, it may penetrate into the lateral branches, even if long.

The group of structures discussed includes *Acanthorhaphe* KSIĄŻKIEWICZ, *Belorhaphe* FUCHS, *Protopaleodictyon* KSIĄŻKIEWICZ, *Urohelminthoida* SACCO.

### Ichnogenus *Acanthorhaphe* KSIĄŻKIEWICZ, 1961

*Type ichnospecies: Acanthorhaphe delicatula* n. ichnosp.

**Diagnosis.** (after KSIĄŻKIEWICZ, 1961*a*). — Hypichnial strings winding in low meanders with lateral short thorn-like appendages on the convex side of the windings.

### *Acanthorhaphe delicatula* n. ichnosp.

(pl. 23, figs 8–10; text-fig. 38)

1970. *Acanthorhaphe* (unnamed), KSIĄŻKIEWICZ, p. 301, fig. 4*b*.
*Holotype*: UJ TF 972 (pl. 22, fig. 8).
*Type locality*: Biała Wyżna near Grybów.
*Type horizon*: Ropianka Beds, Senonian.
*Derivation of the name*: Lat. *delicatulus* — delicate.
*Material*: 18 specimens and a dozen occurrences noted in the field.

**Diagnosis.** — Hypichnial thread-like full (?) burrow, winding in short bends of variable curvature, with short appendages on the convex side.

**Description.** — In the holotype there are four traces, all close together, each about 1 cm long. One trace consists of two tangent bends, one of which is provided with four thorn-like appendages of unequal length; the longest is 5 mm long and arcuate. The thickness of the string is less than 1 mm.

Most of the other specimens consist of only one bend, with four of five appendages. These may be somewhat narrowed at the base and pointed at the outer end, but some are clavate. The curvature of the bends is variable; some traces are semicircular, others almost straight. The trace usually occurs alone, but occasionally may occur scattered in profusion on the sole, in a few cases with some overlapping.

**Sediment.** — Fine-grained, thin-bedded (the thickest 6 cm) sandstones with composite bedding, or horizontal or single-current lamination.

**Association.** — *Protopaleodictyon submontanum*, small *Sabularia*.

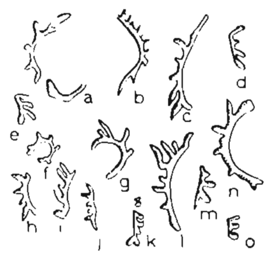


Fig. 38
*Acanthorhaphe delicatula* n. ichnosp.
a Lipnica Mała, Variegated Shales, UJ TF 1322; b Zbludza, Beloveza Beds, UJ TF 2001; c Smrekowiec, Ropianka Beds, UJ TF 1745; d Lipnica Wielka, Beloveza Beds, UJ TF 1328; e Lipnica Mała, Beloveza Beds, UJ TF 1327; f Lipnica Mała, Variegated Shales, UJ TF 877; g Smrekowiec, Ropianka Beds, UJ TF 1745; h Zubrzyca Górna, Beloveza Beds, UJ TF 1324; i Lipnica Mała, Beloveza Beds UJ TF 1326; j Lipnica Wielka, Beloveza Beds, UJ TF, 1323; k Lipnica Wielka, Beloveza Beds, UJ TF 1334; l Lipnica Wielka, Beloveza Beds, UJ TF 1328; m Zubrzyca Górna, Beloveza Beds, UJ TF 1324; n Romanowa Wola, Inoceramian Beds, UJ TF 1499; o Podwilk, Beloveza Beds, UJ- TF 1325. All figures × 0.5

**Origin.** — In the holotype the trace occurs on a lineated underface and intersects delicate sole structures. In a few cases the cylindrical form of the string is easily seen. Evidently post-depositional.

**Occurrence.** — Senonian — Inoceramian Beds: Wołodź, Romanowa Wola; Lower Istebna Beds: Czarnorzeki (in the interbed of fucoid marls); Ropianka Beds: Chyżówki, Limanowa; Wola Krogulecka, Grybów, Biała Wyżna, Smrekowiec, Uście Gorlickie, Siary; Sromowce Beds: Sromowce Wyżne. Palaeocene — Upper Istebna Beds: Targoszów. Lower Eocene — Beloveza Beds (fairly frequent): Złatna, Lipnica Wielka, Lipnica Mała, Zubrzyca Górna, Podwilk, Sidzina, Zbludza. Middle Eocene — Hieroglyphic Beds: Milówka, Zalesie, Brzeźna.

### *Acanthorhaphe incerta* Książkiewicz, 1970
(pl. 23, figs 6, 7)

1970. *Acanthorhaphe incerta* ichnosp. nov., Książkiewicz, p. 301, fig. 4*a*.
*Holotype*: UJ TF 1441 (pl. 23, fig. 6).
*Type locality*: Goleszów near Cieszyn.
*Type horizon*: Cieszyn Limestone, Berriasian.
*Derivation of the name*: the course of the windings is interrupted and therefore uncertain.
*Material*: 2 slabs, each with a few traces, and some occurrences noted in the field.

**Diagnosis.** — Hypichnial thread-sized full burrow or cast, winding in low meanders with lateral appendages on the convex side.

**Description.** — The string is 1 mm wide or less, very low. The meanders are of small amplitude (2–3 mm) and 1 to 2 cm long, usually aligned along a definite path, but interrupted. Appendages of various lengths (1–2 mm) occur on the convex side of the meanders at irregular intervals, 2 or 3 on one bend. They are thick at the base and pointed at their terminations.

**Sediment.** — Thin-bedded (3–4 cm), fine-grained limestones or sandstones, horizontally laminated. The filling material is slightly coarser than in the host rock.

**Occurrence.** — Berriasian — Cieszyn Limestone: Goleszów (the main quarry). Hauterivian — Grodziszcze Beds: Żegocina.

## Ichnogenus *Belorhaphe* FUCHS, 1895

*Type ichnospecies: Belorhaphe zickzack* (HEER) (HÄNTZSCHEL, 1962).

### *Belorhaphe zickzack* (HEER, 1876)
(pl. 24, fig. 1; text-fig. 39)

1876. *Cylindrites Zickzack* HR., HEER, p. 159, pl. 68, fig. 10.
*Material*: 15 slabs, some with numerous traces.

**Description.** — The basic feature of this type is the presence of small triangular meanders with short appendages on the apices (FUCHS, 1895, pl. 4, fig. 4). In the material collected such meanders in well-developed specimens are aligned in first-order meanders of variable shape: some are low and broad (pl. 24, fig. 1; text-fig. 39*a*), others relatively narrow (text-fig. 39*c*). The second-order triangular meanders are usually 4–5 mm high and 6–7 mm wide at the base with an apical angle of 65 to 75°. Occasionally there are much smaller specimens, with triangular

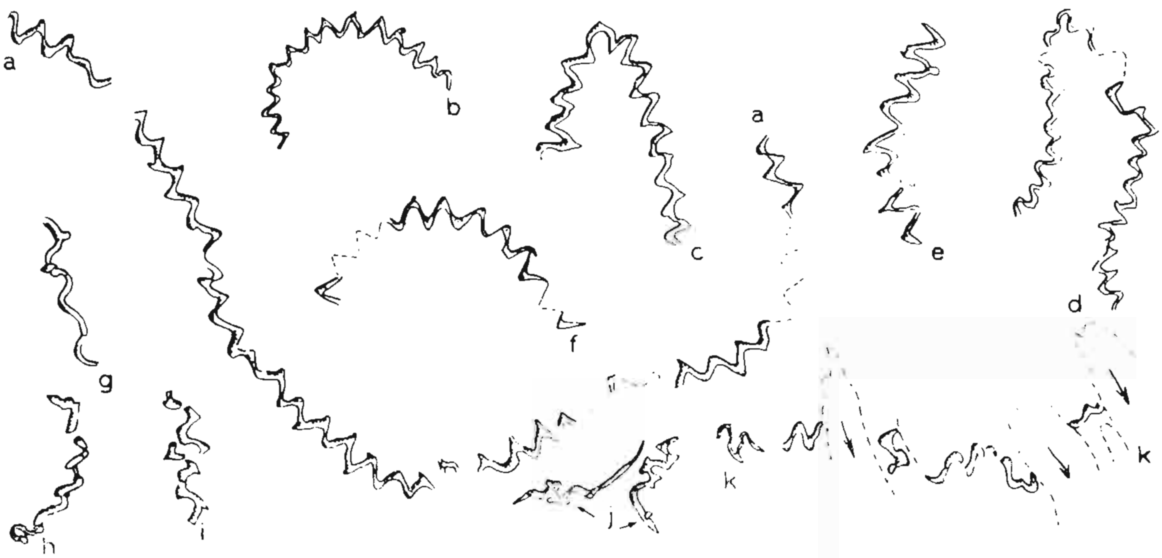



Fig. 39
*Belorhaphe* FUCHS
a–f *Belorhaphe zickzack* (HEER): a Jaroszowice, Upper Cieszyn Shales, UJ TF 119; b Gorzeń Górny, Upper Cieszyn Shales, UJ TF 1414; c Sidzina, Beloveza Beds, UJ TF 1443; d Żegocina, Grodziszcze Beds, UJ TF 1016; e Wiśniowa, Upper Cieszyn Shales, UJ TF 1168; f Żegocina, Grodziszcze Beds, UJ TF 1019; g *Belorhaphe*? Lipowe, Variegated Shales, UJ TF 653; h *B. fabregae* (AZPEITIA)? Sidzina, Beloveza Beds, UJ TF 1037; i *B. fabregae* (AZPEITIA), Sidzina, Beloveza Beds, UJ TF 1666; j *Belorhaphe zickzack*, a form intermediate between *Belorhaphe* and *Paleomeandron*, Jaworki, Sromowce Beds, UJ TF 1445; k *B. fabregae* (AZPEITIA), Zubrzyca Górna, UJ TF 1672. All figures × 0.5

meanders 2.5 mm in height. In many specimens the apical juncture of the arms of the triangular meanders is sometimes rounded. The inner side of the juncture is always rounder than the outer one. The apical appendages, triangular in shape, are 0.5 to 1 mm long. They are thickened at the base. On some apices there are no appendages; instead they may be swollen into a tubercule. The surface of the string is smooth, but in one specimen (UJ TF 1874, Porąbka, Lower Lower Godula Beds) delicate transverse striae (peristaltic?) are visible.

In some slabs the meanders cover the sole profusely, but never intersect one another.

**Sediment.** — Fine-grained, thin-bedded (up to 6 cm) horizontally or single-current laminated sandstones.

**Association.** — In the Cieszyn Limestone togethei with *Sublorenzinia plana*, in the Upper Cieszyn Shales with a *Helminthopsis*. In one instance intersected by *Megagrapton irregulare*.

**Origin.** — In several cases the trace is of cylindrical shape. It also crosses flute casts. This suggests that it is post-depositional (KSIĄŻKIEWICZ, 1970, KERN & WARME, 1974, p. 898). One specimen, however, seems to be intersected by some ridge-like swells, presumably current-formed.

**Occurrence.** — Berriasian — Cieszyn Limestone: Goleszów (the main quarry). Valanginian — Upper Cieszyn Shales: Gorzeń Górny, Jaroszowice. Hauterivian — Grodziszcze Beds (frequent): Lipnik (and other localities reported from the Bielsko area by NOWAK, 1970), Koźmice Wielkie, Porąbka Uszewska, Wiśniowa (the stream Marków), Żegocina, Brzyska (the stream on the slope of Mt. Liwocz). Cenomanian — Lower Godula Beds: Porąbka; Wiśniowa (the stream on the slope of Mt. Ciecień). Turonian — Middle Godula Beds: Targoszów. Senonian — Inoceramian Beds: Kalwaria Pacławska; Ropianka Beds: Limanowa, Kąclowa, Uście Gorlickie. Sromowce Beds: Jaworki (a doubtful specimen, text-fig. 39*j*). Lower Eocene — Beloveza Beds: Zubrzyca Górna, Sidzina (the stream across the Kiełek range). Middle Eocene — Hieroglyphic Beds: Skomielna Czarna, Żubracze; Łącko Beds: Sidzina.

### *Belorhaphe fabregae* (AZPEITIA, 1933)

(pl. 24, fig. 2; text-fig. 39*i*, *k*)

1933. *Helicolithus fabregae* n. sp., AZPEITIA, p. 52, pl. 3, fig. 10; pl. 10, fig. 21A.
*Material*: 13 specimens, 1 slab with numerous traces.

**Description.** — The width of the string is somewhat larger than in *B. zickzack*, and the triangular meanders are correspondingly larger. The apical appendages are usually small or scarcely developed, but the juncture of the arms is often provided with a tubercule. Some of the apical bends are sinusoidal and their inner side is round. In some specimens the meanders are not triangular but trapezoidal, recalling *Paleomeandron*. They may also be sinusoidal, resembling *Cochlichnus* (text-fig. 39*g*). The character of the first-order meanders is unknown, with the exception of one specimen illustrated in pl. 24, fig. 2. This kind occurs in the form of small fragments.

**Remarks.** — Our specimens fit well with the description and figure given by AZPEITIA. The presence of tubercules on the apices and the occasional stitch-like contacts between the arms of the meanders (text-fig. 39*h*) may confirm his presumption that the animal when changing its course made an overturn in a similar way to *Helicolithus*. In its triangular meanders this type resembles *Belorhaphe* more than *Helicolithus*. Its first-order meanders, as indicated by the specimen pictured in pl. 24, fig. 2, presumably are also more like those in *Belorhaphe* than in the last-named type.

**Sediment.** — Thin-bedded (up to 12 cm), fine-grained sandstones, graded, horizontally or diagonally laminated.

**Origin.** — In one specimen the string is cylindrical and adherent to the sole. In other specimens it is not so clear, but the re-entrants at the junction of the string with the sole also suggest a cylindrical shape. In one specimen, however, the trace is clearly intersected by flute casts (text-fig. 39*k*).

**Occurrence.** — Senonian — Ropianka Beds: Limanowa (the hamlet Marciszów). Palaeocene — Szczawnica Beds: Grywałd. Lower Eocene — Variegated Beds: Lipowe; Beloveza Beds: Lipnica Mała, Zubrzyca Górna, Sidzina, Myślec. Middle Eocene — Pasierbiec Sandstone: Osielec; Łącko Beds: Zubrzyca Górna (the hamlet Moniaków — KSIĄŻKIEWICZ, 1961*a*), Naszacowice, Kamienica near Nowy Sącz; Hieroglyphic Beds: Daliowa, Komańcza.

## Ichnogenus *Protopaleodictyon* KSIĄŻKIEWICZ, 1958

*Type ichnospecies: Protopaleodictyon incompositum* KSIĄŻKIEWICZ.

**Diagnosis.** — Hypichnial more or less regular meanders with one or two appendages usually branching from the apex of the meanders.

**Remarks.** — This term (first spelled *Protopalaeodictyon*) was proposed by the author (KSIĄŻKIEWICZ, 1958, pl. 2, fig. 1, also 1960, as *Protopalaeodictyon* n. f., pp. 751, 745, pl. 1, fig. 5 and text-fig. 1) because the trace in many cases occurs in the form of an incomplete network. It is now thought that the traces previously classified as *Palaeochorda* (KSIĄŻKIEWICZ, 1961 *a*, 1970) may also be included in this ichnogenus (see the discussion below).

### *Protopaleodictyon incompositum* KSIĄŻKIEWICZ, 1970
(pl. 24, figs 3, 4; text-fig. 40)

1970. *Protopaleodictyon incompositum* ichnosp. nov., KSIĄŻKIEWICZ, p. 303, fig. 4*e*.
*Holotype*: UJ TF 1484 (pl. 24, fig. 3).
*Type locality*: Osielec, Mt. Przykrzec, near Jordanów.
*Type horizon*: Hieroglyphic Beds, Middle Eocene.
*Derivation of the name*: Lat. *incompositus* — not composite; if the trace occurs in a network form, it is not complete.
*Material*: 20 specimens and a few occurrences noted in the field.

**Diagnosis.** — Hypichnial string-sized full burrow, forming composite meanders with short appendages branching on the apical bends of the second-order meanders. When the sole is densely covered an incomplete network may be formed.

**Description.** — In the holotype the string is 1.5 mm wide and on the average 0.5 mm high. It is wound in composite meanders. The first-order meanders are 9 to 10 cm high, and 2.5 cm broad at the base. Their axes are approximately parallel to one another. The secondary meanders are almost sinuous in their course, about 1 cm high and 1 cm wide at their base. The appendages are placed on the apices of the second-order meanders. They are of variable length, for the most part 3–5 mm, occasionally 10 mm long. In most cases only one appendix branches from the apex, but in some there are two appendages branching on either side of the apex. Some of the second-order meanders have no appendages. This refers particularly to the apices situated on the inner side of the first-order meanders. The trace densely covers the sole.

There is not much diversity in size and shape within this type. In some instances the appendages are much longer than in the holotype (up to 20 mm, text-fig. 40*d, g, j, m*), in others they are quite short (text-fig. 40*b, c*). Their length may be variable in one and the same specimen. The density of the covering of the sole varies. In some, rather rare, cases the trace occurs singly, but in most cases it occurs profusely on the sole and may cover it more densely than in the holotype (text-fig. 40*i*). If the first-order meanders are situated close to one another, the outer appendages may come to an almost direct contact and a network is formed (text-fig. 40*f, i*).

**Remarks.** — The first-order meanders of this type recall the pattern of meandering in *Cosmorhaphe fuchsi*. It may be said that the type discussed is the *Cosmorhaphe* but provided with appendages.

This trace seems to be widely distributed. SEILACHER (1959, tab. 1, fig. 11) pictures an almost identical form, and TANAKA (1971) reports a similar, although not identical, kind from the Japanese flysch.

**Sediment.** — Fine-grained, horizontally or obliquely laminated sandstones, up to 15 cm thick.

**Association.** — Small *Spirophycus, Strobilorhaphe pusilla* posterior to this trace.

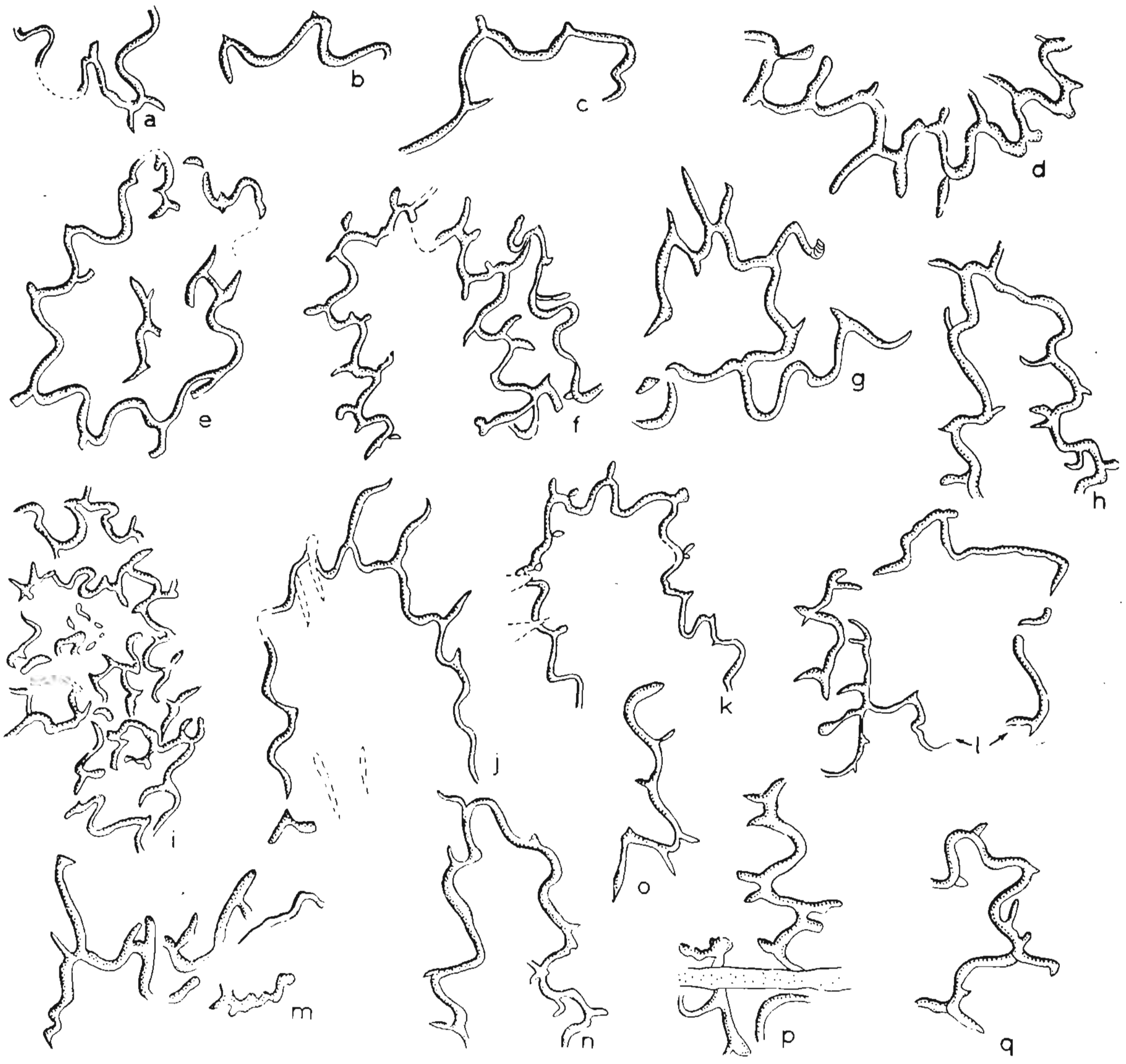
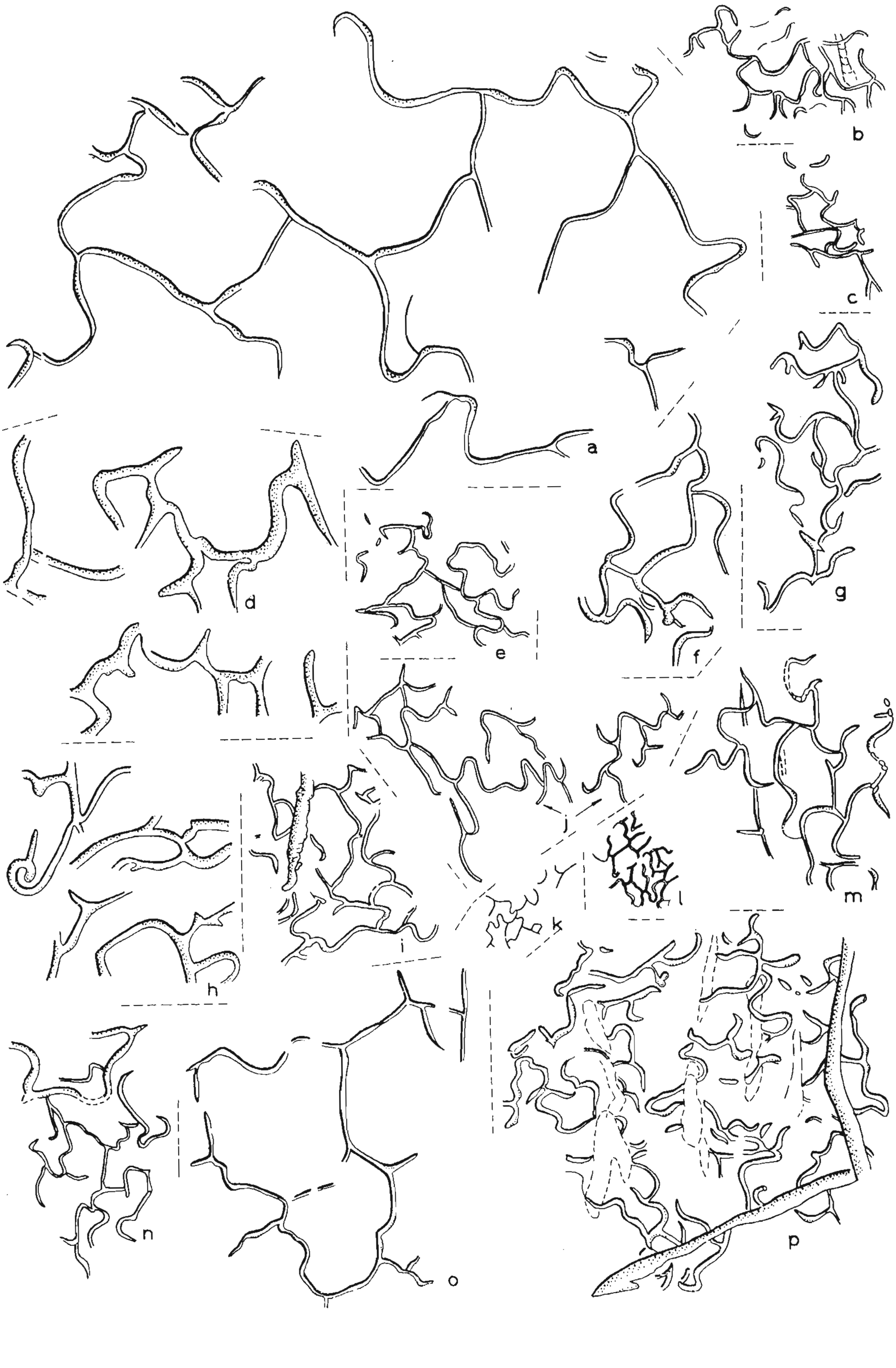



Fig. 40
*Protopaleodictyon incompositum* KSIĄŻKIEWICZ
a Maruszyna, Trawne Beds, UJ TF 336; b Zubrzyca Górna, Beloveza Beds, UJ TF 395; c Lubomierz, Variegated Shales, UJ TF 2051; d Uście Gorlickie, Beloveza Beds, UJ TF 1554; e Osielec, Hieroglyphic Beds (field drawing); f Jordanów, Hieroglyphic Beds, UJ TF 338; g Osielec, Hieroglyphic Beds, UJ TF 900; h Stara Wieś, Variegated Shales. UJ TF 709; i Łętownia Górna, Hieroglyphic Beds, UJ TF 340; j Osielec, Mt. Przykrzec, Hieroglyphic Beds, UJ TF 342; k Jaworki, Magura Sandstone, UJ TF 343; l Lipnica Mała, Beloveza Beds, UJ TF 337; m Huwniki, Inoceramian Beds. UJ TF 723; n Stara Wieś, Variegated Shales, UJ TF 709; o Limanowa, Ropianka Beds (field drawing); p Kąkolówka, Inoceramian Beds (cut across by a *Sabularia*), UJ TF 955; q Jordanów, the hamlet Munkacz, UJ TF 763. All figures × 0.5

**Origin.** — Post-depositional, as indicated by intersection of flute casts and current lineation.

**Occurrence.** — Albian — Trawne Beds: Maruszyna. Senonian — Inoceramian Beds: Kąkolówka, Huwniki; Ropianka Beds: Smrekowiec. Palaeocene-Lower Eocene — Variegated Shales: Zbludza, Stara Wieś, Uście Gorlickie. Lower Eocene — Beloveza Beds: Lipnica Mała, Łętownia Górna, Trzetrzewina, Berest; Ciężkowice Sandstone: Ślemień. Middle Eocene — Hieroglyphic Beds (frequent): Koszarawa, Zawoja (the stream Końskie and other places), Sidzina, Juszczyn; Osielec, Łętownia Górna, Skomielna Czarna, Tokarnia, Jordanów (the hamlet Munkacz), Zalesie, Hańczowa, Zawadka. Upper Eocene — Magura Sandstone (the lowest part): Jaworki.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### *Protopaleodictyon minutum* n. ichnosp.
(pl. 24, fig. 5)

*Holotype*: UJ TF 121 (pl. 24, fig. 5).
*Type locality*: Marcówka near Sucha Beskidzka.
*Type horizon*: Magura Sandstone, Upper Eocene.
*Derivation of the name*: Lat. *minutus* — very small, minute.
*Material*: 2 specimens.

**Diagnosis.** — Hypichnial thread-sized groove cast (?). Sinuous meanders with short appendages or small tubercules on the apices.

**Description.** — In the holotype the string is about 1 mm wide and very low. The meanders are composite. The first-order meanders are a few cm high with their arms 1 to 2 cm apart at the base and the axes roughly parallel. The secondary meanders are low and show a sinuous, not very regular course. Many of them are provided with short triangular spiny appendages or round knobs.

**Remarks.** — This trace resembles those types of *Protopaleodictyon incompositum* that are provided with short appendages, but it is much smaller.

**Sediment.** — Fine-grained, laminated sandstone, 75 cm thick(!).

**Association.** — *Helminthopsis tenuis.*

**Origin.** — It occurs on a striated sole with a few prod marks. A low ridge, parallel to the lineation, traverses the trace but does not much affect its meanders, which are slightly depressed on the traverse (scoured?). Possibly this is a pre-depositional form.

**Occurrence.** — Upper Eocene — Magura Sandstone: Marcówka.

### *Protopaleodictyon submontanum* Azpeitia, 1933
(pl. 25, figs 1-5; text-fig. 41)

1933. *Cylindrites submontanus* n. sp., Azpeitia, p. 44, pl. 10, fig. 21B.
*Material*: 34 specimens and at least the same number of occurrences noted in the field.

**Description.** — Here are assigned hypichnial string- or thread-sized casts and full burrows, irregularly winding and meandering, branching at various points, but mostly at the apical bends of the meanders. Occasionally this branching leads to the formation of irregular networks which consist of meshes varying in size.

The width of the string varies; it is commonly 2–3 mm, rarely 3 and 3.5 mm, but there are a number of specimens in which the width of the string is less than 1 mm (pl. 25, fig. 4). The height of the strings is also variable; the thicker strings may be 1.5 mm high. The surface of the strings is smooth. The meandering is irregular; usually in the same specimen the windings are loose, and in some parts the string is only feebly curved or even straight. Branching occurs at various points, but quite often on the apices of the meanders or winding. The lateral branches usually end at a distance from the main string, but often they join one another and thus form an irregular net. The branching is due either to true or contact dichotomy. The former takes place on the apical bends, the latter on the straighter sectors of the trace. The lateral branches on the whole are less winding than the main string. The meshes are of various sizes and shape.

Fig. 41
*Protopaleodictyon submontanum* (Azpeitia)
a Komańcza, Hieroglyphic Beds (field drawing); b Osielec, Mt. Przykrzec, Hieroglyphic Beds, UJ TF 1258; c Kamionka Wielka, Hieroglyphic Beds, UJ TF 1123; d "*Cylindrites submontanus*" Azpeitia, 1933, pl. 10; e Lipnica Mała, Beloveza Beds, UJ TF 1255; f Jordanów, the hamlet Munkacz, UJ TF 765; g Zubrzyca Górna, Beloveza Beds, UJ TF 454; h "*Palaeochorda marina*" Emmons, Lessertisseur, 1955, fig. 22B, i Juszczyn, the hamlet Kozłownik, UJ TF 1252; j Kamionka Wielka, Hieroglyphic Beds, UJ TF 1123 bis; k Zubrzyca Górna, the hamlet Ochlipów, Beloveza Beds, UJ TF 1156; l Lipowe, Variegated Shales, UJ TF 637; m Komańcza, Hieroglyphic Beds, UJ TF 1148, n Lipnica Mała, Beloveza Beds, UJ TF 1255; o Berest, Beloveza Beds (field drawing); p Lipowe, Variegated Shales, UJ TF 635. All figures × 0.5

Generally, the greater the width of the string, the larger is the size of the mesh. Usually the number of complete meshes in one specimen is small: in a trace covering an area of 300 cm there are only two or three complete and a few almost closed meshes. In many specimens there are no complete meshes at all, but the general character of the trace is the same (pl. 25, fig. 2).

The trace may cover large surfaces of the sole, e.g. at Tokarnia it covers the sole densely over an area of 6 $m^2$.

**Remarks.** — Although there is considerable diversity in size and shape in the material collected, several specimens correspond well to the type described by AZPEITIA. Since the generic term used by him is ambiguous, on the strength of the figure redrawn from the paper of DELGADO (1886) by LESSERTISSEUR (1955, p. 41, fig. 22B), representing a trace very similar to our material and assigned to *Palaeochorda*, I have determined this trace as *Palaeochorda submontana* (KSIĄŻKIEWICZ, 1961*a*, pp. 883, 887, pl. 1, fig. 3). The term *Palaeochorda* was introduced by McCOY (1848) but, as noted by HÄNTZSCHEL (1965), it is synonymous with the *Gordia* of EMMONS (1844). The traces described and illustrated both by EMMONS and McCOY are quite regularly meandering, the meanders overlap or cross one another but there is no branching, whereas the material reproduced by DELGADO (1886, pl. 42 and pl. 39, fig. 2) displays distinct branching. For this reason the term *Palaeochorda* cannot be used for our material. Undoubtedly there is some semblance to *Protopaleodictyon* in the manner of branching and the tendency to form irregular networks.

The trace discussed seems to be similar to the unnamed type illustrated by SEILACHER (1959, p. 1069, fig. 19) and described as "sehr lockeres Maschenwork". The type described by AZPEITIA is regarded by LLARENA (1946) as a disordered *Paleodictyon* net.

*P. submontanum* differs from *P. incompositum* in the less regular course of the first-order meanders and the much longer appendages. The tendency towards formation of nets is more pronounced in *P. submontanum.*

The trace discussed differs from *Irredictyon* VIALOV (1971*a*) in its much more irregular and only occasionally developed network. In *Irredictyon* the sides of the meshes are much straighter, the meshes are quadrilateral, pentagonal or hexagonal, while in *P. montanum* they are quite irregular. The network described by DESIO (1940) as *Eoclathrus Balboi* has also meshes with straighter sides.

There is considerable diversity in the thickness of the strings and the size of the meshes if developed. Since there is an imperceptible gradation between the specimens with thick and very thin strings, it is not possible to divide this type into more than one species, although there is a danger that under the term *P. submontanum* more than one species may be lumped together. In the specimens with thin strings the net is better developed (pl. 25, fig. 4; text-fig. 41*k*, *l*), and perhaps this would form an argument for distinguishing them as separate ichnospecies. But there are intermediate forms between them and the types with thicker strings (text-fig. 41*b*, *c*, *e*). The advancement in maturity of the producing animals or the amount of food might have been responsible for the differences in size.

**Sediment.** — Fine-grained, thin-bedded (most often 5–12 cm, but in one case 50 cm) sandstones, graded, or horizontally and obliquely laminated.

**Association.** — The trace may be intersected by *Fucusopsis annulata*, various types of *Sabularia*, *Protopaleodictyon incompositum* (text-fig. 41*n*). In one specimen it disturbs *Helminthoida alterna.*

**Origin.** — Most of the specimens are casts, but in several instances cylindrical strings occur together with subcylindrical strings. It is possible that the animal did not fill its excavation everywhere and the void parts were filled by the collapsing roof material. A post-depositional origin is indicated by the intersection of the flutes by a trace which they have not disturbed, although its strings may stop short near the flute casts or slightly change their course on contact with it.

**Occurrence.** — This ichnospecies appears first in the Upper Cretaceous, in which it seems to be very rare, occurs in some strength in beds of the Palaeocene-Lower Eocene age, and is common in the Middle Eocene.

Cenomanian — Lower Godula Beds: Jaroszowice. Senonian — Ropianka Beds: Trzebunia, Mszana Dolna. Palaeocene-Lower Eocene — Variegated Shales: Sopotnia Mała, Lipowe, Stara Wieś, Limanowa. Lower Eocene — Beloveza Beds (frequent): Lipnica Wielka, Lipnica Mała, Zubrzyca Górna, Osielec, Zaryte, Szczawa (the stream Głębieniec), Trzetrzewina, Popowice, Berest. Middle Eocene — Hieroglyphic Beds (frequent): Rajcza, Zawoja (the hamlets Policzne, Podpolice and other places), Juszczyn (the hamlet Kozłownik), Osielec (the stream on the slope of Mt. Przykrzec), Tokarnia, Kamionka Wielka, Wysowa, Hańczowa, Komańcza; Łącko Beds: Naszacowice.

### Ichnogenus *Urohelminthoida* Sacco, 1888

*Type ichnospecies*: According to Andrews (1955) *Urohelminthoida appendiculata* (Heer), but Häntzschel (1962) takes *H. dertonensis* Sacco as the type species.

**Remarks.** — This ichnogenus is related to *Helminthoida* owing to its guided meanders, which have short appendages on the apical bends. Some meanders may have no appendages.

**Origin.** — In a few specimens of either of these ichnospecies the cylindrical shape of the strings has been ascertained, but in many cases the evidence is not clear. Probably at least some of the traces of this group are post-depositional. This view may be supposed by the fact that in some cases the burrows occur on two levels, one above the other near the underface (text-fig. 42*b*).

#### *Urohelminthoida appendiculata* (Heer, 1876)
(pl. 26, figs 1–3; text-fig. 42*a–c*)

1876. *Helminthoida appendiculata* Hr., Heer, p. 168, pl. 66, fig. 3.
*Material*: 8 specimens.

**Description.** — The strings are 2–3 mm thick, straight or feebly bent, practically parallel to one another. The appendages are 1–2 cm long. At the forking point one string usually maintains the direction of the appendix and the other makes a bend as seen in the figure of Fuchs (1895, *Hercorhaphe*, pl. 5, fig. 3).

Some specimens differ from the type of Heer by repeated forking (pl. 26, figs 2, 3); the appendix branches into two strings which at a small distance from the forking point dichotomize again.

In some strings, which for the most part are full burrows, some enrichment in coarser grains and mica is noticeable.

**Sediment.** — Fine-grained, graded sandstones, 3–6 cm thick.

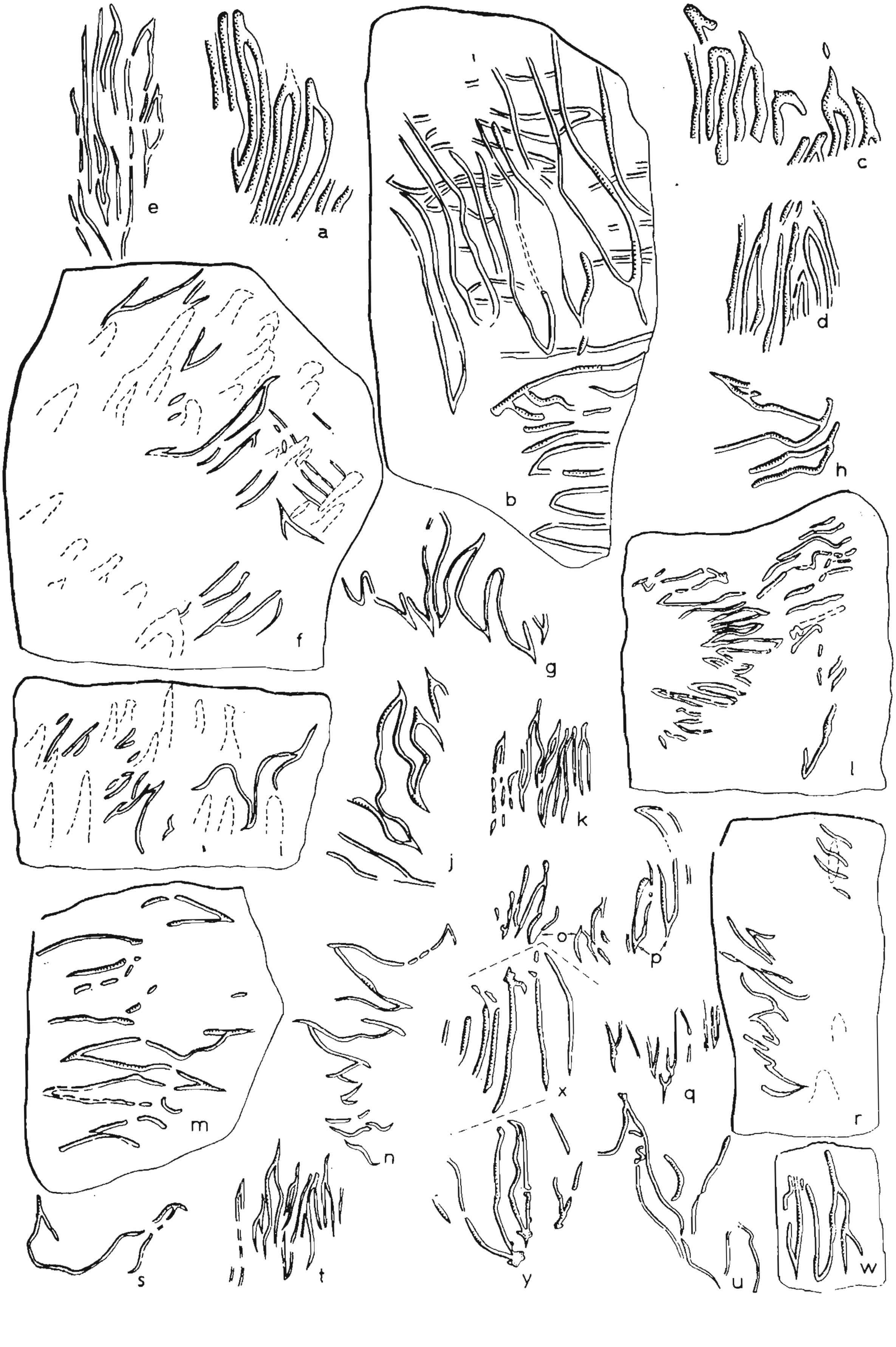
**Association.** — Small *Desmograpton*, *Glockeria parvula*.

**Occurrence.** — Senonian — Ropianka Beds: Lipnica Wielka (the hamlet Kiczora — reported as *Hercorhaphe* Fuchs, Książkiewicz, 1960, pl. 1, figs 2–3), Limanowa, Grybów; Skrzydlna Beds: Skrzydlna. Palaeocene — Szczawnica Beds: Krościenko on the river Dunajec. Palaeocene-Lower Eocene — Variegated Shales: Lipnica Wielka (the hamlet Kiczora).

#### *Urohelminthoida dertonensis* Sacco, 1888
(pl. 26, figs 4, 5; text-fig. 42*e–w*)

1888. *Urohelminthoida dertonensis* Sacc., Sacco., p. 184, pl. 2, fig. 8.
*Material*: 30 specimens.

**Description.** — This is a not uncommon type in the Carpathian flysch but in very few instances is fully developed or preserved. The strings are 0.5 to 1.5 mm wide. The distance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between the forking points varies from 2.5 to 6 cm and may vary in one and the same specimen. The forking angle also varies; it may be as wide as 40°. The length of the appendages is 1 to 12 mm, but usually short appendages predominate. The strings are often not so parallel as in *H. appendiculata*.

All specimens are hypichnial, except for one collected in the Ropianka Beds (Kąclowa), which is endichnial.

The specimens found in the Ciężkowice Sandstone have transverse irregular knobs instead of appendages (pl. 26, fig. 6; text-fig. 42*x*, *y*). They may be related to an unnamed type pictured by SEILACHER (1955, fig. 5, nr 72), in which, however, the transversal position of the appendages is more pronounced.

**Sediment.** — Fine-grained, gradationally or horizontally laminated sandstones, up to 20 cm thick.

**Association.** — May be intersected by *Subphyllochorda*, *Spirophycus*, *Buthotrephis*. Accompanied by *Helminthoida alterna*.

**Occurrence.** — Hauterivian — Grodziszcze Beds: Wiśniowa (the stream Marków), Bieśnik. Senonian — Inoceramian Beds: Rzegocin, Krasice, Kalwaria Pacławska (the stream Sopotnik), Skrzydlna Beds: Przenosza, Skrzydlna; Ropianka Beds: Zawoja, Grzechynia, Limanowa, Wola Krogulecka, Biała Wyżna, Kwiatoń. Palaeocene — Upper Istebna Beds: Tabaszowa, Czarnorzeki; Szczawnica Beds: Krościenko on the river Dunajec (KSIĄŻKIEWICZ. 1961*a*, pl. 2, fig. 4); Grywałd (the stream Tylka). Palaeocene-Lower Eocene — Variegated Shales: Zaryte, Lipowe, Kąclowa. Lower Eocene: Znamirowice (not typical) — Beloveza Beds: Lipnica Wielka, Lipnica Mała, Zubrzyca Górna (the hamlet Ochlipów), Zubrzyca Dolna, Sidzina, Osielec, Łętownia Górna, Szczawa (the stream Głębieniec), Zbludza, Trzetrzewina, Berest. Middle Eocene — Hieroglyphic Beds: Juszczyn, Bieńkówka, Brzeźna, Hańczowa, Komańcza; Łącko Beds: Naszacowice, Myślec. Upper Eocene — Magura Sandstone: Młynne (interbed of thin-bedded sandstones).

## X. NETWORKS

This group includes traces in the form of more or less complete nets with straight or almost straight strings. Here belong *Desmograpton* FUCHS, *Megagrapton* KSIĄŻKIEWICZ, and *Paleodictyon* MENEGHINI. All are hypichnial structures.

### Ichnogenus *Desmograpton* FUCHS

*Type ichnospecies: Desmograpton fuchsi* n. ichnosp.

**Remarks.** — Since FUCHS did not use any specific name, the traces he illustrated (pl. 5, figs 1–2, 4–6) have been taken as the type ichnospecies and named *Desmograpton fuchsi* n. ichnosp.

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Fig. 42

*Urohelminthoida* SACCO

a–c *H. appendiculata* (HEER): a Limanowa, Ropianka Beds, UJ TF 702, b Krościenko, Szczawnica Beds, UJ TF 749; c Limanowa, Ropianka Beds, UJ TF 661; d Limanowa, Ropianka Beds, TF 823; e–w *H. dertonensis* SACCO: e Krościenko, Szczawnica Beds, UJ TF 768; f Zubrzyca Górna, the hamlet Moniaków, Beloveza Beds, UJ TF 358; g Kalwaria Pacławska, Inoceramian Beds, UJ TF 1486; h Lipnica Mała, Beloveza Beds, UJ TF 1593; i Łętownia Górna, Beloveza Beds, UJ TF 355; j Hańczowa, Hieroglyphic Beds, UJ TF 1862; k Szczawa, the stream Głębieniec UJ TF 732; l Tabaszowa, Upper Istebna Beds, UJ TF 348; m Sidzina, Beloveza Beds, UJ TF 352; n Osielec, Beloveza Beds, UJ TF 141; o Myślec, Łącko Beds, UJ TF 974; p Przenosza, Skrzydlna Beds, UJ TF 1134; p Przenosza, Skrzydlna Beds, UJ TF 1150; r Lipnica Mała, Beloveza Beds, UJ TF 344; s Wiśniowa, Grodziszcze Beds, UJ TF 1172; t Szczawa, the stream Głębieniec, Beloveza Beds, UJ TF 2052; u Zubrzyca Górna, Beloveza Beds, UJ TF 360; w Zawoja, the stream Kalinka, Ropianka Beds, UJ TF 351; x *U.* aff. *dertonensis* SACCO, Znamirowice, Ciężkowice Sandstone, UJ TF 346; y *U.* aff. *dertonensis* SACCO, Znamirowice, Ciężkowice Sandstone, UJ TF 144. All figures × 0·5

*Desmograpton fuchsi* n. ichnosp.
(pl. 29, fig. 5; text-fig. 43)

1895. *Desmograpton*, FUCHS, p. 349, pl. 5, figs 1–2, 4–6.
*Lectotype*: FUCHS, 1895, pl. 5, fig. 2.
*Cotype*: UJ TF 1119 (pl. 29, fig. 5).
*Type locality (for the cotype)*: Lipnica Wielka, the hamlet Kiczora, near Nowy Targ.
*Type horizon (for the cotype)*: Ropianka Beds, Senonian.
*Derivation of the name*: in honour of THEODOR FUCHS, Austrian geologist and palaeontologist.
*Material*: 21 specimens.

**Diagnosis.** — Hypichnial narrow, roughly straight and parallel closely spaced string-sized full burrows arranged in bands, with some transverse links between the strings.

**Description.** — The specimen taken for the cotype occurs on the sole in the form of two

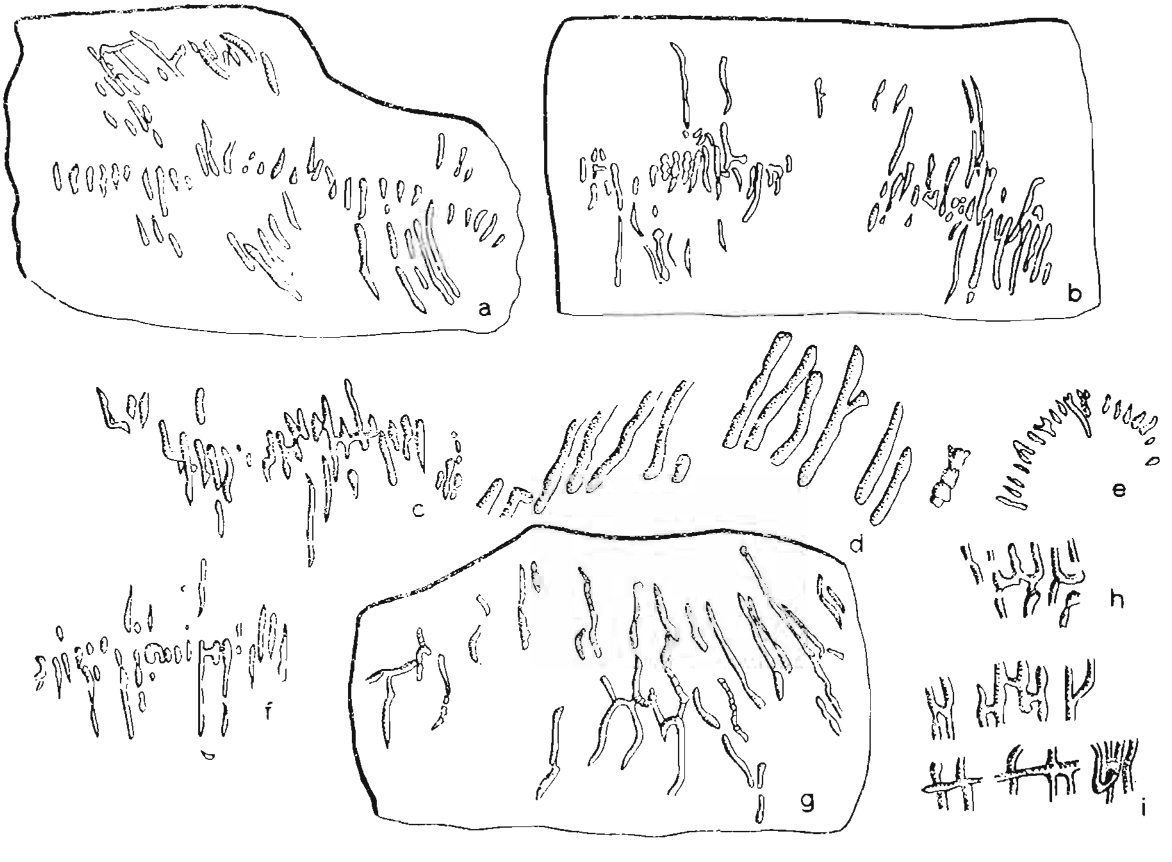



Fig. 43
*Desmograpton fuchsi* n. ichnosp.
[a] Maruszyna, Babiarze Beds, UJ TF 396; [b] Biała Wyżna, Ropianka Beds, UJ TF 1433; [c] Valea de Largu, Rumanian Carpathians, Hangu (= Inoceramian) Beds, UJ TF 1350; [d] Kleczany, Ropianka(?) Beds, (coll. W. SZAJNOCHA), UJ TF 1453; [e] Lipnica Wielka, the hamlet Kiczora, Ropianka Beds, UJ TF 1591; [f] Limanowa, Ropianka Beds, UJ TF 664; [g] Sidzina, the stream Głaza, Beloveza Beds, UJ TF 1452; [h]–[i] various types of transverse links: [h] Wola Krogulecka, Ropianka Beds, UJ TF 2002; [i] Lipnica Wielka, the hamlet Kiczora, UJ TF 1119 and other specimens. All figures × 0.5

bands, one (presented in pl. 29) 18 cm, the other 10 cm long. The strings are 0.6 to 1.0 mm wide. They attain the greatest width in the middle portion of the band, where they are somewhat swollen. Some strings are also swollen at their ends, but most ot them thin out towards their terminations. Their length varies: the longest are 40 mm, but many may be only 8–10 mm long. They are approximately parallel, particularly in the median zone of the band, but towards their ends are often curved. The intervals between the strings are fairly constant, 1.5 to 2 mm wide. There are few interconnecting strings.

In some specimens the strings are slightly thicker (one, text-fig. 43*d*, probably belonging to this ichnospecies, has strings 4 mm wide) and not so closely spaced, while in others they are very thin and short (text-fig. 43*e*). These differences may be due to the different ages of the producing animals. The transversal links may be of various characters (text-fig. 43*h*, *i*). Some are lateral branches of the main string, dichotomizing at a right or an acute angle and thus forming Y- or H-shaped interconnection between the main strings. Some of the transversal links intersect the neighbouring main strings, others form meandering bends in the median zone. In some specimens the transversal links may be entirely absent.

**Remarks.** — If the transversal links in the median zone of the band are absent, doubts may arise whether a specimen of this type actually belongs to *Desmograpton*, since the central part of *Helminthoida crassa* or *Urohelminthoida* if without terminations at either end of the meanders may be similar to *Desmograpton*. A swelling of the strings in the median zone, characteristic of all fully developed specimens, is helpful in these instances.

**Sediment.** — Fine-grained, graded or horizontally laminated sandstones, thin-bedded (in one instance 15 cm thick).

**Association.** — *Urohelminthoida appendiculata*, *Taphrhelminthopsis auricularis*. May be intersected by *Sabularia*.

**Origin.** — In most cases there are no clear indications whether this type is pre- or post-depositional, since the strings are closely fused with the host rock. In the cotype and some other specimens the strings seem to be cylindrical. In one specimen the strings intersect ridge-and-furrow crescentic structures of the sole. It seems that at least part of these traces are post-depositional.

It is not easy to explain the formation of the pattern of parallel strings in *Desmograpton*. Here perhaps the specimen in text-fig. 43*g* may be of some help. In it the apical bends are partly joined and the other ends of the meanders are without termination. This specimen resembles *Helminthoida alterna*, in which the apical bends of two opposing sets of meanders are very near one another. It may be that in *Desmograpton* these bends merge together, and in *H. alterna* they are separated by an empty zone between the two opposing sets. If so, the manner of constructing the network of *Desmograpton* would have been similar to that of *H. alterna*, only the spacing of the arms of the meanders is denser and the arcuate terminal bends shorther and closely linked in *Desmograpton* (text-fig. 43*c*,*f*).

As in helminthoids, polychaete worms were the most probable producers.

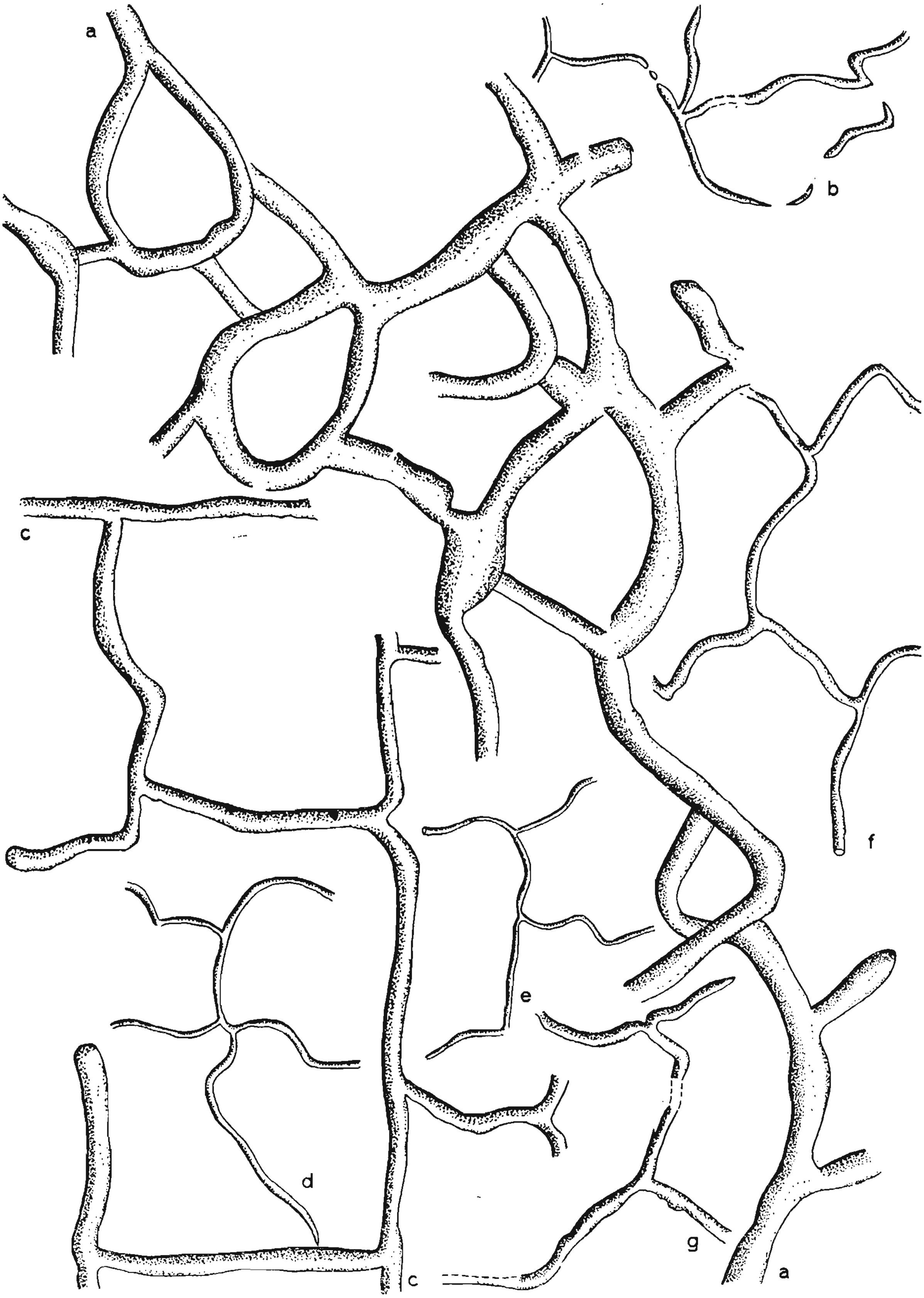
**Occurrence.** — Turonian — Middle Godula Beds: Kocierz. Senonian — Inoceramian Beds: Rzegocin, Kąkolówka, Bachów, Krasiczyn (coll. K. WÓJCIK), Huwniki, Wola Romanowa; Ropianka Beds: Lipnica Wielka (the hamlet Kiczora), Limanowa (the hamlet Marciszów), Klęczany (coll. W. SZAJNOCHA), Wola Brzezińska, Wola Krogulecka, Biała Wyżna; Sromowce Beds: Maruszyna. Palaeocene — Szczawnica Beds: Hałuszowa, Grywałd; Babiarze Beds: Maruszyna (the hamlet Babiarze). Lower Eocene — Beloveza Beds: Sidzina (not typical, text-fig. 43*g*).

### Ichnogenus *Megagrapton* KSIĄŻKIEWICZ, 1968

*Type ichnospecies: Megagrapton irregulare* KSIĄŻKIEWICZ, 1968.

**Diagnosis.** — Hypichnial straight or feebly curved burrow, string-sized, branching at approximately right angles and forming nets composed of irregular, not always closed polygons (KSIĄŻKIEWICZ, 1968).

**Remarks.** — This trace has some resemblance to *Protopaleodictyon submontanum* as it tends to be composed of irregular and incompleted meshes. It differs in the non-meandering, almost straight course of its strings.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### *Megagrapton irregulare* KSIĄŻKIEWICZ, 1968
(pl. 25, figs 6–8; text-fig. 44)

1968. *Megagrapton irregulare* n. "sp.", KSIĄŻKIEWICZ, pp. 5, 14, text-fig. 3.
*Holotype*: UJ TF 809 (pl. 25, fig. 6).
*Type locality*: Berest near Grybów.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: irregular network.
*Material*: 13 specimens.

**Diagnosis.** — Hypichnial string-sized full burrows, straight or weakly curved, branching at irregular intervals mostly at approximately right angles and forming more or less complete irregular polygons.

**Description.** — The holotype consists of cylindrical strings 2 mm wide and up to 1.5 mm high. They are almost straight. At various intervals they branch at approximately right angles. Some of the branches end abruptly, others join and form meshes. A completed mesh is roughly rectangular (4.5×7 cm).

Other specimens show the same main features, but there is considerable diversity in the thickness of the strings and the size of the meshes. The thickness of the strings varies between 1 and 3 mm, the size of the meshes from 3.5×5.5 cm up to meshes 17 cm long. Many of them are not closed.

The specimens illustrated in pl. 25, fig. 9 and text-fig. 44*a* are assigned here with some doubts. These are very thick (up to 12 mm) cylindrical strings, in some parts swollen, ramifying at various angles. The network is highly irregular, the meshes of various size and shape. Perhaps these specimens deserve to be classified as distinct ichnospecies of *Megagrapton*.

**Sediment.** — Thin-bedded (the thickest 20 cm, usually much less), fine-grained sandstones, with composite bedding or horizontally and current-laminated sandstones.

**Association.** — *Belorhaphe*, *Paleodictyon*; in one instance the trace intersects *Sabularia*, in another is intersected by it. It interpenetrates *Strobilorhaphe clavata*.

**Origin.** — The evidently cylindrical form (sometimes the strings adhere to the sole) and intersection of sedimentary structures suggest a post-depositional origin. The abrupt breaks in the string (pl. 25, fig. 7; text-fig. 44*f*) may have been formed when the animal left the interface and descended in to the clay.

**Occurrence.** — Senonian — Ropianka Beds: Limanowa (the hamlet Marciszów), Kąclowa (the thick type); Sromowce Beds: Jaworki (the stream Skalski). Palaeocene-Lower Eocene — Variegated Shales: Stara Wieś, Biczyce (the thick type). Lower Eocene — Ciężkowice Sandstone: Ciężkowice (in shaly interbeds); Beloveza Beds: Lipnica Mała, Zubrzyca Górna (the hamlet Moniaków — KSIĄŻKIEWICZ, 1961*a*, pl. 1, fig. 1–2, reported as *Megagrapton* n. f.); Sidzina (the stream across Mt. Kiełek), Szczawa (the stream Głębieniec), Myślec, Berest. Middle Eocene — Łącko Beds: Myślec. Oligocene — Krosno Beds: Mszana Dolna.

### *Megagrapton tenue* KSIĄŻKIEWICZ, 1968
(pl. 25, fig. 10)

1968. *Megagrapton tenue* n. "sp.", KSIĄŻKIEWICZ, pp. 5, 14, fig. 1.
*Holotype*: UJ TF 391 (pl. 25, fig. 9).
*Type locality*: Goleszów near Cieszyn.

Fig. 44
*Megagrapton irregulare* KSIĄŻKIEWICZ
[a] Kąclowa, Ropianka Beds (after field photography); [b] Lipnica Mała, Beloveza Beds, UJ TF 1343; [c] Zubrzyca Górna, the hamlet Moniaków, Beloveza Beds, UJ TF 2042; [d] Jaworki, the stream Skalski, Sromowce Beds (field drawing); [e] Zubrzyca Górna, Beloveza Beds, UJ TF 1345; [f] Zubrzyca Górna, Beloveza Beds, UJ TF 387; [g] Berest, Beloveza Beds, UJ TF 2053. All figures × 0.5

*Type horizon*: Cieszyn limestone, Berriasian.
*Derivation of the name*: Lat. *tenuis* — very small; a very slender trace.
*Material*: 2 specimens.

**Diagnosis.** — Hypichnial, thread-sized full (?) burrow, ramifying at various intervals and forming a network composed of irregular polygons and rectangles.

**Description.** — In the holotype the string is 1 mm wide. It ramifies at irregular intervals (15–25 mm) at approximately right angles. The strings are straight or weakly curved. The dimensions of the rectangles are variable, the smallest being $15 \times 25$ mm, the largest $25 \times 35$ mm. Some of the polygons are pentagonal. As the strings are not continuous, only a few polygons are closed.

**Remarks.** — Since some of the polygons are pentagonal, the network is somewhat similar to *Paleodictyon*. The size and shape of the polygons in the trace discussed vary, and for the most part are incomplete, while in the species of *Paleodictyon* the differences in the size and shape in one and the same specimen are very small. In addition, in *Paleodictyon* the meshes are closed except for the lateral zones of the nets.

**Sediment.** — Fine-grained limestone, 3 cm thick, with composite bedding.

**Origin.** — As is usually the case with thin strings, it is difficult to determine whether they are cylindrical or not. The trace occurs on an uneven sole, and the string breaks off on all protuberances. It is bordered on one side by a drag mark, but there are no indications that the trace is intersected by it. The string thins out and wanes before reaching the drag mark. Possibly, the animal stopped constructing its net in front of the obstacle, or omitted it by digging into the subjacent clay.

**Occurrence.** — Berriasian — Cieszyn Limestone; Goleszów (the main quarry).

## Ichnogenus *Paleodictyon* MENEGHINI, 1850

*Type ichnospecies: Paleodictyon strozzii* MENEGHINI (HÄNTZSCHEL, 1962).

**Remarks.** — The classification of *Paleodictyon* is based on the size of the meshes, the thickness of the bordering riblets and the regularity or irregularity of the meshes (WANNER, 1949). The last feature seems to depend mainly on the character of the underface: on even, flat soles the meshes are on the whole more regular.

The classification into "subgenera", *Paleodictyon s. str.* and *Glenodictyon*, proposed by VIALOV and GOLEV (1960), is not followed in this paper. This was based on the thickness of the bordering riblets, which may vary in one and the same specimen. The thickness of the riblets may depend to a considerable extent on the position of a riblet in respect to the underface. The riblets are cylindrical or subcylindrical. If the riblet adheres to the underface or lies with its diameter on the same level as the underface, the visible width of the riblet is the greatest. When the riblets are situated more or less above the underface, their apparent width becomes smaller. If the riblets are casts of pre-depositional grooves, their width depends on the depth of scouring.

VIALOV and GOLEV (1960) treat *Pleurodictyon* FUCHS (1895) as a separate "genus", since in this group the bordering riblets are developed in an ellipsoidally swollen form or replaced by tubercules. This distinction is not observed by HÄNTZSCHEL (1965), who regards *Pleurodictyon* as synonymous with *Paleodictyon* (see also NOWAK, 1959). Actually, in the figure given by FUCHS (1895, pl. 6, fig. 1) which is to represent *Pleurodictyon*, some bordering riblets are swollen in the centre, but a good many of them exhibit a normal shape with parallel flanks. Furthermore, in the material collected the networks, in which all or some of the riblets have an abnormal shape, are always developed in distinctly coarser material. This seems to suggest that the producing animal, when working in a coarser material excreted its droppings in a different way than when working in a finer-grained sediment. In these conditions the animal did

Table 16

| | *P. minimum* | | | *P. latum* | | | | *P. intermedium* | | | | *P. strozzii* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Berest, L. Eocene UJ TF 849 | Berest, L. Eocene UJ TF 894 | Jaworki, Senonian UJ TF 169 | Sidzina, L. Eocene UJ TF 1258 | Sidzina, L. Eocene UJ TF 170 | Mymoń, Oligocene UJ TF 836 | Mymoń, Oligocene UJ TF 841 | Wiśniowa, Hauterivian UJ FT 1172 | Mordarka, Senonian UJ TF 644 | Sromowce, W., Senonian UJ TF 67 | Znamirowice, Eocene UJ TF 68 | Jaworki, Senonian UJ TF 330 | Lipnica Wielka, Senonian UJ TF 1102 | Grzechynia, Senonian UJ TF 274 | Berest, L. Eocene UJ TF 846 |
| Riblets mm | 0·3 | 0·3–0·4 | 0·3–0·5 | 0·5–0·7 | 0·5–1·0 | 0·5–0·7 | 0·5–0·6 | 0·7–1·0 | 0·6–1·0 | 0·7 | 0·5–0·7 | 0·6–0·8 | 0·6–0·8 | 0·4–0·8 | 0·3–0·7 |
| Max. length of meshes mm 0·5 | | | 2 | | | | | | | | | | | | |
| 1·0 | | 10 | 10 | 11 | | | 8 | | | 1 | | | | | |
| 1·5 | 10 | 11 | 20 | 15 | 19 | | 18 | | | | | | | | |
| 2·0 | 1 | 1 | 3 | 6 | 15 | 12 | 12 | 13 | 1 | 8 | 2 | | 1 | | |
| 2·5 | | | | 8 | 1 | 5 | 2 | 19 | 4 | 6 | 11 | 3 | 5 | | 1 |
| 3·0 | | | | | | | 3 | 13 | 1 | 3 | 12 | 6 | 23 | 8 | |
| 3·5 | | | | | | | | 8 | | 2 | 4 | 5 | 5 | 8 | 3 |
| 4·0 | | | | | | 1 | | | | | 1 | 2 | 10 | 7 | 5 |
| 4·5 | | | | | | | | | | | | 1 | 3 | 1 | 2 |
| 5·0 | | | | | | | | | | | | 3 | 4 | | 3 |
| 6·0 | | | | | | | | | | | | | | 1 | |

not excrete continuously, but at regular intervals squirted out little jets of the processed material. Since the existence of specimens with a mixed type of ribbing, as seen in the figure of FUCHS and in some of our specimens (pl. 27, figs 15, 17, pl. 29, fig. 1) renders the distinction of *Pleurodictyon* from *Paleodictyon* impossible, the specimens with abnormal riblets are treated here as separate forms of *Paleodictyon*. The classification of these aberrant forms is adapted to that of normal forms: they are assigned to various ichnospecies of *Paleodictyon* on the basis of the size of the meshes and the width of the abnormal riblets. Those with swollen riblets are termed forma *pleurodictyonoides* and the forms in which riblets are replaced by tubercules forma *punctata*.

The existing classification of *Paleodictyon* has many drawbacks. As said above, the width of the bordering riblets may vary in one and the same specimen. In some cases the size and shape of the meshes seem to be influenced by the relief of the sole along which the animal was working (F. SIMPSON, 1967). But when basic features (thickness of the bordering ridges, size of the meshes) are measured, it appears that the networks may be divided into several size classes, between which there is little overlapping (tables 16, 17). This apparently may indicate that specific classification now in use is justified.

Yet there is still another difficulty, recently raised by CHAMBERLAIN (1971), who called attention to the problem of the ontogenetic growth of *Paleodictyon* net producers. It may be envisaged that the differences in the size of the burrows and meshes are due rather to this cause, and not to a specific differentiation. In this respect certain cases are discussed below in the characterizations of the ichnospecies described. Much further study is needed on this problem.

**Origin.** — Older views, epitomized by SACCO (1939), which considered *Paleodictyon* as a body fossil, have been abandoned since SEILACHER (1954, p. 217, fig. 2) suggested that it is a feeding trail. Now there are two problems concerning the origin of *Paleodictyon*: first, whether this trace is pre- or post-depositional; second, how the net-laying animal constructed such a regular network.

The first question is still under discussion. Long ago SQUINABOL (1890, p. 33, fig. 1) found that the bordering riblets are of cylindrical shape. A similar observation was made later by WOOD and SMITH (1958) and NOWAK (1959, fig. 6*l*). On the other hand SEILACHER (1962), who found *Paleodictyon* in pelitic rocks, presumes that it is a pre-depositional mud burrow, excavated and filled with sand by a current. The view of pre-depositional origin is supported by DŻUŁYŃSKI and SANDERS (1962, pl. 1A) who illustrated *Paleodictyon* net intersected by a flute cast. CHAMBERLAIN (1971*a*) treats *Paleodictyon* as "an endogenic scoured and sand cast hyporelief". The views of MIRCEA (1937) and VIALOV (1963, 1964) that the *Paleodictyon* nets may be imprints of tadpoles is also in accordance with the concept of a pre-depositional origin. A strong argument against the view of pre-depositional origin is brought by F. SIMPSON (1967) who, on the basis of the material collected in the Sromowce Beds of the Pieniny zone, noted that larger and more symmetrical meshes occur on the crests of erosional structures (flutes), and smaller ones are developed between these features. The present author (KSIĄŻKIEWICZ, 1970, p. 306) found in a few cases that the riblets are cylindrical (an observation now confirmed by a much richer material) and that in one instance the riblets intersect a clearly post-depositional *Helminthopsis* (KSIĄŻKIEWICZ, 1970, pl. 4, fig. *q*). There are also instances of well-developed networks covering the steep flanks of erosional features on underfaces (pl. 27, fig. 13). In very many specimens the riblets are so well welded to the sole that it is impossible to determine whether they are actually cylindrical and post-depositional, or groove casts and pre-depositional. There are also instances of very tiny meshes occurring on soles of relatively thick sandstones (10 cm). It is difficult to assume that a very small animal managed to build a regular net below a considerable overburden. On the basis of all these facts it may be assumed that many, if not most, of the *Paleodictyon* producers lived and worked below sand layers, but some were able to live in mud, and probably to ingest both mud and fine-grained sand.

It should be added that CRIMES (1973) found in the Spanish flysch both pre- and post-depositional paleodictyons.

The manner of construction of the network poses another problem. SQUINABOL (1890, p. 33), and later FUCHS (1895) and NOWAK (1959), considered that the net was formed of a combination of the *Belorhaphe*-type traces (text-fig. 45*a*). To endorse this view NOWAK claims that *Belorhaphe* and *Paleodictyon* often occur together. This cannot be confirmed by the present author, who collected almost 200 slabs with *Paleodictyon*, and only in very few found *Paleodictyon* and *Belorhaphe* together on the same sole. Moreover, the apical angle of the triangular meanders in *Belorhaphe* are much smaller than the angles in the pentagonal and hexagonal meshes of paleodictyons. There are also very rare cases when the presumably apical appendix directly meets the opposite appendix, as it would be if the *Paleodictyon* network were formed in the way presumed by SQUINABOL (text-fig. 45*a*). Another interpretation was offered by CHAMBERLAIN (1971*a*). According to him the net is built up by a simple meander pattern in which converging meanders overlap (text-fig. 45*b*). This view could be supported if specimens were found in which in the presumably overlapping parts of the meanders the bordering riblets occur one above the other. No such specimens have been detected in the comparatively rich Carpathian material, neither have any specimens with vertical turnings been found which could endorse the interpretation proposed by WEBBY (1969*b*).

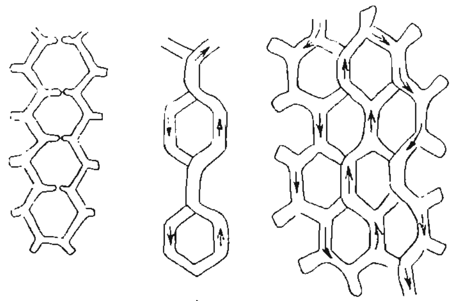


Fig. 45
*Paleodictyon*. The manner of net-laying
[a] interpretation of SQUINABOL — FUCHS — NOWAK; [b] interpretation of CHAMBERLAIN; [c] interpretation of the author

Another interpretations is tentatively put forward here. Generally, in the appendiculate meandering traces the appendages are placed on the apical bends of the meanders *(Protopaleodictyon, Belorhaphe, Urohelminthoida)*, or on the corners of the quadratic meanders, as is the case in *Paleomeandron*. In the latter the meanders may have a trapezoidal form, approximating that of a halved *Paleodictyon* hexagon. If the animal followed such a trapezoidal course and by its nature had the propensity of probing the sand sideways (with its proboscis) it made, like the *Paleomeandron* producer, small processes on the corners of its trapezoidal meanders (text-fig. 45*c*). Initially, the animal formed appendages on both sides of its course, since both were free. When it turned back and thigmotactically meandered closely to the meandering burrows already made, it did not push its proboscis toward the existing trace (because of phobotaxis), but only towards the free side. From the occupied side the animal was repelled either by some sort of chemical sensing or tactile perception. If this explanation is right, paleodictyons would have been formed similarly to *Paleomeandron*, only the meanders were more closely guided, and the lateral protuberances longer.

In the cases when *Paleodictyon* is a full burrow, the problem of filling the lateral appendages is the same as in all meandering forms with lateral branches.

### *Paleodictyon minutissimum* KSIĄŻKIEWICZ, 1970
(pl. 27, figs 1, 2)

1970. *Paleodictyon minutissimum* ichnosp. nov., KSIĄŻKIEWICZ, p. 306, pl. 6*a*, *b*.
*Holotype*: UJ TF 89 (pl. 27, fig. 2).

Table 17

| | *P. miocenicum* | | | | *P. carpathicum* | | | | *P. majus* | | | | *P. regulare* | | | *P. tellinii* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mszana Dl. Senonian UJ TF 1259 | Wola Brzezińska, Palaeocene UJ TF 1012 | Lipnica Mała L. Eocene UJ TF 64 | Mymoń, Oligocene UJ TF 835 | Sidzina, L. Eocene UJ TF 309 | Sidzina, L. Eocene UJ TF 285 | Berest, L. Eocene UJ TF 891 | Koninka, M. Eocene UJ TF 491 | Stara Wieś, L. Eocene UJ TF 660 | Rabka, L. Eocene UJ TF 185 | Lubomierz, L. Eocene UJ TF 173 | Lipnica Mała, L. Eocene UJ TF 186 | Jaworki, Senonian UJ TF 92 | Zubrzyca Górna, L. Eocene UJ TF 167 | Znamirowice, L. Eocene UJ TF 104 | Koninka, Senonian UJ TF 187 | Koninka, Senonian UJ TF 188 | Myślec, L. Eocene UJ TF 977 |
| Riblets (mm) | 1·0–1·2 | 1·2–1·5 | 1·0–1·2 | 1·0–1·4 | 1·0–1·3 | 1·1–1·2 | 1·0–1·2 | 1·0–1·5 | 1·0–1·2 | 1·0–1·5 | 1·0–1·2 | 1·0–1·4 | 2·0–2·5 | 1·6–2·0 | 1·5–2·5 | 0·5 | 0·5–0·6 | 0·5–1·0 |
| Maximum lenght of meshes (mm) | | | | | | | | | | | | | | | | | | |
| 1·0 | | | | | | | | | | | | | | | | | | |
| 1·5 | | | | | | | | | | | | | | | | | | |
| 2·0 | | | | | | | | | | | | | | | | | | |
| 2·5 | | 2 | | 1 | | | | | | | | | | | | | | |
| 3·0 | 1 | 6 | | 1 | | | | | | | | | | | | 1 | | |
| 3·5 | 1 | | 1 | | | | | | | | | | | | | | | |
| 4·0 | 5 | 1 | 10 | 4 | | | | | | | | | | | | 2 | 1 | |
| 4·5 | | 1 | 9 | | | | | | | | | | | | | | 1 | |
| 5·0 | 4 | | 4 | 7 | 1 | 1 | | | | | | | | 1 | | 3 | 3 | |
| 6·0 | 3 | | | 2 | 3 | 2 | 1 | | | | | | | 3 | 4 | 6 | 4 | 1 |
| 7·0 | | | | 1 | 5 | 12 | 5 | 2 | | | | | 8 | 23 | 5 | 3 | 2 | 2 |
| 8·0 | | | | 2 | 8 | 13 | 2 | 7 | 4 | | 3 | | 19 | 11 | 1 | 3 | 3 | 1 |
| 9·0 | | | | | 5 | 2 | 5 | 6 | 6 | 4 | 9 | 1 | 26 | 9 | 3 | | | 2 |
| 10·0 | | | | | | 1 | 3 | 3 | 3 | 7 | 14 | 4 | 31 | 4 | | | | |
| 11·0 | | | | | | | 4 | | 9 | 6 | 12 | 4 | 1 | 1 | | | | |
| 12·0 | | | | | | | | | | 5 | 13 | 3 | | | | | | |
| 13·0 | | | | | | | | | | 2 | 2 | 2 | | | | | | |
| 14·0 | | | | | | | | | | | 1 | 1 | | | | | | |
| 15·0 | | | | | | | | | | | 1 | 1 | | | | | | |

*Type locality*: Sidzina, the stream Kamieński, near Jordanów.
*Type horizon*: Beloveza Beds, Lower Eocene.
*Derivation of the name*: Lat. *minutissimus* — very small.
*Material*: 5 specimens.

**Diagnosis.** — The greatest diameter of the meshes is smaller than 1 mm, the bordering riblets are up to 0.5 mm wide, nets very small.

**Description.** — In the holotype the net is 5×7 mm in area. The riblets are 0.3 to 0.4 mm wide, about 0.2 mm high. The meshes are roughly hexagonal. Their maximum diameter varies between 0.7 and 1.0 mm.

This tiny kind occurs as minute nets consisting of a few meshes in one specimen (pl. 27, fig. 1), or crescentic stripes. The width of the riblets ranges from 0.3 to 0.5 mm, the mesh size from 0.7 to 1.2 mm; it may vary in one and the same specimen.

**Sediment.** — The holotype occurs on the sole of a fine-grained, 2.5 cm thick sandstone, but the Komańcza specimen was found on the sole of a sandstone 10 cm thick.

**Association.** — In two places together with *Paleodictyon carpathicum*. This may lead to a suspicion that it might have been formed by very young individuals of the same producer which made *P. carpathicum*. In one case intersected by *Fucusopsis annulata*.

**Occurrence.** — Lower Eocene — Beloveza Beds: Sidzina, (the stream Kamieński), Zubrzyca Górna (the hamlet Ochlipów). Middle Eocene — Hieroglyphic Beds: Komańcza.

### *Paleodictyon minimum* Sacco, 1888
(pl. 27, figs 3, 4, 6, 7)

1888. *Paleodictyon minimum* Sacc., Sacco, p. 159, pl. 1, fig. 6.
*Material*: 8 specimens.

**Description.** — The meshes are 1–2 mm long, the bordering riblets for the most part 0.25 to 0.5 mm wide, about 0.3 mm high. The width of the riblets may vary in one and the same specimen. It is slightly smaller than in Sacco's definition. The meshes are fairly regular, for the most part hexagonal; in one specimen they are slightly elongated. Some meshes have a tiny tubercule in the centre.

**Remarks.** — This species correspond well with the *Paleodictyon minutum* of Kindelan (1919), but Vialov and Golev (1965) showed that this species does not essentially differ from Sacco's form.

**Sediment.** — Very fine-grained, thin bedded (2.5 to 3 cm, in one instance 9 cm), graded, horizontally laminated or single-current bedded sandstones. Occurs on flat soles, except for the thickest bed, which exhibits small flute casts not substantially influencing the trace.

**Association.** — In one case together with *Paleodictyon carpathicum*. At Mymoń it occurs in the same bed in which nets of *Paleodictyon latum* are abundant. Accompanied by *Halymenidium*, intersected by *Sabularia*.

**Occurrence.** — Senonian — Sromowce Beds: Sromowce Wyżne (the hamlet Kąty), Jaworki (the stream Skalski). Palaeocene-Lower Eocene — Variegated Shales: Trzetrzewina. Lower Eocene — Beloveza Beds: Lipnica Wielka, Lipnica Mała, Sidzina, Berest. Oligocene — Krosno Beds: Mymoń, Jawornik (Nowak, 1959, pl. 6, fig. *d*).

### *Paleodictyon latum* Vialov & Golev, 1965
(pl. 27, fig. 5)

1965. *Paleodictyon (Glenodictyon) latum*, Vialov & Golev, p. 20, pl. 2, fig. 1.
*Material*: 23 specimens.

**Description.** — The thickness of the riblets varies from 0.5 up to 1 mm, but most commonly is 0.5–0.7 mm. The mesh length ranges from 1 to 3 mm, but most commonly is 1.5 to 2 mm (table 16). The meshes are hexagonal and uniform in shape, which according to Vialov and

GOLEV is one of the characteristic features of this ichnospecies. There are, however, specimens with a fairly variable mesh size in one and the same specimen. Some meshes may also be pentagonal or quadratic, or even subcircular. The largest net is 18 cm$^2$.

**Remarks.** — There are some difficulties in distinguishing this species from *P. minimum*. In some specimens the width of the riblets is so variable that it even falls to the width characteristic of *P. minimum*.

**Sediment.** — Fine-grained, thin-bedded sandstones (up to 5 cm, usually less), graded, more often gradationally and horizontally laminated or single-current laminated. The soles of this form are usually flat and smooth. When the surface is fluted the nets develop along the borders of the flute casts.

**Association.** — *Helicolithus* and some not very well developed helminthoids. In one case with *P. carpathicum*, in another with *P. minimum*. The latter occurrence may suggest that *P. latum* represents a more mature stage of the development of the producer. In a number of cases the net is penetrated by *Sabularia simplex*.

**Occurrence.** — Senonian — Inoceramian Beds: Kąkolówka; Gorzeń Beds: Gorzeń Górny; Ropianka Beds: Mordarka, Trzetrzewina; Sromowce Beds: Sromowce Wyżne, Jaworki (the stream Skalski — the nets described by F. SIMPSON, 1967, belong here; most probably he collected them in the Skalski stream, and not in the Biała Woda valley, as he stated, since in the latter there are no beds with *Paleodictyon*, which is very abundant in the former). Palaeocene-Lower Eocene — Variegated Shales: Pewel Wielka. Lower Eocene — Beloveza Beds (fairly frequent): Lipnica Wielka, Lipnica Mała, Zubrzyca Górna (the hamlet Ochlipów), Sidzina, Lubomierz, Myślec, Berest. Middle Eocene — Hieroglyphic Beds: Istebna (the valley of the Olza river), Leśna, Brzeźna. Oligocene — Krosno Beds: Mymoń.

### *Paleodictyon intermedium* KSIĄŻKIEWICZ, 1970

(pl. 27, figs 8, 9)

1970, *Paleodictyon intermedium* ichnosp. nov., KSIĄŻKIEWICZ, p. 306, pl. 4*g*.

*Holotype*: UJ TF 1172 (pl. 27, fig. 8).

*Type locality*: Wiśniowa, the stream Marków, near Myślenice.

*Type horizon*: Grodziszcze Beds, Hauterivian.

*Derivation of the name*: Lat. *intermedius* — intermediate; the type occupies an intermediate position between *P. latum* and *P. miocenicum*.

*Material*: 14 specimens.

**Diagnosis.** — Meshes mostly 2 to 3.5 mm long, the bordering riblets 0.5 to 1 mm wide nets small.

**Description.** — In the holotype the width of the bordering riblets ranges from 0.7 to 1.0 mm; most are 0.7–0.8 mm wide. The maximum length of the meshes varies between 2 and 3.5 mm, but meshes with a length of 2.5 mm are predominant (table 16). The shape of the meshes is very regular; most of them are hexagonal.

In other specimens the bordering riblets are most often 0.5 to 0.7 mm wide and a width of 1 mm is reached rather seldom. The meshes are usually hexagonal, but in some specimens are slightly elongated. The nets are small, the largest is 5.25 cm$^2$ in area.

**Remarks.** — The width of the bordering ridges is almost the same as in *P. latum*, but the meshes are distinctly larger (table 16).

**Sediment.** — Thin-bedded (up to 7 cm), fine-grained, graded or horizontally laminated sandstones. In one instance the net covers a flute cast, in another it is developed on a sole with a ridge-and-furrow lineation.

**Association.** — The holotype is intersected by *Urohelminthoida dertonensis*, some other nets by *Sabularia simplex*. May be accompanied by *Fucusopsis angulata*.

**Occurrence.** — Hauterivian — Grodziszcze Beds: Wiśniowa, (the stream Marków). Senonian — Inoceramian Beds: Łodyna, Markowa; Gorzeń Beds: Gorzeń Górny; Ropianka Beds: Mordarka; Sromowce Beds (frequent): Sromowce Wyżne, Krempachy (the stream Kręty), Jaworki (the stream Skalski). Palaeocene — Szczawnica Beds: Haluszowa. Middle Eocene — Hieroglyphic Beds: Stara Wieś (the slope of Mt. Cichoń).

### *Paleodictyon intermedium* forma *punctata* n. f.

(pl. 27, figs 15, 17)

*Material*: 2 specimens.

**Diagnosis.** — The dimensions of the meshes correspond to those in *P. intermedium*, but the bordering riblets are for the most part replaced by tubercules.

**Description.** — In one specimen (pl. 27, fig. 15) there are 31 hexagonal meshes. Seven of them are bordered by normal continuous riblets with parallel flanks, other by tubercules of the same width (0.5–0.6 mm) or slightly thicker (up to 1 mm) than the riblets. The length of the meshes is 3, 3.5 or 4 mm.

Another specimen (pl. 27, fig. 17) represents a net 12 cm² in area. Most of the meshes are bordered by ridges 0.5 to 1 mm wide. Here and there, instead of riblets there occur tubercules 0.5 to 1 mm wide, round or elliptical. Most of the meshes are 2·5 to 3 mm long.

These specimens are similar to the specimen illustrated by SACCO (1888, p. 161, pl. 1, fig. 1), which he determined as *Paleodictyon* sp. On the basis of this figure VIALOV and GOLEV (1965) created a new form named *Pleurodictyon punctatum*.

**Sediment.** — Both specimens occur on soles of medium-grained sandstones, coarser than the sandstones with normal *P. intermedium*.

**Occurrence.** — Lower Eocene — Ciężkowice Sandstone: Znamirowice.

### *Paleodictyon strozzii* MENEGHINI, 1851

(pl. 27, fig. 10; pl. 28, figs 1, 2)

1851. *Paleodictyon strozzii*, MENEGHINI, p. 249 (no illustration, first illustrated by PERUZZI, 1880 p. 7, pl. 1, fig. 8).
*Material*: 42 specimens.

**Description.** — The largest diameter of the meshes varies between 2.5 and 5.5 mm, but is most often between 3 and 4 mm. The bordering riblets are 0.3 to 1.0 mm wide, mostly 0.5–0.7 mm. The nets are of moderate size, the largest about 47 cm² in area. The meshes, roughly hexagonal, may also be pentagonal or rhomboidal, or elongated in one direction. In one specimen (pl. 27, fig. 10) some riblets are subcircular, bent in one direction, as in the *Squamodictyon* of VIALOV and GOLEV.

**Remarks.** — The original definition of this type is not very precise, and in addition the specimen illustrated by PERUZZI does not exactly correspond with the description of MENEGHINI, as pointed out by VIALOV and GOLEV (1965). The Carpathian specimens correspond well to the mesh size of PERUZZI's figure, but the riblets seem on the whole to be thinner.

**Sediment.** — Fine-grained, mostly very thin-bedded (3–3.5 cm, in one case 10 cm) sandstones, with composite bedding, horizontal gradational lamination or single-current laminated. In one case the net covers a small flute cast and a narrow drag mark, without being interrupted by them. In another instance the nets intersect a grain lineation.

**Association.** — The net may cover the trail of *Taphrhelminthopsis vagans* (KSIĄŻKIEWICZ, 1958, pl. 2, fig. 3), evidently posterior to it. It is intersected by *Sabularia* and *Halymenidium*. Accompanied by *Strobilorhaphe*, *Helminthoida crassa*, *Cosmorhaphe*, and *Protopaleodictyon submontanum*.

**Occurrence.** — Valanginian — Upper Cieszyn Shales: Lipnik near Myślenice. Senonian — Inoceramian Beds: Rzegocin, Wara, Wołodź, Kuźmina, Bachów, Wola Romanowa. Szydłowiec Beds: Kobielnik; Upper Godula Beds: Kocierz; Lower Istebna Beds (interbed of the Inoceramian Beds type): Czchów; Ropianka Beds (frequent): Sopotnia Mała, Lipnica Wielka (the hamlet Kiczora), Grzechynia, Mszana Dolna (the streams on the slope of Mts. Strzebel and Lubogoszcz), Szczawa, Półrzeczki, Wola Krogulecka, Siary, Skwirtne; Sromowce Beds: Jaworki (the stream Skalski). Palaeocene — Upper Istebna Beds: Krzeszów (the stream across Mt. Harańczykowa), Czarnorzeki; Szczawnica Beds: Krościenko on the river Dunajec, Hałuszowa. Palaeocene-Lower Eocene — Variegated Shales: Lipnica Wielka (the hamlet Kiczora), Zbludza, Berest. Lower Eocene — Beloveza Beds (frequent): Złatna, Lipnica Wielka, Lipnica Mała, Zubrzyca Górna, Sidzina, Lubomierz, Myślec, Berest, Hańczowa. Middle Eocene — Hieroglyphic Beds: Osielec (the stream on the slope of Przykrzec Mt.).

### *Paleodictyon miocenicum* SACCO, 1886
(pl. 27, figs 11–14)

1886. *Paleodictyon miocenicum* SACC., SACCO, p. 931, fig. 4.
*Material*: 19 specimens.

**Description.** — According to SACCO the length of the meshes is 3 to 7 mm, the width of the bordering ridges 1 to 1.25 mm. In our material the riblets are mostly 1 mm or slightly wider, and the maximum length of the meshes is 4 to 5 mm (table 17). In some specimens the meshes are hexagonal, in others somewhat elongated. In some specimens there is a tiny tubercule in the centre of the mesh. The riblets may be a little swollen in the middle. The largest net covers an area of 12 $cm^2$.

**Sediment.** — Fine-grained, thin-bedded (1–3, up to 6 cm) sandstones, graded or horizontally laminated.

**Occurrence.** — Berriasian — Cieszyn Limestone: Goleszów (the quarry on Mt. Buczyna), Żywiec. Valanginian — Upper Cieszyn Shales: Żegocina. Senonian — Inoceramian Beds: Kąkolówka, Bachów; Upper Godula Beds: Malinka; Lower Istebna Beds (interbed of the Inoceramian Beds-type): Czchów; Ropianka Beds: Grzechynia, Mszana Dolna (the stream on the slope of Mt. Strzebel), Szczawa, Półrzeczki, Mordarka, Trzetrzewina, Wola Brzezińska. Lower Eocene — Beloveza Beds: Lipnica Mała. Middle Eocene — Hieroglyphic Beds: Istebna (the Olza river), Daliowa. Oligocene — Krosno Beds: Mymoń.

### *Paleodictyon miocenicum* forma *pleurodictyonoides* n. f.
(pl. 27, fig. 16)

The specimen illustrated in pl. 27, fig. 16 has meshes about the same length as in *P. miocenicum* (4 mm), but the riblets are developed as strings thickened in the middle, giving them an ellipsoidal form. They are wider (1.2 to 1.5 mm) than the usual width range in this ichnospecies and in a few places are replaced by round tubercules.

**Sediment.** — Thin-bedded, 2 cm thick, fine-grained sandstone.

**Occurrence.** — Senonian — Skrzydlna Beds: Przenosza (1 specimen).

### *Paleodictyon miocenicum* forma *punctata* n. f.
(pl. 27, figs 18, 19)

*Material*: 3 specimens.

**Diagnosis.** — The size of the meshes is like that in *P. miocenicum* but round tubercules are developed instead of riblets.

**Description.** — The specimens illustrated in pl. 27, figs 18 and 19 were collected from the same bed, yet they show some differences. The specimen in fig. 18 has circular or elliptical tubercules, extremely regularly spaced, as if placed on the corners of a hexagon whose maximum length is 4 to 4.5 mm. The width of the tubercules is 1.5 to 2 mm. The net covers an area of 15 cm². Another specimen shown in fig. 19 has smaller tubercules (1–1.5 mm; only a few reach the width of 2 mm), and the meshes are 3.5 to 4 mm long. This network was situated on the sole only 10 cm from the first. It covers an area of 25 cm². On the same sole there occur small nets composed of a few meshes with dimensions typical of *P. miocenicum*.

**Sediment.** — Medium-grained sandstone, 6 cm thick.

**Occurrence.** — All three specimens found in the Middle Eocene Hieroglyphic Beds at Kamesznica, the stream Janoska.

### *Paleodictyon carpathicum* (MATYASOVSZKY, 1878)
(pl. 28, figs 4, 5)

1878. *Glenodictyum carpathicum* MATY., MATYASOVSZKY, p. 265, pl. 12.
*Material*: 62 specimens and a dozen occurrences noted in the field.

**Description.** — The bordering riblets are fairly variable in width, the thinnest are 0.7 mm, the widest 1.5 mm but they are most frequently about 1 mm. The width may vary in one and the same specimen. Occasionally the riblets are somewhat swollen in the middle, as in the "*Pleurodictyon*" of FUCHS (1895). Their height may reach 1 mm. The variation in size of the meshes is also considerable, as already stressed by VIALOV and GOLEV (1965). In many specimens there are a few meshes with the maximum length smaller than 7 mm, but on the average the meshes 7–8 mm long predominate (table 17). The meshes are often elongated in one direction. They are mostly hexagonal, more rarely pentagonal or irregularly quadratic. The nets are often of considerable size; in one case (Sidzina, the stream Kamieński, Beloveza Beds) the network covers an area of almost 1 m². The bordering riblets appear to be subcylindrical in most cases, but in several instances are clearly cylindrical and may be detached from the sole. In a few cases the filling material is slightly coarser than that of the host rock.

**Sediment.** — Fine-grained, thin-bedded (the thickest 6 cm, most frequently 2.5 to 3 cm), graded, gradationally laminated, also single- or multiple-current laminated sandstones. The nets are developed preferably on flat, even soles. In one case the net is developed with its elongated polygons oriented obliquely in relation to the direction of the grain lineation. If there are any flute casts on the sole, the nets occur between them with no clear indication that they are transsected by flutes. In a few instances the net covers both the flute casts and the depressions between them. On the other hand, in one case the net seems to be cut across by a drag mark, and in another by a flute cast. It seems that most of the nets are post-depositional, but some might have been made before the sand was deposited.

**Association.** — It may occur together with other paleodictyons *(P. minutissimum, minimum, strozzii)*. In one instance the riblets intersect a sinuous string probably belonging to a *Helminthopsis* (pl. 28, fig. 4, see KSIĄŻKIEWICZ, 1970), but in most cases the nets are earlier than other traces: they are intersected by *Cosmorhaphe, Helminthopsis, Subphyllochorda granulata, Fucusopsis annulata* and *Protopaleodictyon submontanum*. Together with *P. carpathicum* there occur *Helminthopsis, Acanthorhaphe delicatula, Strobilorhaphe, Fucusopsis annulata*, and *Protopaleodictyon submontanum*.

**Occurrence.** — Very rare in Cretaceous strata, but becomes very frequent in the Lower Eocene.

Hauterivian — Grodziszcze Beds: Kozy Małe (NOWAK, 1959, pl. 3, fig. *a*). Turonian — Middle Godula Beds: Jaroszowice (the hamlet Gołębiówka). Palaeocene — Upper Istebna Beds: Tabaszowa. Palaeocene-Lower Eocene — Variegated Shales (frequent): Lipnica Mała (the stream Linorka), Osielec, Zaryte, Półrzeczki, Zbludza. Lower Eocene — Beloveza Beds (frequent): Lipnica Mała, Zubrzyca Górna, Sidzina (the stream Kamieński and other places), Ponice, Poręba Wielka, Koninka, Półrzeczki, Zbludza, Wola Brzezińska, Popowice, Myślec, Berest, Tylicz (WĘCŁAWIK, 1969, fig. 1). Middle Eocene — Hieroglyphic Beds: Koninka, Wisłok. Upper Eocene — Magura Sandstone (in thin-bedded intercalations): Tylmanowa, Żegiestów (coll. W. SZAJNOCHA).

### *Paleodictyon regulare* SACCO, 1886
(pl. 28, figs 6, 7; pl. 29, figs 2, 3)

1886. *Paleodictyon regulare* SACC., SACCO, p. 930, pl. 11, fig. 3 (also SACCO, 1899, pl. 2, fig. 11).
*Material*: 5 specimens.

**Description.** — To this ichnospecies are assigned a few specimens varying in character. The specimen shown in pl. 28, fig. 6 corresponds best to the definition of this *Paleodictyon*. The network is very regular (table 17), most of the meshes being 7 to 8 mm long. The riblets are for the most part 1.6 mm wide, some slightly thinner while some attain 2 mm. They are relatively high (about 1 mm) and the network has a marked relief, more marked than in any other *Paleodictyon* type. The meshes are mostly hexagonal. Similar, although not quite identical, specimens have been collected from the Beloveza Beds and Variegated Shales. The specimens found in the Ciężkowice Sandstone (pl. 29, figs 2, 3) are rather different. In one of them some of the meshes are small (4–5 mm in length, which corresponds rather to the mesh size of *P. miocenicum*), but other meshes are larger (6–7 mm). The riblets are thick, 1.5 to 2 and even 2.5 mm. The shape of the meshes is irregular, but the network is flattened by compaction.

**Sediment.** — The specimens from the Beloveza Beds and Variegated Shales occur on the soles of thin-bedded (4 cm), fine-grained, laminated sandstones. The specimens from the Ciężkowice Sandstone occur in medium-grained, graded sandstones, 5 or 5.5 cm thick.

**Occurrence.** — Palaeocene-Lower Eocene — Variegated Shales: Lipnica Mała (the stream Linorka). Lower Eocene — Beloveza Beds: Lipnica Mała (the main stream), Zubrzyca Górna.

### *Paleodictyon regulare* forma *pleurodictyonoides* n. f.
(pl. 29, fig. 1)

**Diagnosis.** — The bordering riblets are ellipsoidal in shape. In the specimen illustrated in pl. 29, fig. 1 most of the bordering riblets are lenticulate. Their width is 2.5 mm on the average, but some are 2.3, others even 4 mm wide; their height is 1.5 to 2 mm. The riblets are built of a material distinctly coarser than that occurring on the sole between and beyond them. The size of the meshes is uniform (table 17), their length varies within narrow limits (7 to 11 mm), and 67% of the meshes are 9 to 11 mm long. The meshes are hexagonal or pentagonal, slightly elongated. The elongation is parallel to small flute casts and a ridge-and-furrow lineation.

**Sediment.** — Medium-grained sandstone, 6 cm thick, graded.

**Occurrence.** — Senonian — Sromowce Beds: Jaworki (the stream Skalski).

### *Paleodictyon majus* MENEGHINI (in coll.?)
(pl. 28, fig. 8)

1879. *Paleodictyon majus* MENEGHINI, DE STEFANI, p. 446 (neither figure nor description).
1880. *Paleodictyon majus* MENEGHINI, PERUZZI, p. 7, fig. 1.
*Material*: 8 specimens.

**Description.** — The width of the bordering riblets is on the average only slightly larger than in *P. carpathicum* (1–1.5 mm). The size of the meshes varies, but most of them are longer than 9 mm (table 17). The largest net covers an area of 540 cm$^2$.

**Remarks.** — There is neither description nor illustration in the paper of MENEGHINI and

SAVI (1851), but both DE STEFANI (1879) and PERUZZI (1880) refer to MENEGHINI as the author of this form. Probably he determined it in a collection. In the first figure of *P. majus* given by PERUZZI the dimensions of the meshes are 9 to 10 mm, as noted by VIALOV and GOLEV (1965, p. 98), although PERUZZI gives the dimensions as 6 to 7 mm. VIALOV and GOLEV (1965) consider this size as still corresponding to the upper size interval within the size limits of the *P. carpathicum* meshes and therefore these authors treat the specimen in PERUZZI's fig. 1 as *Paleodictyon carpathicum* var. *majus*. The specimen his fig. 2 they regard as *Paleodictyon (Glenodictyon) maximum* EICHWALD.

The Carpathian material is too scanty to decide this question. In our specimens some of the meshes are of a size within the limits proposed by VIALOV and GOLEV, but most are over this size (table 17). Therefore it seems that *Paleodictyon majus* may be maintained as a separate ichnospecies. Its mesh size is very much the same as in *P. tauricum* VIALOV and GOLEV, but that type has much thicker riblets (1.5 to 1.8 mm is given as the lower limit).

**Sediment.** — Fine grained, thin-bedded (up to 15 cm) gradationally laminated or single-current laminated sandstones. The nets occur mostly on flat surfaces, which in one case display a distinct grain, in another ridge-and-furrow lineation. The elongation of the meshes is almost at right angles to the orientation of the lineation. The net may also cover small flutes.

**Occurrence.** — Senonian — Skrzydlna Beds (?): Przenosza. Paleocene-Lower Eocene — Variegated Shales: Zaryte, Stara Wieś — Lower Eocene — Beloveza Beds: Lipnica Mała, Rabka (coll. H. ZAPAŁOWICZ), Lubomierz. Oligocene — Krosno Beds: Wujskie (a few meshes of irregular shape).

### *Paleodictyon tellinii* SACCO, 1888
(pl. 28, fig. 3)

1888. *Paleodictyon tellinii* SACC., SACCO, p. 158, pl. 1, figs 2, 3.
*Material*: 7 specimens.

**Description.** — The bordering riblets are very thin (mostly 0.5 mm) and low (0.2 to 0.3 mm). The meshes are irregular, pentagonal or hexagonal, often elongated and of variable size. Most of them are over 5 mm in length, and several are 9 mm long (table 17). The network occurs in one case in stripes on an even sole, in another in a depression between the flute casts, but no intersection by flutes is visible, and the net seems to disappear before reaching the flute cast.

**Remarks.** — VIALOV and GOLEV (1965) regard this form as a variety of *P. strozzii*. Actually, there is no difference in the width of the riblets, but the meshes are for the most part larger than in *P. strozzii* (tables 16 and 17). The collected specimens correspond well with the description of SACCO (1888) who very precisely defined this type and pointed out the differences between *P. strozzii* and *P. tellinii*.

**Sediment.** — Fine-grained, thin-bedded (3–7 cm), graded or single current laminated sandstones.

**Occurrence.** — Berriasian — Cieszyn Limestone: Goleszów (the main quarry — pl. 12, fig. 1). Senonian — Inoceramian Beds: Wara; Lower Istebna Beds (interbed of "fucoid marls"): Czarnorzeki. Gorzeń Beds: Gorzeń Górny. Ropianka Beds: Koninka, Grybów. Lower Eocene — Ciężkowice Sandstone: Znamirowice (cf.).

### *Paleodictyon* aff. *gomezi* AZPEITIA, 1933
(pl. 29, fig. 4)

1933. *Paleodictyon Gomezi* AZPEITIA n. sp., AZPEITIA, p. 43, pl. 9, fig. 20.
*Material*: 1 specimen (found by S. DŻUŁYŃSKI during our joint excursion with Professor E. K. WALTON in 1957).

**Description.** — The specimen is fragmentary, but the shape of the meshes typical of *Paleodictyon* is easily recognizable. The width of the riblets is 3 to 5 mm and their height 2–3 mm;

their length ranges from 30 to 40 mm. The maximum diameter of the meshes is 60 to 70 mm.

The size of the meshes and the length of the riblets correspond well with the types of AZPEITIA, but the width of the riblets is much greater (in the specimen of AZPEITIA only 2.5 mm).

**Sediment.** — Medium-grained, horizontally laminated sandstone.

**Occurrence.** — Lower Eocene — Beloveza Beds: Sidzina.

*Zakład Geologii*
*Uniwersytetu Jagiellońskiego*
*ul. Oleandry 2a*
*30-063 Kraków*
*April, 1976*

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[1]) Received in the final stage of the preparation of this paper.

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# PALAEONTOLOGICAL INDEX

Systematic names cited only are indicated in *italics*; names accompanied by descriptions are indicated in roman letters.

Numbers which indicate the page, on which the species or genus are cited only, are standard; numbers which indicate pages with descriptions, are **bold**.

Numbers with asterisks * indicate pages with figures.

# PLATES

M. KSIĄŻKIEWICZ: TRACE FOSSILS IN THE FLYSCH OF THE POLISH CARPATHIANS

PLATE 1

1. *Mammillichnis aggeris* CHAMBERLAIN. Wujskie, Krosno Beds, UJ TF 118, nat. size.
2. *Mammillichnis aggeris* CHAMBERLAIN. Lipnica Mała, Variegated Shales, UJ TF 1117, nat. size.
3. *Bergaueria prantli* n. ichnosp. Grzechynia, Hieroglyphic Beds, UJ TF 115, nat. size.
4. *Bergaueria prantli* n. ichnosp. Wierzbanowa, Skrzydlna Beds. UJ TF 1178, nat. size.
5. *Bergaueria prantli* n. ichnosp. Limanowa, Ropianka Beds, UJ TF 824, nat. size.
6. *Pararusophycus oblongus* n. ichnosp. Liszna, Hieroglyphic Beds, UJ TF 114, nat. size.
7. *Traucumichnis glaber* n. ichnosp. Wara, Inoceramian Beds, UJ TF 125, nat. size.
8. *Arthrophycus annulatus* n. ichnosp. Znamirowice, Ciężkowice Sandstone, UJ TF 123, 0.5.
9. *Arthrophycus annulatus* n. ichnosp. Krzywcza, Inoceramian Beds, UJ TF 1220, 0.5.
10. *Arthrophycus annulatus* n. ichnosp. Gródek, Ciężkowice Sandstone, UJ TF 122, · 0.5.
11. *Arthrophycus strictus* n. ichnosp. Rzyki, Lgota Beds, UJ TF 131, nat. size.
12. *Arthrophycus strictus* n. ichnosp. Mszana Dolna, Ropianka Beds, UJ TF 124, nat. size.

13—14. *Arthrophycus dzulyński* n. ichnosp. Dębna, Krosno Beds, UJ TF 177, nat. size.

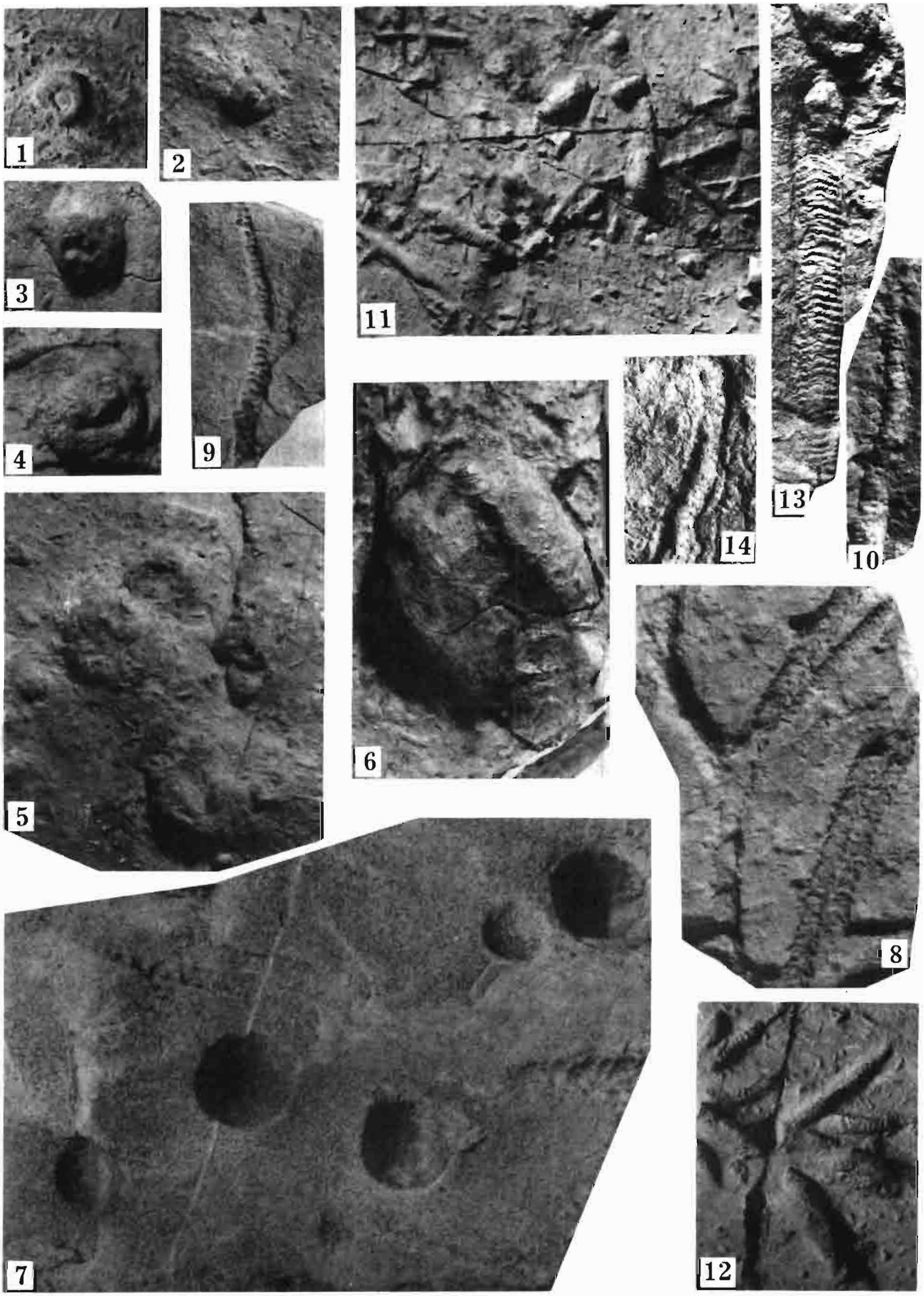


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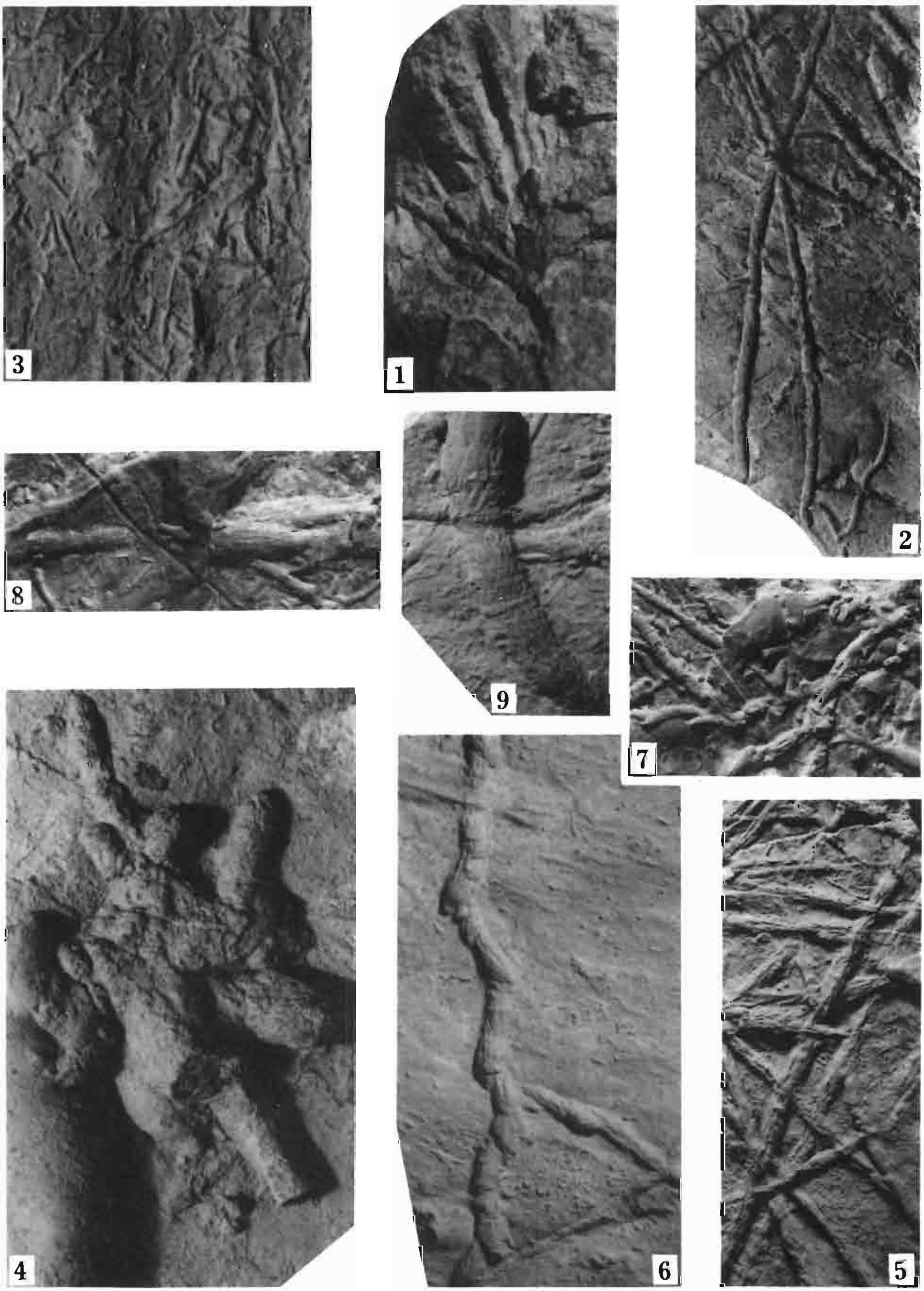
PLATE 2

1. *Phycodes* aff. *harlani* (HALL). Znamirowice, Ciężkowice Sandstone, UJ TF 1590, nat. size.
2. *Sabularia simplex* n. ichnosp. Berest, Beloveza Beds, UJ TF 1477, × 0.5.
3. *Sabularia tenuis* n. ichnosp. Wujskie, Krosno Beds, UJ TF 1687, nat. size.
4. *Sabularia rudis* n. ichnosp. Komańcza, Hieroglyphic Beds, UJ TF 1205, nat. size.
5. *Fucusopsis angulata* PALIBIN. Jaworki, Jarmuta Beds, UJ TF 93, × 0.5.
6. *Fucusopsis annulata* KSIĄŻKIEWICZ. Kamionka Wielka, Hieroglyphic Beds, UJ TF 1263, nat. size,
7. *Fucusopsis annulata* KSIĄŻKIEWICZ, Zubrzyca Górna, Beloveza Beds, UJ TF 87, × 0.5.
8. *Fucusopsis striata* (HALL). Goleszów, Cieszyn Limestone, UJ TF 94, × 0.5.
9. *Planolites reinecki* n. ichnosp. Wola Brzezińska, Ropianka Beds, UJ TF 1015, nat. size.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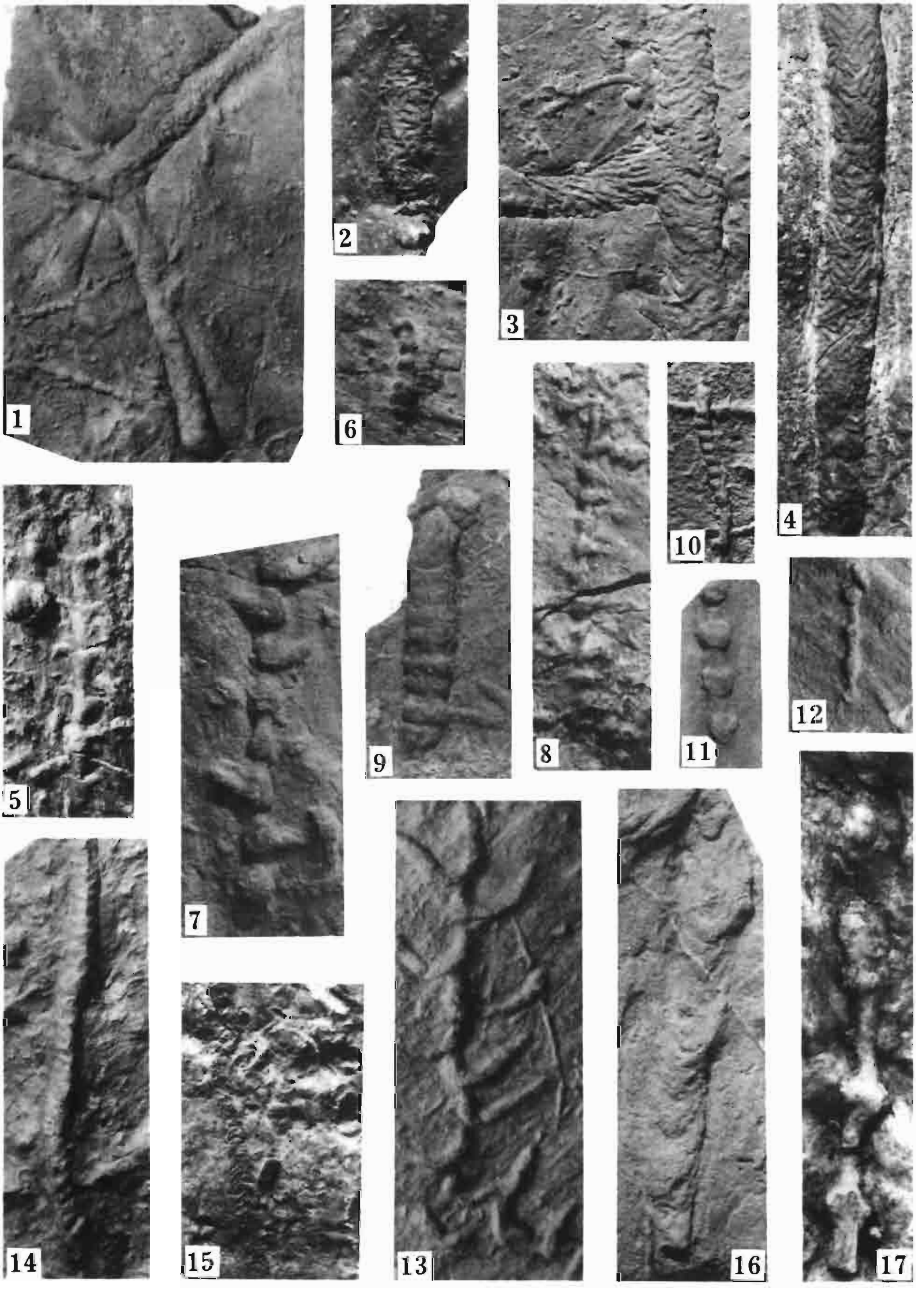
## M. KSIĄŻKIEWICZ: TRACE FOSSILS IN THE FLYSCH OF THE POLISH CARPATHIANS

### PLATE 3

1. *Halymenidium sublumbricoides* (AZPEITIA). Lipnica Mała, Belovcza Beds, UJ TF 80, × 0.5.
2. *Halymenidium sublumbricoides* (AZPEITIA). Daliowa, Hieroglyphic Beds, UJ TF 1810, nat. size.
3. *Halymenidium oraviense* KSIĄŻKIEWICZ. Lipnica Mała, Belovcza Beds, UJ TF 62, nat. size.
4. *Halymenidium oraviense* KSIĄŻKIEWICZ. Lipnica Mała, Belovcza Beds, UJ TF 61, nat. size.
5. *Rhabdoglyphus grossheimi* VASSOEVICH. Jaroszowice, Lower Godula Beds, UJ TF 82, nat. size.
6. *Rhabdoglyphus caliciformis* n. ichnosp. Wola Kroguleckа, Ropianka Beds, UJ TF 1869, nat. size.
7. *Rhabdoglyphus spinosus* n. ichnosp. Wierzbanowa, Skrzydlna Beds, UJ TF 1175, nat. size.
8. *Rhabdoglyphus spinosus* n. ichnosp. Limanowa, Ropianka Beds, UJ TF 710, nat. size.
9. *Rhabdoglyphus sulcatus* n. ichnosp. Mszana Dolna, Ropianka Beds, UJ TF 180, nat. size.
10. *Rhabdoglyphus compositus* n. ichnosp. Tabaszowa, Upper Istebna Beds, UJ TF 179, nat. size.
11. *Rhabdoglyphus caliciformis* n. ichnosp. Godziszów, Cieszyn Limestone, UJ TF 182, nat. size.
12. *Rhabdoglyphus caliciformis* n. ichnosp. Goleszów, Cieszyn Limestone, UJ TF 181, nat. size.
13. *Rhabdoglyphus* aff. *spinosus* n. ichnosp. Wisła, Lower Godula Beds, (coll. J. BURTAN), nat. size.
14. *Keckia annulata* GLOCKER. Krościenko, Szczawnica, Ropianka Beds, UJ TF 893, nat. size.
15. *Keckia* cf. *hoessii* (STERNBERG). Limanowa, Ropianka Beds, UJ TF 833, nat. size.
16. *Keckia hoessii* (STERNBERG). Raciechowice, Grodziszcze Beds, UJ TF 1696.
17. *Rhabdoglyphus* aff. *caliciformis* n. ichnosp. Dobra, Hieroglyphic Beds, UJ TF 2018, nat. size.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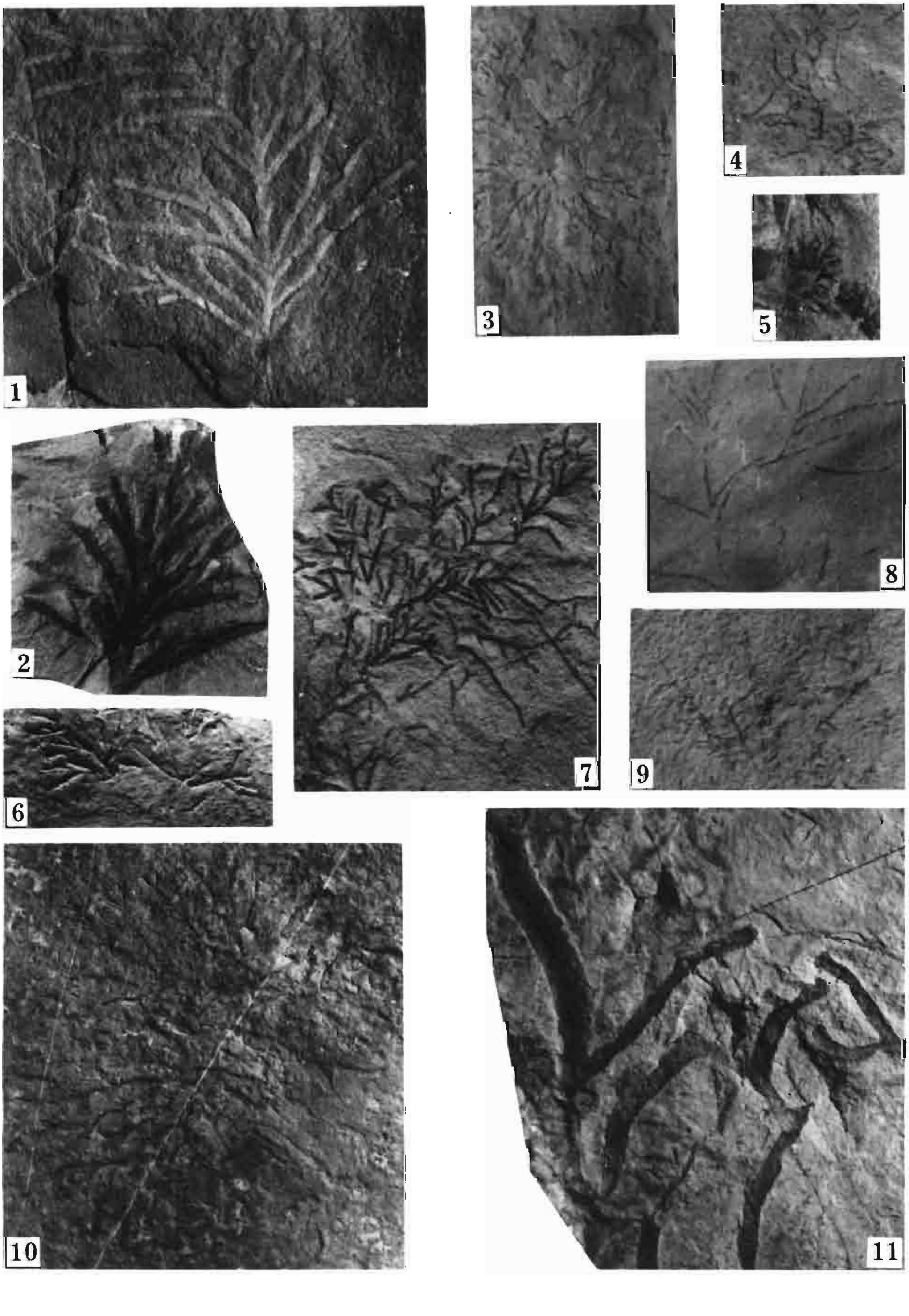
M. KSIĄŻKIEWICZ: TRACE FOSSILS IN THE FLYSCH OF THE POLISH CARPATHIANS

## PLATE 4

1. *Chondrites furcatus* (BRONGNIART). Goleszów, Cieszyn Limestone, UJ TF 145, nat. size.
2. *Chondrites furcatus* (BRONGNIART). Brody, Lgota Beds, UJ TF 1476, nat. size.
3. *Chondrites expansus* FISCHER-OOSTER. Lubomierz, Ropianka Beds, UJ TF 147, 0·5.
4. *Chondrites flexilis* FISCHER-OOSTER. Łodzinka, Inoceramian Beds, UJ TF 146, nat. size.
5. *Chondrites intricatus* (BRONGNIART). Rybotycze, Siliceous Marls, UJ TF 149, nat. size.
6. *Chondrites aequalis* STERNBERG. Wujskie, Krosno Beds, UJ TF 153, nat. size.
7. *Chondrites arbuscula* FISCHER-OOSTER. Rybotycze, Siliceous Marls, UJ TF 150, nat. size.
8. *Chondrites filiformis* FISCHER-OOSTER. Grybów, Ropianka Beds, UJ TF 393, nat. size.
9. *Chondrites patulus* FISCHER-OOSTER. Brzozowiec, Krosno Beds, UJ TF 1214, nat. size.
10. *Chondrites flexilis* FISCHER-OOSTER. Wola Brzezińska, Ropianka Beds, UJ TF 1031, nat. size.
11. *Chondrites affinis* (BRONGNIART). Biała Wyżna, Ropianka Beds, UJ TF 148, nat. size.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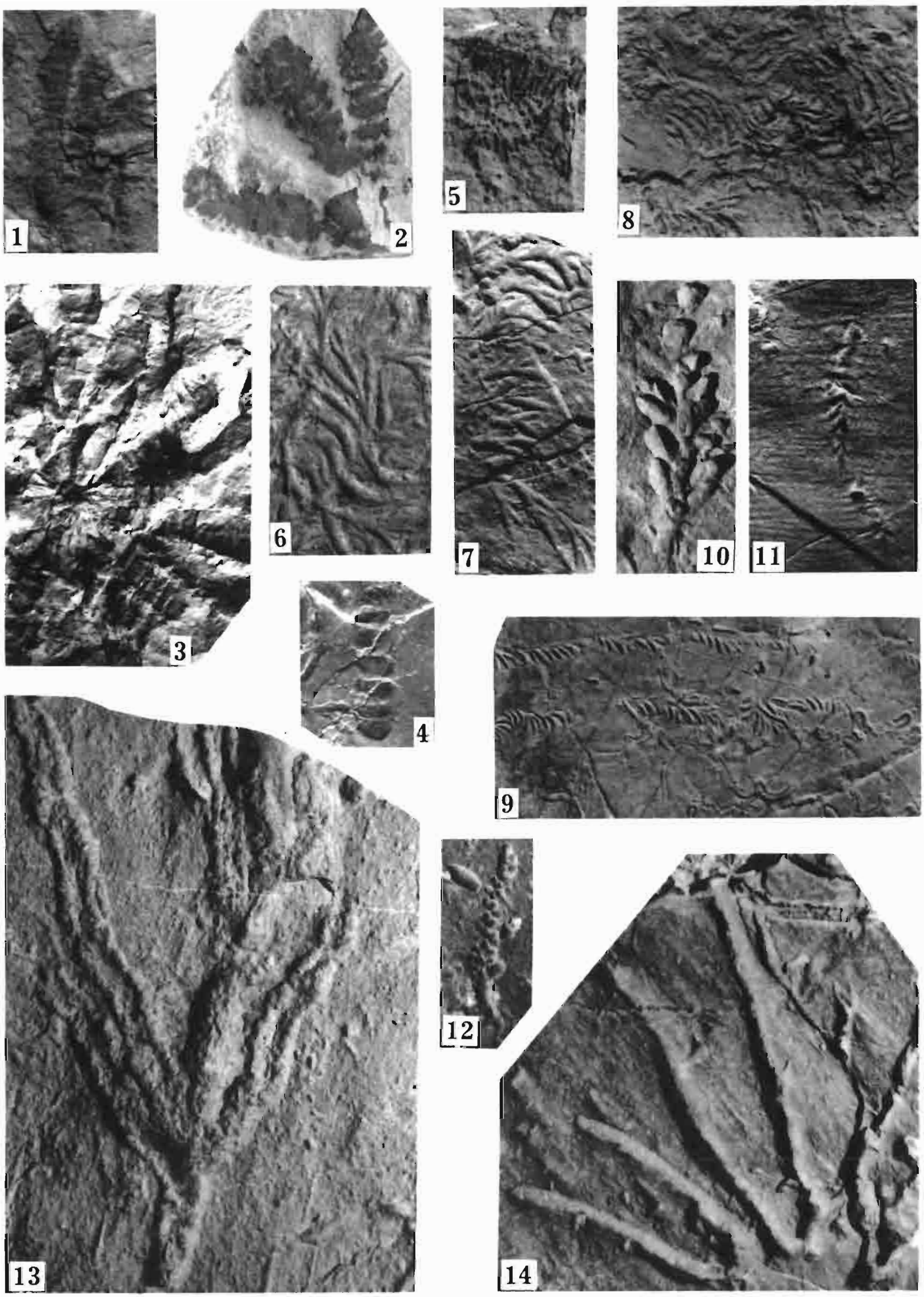
M. KSIĄŻKIEWICZ: TRACE FOSSILS IN THE FLYSCH OF THE POLISH CARPATHIANS

PLATE 5

1. *Taenidium isseli* (SQUINABOL). Grybów, Ropianka Beds, UJ TF 780, nat. size.
2. *Taenidium isseli* (SQUINABOL). Kalwaria Pacławska, Inoceramian Beds, UJ TF 1489, nat. size.
3. *Taenidium fischeri* HEER. Achmata, Caucasus Mts., "Carbonate flysch", Coniacian, UJ TF 1694, nat. size.
4. *Taenidium annulatum* (SCHAFHAUTL). Grybów, Ropianka Beds, UJ TF 395, nat. size.
5. *Bostricophyton pantanellii* SQUINABOL. Biała Wyżna, Ropianka Beds, UJ TF 398, nat. size.
6. *Lophoctenium ramosum* (TOULA). Lipnica Wielka, Variegated Shales, UJ TF 401, nat. size.
7. *Lophoctenium ramosum* (TOULA). Limanowa, Variegated Shales, UJ TF 662, nat. size.
8. *Lophoctenium* aff. *ramosum* (TOULA). Rzeki, Inoceramian Beds, UJ TF 399, nat. size.
9. *Lophoctenium* aff. *comosum* REINH. RICHTER (*Phycosiphon incertum* FISCHER-OOSTER in the lower part of the figure). Lipnica Mała, Variegated Shales, UJ TF 1114, nat. size.
10. *Strobilorhaphe clavata* KSIĄŻKIEWICZ. Lipnica Mała, Beloveza Beds, UJ TF 88, nat. size.
11. *Strobilorhaphe clavata* KSIĄŻKIEWICZ (intersecting the sole lineation). Florynka, Ropianka Beds, UJ TF 913, nat. size.
12. *Strobilorhaphe pusilla* KSIĄŻKIEWICZ. Zubrzyca Górna, Beloveza Beds, UJ TF 90, nat. size.
13. *Buthotrephis bilix* n. ichnosp. Poznachowice, Grodziszcze Beds, UJ TF 1311, nat. size.
14. *Buthotrephis bifurcata* n. ichnosp. Sidzina, Beloveza Beds, UJ TF 1383, × 0.5.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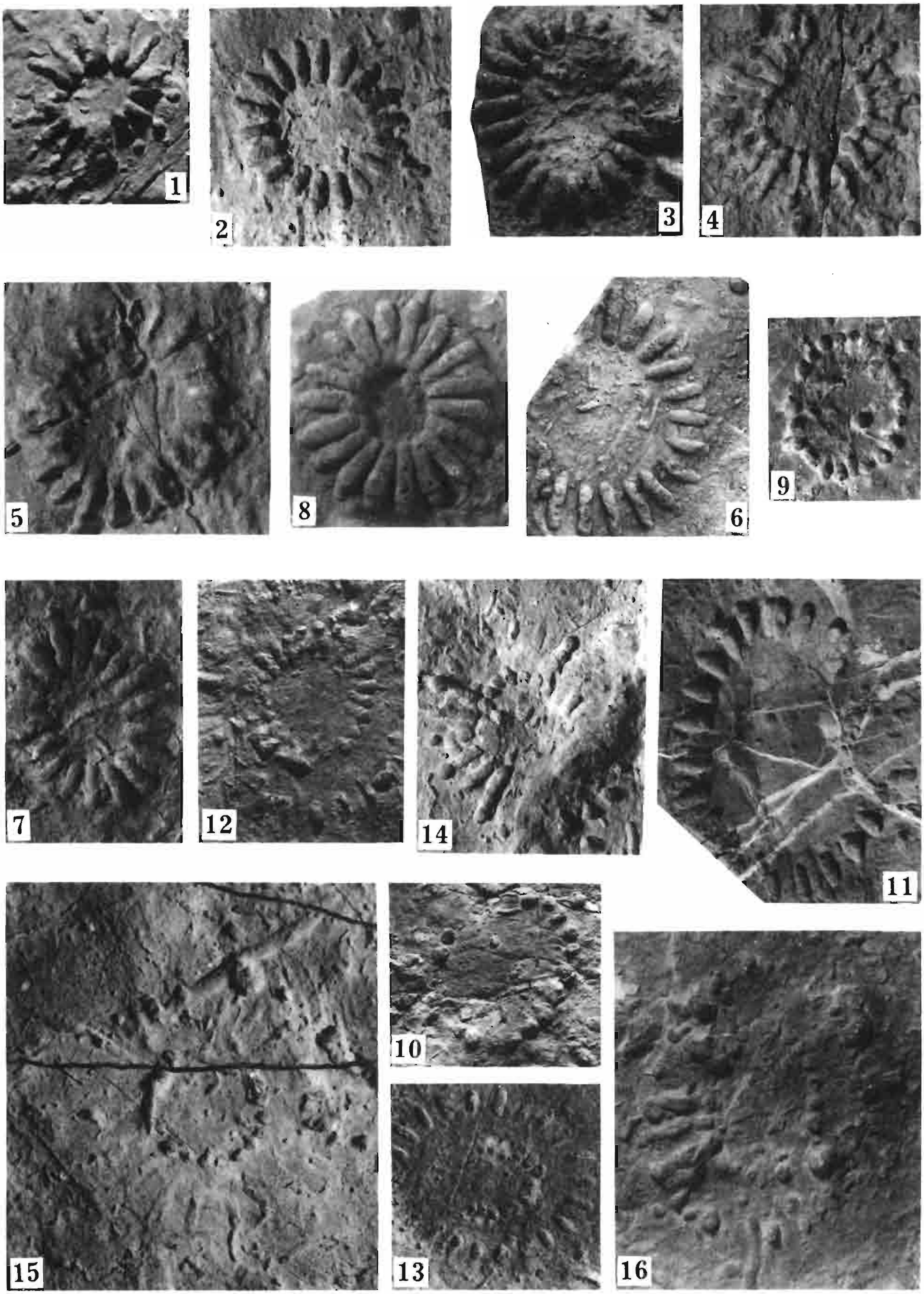
M. KSIĄŻKIEWICZ: TRACE FOSSILS IN THE FLYSCH OF THE POLISH CARPATHIANS

PLATE 6

1. *Lorenzinia* aff. *apenninica* GABELLI. Limanowa, Ropianka Beds, ZNG Cracow, A-I-52/1.
2. *Lorenzinia carpathica* (ZUBER). Lipnica Mała, Variegated Shales, UJ TF 134.
3. *Lorenzinia carpathica* (ZUBER). Unknown locality. AGH (not registered).
4. *Lorenzinia* aff. *carpathica* (ZUBER). Unknown locality. AGH (not registered).
5. *Lorenzinia carpathica* (ZUBER). Wola Brzezińska, Ropianka Beds, UJ TF 1030.
6. *Lorenzinia carpathica* (ZUBER). Limanowa, Ropianka Beds, IG Warsaw, coll. W. SZAJNOCHA.
7. *Lorenzinia carpathica* (ZUBER). Lipnica Mała, Variegated Shales, UJ TF 871.
8. *Lorenzinia kuźniari* n. ichnosp. Wiśnicz, Lower Istebna Beds, ZNG Cracow, A-I-53/1.
9. *Lorenzinia perlata* KSIĄŻKIEWICZ. Lipnica Mała, Variegated Shales, UJ TF 1103.
10. *Lorenzinia perlata* KSIĄŻKIEWICZ. Lipnica Mała, Variegated Shales, UJ TF 84.
11. *Lorenzinia curticostata* n. ichnosp. Lipnica Mala, Variegated Shales, UJ TF 1365.
12. *Lorenzinia moreae* RENZ. Lipnica Mała, Variegated Shales, UJ TF 134.
13. *Lorenzinia moreae* RENZ. Siekierczyna, Ropianka Beds, UJ TF 2022.
14. *Lorenzinia* aff. *moreae* RENZ. Lipnica Mała, Variegated Shales, UJ TF 85.
15. *Lorenzinia* aff. *moreae* RENZ. Lipnica Mala, Variegated Shales, UJ TF 86.
16. *Lorenzinia* aff. *moreae* RENZ. Lipnica Mała, Variegated Shales, UJ TF 1109.

All figures nat. size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M. KSIĄŻKIEWICZ: TRACE FOSSILS IN THE FLYSCH OF THE POLISH CARPATHIANS

PLATE 7

1. *Sublorenzinia nowaki* (KSIĄŻKIEWICZ). Mordarka, Ropianka Beds, UJ TF 650, nat. size.
2. *Sublorenzinia nowaki* (KSIĄŻKIEWICZ). Limanowa, Ropianka Beds, UJ TF 659, × 0.5.
3. *Sublorenzinia nowaki* (KSIĄŻKIEWICZ). Goleszów, Cieszyn Limestone, UJ TF 107, × 0.5.
4. *Sublorenzinia plana* KSIĄŻKIEWICZ. Porąbka, Lower Godula Beds, UJ TF 72, nat. size.
5. *Sublorenzinia plana* KSIĄŻKIEWICZ. Wiśniowa, Middle Godula Beds, UJ TF 1186, × 0.5.
6. *Sublorenzinia plana* KSIĄŻKIEWICZ. Goleszów, Cieszyn Limestone, UJ TF 98, × 0.5.
7. *Sublorenzinia plana* KSIĄŻKIEWICZ. Poznachowice, Upper Cieszyn Shales, UJ TF 1301, × 0.5.
8. *Sublorenzinia plana* KSIĄŻKIEWICZ. Rzyki near Wadowice, Lower Godula Beds, UJ TF 137, × 0.5.
9. *Sublorenzinia pustulosa* n. ichnosp. Krasiczyn, Inoceramian Beds, UJ TF 129, × 0.5.
10. *Sublorenzinia pusilla* n. ichnosp. Sromowce Wyżne, Sromowce Beds, UJ TF 97, nat. size.
11. *Sublorenzinia pusilla* n. ichnosp. Grzechynia, Hieroglyphic Beds, UJ TF 136, nat. size.
12. *Capodistria vettersi* VIALOV (and *Bergaueria prantli* n. ichnosp.). Jaroszowice, Lower Godula Beds, UJ TF 96, nat. size.
13. *Capodistria vettersi* VIALOV. Grybów, Ropianka Beds, UJ TF 109, × 0.5.

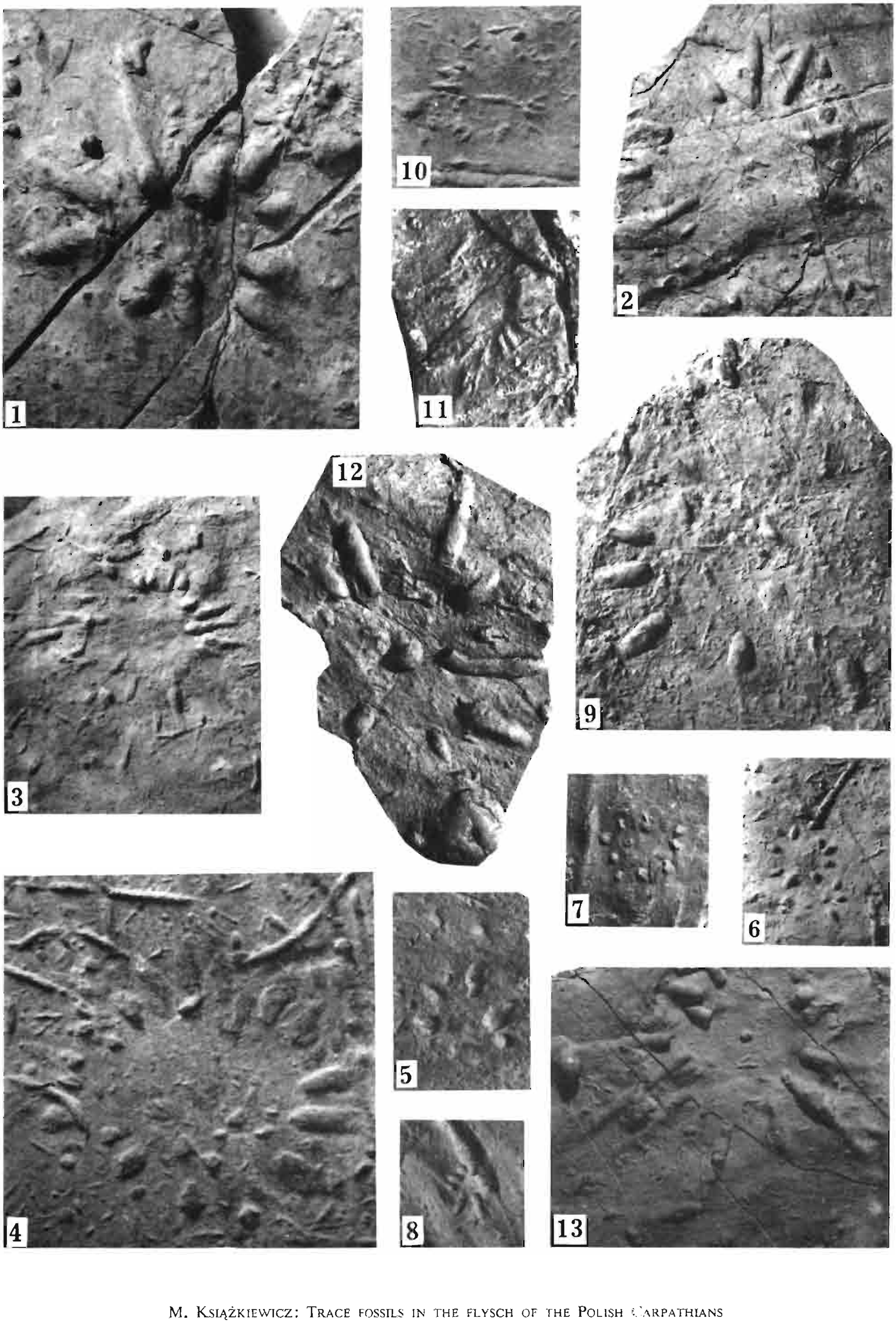
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PLATE 8

1. *Glockeria glockeri* Książkiewicz. Wilamowice, Upper Cieszyn Shales, UJ TF 110.
2. *Gyrophyllites kwassizensis* Glocker. Istebna, Lower Istebna Beds, UJ TF 106.
3. *Glockeria parvula* Książkiewicz. Lipnik near Myślenice, Skrzydlna Beds, UJ TF 108.
4. *Fascisichnium extentum* Książkiewicz. Lipnica Mała, Variegated Shales, UJ TF 1567.

All figures nat. size.

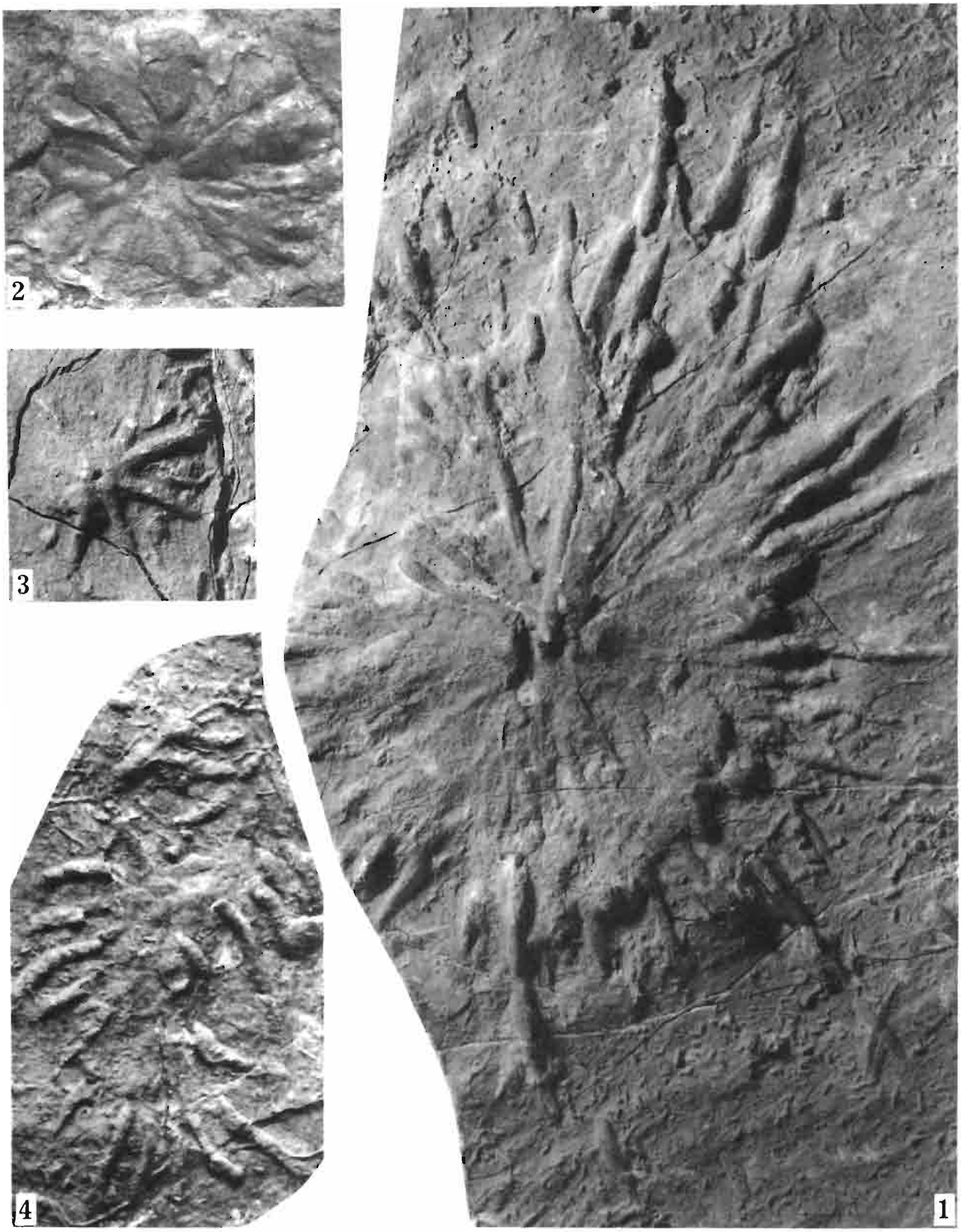

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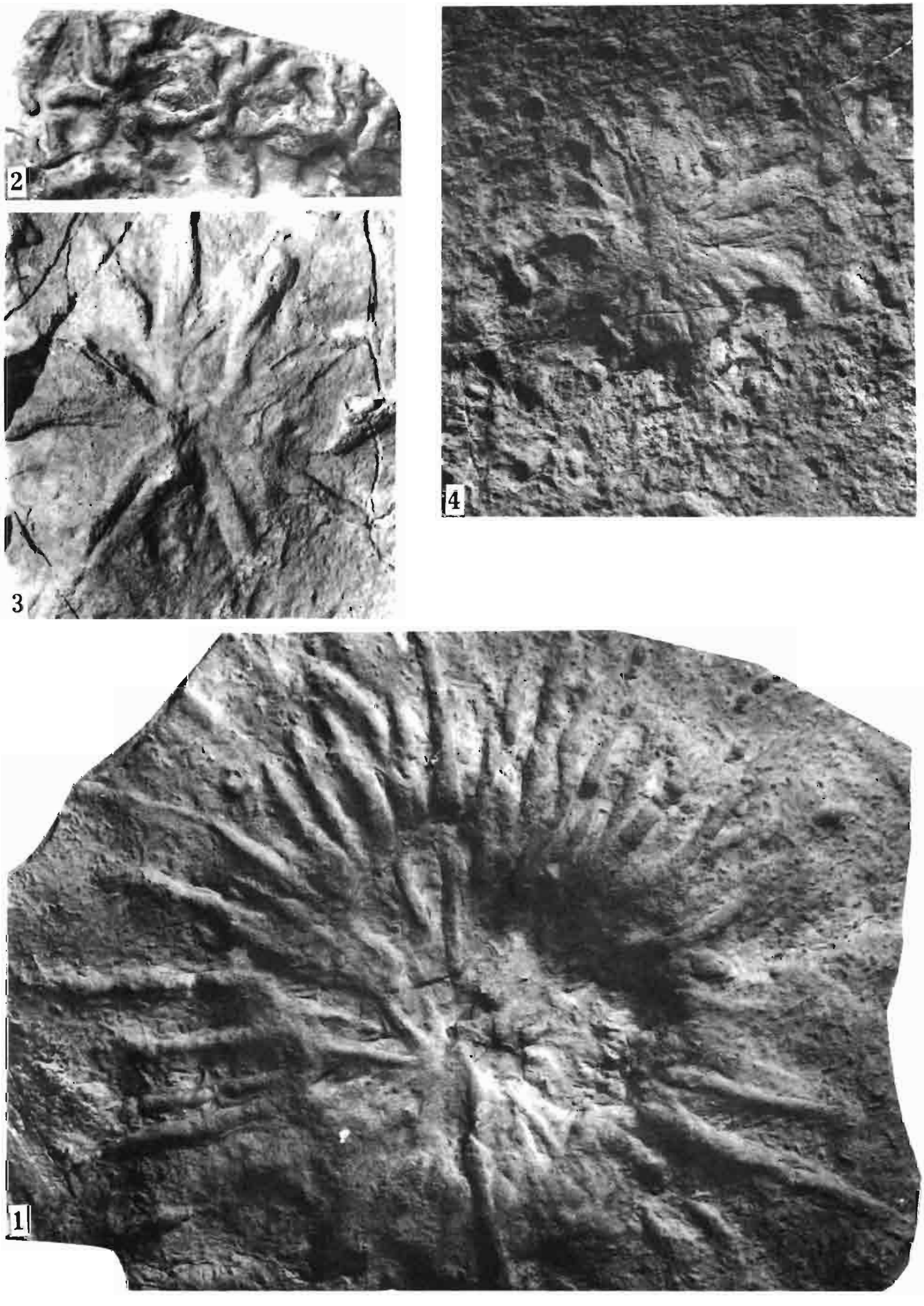
PLATE 9

1. *Glockeria glockeri* KSIĄŻKIEWICZ. Goleszów, Cieszyn Limestone, UJ TF 95.
2. *Glockeria disordinata* n. ichnosp. Krzeszów, Upper Istebna Beds, UJ TF 1735.
3. *Glockeria sparsicostata* KSIĄŻKIEWICZ. Zawoja, Ropianka Beds, UJ TF 210.
4. *Asterichnus* aff. *lawrencensis* BANDEL. Raciechowice, Upper Cieszyn Shales, UJ TF 79.

All figures nat. size.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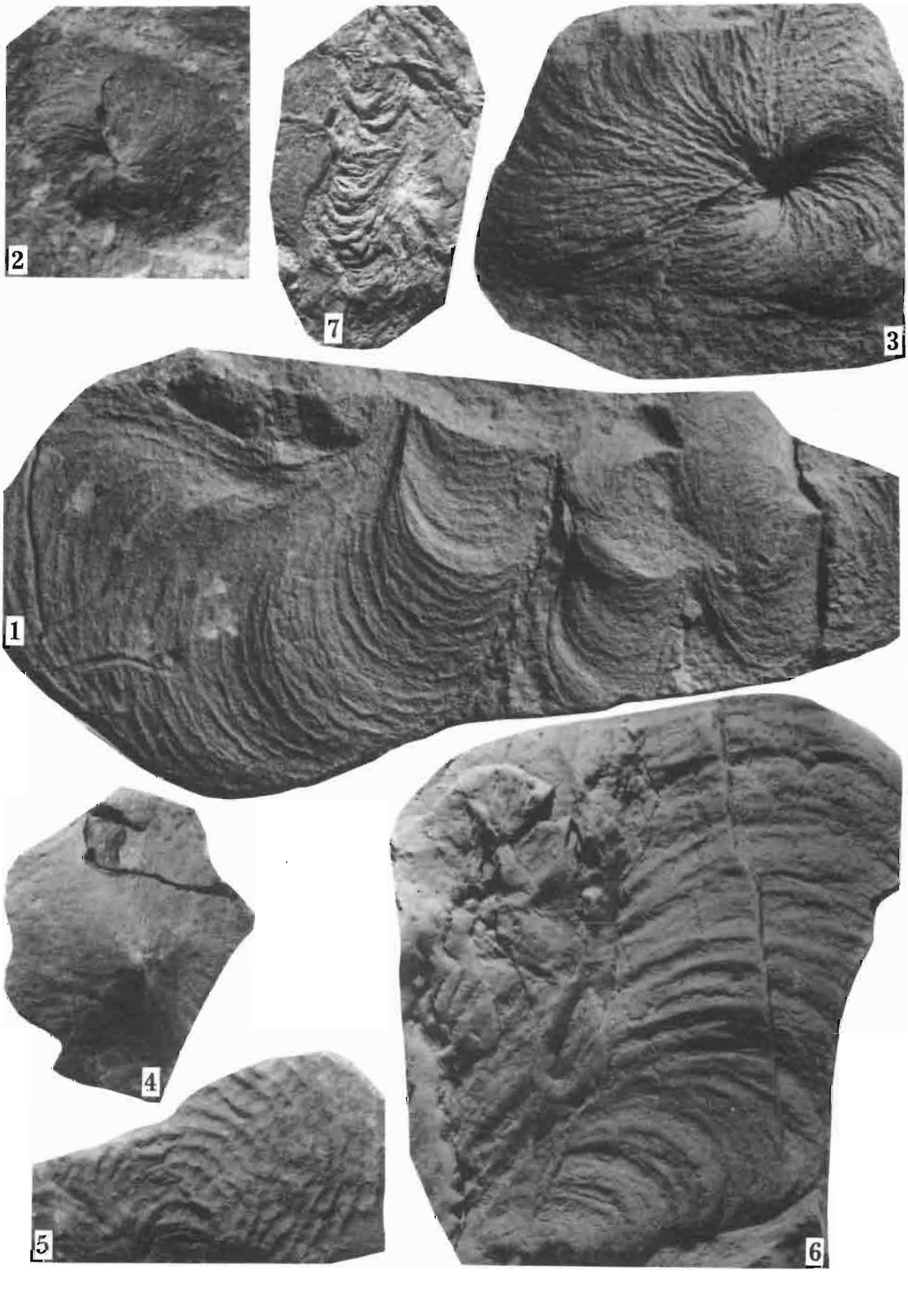
## PLATE 10

1. *Zoophycos insignis* SQUINABOL. Lipnica Wielka, Ropianka Beds, UJ TF 1430, × 0.5.
2. *Zoophycos brianteus* MASSALONGO. Huwniki, Inoceramian Beds, UJ TF 927, × 0.5.
3. *Zoophycos brianteus* MASSALONGO. Bieńkówka, Ropianka Beds, UJ TF 83, × 0.5.
4. *Zoophycos* indet. Zubrzyca Górna, Beloveza Beds, UJ TF 1431, × 0.5.
5. *Zoophycos* indet. Babica, Babica Clays, UJ TF 1603, nat. size.
6. *Zoophycos* indet. Juszczyn, Hieroglyphic Beds, UJ TF 1634, × 0.5.
7. *Zoophycos insignis* SQUINABOL (lower surface). Komańcza, Hieroglyphic Beds, UJ TF 1192, nat. size.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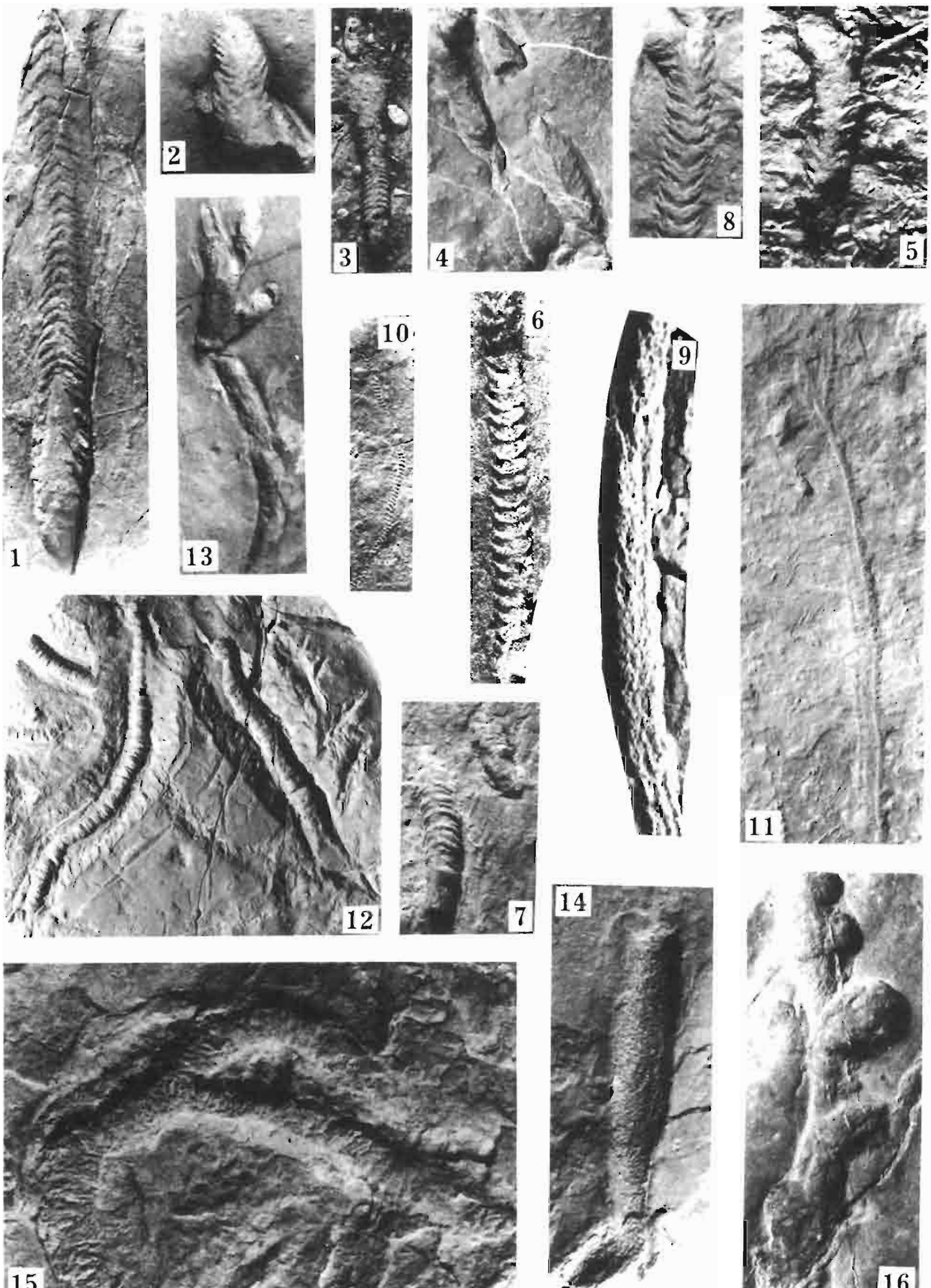
## PLATE 11

1. *Gyrochorte burtani* n. ichnosp. Poznachowice, Grodziszcze Beds, UJ TF 1475, × 0.5.
2. *Gyrochorte burtani* n. ichnosp. Dębna, Krosno Beds, UJ TF 687, nat. size.
3. *Gyrochorte burtani* n. ichnosp. Dębna, Krosno Beds, UJ TF 689, nat. size.
4. *Gyrochorte burtani* n. ichnosp. Wiśniowa, Verovice Shales, UJ TF 1165, nat. size
5. *Gyrochorte burtani* n. ichnosp. Dębna, Krosno Beds, UJ TF 689, nat. size.
6. *Gyrochorte imbricata* n. ichnosp. Gródek, Ciężkowice Sandstone, AGH (not registered).
7. *Gyrochorte imbricata* n. ichnosp. Gródek, Ciężkowice Sandstone, UJ TF 175, nat. size.
8. *Gyrochorte imbricata* n. ichnosp. Gródek, Ciężkowice Sandstone, UJ TF 176, nat. size.
9. *Gyrochorte obliterata* n. ichnosp. Lipnik near Myślenice, Verovice Shales, UJ TF 127, nat. size.
10. *Helicorhaphe tortilis* KSIĄŻKIEWICZ. Lipnica Mała, Beloveza Beds, UJ TF 277, nat. size.
11. *Oniscoidichnus carpathicus* n. ichnosp. Lubomierz, Krosno Beds, UJ TF 1471, nat. size.
12. *Scolicia prisca* DE QUATREFAGES, locomotion trail. Zubrzyca Górna, Beloveza Beds, UJ TF 626, × 0.5.
13. *Naviculichnium marginatum* n. ichnosp. Półrzeczki, Beloveza Beds, UJ TF 760, × 0 5.
14. *Tubulichnium incertum* n. ichnosp. Wola Brzezińska, Ropianka Beds, UJ TF 1026, nat. size.
15. *Tubulichnium incertum* n. ichnosp. Bachów, Inoceramian Beds, UJ TF 938, nat. size.
16. *Strobilorhaphe glandifer* n. ichnosp. Jordanów, Hieroglyphic Beds, UJ TF 764, nat. size.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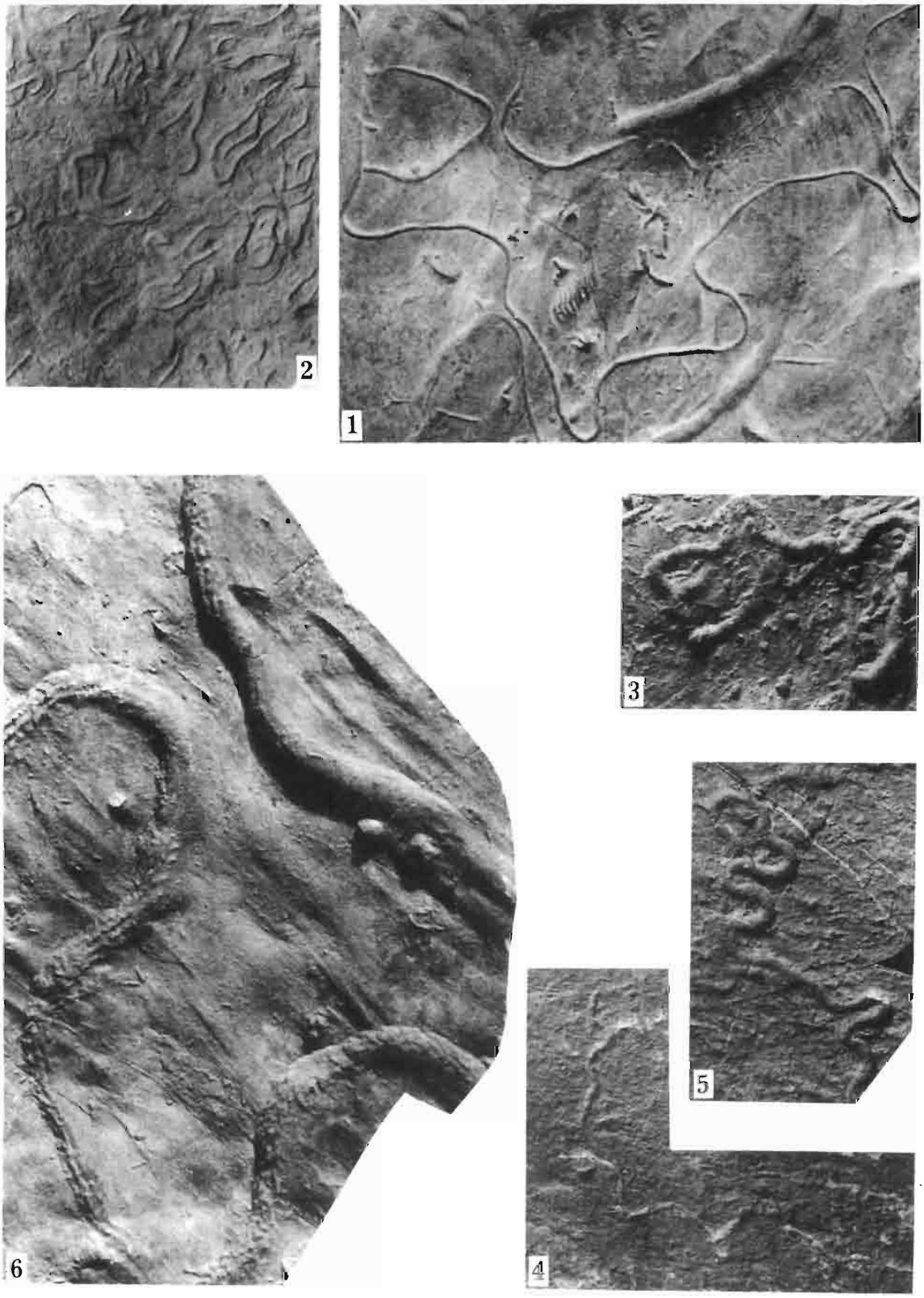
## PLATE 12

1. *Helminthopsis tenuis* KSIĄŻKIEWICZ (in the upper left — *Paleodictyon tellinii* SACCO). Goleszów, Cieszyn Limestone, UJ TF 1465, nat. size.
2. *Helminthopsis irregularis* SCHAFHÄUTL. Jaworki, Sromowce Beds, UJ TF 132, × 0.5.
3. *Helminthopsis hieroglyphica* HEER. Sidzina, Beloveza Beds, UJ TF 1082, × 0.5.
4. *Helminthopsis hieroglyphica* HEER. Radoszyce, Krosno Beds, UJ TF 1320, nat. size.
5. *Helminthopsis abeli* n. ichnosp. Poznachowice, Grodziszcze Beds, UJ TF 1321, × 0.5.
6. *Helminthopsis granulata* KSIĄŻKIEWICZ. Goleszów, Cieszyn Limestone, UJ TF 224, nat. size.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## PLATE 13

1. *Muensteria planicostata* n. ichnosp. Poręba Wielka, Ropianka Beds, UJ TF 133.
2. *Muensteria geniculata* (STERNBERG). Huwniki, Siliceous Marls. UJ TF 1004.
3. *Muensteria hamata* FISCHER-OOSTER. Grybów, Ropianka Beds, UJ TF 154.
4. *Tuberculichnus vagans* n. ichnosp. Sidzina, Beloveza Beds, UJ TF 1036.
5. *Tuberculichnus meandrinus* n. ichnosp. Sidzina, Beloveza Beds, UJ TF 76.
6. *Tuberculichnus meandrinus* n. ichnosp. Huwniki, Inoceramian Beds, UJ TF 917.
7. *Tuberculichnus bulbosus* n. ichnosp. Berest, Variegated Shales, UJ TF 851.

All figures × 0.5

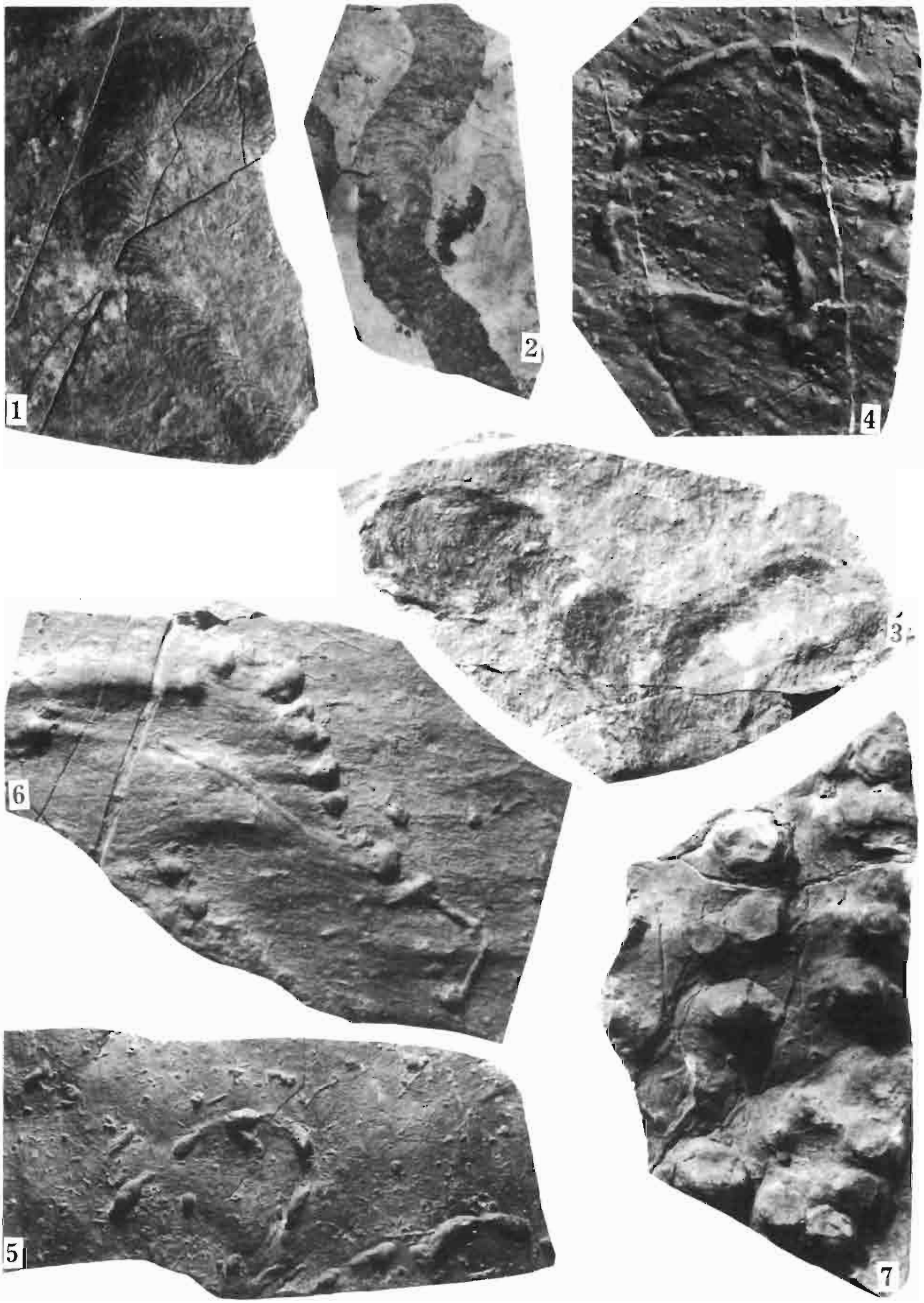

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PLATE 14

1. *Scolicia vertebralis* n. ichnosp. Bachów, Inoceramian Beds, UJ TF 1478, × 0.5.
2. *Scolicia plana* KSIĄŻKIEWICZ. Full burrow form. Jaworki, Skalski stream, UJ TF 498, × 0.5.
3. *Scolicia plana* KSIĄŻKIEWICZ. Locomotion trail form. Sromowce Wyżne, Sromowce Beds, UJ TF 585, × 0.5.
4. *Scolicia plana* KSIĄŻKIEWICZ. Locomotion trail form. Rzyki near Wadowice, UJ TF 621, × 0.5.
5. *Scolicia plana* KSIĄŻKIEWICZ. Szaflary, Sromowce Beds, UJ TF 501, nat. size.
6. *Scolicia vertebralis* n. ichnosp. Bachów, Inoceramian Beds, UJ TF 1478, nat. size.
7. *Scolicia plana* KSIĄŻKIEWICZ. Locomotion trail form. Łączki Kucharskie, Inoceramian Beds, UJ TF 620, × 0.5.
8. *Scolicia prisca* DE QUATREFAGES. Full burrow form. Juszczyn, Hieroglyphic Beds, UJ TF 631, × 0.5.


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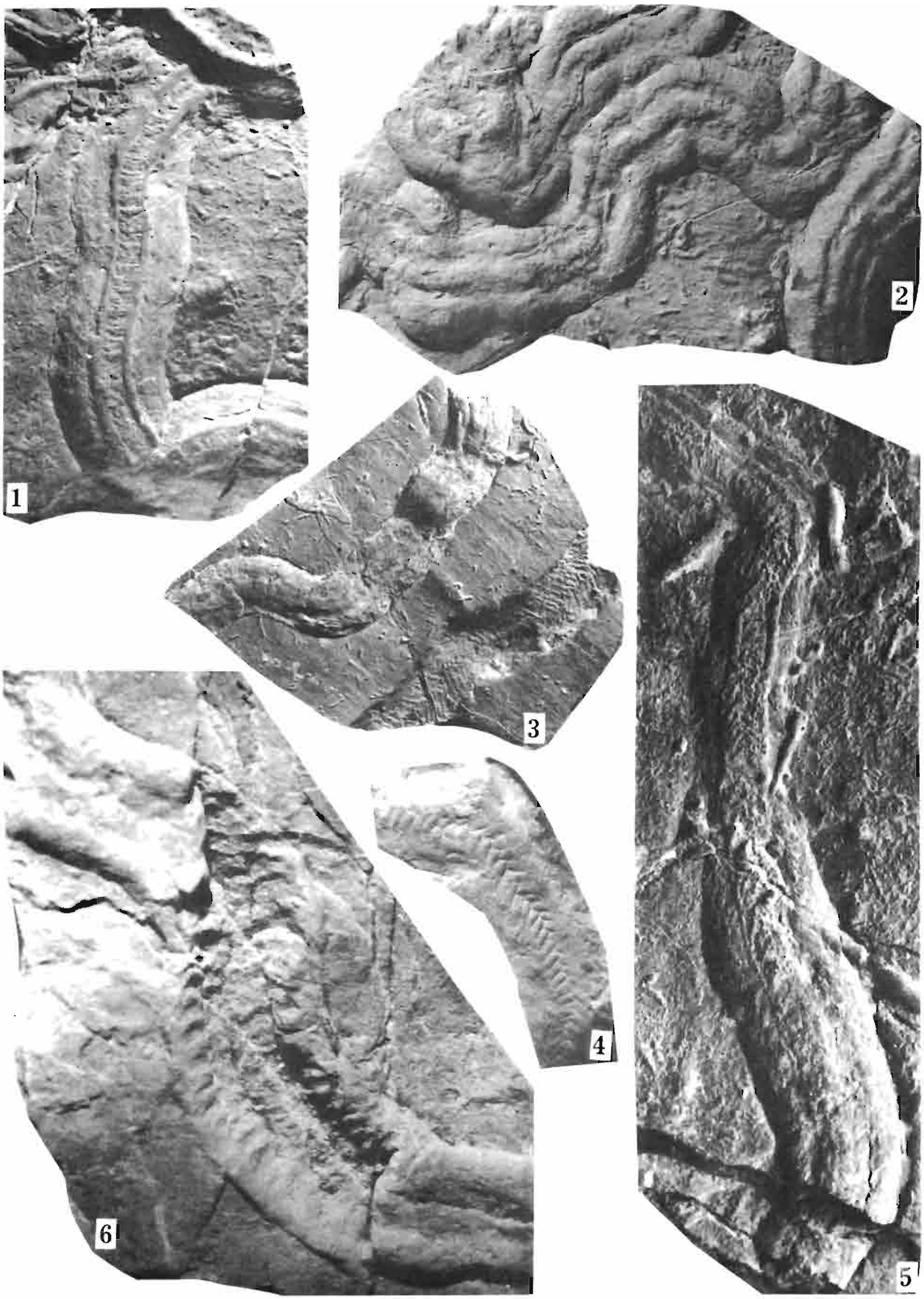
PLATE 15

1. *Subphyllochorda striata* KSIĄŻKIEWICZ. Lubomierz, Beloveza Beds, UJ TF 135, nat. size.
2. *Subphyllochorda rudis* n. ichnosp. Przenosza, Skrzydlna Beds, UJ TF 1211, × 0.5.
3. *Subphyllochorda granulata* KSIĄŻKIEWICZ. Hypichnial full burrow and hypichnial furrow. Lubomierz, Beloveza Beds, UJ TF 143, × 0.5.
4. *Subphyllochorda* indet. Upper surface of the burrow. UJ TF 1358, × 0.5.
5. *Subphyllochorda granulata* KSIĄŻKIEWICZ. Lipnica Wielka, Beloveza Beds, UJ TF 1542, nat. size.
6. *Scolicia prisca* DE QUATREFAGES. Full burrow form; in the part in which the burrow filling is removed, a *Scolicia*-type trail is seen. Zawoja, the stream Końskie, Hieroglyphic Beds, UJ TF 1565, nat. size.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## PLATE 16

1. *Subphyllochorda laevis* KSIĄŻKIEWICZ. Rzyki near Wadowice, Lgota Beds, UJ TF 1548, nat. size.
2. *Subphyllochorda laevis* KSIĄŻKIEWICZ. Krościenko on the river Strwiąż, Krosno Beds, UJ TF 865, × 0.5.
3. *Subphyllochorda laevis* KSIĄŻKIEWICZ. Mszana Dolna, the stream on the slope of Mt. Łubogoszcz, Ropianka Beds, UJ TF 1101, × 0.5.

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M. KSIĄŻKIEWICZ: TRACE FOSSILS IN THE FLYSCH ON THE POLISH CARPATHIANS

## PLATE 17

1. *Taphrhelminthopsis auricularis* Sacco. Lipnica Mała, Beloveza Beds, UJ TF 872.
2. *Taphrhelminthopsis auricularis* Sacco. Berest, Beloveza Beds, UJ TF 785.
3. *Taphrhelminthopsis auricularis* Sacco. Limanowa, Variegated Shales, UJ TF 649.
4. *Taphrhelminthopsis vagans* n. ichnosp. Łączki Kucharskie, Inoceramian Beds, UJ TF 533.
5. *Taphrhelminthopsis vagans* n. ichnosp. Sidzina, Beloveza Beds, UJ TF 869.
6. *Taphrhelminthopsis recta* Sacco. Zubrzyca Górna, Magura Sandstone, UJ TF 870.
7. *Taphrhelminthopsis* indet., probably *T. vagans*. Endichnial full burrow form. Grzechynia, Magura Sandstone, UJ TF 1207.

All figures × 0.5


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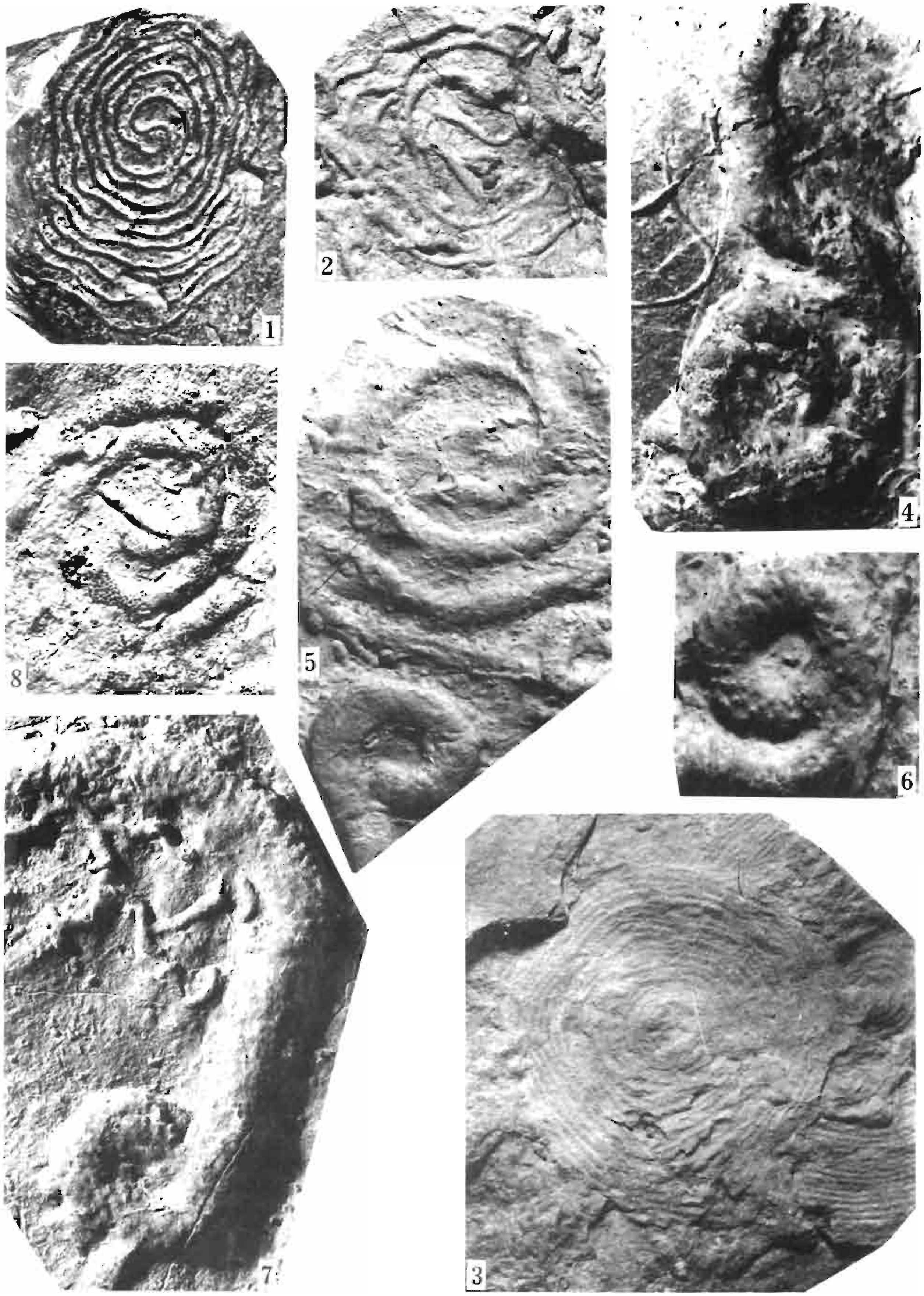
## PLATE 18

1. *Spirorhaphe involuta* (DE STEFANI). Gródek, Ciężkowice, UJ TF 1519, × 0.5.
2. *Spirorhaphe involuta* (DE STEFANI). Gródek, Ciężkowice Sandstone, UJ TF 552, 0.5.
3. *Spirorhaphe zumayensis* (LLARENA). Krościenko on the river Dunajec, Szczawnica Beds, UJ TF 212, nat. size.
4. *Spirophycus bicornis* (HEER). Łętownia Górna, Beloveza Beds, UJ TF 208, nat. size.
5. *Spirophycus bicornis* (HEER). Zawoja, Hieroglyphic Beds, UJ TF 205, × 0.5.
6. *Spirophycus caprinus* (HEER). Łętownia Górna, Beloveza Beds, UJ TF 193, nat. size.
7. *Spirophycus caprinus* (HEER). Łętownia Górna, Beloveza Beds, UJ TF 81, nat. size.
8. *Spirophycus involutissimus* (SACCO). Zawoja, Hieroglyphic Beds, UJ TF 196, nat. size.



M. KSIĄŻKIEWICZ: TRACE FOSSILS IN THE FLYSCH OF THE POLISH CARPATHIANS

PLATE 19

1. *Cosmorhaphe gracilis* n. ichnosp. Kobielnik, Szydłowiec Beds, UJ TF 1162, nat. size.
2. *Cosmorhaphe gracilis* n. ichnosp. Gródek, Ciężkowice Sandstone, UJ TF 91, nat. size.
3. *Cosmorhaphe sinuosa* (AZPEITIA). Lipnica Wielka, Variegated Shales, UJ TF 244, × 0.5.
4. *Cosmorhaphe sinuosa* (AZPEITIA). Szczepanowice, Inoceramian Beds, UJ TF 75, × 0.5.
5. *Cosmorhaphe sinuosa* (AZPEITIA). Lipnica Wielka, Variegated Shales, UJ TF 74, × 0.5.
6. *Cosmorhaphe helminthopsoidea* n. ichnosp. Łętownia Górna, Beloveza Beds, UJ TF 77, × 0.5.
7. *Cosmorhaphe fuchsi* KSIĄŻKIEWICZ. Zubrzyca Górna, Łącko Beds, UJ TF 243, × 0.5.
8. *Helminthoida aculeata* n. ichnosp. Szczawa, the stream Głębieniec, Beloveza Beds, UJ TF 1360, nat. size.
9. *Cosmorhaphe*(?) *tortuosa* KSIĄŻKIEWICZ. Gorlice area? Ropianka Beds? AGH not (registered), nat. size.

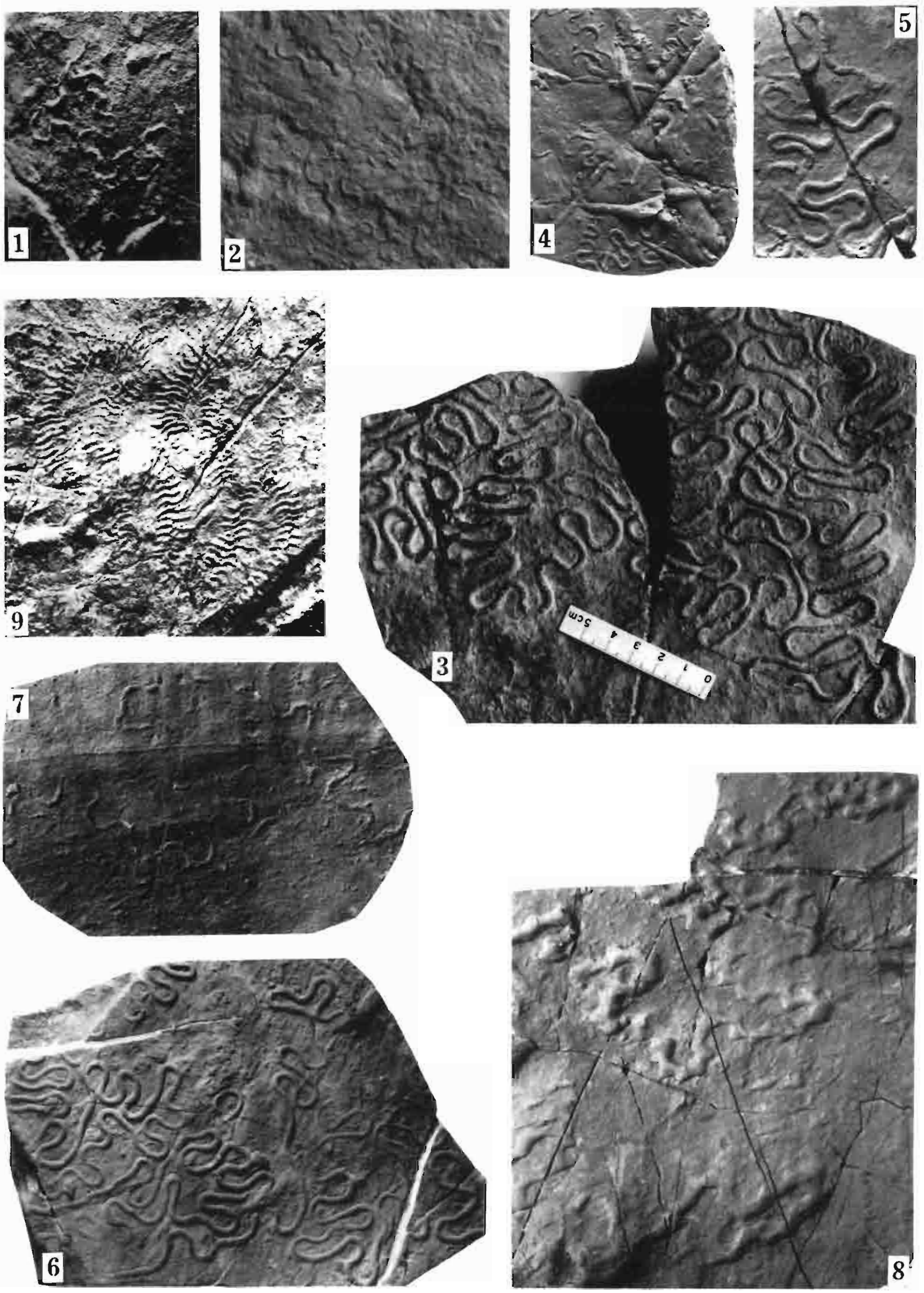

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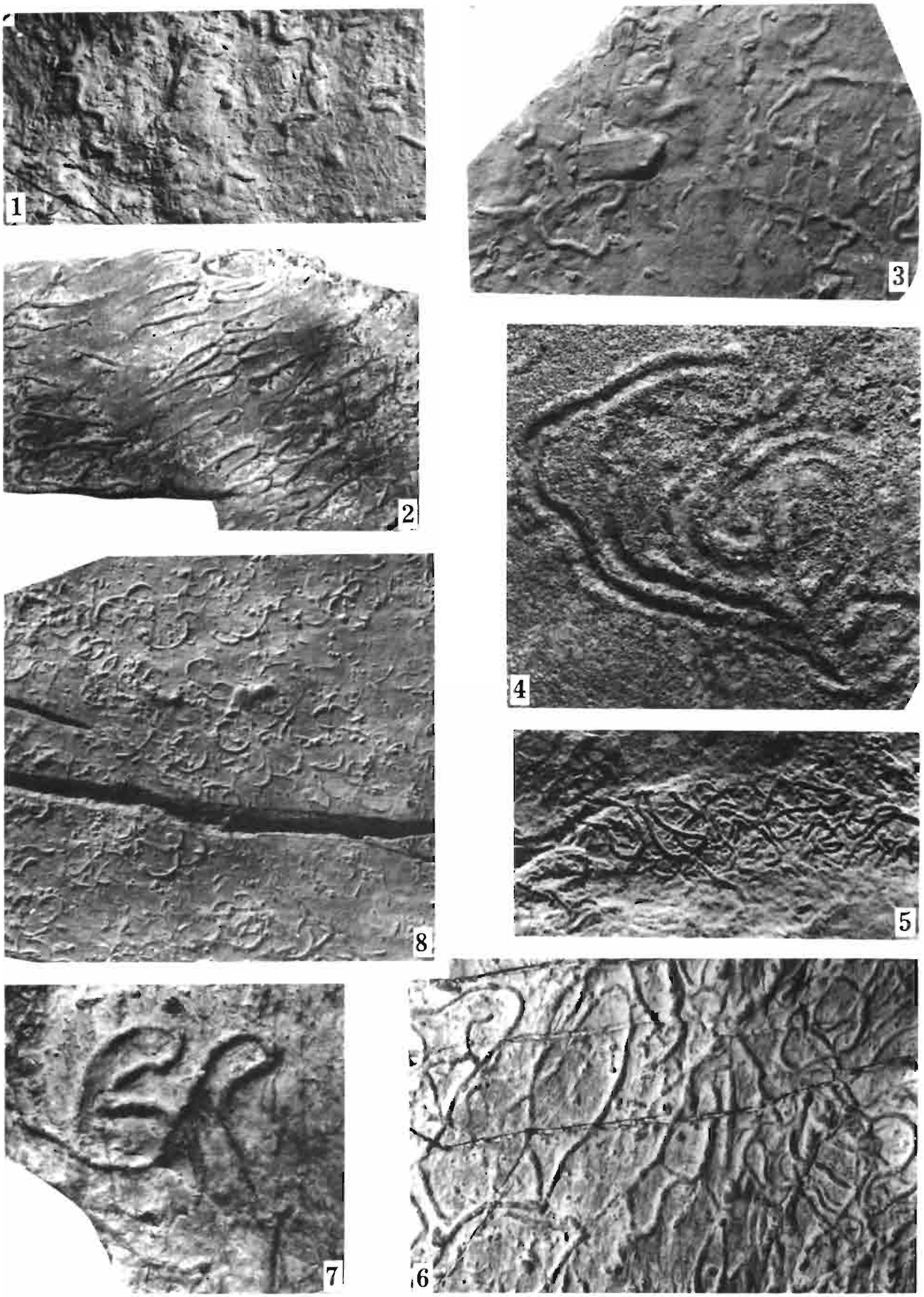
PLATE 20

1. *Cochlichnus* aff. *anguineus* HITCHCOCK. Komańcza, Hieroglyphic Beds, UJ TF 1230, nat. size.
2. *Helminthoida alterna* n. ichnosp. Berest, Beloveza Beds, UJ TF 843, × 0.5.
3. *Helminthoida helminthopsoidea* SACCO. Łętownia Górna, Beloveza Beds, UJ TF 339, nat. size.
4. *Gordia molassica* (HEER). Komańcza, Hieroglyphic Beds, UJ TF 1184, nat. size.
5. *Gordia molassica* (HEER). Huwniki, Inoceramian Beds, UJ TF 1197, nat. size.
6. *Gordia molassica* (HEER). Skrzydlna, Krosno Beds, UJ TF 245, nat. size.
7. *Gordia molassica* (HEER). Juszczyn, Hieroglyphic Beds, UJ TF 1249, nat. size.
8. *Gordia arcuata* n. ichnosp. Wetlina, Krosno Beds, UJ TF 1219, nat. size.



M. KSIĄŻKIEWICZ: TRACE FOSSILS IN THE FLYSCH OF THE POLISH CARPATHIANS

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PLATE 21

1. *Helminthoida labyrinthica* HEER. Lipnica Mała, Ropianka Beds. UJ TF 236, nat. size.
2. *Helminthoida serrata* n. ichnosp. Bieńkówka, Ropianka Beds, UJ TF 105, × 0.5.
3. *Helminthoida crassa* SCHAFHÄUTL. Biała Wyżna, Ropianka Beds, UJ TF 99, nat. size.
4. *Helminthoida crassa* SCHAFHÄUTL. Sromowce Wyżne. Sromowce Beds, UJ TF 103, × 0.5.
5. *Helminthoida crassa* SCHAFHÄUTL. Dźwiniacz Dolny, Krosno Beds, UJ TF 1362, × 0.5.
6. *Helminthoida crassa* SCHAFHÄUTL. Krościenko on the river Dunajec, Szczawnica Beds, UJ TF 750, nat. size.
7. *Helminthoida crassa* SCHAFHÄUTL. Dźwiniacz Dolny, Krosno Beds, UJ TF 1361, × 0.5.
8. *Helminthoida crassa* SCHAFHÄUTL. Znamirowice, Ciężkowice Sandstone, UJ TF 104, × 0.5.
9. *Helminthoida helminthopsoidea* SACCO. Sidzina, Beloveza Beds, UJ TF 102, × 0.5.
10. *Helminthoida miocenica* SACCO. Gorzeń Górny, Gorzeń Beds, UJ TF 1403, nat. size
11. *Helminthoida miocenica* SACCO. Dźwiniacz Dolny, Krosno Beds, UJ TF 714, × 0.5..

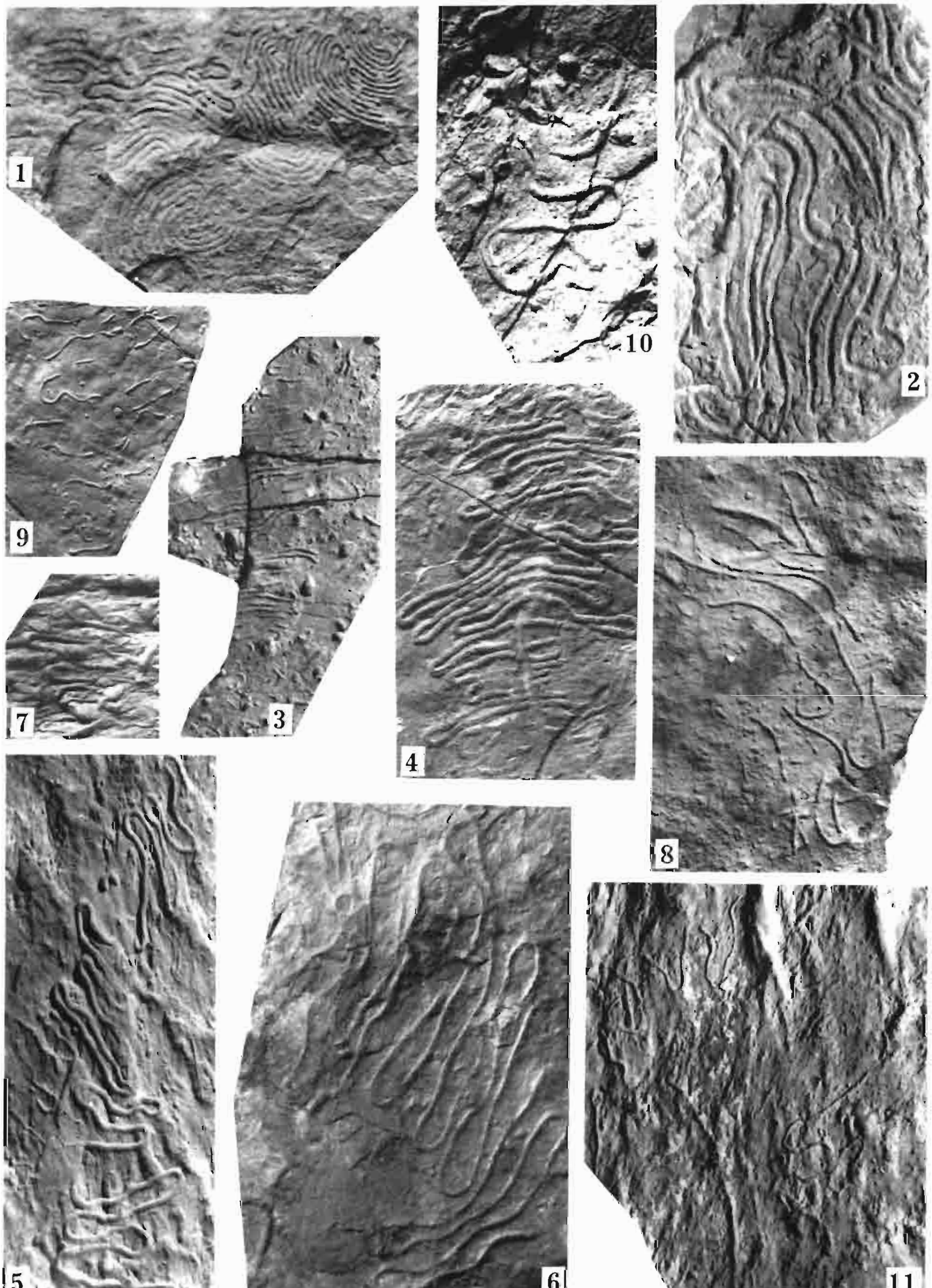

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PLATE 22

1. *Taphrhelminthoida convoluta* n. ichnosp. Berest, Beloveza Beds, UJ TF 813, × 0.5.
2. *Taphrhelminthoida plana* KSIĄŻKIEWICZ. Zubrzyca Górna, the hamlet Ochlipów, UJ TF 1367, × 0.5.
3. *Taphrhelminthoida plana* KSIĄŻKIEWICZ. Zubrzyca Górna, the hamlet Ochlipów, UJ TF 1369, × 0.5.
4. *Paleomeandron rude* PERUZZI. Budzów, the stream Droździna, Hieroglyphic Beds, UJ TF 218, nat. size.

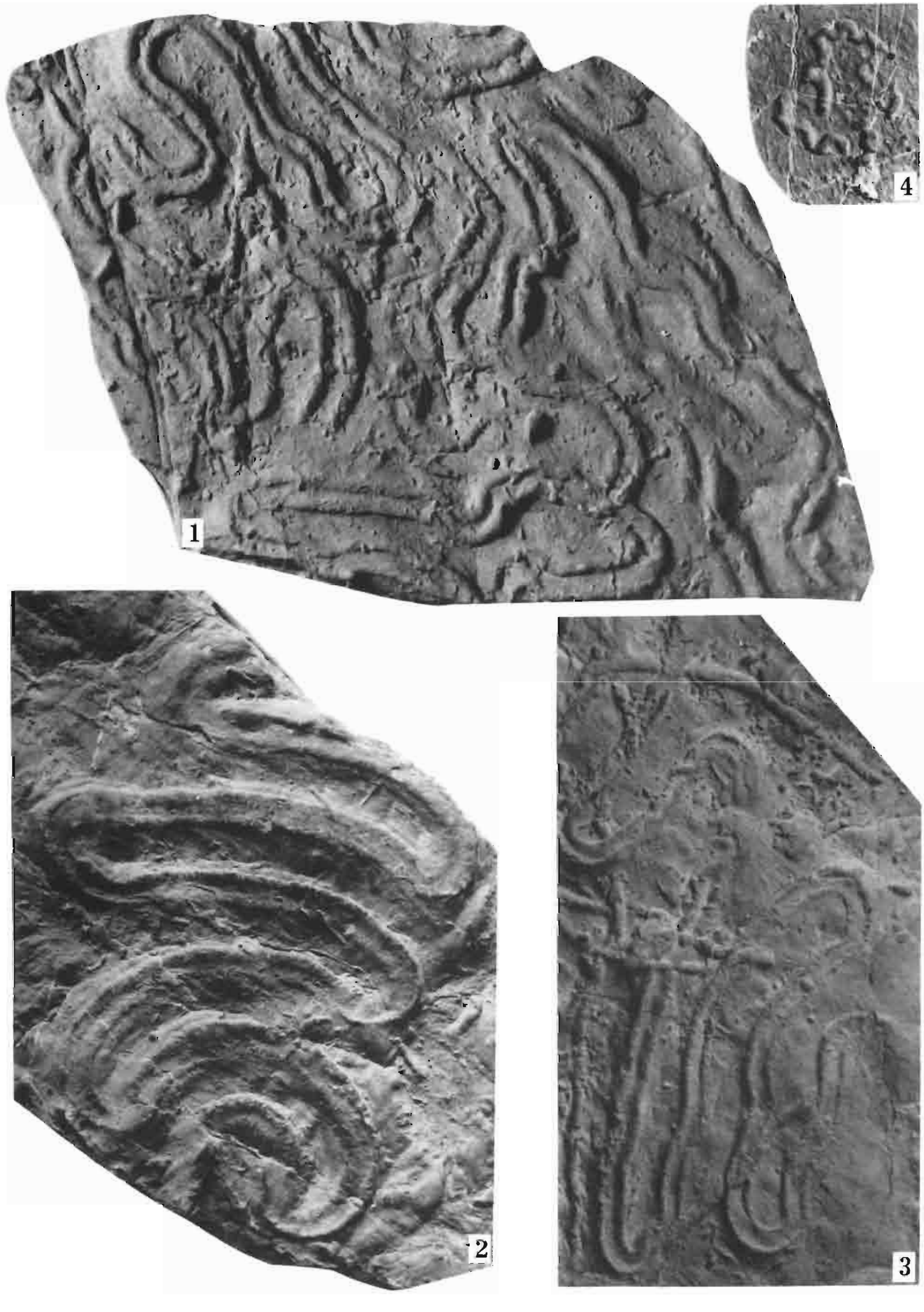
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PLATE 23

1. *Paleomeandron elegans* PERUZZI. Lipnica Mała, Ropianka Beds, UJ TF 220, nat. size.
2. *Paleomeandron rude* PERUZZI. Grzechynia, Hieroglyphic Beds, UJ TF 138, nat. size.
3. *Paleomeandron robustum* KSIĄŻKIEWICZ. Lipnica Mała, Beloveza Beds, UJ TF 231, nat. size.
4. *Helicolithus sampelayoi* AZPEITIA. Homrzyska, Magura Sandstone, UJ TF 227, nat. size.
5. *Taphrhelminthoida convoluta* n. ichnosp. Lipnica Wielka, Beloveza Beds, UJ TF 117, × 0·5.
6. *Acanthorhaphe incerta* KSIĄŻKIEWICZ. Goleszów, Cieszyn Limestone, UJ TF 1441, nat. size.
7. *Acanthorhaphe incerta* KSIĄŻKIEWICZ. Goleszów, Cieszyn Limestone, UJ TF 1441 (the same slab as fig. 6), nat. size.
8. *Acanthorhaphe delicatula* n. ichnosp. Biała Wyżna, Ropianka Beds, UJ TF 972, nat. size.
9. *Acanthorhaphe delicatula* n. ichnosp. Lipnica Mała, Beloveza Beds, UJ TF 1322, nat. size.
10. *Acanthorhaphe delicatula* n. ichnosp. Grybów, Ropianka Beds, UJ TF 1364, nat. size.

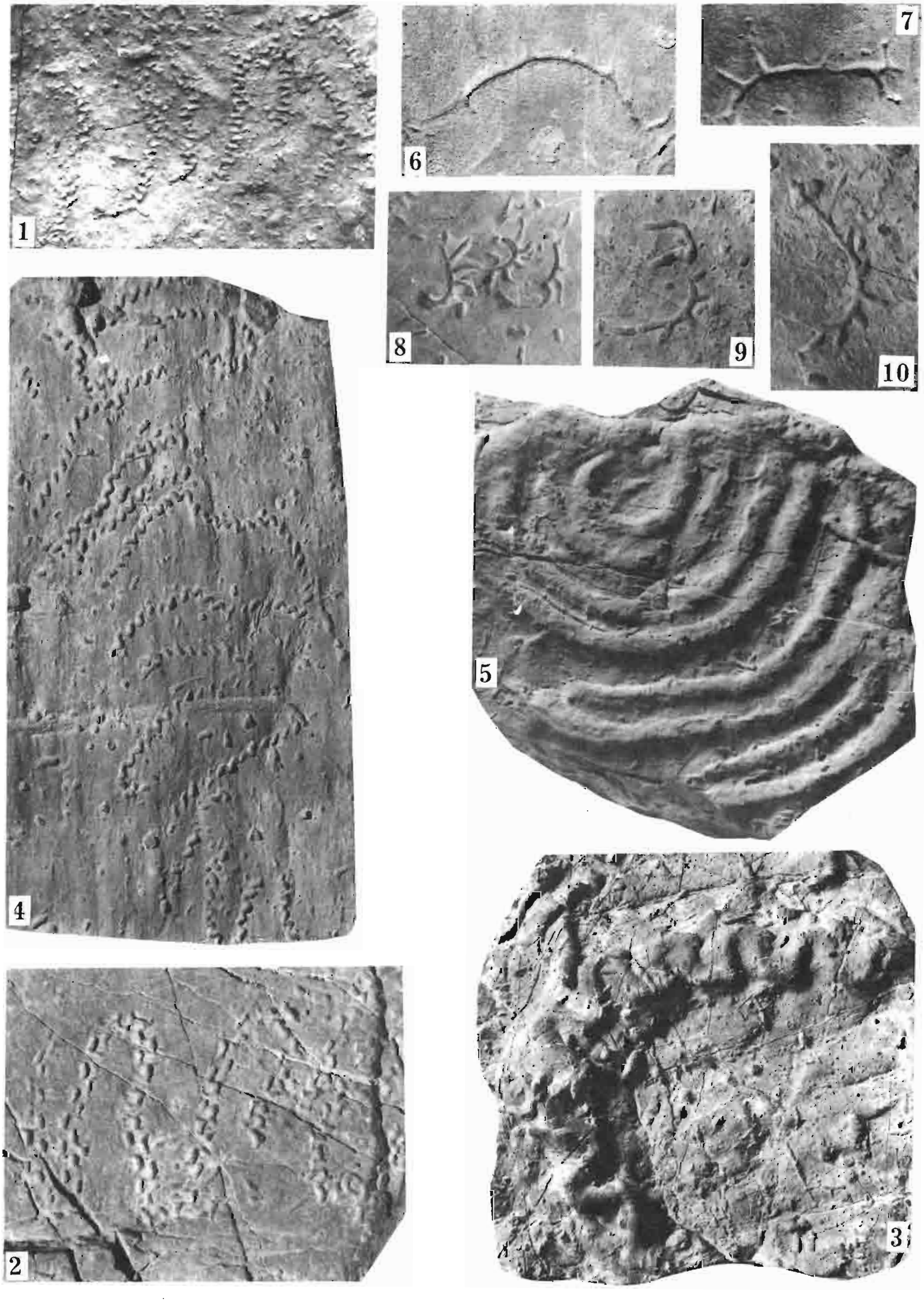
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PLATE 24

1. *Belorhaphe zickzack* (HEER). Jaroszowice, Upper Cieszyn Shales, UJ TF 119, × 0.5.
2. *Belorhaphe fabregae* (AZPEITIA). Zubrzyca Górna, the hamlet Moniaków, Łącko Beds, UJ TF 1442, nat. size.
3. *Protopaleodictyon incompositum* KSIĄŻKIEWICZ. Osielec, Hieroglyphic Beds, UJ TF 1484, nat. size.
4. *Protopaleodictyon incompositum* KSIĄŻKIEWICZ. Osielec, Mt. Przykrzec, Hieroglyphic Beds, UJ TF 130, nat. size.
5. *Protopaleodictyon minutum* n. ichnosp. Marcówka, Magura Sandstone, UJ TF 121, nat. size.

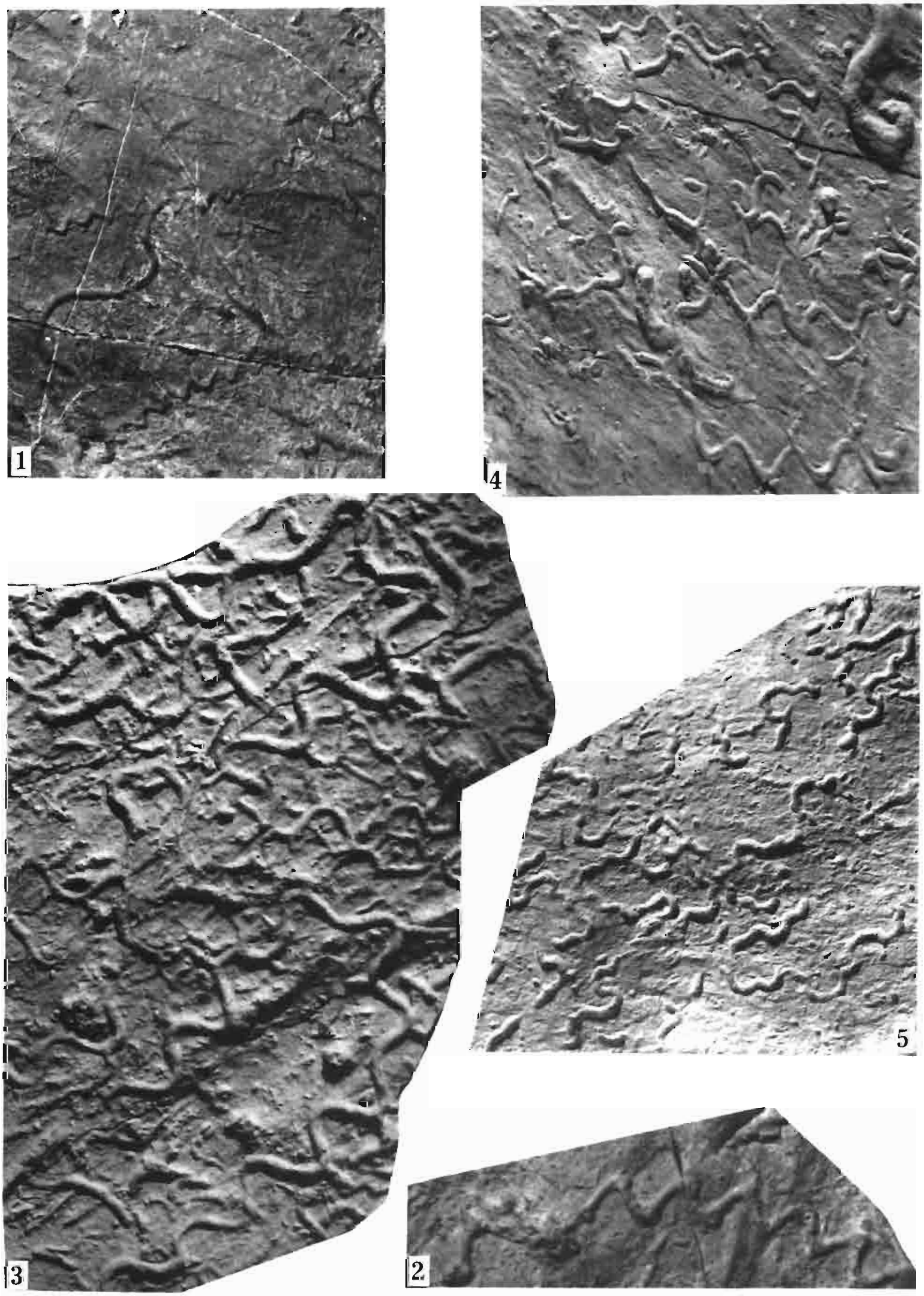
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PLATE 25

1. *Protopaleodictyon submontanum* (AZPEITIA). Tokarnia, Hieroglyphic Beds, UJ TF 793, × 0.5.
2. *Protopaleodictyon submontanum* (AZPEITIA). Lipnica Mała, Beloveza Beds, UJ TF 388, × 0.5.
3. *Protopaleodictyon submontanum* (AZPEITIA). Lipnica Wielka, Beloveza Beds, UJ TF 80, × 0.5.
4. *Protopaleodictyon submontanum* (AZPEITIA). Lipowe, Variegated Shales, UJ TF 640, × 0.5.
5. *Protopaleodictyon submontanum* (AZPEITIA). Lipowe, Variegated Shales, UJ TF 657, nat. size.
6. *Megagrapton irregulare* KSIĄŻKIEWICZ. Berest, Beloveza Beds, UJ TF 809, × 0.5.
7. *Megagrapton irregulare* KSIĄŻKIEWICZ. Zubrzyca Górna, Beloveza Beds, UJ TF 387, × 0.5.
8. *Megagrapton irregulare* KSIĄŻKIEWICZ. Myślec, Łącko Beds, UJ TF 985, × 0.5.
9. *Megagrapton* aff. *irregulare* KSIĄŻKIEWICZ. Biczyce, Variegated Shales, UJ TF 1873, × 0.5.
10. *Megagrapton tenue* KSIĄŻKIEWICZ. Goleszów, Cieszyn Limestone, UJ TF 391, nat. size.

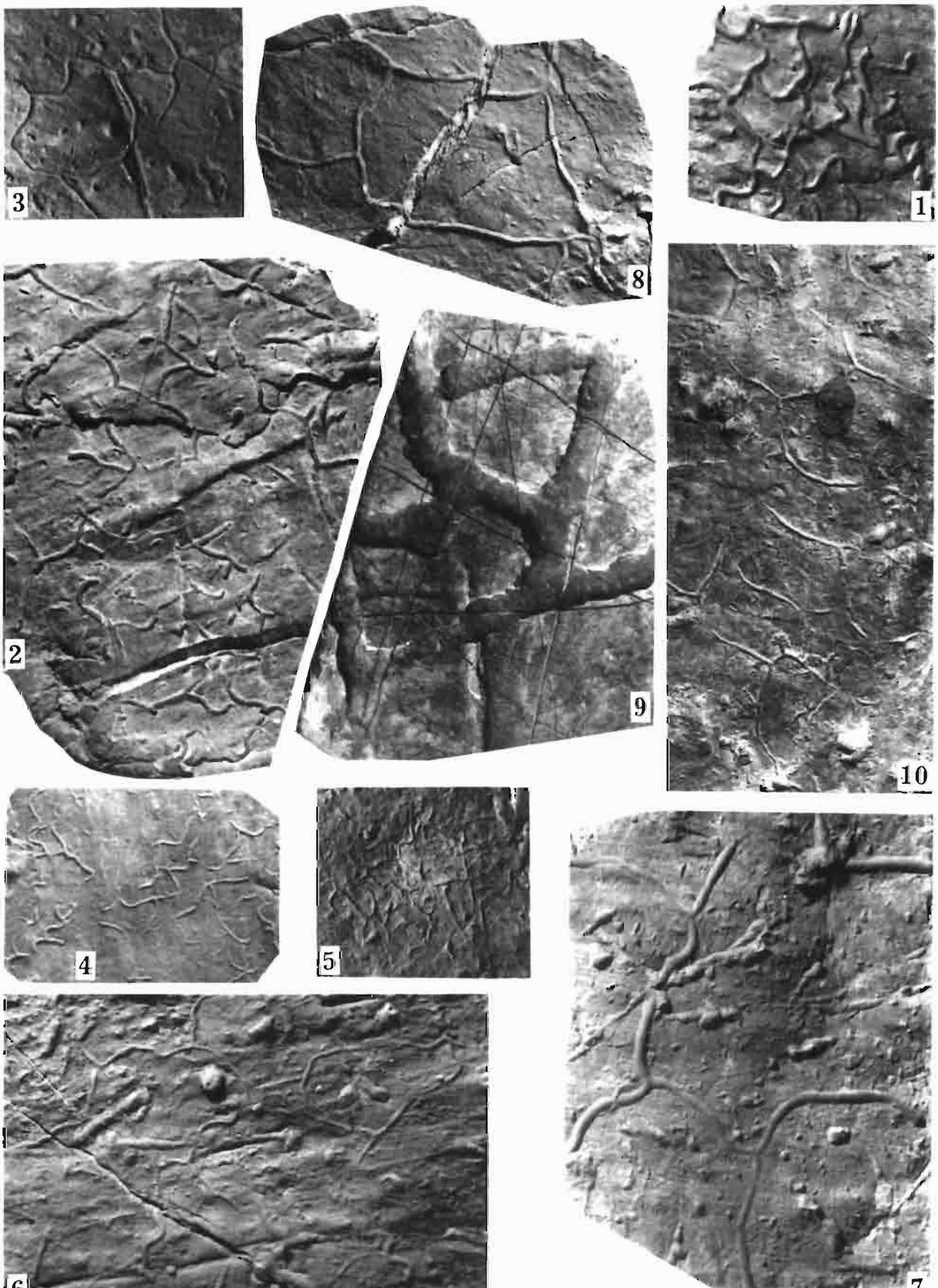
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PLATE 26

1. *Urohelminthoida appendiculata* (HEER). Grybów, Ropianka Beds, UJ TF 120, × 0.5.
2. *Urohelminthoida appendiculata* (HEER). Lipnica Wielka, the hamlet Kiczora, Ropianka Beds, UJ TF 1592, nat. size.
3. *Urohelminthoida appendiculata* (HEER). Around the termination a small *Desmograpton*. Lipnica Wielka, the hamlet Kiczora, Ropianka Beds, UJ TF 1591, nat. size.
4. *Urohelminthoida dertonensis* SACCO. Krościenko on the river Dunajec, Szczawnica Beds, UJ TF 1599, nat. size.
5. *Urohelminthoida dertonensis* SACCO. Osielec, Beloveza Beds, UJ TF 141, nat. size.
6. *Urohelminthoida* aff. *dertonensis* SACCO. Znamirowice, Ciężkowice Sandstone, UJ TF 144, nat. size.

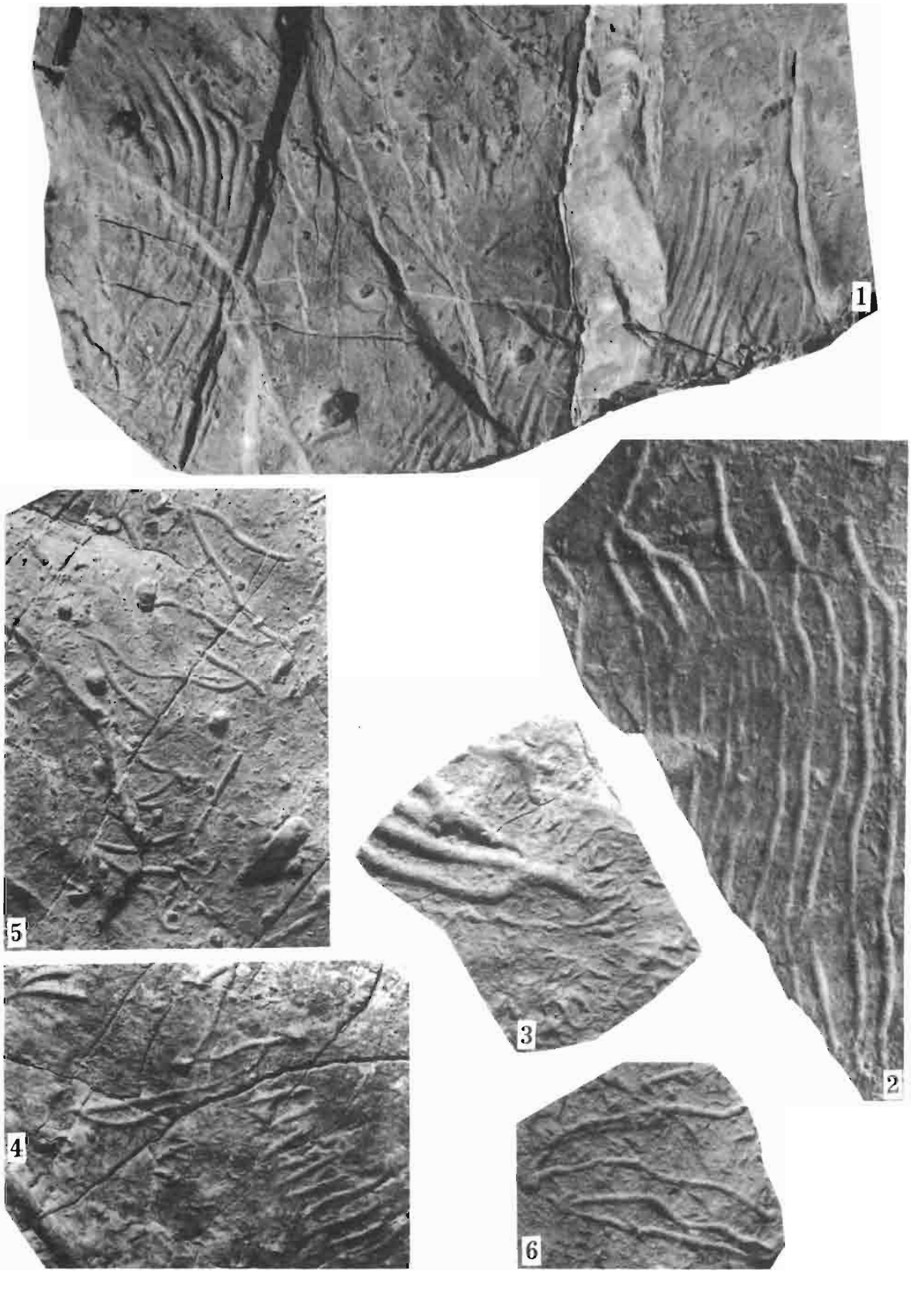

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PLATE 27

1. *Paleodictyon minutissimum* KSIĄŻKIEWICZ. Sidzina, the stream Kamieński, Beloveza Beds, UJ TF 155.
2. *Paleodictyon minutissimum* KSIĄŻKIEWICZ. Sidzina, the stream Kamieński, Beloveza Beds, UJ TF 89.
3. *Paleodictyon minimum* SACCO. Lipnica Mała, Beloveza Beds, UJ TF 317.
4. *Paleodictyon minimum* SACCO. Lipnica Wielka, Beloveza Beds, UJ TF 168.
5. *Paleodictyon latum* VIALOV et GOLEV. Zubrzyca Wielka, hamlet Ochlipów, UJ TF 172.
6. *Paleodictyon minimum* SACCO. Sromowce Wyżne, the stream Limbargowy, Sromowce Beds, UJ TF 111.
7. *Paleodictyon minimum* SACCO. Berest, Beloveza Beds, UJ TF 894.
8. *Paleodictyon intermedium* KSIĄŻKIEWICZ. Wiśniowa, Grodziszcze Beds, UJ TF 1172.
9. *Paleodictyon intermedium* KSIĄŻKIEWICZ. Sromowce Wyżne, Sromowce Beds, UJ TF 67.
10. *Paleodictyon strozzii* MENEGHINI. Jaworki, Sromowce Beds, UJ TF 330.
11. *Paleodictyon miocenicum* SACCO. Lipnica Mała, Beloveza Beds, UJ TF 64.
12. *Paleodictyon miocenicum* SACCO. Mszana Dolna, Ropianka Beds, UJ TF 1259.
13. *Paleodictyon miocenicum* SACCO. Mymoń, Krosno Beds, UJ TF 835.
14. *Paleodictyon miocenicum* SACCO (covering a flute cast). Mymoń, Krosno Beds, UJ TF 835 (the same slab as Fig. 13).
15. *Paleodictyon intermedium* forma *punctata* n. f. Znamirowice, Ciężkowice Sandstone, UJ TF 101.
16. *Paleodictyon miocenicum* forma *pleurodictyonoides* n. f. Przenosza, Skrzydlna Beds, UJ TF 1668.
17. *Paleodictyon intermedium* forma *punctata* n. f. Znamirowice, Ciężkowice Sandstone, UJ TF 78.
18. *Paleodictyon miocenicum* forma *punctata* n. f. Kamesznica, the stream Janoska, Hieroglyphic Beds, UJ TF 1828.
19. *Paleodictyon miocenicum* forma *punctata* n. f. Kamesznica, the stream Janoska, Hieroglyphic Beds, UJ TF 1827.

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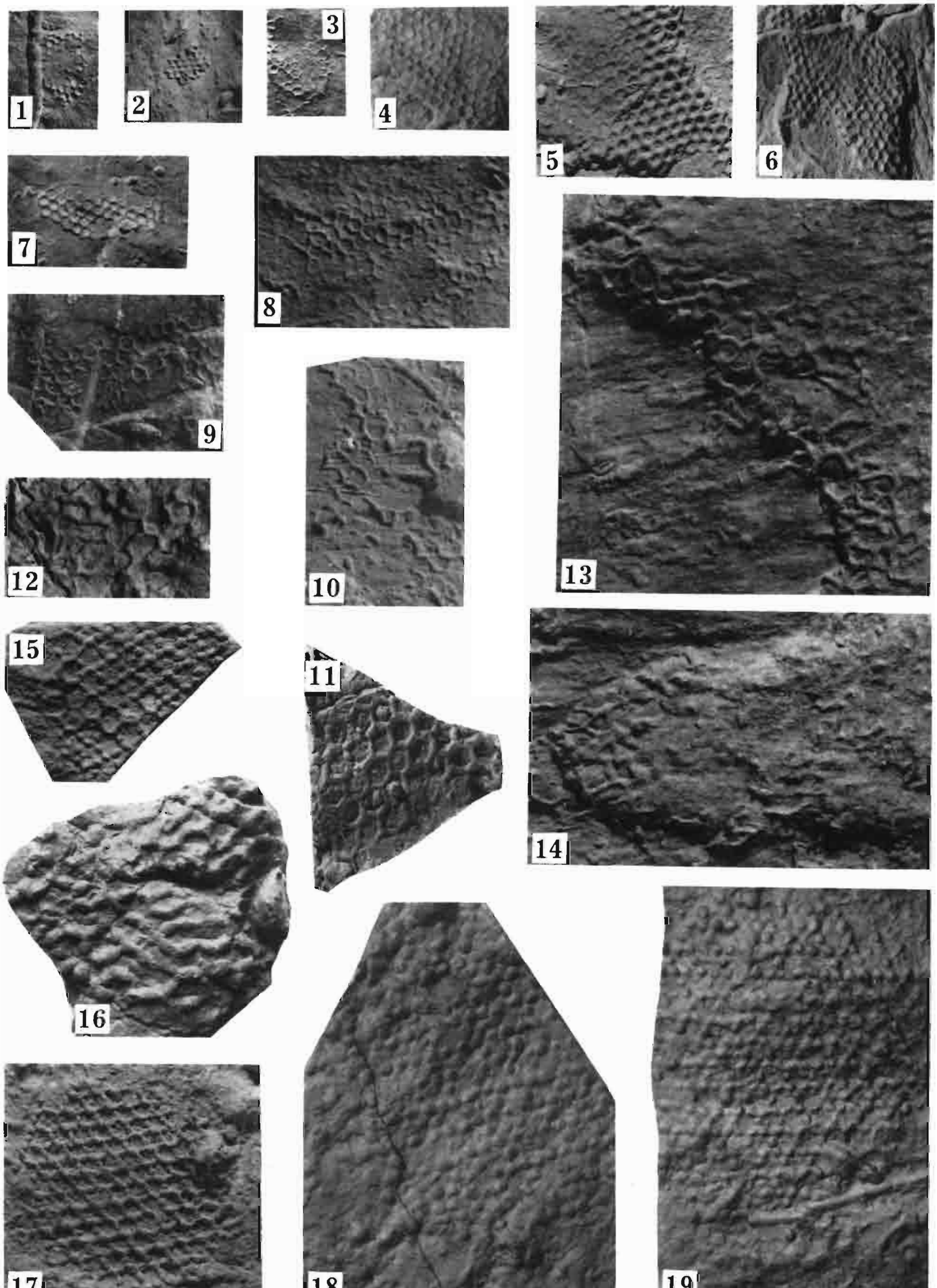


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PLATE 28

1. *Paleodictyon strozzii* MENEGHINI. Lipnica Wielka, Ropianka Beds, UJ TF 1102.
2. *Paleodictyon strozzii* MENEGHINI. Osielec, Mt. Przykrzec, Hieroglyphic Beds, UJ TF 157.
3. *Paleodictyon tellinii* SACCO. Koninka, Ropianka Beds, UJ TF 188.
4. *Paleodictyon carpathicum* MATYASOVSZKY. Lubomierz, Beloveza Beds, UJ TF 158.
5. *Paleodictyon carpathicum* MATYASOVSZKY. Lubomierz, Variegated Shales (coll. J. BURTAN).
6. *Paleodictyon regulare* SACCO. Zubrzyca Górna, Beloveza Beds, UJ TF 167.
7. *Paleodictyon regulare* SACCO. Znamirowice, Ciężkowice Sandstone, UJ TF 104.
8. *Paleodictyon majus* MENEGHINI. Lipnica Mała, Beloveza Beds, UJ TF 186.

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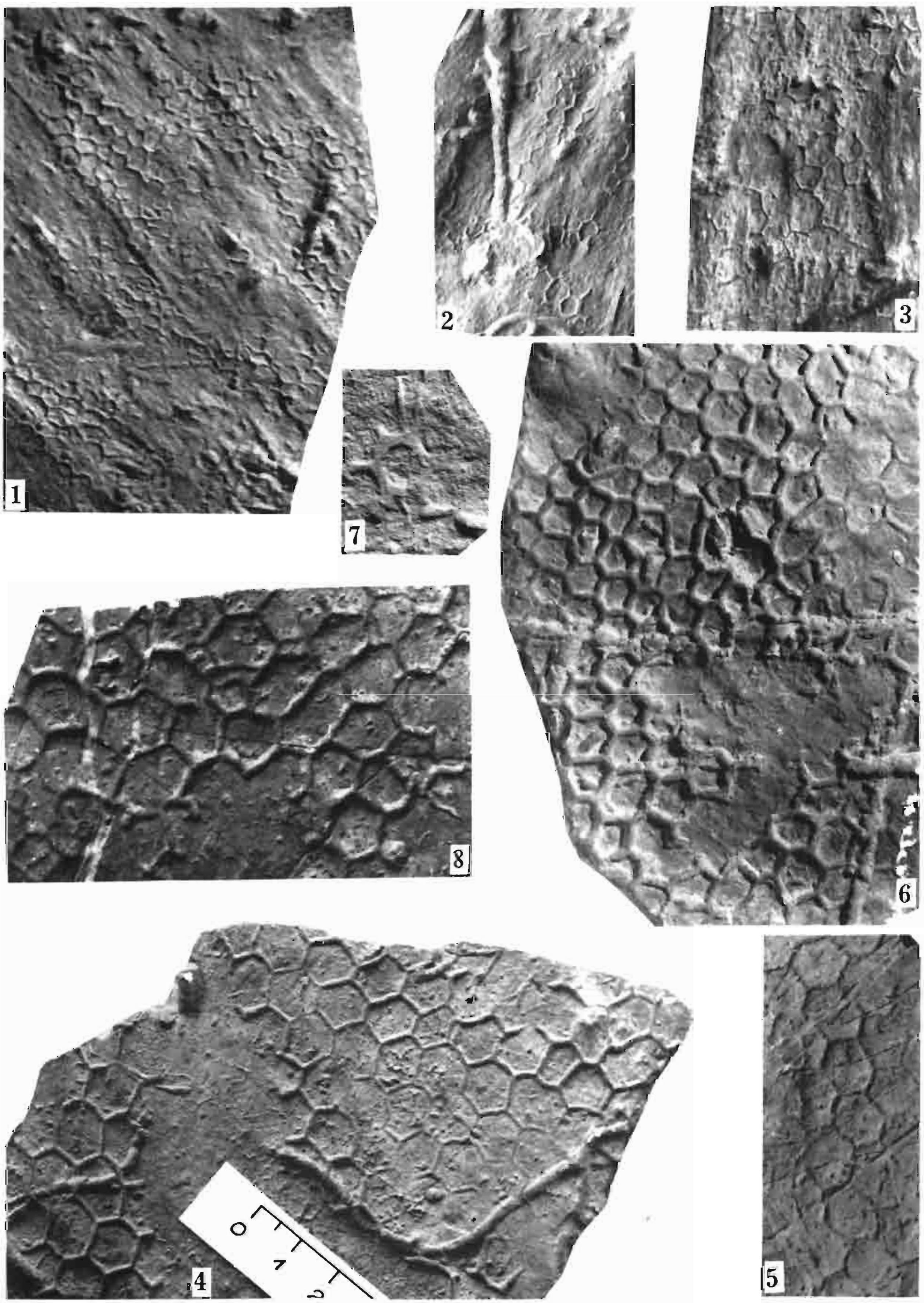
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PLATE 29

1. *Paleodictyon regulare* forma *pleurodictyonoides* n. f. Jaworki, the stream Skalski, Sromowce Bds, UJ TF 92.
2. *Paleodictyon regulare* SACCO. Znamirowice, Ciężkowice Sandstone, UJ TF 112.
3. *Paleodictyon regulare* SACCO. Znamirowice, Ciężkowice Sandstone, UJ TF 113.
4. *Paleodictyon* aff. *gomezi* AZPEITIA. Sidzina, Beloveza Beds, UJ TF 2005.
5. *Desmograpton fuchsi* n. ichnosp. Lipnica Wielka, the hamlet Kiczora, Ropianka Beds, UJ TF 1119.

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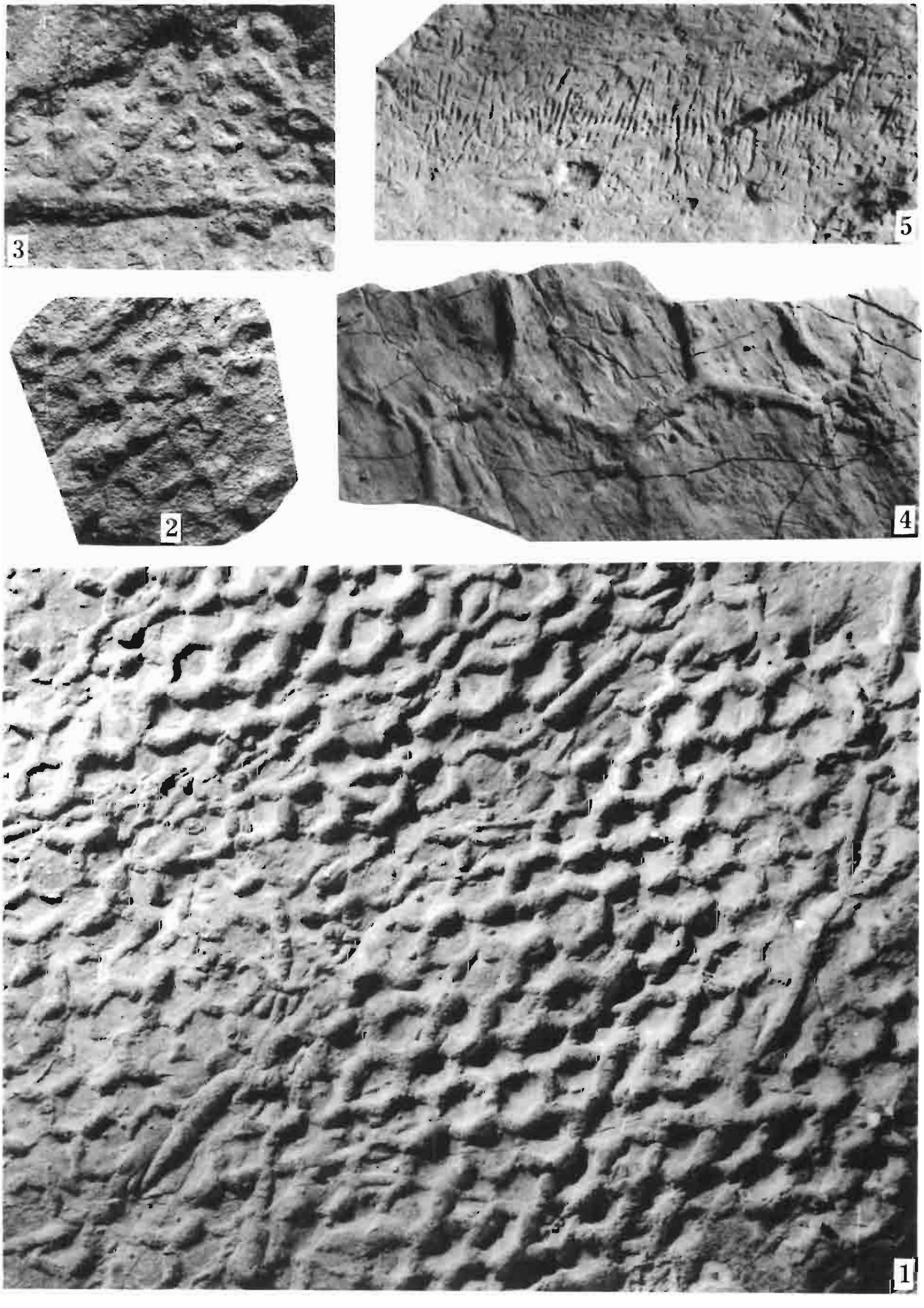
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# ERRATA

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No. 30, 1974 — ZOFIA KIELAN-JAWOROWSKA (Editor). Results of the Polish-Mongolian Palaeontological Expeditions Part. V, 178 pp., 41 text-figs., 51 plates.

No. 31, 1974 — JANINA SZCZECHURA & KRYSTYNA POŻARYSKA. Foraminiferida from the Paleocene of Polish Carpathians (Babice Clays). 142 pp., 4 text-figs., 38 plates.

No. 32, 1975 — WACŁAW BAŁUK. Lower Tortonian gastropods from Korytnica, Poland. Part I. 186 pp., 5 text-figs., 21 plates.

No. 33, 1975 — ZOFIA KIELAN-JAWOROWSKA (Editor). Results of the Polish-Mongolian Palaeontological Expeditions. Part VI. 200 pp., 44 text-figs, 44 plates.

No. 34, 1976 — AURELIA BARBULESCU. Caractéristique stratigraphique des formations coralligènes du Jurassique supérieur de la Dobroudja Centrale (Roumanie). 15 pp., 3 text-figs.
EWA RONIEWICZ. Les Scleractiniaires du Jurassique supérieur de la Dobroudja, Roumanie. 17-121 pp., 9 text-figs, 34 plates.

No. 35, 1977 — ALEKSANDER NOWIŃSKI. Tabulata and Chaetetida from the Devonian and Carboniferous of southern Poland.

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