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TRACE FOSSILS IN THE LOWER CAMBRIAN SEQUENCE IN THE ŚWIĘTOKRZYSKIE MOUNTAINS, CENTRAL POLAND

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The Cambrian sequence of the Świętokrzyskie Mts. (Holy Cross Mts.) is rich both in body fossils and trace fossils. The paper presents results of examination of all Lower Cambrian trace fossils except trilobite traces. The Lower Cambrian trace fossils include 19 ichnogenera (19 ichnospecies). Four new trace fossils have been described: *Multilamella spatiosa* ichnogen. et ichnosp. n., *Elingua convexa* ichnogen. et ichnosp. n., *Cochlichnus annulatus* ichnosp. n., and *Cylindrichnus operosus* ichnosp. n. The trace fossil communities were used to characterize the environmental conditions for each formation recognized in the Lower Cambrian sequence of the Świętokrzyskie Mts.

Key words: Lower Cambrian, trace fossils, ichnological interpretation, Świętokrzyskie Mts.

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INTRODUCTION

The Cambrian rocks were discovered in the Świętokrzyskie Mts. about hundred years ago (Gürich 1892). Both body fossils and trace fossils are common in the rocks. The former occur in nest-like agglomerations in the rocks. The latter are mainly connected with sandy formations. Apart from abundant trilobites, the body fossils include: brachiopods, hyolithids, gastropods, eocrinoids and jellyfishes. Trace fossils, especially those produced by trilobites, are common throughout the Cambrian sequence.

The collection is housed at the Museum of Geological Faculty, Warsaw University (acronyme IGPUW).

INVESTIGATIONS OF CAMBRIAN TRACE FOSSILS IN THE ŚWIĘTOKRZYSKIE MOUNTAINS

The modern description of trace fossils from the Cambrian rocks of the area started at the beginning of the sixties. Trace fossils, however, were often quoted in earlier geological literature, e.g. Czarnocki (1919) noticed

"fucoid sandstones" and "full of hieroglyphs" in the Cambrian sandstones, and mentioned the ichnogenera *Scolithos* and *Cruziana* but without any description, discussion or illustration. Samsonowicz (1934) reported the ichnogenera: *Planolites*, *Cruziana*, *Scolithos* from the eastern part of this area but again without any description or discussion.

The systematic description of trace fossils, especially those from very rich ichnocoenoses of the Upper Cambrian, have been made by Radwański and Roniewicz (1963). They described too a new trace fossil *Aglaspidichnus sanctacrucensis* (Radwański and Roniewicz 1967) and a more than 1.5 m long trilobite-trackway *Cruziana semiplicata* (Radwański and Roniewicz 1972). Other trilobite trace fossils were described by Orłowski, Radwański and Roniewicz (1970, 1971). In addition, the ichnogenera *Gordia* and *Multina* (Orłowski 1968) have been described from the same rocks.

A large specimen of *Cruziana* (Orłowski 1974) was illustrated from the Lower Cambrian rocks.

The occurrence of a new ichnogenus and ichnospecies *Arcuatichnus wimani*, in addition to *Diplocraterion* sp. and *Phycodes* sp. was recorded in the upper part of the Ociesęki Sandstone Formation (Kowalski 1978), as well as *Paleodictyon majus* (Pacześna 1985). *Oldhamia antiqua*, *Planolites montanus*, *P. beverleyensis*, *Phycodes* sp., *?Paleophycus* sp., *?Bunyerichnus* sp., *?Monocraterion* sp. were mentioned from the lowermost Lower Cambrian rocks (Kowalski 1983).

In this paper, all Lower Cambrian trace fossils have been discussed with the exception of those of trilobite origin which will be considered in a separate publication concerning trilobite trace fossils of the whole Cambrian sequence (Orłowski in preparation).

LOWER CAMBRIAN STRATIGRAPHY OF THE ŚWIĘTOKRZYSKIE MOUNTAINS

The Lower, Middle and Upper series within the Cambrian have already been recognized and the lithostratigraphic and biostratigraphic subdivision have been established by the present author (Orłowski 1975, 1985*a*, 1987).

In the Lower Cambrian sequence, five biostratigraphic zones have been recognized and a Barren Interzone below the oldest trilobite Holmia-Schmidtiellus Zone (fig. 1). The characteristics of the zones were given by Orłowski (1987).

Four lithostratigraphic formations were established within the Lower Cambrian of the area (Orłowski 1975, 1985*a*, 1987; Kowalski 1983):

1. The Osiek Sandstone Formation is very thin and known mainly from borings, the outcrops are few and small. The formation comprises yellow and light-grey quartz sandstones and dark-grey quartzitic sandstones. No body fossils have been found in sandstones so

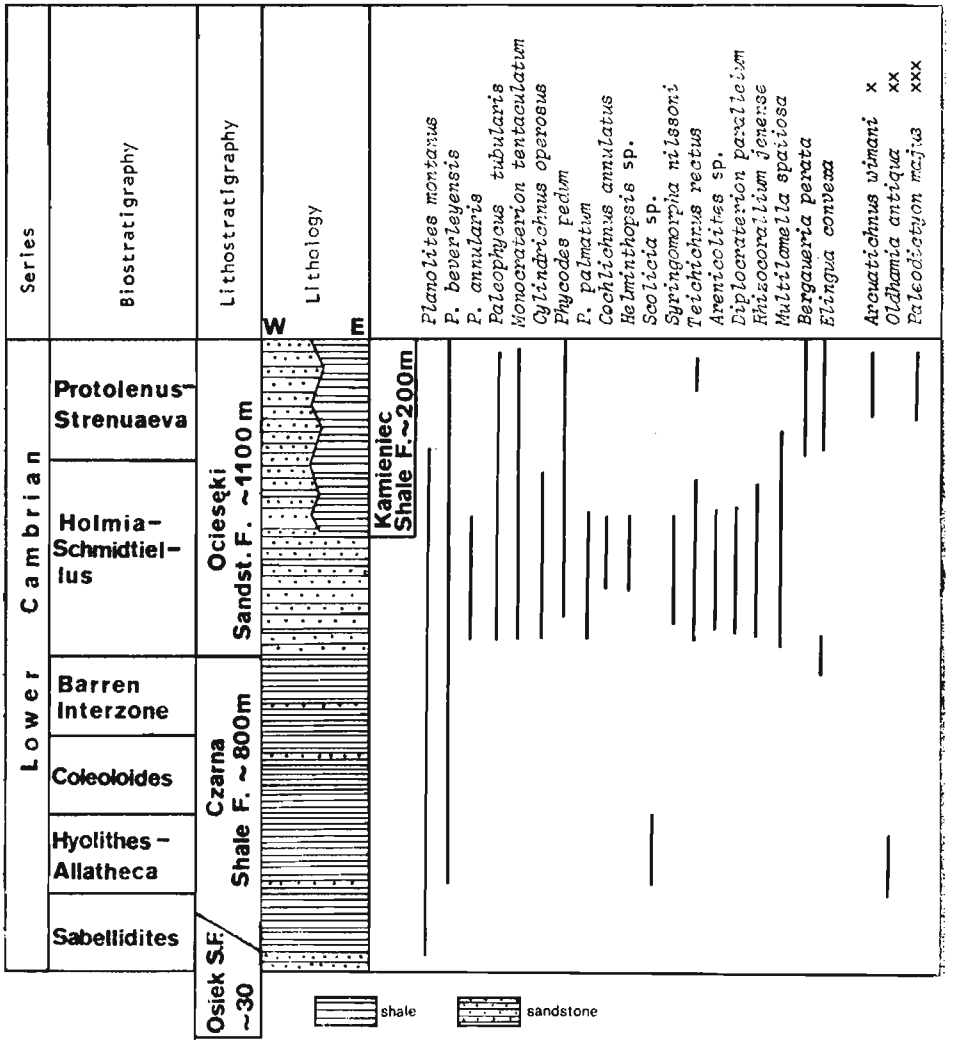

Fig. 1. Trace fossils in Lower Cambrian of the Świętokrzyskie Mts. × after Kowalski 1978, ×× Kowalski 1983, ××× Pacześna 1985.

far. Some trace fossils, e.g. *Planolites montanus*, *Phycodes* sp. and others were mentioned from the upper part of the formation (Kowalski 1983).

2. The Czarna Shale Formation consists of clay and siltstone shales with intercalations of fine-grained siltstones and sandstones; the sandstone intercalations increase in number toward the top of the formation. The thickness is difficult to determine because of intense folding and a blanket of marine Miocene deposits. It may be estimated at 800 m. Within the formation the skeletal fauna is represented by: *Hyolithes czarnae*, *Allatheca kotuszowi* (Orłowski and Waksmundzki 1986); *Prosinuites bornholmiensis*, *Hyolithes* sp., *Aluta* sp., *Bradoria* sp. (Lendzion,

Moczydłowska and Żakowa 1982); *Coleoloides* sp. (Samsonowicz 1962); *Sabellidites cambriensis*, *Vendotaenia major*, *Thallulus carnosus*, *Tyrasotaenia podolica*, *Pilitella composita*, all reported by Kowalski (1983), and by *Platysolenites antiquissimus*. Trace fossils: *Oldhamia antiqua*, *Planolites montanus*, *P. beverleyensis*, ?*Paleophycus* sp., ?*Bunyerichnus* sp., *Monocraterion* sp. were also mentioned from this formation (Kowalski 1983).

3. The Ociesęki Sandstone Formation consists of fine-grained, thin to medium-badded, hard sandstones, with silstone and occasional shale intercalations. The thickness of this formation is greatest in the central part of area, where it goes up to the lowermost Middle Cambrian, and is estimated at 1200 m; the greater part of the formation, reaching 1100 m, belongs to the Lower Cambrian (Orłowski 1975, 1987). The body fossils are very common here, especially the trilobites (for the complete list of trilobites see Orłowski 1985*a*). Holmia-Schmidtiellus Assemblage Zone is characterized by the following trilobites: *Holmia marginata*, *Kjerulfia orcina*, *Schmidtiellus panowi*, *S. nodosus*, *Strenuella polonica*, *Postfallotaspis spinatus*. The Protolenus-Strenuaeva Assemblage Zone in this Formation is documented by trilobites: *Ellipsocephalus sanctacrucensis*, *Strenuaeva orlowinensis*.

4. The Kamieniec Shale Formation is limited to the eastern part of the Świętokrzyskie region and it is represented by clay and clay-siltstone shales with fine-grained sandstone intercalations; rocks are strongly folded in some areas. The thickness of this formation is more than 200 m. The trilobites are less abundant. The Holmia-Schmidtiellus Assemblage Zone is documented in this formation by: *Holmia marginata*, *Micmacca* (*Acanthomicmacca*) *klimontowi*. The Protolenus-Strenuaeva Assemblage Zone is documented by: *Protolenus* (*Protolenus*) *expectans*, *P.* (*Latoucheia*) *glabellosus*, *Strenuaeva trifida*, *Serrodiscus primarius*.

The Lower Cambrian sequence is overlain by thick formations of sandstones and shales belonging to the Middle Cambrian (Orłowski 1985*b*).

REMARKS ON PALEOECOLOGY

Trace fossils are often good indicators of the bathymetry. Seilacher (1960, 1967) admitted that animals producing the communites of trace fossils lived in definite zones of the basin and for that reason are important as depth indicators. This author discriminated the following communities, named after characteristic trace fossils (Seilacher 1967): *Glossofungites* (littoral zone), *Skolithos* (littoral zone), *Cruziana* (littoral zone to wave base), *Zoophycos* (wave base to zone of turbidite deposits), *Neonereites* (turbiditide zone).

Crimes (1970*a*) pointed out the connections of trace fossils with ichnofacies and recognized three types of trace fossils: *facies-independent, facies-influenced, facies-specific*; the last group being the most suitable for analysis of sediments.

The bathymetry of the formations recognized in the Lower Cambrian of Świętokrzyskie Mts may be defined according to trace fossils, but not with the same precision for all. The richest and most diversified community of trace fossils is from the Ociesęki Sandstone Formation. *Cruziana* and other trace fossils made by trilobites are very common here. The following ichnogenera are specific for *Cruziana* facies: *Teichichnus, Multilamella, Cylindrichnus, Monocraterion* and *Diplocraterion*; they are common and well preserved. Facies-specific but not common are: *Phycodes palmatum, Cochlichnus, Helminthopsis, Syringomorpha, Arenicolites, Rhizocorallium. Planolites* is very common but facies-independent in the whole sequence of the Lower Cambrian.

As the communities of trace fossils indicate, the thick sandstones of this formation were deposited in the littoral zone. The lower part of sandstones was deposited at the basin depth near the wave base and the upper part of sandstones in littoral zone in shallower conditions.

The Kamieniec Shale Formation is known as containing rather scarce trace fossils. Most common is *Planolites*, but it is facies-independent. *Cruziana* and other trilobite trace fossils are rare and occur in the upper part of formation. More common are: *Bergaueria, Elingua* and *Phycodes pedum.*

This formation is facies equivalent to the upper part of Ociesęki Sandstone Formation (fig. 1) but from the point of view of lithology and communities of trace fossils it was deposited in a deeper part than the littoral zone of the basin, below the wave base.

The Czarna Shale Formation has a small community of trace fossils. Common is *Planolites* but it is facies-independent, characteristic are *Scolicia* and *Oldhamia*. According to Crimes (1970*a*) *Oldhamia* is typical of the *Nereites* zone and it is known in this position from the Lower Cambrian sequence of Leinster (Eire). The rock types, lack of sedimentological phenomena, and the trace fossils suggest deposition of this formation below wave base, in the deeper part of the basin.

The Osiek Sandstone Formation is poorly exposed, trace fossils are scarce and rocks and trace fossils together do not suggest any definite regime of sedimentation.

It seems that the sedimentation of the Lower Cambrian sequence of this area started in the deeper part of the basin (Czarna Shale Formation, ?*Nereites* zone). The basin grew slowly but consequently shallower toward the top of the sequence (Ociesęki Sandstone Formation, littoral zone) and near the end of the Lower Cambrian Epoch there were two types of sedimentation in the basin: shallower in the western and central part of

the area (Ociesęki Sandstone Formation, *Cruziana* zone) and deeper in the eastern part (Kamieniec Shale Formation, below wave base).

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DESCRIPTIONS

Ichnogenus *Planolites* Nicholson, 1873

To *Planolites* belong straight and curved infilled burrows, of variable lengths. The diameter of burrows varies from 0.5 to 20 mm.

Discussion of this ichnogenus has been given by Alpert (1975) who proposed to separate the ichnogenus *Planolites* from *Paleophycus* by including in the last one, only the burrows with true branching. Pemberton and Frey (1982) discussed carefully the relationships between both ichnogenera and they included in the ichnogenus *Planolites* only monolinear, rarely branched, straight to tortuous, smooth to irregularly walled or annulated burrows, circular to elliptical in cross section, of variable dimensions or configurations; infilling is essentially structureless, differing in lithology from host rocks.

Planolites montanus Richter, 1937
(pl. 13: 1, 2)

Material. — Seventeen specimens, IGUPW/Tf/1/1—17.

Description. — Burrows horizontal, straight to curved, with smooth walls, oval in cross section, diameter 1 to 5 mm, transect individual bedding surfaces.

Remarks. — According to Pemberton and Frey (1982) this ichnospecies includes *Planolites ballandus* Webby, 1970, which is younger synonym of this ichnospecies.

Occurrence. — Lower Cambrian; Ociesęki Sandstone Formation, Igrzyczna hill, Sterczyna hill; Czarna Shale Formation, Kotuszów.

Planolites beverleyensis (Billings, 1862)
(pl. 13: 3, 4)

Material. — Twenty three specimens, IGPUW/Tf/1/21—44.

Description. — Burrows horizontal, cylindrical to flattened, with smooth walls, straight to curved, very regular with small changes of the shape and diameter. Burrows single or densely covering bedding surfaces, overlaping each other. Diameter of burrows from 3 to 10 mm, length to 10 cm. Burrows are often common inside the sandstones and in that case burrows are infilled with clay different in colour from host rocks; sometimes they are empty.

Occurrence. — Lower Cambrian; Czarna Shale Formation, Ołowianka hill, Kotuszów; Ociesęki Sandstone Formation, Igrzyczna hill, Zamczysko hill.

Planolites annularis Walcott, 1890
(pl. 13: 5, 6)

Material. — Three specimens, IGPUW/Tf/1/18—20.

Description. — Horizontal burrows with transverse annulation, diameter constant or burrows slightly narrowing. Their length 6 to 8 cm, diameter 4 to 8 mm.

Remarks. — The main feature of this ichnospecies is the transverse annulation (Alpert 1975, Pemberton and Frey 1982). Specimens described here are only partly annulated, other parts lack annulation due to their weathering.

Occurrence. — Lower Cambrian; Ociesęki Sandstone Formation, Sterczyna Hill, Leśniakowa Dębina hill.

Ichnogenus *Paleophycus* Hall, 1847

According to Alpert (1975) this ichnogenus includes slightly irregular, cylindrical burrows, oblique to the bedding plane. All forms are branched. Pemberton and Frey (1982) include in this ichnogenus branched or unbranched, smooth or ornamented, essentially cylindrical, predominantly horizontal burrows of variable diameter; infillings typically structureless, of the same lithology as host rocks.

Paleophycus tubularis Hall, 1847
(pl. 14: 2, 3; fig. 2)

Material. — Five specimens, IGPUW/Tf/1/45—49.

Description. — Burrows longitudinal, changing in shape, branched, unornamented,

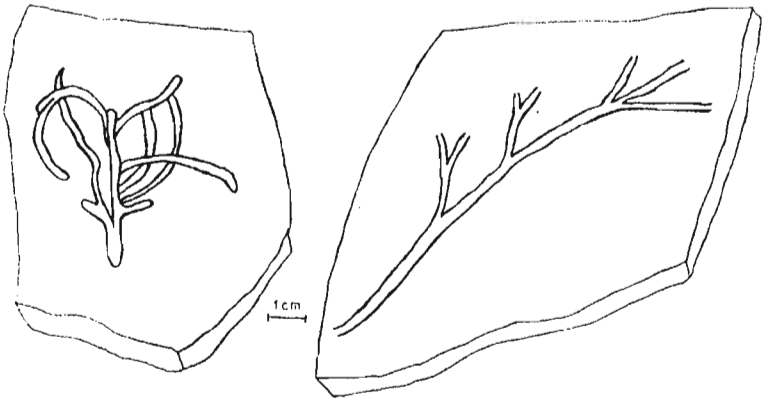

Fig. 2. *Paleophycus tubularis* Hall, 1847: specimens of diverse shapes, IGPUW/Tf/ /1/46, 45.

smooth, with thin walls. In cross section oval, 2 to 3 mm in diameter. Sometimes crowded on the sole of sandstones as positive hyporelief.

Occurrence. — Lower Cambrian; Ociesęki Sandstone Formation, Sterczyna, Jaźwina and Zamczysko hills.

Ichnospecies *Monocraterion* Torell, 1870

The tubes rounded, perpendicular to bedding plane, straight to slightly curved, with the funnel in their upper part. Diameter of tubes 2 to 4 mm, length up to 16 cm. Westergaard (1931) has thoroughly discussed this ichnogenus, and compared it with *Scolithos* specimens which are cylindrical along the whole length. Crimes (1977) has discussed the ways of creation of tubes and their position in relation to the bedding plane.

Monocraterion tentaculatum Torell, 1870
(pl. 14: 1)

Material. — Four specimens, IGPUW/Tf/1/50—53.

Description. — Tubes separated but close to each other covering limited surfaces, oval, perpendicular or slightly oblique to the bedding plane, straight to slightly curved, with long and slender funnel in the upper part. Diameter from 1 to 3 mm in the lower part, diameter of funnel up to 12 cm; length of tubes at least 9 cm.

Remarks. — Specimens are very close to those from Sweden (Westergaard 1931), differing slightly in funnel shape. In the specimens described above funnels are trumpet-shaped.

Occurrence. — Lower Cambrian; Ociesęki Sandstone Formation, Zamczysko, Igrzyczna and Wysokówka hills.

Ichnogenus *Cylindrichnus* Toots, 1966

Subconical forms, straight to weakly curved, composed to concentric structures repeating the shape of outer wall, in cross section circular to oval, from nearly horizontal to vertical.

Cylindrichnus operosus ichnosp. n.
(pl. 15: 1, 2, 3: fig. 3)

Holotype: No IGPUW/Tf/1/55; pl. 15: 3.

Derivation of the name: from Latin *operosus* — elaborated, because of elaborated inner structure.

Type locality: Igrzyczna hill.

Type horizon: Lower Cambrian, Ociesęki Sandstone Formation.

Diagnosis. — Single subconical, vertical pipes, with broad and short funnel, with inner structures repeating the shape of outer wall.

Material. — Seven specimens, IGPUW/Tf/1/55—61.

Description. — Single, vertical pipes changing in shape and size, with smooth walls, narrowing gradually to the bottom, with funnel. In cross section oval or rounded, with many concentric structures. In longitudinal section with many thin walls reaching to the bottom of the pipe. Length of the pipe to 9 cm, diameter about 7 mm, diameter of the funnel from 15 to 25 mm.

Remarks. — New ichnospecies characterized by broad and short funnel and by smaller diameter of pipe; the concentric structures reach the bottom of the pipe.

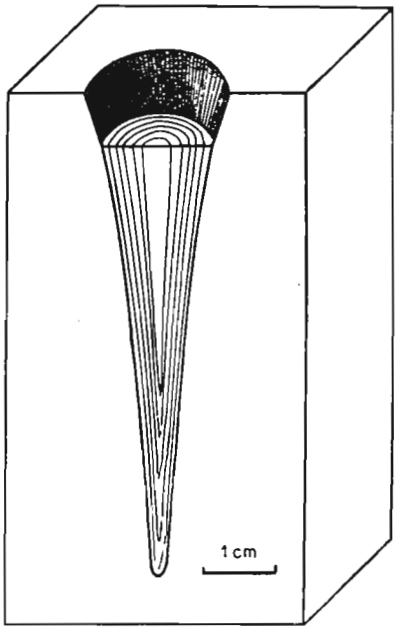

Fig. 3. *Cylindrichnus operosus* ichnosp. n.: schematic drawing of a trace fossils in cross- and longitudinal sections; funnel well visible, IGPUW/Tf/1/55.

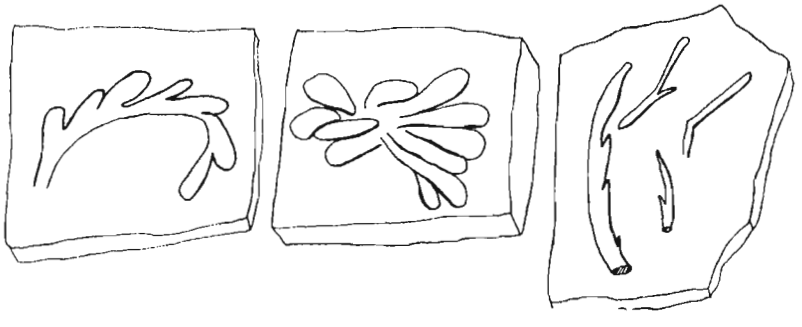

Fig. 4. *Phycodes pedum* Seilacher, 1955: specimens of diverse shapes, IGPUW/Tf/ /1/63, 64, 65.

Ichnogenus *Phycodes Richter*, 1850

Trace fossils as cylindrical infillings on the sole of the sandstone beds, proximal part of the main tunnel unbranched, farther branched into many tunnels, straight and directed upward. Walls smooth or with delicate, longitudinal ridges. Feeding burrows.

Phycodes pedum Seilacher, 1955

(pl. 15: 4. 5; fig. 4)

Material. — Five specimens, IGPUW/Tf/1/62—66.

Description. — Trace fossils varying in shape, preserved as cylindrical, curved

infillings with minor branches separated from main infillings and directed upward to the bedding plane. Walls smooth. Length of the fillings to 7 cm.

Occurrence. — Lower Cambrian; Ociesęki Sandstone Formation, Zamczysko and Wysokówka hills; Kamieniec Shale Formation, Kamieniec.

Phycodes palmatum (Hall, 1852)
(pl. 16: 2)

Material. — Nine specimens, IGPUW/Tf/1/67—75.

Description. — Cylindrical infillings situated on the sole of sandstones, proximal part unbranched, farther producing many branches, horizontal and anteriorly directed upward, walls smooth. Fillings more than 10 cm long and 3 cm high, the diameter of single fillings to 15 mm.

Remarks. — Seilacher (1955) has assigned *Buthotrephis palmata* Hall, 1852 to *Phycodes*, discussed critically the ichnospecies and reconstructed the trace fossils on the basis of the material from the Lower Cambrian of Pakistan. Osgood (1970) pointed out the differences between *B. palmata* and typical ichnospecies belonging to ichnogenus *Phycodes* and decided to use the old name of the ichnogenus.

Occurrence. — Lower Cambrian; Ociesęki Sandstone Formation, Sterczyna hill.

Ichnogenus *Cochlichnus* Hitchcock, 1858

The history of investigation of this ichnogenus was given by Michelau (1956), who also gave a redescription of *Cochlichnus kochi* (Ludwig).

To this ichnogenus belong regularly meandering trails, resembling a sine curve. Annulation of outer walls is characteristic of a new ichnospecies described below.

Cochlichnus annulatus ichnosp. n.
(pl. 16: 1)

Holotype: No IGPUW/Tf/1/76; pl. 16: 1.

Derivation of the name: from Latin *annulatus* — corresponding to the outer wall annulation.

Type locality: Leśniakowa Dębina hill.

Type horizon: Lower Cambrian, Ociesęki Sandstone Formation.

Diagnosis. — Sinous trail inside sandstone, filled with clay, outer walls annulated.

Material. — Two specimens on one piece of sandstone, IGPUW/Tf/1/76.

Description. — Sinuous trail inside sandstone, filled with clay, infillings similar in shape to the shapes of the trails. Outer walls with dense, transverse annulation. The length of the trail 8 cm, its diameter 4 mm.

Occurrence. — As for the holotype.

Ichnogenus *Helminthopsis* Heer, 1877

Simple meandering tracks with smooth walls. The discussion on this ichnogenus with suggestion of new type ichnospecies was given by Książkiewicz (1977).

Helminthopsis sp.
(pl. 15: 6)

Material. — Two specimens, IGPUW/Tf/1/77, 78.

Description. — Track shaped as empty, cylindrical tube, some part of it is collapsed, with wall smooth, strongly but irregularly meandering, with some segments of the track straight. The diameter of the track is 2 to 3 mm, length more than 10 cm, the wall of the tube about 0.2 mm thick.

Remarks. — According to Książkiewicz (1977) *Helminthopsis* is a postdepositional feeding burrow. *Helminthopsis* sp. is slightly similar to *H. abeli* Książkiewicz, 1977 but differs in constant thickness of the track and more regular meandering.

Occurrence. — Lower Cambrian; Ociesęki Sandstone Formation, Leśniakowa Dębina hill.

Ichnogenus *Scolicia* de Quatrefages, 1849

Horizontal, bilaterally symmetrical trails of great variability. Discussion of this trail was given by Smith and Crimes (1983).

Scolicia sp.
(pl. 14: 4)

Material. — Five specimens, IGPUW/Tf/1/79—83.

Description. — Largest trail about 7 cm long and 1.5 cm broad, situated inside the shales. Trail is slightly convex, with three shallow but regular furrows along the whole length.

Remarks. — The specimens described belong to *Subphyllochorda* type (Häntzschel 1975). Smith and Crimes (1983) treat *Scolicia* and *Subphyllochorda* as separated ichnogenera; the last one was made by heart urchins. Paleozoic specimens belonging to *Scolicia* are much simpler than the Mesozoic and Tertiary traces and they should be, in the opinion of the authors mentioned, transferred to another ichnogenus.

Occurrence. — Lower Cambrian; Czarna Shale Formation, Kotuszów.

Ichnogenus *Syringomorpha* Nathorst, 1886

Rollers with the same diameter, touching each other along the whole length and forming complete slab, slightly convex, independent of bedding.

Syringomorpha nilssoni Torell, 1868
(pl. 16: 4, 5)

Material. — Two specimens, IGPUW/Tf/1/85, 86.

Description. — Rollers with smooth walls, diameter 1 to 2 mm and 4 to 5 mm, touching each other along the whole length and forming in this way a complete slab, perpendicular to bedding plane, slightly arched downward. Lower border of the slab sharp, bent downward. Length of the slab to 5 cm, width to 13 cm.

Occurrence. — Lower Cambrian; Ociesęki Sandstone Formation, Sterczyna and Zgórskie hills.

Ichnogenus *Teichichnus* Seilacher, 1955

Trace fossils with spreite, formed by few or many long, horizontal burrows stacked vertical to bedding; burrows from solid structures commonly retrusive inside sandstones. Lower and upper surfaces well preserved, commonly smooth but sometimes covered by longitudinal ridges and grooves.

Teichichnus rectus Seilacher, 1955
(pl. 17: 1—4)

Material. — Eighty eight specimens, IGPUW/Tf/1/87—175.

Description. — Trace fossils with spreite in the shape of small, regular walls with constant thickness, situated vertically to bedding. Each specimen consists of many spreite, repeating the main plan of the trace so their shape is from almost horizontal to strongly convex, retrusive. Lowermost spreite well visible, generally smooth but sometimes covered with longitudinal small ridges. Trace fossils rarely branched. Thickness of trace fossils constant from 10 up to 15 mm, length to 11 cm, height to 6 cm, but the largest specimens are almost 25 mm thick, 17 cm long and 8 cm high.

Remarks. — The material is very rich and well preserved but varying in shape. The most common forms are simple but branched ones have been found as well. This ichnofossil is often associated with *Cruziana*.

Occurrence. — Lower Cambrian; Ociesęki Sandstone Formation, Sterczyna and Igrzyczna hills.

Ichnogenus *Arenicolites* Salter, 1857

Simple U-tubes without spreite, with smooth walls, situated vertically.

Arenicolites sp.
(pl. 16: 3; pl. 20: 1)

Material. — Three specimens, IGPUW/Tf/1/176—178.

Description. — U-shaped tubes with funnel, without spreite, vertical to bedding plane. In cross-section tubes oval to elliptical, walls smooth. Diameter of tubes constant from 2 to 3 mm. The traces are to 5 cm deep and from 3 to 5 cm wide.

Occurrence. — Lower Cambrian; Ociesęki Sandstone Formation, Sterczyna, Igrzyczna and Malkowska hills.

Ichnogenus *Diplocraterion* Torrel, 1870

U-shaped spreite burrows, vertical, dwelling burrows of suspension feeders. Similar burrows have been distinguished as different ichnogenera: *Corophioides* Smith, 1893 and *Polyupsilon* Howell, 1957. Fürsich (1974) has thoroughly discussed the three ichnogenera and ichnospecies and concluded that two latter ichnogenera are junior synonyms of *Diplocraterion*.

Diplocraterion parallelum Torell, 1870
(pl. 18: 6)

1978. *Diplocraterion* sp. Kowalski: pl. 2: 1, 2a, b.

Material. — Six specimens, IGPUW/Tf/1/179—184.

Description. — U-shaped spreite burrows to 10 cm long and 3 cm wide. U-tube about 3 mm in diameter, straight. Spreite irregular, continuous. Aperture unknown.

Remarks. — Specimens illustrated by Kowalski (1978: pl. 2: 1, 2a, b) belong to the same ichnospecies.

Occurrence. — Lower Cambrian; Czarna Shale Formation, Królewice; Ociesęki Sandstone Formation, Sterczyna and Zamczysko hills.

Ichnogenus *Rhizocorallium* Zenker, 1836

U-shaped tubes with spreite repeating the shape of U-tube, parallel to slightly oblique to bedding plane. Crustacean spreite burrow.

Rhizocorallium jenense Zenker, 1836
(pl. 18: 4, 5)

Material. — Three specimens, IGPUW/Tf/1/185—187.

Description. — Horizontal U-shaped thick tubes with spreite, protrusive. Thickness of tubes up to 6 mm, length of trace fossils to 9 cm, width to 5 cm.

Occurrence. — Lower Cambrian; Ociesęki Sandstone Formation, Sterczyna and Zgórskie hills.

Ichnogenus *Multilamella* nov.

Type ichnospecies: *Multilamella spatiosa* nov.

Derivation of the name: after many laminae covering the surface on the sole of sandstone beds.

Diagnosis. — Groups of thin laminae parallel to each other, straight to undulating, covering the surface on the sole of sandstone beds or situated inside the beds near the sole. As a rule, the groups are parallel to the bedding plane, rarely slightly oblique. Single laminae are convex in the same direction. Laminae situated perpendicularly to bedding plane. Groups of laminae are sometimes associated with single, meandering track, oval in cross section, with concave laminae inside, retrusive. Longitudinal tracks often perpendicular to bedding plane and to groups of laminae.

Origin. — These trace fossils probably represent feeding burrows of an animal with longitudinal and narrow body, perhaps a worm or worm-like organism. The laminae were made by the sides of the animal's body. The single, meandering tracks were made by the same animal, which was moving forward horizontally or vertically.

Multilamella spatiosa ichnosp. n.
(pl. 19: 1—4, pl. 20: 2, 3; fig. 5)

Holotype: No IGPUW/Tf/1/185; pl. 19: 4a, b.
Derivation of the name: from Latin *spatiosus*, covering some area.
Type locality: Igrzyczna hill.
Type horizon: Lower Cambrian; Ociesęki Sandstone Formation.
Diagnosis as for the ichnogenus.

Material. — Twenty six specimens, IGPUW/Tf/1/185—211..
Description. — Trace fossils situated on the sole of sandstone bed or inside the bed near the sole. They consist of groups of thin, regular laminae, changing in shape from straight to undulating. In cross section, groups of serially arranged laminae are convex in lateral direction, groups of laminae are protrusive or retrusive.

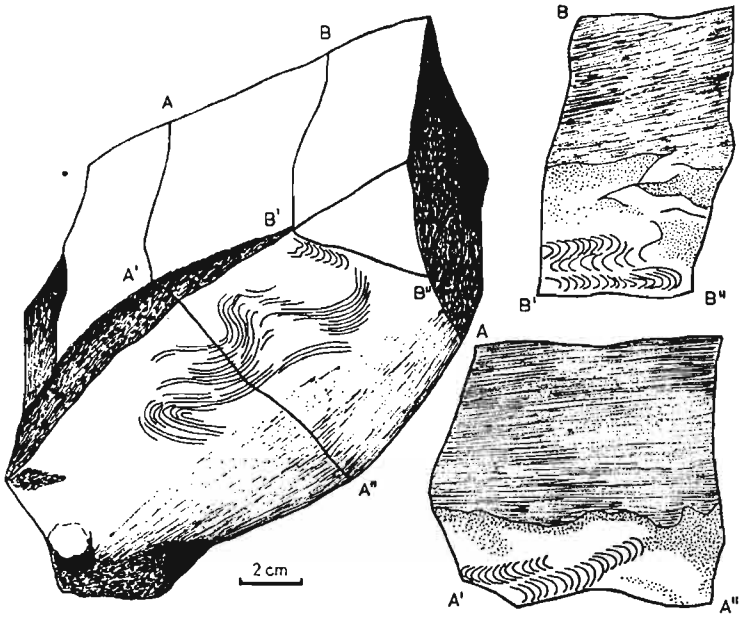

Fig. 5. *Multilamella spatiosa* ichnogen., ichnosp. n.: holotype showing inner structure in sections perpendicular to the bedding plane, IGPUW/Tf/185.

Generally, there are 6 to 10 laminae per 1 cm. The largest surface covered by groups of laminae is about 100 cm². The thickness of trace fossils is to 1 cm. There are occasional tracks, narrow and oval in cross section, connected with groups of laminae but directed often perpendicularly to the upper surface of sandstone beds, retrusive. The tracks are about 4 mm in diameter, straight to meandering, with concave laminae.

Ichnogenus *Bergaueria* Prantl, 1945

Cylindrical protrusions with smooth walls, with lower end rounded.

Bergaueria perata Prantl, 1945
(pl. 18: 3)

Material. — Eight specimens, IGPUW/Tf/1/213—220.

Description. — Cylindrical protrusions with lower end rounded and provided with shallow depression. Specimens single, differing in size, diameter from 15 to 45 mm. Walls with rings parallel to bedding plane.

Occurrence. — Lower Cambrian; Kamieniec Shale Formation, Kamieniec.

Ichnogenus *Elingua* nov.

Type ichnospecies: *Elingua convexa* nov.

Derivation of the name: from Latin *elinguis* — dumb, corresponding to unknown origin of the trace.

Diagnosis. — Trace fossils in the shape of inverted, asymmetrical cone, situated on the sole of the sandstone bed, with concentric, horizontal ridges on the surface. Most probably domichnia.

Remarks. — This trace fossil is similar to *Conichnus* Myannil, but differs in the asymmetry and presence of concentric ridges. The trace resembles *Conostichus* Lesquereux which is a trace fossil with medusean affinity, but it differs in the shape and sculpture of the surface. Very probable, this trace was produced in the samy way as *Bergaueria* Prantl.

This trace fossil is organized in a different way than *Gyrolithes* de Saporta which is a coiled burrow directed upright in deposits, while *Elingua* is an asymmerical cone situated on the lower surface of the sandstone bed.

Elingua convexa ichnosp. n.
(pl. 18: 1, 2; fig. 6)

Holotype: No IGPUW/Tf/1/221; pl. 18: 1a, b.

Derivation of the name: After the shape of fossils.

Type locality: a hill south of the village Nowa Łagowica.

Type horizon: Lower Cambrian; Kamieniec Shale Formation.

Diagnosis as for the ichnogenus.

Material. — Three specimens, IGPUW/Tf/1/221—223.

Description. — Trace fossils in the shape of asymmetrical cone directed down-

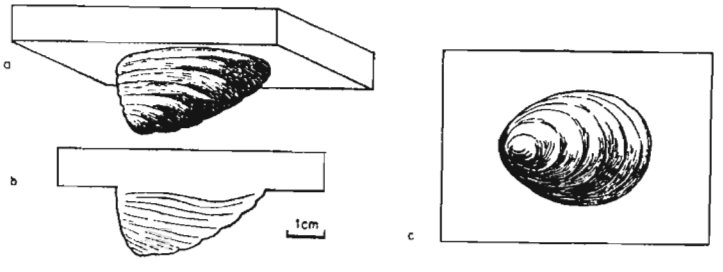

Fig. 6. *Elingua convexa* ichnogen., ichnosp. n. on the rock sole (*a* and *c*) and in longitudinal section (*b*), IGPUW/Tf/1/221.

ward, with upper surface parallel to the bedding plane. The surface covered by delicate lines and thick ripples. The longitudinal section of the cone shows more or less regular internal lamination, repeating the external sculpture of the cone. The length of specimens to 6 cm, width to 5 cm, depth to 3 cm.

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STANISŁAW ORŁOWSKI

ŚLADY ORGANICZNE W PROFILU KAMBRU DOLNEGO GÓR ŚWIĘTOKRZYSKICH

Streszczenie

W pracy przedstawiono opisy i rozprzestrzenienie śladów organicznych w profilu skał kambru dolnego (fig. 1). Zespół śladów organicznych jest najbogatszy w skałach tego właśnie oddziału kambru Gór Świętokrzyskich, gdyż obejmuje 19 ichnorodzajów z 19 ichnogatunkami. Kolekcja śladów została poddana krytycznej analizie, przedstawiono ich opisy wraz z dokumentacją, przy czym w pracy zamieszczono jedynie ślady organiczne dające się sklasyfikować. Większość opisanych tu ichnorodzajów i ichnogatunków znana jest ze skał kambru dolnego wielu profilów Europy i świata, ale są też nowe ichnogatunki: *Cochlichnus annulatus*, *Cylindrichnus operosus* oraz nowe ichnorodzaje wraz z ichnogatunkami: *Multilamella spatiosa*, *Elingua convexa*.

Zespoły śladów organicznych wykorzystano dla odtworzenia środowiska sedy-

mentacji formacji skalnych kambru dolnego. Najpełniejsza charakterystyka ichnologiczna możliwa jest dla piaskowców z Ociesęk (fm). Należą one do facji *Cruziana* i zostały osadzone w dolnej części strefy litoralnej w pobliżu granicy falowania. Natomiast w obrębie formacji o przewadze skał ilastych (formacja łupków Czarnej, formacja łupków z Kamieńca) zespoły śladów organicznych są znacznie uboższe. Różnice w zespołach śladów organicznych i w litologii sugerują iż łupki Czarnej (fm) i łupki Kamieńca (fm) osadziły się w zbiorniku głębszym niż piaskowce z Ociesęk (fm).

EXPLANATION OF PLATE 13—20

All photos in natural size taken by S. Kolanowski

Plate 13

Planolites montanus Richter, 1937

1. Igrzyczna hill, Ociesęki Sandstone Formation. IGPUW/Tf/1/3.
2. Igrzyczna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/1.

Planolites beverleyensis (Billings, 1862)

3. Igrzyczna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/35.
4. Wytoka, Ociesęki Sandstone Formation, IGPUW/Tf/1/27.

Planolites annularis Walcott, 1890

5. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/19.
6. Leśniakowa Dębina hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/18. With the exception of 4, all specimens enlighted from SW.

Plate 14

Monocraterion tentaculatum Torell, 1870

1. Zamczysko hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/53.

Paleophycus tubularis Hall, 1847

2. Jaźwina hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/46.
3. Zamczysko hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/45.

Scolicia sp.

4. Kotuszów, Czarna Shale Formation, IGPUW/Tf/1/79.

Plate 15

Cylindrichnus operosus ichnosp. n.

1. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/58.
2. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/56.
3. Holotype. Igrzyczna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/55.

Phycodes pedum Seilacher, 1955

4. Wysokówka hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/65.
5. With *Monocraterion*. Zamczysko hill, Ociesęki Sandstone Formation, IGPUW/ /Tf/1/64.

Helminthopsis sp.

6. Leśniakowa Dębina hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/77.

5 enlighted from SE.

Plate 16

Cochlichnus annulatus ichnosp. n.

1. Holotype. Leśniakowa Dębina hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/76.

Phycodes palmatum (Hall, 1852)

2. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/69.

Arenicolites sp.

3. Igrzyczna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/176.

Syringomorpha nilssoni Torell, 1868

4. Zgórskie hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/85.
5. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/86.

3 enlighted from SW.

Plate 17

Teichichnus rectus Seilacher, 1955

1. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/87.
2. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/88.
3. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/89.
4. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/90.

Plate 18

Elingua convexa ichnogen. et ichnosp. n.

1*a*, *b*. Holotype. Nowa Łagowica; Kamieniec Shale Formation; *a* top view, *b* lateral view, IGPUW/Tf/1/221.
2. Chęciny, Czarna Shale Formation, IGPUW/Tf/1/222.

Bergaueria perata Prantl, 1945

3. Kamieniec, Kamieniec Shale Formation, IGPUW/Tf/1/213.

Rhizocorallium jenense Zenker, 1936

4. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/185.
5. Fragment of tube arrowed. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/186.

Diplocraterion parallelum Torell, 1870

6. Fragment of tube arrowed. Zamczysko hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/179.

Plate 19

Multilamella spatiosa ichnogen. et ichnosp. n.

1. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/187.
2. Igrzyczna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/186.
3. Cross-section through the trace. Igrzyczna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/197.

4*a*, *b*. Holotype. Igrzyczna hill; Ociesęki Sandstone Formation; *a* lower surface of sandstone, *b* cross-section along the right line, IGPUW/Tf/185.

Plate 20

Arenicolites sp.

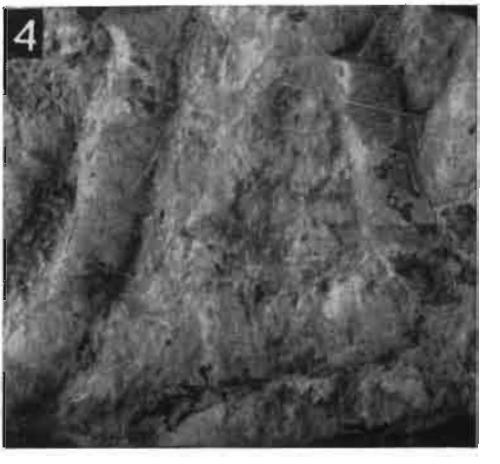
1. Large specimen inside *Cruziana*. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/177.

Multilamella spatiosa ichnogen. et ichnosp. n.

2. Ociesęki, Ociesęki Sandstone Formation, IGPUW/Tf/1/194.
3. Sterczyna hill, Ociesęki Sandstone Formation, IGPUW/Tf/1/196.


2


3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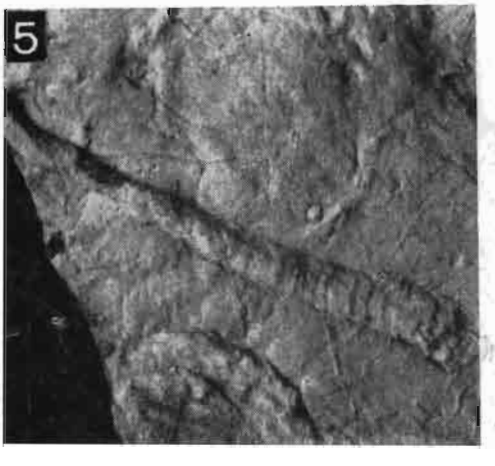
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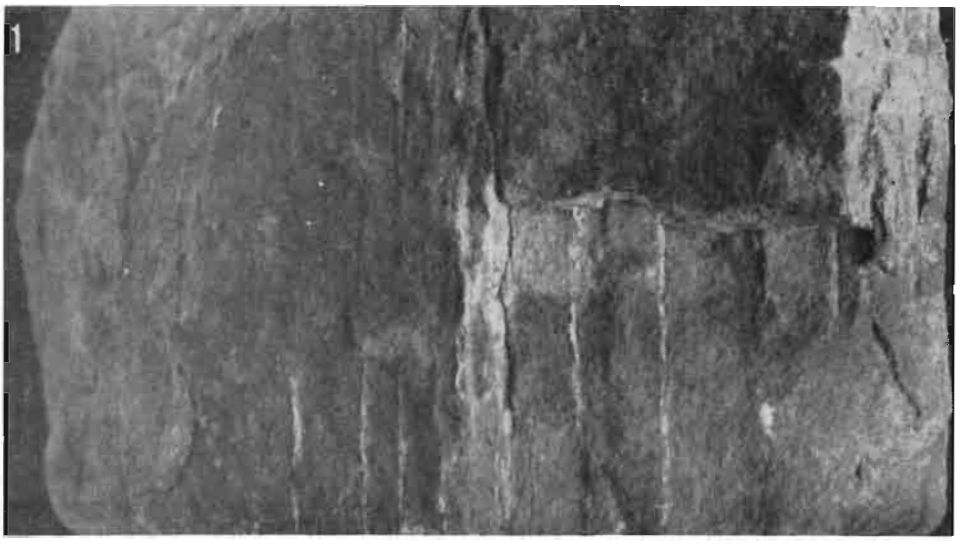
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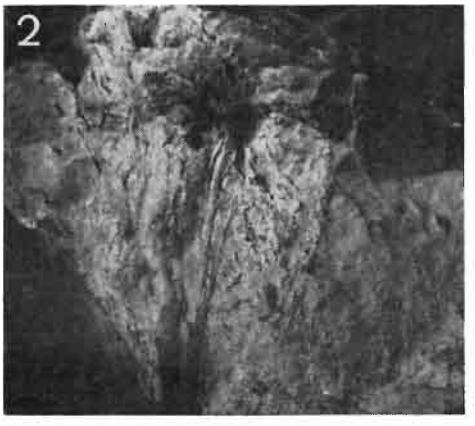
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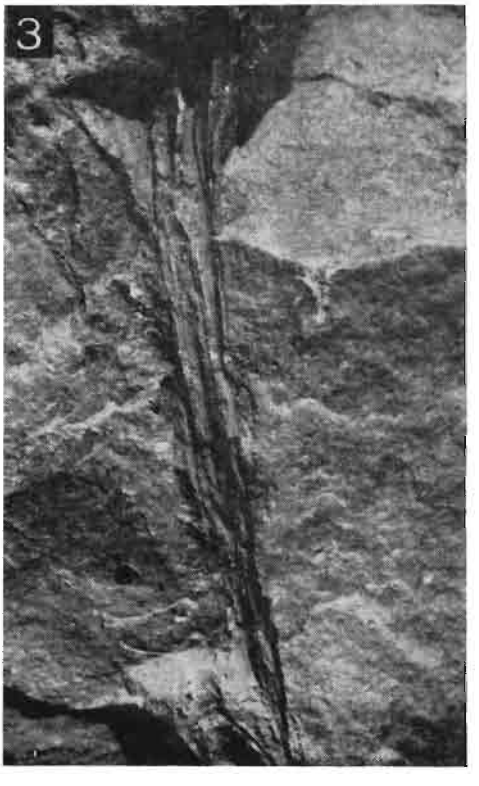
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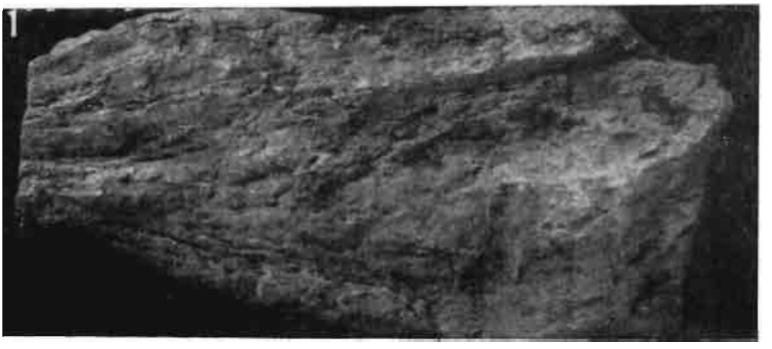
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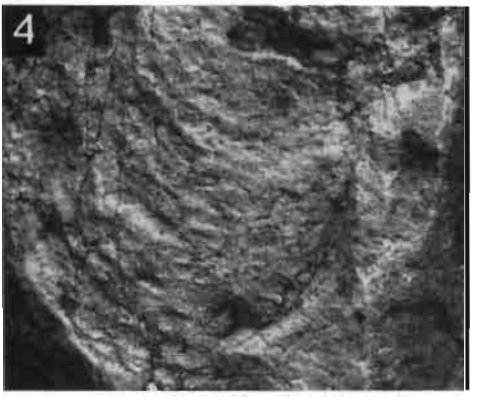
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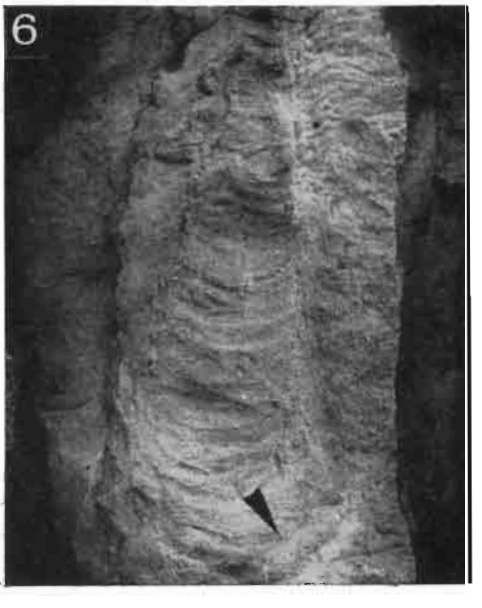
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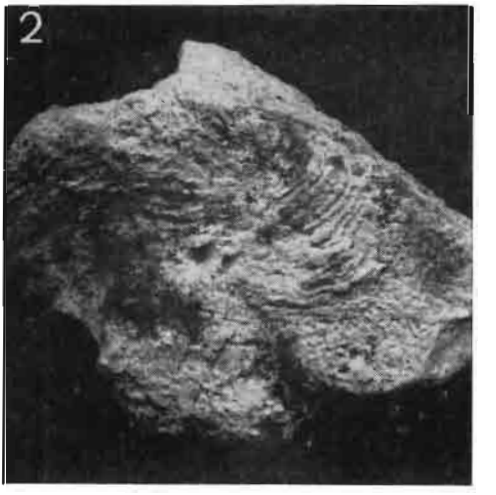
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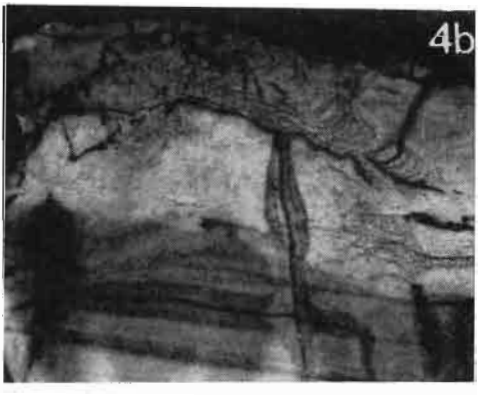
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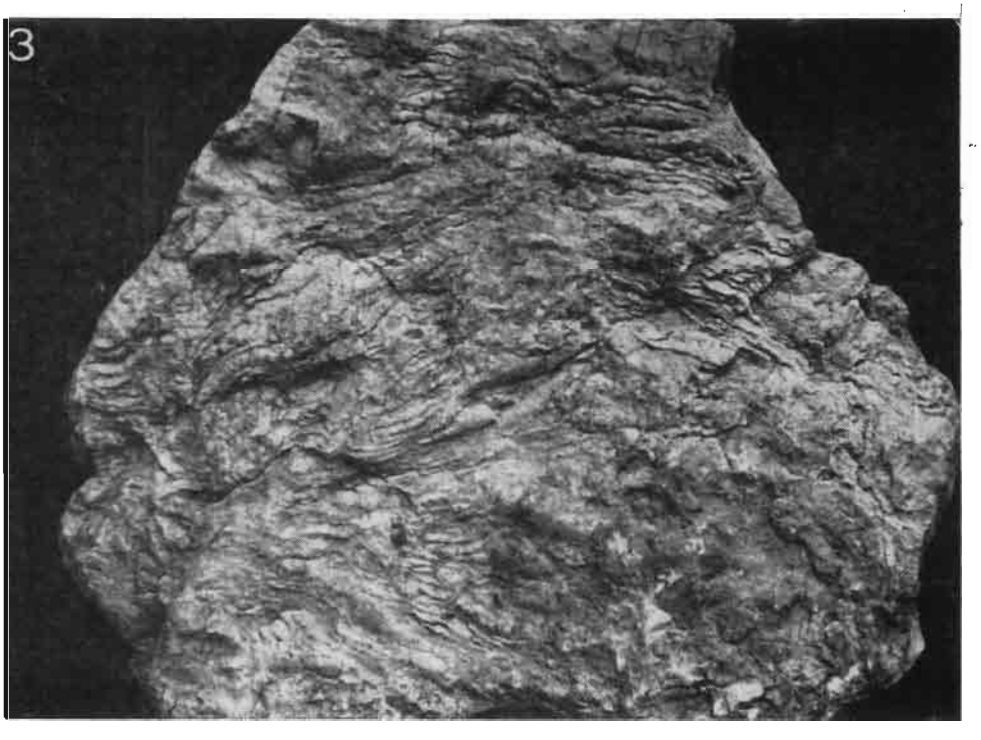
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