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TRACE FOSSILS FROM THE CRETACEOUS ROCKS OF MALLA JOHAR AREA, TETHYS HIMALAYA, UTTAR PRADESH

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ABSTRACT

20 trace fossils namely, *Chondrites, Cylindrichnus, Fucusopsis, Glockeria, Granularia, Gyrolithes, Helminthoida, Neonereites, Nereites, Paleodictyon, Phycosiphon, Planolites, Rhizocorallium, Rhabdoglyphus, Sabularia, Saportia, Scolicia, Subphyllocorda, Zoophycos* and *Ichnogenus A* are described from the Cretaceous succession of Malla Johar area.

The lowermost part of the Cretaceous succession is represented by the upper part of the Spiti Shale, which shows the development of *Chondrites, Gyrolithes* and *Zoophycos*. Conformably overlying the Spiti Shales, the Giumal Sandstone is dominated by *Planolites, Rhizocorallium, Sabularia* and *Scolicia*. The Jhangu Formation which conformably overlies the Giumal Sandstone is dominated by *Chondrites, Cylindrichnus, Helminthoida, Nereites* and *Zoophycos*. The overlying Balcha Dhura Formation is dominantly a volcanic suite of rocks without trace fossils.

The trace fossil assemblage has been divided into four groups on the basis of pattern analysis; viz., Group A: Simple, long, branching and meandering structure, Group B: Spreiten structure, Group C: Rosette structure and Group D: Net work. Out of these four groups Group A is most dominant followed by Groups B, C and D. Ethological interpretation shows that most of the structures are related to the feeding activity or lower invertebrates.

The trace fossil assemblage indicates deeper water conditions supporting the deepening of the Tethys basin which started from the upper part of the Spiti Shale and continued up to the Balcha Dhura Formation.

INTRODUCTION

In the Malla Johar area of the Kumaon Tethys Himalaya, Uttar Pradesh, a thick pile of Cretaceous sediments is well exposed. These rocks are represented by the upper part of the Spiti Shale, the Giumal Sandstone, the Jhangu Formation and the Balcha Dhura Formation belonging to the Sancha Malla Group (Heim and Gansser, 1939; Kumar et al., 1977). Except for the Spiti Shale which contains abundant ammonoids and other megascopic fauna, the remaining formations are totally devoid of body megafossils, although microfossils represented by dinoflagellates, radiolarians and foraminifers are abundantly recorded (Heim and Gansser, 1939; Mamgain and Shastri, 1975; Garg et al., 1981; Jain et al., 1984).

Kumar et al., (1977) have described a number of trace fossils from the Cretaceous succession of the Malla Johar area, which support the bathymetric zonation of Seilacher (1978) based on the pattern analysis. In the light of the above inference a fresh collection of trace fossils was made during the expeditions in 1986 and 1988, and the present paper deals with a detailed study of the trace fossils of the Cretaceous succession of the Malla Johar area. The work is based on the collection made during the above mentioned expeditions and the collection available in the Department of Geology, Lucknow University.

GEOLOGICAL SETTING

The Cretaceous rocks in the Malla Johar area constitute a major part of the Sancha Malla Group which crops out in the Tethys Himalayan zone at an altitude of 4,500 to 6,500 meters. The terrain is very hazardous and the accessibility of the area is only between July to September. For the rest of the year it is covered with snow. The area is approachable by bus from Rishikesh up to Malari and from Malari by mule tracks.

The entire sedimentary succession of the Malla Johar area has been designated by Kumar et al.,

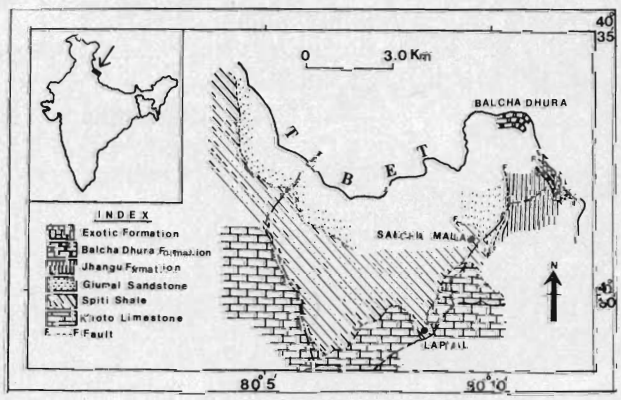

Fig. 1. Location and Geological map of the area

(1977) as the Malla Johar Supergroup. It has been subdivided into four lithostratigraphic groups viz., the Malari Group, the Sumna Group, the Rawalibagar Group and the Sancha Malla Group. The youngest, the Sancha Malla Group is further subdivided into four lithostratigraphic formations represented in stratigraphic order by the Spiti Shale, the Giumal Sandstone, the Jhangu Formation and the Balcha Dhura Formation (Tables 1&2) (Fig. 1). The Spiti Shale is represented by an argillaceous facies and is dominantly made up of black shales having sandy layers in the upper part. The Spiti Shale shows excellent development of ammonoid fauna. Jai Krishna et al., (1982) have assigned a Lower Cretaceous age (up to Valangian or even Lower Hauterivian) to the uppermost 15-20m of the Spiti Shale on the basis of *Neocosmoceras-Distalloceras* ammonoid assemblage. This part contains trace fossils. The boundary is gradational with the overlying Giumal Sandstone. The Giumal Sandstone (Formation) is represented by an arenaceous facies and shows very good trace fossils. The Jhangu Formation represents areno-argillaceous facies and contains the best preserved trace fossils. It shows distinct lower and upper contacts with the Giumal Sandstone and the Balcha Dhura Formation respectively. The radiolarian

Table-1 Stratigraphic division of the Sancha Malla Group (after Kumar et al., 1977).

Group	Formation	Age
	Balcha Dhura Formation (90m)	Eocene (?)
Sancha Malla Group	Jhangu Formation (400m)	Upper Cretaceous
	Giumal Sandstone Formation (400m)	Lower Cretaceous
	Spiti Shale Formation (200m)	Upper Jurassic to Lower Cretaceous

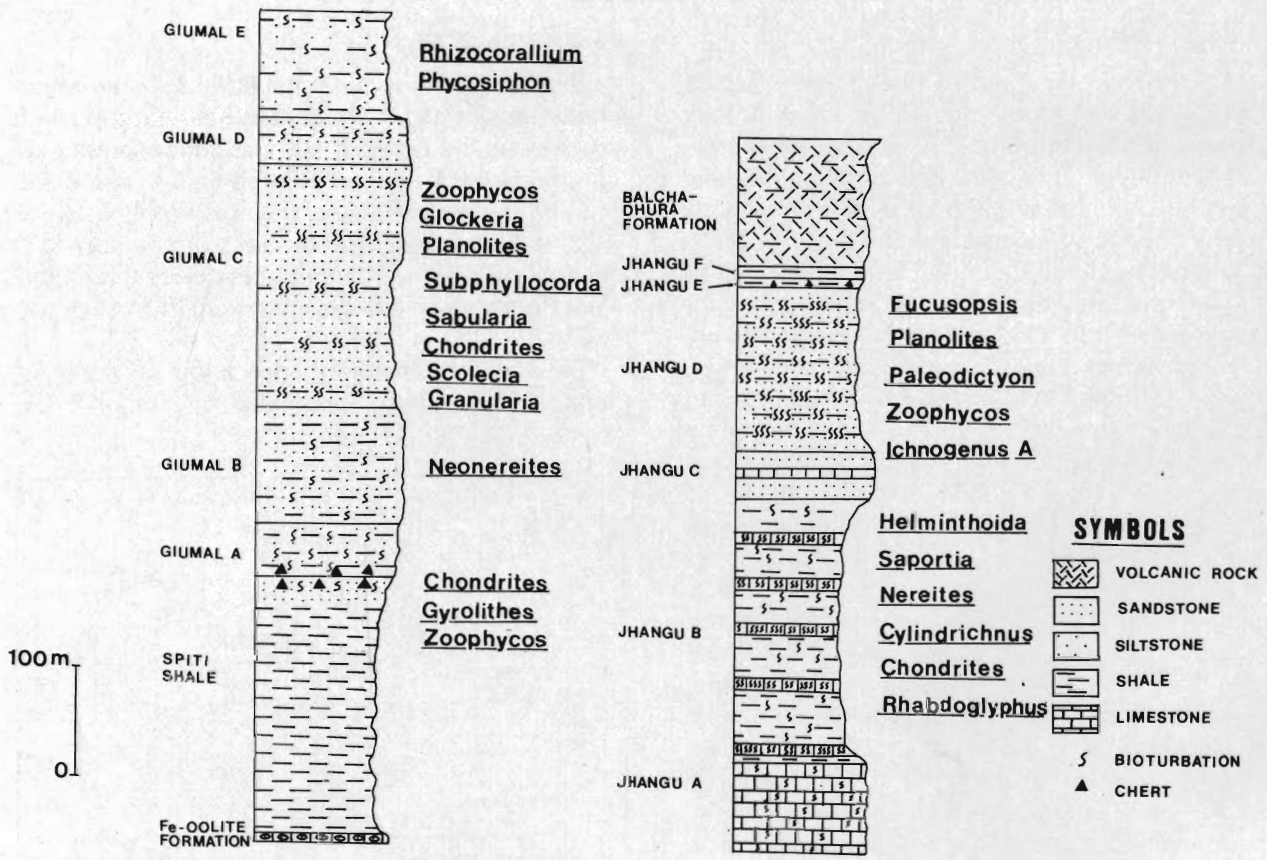

Fig. 2. Litholog showing distribution of the trace fossil assemblage in different formations.

assemblage indicates an Upper Cretaceous age for the Jhangu Formation (Garg et al., 1981). No trace fossil has so far been recorded from the Balcha Dhura Formation which represents dominantly basic volcanic flows with minor deep sea radiolarian oozes and shales. Structurally the area is complicated due to presence of a number of folds and faults.

Table-2 Detailed lithostratigraphy of the Spiti Shale, Giumal Sandstone and Jhangu Formations (after Kumar et al., 1977).

Formation	Member	Lithology	Environment
BALCHA DHURA FORMATION		Basic volcanic rocks interbedded with shale and radiolarian chert	Deep sea
JHANGU FORMATION	Jhangu F (5m)	Red Shale	Deep sea
	Jhangu E (5m)	Red, green shale and chert	Deep sea-Continental margin
	Jhangu D (120m)	Dark greyish green greywacke & shale	Continental margin
	Jhangu C (35m)	Orthoquartzite, calcareous sandstone & limestone with cone in-cone structure	Continental margin
	Jhungu B (135m)	Black shale, marl & limestone	Continental margin
	Jhangu A (65m)	Red foraminiferal limestone	Deep sea
GIUMAL FORMATION	Giumal E (80m)	Shale & siltstone	Continental slope
	Giumal D (30m)	Glauconitic sandstone & shale	Continental margin
	Giumal C (160m)	Glauconitic sandstone & shale	Continental slope
	Giumal B (90m)	Glauconitic sandstone & shale	Continental shelf-Continental slope
	Giumal A (40m)	Shale, siltstone limestone & radiolarian chert	Continental shelf-Continental slope
SPITI SHALE FORMATION (200m)		Black friable shale with upper part containing chert & sandy layers	Shelf mud region

SYSTEMATIC DESCRIPTION OF TRACE FOSSIL

Twenty trace fossil taxa are described from the upper part of the Spiti Shale, the Giumal Sandstone and the Jhangu Formation (Fig. 2). The description of the trace fossils is arranged in an alphabetical order as some of them are present in more than one formations. The preservational terms used in the paper are those of Seilacher (1964 a, b) and Martinsson (1970).

Chondrites STERNBERG,1833
(Plate I — 1-7)

Description: Endichnial, branching tunnels, representing dendritic burrow system of uniform diameter. The branches never anastomose or cut across each other. In most of the cases the burrow fill is darker than the host rock. Branching is generally in the form of side tunnels which deviate at an angle of 30°- 40° from the previous or main tunnel resulting in 'Y' shaped junctions.

Occurrence: It is reported from the Spiti Shale, the Giumal Sandstone and the Jhangu Formation. However, it is most abundant in the Jhangu Formation. In the Giumal Sandstone, it is associated with *Granularia*, and in the Jhangu Formation with *Cylindrichnus* and *Nereites*.

Age: Lower to Upper Cretaceous.

Remarks: Previously reported only from the Spiti Shale by Kumar et al., (1977) *Chondrites* is a facies crossing trace fossil and has been reported from shallow to deep marine environment. It is considered as fodinichnial burrow and the probable producer is vermiform animal (Farrow, 1966; Warme et al., 1973; Fürsich, 1974a; Miller, 1977; Howard and Frey, 1984; Frey and Howard, 1985; D'Alessandro et al., 1986). It has not yet been reported from non-marine sequences. According to Bromley and Ekdale (1984) it can be produced even in anaerobic zone below the surficial oxidized zone.

Cylindrichnus TOOTS in HOWARD, 1966
(Plate III — 6 and 7)

Description: Long, isolated, cylindrical to subcylindrical, tapering downward gently curved burrow. At places burrow filling is replaced by sparry calcite. Exterior is wrinkled. Length of the burrow ranges from 2.5-3.0 cm, maximum diameter 7-8 mm.

Occurrence: Jhangu Formation. *Cylindrichnus* is associated with *Chondrites* and *Nereites*.

Age: Upper Cretaceous.

Remarks: It is generally reported from shallow water environment (Häntzschel, 1975), but presently its association with *Nereites* increases its facies range upto deep water environment. It is considered as feeding structure of a deposit feeding animal (Fürsich, 1974a). Howard and Frey (1984) and Frey and Howard (1985) interpreted it as dwelling or feeding/dwelling structure of a vermiform animal.

Fucusopsis PALIBIN in VASSOEVICH 1932
(Plate IV — 1)

Description: Long, straight to slightly curved burrow with a diameter ranging from 4-11 mm. Rarely branching. Crossing over common. Surface structure is not very clear but a few short longitudinal striations are present. Natural end of the burrow is not clear.

Occurrence: Jhangu Formation.

Age: Upper Cretaceous.

Remarks: Originally regarded as marine alga or inorganic in origin but now considered as burrow of infaunal origin (Häntzschel, 1975). Hakes (1976) considered *Fucusopsis* as fodinichnia of infaunal organisms (?worms). Crimes (1977a) reported it from Eocene deep sea fan environments of Spain and D'Alessandro et al., (1986) reported it from the Eocene turbidites of Italy. Ksiażkiewicz (1977) considered it a post depositional feeding burrow of a priapulid worm. Kumar et al., (1977) have reported it from Ordovician rocks of the present area.

Glockeria KSIAŻKIEWICZ 1968
(Plate III — 4)

Description: Star shaped structure consisting of grooves radiating from a center. The grooves are unbranched and are of more or less of constant width. Central part is poorly preserved. Length of grooves varies from 3.0 to 4.0 cm, width from 4 to 5 mm.

Occurrence: Giumal Sandstone.

Age: Lower Cretaceous.

Remarks: *Glockeria* is considered typical of deep water environments. Crimes (1977b) reported it from Cretaceous deep water sediments of Spain, produced possibly by vermiform organisms. Ksiażkiewicz (1977) considered it a post depositional feeding structure. Kumar et al., (1977) described the same specimen as Ichnogenus H and considered it as feeding structure. Ekdale and Berger (1978) published photographs of recent deep sea trails resembling *Glockeria*. Ksiażkiewicz (1975) considered the trace producing animal as sedentary in nature.

Granularia POMEL 1849
(Plate II — 2)

Description: Horizontal, long, twig shaped branched structure having a length of 20-25 cm and width 5-7 mm. Branching angle varies from 30°-40°. It shows a weathering pattern consisting of small, irregularly arranged, rounded to elliptical depressions which probably represent the former site of clay pellets. The outer margin is some what irregular.

Occurrence: Giumal Sandstone. *Granularia* is preserved in sandstone and associated with *Chondrites*.

Age: Lower Cretaceous.

Remarks: Farrow (1966) considered *Granularia* as an annelid burrow. Crimes (1977a) reported it from sandstones representing deep sea fan of northern Spain. Ksiażkiewicz (1977) described the small elliptical to rounded particles as fecal pellets. Seilacher (1977) interpreted *Granularia* as a deep sea version of shallow marine *Spongeliomorpha* burrow made by decapod crustaceans.

Gyrolithes DE SAPORTIA 1884
(Plate IV — 2)

Description: Spirally coiled burrows oriented more or less vertically on the sediment having a diameter of 1.5-2.0 cm. Burrow is unbranched and burrow wall is generally smooth but some show fine striations on the surface.

Occurrence: Spiti Shale.

Age: Lower Cretaceous.

Remarks: Kumar et al., (1977) described the same sample as *Gyrolithes*. Bromley and Frey (1974) considered it as the dwelling burrow of a crustacean based on its close association with and similarity to *Thalassinoides* and *Ophiomorpha*. Powell (1977) considered it as the burrow of a capitellid polychaete, comparing it with *Notomastodus lobatus* in shape, appearence, dimensions, environment of deposition and co-existing fauna.

Helminthoida SCHAFHAUTL 1851
(Plate II — 6)

Description: A very irregular pattern formed by numerous meanderings of tight cylindrical burrows. Burrow diameter ranges from 2 to 3 mm. Surface is smooth; fill light coloured.

Occurrence: Jhangu Formation.

Age: Upper Cretaceous.

Remarks: The complex burrow pattern is considered to represent the feeding structure of a worm like organism and has been reported from the deep sea environments (Chamberlain, 1975; Crimes, 1977a; Książkiewicz (1977) considered *Helminthoida* a trace fossil of abyssal to bathyal zone and included it in his *Nereites* ichnofacies. D'Alessandro et al., (1986) considered it a feeding structure characterstic of deep water environments.

Neonereites SEILACHER 1960
(Plate II — 5)

Description: Two closely spaced, straight to slightly curved-oblong knobs, preserved as positive hyporelief. Knobs of different rows are not exactly opposite to each other but make an angle. A shallow median furrow divides the structure into two parts. Length of the structure ranges from 8.0-13.0 cm; its width is 1.0 cm.

Occurrence: Giumal Sandstone.

Age: Lower Cretaceous.

Remarks: *Neonereites* is considered as the feeding burrow of worm (Hakes, 1976). Crimes (1977a) reported it from deep sea environments. Fedonkin (1977) considered the rounded knobs as fecal pellets. The present form can be considered as locomotary structure and the knobs are formed during the locomotion due to the rhythemic backward shifting of the soft sediments by the locomotary organs of the animal.

Nereites MAC LEAY 1839
(Plate II — 3 and 4)

Description: Meandering trail consisting of narrow median furrow. On each side of the furrow laterally extended, hemispherical, very fine striated, regularly spaced, pinnate lobes are present. The length of trail ranges from 20-25 cm, its width 8-10 mm.

Occurrence: Jhangu Formation. *Nereites* is associated with *Chondrites* and *Cylindrichnus*.

Age: Upper Cretaceous.

Remarks: It is considered as the feeding and locomotary trail of a worm, probably a polychaete (Hakes, 1976). Kumar et al., (1977) reported it from the same formation and considered it as a feeding structure. Seilacher (1978) considered it as characterstic of the bathyal-abyssal zone i. e., the *Nereites* ichnofacies.

Paleodictyon MENEGHINI 1850
(Plate II — 7)

Description: Hexagonal mesh of 3-11 mm long hypichnial ridges forming a honeycomb like structure. The hexagons are variable in shape due to variable length of ridges. The width of ridges is 1-2 mm and may vary for a unit hexagon. Some mesh have tiny tubercles inside.

Occurrence: Giumal Sandstone.

Age: Lower Cretaceous.

Remarks: Nowak (1959) considered *Paleodictyon* a feeding trail of worm. Webby (1970) reported some irregular crescent like marking resembling *Squamodictyon*, an irregular form of *Paleodictyon* from Lintiss vale bed of Precambrian age and interpreted it as a feeding burrow or surface trail. Crimes (1977b) reported it from Cretaceous deep water environments of Spain and considered it to be formed due to fusion of two parallel sets of *Protopaleodictyon*. Seilacher (1977) made a detailed study of the pattern formed by *Paleodictyon* and considered it a graphoglyptid burrows. He concluded that the majority of the graphoglyptids should not be attributed to sediment eater but rather be compared with the search net of *Paraonis*, a polychaete worm, with which they share the systematic spacing within the search pattern. Książkiewicz (1977), reported it from the Polish Carpathians. D'Alessandro et al., (1986) described it from Eocene turbidites of southern Italy. Kumar et al., (1978) reported it for the first time from the present area from the Jhangu Formation.

Phycosiphon VON FISCHER OOSTER 1858
(Plate IV — 6)

Description: Irregularly meandering trail of 1-2 mm in width. Although the trails are meandering irregularly, they form 'U'shaped loops. However no branching is seen.

Occurrence: Giumal Sandstone.

Age: Lower Cretaceous.

Remarks: Kumar et al., (1977) first reported *Phycosiphon* from the present area. It is considered as a feeding structure (Häntzschel, 1975). Książkiewicz (1977) reported it from the Polish Carpathians as a post depositional feeding trail. D'Alessandro et al., (1986) reported it from Eocene deep water turbidites of southern Italy and considered it a feeding structure.

Planolites NICHOLSON 1873
(Plate IV — 4)

Description: Tube like, densly, horizontal to slightly inclined burrows on the upper surface of the bed. Diameter of the burrow in 3-8 mm and may be cylindrical to elliptical. Surface of the burrow may be smooth or annulated. Generally burrows overlie one another but may run nearly parallel for short distances. Burrow density very high.

Occurrence: Giumal Sandstone and Jhangu Formation.

Age: Lower to Upper Cretaceous.

Remarks: *Planolites* is a facies crossing trace fossil and considered as a feeding burrow of worm like animal (Howard and Frey 1984; Frey and Howard, 1985). Webby (1970) interpreted vertical, horizontal and inclined burrow of *P. ballandus* as actively filled burrows of deposit-feeding infaunal worms. On the basis of modern *Planolites* like trace making animals Curran and Frey (1977) considered many *Planolites* to be a polychaete traces. Ksiażkiewicz (1977) considered *P. reinecki* from Polish Carpathian as a post depositional feeding burrow of a priapulid. Pemberton and Frey (1982) made a detailed study of *Planolites* and suggested that it represents active back filling of sediment in an ephemeral burrow constructed by a mobile deposit feeders.

Rhizocorallium ZENKER 1836
(Plate III — 5)

Description: Horizontal or inclined 'U' shaped, gently curved burrow with spreite. Longitudinal sections show light and dark bands. Length of the entire structure is variable. The burrows are 10 cm long and 2-4 cm wide. Few small rounded to elliptical particles surround the structure.

Occurrence: Giumal Sandstone.

Age: Lower Cretaceous.

Remarks: Kumar et al., (1977) were the first to record *Rhizocorallium* from the present horizon. The structure occurs in a wide range of environments. Farrow (1966) considered it a crustacean burrow. Hakes (1976) interpreted it as domichnia of suspension-feeding animals. Ksiażkiewicz (1977) considered it a post depositional feeding burrow probably of polychaete origin. Seilacher (1978), in his environmental model based on the assemblage, placed it in shallow marine environment. Fürsich (1974b) have identified three species of *Rhizocorallium* and classified them into suspension feeders and deposit feeders. However the present from can not be classified as suspension or deposit feeder because of poor preservation.

Rhabdoglyphus VASSOEVEICH 1951
(Plate IV — 5)

Description: Long, rod shaped, slightly curved burrow, divided by transverse ridges on the upper surface. The burrow is 10 cm long and 9-14 mm wide and is divided into 14 segments. Not all segments are identical in shape and size. The middle six segments are somewhat rectangular in shape and the remaining ones are elliptical to rounded. The roundness increases towards the distant part but could not be confidently inferred due to poor preservation. The dividing ridges are 1-2 mm wide and 1 mm high.

Occurrence: Jhangu Formation.

Age: Upper Cretaceous.

Remarks: *Rhabdoglyphus* is considered as locomotary trail of polychaets worm (Osgood 1970 in Ksiażkiewicz 1977). The specimen is very much similar to the *R. sulcatus* of Ksiażkiewicz (1977) except for the larger dimensions.

Sabularia KSIĄŻKIEWICZ 1977
(Plate III — 3)

Description: Hypichnial, cylindrical, more or less straight, horizontal tube with smooth surface. The burrow end is not very clear due to poor preservation, however the visible length ranges from 0.5-3.0 cm and diameter 2-3 mm. Branching is absent but crossing over is common.

Occurrence: Giumal Sandstone.

Age: Lower Cretaceous.

Remarks: *Sabularia* is regarded as the feeding burrow of polychaete (Ksiażkiewicz 1977). The specimen is very similar to *S. tenuis* of Ksiażkiewicz (1977).

Saportia SQUINABOL 1891
(Plate III — 1)

Description: Long, cylindrical burrows which branch dichotonomously. Branching is in a twig shaped fashion. Diameter of the individual branch is 1.0—1.5 cm. Surface annulated. Length of the burrow is 17.0 cm and branching interval is 2-3 cm. Diameter of the burrow is 1.0-1.5 cm.

Occurrence: Jhangu Formation.

Age: Upper Cretaceous.

Remarks: Kumar *et al.*, (1977) reported it from the present Formation and considered it a feeding structure.

Scolicia DE QUATREFAGES 1849
(Plate II — 1)

Description: Long, horizontal, annulated or striated structure on the upper surface of the sandstone bed. The trail is bordered by a mm wide lateral furrow leaving a 5-8 mm wide median ridge. Median part may be annulated, striated or marked by crescent shaped laminae which are bent in one direction. The lateral furrow may also be marked by fine striations. Length of the trail ranges from 15-20 cm and width is 7-10 mm.

Occurrence: Giumal Sandstone.

Age: Lower Cretaceous.

Remarks: Fürsich (1974a) interpreted *Scolicia* as the endogenic trail of a scavenging gastropod. Ksiażkiewicz (1977), in his detailed study on the morphological characters related with the lithology and animal behaviour, considered it the locomotary trail of a polychaete. Smith and Crimes (1983) made a study of *Scolicia* and pointed out that the Cretaceous forms are more complex than the Palaeozoic forms. According to them the Palaeozoic forms probably produced by gastropods but modern deep sea traces produced by heart urchins look very like *Scolicia*. Howard and Frey (1984) considered it the crawling feeding structure of a gastropod or of other similar habitat.

Subphyllocorda GOTZINGER & BECKER 1932
(Plate IV — 3)

Description: Straight or curved, dense, trails of 3-5 mm width, bordered by a narrow ridge on the sides. The median part is slightly concave. Trail may cross each other or may be in close vicinity with other.

Occurrence: Giumal Sandstone.

Age: Lower Cretaceous

Remarks: The specimen closely resembles *S. levis*, described by Ksiażkiewicz (1977) except for the smaller dimensions. It is considered as the feeding and locomotary trail of holothuroid (Ksiażkiewicz, 1977). Smith and Crimes (1983) interpreted *Subphyllocorda* as burrow formed by heart urchins.

Zoophycos MASSALONGO 1855
(Plate IV — 7,8)

Description: The ichnogenus encompasses a wide variety of forms. Spreiten structure is either flat, curved, inclined or circular. In cross-section the spreiten appear as thin meniscate bands of lamellae alternate light and dark in colour. The light coloured bands are fine, while the dark coloured bands are wide and hemicircular. The length of entire structure ranges from 2-10 cm and width 2-7 cm.

Occurrence: Spiti Shale and Jhangu Formation.

Age: Lower to Upper Cretaceous.

Remarks: Kumar *et al.*, (1977) reported it from the Spiti Shale for the first time. Bhargava et al., (1985) described it from the Permian of the Spiti area, Himachal Pradesh. It is considered as a feeding structure of worm like animal possibly polychaete. Warme et al., (1973) described it from the deep sea core of Maestrichtian age. Fürsich (1974a) reported it from the Jurassic of England. Chamberlain (1975) reported it from deep sea core of Pacific ocean. D'Alessandro *et al.*, (1986) considered it as a complex fodinichnial burrow.

Ichnogenus A
(Plate III — 2)

Description: Long, horizontal or slightly inclined branched cylindrical burrow, ranging in diameter from 7-11 mm. The diameter of a single burrow is constant but may vary after branching. The burrow wall is smooth and burrow fill is structureless. Some components show bulbous enlargement.

Occurrence: Jhangu Formation.

Age: Upper Cretaceous.

Remarks: The structure has a faint resemblance to *Thalassinoides*.

DISCUSSION AND CONCLUSION

1 - Twenty trace fossils from the Cretaceous succession of Malla Johar area, Kumaon Tethys Himalaya have been described (Fig. 2). The distribution of the different trace fossils are given in the Table-3.

2 - The upper part of the Spiti Shale represents an areno-argillaceous facies which contains trace fossil assemblage dominanted by *Chondrites* and *Zoophycus*, although *Gyrolithes* has also been recorded.

3 - In the Giumal Sandstone, *Planolites*, *Rhizocorallium*, *Sabularia* and *Scolicia* are common while *Granularia*, *Neonereites*, *Phycosiphon*, *Paleodictyon*, *Chondrites*, *Glockeria*, and *Subphyllocorda* are rarely recorded.

Table-3 The distribution of the trace fossils in different formations.

No.	Name	Spi. Sh.	Giu Sst.	Jha. Fm.	Etho-logy	Pattern
1.	*Chondrites*	*	*	*	F	Branching
2.	*Cylindrichnus*	–	–	*	F/D	—
3.	*Fucusoposis*	–	–	*	F	—
4.	*Glockeria*	–	*	–	F	Rosette
5.	*Granularia*	–	*	–	F	Branching
6.	*Gyrolithes*	*	–	–	F/D	
7.	*Helminthoida*	–	–	*	F	Meandering
8.	*Neonereites*	–	*	–	F	Simple
9.	*Nereites*	–	–	*	F	Meandering
10.	*Paleodictyon*	–	–	*	F	Network
11.	*Phycosiphon*	–	*	–	F	Meandering
12.	*Planolites*	–	*	*	F	-
13.	*Rhizocorallium*	–	*	–	F	Spreiten
14.	*Rhabdoglyphus*	–	–	*	F	Long
15.	*Sabularia*	–	*	–	F	Simple
16.	*Saportia*	–	–	*	F	Branching
17.	*Scolicia*	–	*	–	F	Branching
18.	*Subphyllocorda*	–	*	–	F	-
19.	*Zoophycos*	*	–	*	F	Spreiten
20.	*Ichnogenus A*	–	–	*	F/D	-

F-Feeding, D-Dwelling, *Present, – Absent.

4 - The Jhangu Formation is dominated by arenoargillaceous facies. This formation is extremely bioturbated, especially the Jhangu B and Jhangu D members are extremely rich in long, branching, feeding and locomotary trails/burrows. The dominant assemblage consists of *Nereites, Chondrites, Cylindrichnus, Helminthoida* and *Planolites.*

In addition *Zoophycus, Saportia, Rhabdoglyphus, Fucusopsis, Paleodictyon, Saportia* and *Ichnogenus A* occur occasionally.

5 - On the basis of pattern analysis, the assemblage can be divided into the following groups:

Group A: Simple, long, branching and meandering structures-*Chondrites, Fucusoposis, Granularia, Helminthoida Neonereites, Nereites, Phycosiphon, Rhabdoglyphus, Saportia, Scolicia* and *Subphyllocorda.*

Group B: Spreiten structures- *Rhizocorallium* and *Zoophycos*

Group C: Rosette structures- *Glockeria*

Group D: Networks- *Paleodictyon*

On the basis of above grouping it is evident that the trace fossil assemblage was dominated by simple, long, branching and meandering structures. Ethologically, the majority of the assemblage represents feeding structures except for a few which, in addition are dwelling structures. The assemblage is dominated by vermiform animal traces (Table-3) and most of them are restricted to the shales which are interbedded with sandstones. The dominance of Group A can be compared with the *Nereites* ichnofacies of Seilacher (1967) which includes long feeding and locomotary trails/burrows formed in bathyal to abyssal depths for exploiting more area due to poor availability of food material. It may be pointed out that the entire Cretaceous sequence except for the Spiti Shale is devoid of megafossils. The absence of the megabody fossils may be due to diagensis (Seilacher, 1978) or due to primary absence of organisms with hard parts.

6 - Considering the lithology, environment of deposition and trace fossil assemblage the results support the earlier conclusion of Kumar et al., (1977) that the deepening of the basin started from the upper part of the Spiti Shale Formation and continued up to the Balcha Dhura Formation. Singh et al., (1980) interpreted the upper part of the Spiti Shale as deeper part of the continental shelf or the shallower part of the continental slope on the basis of radiolarian chert containing deep water microfaunal assemblage and the trace fossil *Zoophycos.*

7 - The trace fossil assemblage of the Giumal Sandstone and Jhangu Formation are very much similar to the *Nereites* ichnofacies of Seilacher (1967, 1978) i.e., zone of systematic grazers and farmers.

8 - The Balcha Dhura Formation is devoid of trace fossil activity. The Formation is characterised by volcanic eruptives interbedded with red shales and radiolarian oozes. The volcanic eruptions originated probably from submarine fissures from which basic lava outpoured. This could have made the conditions unsuitable for the survival of benthic fauna.

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EXPLANATION OF PLATES.

PLATE I

1. Ichnogenus *Chondrites* from the Spiti Shale
2,3,4. Ichnogenus *Chondrites* from the Jhangu Formation.
5,6,7. Ichnogenus *Chondrites* from the Giumal Sandstone.

Scale: 1 Division = Centimeter.

PLATE II

1. Ichnogenus *Scolicia* from the Giumal Sandstone.
2. Ichnogenus *Granularia* from the Giumal Sandstone.
3,4. Ichnogenus *Nereites* from the Jhangu Formation.
5. Ichnogenus *Neonereites* from the Giumal Sandstone.
6. Ichnogenus *Helminthoida* from the Jhangu Formation.
7. Ichnogenus *Paleodictyon* from the Jhangu Formation.

Scale: 1 Division = 1 Centimeter.

PLATE III

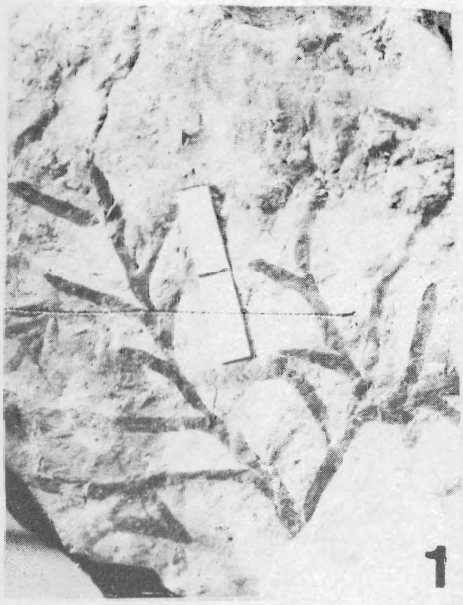
1. Ichnogenus *Saportia* from the Jhangu Formation.
2. Ichnogenus A from the Giumal Sandstone.
3. Ichnogenus *Sabularia* from the Giumal Sandstone.
4. Ichnogenus *Glockeria* from the Giumal Sandstone.
5. Ichnogenus *Rhizocorallium* from the Giumal Sandstone.
6,7. Ichnogenus *Cylindrichnus* from the Jhangu Formation.

Scale 1 Division = 1 Centimeter

PLATE IV

1. Ichnogenus *Fucusopsis* from the Jhangu Formation.
2. Ichnogenus *Gyrolithes* from the Spiti Shale.
3. Ichnogenus *Subphyllocorda* from the Giumal Sandstone.
4. Ichnogenus *Planolites* from the Giumal Sandstone.
5. Ichnogenus *Rhabdoglyphus* from the Jhangu Formation.
6. Ichnogenus *Phycosiphon* from the Giumal Sandstone.
7. Ichnogenus *Zoophycos* from the Spiti Shale.
8. Ichnogenus *Zoophycos* from the Jhangu Formation.

Scale: Division = 1 Centimeter.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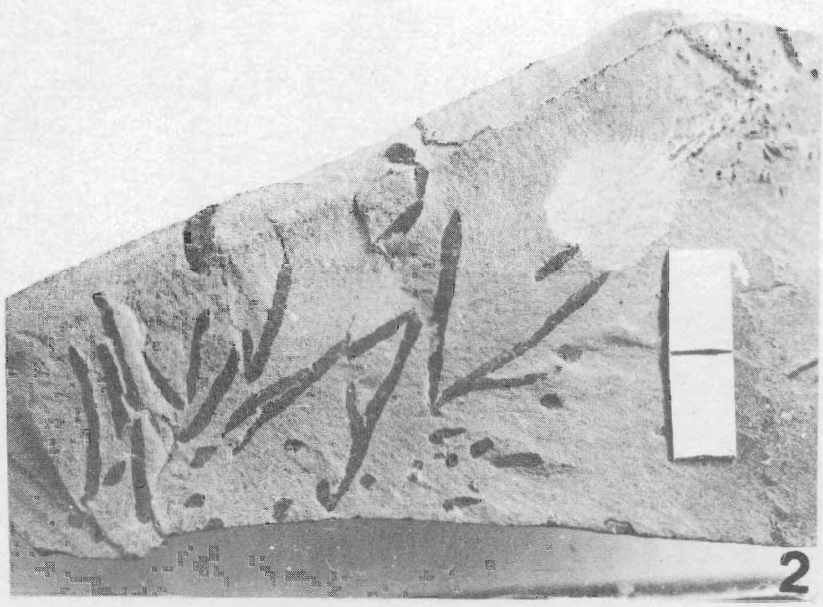
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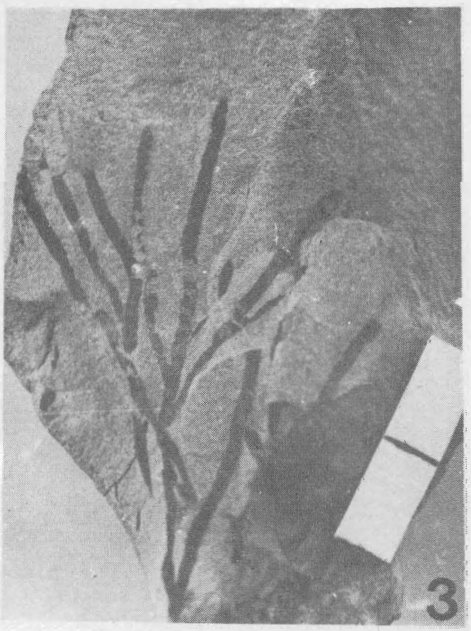
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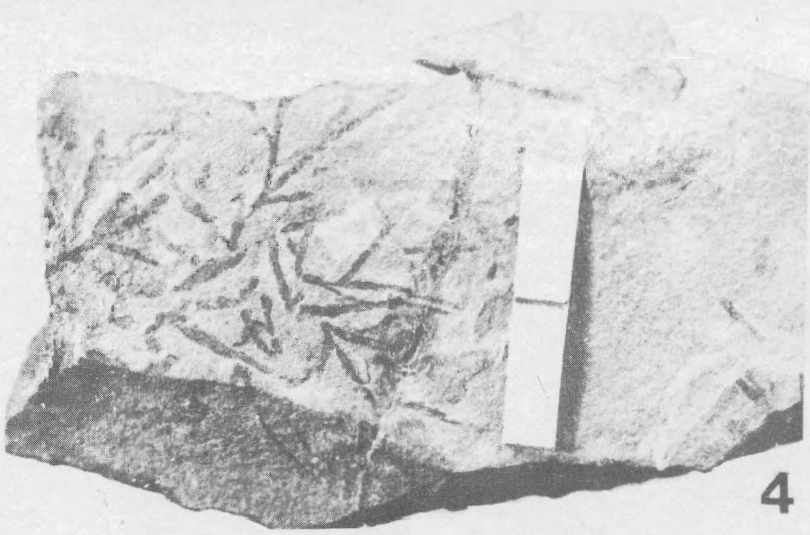
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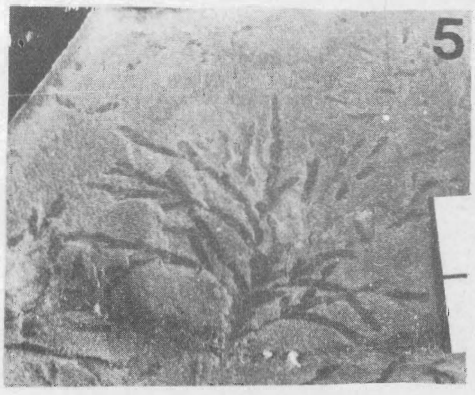
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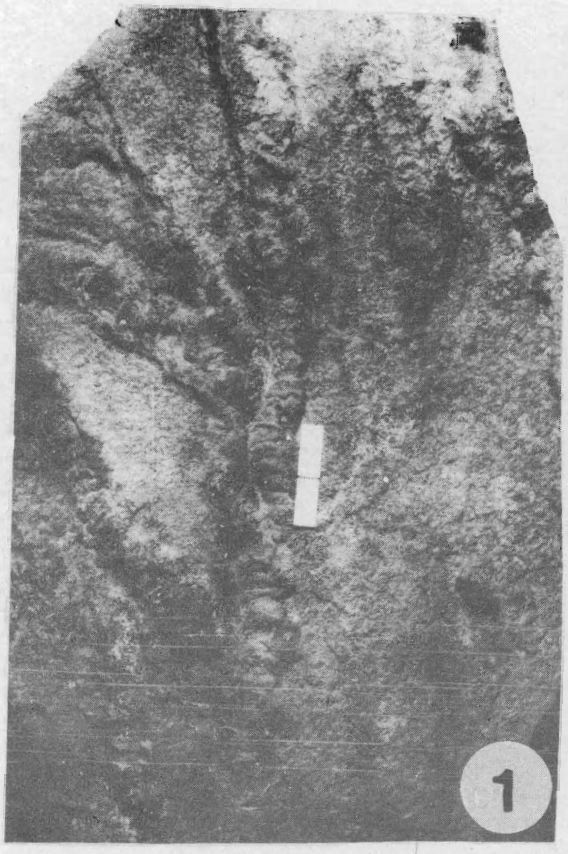
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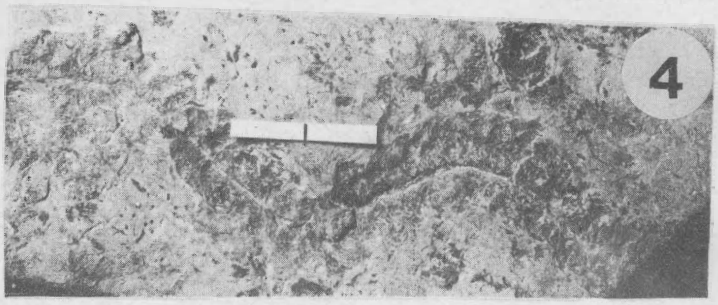
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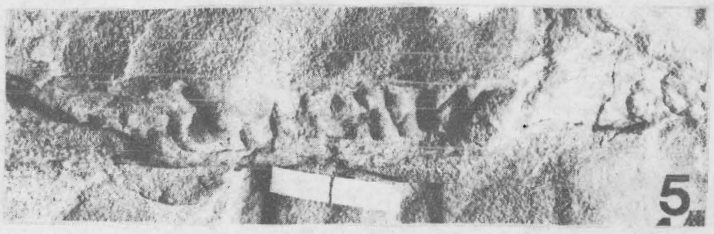
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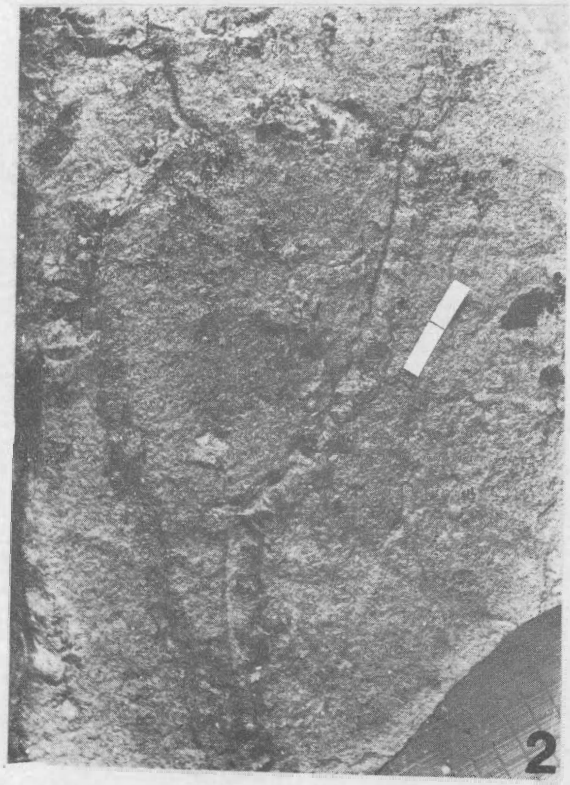
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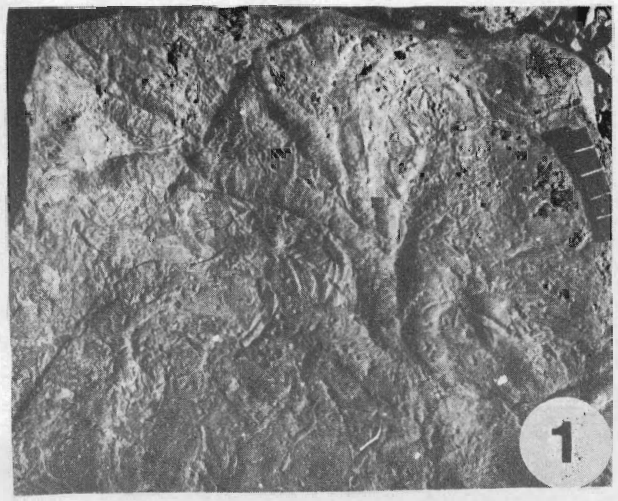
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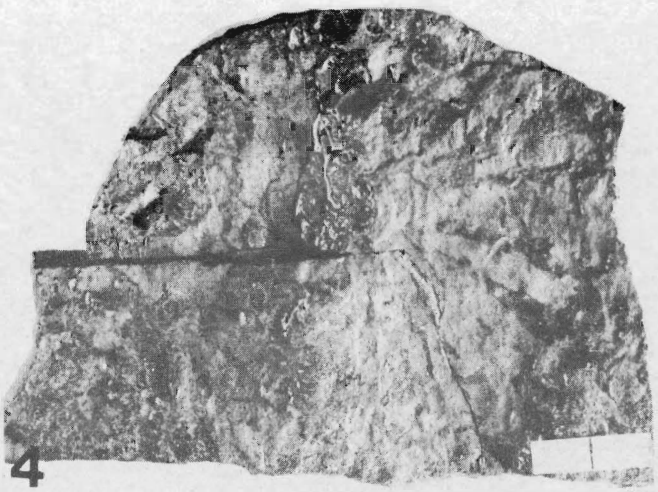
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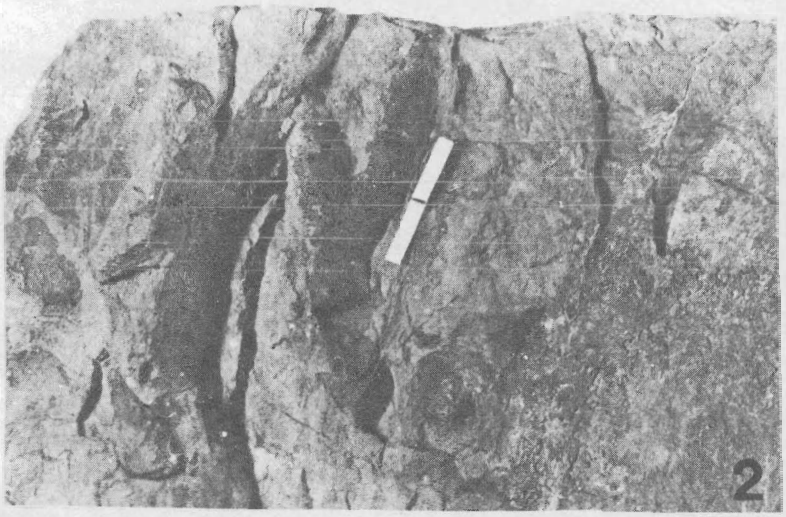
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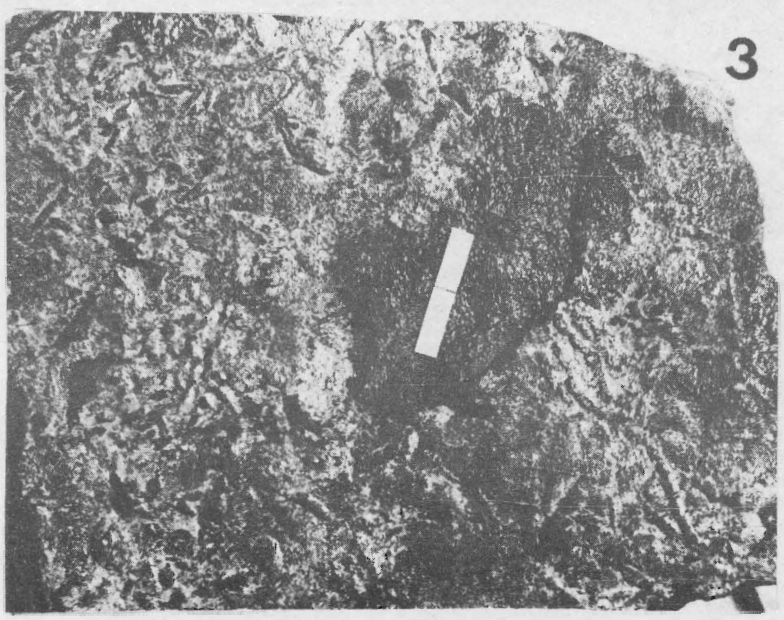
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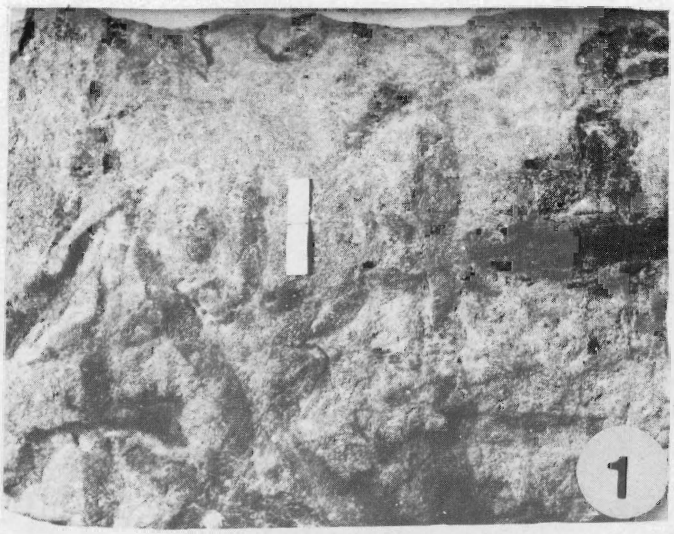
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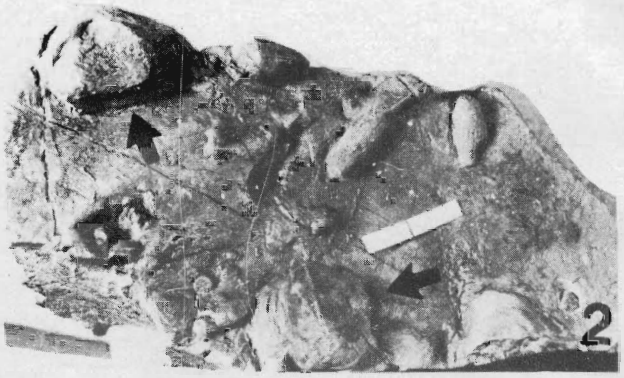
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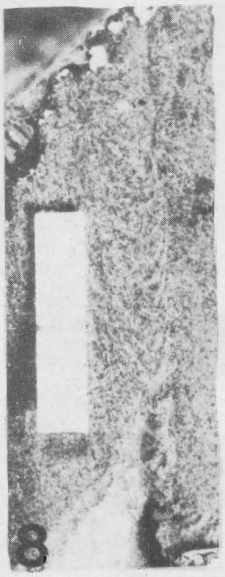
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