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, Fuscopsis, Giokceria, Granularia, Gyrolithes, Helminthoida, Neonereites, Nereites, Paleodictyon, Phycosiphon, Planolites, Rhizocorallium, Rhabdopleurida, 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 Giomal Sandstone is dominated by Planolites, Rhizocorallium, Sabularia and Scolicia. The Jhangu Formation which conformably overlies the Giomal 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: Spriten 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 Giomal 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 megasolfis, 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](image-url)
(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-Distaloceras 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 arenargillaceous 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>
<thead>
<tr>
<th>Group</th>
<th>Formation</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balcha Dhura Group</td>
<td>Balcha Dhura Formation (90m)</td>
<td>Eocene (?)</td>
</tr>
<tr>
<td>Sancha Malla Group</td>
<td>Jhangu Formation (400m)</td>
<td>Upper Cretaceous</td>
</tr>
<tr>
<td></td>
<td>Giumal Sandstone Formation</td>
<td>Lower Cretaceous</td>
</tr>
<tr>
<td></td>
<td>Lower Cretaceous</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spiti Shale Formation (200m)</td>
<td>Upper Jurassic</td>
</tr>
</tbody>
</table>

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

Fig. 2. Lithog 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).

<table>
<thead>
<tr>
<th>Formation</th>
<th>Member</th>
<th>Lithology</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BALCHA DHURA FORMATION</strong></td>
<td></td>
<td>Basic volcanic rocks interbeded with shale and radiolarian chert</td>
<td>Deep sea</td>
</tr>
<tr>
<td>Jhangu F (5m)</td>
<td></td>
<td>Red Shale</td>
<td>Deep sea</td>
</tr>
<tr>
<td>Jhangu E (5m)</td>
<td></td>
<td>Red, green shale and chert</td>
<td>Deep sea-Continental margin</td>
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<tr>
<td>Jhangu D (120m)</td>
<td></td>
<td>Dark greyish green greywacke &amp; shale</td>
<td>Continental margin</td>
</tr>
<tr>
<td>Jhangu C (35m)</td>
<td></td>
<td>Orthoquartzite, cal. Continental margin</td>
<td>Careous sandstone</td>
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<td></td>
<td></td>
<td></td>
<td>&amp; limestone with</td>
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<td></td>
<td></td>
<td></td>
<td>cone in-cone structure</td>
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<tr>
<td>Jhangu B (135m)</td>
<td></td>
<td>Black shale, marl &amp; Continental margin</td>
<td>Limestone</td>
</tr>
<tr>
<td>Jhangu A (65m)</td>
<td></td>
<td>Red foraminiferal limestone</td>
<td>Deep sea</td>
</tr>
<tr>
<td><strong>GIUMAL FORMATION</strong></td>
<td></td>
<td>Shale &amp; siltstone</td>
<td>Continental slope</td>
</tr>
<tr>
<td>Giumal E (80m)</td>
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<td>Glaucolithic sandstone &amp; shale</td>
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<tr>
<td>Giumal D (30m)</td>
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<td>Glaucolithic sandstone &amp; shale</td>
<td>Continental slope</td>
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<tr>
<td>Giumal C (160m)</td>
<td></td>
<td>Continental shelf</td>
<td>Continental slope</td>
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<tr>
<td>Giumal A (40m)</td>
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<td>Continental slope</td>
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<tr>
<td><strong>SPITI SHALE FORMATION</strong> (200m)</td>
<td></td>
<td>Black friable shale with upper part containing chert &amp; sandy layers</td>
<td>Shelf mud region</td>
</tr>
</tbody>
</table>

### 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 preservation 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 Granulina, 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 fadinichnial burrow and the probable producer is vermiciform (Farrow, 1966; Warne et al., 1973; Fürsch, 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 sub-cylindrical, 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 (Fürsch, 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 VASSEOVICH 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). Hakès (1976) considered Fucusopsis as fodinichna of infaunal organisms (?worms). Crimes (1977a) reported it from Eocene deep sea fan environments of Spain and D’Alessandri et al., (1986) reported it from the Eocene turbidites of Italy. Ksiazkiewicz (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 KSIAZKIEWICZ 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. Ksiazkiewicz (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. Ekdal and Berger (1978) published photographs of recent deep sea trails resembling Glockeria. Ksiazkiewicz (1975) considered the trace producing animal as sedentary in nature.

Granularia POMEI 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.


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, appearance, dimensions, environment of deposition and co-existing fauna.

Helminthoida SCHAFAUTLI 1851
(Plate II — 6)

Description: A very irregular pattern formed by numerous meanders 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 characteristic of deep water environments.

Neonereites SEILACHER 1960
(Plate II — 5)

Description: Two closely spaced, straight to slightly curved-elongated knobs, preserved as positive hyporeliefs. 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 locomotory structure and the knobs are formed during the locomotion due to the rhythmic backward shifting of the soft sediments by the locomotory 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 locomotory 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 characteristic of the bathyal-abyssal zone i.e., the Nereites ichnofacies.

Paleodictyon MENEGHINI 1850
(Plate II — 7)

Description: Hexagonal mesh of 3-11 mm long hypichiral 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 Paraonid, 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 (Hantzschel, 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, densely, horizontally 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.


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 domicinia of suspension-feeding animals. Ksiazkiewicz (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 Rhizocoralium 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 locomotory trail of polychaete worm (Osgood 1970 in Ksiazkiewicz 1977). The specimen is very much similar to the R. sulcatus of Ksiazkiewicz (1977) except for the larger dimensions.

Sabularia Ksiazkiewicz 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 (Ksiazkiewicz 1977). The specimen is very similar to S. tenus of Ksiazkiewicz (1977).

Saportia SquinaBol 1891
(Plate III — 1)

Description: Long, cylindrical burrows which branch dichotomously. 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 striactions. Length of the trail ranges from 15-20 cm and width is 7-10 mm.

_Occurrence_: Giumal Sandstone.
_Age_: Lower Cretaceous.

Remarks: Fürsch (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.

_Zooophycos_ 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 Jhang Formation.
_Age_: Lower to Upper Cretaceous.


_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_: Jhang 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, Theithys Himalaya have been described (Fig. 2). The distribution of the different trace fossils are given in Table-3.

2. The upper part of the Spiti Shale represents an arenary-argillaceous facies which contains trace fossil assemblage dominated 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, Paleodiclyon, Chondrites, Glockeria, and Subphyllocorda are rarely recorded.
Table 3: The distribution of the trace fossils in different formations.

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<tbody>
<tr>
<td>1</td>
<td>Chondrites</td>
<td>*</td>
<td>*</td>
<td>F</td>
<td>Branching</td>
<td>F/D</td>
</tr>
<tr>
<td>2</td>
<td>Cylindrichnus</td>
<td>-</td>
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<tr>
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<td>Fucosopsis</td>
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<td>Meandering</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>Planolites</td>
<td>-</td>
<td>*</td>
<td>F</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>Rhizocorallian</td>
<td>-</td>
<td>*</td>
<td>F</td>
<td>Spreiten</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>Rhabdognathus</td>
<td>-</td>
<td>*</td>
<td>F</td>
<td>Long</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>Sabularia</td>
<td>-</td>
<td>*</td>
<td>F</td>
<td>Simple</td>
<td>-</td>
</tr>
<tr>
<td>16</td>
<td>Saportia</td>
<td>-</td>
<td>*</td>
<td>F</td>
<td>Branching</td>
<td>-</td>
</tr>
<tr>
<td>17</td>
<td>Scoldia</td>
<td>-</td>
<td>*</td>
<td>F</td>
<td>Branching</td>
<td>-</td>
</tr>
<tr>
<td>18</td>
<td>Subphyllocorda</td>
<td>-</td>
<td>*</td>
<td>F</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>19</td>
<td>Zoophycos</td>
<td>-</td>
<td>*</td>
<td>F</td>
<td>Spreiten</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>Ichnogenus A</td>
<td>-</td>
<td>*</td>
<td>F/D</td>
<td>-</td>
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</tr>
</tbody>
</table>


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

In addition Zoophycos, Saportia, Rhabdognathus, Fucosopsis, 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, Fucosopsis, Granularia, Helminthoida Neoneiretes, Nereites, Phycisphon, Rhabdognathus, Saportia, Scoldia and Subphyllocorda.

Group B: Spreiten structures-Rhizocorallian and Zoophycos

Group C: Rosette structures- Glackaria

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 locomotory 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 diagenesis (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 eruptions 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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REFERENCES


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 = 1 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 Glochceria from the Giumal Sandstone.
5. Ichnogenus Rhizocorallium from the Giumal Sandstone.
6,7. Ichnogenus Cylindricrush 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 Subphylocorda from the Giumal Sandstone.
4. Ichnogenus Planolites from the Giumal Sandstone.
5. Ichnogenus Rhabdognathus 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.