CHAPTER - IV

CLASSIFICATION AND DESCRIPTION OF TRACE FOSSILS

An increased significance is being attached recently to the trace fossils in environmental and diagenetic interpretations of rock units and in the reconstructions of ancient life and benthic behavioral patterns. To satisfy such diverse interests a consistent workable system of classification and nomenclature is necessary. However, difficulties frequently arise in assessing present taxonomic concepts and in assigning ichnogeneric and ichnospecific names. The terms genera and ichnogenera, and species and ichnospecies are inter-mixed throughout most of the available literature. This is because of the ruling of the International Commission on the Zoological Nomenclature that recognize tracks, trails and burrows named before 1931 as valid genera and species, but does not recognize those named later.

In the present studies ichnogenera and ichnospecies are named according to I.C.Z.N. rules using the binomial system of nomenclature. Descriptive and informal classification terms are used as in Chamberlain (1971; 1977), Fursich (1974); Hantzschal (1962); and Seilacher (1953). Stratonomic Seilacher (1953 a) is considered equal to preservational Seilacher (1964); Phylogenetic, equal to taxonomic Seilacher

(1953 a) and this inturn equal to behavioral Seilacher (1964). All these classifications have been applied to the present studies separately or in combination.

The main purpose of this chapter being description of the trace fossil morphology and their behaviorial characteristics, the aspects of taxonomy, preservation and behavior of the ichnofossils are clearly separated wherever possible in their systematic descriptions. A summary of the stratonomic, phylogenetic and ethologic classifications applied to these fossils is separately given at the end of the chapter.

SYSTEMATIC ICHNOLOGY

DWELLING BURROWS OR DOMICHNIA

ARENICOLITES

Ichnoganus	:	Arenicolites SALTER, 1857
Type species	:	Arenicola carbonaria BINNEY, 1852
Diagnosis	:	Vertical U-tube without spreite.
Ichno species	:	Arenicolites variabilis, FURSICH, 1974 Plate - 1a, b.
Diagnosis	:	Variable, narrow or wide, vertical or slightly oblique; mainly straight circular. U-tubes without Spreite; tube diameter 0.6 to 1.0 cm. (Adapted from Fursich,1974).

PLATE - 1 (a) Arenocolites variabilis in vertical exposures.
Locality - Chitrod.

PLATE - 1 (b) Arenocolites variabilis in vertical exposures.
Locality - Washatwa.

Description :- The Kutch species include vertical or slightly oblique tubes (maximum deviation from the vertical 30° - 35°), very often exhibiting U-turns. The tube diameter varies from 0.6 to 1.0 cm; and the distance between both shafts from 8-12 cm; maximum depth observed was 25 cm. The two shafts of the U-tube are not in the same plane (Plate 1a). Crossing over of burrows is sometimes found. A burrow lining is usually present and consists of dark calcareous clay. The clay linings are arranged parallel to the tube wall (Plate 1a) indicating that the walls are purposely stabilized by the inhabitant.

Preservation :- Full relief; fill identical with the matrix.

Facies :- Occurs in the medium to fine grained sandstones of the Chitrod Member.

Regional and Stratigraphic distribution:- Occurs in the Chitrod and the Washatwa sections of the Washatwa Formation.

Associations :- Diplocraterion parallelum, Spongeliomorpha suevica, Planolites, Chondrites and Lanicodichnus.

Discussion and Interpretation :- Arenicolites variabilis occurs usually in good numbers in the upper parts of the Chitrod Sandstone Member. The proliferation in

the same bed of morphologically different burrows next to each other (Plate 1b), as well as numerous intervening forms favour the assumption that the same animal was responsible for their formation. The lining of the burrows and their stabilization by the regular arrangements of sand grains indicate that the burrows were inhabited by suspension-feeders rather than deposit feeders.

Comparison :- The Chitrod specimen very well compares with A. variabilis described and illustrated by Fursich (1974, p. 6-8). Arenicolites in general has been compared with the burrows of modern Arenicola marina (Binney, 1952; Bather 1925; Trusheim 1934). Richter (1924) and later Wells (1945) pointed out, that Arenicola usually does not build a simple U-tube Walls (1945) also demonstrated that the burrows of Arenicola marina is usually L-shaped, except in rapidly drying sand, where an open U-tube is constructed although the second shaft lacks a mucus-lining. An open U-tube is also required by Arenicola when it burrows in consolidated fine-grained sediments (Sehafer, 1982).

Classification:- A. variabilis specimen from Kutch is considered to belong to the domichnia and to have

formed by a suspension-feeding Polychate rather than a crustacean as in no case scratch marks typical for Crustaceans have been recorded, on it.

Ichno species : Arenicolites statheri BATHER 1925
Plate - 2a, b.

Diagnosis : Straight, Symmetrical Arenicolites.

Description :- Simple U-tubes without spreite. The commonly preserved paired funnel-shaped openings on bedding planes showing a distinct annulation have also been located in Kutch (Plate 2b). The tube diameter ranges from 0.8 to 1.2 cm, and the distance between the two arms varies from 3.5 to 8.5 cm, greatest depth recorded being 15 cm.

Preservation :- Full relief; fill identical with the matrix.

Facies :- Medium to coarse grained sand facies of Chitrod Sandstone Member.

Regional and stratigraphic distribution:- Occurs in the Chitrod Member of the Washatwa Formation. In Chitrod dome section.

Associations :- Spongaliomorpha saxonica, Lanicodiehnus.

Discussion and Interpretation :- The Chitrod specimen of A. statheri is comparable to the one described by Fursich (1974, p. 9).

PLATE - 2 : (a) Arenicolites statheri in vertical section, showing effect of erosion. Locality - Chitrod.

PLATE - 2 (b) Arenicolites statheri in vertical section. Locality - Washatwa.

Ichno species : Arenicolites sparsus SLATER 1857
Plate 3a, b

Diagnosis : Arenicolites sparsus Slater is defined as U-tube structures that lack spreite. The size of the tube or spread of "U"- is variable and smooth.

Description :- Slender, smooth walled tubes 1.0 to 1.5 cm wide that curve from vertical to horizontal. Vertical section upto 16 cm high and horizontal 8-10 cm long. Walls of tubes distinct with diagenetic stain or clay but not particularly lined.

Preservation :- Full relief; fill identical with the matrix.

Facies :- Medium to coarse grained sand facies of the Chitrod Sandstone Member.

Regional and stratigraphic distribution:- Occurs in Chitrod Member of Washatwa Formation.

Association :- Rosselia, Spongeliomorpha.

Discussion and Interpretation:- A. sparsus occurs in the top 5 m of the Chitrod Sandstone Member where the grain size appears to be changing rapidly from medium to coarse sand. A. statheri Bather (1925) differs from A. sparsus by a lining around the tube.

PLATE - 3 (a) Arenicolites sparsus in Chitrod Sandstone.
Locality - Chitrod.

PLATE - 3 (b) Arenicolites sparsus : Locality Chitrod.

Classification :- Intralaminar endogenic full relief; dwelling burrow (Cubichnia); Polychaeta, Insecta, or crustacea (based on ethology extant forms; probably Polychaeta based on ecologic relationships).

Ichno species : Arenicolites nodosa n. Sp.
Plate 4a,b,c.

Diagnosis : Variable, narrow or wide, vertical or slightly oblique, U-tubes without spreite, but often with nodular bulges.

Description :- The Kutch specimen reported to be a new species of Arenicolites include vertical or slightly oblique tubes exhibiting U-turns. The tube diameter varies from 0.5 to 0.7 cm; and the distance between both the shafts from 5 to 8 cm; maximum depth observed is 14 cm. Very often the two shafts of the U-tube are not in the same plane. A burrow lining is usually present. The apertures are not circular but hexagonal or pentagonal in shape (Plate 4c). The central burrow tubes are seldom present.

Preservation :- At times full relief; fill identical with the matrix.

Facies :- Occurs in the medium to coarse-grained portions of the Chitrod Sandstone Member.

PLATE - 4 :(a) Arenicolites nodosa, Arenicolites with nodular surface structure.
Locality -Chitrod.

PLATE - 4 (b) Arenicolites nodosa, in vertical Section.
Locality - Chitrod.

PLATE - 4 (c) Arenicolites nodosa, with burrow lining and hexagonal apertural opening.
Locality - Chitrod.

Regional and stratigraphic distribution:- Located only in the Chitrod Sandstone Member of the Washatwa Formation.

Associations :- Rosselia; Diplocraterion.

Discussion and Interpretation:- Arenicolite nodosa occurs in the upper parts of the Chitrod Sandstone where the lithology becomes more coarser. These burrows are usually short and do not penetrate the sediments to greater depths. It is possible that the same animal that constructed the other Arenicolites burrows was also responsible for making the Arenicolites nodosa which differs from the other varieties in its nodular nature. The linings of the burrows and their stabilization by the regular arrangements of sand-grains indicate that the burrows were inhabited by the suspension-feeders similar to the one responsible for the Arenicolites variabilis and A. statheri,etc.

Classification :- Domichnia of suspension-feeding Polychate.

LANICODICHNA

Ichnogenus : Lanicodichna CHAMBERLAIN 1971

Type species : Lanicodichna metuluta CHAMBERLAIN 1971.

Ichnogenus : Lanicodichna metuluta CHAMBERLAIN 1971
Plate 5.

Description :- Slender vertical galleries that are 1.5 to 2 cm wide and over 20 cm high that make perfect 'U' turns at the bottom. One or more additional vertical galleries merge with the main gallery. Oblique and horizontal galleries are found linking adjacent galleries at the base. One to three vertical galleries branch from the primary gallery and many are smaller than the primary gallery.

Remarks :- Chamberlain 1971 derived the ichnogeneric name from the similarity of the burrows to dwelling tubes of the Polychaete Lanice. The specific name refers to the behaviour of the animal in its apparent preference for sand sized sediment, thus metun- fear, anxiety, luta - mud.

This form is known at present from the Wapanucka Limestones near Hartshorne, Oklahoma (Chamberlain 1971). The Kutch form is comparable to the Hartshorne form but has larger dimensions.

PLATE - 5 : Lanicodichna metulata - with oblique and vertical galleries merging with the main gallery at the base.
Locality - Chitrod.

DIPLOCRATERION

Ichnogenus : Diplocraterion TORELL 1870

Type species : Diplocraterion parallelum TORELL 1870

Diagnosis : Vertical U-shaped Spreiten - burrows; dwelling burrows of suspension-feeders.

Ichno species : Diplocraterion parallelum TORELL 1870. Plate 6 a,b.

Diagnosis : Vertical U-shaped spreiten burrows in which burrow walls are parallel and spreite uni-directional.

Description :- Fairly straight U-tubes, the arms of which are more or less parallel. The diameter of the tubes varies between 1.5 to 1.8 cm, the width of the burrow is 8 to 12 cm. The U-tubes have wall-developed spreite and are found to penetrate the rock down to 20 cm. In Most of the Kutch specimen the Spreite is of retrusive type. Concentric laminae (Plate 5 b) surrounding the aperatures of most D. parallelum show that the tubes are heavily lined. Crisscrossing of up to three super-imposed burrows is observed in our specimens. High burrow density at many places indicates several phases of burrowing. Orientation of the U-tubes, probably in response to the Paleocurrents was observed in a few cases (Plate 6b).

PLATE - 6 (a) : Diplocraterion parallelum, vertical U-shaped Spreiten burrows with burrow walls typically parallel and Spreite unidirectional. Locality - Chitrod.

PLATE - 6 (b) : Diplocraterion parallelum, in bedding plane view. Note the occurrence of Diplocraterion habichi in right side. Locality - Chitrod.

Preservation :- Full relief, endogenic, dwelling burrows (domichnia); by Polychaeta worms.

Facies :- Most common in the fine-to-medium-grained Sandstone of the Chitrod Member. The burrow is also found associated with asymmetric and oscillation ripples.

Regional and stratigraphic distribution :- D. parallelum is common in Chitrod Sandstone Member in Chitrod, Mae and Washatwa Sections.

Associations :- Spongaliomorpha suevica, Diplocraterion habichi, Diplocraterion polyupsilon, Spongeliomorpha nodosa, Planolites, Rhizocorallium. Faecal pallets are found abundantly both in burrows and spreite and around the apertures of the U-tubes.

Discussion and interpretation :- Seilacher (1963) also noted the presence and abundance of faecal pellets in the Spreite of Diplocraterion that could be very similar to those of Kutch. According to Fursich (1974), the densely packed layers of faecal pellets and sediments, as found in the D. parallelum reported by him from the Bencliff Grit and in specimens from Littlemore Clay Beds of England and Normandy suggest that the shifting of burrows was a relatively slow process : Periods during which the inhabitant shifted its burrows (indicated by the layer of sediment) up to one centimeter because of sedimentation alternated

with periods during which the animal was feeding (indicated by the layers of faecal pellets). He further claims that the rhythmic alternations of periods of relatively little sedimentation and non-deposition may be related to a tidal environments.

Arkell (1939) who first described D. parallelum from the Jurassic rocks of England, interpreted them as having been formed by burrowing Polychaete. Hertweck (1970) figured bioturbation structures produced by the Recent Echiurus echiurus from the German Bay, which are very similar to bioturbation structures of D. parallelum. Again, burrows of Recent Corophium are very similar, except for their small size (Schafar 1952). Thus, according to Fursich (1974) it may not be justified to exclude either Polychaetes or Crustaceans as possible producers of D. parallelum, though the presence of scratch marks in some burrows may favour a Crustacean origin. Moreover, there is no doubt that D. parallelum has been produced by a variety of forms (Seilacher, 1957). It is, however very important that the D. parallelum represents burrow made by Suspension-feeders.

Ichno species : Diplocraterion habichi LISSON 1904

Plate 2a (top left hand corner)
6b (Right center)

Diagnosis : Diplocraterion in which arms of the U-tube diverge - upwards.

Description :- The Kutch specimen range in width from 0.5 cm (at the basal parallel part of the burrow) to 1.5 cm (distance of Paired openings). The tube diameter varies from 0.4 to 0.7 cm, on bedding planes, only the paired openings are usually encountered (Plate 6b). These paired openings in the Chitrod specimen are found to have been surrounded by a raised rim.

Preservation :- Full relief; fill identical with the matrix. The raised rim of the openings (Plate 2a) Probably represents early cementation of the Sediment in the vicinity of the U-tube. This could have caused by organic-rich mucus with which the inhabitant lined its burrow (Fursich, 1974).

Facies :- D. habichi is thought to be very good facies indicator. It is invariably found in high-energy sediments: most commonly in trough cross-bedded, well sorted silts and fine-sands.

Regional and stratigraphic distribution:- In parts of Chitrod and Washatwa dome in Washatwa and Lower Kanthkot Formations.

Associations : D. parallelum, Spongeliomorpha nodosa.

Discussion and interpretation:- Vertical Spreiten- burrows are usually regarded as the domichnia of suspension-feeders (Richter 1926, Goldring 1962, Seilacher 1963, 1967). The Spreite being the result of the animal's intention to keep its burrow at a constant depth than the result of mining the sediment for food. The divergence of the arms in D. habichi offers an additional argument for its interpretation as the dwelling burrow of a suspension-feeder (Fursich,1974). The increasing distance between the two apertures of the 'U'-tube as suggested by the above worker, guarantees a better separation of inhalent and exhalent currents.

Howell (1957) regarded D. habichi as the burrow of a Scoleciform annelid. The similarity of D. habichi with burrows of the Recent amphipod Corophium volutator is rather surprising. Furthermore, the environmental range of the two forms is very similar. C. volutator is widespread on the tidal flats of northwestern European Shelf Seas (Fursich, 1974) and the Kutch form of D. habichi probably occurs in similar setting which is shown by its association with ripples, channels and a high amount of fossil wood fragments.

Our inhabitant of D. habichi is therefore, more likely to be found amongst the Crustaceans than the Polychaetes, (Fursich, 1974).

Ichno species : Diplocraterion Polyupsilon SMITH 1983

Corophioides polyupsilon : Smith 1893; p. 282, Pl 10;
Knox, 1973, P. 133-146, Figs. 2-4;
Fursich, 1974 P. 958, Fig. 5
Plate 7.

Diagnosis : Diplocraterion having a partly or totally bidirectional Sperite.

Discussion and interpretation :- D. polyupsilon from the Lower Carboniferous of Scotland has been discussed in detail by Knox (1973). So far, no satisfactory explanation of the bidirectional Sperite has been given by any worker. According to Fursich (1974 b) the Sperite seems to be related to the growth of the animal rather than to erosion or sedimentation.

Preservation : Full relief, fill identical with the matrix. Domichnia of suspension-feeders.

Facies : Same as D. habichi and D. parallelum.

PLATE - 7 : Diplocraterion polyupsilon - Diplocraterion having bidirectional Sperite.
Locality - Chitrod.

RHIZOCORALLIUM

Ichnogenus : Rhizocorallium ZENKER 1836

Type species : U-shaped Spreiten-burrows, parallel or oblique to bedding plane; Limbs more or less parallel and distinct; to bedding Tube diameter; diameter of Spreite 1:5 (adapted from Fursich 1974).

Ichnospecies : Rhizocorallium jefiense ZENKER 1836
Plate 8a.

Diagnosis : More or less straight, short U-shaped Spreiten burrow, oblique to bedding plane and vertically retrusive.

Description :- Tube diameter 1 - 1.4 cm, width of Spreite 4 to 4.2 cm; Vertically retrusive structures, upto 1.5 cm high are present (Plate 8a). The burrows have maximum length of 12 cm and are slightly inclined towards the vertical and are fairly straight. The Spreite is well developed, but no ornamentation has been found on the tube walls. No burrow apertures were observed in the Kutch form. The burrow preserves some very faint scratch-marks, which form straight or slightly curved ridges.

Preservation :- Full relief; fill identical with the matrix.

PLATE - 8 (a) Rizocorallium jenense - U-shaped Spreiten burrow, oblique to bedding plane. Bedding plane view. Locality - Manfara.

PLATE - 8 (b) Rhizocorallium irregularie - Planispiral U-shaped Spreiten burrows, horizontal to the bedding plane. Locality - Chitrod - Kharol Member.

Facies : Rhizocorallium jenense is found in the fine-grained siltstone and mudstone rocks of the Kharol and the Adhoi Member respectively.

Regional and stratigraphic distribution :- Located in the Callovian - Oxfordian Sediments of the Chitrod Manfara Sections.

Associations : Found together with Chondrites, Palaeophyces, Zoophycos, Muensteria, and Gyrochorte.

Discussion and interpretation :- The oblique and Spreiten burrows of Kutch (Plate 8a) undoubtedly belong to Rhizocorallium jenense a trace which represents dwelling burrows of suspension-feeding Crustaceans. This ichnogenus has recently been revised by Fursich (1974). According to him distinction between a deposit feeding origin and a suspension-feeding origin in Rhizocorallium might not always be very easy, if only individual specimens are considered. In the case of whole Rhizocorallium community, however, it should be fairly easy to assign it to one of the two feeding types.

Ichnospecies : Rhizocorallium irregularie MAYER 1954
Plate 8b.

Diagnosis : Long sinuous planispiral U-shaped Spreiten burrows; mostly horizontal (adapted from Fursich 1974).

Description :- The tube diameter varies between 1.5 to 1.7 cm, the width of the Spreite from 2.5 to 2.7 cm. The U-tube is distinctly set off with Spreite. The burrows sharply bend and nearly complete a circle. Total diameter of the circle 12 cm, with the central disc in the form of a raised platform around 5 cm in diameter. The burrow outline varies from sinus, curved to almost planispiral (Plate 8b). The limbs are closely parallel, except where the burrows bend sharply. For most of their part the U-tubes are smooth showing partial effects of diagenesis and erosion. Some very faint scratch marks are found around the specimen.

Preservation :- Full relief; fill identical with the matrix.

Facies :- Occurs in the fine-grained sediments of the Kharol Member.

Regional and stratigraphic distribution:- Found only in the Chitrod Section - Washatwa Formation.

Associations :- Occurs together with Zoophycos, Chondrites and Palaeophycos.

Discussion and interpretation :- *Rhizocorallium irregularie* represents burrows excavated by deposit-feeders. As suggested by Seilacher (1967) the animal used the Spreiten technique for efficient exploitation of the sediment in search for food.

SPONGELIOMORPHA

Ichnogenus :- Spongeliomorpha SAPORTA 1887

Type species :- Spongeliomorpha iberica SAPORTA 1887.

Diagnosis :- Cylindrical branching burrow systems with both vertical and horizontal elements; branching Y - or T - shaped; burrow walls unlined, with pelletal or smooth lining, or covered with longitudinal ridges (scratch marks); dwelling burrows of Crustaceans (adapted from Fursich,1974).

Remarks :- Spongeliomorpha and other similar Crustacean burrows (Ophiomorpha, Thalassinoides) have recently been revised by Fursich (1973). According to him no features worthy of ichnogeneric seperation could be found in these three ichnogenera; consequently, Ophiomorpha Lundgren, 1989 and Thalassinoides Ehrenberg 1944 have been declared by him as junior synonyms of Spongeliomorpha. The present author has also considered the conventional grouping of these ichnospecies.

Ichnospecies :- Spongeliomorpha paradoxica WOODWARD,1830.
Plate 9,a

Diagnosis :- Cylindrical, irregular branching burrow system; burrow diameter is variable; horizontal elements dominate, but vertical elements in some cases become common. Burrow walls unlined, or with smooth linings and with scratch marks (adapted from Fursich, 1973b).

PLATE - 9(a) Spongeliomorpha paradoxica - Cylindrical branching, burrow systems; branching Y- or T-Shaped, burrow diameter is variable.
Locality - Washatwa.

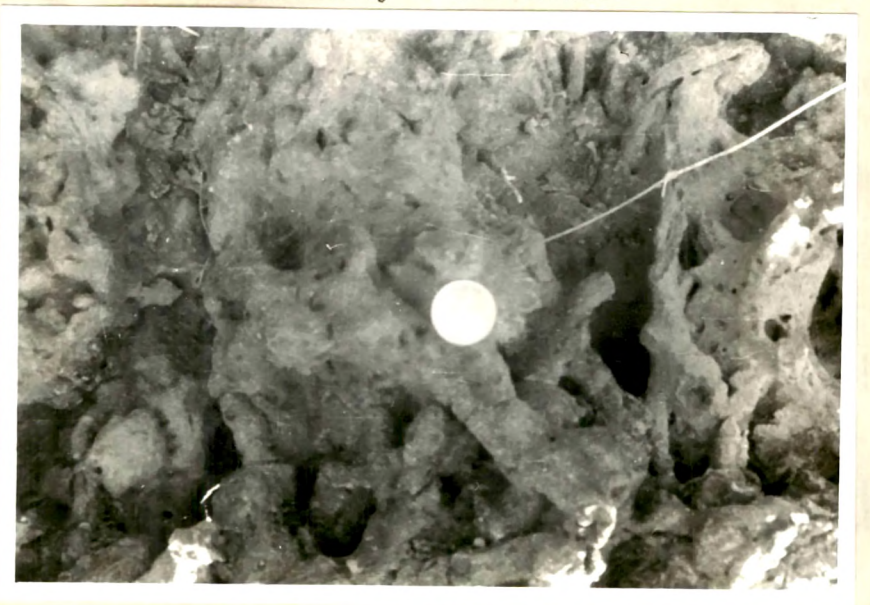

PLATE - 9(b) Spongeliomorpha suevica - Many horizontal, Cylindrical branching burrow systems. Branching dichotomos. Locality-Washatwa.

Description :- Irregular branching system with mostly horizontal elements. Burrows elliptical or rounded to angular in cross sections. The burrow diameter varies considerably. Usually between 2 and 4 cm. Side branches have usually a smaller diameter than the main trunk and often terminates after a short distance. Small proturbances (representing unfinished tunnels) are present everywhere in the system. The individual burrow systems are joined and thus forms extensive networks. The burrow walls are smooth.

Preservation :- Full relief; the burrow fill identical with the matrix.

Facies :- Spongeliomorpha paradoxica occurs in medium to fine-grained sandstones.

Regional and stratigraphical distribution:- A common trace fossil and occurs in the Washatwa, the Kanthkot and the Gamdau Formation.

Discussion and interpretation :- The irregular shape and branching of Sp. paradoxica makes it easily distinguishable from other forms of Spongeliomorpha. The producer is again most likely a decapod crustacean. Burrows of the Recent Alpheus, as figured by Shinn (1968, p. 109), are very similar to those described

by the author which might have been inhabited by a similar decapod.

Classification :- In view of the extensive burrow systems an endobenthonic suspension-feeding/scavenging or even deposit-feeding mode of life of the inhabitant seems likely.

Ichnospecies :- Spongeliomorpha suevica REITH 1932
Plate 9b.

Diagnosis :- Many horizontal, cylindrical branching burrow systems; branching predominantly dichotomous; burrow wall unlined, sometimes covered with scratch marks. Burrow diameter more or less constant except at branching points or turn - around (adapted from Fursich 1974).

Description :- Mainly dichotomously branching burrow systems with a circular, oval or, less often, rounded angular cross-section. The burrows are enlarged at the points of bifurcation which are either Y- or T- shaped (Plate 9b). The angle of bifurcation varies from 35° to 160°. Most burrows are oriented parallel or slightly oblique to the bedding plane. Vertical shafts are rare. The burrow walls are usually smooth. Rarely scratch marks are observed on parts of this burrow system.

Extensive branching has led to the formation of net -work structures in our specimens. Due to compaction, burrow systems are often superimposed one upon another.

Preservation :- Full relief; usually the fill is identical with the matrix.

Facies :- Spongeliomorpha suevica occurs in wide range of facies coarse to fine grained sandstones and in argillaceous fine-sand and mud rocks.

Regional and stratigraphical distribution:-

Common in all units

Associations :- Because of its wide distribution, Sp. suevica is found associated with most other trace fossils, notably Cylindrichnus, Teichichnus, Chondrites, Rhizocorallium etc.

Discussion and Interpretation:- The branching pattern and burrow outline of the Kutch Spongeliomorpha identifies them as Sp. suevica. The absence of vertical shafts in Sp. suevica systems has been commented upon by Fursich (1973). According to him it is most likely, that in these burrow systems the entrance shafts were merely inclined, as is the case in the burrow systems of the Recent Goneplax rhomboides and Nephrops norvegicus (Rice & Chapman 1971).

Classification :- The extensive burrow systems may indicate that the crustaceans were endobenthonic filter-feeding scavengers, i.e. sifting sand for food within the burrows.

Ichnospecies :- Spongeliomorpha nodosa LUNDGREN 1891

Plate 10

Diagnosis :- Branching burrow systems; predominently with Pelletal linning.

Description :- Burrow systems, bifurcating at irregular intervals. At bifurcations and at, turn-arounds; the burrows appear to be enlarged. The burrows range from 0.6 to 1.5 cm in diameter and are characterized by mammillated outer surface (Plate 10). This exterior arrangement is formed by cemented pellets of sediment when found in uncemented sands. The burrow lining is often found cemented by Fe-hydroxide and therefore is more resistant to weathering.

Preservation :- Full relief; fill identical with the matrix.

Facies :- Sp. nodosa occurs in fine-grained sands. As claimed by Fursich (1973) Sp. nodosa is a very good facies indicator.

Regional and stratigraphic distribution :- Sp. nodosa is abundant in the Adhoi Member of the Upper Kanthkot Formation and is located in the Manfara and Mae Section.

PLATE - 10: Spongeliomorpha nodosa - Branching burrow system with characteristic mammillated outer surface. Locality - Manfara

Discussion and interpretation :- The origin and significant of the morphological features of Spongeliomorpha has been discussed by Fursich (1973). According to this worker Sp. nodosa is usually recorded from fine-grained, well-sorted sands and sandstones, often associated with features typical of the littoral and sublittoral environments. The occurrence of Sp. nodosa in the Kutch rocks confirms this observation. It is further proposed that the pelletal lining served the inhabitant to stabilize the burrow walls in the unconsolidated sands of Manfara, thereby keeping the burrow system open while inhabited, and served as a dwelling burrow.

The inhabitant of modern Sp. nodosa system is the shrimp Callianassa major Say(Weimer & Hoyt 1964). The identical shape of fossil and recent systems make it reasonable to interprete the Kutch burrow as domichnia of Callianassids. Furthermore, Callianassa major is a suspension-feeder/scavenger; it feeds on detritus which it obtains by shifting sand. The Sp. nodosa, thus can be interpreted as the burrow of an endobenthonic Suspension-feeder/scavenger which was specially adapted to a life in sands and sandy muds.

ENTEROPNEUSTA BURROWS

Plate 11

cf. "Burrows of Enteropneusta" Kazmierczak and Pszczolkwski, 1969, p. 299-318 Figs. 3,4, 7-9; 5 Pls.; Kennedy, 1975, p. 389, Fig. 17.8; Chamberlain, 1977, p. 12, Fig. 2x.

Description :- These are vertical and horizontal burrows (or hard-ground borings) making partial boxworks ro or stacks with maze. Burrows branching and irregular in size and form, 4-10 mm wide, 30-40 mm high and long branches. No plan pattern is observed in these burrows.

Remarks :- Burrows similar to the Kutch specimens have been described by Chamberlein (1977) from the Ordovician Hanson Creak Formation of Central Navada. Kazmierczak and Pszczolkwski (1969) described Enteropneusta burrows from the Middle Triassic of the Holy Cross Mountains of Poland.

Facies :- Found only in the Chitrod Sandstone Member.

Classification:- Endogenic, full relief; dwelling burrows (domichnia).

PLATE - 11: Enteropneusta burrows - Vertical borrows making partial boxworks or stacks of maze. No plan pattern is observed in these burrows. Locality - Chitrod.

SPIROPHYTON

Ichnogenus : Spirophyton

Plate 12a,b.

No synonymy or information regarding the type species are available even in Hantzschel (1962). The following information correlative to our specimens is adopted from Miller and Johnson (1977, 1981).

Diagnosis :- Simpson (1970) defined Spirophyton as a three dimensional feeding burrow consisting of a central vertical tube around which a speriete is spirally wound and differs from Zoophycos in its smaller size. In the Kutch equivalents, Spirophyton occurs as circular areas (horizontal layers of the spreite) on bedding planes surrounding a central tube (Plate 12a). In the Tally areas described by Miller and Johnson (1981) similar structures like Kutch are found except the top of the specimens are not eroded and spiral lamellai are well preserved.

Description :- In the Kutch correlatives there are well preserved specimens of Spirophyton exposed on the bottom beds of the Chitrod Sandstone Member. These are exposed in the form of domes with lamellae around a central axis (Figs. 12a and b). The domes are generally 1.75 - 3.0 cm in diameter, and about 2-3 cm high. At one place, Spirophyton like traces grade into

PLATE - 12 :(a) Spirophyton Sp. - Spirophyton with circular areas (horizontal layers) on bedding planes surrounding a central tube.

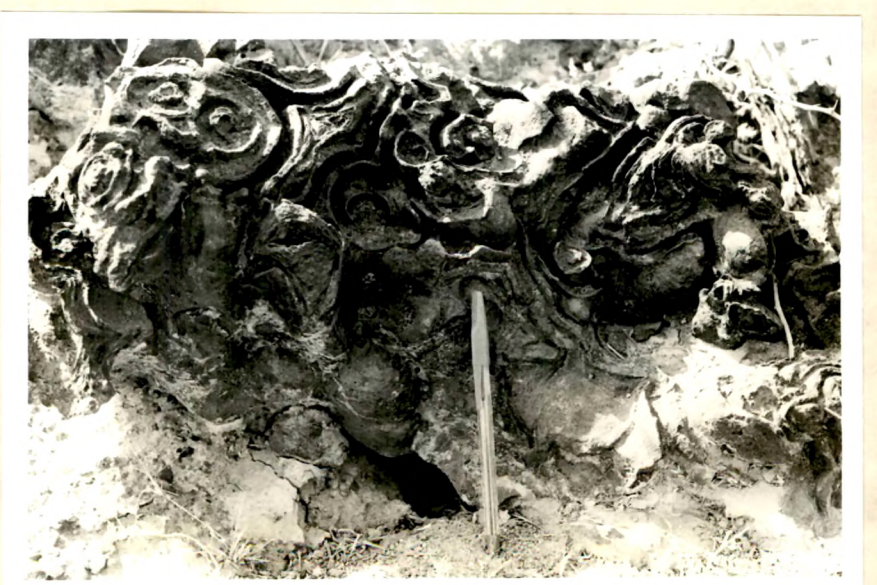

PLATE - 12 (b) Spirophyton Sp. - Spirophyton domes with lamellae around a central tube.

concretionary structures. Thus suggesting a genetic relationship between the traces and concretions. Spirophyton is abundant in the lower part of the Chitrod Sandstone Member south of the Chitrod village where it occurs in densities upto 150-200 m^2 in one bed. In the Chitrod outcrops the Spirophyton is restricted to layers of coarse-grained poorly sorted siltstones and very fine-grained sandstones. The Tally equivalents reported by Miller and Johnson (1977, 1981) are similarly located in the siltstones of the tidal and alluvial facies.

Preservation :- Full relief; All identical with the matrix.

Regional and stratigraphic distribution:- Occurs in the Chitrod Sandstone Member only.

Associations :- Enteropneusta burrows, Rosellia.

Discussion and interpretation :- Simpson (1970) interpreted Spirophyton and Zoophycos as resulting from the feeding activity of a bilaterally symmetrical animal. Other interpretations of the ichnogenus as plants (Loring and Wang, 1971) or body fossils (Plicks,1970) are not accepted by the present author.

SKOLITHOS

Ichnogenus :- Skolithos HALDEMAN, 1840

Type species :- Fucoides ? linearis HALDEMAN 1840.

Diagnosis :- Unbranching, straight vertical burrows.

Remarks :- According to Fursich (1874) the taxonomy of these simple vertical burrows is in urgent need of revision. Morphological features such as funnel-shaped apertures in Monocraterion Torell 1870 or less crowding tubes as in Tigillites Rouault 1850 according to him do not justify separation at the ichnospecific or ichnogeneric level. All straight and unbranching vertical burrows are, therefore, regarded by him as Synonyms of Skolithos Haldeman 1840 which he claims to have priority.

Ichnospecies :- Skolithos verticalis HALL, 1843

Plate 13a, b.

Fucoides verticalis Hall, 1843, p. Fig. 105
Skolithos verticalis Hall, 1852, p.6, Pl. 2, Fig. 3.
Skolithos verticalis Alpart, 1974, p.663-4.

Diagnosis :- Cylindrical burrows, straight or slightly curved, and vertical to inclined, Wall smooth or rarely corrugated.

PLATE - 13 (a) Skolithos verticalis - profusely developed Skolithos vertacalis burrows in Chitrod Sandstones. Locality - Chitrod.

PLATE - 13 (b) Skolithos verticalis - Bedding Plane View - Locality - Washatwa

Description :- Straight and slightly inclined unbranching vertical burrows with a diameter ranging from 0.4 to 1.0 cm. The walls of the burrows are smooth and lack ornamentation. No lining or funnel-shaped apertures have been found in most of the burrow tubes. Observed maximum length of the tube is 15 cm.

Preservation :- Full relief; fill identical with the matrix.

Facies :- Skolithos verticalis is found in the fine-grained Sandstone-Siltstone alternations of the Adhoi Member.

Regional and Stratigraphic distribution :- Found in the fine-grained Sandstone-Siltstones of the Chitrod Member in Chitrod and Washatwa; and in the Fort Sandstone and Adhoi Members in Kanthkot and Manfara Sections.

Associations :- Spongeliomorpha, Spirophyton, Chondrites, Scolicia, Gyrochorte, Cylindrichnus.

Discussion and interpretation:- According to Chamberlain 1977 Skolithos verticalis is widely recognized in shallow-water, intertidal deposits, and in flood-plain facies. Skolithos is interpreted as the dwelling burrow of a suspension feeding animal (Alpert, 1975). According Seilacher (1967) and Crimes (1975) it is common in

Sandstones deposited under high energy tidal and [illegible] nearshore conditions. The Kutch form is envisaged to represent similar environmental aspects.

Classification :- Endogenic, full relief; dwelling (domichnia) or resting (Cubichnia) burrows of insecta and Polychaeta organisms.

MONOCRATERION

Ichnogenus :- Monocraterion TORELL 1870.
Monocraterion Sp.
Plate 14.

Diagnosis :- Vertical, more or less cylindrical shafts having a broad, funnel-like opening at the upper end.

Description :- The trace consists of straight, cylindrical unbranched tubes oriented normal to bedding which very often passes upward into an ovate funnel. The funnel is characterized by the central downward deflection of sedimentary laminae. Funnel width is variable, the maximum observed being 2 cm. Shafts .4 to .5 cm in diameter with maximum observed length of 4 cm.

Preservation :-Endichenia and exichenia burrows; fill identical with the matrix.

Regional and stratigraphic distribution:- Occurs in the Chitrod, Washatwa and Manfara Sections in fine-grained Sandstone rocks.

Discussion and interpretation:- The ichnogenus Monocraterion ranges in age from Cambrian to Jurassic and is typically found in shallow water sediments. Monocraterion has been interpreted as a funnel-shaped top to a Skolithos burrow, the funnel top being

PLATE - 14 : Monocraterion Sp. - Vertical or Cylindrical Shafts having broad, funnel - like opening at the ' upper end. Locality - Tramau.

formed by the upward motion of a suspension feeding annelid in response to higher rates of sedimentation or by feeding movements of the mouth of a burrow (Hallam and Swett 1966).

OPHIOMORPHA

Ichnogenra :- Ophiomorpha LUNDGREN 1871, p. 114-115 Figs. 1.2; Kennedy and Mac Dougall, 1969 p. 459-471, Pls 87-88, Fig. 1; Howard, 1970, p. 163, Fig. 7a.

Diagnosis :- Simple to complex burrow systems distinctly lined with agglutimated pelletoidal sediment. Burrow lining more or less smooth interiorly; densely to sparsely mammalated or nodose exteriorly. Individual pellets or pelletal masses are discoid, ovoid, bilobate, or irregular in shape. Characteristics of the lining also vary within a single specimen (adopted from Frey, Howard and Pryor 1978).

Ichnospecies :- Ophiomorpha nodosa LUNDGREN 1981 Plate 15 a

Diagnosis :- Burrow walls consisting predominently of dense, regularly distributed discoid, ovoid and irregularly polygonal pellets.

Description :- Tunnel trails with tuberclelike or wartlike ornamentation of the outer wall but smooth inside; diameter of the tube variable between 1.5 to 1.7 cm. Maximum observed length of the tube 15 cm.

Preservation :- Full relief; tubes with clayey matrix.

Facies :- Fine-grained sandstone and siltstone facie.

PLATE - 15(a) Ophiomorpha nodosa - Burrow System distinctly lined with agglutinated Pelletoidal sediment. Burrow lining smooth interiorly. In Fort. SSt. Mem. - Locality - Chitrod.

PLATE - 15 (b) Ophiomorpha bornensis - Burrows typically packed with bilobate pellets. Locality - Nara.

Regional and stratigraphical distribution:- Occurs in the Chitrod Sandstone in the Chitrod and Washatwa Section and in the Adhoi Member in Manfara dome Section.

Discussion and interpretation:- The extant ghost shrimp Callianassa major Say makes this distinctive trace fossil called Ophiomorpha nodosa Lundgren consisting of a tube with a nodosa, pelleted wall (Chamberlain and Baer, 1973). O. nodosa has further proven to be a useful trace fossil because it is distinctive and because it is restricted mainly to the beach environment (Weimer and Hoyt, 1964).

Ichnospecies :- Ophiomorpha borneensis KEIJ 1965 Plate 15b.

Type species :- Ophiomorpha borneensis Keij 1965, p. 224-226. text figs. 2, Pl. 29, Fig. 1-8; Broomley and Frey, 1974, p. 329.

Diagnosis :- Burrow walls consisting predominently of dense regularly distributed bilobate pellets.

Description :- Burrows typically outwardly packed with bilobate pellets. Rare to scattered ovoid or "single" pellets are also found together with the bilobed pellets but are subordinate in number.

Discussion and interpretation:- This form of Ophiomorpha was located from the Chitrod and the Manfara Section only. According to Frey et. al. (1978) the morphology of this form overlaps with its other forms like O. nodosa and O. irregulaire which could be genetically related. Fursich (1973) considered O. borneensis to be synonym of Spongeliomorpha saxonica but failed to consider the bilobate pellets.

CYLINDRICHNUS

Ichnogenus :- Cylindrichnus HOWARD 1966
Cylindrichnus Sp.
Plate 16a

Type species :- Cylindrichnus HOWARD 1966, p. 45, Fig. 10
Fursich 1974, p. 31.

Diagnosis :- Simple cylindrical tubes with central or excentric core, surrounded by concentric layers.

Preservation :- Preserved mainly as endichnia; full relief.

Description :- Simple, subcylindrical to subconical burrows vertical to horizontal, straight to slightly curved, having concentrically layered walls.

Facies :- Found in fine-grained Sandstone and Siltstone facies.

Regional and stratigraphical distribution:- Common in the Fort Sandstone and Adhoi Members in Washatwa, Adhoi, Kanthkot, Mae and Manfara Sections.

Associations :- Spongeliomorpha, Chondrites, Planolites.

Discussion and interpretation:- These burrows comprise one end of a spectrum of burrows which culminate at the other end in large Rosselia funnels. Some of the

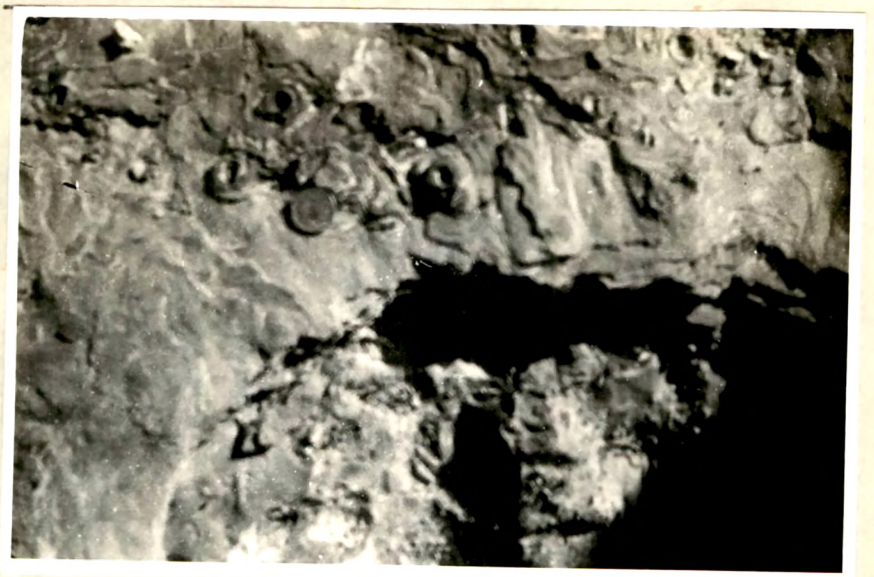

PLATE - 16: (a) Cylindrichnus Sp. Simple cylindrical burrow tubes with central or excentric core, surrounded by Concentric tubes.
Locality - Kanthkot.

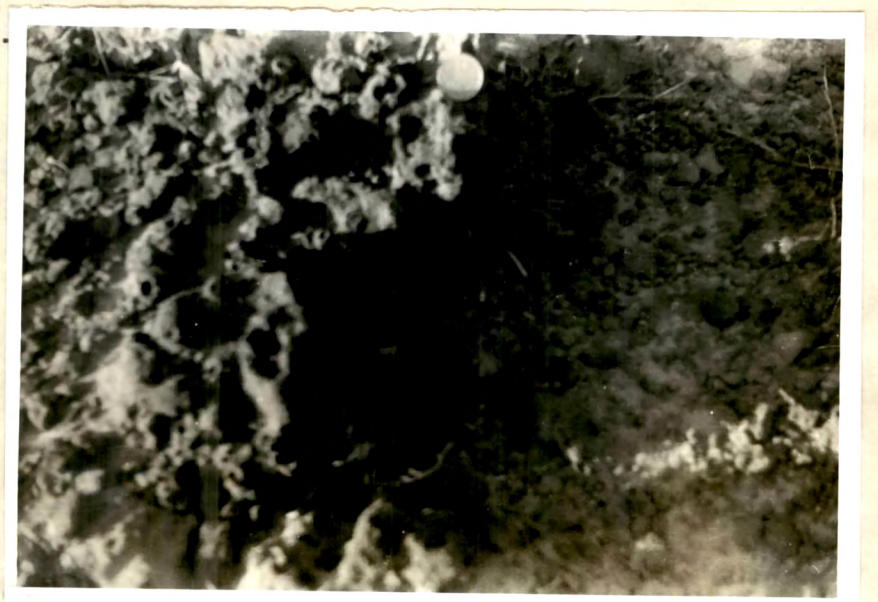

PLATE - 16 (b) Cylindrichnus concentrichnus - Vertical and inclined tubes with an exterior wall of multiple concentric layers.
Locality - Manfara.

burrows are part of a sequence which grades into rod-shaped burrows and Rosselia (Frey & Howard, 1970), others grade into Asterosoma (Frey, 1970). The Kutch specimen of Cylindrichnus are interpreted as dwelling or combined feeding-dwelling structures.

Ichnospecies :- Cylindrichnus concentrichnus HOWARD 1966. Plate 16b.

TypesSpecies :- Cylindrichnus concentrichnus HOWARD, 1966, p. 45, Fig. 10; Frey & Howard, 1982, Figs. 2E, 4F, Howard & Frey, 1984, p. 203-204, Fig. 4.

Diagnosis :- Vertical or inclined, unbranched tubes with an exterior wall of multiple concentric layers.

Description :- Simple cylindrical .5 to .6 cm diameter tubes, inclined at various angles to the bedding planes. Simplest forms have a concentric wall structure in which the tube is central, but others are slightly excentric because the wall structures are towards one side of the tube. Concentric laminae are very fine, and comprise alternating dark material and lighter coloured fine sand or silt.

Preservation :- Full relief; fill of the core either identical with the matrix or consisting of dark clay.

Facies :- C. concentrichnus is found in wide range of facies of fine to medium-grained sandstones and in the fine-grained argillaceous sands.

Regional and stratigraphic distribution :- Common in the Fort Sandstone and Adhoi Members.

Associations :- Chondrites, Planolites, Rhizocorallium, Teichichnus, Spongeliomorpha.

Discussion and interpretation :- C. concentrichnus is a burrow with a relatively small diameter compared to the thick wall which surrounds it. It represents most likely the burrow of a deposit feeder. The inhabitant as claimed by Fursich (1974); possibly removed it faeces not by depositing it outside its burrows as do many other burrow-dwelling organisms (e.g. Arenicola, many crustaceans) but by pressing it into the walls of the burrows. In this way, together with undigested sediment, the alternating layers of the thick burrow walls were formed. As much of this material was pressed onto the burrow floor the burrows frequently underwent a shift in a vertical direction, thus creating the retrusive features.

Judging from its morphology, C. concentrichnus is interpreted to have been produced by a worm-like animal, probably a deposit-feeder.

THALASSINOIDES

Ichnogenus :- Thalassinoides EHRENBERG 1944. P.358; Kennedy, 1967, P. 131-134; Frey, 1970; Howard and Frey, 1984, p. 212,213.

Plate 17.

Diagnosis :- Large burrow systems consisting of smooth-walled, essentially cylindrical components. Branches Y- to T-shaped and typically enlarged at points of bifurcation. Burrow dimensions variable within a given system.

Preservation :- Preserved as epichnia, endichnia, and hypichnia.

Description :- These, very thinly lined to unlined burrow systems are usually found restricted to the fine-grained Sandstone-Siltstone rocks in Kutch. The net-work is largely horizontal and is confined to a single level in the sediment. Bifurcations are Y-shaped with noticeable enlargements at the junctions; some of the branches terminate after a short distance as blind tunnels. The walls are smooth with scratch marks at some places. The burrow diameter varies from 3-5 cm in diameter in some specimens.

Facies :- Fine-grained Sandstone-Siltstone rocks.

PLATE - 17 : Thalassinoides Sp. Large burrow System consisted of smooth-walled cylindrical components. Burrows Y- and T.-shaped enlarged at the point of birfurcation.
Locality - Chitrod.

Regional and stratigraphical distribution:- Occurs in Chitrod, Washatwa, Adhoi, Kanthkot, Mae and Manfara Sections in the Washatwa, Kanthkot and Gamdau Formations.

Associations :- Common trace fossil, associated with most of the trace fossil forms.

Discussion and interpretation :- The unlined burrow systems appear to be characteristic of fine-grained coherent substrates, in which wall reinforcement is unnecessary. The Thalassinoides network probably was constructed in fine sand and subsequently infilled with dark silt and sand. The burrows are interpreted as dwelling or combined feeding-dwelling structures.

Ichnospecies :- Thalassinoides suevicus RIETH 1932.

Plate 18a.

Spongites suevicus quenstedti Reith, 1932, p. 275; Thalassinoides Sp. Howard, 1966, p.48 fig. 14; Thalassinoides suevicus Kennedy, 1967, p. 140,141, Pl. 1 Fig. 2; Thalassinoides suevicus Fursich, 1981, p. 161-165, Figs. 6,7, Pl. 4, Fig. 3, Pl. 6, Fig. 1-3; Howard & Frey, 1984, p. 213, Fig. 24.

Diagnosis :- Predominantly horizontal, more or less regularly branched, essentially cylindrical components forming large burrow systems; dichotomous bifurcations more common than T-shaped branches.

PLATE - 18 : Thalassinoides suevicus - Predominently horizontal, more or less regularly branched, large burrow system with dichotomous bifurcations. Locality - Adhoi.

Preservation :- Preserved as epichnia, endichnia and hypichnia.

Description :- Well-preserved specimens of I. suevicus have segments ranging from 1.5 to 2.5 cm in diameter. Walls are distinct, and some specimens exhibit definite linings. Isolated patches of vague knobs are also very common. Claw-sculpted walls are observed in some specimens.

Facies and Associations :- Same as Thalassinoides Sp.

Discussion and interpretation :- T. suevicus is distinguished from T. Paradoxicus by the irregular branching systems of the latter (Howard and Frey, 1984).

SCOYENIA

Ichnospecies :- Scoyenia gracilis WHITE 1929
Plate 19a, b.

Diagnosis :- Slender rope like remains. Preserved in half relief or as flattened forms; also curved, tapering or leaflike appendages (Hautzschel, 1962, p. W 215).

Description :- Scoyenia gracilis in Kutch is represented by two forms. Form A (Plate 19a) resembles the one illustrated and described by Hantzschel (1962, P. W 212, W 215). It consists of slender rope like structures with diameters of .2 to .5 cm and with characteristic leaf like appendages emerging from a common center. The walls show typical "Peristaltic" annulations (faint rhythmic wave like motions consisting of alternate constrictions and dialations of transverse and longitudinal muscles in the tube), as described by Reineck,(1955). Form 'B' (Plate 19b) is characterized by fill covered with dense ornament of short, fine ridges running longitudinally and corresponding to scratches on the Walls. The diameter of the tubes varies from .5 to 1.5 cm. The tubes usually bear a number of protrubences on its side walls.

PLATE - 19 (a) Scoyenia gracilis - Slender rope like structure with leaf like appendages emerging from the center. Locality - Ramwao

PLATE - 19 (b) Scoyenia gracilis - Large forms, with fine ridges running longitudinally and corresponding scratches on the Walls. A number of protruberances on the side walls. Locality - Hamirpur.

Preservation :- Full relief, fill identical with the matrix.

Facies :- Fine-grained Sandstone-Siltstone beds around Hamirpur and Manfara.

Associations :- Chondrites, Planolites, Skolithos, Thalassanoides.

Discussion and interpretation:- In the thin, flat bedded Sandstone-Siltstones of Manfara the burrows tend to be more horizontal and follow a straight or gently curved course. In thick Sandstones of Hamirpur the burrows are more contorted and the diameter of the burrows show broad range of diameters. Burrows commonly intersect and in some cases the trace maker follows an earlier fill, suddenly quitting it at an angle, thereby producing a false branch. It is difficult to judge the environmental conditions under which S. gracilis was produced. Stanley and Fagerstorm (1974) considered similar burrows to have been constructed by insects in moist sand without water cover, as they located these burrows in association with mud-cracks. According to Bromley and Asgaard (1979) S. gracilis also occurs in beds showing no signs of having suffered desiccation. The author believes that the Kutch form was possibly constructed under very shallow aquatic conditions, and in

Hamirpur where it postdates mud cracks, it formed in resubmerged sediments. The trace maker is further interpreted as a deposit feeder.

FODINICHNIA - (FEEDING TRACES)

MUENSTERIA

Ichnogenus :- Muensteria STERNBERG 1833

Type species :- Muensteria vermicularis STERNBERG 1833, p. 32; Pl.1, Fig. 3 (designated by Andrews 1955, p. 191).

Diagnosis :- Cylindrical tubes with Cup-shaped segments.

Remarks :- Trace fossils with back-fill structures are either called Planolites montanus Richter 1937, Taenidium, Heer 1877, Keckia Glocker 1843 or Muensteria Sternberg 1833. According to Fursich(1974) there is no basic difference between these ichnogenra and the former are, therefore, regarded as synonyms to Muensteria which has priority. According Frey and Howard (1985) Muensteria includes distinctly meniscate, cylindrical to subcylindrical burrows having discernible but lined walls. The taxon as suggested by these authors needs systematic revision. The Kutch forms appear to be correlative to the Corallian (upper Jurassic) species described by Fursich (1974), and are therefore generalised as Muensteria Sp.

Muensteria Sp.

Plate No. 20 a,b &
21 a,c.

Diagnosis :- Large back-filled burrows ranging 1.2 cm across and several cm in length. The burrows are sinuous, curving, and branching, Back-filling consists of fine sediment not disrupting. The more-or-less smooth line of outer wall.

Description :- Three district varieties of this Muensteria Sp. are observed in the Manfara Section. These are recognized as form A, B and C. Form A includes horizontal network of tubes with characteristic back-fill structure (Plate 20 a,b). The tube diameter varies from 0.5 to 1.5 cm. A transverse section reveals an internal structure in the form of Concavo-convex segments. The surface of the burrows clearly indicate the nature of segmentation either by its concentric rings or by its annular constrictions. The animals followed a zigzag pattern which is typically left in its backfill structures. At the junctions the burrows overlap and swell but still retain the basic Muensterial form. Form (B) represents long Muensterial burrow-tubes with variations in its length and diameter. It has constricted ends with backfill elements indicating its fecal nature (Plate 21a) Cup-shaped bulges although greatly reduced in number are still very conspicuously

PLATE - 20 (a) Munesteria Sp. - Form "A" with characteristic backfill structures and rare horizontal network of tubes.
Locality - Manfara.

PLATE - 20 (b) Munesteria Sp. - Long Muensterial burrow tubes with variations in its length and diameters.
Form "B". Locality - Manfara.

developed. This form appears to be the intermediate development between Form A and Form C. The Cup-shape arrangement completely disappears in Form C (Plate 21c) which although is very simple still cannot be missed for the Muensterial nature. This form is considered to be the end member in the series of the Kutch forms A, B, and C.

Facies :- Muensteria Sp. occurs in the fine to medium grained Sandstones and clays in Manfara Section.

Associations :- Cylindrichnus, Gyrochorte, Rhizocorallium, Skolithos, Thalassinoides, Scolicia, Chondrites.

Discussion and interpretations :- In a detailed analysis of Planolites montanus and Taenidium, Richter (in Fursich, 1974, p. 14) interpreted the Cup-shaped segments as back-fill structures made by deposit-feeder. Probably the worm-like animal was eating its way through the sediment and filled the thus created tunnel immediately in a backward direction by the periodic release of waste. These segments of waste were then pressed into each other by animal, resulting in their Cupshaped arrangement. Richter's interpretation is well in agreement with the observations made on the Kutch specimen by the author who therefore regards Muensteria as the fodinichnium of a deposit-feeder (probably a worm).

PLATE - 21 (a) Muensteria Sp. - Slender tubes. Cup-shaped arrangement is greatly reduced. Form "C" Locality - Manfara.

PLATE -21 (b) Muensteria Sp. - The Cup-shaped arrangement completely disappears in the specimen which is considered as the end member of the series A to C. Locality - Manfara.

TAENIDIUM

Ichnogenus :- Taenidium HEER 1877

Type Species :- Taenidium serpentinum HEER 1877, p. 117, Pl.45,Figs.9-10b; Hantzschel,1962, p. W 218.

Diagnosis :- Unbranched cylindrical burrows parallel to the stratification and possessing annular constrictions or transverse segmentation.
Plate 22.

Description :- Linear, tubular galleries 1 to 1.2 cm wide upto 10 cm long, and sand filled. Beaded surface is external expression of subconical segments. In some localities the galleries are profuse and parallel, but in some localities they are solitary.

Preservation :- Full relief or positive hyporelief; fill more or less identical with the matrix.

Facies :- Occurs in fine-grained sand and mud rocks of the Adhoi Member.

Associations :- Muensteria, Cylindrichnus, Gyrochorte, Skolithos.

Discussion and interpretation :- Taenidium serpentinum has been reported from the Mesozoic and Cenozoic flysch of Europe by Heer 1877 and from the Ouachita mountains (Ordovician) by Chamberlain, 1971.

PLATE - 22 : Taenidium serpentinum - Unbranched cylindrical burrow parallel to the stratification and possessing annular constrictions.
Locality - Manfara.

Classification :- Endogenic full relief and intergenic hyporelief; deposit feeding (Pasichnia): Worm (?)

Ichnospecies :- Taenidium kutechnesis n. Sp.
Plate 23 a,b.

Diagnosis :- Unbranched cylindrical burrow parallel to the bedding and possessing transverse segmentation.

Description :- Cylindrical tunnel fillings with segmentation reminiscent of Orthoceras. Segmentations are also indicated on outside by annular constrictions (Plate 23b). — As compared with the T. serpentinum the T. kutechnesis is a much larger form with diameter of the tube 2 cm and 7.5 cm long. The usual Cup-shaped arrangement of the tubular galleries is replaced by transverse segmentation.

Preservation :- Full relief; fill identical with the matrix.

Facies :- Occurs in the fine-grained siltstone and clayey rocks of Mae.

Associations :- Gyrochorte, Skolithos, Planolites.

Discussion and interpretation:- The cylindrical burrow

PLATE - 23 (a) Taenidium kutchnesis - Cylindrical tunnel, where the u-shaped arrangement of the tubular galleries is replaced by transverse segmentation. Locality - Mae.

PLATE - 23 (b) Taenidium kutchnesis - Enlargement of the Specimen in "A".

exhibits typical periodic filling of tunnel in backward direction as in Taenidium. The species however, shows characteristic transverse segmentation instead of the beaded structure and hence has been recognized as a new species from Kutch.

PLANOLITES

Ichnogenus :- Planolites NICHOLSON 1873.

Type Species :- Planolites vulgaries Nicholson and Hinde 1875.

Diagnosis :- Planolites includes unlined, rarely branched, straight to tortuous, smooth to irregularly walled or annulated burrows These burrows are circular to elliptical in cross-section, of variable dimensions, and configurations. In fillings essentially structureless, differing in lithology from host rock.

Remarks :- The definition of Planolites is given by Hantzschel (1962) and Crimes and Anderson (1985). According to these authors Planolites is a broad ichnogenus ranging from Precambrian to Recent and is simple in form that many different animal species were probably responsible for it. This definition is so simple that many irregular burrows can meet the specifications. In the years following Nicholson (1875) work at least 30 additional ichnospecies of Planolites have in some way or another been named and described. Recently Pemberton and Frey (1982) have grouped these species into three distinct forms. Planolites beverleyensis, P. annularis and P. montanus primarily

upon size and curvature, and wall characteristics: (1) Small, Curved to tortuous burrows - P. montanus; (2) Large, Straight to gently curved burrows - P. beverleyensis and ; (3) transversely annulated burrows P. annularis.

Planolites is distinguished from Palaeophycus primarily by having unlined walls and burrows fills differing in texture from that of the adjacent rock. Fills also differ in fabric, composition and colour as well. Infills of Planolites represent sediments processed by the trace maker, especially through deposit feeding activities of mobile endobionts. Careful petrographic study of the specimens and their field relationship with physical stratification has often helped the author for their identification.

Ichnospecies :- Planolites beverleynsis BILLINGS, 1862.
Pemberton and Frey, 1982, p. 866,
Fig. p.1, 2,3,4,5.
Plate 24 a,b.

Diagnosis :- Relatively large, smooth, straight or slightly to gently curved or undulose cylindrical burrows.

PLATE - 24 (a) Planolites beverleynsis - Relatively large smooth, cylindrical unlined burrows.
Locality - Chitrod.

PLATE - 24 (b) Planolites vulgaris - Slender smooth burrows.
Locality - Washatwa.

Description :- Cylindrical, smooth walled (Plate 24b) to irregularly branched and unbranched burrows (Plate 24a), typically oriented more or less parallel to bedding. Rare specimens display discontinuous, poorly developed annulations. The occurrence of these burrows range from single (Plate 24,b), isolated specimens to crowded masses in which crossovers, interruptions and reburrowed segments are common.

Preservation :- Full relief; infillings of P. beverleyensis vary somewhat with the lithology of the host sediments (Plate 24a). In thinly bedded sandstones and shales, burrows crossing interfacies are filled with clayey sand and in sandstone beds and shale beds an obvious mixture of sediments is observed.

Facies :- P. beverleyensis is not a facies indicator; it occurs in all types of sediments, ranging from fine-grained sands of Chitrod and Washatwa to the argillaceous silts of Adhoi and Manfara.

Regional and stratigraphic distribution:- From Chitrod to Manfara widespread in most of the stratigraphic units.

Associations :- P. beverleyensis occurs together with all other elements of Kutch trace fossil fauna, without any obvious preferences.

Discussion and interpretation :- P. beverleyensis is distinguishable from P. montanus primarily by the large size, and "graceful curvature" of the former. The irregular and oblique orientation of the burrows according to Fursich (1974) seems to indicate that their producers lacked geotaxis.

Classification :- Endochnia, hypichnial ridges and epichnial grooves.

Ichnospecies :- Planolites annularis WALCOTT, 1890.
Plate 25

Description :- Transversely annulated horizontal burrow, sandstone filled, in full relief in the Sandstone Sole. Burrow diameter 1.5 to 2 cm and maximum observed length is 8 cm. Spacing between annulations 1-2 cm. The structure in Plate 25 is possibly a "mold" of the Planolites annularis burrow. Branching characteristic in the specimen is somewhat reminiscent of Thalassinoides.

Discussion and interpretations:- The burrow compares wall in diameter and morphology with Walcott's holotype figured by Osgood (1970, Pl.77, Fig. 3), although the annulations of the Kutch Specimen are more distinct, with greater separation.

PLATE - 25 : Planolites annularis - Transversely annulated horizontal burrows.

Locality - Kanthkot.

Ichnospecies :- Planolites montanus RICHTER, 1937.
Plate 26a, b.

Type Species :- Planolites montanus Richter, 1937, p. 151 Figs. 1-5; Pemberton and Frey, 1982, p. 869, 870, Pl. 2, Figs, 4,7, Pl. 3, Fig. 9; Howard and Frey, 1984, p. 207, Fig. 15.

Diagnosis :- Relatively small, smooth walled, rarely branched, typically curved to undulant or contorted burrows.

Description :- Irregular, cylindrical, sinuous, undulant and meanderous small burrows with a general tendency towards horizontal development. Burrows diameter is more or less constant. In the Kutch specimen it ranges from 1 to 1.5 cm. True branching is relatively rare. Crossovers, interpenetrations and reburrowed segments are abundant and profuse (Plate 26a, b). Horizontal erosional truncation of vertically or obliquely oriented segments give the appearance of knobby bedding surfaces.

Two distinct size classes of P. montanus were observed in Kutch. The larger form (Plate 26a,b) is considered as typical of the ichnospecies (Pemberton and Frey, 1982). The smaller form is locally found only in Hamirpur is described separately.

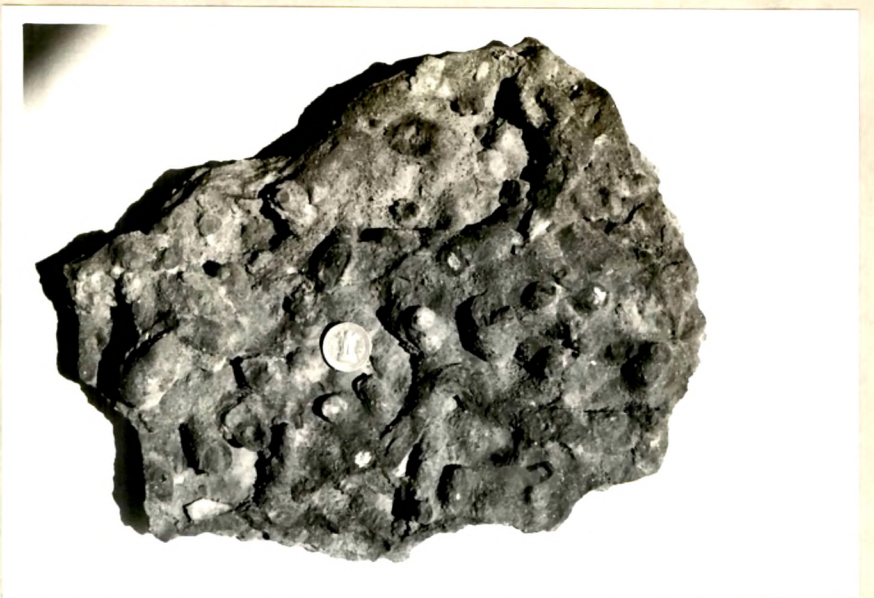

PLATE - 26 (a) Planolites montanus - Relatively small, smooth walled, contorted burrows.
Locality - Chitrod.

PLATE - 26 (b) Planolites montanus - Smooth walled, typically curved to undulant Planolites burrows with tendency to reburrow itself.
Locality - Manfara.

Preservation :- Full relief; burrow fill tends to consists of cleaner, better sorted sediments than the host material

Facies :- Fine grained siltstone-clay rocks of Manfara.

Stratigraphic distribution:- Occurs in the Adhoi Member of Kanthkot Formation.

Discussion and interpretation:- The consistently smaller size and more tortuous course distinguishes P. montanus from P. beverleyensis. According to Frey and Howard (1985) the burrowing of the older burrows in P. montanus represents feeding probes for nutrient-enriched sediment left by the original trace maker, or locomotory excursions along weaknesses in sediment created during fabrication of the original burrow (Pemberton and Frey, 1982).

Classification :- Endichnia, hypichnia ridges and epichnial grooves.

Ichnospecies :- Planolites montanus RICHER, 1937
(small form)
Plate 27

PLATE - 27 : Planolites montanus - Tiny tortuous burrows having unlined walls.

Locality - Hamirpur.

Description :- Tiny tortuous burrows having unlined walls and structureless sediment fills typically differing in colour from the host matrix are the characteristic of this taxon. Virtually all specimen are distinctly less than 1 mm in diameter.

Stratigraphic distribution :- These forms are located in the middle parts of the Kanthkot Formation in the area around Hamirpur.

Discussion and interpretation:- These small burrows are virtually identical to typical specimens of Planolites montanus in all respects other than absolute size. Like the large form, the tiny variety is also located intrastratally.

PYRITE TUBES

Plate 28

Pyrite tubes are commonly found in the calcareous sandstone and siltstone units in Chitrod, Washatwa, Adhoi, Mae and Manfara dome sections. The occurrence of these tubes is generally restricted to the Chitrod Member, the Fort Sandstone Member and the Adhoi Member. The diameter of these simple burrow tubes usually ranges from 0.2 to 1.0 cm. The burrows do not show any preferred orientation and are found in a vertical, oblique and horizontal position in the sediment. In some cases the pyrite fill is weathered into Fe-hydroxid. Other trace found with these are Planolites and Chondrites.

Pyrite tubes are interpreted as the burrows of deposit feeders (annelids, nuculid bivalves etc.). A fairly high concentration of organic matter in the burrow fill is throught to be responsible for the formation, during early diagenetic stages, of Pyrite in this microenvironment. Similar tubes have been reported by Fursich (1977) from the Corallian (upper Jurassic) deposits of England and Normandy.

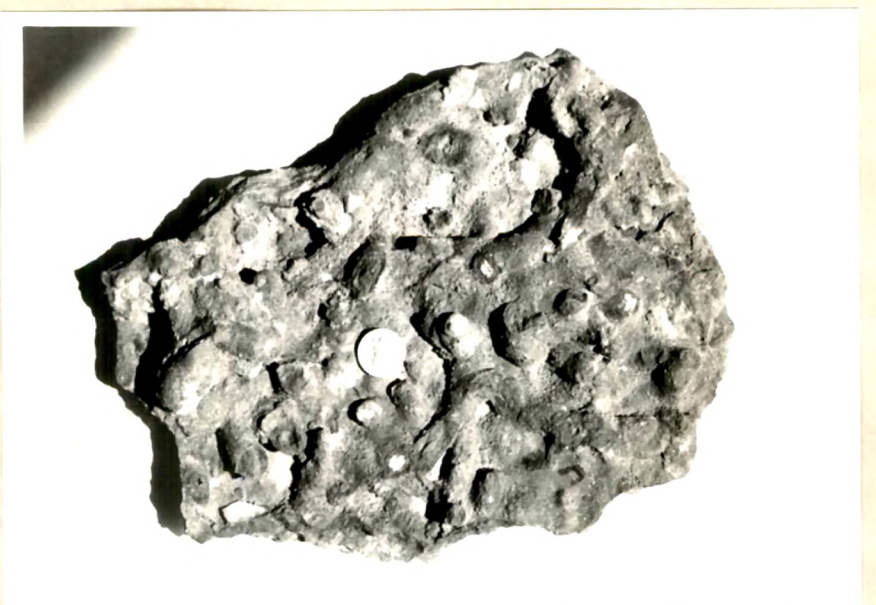

PLATE - 28 : Pyrite tubes - Burrows of deposit feeders, where Pyrite fill is weathered into Fe-hydroxide.

Locality - Adhoi.

PALAEOPHYCUS

Ichnogenus :- Palaeophycus HALL, 1847

Type Species :- Palaeophycus Hall, 1847, p. 7, 8, 63; Hantzschel, 1975, P. 88, W 87; Pemberton and Frey 1982, p. 848-856; Howard and Frey, 1984, p. 206.

Diagnosis :- Infrequently branched, distinctly lined, essentially cylindrical, predominantly horizontal to inclined burrows in which the sediment fill is typically of the same lithology and texture as the host stratum. Palaeophycus is distinguished from Planolites by having a distinct wall lining and sediment fill typically different from the lithology of the host stratum.

Palaeophycus originally defined by Hall (1847) has confusing taxonomic history. As many as 54 ichnospecies are assigned to Palaeophycus. Pemberton and Frey (1982, p. 853) in their latest work recommend only five species of Palaeophycus, based primarily upon wall linings and burrow sculptings:

(1) Distinctly lined, smooth walled, unornamented burrows:
   (a) Thick walled burrows - P. heberti
   (b) Thin walled burrows - P. tubularis

(2) Very thinly lined, longitudinally striated burrows:

(a) Continuous parallel striae - P. striatus
(b) Irregularly anastomosing striae. - P. sulcatus
(c) Alternately striae and annulate. - P. alternatus

Classification :- Interlaminan and intergenic burrows, full relief; crawling or feeding traces (repichnia or Pascichnia); worm (?), Chamberlain (1977,p. 16).

Ichnospecies :- Palaeophycus tubularis HALL, 1847.
Plate 29a, b.

Diagnosis :- Thinly lined unornamented, straight to sinuous cylindrical burrows of variable diameter (Plate 29a).

Description :- Cylindrical, straight (Plate 29a) or less frequently branched burrows, parallel or slightly oblique to the stratification. (Plate 29b). Branching is irregular with angles varying from 10-70°. Burrow walls are irregular and the burrow fill is structureless and lithologically identical to the surrounding matrix. Burrow segments in (Plate 29b) exhibit physical collapse features, representing incomplete filling by sediments. Width and length of the burrow tubes in both the specimens are variable from a few millimeters to 1 and 7 cm, respectively.

PLATE - 29 (a) Paleophycus tubularis - Thinly lined unornamented cylindrical burrows of variable diameters. - Locality - Adhoi.

PLATE - 29(b) Paleophycus tubularis - Collapse structures of P. tubularis indicating incompletely filled Sediments. Locality - Washtwa.

Preservation :- Preserved as endichnia, hypochnia or Epichnia.

Facies :- Occurs in fine-grained sandstones of Adhoi, Mae and Manfara.

Stratigraphic distribution :- Lower and upper Kanthkot Formation.

Discussion and interpretation:- P. tubularis is distinguished from Planolites primarily by wall linings and the character of the burrow fill. Infills of Palaeophycus represent passive, gravity-induced sedimentation within open lined burrows. Collapse features (29 b) show that segments were incompletely filled by this process.

Ichnospecies :- Palaeophycus striatus PEMBERTON and FREY, 1982.
Plate 30a, b.

Diagnosis :- Cylindrical to subcylindrical thinly lined burrows ornamented with threadlike striations.

Description :- Burrows infrequently branched, more or less straight, distinctly sculpted with interwoven small ridges and grooves. Crossovers and interpenetrations are common in some specimens.

Preservation :- Full relief; burrow fill identical with the surrounding matrix. Matrix adjacent to

PLATE - 30(a) Paleophycus striatus - Cylindrical, thinly lined burrows ornamented with threadlike striations. Locality - Manfara. Also note development of Skolithos.

PLATE - 30 (b) Paleophycus striatus - Another specimen from the same Locality.

base of burrow exhibit tensional microfaults.

Facies :- Fine-grained sandstones of Washatwa and Manfara.

Regional and stratigraphical interpretations:- Occurs in the Washatwa and Kanthkot Formations.

Discussion and interpretation :- P. striatus is distinguished from P. laternatus by consisting longitudinal striations rather than alternating striations in the latter.

Classification :- Preserved as epichnia near lithologic interfaces or more commonly as hypichnial ridges.

Ichnospecies :- Palaeophycus alternatus PEMBERTON and FREY, 1982, p. 863, Pl. 2,3,4.
Plate 31.

Diagnosis :- Alternately striate and annulate burrows of periodically varying diameter.

Description :- Slightly curved, thinly lined burrows of regularly varying diamensions, finely striated longitudinally and in places distinctly annulated. Striae consists of thin wary ridges and grooves, best developed where annulations are absent. Where annuli are well

PLATE - 31 : Paleophycus alternatus - Alternately striate and annulate burrows of varying diameters.
Locality - Washatwa.

developed, 4 to 5 per cm, burrow diameter decreases. The specimens are rarely branched and exhibit little burrow collapse.

Preservation :- Preserved as epichnial ridges. Full relief; burrow fill identical with the matrix.

Regional and stratigraphic distribution :- Occur in the Adhoi Member of the Manfara section.

Discussion and interpretation:- The periodic change from striate to annulate parts of burrows according to Pemberton and Frey (1982) reflects a change from direct locomotory to peristatic movements by the trace maker.

CHONDRITES

Ichnogenus :- Chondrites VON STERNBERG 1853

Types species :- Fucoides targionii Brongniart, 1828, p. 56, Pl.4, 2-6 (designated by Andrens 1955, p. 130); Chondrites Sp. Howard, 1966 b, p. 43; Howard and Frey 1984, p. 202-203, Fig. 6.

Diagnosis :- Dendritic, smooth walled, regularly but asymmetrically ramifying small burrow systems that do not interpenetrate or inter-connect. Diameter of components within a given system remains essentially constant.

Remarks :- Chondrites is a well established genus that is generally easily recognized and understood, but that contains so many species that it is difficult to determine its synonymy. More than 170 species of Chondrites have been named (Chamberlain, 1977), and are probably junior synonyms of the few species first named by Brongniart (1823, 1828). Chondrites is thought to be produced by a variety of organisms such as Sipunculids, Polychaetes, Anthoptiloid sea pens and arthopods (Pickerill et al., 1984, p. 419).

According to Frey and Howard (1985) identification of the ichnospecies must await monographic

restudy of the Chondrites ichnogenus. The material studied by the author although appears belonging to some new varieties of Chondrites forms its assignment to different species has not been attempted in this studies. At least four species are present in the Kutch material; preserved as hypichnia and exichnia, and interpreted as feeding structures.

Chondrites species A

Plate - 32a

This species is located in the Chitrod Sandstone Member. The burrow system is densely packed with horizontal network of tubes. The tube diameter ranges from 0.1 - 0.3 cm and is constant within one tunnel system. Regular branching can be observed in some specimen. The trace is associated with Planolites, Pyrite tubes, Sp. Suevica.

Chondrites species B

Plate - 32b

The species displays relatively flat burrows that branch more or less regularly and are of even width throughout. System upto 10 cm across. Burrows 1 to 4 mm in diameter. Single main burrow shows two primary galleries branching in opposite directions. Some secondary branches are also observed in the specimen (Plate 32b). Occurring in Adhoi Member in Manfara Section.

PLATE - 32 (a) Chondrites Sp. A. - Dendritic, smooth walled asymmetrically ramifying burrow system.
Locality - Chitrod.

Chondrites

PLATE - 32 (b) Chondrites Sp. B - Relatively flat burrows that branch regularly and are of even width throughout Locality - Manfara.

Chondrite Species C

Plate - 33a

Chondrites type C is a smaller and essentially horizontal network preserved as mold on the bedding plain. The burrow system is without consistent pattern, but individual burrows were more or less regular in appearance. Burrows less than 1 mm in diameter; maximum lateral spread of a single frond along a bedding plane, about 4 cm. Occurrence in the Adhoi Member at Mae, Manfara sections.

Chondrite Species D

Plate - 33b.

Several mud and sand filled endogenic burrows, with nearly vertical tunnels. There are a number of short, straight secondary galleries that show a tendency to become horizontal distally. All burrows have smooth walls and are 1 to 1.5 mm wide and show no appreciable widening or thinning. Preserved as full relief, with tubes fill in most cases darker than the surrounding sediment and highly argillaceous. Occurs in the thin bedded argillaceous and silty sediments in Washatwa, Halrae, Mae and Manfara sections.

PLATE - 33 (a) Chondrites Sp. C - Tiny, essentially horizontal network of burrows (mold) on the bedding plain. Locality - Hamirpur.

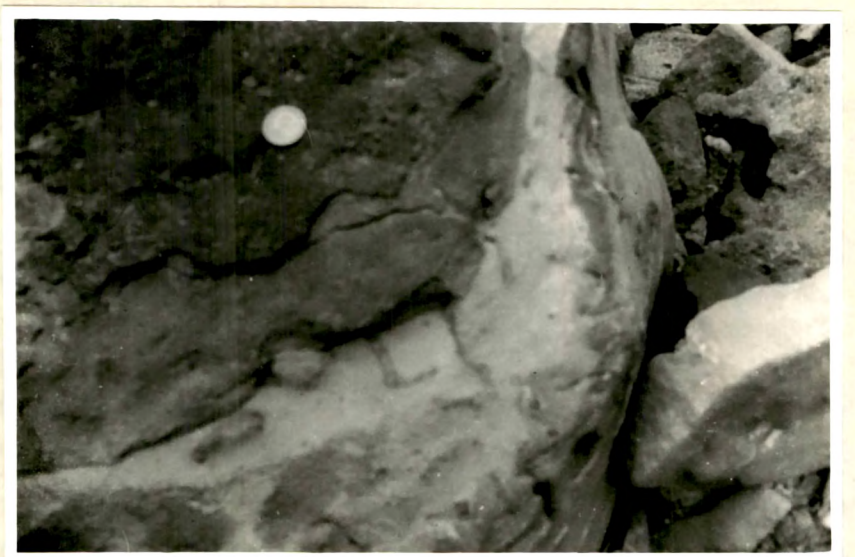

PLATE - 33 (b) Chondrites Sp. D. Tiny, Vertical burrow tunnels with tendency to become horizontal distally. Locality - Mae.

PHYCODES

Ichnospecies :- Phycodes RICHTER, 1850.

Diagnosis :- Fan or radial system of horizontal branching burrows. Burrows essentially uniform width throughout, long, linear or slightly curving. Branching close together.

Ichnospecies :- Phycodes palmatum HALL, 1852; Crimes and Anderson, 1985, p. 330, Fig. 6.15, 6.17.

Plate 34 a.

Description :- Large bundles of burrows with minimal spreite development, sandstone filled. Individual burrows mostly 1 to 1.5 cm in diameter, complete trace 7-8 cm long. Burrows spread out from place of origin like a bunch of flowers.

Preservation :- Endogenic full reliefs; deposit feeding (fodinichnia); Worm (?) burrows.

Facies :- Fine-grained sandstone-siltstone facies of the Kharol Member in Washatwa Formation.

Associations :- Planolites, Chondrites, Rhizocorallium.

PLATE - 34 (a) Phycodes palmatum - Fan or radial system of horizontal branching burrows.
Locality - Chitrod. Arrow indicate P. coronatum.

PLATE - 34 (b) Phycodes coronatum - Coronate-like arrangement of burrows.
Locality - Chitrod.

Discussion and interpretations:- These are large burrow systems similar in size and form to examples described by Crimes and Anderson (1985) from the lower Paleozoic of Newfoundland (Canada).

Ichnospecies :- Phycodes coronatum CRIMES AND ANDERSON, 1985, p. 329, Figs. 10-5, 10.6, 11.

Plate 34a,b.

Diagnosis :- Burrow circular, parallel to bedding with vertical branches from outer margin of circle (Plate 34a right corner). The name indicates Coronet-like arrangement of burrows (Plate 34b).

Description :- Circular burrows including about 12 small knobs on its outer margin, representing roots of vertical ascending burrows. Diameter of complete system about 5 cm. circular burrow and knobs about 0.5 to 0.6 cm diameter.

Association :- Closely associated with P. palmatum burrow system (Plate 34a).

ASTEROSOMA

Ichnogenus :- Asterosoma V. OTTO, 1854.

Type species :- Asterosoma radiciforme V. Otto, 1854; p.15, Pl.2, Fig. 4; Pl. 3, Fig. 1-2.

Diagnosis :- Star-shaped positive hyporeliefs with bulbous rays which taper towards the ends; centre elevated (after Fursich, 1974).

Ichnospecies :- Asterosoma radiciforme V. OTTO, 1854. Plate 35a,b.

Description :- The Kutch specimens consists of elliptical and club-shaped tubes originating from a central point (Plate 35a,b). The tubes have a bulbous middle region, and a rounded distal termination. The club-shaped tubes are arranged in a semi-circle; their internal structure consists of concentric laminae. The external surface of the tubes is smooth except for a few constrictions. Individual burrows range from 0.6 to 1.75 cm in diameter and about 4-6 cm in length, and most are inclined to the bedding at approximately 25°. Many of the tubes have several smaller branches fanning from the end.

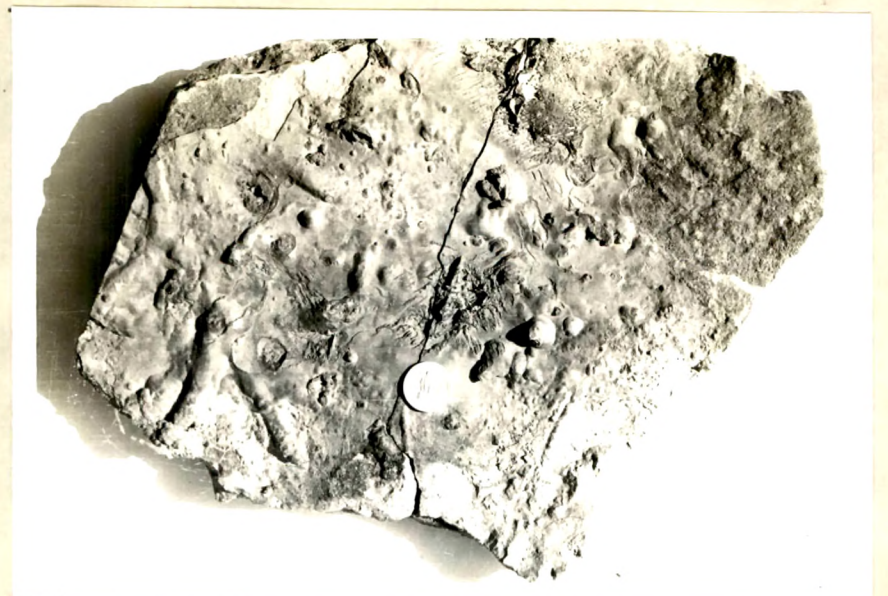

PLATE - 35 (a) Asterosoma radiciforme - Star-shaped bulbos rays which taper towards the ends. Note badly preserved -- reminant of either a worm or a Crustacean in the center. Arrow indicates Phycodes coronatum. Locality - Manfara.

PLATE-35 (b) Asterosoma radiciforme - Bulbos rays of A. radiciforme. Locality - Manfara.

Preservation :- Preserved on bottom of thin bedded sandstone beds as convex hyporelief and as full relief within the beds.

Facies :- Fine-grained silty sandstone in Manfara-Adhoi Member.

Associations :- Phycodos coronatum, Muensteria, Gyrochorte.

Discussion and interpretation :- The tubular nature of the galleries and manner of sediment working of Asterosoma and similar burrows suggests the feeding pattern of a worm. The animal seems to have repeatedly probed into the sediment to enlarge the gallery and work more and more sediment vertically and laterally. The nature of the crushed remains badly preserved along with the Kutch specimen (Plate 35b) confirms the assumption that the burrows are made by worms, which exploited the sediments in a radial direction starting from a central tube. Close association of Phycodes coronataum suggest the same worm responsible for the construction both these varieties of burrows.

GYROPHYLLITES

Ichnogenus :- Gyrophyllites GLOCKER, 1841.

Type species :- Gyrophyllites Glocker 1841, P. 322, Fig. , p. 322; Fursich, 1974, p. 38, Fig. 31a,c.

Diagnosis :- Vertical shafts from which rosettes of short, simple (feeding) tunnels radiate at different levels, as in a mine.

Gyrophyllites Sp.

Plate 36

Description :- Rosette-like trace fossils, consisting of 8-10 flat, petal-shaped radiating grooves bearing rounded plugs inside. In the centre, a plug of 0.6 to 0.7 cm in diameter is also visible. The diameter of the whole structure varies from 3 to 4 cm. The radiating grooves are arranged fairly regularly and are separated from each other by a pronounced rim.

Preservation :- Negative epirelief.

Facies :- Fine-grained sandstones in Manfara and Mae section. (Adhoi Member).

Associations :- Gyrochorte, Muensteria, Scolicia.

PLATE - 36 : Gyrophyllites Sp. - Vertical Shafts from which rosettes of short, simple tunnels radiate - Locality - Mae.

Discussion and interpretations:- Fursich (1974, Fig. 31,32) figured star-like trace fossil from the upper Jurassic of England and Normandy which are of more or less the same shape as the Kutch forms. Similar fossils have, till recently been described as fossil medusae as in the case of Palaeosemaeostoma. Their interpretation as trace fossil as suggested by Fursich (1974) is far more logical. The central plug according to him is easier to explain as central shaft than as the pedicle of the medusa. This shaft was inhabitated by an organism which was also responsible for the rosette pattern. It is very likely, that the rosettes form the only preserved part of a three-diamensional feeding system and have, therefore, been included into Gyrophyllites Glocker, 1841.

GYROLITHUS

Ichnogenus :- Gyrolithus DE SAPORTA, 1884

Ichnospecies :- Gyrolithus polonicus Fedonkin, 1980. Plate 37.

Diagnosis :- Dextrally or sinistrally coiled burrows, upright in deposit, surface with rounded or elongated processes.

Description :- Sand infilled on sandstone sole consisting of a burrow forming an almost complete circle. In the Kutch specimen the diameter of the burrow is about 2.5 cm and diameter of the complete trace 8 cm (Plate 37). Diameter of the whole system is almost uniform.

Facies :- Fine-grained sandstone of Adhoi Member in Manfara section.

Associations :- Gyrochorte, Phycodes

Interpretation :- As suggested by Hantzschel (1962), these burrows are probably made by decapods.

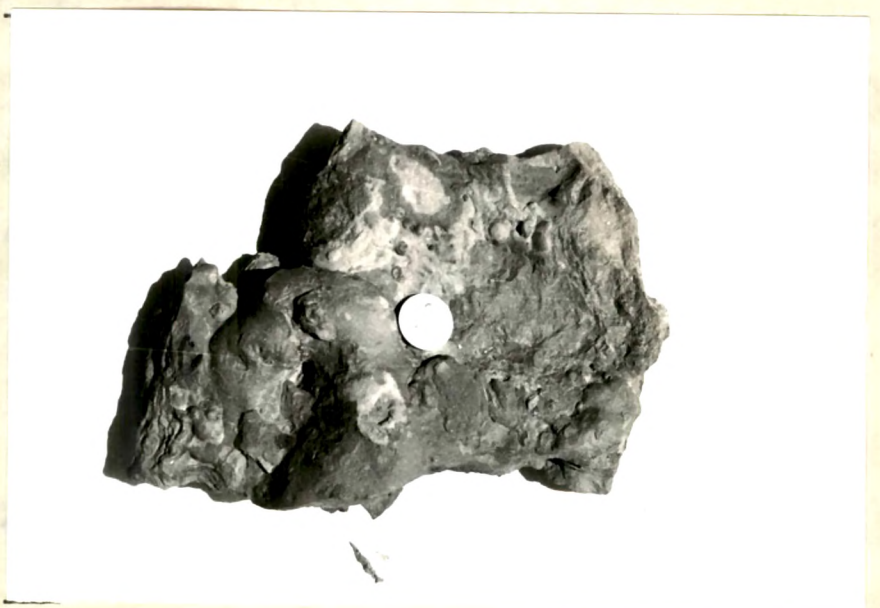

PLATE - 37 : Gyrolithus poionicus - Coiled burrows, Surface with rounded or elongated processes.
Locality - Manfara.

TEICHICHNUS

Ichnogenus :- Teichichnus SEILACHER, 1955, p. 378,379; Seilacher 1957, Fig. 2, Pl. 23, Fig. 2; Martinsson, 1965, p. 211-219; Frey, 1970, p. 17; Fursich, 1974, p.40, Fig. 33; Frey and Howard 1985, p. 391, 392, Figs. 21,22,23.

Diagnosis :- Bladelike and gently curved, rarely branched spreiten structures consisting of several closely concentric, horizontal or inclined, longitudinally nested burrows inosculating to simple, singular tunnels. Burrows within a given spreite displaced upward (retrusive) or downward (protrusive), and oriented at various angles with respect to bedding.

Remarks :- Teichichnus is plagued by considerable ambiguity in the literature. Some of the "teichichnians" described by Martinsson (1965) and Pedersen and Surlyk (1983) according to Frey and Howard (1985) seem to have more common with Phycodes (Seilacher, 1955), or Trichophycus (Osgood, 1970; Frey and Chowns, 1972), than with Teichichnus. Similarly, many of the "teichichnians" described by Chisholm (1970) are referrable to Rhizocorallium or other spreiten burrows (Sellwood 1970; Fursich, 1974). In Teichichnus, the last-formed burrow tends to be considerably less distinct

within the spreite itself than are those of Rhizocorallium, and Diplocraterion, and individual burrows comprising the Spreite are more tightly knit and more nearly plannar in replication than those of Phycodes or Trichophycos.

Ichnospecies :- Teichichnus rectus Seilacher, 1955. Plate 38 a.

Diagnosis :- Teichichnus that has the spreite more or less straight and lies in a vertical plane; longitudinal axes of spreiten oriented at various angles with respect to bedding.

Description :- Long, wall-like burrows formed by vertical displacement of horizontal and oblique tubes. The retrusive part of the Kutch specimen (Plate 38a) is very well preserved. This retrusive part is straight to somewhat sinuous and does not show any signs of branching. Later displacement in the vertical plane can be observed in the Kutch specimen. It is found lying at an angle of about 35° to the horizontal in the sediment. Darker, highly argillaceous materials marks the individual laminae of the retrusive structure thereby making the internal structure more easily visible. The diameter of the final burrow on top of

PLATE - 38 (a) Teichchnus rectus - Specimen with Spereite more or less straight but oriented at angles to the bedding. Locality - Kanthkot.

PLATE - 38 (b) Teichchnus repandus - Teichchnus with retrusive Spreite having a characteristic U-shaped plain view. Locality - Kanthkot.

retrusive part is considerably smaller than the diameter of the basal part.

Preservation :- Full relief; fill identical with the matrix.

Facies :- T. rectus is common in the silt and fine sands of the Fort Sandstone Member, especially in the Kanthkot Section.

Associations :- Spongeliomorpha, Cylindrichnus, Planolites.

Discussion and interpretation :- Seilacher (1955, p. 122) interpreted Teichichnus as the result of the upward shift of a more or less horizontal burrow which might be U-shaped. Chisholm, 1970 (in Fursich, 1924,p.41) described Teichichnus and found forms intermediate between Teichichnus and Rhizocorallium and suggested that these two ichnogenra and Diplocraterion are closely related to each other. Fursich (1974), however, suggests that this relationship is purely morphological one and does not indicate similar behaviour or a related trace maker. Seilacher (1957, p. 203) has figured structures comparable to Teichichnus made by the Recent Nereis diversicolor.

Classification :- Endogenic full relief and intergenic hyporelief; deposit feeding (fodinichnia) worm ? (Chamberlain, 1977).

Ichnospecies :- Teichichnus repandus - CHAMBERLAIN, 1977, p. 20, Fig. 5 H-I.
Plate 38 b

Diagnosis :- Teichichnians in which the plane containing the spreite is persistantly and markedly inclined with respect to bedding. The retrusive spreite furthermore having a characteristic U-shaped plain view.

Description :- The Kutch specimen of T. repandus include consistently inclined, Planner to subplanner Spreiten, gently curved U-shaped burrows. Individual burrows comprising the Spreite commonly exhibit vague small buldges, imparting an obscure annulate aspect to the burrow walls. Prominent pustule-like buldges are also present. The Kutch specimen very well compares with that of the Chamberlain (1977). This specimen is U-shaped form with 5 to 6 cm width, 1 to 2 mm high and 6 to 7.5 cm long.

Facies :- Fine to medium-grained sandstone in the Fort Sandstone Member, especially in Kanthkot.

Discussion and interpretation :- As interpreted by Warme, Kennedy, and Schneiderman (1973), Teichichnus is a eurybathic species known from the abyssal cores of the Deep Sea Drilling Project (DSDP) in equitorial pacific. According to Fursich (1975) this species

also occurs in shallow, nearshore subtidal areas as well as lagoons. The Kutch Specimen indicate one [illegible] of such an environment as envisaged by Fursich (1975).

ROSSELIA

Ichnogenus :- Rosselia DAHMER, 1937.

Ichnospecies :- Rosselia Dahmer, 1937, p. 532, 533; Chamberlain 1971, p. 240; Frey and Howard, 1985, p. 388,389, Figs. 20.1, 20.8.

Diagnosis :- Conical to irregularly bulbos or funnel-shaped structures, vertical to horizontal, consisting either of a small central burrow surrounded by broad, cone-in-cone laminae, or of Spreite-like helicoid swirls surrounding a cone, both tapering downward to a concentrically walled, subcylindrical stem. (Adopted from Frey and Howard, 1985).

Remarks :- The basal stem of Rosselia typically is identical in construction to Cylindrichnus concentricus. Although the overlap in morphology presents a potential problem differentiating these ichnogenra, it does help distinguish Rosselia from Monocraterion, the base of which is a simple shaft. In addition, laminae with Rosselia reflect obvious sediment processing by a deposit feeder, whereas those in Monocraterion indicate predominently physical processing, possibly combined

with an escape response by the organism. Conceivably, some previous work on Monocraterion inadvertently incorporated specimens of Rosselia socialis, thereby additing to the early confusion in interpreting Monocraterion and perhaps accounting for the paucity of literature. Citations of Rosselia (To complicate matters further, Monocraterion probably is congeneric with Skolithos. —— Frey and Howard, 1985, p.388)

Similarly, Chamberlain (1971, p. 232,240), and others noted a similarity in fabrication between Asterosoma and Rosselia, and this relationship also needs further study. Such observations including occasional but complete intergradations among specimens individually referrable to Skolithos, Cylindrichnus, Rosselia, and Asterosoma has led to the earlier inconsistencies in nomenclature. However, considered from a strict ethological view point, Rosselia has been retained by the present author as a separate ichnogeneric form.

Polycylindrichnus (Fournier, Pemberton and Rosk, 1980), is similar to Rosselia in many respects but lacks the characteristic small, central core. A significantly different form of behaviour is suggested by this structure, although it, too, needs additional clarification with the above group of trace fossils.

As claimed by Frey and Howard (1985) the greatest potential problem in differentiating all these ichnogenra results not from similarities in fabrication, but rather, from the vagaries of preservation. Among vertical or steeply inclined specimens, for example, severe substrate erosion could reduce Rosselia to its Cylindrichnus like stem, In most cases, however, sufficient numbers of gently inclined to horizontal specimens were found to help document both the fabrication and preservation of the original burrows.

Ichnogenus :- Rosselia socialis Dahmer, 1937.
Plate 39.

Diagnosis :- Conical to irregular bulbous structures, essentially vertical consisting of a small central burrow surrounded by broad, concentric funnel-like laminae, tapering downward to a concentrically walled stem.

Description :- The Rosselia socialis of Kutch is usually located in colonial forms. Most of these specimen are large, elongated, inverted cones. A few are squat and bulbous, and these tend to be the forms with larger diameters. Orientations are predominantly vertical to slightly inclined. The largest single specimen observed include 6.5 cm in diameter with maximum length of 45 cm.

PLATE - 39 : Rosselia socialis - Conical bulbos structures consisting of a central burrow surrounded by concentric funnel-like laminae.

Locality - Chitrod.

Most of the specimens are circular in cross-section (Plate 39), although a few are elliptical. The latter show no particular preferred orientation.

Preservation :- Preserved as endichnia.

Facies :- Occurs in the Chitrod Sandstone Member in the vicinity of the Chitrod dome.

Association :- Cylindrichnus concentricus, Spirophyton, Thalassinoides.

Discussion and interpretation:- Isolated subconical specimens of Cylindrichnus concentricus tend to develop the morphology of small, incompletely expanded specimen of Rosselia socialis. However, of R. socielis readily distinguish it from C. concentrichnus.

Classification :- R. socialis preserved as endichnia is interpreted as feeding structures.

ZOOPHYCOS

Ichnogenus :- Zoophycos MASSALONGO, 1855.

Ichnospecies :- Zoophycos circinnatus Bronguiart, 1828, Chamberlain, 1971, p. 242, Pl.29; Bottjar, 1985, p. 292, Fig. 7.4. Plate 40.

Diagnosis :- Zoophycos is a variably shaped Spreiten structured composed of numerous small protrusive more or less U- or J-shaped burrows of variable length and orientation with Spreiten arranged as tabular or helicoid spirels giving an overall circular, elliptical or lobate shape (Hantzschal, 1962).

Description :- The Kutch specimen is typically planar, horizontal with uniformly thick laminae. Maximum vertical thickness is 1 to 2 mm; length of the laminae 25 cm. Cross-section of the laminae commonly with lunate structures (Plate 40). Colour of lunar different from main burrow fill, but same as surrounding sediment. Lunae composed of grains coarser than those of intervening sediment. The original protrusive Spreite in the Kutch specimen appears to be polished smooth because of erosion.

PLATE - 40 : Zoophycos circinnatus - Planner, horizontal burrows with Spreiten arranged as helicoid spirals. Locality - Chitrod.

Preservation :- Endogenic; full relief.

Facies :- Occurs in Chitrod Sandstone Member, locality Chitrod and Washatwa and in Adhoi Member in Manfara.

Discussion and interpretation :- Zoophycos is generally believed to be the structure of a sediment-mining organism, but the specific affinities of the organism are unknown. It is, however, attributed to the deposit-feeding activity of Polychaetes (Bischoff, 1968), Sipunculids (Wetzel and Werner, 1981), and Umbellulids (Bradly, 1973).

Classification :- Endogenic, full relief; deposit feeding (Pascichnia); Polychaete (?).

REPICHNIA - (CRAWLING TRACES)

GYROCHORTE

Ichnogenus :- Gyrochorte · HEER, 1865

Type Species :- Gyrochorte comosa HEER, 1865, p. 142, Pl. 9, Fig. 12; Fursich, 1974, p. 42, Fig. 34.

Diagnosis :- Ridges on bedding planes with biserially arranged, obliquely aligned transverse pads, both series separated by median furrow.

Ichnospecies :- Gyrochorte comosa Heer, 1865.

Plate 41 a,b.

Diagnosis :- The Kutch specimen typically shows the development of sides on the bedding planes with biserially arranged obliquely alligned transverse pads, both series are separated by median furrow.

Description :- The trace includes long winding ridges on the upper surface of sandstone beds, with the width of ridges 0.3 - 0.7 cm; and maximum length observed around 60 cms. The height of the relief is usually less than 1 mm. The angle between the pads and the median furrow varies from 45° to 55°. The ridges at places end abruptly. Crossing over occurs

Plate - 41(a) Gyrochorte comosa - Ridges on the bedding planes with biserically arranged and obliquely aligned transverse pads.
Locality - Manfara.

Plate - 41 (b) Gyrochorte comosa - Another specimen of the same Locality - Manfara.

frequently in such a way that the earlier formed ridge is not destroyed.

Preservation :- Endogenic scour cast.

Facies :- G. comosa occurs in fine-grained sandstone and siltstones of the Kanthkot Formation, very often associated with asymmetric or oscillation ripples.

Regional and stratigraphic distribution:- Occurs in Washatwa, Adhoi, Nara, Mae and Manfara sections, in both the Upper and Lower Kanthkot Formations.

Associations :- Muensteria, Scolicia, Gyrophyllites, Skolithos, Cylindrichnus.

Discussion and interpretation:- After early interpretations, — such as impressions of Ophiurids (Quenstedt, 1858) or egg strings of molluscs (Heer, 1865) as in (Fursich, 1974, p. 43), Gyrochorte was later thought to represent tunnel structures, made by amphipods. Weiss (1940, 1941) and Seilacher (1955), however, interpreted Gyrochorte as produced by a polychaete or worm-like animal moving obliquely through the sediment. Hallam (1970) discussed the origin of Gyrochorte at some length and concluded that the previous interpretation i.e. the ridges as the product of tunneling amphipods seems to be more

likely than Wess' model. Recently, Heinberg (1973) was able to show in a detailed study, based on excellently preserved material from East Greenland, that Wess' Interpretation was correct and that Gyrochorte in fact produced by an elongate organism moving obliquely through the sediment in search of food.

HELMINTHOIDA

Ichnogenus :- Helminthoida SCHAFHAUTL, 1851.

Diagnosis :- Smooth, numerous, parallel, equidistant, concentric furrows about 2 mm wide. According to Rudolf Richter the trace comprises "guided meanders".

Remarks :- According to Crimes and Anderson (1985, p. 321) this ichnogenus was introduced for burrows with numerous very regular meanders, often parallel and closely spaced.

Ichnospecies :- Helmintoida crassa Schafhautl, 1851. Plate 42a.

Diagnosis :- The specimen with numerous meanders, very closely spaced.

Description :- Meanders 0.2 to 0.6 cm in diameter preserved on Sandstone soles. This form includes compressed meanders and shows much diversity due to closeness of the individual concentric furrows and loops. Some of these meanders show tendency to coil. Surface of the burrow smooth except where some transverse annulations are present.

Preservation :- Endogenic; Full relief.

PLATE - 42 (a) Helmintoida crassa - Burrows with numerous closely spaced meanders.
Locality - Manfara.

PLATE - 42 (b) Helmintoida crassa- Another specimen from the same Locality - Manfara.

Facies :- Fine-grained Sandstone of Chitrod and Adhoi Members respectively.

Regional and stratigraphic distribution:- Occurs in Chitrod and Manfara Sections in Washatwa and Kanthkot Formations.

Discussion and interpretation:- The specimen in Plate 42 is close to Crimes and Anderson (1985, P. 7, Fig. 1), in the tight meander pattern with a tendency of concentric furrows, but differs in its simple meandering pattern with tendency to coiling. It differs only in the burrows being slightly irregular, however, the precise meandering pattern of the species cannot be ignored.

Ichnospecies :- Helminthoida miocenica Sacco, 1886.
Plate 42.

Description :- Smooth burrows in full relief preserved on sandstone soles, showing a meandering less tight and regular than in H. crassa. Burrows with about 0.6 cm. Some burrows cross-cut the others. Occurrence of these traces restricted to the Adhoi Member in Manfara Section.

HELMINTHOPSIS

Ichnogenus :- Helminthopsis HEER, 1877

Diagnosis :- Simple meandering tracks, but not as strictly developed as Helminthoida.

Ichnospecies :- Helminthopsis abeli Ksiazkiewicz, 1977; Crimes and Anderson, 1985, p. 325, Figs. 6.9, 6.10, 7.6, 7.7.

Plate 43 a,b.

Description :- Smooth, sandstone filled burrows preserved on upper as well as lower bedding surfaces. Burrow diameter is 0.4-0.8 cm. Some traces traceable over 0.5 to 1 m in length. Meanders are variable but often show tendency to loop.

Preservation :- Endogenic; Full relief.

Facies :- Shale rocks in the Kanthkot Formation.

Regional and stratigraphic distribution:- Occurs in Manfara and Mae Sections only.

Discussion and interpretation:- Differs from Helminthoida crassa in its loosely meandering pattern. According to Crimes and Anderson (1985) both these traces may have been made by the same animal.

PLATE - 43 (a) Helminithopsis abeli - Smooth sandstone fill meandering patterns.
Locality - Manfara.

PLATE - 43 (B) Helminithopsis abeli - Another specimen
. Locality - Mae.

NEONERITES

Ichnospecies :- Neoneriten uniserialis SEILACHAR, 1960; Crimes and Anderson, 1985, p. 627, Fig. 10.2.
Plate 44 a.

Diagnosis :- Curved, chain of uniserially arranged Sediment pods.

Description :- The Kutch specimen of Neonerites uniserialis typically displays a single row of small, unornamented sand-filled spheres with 0.5 cm diameter, forming a striight or slightly curved chain on sole of sandstones. Spheres either isolate or adjacent but never overlapping. Chains 15 to 20 cm in length.

Preservation :- Preserved in convex hyporelief.

Facies :- Sandstone-siltstones of Adhoi Member in Manfara.

Associations :- Gyrochorte, Paleophycus, Rhizocorallium.

Discussion and interpretation:- The Kutch specimen confirms in size and morphology with material figured by Crimes and Anderson 1985, and that of Seilacher, L. Jurassic-M. Jurassic (in Hantzschel, 1962, p. 205).

PLATE - 44 (a) Neonerites uniserialis - Curved chain of Uniserially arranged sediment pods.
Locality - Manfara.

PLATE - 44 (b) Nereites Sp. Meandering feeding trails with narrow central axis and regularly spaced lateral lobelike elevations.
Locality - Ramwao

NEREITES

Ichnogenus :- Nereites MACLEAY, 1839

Nereites Sp.

Plate 44 b.

Diagnosis :- Meandering feeding trails with narrow central axis and regularly spaced, lateral, leaf-shaped or lobelike, finely striated elevations.

Description :- Irregular meanderings on top surface of sandstone beds comprising median tape-like furrow, flanked on both sides by Smooth, Ovate lobes. Width of trails about 1 to 2 cm; however trails highly variable in width and length. Maximum observed length 20 cm.

Preservation :- Convex hyporelief.

Facies :- Sandstone-Siltstone facies in Manfara, Ramwa

Associations :- Scolicia, Palaeodiction.

Discussion and interpretation:- Nereites is considered by Seilacher (1964) to be typical of deep water but examples have been described from undoubted shallow-water sediments, in the Carboniferous of Kansas (Hakes,1976);

Devonian of north Spain (Garcia Ramos, 1976); and the Precambrian- Cambrian Name Group of Nambia (Crimes and Grams, 1982); in Crimes and Anderson,1985 (p. 327). According to Hantzschel (1962) the trails are made by annelids, or gasterpods.

CURVOLITHOS

Technogenus :- Curvolithos FRITCH, 1908.
Curvolithos Sp.
Plate 45.

Diagnosis :- Trilobate, sinuous to meandering and horizontal trails. The trails are ribbon-shaped, flat, consisting of 3 parts, with broad smooth central stripe, and lateral ridges.

Preservation :- Preserved as hypichnia.

Description :- Straight, horizontal traces, preserved on the fine-grained Sandstone Sole and consisting of broad smooth, central stripe and narrow lateral ridges. Trails 1.5 to 1.7 cm across, extending many centimeters through tortuous paths. Faint oblique annulations observed in places along lateral parts of central lobe. Sharp median ridge well developed.

Association :- Gyrochorte, Neonerites.

Facies :- Fine-grained Sandstone, siltstone, facies of Adhoi Member in Manfara.

Discussion and interpretation:- Curvolithos is interpreted as Combined Crawling-grazing traces by Frey and Chowns (1972). According to Hantzschel (1962,p. 189) this form ranging from Cambrian to Tertiary is produced by Gastropods.

PLATE - 45 : Curvolithos Sp. - Trilobate meandering ribbon shaped trails.

Locality - Manfara.

DIDYMAULICHNUS

Ichnogenus :- Didymaulichnus mittensis YOUNG, 1972

Diagnosis :- Smooth, straight and gently curving burrows consisting of two lobes separated centrally by distinct furrow and flanked laterally by bevels which are not continuous. Traces commonly crossing and occurring in profusion on bedding planes.

Didymaulichnus Sp.

Plate 46

Description :- Bilobed structure preserved in convex relief on soles of beds. Lobes divided by a well-defined medial furrow. Trace 0.5 to 1 cm wide, about 1 mm deep and extends for over 10 cm. Surfaces of lobes are smooth to slightly undulatory. Two traces are found intersecting at the centre.

Preservation :- Preserved in positive relief on Sandstone Siltstone Soles in Mae and Manfara Sections.

Association :- Scolicia, Crossopodia

Discussion and interpretation:- As suggested by Hakes (1977), the trace is thought to be the trail of gastropod. Similar traces have been reported by him from the Pennsylvanian rocks of Kansas, U.S.A.

PLATE - 46 : Didymaulichnus Sp. - Bilobed structures with a distinct central furrows.
Locality - Mae.

SCALARITUBA

Ichnogenus :- Scalarituba WELLER, 1899.

Diagnosis :- Straight or sinuous burrows upto 1 cm wide and characterized by closely spread (2-3 mm) transverse Scalariform ridges. Burrows are parallel to Stratification.

Ichnospecies :- Scalarituba missouriensis Weller,1899, p.12, Pl.6, Fig. 1;
Neonereites uniserialis Seilacher, 1960, p.48, Text fig. 3, Pl.2, Fig. 1;Hantschel, 1962, p. 205, fig. 126-1; Chamberlain, 1971, p. 229, Pl. 31, fig. 1,2.

Plate 47.

Description :- Continuous, semicircular, flat, looping meanders. Strings 3-4 mm wide, loops 5-6 mm across and 5 to 10 cm long. The traces are typically parallel to the stratification, with irregular biserially arranged lobes and punctules. Lateral to each lateral lobe on some specimen is a narrow, hemicircular furrow (faintly seen).

Preservation :- Epigenic; full relief.

Facies :- Fine-grained, Sandstone, Shale rocks in Washatwa, Mae, Nara, Manfara Section.

PLATE - 47 : Scalarituba missouriensis - Sinuous burrows, characterized by closely spread transverse Scalariform ridges.
Locality - Nara.

Associations :- Nereites, Neonereites, Helminothopsis.

Discussion and interpretation:- According to Chamberlain (1977) Scalarituba missouriensis (fecal-ribbon form) is a cosmopolitian and eurybathic form found in the intermediate depth and deep water facies and that Scalarituba missouriensis, Nereites uniserialis, and Nereites biserials probably are synonyms. The Kutch structure (Plate 47) shows close development of these traces and possibly indicate closely related animal working on these structures.

Classification :- Interlaminar full reliefs; feeding trails (Pascichnia); Worm ?

SCOLICOID GROUP
(Crawling Trails)

Diagnosis :- Scolicia sensu lato include several varieties of crawling traces that are present on the top of Sandstone beds preserved either as furrows in negative relief and showing transverse backfill laminae or as meandering burrows with lunate backfilled internal structure. Some of these structures extend several meters on ripple marked beds.

Remarks :- Several forms of Solicia have been photographed by the author from both the arenaceous and argillaceous facies of the eastern Kutch. These are represented by highly variable endogenic trails, usually of a highly flattened ribbon like shape often with transverse pads of sediments. Longitudinal furrows in various arrangements are observed in these specimens. Recognition of similar situation led Seilacher (1955) and Hantzschel (1962) to suggest several probable generic synonyms for Scolicia, e.g. Bolonia, Pasmmichnites, Curvolithos etc. Some of these forms located in the eastern Kutch are described herein under their original generic names. It should,however, be noted that the classification of Scolicia is still in confusion. Scolicia prisca has been attributed

to furrowing echinoids (Smith and Crimes, 1983) but other related examples have commonly been ascribed to gastropods (e.g. Ksiazkiewicz, 1977).

Ichnospecies :- Scolicia parkerensis Fenton and Fenton, 1937, p. 1080, Pl. 1; Hantzschel,1962, p. 185, fig. 110-4; Chamberlain , 1971, p. 228, Pl. 29, fig. 4; Text fig. 4H.

Plate 48 a,b.

Description :- Subangular furrows, approximately 1-2 cm wide, 1 to 2 mm deep, 8-10 cm long, having narrow lateral ridges. Each ridge 2 mm wide and 1 mm high and showing transverse peristaltic striae. Irregular meander pattern across the top of Sandstone beds and sometimes penetrating into the bed.

Preservation :- Epigenic or endogenic; full relief.

Facies :- Fine-grained sandstone and shale facies in Ramwao and Mae sections.

Association :- Crossopodia, Walcottia, Scolicia-prisca.

Discussion and Interpretation:- Fenton (1937) reported similar forms from the Pennsylvanian of Texas and Chamberlain (1971) from the Atoka Formation, U.S.A. Chamberlain recognises his forms as crawling trails (repichnia) of gastropod (?). The Kutch forms associated with crossopodia and Walcottia bear conclusive evidence for these

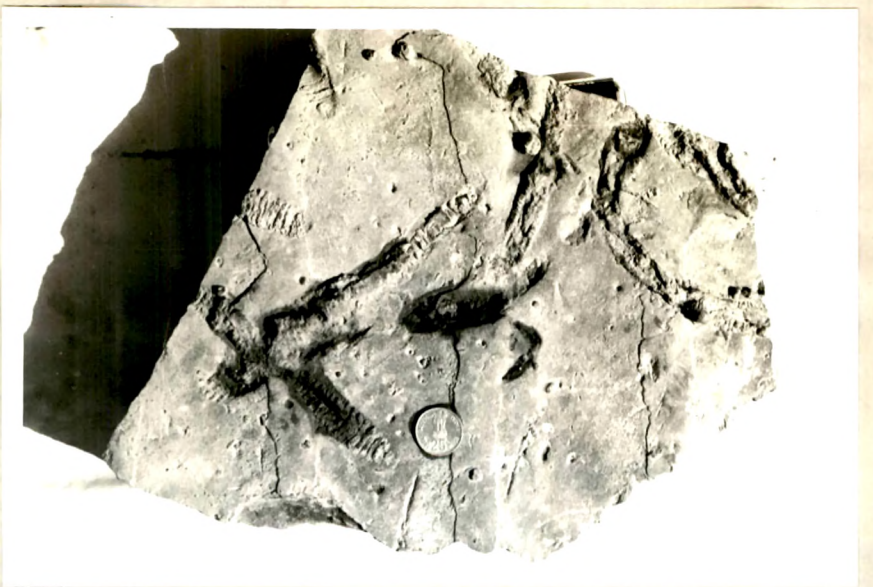

PLATE - 48 (a) Scolicia parkerensis - Subangular furrows having narrow lateral ridges, sometime penetrating into the bed. Note Crassapodia in the left. Locality - Manfara.

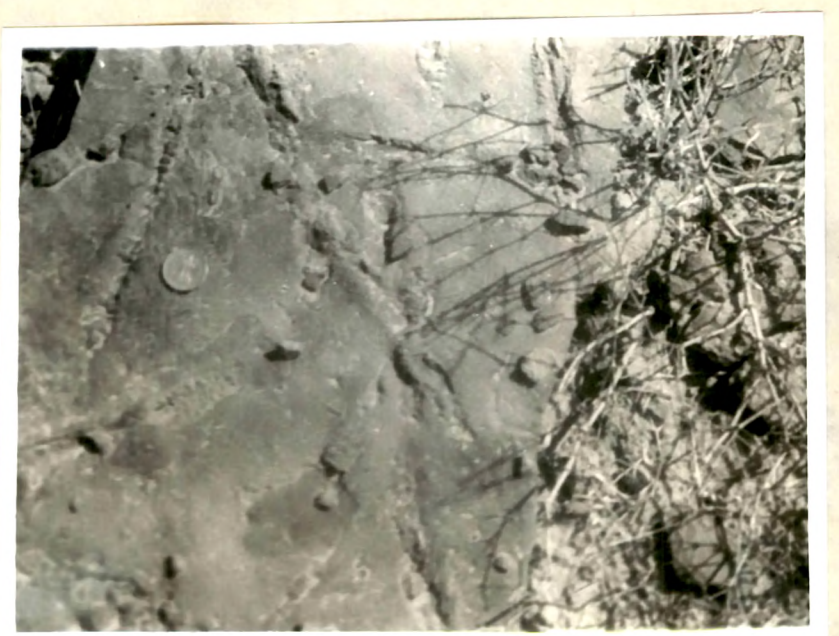

PLATE - 48(b) Scolicia parkerensis - Specimens from Locality - Washatwa.

traces being made by worm like organisms.

Ichnospecies :- Scolicia prisca DE QUATREFAGES, 1849 p.265; Hantzschel,1962, p. 215, Fig. 132,4.

Plate - 49, 48 b.

Description :- Several variations of similar forms occur in the Kutch Sediments. A relatively wide form is an angular furrows 2 cm wide and 0.1 cm deep with small lateral ridges, shaped in an irregular meander (Plate 48 b).

Another form consists of a relatively large median ridge, separated from lateral compressional ridges by three convex angular furrows. Median ridge is approximately twice as wide as lateral ridges. Burrow width 2 cm maximum in the center. Irregular strie form peristaltic motion common across ridges.

Preservation :- Intergenic, epirelief; crawling trail.

Facies :- Fine-grained Sandstone, Shale facies in Chitrod, Mae, and Manfara Sections.

Stratigraphic distribution :- Restricted to the Kharol Shale Member and the Adhoi Member.

Association :- Scolicia parkerensis, Crossopodia, Walcottia, Gyrochorte.

PLATE - 49 : Scolicia prisca - Specimen with flattened ribbon shape form with transverse pads in an irregular meander.
Locality - Mae

Discussion and interpretation:- The internal structure displayed by the trail seems to be more complex than thought earlier to interprete Scolicia made by gastropod. The Kutch Specimens show structures suggestive of rigid appendages and can be attributed to some crustaceans.

BOLONIA

Ichnogenus :- Bolonia MEUNIER, 1886.

Ichnospecies :- Bolonia lata Meunier, 1886.
p. 567, Pl. 30, Fig. 8.

Plate 50

Description :- Angular meandering furrow preserved as an epirelief with narrow, rounded lateral compression ridges on both sides. Trace 0.8 to 2 cm wide and 0.1 cm high and 8-10 cm in length. Slightly irregular marks across furrow, probably caused by compression during peristaltic motion of animal.

Discussion and interpretation:- Like the type species reported from the Upper Jurassic of France where it is associated with Crossopodia, the Kutch species of Bolonia also is developed in association with Crossopodia trace (Plate 50).

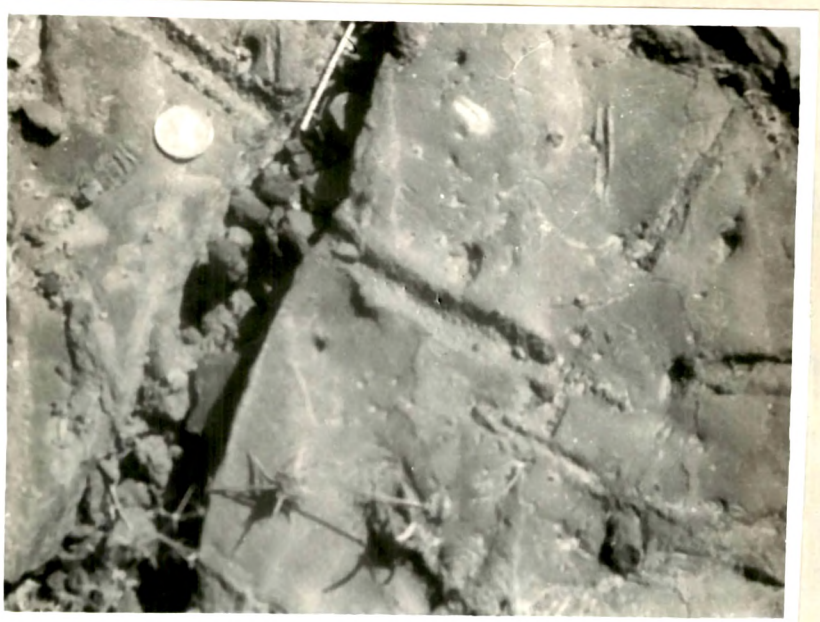

PLATE - 50 : Bolonia lata - Angular meandering furrow - Locality - Mae.
Note:- Crossopodia near the coin.

LAMINITES

Plate 51

Ichnospecies :- Laminites kaitiensis GHENT AND HENDERSON, 1966, p. 158, Pl. 1,2; Chamberlain, 1971 p. 226, Pl. 29, fig. 11.

Description :- These structures located in Adhoi dome section, consists of large, Subcylindrical burrows horizontal in the sediment, and obliquotransversely packed with 0.4 to 0.5 cm thick. Laminae alternating with fecal (?) or clay films. Structure 8-10 cm across. The structures display large scale undulations or meanderings. Laminae biconcave with median part bowed in the same direction as margins; probably towards direction of movement.

Discussion and interpretation:- Laminites is a rare structure and not much information could be available on the same. L. kaitiensis to which the Kutch specimen approximately resembles (in Chamberlain, 1971) as reported by Ghent and Henderson from the Miocene of New-Zealand. Sedimentologic and Palaeontologic evidence cited by these authors indicate 4000 feet depth for this structure. Chamberlain (1971), however found similar structures associated in Ouachita Mountains (Mississippian-Pennsylvanian) with Zoophycos, Asterosoma and Scalaritube and suggests shallow depth for Laminites. The

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PLATE - 50 : Laminites kaitiensis - Large subcylindrical burrows, horizontal in the sediment and obliquotransversely packed with clay films. Locality - Adhoi.

Kutch form associated with asymmetric ripple marks clearly indicates their shallow environments. As suggested by Ghent and Henderson (1966, p. 160, in Chamberlain, 1971) the size and behaviour indicated by the Laminites burrows in Kutch is indicative of their holothurian trace originators.

SPIROPHYCUS

Ichnogenus :- Spirophycus bicornis HEER, 1877; Munsteria bicornis Heer, 1877, p. 165, Pl.66,Fig. 1 b, 2; Sacco, 1888, p. 169, Pl. 2, Figs. 4,12, Spirophycus bicornis Hantzschel, 1962, P. 215, Fig. 134 1a,b; Chamberlain, 1971, p. 231, Pl. 32, Fig. 1.

Ichnospecies :- Spirophycus bicornis Heer, 1877, Plate 52.

Diagnosis :- Transversely folded or rugose cylindrical bulges, curved liked horns or bent spirally at the end.

Description :- The Kutch specimens are cylindrical sand filled galleries preserved as convex hyporeliefs. These traces efficiently display broad-looped meander patterns with some spirals. External surface is essentially rough with slight constricting and bulging parts. Size ranges from 6-8 cm thick and the trace extends for more than 60 cm. Most of these structures are endogenic in mud and preserved by scouring and casting.

Facies :- Fine-grained sandstone and shale rock facies in Adhoi Member; locality Manfara.

PLATE - 52 : Spirophycus bicornis, Rugose, Cylindrical bulges, bend spirally at the end.
Locality - Manfara.

Associations :- Scolicia, Gyrophyllites, Holothuroid trails.

Discussion and interpretation:- Cylindrical burrows of Spirophycus are identified by Chamberlain (1971) from the Mississippien-Pennsylvanian sandstones of the Ouachita Mountain, U.S.A. He has quoted Bourne and Heezen (1965) reporting forms of Spirophycus type and size with systematic meander patterns from the modern oceans at depths always greater than 4000 meters. While Cullen (1967) as further reported by him showed similar but smaller forms from the Tertiary of New Zealand and thought to have come from shallow water deposits. The Kutch forms do not appear to be from very great depths.

ECHINOID AND HOLOCHUROID TRAILS

Plate 53 a,b.

Description :- These are once again rare trace fossils and no Taxonomic work on these aspects could be found. Reference to similar forms was found in Ekdale and Berger (1978) who have reported similar structures in deep-sea ichnofacies of the western equatorial Pacific. According to these authors "echinoid trails" are the most abundant and easily recognized trails in their Sea bottom photographs where echnoids must have been ploughing across the sediments. Such trails as reported by them typically consists of a ridge of sediment (often bilobed with a central furrow), and usually occurring in loose, irregular meander patterns. They saw no creatures in the act of making the trails, however, Heezen and Hollister (1971) as referred by them show that identical trails are indeed produced by wandering echnoids elsewhere in the deep sea.

Echnoids trails resembling those in authors photographs have been seen at abyssal depths in most parts of the World. According to Kern and Warme(1974) similar trace fossils in land based sections have been described as Scolicia, although deep-sea echinoids trails apparently lack the characteristic central ridge.

PLATE - 53 (a) Echinoid & Holothuroid Trails - Note bulges, bent spirally at the end. Locality - Manfara.

PLATE - 53(a) Echinoid & Holothuroid Trails: Complete view These trails are comparable to similar trails from deeper,parts of the Ocean(in D.S.D.P.) Locality - Manfara.

The "holothuroid trails" according to Ekdale and Berger (1978) are broader and higher than those of the echinoids, and their width and shape are very irregular. Moreover, they lack the central furrow that characterizes many of the echnoid trails. The Manfara trails in Kutch (Plate 53 a,b) indicate both these patterns and could have resulted from both echinoids and holothuroid varieties, closely associated Gyrophyllite structures confirm existence of holothuroids (Plate 53).

LOPHOCTENIUM

Ichnospecies :- Lophoctenium RAMOSUM (Toula); Criophycus ramosus Seilacher, 1954, Pl.8, Fig. 5, Chamberlain, p. 237, Pl. 32, Fig. 8.

Plate 54.

Diagnosis :- Total structure in Lophoctenian is that of several "rooster tails". The Sperite galleries, are filled obliquotransversely and alternately with sand and mud or faecal (?) material as compared to the lateral packing of Zoophycos.

Description :- The trace shows intergenic convex hypo-relief; Irregular rooster-tail structure built of curving ridges. Main ridge is built of short ridges 3 to 4 cm wide and 6 to 8cm long that branch irregularly from both sides.

Facies :- Found in the Kharol Member of the Washatwa Formation in Chitrod.

Associations :- Rhizocorallium, Zoophycos.

Discussion and interpretation:- According to Chamberlain (1971) Lophoctenium ramosum is created by an animal, probably a worm that pushed forward into sand slightly above sand and mud interface. It perhaps pressed sand downward, withdrew and forged ahead to the right or left of main gallery, withdrew slightly and then forged ahead on course of main gallery, withdrew slightly and forged to the right or left of main gallery again.

PLATE - 54 : Lophoctenium ramosus - Rooster trails.
Locality - Chitrod.

PELECYPODICHNUS

Ichnogenus :- Pelecypodichnus SEILACHER, 1953

Type Species :- Pelecypodichnus amygdaloides Seilacher, 1953.

Diagnosis :- Almond-shaped structures preserved in either convex relief on the soles of beds or concave relief on the tops.

Pelecypodichnus Sp.

Plate 55 and 56 (arrow)

Description :- Small almond shaped (2 to 4 cm wide and 3 to 5 cm long) structures with concave relief on the tops of sandstone beds.

Facies :- Kharol Member and Adhoi Member fine-grained sediments.

Association :- Rhizocorallium, Zoophycos, Paleodicton.

Discussion and interpretation:- Eager, 1974 (in Hakes,1970) demonstrated that the non-marine bivalve Carbonicola was the likely producer of some forms of Pelecypodichnus is also reported from fully marine environments by Seilacher (1953), It is therefore, not possible to indicate a definite producer or a salinity range on these basis. The Kutch forms by its association appears to have marine influence.

PLATE - 55: Pelecypodichnus Sp. - Small almond shape structures preserved as concave relief.
Locality - Hamirpur.

PALEODICTON

Ichnogenus :- Paleodicton MENEGHINI, 1850

Diagnosis :- Regular hexagonal honeycomb-like network, of ridges preserved in hyporelief.

Remarks :- Paleodicton is a distinctive trace fossil consisting of a regular or irregular net. According to Chamberlein (1971) more than 10 generic and more than 20 specific names have been proposed for this trace. Specimens of Paleodicton in Kutch are not common enough to solve any specific synonymy problems.

Paleodicton Sp.

Plate 56

Description :- Burrows represent extensive sand-cast net with irregular mesh of hexagonal structures. Burrows originally endogenic in mud now appears to be preserved as convex hyporelief. Mesh of moderate size 2-3 cm across.

Facies :- Occurs in the fine grained sandstone and shale rocks of Kharol Member and Adhoi Member in Chitrod, Washatwa and Manfara Sections.

PLATE - 56 : Paleodicton Sp. - Burrow mesh of hexagonal structures.
Locality - Manfara.
Note: The presence of Pelecypodichnus.

Association :- Paleocypodichnus, Zoophycos

Discussion and interpretation:- According to Chamberlain (1971), Paleodicton is created by a burrowing animal that strictly avoid any double coverage of the same sediment.

LAEVICYCLUS

Ichnogenus :- Laevicyclus QUENSTEDT, 1879.

Ichnospecies :- Lavicyclus Sp., Hantzschel 1862, P 201, Fig. 123, 3.
Plate 57.

Description :- These are approximately cylindrical bodies standing at right angles to bedding plane. Diameter variable in the same specimen. The structure is perforated by a central canal and is very well preserved in the Kutch specimen. Lavicyclus has a typical appearance and is visible on the bedding planes as regular concentric circles with diameter of 2-3 cm.

Facies :- Occurs in the fine-grained sandstone and clay rocks in Nara Section - Adhoi Member.

Associations :- Spongeliomorpha.

Discussion and interpretation:- Quenstedt, 1912 (in Hantzschel 1962,P. 201) interpreted these structures as corals; Philipp (1904), and Wurm (1912) as organisms of unknown affinities; by M. Schmidt (1934) as inorganic, made by gas exhalation and water under pressure within sediments; by Seilacher (1953) as trace fossils (feeding burrows) comparable with dwelling shaft and scraping circles of Recent annelid worm Scolecolepis. In this

PLATE - 57 : Laevicyclus Sp. - Cylindrical bodies standing at right angles to bedding planes. Association of this form with Spongeliomorpha is intresting. Locality - Manfara.

background it is interesting to note that the Kutch structures are closely associated with Spongeliomorpha and therefore could be more akin to the Crustaceans rather than worms.

CUBICHNIA
(Resting Traces)

BERGAUERIA

Ichnogenus :- Bergaueria PRANTL, 1946.

Type Species :- Bergaueria perata Prantl, 1946, p. 52.

Diagnosis :- Broad, unlined vertical cylinders; U-shaped in cross-section.

Ichnospecies :- Bergaueria perata Prantl, 1946;
Fursich, 1974, p. 2, Fig. 3.
Plate 58.

Diagnosis :- Broad, unlined vertical cylinders; U-shaped in cross-section.

Description :- Broad vertical cylinders of which lower end is rounded with shallow trough. Diameter of the cylindrical structure 4-5 cm, depth 4-6 cm; burrow walls smooth without lining.

Preservation :- Positive hyporelief; fill identical with the overlying sediment.

Facies :- Well-sorted fine-grained sandstone in Adhoi and Washatwa sections.

PLATE - 58 : Bergaueria perata - Broad, unlined vertical cylinders in which lower end is rounded.
Locality - Adhoi.
Note:- The specimen of Laevicyclus by its side.

Associations :- Found associated with Spongeliomorpha.

Discussion and interpretation:- Prantl (1946) as quoted by Fursich (1974) suggested that Bergaueria perata might represent the burrows of some anthozoans or allied forms. Whilst Seilacher, regarded them as domichnia of partly burrowed actinians. Hantzschel (1962) thought it likely that they are resting traces of "burrowing" actinians. The lack of any lining according to Fursich (1974) suggests that B. perata might belong to the Cubichnia rather than to the Domichnia. The author is in agreement with Hantzschel (1962) and interprets his Kutch traces as the resting traces of actinians.

CROSSOPODIA

Ichnogenus :- Crossopodia M'COY, 1851.

Crossopodia Sp.

Plate 59 a,b.

Diagnosis :- Crossopodia are highly variable endogenic trails, that are usually of flattened tapering shapes with transverse pads of sediments. Longitudinal furrow in some form also occurs.

Description :- The Kutch specimens identified as Crossopodia are distinct, unbranched, straight to slightly curved trackways and resting traces probably of arthropod or annelids. Many specimens are found tapering towards both the ends. The traces in the author's collection indicates length of the specimen variable from 7 to 9 cm although some are shorter than 4 cm. The overall width of the specimen is also variable and is found ranging between 1.5 to 2 cm. The median furrow whenever present is of varying diameter, and usually narrow. The arrangement of the lateral pads is very distinct and symmetrical; opposing pads forming high obtuse angles. Differences of obliqueness of pads do not correspond with specimen size or lithology of

PLATE - 59 (a) Crossopodia Sp. Traces with flat tapering shapes having transverse pads of Sediments. Specimen with longitudinal furrow.
Locality - Mae.

PLATE - 59 (b) Crossopodia Sp. Large form, without longitudinal furrow.
Locality - Mae.

sediment but seemingly indicate different modes of animal behaviour. The general orientation of the pads on the other hand seems useful in determining the direction in which the trace-making animal moved.

Facies :- Fine-grained sandstone, shales in Kharol and Adhoi Members; Chitrod, Mae and Manfara sections.

Associations :- Scolicia parkerensis, Bolonia, Walcottia.

Discussion and interpretations:- The specimens from Kutch are found approaching in this general form and appearance to those described and illustrated by Hattin and Frey (1969, p. 1435-1440, Fig. 2). Because of individual variations in minor and gross structures of the Crossopodia in general, the author is disinclined at present to assign a trival name to his Kutch specimens.

Classification :- The claw marks around the specimen indicate that the Crossopodia Sp. was formed by worms or arthropod - Repichnia or Cubichnia.

WALCOTTIA

Ichnogenus :- Walcottia MILLER and DYER, 1878.

Diagnosis :- The name Walcottia was established for, "long, tapering, rugose, flexuous bodies, worm-like in form, which come to a point in one end and are enlarged at the other, or present the appearance of suddenly bending down and entering the rocks (Miller and Dyer, 1878 in Benton and Grey 1981, p. 686).

Remarks :- The type specimens of the type species W. rugosa from the Upper Ordovician of Cincinnati were refigured by Osgood (1970, p. 67, fig. 6; Pl.69,fig.5). But Walcottia is relegated to "unauthorized and unrecognizable genera" in the Treatise by Hantzschel (1962, p. 243). However, the species of Walcottia rugosa is well figured and described by Osgood (1970) and the author feels that it should be reinstated as a valid trace fossil genus name.

Walcottia Sp.

Plate 60

Description :- The Kutch Forms are unbranched, horizontal, long tapering flexuous bodies, are worm like in form

PLATE - 60 : Walcottia Sp. - Long, tapering, flexuous worm like form with well documented transverse sediment pads. Note Gyrochorte trail below the Specimen. Locality - Mae.

and circular to elliptical in cross-section. Maximum diameter noted is 2 cm with maximum length of 14.5 cm. Biserially arranged transverse pads of sediments are very distinct and symmetrical, with opposing pads forming highly obtuse angles. Some pads are inclined towards the bedding planes at an angle of 45°; their thickness varies between 0.1 to 0.2 cm. A median furrow is developed in some specimens. The cross-section of the specimen is heart-shaped. Irregular scratch marks at various points along the sides of the specimen are very well seen.

Preservation :- Positive epirelief; fill identical with the matrix.

Facies :- Occurs in the fine-grained sandstone, Shale rocks in Mae and Manfara section.

Associations :- Crossopodia, Bolonia, Gyrochorte.

Discussion and interpretation:- The presence of paired appendages in the Kutch specimen indicate an arthropod or worm. On the basis of the preservation of the trace and distribution of the paired appendages it is proposed that the animal normally did not required extensive leg kicks for progression through the sediment, but occassionally had to stabilize itself by extending its appendages.

Classification :- Interpreted as repichnia and cubichnia of a worm or an arthropod.

BOX WORK BURROWS

Plate 61.

Cf. burrows in hardground, "network of thalassinoid burrows" Broomley, 1968, p. 247-248, fig. 1.

Description :- Maze and boxworks of tunnels with numerous branches and individual tunnels.

Interpretation :- Bromley (1968, 1975) described similar burrows in hardground made by thalassinoid shrimp from the Cretaceous of Denmark and England. Similar burrows have been reported by Chamberlain (1977) from the Ordovician of Central Nevada, U.S.A. The Kutch specimens occurring in the Chitrod Sandstone Member resembles these forms.

Classification :- Endogenic full relief; dwelling burrow (domichnia) or deposit feeding (fodinichnia): Crustaceans ?

PLATE - 61 : Box Work Burrows - Maze and boxwork of tunnels possibly made by Thalassinoides Shrimps.
Locality - Chitrod.

OTHER TRACES

In addition to those described previously, the Kutch succession also contains other traces which have not been satisfactorily identified. These include the following

(a) Pelecypod trails from Washatwa (Plate 69).

(b) Thalassinoides brood structure from Chitrod.

(c) Escape structures from Mae.

(d) Faecal pellets (Plate 55) from Hamirpur.

(e) Vertebrate tracks from Mae.

Classification of trace fossils of the WASHATWA Formation

ETHOLOGIC	ICHNOGENUS	STRATINOMIC	PHYLOGENETIC
I Cubichnia - Shallow resting traces	Pelecypodichnus	intergenic ; hyporelief	Mollusca Pelecypoda
II Domichnia - Permanent shelters of ragile or hemisessile animals procuring food outside sediment	Arenicolites	endogenic , full relief	Annelia ? Polychaeta
	Lanicodichnus	,, ,,	,,
	Diplacraterion	,, ,,	Worms crustaceans
	Skolithos	,, ,,	Worms
	Rhizocorallium	,, ,,	Crutacean , ephimerids or annelida
	Ophiomorpha	,, ,,	Annelida
	Thalassinoides	,, ,,	Crustacean
III Repichnia - trail or burrows left during direction locomotion 1 Epifaunal trails 2 Simple infauna many back filled with fecal or sediment string.	Planolites	intergenic , hyporeliet	Annelida ? Polychaeta
IV Deposite feeding petterns A - Pascichnia 1 - Vagile meander with lateral sand packing 2 - Vagile mud ingestors with simple back filling B - Fodinichinia - feeding patterns which also served as shelter 1 - Sediment probers a - Downward spreading (i) Withdrards & leanes void (ii) Withrards & backfills 2 - Sediment processors a - Sheath builders b - Spraite builders (i) Looped with lateral working	Chondrites	endogenic , full & hypore-lief	Annelida ? Polychate
	Rosselia	endogenic , hyporelief	,,
	Zoophycos	endogenic , fullrelief	Annelida ? Polychate

Table. IV / 1.

Classification of trace fossils of the KANTHKOT Formation

ETHOLOGIC	ICHNOGENRA	STRATINOMIC	POLYGENETIC
I Cubichnia - shallow resting traces	Pelecypodichnus	intergenic, full relief	Mollusca - Pelecypoda
	Gyrophyllites	endogenic, negative epirelief	Medusae (?)
	Crossopodia	,, ,,	Arthopoda
	Walcottia	,, ,,	- worm
II Domichnia Permanent shelters of vagil or hemisessile animals procuring food outside sediment	Arenicolites	endogenic, full relief	Annelida ? polychaeta
	Lanicodichnus	,, ,,	,,
	Diplocraterion	,, ,,	,,
	Skolithos	,, ,,	,,
	Rhizocorallium	,, ,,	Crustacean, ephimerids or annelida
	Ophiomorpha	,, ,,	Annelida
	Cylindrichnus	,, ,,	Annelida ? polychaeta
	Thalassinoides	,, ,,	Crustacaen
III Repichnia - trails or burrow left during directed locomotion 1 Epifaunal trails 2 Simple infauna burrow, mainly back filled with fecal or sediment string	Scolicia	epi; endo-, intergenic epi-, hypo-, full relief	Gastropoda prosobranchia
	Mantle burrow	,,	,,
	Bolonia	,,	,,
	Gyrochorte	negative epirelief	Worm
	Laminites	endogenic; full relief	Holothuroidea
	Planolites	intergenic, hyporelief	,,
	Taenidium	endogenic, scour-cast hyporelief	Worm

(contd.)

Table. IV / 2.

Classification of trace fossils of the KANTHKOT Formation 240 (contd.)

ETHOLOGIC	ICHNOGENRA	STRATINOMIC	POLYGENETIC
IV Deposit feeding patterns			
A - Pascichnia Winding trails or burrows reflecting grazing or tunneling search for food & avoiding double coverage			
1 Vagile meander with lateral sand packing.	Scalarituba	endogenic, epi- hyporelief	Annelide ? Polychate
2 Vagile mud ingestors with simple back filling.	Helmenthopsis Paleodiction	endogenic, scour-cast, hyporelief	Annelide ? Polychate
B - Fodinichnia feeding pattern wich also served as shelters			
1 Sediment Probers	Chondrites	endogenic, full and	Annelide
(a) Downward spreading		hyporelief	? Polychate
(i) Withdraws and leaves voids.			
(ii) Withdrawz and backfills	Muensteria	inter - endogenic	Worm
(b) Upward spreading		hyporelief	
2 Sediment processors	Rosselia	endogenic, full relief	Annelide
(a) Sheath builders			Crustaceans
(b) Spraite builders			
(i) Looped with lateral working	Zoophycos	endogenic, full relief	Polychaeta

Classification of trace fossils in GAMDAU Formation 241

ETHOLOGIC	ICHNOGENUS	STRATINOMIC	PHYLOGENETIC
Cubichnia	Palecypodichnus	Intergenic ; hyporelief	Mollusca , Pelecypoda
Domichnia	Skolithos Thalassnoides Ophiomorpha	endogenic , full relief	Worms Crustaceans Annelida ? Polychaeta Crustaceans
Repichnia	Planolites	Intergenic, hyporelief	Annelida ? Polychaeta
Pascichnia Eodinichnia	Chondrites	endogenic , full and hyporelief	Annelida ? Polychaeta

Table. IV / 3.