Chapter - 7

DESCRIPTION OF ICHNOFOSSILS

VII. 1. INTRODUCTION:

Organisms leave their markings in most sedimentary settings either directly in the form of body fossils or indirectly as biogenic structures (trace fossils). Varieties of such organisms today virtually inhabit every environment on the Earth, and sedimentary record tells us that this has been the case throughout the greater part of earths' history. An increased significance is being considered 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 the above mentioned 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 term genera and ichnogenera, and species and ichnospecies are intermixed throughout most of the available literature. This is because of the ruling of the International Commission on the Zoological Nomenclature that recognized tracks, trails and burrows named before 1931 as valid genera and species, but does not recognized 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); Hantzschel (1962); and Seilacher (1953). Stratonomic classification of Seilacher (1953a) is considered equal to preservational classification of Seilacher (1964); phylogenetic, equal to taxonomic classification of Seilacher (1953a) and this in turn equal to behavioral classification by Seilacher (1953a, 1964). All these classifications have been applied to

TABLE - 10 CLASSIFICATION OF TRACE FOSSILS ACCORDING TO THEIR ETHOLOGICAL GROUPS

DOMICHNIA *DWELLING BURROWS*	FODINICHNIA *FEEDING BURROWS*	PASCICHNIA *GRAZING TRACES*	REPICHNIA *CRAWLING TRAILS*	CUBICHNIA *RESTING TRACES*
Arenicolites	Bifungites	Circulichnus	Bolonia	Asteriacites
Corophioides	Chondrites	Cochlichnus	Crossopodia	Bergaueria
Cylindrichnus	Granularia	Fustiglyphus	Didymaulichnus	Conostichus
Cylindricum	Gyrolithes	Helminthopsis	Gyrochorte	
Diplocraterion	Gyrophyllites	Megagrapton	Isopodichnus	
Enteropneusta	Keckia	Muensteria	Neonereites	
Histioderma	Laevicyclus	Oldhamia	Palaeobullia	
Monocraterion	Phycodes	Planolites	Scolicia	
Ophiomorpha	Rhizocorallium	Protopaleodictyon		
Palaeophycus	Rosselia	Strobilorhaphe		
Skolithos	Scalarituba			
Stipsellus	Spirophyton			
Tisoa	Taenidium			
Trichichnus	Thalassinoides			
	Yakutatia			
	Zoophycos			

the studies by the author either separately or in combination.The main purpose of this chapter, however, being description of the trace fossil morphology and their behavioral characteristics, the aspects of taxonomy, preservation and behavior of the ichnofossils are clearly separated wherever possible in their systematic descriptions.

Trace fossils are described alphabetically and divided in to five different categories as listed in table-10. A summary of the stratonomic, phylogenetic and ethologic classifications applied to these fossils is separately given at the end of the chapter (table-11) alongwith distribution of ichnogenera in various Members and Lithofacies (table-12).

VII. 2. DESCRIPTION OF TRACE FOSSILS:

ICHNOGENUS

Arenicolites SALTER, 1857.

Diagnosis: Simple U-tube without spreite, perpendicular to bedding; varying in size, tube diameter, distance of limbs, and depth of burrows; limbs rarely somewhat branched, some with funnel shaped opening; walls commonly smooth, occasionally lined or sculptured; burrows may reach considerable depth.

ICHNOSPECIES

Arenicolites sp. SALTER, 1857.

Plate 15a

Description: The Kutch specimen has both the limbs parallel, and are perpendicular to the bedding plane. It shows larger funnel shape opening with circular to sub-circular aperture. Burrow wall smooth with lining Burrow diameter varies in the tube, which is less below the throat of funnel

(0 33 cm) and more (1.0 cm) at base. Maximum observed length is 9.5 cm and distance between the two limbs is 3.0 cm.

Dimensions vary in different burrows. Very often two shafts of 'U' burrow are not in the same plane. Base is almost flat.

Preservation: Full relief, endichnial burrow with fill white light coloured fine different than the surrounding sediments.

Facies: Massive Sandstone.

Stratigraphic Distribution: Tapkeshwari Member - Umia Formation. Occurs near Observatory.

Association: *Skolithos, Monocraterion, Arenicolites nodosa.*

Remarks: It is different than the *A. carbonarius, A. nodosa, A. franconicus, A. statheri* etc. by its typical characteristics like - parallel tubes without spreite, perpendicular to the bedding and with variation in burrow diameter and large funnel shape opening with circular semicircular aperture as well as heterogeneous fill.

ICHNOSPECIES

Arenicolites carbonarius BINNEY, 1852, p. 192. EAGER et. al., 1985, p. 132, pl. 13.

Plate-15, b

Diagnosis: Vertical to slightly oblique U-tube without spreiten. Tubes are cylindrical, smooth walled with mud lining or mud sand filling. Uband on one limb may show slight vertical or lateral migration but no true spreiten are formed. Dimensions vary in different burrow populations.

a *Arenicolites Sp.*

bi *Arenicolites carbonarius*
ii Chondrites Sp. A

Description: The Kutch specimen *Arenicolites carbonarius* have both the limbs parallel and shows some inclination to the bedding plane. In rare cases it shows funnel shape opening. Burrow wall smooth with mud lining. U-bend at places show some lateral and vertical migration. Burrow diameter is almost constant through out with slight thinning at base (plate-15b). Dimensions vary in different burrow populations. Maximum observed length is 10.5 cm and minimum 5.0 cm. Maximum diameter is 1.4 cm and minimum about 0.6 cm. Both the limbs are 2 cm apart in the photographed burrow.

Remarks: This ichnospecies is regarded as the type species of *Arenicolites* (Hantzschel, 1975). As reported by Eager et. al., (1985) in Curren (1985 p.136), this ichnospecies is at present under re-description and further analysis by J.E.Polland and P.D.Hardy.

Preservation: Full relief, fill heterogeneous to matrix (reddish brown ferruginous).

Facies: Oolitic Limestone.

Stratigraphic Distribution: Occurs in Dhosa Oolite Member (near temple at 9.0 km on Bhuj-Mandvi road).

Association: *Chondrites*, *Zoophycos*.

Discussion and Interpretation: The lining of the burrow, their stabilization by the regular arrangement of mud, and heterogeneous fill indicate that the burrow were inhabited by suspension feeders rather than deposit feeders.

ICHNOSPECIES

Arenicolites nodosa SHRINGARPURE, 1985.

Plate-16, a

Diagnosis: Variable, narrow to wide, vertical to slightly oblique, Utubes without spreite, but often with nodular bulges.

Description: The Kutch specimen reported to be a new species of *Arenicolites* (Shringarpure, 1985), include vertical to slightly oblique tubes exhibiting U-turns. The tube diameter from 0.5 to 1.0 cm, and distance between both the shafts from 5.0 to 8.0 cm, maximum depth observed is 30.0 cm. Very often the two shafts of the U-tube are not in the same plane. A burrow lining is usually present. The aperture are semicircular or hexagonal or pentagonal (polygonal) in shape (plate-16a). The central burrow tubes are seldom present. Burrows show nodular bulges.

Preservation: Full relief, fill identical with the matrix.

Facies: Occurs in the Massive Sandstone facies.

Stratigraphic Distribution: Located in Tapkeshwari Member of the Umia Formation near Bharapar Sanatorium. Occurs in medium to coarse grained rocks.

Association: *Arenicolites* sp., *Monocraterion*, *Skolithos*.

Discussion and Interpretation: *Arenicolites nodosa* occurs in the upper parts of the Massive Sandstone Facies where the lithology becomes 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 lining of the burrows and their stabilization by

the regular arrangement of sand grains indicate that the burrows were inhabited by the suspension feeders similar to the one responsible for the *Arenicolites variabilis*, and A. *carbonarius* etc., (Shringarpure, 1985). It is considered as dwelling burrow of suspension feeding polychaete by Shringarpure (1985).

ICHNOSPECIES

Arenicolites franconicus TRUSHEIM, 1934.

Plate-16 b

Diagnosis: Variable, narrow to wide, vertical to slightly oblique Utube without spreite and often with funnel shape opening of at least one tube.

Description: The specimen shows both the limbs sub-parallel to each other and slightly oblique to the bedding plane The limbs produce narrow V - shape with rounded base. It shows funnel shape opening of right side tube, where opening of the funnel shape tube is at slightly upper level than the left side tube without funnel, i.e. opening of the tubes are at different level. Burrow walls are smooth with thin mud lining and without spreiten structure. Burrow diameter is almost constant with slight thickening at lower end. The length of the burrow is 6.0 cm, distance between two limbs near opening is 1.2 cm, which decreases downwards. Diameter of the limbs is 0.8 cm. Left limb shows slight curvature. Burrow is filled with dark, finer material than the surrounding.

Preservation: Full relief, endichnial burrow with dark reddish brown finer sediments.

Facies: Massive Sandstone.

Stratigraphic Distribution: Tapkeshwari Member of Umia Formation near the Observatory.

Association: *Ophiomorpha*, *Diplocraterion*.

a. *Arenicolites nodosa*

b. *Arenicolites franconicus*

ICHNOGENUS

Asteriacites VON SCHLOTHEIM, 1820, p. 324.

Diagnosis: Impressions in form of asteroids or ophiuroids, with transversely sculptured arms; their striae produced by activity of digging tube feet; often intersected by traces of neighbouring animals ("horizontal repetition") or (as reaction to rapid sedimentation) "vertical repetition"; morphology dependent on preservation as convex hyporelief or concave epirelief.

ICHNOSPECIES

Asteriacites quinquefolius QUENSTEDT, 1876.

Plate-17 a & b

Diagnosis: Conical, sub-conical or sub-cylindrical biogenic structures with pentameral symmetry on sides, depressions coarsely striated with double rows of nodes or rounded radial grooves.

Description: The Kutch specimen of *Asteriacites quinquefolius* is star like trace fossil having five arms projecting outward from a center, tapering towards the end. It contains conical impressions with pentameral symmetry in form of asteroids with transverse sculptured arms. Occurs in form of concave epirelief on casting medium. Arms are transversely striated, and in some cases double rows of transverse grooves present. Distance between the striae or grooves is 1.0 to 2.0 mm. Each arm is 1.5 cm to 4.0 cm in length and diameter of 1.0 cm. Central portion is approximately 2.0 cm in diameter and knobby. The total diameter of the structure is 3.0 to 8.0 cm. Impressions are 2.0 to 4.0 mm deep with raised rims. Horizontal repetition produced by movement of the same animal can be seen (plate-17, a) or movement of animal by multiple hazy or indistinct impressions of arms can be envisaged.

Preservation: Concave epirelief, epichinia.

a. *Asteriacites quinquefolius*

b. *Asteriacites quinquefolius*

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Tapkeshwari Member of Umia Formation near the Observatory

Association: *Thalassinoides, Rhizocorallium, Cylindricum, Gyrochorte.*

Discussion and Interpretation: Interpreted by Seilacher (1953b) as resting traces of Asterozoa, produced by star fishes.

ICHNOSPECIES

Asteriacites lumbricalis SEILACHER, 1953, p. 93.

Plate-18

Diagnosis: Conical, sub-conical or sub-cylindrical biogenic impressions in form of Ophiuroids, with transversely sculptured arms.

Description: The Kutch specimen of A. lumbricalis is radiating resting impression in form of Ophiuroids having five arms projecting out ward from a center. The arms show constant width of 0.75 cm with sudden tapering at the end. The arms are 5.5 to 9.0 cm in length, straight to curved on the bedding plane. Full lengths of arms are most probably not preserved. Central portion is approximately 1.2 cm in diameter. Arms produce acute (30°) to obtuse (110°) angle with each other Total diameter of the structure is about 15.0 cm. Ornamentation in the structure has not been observed due to poor **Preservation**

Preservation: Concave epirelief.

Facies: It occurs in Laminated Shale Siltstone facies.

Asteriacites lumbricalis

Stratigraphic Distribution: It occurs in Marutonk Dungar Member of Katrol Formation on exposures about 2.0 to 3.0 km south of Gangeshwar.

Association: *Thalassinoides*, *Histioderma*, *Phycodes*.

Discussion and Interpretation: Three different specimens from the Pennsylvanian of USA (Oklahoma) were ascribed to *Asteriacites* by Chamberlain (1971a, p.219), who named them A. lumbricalis and regarded them as true *Asteriacites* resting trace fossils, but his proposal to expand the **Diagnosis** based on these forms was not accepted. Earlier such structures were regarded as body fossils of asteroids (ventral casts) by Knorr & Walch (1769) and Goldfuss (1833). These are interpreted by Seilacher (1953b) as resting traces of Asterozoa such as Asterias lumbricalis, SCHLOTHEIM, produced by Ophiuroids.

ICHNOGENUS

Bergaueria PRANTL, 1946.

Diagnosis: *Bergauerıa* are cylindrical protrusive burrows with smooth walls. Length and diameter of such burrow is sub-equal, lower ends rounded, with shallow depression which is some times surrounded by six to eight very short radially arranged tubercles. Some species display biradially symmetrical impressions on ventral surface.

Remarks: *Bergauerıa* PRANTL, 1946, contains seven ichnospecies that makes it difficult to determine in synonymy. However, recently Pemberton et. al. [1988] described four ichnospecies on the characteristic of the distal termination and wall lining.

1. Distinctly lined, unornamented burrows: [a] Thick walled burrows - B langi.

   [b] Thin walled burrows - B.hemispherica.

2. Very thin lined, distally ornamented burrows: [a] Radiating ridges - B.radiata.

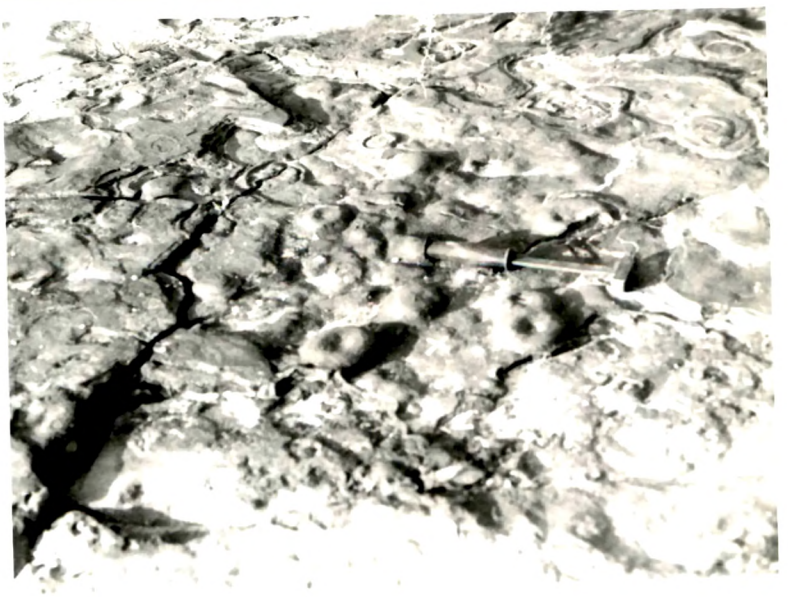
   [b] Ridges faint or lacking - B.perata.

ICHNOSPECIES

Bergaueria *Sp.* PRANTL, 1946.

Plate-19

Description: Broad vertical cylinders, of which lower end is rounded with shallow trough. Diameter of the cylindrical structures 6.0 to 9.0 cm, depth 6.0 to 8.0 cm, burrow walls smooth without lining. Projected on the bedding plane in form of shallow depressions with thick raised rims, which is expression of protrusive nature.



Bergaueria Sp.

Discussion and Interpretation: Prantl (1946), as quoted by Fursich (1974), suggested that *Bergaueria Sp.* might represent the burrows of some anthozoan or allied forms. Whilst Seilacher regarded them as domichnia of partly burrowed actinians. Hantzschel (1962, 1975) thought that, they are resting traces of burrowing actinians. The lack of any lining, according to Fursich (1974), suggests that *Bergaueria Sp.* might belong to the cubichnia rather than to the domichnia. The author agrees with Hantzschel (1962, 1975) and interprets his Kutch traces as the resting traces of actinians.

Preservation: Positive epirelief, full relief, fill identical with the host sediment.

Facies: Massive Sandstone.

Stratigraphic Distribution: It occurs in Tapkeshwari Member.

Association: *Rhizocorallium*, *Cylindricum.*

ICHNOGENUS

Bifungites DESIO, 1940, p. 78.

Diagnosis: Structures dumbbell like or arrow shaped, 1.0 to 5.0 cm. long.

ICHNOSPECIES

Bifungites *Sp.* DESIO, 1940.

Plate-20

Description: The Kutch forms of *Bifungites* are dumbbell like or double headed hammer like structures with a length of 9.0 cm. The ends are hemispheric to cylindrical blunt hammer like. Diameter of the structure is 1.0 to 1.2 cm and diameter of dumbbell shape 1.2 to 2.4 cm and length of hammer head is up to 4.0 cm. Fill identical to the host rock. Structures are found on the bedding planes.

Discussion and Interpretation: Interpreted by Desio as fucoid or colonial animal. It is regarded by Seilacher (1955, fig.5; 1969a, p.112) as special kind of Preservation of protrusive vertical U - tube representing feeding burrow.

Preservation: Positive epirelief.

Facies: Laminated Shale Siltstone, Sheet Sandstone, Dark Shale Siltstone Sandstone, Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Jamaywadi Member and Tapkeshwari Member..

Association: *Planolites, Cochlichnus, Laevicyclus, Helminthopsis.*

(i) *Bifungites Sp.*

(ii) *Cochlichnus* kochi

ICHNOGENUS

Bolonia MEUNIER, 1886.

ICHNOSPECIES

Bolonia lata MEUNIER, 1886, p. 567, pl. 30, fig. 8.

Plate-21

Description: Angular meandering furrow preserved as an epirelief with narrow rounded lateral compressional ridges on both the sides. Traces 1.0 to 1.5 cm wide, 0.2 to 0.3 cm deep and 4.0 to 10.0 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*, in Kutch also *Bolonia* is developed in association with *Crossopodia* trace in Mai dome in Wagad island (Shringarpure, 1985) and in Khadir island (Vaishnav, 1991). But in mainland Kutch - in Ler Amundra anticline, it is associated with *Muensteria* - maniscate burrow.

Preservation: Concave epirelief.

Facies: Sheet Sandstone (SS).

Stratigraphic Distribution: It occurs in Jamaywadi Member of Chari Formation south of Madhapar in sandstone quarries.

Association: *Palaeophycus, Podichnus, Muensteria, Ophiomorpha.*

Bolonia lata

ICHNOGENUS

Chondrites VON STERNBERG, 1833, p. 25.

Type Species: Fucoides lycopodioides BRONGNIART, 1828, p. 72.

Diagnosis: Plant like dendritic patterns of small cylindrical ramifying tunnel systems. Individual tunnels neither crossing each other nor interpenetrating. One or few main axes open to the surface; branching tunnels trending downward across bedding and then mostly lying parallel to bedding planes or may branch in regular or irregular patterns, angles of branches may be variable or 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 siphunculids, polychaetes, anthoptiloid sea pens and arthropods [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 two species generalization are present in Kutch material, preserved on endichnia and exhichnia and interpreted as feeding structures

ICHNOSPECIES

Chondrites *Sp.* A

Plate-15, b

Description: Dendritic branching structure oriented vertical or oblique to the bedding with no evidences of vertical surfacial expression. Burrow wall smooth, slightly irregular, asymmetrical branched burrow system. Main axis is almost vertical to the bedding; branching tunnels trending down ward obliquely. Angle of branches is variable. Burrow diameter almost constant, which is 1.0 mm. Individual tunnels vary in length from 0.5 to 1.5 cm. Branching frequent and commonly pinnate. Burrow fill is darker in colour than the enclosing sediments.

Preservation: Preserved as endichnia.

Facies: Oolitic Limestone.

Stratigraphic Distribution: It occurs in Dhosa Oolite Member of Chari Formation.

Association: *Zoophycos.*

ICHNOSPECIES

Chondrites *Sp.* B

Plate-22

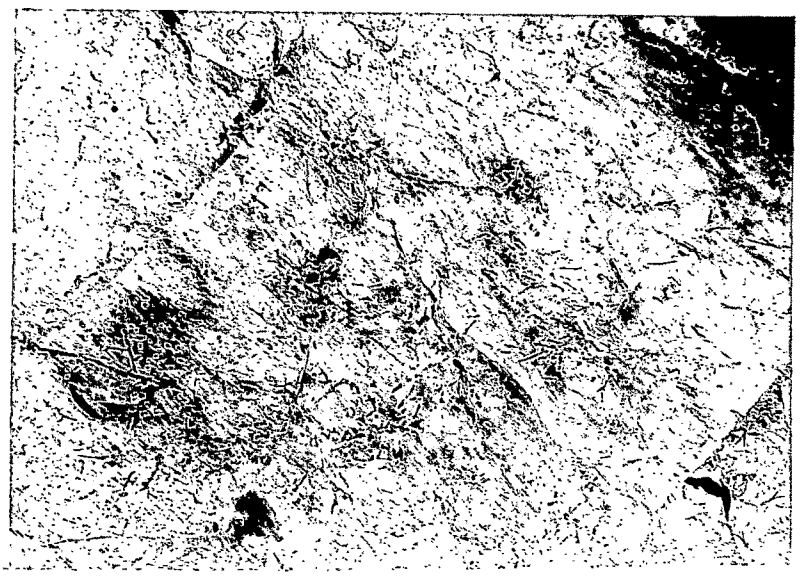
Description: Three dimensional plant like dendritic patterns of cylindrical ramifying tunnel system. The branches are more or less regular and vertical or inclined to the bedding plane and becomes horizontal laterally. The main axis is almost vertical or inclined with diameter of about 3.0 to4.0 mm which remains constant in the branches. The main axes extends up to 25.0 cm. First and second order branching is common with small off shoots of third order galleries. Length of

branches varies from 3.0 cm to 12.0 cm. Individual tunnels neither crossing each other nor interpenetrating. Angle of branching almost constant between 60° to 70°.

Preservation: Preserved as endichnia. **Facies**: Laminated Shale Siltstone.

Stratigraphic Distribution: It occurs in Tapkeshwari Member of Umia Formation.

Association: *Ophiomorpha, Thalassinoides, Planolites, Palaeophycus.*



Chondrites Sp. B

ICHNOGENUS

Circulichnus VYALOV, 1971, p. 91.

Type Species: *Circulichnus* montanus VYALOV, 1971.

Diagnosis: Ring shaped trace, almost circular, formed by some cylindrical object.

ICHNOSPECIES

Circulichnus montanus VYALOV, 1971, p. 91.

Pickerill and Keppie, 1981, and McCann and Pickerill, 1988, p. 334.

Plate-23

Diagnosis: Smooth, circular, unlined burrow; burrow diameter constant in individual specimen.

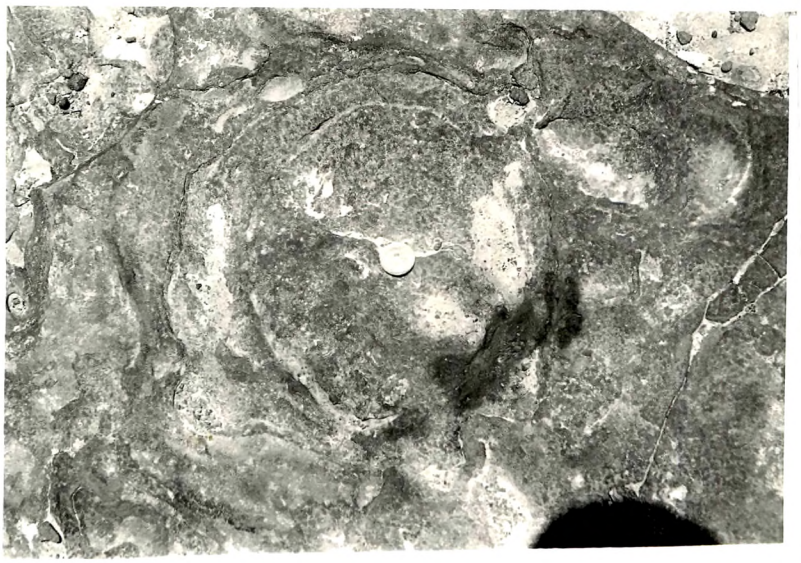
Description: A number of specimens of C. montanus are observed in Kutch. Burrows are smooth, circular to elliptical in outline and unlined. They are essentially parallel to the bedding plane and preserved in concave and convex epirelief. Peripheral or outer diameter is about 37.2 cm and burrow diameter is about 3.6 cm. Thickness of the individual species is through out constant. Burrow filled with fine grained particles which are identical to the surrounding matrix. Some times burrows are completely weathered and unfilled structures are very common.

Preservation: Full relief, convex and concave epirelief & hyporelief. **Facies**: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Tapkeshwari Member of Umia Formation.

Association: *Gyrochorte, Oldhamia, Rhizocorallium, Yakutatia, Skolithos, Diplocraterion, Palaeophycus, Planolites*

Remarks: It is considered as a feeding trail - pascichnia.



Circulichnus montanus

ICHNOGENUS

Cochlichnus HITCHCOCK, 1858.

Diagnosis: Regularly meandering smooth trails, resembling sine curve.

Remarks: There are three recognized ichnospecies of *Cochlichnus*, namely C.anguineus Hitchcock, 1858; C.kochi Ludwig, 1968; and C.serpens, Webby, 1970; whose definition and differentiation in the literature is confusing and can best be regarded as conspecific. The Kutch specimen probably represent the mould of trails, which are identical to Ludwig, 1968, & Webby, 1970, described *Cochlichnus* kochi and *Cochlichnus* serpens burrows respectively. According to Eager et. al. [1985], *Cochlichnus* are crawling traces and probably feeding structures of small worm or worm like animals. *Cochlichnus* has been recorded in sediments of supposed low salinity palaeoenvironments [Hakes, 1976].

ICHNOSPECIES

Cochlichnus kochi LUDWIG, 1968.

Plate-20

Diagnosis: Regular gently meandering, smooth unbranched trails with small parallel ridges on both the sides.

Description: Sinusoidal trails preserved as mould in form of convex hyporelief on the lower surface of the beds. The trail shows two gently raised rims on both the sides, running in a parallel manner. The meanders are regular, trail is without any ornamentation and resembles sine curves. The specimen shows maximum length of about 23.0 cm with a constant diameter

which is about 1.2 cm. Amplitude of sine curve is 1.5 to 3.0 cm and wave length is 5.0 to 8.0 cm.

Preservation: Burrow preserved in convex hyporelief, sediment fill identical to host rock.

Facies: Laminated Shale Siltstone, and Massive Sandstone.

Stratigraphic Distribution: It occurs in Jamaywadi Member.

Association: *Bifungites*, *Thalassinoides*, *Ophiomorpha*, *Palaeophycus*.

ICHNOSPECIES

Cochlichnus serpens WEBBY, 1970.

Plate-24

Diagnosis: Regular meandering, smooth, unbranched, sinusoidal, unlined burrows.

Description: Sinuous trails preserved as mould on the lower surface of beds. The collected specimen shows trails having length about 18.0 cm, diameter is constant through out being 1.0 cm. Amplitude of sine curve is 2.0 to 3.0 cm, wave length of 6.0 to 9.0 cm. The trails are without any ornamentation and meanders are slightly irregular.

Preservation: Burrow preserved in convex hyporelief, sediment fill identical to host rock.

Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: It occurs in Marutonk Dungar Member of Katrol Formation.

Association: *Palaeophycus*, *Chondrites*, *Phycodes*, *Histioderma*, *Planolites*.

Cochlichnus serpens

ICHNOGENUS

Conostichus LESQUEREUX, 1876, p. 142.

Type Species: *Conostichus* ornatus, Lesquereux, 1876.

Diagnosis: Conical to subconical, vertical burrows, most of which display a duodecimal symmetry on the apex and sides. Most walls are fluted by transverse constrictions and longitudinal ridges and furrows. Well developed apical disc and central subcylindrical core may or may not be present. Burrow fills may be structureless or composed of concentric conical or subconical laminae.

Remarks: *Conostichus* encompasses a virtually complete range of conical forms, from low wide cones having slightly sloping sides to high narrow cones having flat apices and nearly parallel sides (Chamberlain, 1971). Overall dimensions are variable, but generally the diameter is equal or less than the height. Recently, Pemberton et al, (1988) recognised five ichnospecies of *Conostichus*, on the basis of well developed ornamentation and inclusion of apical disc, transverse constrictions, and longitudinal ridges, and furrows. The overall geometry of *Conostichus* and the well developed apical disc and surface ornamentation in *Conostichus* therefore distinguish it from *Bergaueria*, Conichnus and Dolopichnus. The following ichnospecies are described by Pemberton et al, (1988), primarily on the basis of overall burrow geometry and characteristics of apical disc:

1. Strongly conical burrow form -

(a) Narrow short apical disc - C. broadheadi

2. Conical to subconical burrow form -

(a) Broad planar apical disc having strong septation - C. ornatus,(b) Broad planar apical disc having moderate septation - C. typicus,(c) Small narrow apical disc having weak septation - C. stonti.

3. Subcylindrical burrow form -

(a) Broad flat apical disc having weak septation - C. wycherlyi

ICHNOSPECIES

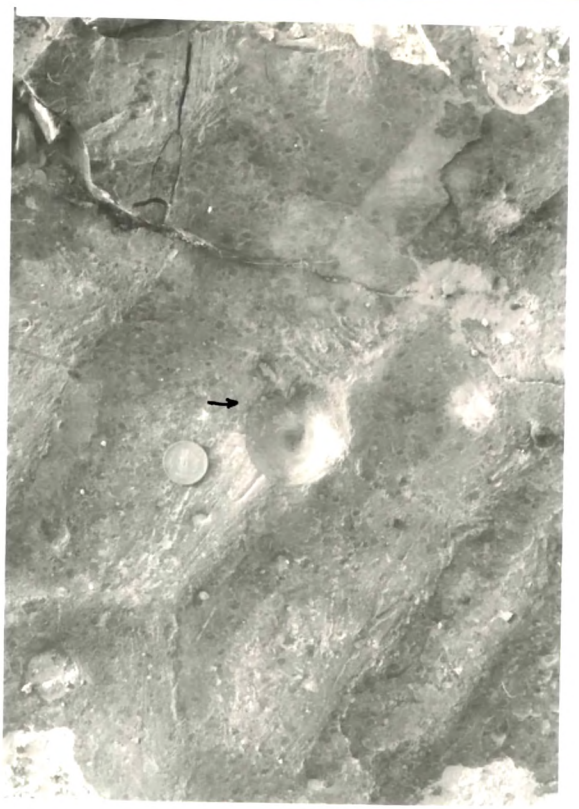
Conostichus wycherlyi KING, 1955, p. 158.

Plate-25

Diagnosis: Subcylindrical conostichus having weakly developed transverse constrictions and longitudinal furrows, broad planar apical disc having weak septation.

Description: Relatively large, broad, conical structure displaying circular cross section. Burrow walls are eroded in most of the burrow system but some where preserved. Also consists indistinct transverse constrictions and longitudinal furrows. Dimensions of the burrow varies in different burrow population, height up to 8.0 cm and diameter varies from 4.0 to 10.0 cm. The apical disk is characteristically broad and flat, eroded in most of the traces and appearing as circular opening with diameter of 2.0 to 4.0 cm.

Discussion and Interpretation: *Conostichus* wycherlyi is distinguished from other ichnospecies of *Conostichus* by its cylindrical shape and its broad, flat apical disc. *Conostichus* was originally interpreted as an algae (Lesquereux, 1876, 1880, 1883) or a sponge (Lesquereux, 1880). Its medusoid affinities were recognised earlier by Fuchs (1895). Chamberlain (1971) interpreted it as dwelling burrows of actinians, and feeding cones of Arenicola like worm (Berthel and Barth, 1972).



Conostichus wycherlyi

Stratigraphic Distribution: Occurs in Tapkeshwari Member.

Lithofacies: Rippled Ferruginous Sandstone Siltstone Shale.

Association: *Asteriacites, Palaeobullia, Palaeophycus, Rhizocorallium.*

ICHNOGENUS

Corophioides SMITH, 1893, p 292.

Diagnosis: U-shape spreiten burrows similar to *Rhizocorallium*, but shorter and always perpendicular to the bedding plane (Richter, 1926). Both limbs of each successive U-tube typically show lateral displacement from limbs of preceding U-tube.

ICHNOSPECIES

Corophioides luniformis BLANCKENHORN, 1916, p. 39.

Plate-26

Diagnosis: U-shape spreiten burrows consisting crescent shape grooves in bedding planes produced by erosion of burrows to their basal ends.

Description: U-shape spreiten burrows exactly perpendicular to the bedding planes and shorter in length (to the *Rhizocorallium*) which is up to 20.0 cm. Rounded basal ends of the burrows show slight deviation from verticality, or curvature, which on erosion show crescent shape grooves in the bedding plane. Projection of the upper ends of the burrows on bedding planes are found in form of 2.0 to 3.0 cm long equidimensional shallow grooves, in some cases with two holes in place of projecting U-tubes at both the ends. Both limbs of successive Utube typically show lateral shifting from preceding U-tube. Interpenetration is a common feature. Spreites are unequal in distance (0.5 to 1.0 cm) and asymmetric and protrusive. Burrows are filled by light coloured slightly finer material than the surroundings. Burrow width is about 2.5 to 4.0 cm. Burrow tubes are parallel to each other.

Discussion and Interpretation: Vertical spreiten burrows are usually regarded as the domichnia of suspension feeders (Richter, 1926; Goldering, 1962; Seilacher, 1963, 1967). The interpenetration

and shifting provides evidences for the above view in Kutch specimen. The spreiten is the result of the organisms efforts to keep its burrow at a constant depth and not the result of mining the sediments for food. Shifting of the burrow tubes also indicates same thing.

The burrows may be of similar type of organisms to present day Corophium, which are very similar to *Diplocraterion* except their smaller size (Schafur, 1952) and absence of funnel shape opening. Burrows are differing to the *Rhizocorallium* by prominent vertical orientation. High angle inclination near lower end may have been produced as a result of protection against prominent higher energy currents in the initial stage of burrowing which may be absent in many cases, rather than for feeding as in case of *Rhizocorallium.*

The burrows are different than the *Diplocraterion* by absence of funnel shape opening, equidimensional linear projection on the bedding plane and heterogeneous fill.

Preservation: Full relief.

Facies: Bioturbated Sandstone.

Stratigraphic Distribution: It occurs in Bharapar Member of Bhuj Formation, near Bhuj.

Association: *Diplocraterion, Skolithos, Arenicolites, Stipsellus.*

Corophioides luniformis

ICHNOGENUS

Crossopodia M'COY, 1851, p. 395.

Diagnosis: Meandering, curved, or straight trails, width about 1.0 cm, with broad dense fringe on each side, mostly with median furrow.

ICHNOSPECIES

Crossopodia *Sp.* M'COY, 1851.

Plate-27

Description: The Kutch specimen identified as *Crossopodia* are distinct, unbranched, straight to gently curved trails (track ways) probably of arthropod or annelids. Many specimens are found tapering towards both the sides by blunt rounded ends. Traces are covered by finer sediments and show poorly exposed median furrow. Fringes are broad dense on each side with almost perpendicular orientation to the furrow, and curved. The arrangement of the lateral pods (fringes) is very distinct and symmetrical; opposing pods are forming high obtuse angle to almost perpendicular to the furrows. Differences of obliqueness of pods do not correspond with specimen size or lithology of sediment but seemingly indicate different modes of animal behaviour. The general orientation of pods on the other hand seem useful in determining the direction in which the trace making animal moved. The trace in the photograph shows length of more than 12.0 cm and width ranging between 1.0 cm to 1.6 cm.

Discussion and Interpretation: The specimen from Kutch are found approaching in their general form and appearance as those described and illustrated by Hattain and Frey (1969). It is interpreted as crawling trail.

Preservation: Convex epirelief.

Facies: Rippled Ferruginous Sandstone Siltstone Shale

Stratigraphic Distribution: It occurs in Tapkeshwari Member.

Association: *Thalassinoides, Rhizocorallium, Asteriacites, Gyrochorte, Palaeobullia.*

Crossopodia Sp.

ICHNOGENUS

Cylindrichnus TOOTS in HOWARD, 1966.

Diagnosis: Subconical form, weakly curved, circular to oval in cross section with diameter of 10.0 to 20.0 mm, most commonly 12.0 to 15.0 mm, central core 2.0 to 4.0 mm, exterior wall composed of concentric layers, preserved in full relief, orientation from nearly horizontal to vertical.

ICHNOSPECIES

Cylindrichnus *Sp.* TOOTS in HOWARD, 1966.

Plate-28

Description: Simple cylindrical tube having diameter of 3.0 to 5.2 cm and inclined at various angles to vertical to the bedding plane. Simplest forms have a concentric wall structure in which the tube is central, but others may be slightly eccentric because wall structures are biased towards very fine material Interpreted as permanent burrow (domichnia) of filter feeding organisms by Frey and Howard (1970).

Discussion and Interpretation: The species is defined in part on the basis of the presence of internal concentric laminae in cross section of *Cylindrichnus*. Such fine scale structure is preserved in purplish to reddish brown sandstone of Tapkeshwari Member. The general geometry of the genus is considered here to be a reliable taxonomic criteria. Here, it is present along with algal mates (stromatolites).

Preservation: Full relief, endichnial burrows, fill of the core either with the surrounding matrix or consisting alternating dark and lighter coloured material.

Cylindrichnus Sp.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in the Tapkeshwari Member.

Association: *Skolithos*, *Diplocraterion*, *Gyrochorte*, *Rhizocorallium*.

ICHNOGENUS

Cylindricum LINCK, 1949, p. 19.

Diagnosis: *Cylindricum* are plug shaped burrows like test tubes, rounded at lower end. Walls of the burrows are smooth. Burrows oriented perpendicular to bedding plane.

ICHNOSPECIES

Cylindricum *Sp.* LINCK, 1949.

Plate-29

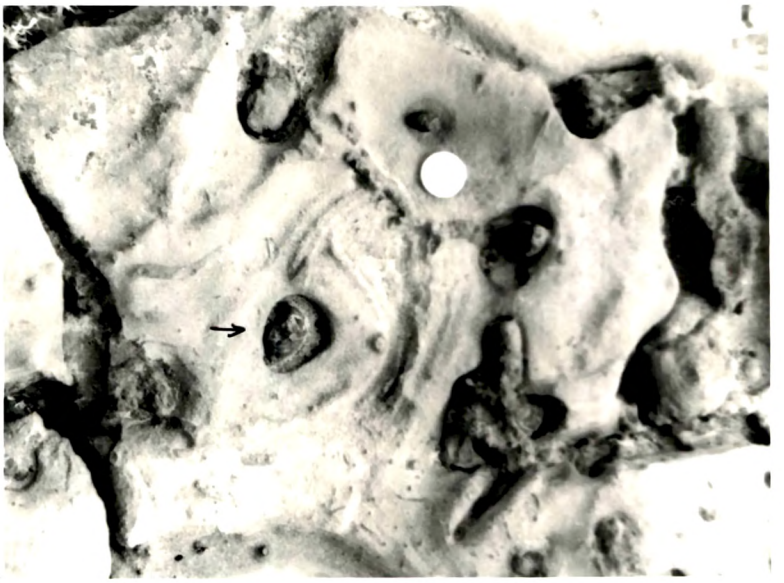
Description: Simple, straight, vertical to steeply inclined, smooth cylindrical to subcylindrical unbranched burrows having distinct wall like structure. It occurs in group or as isolated individual on bedding plane. Mostly circular or elliptical in cross section. The maximum observed length in field is about 12.0 cm and diameter varies from 2.5 to 4.5 cm. Burrow filled with material identical to surrounding host sediments. Lower end is rounded.

Preservation: Full relief, preserved mainly as endichnia, fill identical to matrix.

Facies: Sheet Sandstone.

Stratigraphic Distribution: It occurs in Jadura Member of Katrol Formation.

Association: *Cylindrichnus*, *Skolithos*, *Monocraterion*, *Planolites*.



Cylindricum Sp.

ICHNOGENUS

Didymaulichnus 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.

ICHNOSPECIES

Didymaulichnus lyelli ROUAULT, 1870.

Plate-30.

Diagnosis: Simple, smooth, gently curving bilobate trails preserved in convex hyporelief, parallel to bedding. Lobes, separated by distinct furrow, may have asymmetric "marginal bevels". Trails at places overlap and truncate over one another.

Description: Long, straight to gently curved trail consisting of two distinct lobes separated centrally by very narrow median furrow. Surfaces of lobes are smooth to slightly undulatory and parallel to bedding plane. The trace is 0.8 cm wide, 0.4 cm high, and extends for over 30.0 cm. In some specimens traces are commonly crossing, and occurring in profusion on bedding planes. *Didymaulichnus* is generally regarded as a surface trail probably of a Mollusc (Hakes, 1976).

Preservation: Positive hyporelief, full relief.

Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: Occurs in Jadura Member of Katrol Formation.

Association. *Gyrochorte*, *Planolites*, *Isopodichnus*, *Oldhamia*, *Scolicia*.

Didymaulichnus lyelli

ICHNOGENUS

Diplocraterion TORELL, 1870.

Type Species: *Diplocraterion* parallelum Richter, 1926, p. 213.

Diagnosis: U-shaped burrow with spreite, vertical to bedding plane, limbs of U - parallel, both limbs of successive U-tube confluent with limbs of preceding U-tube, opening of tubes mostly funnel shaped, commonly protrusive, but retrusive forms also observed, bottom of burrow semicircular, rarely straight, horizontal cross section on bedding planes dumbbell shaped, diameter of tubes 5.0 to 15.0 mm; distance between limbs 1.0 to 7.0 cm, depth of burrow 2.0 to 15.0 cm.

ICHNOSPECIES

Diplocraterion *Sp.* TORELL, 1870.

Plate-31.

Description: U-shaped burrows oriented almost perpendicular or slightly inclined to bedding near opening and gently to sharply curved to become almost horizontal near bottom. Burrows are containing spreite and with funnel shape aperture. Upper 3.0 to 5.0 cm part near opening is without spreiten and slightly diverging V shaped, remaining part of the limbs of U-tube parallel with spreiten. The single tube is circular in cross section and entire burrow is dumbbell shape. Bottom of burrow semicircular. The burrow diameter is about 7.0 to 9.0 mm and tubes are 2.1 cm apart from each other. It extends up to a depth of 27.0 cm and its length is more than 45.0 cm (plate-31). The spreite is well developed, which is protrusive and slightly irregular at a distance of 3.0 to 6.0 mm.

Preservation: Full relief, endogenic, fill slightly finer and darker than the host sediments. Domichnian of suspension feeders.

Diplocraterion Sp.

Facies: Massive Sandstone.

Stratigraphic Distribution: It occurs in Tapkeshwari Member.

Association: *Arenicolites, Skolithos, Rhizocorallium.*

Remarks: *Diplocraterion Sp.* differs from D.parallelum by curving or arch shape nature, inclination to the bedding plane, divergence of limbs and absence of spreiten in few centimeters of upper part, and tendency of it to become almost subparallel to the bedding plane.

Discussion and Interpretation: The divergence of the arms in some of the specimens of *Diplocraterion Sp.*, offers an additional argument for interpretation of the genus as the dwelling burrow of a suspension feeding animal (Fursich, 1974). The absence of spreiten in upper few centimeter part supports this view. 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.

ICHNOSPECIES

Diplocraterion parallelum RICHTER, 1926, p. 213.

Plate-32, a & b.

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

Description: Fairly straight U-tubes, the arms of which are more or less parallel, oriented perpendicular to the bedding, containing spreite and with funnel shape aperture. The burrows are circular in cross section. The diameter of tubes is 0.5 to 0.8 cm and 2.0 to 9.0 cm apart from each

other. The U-tubes have poor to well developed spreite. These are found to penetrate the rock down to 40.0 cm. The spreite is protrusive. Criss crossing of superimposed burrows is observed in Kutch specimen High burrow density at many places indicates severe phases of burrowing. Burrow collapse structure have been observed in few cases. Orientation of the U-tubes, probably in response to the palaeocurrents was observed in few cases.

Preservation: Full relief, endogenic, fill identical with the surrounding substrate. Domichnian of suspension feeders.

Facies: Bioturbated Sandstone, Massive Sandstone, Sheet Sandstone.

Stratigraphic Distribution: It occur in Jamaywadi Member, Tapkeshwari Member and Bharapar Member.

Association: *Arenicolites*, *Cylindrichnus*, *Monocraterion*, *Skolithos*, *Planolites*, *Palaeophycus*.

Discussion and Interpretation: Vertical spreiten burrows are usually regarded as the domichnia of suspension feeders (Richter, 1926; Goldering, 1962; Seilacher, 1963, 1967). The spreite is the result of the organism's efforts to keep its burrow at a constant depth and not the result of mining the sediment for food. Arkell (1939) and Howell (1957) regarded *Diplocraterion* as the burrow of a polychaete. Hertwek (1970) figures bioturbation structures produced by the recent Echiurus echiurus from the German Bay, which are very similar to bioturbation structures of *Diplocraterion*. Again, burrows of present Corophium are very similar except for their smaller size (Schafur, 1952). According to Fursich (1974), it may not be justified to exclude either polychaete or

a. *Diplocraterion* parallelum

b. *Diplocraterion* parallelum

crustacean as possible producers of *Diplocraterion*, though the absence of scratch marks in tube walls may favour a polychaete origin. Moreover, there is no doubt that *Diplocraterion* has been produced by a variety of forms (Seilacher, 1957). It is, however, very important that the *Diplocraterion* represents burrow made by suspension feeders.The occurrence of burrows at different level in a bed and sudden tapering without Preservation of funnel shape opening (plate-32 a & b) in majority of the cases depicts episodic erosional and depositional events. Burrow density, most probably, does not indicate population of animals, but it suggest organisms intention to maintain constant depth by preparing new burrow and abandoning old one, which is partially eroded and later buried under episodic sedimentation. Fursich (1974) claims that the rhythmic alternation of periods of sedimentation and nondeposition may be related to a tidal environment.

ICHNOGENUS

Enteropneusta burrows KAZMIERCZAK & PSZCZOLKWSKI, 1969, p. 299-318, figs. 3, 4, 7-9; 5 plates;

KENNEDY, 1975, p. 389, fig. 17.8;

CHAMBERLAIN, 1977, P. 12, FIG. 2x.

Plate-33.

Description: These are vertical, inclined and horizontal burrows (or hard ground borings ?) making partial box works or stacks with maze. Burrows branching and irregular in size and form, 4.0-10.0 mm in diameter, 5.0-6.0 cm high and with long branches. No planned patterns is observed in these burrows. Burrow lining is thick and hard and resistant.

Remarks: Burrows similar to the Kutch specimen have been described by Chamberlain (1977) from Ordovician Hanson Creek Formation of Central Nevada. Kazmierczak and Pszczolkwzki (1969) described *Enteropneusta burrows* from the Middle Triassic of the Holy Cross Mountains of Poland.

Preservation: Endichnial burrows with full relief. Fill identical to the matrix. Dwelling burrows (domichnia).

Facies: Found in the Massive Sandstone and Bioturbated Sandstone. **Stratigraphic Distribution**: It occurs in Tapkeshwari Member and Bharapar Member.

Association: *Skolithos*, *Monocraterion*, *Arenicolites*.

Enteropneusta burrows

ICHNOGENUS

Fustiglyphus VYALOV, 1971, p. 90.

ICHNOSPECIES

Fustiglyphus *Sp.* VYALOV, 1971.

Plate-34.

Diagnosis: Straight strings or narrow cylinders of varying length encircled by ring like knots or well defined swelling at regular or varying intervals, rosary like.

Remarks: Initially Vassoevich [1951] described Rhabdoglyphus, but an adequate Description of this genus had not been provided. The Rhabdoglyphus is subsequently been described by Boucek and Elias [1962]. Boucek and Elias seem to have only expanded the Description of Rhabdoglyphus and complicated matters by figuring specimens much different from the material described by Vassoevich originally. This has been pointed out by Ksiazkiewicz [1970, p. 286-287]. As a result, the figured specimens of Boucek and Elias have been mistakenly considered Rhabdoglyphus by Hantzschel [1965, p. 75, 1966, p. 15] and Osgood [1970, p. 369]. Vyalov [1971, p. 90] finally clarified matters by introducing the new name *Fustiglyphus* for the material by Boucek and Elias.

Description: The Kutch specimen is essentially horizontal, straight to gently curved cylindrical burrows consisting of varying length encircled by double or single ring like knots. The length of the burrow is about 17.0 cm, diameter of 3.0 cm, knots are 0.5 to 1.5 cm wide and about 6.0 to 8.0 cm apart from one another. Burrow fill identical to host sediments.

Preservation: Positive hyporelief, full relief.

Facies: Laminated Shale Siltstone, Sheet Sandstone.

Fustiglyphus Sp.

Stratigraphic Distribution: It occurs in Marutonk Dungar Member of Katrol Formation.**Association**: *Phycodes*, *Planolites*, *Palaeophycus*, *Thalassinoides*.

Discussion and Interpretation: It is considered as a variety of repichnia or fodinichnia, and believed by Boucek and Elias (1962) to be made by amphipod or gasteropod or even a holothuroid similar to Leptosynapta.

ICHNOGENUS

Granularia POMEL, 1849, p. 333.

Diagnosis: Elongated fillings of burrows; long, diameter up to about 15.0 mm; twig shaped, with rather regular branching; walls originally lined with clay particles.

ICHNOSPECIES

Granularia *Sp.* POMEL, 1849.

Plate-35

Description: Horizontal, cylindrical burrows preserved as convex epichnia or endichnia, which show diachotonous branching, internally lined by small or minute circular to elongated pellets which are formed from clay particles. Burrow 29.0 cm long, straight to slightly curved and almost subcircular to ovate in cross section. The diameter is 2.0 cm which is almost constant through out the length, except swelling in some cases at point of branching. Branches always at acute angles, but angle variation is noted (40° to 60°).

Preservation: Convex epirelief, full relief, endogenic.

Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: It occurs in Marutonk Dungar Member on way to the Jadura, about 6.0 km away from Bhuj, in a nala section.

Association: *Palaeophycus*, *Planolites*, *Thalassinoides*, *Ophiomorpha*.

Granularia Sp.

ICHNOGENUS

Gyrochorte HEER, 1865, p. 142.

Diagnosis: Trace up to 5.0 mm wide in epirelief preserved as plaited ridges with biserially arranged, obliquely aligned pods of sediment, in hyporelief preserved as smooth biserial grooves separated by median ridges; course strongly winding and direction changing sharply, trace may intersect itself or other traces, ridges and their grooves may be separated by vertical distance of 1.0 cm; usually preserved in clastic sediments.

ICHNOSPECIES

Gyrochorte comosa HEER, 1865.

Plate-36, a & b.

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

Description: The trace includes long winding ridges on the upper surface of the bedding plane, with the width of ridges 0.3 to 0.6 cm and maximum observed length is about 67.0 cm. The height of the relief is usually less than 0.1 cm. The trails usually consist two lobes showing biserial arrangement separated by median furrow. Each lobe consists uniformly developed obliquely aligned pods. The angle between the pods and the median furrow varies from 40° to 55°. The ridges at places end abruptly. Crossing over occurs frequently in such a way that the earlier formed ridges are not destroyed. The distance between successive pods varies from 0.1 to 0.3 mm.

Discussion and Interpretation: After early interpretations such as impressions of ophiuroids (Quenstedt, 1858) or egg strings of mollusca (Heer, 1865, as in Fursich, 1974), *Gyrochorte* was

a. *Gyrochorte* comosa

b) *Gyrochorte* comosa
ii Oldhamia sp.

later thought to represent tunnel structure, made by amphipods. Weiss (1940, 1941) and Seilacher (1955) however, interpreted *Gyrochorte* as produced by a polychaete or worm like animal moving obliquely through sediment.

Hallam (1980) 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 Weiss's model. Recently, Heinberg (1973) was able to show in a detailed study, based on excellently preserved material from East Greenland, that Weiss's interpretation was correct and that *Gyrochorte* in fact produced by an elongate organism moving obliquely through the sediment in search of food.

Preservation: Endogenic scour cast, convex and concave epirelief.

Facies: Laminated Shale Siltstone, Sheet Sandstone, Rippled Ferruginous Sandstone Siltstone Shale, Massive Sandstone.

Stratigraphic Distribution: It occurs in the Jamaywadi Member, Gangeshwar Member, Jadura Member, & Tapkeshwari Member.

Association: *Crossopodia, Didymaulichnus, Scolicia, Rhizocorallium, Thalassinoides, Asteriacites, Oldhamia, Circulichnus, Yakutatia.*

ICHNOGENUS

Gyrolithes DE SAPORTA, 1884, P. 27

Type Species: Siphodendron girardoti DE SAPORTA, 1884.

Diagnosis: Dextrally or sinistrally coiled burrows up to several cm in diameter, some times with rounded or elongated process which may be branching near upper end, diameter of whorls mostly uniform, vertically oriented, up to several decimeters high.

ICHNOSPECIES

Gyrolithes saxonicus HANTZSCHEL, 1934.

Plate-37.

Diagnosis: Dextrally or sinistrally coiled burrows, upright in deposit, without surface ornamentation.

Description: The Kutch specimen is sinistrally coiled, filled with host sediment and occurs three dimensionally consisting of a burrow forming spring like spirally coiled structure. The diameter of the burrow is about 1.4 cm, and outer diameter of the whorl is about 11.0 cm. Diameter of whole burrow system is more or less constant, which is vertically oriented and observed specimen is about 7.0 cm high. No ornamentation or branching has been observed.

Discussion and Interpretation: *Gyrolithes* burrows are most probably made by decapod crustaceans (Hantzschel, 1975).

Preservation: Full relief, endichnial burrows in filled identical to surrounding substrate.

Facies. Massive Sandstone.

Gyrolithes saxonicus

Stratigraphic Distribution: It occurs in Jadura Member

ICHNOGENUS

Gyrophyllites GLOCKER, 1841, p. 322.

Type Species: *Gyrophyllites* kwassizensis GLOCKER, 1841.

Diagnosis: Vertical or oblique shaft from which 5 to 20 (average 10) club or leaf shaped tunnels radiate at different levels in whorled or helical arrangement.

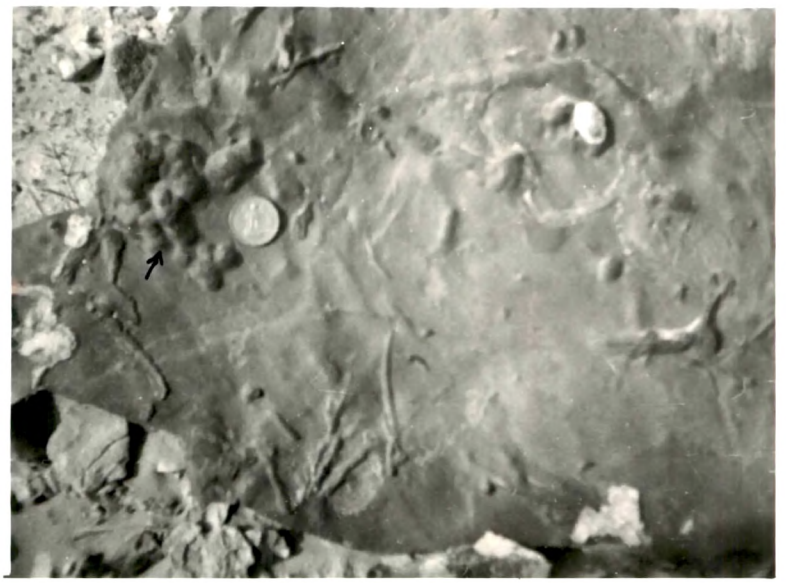
ICHNOSPECIES

Gyrophyllites *Sp.* GLOCKER, 1841.

Plate-38.

Description: The Kutch specimen consists of vertical or steeply inclined shafts from which elongated oval shape tunnels radiate at different levels in whorl or helical arrangement to produce a conical structure. The entire structure is volcano shape conical with crater like depression of shaft at the center. The diameter of plug or shaft is 0.6 to 0.7 cm. The tunnels are dipping down ward away from the shaft, which contains rosette like appearance and up to 6.0 cm elongation. The tunnel diameter varies from 0.5 to 1.5 cm and becomes larger upward, and shows spreiten structure. The structure contains about 9.0 to 10.0 tunnels. Complete sequence of tunnels producing rosettes of various sizes connected by the central shaft are ending in funnel shaped aperture above highest rosette. The structure is 8.0 to 11.0 cm in diameter and up to 3.5 cm in height on bedding plane. The radiating tunnels or grooves are arranged fairly regularly and are separated from each other by a pronounced rim.

Discussion and Interpretation: The spreiten of the tunnels and radiate arrangement depicts that the structure is produced as a result of probing of sediments by trace making organism for food. The leaf shape tunnels are considered as of feeding type by Hantzschel (1975). Fursich (1974, fig. 31,



Gyrophyllites Sp.

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 madusae 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 madusa. This shaft was inhabited 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 dimensional feeding system and have, therefore, been included into *Gyrophyllites* Glocker, 1841.

Preservation: Positive epirelief.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Tapkeshwari Member.

Association: *Planolites*, *Palaeophycus*, *Palaeobullia*, *Thalassinoides*, *Asteriacites*.

ICHNOGENUS

Helminthopsis HEER, 1877, p. 116.

Diagnosis: Simple meandering smooth trails. Not as strictly developed as Helminthoida, in parts with marginal ridges.

ICHNOSPECIES

Helminthopsis abeli KSIAZKIEWICZ, 1977.

Plate-39, a

Diagnosis: Smooth, unbranched, gently meandering, more typically loose winding trails, burrow constant through out, low relief.

Description: The Kutch specimens of *Helminthopsis* abeli are smooth, unbranched, horizontal to subhorizontal trails, filled with fine grained sand size particles and preserved on upper ripple marked bedding surfaces. Burrow diameter is constant through out and fill is identical to host rock. Burrow is slightly meandering. Maximum observed length is about 35.0 cm with diameter of 1.5 cm.

Discussion and Interpretation: These traces closely resemble Helminthoida illustrated by Chamberlain (1971, fig. 118). However, the specimens from Kutch are placed in ichnogenus *Helminthopsis* because they lack the regular, tight meandering pattern of Helminthoida. *Helminthopsis* has been considered as an endogenic feeding trail of a worm (Chamberlain, 1971). It has been described from marine to intertidal Facies by Miller and Knox (1985).

Preservation: Convex hyporelief, full relief.

a. *Helminthopsis* abeli

b. *Helminthopsis* hieroglyphica

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It is found in the Tapkeshwari Member.

Association: *Palaeobullia*, planolites, palaeophycus, *Gyrochorte*, *Rhizocorallium.*

ICHNOSPECIES

Helminthopsis hieroglyphica HEER in MAILLARD, 1877.

Plate-39, b.

Diagnosis: Smooth, unbranched, irregularly winding burrows, typically alternating between winding and straight course.

Description: Variably preserved, smooth, unbranched, straight to irregularly winding burrows. Burrow diameter 0.4 cm, constant along length, typically short. Maximum observed length is about 22.0 cm. Burrow fill same as enclosing sediment. Cross overs of same and different burrows is a common feature.

Discussion and Interpretation: H. abeli (Ksiazkiewicz, 1977) is gently meandering, while H. heiroglyphica (Maillard, 1877) is irregularly winding burrow, with typically alternating winding and straight course

Helminthopsis is a very simple burrow system ranging in age from late Precambrian (Webby, 1970) to Holocene (Swinbunks and Murray, 1981) and is a eurybathic form. *Helminthopsis* ichnospecies are differentiated on simple parameters such as burrow diameter, presence or absence of surface ornamentation and style and dimensions of winding and/or meandering (Ksiazkiewicz, 1977).

Preservation: Preserved in concave and convex epirelief and convex hyporelief.

Facies: Laminated Shale Siltstone, Sheet Sandstone, Dark Shale Siltstone Sandstone.

Stratigraphic Distribution: It occurs in Jamaywadi Member of Chari Formation.

Association: *Bifungites*, *Planolites*, *Phycodes*, *Laevicyclus*, Arthropod resting trace, *Diplocraterion*.

ICHNOGENUS

Histioderma KINAHAN, 1858, p. 70.

Type Species: *Histioderma* hibernicum KINAHAN, 1858, p. 70.

ICHNOSPECIES

Histioderma hibernica HALLISSY, 1939.

Plate-40.

Diagnosis: Curved tubes, upper extremities trumpet shaped, lower turned up at right angle to bedding plane; upper portion of tubes marked by several ridges crossing each other at irregular intervals. [Dwelling burrows].

Description: Gently curved, highly inclined tubes with trumpet shaped opening consisting several ridges parallel or inclined to the burrow length in an irregular manner and at varying interval. Lower part more or less turns up right angle to the bedding plane. Outer diameter of the burrow on the bedding plane is 4.0 to 5.0 cm, near its neck it is about 1.0 cm, which is about 2.5 to 5.0 cm below the surface opening, from where diameter remains constant and tapers in an acute to obtuse rounded end. Burrow length varies from 4.0 to 8.0 cm in Kutch specimen. The tube below the trumpet shape may show parallel ridges but normally it is smooth. Aperture of the burrow varies in shape in Kutch specimen from circular to oval to polygonal.

Remarks: *Histioderma* differs from *Monocraterion* by internal structure in the funnel shape and tube, which contains irregular ridges parallel or oblique to the burrow length and by dimensions of funnels which are larger, in the former.

Preservation: Full relief, or concave epirelief. Fill finer than the host sediment, similar to the overlying sediment. Mostly empty.

Histioderma hibernica

Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: It occurs in Marutonk Dungar Member of Katrol Formation.

Association: *Palaeophycus, Planolites, Phycodes, Chondrites, Cochlichnus.*

ICHNOGENUS

Isopodichnus BORNEMANN, 1889, p. 25.

ICHNOSPECIES

Isopodichnus problematicus SCHINDEWOLF, 1928.

Plate-41.

Diagnosis: Dimorphous trace fossils consisting of small, straight or curved double ribbon trails up to about 6.0 mm. wide transversely striated by fine furrows, both "ribbons" separated by median ridge, trail may be intermittent, associated with "coffee-bean" shaped impressions of corresponding size.

Description: The Kutch form is straight to gently curved, parallel to the bedding plane and consisting of series of coffee bean shaped (double ribbon) like bilobed trails separated by median furrow (0.1 to 0.15 cm deep). Commonly, small band like structure also consists of unevenly spaced transverse ridges on the lobes. The maximum observed length is about 22.5 cm, width 0.6 to 0.7 cm, with coffee bean shaped parts having dimension of 0.7 to 0.8 cm. It is interpreted as locomotary trails of small arthropods (Seilacher, 1963; Bromley and Asgaard, 1972).

Preservation: Preserved in convex relief on soles of beds (hypichnia).

Facies: Laminated Shale Sandstone.

Stratigraphic Distribution: It occurs in the Jadura Member near Satellite Earth Station, Mundra Road.

Association: *Didymaulichnus*, *Gyrochorte*, *Palaeophycus*, *Oldhamia*.

Isopodichnus problematicus

ICHNOGENUS

Keckia GLOCKER, 1841, p. 319.

Diagnosis: Fillings of cylindrical tunnels with transverse annulation, single `segments' bent, burrows straight or slightly curved, branched, 1.0 to 2.0 cm. wide of varying length, lying on bedding plane, similar to *Taenidium* but much larger, filling probably faecal material passed through gut of animal.

ICHNOSPECIES

Keckia *Sp.* GLOCKER, 1841.

Plate-42, a.

Description: *Keckia Sp.* is cylindrical burrow with distinct meniscate structure. The burrow is sediment filled, unbranched to rarely branched, zig-zag to gently curved, thickly lined, which are lying parallel to the bedding plane. Transverse annulations are symmetrical with uniform, bent, regularly arranged segments. Annulations are also continued and continuously present in the thick burrow lining, and expressed on the outer surface in form of arcuate meniscae. Length of the burrow is about 8.0 to10.0 cm, and diameter of about 1.5 cm. Transverse lamination is more or less equidistant (0.35 cm). Fill is identical to the host rock.

Remarks: In the Kutch specimens *Keckia Sp.* is different than the K. annulata by its thick lining, distinct meniscate structure, mostly unbranched nature, less length, slightly more diameter, larger distance among annulation, and by the presence of annulation in the burrow linings.

Preservation: Convex epirelief and full relief (endichnial burrow). Actively filled.

a. *Keckia Sp.*

b. *Keckia* annulata

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in tidal flat deposits of Tapkeshwari Member of Umia Formation, near Bharapar Sanatorium.

Association: *Rhizocorallium*, *Gyrochorte*, *Taenidium*, *Keckia* annulata, *Circulichnus*, *Yakutatia*, *Diplocraterion*, *Thalassinoides*.

ICHNOSPECIES

Keckia annulata GLOCKER, 1841.

Plate-42, b.

Diagnosis: Cylindrical, gently curved, with equidistant transverse annulations. Burrow diameter through out constant.

Description: K. annulata is sediment filled cylindrical, branched, gently curved to undulose, thinly lined horizontal burrows. Symmetric to asymmetric transverse annulations are present with single bent segment. Annulations are projected on the outer surface by arcuate meniscae. Length of the burrow is up to 32.0 cm, with variation in the diameter of same tunnel from 0.5 to 1.25 cm. Transverse laminae is more or less equidistant (0.15 cm). Burrow lying on bedding plane with fill identical to the host rock. Branches are parallel to subparallel with each other.

Discussion and Interpretation: *Keckia* (Glocker, 1841) is similar to *Taenidium* (Heer, 1877) but much large in size than the latter.

Preservation: Concave and convex epirelief, endichnial burrows, active fill identical to the matrix.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Tapkeshwari Member of Umia Formation.

Association: *Planolites*, *Palaeophycus*, *Thalassinoides*, *Rhizocorallium*, *Taenidium*, *Gyrochorte*, *Circulichnus*.

ICHNOGENUS

Laevicyclus QUENSTEDT, 1879, p. 577.

Diagnosis: Approximately cylindrical bodies standing at right angle to bedding plane, diameter variable in same specimen, perforated by central canal, visible on bedding planes as regular concentric circles with diameter of several centimeter.

ICHNOSPECIES

Laevicyclus *Sp.* QUENSTEDT, 1879;

HANTZSCHEL, 1975, P. w77, w78, fig. 47.5; SEILACHER, 1953, p. 270, 1955, p. 389;

JORDON, 1985, p. 292, fig. 10c; OSGOOD, 1970, p. 396.

Plate-43

Discussion and Interpretation: Quenstedt (1879, p. 577, in Hantzschel, 1975, p. w78) interpreted these structures as corals; Philipp (1904, p. 59) and Wurm (1912, p. 128), as organisms of unknown affinities; by Schmidt (1934, p. 18-27) as inorganic, made by gas exhalations and water under pressure within sediment; and by Seilacher (1953, p.270, 1955, p. 389) the trace fossil as a feeding burrow. Seilacher as quoted by Hantzschel, 1962, compared it with the dwelling tube and scraping circles of Scolecolepis a recent annilid worm.

Preservation: Only the circular concentric upper part of the burrow in form of positive epirelief. Full relief. Preserved in fine grained sandstone. Fill identical to the matrix.

Facies: Laminated Shale Siltstone, Sheet Sandstone, Dark Shale Siltstone Sandstone.

Stratigraphic Distribution: It occurs in Jamaywadi Member of Chari Formation in quarries south of Madhapar.

Association: *Isopodichnus*, Arthropod resting trace, *Planolites*, *Bifungites*, *Helminthopsis*.

i *Laevicyclus Sp.*
ii Arthropod resting trace
iii planolites

ICHNOGENUS

Megagrapton KSIAZWIEWICZ, 1968, P. 5, 14.

Diagnosis: Networks consisting of irregular polygons and rectangles which are never closed, formed by slightly curved or straight cylindrical strings, 1 to 5 mm. wide, rather regular intervals of branching at nearly right angles.

ICHNOSPECIES

Megagrapton *Sp.* KSIAZWIEWICZ, 1968.

Plate-44.

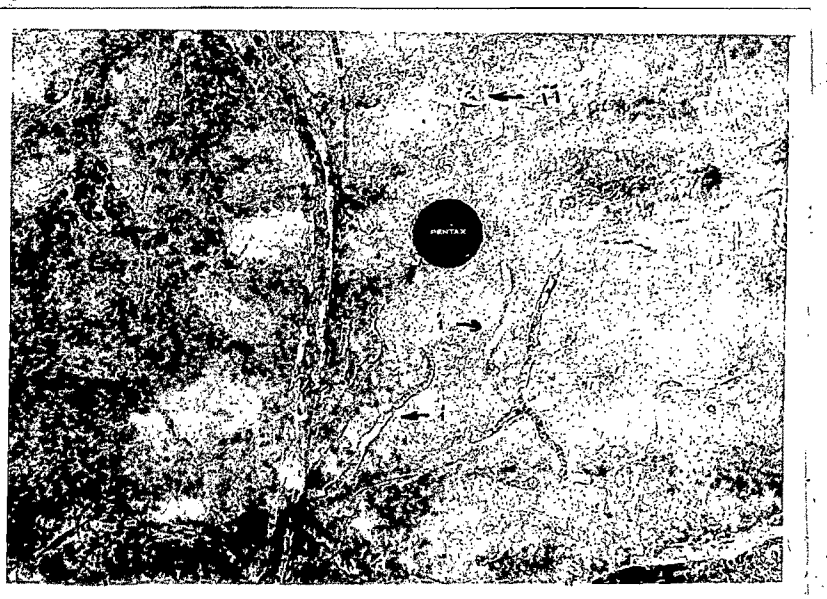
Description: The Kutch forms are small with relatively few wide net work of irregular open polygons or meshes. Burrows are circular in cross section, form slightly curved or straight cylindrical strings with diameter of 0.5 to 0.6 cm and found to associate on the same bedding plane.

Preservation. Positive hyporelief, endichinial burrow. Fill darker than the host sediments.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: Found in the Tapkeshwari Member.

Association: *Gyrochorte, Palaeobullia, Planolites, Rhizocorallium, Thalassinoides, Bifungites, Scolicia, Cylindricum, Chondrites.*



i *Megagrapton Sp.*
ii Asteriacites

ICHNOGENUS

Monocraterion TORELL, 1870, p. 13.

Diagnosis: "Trumpet pipes", funnel structure penetrated by central straight or slightly curved plugged tube, perpendicular to bedding plane, never branched, diameter commonly 5 mm.; up to 8 cm. long, funnel simple or multiple, diameter of funnels usually 1 to 4 cm.; greatest depth about 2 cm.; tubes commonly abundant but never crowded like *Skolithos*. Funnel obviously constructed by upward migration of animal, inhabiting tube is reflected by downward warping of surrounding bedding planes toward central tube.

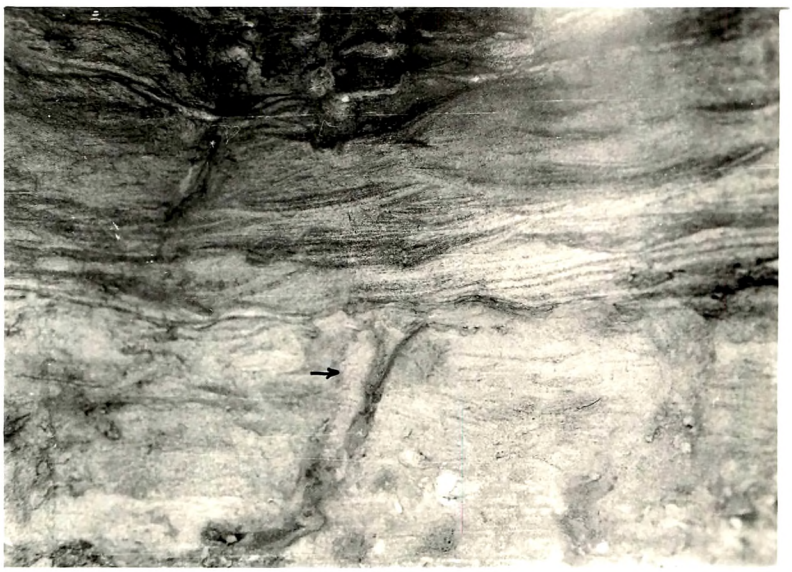
ICHNOSPECIES

Monocraterion tentaculatum TORELL, 1870.

Plate-45.

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

Description: The trace consists of straight to slightly curved cylindrical burrows, which are unbranched and filled with surrounding substrate. They occur as either closely spaced or isolated on bedding plane, mostly seen as circular to subcircular outline on the top surface or in vertical section in form of two dimensional tubes. Burrows oriented normal to steeply inclined to the bedding plane, which very often pass upward into ovate funnel, and downward into curvature with rounded almost horizontally oriented lower ends. Several specimens show funnels with raised rims, which may reflect lining to the funnels. Funnel diameter is variable, the maximum observed being 4.5 cm at the uppermost widest part, shaft diameter varies from 1.0 to 2.0 cm, with maximum observed length of 20.0 cm. Funnels vary in height in different burrow population.



Monocraterion tentaculatum

Discussion and Interpretation: The author found frequently, *Monocraterion* in association with *Skolithos* burrows. This confirms the view of Hallam and Swett (1966) that the difference between the burrows of these two ichnogenera is not due to different trace maker organisms but to different rate of sedimentation *Skolithos* is formed under conditions of slow sedimentation and *Monocraterion* occurs with conditions of relatively rapid sedimentation. *Monocraterion* is considered to be the dwelling structures of a worm like organisms, possibly a polychaete, for which the tube of Diapatra cuprea may be a modern analog (Myers 1970, Barwis, 1985). *Monocraterion* also occurs in high densities.

Preservation. Positive epichnia, circular scour with resistant burrow, endichnial burrow.

Facies. Massive Sandstone, Rippled Ferruginous Sandstone Siltstone Shale, Bioturbated Sandstone.

Stratigraphic Distribution. It occurs in Tapkeshwari Member and Bharapar Member.

Association: *Skolithos*, *Arenicolites*, *Ophiomorpha*, *Cylindrichnus*.

ICHNOGENUS

Muensteria VON STERNBERG, 1833, P. 31.

Diagnosis: Long, horizontal to sub-horizontal, straight to slightly curved, unbranched, unlined cylindrical borrow. Arcuate meniscate structure indicate backfilling traces.

Remarks: Trace fossils with back-fill structures are either called *Planolites* montanus [Richter, 1937], *Taenidium* [Heer, 1877], *Keckia* [Glocker, 1841] or *Muensteria* [Sternberg, 1833]. According to Fursich [1974] there is no basic difference among these ichnogenera, and the former are, therefore, regarded as synonyms to *Muensteria* which has priority. According to Frey and Howard [1985] *Muensteria* includes distinctly maniscate, cylindrical to subcylindrical burrows having discernible but lined walls. The taxon, as suggested by these authors, need systematic revision. The Kutch forms appear to be correlative to the coralline [upper Jurassic] specimens described by Fursich [1974] and are, therefore, generalized as *Muensteria Sp.*

ICHNOSPECIES

Muensteria *Sp.* STERNBERG, 1833, p. 31.

Plate-46.

Description: The Kutch specimens are long, horizontal to subhorizontal, straight to slightly curved, to moderately sinus unbranched, distinctly transverse meniscate, cylindrical to subcylindrical burrows having discernible but lined walls. These are arcuate meniscate structures indicating back filling traces. The transverse section also reveals an intricate structure in the form of concave - convex concentric segments. Laminae are parallel to one another. The surface of the burrows clearly indicate the nature of segmentation either by its concentric rings or by its annular constrictions. The maximum observed length of the burrow is about 47.0 cm,

Muensteria Sp.

width varies between 0.5 to 1.5 cm. The transverse annulation is spaced at 0.3 to 0.5 cm interval. Burrows are circular to subcircular in cross section.

Preservation: Full relief, concave epirelief.

Facies: Laminated Shale Siltstone, Sheet Sandstone.

Stratigraphic Distribution: It occurs in Jamaywadi Member near Jamaywadi.

Association: *Ophiomorpha, Bolonia, Palaeophycus, Planolites, Cochlichnus.*

Discussion and Interpretation: Trace fossils with back fill structures have been called *Planolites* (Richter, 1837; Webby, 1970); *Taenidium* (Heer, 1877, Hakes, 1976); and *Muensteria* (Sternberg, 1833). In a detailed analysis of *Planolites* montanus and *Taenidium,* Richter (in Fursich, 1974, p. 14) interpreted cup shaped segments as back fill structures made by deposit feeders. Annulations suggest that the burrows may have a meniscate back fill within them. 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 in to each other by animal, resulting in their annulated arrangement. Richter's interpretation is in agreement with the observations made on the Kutch specimen by the author who therefore regards *Muensteria* as the fodinichnia of a deposit feeder (probably a worm). Burrows of this type are considered to be Facies independent, since they have been reported from flysch Facies (Heer, 1976; McCann and Pickerill, 1988) and to non-marine sediments (Seilacher, 1963; Stanley and Fagerstorm, 1974, and Squire and Advocate, 1984).

ICHNOGENUS

Neonereites SEILACHER, 1960, p. 48.

Diagnosis: Bimorphous, shape depending on its hypichnial or exichnial Preservation; as negative epireliefs consisting of irregularly curved chains of deep, smooth walled dimples; chain restricted in length, some bordered laterally by flabby structures caused by borrowing; corresponding hypichnia form a median string, irregularly curving or straight or rarely meandering, consisting of single or double lined clay (fecal) pellets or small plates.

ICHNOSPECIES

Neonereites biserialis SEILACHER, 1960.

Plate-47.

Diagnosis: Curved, chain of biserially arranged depressions or sediment pods.

Description: The Kutch specimen of *Neonereites* biserialis typically displays a double row of small, unornamented, deep, smooth walled dimples and elongated depressions, with 0.1 to 0.15 cm diameter, forming a straight to irregularly curved chain on bedding plane with a median string. Depressions either adjacent to slightly overlapping but never isolated. Chain is very short, only 4.0 - 5.0 cm in length. Specimen shows flabby structures on lateral borders caused by burrowing.

Preservation: Preserved in concave epirelief.

Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: Occurs in Jadura Member of Katrol Formation near Satellite Earth Station.

(i) *Neonereites* biserialis

(ii) *Phycodes* palmatum

Association: *Gyrochorte*, *Phycodes*, *Planolites*, *Palaeophycus*, *Trichichnus*, *Oldhamia*,, *Isopodichnus*.

Discussion and Interpretation: The Kutch specimen confirms in size and morphology with material figured by Seilacher, 1960, from Middle Jurassic (in Hantzschel, 1975, p.84). Interpreted to be post depositional internal burrow by Hantzschel (1975). According to Seilacher (1962, p.233) *Neonereites* is possibly the irregular counter part of Helminthoida labyrinthica HEER in sandy environments.

ICHNOGENUS

Oldhamia FORBES, 1849, p. 20.

Type Species: Murchisonites forbesi GOEPPERT, 1860, p. 441.

Diagnosis: Bunches of fine rills radiating from joints of sympodial axis.

ICHNOSPECIES

Oldhamia *Sp.* FORBES, 1849.

Plate-48.

Description: The Kutch specimen of *Oldhamia* contains radiating bunches of fine rills or fine elongated linear grooves, normally 2.0 to 3.0 cm in length, in some cases upto 8.0 cm. Laterally terminal rills are producing acute angles in between 20° to 60°. Rills are attached to the straight or curved sympodial axis only 1.0 to 6.0 cm in length, commonly made up of single rill (linear depression) but sometimes partially shows 2 to 3 rills Bunches of rills may found attached to one end or both the ends of the axis; but many rills may be present at one of the ends when bunches present on both the ends.

Discussion and Interpretation: The structure represents a grazing pattern. Numerous explanations of origin have been proposed, such as remains of algae, hydrozoans, bryozoans or of inorganic origin. First interpretation as trace fossil is given by Ruedemann (1942) as radiating feeding trails supposedly made by worms.

Preservations: Negative epirelief.

Facies: Laminated Shale Siltstone, Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Jadura Member and Tapkeshwari Member.

Association: *Gyrochorte, Isopodichnus, Trichichnus, Phycodes.*

i *Oldhamia Sp.*
ii Gyrochorte comosa

ICHNOGENUS

Ophiomorpha LUNDGREN, 1891, p. 114.

Diagnosis: Three dimensional burrow systems, vertical and horizontal, cylindrical tunnels dichotomously branching, generally at acute angles, with local swelling close to or at points of branching, tunnels internally smooth, but outer surface of burrow lining characteristically mammilate due to presence of discoidal or ovoid pellets, which are several mm., rarely more in diameter; tunnels may also be only partly lined by small pellets; longitudinal ridges occur on outer surface of some burrow fillings. Occasionally penetrating sediment for more than 1.0 m. in depth.

ICHNOSPECIES

Ophiomorpha *nodosa* LUNDGREN, 1891.

Plate-49

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

Description: The Kutch specimens of *Ophiomorpha nodosa* are usually in the large scale, branched or unbranched burrow systems of vertical shafts and horizontal to inclined tunnels. Almond shape structures are very common on bedding plane view. The walls of the burrow are usually smooth on their interior and typically mammilated exterior surfaces. The exterior burrow wall consists white calcareous lining with poorly developed pellets. Length and diameter of burrows are variable in different burrow population. Somewhat enlarged chambers occur at point of bifurcation. Diameter of the burrow is upto 1.6 cm and length is upto 50.0 cm. No apertural necks observed. Funnel shape

structures observed on upper part of the burrows. Burrows are filled with the sediment similar to that of the surrounding substrate, but unfilled tube segments are also very common.

Preservation: Full relief, burrow fill identical to the matrix.

Facies: Coarse Grained Cross Bedded Sandstone.

Stratigraphic Distribution: It occurs in Bharapar Member of Bhuj Formation.

Association: Monodominant.

Discussion and Interpretation: The ichnogenera *Ophiomorpha* Lundgren, 1891, and *Thalassinoides* Ehrenberg, 1944, were treated as junior subjective synonyms of Spongiliomorpha Saporta, 1887, by Fursich (1973), who recognised O. *nodosa* as valid ichnospecies. This assessment subsequently was challenged on a number of points by Bromley and Frey (1974, p. 312, 313) and later Frey et. al. (1978) not only on recognizing the ichnogenus *Ophiomorpha* but also in their redefinition of its species.

Jurassic burrow forms in Kutch clearly can be referable to O. *nodosa*, the type Species, characterised by dense, regularly distributed, predominantly single pellet mode of wall formation (Frey et. al., 1978). According to Frey et. al. (1978), O. *nodosa*, burrows are formed by macro invertebrate Callianassa major Say, and other callianassid species, which live in near shore and lower fore shore of barrier island beaches in normal marine salinity.

Ophiomorpha nodosa

ICHNOGENUS

Palaeobullia GOTZINGER AND BECKER, 1932, p. 379.

Diagnosis: Horizontal bilaterally symmetrical gasteropod trails of great variability, long, band like; morphology as surface trails.

ICHNOSPECIES

Palaeobullia Sp. GOTZINGER AND BECKER, 1932.

Plate-50.

Description: The Kutch specimen represents horizontal bilaterally symmetrical gasteropod trails, representing a true surface trail of negative and positive epirelief. It is long, band like, consisting of ribbon like or ridge like convex median axis, with almost constant width of 1.3 cm. Two lateral parts are parallel to the median axis and convex ridge like but width is less, varying from 0.3 cm to 1.0 cm. The trails are slightly meandering to curving and mostly lateral ridges are thinning to absent at curvatures and bending. The median axis and lateral ridges are separated by two furrows running parallel to the length. Sculpture almost absent. Maximum observed length is approximately 55.0 cm.

Preservation: Concave and convex epirelief.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Tapkeshwari Member of Umia Formation near Observatory.

Discussion and Interpretation: Morphology of the trails *Palaeobullia* depend on their origin as surface trail caused by different methods of creeping and removing sediments. Ribbed or striae or gill like sculpture may produce as a result of different methods of creeping. The *Palaeobullia* is now regarded as creeping or feeding trail or both of burrowing gasteropods, and occurs in wide range of

facies from *Nereites* to *Cruziana*. Nomenclature treatment of these variable trails is difficult (Ksiazkiewicz, 1970; Seilacher, 1955).

Palaeobullia Sp.

ICHNOGENUS

Palaeophycus HALL, 1847.

Type Species: *Palaeophycus* tubularis HALL, 1847; HANTZSCHEL, 1975; PEMBERTON & FREY, 1982; HOWARD & FREY, 1984.

Diagnosis: Cylindrical or subcylindrical burrows, usually sinuous, oriented more or less obliquely to bedding. Commonly unbranched, though may be branched occasionally. Surface of walls smooth or rarely with faint longitudinal striae. *Palaeophycus* is distinguished from *Planolites* by having a distinct wall lining and sediment fill typically different from the lithology of the host sediments.

Remarks: *Palaeophycus* originally defined by Hall [1847] has confusing taxonomic nomenclatural history. There are 54 ichnospecies assigned to *Palaeophycus*. Pemberton and Frey [1982] grouped these into five main species of *Palaeophycus*. These are recognized on the basis of wall linings and burrow sculpting as:

[1] Distinctly lined, smooth walled, unornamented burrows.

[a] Thick walled burrows - P. Heberti,

[b] Thin walled burrows - P. tubularis.

[2] Very thinly lined longitudinal striated burrows. [a] Continuous parallel striae - P. striatus,

[b] Irregularly anastomosing striae - P. sulcatus, [c] Alternatively striae and annulate - P. alternatus.

ICHNOSPECIES

Palaeophycus heberti SAPORTA, 1872, PEMBERTON AND FREY, 1982.

Plate-51, a.

Diagnosis: Smooth, unornamented, thickly lined, cylindrical burrows.

Description: Straight to slightly curved, branched to unbranched, smooth walled cylindrical burrows. Diameter more or less become constant, collapsed burrows are common. Burrow wall linings typically consist of agglutinated sediment, coarser and better arranged than the host rock. Burrow length is about 9.0 cm and diameter of 1.5 cm. Burrow fill is structureless and identical to enclosing sediments. Outer wall shows faint transverse striations. Thick wall of the burrow can be seen alongwith smooth burrow fill inside, exposed due to differential (uneven) weathering. Burrow is slightly compressed - subcylindrical to oval.

Discussion and Interpretation: Original specimens of *Palaeophycus* heberti were assigned initially to the ichnogenus Siphonites (Saporta, 1872), subsequently their affinity with *Palaeophycus* was noted by Saporta and Marion, (1883). Pemberton and Frey (1982) confirmed Siphonites as a junior synonym of *Palaeophycus*.

The thick wall lining distinguishes P. heberti from P. tubularis. Interpenetration and branchings are some what less common than to P. tubularis.

Preservation. Full relief, convex epirelief.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Tapkeshwari Member of Umia Formation.

a. *Palaeophycus* heberti

b. *Palaeophycus* tubularis

Association: *Asteriacites, Rhizocorallium, Thalassinoides, Planolites, Palaeobullia.*

ICHNOSPECIES

Palaeophycus tubularis HALL, 1847,

PEMBERTON AND FREY, 1982.

Plate-51, b.

Diagnosis: Thinly lined, unornamented, straight to sinuous cylindrical burrows of variable diameter.

Description: Cylindrical to slightly flattened, straight to slightly curved, more or less smooth walled burrows, parallel to slightly oblique to the bedding plane. Branching is rare. Burrow wall is thinly lined and irregular. The burrow fill is structureless and identical to the host rock. Width and the length of the burrow tubes are variable in different burrow population. Maximum observed length is 15.0 cm with diameter of 2.0 cm. Burrow collapse structures are common, representing incomplete filling by sediments.

Discussion and Interpretation: *P. tubularis*, the type species of *Palaeophycus* is distinguished from *P. heberti* by the consistently thicker wall lining of the latter, and from the other species by the absence of persistent, well developed striae (Pemberton and Frey, 1982). In fills of *Palaeophycus* represents passive, gravity induced sedimentation within open lined burrows.

Preservation: Preserved as endichnia, hypichnia or epichnia.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Tapkeshwari Member and Jadura Member.

Association: *Planolites, Muensteria, Thalassinoides, Rhizocorallium, Scalarituba, Asteriacites.*

ICHNOSPECIES

Palaeophycus striatus HALL, 1852;

PEMBERTON AND FREY, 1982; McCANN AND PICKERILL, 1988.

Plate-52, a.

Diagnosis: Cylindrical to subcylindrical thinly lined burrows ornamented with thread like striations.

Description: Cylindrical, infrequently branched, straight to undulose or flexious burrows bearing numerous fine continuous essentially parallel longitudinal striations. Burrow tends to exhibit less collapse compare to other species. Length of the burrow is 32.0 cm and diameter varies from 1.6 to 2.5 cm Burrow fill structureless and identical to the enclosing sediments. Cross overs and interpenetrations are common in some specimens. Burrow lining is very thin and not well preserved in the photographed specimen.

Preservation: Preserved as epichnia near lithologic interfaces, and as full relief.

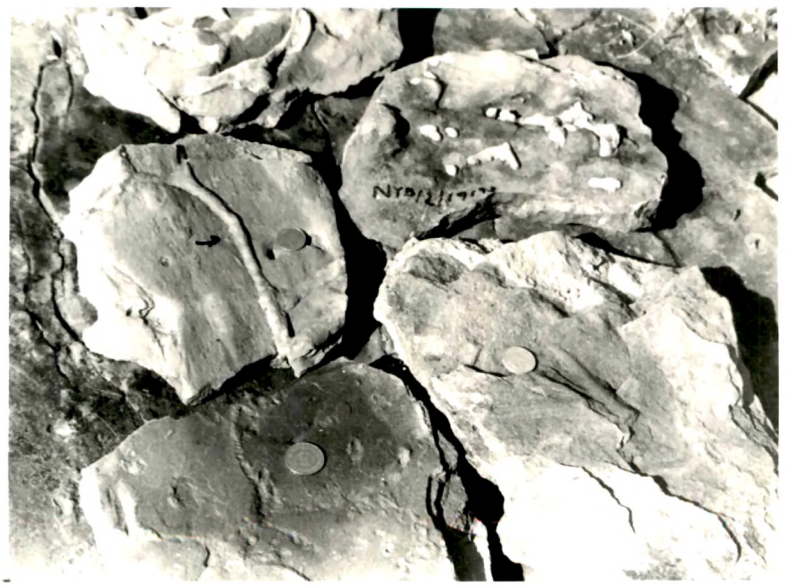
Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: It occurs in the Marutonk Dungar Member.

Association: *Planolites, Rhizocorallium, Histioderma.*

Discussion and Interpretation: *P. striatus* is distinguished from *P. alternatus* by consisting longitudinal striations rather than alternating striations in the latter.

a. *Palaeophycus* striatus



b. *Palaeophycus* sulcatus

ICHNOSPECIES

Palaeophycus sulcatus MILLER AND DYER, 1878; PEMBERTON AND FREY, 1982; McCANN AND PICKERILL, 1988.

Plate-52, b.

Diagnosis: Irregularly subcylindrical, thinly lined burrows ornamented with sharp, anastomosing, thread like striations.

Description: Burrow infrequently branched, curved, thinly lined, slightly oblique to horizontal, distinctly sculptured with interwoven small ridges and grooves. Cross overs and interpenetrations are common in some specimens. Length of the burrow is 25.0 cm and diameter 0.5 to 1.5 cm. Burrow diameter some what varies from one side to another. Burrow fill structureless and identical to enclosing sediment.

Discussion and Interpretation: The close affinity between *Fucusopsis* and *Palaeophycus* or *Planolites* was recognized by Osgood (1970), but he suggested that synonym awaits reassessment of *Palaeophycus*. Pemberton and Frey (1982) confirms that Fucusopsis is junior synonym of *Palaeophycus*, although the original concept of Fucusopsis remains valid at the species level. The material of Miller and Dyer (1878) thus become type specimen and name bearers for this ichnospecies. Burrow collapse features are some what less common in *P. sulcatus* than in *P. tubularis* and *P. heberti*. *P. sulcatus* is distinguished from *P. striatus* by anastomosing, rather longitudinal striations, and from *P. alternatus* by consistent, rather than alternating striations.

Preservation: Semirelief, endichnial burrow.

Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: It occurs in Jamaywadi Member near quarries south of Madhapar.

Association: *Planolites, Ophiomorpha, Thalassinoides, Gyrochorte.*

ICHNOSPECIES

Palaeophycus alternatus PEMBERTON AND FREY, 1982, p. 863, pl. 2, 3, 4.

Plate-53.

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

Description: Slightly curved, thinly lined burrows of regular varying dimensions, finely striated longitudinally and in places distinctly annulated. Striae consists of thin wavy ridges and grooves best developed where annulations are absent, where annuli are well developed 3.0 to 5.0 per centimeter. Burrow length is 18.0 cm and width is 1.3 to 1.8 cm. The specimens are rarely branched and exhibit little burrow collapse.

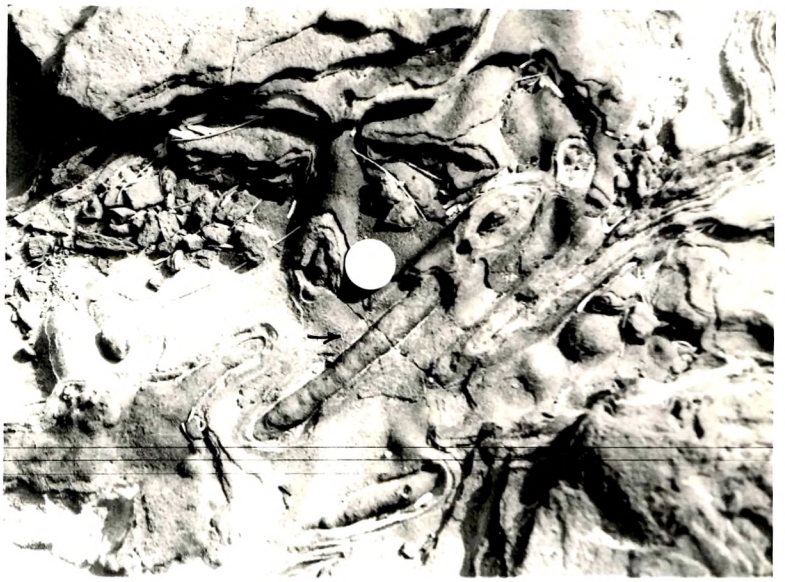
Discussion and Interpretation: Although known specimens are less common than those of other ichnospecies, the ethological pattern represented is significant and distinctive, the periodic change from predominantly striae to predominantly annulate parts of burrow evidently reflects a change from direct locomotion to peristaltic movements by the trace makers.

Preservation: Preserved as convex epirelief and full relief. Burrow fill identical to the surrounding sediments.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Tapkeshwari Member of Umia Formation near Jadura and near Sanatorium.

Association: *Planolites, Thalassinoides, Rhizocorallium, Scolicia, Diplocraterion, Circulichnus, Yakutatia.*



Palaeophycus alternatus

ICHNOGENUS

Phycodes RICHTER, 1850, p. 205.

Diagnosis: Bundled structures of flabellate or broom-like pattern consisting of horizontal tunnels, proximal part of main tunnels unbranched, distal tunnels divide at acute angles into several free cylindrical tunnels showing delicate annulation beneath thin smooth "bark", main branches may show structure similar to retrusive spreiten; vary considerably in morphology from type species which is also variable, about 15 cm. long in entirely; generally preserved as convex hyporelief in quartzites.

ICHNOSPECIES

Phycodes *Sp.* RICHTER, 1850.

Plate-54, a.

Description: Horizontal, ramifying and branching burrow systems. The burrow possesses a tube like form (common burrow) proximally but distally split into finger like straight to gently curved branches. Common burrow may be unilobed, bilobed or rarely trilobed, 0.5 to 0.8 cm in diameter and 5.0 to 7.0 cm in length. Cross section of the burrows may form a broad net like pattern. The branches terminations may occur in isolation or may overlie one another. The branching burrows are in semi-radiating in form.

Preservation: Full relief, convex hyporelief.

Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: It occurs in Jamaywadi Member.

Association: *Bifungites, Gyrochorte, Laevicyclus, Planolites, Palaeophycus.*

a. (i) *Phycodes Sp.* (ii) *Phycodes pedum*

(iii) *Planolites annularis*

b. *Phycodes* circinnatum

Discussion and Interpretation: *Phycodes* represents the systematic mining by a worm having a fixed base, moving downward and outward through the sediments. Externally the burrows are smooth and they, some times, have a bioturbated filling.

ICHNOSPECIES

Phycodes palmatum HALL, 1852.

Plate-47.

Diagnosis: Fan or radial system of horizontal branching burrows. Burrow essentially uniform through out, long, linear or slightly curving, branching close together.

Description: The Kutch specimens are characterised by long, thick, horizontal arm like burrows with palmately (finger like) branching burrow system which are more or less parallel to almost right angle to each other and terminates in rounded end. The branching burrows are unilobed, the individual burrow is about 4.0 to 5.0 cm long, 0.9 to 1.2 cm in diameter. The palm dimension is 2*3 cm and main tubes are 4.0 cm long and 1.2 cm in diameter.

Preservation: Full relief, convex hyporelief, fill identical to substrate.

Facies: Laminated Shale Siltstone, Sheet Sandstone.

Stratigraphic Distribution: It occurs in the Jamaywadi Member and Jadura Member.

Association: *Planolites, Palaeophycus, Neonereites, Trichichnus, Gyrochorte, Oldhamia.*

Discussion and Interpretation: The tunnels of *Phycodes* palmatum are more slender and finger like than the club shape tunnels of Asterosoma radiciforma. In addition they branch from a single burrow of nearly horizontal orientation, whereas Asterosoma radiciforma is a central shaft like burrow enters the radiating patterns at a hinge. It differs from *Phycodes* curvipalmatum by its larger size,

straight nature and lack of recurvature. *Phycodes* commonly occurs in the offshore portion of the tidal zone where sufficient organic material can accumulate and support deposit feeding endobenthos (Martino, 1989).

ICHNOSPECIES

Phycodes circinnatum RICHTER, 1853, p. 20.

Plate-54, b

Diagnosis: Bundled structures of flabellate or broom like pattern, consisting of horizontal tunnels.

Description: The Kutch specimens are characterised by bundled structure of horizontal tunnels with slightly circular or arch shape main burrow in vertical plane. Proximal part of the main tunnel unbranched, divides in to 6 to 7 branches in distal part, which are subparallel up to certain distance. Branching burrows on the periphery show some divergence from the main system. The diameter of the main burrow is 1.0 cm and length is 7.7 cm. The branches are 0.5 to 0.7 cm in diameter and 4.0 to 6.0 cm in length

Preservation: Full relief, convex hyporelief, fill identical to substrate.

Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: It occurs in the Jamaywadi Member.

Association: *Planolites*, *Palaeophycus*, *Helminthopsis*.

ICHNOSPECIES

Phycodes pedum SEILACHER, 1955.

Plate-54, a.

Diagnosis: Horizontal arch shape tunnels with feather stitch like pattern of branching tunnels.

Description: Almost circular, semicircular, arch shape to subtriangular burrow system with very small branches, which are almost tangential to the main burrow and off shooting towards distal end. The small free tunnels (branches) are forming acute angle with main burrow and found more or less parallel to it. The branches project out from the main burrow after 1.5 to 2.5 cm distance from proximal end at a regular interval of 0.5 cm. The length of the main tunnel is 12.0 to 15.0 cm with a diameter of 0.3 to 0.5 cm. The branches are 0.5 to 1.0 cm in length and 0.3 to 0.5 cm in diameter. The distal end tapers in a rounded shape. Feeding tunnels show falcate or feather stitch like pattern.

Preservation: Full relief, convex hyporelief, fill identical to substrate.

Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: It occurs in the Jamaywadi Member.

Association: *Planolites, Palaeophycus, Phycodes Sp., Helminthopsis.*

Discussion and Interpretation: These are burrow systems similar in size and form to examples described by Seilacher (1955) from the Cambrian of Salt Range (Pakistan). It represents the systematic mining by a worm like animal having a fixed base and moving forward and outward through the sediments in the distal portion of tidal zone where sufficient organic material can accumulate and support deposit feeding endobenthos (Martino, 1989).

ICHNOGENUS

Planolites NICHOLSON, 1873. p. 289

Type Species: *Planolites* vulgaries Nicholson and Hinde, 1875, p. 139.

Diagnosis: Unlined, rarely branched, straight to tortuous, smooth to irregular walled or annulated burrows, circular or elliptical in cross section of variable dimension and configuration, 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 year following Nicholson (1873) work, at least 30 additional ichnospecies of *Planolites* have in same 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,

[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 rocks. Fill also differ in fabric, composition and colour as well. In fills 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 beverleyensis BILLINGS, 1862;

PEMBERTON AND FREY, 1982; FILLON AND PICKERILL, 1984; McCANN AND PICKERILL, 1988.

Plate-55, a.

Diagnosis: Relatively large, smooth to some what irregularly walled, straight to gently curved or undulose, essentially cylindrical burrows.

Description: Predominantly cylindrical, smooth walled, unlined, straight to gently curved, unbranched to rarely irregularly branched burrows, oriented more or less parallel to the bedding plane. Rare specimens display discontinuous poorly developed annulations. Burrows occur as single isolated specimen to crowded masses, in which cross overs, interpenetrations are common. Dimensions varies in different burrow populations. Length of the burrow varies from 24.0 to 28.0 cm and diameter from 0.5 cm to 2.5 cm.

Discussion and Interpretation: *Planolites* Nicholson (1873) and its ichnospecies have been reviewed by Pemberton and Frey (1982), and as previously noted, apart from minor amendation at the ichnogeneric level by Fillon and Pickerill (1984), is considered the most workable nomenclatural system. Pemberton and Frey (1982), used size, curvature and wall characteristics to differentiate among the three ichnospecies they regarded recognisable, namely P. beverleyensis Billings, (1862), P. annularis Walcott, (1890), and P. montanus Richter, (1937).

Planolites annularis is distinctly annulated and is the most easily recognisable of the three ichnospecies. Unfortunately, the Kutch specimens overlap in size between P. beverleyensis and P. montanus as indicated by Pemberton and Frey (1982), [P. beverleyensis - average 10.0 mm, rarely less than 8.0 mm; P. montanus average 3.0 mm, rarely greater than 5.0 mm]. However, P. montanus tends to be more contorted and therefore, the specimens are considered to be more akin to P. beverleyensis. *Planolites* represents endichnial burrow produced and actively filled by deposit feeding endobenthos (pemberton and Frey, 1982) or worm like animals (Hantzschel, 1975). P. beverleyensis is distinguishable from P. montanus primarily by the large size, and 'graceful curvatures' of the former.

Preservation: Preserved as hypichnia, epichnial and endichnial ridges.

Facies: Laminated Shale Siltstone, Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in the Jadura Member and Tapkeshwari Member.

Association: *Palaeophycus*, *Phycodes*, *Thalassinoides*, *Chondrites*, *Gyrophyllites*.

ICHNOSPECIES

Planolites montanus WALCOTT, 1890.

Plate-55, b.

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

Description: Irregular, cylindrical, sinuous, undulose and meanderous small horizontal burrows. Burrow length and diameter more or less constant, but in some cases it shows small scale variations. True branching is relatively rare. Horizontal erosional truncation of vertically or

a. *Planolites* beverleyensis

b. *Planolites* montanus

obliquely oriented segments gives appearance of knobby bedding surfaces. Cross overs, interpenetrations and reburrowed segments are abundant and profuse. Burrow fills tend to consist of cleaner, better sorted sediments than the host rock. The Kutch specimens have a length of 3.0 to 7.0 cm and diameter of 0.8 to 1.2 cm.

Discussion and Interpretation: P. beverleyensis and P. annularis are more abundant in Kutch than the P. montanus. The specimen has consistently smaller size and more tortuous appearance which distinguishes P. montanus from P. beverleyensis (Pemberton and Frey, 1982).

Preservation: Preserved as endichnial and epichnial burrows.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in the Tapkeshwari Member of the Umia Formation in a nala section 1.0 km north of Bharapar.

Association: *Rhizocorallium*, *Asteriacites*, *Rosselia*, *Palaeophycus*, Arthropod resting trace.

ICHNOSPECIES

Planolites annularis WALCOTT, 1890.

Plate-54, a.

Diagnosis: Distinctly annulated, cylindrical to subcylindrical burrows.

Description: Predominantly horizontal, straight to sinuous or undulose or curved semicircular burrows exhibiting prominent transverse annulations. Annulations are almost of equal size, identical pattern and regular spacing. Burrow tends to be of more or less constant diameter. Most of the burrows are straight to slightly curved and are oriented parallel or subparallel to the bedding. True

branching has not been observed. Length of the burrows varies from 10.0 to 30.0 cm with diameter range of 1.5 to 2.5 cm. Spacing between annulations is 0.25 cm to 1.0 cm.

Discussion and Interpretation: P. annularis is distinguished from other two species of *Planolites* by its distinct annulations (Pemberton and Frey, 1982). Annulations presumably reflect peristaltic movements by the trace maker. The burrow compares wall in diameter and morphology with Walcott's holotype figured by Osgood (1970, p. 1:77, fig. 3), although the annulations of the Kutch specimen are more distinct.

Preservation: Preserved as hypichnial ridges, epichnial ridges and shallow endichnia.

Facies: Laminated Shale Siltstone, Sheet Sandstone, Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Jamaywadi Member and Tapkeshwari Member.

Association: *Phycodes*, *Gyrochorte*, *Thalassinoides*, Arthropod crawling trail.

ICHNOGENUS

Protopaleodictyon KSIAZKIEWICZ, 1970, P. 303.

Diagnosis: Initial, irregular form of Paleodictyon, quite variable, less regular, not strictly polygonal pattern; mostly meanders with ramifications on their apices.

ICHNOSPECIES

Protopaleodictyon incompositum KSIAZKIEWICZ, 1970, P. 302.

Plate-56.

Diagnosis: Quite variable, irregular, honeycomb like network of ridges with not strictly polygonal patterns and considerably varying size. Mostly meanders with ramifications on their apices.

Description: The Kutch forms are initial, irregular, quite variable, not strictly polygonal patterns of honeycomb like network of burrows, considerably varying in size of reticulate pattern from 1.0 * 3.0 cm, 2.0 * 3.0 cm, 5.0 * 2.0 cm, 3.0 * 3.0 cm, 7.0 * 3.0 cm to 2.0 * 1.0 cm etc. The burrows are mostly meandering with ramifications on their apices. The burrows are less regular in diameter from 0.75 to 0.5 cm with thinning or tapering of branches. The meshes are subrounded to irregular and it is difficult to calculate number of sides. Angle of sides also varies from acute to obtuse.

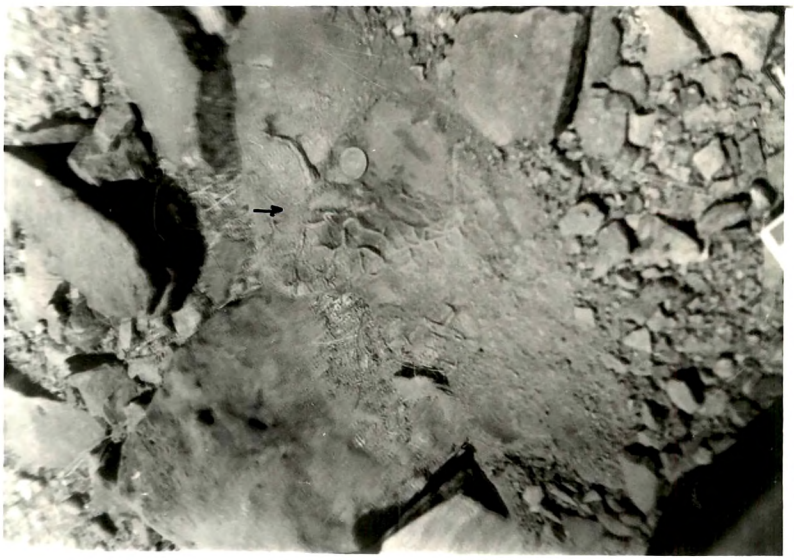
Discussion and Interpretation: It is considered as initial, incomplete, irregular form of Paleodictyon (Hantzschel, 1975), which is thought to be grazing trails (Seilacher, 1954, 1955). According to Wood and Smith (1959, p. 167), such forms are made by burrowing animals at interfaces of sandy and muddy sediments. The worm mining systematics explanations (Webby, 1969a, p. 87) assumes that producer is highly sensitive to thigmotaxis. It occurs in flysch, molasse facies and epicontinental environments and represents Nereites facies.

Preservation: Full relief, convex epirelief. Fill identical to the host matrix.

Facies: Sheet Sandstone.

Stratigraphic Distribution: It occurs in Jamaywadi Member.

Association: *Palaeophycus*, *Gyrochorte*, *Rhizocorallium.*



Protopaleodictyon incompositum

ICHNOGENUS

Rhizocorallium ZENKER, 1836.

Diagnosis: U-shaped spreiten burrows, parallel or oblique to bedding plane, limbs more or less parallel and distinct.

ICHNOSPECIES

Rhizocorallium *Sp.* ZENKER, 1836.

Plate-57, a.

Description: *Rhizocorallium Sp.* is long sinuous to curved, horizontal to subhorizontal, branched, U-shape burrow containing spreiten. It is recognised by two parallel marginal tubes separated by a furrow with closely spaced regular retrusive asymmetrical spreiten, preserved on bedding plane. The tubes are preserved by fine grained sediments. The limbs are parallel except the parts where it bend sharply. Faint scratch marks are present on the burrow tubes. Tubes are circular to oval in cross section with maximum diameter of 1.0 cm. The distance between the two arms ranges from 3.0 to 5.0 cm. After crossing symmetrical ripple marks in an oblique manner, the retrusive burrows takes a sharp almost opposite turn overlapping earlier producing structure initially, and moves across the ripple marks, to produce bifurcation. The length of the first formed structure is about 25.0 cm, while length of the structure after sharp turn is approximately 50.0 cm. The *Rhizocorallium Sp.* tubes in Kutch extends horizontally parallel to the bedding plane on the ripple marks on its bottom part, and becomes subhorizontal to perpendicular to the bedding plane towards its initial part. Here, only lower part of the burrow appears to have been preserved.

Preservation: Full relief, filled with the identical matrix to the host sediment.

a. *Rhizocorallium Sp.*

b. *Rhizocorallium* jenense

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: Tapkeshwari Member.

Association: *Keckia, Planolites, Palaeophycus, Gyrochorte, Taenidium.*

Discussion and Interpretation: The Kutch *Rhizocorallium Sp.* is a long and sinuous to curved form with exclusively retrusive spreiten which mostly cross the ripple crests. This may be burrow of deposit feeding animals excavating nutrient rich sediments on the rippled top as in case of other species of *Rhizocorallium* (Fursich, 1974b, Eager et al., 1985). Scratch marks on the burrow walls of Kutch specimen depicts that the animal may be a deposit feeding crustacean (Seilacher, 1967; Crimes, 1975). The sharp turn of the burrow depicts sensibility of the animal about the nutrient rich deposits.

ICHNOSPECIES

Rhizocorallium jenense ZENKER, 1836.

Plate-57, b.

Diagnosis: Simple U-tube with spreite, generally protrusive or some times retrusive, some what oblique to the bedding, "arms" more or less parallel several centimeter apart, very rarely branched, occasionally with lateral flaps, tube relatively thick, commonly initially vertical for several centimeter downward, than sharply bending at right angle, outer side of many tubes often marked by numerous striae interpreted as scratch marking indicative of crustaceans, pills of ellipsoidal excrements may be incorporated in walls or within tube, median line of "U" often curved, horizontal forms on bedding planes characteristically winding.

Description: R. jenense is long sinuous, horizontal to subhorizontal, unbranched U-shape tube containing spreiten. It is easily recognised by U-tubes lying on bedding plane. The tubes are filled with fine to medium grained sediments. Usually each arm of the tubes is 15.0-18.0 cm long and 1.5 cm wide The distance between the arms is about 2.0 cm. Spreiten commonly are 0.3 cm thick. Very often R. jenense tubes in Kutch extends subhorizontally and follow the ripple crest on to the top of the sediments until the lower end of the tube become horizontal, parallel to bedding plane. After the compaction only the lower part of the burrow appears to have been preserved. Burrows preserved almost parallel to the ripple marks.

Preservation: Full relief, filled with the identical matrix.

Facies: Rippled Ferruginous Sandstone Siltstone Shale, Sheet Sandstone, Laminated Shale Siltstone, Massive Sandstone.

Stratigraphic Distribution: It occurs in Jamaywadi Member, Gangeshwar Member, Ler Member, Marutonk Dungar Member, Jadura Member and Tapkeshwari Member.

Association: *Palaeophycus*, *Planolites*, *Phycodes*, *Ophiomorpha*, *Skolithos*, *Asteriacites*, *Thalassinoides*, *Gyrochorte*.

Discussion and Interpretation: The Kutch R. jenense has a long and somewhat sinuous form with exclusively protrusive spreiten that almost follow the ripple surface. Similar forms were interpreted by Fursich (1974b) as the burrow of deposit feeding animals mining nutrient rich sediment on the rippled top. Faint scratch marks on the tube walls of Kutch specimen suggest that the animal may have been a deposit feeding crustacean. Such an observation is also made by Seilacher (1967) and Crimes (1975).

ICHNOSPECIES

Rhizocorallium irregularie MAYER, 1954.

Plate-58.

Diagnosis: Long, straight or slightly sinuous, planispiral, U-shaped spreiten burrows, mostly horizontal.

Description: Long, straight to sinuous, horizontal, unbranched, Ushaped spreiten burrow. The structure consists of partial Preservation of two parallel marginal tubes of lateral burrows separated by a furrow curving numerous, closely spaced irregular retrusive asymmetrical spreiten. The burrow out line is straight to sinuous and curved. The limbs are closely parallel, except where the burrows bend sharply. Some very faint scratch marks are found on the burrow tubes. Tubes are circular to oval in cross section with maximum diameter of 1.0 cm. The distance between the two arms varies from 2.0 to 4.0 cm. Maximum observed length is 30.0 cm. Burrow aperture has not been observed in Kutch form. The burrow some times nearly complete a circle.

Preservation: Negative epirelief.

Facies: Laminated Shale Siltstone, Sheet Sandstone, Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Jamaywadi Member, Ler Member, Marutonk Dungar Member, Jadura Member and Tapkeshwari Member.

Association: *Palaeophycus, Planolites, Skolithos, Asteriacites, Thalassinoides.*

Discussion and Interpretation: The traces crossing several symmetrical ripples and mining nutrient rich sediments on the top of the ripples indicate burrow of deposit feeding crustacean animals

Rhizocorallium irregularie

(Fursich, 1974b; Eager et al. 1985). As suggested by Seilacher (1967) the animal used the spreiten technique for efficient exploration of the sediment in search for food.

Remarks: *Rhizocorallium Sp.* differs from *R. irregularie* and *R. jenense* by bifurcating branching and retrusive form. *R. irregularie* differs from *R. jenense* having very long sinuous parallel burrow system with intervening asymmetrical protrusive spreiten.

ICHNOGENUS

Rosselia DAHMER, 1937, p. 532.

Type Species: *Rosselia socialis* Dahmer, 1937.

Diagnosis: Cylindrical pencil thick burrows, commonly oblique to bedding, lower end not observed, opening expanded and filled with concentric layers of matrix, which as a rule are strongly weathered.

ICHNOSPECIES

Rosselia *Sp.* DAHMER, 1937, p. 532.

Plate-59.

Description: The Kutch specimen *Rosselia Sp.* is funnel shaped vertical or oblique burrow preserved in full relief. Upper flared portion is upto 4.0 cm in diameter and characterised by concentrically laminated fill. Depth of the burrow is upto 13.0 cm. Most of the specimens are circular in cross section, although a few are elliptical.

Discussion and Interpretation: Funnel shape morphology in the Kutch specimens is variable. Many specimens have steep-sided funnel which are identical to *Monocraterion*. Few specimens are exposed on bedding plane. Flared portions of these burrows are characterized by concentric laminae tapering downward into a concentric walled stem.

Chamberlain (1971) interpreted *Rosselia* as a feeding burrow made by worm-like animal but some specimens of *Rosselia* may be dwelling burrows as argued by Chamberlain and Clark (1973).

Preservation: Full relief.

Facies: Sheet Sandstone, Massive Sandstone.

Stratigraphic Distribution: It occurs in Jadura Member and Tapkeshwari Member.

Association: *Arenicolites, Spirophyton, Diplocraterion.*

Rosselia Sp.

ICHNOGENUS

Scalarituba WELLER, 1899, p. 12.

Type Species: *Scalarituba* missouriensis Weller, 1899.

Diagnosis: Sub-cylindrical burrows, 2.0 to 10.0 mm. in diameter, sinuous, parallel, oblique or nearly vertical to bedding; marked by transverse "scalariform" ridges situated at average distance of 2 to 3 mm., which may be only poorly preserved or lacking in argillaceous rocks.

ICHNOSPECIES

Scalarituba *Sp.* WELLER, 1899.

Plate-60.

Description: Straight to sinus, subcylindrical back fill burrows, oriented parallel to bedding plane. Burrow 10.0 to 22.0 cm long, 6.0 mm in diameter, marked by curved transverse ridged, 2.0 to 3.0 mm apart, producing successive conical structures.

Preservation: Epichnial burrows, filled with identical matrix.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Tapkeshwari Member.

Association: *Cylindricum*, Beaconichnus, *Thalassinoides*, *Asteriacites*, *Helminthopsis*, *Gyrochorte*.

Discussion and Interpretation: It occurs in abundance in silty sequences. It is to be interpreted as internal trail. According to Henbest (1960, p. B383) and Conkin and Conkin (1968, p. 5), the trail is made by sediment eating worm or worm like organism living in shallow marine or even tidal flat environment. Seilacher (1964c, p.309) reported occurrence of this ichnogenus from Cruziana, *Zoophycos* and *Nereites* facies related to depth, which would mean occurring from epicontinental to geosynclinal environments.

Scalarituba Sp.

ICHNOGENUS

Scolicia DE QUATREFAGES, 1849, p. 265.

Diagnosis: Horizontal, bilaterally symmetrical gastropod trails of great variability, long band like morphology depending on their origin as surface trails or internal trails; varied sculpture caused by different methods of burrowing, creeping and removing sediment, up to about 4.0 cm. Wide.

Remarks: Classification of *Scolicia* and the "*Scolicia* Group" is confused and clearly warrants a thorough taxonomic revision (Hantzschel, 1975; Smith and Crimes, 1983). This group is represented by highly variable endogenic trails, usually of a highly flattened ribbon like shape, often with transverse pads of sediments. Longitudinal burrows in various arrangements are observed in these species. Recognition of similar situation led Seilacher (1955) and Hantzschel (1962, 1975) to suggest several probable generic synonyms for *Scolicia* e.g. *Bolonia*, Psammichnites, Curvolithus, Olivellites etc. Some of these forms located in the Kutch are described under their original generic names. *Scolicia* has been attributed to the creeping or feeding activities of gasteropods (Hantzschel 1975, Ksiazkiewicz 1977) or furrowing echinoids (Smith and Crimes 1983). *Scolicia* is a eurybathic trace fossil and has been reported in strata of early Cambrian (Crimes and Anderson, 1985) to Recent (Kichell and Clark, 1979).

ICHNOSPECIES

Scolicia *Sp.* DE QUATREFAGES, 1849.

Plate-61

Description: The form is straight to gently curved, horizontal, bilaterally symmetrical, flat ribbon shape trail with broad V-shape cross section. The trail contains two parallel lobes separated by median furrow. Lobes comprise evenly spaced series of obliquely transverse fine pods (ridges)

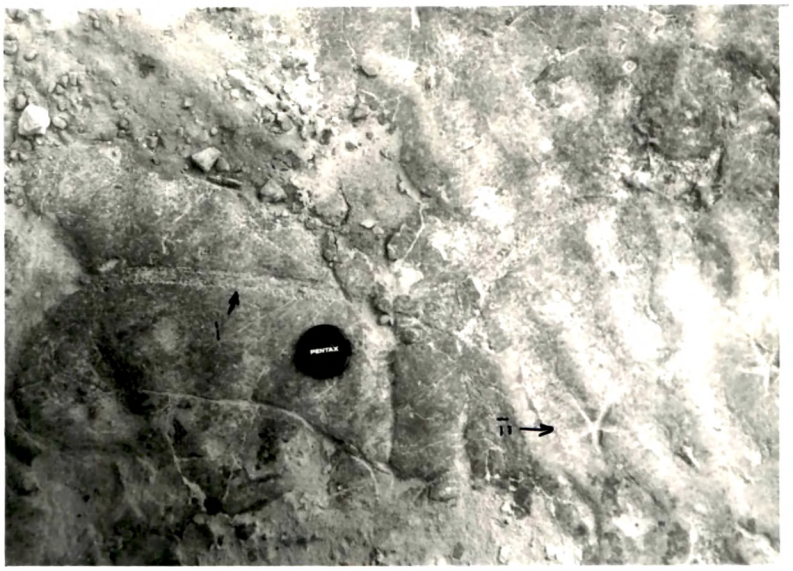
preserved in concave epirelief. The trail is typically 3.0 cm wide, about 75.0 cm in length, pod dimension 1.6 cm * 0.7 cm and median furrow is 0.3 to 0.4 cm in width.

Preservation: Concave epirelief, full relief.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: Occurs in Tapkeshwari Member.

Association: *Crossopodia*, *Asteriacites*, *Thalassinoides*, *Taenidium*, *Rhizocorallium*, *Bifungites*, *Cylindricum*.



i *Scolicia Sp.*
ii Asteriacites

ICHNOGENUS

Skolithos HALDEMAN, 1840, p. 3.

Diagnosis: "Ordinary Pipes", straight tubes or pipes perpendicular to bedding and parallel to each other, subcylindrical, unbranched, 1.0 to 15.0 mm. in diameter constant for each tube, few cm. up to 30.0 cm, [maximum 100.0 cm] long, inner walls may be finely annulated, tubes commonly closely crowded, but, also may show widely spaced gradations, frequent in arenaceous sediments.

Remarks: According to Fursich (1974), the taxonomy of these simple vertical burrows is in urgent need of revision. Morphological features such as funnel shaped aperture in *Monocraterion* Torell (1870) or less crowding tubes as in Tigillites Ronalt (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 *Sp.* HALDEMAN, 1840.

Plate-62, a.

Description: Inclined (40° to 60°), straight to curved, unbranched, cylindrical or subcylindrical lined burrows with a structureless fill. Burrow tubes are without funnel shape aperture. It occurs isolated to moderately crowded on bedding planes and cliff sections. Burrow walls distinct with lining and without ornamentation. Burrow tubes moderately to steeply inclined to the bedding plane, mostly curved to straight and passes from one bed to another, in many cases, changing inclination at the bedding plane. Burrow tubes have diameter of 0.6 to 1.0 cm, with a maximum observed length of about 10.0 cm. Burrow fill is identical to the matrix.

Preservation: Full relief.

Facies: Bioturbated Sandstone, and Massive Sandstone.

Stratigraphic Distribution: It occurs in Bharapar Member and Tapkeshwari Member.

Association: *Arenicolites, Monocraterion, Rosselia.*

Discussion and Interpretation: *Skolithos* are regarded as dwelling burrows of suspension feeding polychaete or phoroid by Pemberton and Frey (1984). The inclination of the burrows may be due to prominently unidirectional higher energy conditions and for better food gathering. The curved nature may be in response to uneven sedimentation rates and due to the organisms' efforts to maintaining level and coping up with renewed sedimentation.

ICHNOSPECIES

Skolithos linearis HALDEMAN, 1840.

Plate-62, b.

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

Remarks: *Skolithos linearis* is the only ichnospecies of *Skolithos* described by Alpert (1974), that can be accommodate the lengths attained by the vertical burrows in Kutch specimens.

Description: Straight to slightly curved, vertical or steeply inclined, unbranched, cylindrical or subcylindrical, lined or unlined burrows, perpendicular to the bedding plane with a structureless fill. Burrow tubes are without funnel shape aperture. It occurs crowded or isolated on the bedding plane as well as in vertical section. Burrow wall distinct, and without lining and ornamentation.

a. *Skolithos Sp.*

b. *Skolithos* linearis

Burrow tubes have diameter of 0.75 to 3.0 cm with a maximum observed length of about 25.0 cm. Burrow fill is identical to the host sediments.

Preservation: Full relief.

Facies: Bioturbated Sandstone.

Stratigraphic Distribution: It occurs in Bharapar Member of Bhuj Formation, near Bhuj.

Association: *Arenicolites, Diplocraterion, Monocraterion.*

Discussion and Interpretation: The BM specimens clearly fall within the range of *Skolithos* linearis. Specimens are morphologically like those described by Alpert (1974), Curren and Frey (1977), and Curren (1985). Alpert (1974) suggested that *Skolithos* may have been dwelling burrow of an annelid or phoroid Pemberton and Frey (1984), concluded that *Skolithos* represents the dwelling burrow of suspension feeding polychaete or phoroid. According to Chamberlain (1977), *Skolithos* is widely recognised in shallow water intertidal deposits, and in flood plain Facies. According to Seilacher (1967) and Crimes (1975), it is common in sandstone deposited under high energy tidal and near shore conditions. The Kutch form is envisaged to represent similar environmental aspects.

ICHNOGENUS

Spirophyton HALL, 1863.

Diagnosis: Similar to spirally coiled forms of *Zoophycos* but differing by smaller size and by circular outline of laminae which are also compared to lamillae, laminae not tending to lobate forms, 1.0 to 4.0 mm thick, sloping outward from axis, then flatting and bent upward to margin in dextrogyrate or sinistral spirals, curving ridges on laminae convex in the sense of the rotation, diameter of last whorl up to about 10.0 cm; central axis J-shaped.

Remarks: Simpson (1970) defined *Spirophyton* as a three dimensional feeding burrow consisting of a central vertical tube around which a spreite 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. 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 lamillae are well preserved.

ICHNOSPECIES

Spirophyton *Sp.* HALL, 1863.

Plate-63.

Description: Spirally coiled burrows oriented vertically more or less perpendicular to the bedding plane and composed of thin laminae around the central axis. Dimensions of burrows varies in different burrow populations. The maximum observed outer diameter is being 5.5 cm; with central axis J-shaped with diameter of 0.8 to 1.0 cm. Length varies from 5.0 to 9.0 cm. The distance

between concentric lamillae varies from 0.05 to 0.4 cm. Laminae of two to three adjacent tubes are found intersecting with each other.

Preservation: Full relief. Fill identical with the matrix.

Facies: Rippled Ferruginous Sandstone Siltstone Shale, Sheet Sandstone.

Stratigraphic Distribution: It occurs in the Tapkeshwari Member and Jadura Member.

Association: *Skolithos*, *Diplocraterion*, *Rhizocorallium*, *Circulichnus*, *Yakutatia*.

Discussion and Interpretation: Simpson (1970) interpreted *Spirophyton* and *Zoophycos* as resulting from the feeding activities of a bilaterally symmetrical animal.

Spirophyton Sp.

ICHNOGENUS

Stipsellus HOWELL, 1957, p. 18.

Diagnosis: Perpendicular, cylindrical burrows, spaced about 2.0 cm apart in sediment, diameter about 1.0 cm; containing ring like expanded belts regularly distributed throughout length of tube; perhaps identical with Trachyderma serrata SALTER, 1864.

ICHNOSPECIES

Stipsellus annulatus HOWELL, 1957.

Plate-64

Diagnosis: Vertical, cylindrical tubes consisting ring like expanded belts regularly arranged throughout the burrow.

Description: The Kutch specimen are almost vertical or perpendicular to the bedding plane. These cylindrical burrows are with a diameter of 1.5 to 2.0 cm. The burrows are spaced about 12.0 to 15.0 cm apart in sediment. The burrows are characterised by ring like nodes or expanded belts spaced regularly throughout the length of burrows at a distance of 3.0 cm. Rings are about 0.2 to 0.3 cm in thickness, and 0.5 cm in width. The burrows are filled with material identical to the host sediments, and contains distinct thick burrow lining. The maximum observed length is 35.0 cm.

Discussion and Interpretation: The burrows are differing from *Skolithos* by distinct ring like expanded belts regularly distributed throughout length of tube.

Preservation: Full relief in form of raised convex epirelief.

Facies: Bioturbated Sandstone.

Stratigraphic Distribution: It occurs in Bharapar Member of Bhuj Formation near Bhuj.

Association: *Skolithos*, *Arenicolites*, *Diplocraterion*, *Monocraterion*.

Stipsellus annulatus

ICHNOGENUS

Strobilorhaphe KSIAZKIEWICZ, 1968, p. 8 & 15.

Type Species: *Strobilorhaphe* clavata KSIAZKIEWICZ, 1968.

Diagnosis: Short narrow string, with 3.0 to 4.0 ranges of small pearl like knobs about 7.0 mm long, laterally protruding from string; entire trail cone shaped, usually 3.0 to 4.0 cm long, 1.0 to 1.5 cm wide.

ICHNOSPECIES

Strobilorhaphe pusilla KSIAZKIEWICZ, 1968.

Plate-65.

Diagnosis: Short, narrow trail, with 3.0 to 4.0 ranges of small pearl like knobs.

Description: The trail consists of three to four rows of irregularly arranged small pearl like hemispherical granules without any preferential protrusion. The Kutch specimens are 3.0 to 6.0 cm long, 0.4 to 0.8 cm wide and 0.2 to 0.4 cm high, usually occurs in cone shape short narrow strings (shows tapering by one knob at one end and widening having three-four knobs at other end). The Kutch specimens are more or less oriented in one direction.

Discussion and Interpretation: The Kutch specimens are identical with those described from Beloveza beds of lower Eocene age, Poland (Ksiazkiewicz, 1968). The Europe specimens are described in flysch deposits, while Kutch specimens are found in estuarine facies.

Preservation: Convex epirelief, fill identical to the matrix.

Facies: Cross Bedded Coarse Grained Sandstone.

Stratigraphic Distribution: It occurs in fine dark red brown siltstones of Bharapar Member of Bhuj Formation.

Association: *Ophiomorpha.*

Strobilorhaphe pusilla

ICHNOGENUS

Taenidium HEER, 1877, p. 117.

Type Species: *Taenidium* serpentinum Heer, 1877.

ICHNOSPECIES

Taenidium serpentinum HEER, 1877.

Plate-66, a.

Diagnosis: Cylindrical burrows with distinct stuffed structure, mostly branched, umbellated, root like system of burrow radiating downward, burrows with transverse segmentation, reminiscent of "Orthoceras" segmentation may also be observed on outside as annular constrictions.

Description: Horizontal, undulose, cylindrical tubes, up to 35.0 cm long and 1.0 cm wide possessing symmetrically arranged distinct transverse annulations - 0.25 cm apart. Burrow preserved as full relief and concave and convex epirelief with finer and darker fill to the host sediments. Segmentation is also projected out side by hazy annular constrictions. Burrow shows distinct stuffed structure with branched umbellate root like system. Branches are 10.0 to 22.0 cm long.

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). The cylindrical burrows exhibits typical periodic filling of tunnel in backward direction.

Preservation: Concave and convex epirelief, endichnial burrows. Actively filled, finer and darker fill than the host matrix.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Tapkeshwari Member near Observatory.

Asssociation: *Asteriacites*, *Thalassinoides*, *Palaeobullia*, *Scalarituba*, *Rhizocorallium*, *Palaeophycus*, *Planolites*, *Crossopodia*.

ICHNOSPECIES

Taenidium isseli SEQINABOL, 1887;

McCANN AND PICKERILL, 1988, p. 342.

Plate-66, b.

Description: Epichnial, compactionally flattened burrows, up to 20.0 cm long, 1.8 to 2.5 cm wide, possessing symmetrically arranged and distinct transverse annulations - two to three per centimeter, which impart a lobate like character to the outer, clearly defined sharp, unlined burrow wall. Fill identical to the host sediments. Burrows typically unbranched to rarely branched, curved to gently undulose.

Remarks: *Taenidium* may prove to be a candidate for synonymy with *Muensteria* (McCann and Pickerill, 1988). However, until the detailed synonymy of these and other meniscate or annulated burrows is undertaken, both the ichnogenera have been regarded as available. From reviewing available literature, McCann and Pickerill (1988) have suggested that these two ichnogenera can

a. *Taenidium serpentinum*

b. *Taenidium isseli*

readily be separated by adopting a combination of the following criteria: (1) Size: *Taenidium* is commonly smaller; (2) Branching: *Taenidium* is commonly branched, *Muensteria* is not; (3) Internal structure: *Taenidium* possesses generally straight or weakly curved transverse ornamentation, whereas the meniscae in *Muensteria* are arcuate; and (4) Form: *Taenidium* is a distinctly annulated burrow, while *Muensteria* is smooth and its meniscae are decidedly internal and are not reflected in the external morphology (Fursich, 1974; Hantzschel, 1975; Ksiazkiewicz, 1977; Kern, 1978). *Taenidium isseli* (Seqinabol, 1887) is not a commonly reported ichnospecies but has been figured and/or described by Papp (1941), Hantzschel (1962, 1975) and Ksiazkiewicz (1977). The ichnogenus is a eurybathic form and has been reported in strata of Ordovician (Pickerill, 1980) to Tertiary (Hantzschel, 1975) age. The *T. isseli* is different than the *T. serpentinum* by former's unbranching to rarely branching, compressional flattening, slight curving to gentle undulose nature.

Preservation: Convex epirelief and full relief.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Tapkeshwari Member of Umia Formation.

Association: *Keckia, Rhizocorallium, Planolites, Palaeophycus, Skolithos, Diplocraterion.*

ICHNOGENUS

Thalassinoides EHRENBERG, 1944, p. 350.

Diagnosis: Cylindrical burrows forming three dimensional branching system consisting of horizontal network connected to surface by more or less vertical shafts. 1.0 mm to about 20.0 mm in diameter, regularly branching, Y-shaped bifurcations in horizontal systems forming polygons, typical swelling at points of branching or else where.

ICHNOSPECIES

Thalassinoides *Sp.* EHRENBERG, 1944.

Plate-67, a (upper).

Description: Three dimensional branching system consisting of horizontal network forming cylindrical burrows about 5.0 to 10.0 mm in diameter. Burrows show regular branching and Y-shape bifurcations at about 5.0 to 8.0 cm interval in the horizontal system. Typical swelling is found at the branching or inbetween. Angle of branching varies from 60° to 150°. Fill identical to the surrounding matrix.

Preservation: Preserved as epichnia, endichnia and hypichnia.

Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: It occurs in calcareous siltstone of Jamaywadi Member in Chari Formation.

Association: *Planolites, Palaeophycus, Bifungites, Cochlichnus, Ophiomorpha.*

ICHNOSPECIES

Thalassinoides suevicus KENNEDY, 1967.

Plate-67, b.

Diagnosis: Large and ideomorphic, predominantly horizontal, more or less regularly branched, essentially cylindrical components forming large burrow system. Diachotonous bifurcation more common than T-shape branching, and typically enlarge at points of bifurcation. Burrow dimensions variable within a given system

Description: Large horizontal, smooth, cylindrical, depressed, Y-shape branching burrow system with a linear furrow on dorsal part of burrow in some cases. The burrows are circular to oval in cross section and enlarging at points of bifurcation. Orientation and spacing of branching is regular. The burrows are smooth with distinct wall. The burrow fill has the same texture and colour as the surrounding sediments. Maximum observed length is more than 90.0 cm with a diameter of about 5.0 cm. Commonly it has been observed that one branch produces off shoot immediately within 10.0 cm from point of branching while another branch runs up to 30.0-40.0 cm without branching

Preservation: Preserved as epichnia, endichnia and hypichnia.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Tapkeshwari Member of Umia Formation, near Observatory, Bhuj.

Association: *Planolites*, *Palaeophycus*, *Asteriacites*, Beaconichnus, *Scalarituba*, *Rhizocorallium*.

Discussion and Interpretation: These, very thinly lined to unlined burrow systems are usually found restricted to the fine grained sandstone siltstone rocks in Kutch. The network is largely horizontal forming polygons and is confined to a single level in the sediments. The unlined burrow systems appear to be characteristic of fine grained coherent substrates, in which wall reinforcement is unnecessary.

Thalassinoides is a common and wide spread ichnogenus in Mesozoic and Tertiary rocks (Frey, 1975). Typically, the regular branching network form polygons with swelling common at points of bifurcation (Hantzschel, 1975; p. 116-117). Because of these features, which are shown by specimens from the Tapkeshwari Member, they are included in the ichnospecies *Thalassinoides* suevicus. *Thalassinoides* is interpreted as a dwelling/feeding burrow of one or more crustaceans - the interpretation is corroborated by occurrence of Thalassinid shrimps by Hantzschel (1975) within burrows.

ICHNOSPECIES

Thalassinoides paradoxicus KENNEDY, 1967.

Plate-67, a (lower).

Diagnosis: Small burrow systems consisting of smooth walls, essentially cylindrical. Branches are irregular and typically enlarged at points of bifurcation. Burrow dimensions variable within a given system.

Description: Burrow systems are irregular, smooth, branched and spread on the bedding plane. Branching is stenomorphic and angle varies from 40° to 90°. Bifurcation is very common within short distances and in different directions.Burrows circular in cross section and swelling at points of

branching. Burrow diameter varies in same specimen from 0.5 to 1.0 cm. Burrow fill is similar to the surrounding matrix.

Preservation: Preserved as epichnia, endichnia and hypichnia.

Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: It occurs in calcareous siltstone of Jamaywadi Member in Chari Formation.

Association: *Thalassinoides Sp., Planolites, Palaeophycus, Bifungites, Cochlichnus, Ophiomorpha.*

a. (i) *Thalassinoides Sp.*.

(ii) *Thalassinoides paradoxicus*

b. *Thalassinoides suevicus*

ICHNOGENUS

Tisoa DE SERRES, 1840, p. 6.

ICHNOSPECIES

Tisoa siphonalis DE SERRES, 1840; GOTTIS, 1954.

Plate-68.

Diagnosis: Vertical U-shaped cylindrical tubes with closely oppressed limbs; individual tubes 2.0 to 3.0 mm in diameter, lying 1.0 to 15.0 mm apart, rarely branched; principally form axis of elongated conical concretions 1.0 m or more long; basal part of 'U' commonly not preserved; burrow walls usually lined, occasionally striated; transitional forms difficult to distinguish from *Arenicolites*.

Description: Small vertical U-shape cylindrical tubes without spreite and closely oppressed limbs. Burrow walls smooth with mud filling. Basal part of U-tube is preserved. Length of the burrow is 6.0 cm and individual tube is 0.4 to 0.5 cm in diameter lying 0.3 to 0.7 cm apart, and not branched. Plan view of a single tube is circular on bedding plane or in cross section.

Discussion and Interpretation: *Tisoa* siphonalis is transitional form of *Arenicolites*, in which two limbs are closely oppressed and perpendicular to the bedding plane. It is regarded as dwelling burrow. According to Frey and Cowles (1969, p. 20; 1972), it is probably made by a shrimp or amphipod like arthropod rather than by worm

Preservation: Full relief, filled with mud.

Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: It occurs in Ler Member near Gangeshwar Temple, south of Bhuj.

Association: *Arenicolites, Rhizocorallium, Planolites, Thalassinoides, Ophiomorpha.*

Tisoa siphonalis

ICHNOGENUS

Trichichnus FREY, 1970, p. 20.

ICHNOSPECIES

Trichichnus linearis FREY, 1970, p. 20.

Plate-69.

Diagnosis: Thread like, cylindrical burrows, 10.0 mm to 35.0 mm long; diameter less than 1.0 mm; straight or very slightly curved; branched or unbranched; typically vertical but also inclined to bedding plane or horizontal, with distinct walls, commonly lined with diagenetic minerals such as pyrite or rarely calcite.

Description: Very thin, slender thread like cylindrical burrows with a diameter of 1.0 to 2.0 mm and length of 1.0 to 7.0 cm. Burrows are arranged almost perpendicular to the bedding plane which are straightly curved to uneven showing bifurcation at lower or upper or both the ends in form of 'U' or 'V' shape. Many of them are not branched and few are partly inclined. Burrow walls are distinctly lined.

Discussion and Interpretation: *Trichichnus* is interpreted possibly as combined feeding & dwelling burrow of very small deposit feeding animal.

Preservation: Full relief, endichnia.

Facies: Laminated Shale Siltstone.

Stratigraphic Distribution: It occurs in Jadura Member of Katrol Formation near Satellite Earth Station..

Association: *Oldhamia, Isopodichnus, Gyrochorte, Phycodes, Planolites, Neonereites.*

Trichichnus linearis

ICHNOGENUS

Yakutatia HANTZSCHEL, 1962, p. W220.

Type Species: *Yakutatia emersoni* ULRICH, 1904.

Diagnosis: Cylindrical burrows, varying in thickness from 2.0 to 6.0 mm; bifurcating 1.0 to 3.0 times, forming 1-7 volutions about acuminate inner extremity; outer end obtuse.

ICHNOSPECIES

Yakutatia emersoni ULRICH, 1904, p. 140.

Plate-70.

Description: Trace comprises a single curved burrow which ramifies 1-3 times, branching typically occurring on inner concave side of initial burrow, more rarely on outer convex side. Branching initiated close to the acuminate termination of the initial burrow. Individual branches curve in the same direction or opposite direction to the initial burrow to produce a coiled or spiraled pattern. Diameter of individual burrow is 3.0 to 6.0 mm, variable longitudinally. Over all burrow system 5.0-8.0 cm wide to 16.0-20.0 cm long. Burrows smooth, unornamented, and preserved in convex epirelief

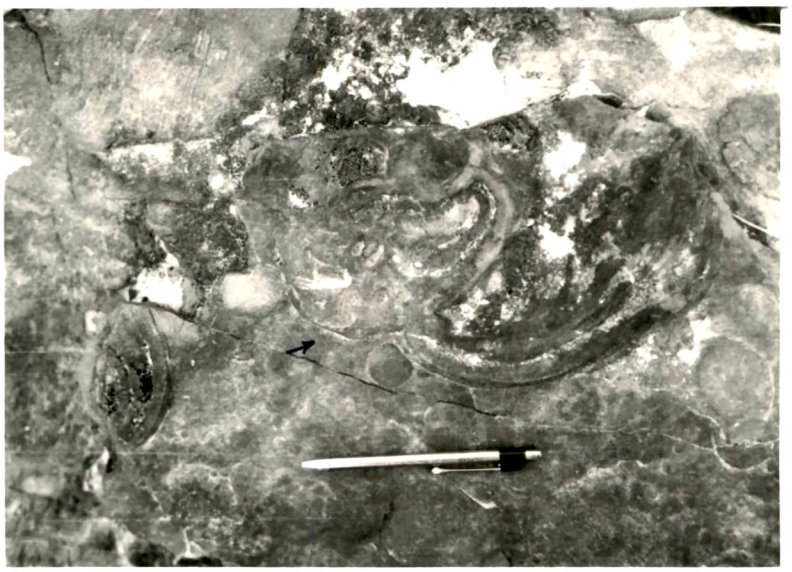
Remarks: The Kutch specimen of Y. emersoni is similar to that described by McCann and Pickerill (1988), Hantzschel (1962), Seilacher (1977), and Ulrich (1904).

Preservation: Convex epirelief.

Facies: Rippled Ferruginous Sandstone Siltstone Shale.

Stratigraphic Distribution: It occurs in Tapkeshwari Member of Umia Formation.

Association: *Gyrochorte*, *Rhizocorallium*, *Diplocraterion*, *Skolithos*, *Palaeophycus*, *Planolites*, *Circulichnus*, *Cylindrichnus*.



Yakutatia emersoni

ICHNOGENUS

Zoophycos MASSALONGO, 1855, p. 48.

Diagnosis: Shallowly conical, spiral form, consisting of three main parts; spirally coiled spreite, major and minor lamillae contained within the lamina, and a cylindrical tunnel, axis of spiral vertical to bedding, height small, single volutions cone like, sloping outward, diameter of successive whorls generally increasing downward, occasional inverse direction of coiling, base diameter of structure up to 60.0 cm or more, whorls comprising lamina variable in outline; circular, arcuate or lobate, occasionally first volutions lobate and larger and deeper ones nearly circular in outline, laminae exhibit major and minor lamillae, appear lunate in cross section, and curve radially from axis of spiral, major lamillae branch at acute angle toward axis forming minor lamillae, cylindrical tunnels with axial and marginal part forms the axis of spreite, has same thickness as spreite, may continue for a part or for whole length of lamina and then may be open to sediment at both ends, planar forms of *Zoophycos* similar to closed spiral spreite, may also be antler like, thickness 1.0 to 7.o mm.

ICHNOSPECIES

Zoophycos *brianteus* MASSALONGO, 1855.

Plate-71.

Description: The Kutch specimens are curved horizontal to subhorizontal with a planar imprint of an uncoiled spiral arrangement and unevenly thick laminae. The spreite appears in cross section as a series of thick irregularly lunate or crescent form packed tightly together in a curved concave up single line with variable length.

Zoophycos brianteus

Maximum vertical thickness is 1.0 mm; length of the laminae is up to 18.0 cm; width varies from 0.5 mm to 6.0 mm and diameter of the structure is 14.0 cm. In filling material is different than the surrounding sediments and material is finer ferruginous than those of intervening sediment. The spreiten is protrusive. Minor lamellae contained within the lamina can be seen in the specimen. Central axial cylindrical tunnel in form of semicircle is present in plan view with a diameter of approximately 1.5 cm. Whorls comprising lamina are arcuate in outline. Marginal tunnel is almost similar to the other lamina.

Discussion and Interpretation: The successive addition of arcuate or lunate laminae in *Zoophycos brianteus* is displayed by the addition of new segment constructed along side the previous one as the animal retracted and proceeded on its new course. This type of burrow indicates efficient exploitation of a nutrient rich substrate. Each course of the burrow represents the action of a vermiform organism as it moves in the substrate and ingest sediment. The outer edge of the spreite consist of marginal tunnel. This is possibly an open tube maintained by the organism while it probe in the sediment in closely spaced lamellae which branch off the marginal tube (Ekdale, 1977). The structure is attributed to the deposit feeding activity of Polychaete (Bischoff, 1968), Sipunculids (Wetzel and Warner, 1981), and Umbellulids (Bradly, 1973). *Zoophycos* is regarded as an intrastratal trace made by soft bodied, worm like animals engaged in a systematic pattern of grazing (Hantzschel, 1975). Although, originally interpreted as trace which is characteristic of outer subtidal to bathyal marine environments Recent workers have reported occurrences in shallow subtidal (Simpson, 1970; Martino and Curren, 1982), interdistributary bay (Tonkard and Barwis,

1982), back barrier lagoonal (Miller and Knox, 1985), intertidal (Miller and Johnson, 1981), and marginal marine (Martino, 1989) environments.

Preservation: Endogenic, full relief, fill heterogeneous to matrix.

Facies: Oolitic Limestone.

Stratigraphic Distribution: It occurs in the Dhosa Oolite Member.

Association: *Chondrites.*

TABLE - 11: ETHOLOGICAL, STRATONOMIC AND PHYLOGENETIC CLASSIFICATION OF THE TRACE FOSSILS IN THE MESOZOIC SEQUENCE OF THE STUDY AREA.

ETHOLOGICAL	ICHNOGENERA	STRATONOMIC	PHYLOGENE
I) DOMICHNIA (DWELLING STRUCTURES) Permanent shelters of vagile or hemi-sessile animals procuring food outside sediment	Arenicolites	Endogenic, Full relief	Polychaete/Annelid/Crustacean
	Corophioides	Endogenic, Full relief	Corophium
	Cylindrichnus	Endogenic, Full relief	Annelid/Polychaete/Crustacean
	Cylindricum	Endogenic, Full relief	Annelid/Polychaete/Crustacean
	Diplocraterion	Endogenic, Full relief	Crustacean/Polychaete/Annelid/Worm
	Histioderma	Endogenic, Full relief	Polychaete/Crustacean
	Monocraterion	Endogenic, Full relief	Worm
	Ophiomorpha	Endogenic, Full relief	Callianassid major
	Palaeophycus	Intergenic, Hyporelief Epirelief	Worm/Crustacean/Polychaete
	Skolithos	Endogenic, Full relief	Worm
	Stipsellus	Endogenic, Full relief	Polychaete
	Tisoa	Endogenic, Full relief	Shrimp/Amphipod/Arthropod/Worm
	Trichichnus	Endogenic, Full relief	Polychaete/Worm
I) FODINICHNIA (FEEDING TRACE) Deposit feeding burrows which also served as shelter.	Bifungites	Epigenic, Epirelief	Worm
	Chondrites	Endogenic, Full relief	Worm/Polychaete/Sipunculid/Annelid
	Granularia	Endogenic, Full relief	
	Gyrolithes	Endogenic, Full relief	Decapod crustacean
	Gyrophyllites	Endogenic, Positive Epirelief	Medusae
	Keckia	Inter-, Endo-genic, Epi-, Hypo-relief	Worm/Holothurian
	Laevicyclus	Inter-, Endo-genic, Full relief	Annelid (Scolecolepis)/Ephemerids
	Phycodes	Intergenic, Hyporelief	Polychaete/Worm
	Rhizocorallium	Endogenic, Full relief	Crustacean/Annelid
	Rosselia	Endogenic, Hyporelief	Annelid/Crustacean/Polychaete
	Scalarituba	Endo-, Inter-genic, Full relief, Epirelief	Worm/Annelid/Polychaete
	Spirophyton	Endogenic, Full relief	Polychaete
	Taenidium	Endogenic, Hyporelief	Worm
	Thalassinoides	Endogenic, Full relief	Crustacean
	Yakutatia	Epi-, Endo-genic Full relief	-
	Zoophycos	Endogenic, Full relief	Polychaete/Annelid

ETHOLOGICAL	ICHNOGENERA	STRATONOMIC	PHYLOGENE
II) PASCICHNIA (GRAZING TRACE) Deposit feeding vagile mud ingesters with simple back filling	Circulichnus	Intergenic, Full relief, Epirelief	Worm
	Cochlichnus	Epi-, Endo-genic, Epi-, Hypo-relief	Annelid/Pelecypod
	Fustiglyphus	Positive Epirelief	Annelid
		Endogenic, Full relief	
	Helminthopsis	Intergenic, Epi-, Hypo-relief	Annelid/Polychaete
	Megagrapton	Endichnia, Positive Epirelief	
	Muensteria	Inter-, Endo-genic, Hypo-, Epi-relief	Worm
	Oldhamia	Epigenic, Epirelief	Worm
	Planolites	Intergenic, Epi-, Hypo-relief	Annelid/Polychaete/Worm
	Protopaleodictyon	Endogenic, Hyporelief	Annelid/Polychaete
	Strobilorhaphe	Epigenic, Epirelief	-
) REPICHNIA (CRAWLING TRAILS) Trails left during action of locomotion.	Bolonia	Epi-, Endo-, Inter-genic	Gasteropod (Prosobranchia)
		Epi-, Hypo-relief	
	Crossopodia	Endogenic, Negative Epirelief	Arthropod
	Didymaulichnus	Intergenic, Hyporelief	Gasteropod
	Gyrochorte	Positive- Negative- Epirelief	Apalcophore
	Isopodichnus	Intergenic, Hyporelief	Arthropod
	Neonereites	Convex Hyporelief,	Gasteropod/Annelid
	Palaeobullia	Epigenic, Negative Epirelief	Gasteropod
	Scolicia	Epigenic, Epirelief	Holothurian/Gasteropod/Prosobranchia
CUBICHNIA (RESTING TRACE) Structure made by vagile benthos digging down for temporary rest or prey	Asteriacites	Intergenic, Epichnial, Negative Epirelief	Asterozoa-Asteroids/Ophiuroids
	Bergaueria	Intergenic, Epi-, Hyporelief	Actinarian sea anemone/Coelenterate
	Conostichus	Epichnial, Negative Epirelief	Worm

TABLE - 12: DISTRIBUTION OF ICHNOGENERA IN VARIOUS MEMBERS AND LITHOFACIES

MEMB	ICHNOGENERA	LITHOFACIES														
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
	Bifungites	oo	oo	oo												
	Bolonia	oo	++													
	Cochlichnus	##	##													
	Didymaulichnus	++														
J	Diplocraterion		##													
	Granularia	oo	oo													
	Gyrochorte	++	++	oo												
	Helminthopsis		++	oo												
	Isopodichnus	oo	oo													
W	Laevicyclus	##	oo	oo												
	Muensteria		++													
	Ophiomorpha	##	oo													
	Palaeophycus	++	++	oo												
	Planolites	++	++	oo												
M	Phycodes	oo	##	##												
	Protopaleodictyon		##	##												
	Rhyzocorallium	##	##													
	Thalassinoides	++	++													
	Tisoa	++	oo													
	Arenicolites					oo	oo									
G	Diplocraterion					oo	oo									
	Isopodichnus					##										
	Monocraterion					oo	oo									
M	Skolithos					oo	oo									
	Thalassinoides					##										
	Bolonia	##														
	Chondrites	oo	oo								oo					
	Cylindricum							oo								
	Diplocraterion		oo					oo								
L	Gyrochorte	oo														
	Monocraterion	##						oo								
	Ophiomorpha	##														
	Palaeophycus	oo														
	Planolites	oo														
M	Rhizocorallium	++														
	Skolithos	##														
	Scolicia	##														
	Thalassinoides	##						oo			oo					
	Tisoa	oo														
	Arenicolites											##				
D	Chondrites											##				
	Palaeophycus											oo				
O	Planolites											oo				
	Rhizocorallium	oo														
M	Zoophycos											oo				

MEMB	ICHNOGENERA	LITHOFACIES														
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
	Monocraterion								##							
G	Palaeophycus								##							
R	Skolithos								##							
M	Thalassinoides								##							
	Arenicolites	##														
	Chondrites	##														
	Cochlichnus	oo														
	Cylindricum		++													
M	Fustiglyphus	oo	oo													
	Granularia	oo														
	Gyrochorte	++														
	Histioderma	##														
	Laevicyclus	##														
D	Monocraterion		oo													
	Ophiomorpha	##														
	Palaeophycus	++														
	Phycodes	++														
	Planolites	++														
M	Rhizocorallium	oo														
	Rosselia	oo	++													
	Skolithos	oo	oo													
	Thalassinoides	oo														
	Tisoa	oo														
	Chondrites		oo													
	Cochlichnus	oo														
	Corophioides	##														
	Cylindricum	oo	++													
	Didymaulichnus	++														
	Gyrochorte	**														
J	Gyrolithes					++										
	Isopodichnus	oo														
	Laevicyclus	oo														
	Monocraterion		++													
	Neonereites	oo														
	Oldhamia	++														
	Ophiomorpha	oo														
M	Palaeophycus	++	oo													
	Phycodes	++														
	Planolites	++	oo													
	Rhizocorallium	oo														
	Rosselia		++													
	Scolicia	oo														
	Spirophyton		++													
	Trichichnus	**														

MEMB	ICHNOGENERA	LITHOFACIES														
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
	Arenicolites					oo										
	Asteriacites				**											
	Bergaueria				++	oo	++									
	Bifungites				++											
	Chondrites	**														
	Circulichnus				##											
	Conostichus				oo											
	Crossopodia				oo											
	Cylindrichnus				oo											
T	Cylindricum		oo		++											
	Diplocraterion				++	##	oo									
	Enteropneusta burr					oo										
	Gyrochorte		oo		**											
	Gyrophyllites				##											
	Helminthopsis				oo											
	Isopodichnus				oo											
	Keckia				++											
	Laevicyclus				oo											
	Megagrapton				##											
	Monocraterion		oo		##	##	oo									
	Oldhamia				oo											
	Ophiomorpha				##	##										
	Palaeobullia				oo											
	Palaeophycus				++											
	Phycodes				++	##										
M	Planolites				++											
	Rhizocorallium				**		oo									
	Scalarituba				oo											
	Scolicia				++											
	Skolithos				oo	oo	oo									
	Spirophyton				++											
	Stipsellus				##											
	Taenidium				oo											
	Thalassinoides		oo		++	##										
	Yakutatia				oo											
	Arenicolites													++	oo	
	Corophioides													++		
	Diplocraterion													**		
	Enteropneusta burr													++		
B	Laevicyclus													oo		
	Monocraterion													oo	oo	oo
	Ophiomorpha													oo		++
	Planolites													##		
	Rosselia													oo	oo	
M	Skolithos													**	oo	oo
	Spirophyton													##		
	Stipsellus													++		
	Strobilorhaphe															++
	Thalassinoides													##		

LITHOFACIES

1. LAMINATED SHALE SILTSTONE ----------(LSS)
2. SHEET SANDSTONE ----------(SS)
3. DARK SHALE SILTSTONE SANDSTONE ----------(DSSS)
4. RIPPLED FERRUGINOUS SANDSTONE SILTSTONE SHALE (RFSSS)
5. MASSIVE SANDSTONE ----------(MS)
6. HERRINGBONE SANDSTONE ----------(HS)
7. BIVALVE SANDSTONE ----------(BS)
8. OYSTER SANDSTONE ----------(OS)
9. BIOCLASTIC LIMESTONE ----------(BL)
10. INTRAFORMATIONAL CONGLOMERATE ----------(IC)
11. OOLITIC LIMESTONE ----------(OL)
12. EXTRABASINAL OLIGOMICTIC CONGLOMERATE ----------(EOC)
13. BIOTURBATED SANDSTONE ----------(BTS)
14. VARIEGATED, SHALE ----------(VS)
15. CROSS BEDDED COARSE GRAINED SANDSTONE --------(CBCGS)

MEMBERS

JWM	–	JAMAYWADI MEMBER
GM	–	GANGESHWAR MEMBER
LM	–	LER MEMBER
DOM	–	DHOSA OOLITE MEMBER
GRM	–	GUNAWARI RIVER MEMBER
MDM	–	MARUTONK DUNGAR MEMBER
JM	–	JADURA MEMBER
TM	–	TAPKESHWARI MEMBER
BM	–	BHARAPAR MEMBER

SYMBOLS

**	=	ABUNDANT	++	=	COMMON
oo	=	SPARSE	##	=	RARE