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Ichnofossil assemblage of Bhuban Formation (Surma Group) from Zuangtui area, Aizawl, Mizoram

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Abstract

Bhuban succession of Surma Group (early to middle Miocene) is well exposed in Zuangtui section of Aizawl district of Mizoram and comprises ~40 m thick sequence of alternating sandstone, siltstone and shale and their admixtures in various proportion. Highly bioturbated rocks of this section show behaviorally diverse groups of trace fossils. A total of 17 ichnospecies have been identified from this section. These are *Cochlichnus anguineus, Diplopodichnus biformis, Funalichnus bhubani, Gordia marina, Palaeophycus striatus, P. tubularis, Planolites beverleyensis, Planolites* isp., *Psilonichnus upsilon, Psilonichnus* isp., *Rhizocorallium* isp. Type A, *Rhizocorallium* isp. Type B, *Skolithos* isp., *Teredolites clavatus, T. longissimus, Thalassinoides horizontalis* and *T. suevicus*. These trace fossils represent the record of *Skolithos, Cruziana* and *Teredolites* ichnofacies and at places the mixed *Skolithos-Cruziana* ichnofacies. *Teredolites* infested log-grounds and the other ichnological evidences indicates that the rocks of Bhuban Formation exposed in Zuangtui area, Aizawl district of Mizoram were deposited under near shore high energy conditions.

Key words: Ichnofossils; depositional environment; Bhuban Formation; Surma Group; Aizawl.

Introduction

The Surma Group of rocks in Mizoram exhibit a rich and diversified assemblage of body fossils[9,53,54,58-60,62-69] and trace fossils.[37,41,42,50-52,70,71] Trace fossils can be used as a useful tool for interpretation of palaeoenvironmental and stratigraphic framework in the absence of body fossils.[40,44,57]

The Miocene rocks of Bhuban Formation are well exposed in the Zuangtui area of Aizawl district. A ~40 m thick sequence of the Bhuban rocks consisting of sandstone, siltstone, shale and their admixtures in various proportions has been measured in this section. The succession contains well-preserved, diverse trace fossil assemblages which are useful indicators of the environmental conditions prevailing during the time of deposition. Therefore, the main purpose of the present paper is to describe the trace fos-

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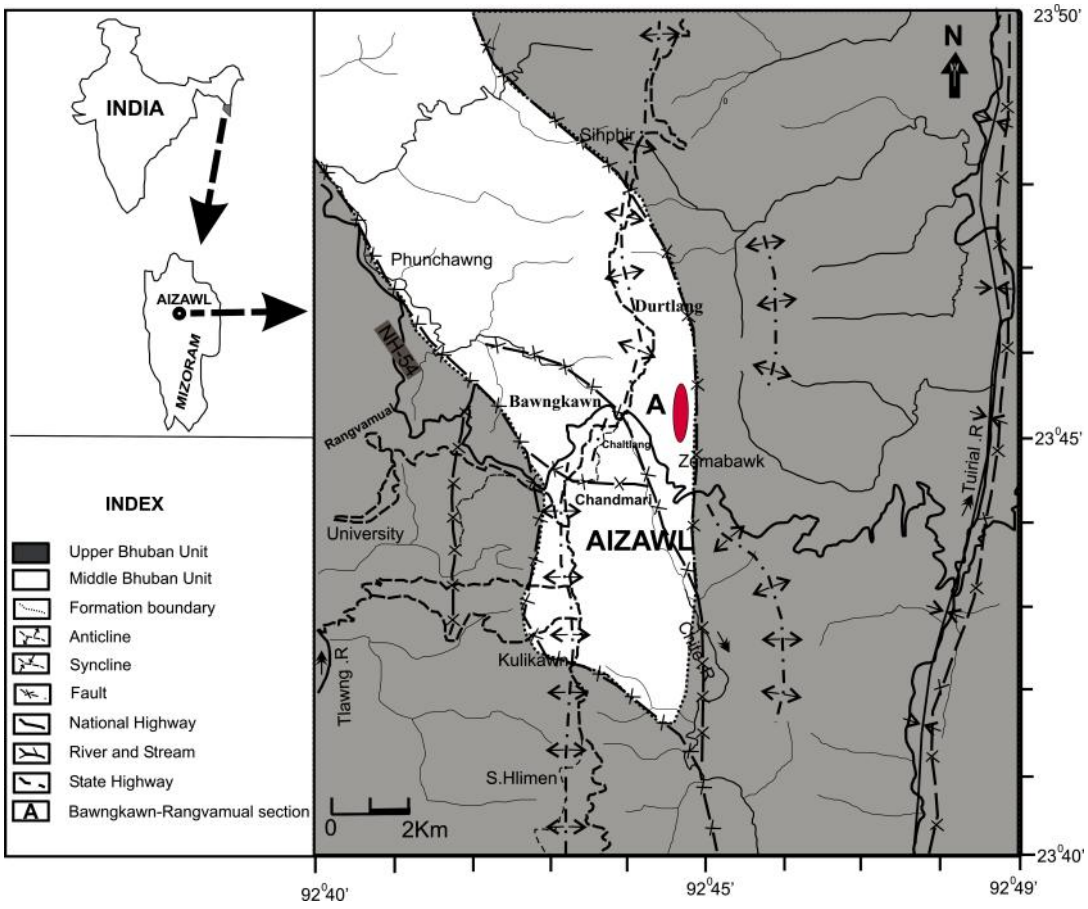

Figure 1. Location map of the study area (after Malsawma *et al.* 2010).

sils assemblage from this section and their palaeoenvironmental significance.

Location and geological setting

The study area is located in the northern part of Aizawl city, and falls under the Survey of India Topo-Sheet no. 84A/9 and between latitude 23˚46'18.9" to 23˚46'21.36" N and longitude 92˚44'53.15" to 92˚44'53.43" E (Fig. 1). At the study site, the Middle Bhuban Unit of Bhuban Formation is well exposed, along a small road cut section which provides well developed exposed sequence. The Tertiary sedimentary succession of Mizoram has been grouped into the Barail (Oligocene), the Surma (Lower to Middle Miocene) and the Tipam Groups (Upper Miocene to early Pliocene) in the ascending order. The Lower-Middle Miocene rocks of Mizoram are represented by Surma Group of rocks which has been subdivided into Bhuban and Bokabil Formation. Bhuban Formation is the best and thickest developed lithostratigraphic unit in Mizoram, it attains a thickness about 5000 m. This Formation is further subdivided into Lower, Middle and Upper Bhuban units. The entire sedimentary column of the formation is a repetitive succession of arenaceous and argillaceous rocks. The main lithologies exposed are sandstone, siltstone, shale, mudstone and their admixtures in various proportions and few pockets of shell limestone, calcareous sandstone and intraformational conglomerate (Fig. 2).[64] The stratigraphic succession with the lithological

Table 1. Stratigraphic succession of Mizoram (modified after Karunakaran 1974 and Ganju 1975).

Age	*Group*	*Formation*	*Unit*	*Generalized Lithology*
Recent	Alluvium			Silt, clay and gravel
		----------Unconformity----------		
Early Pliocene to Late Miocene	Tipam (+900 m)			Friable sandstone with occasional clay bands
		----------Conformable and transitional contact----------		
Miocene to Upper Oligocene		Bokabil (+950 m)		Shale, siltstone and sandstone
			----------Conformable and transitional contact----------	
	S U R M A (+5950 m)	B H U B A N (5000 m)	Upper Bhuban (1100m)	Arenaceous predominating with sandstone, shale and siltstone
			-------Conformable and transitional contact--	
			Middle Bhuban (3000m)	Argillaceous predominating with shale, siltstone-shale alternations ans sandstone
			-------Conformable and transitional contact--	
			Lower Bhuban (900m)	Arenaceous predominating with sandstone and silty-shale
		----------Unconformity obliterated by faults----------		
Oligocene	Barail (+3000 m)			Shale, siltstone and sandstone
		----------Lower contact not seen----------		

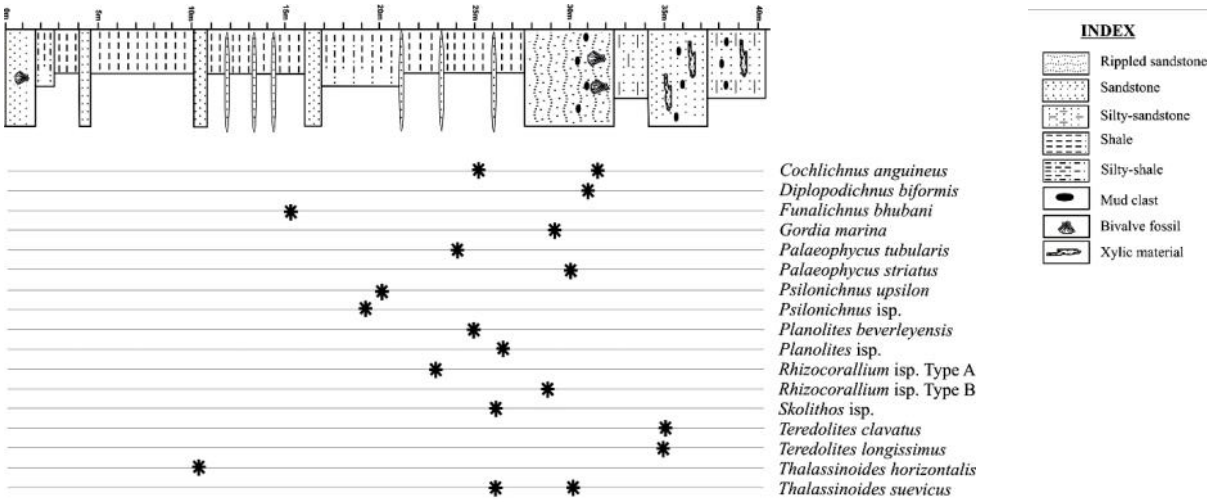

Figure 2. Generalized lithocolumn of the study area showing the distribution of the trace fossils.

characteristics of each unit is given in Table 1.[19,27]

Materials and Methods

The trace fossils collected from the Bhuban Formation (Surma Group) are thoroughly studied group wise up to species level for their systematic paleontological description with the help of type material and available literature in the laboratory. The data regarding the distribution pattern of fossils in the sediments such as orientation, density and state of preservation, their association, relationship with the enclosing sediments are also collected in order to decipher the depositional environment of the associated sediments.

Systematic Description

All the ichnospecies described and illustrated in this thesis are archived in the Palaeontology Laboratory of the Department of Geology, Mizoram University, Aizawl, Mizoram. These include *Cochlichnus anguineus, Diplopodichnus biformis, Funalichnus bhubani*, *Gordia marina*, *Palaeophycus striatus*, *P. tubularis*, *Planolites beverleyensis*, *Planolites* isp., *Psilonichnus upsilon, Psilonichnus* isp., *Rhizocorallium* isp. Type A, *Rhizocorallium* isp. Type B, *Skolithos* isp., *Teredolites clavatus*, *T. longissimus*, *Thalassinoides horizontalis* and *T. suevicus*. In the present study, ichnogenera and ichnospecies are named using the binomial system of nomenclature and described alphabetically.

Ichnogenus *Cochlichnus* Hitchcock, 1858
Ichnospecies *Cochlichnus anguineus* Hitchcock, 1858 (Figure 3a)
Material: Specimen no Geol/ZTF/1.
Description: Smooth, sinusoidal, horizontal, unlined and unbranched feeding trails, preserved as convex epirelief. The burrow filled is identical to the surrounding rocks. Maximum observed length is about 60 cm and diameter ranges from 2 to 3 cm.
Remarks: The present specimen shows regular sinousity in structures which is similar to *C. anguineus* Hitchcock. Eager *et al.*[11] suggested that *Cochlichnus* are the crawling traces and probably are the feeding structures of small worms or worm like animals. Hakes[20] reported *Cochlichnus* in sediments of supposedly low salinity palaeoenvironment. In the context of Mizoram, Tiwari *et al.*[70] and Rajkonwar *et al.*[51] reported and described *Cochlichnus anguineus* from the Middle Bhuban Unit of Bhuban Formation, Surma Group of Aizawl.
Occurrence: Silty-sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnogenus *Diplopodichnus* Brady, 1947
Ichnospecies *Diplopodichnus biformis* Brady, 1947 (Figure 3d)
Material: Specimen no Geol/ZTF/3.
Description: Simple, smooth, straight to gently curved trails with distinct median furrow. Trails preserved as convex epirelief and parallel to the bedding plane. Maximum observed length is about 8 cm and diameter is 2 mm.
Remarks: The general morphology and orientation of the ichnogenera represents crawling trails of molluscan origin.[24] The present traces are similar with *Diplopodichnus biformis* described by Keighley & Pickerill[28] and Buatois *et al.*[8] Buatois *et al.*[8] considered *Diplopodichnus* as a marine and non-marine Paleozoic trace fossil with possible range into the Late Proterozoic. It was also reported in Lower Triassic playa sediments of Germany, Middle Triassic carbonates of Poland and in Late Triassic deep lacustrine sediments of Argentina.[31,32,43] The present specimen is the first record of *Diplopodichnus* from the Surma rocks of Mizoram as well as other Miocene succession in India.
Occurrence: Sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnnogenus *Funalichnus* Pokorny, 2008
Ichnospecies *Funalichnus bhubani* Tiwari *et al.* 2013 (Figure 3c)
Material: Specimen no Geol/ZTF/2.

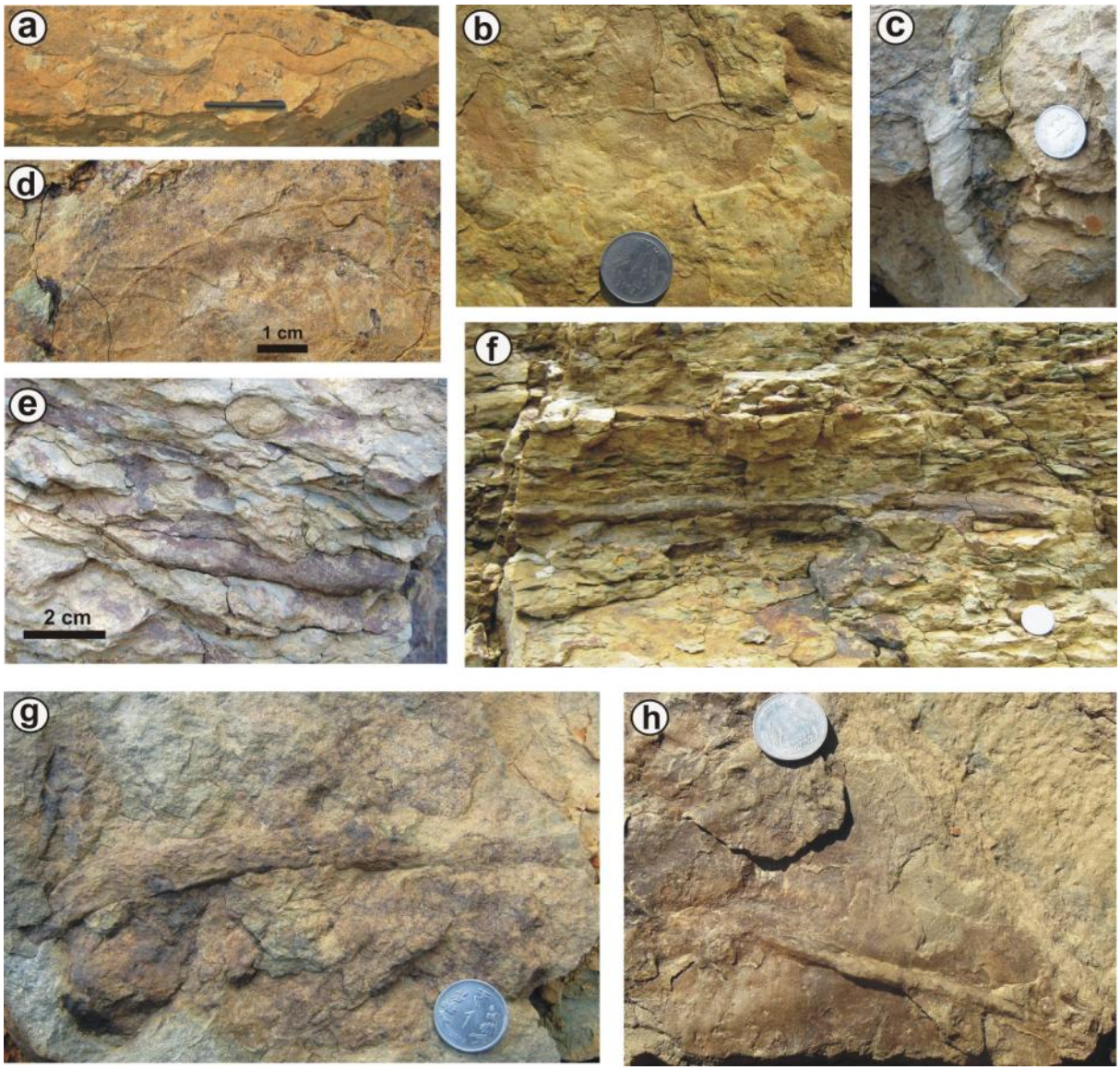

Figure 3. a. *Cochlichnus anguineus*, b. *Gordia marina*, c. *Funalichnus bhubani*, d. *Diplopodichnus biformis*, e. *Planolites* isp., f. *Planolites beverleyensis*, g. *Palaeophycus striatus*, h. *Palaeophycus tubularis*.

Description: The burrow is long, isolated, unbranched, vertical, straight to gently curved, endichnial and unlined burrow. The cylindrical body of the burrow shows slightly tapering at the bottom part. The burrow consists of a number of small cylindrical segments. The individual segments are smooth and slightly higher as compared to the interspaces, which are usually parallel to the bedding plane and are inclined to right or left sides. The burrow is circular to subcircular in cross section. Maximum length of the burrow is 12 cm and diameter ranges from 1.2 to 2 cm.

Remarks: Pokorny[49] described *Funalichnus* from the Upper Cretaceous of the Bohemian Basin, Czech Republic and include the type ich-

nospecies *Funalichnus strangulatus*. The present burrow of *Funalichnus* is similar with *Funalichnus bhubani* described by Tiwari *et al.*[71] from the Bhuban Formation of Surma Group of Aizawl. Tiwari *et al.*[71] suggested that the vertical nature and cylindrical segment form of *Funalichnus bhubani* indicates that the animal excavated the surrounding compact sediments to its body length and pushed the sediments periodically downward to maintain its position. Periodically filled structures are interpreted as a dwelling structure that may have had some combined feeding habits.

Occurrence: Sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnogenus *Gordia* Emmons, 1844
Ichnospecies *Gordia marina* Emmons, 1844 (Figure 3b)
Material: Specimen no Geol/ZTF/12.
Description: Straight to gently curved, long, smooth, slender trail. The trail is unbranched and uniform in thickness, which is 7 cm long and 0.3 cm wide. The sediments in the trail is similar with the surrounding rocks.

Remarks: The present specimen does not possess the regular sinuous of *Cochlichnus*, the loose meanders of *Helminthopsis* and regular meanders of *Cosmorhaphe*, therefore it is placed under *Gordia marina*. Hantzschel[24] considered *G. marina* as a scavenging or grazing trails of vermiform organisms. Rajkonwar *et al.*[50] reported *G. marina* for the first time from the Bhuban Formation of Aizawl district of Mizoram.

Occurrence: Sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnogenus *Paleophycus* Hall, 1847
Ichnospecies *Paleophycus striatus* Hall, 1852 (Figure 3g)
Material: Specimen no Geol/ZTF/7.
Description: Burrow is hypichnial, full relief, unbranched, thinly lined burrow having faint striations. The burrow preserved horizontal to the bedding plane. The observed length of is 18 cm and diameter is 1.8 to 2 cm. The burrow material is identical to the host rock.

Remarks: The gross morphology of the ichnospecies resembles with *Palaeophycus striatus* described by Tiwari *et al.*[70] and Rajkonwar *et al.*[50] from the Surma succession of Northeast India. *P. striatus* differs from the rest of the ichnospecies of *Paleophycus* in having striations.

Occurrence: Sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnospecies *Palaeophycus tubularis* Hall, 1847 (Figure 3h)
Material: Specimen no Geol/ZTF/6.
Description: The burrow is cylindrical, full relief, long, smooth, unbranched, straight to slightly curved and preserved parallel to the bedding plane. The burrow fill is structureless and similar to the host rock. The maximum observed length of the burrow is 12 cm and diameter is 0.8 to 1 cm.

Remarks: The present specimen is identified as *Palaeophycus tubularis* on account of its horizontal smooth, straight, long and unbrached burrows with distinct lining. *Palaeophycus* is a eury-benthic facies-crossing form produced probably by polychaetes or annelids.[48] It can reasonably be compared with the form described by Patel *et al.*[47], Badve[1] and Kundal & Sanganwar[34] from the Bagh Group of Madhya Pradesh. Singh *et al.*[57] documented this species from Boka -Bil Formation (late Oligocene to Miocene) of Manipur. Tiwari *et al.*[70] and Rajkonwar *et al.*[50] described this species from the Bhuban Formation of Aizawl, Mizoram.

Occurrence: Silty-sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnogenus *Planolites* Nicholson, 1873
Ichnospecies *Planolites beverleyensis* Billings, 1862 (Figure 3f)
Material: Specimen no Geol/ZTF/13.
Description: The burrow is simple, straight

to slightly curved, unbranched, semicircular in cross section and horizontal to the bedding plane. The colour of the sediments in the burrow is different from the host rock. The maximum observed length of the burrow is 32 cm and diameter ranging from 1.8 to 2.5 cm.

Remarks: The present specimen shows the typical morphological characters of *Planolites beverleyensis*.[48] The ichnospecies has been reported by various workers from different parts of India.[3,33-35,57] *P. beverleyensis* has been described by Tiwari *et al.*[70] and Rajkonwar *et al*.[50,52] from the Bhuban Formation of Aizawl, Mizoram.

Occurrence: Sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnospecies *Planolites* isp. (Figure 3e)

Material: Specimen no Geol/ZTF/14.

Description: Simple, horizontal, endichnial, long, cylindrical, smooth-walled, unlined, straight to gently curved, unbranched burrow and oriented parallel to bedding plane. The sediment fill in the burrow is different from the host sediment.

Remarks: Since the observed burrows are unbranched, unlined, preserved parallel to the bedding and the burrow fill is different from the host rock, hence placed under the ichnogenus *Planolites* Nicholson. Due to lack of more detail morphologic feature, they are described as *Planolites* isp. and kept under open nomenclature.

Occurrence: Silty-sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnogenus *Psilonichnus* Fursich, 1981

Ichnospecies *Psilonichnus upsilon* Frey *et al.* 1984 (Figure 4a & b)

Material: Field photograph of silty-sandstone with a full relief burrow.

Description: Burrows inclined, I-shaped, some are branched at the lower part, the branches are different from each other in terms of size and shape. Dimensions of the burrows vary in different burrow population but are constant in a given burrow. Maximum observed length is 32 cm and diameter ranges from 1.8 to 2.2 cm. The burrow fill is identical to the surrounding rocks.

Remarks: Present ichnospecies resembles very well with *Psilonichnus upsilon* reported by Singh *et al*.[57] from the Bokabil Formation of Manipur and Rajkonwar *et al*.[50] from Bhuban Formation of Mizoram. This ichnospecies has also been reported by Frey *et al*.[16] and Kundal & Dharashivkar.[33]

Occurrence: Silty-sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnospecies *Psilonichnus* isp. (Figure 4c)

Material: Specimen no Geol/ZTF/8 and 9.

Description: The burrow is simple, isolated, I-shape, unbranched, unlined and vertical to incline to the bedding planes. The burrow material is almost similar with the host rock. The maximum observed length of the burrow is 8.5 cm and diameter is 1.8 to 2 cm.

Remarks: The overall morphological character of the present burrow is resembles with the ichnogenus *Psilonichnus*.[17] The species level identification has not been attempted due to lack of enough significant characters.

Occurrence: Silty-sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnogenus *Rhizocorallium* Zenker, 1836

Ichnospecies *Rhizocorallium* isp. Type A (Figure 5d)

Material: Field photograph of silty-sandstone with a full relief burrow.

Description: Epichnial, semi relief, straight, unbranched, U-shaped burrow containing spreiten and preserved horizontal to the bedding. The limbs of the burrow are filled with fine to medium grained sediments identical to the host rock. The distance between two limbs is 3.5 cm; maximum observed length of the burrow is about 9 cm.

Remarks: The present specimen is partly weathered due to exposure to the environment.

Due to presence of spreiten and horizontal to the bedding plane, it is placed under the ichnogenus *Rhizocorallium* Zenker.

Occurrence: Silty-sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnospecies *Rhizocorallium* isp. Type B (Figure 3e)

Material: Field photograph of grey sandstone with a full relief burrow.

Description: The burrow is endichnial, sinuous, unbranched, U-shaped tubes containing spreiten and disposed parallel to the bedding plane. The burrow is poorly preserved and maximum observed length is 5.5 cm, the marginal tubes are 1 to 1.2 cm apart from each other and the tube diameter is 0.2 cm.

Remarks: The present burrow is a U-shaped burrow with spreiten and occurs parallel to the bedding plane, therefore it is placed under the ichnogenus *Rhizocorallium* Zenker. Although, the overall morphology of the burrow is resembles with *Rhizocorallium*, it is very small in overall dimension and poorly preserved, therefore, identification at the species level has not been attempted.

Occurrence: Sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnogenus *Skolithos* Haldemann, 1840

Ichnospecies *Skolithos* isp. (Figure 4d & e)

Material: Specimen no Geol/ZTF/15.

Description: Burrows occur as solitary cylindrical, unbranched tubes disposed perpendicular to the bedding plane. Surface annulations are not seen. The lengths of the burrows are 4cm and diameter 8 to 10mm.

Remarks: Present specimens are placed under *Skolithos* isp. as these exhibit uniform diameter throughout the cylindrical tubes, perpendicular to bedding plane and surface annulations are not visible. Since the burrows are perpendicular to the bedding plane, the surface annulations are not seen, therefore the present burrows are described as *Skolithos* isp. and kept in open nomenclature.[24] They are interpreted morphologically as shaft and ethologically as domichnia.

Occurrence: Silty-sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnogenus *Teredolites* Leymerie, 1842

Ichnospecies *Teredolites clavatus* Leymerie, 1842 (Figure 4g, h & i)

Material: Specimen no Geol/ZTF/10 and 11.

Description: Borings are clavate shaped, densely crowded, predominantly perpendicular to the grain in woody substrates, varying length between 2-10 mm and width between 3-5 mm. The bores are appearing round to oval, occasionally club shaped, having length-width ratio-usually less than 5.

Remarks: Present ichnofossils exhibit similar morphological characteristics described by Leymerie.[36] *Teredolites* is restricted to borings in xylic material whereas *Gastrochaenolites* for equivalent borings in lithic material.[29] *T. clavatus* was reported by several workers from various Cretaceous and Tertiary sediments of the world.[10,29,36] It was reported by Mehrotra *et al.*[41] for the first time from the Bhuban Formation of Mizoram. Recently, Rajkonwar *et al*.[52] reported T. clavatus from Upper Bhuban Unit of the Bhuban Formation in Aizawl.

Occurrence: Silty-sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnospecies *Teredolites longissimus* Kelly and Bromley, 1984 (Figure 4f, g & h)

Material: Specimen no Geol/ZTF/5.

Description: Specimens are preserved as grouped or isolated sand-filled tubes, incompletely and variably preserved. Tubes are commonly elongated, sinuous to contorted and densely-packed. The lengths of the tubes are ranges from 15-52 mm and mean diameter of tubes is 3-5 mm. The clavate shape is clearly noted to indicate its distinct feature, however, in general it is poorly preserved.

Remarks: The present specimens are similar

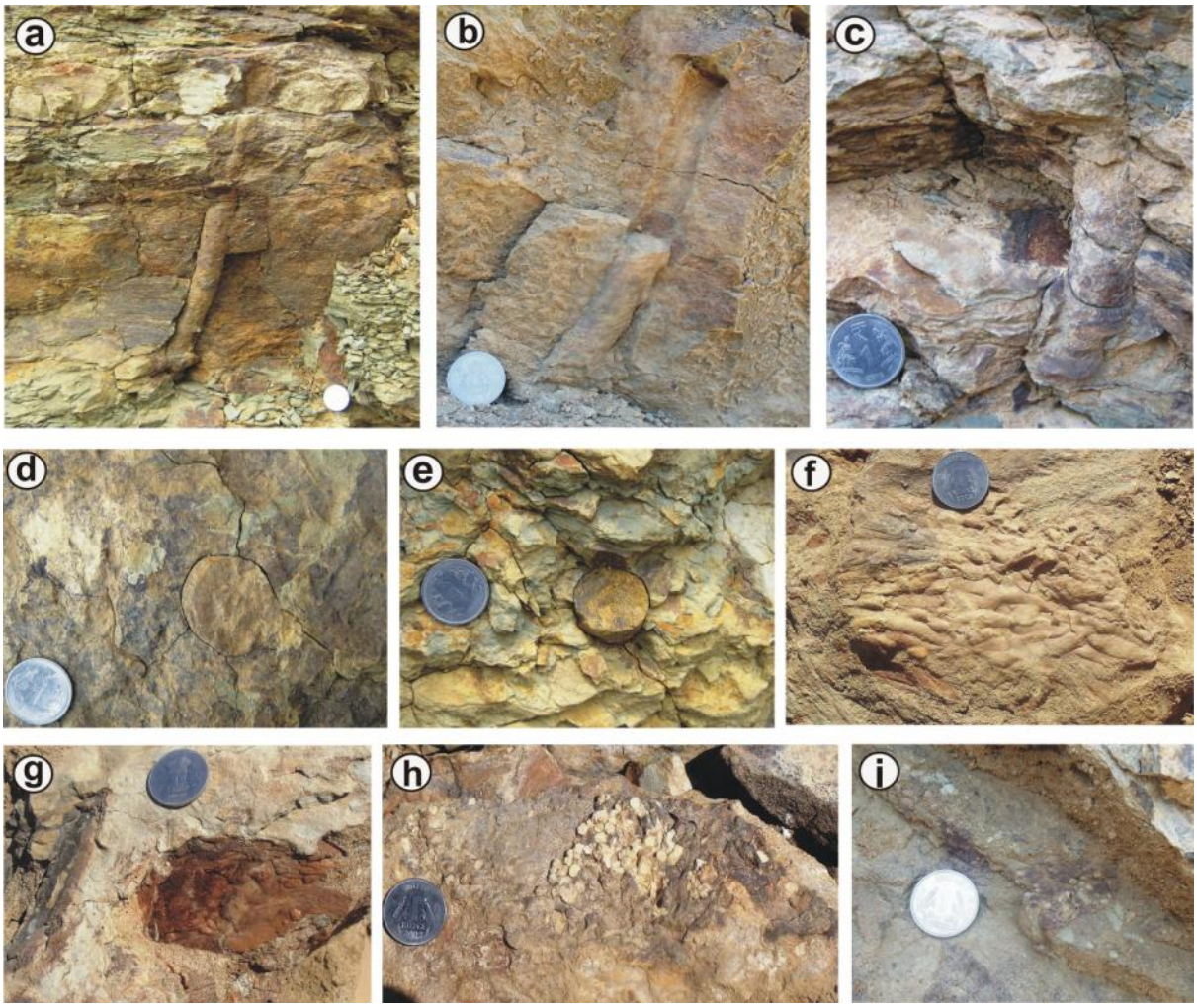

Figure 4. a. *Psilonichnus upsilon*, b. *Psilonichnus upsilon*, c. *Psilonichnus* isp., d. *Skolithos* isp., e. *Skolithos* isp., f. *Teredolites longissimus*, g. *Teredolites clavatus* and *T. longissimus*, h. *Teredolites clavatus* and *T. longissimus*, i. *Teredolites clavatus*.

with *Teredolites longissimus* described by Kelly and Bromley[29]. This ichnospecies predominantly develops parallel to the wood grain, having length-width ratio-usually greater than 5. For the first time Rajkonwar *et al*.[52] reported *Teredolites longissimus* from Upper Bhuban Unit of the Bhuban Formation in Aizawl.

Occurrence: Silty-sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnogenus *Thalassinoides* Ehrenberg, 1944

Ichnospecies *Thalassinoides horizontalis* Myrow, 1995 (Figure 5a)

Material: Field photograph of grey sandstone with a full relief burrow.

Description: Endichnial, smooth walled, unlined, three dimensional, horizontal burrow system showing Y/T shaped branching. Tunnels are straight to curve disposed parallel to the bedding plane and bifurcates at an angle of 95°-125°. A diameter of the burrows varies from 2.2-

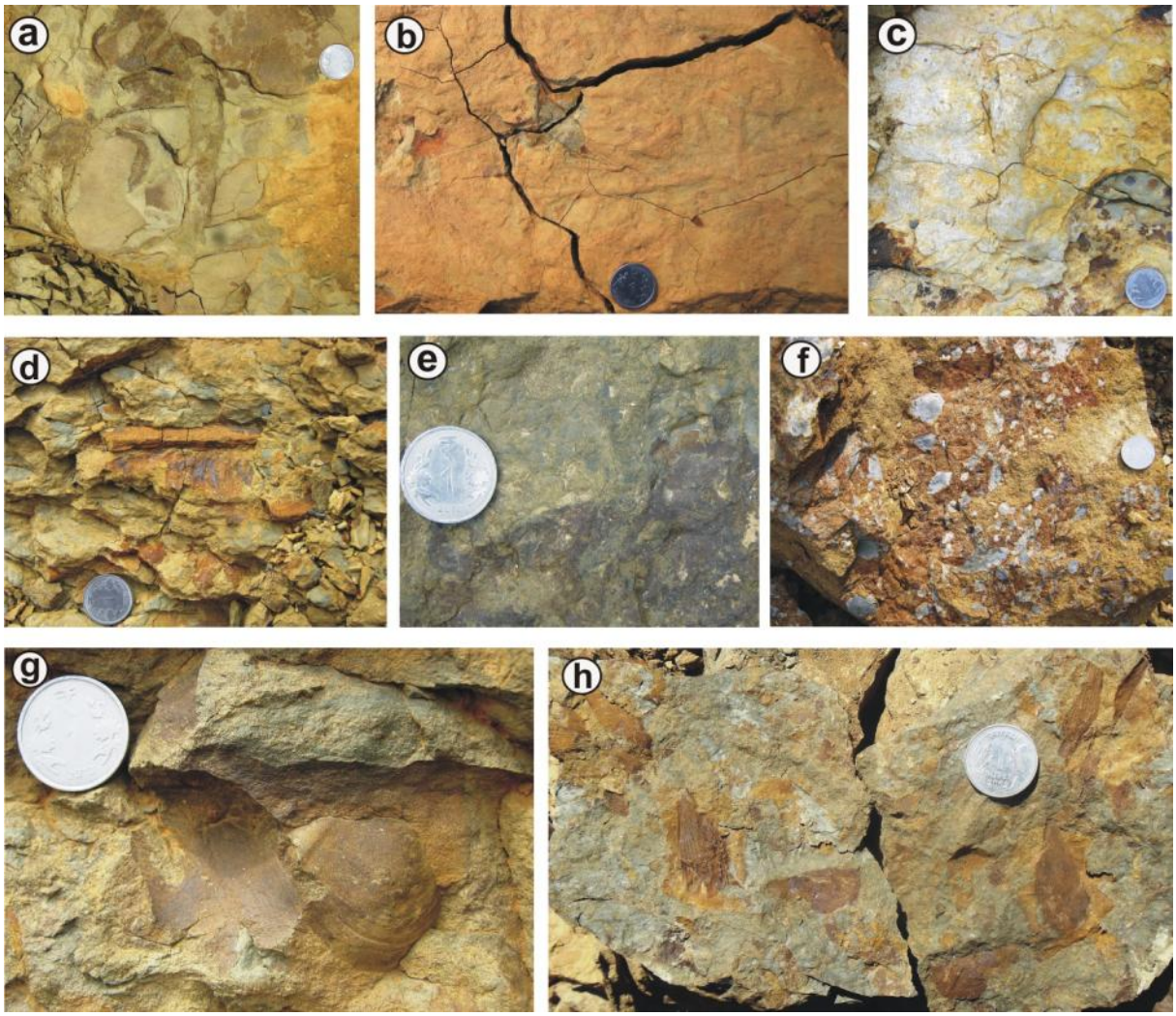

Figure 5. a. *Thalassinoides horizontalis*, b. *Thalassinoides suevicus*, c. *Thalassinoides suevicus*, d. *Rhizocorallium* isp. Type-A, e. *Rhizocorallium* isp. Type-B, f. Mud clast in brown coloured, medium grained sandstone, g. Bivalve cast (*Apolymetis* sp.) preserved in the bottom most medium grained sandstone, h. Bivalve *Pinna* preserved in grey sandstone.

3.5 cm.

Remarks: *Thalassinoides horizontalis* can be differentiated from the other ichnospecies of *Thalassinoides* in lack of the vertical component[45] and as occurring underneath the bedding plane. The morphological features of the present specimen resembles very well with the form described as *T. horizontalis* by Tiwari *et al.*[70] and Rajkonwar *et al*.[50] from the Bhuban Formation of Mizoram.

Occurrence: Sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Ichnospecies *Thalassinoides suevicus* Rieth, 1932 (Figure 5b & c)

Material: Specimen no Geol/ZTF/4.

Description: Profusely branched, Y-shaped, unornamented and irregular burrows passively filled and disposed; horizontal to oblique to the bedding plane. The burrows are spread over the

bedding plane. Main burrow is 4 to 8 mm in diameter. Sediment fill is different than the host sediment.

Remarks: The present burrows are very densely branched and thereby placed under *Thalassinoides suevicus*. Kundal & Sanganwar[34] and Kundal & Dharashivkar[33] also reported this ichnospecies from the Nimar sandstone Formation, Bagh Group of M.P and Neogene and Quarternary deposits of Dwarka-Okha area, Gujarat respectively.

Occurrence: Sandstone, Middle Bhuban Unit of Bhuban Formation, Surma group of Zuangtui area, Aizawl, Mizoram.

Discussion and Conclusion

Vertical endichnial burrows of *Funalichnus bhubani*, *Psilonichnus upsilon* and *Skolithos* occur in silty-shale and shale beds exposed in the middle part of the succession are typical member of *Skolithos* ichnofacies.[38,56] Frey *et al*.[16] defined *Psilonichnus upsilon* based on unlined, sparsely branched, sub-vertical burrows that occur in back-beach and lower costal dune facies. The trace maker of *Psilonichnus upsilon* as the extant ghost crab *Ocypode quadrata*, elucidated by polyester casts of J-shaped burrows from the lower backshore areas. The *Skolithos* ichnofacies indicates the unconsolidated and shifting nature of the substrate, high energy conditions and a rapid change in the sedimentation rate and erosion of surface sediments.[57,72] *Funalichnus bhubani* indicates the changes in the colonization pattern of the benthic community.[71] Abundance of these biogenic structures and sedimentary characteristics may be attributed to a relatively moderate to high wave and current energy conditions and shifting of substrate exploited by the opportunistic animals in the foreshore/shoreface environments. Moreover, associated genera are intimately related to high energy shoreface environment indicating that the producer of the *Funalichnus* also occupied similar type of environmental set-up. The high abundance of horizontal deposit feeding traces namely, *Cochlichnus*, *Planolites*, *Palaeophycus*, *Rhizocorallium* and *Thalassinoides suevicus* are indicative of extremely quiet water conditions with less reworking where organic matter was being deposited along with the sediments.[26] This assemblage represents transitional zone to lower shoreface environment, somewhat quieter offshore conditions; most probably the lowest energy levels.[18] Bromley (1990) considered it as semi vagile and vagile, middle level deposit feeder structures, present in oxygenated situations. Because of lower energy level, less abrupt shifting of sediments and less change in temperature and salinity, *Planolites-Palaeophycus* assemblage characterized by feeding and grazing traces of most probably originators like polychaetes. The *Thalassinoides* are frequently related to the oxygenated situations and soft but fairly cohesive substrates.[5,7,13,30] This assemblage shows predominance of the deposit as well as the suspension feeder crustaceans and polychaetes. Overall this assemblage consists of dominant horizontal feeding structures suggests the low to moderate energy conditions, unstable, soft, unconsolidated substrate of the shoreface environment. *Cochlichnus* is a crawling trace and probably the feeding structures of small worms or worm-like animals[11] and reported in sediments of low salinity palaeoenvironment. The xylic material which hosts the *Teredolites* is interpreted to have either been carried down shallow distributary channels and trapped on flanking sand flats or was stranded on flats during the transgressive episodes that generated the flooding surfaces.[10,61] During the Lower Miocene time the rocks formed in Mizoram area were deposited in shallow marine setup, whereas this area has now turned into a positive land mass as a result of the withdrawal of the sea.

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