Trace fossils from Talchir carbonate concretions, Giridih basin, Jharkhand

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The carbonate concretions occurring at the bottom of Talchir fissile shale facies preserved signatures of various trace fossils along with a cast of doubtful organisms and cyanobacterial mat structures. The host shale deposited under glacial melt water fed lacustrine condition. The concretions, formed in poorly oxygenated conditions, are either of syndepositional origin and/or deposited a little below the sediment water interface and were later exhumed to the depositional surface due to erosion of soft mud overlying them.

The trace fossils are both megascopic and microscopic in nature. The megascopic trace fossils are identified on the basis of their morphology as *Monocraterion* and *Rhizocorallium*. Some of the megascopic structures described remain problematic at present. The microscopic trace fossils are formed due to the activity of marine meiofauna (possibly by nematodes), which, although produced morphologically show similar traces of known larger ichnogeneras but much smaller than them. The discovery of these trace fossils apparently indicate the influx of saline water into a lacustrine domain during the Talchir sedimentation at Giridih basin. Moreover, presence of the above two megascopic trace fossils in the marine lacustrine carbonate concretions may lead researchers to consider their much wider environmental significance than hitherto believed.

1. Introduction

The Talchir Group that marks the beginning of Gondwana sedimentation in India is traditionally considered to be of glacial and fluviolacustrine origin (Blanford *et al* 1856; Rao 1957; Niyogi 1961; Ghosh and Mitra 1975; Sen 1991; Sen and Banerjee 1991; and others), except for a few well-established fossiliferous sequences reported from Umaria (Reed 1928) and Manendragarh in Madhya Pradesh (Ghosh 1954) and Daltonganj in Jharkhand (Dutta 1965). But this concept is under the scanner after the documentation of various signatures of marine environment from several Gondwana basins of India. Fossil polyplacophora (Sengupta *et al* 1999) and foraminifers (Pal *et al* 1994) from Talchir sediments, West Bokaro basin; marine pelecypods from Ranigunj basin (Chandra 1994); marine bivalves and brachiopods from the Talchir formation of Son-Mahanadi basin (Casshyap and Arora 1994); marine coccoliths from the Talchir formation, Ramgarh coal field (Chaudhuri and Mandal 1989); trace fossils from the Talchir formation of Raniganj and Deogarh coal fields (Guha *et al* 1994); and marine algal stromatolites and colonial cyanophytes from the Talchir formation, Talchir basin, Orissa (De 1999) are some of the important findings. Mohanty and Das (1997) reported microbial mat from Talchir basin, Orissa and inferred periodic influx of saline water into the lacustrine domain based on the stable isotope analysis. The sedimentary structures and trace fossils preserved in the Talchir formation of Sahajuri basin indicates its deposition under glaciomarine deltaic environment (Bhattacharya *et al* 2004; Chakraborty and Bhattacharya 2005). Chakraborty (1993) indicated

Keywords. Trace fossils; Talchir Group; concretions; Giridih basin; environment.

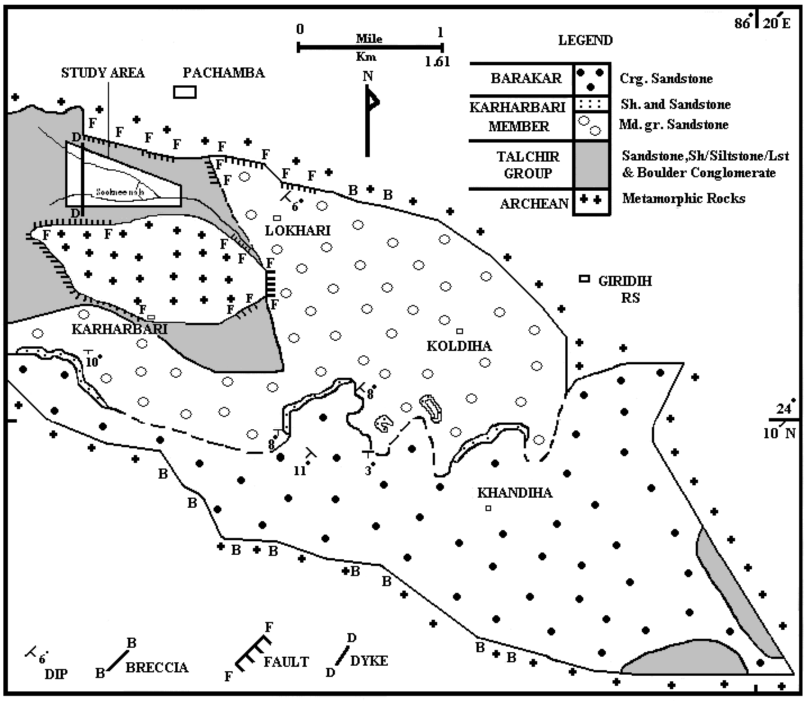


Figure 1. Geological map of Giridih basin (redrawn after Das 1986; Sengupta *et al* 1988).

marine influence during the deposition of the Talchir group of sediments, Giridih basin on the basis of trace fossils preserved in sandstone.

Concretions and nodules are considered very important because they often provide 'frozen records' of the condition of the sediment at the time of deposition and consolidation processes (Raisewell 1971; Selles-Martinez 1996). Concretions are also given lot of importance because they may often preserve fossils and other biogenic structures. The concretions/nodules found in the Talchir sediment of different Indian Gondwana basins, were predominantly made up of calcareous material (Ghosh *et al* 2002; Das and Goyal 2007). Based on the trace element and isotopic studies Ghosh *et al* (2002) suggested fresh water lacustrine depositional environmental condition for the concretions of West Bokaro, Ramgarh (Damodar valley basin), and Talchir (Mahanadi valley basin). The carbonate concretions of various shapes and sizes are found in the Talchir Group sediment, Giridih basin (Damodar valley), Jharkhand. Das and Goyal (2007) studied these concretions for their various crack morphologies. These carbonate concretions have preserved various megascopic trace fossils, doubtful impressions of body fossils, and various signatures of microscopic trace fossils. The objectives of this paper are to describe the above findings and correlate them to a possible environmental set up during the Talchir group sedimentation at Giridih basin.

2. Geological setting

The Giridih Gondwana basin, a small WNW-ESE trending basin in eastern India includes Permocarboniferous sediments belonging to the Talchir group, the Karharbari and Barakar members (Sengupta *et al* 1988). The presence of a large inlier of Precambrian rocks within the Gondwana sediments is an interesting feature. The inlier is bounded by normal faults on all sides. The Talchir group sediments are predominantly present in the western part of the basin (figure 1). The Talchir group directly overlies precambrian gneissic rocks and in turn are overlain by Karharbari member. The boundary between the Talchir group and the Karharbari member is gradational to the south but a N–S trending fault separates them towards the east. The northern boundary of Talchir group against Precambrian rocks is marked by prominent faulting while the western boundary is an erosional unconformity.

The Talchir group sediments which are mainly exposed in and around the Sooknee Nala (western part) comprises basal boulder conglomerate facies succeeded by khaki-green fissile shale facies, and an upper sandstone facies (table 1). The carbonate concretions, occurring at the bottom part of fissile shale facies, are well exposed at the bed in the north-western part of Sooknee Nala (plate 1A). For detail geologic setting please see Sen (1991). The glacial melt water-fed lacustrine and turbidity

Table 1. *Lithofacies variations at the study area.*

Lithofacies	Description	Trace fossils
C. Sandstone	Massive, matrix supported conglomerate with angular clasts. It laterally as well as vertically changes to fine grained, yellowish, feldspathic sandstone with sporadic pebbles. Sandstone shows parallel lamination, cross-lamination, and convolute lamination.	Not reported.
B. Shale	Khaki-green fissile shale with dropstones. The lower part is massive greyish black diamictite with negligible clast content. The diamictite passes upward into bluish-grey laminated calcareous siltstone which is often sandy. The carbonate concretions occurring at the bottom of fissile shale and above siltstone. Some of the concretions show dropstones. The shale facies also contains few stringers of fine grained laminated sandstone and siltstone. The sandstone shows ripple-drift lamination. Striations and chatter marks preserved on the siltstone. The upper part of the facies is weakly stratified and interlayered with rhythmites.	Burrows in the sandstone: *Zoophycos, Skolithos, Planolite* and *Teichichnus* (Chakraborty 1993). Trace fossils in the carbonate concretions (this paper).
A. Boulder conglomerate (Diamictite)	Massive, poorly sorted conglomerate with clayey and sandy matrix. The clasts are dominantly cobble size with occasional boulders. Boulders are often faceted. The conglomerate passes upward in to a bluish-grey fine grained laminated calcareous siltstone. The siltstone in places sandy and cross-laminated.	Horizontal and vertical burrows in siltstone (Sen 1991). Burrows are not classified.

current deposition is suggested for the shale lithofacies (Sen 1991).

3. Carbonate concretions

The concretions occur as laminated bodies of varying shapes and sizes. The laminations of the shale could be traced in continuity to the concretions. The concretions are grey-black coloured, dense and compact with diameters varying between 4 cm and 50 cm. On the basis of their morphology Das and Goyal (2007) classified them into three categories: cabbages like growth, domed up growth structure with laminae are warped towards periphery, and discoid bodies with concentric structure at plan view. The vertical axis in all the above varieties is smaller than horizontal axis. Some of the concretions show the presence of dropstones, both, on the surface as well as within them (plate 1B). The vertical section of discoidal concretions show two types of layering: **(i)** laminae are tapered to the major axis of the concretion, and **(ii)** parallel laminae without any deformation. In both the cases, they show repeated parallel layers of dark black coloured, fine grained, crinkled layer and relatively lighter grey coloured, fine grained layer (plate 1C). These layers have developed due to seasonally changing water depths corresponding to fluctuations in light intensities which triggered the stacked buildup of sets of dark and light laminae. The dark horizontal layers are rich in filamentous cyanobacterial mat formed during the winter, whereas the light layers rich in sediment formed during the summer (Gerdes 2007). The deformed laminae are of syncompactional origin with the host shale. At small depths with continuous deposition sediment compacts rapidly and growing concretion develops deformed laminae (Raisewell 1971). The concretions are predominantly made up of calcite and quartz with little feldspar, pyrite and clay minerals (illite and chlorite). The insoluble residue content of these bodies varies between 30% and 38%. The organic matter content varies between 0.5% and 1.5% (Goyal 2005). Das and Goyal (2007) suggested that some of the concretions were clearly of syndepositional origin, whereas, some were formed a little below the sediment water interface, later exhumed to the depositional surface by erosion of the soft mud overlying them,

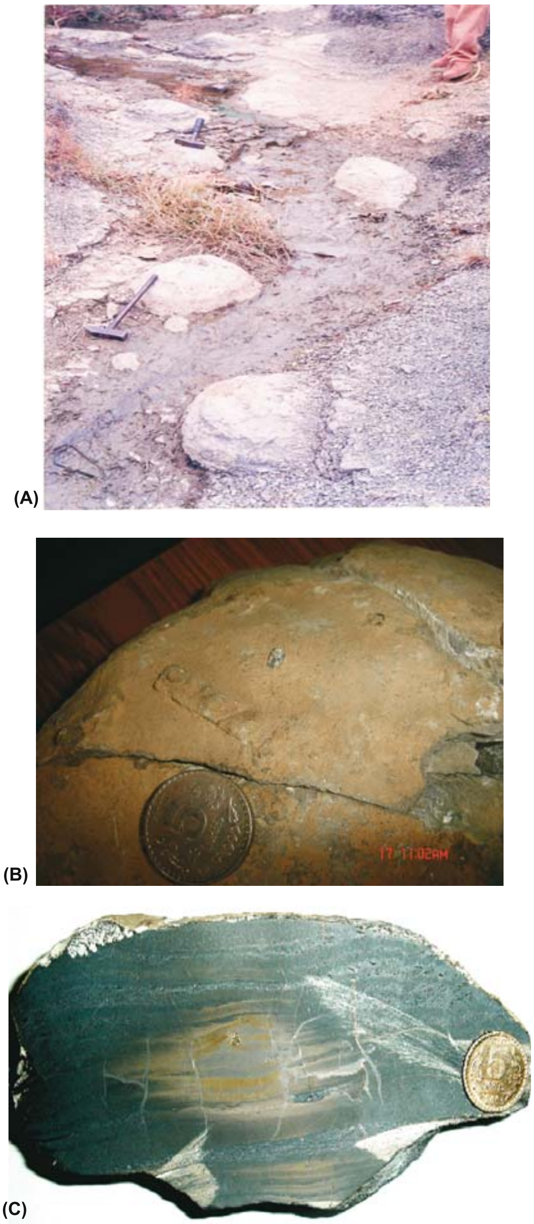


Plate 1. The carbonate concretions: **(A)** The concretions occurring at the bottom of fissile shale facies in the Sooknee Nala bed. Hammer length: 31 cm. **(B)** The various sized dropstones attached on the concretion. Coin diameter 23 mm. **(C)** The vertical section of a concretion showing light and dark (filamentuous mat) laminae. Yellow colour of laminae indicates weathering products of pyrite. Coin diameter 23 mm.

which allowed organisms to bore into them. The grey-black colour, presence of pyrite and organic matter in these concretions indicate that these were formed under poorly oxygenated conditions.

4. Methodology

The organo-sedimentary structures are observed after careful study of outcrops, either by breaking concretions, removing, or by cutting concretions parallel/vertical to the laminations. Some of the above structures are preserved as casts in calcareous concretions and others are traced by their physical appearances, both, in hand specimens and in thin sections. All the organo-sedimentary structures are photographed, majority of them sampled and kept with the first author at the Department of Earth and Planetary Sciences, University of Allahabad, Allahabad, India. The above structures which were studied in hand specimen and in the field are described as megascopic structures, whereas, the structures studied in thin sections are described as microscopic ones (table 2). The trace fossils are identified and named after Benton and Harper (1997) and Lindholm (1987). The microscopic trace fossil signatures are morphologically compared to the traces of large known icnogeneras. The depositional environmental conditions for trace fossils are suggested after Seilacher (1967, 1978) and Frey (1975).

5. Discussion

The deposition of these concretions occurred under poorly oxygenated lacustrine conditions. Seasonal cooling and warming helped in the development of biovarvite during the formation of concretions. These kinds of laminations are also in favour of marine lacustrine conditions. The poorly oxygenated condition is not very suitable for active growth of benthos (Sengupta 2007). But table 2 shows that these concretions have preserved a good number of trace fossils. Trace fossils, reflect behaviour and morphology of the metazoans that formed them and exhibit great diversity and complexity of morphology (Gong and Si 2002; others). Earlier several workers reported trace fossils from the restricted lagoon mud and dysaerobic depositional conditions (Jamieson 1969; Arya and Rao 1979; Wignall 1991; Das and Rao 1992). Pike *et al* (2001) reported abundant meiofauna (nematode burrows) in the recent severely dysoxic, laminated sediments from the Santa Barbara basin, California margin, and also microcavities and microtunnels in laminated deglacial sediments from Palmer Deep, west Antarctic Peninsula. All of them indicated that although environment was fetid, it supported a benthonic community of predominantly soft bodied mud ingesting organisms. The *Monocraterion* of *Skolithos* ichnofacies is widespread in littoral sandy to rocky shores with high energy conditions (Seilacher 1967; Crimes 1975; Frey 1975; Rhoads 1975). The trace fossil *Rhizocorallium* of *Cruziana* ichnofacies also indicates a shallow marine condition. The environmental conditions for these trace fossils do not suit the suggested glacio-lacustrine

Table 2. *Description of the various trace fossils and doubtful organo-sedimentary structures.*

Description of trace fossil morphology	Ichnotaxa	Remarks
A. Megascopic trace fossils:		
Opening with concentric rings on plan view, diameter varies between 0.5 and 2 cm; vertical to subvertical tubular structures; discordant to the laminations; unbranched; funnel top; either retrussive meniscus filling type or protrussive spreites; length varies between 3 and 12 cm; chambers filled with either limonitic or pyritic material. (Plate 2A, B and C)	*Monocraterion* of *Skolithos* ichnofacies	*Monocraterion* represents dwelling burrows inhabitated by gregarious, suspension feeding worm like animal; shallow marine (littoral) environment.
U-shaped burrow with spreite, subhorizontal; full relief; burrow filled with calcareous mud and clayey material; burrow dim. 1.0 cm, length 2.5 cm and distance between the limbs of U – 1.3 cm. (Plate 2D)	*Rhizocorallium* of *Cruziana* ichnofacies	Burrows of deposit-feeding animals or dwelling burrows of filter feeders. Littoral to neritic environment.
Concave cast of some material at the base of one of the concretions; prominent boundary of cast with umbo like feature; growth structure of concretion can be seen around the cast. The maximum length 6.9 cm and width 5 cm. (Plate 2E)	Not known	The cast is likely to be of unknown bivalvia(?).
Slightly elliptical cast of a material inside of a broken concretion; central ridge; two lobes at the apex are extended to the bottom; length 2.3 cm and width 1.4 cm (Plate 2F)	Not known	The cast is of soft bodied organism at present remained problematical.
B. Microscopic trace fossils:		
Vertical to slightly inclined, straight, discordant to the lamination; unbranched; uniform width (0.2–0.3 mm) along length; slightly tapering lower end, weak lining at the wall; internal cavity filled with non-laminated almost homogeneous lime mud. Length 2–2.5 mm. (Plate 3A)	Trace of meiofauna Trichichnus(?) isp.	Morphologically very similar to *Skolithos* but much smaller than those. Trichichnus reported from shelf area (Frey 1975).
Tubular, funnel top; concentric opening (plan) (diameter 0.25–0.45 mm); vertical to subvertical, straight, discordant to the lamination; unbranched; thin lining, meniscus type spreite; tapering bottom; filled with alternately dark lime mud/pyritic material and lighter coloured lime mud, length: 1–2 mm. (Plate 3B, C and D)	Trace of meiofauna	Morphologically similar to *Monocraterion* but of microscopic scale.
Tubular structures, vertical to subvertical, discordant to the lamination; slightly swollen central part of the tube; meniscus filling type spreite; filled with alternate light and dark coloured lime mud; tapered top and bottom; outer surface of tubes marked by numerous striae, length: 0.45–0.5 mm. (Plate 3E)	Meiofaunal trace	Morphologically very similar to *Rhizocorallium* of *Glossifungites* ichnofacies.
Vertical to subvertical, discordant to the lamination; unbranched; tapered top and bottom; non-uniform thickness; length and width widely vary; laminae slightly bent into the burrow chamber; cavity filled with either homogeneous lime mud or alternating lime mud and sparry calcite with few fragments of laminae. (Plate 4A and B)	Meiofaunal trace	Burrow structure likely to be due to bivalve boring, commonly found in shoreline rocks or in lithified limestone hard grounds on the seabed.
Long tubular, horizontal branching; oblique to the laminations; uniform width ($\sim$0.1 mm); filled with homogeneous lime mud. (Plate 4C)	Meiofaunal trace	Morphologically similar to *Thallassinoid* of *Glossifungites* ichnofacies.

Table 2. *(Continued).*

Description of trace fossil morphology	Ichnotaxa	Remarks
Small tubular; branched; straight to slightly curved; thickness variable (<0.1–2 mm); filled with lighter coloured lime mud. (Plate 4D)	*Chondrites* (?) of *Cruziana* ichnofacies	Feeding burrow of sediment eating wormlike organism, marine littoral to abyssal depth.
Radiating traces of vaguely defined tubes from a central point; almost circular in plan (diameter 1.4 mm); filled with alternately slightly dark and light coloured lime mud with some silt to clay sized detrital grains. (Plate 4E)	Trace of meiofauna	The trace fossil morphologically similiar to the *Zoophycos* (spiral) type.
The structures occurring parallel to lamination; two lobes with a central ridge, lobe width: 0.15–0.2 mm, lobes have very fine rib like features occurring at an angle to the central ridge; lobes filled with lime mud and silt-clay sized detrital grains. (Plate 5A and B)	Meiofaunal trace	The structures are morphologically similar to trace fossil *Cruziana* of *Cruziana* cihnofacies.
Horizontal tubular structure, curved, almost uniform width (~ 0.13 mm); unbranched; wall partly lined with bright coloured lime mud and detrital grains; filled with homogeneous lime mud; length 0.4 mm; pyrite patches present. (Plate 5C)	Meiofaunal trace	The trace morphologically comparable to *Teichichnus* tube of *Cruziana* ichnofacies.
Wavy, bundle of thin tubes; discontinuous; parallel to the laminations; made of light coloured lime mud. (Plate 5D)	Sheath bundle of *Microcoleus chthonoplastes*	A species capable of sediment binding (Gerdes 2007).
Dark coloured, crinkcled, discontinuous; thin layers; parallel to the laminations; interlayered with lighter coloured lime mud; often surrounded by spar. (Plate 5E)	Cyanobacterial mats	Biovarvites showing sequence of filamentuous mat (dark laminae: winter mat, light laminae: summer mat). Mats destroyed by critical point drying. Common in peritidal lagoons.

environment of deposition of the host shale, as well as of concretions. But the trace fossils observed here are indeed morphologically similar to the above known ichnogeneras. Chakraborty (1993) also indicated marine influence during the Talchir group sedimentation, Giridih basin on the basis of trace fossils (*Zoophycos, Planolite, Skolithos* and *Teichichnus*) observed in the sandstone associated with shale facies. These observations apparently indicate influx of saline water into a lacustrine domain during the sedimentation of Talchir fissile shale lithofacies at Giridih basin.

The crinkled and discontinuous laminae that make up the calcareous laminated concretion have a close resemblance to cyanobacterial mats (Gerdes 2007). These types of algal laminations were described as horizontal stromatolites probably *Weedia* type (Pettijohn 1975). Similar types of laminae were also reported earlier from the Proterozoic Charmuria limestone of Chattisgarh (Das and Rao 1992), Narji limestone of Kurnool basins (Arya and Rao 1979), Cretaceous algal-deposits of Valencia, Spain (Monty 1981), Proterozoic sediments of South Africa (Bertrand-Sarfati and Pentecost 1992), and Saltworks, Canary Islands, Spain (Gerdes *et al* 1991, 2007). Bertrand-Sarfati and Pentecost (1992) described such dark, often discontinuous growth of algae as Tussocky structure and compared them with modern stromatolite builder *Rivularia*. If algae were actively present during the growth of these concretions then the question that arises is whether the other microscopic organo-sedimentary structures are also due to the activity of algae. Milliman (1974) suggested that endolithic algal colonies can bore their substrates. The diameters of algal borings (Golubic 1969) range from 5–15 μm, while the diameters of these micro-organo-sedimentary structures are much larger than this size. Thus the algae as agents of these borings are ruled out. Fungi and bacteria may also be ruled out as active borers for the similar reason. These microscopic structures apparently seem to be made by meiofauna (animal ranging in size from approximately 0.1 mm to 1 mm that live within the sediment). They have made morphologically similar signatures in sediments to larger known ichnogeneras reported mostly from the sandy horizons, but much smaller than them.

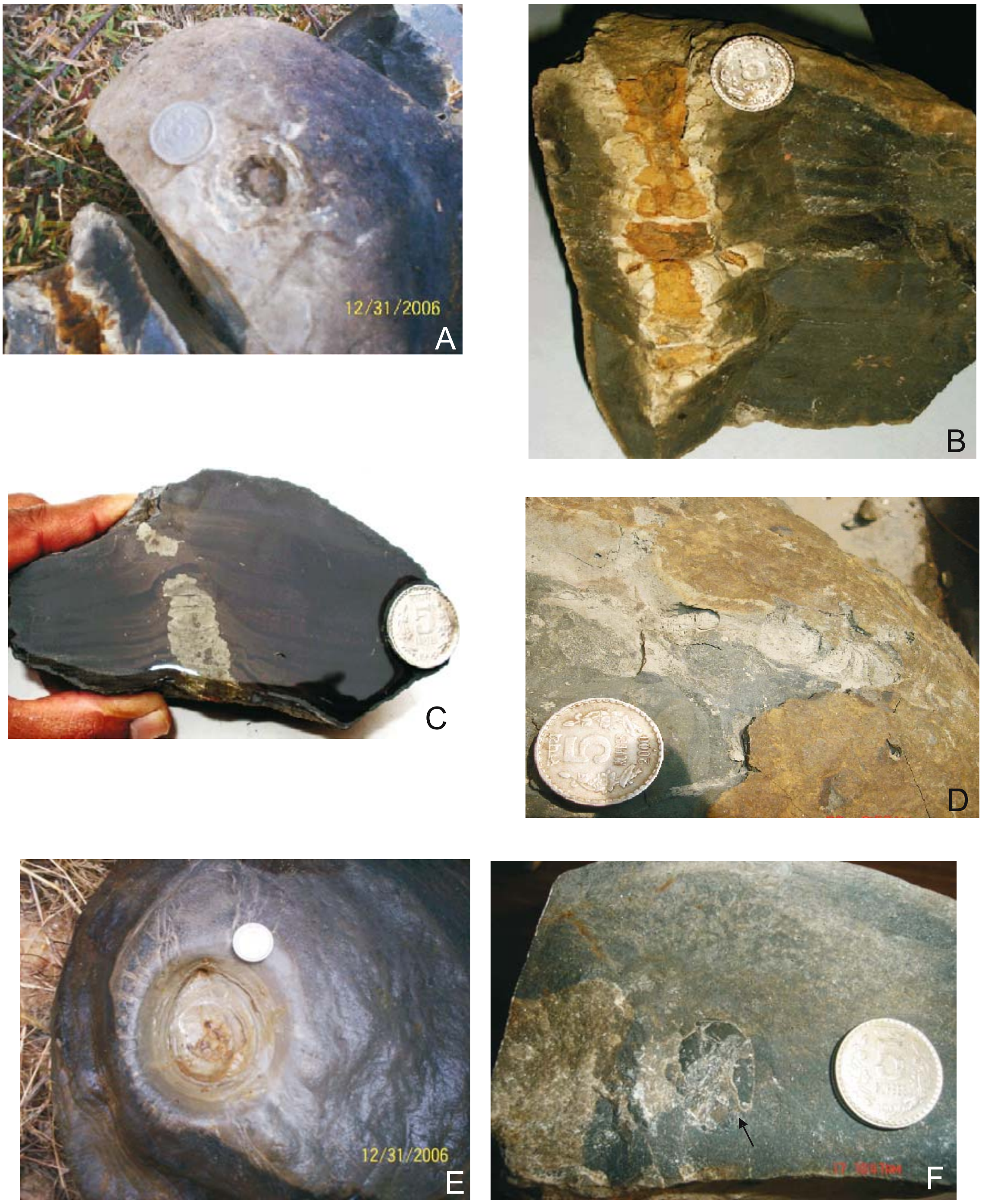
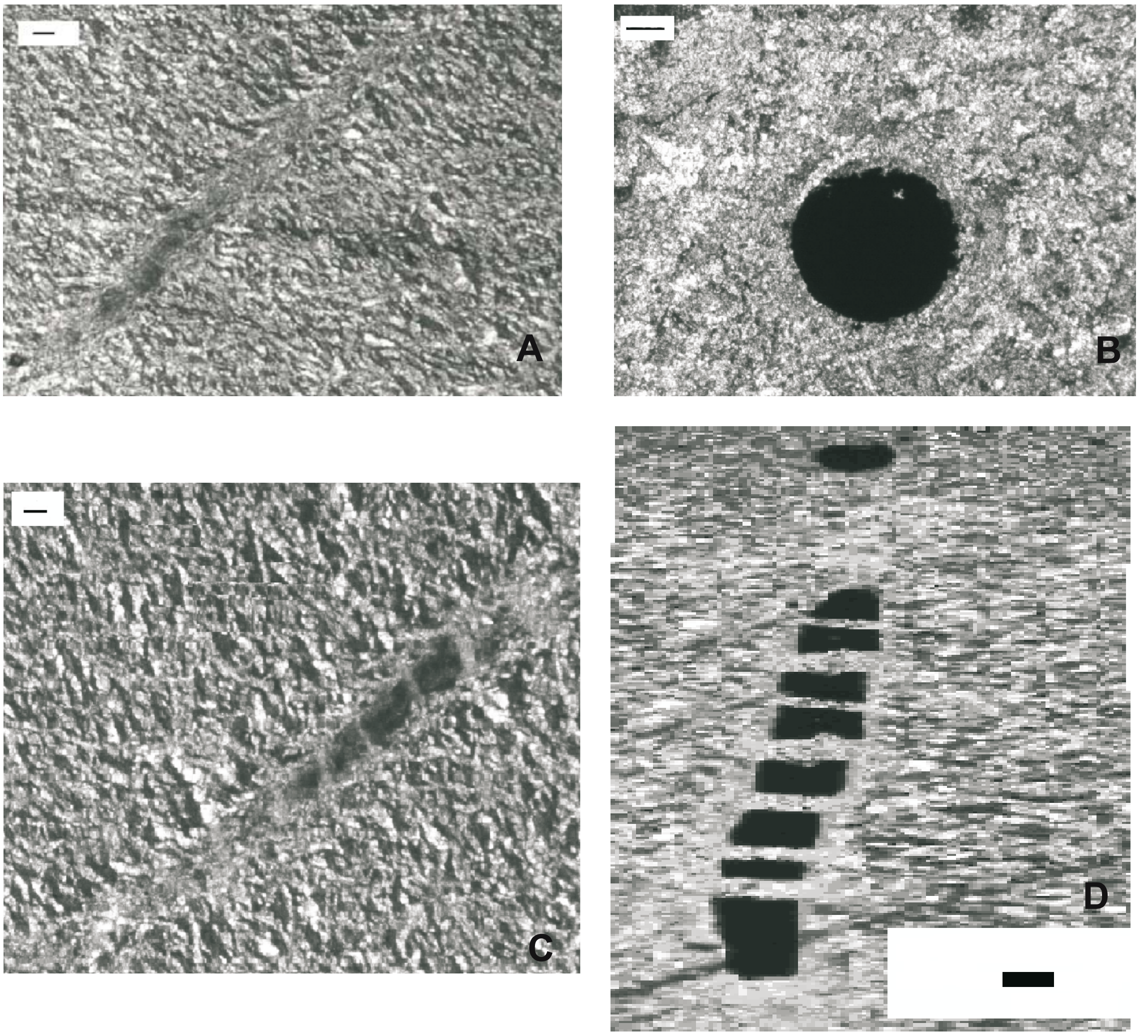


Plate 2. Megascopic trace fossils (coin is used as scale, diameter: 23 mm). **(A)** *Monocraterion* (plan view): an opening with concentric rims. The mouth of the hole is filled with pyrite. **(B)** and **(C)** The vertical section of the concretions showing trace fossil *Monocraterion* with two different types of spreites. The internal cavity is filled with pyrite/limonitic material. **(D)** *Rhizocorallium*: the U-shaped burrow with spreite (plan view). **(E)** The cast of an unknown bivalvia observed at the base of one of the concretions in the field. **(F)** The cast of an unknown soft bodied organism observed inside of a broken concretion (shown by an arrow).

The morphological behaviour of these micro-trace fossils are compared to the traces of larger known ichnogeneras because, there is very little information about the effects and implications of meiofaunal burrowing on the geological record (Meadows *et al* 1994; Pike *et al* 2001; and others), although origin and economic assessment of meiofauna is a well-developed subject (Boaden 1989; Platt 1989; Funch 2002). However, the meiofauna are by no means a homogeneous ecological group. There is a wide diversity of habitat in which meiofauna live. In general, sediment grain-size is a primary factor



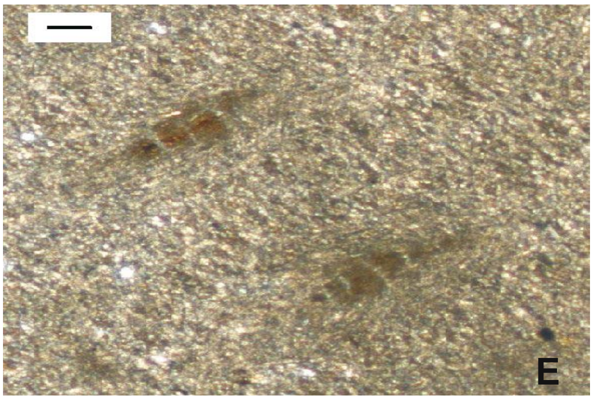
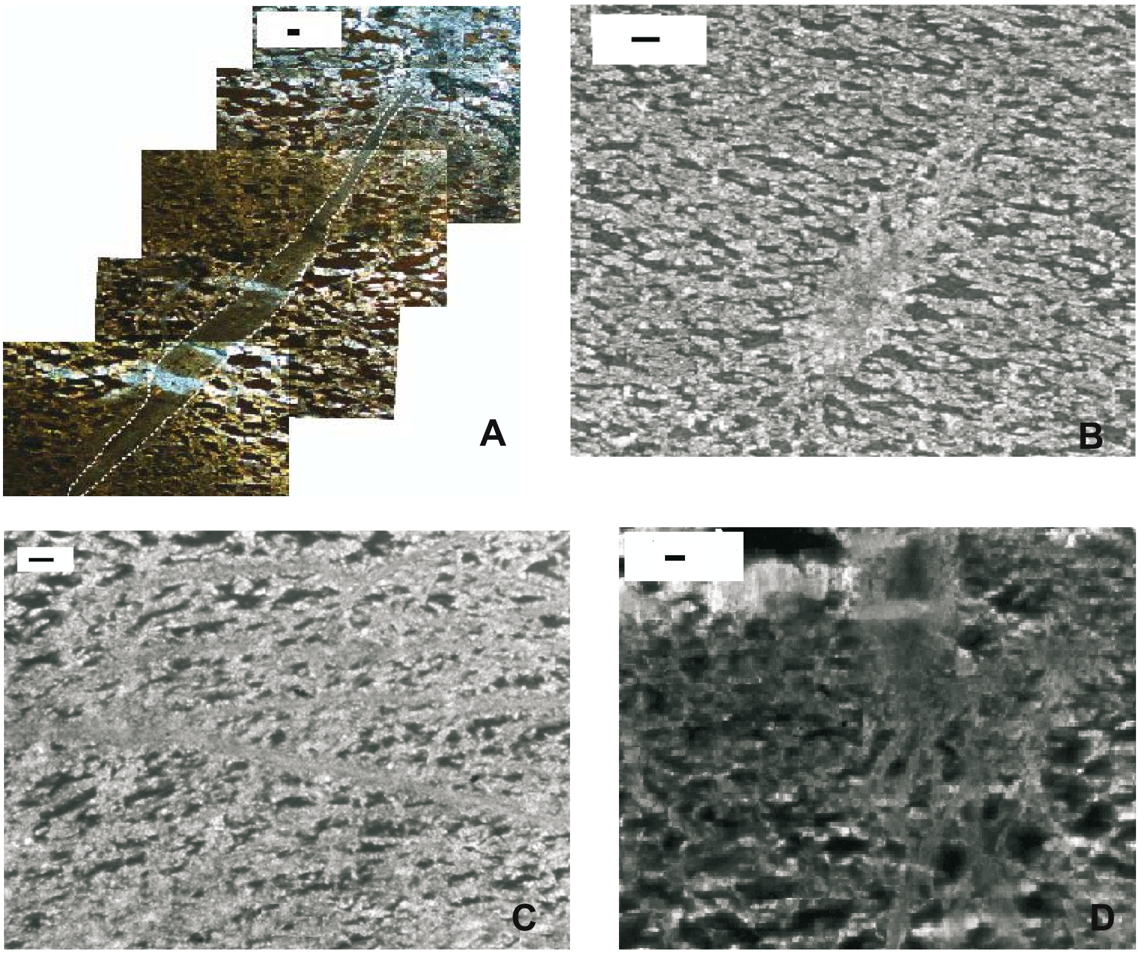


Plate 3. Thin section images of trace fossils. Uncrossed. Thin sections made perpendicular (**A**, **C**, **D**, and **E**), and parallel to the laminations **(B)**. (Scale bar = 100 μm.) **(A)** A vertical burrow, without internal laminae. The cavity is filled with lime mud. **(B)** An opening with concentric rims. The mouth is filled with pyrite. **(C)** and **(D)** are sectional views of this trace fossil. **(C)** and **(D)** Vertical to subvertical, discordant to the laminations, tubular micro-trace fossils with meniscus type spreite. Funnel top is visible in **(C)**. Cavities filled with alternately dark and light coloured lime mud/pyritic material. **(E)** Vertical to subvertical, discordant to the lamination, tubular structures with swollen central part. Tapered top and bottom. Meniscus filling type spreite; outer surface marked with numerous striae. Filled with alternately dark and light lime mud.

affecting the abundance and species composition of meiofaunal organisms. Nematodes (permanent meiofauna) regularly dominate the meiofauna in sediment. The length of marine nematodes is usually around 1–3 mm. The smallest nematodes are smaller than 0.2 mm. The dimensions of marine nematodes conform to the dimensions of the micro-trace fossils found here. The nematodes are usually bound to the substrate. They can live from dry dune sand, to beach sand, down to hadal zone (Riemann 1979). The above observations indicate that these micro-traces are possibly made by nematodes of marine origin. Further, if the observed variation in morphological structures is considered to be due to ichnodiversity, then the environment is likely to have had characteristic marine influence during sedimentation. The preservation of such microscopic traces in these concretions also



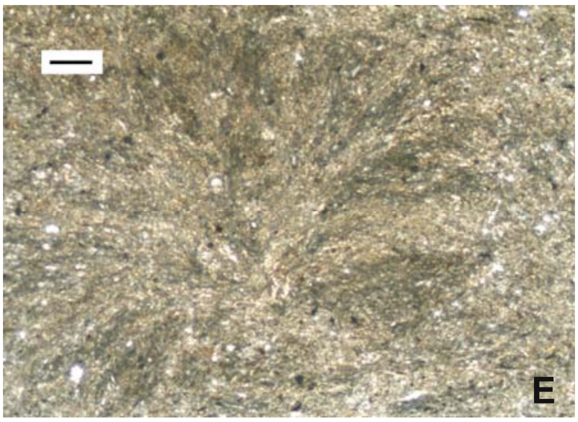
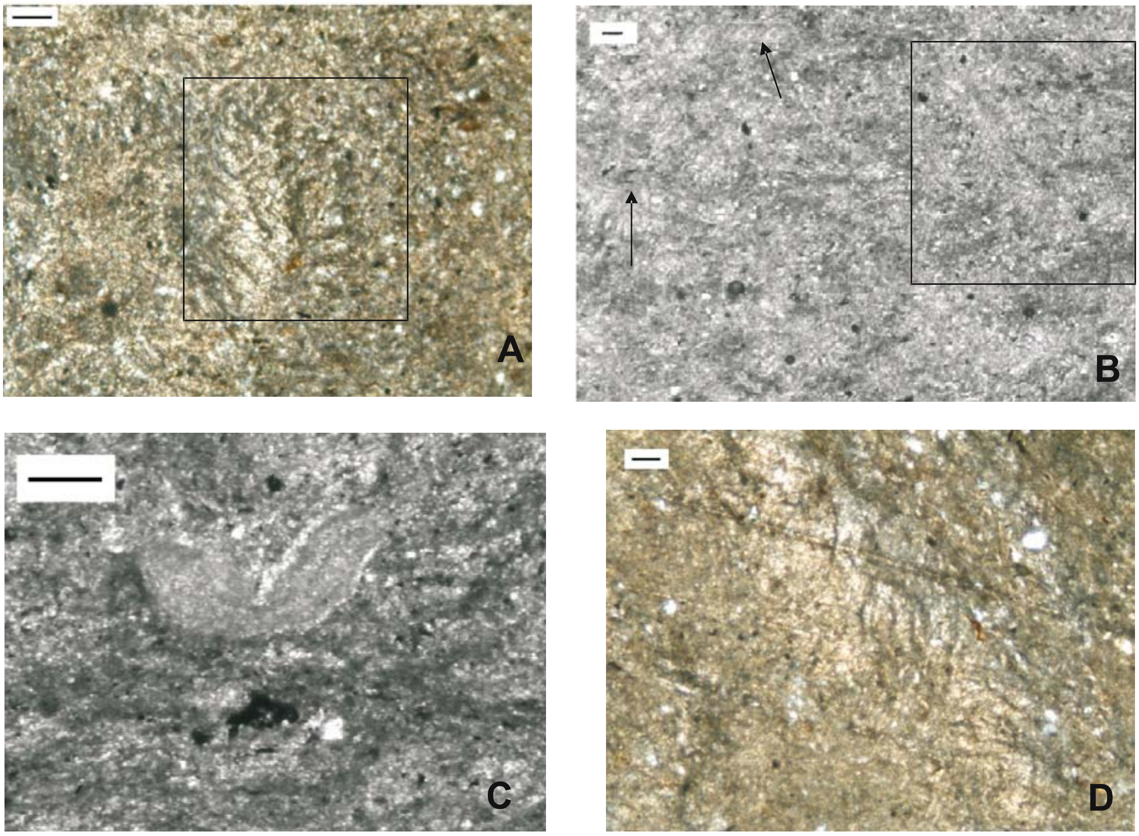


Plate 4. Thin section images of trace fossils. Uncrossed. Thin sections made perpendicular (**A**–**D**), and parallel to the laminations **(E)**. (Scale bar = 100 μm.) **(A)** and **(B)** Vertical to subvertical burrows; discordant to the laminations; laminae slightly bent into burrow chamber; cavity filled with either homogeneous lime mud or alternating lime mud and spar with few fragments of laminae. The trace fossils are of bivalve (?) boring. **(C)** The several long-branched tubular structures occurring oblique to the laminations. Tubes are made up of lime mud. **(D)** The small-branched, straight to slightly curved tubular structures. Tubes are filled with lighter coloured lime mud. **(E)** The microstructure consists of radiating traces of vaguely defined tubes from a central point. Almost circular in plan. It is filled with lime mud and silt-clay sized detrital particles.

indicate that they were formed immediately after the deposition of sediment. The pyritic burrow fillings probably occurred partly due to pyritization of organic matter derived from the burrowing organism and partly due to foreign material (Thomsen and Vorren 1984).

6. Conclusions

The carbonate concretions occurring at the bottom of Talchir fissile shale preserved signatures of various trace fossils along with cast of doubtful organisms and cyanobacterial mats. The host shale deposited under glacial melt water-fed lacustrine condition. The grey-black coloured calcareous concretions are of different morphology. They have formed in poorly oxygenated lacustrine conditions. The concretions are either of syndepositional origin and/or deposited a little below the sediment water interface and later exhumed to the depositional surface due to erosion of soft mud overlying them.



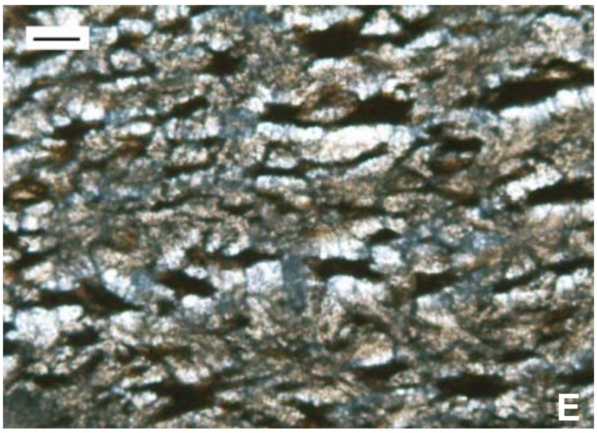


Plate 5. Thin section images of trace fossils. Uncrossed. Thin sections made parallel (**A**–**C**), and perpendicular (**D**–**E**) to the laminations. (Scale bar = 100 μm.) **(A)** and **(B)** The bi-lobed structures with a central ridge (in boxes). The lobes have fine ribs. Ribs are occurring at an angle to the central ridge. Lobes filled with lime mud and silt-clay sized detrital particles. (B) also shows few doubtful signatures of trace fossils (see arrow marks). **(C)** The horizontal, curved tubular structure. Wall partly lined with bright lime mud and detrital grains. Cavity filled with homogeneous lime mud. Pyrite patches present. **(D)** The wavy, bundle of thin discontinuous tubes occurring parallel to the laminations. Tubes made up of lime mud. Sheath bundle of *M. chthonoplastes.* **(E)** Dark crinkled, discontinuous thin layers (cyanobacterial mats) occurring parallel to the laminations. These are interlayered with lighter coloured lime mud. The discontinuous layers are often surrounded by spar.

The trace fossils are both megascopic and microscopic in nature. The megascopic trace fossils are identified on the basis of their morphology as *Monocraterion* and *Rhizocorallium.* The other two megascopic structures described remain problematic at present. The microscopic trace fossils are formed due to the activity of marine meiofauna (possibly by nematodes), which, although produced morphologically show similar traces of known larger ichnogeneras but much smaller than them. The megascopic trace fossils although indicating shallow marine environmental condition, do not conform to the environment of deposition of host shale and concretions. The discovery of these trace fossils apparently indicate influx of saline water into a lacustrine domain during the Talchir sedimentation at Giridih basin. Moreover, the presence of these trace fossils in the marine lacustrine carbonate concretions may lead researchers to consider their much wider environmental significance than hitherto believed.

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