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TRACE FOSSILS FROM OLIGOCENE BARAIL SEDIMENTS IN AND AROUND JOTSOMA, KOHIMA, NAGALAND: IMPLICATIONS FOR PALAEOENVIRONMENT

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ABSTRACT

Oligocene Barail sediments lying approximately 5 km towards the west of Kohima town are dominantly arenaceous in composition, and are represented by multi-story medium to coarse grained sandstones with minor intercalations of fine sand-silt-shale units. Sedimentary structures encountered in the study area include wave and interference ripples, plane/cross-laminations, channels of varied dimensions and parting lineation. However, presence of linguoid ripples within clean sands in conjugation with black shaleat upper stratigraphic levels makes the area very conspicuous. In Barail sediments trace fossils and leaf impressions arequite common though they are devoid of body fossils. Traces are relatively abundantand moderately diverse and belong to either *Skolithos* or *Cruziana* ichno facies. Atplaces, intensive bioturbation has imported a mottled character to these sediments. Among the trace fossils, *Skolithos* are quite common. Other trace fossils include *Ophiomorpha,Thalassinoides, Gyrochorte, Planolites,* and *Chondrites.* Analysis of trace fossil assemblage and sedimentary structures suggest a near shoreshallow-marine environmental set-up with fluctuating energy regime.

Key words: Oligocene, Barail sediments, trace fossils, palaeoenvironment, Nagaland.

INTRODUCTION

Trace fossils play a very important role in understanding palaecology and palaeoenvironment especially where body fossils are absent. In the recent years a large number of publications on the application of trace fossils in basin research signify their importance (Patel *et al.*, 2008; Singh *et al.*, 2008; Singh *et al.*, 2010; Tiwari *et al.*, 2011; Desai, 2016 and many more). However, in many cases, it has been underestimated. Trace fossils assemblage has been successfully used specially in shallow marine deposits (Pemberton *et al.*, 1982; Ekdale *et al.*, 1984; Bromley, 1996). It has also been utilized in Cambrian and Proterozoic-Phanerozoic stratigraphy (Sarkar *et al.*, 1996; Seilacher *et al.*, 1998; Tiwari and Parcha, 2006; Desai *et al.*, 2010 and Desai, 2016). Patel *et al.* (2008) and Patel and Desai (2009) have successfully used trace fossils for understanding the palaeoecology and palaeoenvironment in mainland Kachchh, Western India. Application of trace fossils in understanding the palaeoecology and palaeoenvironment of the Cenozoic sediments of North East India have been attempted by many workers in Manipur (Singh *et al.*, 2008 and Singh *et al.*, 2010) and Mizoram (Tiwari *et al.*, 2011). However, in Nagaland, not much published data on trace fossils are available.

Through the present work, an attempt, for the first time, has been made to use trace fossils for palaeoecology and palaeoenvironmental reconstruction.

Study Area

The study area lies approximately 5 km towards the west of Kohima town and is a part of the Inner Fold Belt; comprising of the Disang Group of argillaceous sediments, the Disang-Barail Transitional Sequence (DBTS) of mixed lithology (Srivastava *et al.*, 2004; Fig. 1) and arenaceous Barail sediments (Table-1). The Barail Group which conformably overlies the mixed lithology of Disang-Barail Transition, exhibits extensive development of Fine to medium grained multistoried thickly bedded sandstones and thinly bedded fine sandstone-silt/shale units.

Table 1. Lithostratigraphy of the study area

Sequence	Age	Lithology
Barail Group (Krishnan, 1982)	Oligocene	Sandstone with minor shales
Disang-Barail Transitional Sequence (Pandey and Srivastava, 1998)	Upper Eocene	Sand, silt and shale alternations
Disang Group (Krishnan, 1982)	Upper Cretaceous to Middle Eocene	Shale with minor sandstones

Sedimentary structures observed in thestudy area include interference ripples, plane laminations, cross-laminations and channels of varied dimensions and parting lineations (Fig. 2 a,b,c,d). At places, intensive bioturbation has imported a mottled character to these sediments. Srivastava and Pandey (2011) and Srivastava (2013), using petrography, heavy minerals and geochemistry, have attempted provenance interpretations for these sediments. No attempts have so far been made to use trace fossils for understanding palaeoenviroment and palaeoecology of these sediments.

Lithofacies

Altogether five major lithofacies, based on various parameters (Selley, 1976) have been identified (Miall, 1990), described and analyzed for environmental interpretations (Table 2).

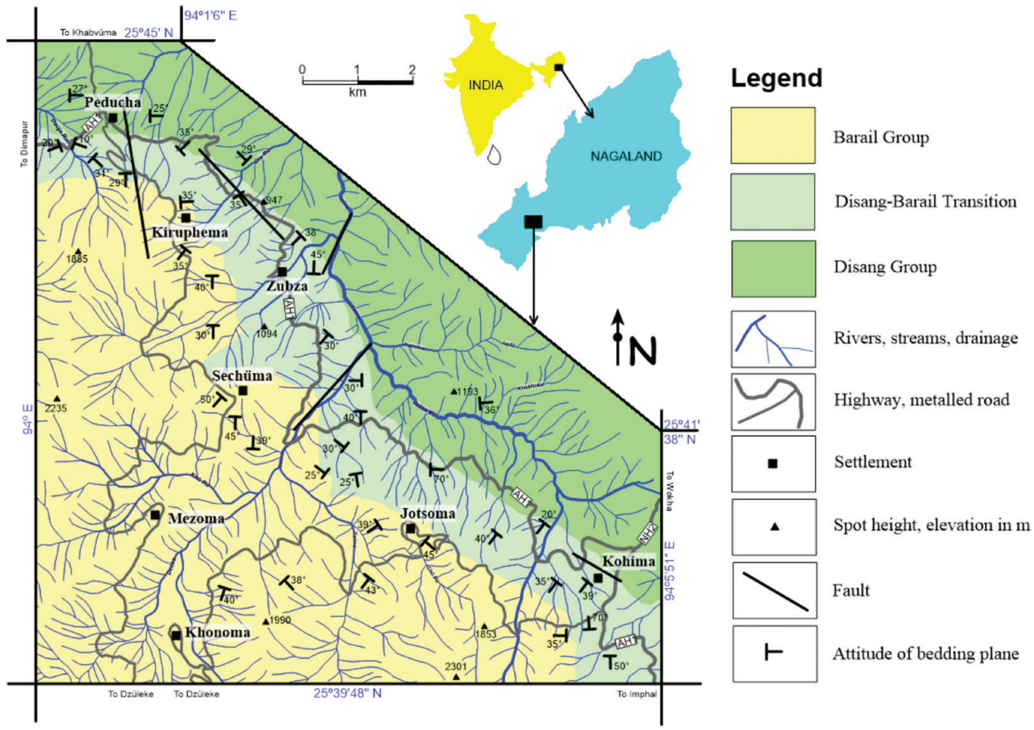

Fig. 1. Geological map of the study area (modified after Srivastava, 2004).

Table 2. Lithofacies scheme for Barail Sediments of the study area.

Facies code	Lithofacies	Sedimentary structures
Sm	Fine to medium sandsstones	Thickly bedded massive sandstones with burrow mark and channels
Sl	Very fine to medium sandstones	Plane laminations, interference ripples
Fx	Fine to medium sandstones	Fine cross laminations, small dimension channels
Fsm	Siltstones-Shale	Laminations,Bioturbation
Fl	Mudstone	Plane laminations,Bioturbation

1. ***Fine to medium sandstone facies* -** This facies is characterized by fine to medium grained sandstone. The thickness of sandstone beds varies between 1 to 4 metres. Vertical burrows are very common. Trace fossils recorded from this facies includes *Skolithos* and *Planolites* isp and *Ophiomorpha nodosa.*
2. ***Plane laminated fine to very fine sandstone facies* -** This facies is characterized by very fine to fine grained sandstones. Interference ripples, plane laminations and moderate bioturbation are common. Its thickness ranges between a few centimetres to a meter. This facies is represented by *Gyrochorte comosa* and *Ophiomorpha* isp.
3. ***Fine cross laminated sandstone facies* -** Fine to medium sandstones possessing fine cross lamination with occasional small scale channels are the main characteristics of this facies. Its thickness ranges between 5 cm to 40 cm. *Gyrochorte comosa* and *Thalassinoides horizontalitis* have been recorded from this lithofacies.
4. ***Shale-silt facies* -** Strong bioturbation with burrows marks are prominent features of this facies. Thickness varies from 2.5 to 20 cm. This facies is represented by *Chondrites*, and *Gyrochorte comosa* isp.

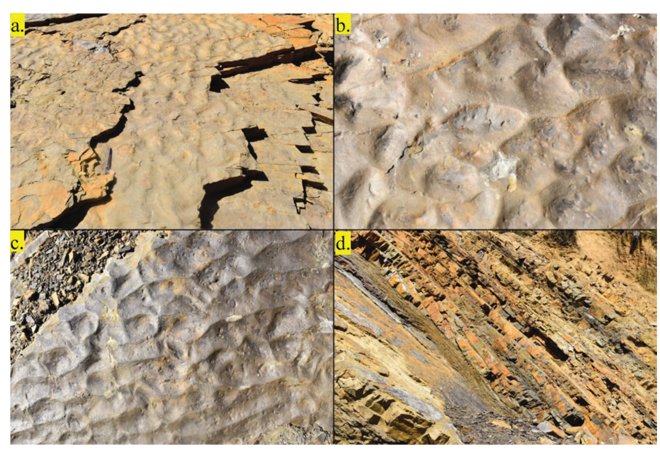

Fig. 2: a. linguoid ripples b. bifurcating ripples c. interference ripples d. channels.

5. ***Mudstone facies* -** This facies is represented by mud lithology showing plane laminationsand ripple marks, at places strongly bioturbated. Thickness of beds ranges from few cm to a meter. *Thalassinoides* and *Chondrites* isp are the traces recorded within this facies.

Description of Trace fossils

Chondrites isp (Fig. 3a) is a three dimensional systems of branching cylindrical tunnels where individual tunnel segments are generally straight and tunnel diameter is varying between 0.5 and 5 mm. Branches do not intersect each other. These are found to be associated with dominantly mud lithology showing full relief. *Chondrites* traces are reported from littoral environment

Fig. 3. a. *Chondrites* b. and c. *Gyrochorte comosa* d. and e. *Ophiomorpha nodosa* f. *Skolithos linearis* g. *Skolithos linearis* h. and i. *Planolites* j. *Thalassinoides horizontilites* k. and l. *Skolithos linearis*.

(Patel and Desai, 2009) and are the traces produced by feeding burrows of sediments-eating worm or Polychaetes.

***Gyrochortecomosa* Heer, 1865** (Fig. 3b, 3c): These are unbranched, winding, plaited, bilobed trails separated by a median furrow with obliquely aligned sediments, preserved as ridges in positive epirelief. This is in agreement with generic characters of *Gyrochorte comosa* Heer (Haentzschel, 1975). Patel *et al.* (2008) and Singh *et al.* (2010) have reported this ichnospecies from Kachchh, Gujarat and Manipur respectively. This ichnospecies is very common in fine grained sandstone facies.

***Ophiomorpha nodosa* Lundgren 1891** (Fig. 3d, 3e): Burrow walls are consisting predominantly of dense pelletal horizontal burrows. Burrow material is different than the sediments it is found associated with. Exterior surface lined with ridges covering the tube. One side of the tube is slightly acute whereas other end is rounded in shape showing full relief. This ichnospecies is very common in fine to medium grained sandstone facies. Singh *et al.* (2008) have reported this ichnospecies from Upper Eocene-Lower Oligocene transition of Manipur.

***Skolithos linearis* Haldeman, 1840** (Fig. 3f, 3g, 3k, 3i): *Skolithos linearis* is one of the most common trace fossil reported from the massive sandstone facies of the study area. These are straight, unbranched structures showing full relief. Straightand unbranched trace fossils have a diameter between 1-15 mm. Such trace fossils have been reported from sandy litoral environment (Selley, 2000) and supposed to be produced by gregarious suspension-feeding organism (Patel and Desai, 2009).

Planolites isp (Fig. 3h, 3i) are unbranched cylindrical or sub-cylindrical in filled burrows, which are generally horizontal; and are straight to gently curved and commonly overlap one another. They show a circular or elliptical shape in cross section is straight or curved with smooth walls and showingfull relief or positive hypo-relief. Burrow fills are generally structureless. In the present study area, they have been reported from both fine grained sand-mud lithologies. *Planolites* is interpreted as feeding traces produced by deposit feederssuch as worms from Littoral environment (Pemberton and Frey, 1982).

***Thalassinoides horizontalites* Woodward, 1830** (Fig.3j): This is recorded from a quarry section on Jotsoma-Agri road. *Thalassinoides horizontilites* consists of three dimensional structures with horizontal network, generally swollen at Y-shaped junction. *Thalassinoides,* though most characteristic of shallow marine environment, is considered as a facies crossing form (Uchman, 2011). *Thalassinoides* is also reported from deep marine environment (Srivastava *et al.*, 2017). This type of traces can be produced mainly by crustaceans or other type of arthropods (Frey *et al.*, 1984; Bromley, 1996; Ekdale, 1992). These traces are generally related to oxygenated situations and soft but cohesive sediments (Ekdale *et al.*, 1984; Bromley, 1990). Such traces are believed to be feeding and dwelling burrows of crustaceans.

DISCUSSION

Trace fossils have an edge over body fossils, as they are always formed in situ and cannot be reworked. Environmental parameters such as energy and oxygen levels, salinity and substrate control the occurrence and distribution of trace fossils. According to Seilacher (1967), there is a clear relationship between distribution pattern, bathymetry and hydrodynamic condition. In the present study area a number of trace fossils have been recorded along with some leaf impression. Traces are relatively abundant and moderately diverse and they belong to either *Skolithos* or *Cruziana* ichno facies.

The *Skolithos* ichno facies is related to relatively high level of wave or current energy and typically develop in clean, well sorted, loses or shifting particulate substrates. Such conditions commonly occur on the shoreface and sheltered foreshore, but similar conditions also occur in wide range of high energy shallow water environment (MacEachern *et al.*, 2007). According to Schlirf and Uchman (2005), *Skolithos* is domichnion structure produced by phoroids or annelids. Idealized shoreface models for trace fossils suggested by Frey *et al.* (1990) and MacEachern (1995) suggest that *Skolithos* ichnofacies generally grades seaward into *Cruziana* ichnofacies. Both *Ophiomorpha* and *Skolithos* are reported from the environment characterized by frequent high energy events and changes in sedimentation rate (Walker and James, 1992; Singh *et al.*, 2008). *Planolites* occur few centimetres below the sediment-water interface and indicates unconsolidated substrate with relatively moderate to low energy shoreface/offshore conditions (Tiwari *et al.*, 2011).

Cruziana ichnofacies occurs where current action is less intense and food settles at the bottom. Such conditions are generally met at comparatively deeper water such as shelf areas. Tracks, trails as well as tunnels dominate in such zones. Deposit feeders dominate in this zone. *Cruziana* ichnofacies in the study area is represented by *Gyrochorte comosa, Thalassinoides horizontilites,Ophiomorpha nodosa* and *Chondrites* isp. This assemblage is characteristic of poorly sorted and unconsolidated muddy substrate in shallow marine settings having uniform salinity under moderate energy conditions below fair weather wave base but above storm wave base. Presence of *Gyrochorte comosa* also suggested well oxygenated, low rate of sedimentation, fluctuating energy condition and shallow marine environment with abundant surface food sources (Gilbert and Benner, 2002). Conditions typically range from moderate energy level line below fair weather (min.) wave base but above storm wave base, to lower energy level in deeper quieter waters. The most common settings correspond to the offshore extending to the very distal fringe of the lower shore face (MacEachern *et al.*, 2007).

The *Skolithos* ichnofacies generally grades seaward into *Cruziana* ichnofacies, as was presented in some idealized shore face models for ichnofacies (Frey *et al.,* 1990; Pemberton and MacEachern,1995). Presence of *Planolites, Ophiomorpha, Thalassinoides, Gyrochorte* and *Chondrites* in these sediments indicates a shallow marine environment with occasional deep water conditions within shoreface setup. Intense bioturbation and rich trace fossil assemblage indicate good oxygenation and food availability. Dominance of *Skolithos* ichnofacies at higher stratigraphic level suggests nearness to the palaeoshore line. Analysis of lithofacies identified in the study area also suggests that these sediments were deposited in a shallow marine environment with fluctuating sea levels and energy within tectonically unstable conditions. This is in conformity with the inferences drawn from trace fossil analysis.

CONCLUSION

Distribution pattern of the ichnofacies suggests that the sediments of the study area were deposited under frequently fluctuating sea, having moderate to strong energy levels, within shoreface environment rich in nutrients. It also indicates a tectonically controlled fluctuating environmental regime under dominantly regressive phase with occasional transgression. There was a progressive decrease in energy across the shelf resulting in development of Cruziana type settings.

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