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Ichnology of a Late Palaeozoic ice-marginal shallow marine succession: Talchir Formation, Satpura Gondwana basin, central India

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ABSTRACT

The Late Palaeozoic, glaciomarine Talchir Formation in the Satpura Gondwana basin, central India hosts sparse to profuse trace fossils of various kinds, although sporadically. Among the three principal depositional systems that gave rise to the Talchir succession, deposits of the ice-contact fan delta system and the glacial outwash braidplain delta system lack trace fossils of any kind. On the other hand, within the deposits of the storm wave-dominated, shoreface–shelf system a variety of animal traces is present including simple locomotion traces and non-descript bioturbation. Three trace fossil assemblages could be recognized within these deposits. Assemblage-I is dominated by *Cylindrichnus* of the *Skolithos* ichnofacies that occurs in storm laid, medium to fine sandstones deposited in shoreface and transitional shoreface–inner shelf environments. In contrast, assemblage-II comprising dominantly horizontal, grazing-cum-deposit-feeding traces *Cochlichnus*, *Helminthopsis*, *Phycosiphon*, *Planolites*, *Archaeonassa* and *Psammichnites* occurs on decimeter-thick sandstone beds interlayered with mudstones deposited in lower shoreface to inner shelf environments. Trace fossil assemblage-III is known from a 6.9 m thick, outer shelf to lower shoreface, progradational succession showing a vertical transition from dark gray mudstone to fine sandstone. The middle part of this particular section shows *Rhizocorallium* and flat-type *Zoophycos*, whereas the upper part hosts profuse *Cylindrichnus* along with *Rosselia* and *Teichichnus* in lesser proportions. This assemblage is comparable to the marine ichnofacies succession combining elements of both *Skolithos* and *Cruziana* ichnofacies.

The characteristic features of the Talchir trace fossil assemblages are: (i) low ichnodiversity, (ii) presence of forms typically found the in marine environment, (iii) co-occurrences of vertical and horizontal traces of *Skolithos* and *Cruziana* ichnofacies, (iv) presence of simple structures formed by trophic generalists, (v) abundance of certain forms, and (vi) presence of monospecific suites. These characters are akin to those of brackish water ichnofaunas. In the Talchir succession, the transition from an ice-contact fan delta system to a relatively ice-free open marine system indicates an enormous flux of fresh water into the sea reducing its overall salinity. Predominance of annelid and worm traces and the rarity of crustacean burrows in the Talchir strata also suggest a stressful environment due to the prevailing cold climate and a lower than normal marine salinity. It thus appears that mixing of fresh water during deglaciation might be a key controlling factor in shaping the characters of ichnofaunas in glacially influenced shallow marine environments.

1. Introduction

The Gondwana Ice Age extended over a period of at least 90 my and marks the longest glacial event of the Phanerozoic (Buatois et al., 2006). The direct impact of glaciation and deglaciation episodes on biotic communities still remains to be fully explored. In part, the lack of studies is due to the low preservation potential of shelly faunas in marine environments adjacent to glaciated margins. In successions lacking body fossils ichnologic evidence provides a proxy to reconstruct palaeoecosystems. Late Palaeozoic rocks in different Gondwana basins comprise glacial diamictites and post-glacial siltstones and shales that contain distinctive ichnofaunas. The post-glacial strata were deposited during events of extreme fresh water release into coastal areas in consequence to melting of the Gondwana ice masses. The depositional environment of transgressive and early highstand post-glacial, fine-grained deposits that host varieties of trace fossils, has been controversial with interpretations ranging from freshwater lacustrine systems to brackish water estuarine and even fully marine shelf (Pazos, 2002; Buatois et al., 2006).

The study of trace fossils preserved in post-glacial, fine-grained strata that lack body fossils, is important because it may provide evidence for reconstructing the effects of glacial and deglacial events, and also of climatic amelioration related with ultimate deglaciation on biotic communities. Despite this importance, published literature on ichnology of Late Palaeozoic glaciomarine strata is too sparse to allow

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comprehensive generalization of ichnofossil variations in ice-marginal marine environments.

In peninsular India, Late Paleozoic Gondwana strata are preserved in a number of disparate basins (Fig. 1), and in all of them the successions begin with glaciogenic deposits assigned as the Talchir Formation that everywhere unconformably overlies the Precambrian basement. There are only a few studies on the trace fossils of the Talchir Formation. Guha et al. (1994) reported trace fossils from the Talchir strata in the Raniganj basin and Deogarh group of basins (Fig. 1; Jainti, Saharjuri and Kundit Kuraiah basins) though detailed descriptions of individual trace fossils and their interpretations are lacking. Only recently Chakraborty and Bhattacharya (2005) and Bhattacharya and Bhattacharya (2007) have described different ichnofacies in the context of palaeoecological controls and environment of deposition in an ice-marginal shallow marine succession of the Talchir Formation in the Saharjuri and Raniganj basins respectively.

Recently conducted systematic analyses of the sedimentological features of the Talchir Formation in the Satpura basin (Ghosh, 2003, 2006; Chakraborty and Ghosh, 2008) have led to the identification of different storm-wave-affected glaciomarine facies as well as Permian fossils of marine bivalves and abundant trace fossils in the said succession. In view of the new findings of marine fossils and refined sedimentological interpretation, the present study was undertaken to examine the diversity and abundance of trace fossils, to record new forms, if any, and track the sedimentologic and stratigraphic distribution of trace fossils in order to relate them to allied environmental gradients. The impact of glaciation and deglaciation episodes on biotic communities as reflected by the trace fossil assemblages in a glaciomarine environment in contrast to that of a marginal marine environment without any glacial influence is worth analyzing.

2. Depositional setting

The Satpura Gondwana basin is intracratonic in nature, and is considered to be of pull-apart origin (Chakraborty and Ghosh, 2005; Fig. 1). The basin is filled with a siliciclastic succession (c. 5-km thick) spanning between Permian and Cretaceous. The present study deals with the lowermost unit of the Gondwana succession i.e. the Talchir Formation (200–400 m thick), which nonconformably overlies the Precambrian basement, and is gradationally overlain by the coal-bearing Barakar Formation (Fig. 2). The Talchir Formation (Permian) developed under a glacial regime (Chakraborty and Ghosh, 2008), and the presence of marine bivalves, and palynomorphs (Ghosh, 2003, 2006) indicates sedimentation in a proglacial marine environment (cf. Casshyap and Qidwai, 1974; Ghosh, 2006; Chakraborty and Ghosh, 2008).

The dominant lithologies of the Talchir Formation in the Satpura basin include conglomerate, pebbly sandstone, sandstone and mudstone with minor limestone. Altogether, three facies associations have been recognized in the Talchir Formation (Table 1). Whereas facies association-1 (FA-1) is the product of ice-contact fan delta dominated by sediment gravity flows, facies association-2 (FA-2) represents braidplain delta fed by glacial outwash. On the other hand, facies association-3 (FA-3) reflects an open-marine, tide/wave-affected shoreface to shelf environment (Fig. 3). The passage from ice-contact fan delta to wave/tide affected shoreface–shelf through braidplain delta is probably a consequence of progressive melting and retreat of glaciers. The Talchir succession reveals an overall fining and deepening upwards trend, and in many places is topped by thick shelfal mudstones. It gradually gives way to the shallowing upwards, progradational deltaic succession of the coal-bearing Barakar Formation representing a transition from a cold to warm/humid climatic condition (Ghosh et al., 2004) as also observed in other Gondwana basins of the world (cf. Eyles et al., 2003).

The trace fossils encountered in the Talchir formation are mostly confined to the storm wave-influenced shoreface–shelf deposits i.e. FA-3 (Figs. 3, 4) corresponding to maximum glacial melting.

3. Description of the trace fossils

Ichnotaxa are listed alphabetically. Most of the specimens described are housed at the collections of the Geological Studies Unit, Indian Statistical Institute, Kolkata. Specimens, which were difficult to collect without damage, were studied directly in the field.

3.1. Ichnogenus *Archaeonassa*

Fig. 5a

Description: These are straight to slightly sinuous, epichnial grooves preserved as negative epirelief on top of fine sandstone beds, at places rippled. At places two individuals cross cut each other. In the cross-sectional view the grooves commonly display a v-shaped morphology tapering downwards (Fig. 5a). In many specimens, ridges flanking the grooves are poorly developed. Trace width varies from 3 mm to 21 mm. Maximum length observed is 17 cm. Besides the linear traces there are many semi-circular to tear shaped small pits on bedding surfaces. Many linear traces appear to terminate at the shallow pits. This ichnotaxon occurs as monospecific assemblage in facies 3-B of an inner shelf to outer shelf transition environment (Fig. 4a).

Remarks: The ichnotaxonomic status of *Archaeonassa* is still uncertain (Buckman, 1994; Yochelson and Fedonkin, 1997). A single ichnospecies *Archaeonassa fossulata* is known from upper offshore facies in lower Palaeozoic strata of Argentina (Mangano et al., 2005). It is interpreted as grazing trace produced by a wide variety of invertebrates, including arthropods and molluscs (cf. Buckman, 1994; Yochelson and Fedonkin, 1997).

3.2. Ichnogenus (?) *Asterosoma*

Fig. 5b

Description: These are very uncommon and occur as almost full relief endichnial structures in hummocky cross-stratified, shoreface sandstone (facies 3-A, Fig. 4c) (Fig. 4b). In bedding plane perpendicular section these comprise a few cylindrical to bulbuous tubes radiating outward and upward from a common point at the base. Individual tube ranges from 7 to 11 mm in diameter and from 1.5 to 5 cm in length, and most are inclined to the bedding at high angles. The burrows taper towards the bottom (Fig. 5b). Unlike those reported by others, the structures under the present study lack longitudinal striations.

Remarks: *Asterosoma* possibly represent deposit-feeding activity of worms/annelids (cf. Chamberlain, 1971; Vossler and Pemberton, 1989). Mesozoic forms have been interpreted as produced by decapod crustaceans (Hantzschel, 1975). Miller and Knox (1985) reported *Asterosoma* from Pennsylvanian lower tidal flat/tidal delta deposits. Elsewhere, *Asterosoma* have been reported from shoreface to offshore deposits (Farrow, 1966; Frey and Howard, 1970; Vossler and Pemberton, 1989).

3.3. Ichnogenus *Cochlichnus*

Fig. 5c

Description: The burrows occur as epichnial ridges along the interface of sandstone and black shale (facies 3-B) of the inner shelf to outer shelf transition setting (Fig. 4a). These are winding to sinuous traces, often in sine curve form, showing regularity. Individuals are 1.5–2 mm wide, with an average wavelength of about 1 cm (Fig. 5c). Maximum length noted for an individual is about 10 cm. Crossover is absent but in many cases branching is noted.