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ORIGINAL PAPER

Trace fossils and their palaeoenvironmental significance in the Lameta Formation of Salbardi and Belkher area, district Amravati, Maharashtra, India

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Abstract Trace fossils namely, *Planolites*, *Planolites montanus*, *Thalassinoides* and stuff burrows belonging to the Lameta Formation of Central India are reported for the first time from two new localities, i.e., Salbardi and Belkher area. Both the exposures are well represented by the typical marker lithounits as of Jabalpur, Nand-Dongargaon area of central India, i.e., greenish yellow sandstone, clays of various shades, chertified and brecciated limestones, etc. These successions are devoid of megaforal remains, therefore, these biogenic structures play a significant role in the interpretation of palaeoenvironment and palaeoecology during the deposition of the Lameta sediments. The trace fossils assemblage shows that the benthonic community was mainly polychaetes and crustaceans.

Keywords Trace fossils · Lameta · Palaeoecology · Palaeoenvironment · Maharashtra

Introduction

Trace fossils from the Lameta Formation and co-eval deposits are well reported from various parts of central India viz., Jabalpur area (Kumar and Tandon 1977, 1978, 1979; Singh 1981; Saha et al. 2010); Nand-Dongargon basin of Nagpur and Chhindwada districts, Maharashtra (Mohabey et al. 1993; Mohabey 1996a; Mohabey and Udoji 1996); Nimar Sandstone, Bagh Beds of Madhya Pradesh (Singh and Dayal 1979; Sanganwar and Kundal 1997; Kundal and Sanganwar 1998, 2000); Bagh Beds, Amba Dongar area, (Verma 1971) and Kheda district, Gujarat (Mohabey 1996b); Bagh Bed of Narmada valley (Chiplonkar and Badve 1969; Chiplonkar and Ghare 1975) etc. These trace fossils proved to be an important tool as they have been widely used to reconstruct the depositional environment which is still a matter of debate, i.e., fluvial or shallow marine.

The present report of trace fossils is from two new localities viz., Salbardi (lat. 21⁰25′15″ N: long.78⁰00′00″E) and Belkher area (lat. 21⁰21′48″ N: long.77⁰31′23″E), falling at the boundary of districts Amravati, Maharashtra and Betul, Madhya Pradesh. The biogenic structures, though less, but significant because both the successions are devoid of megafaunal remains. The study includes taxonomy and systematic description of the trace fossils and their significance in palaeoecological and palaeoenvironmental reconstructions.

Geology and stratigraphy

The localized outcrops of the Lameta sediments, along with the upper most Gondwanas are exposed as tectonic inliers in the widespread Deccan Trap country due to the E–W trending Satpura Fault (Fig. 1). Two such inliers are located at Salbardi and Belkher area, of which, the previous lies at about 60 km east of later. Quartz-feldsphathic gneiss of Archaean age forms the basement and is well exposed at Salbardi area. The Gondwana succession represented by arenaceous to argillaceous sediments rests unconformably on Achaean rocks. It is disconformably overlain by the calc-marl-arenaceous sediments of the Lameta Formation. Deccan Traps, represented by nonporphyritic to porphyritic basalts, overlie this sedimentary succession and make a regional exposure (Table 1). On the basis of rich and

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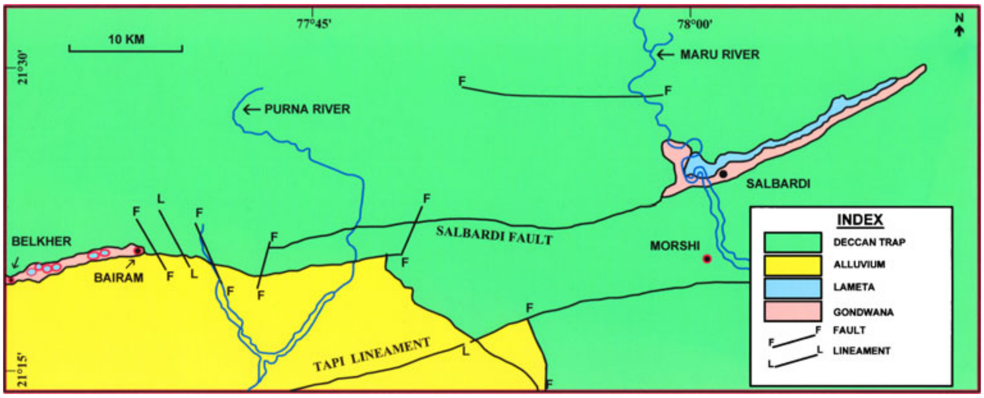

Fig. 1 Generalized geological map of Belkher and Salbardi area (GSI 2001, 2002)

diversified assemblage of pteridophytic and gymnospermous leaves of the Gondwana succession of Belkher area is assigned an Early Cretaceous age (Srivastava et al. 2001, 2003). The same age has also been assigned to coeval Gondwana exposure of Salbardi area, which is based on its lithological correlatebility and similarity of lithofacies architecture with those of Belkher area (Srivastava and Mankar 2008).

Field observations

Lithosections of the Lameta succession, exposed at Salbardi (34 m) and Belkher (47 m) area are more or less similar. The contact of the Gondwana and the Lameta rocks is sharp and well exposed in Salbardi area, represented by coarse grained, pebbly sandstones of Gondwana, underlying the reddish brown, medium grained, poorly cemented sandstones of the Lameta Formation. The lithocolumns of Lameta in both the localities are represented by medium- to coarse-grained sandstones, greenish gray and dark reddish brown clays, and nodular, certified, brecciated limestone apart from calcrete horizons at Salbardi area (Figs. 2a,b).

The litholog is occupied by 1–5 m of moderately reddish brown, grayish green, grayish orange to brownish black, medium to coarse grained, dominantly thinly bedded sandstone units at the base. These are poorly cemented and friable units. Sedimentary structures are represented by poorly preserved plane beddings and small scale cross-beddings (Fig. 3a). A 2-m thick brownish black, medium-grained sandstone unit is recorded in Belkher area showing high bioturbation. Local preservation of burrows is noticeable in arenaceous units of both the sections.

The clay rich units of both the successions are grayish green, reddish brown, and yellowish orange in colors (Fig. 3b). With increasing quantity of siliceous and calcareous contents, it grades to siltstone and marl. Sedimentary structures are faint horizontal laminations. At a few places, the clay is mixed with whitish thin film of gypsum. Locally, the yellowish clay shows sub spherical nodules of 10–15 cm diameter.

The upper part of both the lithosections are almost similar, represented by nodular, chertified, and brecciated limestone. The nodular limestone is bluish gray, micritic with varying proportions of chert clasts. Ferruginous concretions are common. Bedding structures are indistinct except rare presence of faint laminations. The overlying unit is highly chertified showing alternations of silicified and nodular micritic horizons (Fig. 3c). The brecciated limestone is well developed at Salbardi area in which angular fragments of nodular limestones, cherts, basalts, etc. are embedded in fine-grained micritic carbonate.

Table 1 Generalized stratigraphic succession of the area

Age	Lithounits	Rock types
Quaternary		Soil and alluvium
Unconformity		
L. Cretaceous to Eocene	Deccan Trap	Non-porphyritic and porphyritic basalts
Unconformity		
L. Cretaceous	Lameta	Sandstone, mudstone and limestone
Disconformity		
E. Cretaceous	Upper Gondwana	Sandstone, siltstone, conglomerate, clay and mudstone
Unconformity		
Archaean		Quartzo-feldspathic gneiss with dolerite intrusions

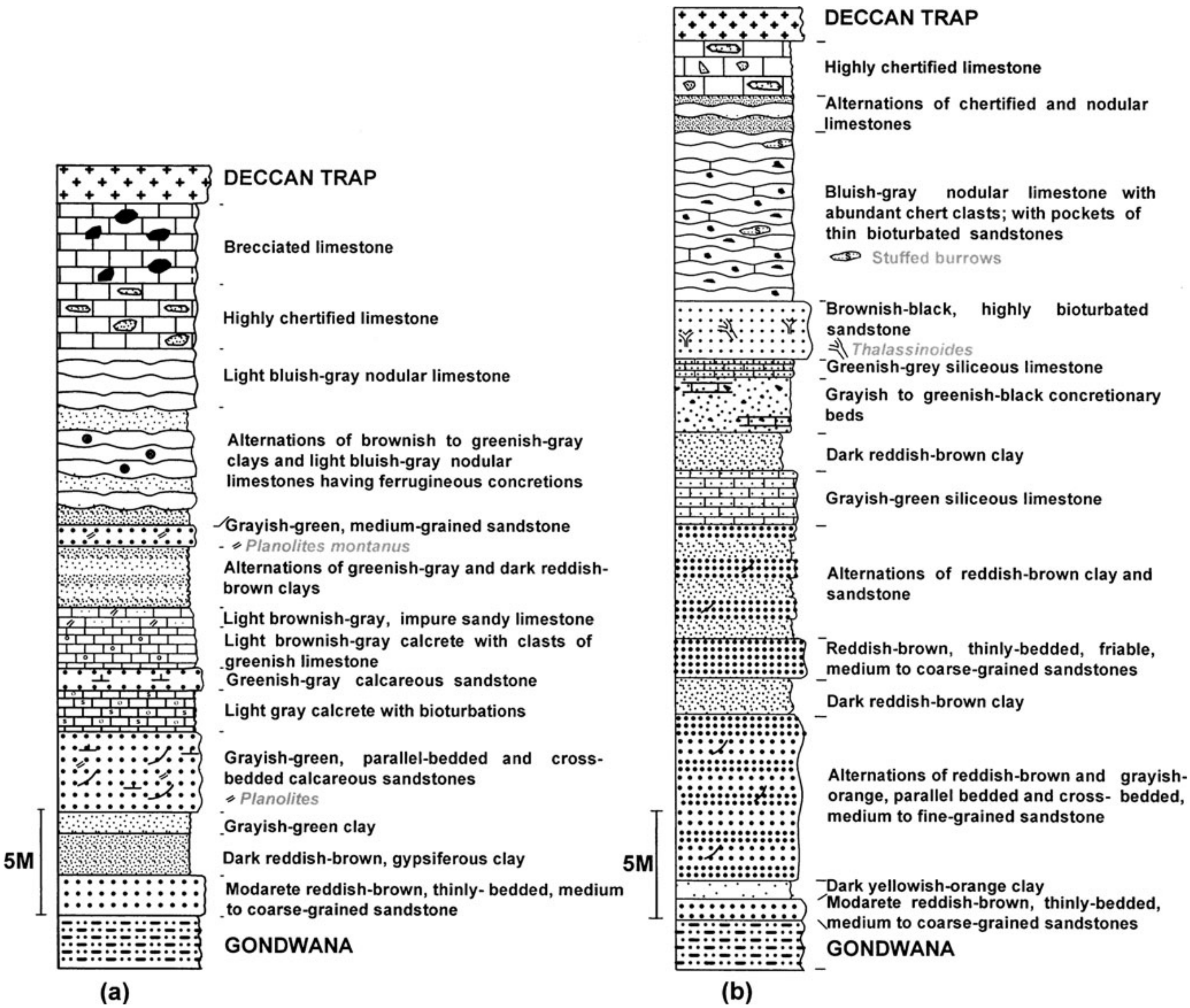

Fig. 2 Detailed sedimentological logs of Lameta successions exposed at Salbardi area (**a**) and Belkher area (**b**)

Two calcrete horizons are recorded in Salbardi area. The lower is about 2-m thick, compact, brecciated, and micritic in nature (Fig. 3d). The upper is 3-m thick, light brownish gray unit that contains comparatively more argillaceous and arenaceous materials. Abundant clasts of chert, green grayish, and reddish brown sandstones are frequently noticed. Sand pockets and thin horizons of calcareous sand are common. Vertical burrows are present.

Systematic description of trace fossils

Planolites Nicholson, 1873

Description Cylindrical to subcylindrical, elongated, straight to gently curved, unbranched, epichnial burrows of almost uniform diameter, rarely undulose. The burrow surface is smooth, and the fill is similar to host rock, i.e., medium to fine grained, greenish gray, calcareous sandstone. The diameter ranges from 0.6 to 0.8 cm, whereas, the length from 8 to 12 cm (Fig. 4a).

Occurrence The burrows are recorded on the upper surface of 30 cm thick horizons of grayish green, parallel-bedded, and cross-bedded calcareous sandstones of Salbardi area.

Planolites montanus Richter, 1937

Description Simple, unbranched, horizontal burrows, preserved as positive epirelief, which may be locally undulose and tortuous. It may cross each other and mostly follow the bedding plane. The structure is highly

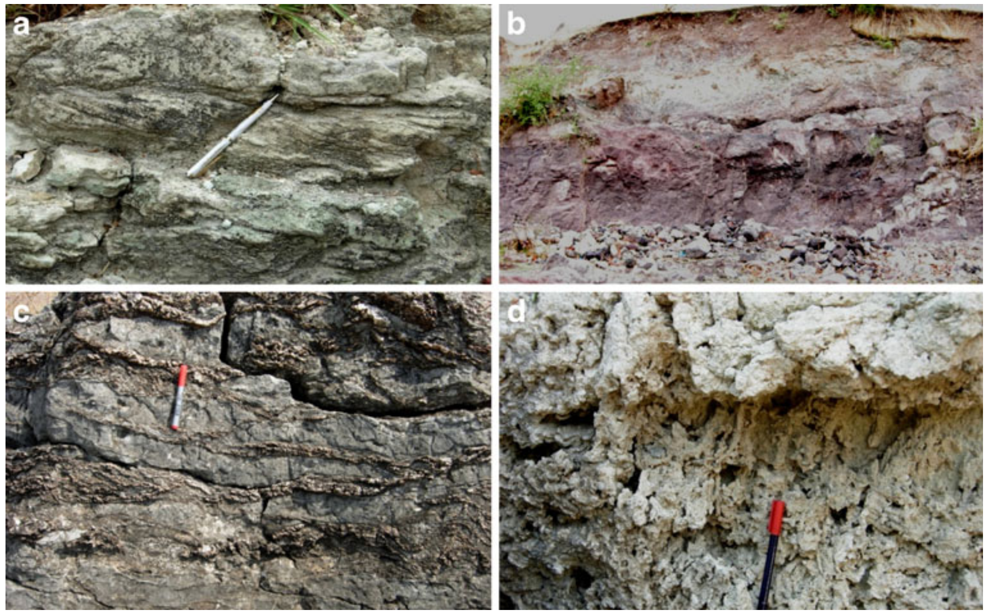

Fig. 3 Photographs showing- **a**) grayish green, medium sandstone showing cross beddings at Salbardi area, **b**) reddish brown to greenish gray clays at Belkher area, **c**) alternations of medium to dark brown, hard and compact chertified limestone with bluish gray nodular limestone (Belkher area), and **d**) grayish white, hard and compact, micritic calcrete having vertical tubes (Salbardi area)

ferrugenized giving a dark brown coloration. The diameter varies from 0.3 to 0.5 cm; maximum length up to 12 cm (Fig. 4b).

Occurrence On the bedding plane of 80-cm thick, grayish green, medium-grained sandstone of Salbardi area.

Remark Planolites is a very common trace fossil, which is widely reported from marine to non marine environments and considered as fodichnia of lower invertebrates (Häntzschel 1975; Bromley and Asgaard 1979; Pemberton and Frey 1982; Mikuláš and Martinek 2006). Besides wide occurrence of *Planolites* in marine successions, it is quite common in non marine fluvial deposits also, i.e., Cretaceous flood plain deposits of Hasandong and Junju Formations, Korea (Kim et al. 2002); Carboniferous Tupe Formation, western Argentina (Buatois and Mángano 2002, 2004). Mikuláš and Martinek (2006) reported *P. montanus* form Carboniferous to Permian of lacustarine and fluvial deposits of Boskovice basin, Czech Republic. The *Planolites*-produce may be a group of vermiform lower invertebrates, perhaps polychaetes (Pemberton and Frey 1982) or arthropods (Buatois and Mángano 1993; Kim et al. 2002). *P. montanus* is identified because of more tortuous nature of burrow (Pemberton and Frey 1982)

Thalassinoides Ehrenberg, 1944

Description Simple, vertical to inclined, sample to twig shape, branched burrows which normally show a swelling tendency at the point of bifurcation. In cross-sections, it is circular to subcircular in shape. Outer surface is smooth to granular. The infilling material is fine-grained, reddish brown sandstone as of the host rock. Diameter of the burrows varies from 1 to 1.3 cm, length up to 6 cm (Fig. 4c).

Occurrence The burrows are densely packed in 1–2 m thick, brownish black, medium to coarse-grained sandstones exposed at Belkher area. The entire bed is highly bioturbated.

Remark Thalassinoides is considered as a fodichnial structure, produced by crustaceans (Frey et al. 1984; Bromley 1996; Ekdale and Bromley 2003). It is widely reported from the shallow to deep marine environments (Bromley and Frey 1974; Demircan 2008); however, non marine occurrences are also in plenty (Pollard 1998; Buatois and Mángano 2004; Belt et al. 2005). *Thalassinoides* from nonmarine fluvial environment are well reported from flood plain Cretaceous deposits of Hasandong and Junji formations, Korea (Kim et al. 2002) and fresh water facies of Tongne River Member, Williston Basin (Belt et al. 2005).

Small stuffed burrows

Description These are small, vertical to inclined, unbranched, closely packed, cylindrical burrows. The burrow surface is rough; yellowish brown to reddish brown lining of 1–2 mm is distinct in cross-sections, whereas, the fill is medium to coarse grained calcareous sandstone, which leaves columnar hollow structures after erosion. In cross-sections, the burrows are represented by circular to elliptical and irregular structures. Diameter ranges from 0.4 to 1 cm; length up to 1.5 cm (Fig. 4d).

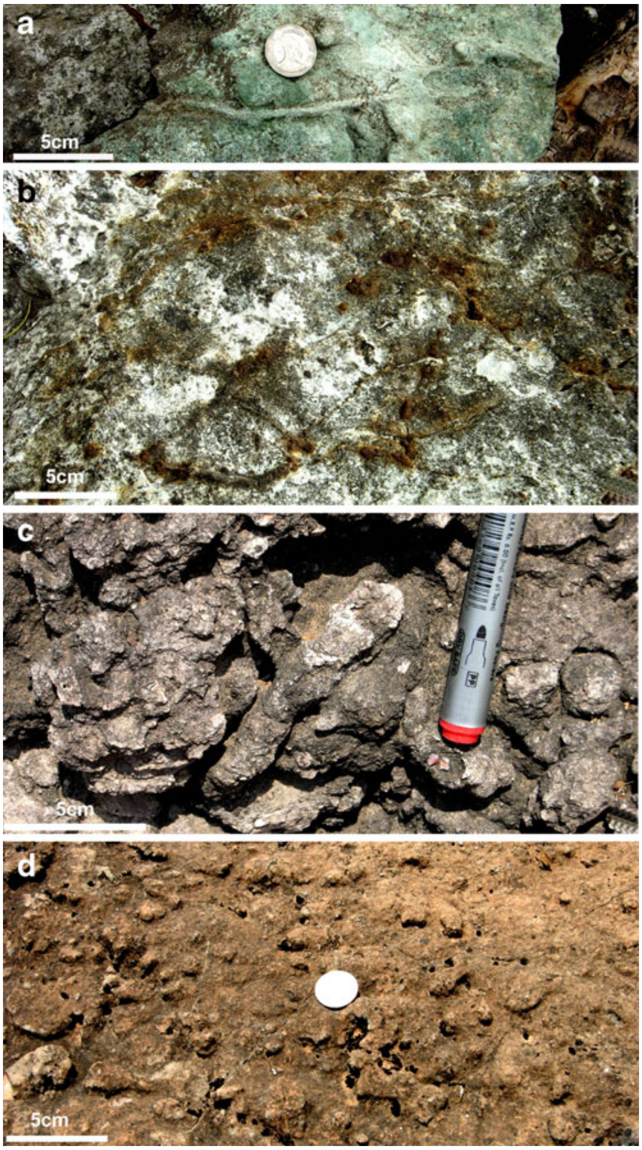

Fig. 4 Photographs showing- **a**) cylindrical, straight to gently curved, unbranched burrow of *Planolites* (Salbardi area), **b**) highly ferruginized, simple, undulose burrows of *P. montanus* (Salbardi area), **c**) vertical to inclined, cylindrical to sub-cylindrical, densely packed burrows of *Thalassinoides* (Belkher area), and **d**) vertical to inclined, unbranched, cylindrical stuffed burrows (Belkher area)

Occurrence The burrows are restricted to 10–15 cm thick, small, flat bedded patches of medium- to coarse-grained sandstone. These small patches are recorded at two adjacent places, on the top surface of bluish gray, nodular, chertified limestone beds of Belkher area.

Result and discussion

Trace fossils, namely *Planolites*, *P. montanus*, *Thalassinoides*, and stuff burrows are reported from two Lameta successions exposed at Salbardi and Belkher area. So far, both the exposures lacks sedimentological and palaeobiological studies; and, the reported trace fossils are the only tools to interpret about the benthonic community and their behaviors. The traces fossils are confined to the sandy horizons, represented by medium to fine grained arenaceous horizons showing poor preservations of cross-laminations and parallel laminations, depicting medium energy condition of deposition. The assemblage is dominated by feeding and dwelling structure of soft-bodied animals. On the basis of trace making animals, it is interpreted that the benthonic community was dominated by crustaceans and polychaetes.

Planolites and *P. montanus* are facies crossing ichnotaxa ranging from nonmarine to marine environments and are comparatively less significant for interpretation of depositional environment. *Thalassinoides* and other crustacean burrows are widely reported from other localities of Lameta and Bagh Beds exposed in Central India (Kumar and Tandon 1979; Singh et al. 1983; Kundal and Sanganwar 2000; Mohabey and Udoji 1996; Singh and Dayal 1979). Sanganwar and Kundal (1997) and Kundal and Sanganwar (1998) reported *Thalassinoides* from the Nimar Sandstone Formation of the Bagh Group and interpreted sublittoral to near-shore environments with moderately high energy conditions. Similarly, it is also reported from Mottled nodular sandstone and Upper Sandstone members of Jabalpur Formation, representing (?) shallow marine coastal complex (Kumar and Tandon 1979; Singh 1981). Recently, Saha et al. (2010) reported *Thalassinoides* from the Lameta Formation of Jabalpur area.

The depositional environment of the Lameta Formation is a matter of discussion from a long time, i.e., costal complex (Kumar and Tandon 1979; Singh 1981; Singh et al. 1983; Saha et al. 2010) and fresh water (Brookfield and Sahni 1987; and Tandon et al. 1995). Brookfield and Sahni (1987) and Tandon et al. (1995), argued about the environment of deposition of Lameta succession of Jabalpur area and suggested fluvial to palacustrine environments. These reconstructions of palaenvironments are mainly based on the characteristic deposits and sedimentary structures like calcrete horizons, mud filled channels, intraformational layers, etc. in addition, to the faunal contents. Similarly, a lacustrine environment is suggested for the co-eval Lameta exposures of Nand-Dongargaon inland basin, which is also based on the lithofacies architecture (Mohabey and Samant 2005; Tripathi 2005). The other group advocating costal complex lagoonal setting emphasise on green sandstone, multistoried sandstone complex of vast lateral extent, reptlian eggs, and trace fossils of marine affinity, etc. Tidal-intertidal-supratidal environment setting or short time marine incursion during the deposition of Lameta sediments in the type locality of Jabalpur cannot be ruled out, as, the succession shows good presentation of diverse marine ichonotaxa represented by *Skolithos* and *Cruziana* ichnofacies (Shukla and Srivastava 2008). The marine incursion even in post-Lameta times is also evident by the presence of ostracods and formanifers from Intertrappean sediments of Chhindwara districts (Keller et al. 2009a, b).

In the present case, both the exposures under investigation show good development of brownish to greenish gray clays, greenish sandstone, nodular beds, calcrete horizons, brecciated limestone, etc. which are taken as representative lithounits to considered fluvial to palacustarine environments for Lameta sediments of Jabalpur area (Brookfield and Sahni 1987; Tandon et al. 1995) and Nand-Dongargaon basin (Mohabey and Samant 2005 and Tripathi 2005). Therefore, the authors also suggest the same environments for the exposures of Salbardi and Belkher area. The trace fossil assemblage also finds a best-fit position in the proposed environment, though, not specific.

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