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The wood-boring trace fossil *Asthenopodichnium* from Palaeocene sediments of the Barmer Hill Formation, western Rajasthan, India

S. C. Mathur[1], N. S. Shekhawat[1], S. L. Nama[2], C. P. Khichi[1], A. Soni[1], Saurabh Mathur[1] and V. S. Parihar[1,*]

[1]Department of Geology, and
[2]Department of Zoology, Jai Narain Vyas University, Jodhpur 342 005, India

The present study documents the wood-boring trace fossil *Asthenopodichnium* from the Palaeocene sediments of the Barmer Hill Formation (BHF) in the Barmer Basin, Western Rajasthan, India. The *Asthenopodichnium* trace fossils are loosely to tightly packed, pouch-like burrows or almond-shaped structures identified as *Asthenopodichnium lignorum*, whereas lozenge and J-shaped structures are designated as *Asthenopodichnium lithuanicum*. The *A. lignorum* trace markers are considered to be the feeding and dwelling burrows produced by wood-rotting fungi, whereas *A. lithuanicum* are interpreted as feeding and dwelling burrows produced by Mayfly nymphs and larvae. The sedimentological and palaeontological studies of trace fossil-bearing horizons of BHF suggest freshwater fluvial sedimentary environment with humid to sub-humid climate.

Keywords: *Asthenopodichnium*, freshwater environment, trace-fossils, wood-rotting fungi.

GLOBALLY, the oldest wood-boring trace fossils were reported from the Carboniferous and Early Permian sediments[1–7]. Later, the diverse insect records matching the number of modern insect families were reported from Cretaceous and Neogene deposits of Germany[8,9]. All these reports were from marine sediments. However, very little is known about wood-boring trace fossils from freshwater environment. Initially, the ichnogenus *Asthenopodichnium* and ichnospecies *Asthenopodichnium xylobiontum* were described from Late Neogene wood in Austria[10]. The pouch-like *Asthenopodichnium* wood-boring trace fossils have also been reported as *A. lithuanicum*, from Neogene coal layer in northeastern Lithuania[11] and *A. xylobiontum* from Late Cretaceous Wahweap Formation, Utah, USA[12]. Subsequently, *A. lignorum* was recorded from Early Miocene of Didot Island, New Caledonia[13] and from the Upper Cretaceous Kirtland Formation of San Juan Basin, New Mexico[14]. The wood-boring *Asthenopodichnium* trace fossils from these localities are small, U-shaped or pouch-like burrow structures in wooden, organic-rich siltstone or on bone substrates[10,11].

*For correspondence. (e-mail: geoparihar@gmail.com)

The ichnogenus *Asthenopodichnium* is represented by three ichnospecies, viz. *A. xylobiontum*[10], *A. ossibiontum*[15] and *A. lithuanicum*[11]; *A. xylobiontum* and *A. ossibiontum* have a similar pouch-like morphology. However, *A. xylobiontum* burrow traces occur in woody substrates and *A. ossibiontum* is restricted to bone substrates[10,15]. *A. lithuanicum* is a small pouch-like burrow which display a J-shaped limb that is distinctly wider than other parts of the pouch[11]. A new ichnospecies having lozenge or almond-shaped, small, pouch-like burrow structure produced particularly by wood-rotting fungi is designated as *A. lignoram*[13,14,16].

The *Asthenopodichnium* (*A. lignorum* and *A. lithuanicum*) wood-boring trace fossils in the present study are

Figure 1. ***a***, Field photograph showing *Asthenopodichnium* trace fossil-bearing wood log in fine-grained sandstone of cycle 1 of Barmer Hill Formation at Gehun section, Barmer Basin, western Rajasthan, India. ***b***, Close-up view of *Asthenopodichnium* wood-boring trace fossil-bearing horizon at the Gehun section.

found in yellowish to yellowish-brown, fine-grained sandstone of Barmer Hill Formation (BHF) in the Barmer Basin at the Gehun section (Figure 1). The Gehun section is located about 5 km from the Barmer Railway Station in Barmer city, western Rajasthan, India (Figure 2).

To the best of our knowledge, the wood-boring trace fossil *Asthenopodichnium* was not reported earlier from the Indian Palaeocene stratigraphic record. Infect, the insect-generated trace fossils should be more abundant due to their diversification in the Palaeocene geological records of India. However, their under-recognition and possible under-representation need to be addressed now. The objectives of the present study are: (i) to document the wood-boring trace fossils (both *A. lignorum* and *A. lithuanicum*)) from the BHF and (ii) to discusses the age and palaeoenvironmental setting of these trace-fossil bearing horizons of BHF.

The siliciclastic rocks of the study area presently named as BHF[17] which were earlier known as Balmir Bed[18,19] and Barmer Sandstone[20,21]. The outcrops of BHF are extended from Barmer city to about 12 km in the northwestern direction up to Lunu village on the Barmer–Bishala road (Figure 2). BHF is resting unconformably on rhyolite probably of Late Cretaceous age[22,23]. BHF is divided into lower and upper members. The lower member comprises at least four fining-upward cycles of siliciclastic facies. The individual cycle commences with conglomerate at the base followed by coarse to fine pebbly sandstone, coarse-grained sandstone, medium-grained sandstone, fine-grained sandstone and occasionally siltstone at the top (Figure 3). Sandy, channel leg to channel-dominated, meandering rivers, reflected by the partial development of trough cross-beds, characterize the depositional setting of the lower member of BHF with local sediment source from rhyolite[22–24].

The *Asthenopodichnium* trace fossils are well preserved in 10–20 cm thick and about 0.3–1.2 m long wood logs in fine-grained sandstones of cycles 1–4 in the 50 m thick Gehun section of the BHF (Figures 1 and 3). The ill-preserved but larger *Asthenopodichnium* also occur at the 50 m thick Lunu hill section, having six fining-upward cycles of siliciclastic rocks. Dominantly, at both sections, the longer directions of trace fossils are arranged parallel to bedding of sandstone and show imbrications. The almond-shape and pouch-like *Asthenopodichnium* generally have iron-rich rinds around them[25]. The iron rind of *Asthenopodichnium* is composed of goethite and partly of hematite[23]. Sometimes, these trace fossils are found in small patches and clusters in the wood logs in the same horizon at several places in fine-grained sandstone of BHF.

Here we report two wood-boring *Asthenopodichnium* trace fossils from yellowish to yellowish brown, fine-grained sandstone of BHF. They are assigned as *A. lignorum* and *A. lithuanicum*, which are abundantly well-preserved and uniformly distributed in fine-grained

Figure 2. Location of *Asthenopodichnium* trace fossil-bearing Gehun and Lunu sections of BHF of the Barmer Basin, western Rajasthan, India.

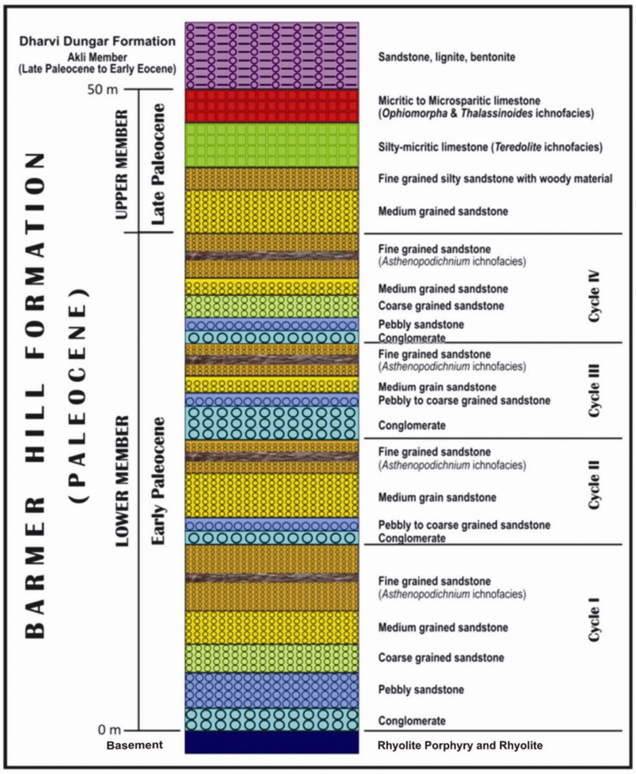

Figure 3. Generalized lithostratigraphy of BHF at Gehun section.

sandstone in an ideal and excellent forms of *Asthenopodichnium* trace fossils. The excellent outcrop for the present study of wood-boring trace fossils is available mainly at Gehun section of BHF (Figure 1).

Systematic ichnology

Ichnogenus: *Asthenopodichnium*[10]

Ichnospecies: *Asthenopodichnium lignorum isp.*[13,16] (Figures 1 and 4)

Material: Specimen nos. DG/JNVU/BHF/TF/6 Slabs and field photographs.

Diagnosis: Small, pouch-like, lozenge or almond-shaped burrow structures in wooden substrate and iron-rich fine-grained sandstone.

Description: Small, tightly packed, lozenge or almond-shaped pouch-like burrows that have a long axis terminating in rounded to angular ends, preserved probably as iron-oxide rind casts of wood fragments and logs. The horizontal cross-section shows that the burrow pouches display a lozenge or almond-shaped structure and usually more or less horizontal or parallel to the bedding plane. The lozenge or almond-shaped burrow pouches are 3–7.5 mm wide and their length is about 1–2.3 cm; all the small and large lozenges are almost of similar width and thickness respectively. The pouches-like burrows are filled with fine-grained siliciclastic matrix. They are scattered tightly on the surface of the fine-grained sandstone with preferred orientation, but they sometimes tend to occur in clusters. These, *A. lignorum* trace fossils occur as 10–20 cm thick and 0.3–1.3 m long wood logs preserved in the fine-grained sandstone of about 1.4–1.8 m thickness.

Remarks: The *A. xylobiontum* and *A. lithuanicum* trace fossils are feeding and dwelling, small, pouch-like burrows produced by Mayfly nymphs and larvae. The amphipods and isopods (arthropods) are also possible trace markers[11,12], whereas *A. lignorum* is particularly produced by wood-rotting fungi[13,16]. The present lozenge or almond-shaped small, pouch-like burrow structures are similar to *A. lignorum* of Early Miocene in the northern part of small island structures of Didot, New Caledonia[13] and *A. lignorum* from Kirtland Formation of San Juan Basin, New Mexico[14]. Hence, we designate them as *A. lignorum.* Though these structures can be correlated to *A. xylobiontum*, *A. ossibiontum* and *A.* lithuanicum[11,12], they differ in their lonzenge or almond-shaped pouch-like burrows.

Occurrence: Yellowish to yellowish-brown, fine-grained sandstone, Barmer Hill Formation, Barmer Basin, Gehun section, Barmer.

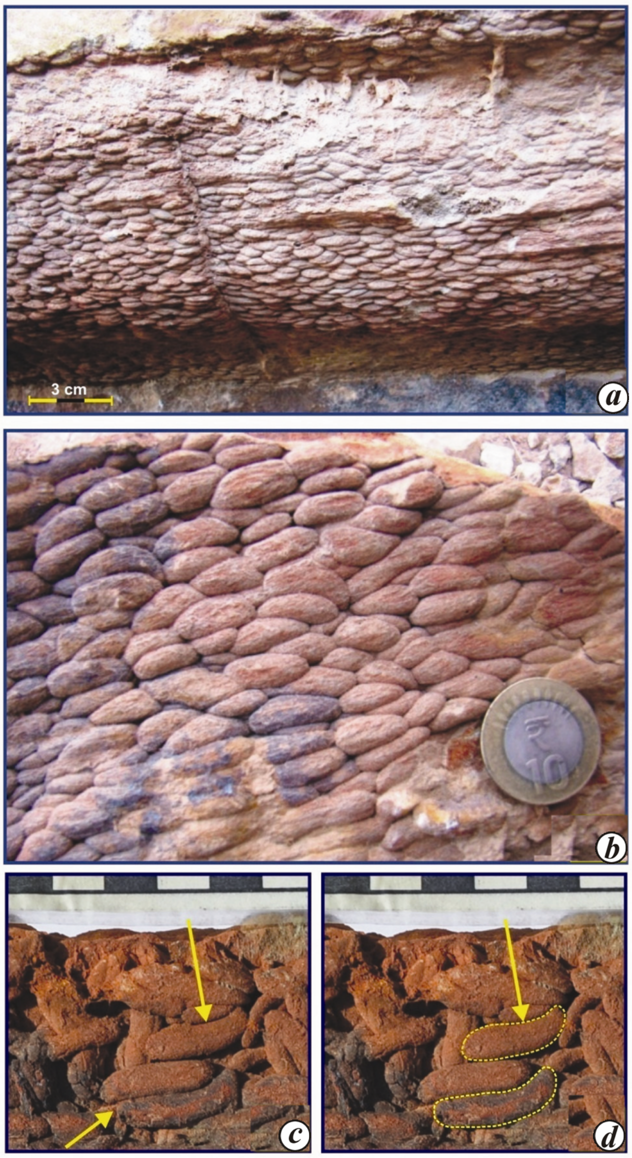

Figure 4. ***a***, Field photograph of a log showing small, tightly packed, lozenge or almond-shaped pouch-like *Asthenopodichnium* wood-boring traces. ***b***, Close-up view of wood-boring trace fossils showing their size, near parallelism of long axis and near similarity in their size. Note: Tightly packed pouches, superimposed, slight angular variation and dense clustering of traces of *A. lignorum*. ***c***, Photograph showing small, loosely to tightly packed fossils. ***d***, Outline of *A. lithuanicum* showing distinct J shape as seen in ***c***.

Ichnogenus: *Asthenopodichnium*[10]

Ichnospecies: *Asthenopodichnium lithuanicum isp.*[11] (Figure 4 *c* and *d*).

Material: Specimen nos. DG/JNVU/BHF/TF/2 Slabs.

Diagnosis: Small, pouch-like structures in wooden, organic-rich siltstone or bone substrate, and iron-rich, fine-grained sandstone which displays a J-shaped limb that is distinctly wider than the other parts of the pouch.

Description: Small, loosely to tightly packed, J-shaped limb, pouch-like structures preserved probably as iron-oxide rind casts of wood fragments and logs. The burrow pouches are usually more or less horizontal or parallel to the bedding plane, sometimes they are vertical and inclined. The horizontal cross-section shows that the burrows display a distinct limb on only one side; they are J-shaped rather than U-shaped structures and the limb is distinctly wider than the remaining parts of the pouch. The pouches are 5–6.5 mm wide and about 2.1–2.7 cm in length, and the burrows are filled with siliciclastic matrix. They are scattered on the surface of the yellowish to yellowish-brown, fine-grained sandstone with preferred orientation and tend to occur in clusters as well. These *A. lithuanicum* trace fossils occur in the same *A. lignoram*-bearing horizon of fine-grained sandstones of the lower member of BHF.

Remarks: The *A. lithuanicum* trace fossils are feeding and dwelling, small, pouch-like burrows produced by Mayfly larvae. The arthropods (amphipods and isopods) are also possible trace markers[11]. The present pouch-like burrow structures are similar to those of *A. lithuanicum*[11]. Hence, we designate to them as *A. lithuanicum.* They can also be correlated to *A. xylobiontum* and *A. ossibiontum*[11,12], but differ in their distinct J-shaped limb that is wider than the remaining parts of the pouch.

Occurrence: Yellowish to yellowish-brown fine-grained sandstone, Barmer Hill Formation, Barmer Basin, Gehun section, Barmer.

This is the first report of ichnogenus *Asthenopodichnium* from BHF. Both *A. lignorum* and *A. lithuanicum* occur in the fine-grained sandstone bedding surfaces, which clearly indicates freshwater fluvial sedimentary environment[11,12].

No age can be assigned on the basis of these freshwater trace fossils, as they are long-ranging from Late Cretaceous to Recent[11,12]. However, based on the presence of floral assemblage, viz. *Cycades*, *Ptillophyllum Acutifoilum*, *Phlebopteris* and *Matoniaceous fern*, BHF has been assigned to Palaeocene age[22,26].

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Risk factors for seropositivity to feline retroviruses among owned domestic cats in Valdivia, southern Chile

L. Azócar-Aedo[1,]* and G. Monti[2]

[1]Graduate School, Faculty of Veterinary Sciences, Universidad Austral de Chile, Valdivia, Chile
[2]Preventive Veterinary Medicine Department, Faculty of Veterinary Sciences, Universidad Austral de Chile, Valdivia, Chile

We identified risk factors associated with seropositivity to feline leukaemia virus (FeLV) or feline immunodeficiency virus (FIV) and the association between seropositivity to these retroviruses and the presence of clinical signs. Cats under veterinary care had lower risk of FeLV seropositivity and male cats had higher risk of FIV seropositivity. FeLV seropositive animals had higher odds of non-specific clinical signs and reproductive disorders. FIV seropositive cats had higher odds of buccal alterations. These findings are useful to obtain a first approach to identifying felines that need the application of diagnostic tests for retroviral infections.

Keywords: Feline leukaemia virus, feline immunodeficiency virus, immunochromatography, risk factors, seropositivity.

FELINE leukaemia virus (FeLV) and feline immunodeficiency virus (FIV) are important pathogens among domestic cat populations worldwide. Infections caused by these viruses are frequently present in clinical practice and they are associated with a high morbidity[1,2].

*For correspondence. (e-mail: luciaazocaraedo@gmail.com)