

Article

Paleoenvironmental significance of ichnofossils from the Kand Formation of the Cambay Basin, Gujarat, India

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Abstract

The present paper documents five ichnospecies from the sediments of the Kand Formation (late Miocene) of the Narmada Block of the Cambay Basin, namely, *Laevicyclus mongraensis*, *Planolites beverlensis*, *Planolite montanus*, *Thalassonoids paradoxicum* and *Thalassonoids suevicus*. Both the vertical and horizontal biogenic structures are common in the calcareous sandstone, but the horizontal biogenic structures dominate. The ichnofossils, namely, *Laevicyclus mongraensis*, *Thalassonoids paradoxicum* and *Thalassonoids suevicus* are ethologically domichnia, these dwelling biogenic structures formed by suspension feeders (fish, crustaceans, bivalves, sponges, cnidarians etc), in search of food at sediment water interface. The ichnofossils, namely, *Planolites beverlensis* and *Planolite montanus* are ethologically fodinichnia, these are feeding biogenic structures formed by deposit feeders (earthworms, sea stars, crabs, polychaetes etc). The present ichnofossils from the Kand Formation indicate that the sediments of the Kand Formation were deposited in shallow water marine environment with moderate to low energy conditions, all the burrows were made in soft substrate before the consolidation of the sediments and the sediments (calcareous sandstone) had good nutrients for the survival of both suspension and deposit feeders.

Keywords paleoenvironment; late Miocene; Kand Formation; India.

1 Introduction

The Cenozoic sediments of the Cambay Basin are exposed in and around Ankleshwar between Narmada and Kim rivers. Kundal et al., (2005) have documented five ichnofossils, namely, *Keckia annulata*, *Ophiomorpha nodosa*, *Paleophycus tubularis*, *Planolites beverleyensis*, *P. montanus*, *Thalassinoides paradoxicus* and *Skolithos* isp. from the late Eocene to early Miocene sediments of the Cambay basin. The present paper documents additional ichnofossils from the Cenozoic sediments the Kand Formation of the Cambay basin, Gujarat, namely, *Laevicyclus mongraensis*, *Planolite montanus*, *Planolites beverlensis*, *Thalassonoids paradoxicum* and *Thalassonoids suevicus*.

2 Geological Setting

Mathur et al., (1968) have divided the Cambay Basin into four major blocks which, from north to south, are: Ahmedabad-Mehsana Block, Cambay-Tarapur Block, Jambusar-Broach Block and Narmada Block (Fig.1).

The exposed Cenozoic sediments of the Cambay Basin are divided into five as Vagadkhol Formation (? Palaeocene), Dinod Formation (late Eocene), Babaguru Formation (early Miocene), Kand Formation (middle to late Miocene) and Jhagadia Formation (early Pliocene) (Agrawal, 1986).

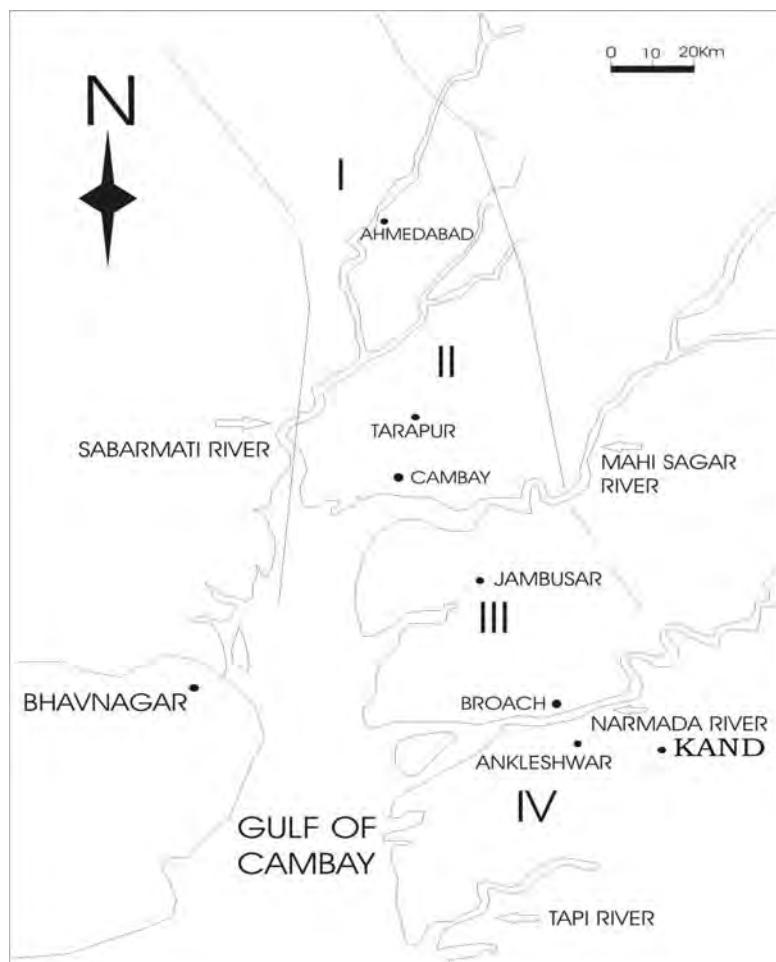


Fig. 1 Location map of the study area (Mathur et al., 1968)

The Vagadkhol Formation consists of conglomerates, variegated clays and siltstone. It is unfossiliferous and doubtfully dated as Palaeocene. It is overlain by the Dinod Formation which consists of fossiliferous limestone, marls and marly limestone. The Dinod Formation is dated as Late Eocene. The Babaguru Formation overlies the Dinod Formation comprising the ferruginous conglomerate and clays, dated as Early Miocene. It is succeeded by the Kand Formation which consists of conglomerate, fossiliferous limestone and calcareous sandstone, dated the Middle to Late Miocene. The overlying Jhagadia Formation is made up of mainly sandstone, gritstone, conglomerates and breccia. It is unfossiliferous and has been dated as Early Pliocene. The Holocene sediments are known as Narmada Formation which consists of sandstone, silts, clays and gravels. The following onshore Cenozoic Stratigraphy of the Cambay Basin is given as based on Agrawal (1986) (Table 1).

Table 1 The Cenozoic Stratigraphy of the Cambay Basin, (Agrawal, 1986)

Subsurface	Surface
Gujarat Alluvium	Narmada Formation
-----Unconformity-----	
Jambusar Formation	Absent
Broach Formation	Absent
Jhagadia Formation	Jhagadia Formation
-----Unconformity-----	
Kand Formation	Kand Formation
-----Unconformity-----	
Babaguru Formation	Babaguru Formation
-----Unconformity-----	
Tarkeshwar Formation	Absent
-----Unconformity-----	
Ankaleshwar Formation	Dinod Formation
-----Unconformity-----	
Cambay Shale Formation	Absent
-----Unconformity-----	
Vagadkhol Formation	Vagadkhol Formation
-----Nonconformity-----	
Deccan Trap	Deccan Trap

3 Systematic Taxonomy

This study of Palichnology follows the Treatise on Invertebrate Paleontology (Haentschel, 1975). The morphological classification of Simpson (1975), ethological classification of Seilacher (1964) and facies classification of Seilacher (1964, 1967) are adopted in the present paper.

(1) Ichnogenus: *Laevicyclus* Quensdet, 1879

Diagnosis: Vertical to slightly inclined burrows consisting of scraping circles surrounding a central vertical shaft, perpendicular to the bedding planes.

(2) Ichnospecies: *Laevicyclus mongraensis* Verma, 1971

(Pl. I, Fig. 6)

Diagnosis: Vertical to slightly inclined burrows perpendicular to the bedding planes, scraping circles surrounding a central vertical shaft, two distinct circles visible in transverse section Verma (1971).

Description: Scraping circle surrounding a central vertical shaft, perpendicular to inclined to the bedding plane and preserved as positive epirelief. The diameter of the central shaft is 15 mm and 25 mm of scraping circle.

PLATE I

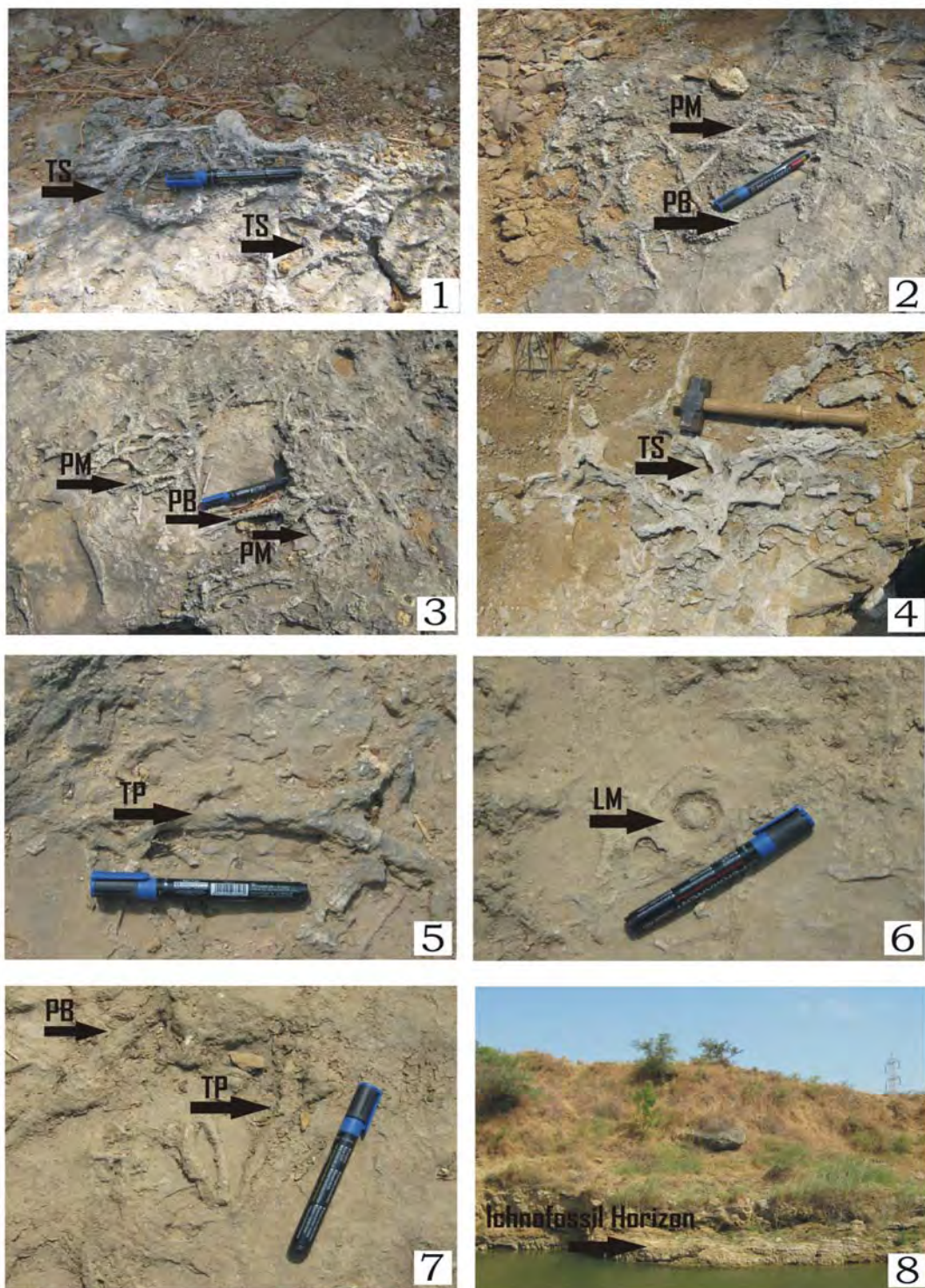


Plate I Ichnofossils from calcareous sandstone of the Kand Formation, Cambay Basin, Gujarat, India. (1) *Thalassonoids suevicus*, horizontal burrows with complex branching; (2) a) *Planolites beverlensis*, horizontal unlined thick burrow and b) *Planolites montanus*, horizontal unlined thick burrow; (3) a) *Planolites montanus*, horizontal unlined thick burrow and b) *Planolites beverlensis*, horizontal unlined thick burrow; (4) *Thalassonoids suevicus*, horizontal burrows with complex branching; (5) *Thalassonoids paradoxicum* horizontal burrows with simple branching; (6) *Laevicyclus mongraensis*, vertical burrow with central shaft; (7) a) *Planolites beverlensis* horizontal unlined thick burrow and b) *Thalassonoids paradoxicum*, horizontal burrows with simple branching; (8) outcrop showing ichnofossils horizon.

Remarks: Scraping circle surrounds a central vertical shaft. Burrow is perpendicular to inclined to the bedding plane and preserved as positive epirelief. Diameter of central shaft and scraping circles show close similarities with *Laevicyclus mongraensis*, Verma. Verma (1971) originally described it from Nimar Sandstone at Mongra, Amba Dongar area, Gujarat. They are morphologically shaft and ethologically domichnia. Kundal and Sanganwar (1998) reported this species from Bagh Group of Madhya Pradesh while Kundal and Dharashivkar (2006) documented this species from Shankhodhar Sand-Clay Member, Dingshwar Mahadev Cliff, Gujarat.

Occurrence: Ferruginous sandstone of the Babaguru Formation, exposed at Bhilod Village, Amravati river section.

(3) Ichnogenus: ***Planolites* Nicholson, 1873**

Diagnosis: Unlined, rarely branched, straight to tortuous, smooth to irregularly walled, elliptical to circular in cross-section, variable dimensions, burrow fill different in lithology from host rock, colour of burrow differ from that of host rock. (Pemberton and Frey, 1982)

(4) Ichnospecies: ***Planolites beverleyensis* Billings, 1862**

(Pl. I, Figs. 2, 3, 7)

Diagnosis: straight to gently curved or tortuous cylindrical burrow burrows, smooth and thick.

Description: Burrows are preserved as positive epi-relief, dominantly cylindrical ridges, straight to slightly curved burrow without lining, disposed parallel to the bedding plane, circular to semicircular in cross section, burrow fill material is different from the host rock. Burrows are crowded and some crossovers others. Dimensions vary from burrow to burrow. The length of the burrow varied from 6-14 cm and width from 6-10 mm.

Remark: As, the burrow fill is different from that of the host rock and burrows are straight to tortuous, they are identified as *Planolites beverleyensis* (Billings) (Pemberton and Frey, 1982). They are interpreted ethologically as fodinichnia and morphologically as tunnel. Borkar and Kulkarni (1992) and Kundal and Sanganwar (1998, 2000) recorded *Planolites beverleyensis* (Billings) from Wadhawan Formation of Gujarat and Bagh Group of Madhya Pradesh, respectively. Kundal et al., (2005) documented it from Babaguru Formation at Bhilod village, Broach district, Gujarat. Kundal and Dharashivkar (2006) recorded this species from Shankhodhar Sand-Clay Member Dwarka Formation. Kundal and Mude (2008) documented it from the Neogene-Quaternary sediments of the Porbandar area, Gujarat. Mude et al., (2012) recorded it from the Ambalapuzha Formation (Mio-Pliocene), Varkala cliff section, Kerala, South India.

Occurrence: Calcareous sandstone of the Kand Formation, exposed at nala section near Kand village

(5) Ichnospecies: ***Planolites montanus* Nicholson, 1873**

(Pl. I, Figs.2,3)

Diagnosis: straight to gently curved or tortuous cylindrical burrow burrows, smooth thin and very small.

Description: Straight, undulose, tortuous, unlined burrow, disposed parallel to the bedding plane, infilled material in the burrow is different than that of host rock. The diameter of the burrows varies from 3 to 5 mm.

Remarks: Burrows are straight, undulose, tortuous and isolated. They are disposed parallel to the bedding plane and preserved as positive epirelief. They are an unlined burrow infilled with sediments having textural and fabricational characters different from host rock. Present burrows are small in diameter and tortuous in

nature. Hence, they are placed under *Planolites montanus* Richter (Pemberton and Frey, 1982). They are interpreted ethologically as fodinichnia and morphologically as tunnel. Many researchers like Badve and Ghare (1978, 1980); Sanganwar and Kundal (1997); Kundal and Sanganwar (1998, 2000) reported this ichnospecies from Bagh Group of Madhya Pradesh while Chiplonkar and Ghare (1979) documented from Trichinopoly Group, Tamil Nadu. Kundal et al., (2005) documented this from Babaguru Formation at Bhilod village, Broach district, Gujarat. Kundal and Dharashivkar (2006) reported this ichnospecies from *Shankhodhar Sand Clay Member (Dwarka Formation) at Dingeshwar Mahadev cliff*.

Occurrence: Calcareous sandstone of the Kand Formation, exposed at nala section near kand village.

(6) Ichnogenus : ***Thalassinoides* Ehrenberg, 1944**

Diagnosis: Cylindrical burrows forming three dimensional branching systems consisting of horizontal network connected to surface by more or less vertical shaft. Regularly branching, Y to T shaped bifurcations in horizontal system is forming polygons, typical swelling at points of branching or elsewhere.

(7) Ichnospecies: ***Thalassinoides paradoxicum* Woodward, 1830**

(In: Curran and Frey, 1977)

(Pl. I, Figs. 5, 7)

Diagnosis: Predominantly horizontal, isolated and unbranched, simple Y-shaped burrows, disposed horizontal to the bedding planes (Howard and Frey, 1984)

Description: Y-shaped isolate burrow, swelling at the point of bifurcation with smooth surface and unornamented. The diameter of the burrow varies from 20 to 25 mm and slightly swelling at the point of bifurcation.

Remarks: The present burrows are isolated, Y-shaped and unornamented and thus they are identified and described as *Thalassinoides paradoxides*. They are interpreted ethologically as domichnia and morphologically as tunnel. Sanganwar and Kundal (1997) and Kundal and Sanganwar (1998) respectively documented this from the Nimar Sandstone Formation at Yelam, Barwah, Khargaon district, Madhya Pradesh and Hardaspur, Jobat, Jhabua district.

Occurrence: Calcareous sandstone of the Kand Formation, exposed at nala section near kand village.

(8) Ichnospecies: ***Thalassinoides suevicus*, Kennedy, 1967**

(Pl. I, Figs.1, 4)

Diagnosis: Predominantly horizontal, Simple Y-shaped to complex branching, essentially cylindrical burrow system consists of a horizontal network connected to the surface by a more or less vertical shaft; dichotomous bifurcation are more common than T-branches (Howard and Frey, 1984)

Description: Y-shaped to complex burrow, swelling at the point of bifurcation with smooth surface and unornamented, parallel to the bedding plane. The diameter of the burrows varies from 25 to 35 mm.

Remarks: The burrows are Y-shaped to complex and disposed parallel to the bedding plane without ornamentation, exhibiting swelling at the point of bifurcation. The present burrows show most of the characters similar to that of *Thalassinoides suevicus*, hence these are described as *Thalassinoides suevicus*. They are interpreted ethologically as domichnia and morphologically as tunnel. Kundal and Dharashivkar (2006) recorded this ichnospecies from Dwarka-Oka area, Gujarat. Nagendra et al., (2010) documented this species from Kulakkalnattam Sandstone of Garudamangalam Formation, Ariyalur, Tamil Nadu.

Occurrence: Calcareous sandstone of the Kand Formation, exposed at nala section near kand village.

4 Discussion and Conclusions

The ichnofossils / ichnofossils assemblage offers an excellent opportunity to reconstruct paleoenvironment and paleobathymetry of the sediments (Seilacher, 1967). Many times due to various unfavourable conditions, it is not possible to the buried organisms under the pile of the sediments, to be preserved as fossils. In such case, behavioral structures (biogenic structures) produced in / on sediments by these organisms, play a significant role for the interpretation of these sediments. Frey and Pemberton (1985) have grouped all the ichnofossils into eight ichnofacies on the basis of their morphology and occurrence from rocky coast to abyssal zone. The vertical or vertical to slightly inclined biogenic structures are commonly recognized from semi-consolidated substrate (Frey and Pemberton, 1985) and they are characteristic features of the nearshore / foreshore marine environment, with moderate to high energy conditions (Seilacher, 1967). The horizontal structures are the members of the *Cruziana* ichnofacies and generally occur in shallow water marine environment with reducing energy (Seilacher, 1967).

The present paper documents five ichnospecies from the sediments of the Kand Formation (late Miocene) of the Narmada Block of the Cambay Basin, namely, *Laevicyclus mongraensis*, *Planolites berverlensis*, *Planolite montanus*, *Thalassonoids paradoxicum* and *Thalassonoids suevicus*.

The domichnia ichnofossils, namely, *Laevicyclus mongraensis*, *Thalassonoids paradoxicum* and *Thalassonoids suevicus* are dwelling biogenic structures which were formed by suspension feeders (fish, crustaceans, bivalves, sponges, cnidarians etc), in search of food at sediment water interface. The fodinichnia ichnofossils, namely, *Planolites berverlensis* and *Planolite montanus* are feeding biogenic structures which were formed by deposit feeders (earthworms, sea stars, crabs, polychaetes etc). The ichnofossils from the Kand Formation point out that the sediments of the Kand Formation were deposited in shallow water marine environment with moderate to low energy conditions. All the burrows were made in soft substrate before the consolidation of the sediments and the sediments (calcareous sandstone) had good nutrients for the survival of both suspension and deposit feeders.

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