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Ichnotaxonomy of the deposits of the Lower Member of the Himmatnagar Sandstone Formation, Sabarkantha, Gujarat, Western India

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Abstract: The Lower Member of the Himmatnagar Sandstone Formation, outcropping south of Sapteshwar and north of Kadoli Village in the Sabarkantha District of North Gujarat, contains a prolific record of trace fossils. These well-preserved sandstone units are interpreted as shallow marine deposits, characterized by a transition between the *Cruziana* and *Skolithos* ichnofacies. The identified ichnobiota comprises *Diplocraterion* cf. *parallelum*, *Lockeia siliquaria*, *Ophiomorpha* isp. and *Thalassionides suevicus*.

Index Terms – Ichnology, Himmatnagar Sandstone Formation, Lower Member, Lower Cretaceous

I. INTRODUCTION

The Himmatnagar Sandstone Formation comprises two distinct lithostratigraphic units, namely the Lower Member and the Upper Member. The Lower Member is characterized by a diverse and well-preserved assemblage of trace fossils. Previous ichnological studies of these sediments have been reported by Bhatt et al. (2016) and Thakar and Solanki (2025). The outcrop is located in the north of the Sabarkantha District, Gujarat. The present investigation seeks to establish an ichnotaxonomic framework for the Lower Member of the Lower Cretaceous of the Himmatnagar Sandstone Formation. In this study, ichnogenera and ichnospecies are described following the binomial nomenclatural system in compliance with the International Code of Zoological Nomenclature (ICZN).

II. GEOLOGICAL LOCATION AND STRATIGRAPHY

The study is carried out in the northern part of the Gujarat State and encompasses the Lower Member of the Himmatnagar Sandstone Formation. The study area lies approximately 30 km northwest of the Himmatnagar Town, within Sabarkantha District, about 5 km north of Kadoli Village, adjacent to Sapteshwar Temple, and extending 3 km further north near Arsodiya Village (Figure 1). The study area extends between the coordinates 73°49′3.48″E, 23°42′48.04″N and 72°49′13.71″E, 23°42′7.13″N, covers the lower part of the Lower Member of the Himmatnagar Sandstone Formation. The Mesozoic rocks exposed in the area span from Neocomian to Albian, representing the early to middle Cretaceous, and are overlain by the Deccan Traps (Bhatt et al., 2016). The Himmatnagar Sandstone Formation primarily exhibits a horizontal to sub-horizontal orientation, visible in stream and river sections, below thin alluvium cover. The trace fossils are preserved within ferruginous sandstone, gritty sandstone, and argillaceous sandstone lithofacies. The unconformable junction between the Lower Member and Upper Member is visible at a few exposures near Sapteshwar, and the unconformity on the Upper Member is also visible.

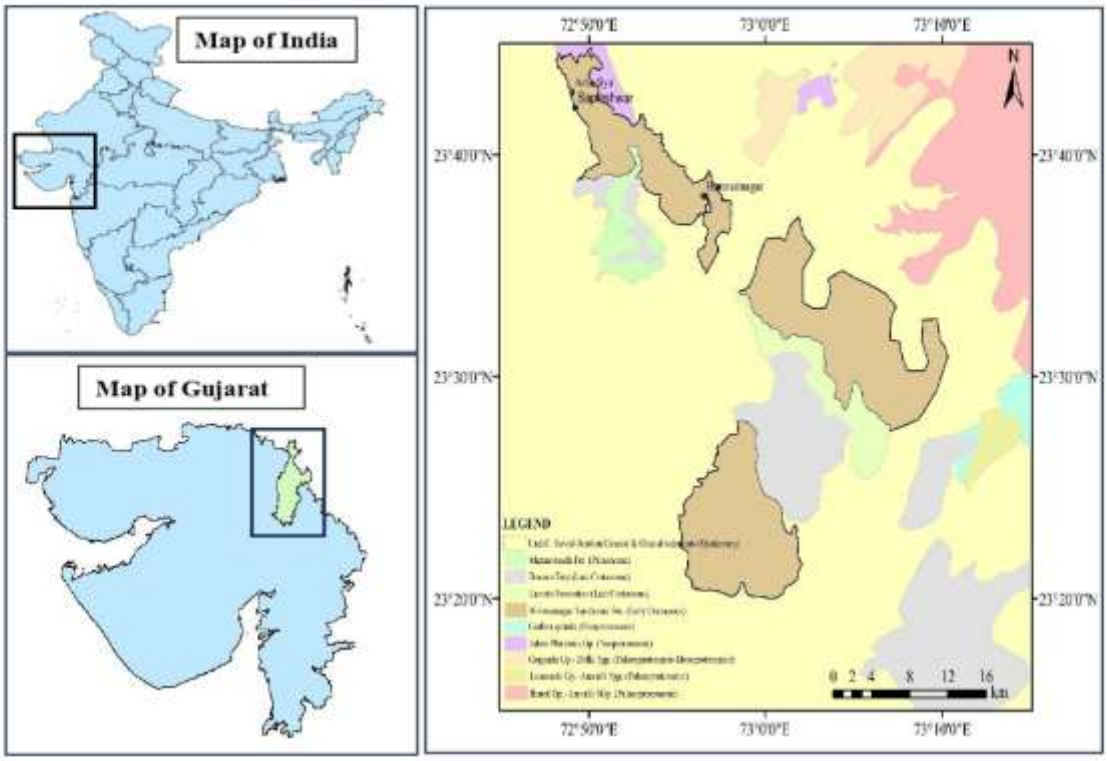

Fig. 1: Geological map of Himmatnagar Sandstone Formation (modified from Thakar and Solanki, 2025).

III. SYSTEMATIC ICHNOLOGY

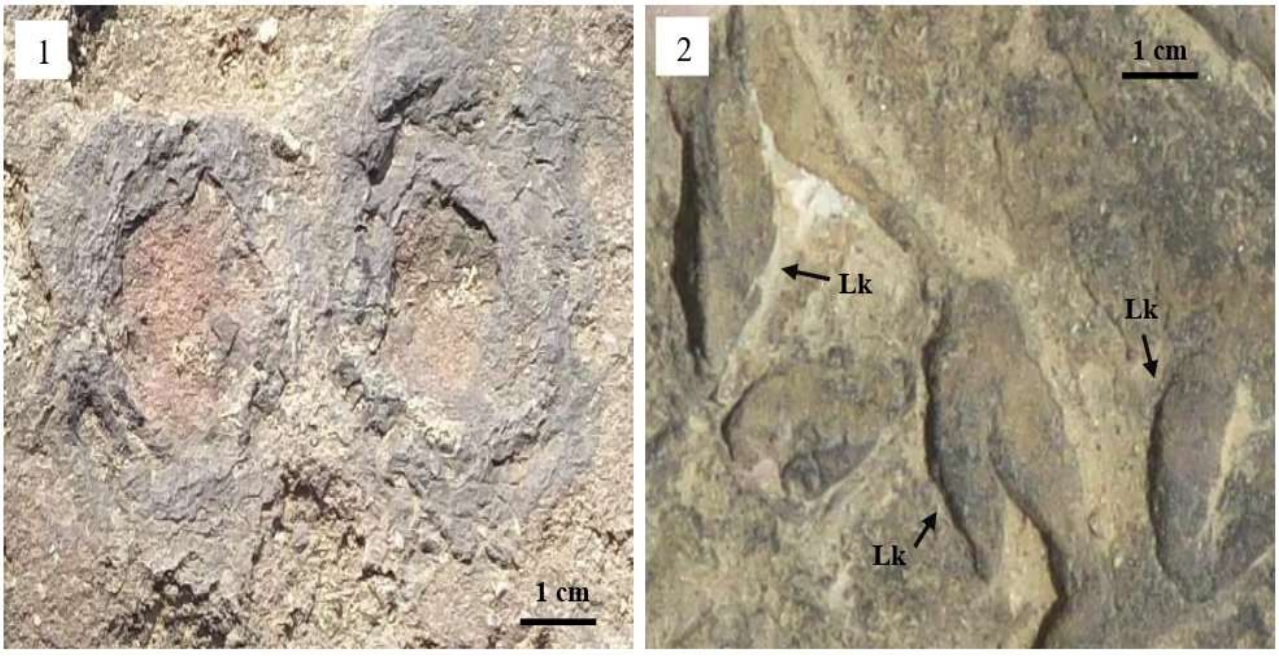

Plate 1: Trace fossils from the Lower Member of the Himmatnagar Sandstone Formation. (1) ***Diplocraterion* cf. *parallelum*** in the ferruginous sandstone near Sapteshwar. Scale: 1 cm., (2) ***Lockeia siliquaria* (Lk)** occurring in ferruginous sandstone near Sapteshwar. Scale: 1 cm, (3) ***Ophiomorpha isp.*** occurring in silty shale near Arsodiya Village. Scale: 2 cm and (4) ***Thalassinoides suevicus*** occurring in ferruginous sandstone near Sapteshwar. Scale: 2 cm.

Ichnogenus: *Diplocraterion* Torell, 1870

Ichnospecies: *Diplocraterion* cf. *parallelum* Richter, 1926

(Plate 1, Fig 1)

Description: Paired, parallel, straight vertical tubes connected by poorly-developed spreiten structures. Perpendicular orientation to the bedding plane with narrow opening on surface. The tube diameter ranges between 0.5 and 0.65 cm, while the distance between the limbs are 0.5-0.55 cm.

Occurrence: Gritty sandstone facies of upper part of the Lower Member, Himmatnagar Sandstone Formation.

Remarks: *Diplocraterion* is classified as a permanent dwelling structure (Bromley, 1996). The burrow is interpreted as dwelling burrow of polychaete annelids, crustaceans, or other suspension feeding animal (Fillion and Pickerill, 1990). *Diplocraterion* ranges from the Lower Cambrian to Tertiary and serves as an indicator of high wave-energy environment (Häntzschel, 1975) and is interpreted as marine intertidal in origin (Seilacher, 1967). It highly valuable in sedimentological studies (Goldring, 1964) and in the interpretation of depositional environments (Fürsich, 1975).

Ichnogenus: *Lockeia* JAMES, 1879

Ichnospecies: *Lockeia siliquaria* James 1879

(Plate 1, Fig 2)

Description: Small, convex, hypichnial, almond-shaped oblong parallel to sub-parallel bodies with tapering to sharp and obtuse points at both ends. The observed length ranges from 1.1-2.3 cm, width 0.5-0.6 cm and height of 0.3-0.5 cm.

Occurrence: Ferruginous sandstone facies of lower part of the Lower Member, Himmatnagar Sandstone Formation.

Remarks: The traces exhibit morphological features and modes of occurrence identical to *Lockeia siliquaria* (James, 1879). This ichnospecies has been interpreted as a bivalve resting trace (Seilacher and Seilacher, 1994). Ethologically, *Lockeia siliquaria* either represents fugichnial response to changing environmental conditions, rather than short-lived resting traces (Mangano et al., 1998).

Ichnogenus: *Ophiomorpha* LUNDGREN, 1891

Ichnospecies: *Ophiomorpha* isp.

(Plate 1, Fig 3)

Description: Endichnial, vertically inclined, branched. The burrow wall exhibits a distinct lining; the outer wall shows a knobby texture that is poorly defined.

Occurrence: Argillaceous sandstone facies of lower part of the Lower Member, Himmatnagar Sandstone Formation.

Remarks: *Ophiomorpha* refers to branching burrows with either horizontal, oblique or vertical box-like networks (Lokho and Singh, 2013). The *Ophiomorpha* is a characteristic trace fossil for the high energy, mobile substrate belonging to shallow marine environment, especially subtidal to lower intertidal zone (Patel and Desai, 2009).

Ichnogenus: *Thalassinoides* EHRENBERG, 1944

Ichnospecies: *Thalassionides suevicus* Rieth, 1932

(Plate 1, Fig 4)

Description: Unornamented, smooth-walled, horizontal to slightly oblique, three-dimensional branched burrow system. The length varies from 8-10 cm and diameter form 1-2.5 cm. The burrow structure exhibits configurations of Y-shaped branching, accompanied by irregular expansions at the points of bifurcation.

Occurrence: Ferruginous Sandstone facies of lower part of the Lower Member, Himmatnagar Sandstone Formation.

Remarks: *Thalassinoides* is considered to be a dwelling and feeding structure of decapod crustaceans (Myrow, 1995; Carvalho et al., 2007). The ichnogenus *Thalassinoides* is facies-crossing and produced by crustaceans (Frey et al., 1984; Knaust, 2017), ranging from shallow to deep-water environments (Ehrenberg, 1938; Uchman, 1995; Myrow, 1995; Kim et al., 2002).

IV CONCLUSION

The Lower Member of the Himmatnagar Sandstone Formation is exposed near Sapteshwar and Arsodiya Village in the Sabarkantha District, preserves a diverse and well-defined assemblage of trace fossils within ferruginous sandstone, gritty sandstone and argillaceous sandstone lithofacies. The presence of vertical dwelling structures such as *Diplocraterion* suggests a high-energy depositional environment, whereas horizontal to oblique burrows such as *Ophiomorpha* and *Thalassinoides*, interpreted as dwelling and feeding structures, along with the resting trace *Lockeia*, indicate deposition under moderate to low energy conditions. The ichnoassemblage suggests a transitional ichnofacies regime between the *Cruziana* and *Skolithos* ichnofacies, characteristic of shifting hydrodynamic conditions within a shallow marine environment, likely spanning middle to upper shoreface to foreshore setting.

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