Habitable Planet, 2026, 2(1), 149–158

Scilight

Habitable Planet

Journal Homepage: https://www.sciltp.com/journals/hp

Article

First Record of Ichnogenus *Furculosus* from Western India: Clues to Early Cambrian Behavioral Evolution

S. Ahmad* and S. K. Pandey*

Birbal Sahni Institute of Palaeosciences, 53 University Road, Lucknow-226007, India

* Correspondence: ahmadsgeo@gmail.com, skpandey@bsip.res.in

ABSTRACT

This paper documents the occurrence of the trace fossil *Furculosus* from the Nagaur Sandstone of the Marwar Supergroup, exposed near Dulmera village, Bikaner District, Western India for the first time. The ichnofossils occur within fine- to medium-grained ferruginous sandstone beds displaying well-developed ripple lamination and moderate bioturbation. The specimens of Ichnogenus *Furculosus* are characterized by gently curved, bifurcating, bilobate burrows commonly considered as passive burrow consistent with the diagnosis of *Furculosus carpathicus* previously known from the Lower Cambrian of Europe. The occurrence of Ichnogenus *Furculosus* in the Nagaur Sandstone expands its palaeogeographic range into the Indian subcontinent and provides new insights into the behavioral and ecological strategies of early benthic infauna inhabiting shallow-marine substrates during the onset of the Cambrian Substrate Revolution (CSR). The associated ichnoassemblage, comprising *Furculosus*, *Planolites, Palaeophycus*, and *Diplocraterion*, represents a *Cruziana* Ichnofacies indicative of a low- to moderate-energy, well-oxygenated foreshore environment conducive to deposit-feeding activity.

ARTICLE INFO

History:

Received: 03 December 2025
Revised: 23 December 2025
Accepted: 07 January 2026
Published: 14 January 2026

Keywords:

Furculosus;
Nagaur Sandstone;
Marwar Supergroup;
Early Cambrian;
India

Citation:

Ahmad, S.; Pandey, S. K. First Record of Ichnogenus *Furculosus* from Western India: Clues to Early Cambrian Behavioral Evolution. *Habitable Planet* **2026**, *2*(1), 149–158. https://doi.org/10.63335/j.hp.2026.0031

Research Highlights

- First report of trace fossil *Furculosus* from the Nagaur Sandstone of the Marwar Supergroup.
- Insights into the behavioral and ecological strategies of early benthic infauna inhabiting shallow-marine substrates.
- The associated ichnoassemblage indicate a low- to moderate-energy, well-oxygenated foreshore environment conducive to deposit-feeding activity.

1. Introduction

Trace fossils represent the behavioral record of ancient benthic organisms and serve as powerful tools for interpreting palaeoenvironmental conditions and early animal evolution [1, 2]. The Lower Cambrian Nagaur Sandstone of the Marwar Supergroup is a key sedimentary succession that preserves a diverse suite of ichnofossils marking the transition from the Precambrian microbial world to complex infaunal ecosystems of Lower Cambrian Period. Previous studies have reported ichnogenera such as *Skolithos*, *Diplocraterion*, *Cruziana*, *Monomorphichnus, T. Pedum* and *Planolites*, etc. [3–6] which collectively indicate shallow-marine depositional conditions during the early Cambrian. The present report adds *Furculosus* to this ichnofaunal assemblage, marking its first occurrence in India. Originally described by Roniewicz and Pieńkowski [7], from the Carpathians. *Furculosus carpathicus* is characterized by cylindrical burrow exhibiting tightly coiled, fork-like loops. These loops are arranged in a compact manner, with the terminal segments oriented either parallel or diverging. The overall morphology suggests a complex, characteristic of organisms interacting with the substrate in a controlled, directional manner. The overall morphology reflects a high degree of behavioral organization, indicating controlled and repetitive substrate interaction by worm-like deposit feeders. The structured, tightly coiled burrow geometry suggests deliberate feeding strategies linked to efficient sediment exploitation, representing an advanced benthic behavioral adaptation associated with the early Cambrian Substrate Revolution [8]. The burrow interpreted as the feeding structures of worm-like deposit feeders. The burrow morphology of *Furculosus carpathicus* shows close functional similarities to feeding traces produced by modern worm-like deposit feeders, particularly polychaetes, which generate repetitive, looping structures during systematic sediment exploitation. The association of this ichnotaxon with shallow-marine trace fossil assemblages typical of the Cruziana ichnofacies suggests deposition under soft to semi-consolidated substrate conditions. Such substrate consistency would have facilitated controlled burrow construction and reflects increasing bioturbation intensity characteristic of the early Cambrian Substrate Revolution [8]. The complex, repetitive looping geometry of *Furculosus carpathicus* reflects intensified bioturbation and systematic sediment reworking, key behavioral features associated with the early Cambrian Substrate Revolution. This study not only extends the stratigraphic and palaeogeographic range of this ichnotaxon but also contributes to understanding benthic behavioral innovations associated with the early Cambrian Substrate Revolution.

2. Geological Setting

The Nagaur Sandstone, constituting the uppermost unit of the Marwar Supergroup (Figure 1), covers an area of about 51000 Sq. km, represents the youngest siliciclastic succession of this late Neoproterozoic–Early Cambrian sequence deposited along the northwestern margin of the Indian Shield [9]. The Nagaur Sandstone is the youngest formation of the Marwar Supergroup, succeeding the Tunkliyan Sandstone (Table 1). It unconformably overlies the carbonates of the Bilara Group and is extensively exposed near Nagaur and Dulmera in Bikaner District, western Rajasthan [9]. Stratigraphically Nagaur Group, comprises reddish-brown to purple, ferruginous, fine- to medium-grained quartz arenites with interbedded siltstone and thin mudstone lenses, and locally developed basal conglomerates, [10, 11] such as the $\sim$5 m-thick Khichan Conglomerate near Phalodi, composed of cobbles and pebbles in a sandy-calcareous matrix [9]. The succession exhibits a thick profile of red to brick-red sandstones, siltstones, and claystones, capped in some areas by extensive evaporite horizons comprising limestone, dolomitized limestone, dolomite, gypsum, anhydrite, halite, and minor potash salts [9], while the overlying Tunklian Sandstone consists of brick-red claystones, siltstones, calcareous clays, and gritty to pebbly sandstones containing fragments of chert, quartzite, etc. [9]. Sedimentary structures such as planar and trough cross-bedding, ripple lamination, desiccation cracks, adhesion features, and small-scale hummocky cross stratification indicate deposition in tidally influenced shallow-marine to nearshore environments, occasionally subjected to subaerial exposure, with evaporitic layers reflecting episodes of hypersalinity [5]. The formation is notable for its diverse Early Cambrian ichnofauna, including *Rusophycus, Cruziana, Treptichnus, Palaeophycus, Skolithos, Bergaueria, Monocraterion, Diplichnites,* [5, 6, 10–12] and present report *Furculosus*, preserved as hypichnia in moderately bioturbated fine-grained sandstone beds interbedded with ripple-laminated bedding planes. These trace fossils document active infaunal feeding and benthic behaviors, providing strong evidence for a Lower Cambrian age ($\sim$521–509 Ma) and offering critical insights into shallow-marine depositional dynamics, substrate conditions, and early metazoan activity during the Cambrian Explosion in the Indian subcontinent [3, 13]. In the absence of direct radiometric age constraints, the Nagaur Sandstone is assigned a Lower Cambrian age based on its stratigraphic position above the Ediacaran Bilara Group and the occurrence of diagnostic Early Cambrian ichnotaxa, including *Cruziana*, *Rusophycus*, and *Treptichnus*, which provide robust regional biostratigraphic correlation [3, 6, 11].

3. Materials and Methods

The specimens ($n = 25$) were collected from well-exposed quarry at Dulmera village, located in Lunkaransar tehsil of Bikaner district in Rajasthan, India. It is situated 15 km away from sub-district headquarter Lunkaransar (tehsildar office) and 57 km away from district headquarter Bikaner. Standard ichnological methods were employed, including detailed field observations, stratigraphic logging, and morphometric analysis. The specimens were photographed in natural light and examined under low-angle illumination to enhance morphological contrast. Burrow dimensions (length, width, relief) and features were measured using digital calipers. Comparisons were made with type material of *Furculosus carpathicus* from the European Cambrian sequences and related ichnotaxa documented in ichnological literature.

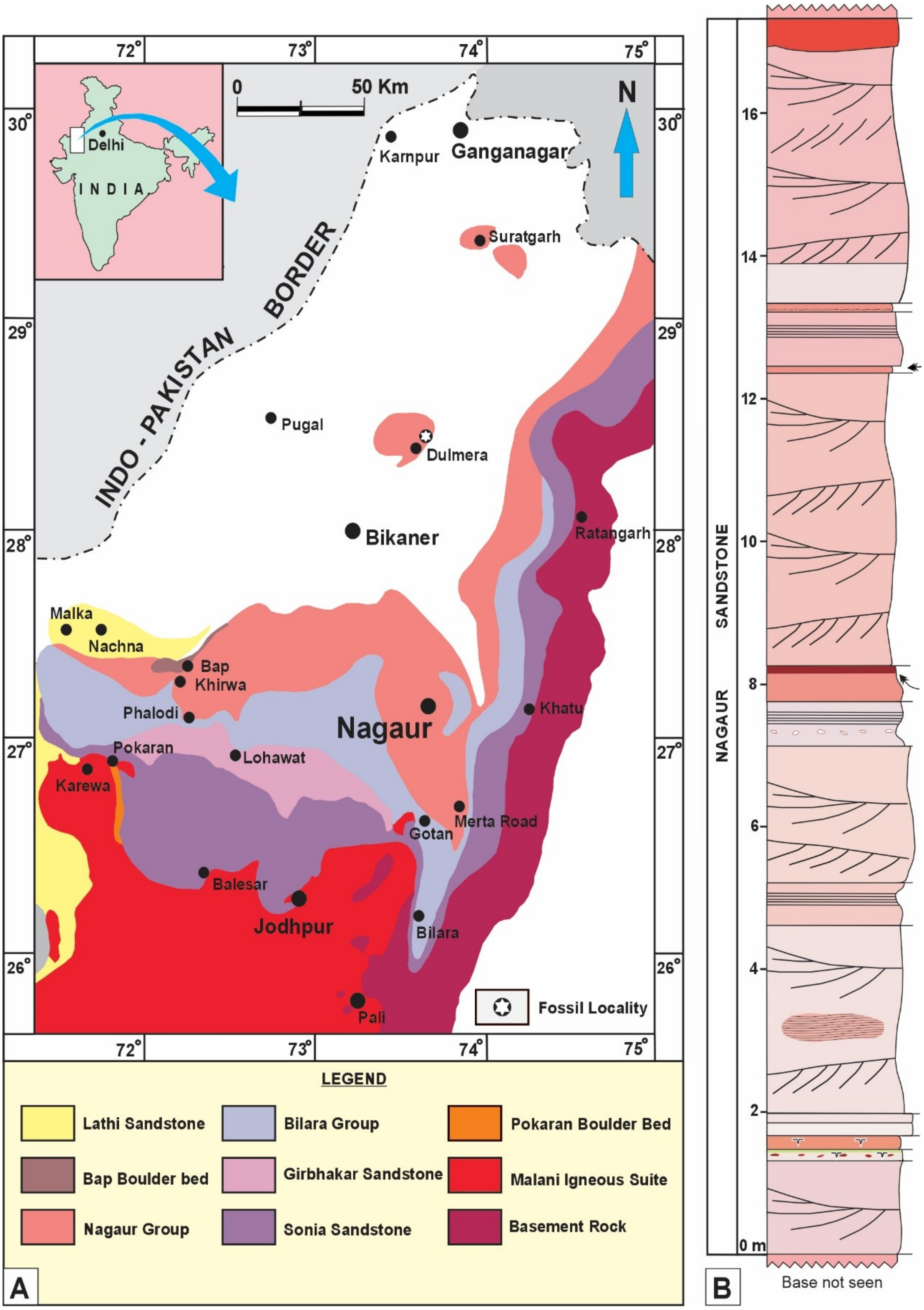

Figure 1. (**A**) Generalized geological map of the Marwar Supergroup, modified from [9] illustrating the regional distribution of lithostratigraphic units. The fossil locality is marked by a white star. (**B**) Lithostratigraphic profile of the Nagaur Sandstone, Nagaur Group, Marwar Supergroup, highlighting its sedimentary characteristics and stratigraphic context.

Table 1. Generalized lithostratigraphic succession of the Marwar Supergroup, after Pareek [9] providing a regional framework for sedimentary basin evolution.

Age	Supergroup	Group	Formation	Lithology
Permo-Carboniferous			Bap Boulder Bed	Subrounded, ellipsoidal cobbles and pebbles
Unconformity				
Ediacaran to Middle Cambrian	**Marwar**	Nagaur Group (75–500 m) $<$ 540 Ma (DZ LAICPMS)	Tunklian Sandstone	Brick red sandstone, siltstone & red claystone
			Nagaur Sandstone	Brick red sandstone, siltstone & red and green clay beds
		Bilara Group (100–300 m)	Pondlo Dolomite	Cherty dolomitic limestone, siliceous oolites and pesolites with subordinate claystone, siltstone at places
			Gotan Limestone	Dark grey laminated limestone with bands of clay, chert and dolomite
			Dhanapa Dolomite	Stromatolitic limestone, dolomite, siliceous dolomitic limestone and laminated and nodular chert at the base
		Jodhpur Group (125–240 m)	Girbhakar Sandstone	Brick-red sandstone, siltstone and shale, pebbly to gritty near top
			Sonia Sandstone	Maroon siltstone and shale, cream-colored sandstone with sedimentary structures. Banded chert-jasper, subordinate dolomite and sandstone
			Pokran Boulder Bed	Subrounded, ellipsoidal cobbles, pebbles and sandstone
Unconformity				
779–681 Ma	Malani Igneous Suite			

4. Systematic Ichnology

Ichnogenus *Furculosus* Roniewicz and Pieńkowski [7],
Furculosus carpathicus [7]

Diagnosis: Cylindrical burrow forming tight, U-Shaped with ending parallel or diverging.

Material: Well-preserved specimens from Nagaur Sandstone, Marwar Supergroup.

Locality: Dulmera village, Bikaner District, Rajasthan, India.

Description: The trace fossil (Figure 2B) consists of a well-defined U-shaped burrow composed of two parallel limbs connected by a smoothly curved basal segment. The structure is swollen in the middle portion and becomes progressively deeper and narrower toward both distal ends. The burrow measures 8–12 cm in total length, with the tubular diameter ranging from ~ 2 cm in the curved portion to ~ 1 cm along the straight limbs, producing an overall width of approximately 3 cm and a relief of 1.4 cm. The external surface is smooth and unornamented, lacking both transverse and longitudinal markings. The burrow is preserved as a hypichnial impression on the basal surface of a sandstone bed. It shows no branching, and the distal termini are gently tapering, consistent with the directed movement of the tracemaker. The pronounced U-shaped geometry and uniform morphology strongly support its interpretation as a deliberate dwelling or feeding trace.

Remarks: The specimen from the Nagaur Sandstone exhibits strong morphological affinity with *Furculosus carpathicus*, originally described by Roniewicz and Pieńkowski [7] from the Carpathians. While the Carpathian specimens are relatively small (4–7.5 cm in length, 1.6–3.2 cm in width, with loop diameters of 4–9 mm), the Nagaur trace is notably larger, potentially reflecting ontogenetic variation or substrate-dependent growth. Such size differences may also indicate variations in environmental conditions or nutrient availability influencing trace-maker behavior. Rather than being confined to a horizontal plane, the trace follows a low-angle surface at the sand–clay boundary, suggesting that the tracemaker exploited the interface between sediment layers while feeding. This behavior implies selective interaction with microenvironments within the substrate, possibly to access organic material concentrated along the lithological boundary. Figure 3B,C illustrates, respectively, the spatial distribution of the trace on the bed sole and a reconstruction of its three-dimensional form, highlighting its complex morphology. Overall, the Nagaur specimen not only expands the known size range of *F. carpathicus* but also provides insights into behavioral plasticity and substrate utilization of early benthic organisms in shallow-marine settings. Although the Nagaur specimen exceeds the size range of previously described material, it closely conforms to the diagnostic morphological attributes of *Furculosus carpathicus*. The increased size is interpreted as reflecting behavioral or environmental variability rather than ichnotaxonomic distinction, and therefore represents an expansion of the known size range of this ichnotaxon.

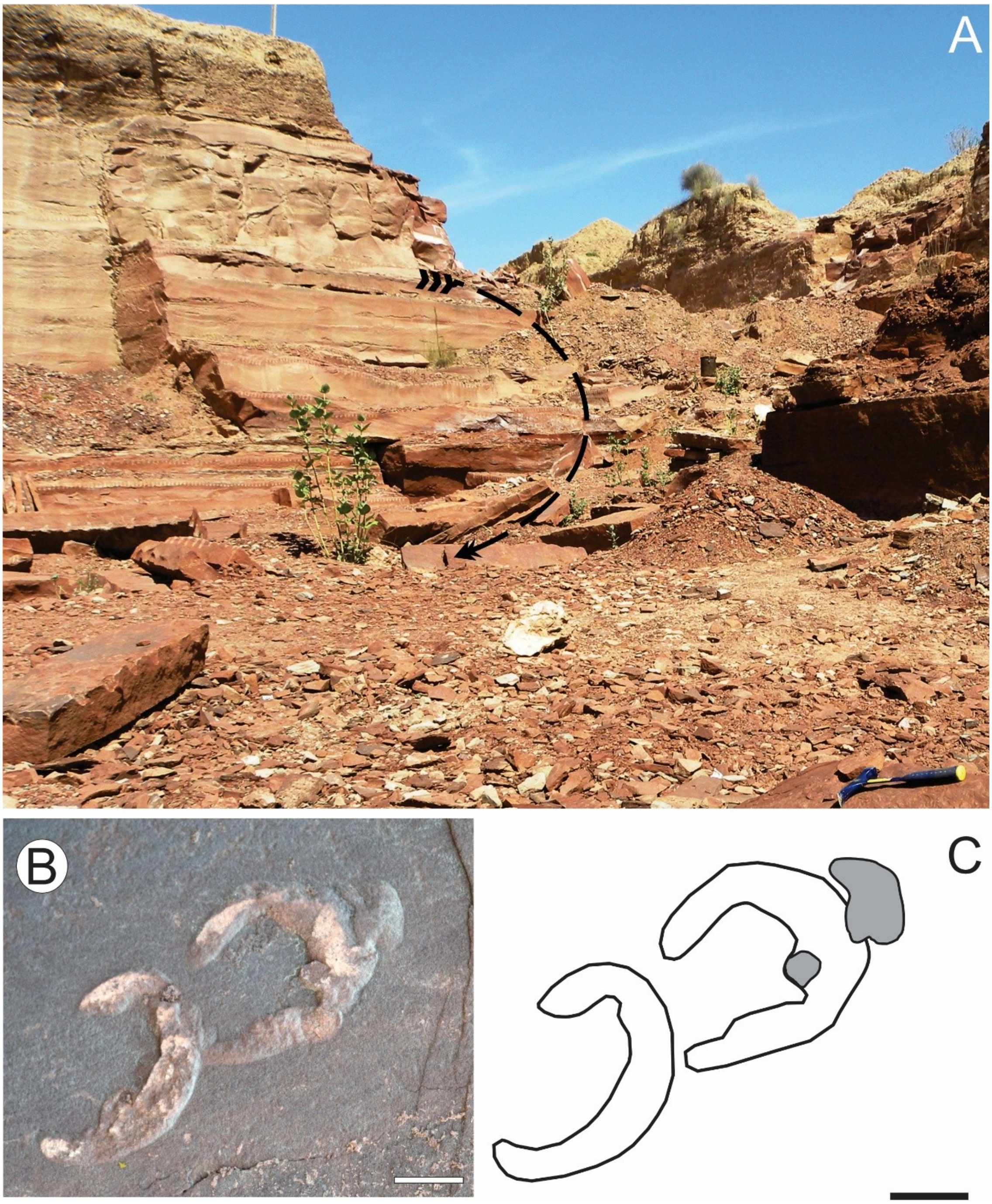

Figure 2. (**A**) Field photograph of Dulmera sandstone quarry from where the fossil discovered (see arrow for position). (**B**) Field photograph of the *Furculosus carpathicus* burrow preserved as hypichnial. **(C)** Line diagram of *Furculosus* trace fossil (for B and C-Scale bar $= 2$ cm).

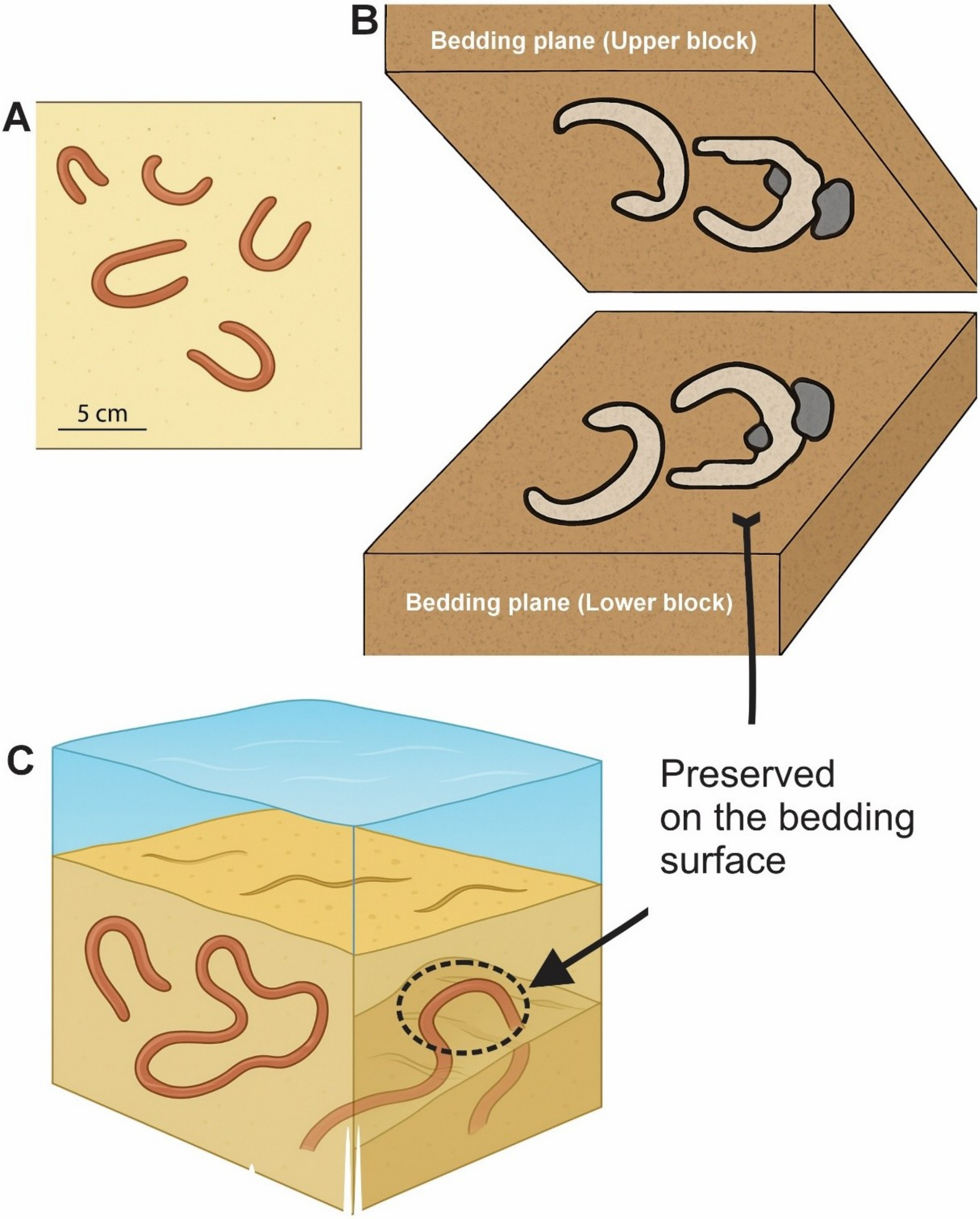

Figure 3. (**A**) surface view of schematic taphonomic model showing "U" shaped morphology. (**B**) Showing the two blocks (upper and lower bedding plane) to understand the preserved specimen. (**C**) A 3D visualization showing how the trace-maker formed the structure and how this morphology is expressed in the modern preserved specimen.

5. Distinction of *Furculosus* from Sedimentary Structures

To confirm *Furculosus* in the Nagaur Sandstone, we must closely examine both the sedimentology and the morphology to ensure it is not mistaken for branching sedimentary structures that naturally form in the rock. Ichnogenus *Furculosus* is characterized by regular, to forked tubular ridges of consistent diameter, smooth margins, and cross-cutting relationships indicative of deliberate biogenic behavior [7]. In contrast, fluid-escape structures, soft-sediment deformation features, load casts, and syneresis cracks typically lack internal architectural regularity, exhibit abrupt tapering or irregular terminations, and are often associated with deformation features such as dikes, dish structures, or injected fills [14, 15]. Diagnostic differentiation therefore depends upon (1) morphological consistency, including tube diameter, and surface texture; (2) sedimentary context, reflected in the absence of injected sand or pervasive deformation; and (3) stratigraphic relationships, such as cross-cutting or overprinting indicative of organismal activity rather than syn-depositional fluidization. Standard ichnological criteria and taphonomic reasoning should thus be applied [1, 16] to confirm a biogenic origin prior to referring any structure to *Furculosus*.

Furculosus is typically represented by a pair of gently diverging limbs forming a distinct U-shaped structure, on the soles of fine-grained sandstone beds. The specimens are smooth, and connected by a rounded apex that frequently exhibits faint spreiten-like lamination or meniscate backfill, reflecting systematic excavation behavior by a benthic infaunal organism. In contrast, sedimentary features such as fluid-escape structures or load casts reveal no evidence of behavioral patterning, lack spreiten or meniscate fill, and display highly variable geometries influenced by hydraulic or compactional stresses. Similarly, tool marks, groove casts, or current-aligned linear features are unidirectional and parallel to paleoflow, exhibiting sharp ridges or fluted terminations inconsistent with the symmetrical morphology of *Furculosus*. Furthermore, the consistent orientation and spacing of *Furculosus* traces on multiple bedding planes within the Dulmera section suggest repetitive biological activity rather than random physical processes. The combination of morphological regularity, internal structure, and stratigraphic recurrence collectively confirms the biogenic origin of *Furculosus*, distinguishing it decisively from abiogenic sedimentary features and affirming its ichnological identity as a true behavioral trace fossil.

5.1. Global Occurrences and Significance of Furculosus

Furculosus was first described from the Early Cambrian strata of the Carpathian region in Europe and later recognized in the Iberian Peninsula, Baltica, and Scandinavia. Reports from the Upper Paleocene of the Zumaya Section, Northern Spain [17, 18] documented occurrences from NLH, Spathian WP, Chaohu, Yangtze Gorge, south China. The new discovery from the Nagaur Sandstone in India represents the first occurrence from the Indian succession. The occurrence of *Furculosus* in the Nagaur Sandstone provides a valuable ichnostratigraphic marker for global correlation of early Cambrian shallow-marine sequences. The associated *Cruziana* Ichnofacies parallels those in the Iberian, Baltic, and Chinese successions, indicating synchronous colonization of stabilized substrates across continental shelves. This discovery strengthens correlations between the Marwar Supergroup and equivalent Cambrian successions in Southern China and other coeval successions, supporting the global extent of the early Cambrian substrate revolution [8]. Thus, the Indian occurrence of *Furculosus* adds a critical paleobiogeographic datapoint for reconstructing early benthic ecosystem expansion at the dawn of the Phanerozoic.

5.2. Taphonomy and Paleoecological Implications

The depositional model (Figures 2C and 3A–C) depicts *Furculosus* burrows formed within a foreshore environment. During fair-weather conditions, the substrate stabilized, allowing colonization by infaunal deposit feeders. The tracemaker excavated shallow, arcuate feeding burrows just below the sediment water interface, generating complex, bifurcating patterns. During episodic storm events sediments were reworked, obliterating earlier traces and depositing new sand layers. Post-storm stabilization enabled recolonization, producing overlapping ichnofaunal assemblages dominated by *Furculosus* and *Planolites*. This cyclic colonization behavior indicates adaptive exploitation of transient nutrient-rich substrates and underscores the growing complexity of early Cambrian benthic communities [19].

5.3. Principal Component Analysis (PCA) Interpretation

The Principal Component Analysis (PCA) of the morphometric dataset reveals that the majority of variation among the 25 measured specimens is strongly size dependent (Figure 4). The first principal component (PC1) accounts for 91.5% of the total variance, indicating that variation in length, width, relief, and distance between curved ends is highly correlated and collectively define a single dominant axis of morphological change. All variables load positively on PC1, confirming that this component primarily represents overall enlargement or reduction of the trace morphology rather than changes in shape proportions.

The second principal component (PC2) explains an additional 6.0% of variance and is driven mainly by the contrasting contribution of distance between curved ends relative to the other dimensions. This suggests that PC2 captures subtle shape-related differences, particularly reflecting variations in the terminal curvature spacing independent of general size. However, the low variance associated with PC2 indicates that such shape modifications are minor within the assemblage. The PCA scatter plot shows a compact cluster of points along PC2 and an elongation along PC1, illustrating that specimens differ predominantly in size while maintaining similar overall proportions. The limited spread along PC2, PC3, and PC4 further supports the interpretation of low morphological disparity and a morphologically conservative assemblage. This pattern may reflect consistent behavioral patterns of the trace-making organism, uniform substrate conditions, or a single ichnotaxonomic affinity across the sampled, specimens, conclusively, PCA demonstrates that size variation is the primary driver of morphological differences, with only minor contributions from shape attributes. This size-dominated morphospace aligns with a relatively uniform and functionally similar group of trace fossils.

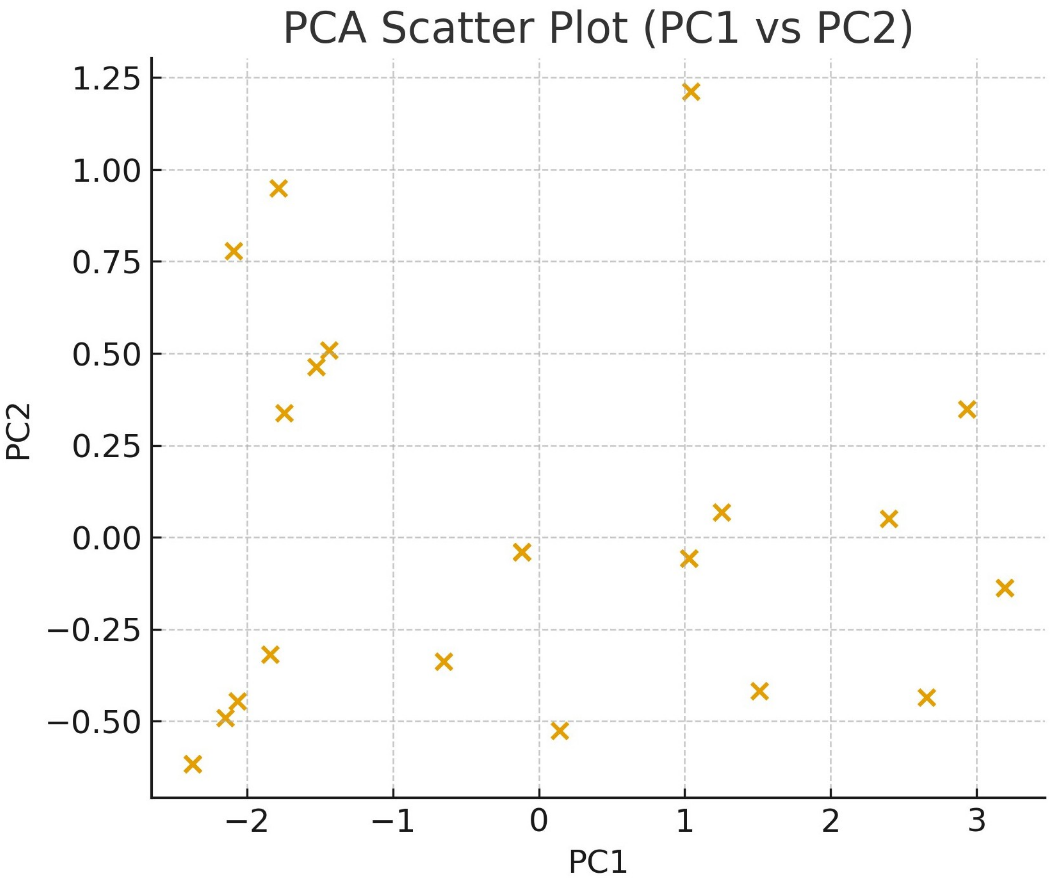

Figure 4. PCA plot of standardized morphometric data showing specimen distribution along PC1 (91.5%) and PC2 (6.0%). The clustering indicates low morphological variability and strong size control on overall trace fossil form.

6. Discussion

The Marwar Supergroup specimen differs substantially from the *Furculosus* morphotype, which has been interpreted as the preserved distal, sub-horizontal segment of the much larger U-shaped burrow system of *Tisoa siphonalis* [20]. Although morphological similarities between *Furculosus* and *Tisoa* have been discussed in the context of preservational variability [20], both remain distinct ichnogenera, differing fundamentally in burrow architecture, internal organization, and taphonomic expression; the Nagaur specimens clearly conform to the diagnostic morphology of the present trace fossil. *Furculosus carpathicus* is characterized by cylindrical, tightly looping, fork-like U-shaped tubes with parallel or slightly diverging ends, typically occurring along the sand–clay boundary at the base of sandstone beds. These structures represent only the terminal, horizontal loops of a more complex burrow architecture. In contrast, the specimen from the Marwar Supergroup preserves the entire U-shaped configuration, including a swollen central curvature, progressively tapering distal limbs, and a clearly expressed hypichnial relief. Rather than a simple fork-like loop, it constitutes a fully developed U-shaped domichnion, lacking the tight curvature and repeated horizontal inflections characteristic of *Furculosus*. Furthermore, the Cambrian age of the Marwar Supergroup aligns with the established stratigraphic range of *Tisoa* extending from the Cambrian to the Recent rather than with the Oligocene age of *Furculosus* sensu stricto. These combined morphological and stratigraphic distinctions support assignment of the trace to the broader *Tisoa* morphotype rather than to the restricted *Furculosus* expression. Although *Furculosus* was originally described from Oligocene strata, its morphology reflects a behavioral strategy rather than a body-fossil lineage [7]. Trace fossils commonly possess extensive stratigraphic ranges because similar infaunal behaviors may evolve repeatedly among unrelated organisms. As noted by [20], the features attributed to *Furculosus* represent only the distal, horizontal expression of the U-shaped burrow system of *Tisoa siphonalis*. Consequently, the appearance of a comparable U-shaped architecture in the Cambrian Marwar Supergroup is fully consistent with ichnological principles and reflects either the long-term persistence or the convergent emergence of similar feeding and dwelling behaviors. The Cambrian specimen therefore records an early manifestation of this behavioral repertoire rather than an anomaly in stratigraphic occurrence.

The occurrence of this *Furculosus* form in the Nagaur Sandstone at Dulmera constitutes an important addition to the ichnological record of the Indian Cambrian. Its association with *Planolites*, *Palaeophycus* *tubularis*, and *Diplocraterion* is indicative of the Cruziana Ichnofacies, typically developed under fair-weather wave-base conditions within the lower shoreface [4]. Although U-shaped burrows are commonly interpreted as domichnia, the tightly coiled, forked looping architecture of the Nagaur *Furculosus* trace indicates repeated sediment reworking and feeding-related substrate exploitation. The structure is therefore interpreted as reflecting predominantly fodinichnial behavior, possibly combined with temporary dwelling activity, within a Cruziana Ichnofacies setting. Its geometry suggests methodical grazing behavior involving lateral movement and periodic reorientation, consistent with the substrate exploitation strategies that proliferated during the early Cambrian Substrate Revolution. The Dulmera ichnoassemblage underscores the expansion of complex infaunal behavior into shallow-marine siliciclastic settings across the Indian subcontinent [11, 21]. The alternating storm-generated beds and fair-weather colonization surfaces point to repeated episodes of substrate disturbance and recolonization, reflecting dynamic benthic ecosystem restructuring in early Cambrian seas [22].

7. Conclusions

Furculosus is reported for the first time from the Nagaur Sandstone (Marwar Supergroup) near Dulmera village, Bikaner District, thereby extending its palaeogeographic range and global distribution to the Indian subcontinent. The morphometric evaluation, supported by PCA, demonstrates that the assemblage exhibits predominantly size-controlled variation with minimal shape disparity, reinforcing the taxonomic consistency of the material and affirming its ichnological affinity with previously documented *Furculosus* specimens worldwide. The strong size-dominated signal revealed by PCA underscores a stable behavioral pattern and uniform mode of substrate interaction, consistent with a systematic deposit-feeding strategy characteristic of early Cambrian infaunal organisms, and clearly distinguishes these traces from abiotic sedimentary structures.

This occurrence represents a significant ichnostratigraphic marker, facilitating high-resolution correlation of early Cambrian shallow-marine successions across regions such as South China, Australia, and South America. The ichnodiversity and morphometric coherence observed in the Nagaur Sandstone provide critical insights into the behavioral diversification of early bilaterians during the Cambrian Substrate Revolution, typifying the Cruziana Ichnofacies and reflecting a shallow-marine, lower-shoreface depositional environment. The well-preserved traces, coupled with their tightly clustered morphospace, suggest organized foraging behavior and advanced substrate exploitation strategies, marking an important phase in early metazoan ecological evolution.

This contribution is particularly important as it bridges a major palaeobiogeographic gap in the ichnological record of the Indian subcontinent and strengthens the global framework for correlating early Cambrian ecosystems. By documenting the emergence of complex infaunal activity and enhanced sediment utilization and by quantitatively demonstrating morphological stability through PCA this study provides robust evidence of India's integral role in the worldwide narrative of the Cambrian Substrate Revolution. It underscores how regional ichnological and morphometric data from the Marwar Basin can refine global models of early metazoan ecological innovation, substrate colonization, and environmental transformation at the dawn of complex animal life.

Author Contributions

S.A.: Conceptualization; Investigation, Methodology; Writing original draft; S.K.P.: Supervision; Project administration, Validation; Writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or non-for-profit sectors.

Institutional Review Board Statement

Not applicable

Informed Consent Statement

Not applicable.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgement

S.A., S.K.P. acknowledges and appreciates the support from the Director of BSIP, for providing facilities to carry out the investigation and permission to publish this work. S.A. acknowledges the CSIR, New Delhi, for financial support received in the form of Senior Research Associateship (Pool Scientists' Scheme, Id No. 3510103; file no 13(9232-A)/2023-Pool).

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

References

1. Buatois, L.A.; Mángano, M.G. *Ichnology: Organism–Substrate Interactions in Space and Time*; Cambridge University Press: Cambridge, UK, 2011.

2. Seilacher, A. *Trace Fossil Analysis*; Springer-Verlag: Berlin, Germany, 2007.
3. Ahmad, S.; Kumar, S. Trace fossil assemblage from the Nagaur Group, western India. *J. Palaeontol. Soc. India* **2014**, *59*, 231–246. https://doi.org/10.1177/0971102320140208
4. Ahmad, S.; Pandey, S.K.; Sharma, M.; et al., The early cambrian (series 2, stage 3) burrows from the Nagaur Sandstone, Marwar Supergroup, Rajasthan, India: Palaeoenvironmental and Palaeoecological considerations. *J. Palaeontol. Soc. India* **2021**, *66*, 271–289. https://doi.org/10.1177/0971102320210212
5. Kumar, S.; Pandey, S. K. Trace fossils from the Nagaur Sandstone, Marwar Supergroup, Dulmera area, Bikaner District, Rajasthan, India. *J. Asian Earth Sci.* **2010**, *38*, 77–85. https://doi.org/10.1016/j.jseaes.2009.10.003
6. Srivastava, P. *Treptichnus pedum*: An Ichnofossil representing Ediacaran–Cambrian boundary in the Nagaur group, the Marwar supergroup, Rajasthan, India. *Proc. Natl. Acad Sci. USA* **2012**, *78*, 161–169.
7. Roniewicz, P.; Pieńkowski, G. Trace fossils of the Podhale Flysch Basin. In *Trace Fossils 2*; Crimes, T.P., Harper, J.C., Eds.; Geological Journal Special Issue 9; Seel House Press: Liverpool, UK, 1977; pp. 273–288.
8. Bottjer, D.J.; Hagadorn, J.W.; Dornbos, S.Q. The Cambrian Substrate Revolution. *GSA Today* **2000**, *10*, 1–7.
9. Pareek, H. S. *Pre-Quaternary Geology and Mineral Resources of Northwestern Rajasthan*; Memoirs of the Geological Survey of India 115; Geological Survey of India: India, 1984; pp. 1–99.
10. Kumar, S. Stratigraphy and correlation of the Neoproterozoic deposits of central and western India: An overview. *Geol. Soc. Spec. Publ.* **2012**, *366*, 75–90. https://doi.org/10.1144/SP366.6.
11. Sharma, M.; Ahmad, S.; Pandey, S.K.; et.al., On the Ichnofossil *Treptichnus pedum*: Inferences from the Nagaur Sandstone, Marwar Supergroup, India. *Bull. Geosci.* **2018**, *93*, 305–325. https://doi.org/10.3140/bull.geosci.1666.
12. Kumar, S.; Pandey, S.K. Discovery of trilobite trace fossils from the Nagaur Sandstone, the Marwar Supergroup, Dulmera area, Bikaner district, Rajasthan. *Curr. Sci.* **2008**, *95*, 1081–1085.
13. Hughes, N.C. The Cambrian Palaeontological record of the Indian subcontinent. *Earth-Sci. Rev.* **2016**, *159*, 428–461. https://doi.org/10.1016/j.earscirev.2016.06.004
14. Buck, S.G.; Goldring, R. Conical sedimentary structures, trace fossils or not? Observations, experiments, and review. *J. Sediment. Res.* **2003**, *73*, 338–353. https://doi.org/10.1306/091602730338
15. Pratt, B.R. Syneresis cracks: Subaqueous shrinkage in argillaceous sediments caused by earthquake-induced dewatering. *Sediment. Geol.* **1998**, *117*, 1–10. https://doi.org/10.1016/S0037-0738(98)00023-2
16. Knaust, D.; Bromley, R.G., Eds. *Trace Fossils as Indicators of Sedimentary Environments*; Developments in Sedimentology, Volume 64; Elsevier: Amsterdam, The Netherlands, 2012; pp. 79–101.
17. Chen, Z.-Q.; Tong, J.; Fraiser, M.L. Trace fossil evidence for restoration of marine ecosystems following the end-Permian mass extinction in the Lower Yangtze region, South China. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2011**, *299*, 449–474. https://doi.org/10.1016/j.palaeo.2010.11.023
18. Giannetti, A.; McCann, T. The upper Paleocene of the Zumaya section (Northern Spain): Review of the ichnological content and preliminary palaeoecological interpretation. *Ichnos* **2010**, *17*, 137–161. https://doi.org/10.1080/10420941003659550
19. Pemberton, S.G.; Frey, R.W. Quantitative methods in ichnology: Spatial distribution among populations. *Lethaia* **1984**, *17*, 33–49. https://doi.org/10.1111/j.1502-3931.1984.tb00663.x
20. Knaust, D. The enigmatic trace fossil *Tisoa de Serres*, 1840. *Earth-Sci. Rev.* **2019**, *188*, 123–147. https://doi.org/10.1016/j.earscirev.2018.11.001
21. Paliwal, B.S. The Marwar Supergroup: An appraisal of its stratigraphy, sedimentology and basin evolution. *J. Geol. Soc. India* **2008**, *72*, 327–338. https://doi.org/10.1016/10.17491/jgsi/2008/720132
22. Mángano, M.G.; Buatois, L.A. The rise and early evolution of animals: Where do we stand from a trace-fossil perspective? *Interface Focus* **2020**, *10*, 20190103. https://doi.org/10.1098/rsfs.2019.0103