Finkoella: a sack-like Ediacaran soft-bodied fossil from the Marwar Supergroup, western Rajasthan, India

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The present study reports the well-preserved Ediacaran sack-like soft-bodied fossils assigned as *Finkoella ukrainica* and *Finkoella oblonga* from the Sonia Formation of the Jodhpur Group, Marwar Supergroup, western Rajasthan, India. The *F. ukrainica* is found in elliptical, ovate-shaped and sometimes oblong or cucumber-shaped forms with a distinct short neck, and a small circular protrusion or depression may be present on the organism. *F. oblonga* is elongated, ovate to cucumber-shaped fossil specimen with poorly preserved six longitudinal low grooves and ridges arranged parallel to the marginal ridges of the organism. Both *F. ukrainica* and *F. oblonga* are also well comparable to the type materials of Ukraine in the preservation of concave (negative relief) and convex (positive relief) with oral/atrial siphons, double marginal ridges/grooves and elevated edges in the Sonia Formation. The *Finkoella* fossil remains are believed to be the flattened bodies of tunicate organisms. Similar sack-shaped *Burykhia* fossils recorded in the White Sea of Russia contrasted to sponges and similar hollow-shaped organisms have been interpreted and compared with lichenized fungi and fungal affinity. Thus, the biological affinity of the *Finkoella* organism is still unresolved.

Keywords: Ediacaran, *Finkoella*, Marwar Supergroup, sack-like bodied fossil, tunicate organisms, western Rajasthan.

THE globally occurring strata of the middle to late Ediacaran Period contain the oldest macroscopic, soft-bodied morphologically complex multicellular organisms that have been listed in the Ediacaran Biota[1–5]. These Ediacaran organisms probably represent a wide range of eukaryotic groups, including the stem group and crown group of bilaterian metazoans, algae, lichens and extinct clades in the early evolution of complex life forms[2,6–8]. In western Rajasthan, the Sonia Formation is best exposed through open-cast sandstone mining in the Sursagar area of Jodhpur district to preserve Ediacaran fossil forms such as *Aspidella*[9,10], *Hiemalora stellaris*[11], large Ediacaran discs[12,13], trilobozoan organisms[13,14], *Thectardis avalonensis*[15], *Parvancorina*[16], *Nimbia*[17] and various algal mat-structures[13,18]. This article describes the soft-bodied sack-like fossil remains attributed to *F. ukrainica* and *F. oblonga* from medium- to fine-grained sandstone facies of the Sonia Formation (exposed in the Sursagar area) of the Jodhpur Group of the Marwar Supergroup. The studied fossil-bearing Sursagar area is located about 8 km to the north of Jodhpur district, western Rajasthan, India (Figure 1). The gathered representative samples of *Finkoella* have been housed in the Department of Geology, Jai Narain Vyas University, Jodhpur, as repositories labelled as DG/JNVU/MSG/FN-437 (Figure 2 *h*) and DG/JNVU/MSG/FN-438 (Figure 2 *i*). The present study aims to report the fossil remains of both *F. ukrainica* and *F. oblonga* species in the Sonia Formation with systematic palaeontology and correlations to the described *Finkoella* organisms from their type locality, i.e. the upper Ediacaran shallow-marine deposits of Lomozov and Yampol members of the Mogilev Formation of Ukraine[19].

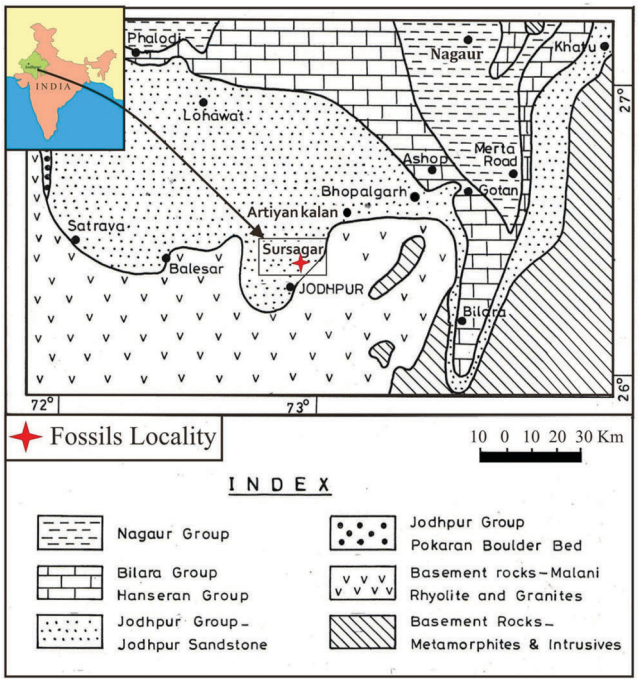

Figure 1. Geological map of western Rajasthan showing distribution of rocks of the Marwar Supergroup and location of *Finkoella* Ediacaran organisms bearing Sonia Sandstone exposed at Sursagar area of Jodhpur district[19].

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Geology of the study area

The unmetamorphosed and undeformed rocks of the Marwar Supergroup (MSG) were formerly known as the 'Trans-Aravalli Vindhyans'[20]. It is around 1000 m thick and comprises mainly arenaceous and calcareous sediments with evaporite deposits[21,22]. MSG occupies a large area in the northwest of Rajasthan, including Jodhpur, Pali, Khatu, Bilara, Nagaur, Phalodi, Pokaran, Bikaner and Jaisalmer[22–24]. The Marwar Supergroup unconformably overlies on the Malani igneous suites, which have been dated from 780 to 680 Ma (refs 25, 26); 771 ± 05 Ma (ref. 27) and is underlain by permo-carboniferous bap boulder beds[22]. MSG is separated into three groups: the basal Jodhpur Group, the middle Bilara Group and the Nagaur Group at the top[22]. The Jodhpur Group is stratigraphically divided into the Pokaran Boulder Bed, the Sonia Formation, and the Girbhakar Formation. By stratigraphic order, the Bilara Group is divided into the Dhannapah dolomite, Gotan limestone and Pondlo dolomite formations, and the Nagaur Group is divided into the lower Nagaur Formation and the upper Tunklian Formation[22] (Table 1). The strata of the Sonia Formation are less disturbed, almost horizontal, and contain coarse- to fine-grained sandstone, siltstone, shale, and a few conglomeratic sandstone beds[24]. The sandstones of the Sonia Formation are mostly made up of quartz arenite facies and exhibit excellent preservation of sedimentary structures like laminations, various ripple-marks, cross-beddings, tough cross-bedding, graded bedding and rain-prints[24,28]. The Ediacaran age has been suggested for Sonia Sandstone based on the previous records of the Ediacaran fossil forms[9–17,29,30]. According to an isotopic analysis of Bilara carbonates, the Bilara Group is believed to be Late Ediacaran to Early Cambrian in age[31], but the Nagaur Group has been ascribed an Early Cambrian age based on trilobite trace fossils[32]. The recorded *F. ukrainica* and *F. oblonga* fossil remains bearing the Sonia Formation are exposed in the Sursagar area of Jodhpur district, western Rajasthan (Figure 1). A generalized lithostratigraphic section of *Finkoella* fossil remains with other Ediacaran fossil assemblages bearing the Sonia Formation of the Sursagar area is given in Figure 3.

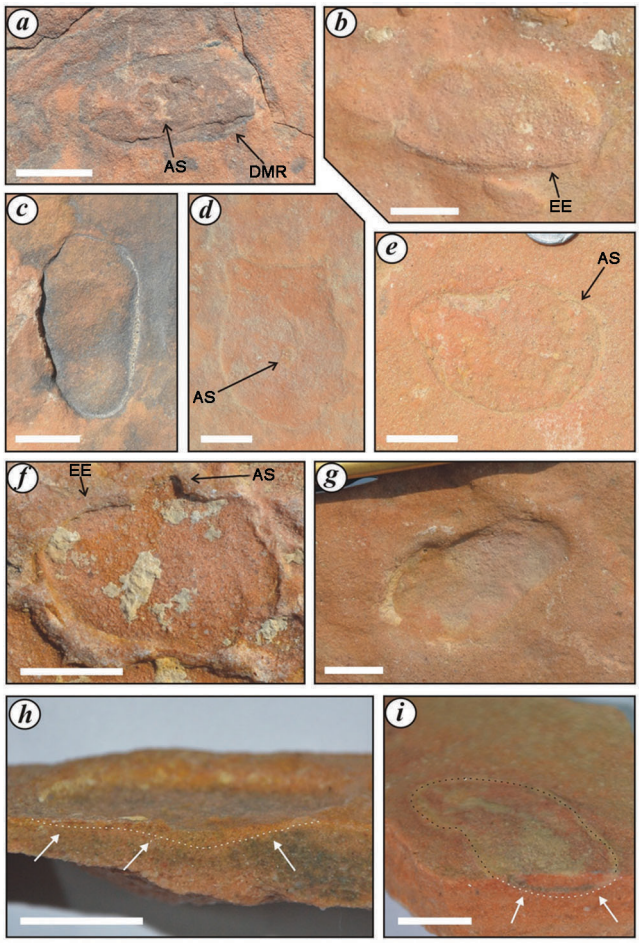

Figure 2. ***a***, Field photograph of *F. ukrainica* is found with atrial siphon (AS) and double marginal ridge (DMR). ***b***, Field photograph of *F. ukrainica* specimen is preserved with elevated edges (EE). ***c***, Field photograph of *F. ukrainica* specimen is preserved with negative relief. ***d***, ***e***, Close-up views of *F. ukrainica* specimens are occurred with oral siphon (OS) and AS, sharp marginal boundaries, and one end of the organism being more elongated while the other opposite end is more rounded. ***f***, Field photograph of *F. ukrainica* specimen occurred with a small circular depression (AS) and sharp EE. ***g***, Field photograph of *F. oblonga* shows it as an elongated ovate to cucumber-shaped organism with poorly preserved six longitudinal low ridges and grooves that are positioned parallel to the organism's peripheral ridges. ***h***, Cross-section view of medium to fine-grained sandstone which in dark-brownish layer showing organic matter of the *F. ukrainica* organism (DG/JNVU/MSG/FN-437) marked with white outlines which clearly differentiates the host rocks sediments. ***i***, Cross-section view of medium to fine-grained sandstone which in dark-brownish to greyish layer showing organic matter of the *F. ukrainica* organism (DG/JNVU/MSG/FN-438) marked with white out-lines and clearly differentiates the host rocks sediments. Scale: Bar is equal to 2 cm.

Systematic palaeontology

Genus: *Finkoella*[19].

Type species: *Finkoella ukrainica*[19].

Finkoella ukrainica (Figures 2 *a–f*, *h*, *i* and 4 *a–f*).

Materials: Twenty specimens were measured on medium- to fine-grained sandstone slabs of the Sonia Formation.

Description: The *Finkoella ukrainica* are found in oval to elliptical shapes (Figures 2 *d*, *e*, *i* and 4) and sometimes oblong or cucumber-shaped (Figure 2 *a–c*) with a distinct short neck (Figure 4 *a*) and a small circular protrusion or depression may be present on the organisms. These are preserved with convex/positive relief (Figures 2 *a*, *b*, *d*, *e*, *i* and 4 *a–f*) and concave/negative relief (Figure 2 *c*, *f*, *h*) in medium- to fine-grained sandstone bedding planes of the Sonia Formation. Generally, these structures have

Table 1. Stratigraphic succession of the Marwar Supergroup, Western Rajasthan, India[22]

Permo-carboniferous	Bap boulder bed	Rounded, sub-rounded, ellipsoidal pebbles and cobbles	
Marwar Supergroup (Late Neoproterzoic to Early Cambrian)	Nagaur Group (75–500 m)	Tunklian Sandstone Nagaur Sandstone	
	Hanseran Group (up to 60 m)	Clay stone, silt stone, dolostone, anhydrite, halite	
	Bilara Group (100–300 m)	Pondlo dolomite Gotan limestone Dhanapah dolomite	
	Jodhpur Group (125–340 m)	Girbhakar Sandstone	Buff, brownish, purplish to reddish white, spotted, gritty, pebbly, massive to thickly bedded sandstone and siltstone sequence.
		Sonia Sandstone	Yellowish brown, purple, pinkish brown medium to fine grained, fine grained sandstone, brown siltstone and shale and few conglomeratic beds.
		Pokaran Boulder Beds	Sandstone, silty and shaly sandstone. Massive conglomerate, boulder spread and stratified conglomerate.
Malani igneous suite: 780–680 Ma (refs 25, 26) and 771 ± 05 Ma (U–Pb)[27]			

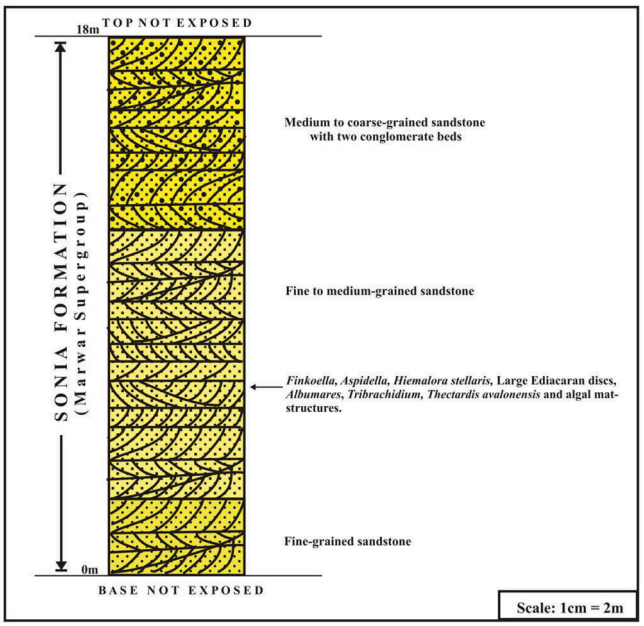

Figure 3. A generalized lithostratigraphic section of Sonia Sandstone of Jodhpur Group of the Marwar Supergroup showing *Finkoella* organisms with other Ediacaran fossil assemblages bearing horizons[9].

smooth surfaces and sharp marginal boundaries, and one end of the organism is more elongated, whereas the other opposite end is more rounded (Figures 2 *d*, *e*, *i* and 4 *a*, *c*, *e*). In one specimen of *F. ukrainica*, a well-preserved short neck (about 4 mm long and 8 mm wide) has been found on the more rounded end of the organism (Figure 4 *a*). A short, protruded part has also been found on the more elongated end of the organisms (Figure 2 *d*, *e*). Generally, a small knob-like protrusion (Figures 2 *a*, *e* and 4 *c*) and a small knob-like depression (Figure 4 *a*, *e*) are present on the central part of the organisms (Figures 2 *a*, *d* and 4 *a*, *c*, *e*), as well as in one specimen where this may be found on the more rounded end (Figure 2 *e*). Most of the *F. ukrainica* found here has sharp, distinct marginal boundaries (Figures 2 *c–f*, *h*, *i* and 4 *a*, *e*), as well as some with sharp elevated edges (EE) that are 2–4 mm wide (Figures 2 *a*, *b*, *e* and 4 *c*, *e*). The eleven specimens of *F. ukrainica* illustrated here have length × width measurements of 40 mm × 23 mm (Figure 4 *a*), 70 mm × 45 mm (Figure 4 *c*), 80 mm × 50 mm (Figure 4 *e*), 55 mm × 25 mm (Figure 2 *a*), 80 mm × 45 mm (Figure 2 *b*), 70 mm × 35 mm (Figure 2 *c*), 90 mm × 50 mm (Figure 2 *d*), 60 mm × 35 mm (Figure 2 *e*), 50 mm × 35 mm (Figure 2 *f*), 35 mm × 20 mm (Figure 2 *h*) and 35 mm × 30 mm (Figure 2 *i*) respectively, and exhibit variable sizes.

Remarks: These sack-like soft-bodied fossil specimens examined here are assigned as *F. ukrainica* because they closely resemble the diagnostic characteristics of *F. ukrainica* described from the Lomozov and Yampol members of the upper Ediacaran shallow-marine Mogilev Formation of Ukraine[19]. These specimens are also well comparable to the type materials[19] preserved with convex (positive relief) and concave (negative relief) in medium- to fine-grained sandstone bedding planes, as well as one specimen preserved with shale intraclasts (Figure 2 *a*) of the Sonia Formation. The present *F. ukrainica* specimens in Sonia Sandstone have significantly larger length ranges of 40–90 mm and width ranges of 20–50 mm than the type material, i.e. length ranges of 5–110 mm and width ranges of 5–55 mm (ref. 20). These *F. ukrainica* have shown gregarious characteristics in their type locality, i.e. the upper Ediacaran shallow-marine deposits of Lomozov and Yampol members of the Mogilev Formation in Ukraine[20]. Still these are scattered in the Sonia Formation with the other Ediacaran taxa.

Occurrences: Yellowish-pinkish brown medium- to fine-grained sandstone bedding planes of the Sonia Formation of the Jodhpur Group, Marwar Supergroup, which are exposed in the Sursagar area of Jodhpur District, western Rajasthan, India.

Finkoella oblonga sp. (Figure 2 *g*).

Materials: One specimen was measured on medium- to fine-grained sandstone slab of the Sonia Formation.

Description: In the Sonia Formation, one specimen of *F. oblonga* is found as an elongated ovate to cucumber-shaped specimen with poorly preserved six longitudinal low ridges and grooves positioned parallel to the organism's peripheral ridges (Figure 2 *g*). These six longitudinal low ridges and grooves have disappeared towards the semi-circular distal end. Still, the larger part of the fossil specimen is covered with mineral grain corrugations without any patterns. The *F. oblonga* is preserved with concave (negative) relief (Figure 2 *g*) on medium- to fine-grained sandstone bedding planes. In the Sonia Formation, the *F. oblonga* specimen has been recorded with a length × width of 90 mm × 40 mm (Figure 2 *g*). The organism's elevated or depressed edges are usually shown as double ridges that are clear, distinct and 2–3 mm wide (Figure 2 *g*).

Remarks: These elongated ovate (cucumber-shaped) fossil specimens examined here are assigned as *Finkoella oblonga* because they closely resemble the diagnostic characteristics of *F. oblonga*, described from the upper Ediacaran shallow-marine deposits of Lomozov and Yampol members of the Mogilev Formation of Ukraine[19]. The *F. oblonga* (Figure 2 *g*) is also well comparable to the type materials of Ukraine[19] as preserved with concave (negative relief), double marginal ridges (DMR) and elevated edges (EE) on medium- to fine-grained sandstone bedding planes of the Sonia Formation.

Occurrences: Yellowish-pinkish brown medium- to fine-grained sandstone bedding planes of the Sonia Formation of the Jodhpur Group, Marwar Supergroup, which are exposed in the Sursagar area of Jodhpur District, western Rajasthan, India.

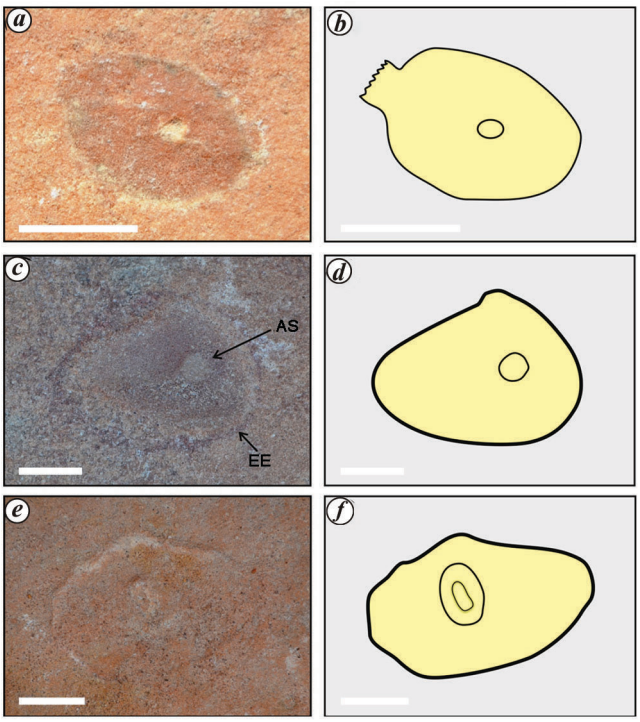

Figure 4. ***a***, Field photograph of a well-preserved *F. ukrainica* specimen occurred as in oval to elliptical shapes with a distinct short neck and a small circular depression present on the organism. ***b***, Sketch diagram of *F. ukrainica* specimen shown in Figure 4 *a*. ***c***, Field photograph of *F. ukrainica* specimen occurred as with a small circular protrusion (AS) and sharp EE. ***d***, Sketch diagram of *F. ukrainica* specimen shown in Figure 4 *c*. ***e***, Close-up view of oval and elliptical shape *F. ukrainica* specimen is found in medium- to fine-grained sandstone bedding planes of the Sonia Formation in the Sursagar area. ***f***, Sketch diagram of *F. ukrainica* specimen shown in Figure 4 *e*. Scale: Bar is equal to 2 cm.

Discussions

The *Finkoella* organisms are believed to be flattened bodies of tunicate organisms based on their overall morphology, like the sack-shaped soft-bodied with two siphons and have similarities with the tunicate organisms of the Ascidiacea group[19]. The short, sharp or distinct neck of *Finkoella* has been considered as an oral (inhalant) siphon (Figure 4 *a*), whereas a small circular or knob-like protrusion or depression present on the central part of the *Finkoella* organisms has been considered as an atrial (exhalant) siphon (Figures 2 *a*, *d*, *e* and 4 *a*, *c*, *e*). The EE (Figures 2 *b*, *e* and 4 *c*) and double marginal ridges/grooves (DMR/DMG) (Figure 2 *a* and *f*) are the remains of compressed elastic sacks. They can be considered tunica of the tunicate organisms. The bulges or bumps of the fossil specimens of *Finkoella* organisms can be interpreted as the internal organs of tunicate organisms[19]. Fedonkin *et al.*[33] describe a similar sack-shaped fossil, *Burykhia*, from the Vendian White Sea of Russia and contrast it with sponges. Similar hollow-shaped organisms have been interpreted and compared with lichenized fungi and fungal affinity[6,34]. However, the *Finkoella* organism is still a problematic Ediacaran animal, like many other Ediacaran organisms, so the biological affinity of the *Finkoella* organism is still unresolved.

The presently recorded fossil remains of *Finkoella* organisms (both forms, i.e. *F. ukrainica* and *F. oblonga*) have been reported from the bedding planes of medium- to fine-grained sandstone, as well as one specimen preserved with shale intraclasts (Figure 2 *a*) in the Sonia Sandstone of the Jodhpur Group of the Marwar Supergroup. These sandstone strata consist mostly of quartz arenitic, with intercalations of shale and siltstone (Figure 3). These sandstone strata have been formed by the lithification of medium- to fine-grained sediments in the Marwar Basin, which were floored with microbial mats during the Ediacaran period. The *Finkoella* organisms have been buried in dead or alive forms in the Sonia Formation. Then, throughout the fossilization process (taphonomic events), they were somewhat

squashed by the weight of the sediments and cast by sandstones, with three-dimensional preservation aided/facilitated by organic-rich silica deposition[35] and covered by the algal or microbial mats (Figures 2 and 4). These organic-rich silicas have been preserved in the *F. ukrainica* and *F. oblonga* species as fossil specimens in terrestrial to marginal-marine environmental settings. The possibility of these *Finkoella* organisms being inorganic in origin is also ruled out, as they do not resemble inorganic structures. Here, in Figure 2 *h*, the *Finkoella* organism is preserved with negative relief, and in Figure 2 *i*, the *Finkoella* organism is preserved with positive relief in medium- to fine-grained sandstone. In cross-section, the dark-brownish layer (Figure 2 *h*) and dark-brownish to greyish layers (Figure 2 *i*) show the organic matter of these organisms, marked by white-coloured outlines that differentiate it from the host rock sediments of the medium- to fine-grained sandstone. These preserved organic matters of *Finkoella* organisms (Figure 2 *h* and *i*) in medium- to fine-grained sandstone of the Sonia Sandstone of the Marwar Supergroup rule out its sedimentary origin.

The *Finkoella* (sack-like soft-bodied) fossils were originally described from the upper Ediacaran shallow-marine deposits of Lomozov and Yampol members of the Mogilev Formation of Ukraine[19]. In the present study, *Finkoella* (both *F. ukrainica* and *F. oblonga* species) fossils have been found in yellowish-pinkish brown medium- to fine-grained sandstone strata of the Sonia Sandstone. These sandstone strata also have various types of ripple marks with mostly remains of Ediacaran benthic organisms such as *Aspidella*[9,10], *Hiemalora stellaris*[11], large Ediacaran discs[12,13], trilobozoan organisms[13,14], *Thectardis avalonensis*[15], *Parvancorina*[16], *Nimbia*[17] and various algal mat-structures[13,18]. The Sonia Formation consists of light brown, yellowish to pinkish brown and reddish brown sandstones with intercalations of maroon to reddish brown shales and siltstones and is thought to have formed in a deltaic and beach environment[24,28]. According to Chauhan[24], the overlying Girbhakar Formation is composed of gritty and pebbly sandstone of fluvial origin. The Sonia Formation also contains thin patches or beds of maroon-to-reddish-brown shales and siltstone between the *Finkoella* and other Ediacaran fossil-bearing sandstone strata (Figure 3) and implies paleosol depositional models. Therefore, this study suggests that the Sonia Formation of the Jodhpur Group of the Marwar Supergroup was deposited in terrestrial to marginal-marine environments with moderate hydrodynamics.

Conclusions

In this study, two species of sack-shaped soft-bodied *Finkoella* organisms (*F. ukrainica* and *F. oblonga*) have been documented from the Sonia Formation of the Jodhpur Group, Marwar Supergroup, western Rajasthan, India. This is the first discovery of Ediacaran fossil remains of *Finkoella* organisms in India after the Ukraine. This occurrence of *Finkoella* organisms in Sonia Formation has significantly larger length ranges of 40–90 mm and width ranges of 20–50 mm than the type material, i.e. length ranges of 5–110 mm and width ranges of 5–55 mm (ref. 20), which suggests their adult forms are found in Sonia Formation.

These *Finkoella* organisms have shown gregarious characteristics in their type locality, i.e. the upper Ediacaran shallow-marine deposits of Lomozov and Yampol members of the Mogilev Formation in Ukraine[19]. Still, here in the Sonia Formation, they are found in scattered form in terrestrial to marginal-marine environments with the other Ediacaran fossil assemblages like *Aspidella*[9,10], *Hiemalora stellaris*[11], large Ediacaran discs[12,13] trilobozoan organisms[13,14], *Thectardis avalonensis*[15], *Parvancorina*[16], *Nimbia*[17] and various algal mat-structures[13,18].

1. Narbonne, G. M., The Ediacara biota: Neoproterozoic origin of animals and their ecosystems. *Annu. Rev. Earth Plant Sci*., 2005, **33**, 421–442.
2. Xiao, S. and Laflamme, M., On the eve of animal radiation: phylogeny, ecology and evolution of the Ediacara biota. *Trends Ecol. Evol*., 2009, **24**, 31–40.
3. Laflamme, M., Darroch, S. A. F., Tweedt, S. M., Peterson, K. J. and Erwin, D. H., The end of the Ediacara biota: Extinction, biotic replacement, or Cheshire Cat? *Gondwana Res.*, 2013, **23**, 558–573.
4. Liu, A. G., Brasier, M. D., Bogolepova, O. K., Raevskaya, E. G. and Gubanov, A. P., First report of a newly discovered Ediacaran biota from the Irkineeva Uplift, East Siberia. *Newsl. Stratigr*., 2013, **46**(2), 95–110.
5. Droser, M. L., Tarhan, L. G. and Gehling, J. G., The rise of animals in a changing environment: global ecological innovation in the Late Ediacaran. *Annu. Rev. Earth Plant. Sci.*, 2017, **45**, 593–617.
6. Retallack, G. J., Were the Ediacaran fossils lichens? *Paleobiology*, 1994, **20**, 523–544.
7. Narbonne, G. M., The Ediacara biota: a terminal Neoproterozoic experiment in the evolution of life. *Geol. Soc. Am. Today*, 1998, **8**, 1–6.
8. Erwin, D. H., Laflamme, M., Tweedt, S. M., Sperling, E. A., Pisani, D. and Peterson, K. J., The Cambrian conundrum: early divergence and later ecological success in the early history of animals. *Science*, 2011, **334**(6059), 1091–1097.
9. Kumar, S. and Pandey, S. K., Note in the occurrence of *Arumberia bankshi* and associated fossils from the Jodhpur sandstone, Marwar Supergroup, western Rajasthan. *J. Palaeontol. Soc. India*, 2009, **4**(2), 41–48.
10. Parihar, V. S., Ram, H., Nama, S. L. and Mathur, S. C., *Aspidella*: the Ediacaran Body fossil from the Jodhpur sandstone of Marwar Supoergroup, Sursagar area, Jodhpur, Western Rajasthan, India. *Estud. Geol. Madrid*, 2019, **75**(2), e109.
11. Parihar, V. S., Hukmaram, Kumar, P., Khichi, C. P. and Harsh, A., *Hiemalora stellaris* from Ediacaran Sonia Sandstone of Jodhpur Group of Marwar Supergroup, Western Rajasthan, India. *J. Geol. Soc. India*, 2021, **97**, 1447–1453.
12. Srivastava, P., Largest Ediacaran discs from the Jodhpur sandstone, Marwar Supergroup, India: their palaeobiological significance. *Geosci. Front.*, 2014, **5**(2), 183–191.
13. Parihar, V. S., New record of Ediacaran biota from the Jodhpur sandstone of Marwar Supergroup, western Rajasthan, India. *Estud. Geol. Madrid*, 2019, **75**(2), e108.

14. Parihar, V. S., Hukmaram, Kumar, P. and Harsh, A., Trilobozoans (Tribrachidium & Albumares) Ediacaran organisms from Marwar Supergroup, Western India. *Curr. Sci.*, 2023, **124**(4), 1452–1458.
15. Parihar, V. S., Hukmaram, Kumar, P. and Harsh, A., The triangular-shaped Ediacaran fossil *Thectardis avalonensis* from Sonia sandstone of Jodhpur Group, Marwar Supergroup, Western India. *Curr. Sci.*, 2023, **124**(9), 1095–1100.
16. Parihar, V. S., Chouhan, H. R., Kumar, P. and Harsh, A., The anchor-shaped Ediacaran organism *Parvancorina* from Marwar Supergroup, India. *J. Earth Syst. Sci.*, 2023, **132**, 187; https://doi.org/10.1007/s12040-023-02205-y.
17. Hukmaram, Harsh, A., Kumar, P. and Parihar, V. S., *Nimbia*: the discoid organisms from Ediacaran Sonia Sandstone of Jodhpur Group, Marwar Supergroup, western India. *Curr. Sci.*, 2023, **125**(9), 999–1004.
18. Sarkar, S., Bose, P. K., Samanta, P., Sengupta, P. and Erikssion, G., Microbial mediated structures in the Ediacaran Sonia sandstone, Rajasthan, India and their implications for Proterozoic sedimentation. *Precambrian Res.*, 2008, **162**, 248–263.
19. Martyshyn, A. and Uchman, A., New Ediacaran fossils from the Ukraine, some with a putative tunicate relationship. *PalZ*, 2021, **95**(4), 623–639.
20. Heron, A. M., The Vindhyans of western Rajputana. *Rec. Geol. Surv. India*, 1932, **65**(4), 457–489.
21. Pareek, H. S., Configuration and sedimentary stratigraphy of western Rajasthan. *J. Geol. Soc. India*, 1981, **22**, 517–523.
22. Pareek, H. S., Pre-Quarternary geology and mineral resources of north-western Rajasthan. *Geol. Soc. Ind. Mem.*, 1984, **115**, 99.
23. Khan, E. A., Geological mapping in parts of Jodhpur and Nagaur district, Rajasthan. In Seminar on Oil, Gas and Lignite scenario with special reference to Rajasthan, 1971, pp. 69–72.
24. Chauhan, D. S., Ram, B. and Ram, N., Jodhpur sandstone: a gift of Ancient Beaches of Western Rajasthan. *J. Geol. Soc. India*, 2004, **64**, 265–276.
25. Crawford, A. R. and Compston, W., The age of the Vindhyan system of peninsular India. *Quart. J. Geol. Soc. London*, 1970, **125**, 251–371.
26. Rathore, S. S., Venkatesan, T. R. and Shrivastava, R. C., Rb–Sr isotope dating of Neoproterozoic (Malani group) magmatism from southwest Rajathan, India: evidence of younger Pan-African thermal event by ^{40}Ar–^{39}Ar studies. *Gondwana Res.*, 1999, **2**(2), 271–281.
27. Gregory, L. C., Meert, J. G., Bingen, B. H., Pandit, M. K. and Torsvik, T. H., Paleomagnetic and geochronologic study of Malani Igneous suite, NW India: implications for the configuration of Rodinia and the assembly of Gondwana. *Precambrian Res.*, 2009, **170**, 13–26.
28. Chauhan, D. S., Mathur, K. M. and Ram, N., Geological nature of the Pokaran boulder Bed: Palaeoenvironment, Palaeoclimatic and stratigraphic implication. *J. Geol. Soc. India*, 2001, **58**, 425–433.
29. Raghav, K. S., De, C. and Jain, R. L., The first record of Vendian Medusoid and trace fossil-bearing algal mat-ground from the basal part of the Marwar Supergroup of Rajasthan. *Indian Minerals*, 2005, **59**, 23–30.
30. Parihar, V. S., Gaur, V., Nama, S. L. and Mathur, S. C., New report of *Arumberia banksi* (*Ediacaran affinity*) Mat structures from the Girbhakar Sandstone of Marwar Supergroup, Bhopalgarh area, Jodhpur, Western Rajasthan, India. In *Frontiers of Earth Sciences* (eds Shrivastava, K. L. and Shrivastava, P. K.), Scientific Publishers, Jodhpur, India, 2015, pp. 385–392.
31. Ansari, A. H. and Pandey, S. K., Authigenitic $\delta^{13}C$-carb negative excursion in the late Ediacaran-early Cambrian Bilara Group, Marwar Supergroup, India. *J. Geol. Soc. India*, 2021, **97**, 615–624.
32. Kumar, S. and Pandey, S. K., Discovery of Trilobite trace fossils from the Nagaur sandstone, Marwar Supergroup, Dulmera Area, Bikaner district, Rajasthan, India. *Curr. Sci.*, 2008, **94**, 1081–1084.
33. Fedonkin, M. A., Vickers-Rich, P., Swalla, B. J., Trusler, P. and Hall, M., A new metazoan from the Vendian of the White Sea, Russia, with possible affinities to the ascidians. *Paleontol. J.*, 2012, **46**, 1–11.
34. Retallack, G. J., Ediacaran periglacial sedimentary structures. *J. Palaeosciences*, 2021, **70**(1–2), 5–30.
35. Tarhan, L. G., Droser, M. L. and Gehling, J. G., Depositional and preservational environments of the Ediacara Member, Rawnsley Quartzite (South Australia): assessment of paleoenvironmental proxies and the timing of 'ferruginization'. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 2015, **434**, 4–13.

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