



GR Letter

Stinging News: ‘*Dickinsonia*’ discovered in the Upper Vindhyan of India not worth the buzzJoseph G. Meert^{a,*}, Manoj K. Pandit^b, Samuel Kwafo^a, Ananya Singha^a^a Department of Earth and Planetary Sciences, University of Florida, Gainesville, FL 32611, United States^b Department of Geology, University of Rajasthan, Jaipur, Rajasthan, India

ARTICLE INFO

Article history:

Received 8 December 2022

Revised 9 January 2023

Accepted 9 January 2023

Available online 13 January 2023

Handling Editor: M. Santosh

Keywords:

Dickinsonia

Ediacaran

Apis dorsata

Pseudofossil

Vindhyan

ABSTRACT

A recent report of *Dickinsonia tenuis* ‘hiding in plain sight’ at the Bhimbetka rock shelters in rocks of the Maihar sandstone (Upper Vindhyan) has important implications for paleogeography and the age of the Upper Vindhyan. We visited the site in December 2022 and found the evidence for *Dickinsonia* lacking. The ‘fossil’ resembles decayed parts of modern *Apis dorsata* (giant honeybees) hives. In this contribution, we note the structural similarities between “*Dickinsonia*” and honey and pollen stores of recently decayed bee nests. A closer view of the photos provided in the original paper reveals honeycombed structures within the purported fossil. We also note that the fossil is not located on a bedding surface and is not a part of the rock, but rather is attached as a ‘tracery of waxy material’ above the surface. The remaining paleogeographic conclusions of that paper are also negated by this new discovery.

© 2023 International Association for Gondwana Research. Published by Elsevier B.V. All rights reserved.

1. Introduction

The Vindhyan Basin is in north-central India and is one of several large “Purana” (=ancient) sedimentary basins in Peninsular India. The basin covers more than 1.6 million square kilometers with a total estimated thickness of ~5000 m (Fig. 1). This roughly E – W trending basin is subdivided into eastern (Son Valley) and western (Chambal Valley/Rajasthan) domains and comprises two distinct sedimentary sequences separated by an angular unconformity. In the Son Valley region, the lower Vindhyan (Semri) consists of (from oldest to youngest); the Mirzapur, Deonar, Kheinhua and Rhotas Groups (Malone et al., 2008). Numerous U-Pb ages on interbedded ash units constrain the depositional history of the Lower Vindhyan to between ~1800–1600 Ma (Ray et al., 2002, 2003; Rasmussen et al., 2002; Bickford et al., 2017). The age of the Upper Vindhyan Kaimur, Rewa and Bhandar sequences is controversial (De, 2003; De, 2006; Kumar, 2012, 2016; Meert and Pandit, 2015; Basu and Bickford, 2015). The lowermost Kaimur sandstone is intruded by the 1073 Ma Majhgawan kimberlite (Gregory et al., 2006) indicating that the basin was already active at that time. A less well-defined Re-Os age of 1210 +/- 52 Ma was obtained from the black shales within the upper part of the

Kaimur (Tripathy and Singh, 2015). The Rewa sandstone rests conformably on the Kaimur sandstone and contains traces of diamond likely sourced from the kimberlite making it younger than 1073 Ma (Kumar, 2016). There are no reliable ages from the Bhandar Formation although there are several attempts to date limestones using Pb-Pb methods (Gopalan et al., 2013). These ages range from 866 to 1073 Ma with large errors. All are consistent with a closure age for the Upper Vindhyan ~1000 Ma.

2. Faunal evidence for the age of the Upper Vindhyan

Within the Son Valley sector, two sedimentary packages lie above the dated limestones known as the Sirbu shale and Maihar sandstone. Kumar (2016) argued that these two units may be considerably younger based on fossil findings of *Arumberia banksi* and *Beltanelliformis minutae* (Kumar and Pandey, 2008). The latter fossil was recently categorized as cyanobacteria (Bobrovskiy et al., 2018b). The nature of the enigmatic fossil/structure of *Arumberia banksi* is controversial with various authors suggesting that it is a sedimentary structure or organic-sedimentary structure (McIlroy and Walter, 1997; Jensen et al., 2005; Becker-Kerber et al., 2020) whilst others argue for a biological origin (McMahon et al., 2022; Retallack and Broz, 2021). McMahon et al. (2022) argue that *Arumberia* is restricted to the 560–520 Ma interval; however older *Arumberia* occurrences are known from Baltica (573 Ma;

* Corresponding author.

E-mail address: jmeert@ufl.edu (J.G. Meert).

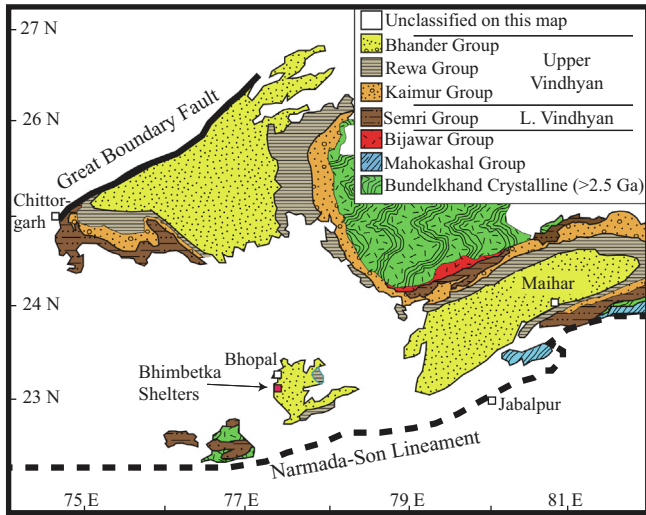


Fig. 1. Generalized geological map of the Son Valley area of Vindhyan Basin and other tectonic/geological elements on the Northern Indian Block. Bhopal inlier hosts the Bhimbetka Natural rock shelters (red square). Map after Bose et al., 2015. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Razumovsky et al., 2020) and Scotland (~1.0 Ga; Callow et al., 2011). The recent report of *Dickinsonia tenuis* from the Maihar sandstone near Bhopal is a potentially critical time marker due to its limited range and identity as an animal fossil (Bobrovskiy et al., 2018a; Retallack et al., 2021).

3. Other age constraints on the Upper Vindhyan

Early detrital zircon studies from the Upper Vindhyan show a unique pattern with a notable lack of zircons younger than 1.0 Ga (Malone et al., 2008; McKenzie et al., 2011; Turner et al., 2014). This age distribution was confirmed recently for the Maihar sandstone (Lan et al., 2021); however, an early publication (Lan et al., 2020) yielded a single zircon age of 548 Ma from the same unit. The 548 Ma age was used by the authors to assert that Vindhyan sedimentation continued well into the Ediacaran. This youngest age would be consistent with the presence of *Dickinsonia* in the Maihar sandstone.

Malone et al. (2008) argued that the similarity between paleomagnetic data from the Rewa-Bhandar sandstones and limestones overlapped well with that of the Majhgawan kimberlite (Gregory et al., 2006). They argued that the similarity between these poles along with the lack of detrital zircons < 1000 Ma indicated that basin closure took place in the early Tonian. Subsequent paleomagnetic work on the 1.1 Ga Great Dyke of Mahoba (Pradhan et al., 2012) yielded similar results with Bhandar-Rewa and Majhgawan lending further support to the hypothesis that Upper Vindhyan sedimentation ceased around 1.0 Ga. Meert and Pandit (2015) argued that basin closure resulted from collision of the Northern Indian Block (NIB) with the South Indian Block (SIB) along the Central Indian Tectonic Zone (CITZ) at around 1.0 Ga (Bhowmik, 2019). Collisional orogenesis also took place in the Aravalli-Delhi region during the Tonian-Cryogenian interval (900–680 Ma; Singh et al., 2021).

4. *Dickinsonia tenuis* or *Apis dorsata*?

In a landmark study, Bobrovskiy et al. (2018b) argued that *Dickinsonia* represents one of the oldest animals on Earth.

The presence of this fossil in the Maihar sandstone would therefore end discussion on the age of the Upper Bhandar sequence and place it squarely in the Ediacaran Period. The finding would also suggest that paleomagnetic data from the Bhandar-Rewa is of the same age or, alternatively, was remagnetized sometime after deposition. Due to the relatively undisturbed nature of the Vindhyan sediments, there is no field test demonstrating the primary nature of the remanence. Malone et al. (2008) argued for a likely primary remanence based on the presence of stata-bound magnetic reversals, which is suggestive, but not conclusive of a primary remanence (Meert et al., 2020; Meert et al., 2021).

Retallack et al. (2021) reported the serendipitous find of *Dickinsonia* 'hiding in plain sight' at Bhimbetka rocks just south of Bhopal India (a UNESCO heritage site; Fig. 2).

We argue that the report of an isolated occurrence of *Dickinsonia* at Bhimbetka is a case of mistaken identity. The shapes, forms and mode of occurrence are not consistent with other occurrences of *Dickinsonia*. Moreover, we note the presence of myriad giant honeybee hives (Fig. 3) within the rock crevices that show remarkable similarities to the purported fossil of *Dickinsonia* described by Retallack et al. (2021). Based on the following observations, we reject the finding and offer an alternative, albeit mundane explanation for the apparent isolated *Dickinsonia* fossil:

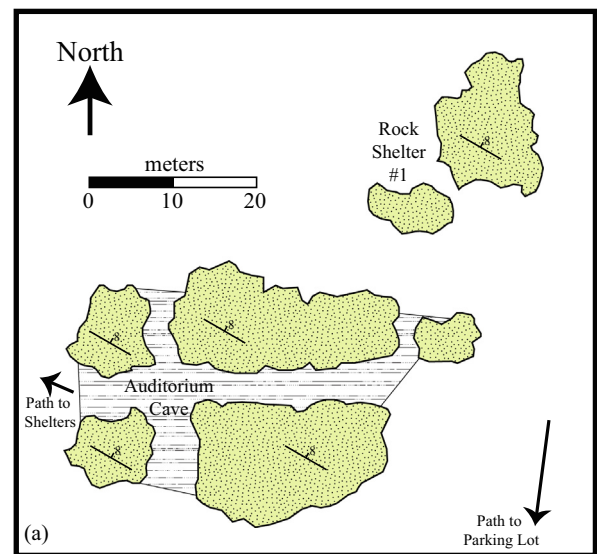


Fig. 2. Map of the UNESCO Heritage site at the Bhimbetka rocks shelters south of Bhopal, India after Bednarik (2019). Strike/dip symbols shown on Auditorium shelter. (b) Auditorium cave entrance photo looking west (~270). Red arrow points to "*Dickinsonia*". Inset: Enlarged view of the fossil located along a fracture. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

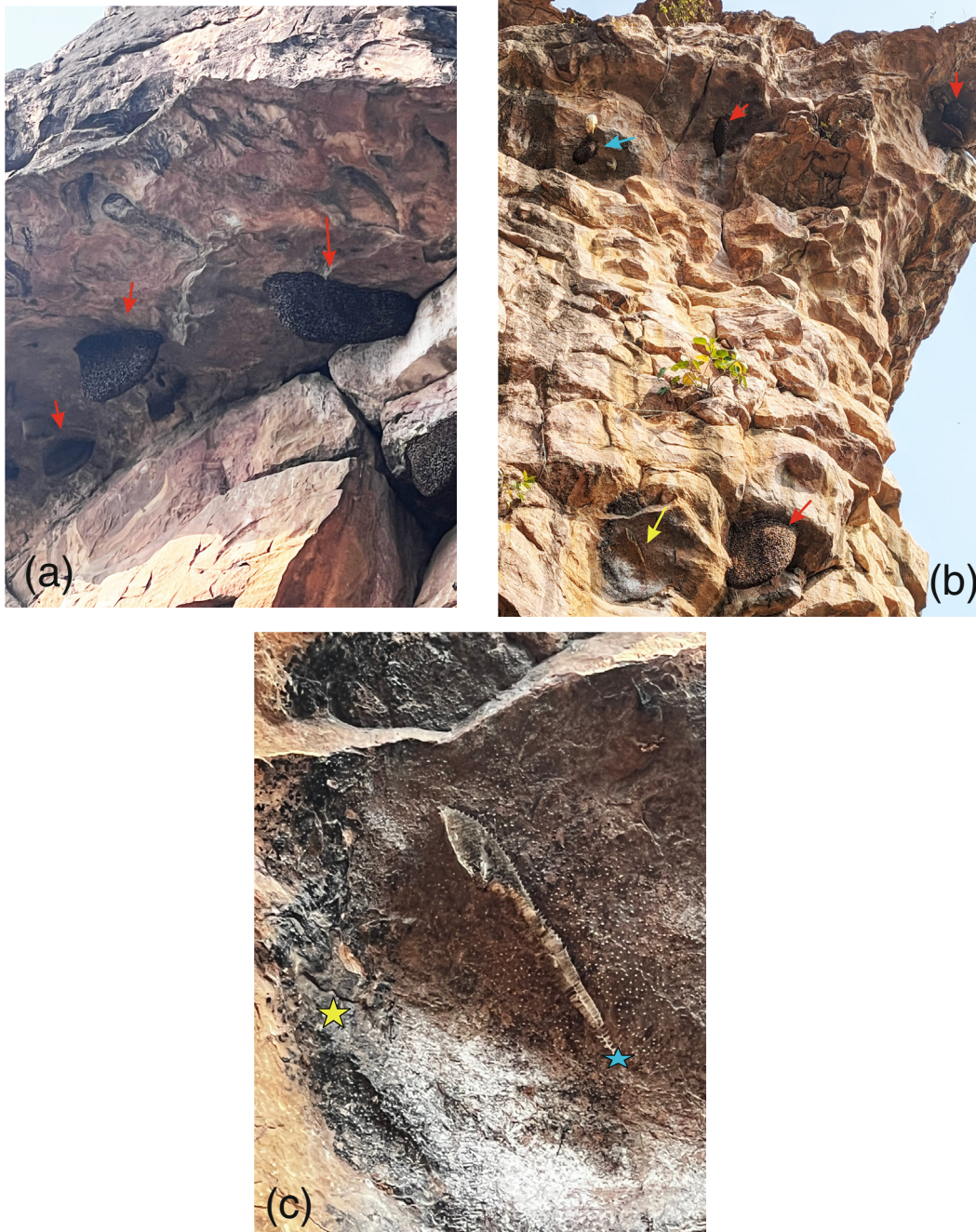


Fig. 3. Photos of active/decaying hives at the Bhimbetka site (a) red arrows point to active lenticular-shaped hives some 15–20 m above the amphitheater floor; (b) red arrows active hives, blue arrows decaying hive, yellow arrow hive central support structure surrounded by ‘ghost’ sooty material outlining the main hive; (c) enlarged waxy central support structure. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4.1. Key observations

(1) *Beehive activity-* Retallack et al. (2021) argued that high-resolution photos of the fossil demonstrate a morphology like *Dickinsonia*. On arrival, we noticed that the rocks at Bhimbetka were replete with giant honeybee nests (*Apis dorsata*; Sihag, 2017). The nests resided under ledges in

the jointed/broken Maihar sandstone and ranged in size from 0.25 to 0.5 m in length or diameter (Fig. 3). These sizes are estimates because most were located 10–20 m or more above ground level. Hive shapes were oval or lenticular. Most of the hives show a dark staining around the hive that might be mistaken for soot (Fig. 3-yellow star).

(2) The 'fossil' is not located on a bedding plane- The Maihar sandstone at Bhimbetka is dipping shallowly to the NE (Strike: 300; Dip: 8; Fig. 2a). The bedding can be readily observed in Fig. 2b. The most common mode of preservation for *Dickinsonia* is expressed in negative relief on the base of sandstone beds (Gehling, 1999; Tarhan et al., 2016). The archway on which the fossil was located represents a fracture/joint along which part of the overlying material collapsed to form the cave. A photo taken sub-parallel to essentially flat-lying bedding (even taken below the fossil) therefore would not reveal much of the fossil. The photo in Fig. 2c shows a full view of the fossil indicating that the impression is located on a tilted fracture surface and therefore at an angle to bedding.

4.2. Secondary observations

(1) *Rapid decay of the fossil:* Fig. 4a shows the image used in Retallack et al. (2021) which was taken in early 2019 alongside our image taken Dec 3, 2022 (Fig. 4b). Much of the central part of *Dickinsonia* is now gone. The discovery team argued in news reports (see above) that the soot from the Neolithic fires was causing the decay. A more parsimonious explanation is that the organic material produced by the honeybees is susceptible to decay over a relatively short time interval. We enlarged a portion of the high-resolution image published by Retallack et al. (2021) where a honeycomb structure is highlighted (Fig. 4c). This honeycomb struc-

ture was apparently missed when the authors analyzed their photo.

(2) *Beeswax, propolis and honey/pollen stores:* We found an abandoned and decaying hive located 15–20 m above ground-level near the auditorium entrance. This photo shows various parts of the hive including the relict hive (red, Fig. 5a), the honeycombed inner nest structure (green) and the waxy honey-pollen store attachment to the rock surface (blue). Propolis is sticky, brown-colored material composed of a mix of beeswax, saliva and plant resins used as 'glue' to repair and give integrity to the hive (Bankova et al., 2000; Rajput et al., 2022). Propolis may be responsible for the dark staining around abandoned nest sites (Fig. 5a, 3c). Beeswax is used to construct the hive resulting in a characteristic honeycomb shape. Note that the shape of the honey and pollen store in Fig. 5b closely resembles the *Dickinsonia* described in Retallack et al. (2021). In this photo the 'Dickinsonia-like' shape is also attached both the the underside of the outcrop and wraps around a nearly vertical surface (yellow star-underside; blue star- vertical). A modern honey and pollen store is shown in Fig. 5c (Neupane et al., 2016). The honey and pollen store neatly explains the 'tracery of white waxy material' noted in the Retallack et al. (2021) manuscript.

(3) *Detached Material:* The 'fossil' is not part of the rock, but is a surficial feature raised above the rock surface (see Fig. 6-a,b,c). The material appears to be a waxy material like that observed in modern beehives (see Fig. 5).

(4) *Isolated occurrence:* If this were *Dickinsonia*, it would be the only observation of *Dickinsonia* within the Upper Vindhyan. We

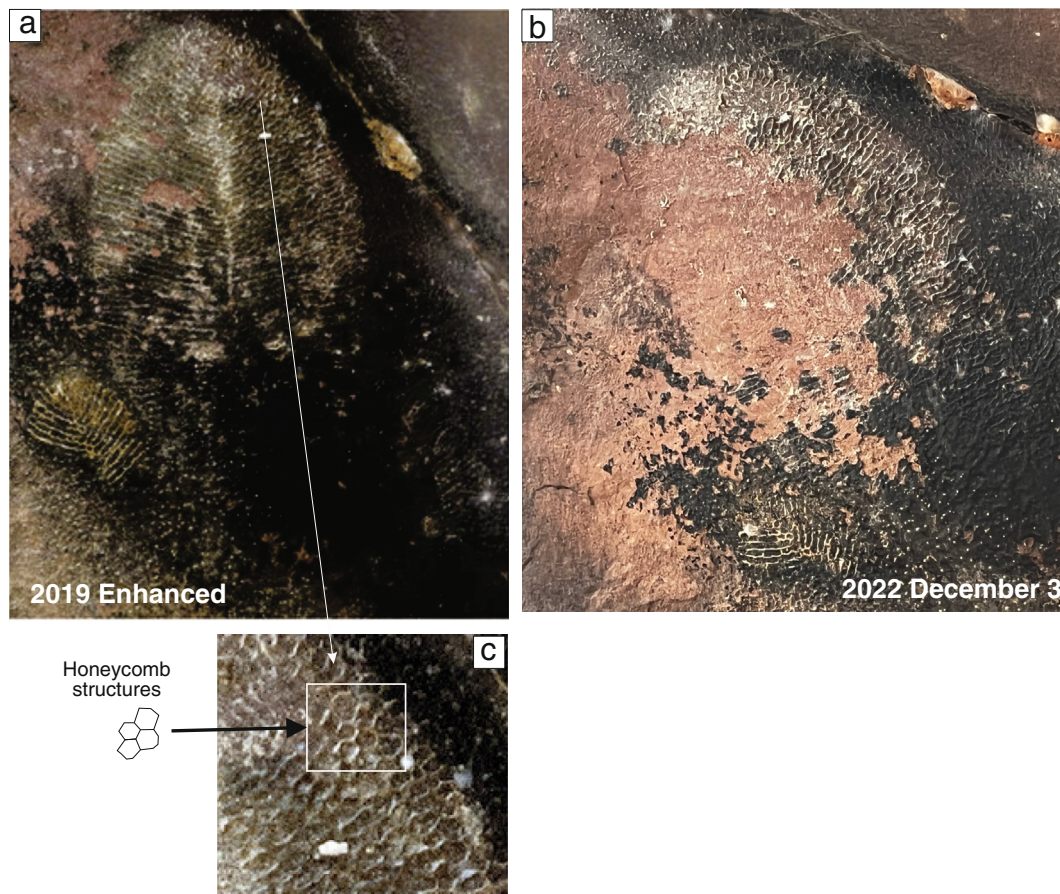


Fig. 4. Rapid decay of "*Dickinsonia*"; (a) photo from Retallack et al. (2021) taken in early 2019; (b) Photo taken by the current authors Dec 3, 2022 (c) enlarged photo from Fig. 2b in Retallack et al. (2021) showing honeycomb structures consistent with a bee origin.

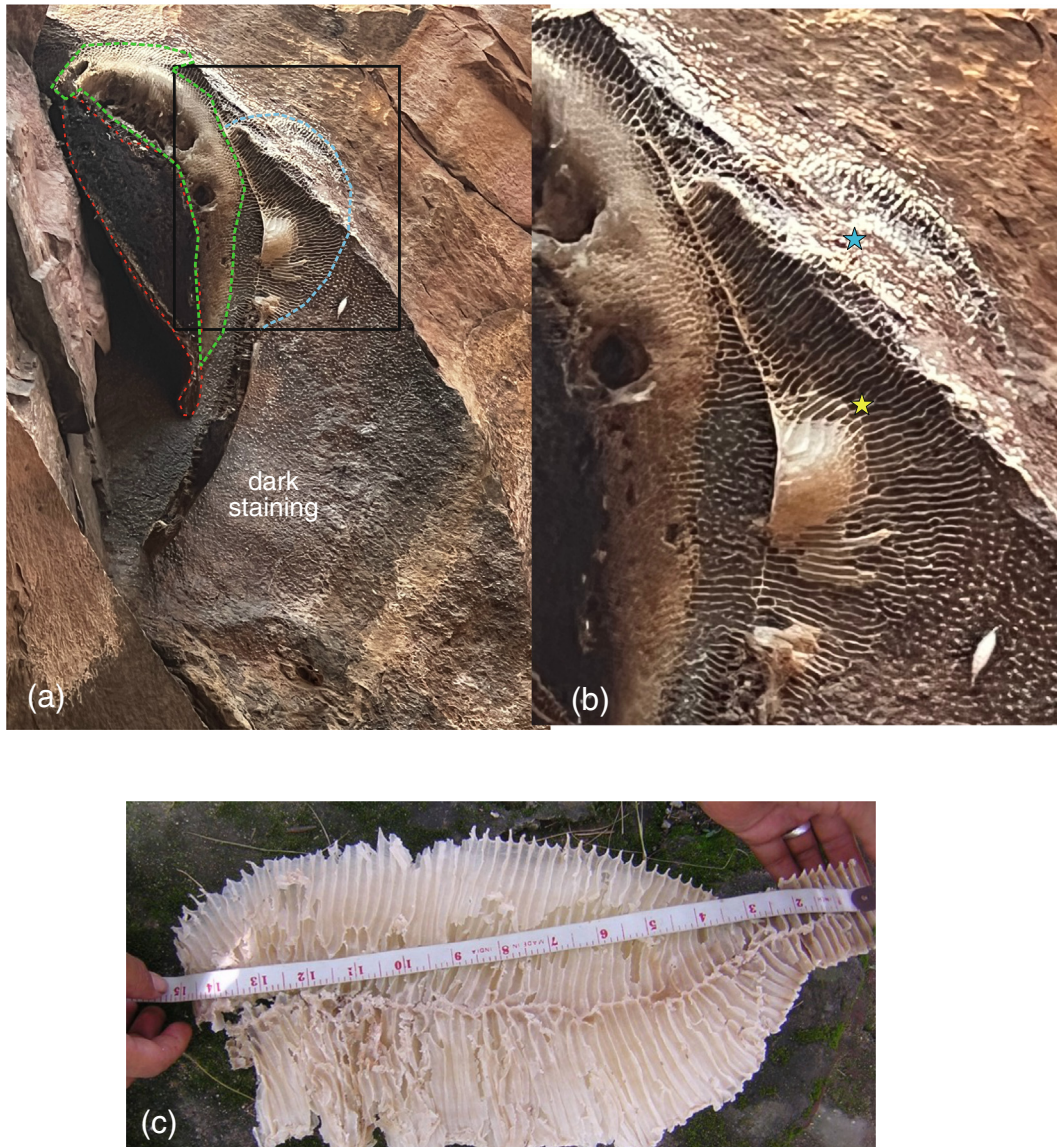


Fig. 5. (a) Partially decayed honeybee nest at Bhimbetka showing remaining hive (red); honeycomb structure (green) and honey and pollen store (blue). The blue region has a shape resembling 'Dickinsonia' in Fig. 4a. Honeybee hives leave a dark residue which might be confused with soot from 'Neolithic' fires (as described by the Retallack et al. (2021) in various news reports...<https://www.theweek.in/theweek/specials/2021/02/19/return-of-the-past.html>). (c) Honey and pollen store removed from a nest of *Apis dorsata* (Neupane et al., 2013). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

spent two days in the field looking at other outcrops in the immediate area (and around Bhopal) without success. We admit the absence of evidence is not evidence of absence, but given the remaining evidence cited in this paper, we argue that an Ediacaran age based on the alleged discovery of *Dickinsonia* is not supported at this time.

5. Conclusions

Dickinsonia tenuis was reported in the Maihar sandstone at the Bhimbetka Shelters near Bhopal India. A closer look demonstrates that the impression resulted from decay of a modern beehive which was attached to a fractured rock surface which, at first

glance, resembles *Dickinsonia*. Given that the hives have the similar shapes and morphologies to *Dickinsonia*, we conclude that the fossil is simply the remanent of a giant beehive. Retallack et al. (2021) discuss paleogeographic options for India and Australia based on the assumption that the Bhandar-Rewa formations are Ediacaran in age. We argue that the age of the Upper Vindhyan remains contested and paleomagnetic data from these units therefore should not be used for Ediacaran paleogeographic reconstructions. Paleomagnetic data from the Marwar Supergroup (Davis et al., 2014) are distinct from the Bhandar-Rewa data used by Torsvik and Cocks (2013). Although the data from the Marwar Supergroup support an equatorial position for India, they do not fit either the paleomagnetic or the TPW framework shown in the Torsvik and Cocks (2013) reconstructions.

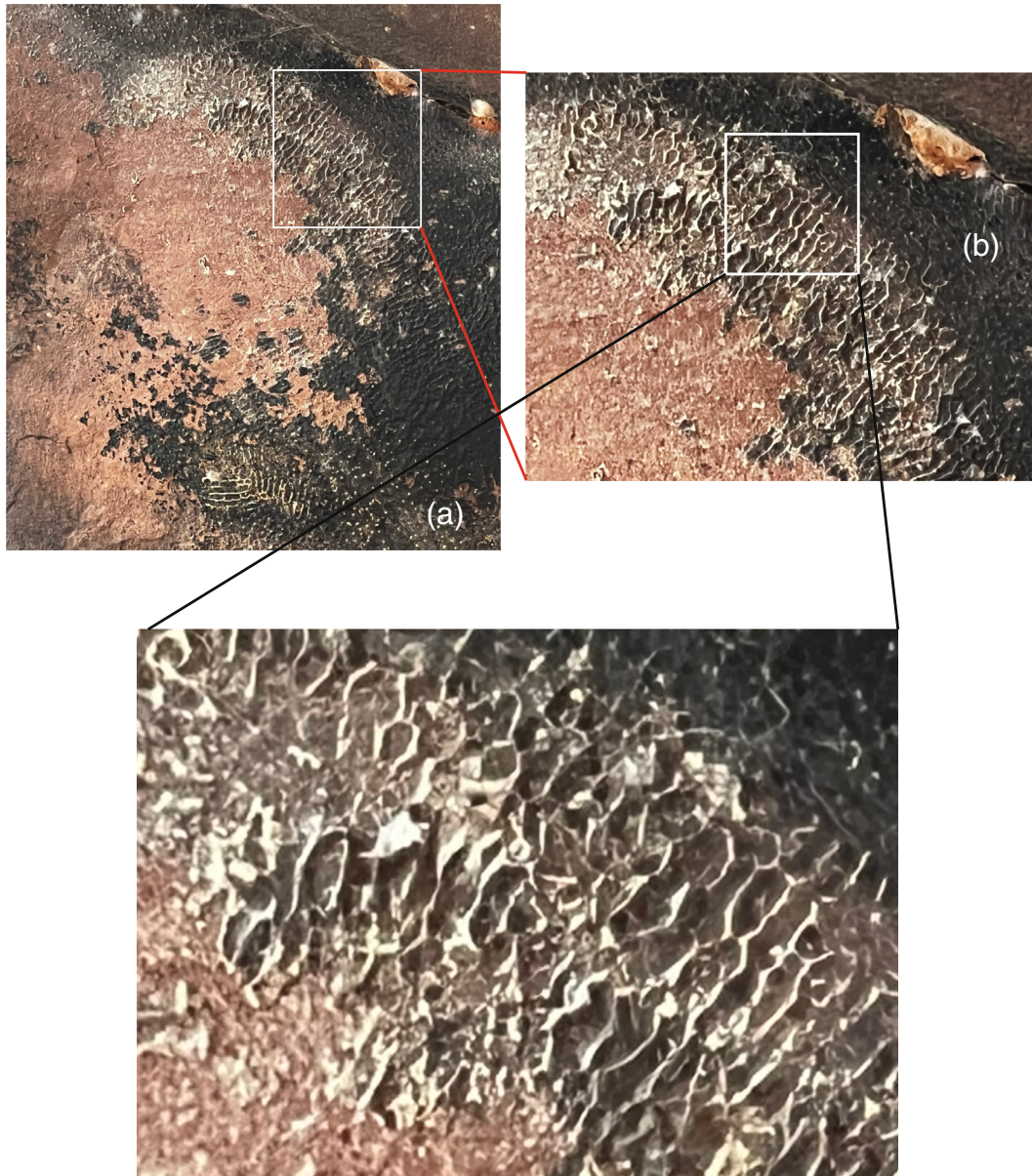


Fig. 6. (a) The complete ‘*Dickinsonia*’ fossil shown in a Dec 3, 2022 photo (Iphone Pro Max 77 mm, $f = 2.8$); (b) Zoomed photo showing raised ‘wax’ structures attached to the rock surface rather than part of the rock surface; (c) further zoomed image of the surficial wax structures (white). Note some have slightly elongated honeycomb structures (compare to Fig. 4c).

CRediT authorship contribution statement

Joseph G. Meert: Conceptualization, Funding acquisition, Investigation, Writing - original draft, Writing - review & editing. **Manoj K. Pandit:** Conceptualization, Investigation, Writing - review & editing. **Samuel Kwafo:** Conceptualization, Investigation. **Ananya Singha:** Conceptualization, Investigation.

Declaration of Competing 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.

Acknowledgements

We followed best ethical practices at the UNESCO site. Our samples consisted solely of photographs and the only measurements

were Brunton-based strike and dip measurements. The authors would like to thank Dr. Cameron Jack (University of Florida Institute for Agricultural and Food Sciences) for his helpful advice on the nesting structures of Asian honeybees. We also thank anonymous reviews and comments that helped improve this manuscript. Work was supported by a grant by the US National Science Foundation (EAR18-50693). The conclusions and observations reflect those of the authors and not of the granting agency.

References

- Bankova, V.S., de Castro, S.L., Marcucci, M.C., 2000. Propolis: recent advances in chemistry and plant origin. *Apidologie* 31, 3–15.
- Basu, A., Bickford, M.E., 2015. An alternate perspective on the opening and closing of the Intracratonic Purana Basins in Peninsular India. *J. Geol. Soc. India* 85, 5–25.
- Becker-Kerber, B., Paim, P.S.G., Junior, F.C., Girelli, T.J., da Rosa, A.L.Z., El Albani, A., Osés, G.L., Prado, G.M., Figueiredo, M., Simões, L.S.A., Pacheco, M.L.A.F., 2020. The oldest record of Ediacaran macrofossils in Gondwana (~ 563 Ma, Itajaí Basin, Brazil). *Gondwana Res.* 84, 211–228.

- Bednarik, R.G., 2019. Drevneischie v mire petroglifi (the earliest petroglyphs in the world). *Kuzbassvuzizdat Kemerovo (Trudy SAIPI)* 12, 85–100.
- Bhowmik, S.K., 2019. The current state of orogenesis in the Central Indian Tectonic Zone: A view from the southern margin. *Geol. J.* 54, 2912–2934.
- Bickford, M.E., Mishra, M., Mueller, P.A., Kamenov, G.D., Schieber, J., Basu, A., 2017. U-Pb and Hf isotopic compositions of magmatic zircons from a rhyolite flow in the porcellanite formation in the Vindhyan Supergroup, Son Valley (India): Implications for tectonic significance. *J. Geol.* 125, 367–379.
- Bobrovskiy, I., Hope, J.M., Ivantsov, A., Nettersheim, B.J., Hallman, C., Brocks, J.J., 2018a. Ancient steroids establish the Ediacaran fossil Dickinsonia as one of the earliest animals. *Science* 361, 1246–1249.
- Bobrovskiy, I., Hope, J.M., Krasnova, A., Ivantsov, A., Brocks, J.J., 2018b. Molecular fossils from organically preserved Ediacara biota reveal cyanobacterial origin for *Beltanelliformis*. *Nat. Ecol. Evol.* 2, 437–440.
- Bose, P.K., Sarkar, S., Das, N.G., Banerjee, S., Mandal, A., Chakraborty, N., 2015. Proterozoic Vindhyan Basin: configuration and evolution. *Geol. Soc. Lond. Memoir* 43, 85–102.
- Callow, R.H.T., Battison, L., Brasier, M.D., 2011. Diverse microbially induced sedimentary structures from 1 Ga lakes of the Daibag Formation, Torridon Group, *Sedimentary Geol.*, 239, 117–1.
- Davis, J.K., Meert, J.G., Pandit, M.K., 2014. Paleomagnetic analysis of the Marwar Supergroup, Rajasthan, India and proposed interbasinal correlations. *J. Asian Earth Sci.* 91, 339–351.
- De, C., 2003. Possible organisms similar to Ediacaran forms from the Bhandar Group, Vindhyan Supergroup, Late Neoproterozoic of India. *J. Asian Earth Sci.* 21, 387–395.
- De, C., 2006. Ediacara fossil assemblage in the Upper Vindhyan of Central India and its significance. *J. Asian Earth Sci.* 27, 660–683.
- Gehling, J.G., 1999. Microbial mats in terminal Proterozoic siliciclastics: Ediacaran death masks. *PALAIOS* 14, 40–57.
- Gregory, L.C., Meert, J.G., Pandit, M.K., Pradhan, V.R., Endale, T., Malone, S.J., 2006. A paleomagnetic and geochronologic study of the Majhgawan kimberlite, India: Implications for the age of the Upper Vindhyan Supergroup. *Precamb. Res.* 149, 65–75.
- Gopalan, K., Kumar, A., Kumar, S. and Vijayagopal. 2013. Depositional history of the Upper Vindhyan succession, central India: Time constraints from Pb-Pb isochron ages of its carbonate contents. *Precambrian Research*, 233, 108–117.
- Jensen, S., Droser, M.L., Gehling, J.G., 2005. Trace fossil preservation and the early evolution of animals. *Palaeogeography, Palaeoclimatology, Palaeoecology* 220, 19–29.
- Kumar, S., Pandey, S.K., 2008. Arumberia and associated fossils from the Neoproterozoic Maihar Sandstone, Vindhyan Supergroup, Central India. *J. Palaeontol. Soc. India* 53, 83–97.
- Kumar, S., 2012. Stratigraphy and correlation of the Neoproterozoic deposits of central and western India: an overview. *Geol. Soc. Lond. Spec. Publ.* 366, 75–90.
- Kumar, S., 2016. Megafossils from the Vindhyan basin, central India: An overview. *J. Paleontol. Soc. India* 61, 273–286.
- Lan, Z., Zhang, S., Li, X.-H., Pandey, S.K., Sharma, M., Shukla, Y., Ahmad, S., Sarkar, S., Zhai, M., 2020. Towards resolving the 'jigsaw puzzle' and age-fossil inconsistency within East Gondwana. *Precamb. Res.* 345. <https://doi.org/10.1016/j.precamres.2020.105779>.
- Lan, Z., Pandey, S.K., Zhang, S., Sharma, M., Gao, Y., Wu, S., 2021. Precambrian crustal evolution in Northern India block: evidence from detrital zircon U-Pb ages and Hf isotopes. *Precambrian Research*, 361, doi: <https://doi.org/10.1016/j.precamres.2021.106238>.
- Malone, S.J., Meert, J.G., Banerjee, D.M., Pandit, M.K., Tamrat, E., Kamenov, G.D., Pradhan, V.R., Sohl, L.E., 2008. Paleomagnetism and detrital zircon geochronology of the Upper Vindhyan sequence, Son Valley and Rajasthan, India: A ca. 1000 Ma closure age for the Purana basins? *Precamb. Res.* 164, 137–159.
- McKenzie, N.R., Hughes, N.C., Myrow, P.M., Xiao, S., Sharma, M., 2011. Correlation of Precambrian–Cambrian sedimentary successions across northern India and the utility of isotopic signatures of Himalayan lithotectonic zones. *Earth Planet. Sci. Lett.* 312, 471–483.
- McMahon, W.J., Davies, N.S., Liu, A.G., Went, D.J., 2022. Engima Variations: Characteristics and Likely Origin of the Problematic Structure *Arumberia*, as recognized from an exceptional bedding plane exposure and the global record. *Geol. Mag.* 159, 1–20.
- Meert, J.G., Pandit, M.K., 2015. Precambrian Evolution of Peninsular India and its Link to Basin evolution. *Geol. Soc. Lond. Spec. Publ.* 43, 29–54.
- Meert, J.G., Pivarunas, A.F., Evans, D.A.D., Pisarevsky, S.A., Pesonen, L.J., Li, Z.X., Elming, S.A., Miller, S.R., Zhang, S., Salminen, J., 2020. The magnificent seven: A proposal for the modest revision of the quality index. *Tectonophysics* 790. <https://doi.org/10.1016/j.tecto.2020.228549>.
- Meert, J.G., Pivarunas, A.F., Miller, S.R., Pandit, M.K., Sinha, A.K., 2021. Chapter 10. The Precambrian drift history and paleogeography of India, in: Pesonen et al. (eds) *Ancient Supercontinents and the Palaeogeography of the Earth*. ISBN:978-0-12-818533-9, 470 pp.
- Neupane, K.R., Woyke, J., Poudel, S.M., 2013. Nesting site preference and behavior of giant honey bee, *Apis dorsata*. *Proceedings of the XXXVIII International Apicultural Congress, Kiev, Ukraine*, 1–9. doi:<https://doi.org/10.13140/RG.2.1.4840.0407>.
- Pradhan, V.R., Meert, J.G., Pandit, M.K., Kamenov, G.D., Mondal, E.A., 2012. Tectonic evolution of the Precambrian Bundelkhand craton, central India: Insights from paleomagnetic and geochronological studies on the mafic dyke swarms. *Precamb. Res.* 198–199, 51–76.
- Rajput, J.M., Sheikh, A., Khan, G.J., 2022. Bee Propolis: A comprehensive review. *International Journal of Pharmaceutical Research and Applications* 7, 835–845.
- Rasmussen, B., Bose, P.K., Sakar, S., Banerjee, S., Fletcher, I.R., McNaughton, N.J., 2002. 1.6 Ga U-Pb zircon age for the Chorhat Sandstone, Lower Vindhyan, India: Possible implications for the early evolution of animals. *Geology* 20, 103–106.
- Ray, J.S., Martin, M.W., Veizer, J., Bowring, S.A., 2002. U-Pb Zircon dating and Sr isotope systematic of the Vindhyan SuperGroup, India. *Geology* 30, 131–134.
- Ray, J.S., Veizer, J., Davis, W.J., 2003. C, O, Sr and Pb isotope systematics of carbonate sequences of the Vindhyan Supergroup, India: Age, diagenesis, correlations, and implications for global events. *Precamb. Res.* 121, 103–140.
- Retallack, G.J., Broz, A.P., 2021. *Arumberia* and other Ediacaran fossils of central Australia. *Hist. Biol.* 33, 1964–1988.
- Retallack, G.J., Matthews, N.A., Master, S., Khangar, R.G., Khan, M., 2021. Dickinsonia discovered in India and late Ediacaran biogeography. *Gondwana Research* 90, 165–170.
- Sihag, R.C., 2017. Nesting behavior and nest site preference and behavior of giant honey bee (*Apis dorsata*) in the semi-arid environment of NW India. *J. Apic. Res.* 56, 452–466.
- Singh, S., De Waele, B., Shukla, A., Umsankar, B.H., Biswal, T.K., 2021. Tectonic fabric, geochemistry, and zircon-monazite geochronology as proxies to date an orogeny: Example of South Delhi Orogeny, NW India, and implications for East Gondwana tectonics. *Front. Earth Sci.* <https://doi.org/10.3389/feart.2020.594355>.
- Tarhan, L.G., Hood, A., Droser, M.L., Gehling, J.G., Briggs, D.E.G., 2016. Exceptional preservation of soft-bodied Ediacara Biota promoted by silica-rich oceans. *Geology* 44, 951–954.
- Torsvik, T.H., Cocks, L.R.M., 2013. Gondwana from top to base in space and time. *Gondwana Research* 24, 999–1030.
- Tripathy, R., Singh, S.K., 2015. Re-Os depositional age for black shales from the Kaimur Group, Upper Vindhyan, India. *Chem. Geol.* 413, 63–72.
- Turner, C.C., Meert, J.G., Pandit, M.K., Kamenov, G.D., 2014. A detrital zircon U-Pb and Hf isotopic transect across the Son Valley sector of the Vindhyan basin, India: Implications for basin evolution and paleogeography. *Gondwana Research* 26, 348–364.