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ABSTRACT

Dickinsonia is an enigmatic fossil of Ediacaran age, variously interpreted as a lichen, foraminiferan, placozoan, cnidarian or worm, and now Evans et al. (2015) have provided documentation of new and informative specimens from Nilpena in the Flinders Ranges of South Australia. They consider missing marginal slivers evidence for soft bodied, free living *Dickinsonia* lifted by current, but such marginal dismemberment of *Dickinsonia* by currents requires attachment of the rest of the body to the substrate more firmly than body cohesion. Unidirectional orientation of missing pieces of *Dickinsonia* was considered evidence of shallow marine storms, but such directed currents are found in floods or tsunamis. Finally, curved conchoidal fracture of the missing slivers reveals that the unskeletonized carapace of *Dickinsonia* was not always soft and flexible, but sometimes hardened, perhaps by desiccation or freezing.

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1. Missing pieces indicative of attachment or free living?

Evans et al. (2015) document 83 specimens of *Dickinsonia* with a marginal sliver missing (Fig. 1A), bent upwards, or folded over (Fig. 1B), and interpret this as evidence “that *Dickinsonia* was easily separated from the sea floor and was not attached to the substrate on which it lived.” This conclusion is contrary to experience with transport of fossils by tsunamis, storms or floods, in which only attached forms, such as trees, bushes and seaweeds, are dismembered, but unattached forms such as crabs, jellyfish, starfish and humans are drowned and bruised, but remain intact (Peters et al., 2007; Szczuciński et al., 2012). In order to rip off, lift up, or fold over a marginal sliver of *Dickinsonia*, its body must be broken by the force of current, so that body cohesion was less than adhesive forces to the substrate, where most of the fossil remains undeformed. If there were no adhesion to the substrate the whole body would become flotsam of floods, storms or tsunamis. Similarly when removing a bumper sticker, it comes off in strips rather than entire, but the weak adhesion of a suction decal allows removal intact. Almost all *Dickinsonia*, including missing-piece specimens, have marginal rims within microbially textured surfaces (“old elephant skin”) suggestive of life position on stable surfaces (Evans et al., 2015). Sliced and diced missing pieces of *Dickinsonia* have also been found jumbled across bedding planes in massive sandstone paleochannels (Gehling and Droser, 2013, Fig. 2D). In paleochannel facies *Dickinsonia* slices are preserved across bedding planes, and have not yet been documented entire.

Other lines of evidence that *Dickinsonia* was sessile include the following (Retallack, 2007): (1) reaction rims of specimens side by side (interpreted as allelopathic avoidance), (2) lack of overlapping specimens (interpreted as life spacing rather than current accumulation), (3) disturbance of sediment beneath dismembered specimens (broken on substrate rather than in water column), (4) negatively skewed size-distributions (indeterminate growth), and (5) radially striated marginal rims (perhaps shrinkage drag, but more likely hypothallial margins). In addition, (6) many Ediacaran fossils were found in life position within well drained gypsic and calcic paleosols, and (7) thin sections show rhizine-like tubules penetrating downward from *Dickinsonia* into the substrate (Retallack, 2013). Evans et al. (2015) cite other evidence for motile *Dickinsonia*, such as sequential imprints interpreted as intermittent feeding trails (Ivantsov, 2011), but these can be interpreted as aligned cohorts of poorly preserved specimens comparable with fairy rings (Retallack, 2013).

2. Missing piece orientation due to floods, tsunamis or storms?

Also novel are observations of Evans et al. (2015) that the missing-pieces of *Dickinsonia* are in the same compass orientation within each bed, although sometimes opposed from bed to bed. Each population of mutilated *Dickinsonia* thus experienced a strong unidirectional current before burial. Floods or tsunamis better explain unidirectional currents than “alignment of lifted sections during storm activity” in a shallow marine shoreface Evans et al., (2015), because marine storms have multiple current directions producing radially sloping, hummocky bedding

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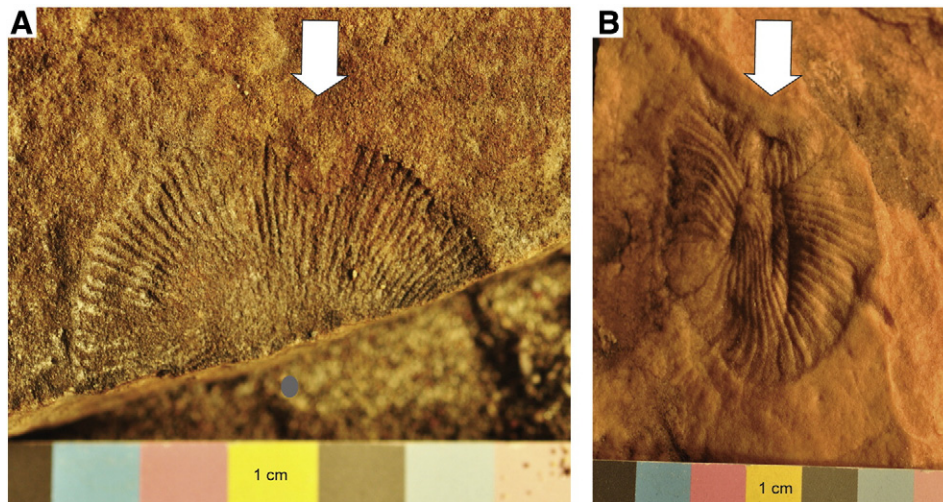


Fig. 1. *Dickinsonia costata* from the Ediacaran, Ediacara Member of the Rawnley Quartzite, showing a missing marginal piece (arrow) of a rigid individual (A) and marginal overfolding (arrow) of a pliable individual (B). Panel B is a cast of South Australian Museum specimen P13799 in the Condon Collection of the Museum of Natural and Cultural History, University of Oregon (as F113142), and collected in the Ediacara Hills, and panel A is Condon Collection F34287 from Brachina Gorge.

(Dott and Bourgeois, 1982). Although hummocky bedding has been thought present at Nilpena, long-awaited documentation (Tarhan et al., 2015) now reveals that the “hummocky cross beds” there were low (4 cm) isolated megaripples, unlike genuine large (25–20 cm thick) hummocky bedding in thick (1–2 m) cosets (Dott and Bourgeois, 1982).

Other evidence for floods include (Retallack, 2012, 2013; Retallack, et al., 2014); (1) paleovalleys (300 m relief on base of Ediacara Member), (2) paleochannels (trough cross bedded sandstone with red and green intraformational claystone breccias), (3) floodplains (red beds with mainly unsorted silt of loessites and linguoid ripples), and (4) paleosols (massive beds with calcareous nodules showing highly correlated stable isotopes and chemical mass balance of hydrolytic weathering). No examples of tsunamites have been recorded from Ediacaran passive margin sequences of South Australia (Retallack, et al., 2014), but tsunamites do bury paleosols with Ediacaran fossils in Newfoundland (Retallack, 2014).

3. Curved breakage of pliable or rigid carapace?

Not only were these newly reported fossils buckled or broken through the body, rather than simply dislodged from the substrate, but some slivers “appear to have been cleanly cut from the organism” (Evans et al., 2015). Furthermore this curve cuts across the grain of the body segments and is in rigidly ribbed specimens (Fig. 1A), unlike folded over specimens with rumpled and likely pliable carapace (Fig. 1B). All observers agree that Ediacaran fossils had a stiff biopolymer to explain their unusual positive relief with respect to their substrate, but that biopolymer varied in firmness from pliable and deformable (Fig. 1B) to stiff and rigid (Fig. 1A). The broken edge of stiff *Dickinsonia* (Fig. 1A; also Evans et al., 2015, Fig. 3b–d) reveals cross struts of the areolation (“pneu structure”) seen in thin section (Retallack, 2013) and inferred from architecture (Seilacher and Gishlick, 2015).

This curve of missing pieces is like a conchoidal fracture as observed in old desiccated or frozen shark or ray capsules, whereas other *Dickinsonia* were more pliable, like viable and moist shark and ray capsules (Ishihara et al., 2012). Similarly, lichens are pliable in parts that are young or dewy, but brittle where old and frozen, and dispersed parts are vegetative propagules (Brodo et al., 2001). This variation in pliability may be related to exposure to cold or drying as in elasmobranch capsules, but also may be a function of oxidative aging of the biopolymer (Koob and Cox, 1990). This cannot be the whole answer because large plially deformed specimens of *Dickinsonia* also are known (Gehling and Droser, 2013). Another alternative is that the curved pieces are

fatal bites by predators, which are unknown as old as Ediacaran (Seilacher and Gishlick, 2015). Selective removal of a slice of lichen by pathogenic bacteria, fungi or protistan attack also is plausible for Ediacaran terrestrial communities (Retallack, 2013), but bitten and diseased *Dickinsonia* are hypotheses falsified by the strong orientation of the missing pieces, documented by Evans et al. (2015).

Other evidence for desiccation during deposition of the Ediacara Member in South Australia include (Retallack, 2012, 2013); (1) Aridosol paleosols (profiles with shallow gypsic and calcic horizons), and (2) loessites (beds of dominantly angular silt). Other evidence for freezing during deposition of the Ediacara Member includes (Retallack et al., 2014): (1) tillites (in laterally equivalent Billy Springs Formation), (2) periglacial convolutions (multiple generation frost heave in Warrutu paleosol), (3) thufur mounds (uparched Muru paleosol surface horizons), (4) low chemical index of alteration (modest weathering of alkali and alkali earths elements) and (5) ice needle casts (alternatively interpreted as molluscan radular scratching).

4. Conclusions

Regardless of whether *Dickinsonia* was animal or vegetable, the new and revealing specimens reported by Evans et al. (2015) demonstrate that they lived firmly attached to the substrate, although marginal slivers could be folded over (Fig. 1B) or removed (Fig. 1A) by strong unidirectional currents. There also is a spectrum of pliable to rigid deformation or dismemberment revealed by the new specimens of Evans et al. (2015), perhaps related to freezing or desiccation. This new biophysical and life style evidence of Evans et al. (2015) allows a variety of interpretations of *Dickinsonia* as sessile lichens, foraminifera, or cnidarians, but falsifies interpretation as motile jellyfish, placozoans or worms.

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