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Exceptional preservation of soft-bodied Ediacara Biota promoted by silica-rich oceans

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We recently documented paleontological, petrographic and geochemical evidence in support of our novel silica cementation-driven mechanism for Ediacara-style fossilization (Tarhan et al., 2016). Retallack (2016b) accepts the evidence for early silica cementation but posits the process was terrestrial. Specifically, he suggests that the Ge/Si values we reported for silica cements from the classic Ediacara Member of South Australia, which hosts the Ediacara Biota, indicate a terrestrial paleosol rather than a marine origin. He defends that contention by reiterating arguments (e.g., Retallack, 1994, 2013, 2016a) in support of his belief that the Ediacara Member represents a paleosol. Retallack (2016b) notes that the median Ge/Si values we measured in Ediacara silica cements and associated quartz grains overlap with Ge/Si values measured from modern and putative ancient soils, and he asserts a lack of overlap with marine-sourced Ge/Si values. However, Retallack's arguments concerning soil clays are not relevant. Both terrestrial and marine clays are commonly characterized by heavy Ge/Si values (see Kump et al., 2000, and references therein). There are, moreover, no clays (nor iron oxides) present in our Ediacara samples, despite the presence of intact feldspars, which further refutes a paleosol origin for these arenites. Thus, a perceived overlap with soil Ge/Si values is neither remarkable nor diagnostic of a pedogenic origin for the Ediacara Member. Marine Ge/Si values varied widely through Earth's history, particularly during the Proterozoic, prior to the advent of silica biomineralization (e.g., Shen et al., 2011). Moreover, both modern and sedimentary data indicate that benthic processes (e.g., complexation of Ge with organic compounds: Pokrovski and Schott, 1998) can result in pore-water enrichment in Ge and thus higher Ge/Si values in authigenic silica, as we argued for the Ediacara cements. In light of these well-known considerations, our observed cement Ge/Si values fall well within the range expected for marine authigenic cements.

Retallack (e.g., 1994, 2013, 2016a) previously attempted to demonstrate that the Ediacara Member was deposited in a terrestrial environment. However, these attempts relied on proxies which are neither convincing nor diagnostic of a paleosol origin, and have already been refuted (e.g., Xiao et al., 2014; Tarhan et al., 2015). As with the Ge/Si ratios, Retallack has conflated geochemical or mineralogical signatures that can occur in terrestrial settings (but are also known to occur in marine systems) with evidence for a terrestrial origin. Furthermore, the Ediacara Member contains abundant sedimentological and paleontological evidence of a subaqueous, marine depositional environment and habitat for the Ediacara Biota (e.g., Gehling and Droser, 2013; Xiao et al., 2014). The richest Ediacara Member fossil assemblages, for example, occur along the surfaces of oscillation-rippled mature sandstones, and current-aligned and current-perturbed fossil assemblages are common.

Retallack (2016b) also argues that Ediacara-style preservation did not disappear in the early–middle Paleozoic, concomitant with the radiation of silica-biomineralizing organisms, pointing to Carboniferous and younger permineralized plant deposits as examples. However, Ediacara-style preservation—fossilization of soft-bodied organisms as sandstone casts and molds—is a process fundamentally distinct from sinter- and groundwater-mediated permineralization and petrification of plants in continental environments. The early-stage silica cementation of mature sandstones, which we observe in Ediacara fossils, is very different from permineralization or silica replacement. Moreover, multiple lines of evidence indicate that Ediacara organisms were neither plants nor lichens, but populated benthic marine communities which included stem- and crown-group animals, as well as macroalgae (Xiao et al., 2013; Droser et al., 2016). The early silica cementation mechanism that we proposed (Tarhan et al., 2016) obviates the need for recalcitrant components such as lignin to explain the preservation of Ediacara organisms (contra Retallack, 1994). Furthermore, the co-occurrence of signature species such as *Dickinsonia costata*, *Kimberella quadrata*, *Tribrachidium heraldicum*, *Charnia masoni*, and *Parvancorina minchami* in Ediacaran strata on widely separated continental fragments around the world is consistent with marine dispersal and very difficult to reconcile with a terrestrial interpretation of the Ediacara Biota. In sum, our paleontological, petrographic and geochemical data not only indicate that marine-derived silica cementation played an integral role in the fossilization of Earth's earliest complex communities, but also robustly support a marine paleoenvironment for the Ediacara Member.

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