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Forum Comment

The oldest evidence of bioturbation on Earth

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Here we question the conclusions of Rogov et al. (2012), who claim to describe "the oldest evidence of bioturbation on Earth" in the form of meniscate backfilled burrows and escape traces from late Ediacaran carbonates of the Siberian Khatyspyt Formation. Because trace fossils can constrain early Metazoan origins, and are used to define the base of the Cambrian Period (Brasier et al., 1994), such a significant claim requires justification by careful interpretation of the material, and critical analysis, both of which appear wanting here. Although we agree that multiple biological and ecological revolutions took place during the late Ediacaran Period, we question whether those events can be tied to these problematic fossils.

Numerous concavo-convex structures preserved either three-dimensionally in beds up to 50 mm thick, or compressed on bedding plane upper surfaces, are interpreted as "intensely bioturbated ichnofabric" with discrete burrows exhibiting meniscate backfill, resulting from food-seeking behavior (Rogov et al., p. 395). Those authors questionably assign this fabric to the ichnogenus *Nenoxites* (an interface trace fossil that, by diagnosis, has limited ichnofabric-forming potential).

Rogov et al. (p. 397) argue, presumably on the basis of meniscate backfill as complex behavior, that the putative ichnofabric is "the most reliable paleontological evidence for the existence of triploblastic Eumetazoa at ca. 555 Ma." No strong evidence is provided to support the interpretation of the arcuate structures as meniscate backfill of burrows. The apparent lack of cross-cutting relationships in such a dense ichnofabric is anomalous, yet not discussed. Grain size and mineralogical data, which may allow assessment of the inference that the light-dark color banding relates to sediment sorting in burrows, is lacking. The presence of irregularly distributed bridges between the inferred meniscae (Rogov et al., 2012, their figures 2B and DR2) is inconsistent with a meniscate mode of formation; such bridges are not seen in authenticated Phanerozoic meniscate burrows.

Sediment fabrics across the Proterozoic–Cambrian transition are well studied, with ichnofabrics showing the sediment-sorting behavior that results in meniscate backfill otherwise first recorded in Tommotian age strata. The absence of such ichnofabrics in intermediate strata worldwide makes the authors' inferences difficult to reconcile, and necessitates careful verification. Clarification of how the proposed ichnofabric and discrete traces interrelate, perhaps via study of petrographic thin sections, would be invaluable. Serial sectioning or CT-scanning would also reveal the true three-dimensional morphology (cf. Bednarz and McIlroy, 2012), without which interpretation as the world's oldest ichnofabric would seem premature.

We agree that the Khatyspyt 'ichnofossil' material shows strong similarities to the Ediacaran fossils *Helanoichnus helanensis*, *Shaanxilithes ningqiangensis*, *Palaeopascichnus minimus*, *P. meniscatus*, and *P. jiumenensis*, but these forms are widely regarded as body fossils (e.g., Jensen et al., 2006; Shen et al., 2007; Antcliffe et al., 2011). Features used by Shen et al. (2007) to demonstrate body fossils are also observed in the Khatyspyt material, notably: (1) sudden changes in thickness of candidate traces better explained as folding of a tube (see Rogov et al., their figures 3D and 3F left); (2) displacement and convergence/divergence of segments, which may result from bending (e.g., their figures 3E and DR2); and (3) apparent indentations in tubular taxa (their figure 3C; see also Jensen et al., 2006). We note that the Khatyspyt material closely resembles dense populations of lightly biomineralized tubular taxa known from the latest Ediacaran, especially the Spanish *Cloudina* bioherms described by Cortijo et al. (2010). The proposed escape trace (Rogov et al.'s figure DR2) could be compared to the stacked conical walls of *Cloudina*, while a circular cross-section visible on the left-hand edge of their figure DR2 is also consistent with a thick-rimmed annulated tubular taxon.

Direct dating of the Khatyspyt successions only constrains this assemblage to older than 543.9 ± 0.9 Ma, while the date presented for correlated occurrences of *Nenoxites* in the Ust-Yudoma Formation, Eastern Siberia (553 Ma) has a large error bar of ±23 m.y. (Rogov et al., and references therein). This permits the possibility that the Khatyspyt material is earliest Cambrian in age. The position of the section just below the biomineralized tubular fossil *Cambrotubulus* is consistent with close proximity to the Cambrian boundary (Brasier et al., 1996), bringing the assemblage within range of *Cloudina* occurrences globally (Amthor et al., 2003). Precise geochronological dating is therefore required to rule out a younger age for this interesting assemblage.

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