



“Soft-shelled” monothalamid foraminifers as a modern analogue of early life

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According to the fossil record, the earliest undoubted foraminifers are found in the Early Cambrian, where they are represented by tubular agglutinated forms, thought to be the most primitive foraminiferal morphotypes. The numerous foraminifers with single-chambered, organic-walled tests (i.e. ‘soft-shelled’ monothalamids) exist in the deep sea and are difficult to preserve as fossils. Molecular phylogenetic data tell us that these ‘primitive’ taxa include the deepest foraminiferal clades, originating around 600 - 900 Ma. We found many soft-shelled monothalamids in sediment samples from deep trenches, including the Challenger Deep (Marianas Trench) and the Horizon Deep (Tonga Trench). Both deeps exceed 10,000 m water depth, well below the carbonate compensation depth, which represents an environmental barrier for calcareous foraminifera. The foraminifera at these extreme hadal sites include tubular and globular forms with organic walls, among which species of the genera *Nodellum* and *Resigella* are particularly abundant. Some forms selectively agglutinate minute flakes of clay minerals on the surface of the organic test. Many soft-shelled monothalamids, including most of those in deep trenches, contain stercomata, the function of which is currently unknown. Gromiids (a rhizarian group related to foraminifera) also accumulate stercomata in their sack-shaped tests. This suggests the possibility that the function of these waste particles is to add bulk, like the filling of soft bags or pillows. We suggest that the monothalamid foraminifera that dominate small-sized eukaryotes in extreme hadal settings may provide clues to understanding the biology and ecology of early life in Neoproterozoic sedimented habitats.