Rugosoopsis – A New Group of Upper Riphean Animals

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Molecular clocks broadly give evidence of quite deep, Mesoproterozoic evolutionary roots for metazoans. The direct evidence of the origin of animal life can be found by the fossils they formed, a diverse biota assemblage with a variety of preservational modes.

Abundant, well preserved and highly biodiverse microfossil assemblages are known as the Lakhanda microbiota (from the Upper Riphean, dated at 1025-1010 Ma, in the Uchur-Mayai region of southeastern Siberia). *Rugosoopsis* microfossils with very long (up to 1 mm, pl. 1) narrow ribbon-like filaments have been discovered in the Kumakhin Member.

Microfossils assigned to the formal genus *Rugosoopsis* have, as a type species, *R. tenuis*. *Rugosoopsis* has a uniform shape, with prominent closely transversely spaced wrinkles on the outer surface (Timofeev & Hermann, 1979, pl.29, fig.5, 7). Width varies from 25 to 50 micrometers, constant throughout the length; some filaments show thick basal terminations

Abundant *Rugosoopsis* are now known in shales of the Ignikan Formation in the upper part of the Lakhanda Group. Numerous *Rugosoopsis* with better preservation and greater width (up to 140 micrometers, with length up to 3 mm), have been preserved on organic sapropel films. Such fragments of these films (0.5 x 0.5 cm) can preserve up to 20 narrow filamentous and ribbon-like microfossils of *Rugosoopsis*, with varying preservation.

Perhaps *Rugosoopsis* is a kind of cyanobacteria. N. Butterfield demonstrated the double-layer structure of *Rugosoopsis* and the presence on its surface of a *Lyngbya* - like outer sheath (Butterfield, Knoll & Swett, 1994; Butterfield, 2001; Samuelsson & Butterfield, 2001). Butterfield (2001) described this organic material as a "distinctive inner tabular sheath surrounded by a less substantial transversely oriented outer sheath, which can sometimes give the (false) impressions of a cellular trichome”. He noted the tendency for a loss the outer layer in shale-hosted specimens.

That is correct, but we suggest that *Rugosoopsis* are instead the oldest, microscopic vermiform organisms. *Rugosoopsis* appears to have a multicellular layer of parenchyma, which is covered by a wrinkled layer. Multicellular tissue appears to be composed of small spherical cells (2-3 micrometers) with narrow intervals between cells, which are arranged in a single layer. We interpret his layer as epithelium – tissue with very little substance between cells, a thin membrane covering the outside and inside of the body. The epithelium can develop into a cuticle – a thin layer of non-cellular material, and in the case of *Rugosoopsis*, may be the outer wrinkled layer. Some peculiar structures observed in *Rugosoopsis* include a system of horizontal, narrow, dense belts, which appear to subdivide the body into several parts. Sometimes, the long body of *Rugosoopsis* is broken across into several short fragments with the development of hemispherical terminations. *Rugosoopsis* may be divided, but does not fall apart and is instead preserved as one elongate vermiform, where fragmentized parts of body have rounded terminations. This process resembles parathomia.

Typical morphology of closely spaced wrinkles on the body’s outer surface resembles the Late Vendian - Early Cambrian *Sabellidites*, even more the smallest representatives in the genus *Sokolovina* Kirjanov, 1968 (Sokolov, 1998). Different types of *Rugosoopsis* preservation can be explained by the presence of numerous bacterial microorganisms on the body of *Rugosoopsis* and on organic films. One part of those bacterial remains resembles *Primoflagella*, described by M.B. Gnilovskaya (1979).

Bacteria were developed on the vendotaenia tissue and may be actinomycetes. Morphologically, the body of *Primoflagella* resembles short filaments with the upper part rounded and the lower part narrowed, where branched mycelium invade the vendotaenia tissue. Riphean bacteria do not have such mycelium.

Other bacterial organisms are preserved as mat-building, narrow filaments, described as actinomycetes and attributed to *Archaeotrichion lacerum* Hermann, 1989 (Jankauskas et al., 1989). Bacterial activities had a direct influence on the preservation of any organic remains. Sometimes, the outer wrinkled morphology is decayed and filaments have a smooth surface. The thin epithelium membrane in *Rugosoopsis* may be preserved best after grazing of the outer wrinkled layer of cuticle by other organisms. Bacterial remains are seen on *Rugosoopsis* filaments from the material of Lone Land Formation fig.3 A-D (Samuelsson & Butterfield, 2001).

Rugosoopsis organisms inhabited the bottom, where they likely existed alongside saprophytic microbes on finely dispersed organic debris. The community of *Rugosoopsis* and bacterial organisms appears to represent a stable trophic system with expected producers and consumers (Zavarzin, 1993). *Rugosoopsis*, in Late Riphean times had developed a tough, non-mineralized cuticle, ornamented by crossed wrinkles in order to protect the inner soft-parts of the body. The exceptional preservation of such non-mineralized organic remains depended on favourable sedimentary environments that are exposed in the Lakhanda Basin, with the biota preserved in fine-grained clays where enzyme interaction with the mineral surface in clay-polymer matrix insured imprinting of fine detail (Butterfield, 1990; Korneeva, 2002). Microfossils making up the Lakhanda Microbiota are similar in preservation style to fossils in the Burgess Shale –and the microscopic Metazoa preserved in the Lakhanda sediments are older than the Ediacara macroscopic metazoans. Among the explanations of early origin and long cryptic evolution of primary metazoan phyla, which were restricted to spatially limited habitats (relatively cold and well oxygenated basins, Fedonkin, 1992, 2003), we support the idea of a slow evolution during the Neoproterozoic (moderate concentration of free oxygen and heavy metals, that restrict biological complexity growth and the eukaryotization of biosphere, Sochava, Podkovyrov, 1993). Rapid Metazoa radiation linked with abrupt geodynamic changes in Vendian (590-540 Ma) "..can be considered as an evolutionary response to the geochemical deterioration of environment" (Fedonkin, 2003) in conditions of growing concentration of free oxygen that dramatically accelerated biological complexity.

Plate 1

1 – *Rugosoopsis* subdivided into some fragments with hemispherical terminations, fixed on organic sapropel films.

2 – *Rugosoopsis* without typical morphology, degraded by bacterial activity.

3 – *R. tenuis*, holotype.

4 - Isolated fragment of *Rugosoopsis* with different modes of it preservation:

4a – general plane of the filament; 4b – magnified view of the central part of a filament; where the upper, curved termination has no wrinkles and appears as a smooth tube; 4c – magnified view of the upper part of a filament with a partly preserved outer, transversely wrinkled surface; 4d – magnified view of the lower part of the multicellular layer of *Rugosoopsis*.

5 – Fragment of *Rugosoopsis* with the peculiar, annular, narrow belt in the upper part of the photo

6 – Bacterial microorganisms similar to *Primoflagella* visible on the smooth termination of *Rugosoopsis*; notice the preserved narrow horizontal belt.

7 – Numerous *Primoflagella* on the surface of *Rugosoopsis*.

8 – Mat-building *Archaetrichion lacerum*.