Comparative Taphonomy of the Vendian Genera

*Beltanelloides* and *Nemiana* as a Key to their True Nature

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A significant part of the described soft-bodied Neoproterozoic animals are simple rounded or cyclic forms. The fact that often there are few morphologic features preserved creates difficulties with taxonomy. Some genera such as *Inaria* are exceptions to this rule (Grazhdankin, 2000). Taphonomic studies can sometimes give some insights into the real morphology of some of these forms.

*Beltanelloides sorichevae* Sokolov, 1965 is one of these simple forms. This taxon was originally described from sediments of the Upper Vendian of the European Platform, in the White Sea region. Organisms were typically preserved as negative, rounded impressions with thin, irregular concentric wrinkles on the periphery of an organic film. Remains lay in beds of massive, structureless clay. Such imprints had the same structure both on the upper and lower surfaces of the rock. When fossils were found close to one another, they lay preserved on different levels (Fig.1). The enclosing clay deforms both above and below the fossils.

Such features are evidence that *Beltanelloides* was a spherical organism with a thin, but durable envelope and a cavity in its center. Possibly it was a planktonic autotroph – an idea
originally proposed by B. S. Sokolov (1976) and supported by later investigations (Asseeva, 1988; Gnilovskaya, et al., 1988).

The process of forming Beltanelloides imprints may be illustrated by the following four stages (Figs. 2-1 – 2-4):

1. Spherical organisms fall to surface of muddy bottom
2. Organisms buried by mud, still spherical in shape
3. Mud compacted through diagenesis. Beltanelloides also compacted to form flat imprints with an organic film. Upper and lower sediments deformed to fill the space of the inner cavity
4. As a result upper and lower surfaces of clay (double-sided) imprints can be seen.

There is a second type of preservation of Beltanelloides as well. Fossils of this taxon occur in the lower member of the Upper Vendian Zimnie Gory Formation Gory on the White Sea Winter coast. These fossils occur as low, positive in hyporelief, imprints on the lower surfaces of sandstone beds. They are found on the surfaces both with accumulative and erosive features. In dense clusters fossils overlay each other, or, more rarely, they contact each other, deforming slightly in this case (Fig. 3). It means that these clusters were not flat primarily and organisms were buried in the sediment on the different layers. This seems to be evidence of their planktonic nature.

The following sequence is envisioned as to how this sort of accumulation formed (Figs. 2-5 – 2-9):

5. Organisms fall down to a muddy bottom from. Some were buried in the mud partially or entirely
6. As a result of some hydrodynamic event, e.g. a storm current, the thin layer of sand is deposited on top of the organisms and the mud. Depending on local conditions, there may be some erosion and excavation of the levels containing the buried organisms.

7. When the sediments compact, on the boundary of clay and sand, imprints form on the lower surface of those *Beltanelloides* which were immersed in the clay.

8. The result is round positive imprints on the undersides of sandstone beds.

*Nemiana* simplex Palij, 1976 is another genus of round fossils with a simple morphology and irregular concentric wrinkles. It comes mainly from the Upper Vendian of Podolia (Ukraine). Some authors consider *Nemiana* as a junior synonym of *Beltanelloides* (Gureev, 1988). These remains are found on the lower surface of sandstone beds and the typical type of preservation is an imprint with high, positive relief and margins that are submerged into the sandstone layer and this boundary can be traced in cross-section to the center of the fossil. When one examines sections through these fossils it is possible to observe the negative imprints of the upper surface of the organism and the sandstone infill of the space between the fossil and the positive imprint of the lower surface (Fig. 4). So it is possible to think that *Nemiana* preserved as an inner cast of the body of an organism.

The following sequence may explain the *Nemiana* type of preservation (Figs. 2-9 – 2-12):

9. *Nemiana* was a benthic, sac-like organism, round as viewed from above, with an opening on the upper part of the organism. *Nemiana* lived on the muddy bottom, partially submerged in the mud, often living in clusters (monotaxon assemblages).

10. *Nemiana* assemblages were then buried in situ by incoming sand with the sand immediately filling the inner cavities of the organisms.

11. In the process of diagenesis, casts of the cavities become solid quite early. Fossils become compressed slightly so overlying layers were not deformed or pushed up and over the contours of the fossil remains.
12. When found, casts of Nemiana occur on the bottom surfaces of sandstones.

Comparison study of Beltanelloides and Nemiana show differences between the two taxa with regard to their distribution of rock surfaces. Specimens with multiple imprints of Nemiana from the Yampol beds of the Mogilev Formation (Novodnestrovsky Quarry, Podolia, Ukraine) and from the Yorga Formation (Zimnie Gory Location, White Sea Coast, Russia) were used for this comparison. Beltanelloides specimens are from the Lyamza and Zimnie Gory formations (Lyamza and Zimnie Gory localities, White Sea Coast, Russia). The mean diameter of each fossil and the shortest distance between the center of the fossil and the center of the “next-door” neighbor were measured on each of the specimens. From 20 to 125 imprints were measured on each specimen (on average 60).

Such measurements illustrated a significant differences between clusters of Beltanelloides and Nemiana (Fig.5). Statistically significant are difference in the coefficients of variation for the diameter of organisms in the population and coefficients of variation for distance between them. Nemiana assemblages are well-ordered, Beltanelloides more randomly distributed. Such well-ordered arrangement in Nemiana clusters is observed in both loose and dense distributions. Even when individuals do not contact one another, the distance between individuals is regular. This is suggestive of a colonial nature in Nemiana, as opposed to the non-regular allochthonous clusters of Beltanelloides.

Conclusions:

1. Nemiana and Beltanelloides are two quite distinct groups of Vendian organisms with different morphologies, ecologies, and have produced quite different taphocenoses.
2. There are two main types of Beltanelloides preservation:
   a. Double-sided imprints with negative relief and phytoleima in clay.
   b. Positive in hyporelief imprints on the bottom surface of sandstone layers.
3. Beltanelloides and Nemiana form different types of “death assemblages,” the
difference being due to the ecological niches that were occupied by each organism. It may be documented both by taphonomic and biometric methods. There is no evidence about findings of *Nemiana* and *Beltanelloides* from the same surfaces or even members. So in future investigations it is possible to link these fossils with the different types of paleoecological environments in Vendian basins.

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References


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Figure 1. *Beltanelloides sorichevae* Sokolov, 1965. Russia, Archangelsk Region, Lyamtca locality, Upper Vendian, Lyamtca Formation. Scale 1 cm. If the broken surface of the clay shears near such organic remains, but does not split open completely, it is possible to observe deformation of the clay above and below the fossil.

Figure 2. Taphonomic reconstructions.

1-4 - *Beltanelloides sorichevae*, typical preservation;

2-8 - *Beltanelloides sorichevae*, second type of preservation - on the bottom surface of sandstone layers;

9-12 - *Nemiana simplex*.

Figure 3. *Beltanelloides sorichevae* Sokolov, 1965. Russia, Archangelsk Region, Zimnie Gory locality, Upper Vendian, Zimnie Gory Formation, lower member. Scale 10 cm.

Figure 4. PIN 3993/5611 *Nemiana symplex* Palij, 1976. Russia, Archangelsk Region, Zimnie Gory locality, Upper Vendian, Yorga Formation, third member of the first mesocycle. Scale 1 cm.

Figure 5. Dendrogram of the linkage of samples using non-metric statistics. The difference between location of the clusters of *Nemiana* and *Beltanelloides* is quite noticeable.