

# Comparative taphonomy of Vendian genera *Beltanelloides* and *Nemiana*: taxonomy and lifestyle

M. V. LEONOV

*Paleontological Institute Russian Academy of Science, 117868 Profsoyuznaya Street, 123, Moscow, Russia (e-mail: maxleon@narod.ru)*

**Abstract:** Taphonomic analysis of new material from Vendian sequences of the White Sea and southwestern Ukraine provides data for a better definition of both the widely distributed fossil taxa of *Beltanelloides* and *Nemiana*. A new type of *Beltanelloides* preservation is described, so it is now possible to attribute some sandstone imprints to this taxon. *Nemiana simplex* seems to have a lifestyle and level of body organization comparable with that of sponges. The narrow range of facies in which *Nemiana* occurs, when compared to the much broader range of *Beltanelloides*, is compelling evidence for a benthic lifestyle of *Nemiana*.

This paper clarifies the taxonomy and palaeoecology of two groups of widely distributed genera of Neoproterozoic organisms. Both genera are characterized by a simple shape, which makes comparisons and diagnosis difficult. Study of taphonomy and palaeoecology of fossils are the methods that may help us to solve some problems. Such types of investigations (Gehling 1999; Grazhdankin 2000) result in some progress in our understanding of the nature of some soft-bodied organisms. Biometric comparisons (Laflamme *et al.* 2004) also produce results that have essential significance for taxonomic comparison of Vendian fossils.

## Material and methods

The basis for the study is the author's collection and observations of the range of Upper Neoproterozoic outcrops on the Eastern European Platform, studied during field trips between 2000 and 2004. Collections of the Paleontological Institute, Russian Academy of Science in Moscow were also most useful. Material was collected from the Upper Vendian sequences of Podolia and the White Sea region (Ediacaran in age), referred to the uppermost part of the Vendian sequence (Redkino and Kotlin regional stages) (Aksenov *et al.* 1978). Additionally, biometric analysis utilized images from publications (Palij 1976; Fedonkin 1985).

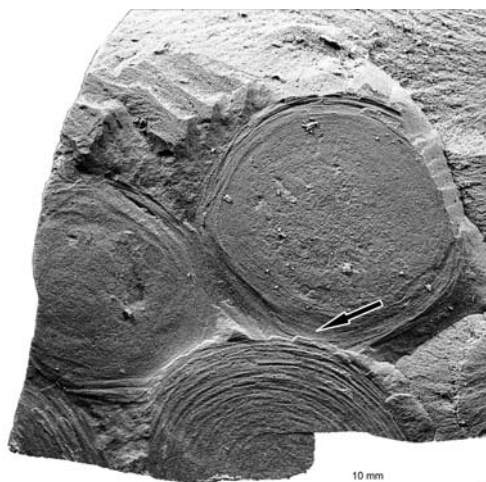
Collections from the type regions and from many stratigraphic levels were available, making it possible to determine taphocoenoses typical for each taxon. Some unusual forms of preservation were observed. In addition to the field studies, biometric analysis was carried out.

*Beltanelloides sorichevae* was first described in 1965 and further diagnosed in 1972 (Sokolov 1972). The fossils are round imprints, with very

thin concentric wrinkles around the periphery, preserved as carbonaceous films. The type material was recovered from Vendian deposits of the Onega Peninsula (White Sea area, northern Russia) and from the Odessa borehole (southern Ukraine). These remains were thought to be planktonic, colonial algae, similar in general morphology to the extent *Volvox* (Chlorophyta) (Sokolov 1965; Gnilovskaya *et al.* 1988). *Beltanelloides* may well be algal, but some forms previously included in this genus (for example, '*Beltanelloides*' from the Bernashevka Formation of Podolia, Ukraine) appear to be truly benthic organisms, possibly related to *Moraniales* (Aseeva 1988).

*Nemiana simplex* (Palij 1976) is a name applied to a second type of round imprints, originally described from the Upper Vendian sequence of Podolia (Ukraine) from the Redkino Regional Stage, Mogilev and Yampol formations (Palij 1976). *Nemiana* remains are also known from the Kotlin Regional Stage, Yorga Formation of the White Sea region, Russia (Fendonkin 1985), the Neoproterozoic sequence of the Wernecke Mountains, Canada (Narbonne & Hofmann 1987) ('*Beltanelliformis brunssae*' specimens on pl. 74, fig. 5–7 and pl. 75, fig. 1–8), and the Kliphoeck Member of the Neoproterozoic Dabis Formation of Namibia (Jenkins 1992). These imprints have a very well-defined shape, with high relief, preserved on the soles of sandstone beds, which can be found as single individuals or more often in dense groupings. Typically these fossils are best preserved at a clay/sandstone boundary.

*Tirasiana disciformis* (Palij 1976) is yet another form that is morphologically similar to *Nemiana*, but it differs in having a central peak preserved in positive hyporelief. Many examples that were originally described as *T. disciformis* on the basis of characteristics of the peripheral zone (e.g. Palij



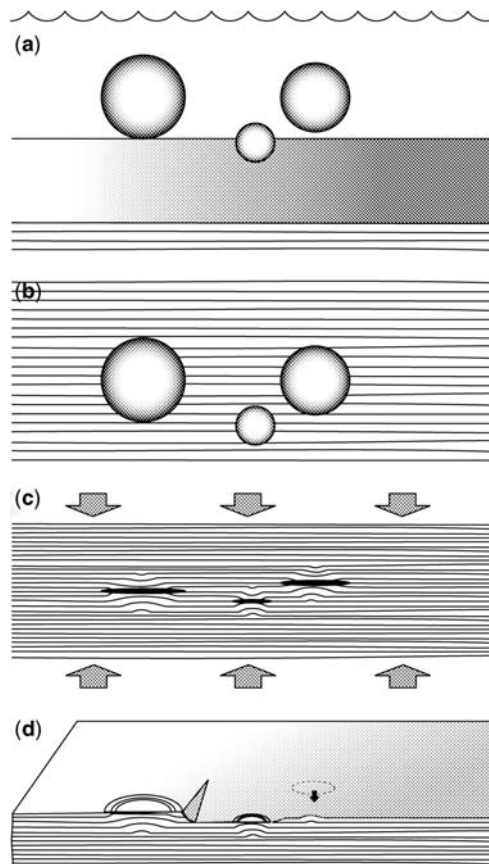
**Fig. 1.** PIN 5079/9 *Beltanelloides sorichevae*. Upper Vendian sequence, Redkino Regional Stage, Arkhangelsk region, Lyamtsa locality, Russia. Top surface of the split rock. Arrow marks an individual overlapping another.

1976, pl. XXIII, figs 1, 2), appear to represent a relatively large form of *Nemiana*. This idea is supported by the observation of a morphological series of *Nemiana* specimens that demonstrates that, as specimens increase in size, concentric rings can be discerned along their margins (Fig. 11; Palij 1976, pl. XXII, fig. 3).

Some researchers consider *Nemiana* a junior synonym of *Beltanelloides* and refer to these fossils as *Beltanelloides simplex* (Gureev 1988). Narbonne & Hofmann (1987) agree with this interpretation of *Beltanelliformes brunsa* and *Nemiana simplex* noted above. They have suggested

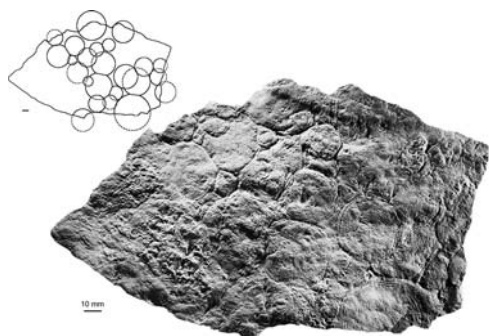


**Fig. 2.** PIN 5079/13 *Beltanelloides sorichevae*. Upper Vendian sequence, Redkino Regional Stage, Arkhangelsk region, Lyamtsa locality, Russia. Top surface of the split rock. Arrow marks an individual that lies in the rock but is not seen on the break surface.



**Fig. 3.** Taphonomic scenario for preservation of *Beltanelloides sorichevae* (typical preservation). (a) Spherical, planktonic organisms fall to muddy seafloor. (b) Organisms buried by mud, still spherical in shape. (c) Diagenesis compacts mud. Organisms compacted to form flat imprints surrounded by organic film. Upper and lower layers of sediments deformed and fill space of inner cavity. (d) Upper and lower surfaces of organism (double-sided) leave imprints in the clay.

that the two taxa were simply different types of preservation of the same organism. Recent work, however, does not support this opinion. There are three major features of the genus *Nemiana* that are not characteristic for all other taxa, mentioned above. The first is the nature of the overall shape—hemispherical in hyporelief—of the smaller individuals (diameters of less or about 1 cm). The second feature is the nature of the marginal imprint, which rolls up towards the upper layer and then curves towards the central axis of the fossil. The third feature is nature of the distribution of specimens in dense assemblages. This new feature is specific to *Nemiana* samples from



**Fig. 4.** PIN 5079/52. Second taphonomic scenario for preservation of *Beltanelloides* preservation. Upper Vendian Sequence, Redkino Regional Stage, Zimnie Gory Formation, Arkhangelsk region, Zimnie Gory locality, Russia. Bed sole. Note the overlaying of the clustered individuals.

the type locality in Podolia and must be included in an emended diagnosis of this taxon after revision.

All of these genera seem to be monotypic, but to which higher taxa they belong is yet to be determined.

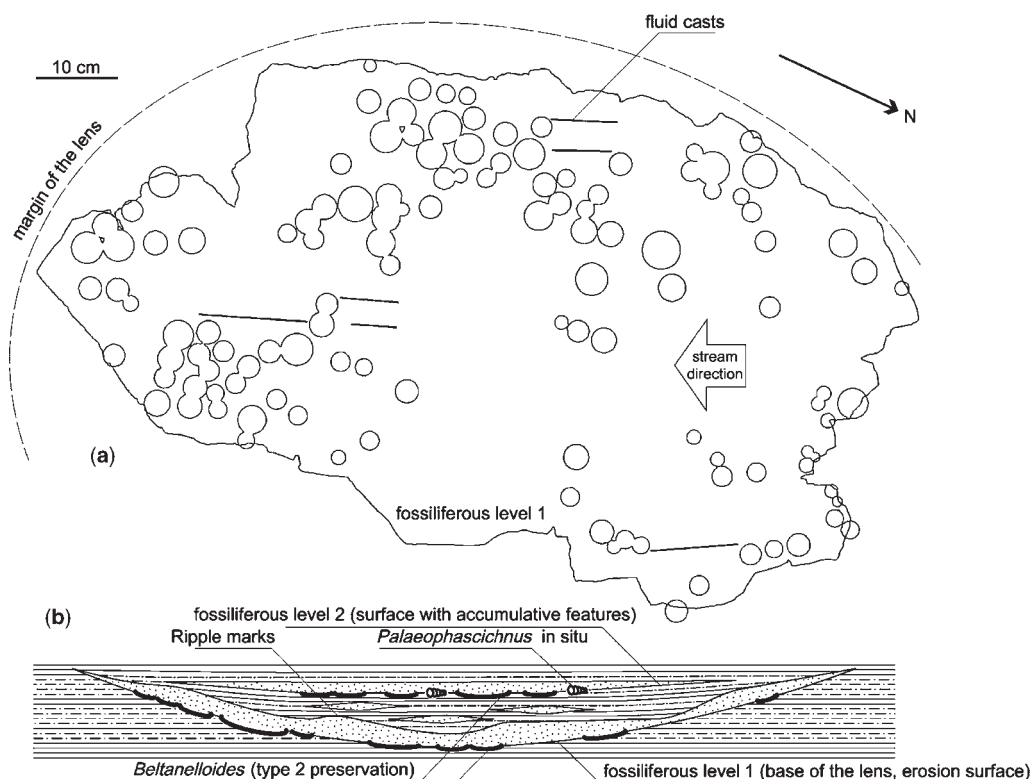
But, first, clear criteria for generic diagnosis on the basis of detailed comparisons, noting the preservational overprints, are needed. The author supports the idea that at least two different taxa, *Beltanelloides* and *Nemiana*, should be recognized.

## Taphonomic analysis

### *Beltanelloides sorichevae*

*Beltanelloides* specimens from the Lyamtsa locality (southwestern Onega Peninsula) were used for study, found in the Lyamtsa Formation (assigned to the Redkino Regional Stage). The Lyamtsa Formation is characterized by thin, chocolate-brown clays with concave break surfaces, lacking visible lamination. These clays form beds up to a few dozens of centimetres that are included in a sequence of rhythmic siltstone–clay interbeds with rare sandstone beds. This complex was likely deposited in a shallow marine shelf environment, below storm wave base.

Fossils are preserved in negative relief on both the upper and lower break surfaces, thus



**Fig. 5.** PIN 5079/51. Second type of *Beltanelloides* preservation, Upper Vendian, Redkino Regional Stage, Zimnie Gory Formation, the first member, Russia, Arkhangelsk region, Zimnie Gory locality. Bed sole: (a) drawing of the bottom surface of the basal sandstone; (b) schematic cross section through the fossiliferous lens.

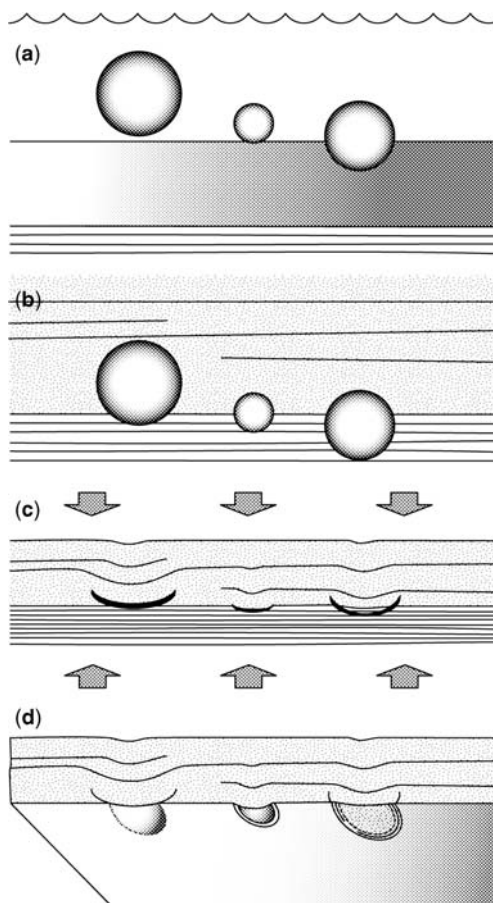


Fig. 6. Taphonomic scheme for *Beltanelloides sorichevae* (second type of preservation).

representing the upper and lower sides of the organism. There is no evidence of a carbonaceous film. An important feature is the overlaying of individuals that can occur in dense clusters (Fig. 1, see arrow). This can be observed on some already published images (Sokolov 1977, p. 437, fig. a; Fedonkin 1985, Pl. FV fig. 2). *Beltanelloides* imprints can also occur on other clay surfaces in a widely spaced distribution of individuals (Fig. 2). Deformation of the clay around the individuals (marked by the arrow) that are preserved in the clays, but have not broken the surface, is visible in some specimens; these represent traces of compaction of *Beltanelloides* from its original spherical shape, within the sediment.

Some conclusions can be drawn from the above observations. Groups of *Beltanelloides* are clusters of individuals. These fossils are randomly distributed in the sediment. This certainly does not disprove their interpretation as remains of spheromorphic,

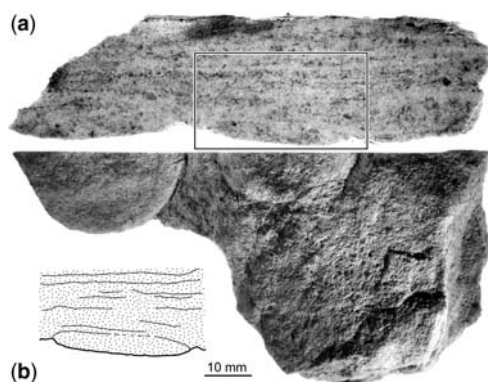
planktonic organisms. Such organisms appear to have had a thin, durable envelope surrounding less dense tissues or a cavity. A sequence of events can be suggested to explain these observations (Fig. 3): first, spherical organisms fell from the water to a muddy ocean floor. Then, these organisms were buried by mud, their form still spherical. The overlying mud, as well as the soft seafloor mud was compacted during diagenesis. At that time the organisms were compressed, forming flat imprints surrounding an organic film. Upper and lower layers of mud then filled the space occupied either by soft tissue that decayed or the inner cavities. What resulted were double-sided imprints with negative relief on the beds above and below, which may still have fragments of organic matter on their surfaces. The fossils occur not only at the boundaries of the layers. Specimens contained within the muds are more common, so the process of forming these fossils is not connected with microbial mat surfaces, as is the case for some Neoproterozoic organisms (Gehling 1999).

Another type of fossil was recovered from the Zimnie Gory locality, on the Winter Coast of the White Sea, northern Russia. These imprints were preserved in the lower member of the Zimnie Gory Formation. They occur in flat hillocks, in positive hyporelief on the bottom surfaces of the sandstones (Fig. 4). These sandstones occur as lens-shaped bodies up to 15 cm in thickness and about 1 metre wide. The lenses have an elliptical shape in plane view and cut into the underlying siltstone and clay-interbedding sequence (Fig. 5). The lower member of the Zimnie Gory Formation appears to have been deposited in a shallow marine basin that developed in valleys with low relief. The base of this sequence appears to be a flooding surface of marine transgression (Grazhdankin 2003). The lower bed within these lens-shaped bodies consists of quartzite with ripple marked top surfaces with an erosional base. The quartzites are overlain by a sandstone and siltstone interbedded unit, which may have formed as microturbidites. So the lower surface of the lenses has erosional character, but some surfaces in the lenses have accumulative character. Such event beds were likely deposited as a result of intensive local stream downcutting, with flow in the direction 120° SE, followed by relatively slow deposition that filled the downcut depression. Occurrence of ripple marks on the top surface of the basal sandstone and the presence of some benthic fossils *in situ*—such as *Palaeopascichnus* supports this interpretation. *Palaeopascichnids* are considered to be sedentary organisms, perhaps similar in morphology, if not actually related, to giant xenophaeophoran protists, which today live in biotopes that are produced by cyanobacterial biofilms (Seilacher *et al.* 2003).

The base of the lens often preserves large clusters of imprints. These organisms which produced the clusters, appear to have been buried simultaneously in one sedimentary event. It is possible to observe the absence of order in imprint distribution on the surface. In dense clusters, individuals are preserved in contact with each other or actually overlay neighbouring individuals to form a multi-layered imprint (Fig. 4). Morphology and taphonomic features of these imprints are very similar to '*Beltanelliformis brunsae*' from the Wernecke Mountains (Narbonne & Hofmann 1987, pl. 74, figs 1, 3). The following sequence is envisioned as to how this sort of accumulation occurred (Fig. 6):

- Organisms fall down to a muddy bottom from the water column. Some were buried in the mud, partially or entirely.
- As a result of some hydrodynamic event, e.g. a storm current, the thin layer of sand is deposited above the organisms and the mud. Depending on local conditions, there may have been some erosion and excavation of some levels containing the buried organisms.
- Upon sediment compaction, on the boundary between the clay and the sand, imprints formed of the lower surface of *Beltanelloides* which were immersed in the clay.
- The end result was a round, positive imprint on the undersides of sandstone beds.

Comparison of the two above-mentioned types of fossil preservation, taking into account the similar dimensions of the fossils under consideration, indicates that different sorts of sedimentary environments can make a difference in the final preservation of an organism.



**Fig. 7.** PIN 3994/1013 *Nemiana simplex*. Upper Vendian sequence, Redkino Regional Stage, Mogilev Formation, Podolia, Ukraine. (a) Cross-section and bottom surface of specimen. (b) drawing of marked fragment in cross-section. Bed sole. Note the absence of deformation of layers over the fossil.

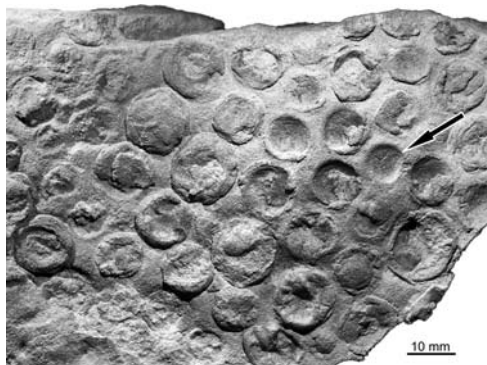
*Beltanelloides* imprints have a broad stratigraphic distribution, from the Lyamtsa Formation, where these fossils occur in beds of massive clays with thin interbedded layers of sandstone, into the lowermost part of the Erga Formation, where imprints occur in sandstone and mudstone interbeds. These fossils are also common at many different levels within the Redkino Series (lower part of the Upper Vendian sequence) of the Eastern European Platform (Sokolov 1973). *Beltanelloides* also occurs in many different facies, supporting the suggestion that they may have been planktonic.

### Nemiana simplex

*Nemiana simplex* was originally described from Podolia, Ukraine, based on specimens from Novodnestrovsky Quarry. This material is from the Yampol beds of the Redkino Regional Stage. The round fossils with a simple morphology and irregular concentric wrinkles, are found on the bottom surfaces (soles) of sandstones.

*Nemiana* is also known from the upper part of the Vendian sequence at the Zimmie Gory and Vavilushkin Creek localities (in the Erga Formation, of the Kotlin Regional Stage), White Sea region, Russia. Fossils from there occur in sandstones that are channel fills.

The high positive hyporelief imprints with margins that disappear into the sandstone are the most common type of preservation. Such a boundary surface can be traced in cross section to the centre of the imprint, forming an incomplete, sac-like inner cast. Such structure is also characteristic for some '*Beltanelliformis brunsae*' specimens



**Fig. 8.** PIN 3993/5611 *Nemiana simplex*. Upper Vendian sequence, Kotlin Regional Stage, Yorga Formation, third member of the first mesocycle, Arkhangelsk Region, Zimmie Gory Locality, Russia. Bed sole. Arrow marks negative imprints of the upper side of organism.

exhibiting *Nemiana*-type preservation' from the Neoproterozoic sequences of NW Canada (Narbonne & Hofmann 1987).

Sometimes the sediment that infills the casts and those that form the overlaying layer is the same, and sometimes gradational lamination in the cast is present. If the fossils have high relief, no compaction of the sediment in the fossils is visible (Fig. 9). Such is evidence that the sand fill of the inner cavity of *Nemiana* occurred before or just at the time of burial. Another type of preservation indicated that compaction has occurred. In this case, low relief casts with deep irregular wrinkles are characteristic of the fossils. A third type of preservation of *Nemiana simplex* is that of negative relief (both epi- and hyporelief) imprints of the external surface of the organism (Fig. 8). These imprints can be viewed when the cast is broken along lamination.

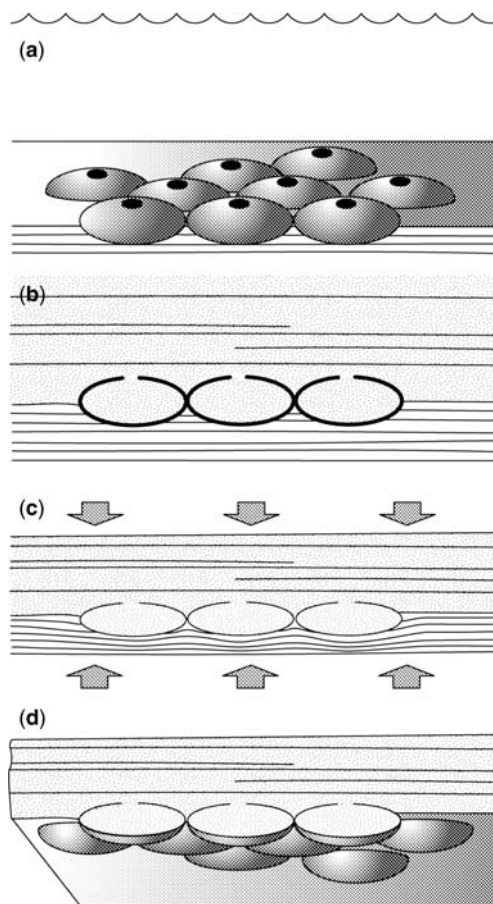


Fig. 9. Taphonomic scenario for preservation of the organism *Nemiana simplex*.

The following sequence may explain *Nemiana* type of preservation (Fig. 9):

- *Nemiana* was a benthic, sac-like organism, round in dorsal view, with an opening on the upper part of the organism. *Nemiana* would have lived on a muddy bottom, partially submerged, often living in clusters (monotaxonomic assemblages).
- Then *Nemiana* individuals were buried *in situ* by incoming sand. The event sediments immediately filled the inner cavities of the organisms.
- In the process of diagenesis, casts of the cavities became solid quite early. Fossils were compressed slightly, so the overlying layers were not deformed or pushed up and over the contours of the fossil remains.
- When found, casts of *Nemiana* occur on the bottom surfaces of sandstones.

*Nemiana* remains tend to occur in relatively dense groups on the surface of sandstones. In such cases all fossils occur on the same level, some individuals may be in contact along their margins. Some deformation of shape occurs, but individual

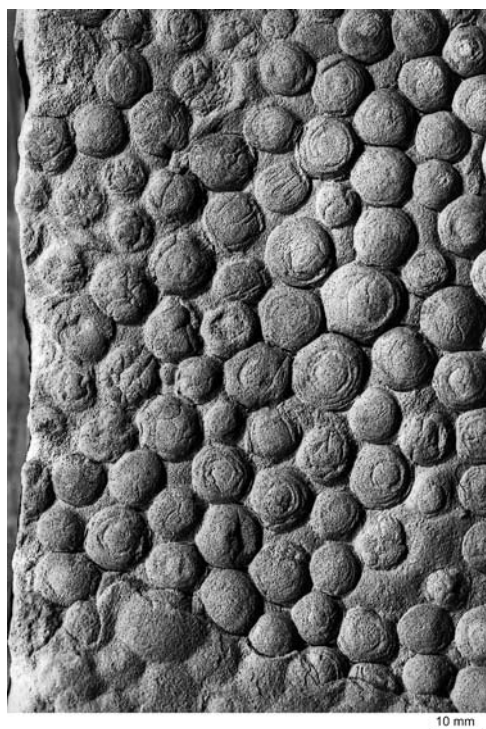


Fig. 10. PIN 3993/5610 *Nemiana simplex*. Upper Vendian sequence, Kotlin Regional Stage, Yorga Formation, third member of the first mesocycle, Archangelsk Region, Zimmie Gory Locality, Russia. Bed sole.



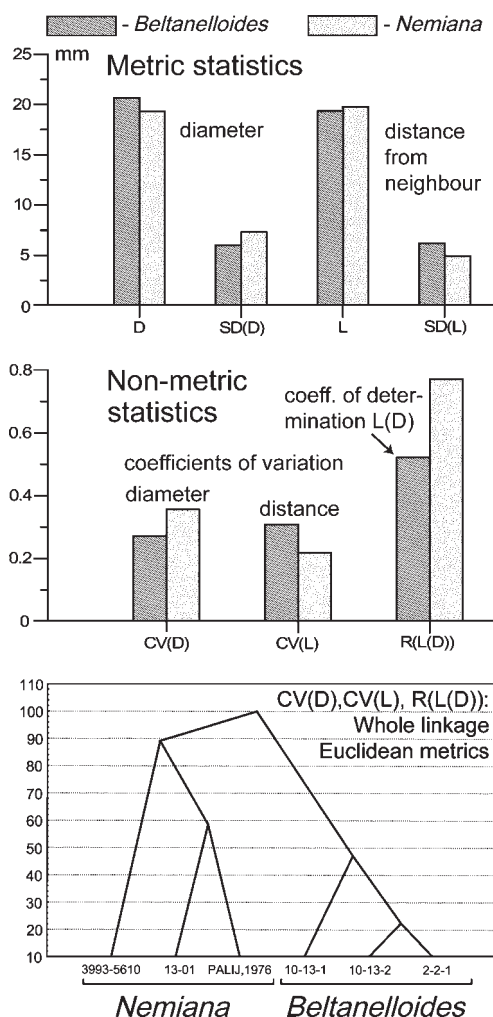
**Fig. 11.** *Nemiana simplex*. Upper Vendian sequence, Redkino Regional Stage, Mogilev Formation, Podolia, Ukraine. Bed sole.

remains usually retain a rounded polygonal form, similar to the regularity of 'honeycomb' structure (Fig. 10). It is important that such order in distribution occurs even when individuals are not in contact (Fig. 11). The distance between individuals remains uniform. It may be interpreted as evidence that *Nemiana* are the remains of benthic sedentary organisms. The absence of any indication of tentacles and the nature of the inner filling of these organisms indicate a sedentary organism. Some modern *Demospongia* are able to agglutinate the sand grains to support their inner fibrous skeleton (Reitner & Worheide 2002) and perhaps this form serves as a good analogue to *Nemiana*. Perhaps *Nemiana simplex* had a lifestyle and level of body organization comparable with that of sponges. The range of facies in which *Nemiana* occurs, when compared to the much broader range of *Beltanelloides* is compelling evidence for a benthic lifestyle of *Nemiana*.

### Biometric analysis

Comparison of the distribution of *Beltanelloides* and *Nemiana* illustrate differences with regard to their distribution in the clusters on the 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, White Sea Coast, Russia) were used for this comparison. *Beltanelloides* specimens are from the Lyamtsa and Zimnie Gory Formations (Lyamtsa and Zimnie Gory localities, White Sea Coast, Russia). The mean diameter of each fossil and the shortest distance between the centre of the fossil and the centre of the 'next-door' neighbour were measured on each of the specimens. From 20–125 imprints were measured on each specimen (on average 60).

Such measurements illustrated a significant difference between clusters of *Beltanelloides* and *Nemiana* (Fig. 12). Metric statistics (means (D, L) and standard deviations (SD, SL) of distance between imprints and diameter of specimens) do not demonstrate sufficient difference. Differences in the coefficients of variation are statistically significant for the diameter of organisms in the population and coefficients of variation for distance between them (non-metric parameters). *Nemiana* assemblages are well ordered, *Beltanelloides* more randomly distributed. Such well-ordered arrangement in *Nemiana* clusters is observed in both loose and dense distributions. This is suggestive of a sedentary form of life for *Nemiana* that were buried *in situ* contrary to the suggestions that they were allochthonous (Seilacher 1997).



**Fig. 12.** Biometrical comparison of specimens with numerous *Nemiana* and *Beltanelloides* imprints.

## Summary

There are two types of *Beltanelloides* preservation: (1) Double-sided imprints with negative relief and phytolite in clay; and (2) positive (in hyporelief) imprints on the bottom surface of sandstone layers.

*Nemiana* and *Beltanelloides* were two quite distinct groups of Ediacaran organisms with different morphologies, ecologies, and have produced quite different taphocoenoses.

*Beltanelloides* were planktonic forms. Fossils of these organisms occur in deposits laid down in many different environments, under both low and high-energy conditions. Fossil-bearing sediments were deposited in middle and upper sublittoral environments, both above and below storm wave base.

*Nemiana* was a benthic organism that occurred, for the most part, in monotaxonomic assemblages. It occurs in very specific types of sediments.

*Beltanelloides* and *Nemiana* form different types of 'death assemblages', the difference being due to their differing lifestyles. This can be documented both by taphonomic and biometric approaches. They do not occur together.

The identification of *Nemiana* and *Beltanelloides* here is quite possible where preservation is good and the samples are large. In the case of *Beltanelloides*, because of its wide geographic distribution, there is good potential for its use as a biostratigraphic tool. It occurs in the Redkino Regional Stage of the Vendian sequence. *Beltanelloides* occurrences from other stratigraphic levels, however, need to be very carefully revised. This study, along with future microstructure analyses of the carbonaceous films associated with this taxon, may lead to a thorough revision of this taxon.

The author is grateful to D. V. Grazhdankin, A. Y. Ivantsov, Y. V. Shuvalova, N. V. Bochkareva and M. A. Fedonkin (Paleontological Institute, Russian Academy of Science, Moscow) for their help with fieldwork and the study of these materials. Special thanks to A. V. Mazin for photographic images for Figs 3, 4, 7, 10, 12. This manuscript has also benefited from comments by P. Vickers-Rich and P. Komarower (Monash University, Australia), and two reviewers, B. MacGabhann and G. Acenolaza. Research was supported by a Russian Fund for Basic Research, grant (RFBR N 02-05-64658) and a Grant of the President (NSH-1790.2003.5). This study is also a part of UNESCO International Geological Correlation Project 493.

## References

AKSENOV, E. M., KELLER, B. M., SOKOLOV, B. S., SOLONTSOV, L. S. & SHULGA, P. L. 1978. General

stratigraphic scheme of Upper Precambrian of Russian platform. *Proceedings of the Academy of Sciences of USSR. Series Geological*, **12**, 17–34 [in Russian].

- ASEEVA, E. A. 1988. Fossil remains of Vendian Thallophyta. In: RYABENKO, V. A., ASSEVA, E. A., FURTES, V. V. ET AL. *Biostratigraphy and Paleogeographic Reconstructions of the Precambrian of Ukraine*. Kiev, Naukova dumka, 81–92 [in Russian].
- FEDONKIN, M. A. 1985. Systematic description of Vendian Metazoa. In: SOKOLOV, B. S. & IVANOVSKY, A. B. (eds) *The Vendian System. Vol. 1. Paleontology*. Nauka, 70–106 [in Russian].
- GEHLING, J. G. 1999. Microbial mats in terminal Proterozoic siliciclastics: Ediacaran death masks. *Palaos*, **14**, 40–57.
- GNULOVSKAYA, M. B., ISTCHENKO, A. A., KOLESNIKOV, CH. M., KORENCHUK, L. V. & UDALTSOV, A. P. 1988. *Vendotaenids of the Eastern-European Platform*. Nauka [in Russian].
- GRAZHDANKIN, D. V. 2000. The Ediacaran Genus *Inaria*: A Taphonomic/Morphodynamic analysis. *Neues Jahrbuch für Mineralogie. Geologie und Paläontologie*, **216**, 1–34.
- GRAZHDANKIN, D. V. 2003. Structure and depositional environment of the Vendian Complex in the South-eastern White Sea Area. *Stratigraphy and Geological Correlation*, **11**, 313–331.
- GUREEV, JU. A. 1988. Soft-bodied fauna of Vendian. In: RYABENKO, V. A., ASSEVA, E. A., FURTES, V. V. ET AL. *Biostratigraphy and Paleogeographic Reconstructions of the Precambrian of Ukraine*. Naukova dumka, Kiev, 81–92 [in Russian].
- JENKINS, R. J. F. 1992. Functional and Ecological Aspects of the Ediacaran Assemblages. In: LIPPS, J. H. & SIGNOR, P. W. (eds) *Origin and Early Evolution of the Metazoa*. Plenum Press, 13–176.
- LAFLAMME, M., NARBONNE, G. M. & ANDERSON, M. M. 2004. Morphometric analysis of the Ediacaran frond *Charniodiscus* from the Mistaken Point Formation, Newfoundland. *Journal of Paleontology*, **78**, 827–837.
- NARBONNE, G. M. & HOFMANN, H. J. 1987. Ediacaran biota of Wernecke Mountains, Yukon, Canada. *Palaentology*, **30**, 647–676.
- PALIJ, V. M. 1976. Remains of soft-bodied and trace fossils from deposits of Upper Precambrian and Lower Cambrian. In: RYABENKO, V. A. (ed.) *Paleontology and Stratigraphy of Upper Precambrian and Lower Paleozoic of the Southwest of Eastern-European Platform*. Naukova dumka, 63–76 [in Russian].
- REITNER, J. & WORHEIDE, G. 2002. Non-Lithistid fossil Demospongiae—Origins of their palaeobiodiversity and highlights in history of preservation. In: HOOPER, J. N. & VAN SOEST, J. N. (eds) *Systema Porifera: A Guide to the Classification of Sponges*. Kluwer Academic, New York, 52–68.
- SEILACHER, A. 1997. Sandkorallen ein ausgestorbener Lebensformtyp. *Fossilen*, **2**, 79–84.
- SEILACHER, A., GRAZHDANKIN, D. & LEGOUTA, A. 2003. Ediacaran biota: The dawn of animal life in

- the shadow of giant protists. *Palaeontological Research*, 7(1), 43–54.
- SOKOLOV, B. S. 1965. The ancient deposits of Early Cambrian and *Sabellitides*. In: SOKOLOV, B. S. (ed.) *Symposium on Paleontology of Precambrian and Early Cambrian*. Novosibirsk, 78–92 [in Russian].
- SOKOLOV, B. S. 1972. Precambrian biosphere in the light of paleontological data. *Vestnik Akademii Nauk SSSR*, 48–54 [in Russian].
- SOKOLOV, B. S. 1973. Vendian of Northern Eurasia. In: PITHCER, M. G. (ed.) *Arctic Geology. Proceedings of the Second International Symposium on Arctic Geology*, 204–218.
- SOKOLOV, B. S. 1977. Organic world of the earth on the way to the Proterozoic differentiation. In: BELOVA, E. V. ET AL. (eds) *250 years of Russian Academy of Sciences*. Nauka, 423–444 [in Russian].