Beltanelliformis brunsae Menner in Keller, Menner, Stepanov & Chumakov, 1974: an Ediacaran fossil from Neoproterozoic of Dobrogea (Romania)

Jean-Paul SAINT MARTIN & Simona SAINT MARTIN
Geodiversitas is indexed in:
- Science Citation Index Expanded (SciSearch®)
- ISI Alerting Services®
- Current Contents® / Physical, Chemical, and Earth Sciences®
- Scopus®

Geodiversitas is distributed electronically by:
- BioOne® (http://www.bioone.org)

Articles and nomenclatural novelties published in Geodiversitas are referenced by:
- ZooBank® (http://zoobank.org)
**Beltanelliformis brunsae** Menner *in* Keller, Menner, Stepanov & Chumakov, 1974: an Ediacaran fossil from Neoproterozoic of Dobrogea (Romania)

**Jean-Paul SAINT MARTIN**
CR2P (CNRS, MNHN, Sorbonne Université), Département Origines et Évolution, Muséum national d’Histoire naturelle, case postale 38, 57 rue Cuvier, F-75231 Paris cedex 05 (France)
jpsmart@mnhn.fr (corresponding author)

**Simona SAINT MARTIN**
CR2P (CNRS, MNHN, Sorbonne Université), Département Origines et Évolution, Muséum national d’Histoire naturelle, case postale 38, 57 rue Cuvier, F-75231 Paris cedex 05 (France) and University of Bucharest, Faculty of Geology and Geophysics, 1 N. Bălcescu ave., 010041 Bucharest (Romania)
simsmart@mnhn.fr

Submitted on 8 January 2018 | Accepted on 5 June 2018 | Published on 22 November 2018

**ABSTRACT**
Ediacaran fossils are now largely known in different parts of the world. However, some countries are poorly documented on these remains. Thus, rare fossils from the Neoproterozoic Histria Formation of central Dobrogea (Romania) have been reported. Two specimens with discoid imprints are described here in detail and assigned to the typical Ediacaran species *Beltanelliformis brunsae* Menner *in* Keller, Menner, Stepanov & Chumakov, 1974. This palaeontological development confirms both the large geographical distribution of this species and the Ediacaran age of the Histria Formation.

**MOTS CLÉS**
Empreintes discoïdes plates, Biota édiacarien, Précambrien, Dobrogea, Roumanie.

**KEY WORDS**
Flat discoid imprints, Ediacaran biota, Precambrian, Dobrogea, Romania.


**RÉSUMÉ**
INTRODUCTION

The period corresponding to the Late Precambrian (Neo-
protrozoic) and the Precambrian-Cambrian boundary is a key moment in the evolution of the biosphere and biodi-
diversity. At this time, the metazoan organisms begin to
be organized in complex aquatic ecosystems prefiguring the “Cambrian revolution” from which the modern living
aquatic world settles durably with its multiple forms of life
(Erwin & Tweedt 2011). The Late Proterozoic fossiliferous
deposits distributed throughout the world have brought
incomparable information, the most famous being that of
Ediacara in Australia, which gave its name to the last period
of the Precambrian, the Ediacaran (~635 to ~541 million
years). Abundant works were dedicated to the identification
and creation of a large number of taxa giving an idea of a
fairly large biodiversity of the Ediacarian biota. Nevertheless,
the interest of scientific community is naturally focused
on the Ediacaran “system” with a particular regard on its
palaeoecological significance in the ancient biosphere and
its place in the general evolution of life (Shen et al. 2008;
Xiao & Laflamme 2008; Peterson et al. 2008; Liu et al.
2010, 2015a; Retallack 2010, 2016; Serezhnikova 2010;
Grazhdankin 2014; Néraudeau 2014; Antcliffe et al.
2015; Droser & Gehling 2015; Tarhan & Laflamme 2015;
Dufour & McIlroy 2016; Bowyer et al. 2017; Briggs 2017;
Budd & Jensen 2017; Reid et al. 2017).

Many deposits have been identified throughout the world
enriching the debate, but without really solving the enig-
matic aspect of this life so little related to the modern world
that will appear very soon after Precambrian-Cambrian
boundary (Shu 2008; Erwin & Tweedt 2011). Considering
this wide range of opinions, any new discovery obviously
provides essential data for the understanding of this disap-
peared ecosystem. The comprehensive reviews of Ediacaran
deposits around the world provide an interesting assessment
of the state of knowledge (McCall 2006; Fedonkin et al.
2007). However, in Europe, apart from the large outcrops
of White Sea in Russia already known, some deposits in
Ukraine, and the famous Charnwood site in England, the
data are much rarer and scattered among various country,
in Northern Europe (Farmer et al. 1992; Högström et al.
2013), in Spain (Cortijo et al. 2015) and in France at the
Ediacarian-Fortunian transition (Gougeon et al. 2018;
Néraudeau et al. 2018). The Precambrian sediments of
Dobrogea in Romania are also potentially able to contain
fossil remains and to provide eventually new lighting about
Ediacaran life. Several works have thus mentioned the
presence in Central Dobrogea (Fig. 1) of some imprints or
traces attributable to elements of the Ediacaran living
et al. 2005; Seghedi 2012). These organic remains are represented
by two kinds of specimens: a “medusoid” imprint identi-
fied as Nemiana simplex Palij, 1976 for one, and multiple
discoid imprints of possible Beltanelloides Sokolov, 1965,
for the other. Traces of activity were also observed and
considered as belong to the Nerites MacLeay in Murchi-son, 1839 ichnofacies. Like the other Ediacaran sites the
presence of microbial mat at the surface of Precambrian
beds was recently highlighted (Saint Martin et al. 2011,
2012). The discovery of Aspidella Billing, 1872 type discs,
which may represent holdfasts of frondose organisms, has
made it possible to add new information and to propose
an idealized reconstitution based on the knowledge of the
moment (Saint Martin et al. 2013). However, observations
made on the available material and the previous proposed
determinations should probably be revised in the light of
the most recent works about Ediacaran organisms. In this
sense, the present preliminary article proposes to examine
a certain type of discoid imprints sampled from the Pre-
cambrian terranes of Central Dobrogea, to give update
identification from comparisons with known data and to
discuss more general consequences.

GEOLOGICAL SETTING

The studied specimens bearing discoid imprints were col-
lected within sediments of the basement in the central
Dobrogea area (Fig. 1A). The central Dobrogea is char-
acterized by large outcrops, especially in the valleys, of
sediments belonging to Precambrian and more particularly
to the Histria Formation (Seghedi & Oaie 1995) corre-
spanding approximately to the “greenschist Formation”
denomination of ancient authors (Fig. 1B). The Histria
Formation, up to 5000 m thick as estimated from geologi-
cal and geophysical data, consists of two coarse members
of sandstone separated by a thinner member with pelites
and siltites (Seghedi & Oaie 1995; Oaie 1999). According
to several works (Seghedi & Oaie 1995; Oaie 1999; Oaie
et al. 2005) considering sedimentological, structural and
mineralogical features, the Histria Formation should be
accumulated in a foreland basin setting, an interpretation
consistent with results of geochemical and detrital zircon
distribution data (Zelaźniewicz et al. 2001, 2009). Min-
eralogical, petrographic and sedimentological data show a
basin sourced by a continental margin dominated by an
active volcanic arc (Oaie et al. 2005; Seghedi et al. 2005).
The low-grade metamorphic (“greenschists”) and weakly
deformed clastic rocks of the Histria Formation were con-
considered as flyschoid-like sediments (Kraütner et al. 1988)
corresponding to median to distal turbiditic sequences
(Oaie 1998; Oaie et al. 2005; Seghedi et al. 2005; Balin-
toni et al. 2011).

A Late Proterozoic-Early Cambrian estimated age for the
sediments of Histria Formation is documented both by geo-
chemical K/Ar datation in the order of ~572 million years
(Giūscă et al. 1967) and palynological assemblages (Kräutner
et al. 1988). On other hand, U/Pb ages based on detrital
zircon suggest a maximum Late Ediacaran depositional age
(Zelaźniewicz et al. 2009; Balintoni et al. 2011). In addition,
the discovery in the fine-grained members of a “medusoid”
imprint identified as Nemiana simplex Palij (Oaie 1992,
1993), a typical Ediacaran fossil, has been invoked to conﬁrm
Beltanelliformis brunsae Menner in Keller et al., 1974: an Ediacaran fossil from Neoproterozoic of Dobrogea (Romania)

However, the characteristics of this sample do not quite match with the original conception of this species (Palij 1976; Palij et al. 1979). Descriptions or discoveries of other fossil remains undoubtedly belonging to the so-called “Ediacaran Biota” would be an additional argument for confirmation of the proposed ages.

The Histria succession is very rich in sedimentary structures represented by large trains of ripples marks well-preserved on some stratification planes (Oaie 1993, 1998; Oaie et al. 2005). The frequent presence of surfaces marked by various wrinkled structures suggests the implication of microbial mats (Saint Martin et al. 2011, 2012) resulting in the formation of MISS (Microbially Induced Sedimentary Structures), often described elsewhere in the deposits of the Upper Proterozoic, especially during the Ediacaran period (Arouiri et al. 2000; Bouougri & Porada 2007; Lan & Chen 2013; Kumar & Ahmad 2014; Parihar et al. 2015; Kolesnikov et al. 2017; Tarhan et al. 2017).

**MATERIAL AND METHODS**

The specimen 1, actually exposed in the gallery of the National Museum of Geology (Bucharest) and registered under no. P 20.996, was collected near the town of Gura Dobrogei, on the banks of the Casimcea River where the Histria Formation is well outcropping. The Precambrian terranes are here tectonized, deformed by faults and folds (Fig. 2A), and good outcrops are therefore quite rare. However, some features of sedimentation can be observed. As in most of the sediments belonging to the Histria formation, it consists of sequences of sandstone deposits and pelites (Seghedi & Oaie 1995; Oaie 1999) that can be structured into large ripple marks (Fig. 2B). Some surfaces exhibit structures similar to MISS of the Arumberia type (Fig. 2C) or elephant skin type (Fig. 2D). Mentioned as representing a “medusoid” imprint (Oaie 1992) close to the genus Beltanelloides (Oaie 1993), the specimen 1 has until now never been described in detail, although it is
Saint Martin J.-P. & Saint Martin S.

Fig. 2. — A-D, Outcrop views of the Gura Dobrogei site: A, general view of Precambrian straightened beds; B, bed surfaces with large ripples; C, MISS (Microbi-ally Induced Sedimentary Structures) of Arumberia type (arrows); D, MISS of "elephant skin" type; E, F, outcrop views of the Histria site; E, view of Precambrian beds; F, Bed surface showing linguoid ripple marks.

an important element of appreciation of possible remains testifying an Ediacaran life in Romanian sediments.

The specimen 2, housed in the collections of the Muséum national d’Histoire naturelle, Paris (MNHN.F.A68682), was sampled at outcrops of the Histria Formation on the edge of Sinoe Lake, near the antic town of Histria during a field campaign (2009) carried out as part of a bilateral research program between the MNHN and the Romanian Geoecomar Institute. The Precambrian sediments here vertically straight-ened outcrop only at a promontory below the ruins on the lake shore (Fig. 2E). There are formed of pelitic successions and only few details of sedimentation are observable. One small surface exhibit ripple marks with a linguoid aspect (Fig. 2F).

In order to appreciate the variations of imprint dimensions, diameter of round imprints or long axis of oval imprints, were measured. Considering the deformations that mostly affect
**Fig. 3.** — *Beltanelliformis brunsae* Menner in Keller, Menner, Stepanov & Chumakov, 1974 from Dobrogea: A, general view of specimen 1; B, detail of the discoid imprints of specimen 1 exhibiting the characteristic small wrinkles at the periphery (black arrow). Note some soft deformities of some individuals (white arrow); C, general view of specimen 2; D, detail of the discoid imprints of the specimen 2 (MNHN.F.A68682) exhibiting the characteristic fine wrinkles at the periphery (black arrows). Some individuals may partially cover others (white arrow). Scale-bar: 1 cm.
the specimen 1, it was considered preferable to measure in addition the surface of each discoid imprint. The surface measurement was so performed using the appropriate functions of the open software Image J.

A section intersecting the surface bearing the imprints and the underlying sediment was made across specimen 2 in order to observe in thin section the main petrographic characteristics.

**DESCRIPTION**

The specimen 1 is of pelitic nature, roughly rectangular, measuring approximately 14 cm in length and 7 cm in width (Fig. 3A). The oxidized ferruginous surface displays 37 visible discoid flat imprints, of which 22 are integrally preserved and can be measured (Fig. 3B). Each discoid individual is smooth at the centre and shows very fine concentric ridges towards the periphery. Discoid individuals are distributed contiguous or very slightly apart. In some cases, some discoid imprints appear to partially cover the neighboring imprint. All the imprints are affected by a unidirectional deformation according to an elongation giving them an oval shape reflecting the posterior tectonic constraints. Other earlier deformations have undoubtedly affected the surface of the sediment: small differences in elevation are observed between individuals with stretching of the wrinkled peripheral structures (Fig. 3B). The length of the long axis of the oval imprints ranges from 1.34 to 1.94 cm with an average of 1.66 cm. These measures show overall certain homogeneity of size.

The specimen 2 constitutes a block cut according to the dominant fracturation showing both the surface and an oblique section of the original sedimentation (Fig. 3C). The surface of the block, strongly ferruginized to a thickness of about 1 mm, is approximately rectangular with a length of about 20 cm over a width of 7 to 8 cm. Discoid imprints on the surface are usually contiguous and also may overlap slightly one to other. They display the same character as the first specimens with a smooth part in the center and a finely wrinkled periphery (Fig. 3D). Unlike specimen 1, the discoid imprints are very slightly deformed with a roughly circular outline. The diameter is quite heterogeneous with values distributed between 1.03 and 2.50 cm for an average of 1.55 cm. The discoid imprints itself concern only a very thin thickness (Fig. 4A). The sample shows a succession of fine-grained beds and very thin beds of coarser siliciclastic sediment. Within these sequences are individualized two bodies of one centimetre thickness with slightly coarser grains structured in micro-HCS (Fig. 4B). The characteristics of the sedimentation revealed by the polished section show that, like most identical fossils around the world, discoid imprints are represented in positive hyporelief, in bed sole position. Given the outcrop conditions, which essentially show the top surfaces of the beds, it is very difficult, if not almost impossible, to observe these fossils in place. This could explain the small number of found samples.

The measurement of the surfaces shows a disparity of average size between the two samples, the individuals of the specimen 2 showing a greater heterogeneity of distribution and on average a larger surface (Fig. 5). This reflects a fairly large variability in size within a sample or between two samples.

**ASSIGNMENT AS BELTANELLIFORMIS BRUNSAE**

The assignment of the studied samples to the Ediacaran fossils mentioned in the abundant literature dedicated to discoidal impressions comes up against the already old problems of a nomenclature mainly related in fact to taphonomic aspects. If we only refer to remains exhibiting exactly the same characteristics, namely the more or less contiguous presence of flat discoid imprints with fine concentric wrinkles at the periphery and a smooth central part, two main designations have been adopted: Beltanelliformis brunsae Menner, in Keller, Menner, Stepanov & Chumakov, 1974 (Keller et al. 1974; Narbonne & Hofmann 1987; Steiner 1996; Xiao et al. 2002; Narbonne 2007; Ivantsov et al. 2014; Ivantsov 2017) or Beltanelloides sorichvae Sokolov, 1972 (Sokolov 1976, 1997; Glaessner 1984; Sokolov & Iwanowski 1990; Fedonkin 1992; Fedonkin & Runnegar 1992; Fedonkin & Vickers-Rich 2007; Leonov 2007a, b; Leonov & Ragozina 2007; Leonov & Rud'ko 2012). However, the adoption of a systematic status is complicated for several reasons according to the authors’ conception and the supposed nature of these fossils: 1) the same designation has been used for variable preservation modes; 2) different names have been assigned to the same type of fossil; 3) different names have been assigned by some authors to fairly similar discoid imprints which are supposed to be different in nature but
corresponding for other authors to the same original type of organism. In general, these are rather gregarious forms preserved in a bag-shaped manner or flat imprints, assuming originally a rather globular form. Narbonne & Hofmann (1987) had already distinguished among these discoid remains a “Beltanelliformis-type”, characterized by the presence of concentric peripheral fine wrinkles, and a “Nemiana-type”, more globose and smooth, corresponding to two taphonomic processes of the same original organism of undefined nature (Narbonne 2007). On the other hand, Leonov (2007a) attributes these two types of preservation to two different organisms: a “Beltanelliformis” form that would be attributable to a planktonic spherical organism and a “Nemiana” form that would result from the dwelling imprint of a benthic bag-shaped organism. It should be noted that this distinction is based in part on measurements showing a significant difference between the two “morphotypes”. The differences in size between our two specimens show that it cannot be a discriminating argument (Fig. 5). The dilemma has been convincingly summarized by the recent comprehensive revision of Ivantsov et al. (2014), which demonstrates that, due to the synonymy and anteriority aspects, our fossils must be better related to Beltanelliformis brunsae. The name Beltanelliformis sorichevae is thus not valid, as indicated by Narbonne & Hofmann (1987) and other authors having often pointed out in synonymy the two species (Fedonkin & Runnegar 1992). As a result, the studied specimens are determined as follow (for complete diagnosis and synonymy, refer to Ivantsov et al. 2014):

Regnum incertae
Genus Beltanelliformis Menner in Keller, Menner, Stepanov & Chumakov, 1974

Beltanelliformis brunsae Menner in Keller, Menner, Stepanov & Chumakov, 1974

REMARK
It should be noted that in this work Beltanelliformis sorichevae Sokolov, 1965 and Nemiana simplex Palij, 1976 are clearly synonymized with Beltanelliformis brunsae.

DISCUSSION
The problem of systematic assignment is closely linked, not only to the taphonomic processes themselves, but also to the inferred original organic nature of these fossils. Thus, the remains comparable to our specimens could be considered at the same time to be fossil bodies, fossil traces or megascopic compression (Hofmann 1992a, b; Runnegar & Fedonkin 1992, Fedonkin & Runnegar 1992, Runnegar 1992a, b; Jensen et al. 2006). Like many other discoidal elements of the Ediacaran biota, Beltanelliformis was first considered as “medusoid” organism (Sokolov 1972; Palij et al. 1979; Fedonkin 1981; Sokolov & Fedonkin 1984). As mentioned above, “Nemiana-type” preservation has been attributed to bag-shaped organisms. For a long time an affinity with benthic coelenterates such as anemones was considered. Various reconstructions have favored this option, these fossils being clearly ranked among the coelenterates (Gureev 1985; Fedonkin 1990, 1992, 1994; Seilacher et al. 2005). On other hand, according to Leonov (2007a), the “Beltanelliformis-type” remains would correspond to spherical floating organisms, formed of a thin and flexible envelope fallen to the bottom and whose compaction would explain the fine concentric lines around the periphery. In the same sense, Ivantsov et al. (2014) consider that the presence of basically plastic prediagenetic distortions, as observed for Romanian specimens, suggests that the envelope of Beltanelliformis was also elastic. If we adopt the idea of a single type of organism, we must reconcile the different types of preservation. Narbonne & Hofmann (1987) proposed a scenario arguing a continuum, but they give no conclusion as to the exact nature of the organism.

Flat discoidal fossils, like that of Dobrogea, have often been interpreted as compressions of more or less spherical organisms, of which, in some cases, there are only traces or organic films, or more rarely both. As a result, they have been compared with other Chuaritie-type Ediacaran fossils known as carbon compressions, algal or microbial in origin (Hofmann 1994; Steiner 1996; Steiner & Reitner 2001; Leonov 2004; Ragozina & Leonov 2004; Grazhdankin et al. 2005, 2007; Xiao & Dong 2006; Leonov 2007a, b; Leonov & Ragozina 2007; Moczydłowska 2008; Ragozina et al. 2016; Bykova 2017; Ye et al. 2017), although this affinity is doubtful for other authors (Narbonne & Hofmann 1987). According to Xiao et al. (2017), stable carbon isotope values for samples of Beltanelliformis preserved as carbonaceous macrofossil do not allow to discriminate between interpretations of this organism as a colonial bacterium or a eukaryotic alga. However, the most recent studies dedicated to biomarkers from Beltanelliformis specimens similar to those of Romania, but with a preserved organic film, favor a microbial origin, probably cyanobacterial (Bobrovskiy et al. 2016, 2017, 2018).
The known occurrences of *Beltanelliformis brunsae* are apparently limited exclusively to the Ediacaran period (= Vendian), being perhaps the most common and widely distributed Ediacaran fossil worldwide (Narbonne 1998; McCall 2006). In the Precambrian of Russia (Siberia, Urals, White Sea, etc) and Ukraine, this common species seems characteristic of the “Upper Vendian” (see review in Ivantsov et al. 2014). In other parts of the world, known occurrences also correspond to the upper Neoproterozoic: Great Britain (Pyle et al. 2004; McIlroy et al. 2005; Liu 2011), Canada and Newfoundland (Hofmann et al. 1983; Liu et al. 2015b), China (Zhao et al. 2004; Wang et al. 2014), Mongolia (Ragozina et al. 2016), South America (Aceñolaza & Alonso 2001; Drefahl & Silva 2007; Netto 2012), Namibia (Wood et al. 2015), Australia (Xiao et al. 2013). However, *Beltanelliformis* has been also reported to be present in even older deposits at about 1GA (Callow et al. 2011). The coexistence of *Aspidella* in the Histria Formation of central Dobrogea (Saint Martin et al. 2013) argues rather for an Ediacarian age. Consequently, Romanian specimens extend westward the distribution field of the species known in East Europe.

Occurrences of *Beltanelliformis* around the world generally concern sediments deposited in shallow water environment (Narbonne & Hofmann 1987; Fedonkin 1992; Narbonne 1998; Aceñolaza & Alonso 2001; Grazhdankin 2004; Pyle et al. 2004; Grazhdankin et al. 2005; McIlroy et al. 2005; Seilacher et al. 2005; Leonov 2007a; Narbonne 2007; Rozhnov 2009; Rozhnov 2010; Liu 2011; Ivantsov et al. 2014; Ivantsov 2017; Liu et al. 2015b; Netto 2012; Grytsenko 2016; Ragozina et al. 2016), sometimes in connection with storm deposits and hummocky cross-stratification (HCS) (Narbonne & Hofmann 1987; Pyle et al. 2004; McCall 2006; Narbonne 2007). If the cyanobacterial nature is proved, we can estimate that *Beltanelliformis* occurrences would correspond to the photic zone. As a consequence, it should be considered that part of the Histria Formation does not correspond to distal turbidites, as has often proposed, but to shallow environments that may be characterized by storm deposits. This trend is consistent with the extensive microbial mat surfaces observed in the Histria Formation (Saint Martin et al. 2011, 2012) and the sedimentological features of the specimen 2.

CONCLUSIONS

The studied specimens unambiguously present exactly the same characteristics as various samples described in the Ediacaran deposits in Podolia, White Sea or Siberia. Although the discussion of their origin is not yet fully decided, recent studies seem to show that the hypothesis of the cyanobacterial colony imprint can be favored. The attribution of these specimens to the Ediacaran morpho-species *Beltanelliformis brunsae* is probably the most acceptable.

The main interesting consequence is the confirmation of the Ediacaran age of the Histria Formation and therefore of the various organic remains known in Central Dobrogea. The deposits of the Histria Formation therefore represent a certain potential for restitution of the Ediacaran life in the Romanian ground. Further systematic field investigations would better measure the abundance and the diversity of the Ediacaran fossils.

Acknowledgements

We address special thanks to Gheorghe Oaie, dear to our memory, who opened the way for the work on the organic remains of Neoproterozoic from Dobrogea and has always supported our investigations. We are also indebted to Antoneta Seghedi who shared with us his perfect knowledge of the field and facilitated the study of the specimen of the Museum of Geology. This work was carried out thanks to the French-Romanian bilateral program, PAI Brâncusi (Nouvelles données sur l’écosystème énigmatique du Précambrien supérieur). It is also a contribution to the ATM (Actions thématiques du Muséum) program of the MNHN (Muséum national d’Histoire naturelle, Paris). During various field researches, we received the friendly help of Jean-Pierre André, Lilian Cazes, Sylvain Charbonnier, Didier Merle and Philippe Richir. The sections and thin sections were performed by Séverin Morel (MNHN). The manuscript has been significantly improved thanks to the recommendations of the two reviewers Y. Ivantsov and D. Néraudeau.

REFERENCES


Pre-Dobrogea – An Overview.

Dobrogea, of morphological disparity of modern metazoan phyla.

PETERSON K. J., COTTON J. A., GEHLING J. G. & PISANI D.

Pre-Dobrogea – An Overview.

S0031030109110021


Submitted on 8 January 2018; accepted on 5 June 2018; published on 22 November 2018.