Morphology of the fossil Pliocene freshwater diatom Aulacoseira bellicosa from Nogaret (Escandorgue Massif, France)

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MORPHOLOGY OF THE FOSSIL PLIOCENE FRESHWATER DIATOM *AULACOSEIRA BELLICOSA* FROM NOGARET (ESCANDORGUE MASSIF, FRANCE)

C. CORNET, J. DAGNELIE*

University of Namur, Department of Geology, 61 rue de Bruxelles, B-5000 Namur, Belgium
** Corresponding author: colette.cornet@fundp.ac.be*

DIATOMS
RESTING SPORES
LATE PLIOCENE
FRESHWATER
AULACOSEIRA
FRANCE

ABSTRACT. – The fossil diatom *Aulacoseira bellicosa* (Héribaud) Simonsen is represented solely by resting spores; valves of the vegetative chain cells have not been preserved. The morphology of these spores from Late Pliocene maar sediments in southern France (Nogaret, south of Massif Central) is described using light and scanning electron microscopy. A comparison is made with literature data on similar spores. The number of areolae in 10 μm and its narrow range differ significantly from that of spores produced by *Aulacoseira skvortzowii/islandica* refuting a possible synonymy. Presumed non-French records of *A. bellicosa* most likely pertain to different taxa.

INTRODUCTION

Light microscope examination showed that the resting spore taxon *Aulacoseira bellicosa* (Héribaud) Simonsen is present in the sediments of the maar crater of Nogaret in the Escandorgue massif (south of the Massif Central, France) (Fig. 1, Cornet 1991). It is a limestone plateau largely covered by thick layers of basalt with a mean altitude of 700 m. K/Ar ages for the regional volcanic activity range from 2.0 to 1.9 Ma. The maar formed from a hydrovolcanic eruption is filled with calcareous laminites rich in diatoms, interbedded with pyroclastic layers and silt. Large mammal fossils found on top of the lake sediments belong to the St Vallier biozone (Villafranchian stage, Late Pliocene) which is 2.0 to 1.7 Ma old (Bruggal *et al*. 1990).

Resting spores are regarded as an ancestral structure which provide survival mechanism against darkness, desiccation and grazing (Hargraves & French 1983, Mc Quoid & Hobson 1996). In this study, valve morphology and fine structure of *A. bellicosa* were investigated by means of light and scanning electron microscopy and compared with the literature data on similar spores. Our results identify significant differences between *A. bellicosa* and the other spores.

MATERIAL AND METHODS

Samples collected from the core NO II taken by Leroy & Seret (1992) were cleaned with hydrochloric acid (10 %) and cold hydrogen peroxide (30 %). Suspensions of cleaned diatoms were rinsed several times with distilled water.

For light microscopy (LM), permanent slides were made with Naphrax® (refraction index = 1.74). Diatoms were viewed using an Axiophot light microscope at a magnification of 1,000X under oil immersion and photographed with an Olympus digital camera. For scanning electron microscopy (SEM), aliquots of clean material were air-dried on aluminium stubs and coated with gold. The photomicrographs were obtained using a Philips XL 20.

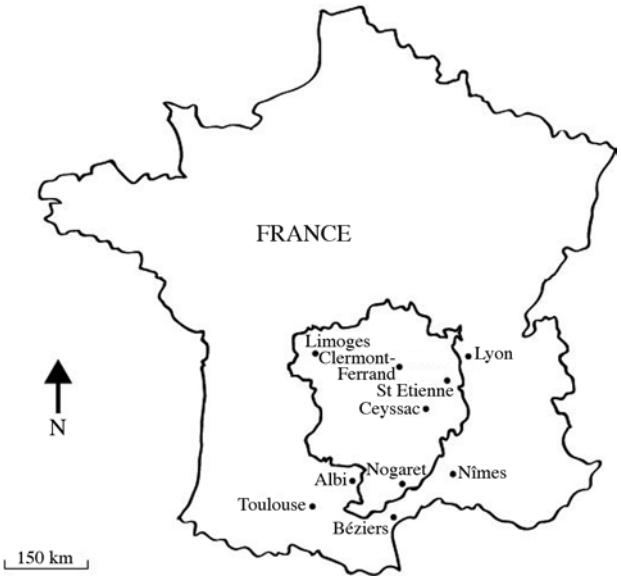

Fig. 1. – Location map of Nogaret and Ceyssac (— limits of the Massif Central).

RESULTS

Aulacoseira bellicosa (Héribaud) Simonsen is only present in the upper part of the core, between 407 and 59 cm depth. The diatom flora includes *Aulacoseira sphaerica* (Héribaud) Simonsen, *Cyclotella comta* var. *lichvinensis* Jousé, *Synedra ulna* var. *danica* (Kütz.) Grun.

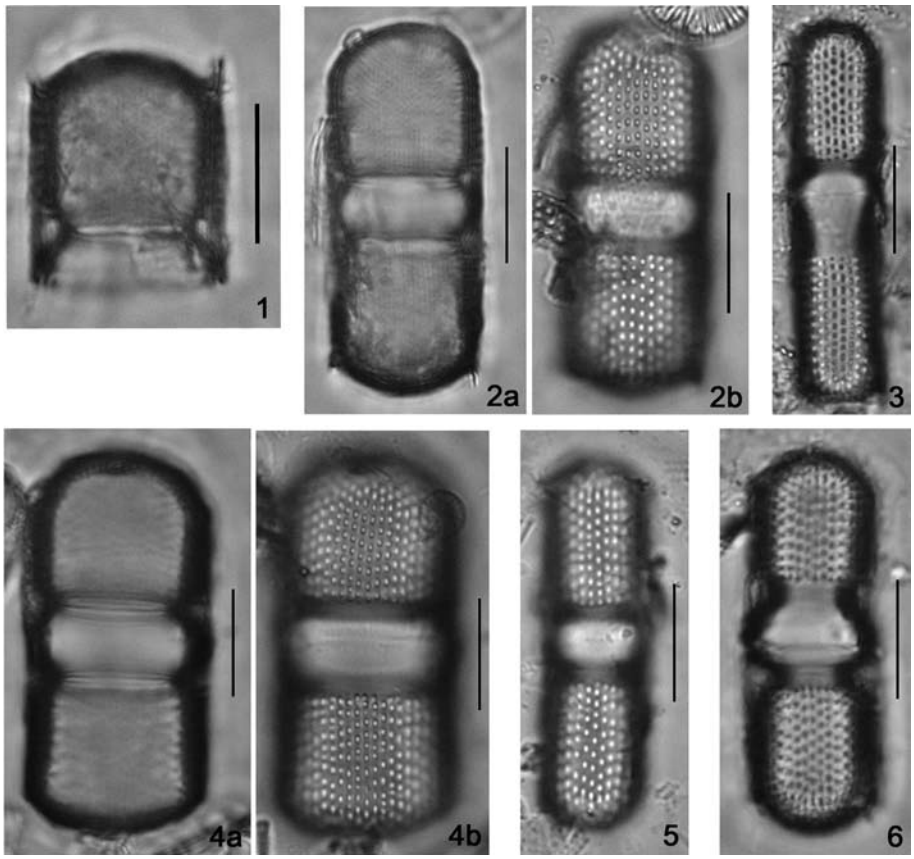

Plate I. – Light micrographs of *Aulacoseira bellicosa*. Scale bars = 10 μm.

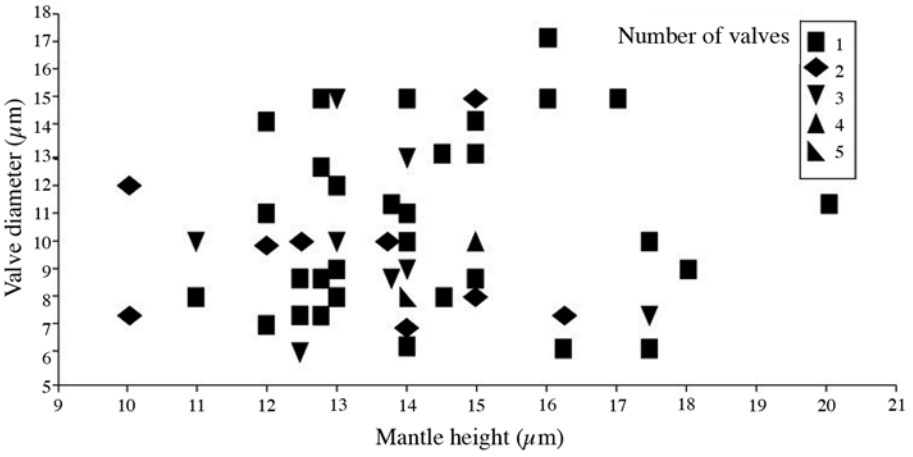

Fig. 2. – Relationship between mantle height and valve diameter of *A. bellicosa* measured on 82 valves from Nogaret.

and even more infrequent specimens of *Cyclotella comta* (Ehr.) Kütz., *Epithemia argus* Kütz., *Cocconeis placentula* Ehr., *Rhopalodia gibba* (Ehr.) O. Müller, *Diploneis ovalis* Kütz., *Cymbella ehrenbergii* Kütz., *Cymatopleura elliptica* (de Breb.) W. Smith. There are many broken fragments and signs of dissolution which indicate poor diatom preservation. So, the fossil assemblage may not accurately reflect the living diatom assemblage at the site.

Light microscopy (Plate I) shows that the frustules of *Aulacoseira bellicosa* consist of heavily silicified valves with a cylindrical mantle and a hemispherical valve face without spines. Only individual frustules or single valves are observed. The relationship between the valve mantle height and the valve diameter, measured on 82 valves, is plotted on the graph in Fig. 2. The diameter varies from 6.3 to 17 μm and the mantle height 10 to 20 μm. No allometric relationship can be found between these two morphometric characteristics. The mantle is ornamented with straight pervalvar uniseriate striae, 10-13 in 10 μm. The areolae vary from rounded to lateral-elongate in shape. The number of areolae per stria varies between 8 and 10 in 10 μm. Because of the geometry of the valves, the valve face is not seen under light microscopy, but under SEM, we observed that areolae are irregularly dispersed

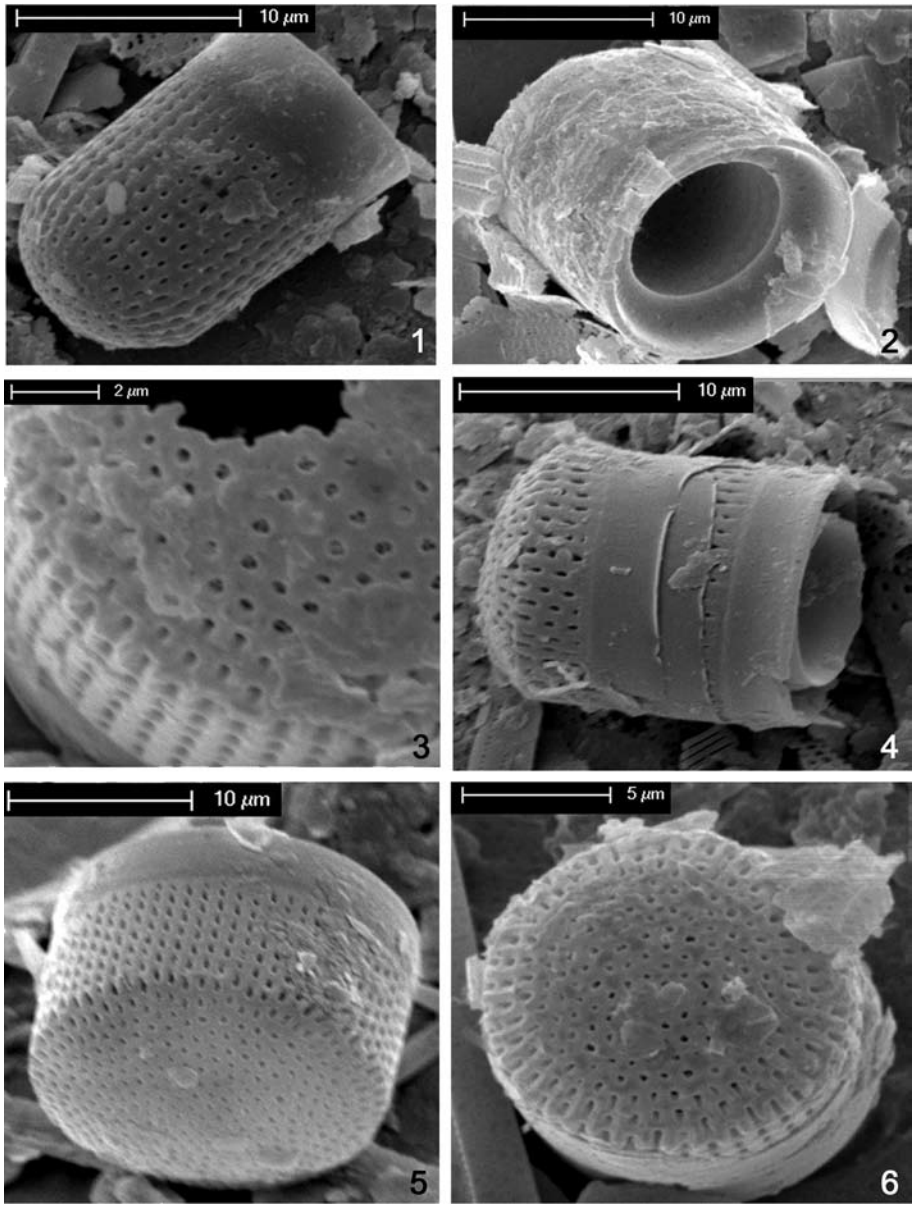

Plate II. – Scanning micrographs of *Aulacoseira bellicosa*. Fig.1, Girdle view showing oval or rounded areolae on the mantle, in straight pervalvar rows, and the collum (distal areolae-free part of the mantle). Fig.2, View on the collum showing the solid broad annular legde ("Ringleiste" in the German literature) projecting into the cell. Fig.3, Detail on the external valve surface showing the areolae occluded by rotae. Fig.4, Mantle covered by the mother cell girdle.Fig.5, Structureless collum and areolae on mantle and valve surface. Fig.6, Valve view showing randomly arranged areolae at the centre and rows near margin of the mantle. Note remains of the mother cell girdle.

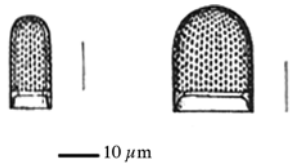

Fig. 3. – *Aulacoseira bellicosa*, Héribaud's figures (1903).

over the central part of the valve and are organized into radial rows at the periphery (Plate II, Fig. 6). The areolae on the valve face have a velum (a structure occluding an areola) of the rota type, i.e. solid single bars crossing the pores; some clearly show a triradiate structure (Plate II, Fig. 3). *A. bellicosa* has a very distinct hyaline (structureless) broad collum, clearly seen in girdle view under light microscopy (Plate I). It is separated from the areolated mantle by a furrow called the sulcus, which is relatively deep. The internal view of the valve (Plate II, Fig. 2) shows the collum projecting inwards from the robust annular legde ("Ringleiste" in the German literature), which extends to a third or a half of the radius of the valve. In some frustules, the mantles are covered by the mother cell girdle (Plate I, Fig. 1, 2a, 4a; Plate II, Figs 4, 6), producing horn-like projections (Plate I, Figs 1, 2a) visible with the light microscope. We found no rimoportulae on the inner surface of the mantle.

DISCUSSION

Héribaud (1903) described for the first time *Melosira bellicosa* from Ceyssac (Velay, east of the Massif Central) (Fig. 1). Erlich (1967) also reported it from other sites in this region (Table I). The material from Nogaret

Table I. – Comparison between *A. bellicosa* and other similar resting spores.

Authors	Name	Valve diameter (µm)	Mantle height (µm)	Number of areolae per 10 µm	Number of striae per 10 µm	Localisation	Stratigraphy
This work 2010	*Aulacoseira bellicosa*	6.3-17	10-20	8-10	10-13	Escandorgue (Massif Central)	Late Pliocene
Heribaud 1903	*Melosira bellicosa*	5-18	12-18	7-8	10-11	Velay (Massif Central)	Late Pliocene
Erlich 1967	*Melosira bellicosa*	6-20	10-20	-	10-12	Velay (Massif Central)	Late Pliocene
Loseva 1980	*A. bellicosa* - spores	3.5-13.5	11.5-25	12-20	14-15	Kama region (Russia)	Late Pliocene
Edlund *et al.* 1996	*A. skvortzowii* - spores	5.2-18.7	12.9-24.2	11.8-16.5	12.0-16.2	Lake Baikal	Recent
Genkal & Bondarenko 2006	*A. islandica* - spores (*A. skvortzowii*)	7.7-14.6	10-17.8	14-16	12-16	Lake Khanta (Russia)	Recent
Popovskaya *et al.* 2002	*A. islandica* - spores	5-18.7	10.3-24.2	12-17	10.8-16.5	Lake Baikal	Recent
Jousé & Mukhina 1978	*Melosira bellicosa*	7-10	8-10	-	-	Black Sea	Late Pliocene
Bradbury 1991	*A.* "auxospore ?"	7.3-14.3	17.5-28.2	7.3-15.8	10-12.9	California	after 200 ka

(Escandorgue, south of the Massif Central) corresponds very well to Heribaud's description and figures (Fig. 3, Table I).

The heavily silicified valves, absence of spines and the domed valve surface with a cylindrical mantle clearly identify *A. bellicosa* as a resting spore. As *A. bellicosa* is always found in a solitary spore form without vegetative cells, we cannot identify the species of *Aulacoseira*. The horn-like projections (Plate I, Figs. 1, 2a) belong to the mother cell girdle and not to the adjacent valve, i.e. the concave hypotheca of the original spore-forming mother valves (Loseva 1980, Edlund *et al.* 1996). This suggests a resting spore formed endogenously, i.e. a single spore formed within the parent cell, as can be observed today in *A. skvortzowii* Edlund, Stoermer & Taylor living in Lake Baikal (Siberia) (Kobanova 2001, Jewson *et al.* 2008).

Loseva (1980) identified fossil spores from Omara (Kama River Basin, Russia) as *A. bellicosa* and further suggested that they represented the spores of *Aulacoseira islandica* (O. Müller) Simonsen. However, the morphometric data (Table I) differ from Héribaud's description and more closely approximate to *A. skvortzowii*. This species had been described by Edlund *et al.* (1996) and previously identified as a number of different taxa, including *A. islandica* (O. Müller) Simonsen and *A. islandica* ssp. *helvetica* (O. Müller) Simonsen. The separation of these species is based primarily on the ability of *A. skvortzowii* to form resting spores. This explains why the baikalian spore-forming algae were described as *A. skvortzowii* or *A. islandica* (Siver & Kling 1997, Popovskaya *et al.* 2002, Genkal & Bondarenko 2006). However, spore-forming *A. islandica* was observed in Lake Khanta (Primorskiy Province, Russia) (Genkal & Bondarenko 2006). Edgar & Theriot (2004) also suggested that the cosmopolitan *A. islandica* may have given rise to the endemic living species *A. skvortzowii*. So the taxonomic status of *A. skvortzowii/islandica* seems to require additional study. Nevertheless, a close affinity if not synonymy between Kama River Basin taxon and the Baikal material may be proposed. And a possible synonymy between *A. bellicosa* and *A. skvortzowii/islandica* is refuted according to the significant difference in the number of areolae in 10 µm (Table I).

A. bellicosa was also reported from Black Sea sediments dating from Late Pliocene (Jousé & Mukhina 1978), but the illustrations and description seem quite different to Héribaud's data (Table I).

Similar frustules from Tule Lake (Siskiyou Country, California) were reported as "auxospore?" which showed some resemblances to *A. islandica*; its principal distribution is in the late Quaternary (after 200 ka) (Bradbury 1991). They are of course resting spores and not auxospores of *Aulacoseira* which are characterized by hemispherical initial valves (Crawford *et al.* 2003). Here also, the number of areolae in 10 µm differs significantly from that of *A. bellicosa* (Table I).

Resting spores of *Aulacoseira italica* (Ehr.) Simonsen emend. Crawford, Likoshway & Jahn have been found in the Miocene diatomite of Santa Fiora (Tuscany) (Crawford *et al*. 2003). But additional study seems to be required as no morphometric data have been given.

Our additional observations corroborate the conclusion of Likhoshway *et al*. (2004) that *A. bellicosa* differs from other *Aulacoseira* spores, both fossil and recent, by a consistently lower density of areolae and its narrowness.

CONCLUSION

The study of the resting spores of *Aulacoseira* have an important interest for the knowledge of the evolution of the diatoms. *Aulacoseira bellicosa* represents the resting spore of a diatom whose vegetative chain cells were not preserved. It is morphologically different from the other fossil and recent resting spores formed by the extant *A. skvortzowii/islandica*. Presumed non-French records of *A. bellicosa* most likely pertain to different entities. *A. bellicosa* should still be considered as a Late Pliocene fossil: "endemic", but with the qualification that it may have had a wider distribution and either became restricted or was preserved only in the Massif Central, from the Velay up to the Escandorgue Massif.

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