

Badenian calcareous nannoplankton from NE Slovenia (Mura depression, western Central Paratethys): paleogeography and paleoecology

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In the beginning of the Middle Miocene the Central Paratethys reached its maximum extent. It consisted of a series of larger and smaller epicontinental tectonic basins. The Badenian corresponds to Langhian and Lower Serravallian of the Mediterranean and was the last fully marine period in the life of Central Paratethys. It also corresponds to the final stage of the Miocene Climatic Optimum (MCO), when favourable environmental conditions allowed for the thriving of diverse calcareous nannoplankton assemblages, producing a fossil record of great biostratigraphic and paleoecological significance.

The Mura depression was one of the smaller basins near the western coast of the Central Paratethys. Seventeen sections, composed of marls and subordinate sandstones, sands and limestones were sampled. A few hundred samples were collected in 10 cm intervals for micropaleontological analyses. One hundred and seven species of calcareous nannoplankton and three species of calcisphere were determined.

The diversity and abundance of nannoplankton allowed a precise dating of individual sections and their correlation. The total time span of the studied strata comprises the interval between the top of biozone NN4 in the early Badenian and the bottom part of biozone NN6 in the late Badenian. This time interval was divided into six shorter intervals. The oldest nannoplankton assemblages are assigned to the top part of biozone NN4, biozone NN5 contains four successive intervals, and the youngest interval corresponds to the lower part of biozone NN6. The composition of nannoplankton assemblages and facies suggest a heterogeneous nature of the Mura Depression, with deep basins in immediate vicinity of shallow marine environments. This is clearly observable at the top of biozone NN5, represented by marl beds with typically pelagic nannoplankton assemblages in one section and shallow-water rhodoliths in several other sections only a few kilometres away.

The pattern of biostratigraphic events observed in the youngest nannoplankton assemblages, belonging at the beginning of the biozone NN6, is paleogeographically significant, since it is nearly identical to that described in the Mediterranean (Fornaciari *et al.*, 1996). The LO of *Sphenolithus heteromorphus*, the FO of *Reticulofenestra pseudumbilica*, the LCO of *Cyclicargolithus floridanus* and the FO of *Calcidiscus macroporus* were observed in both areas in the same succession. The first of these events is nearly synchronous on a global scale, while the others are diachronous in different regions. The close resemblance in the character and the order of observed events indicate that the Slovenian Corridor, a seaway between the Mediter-

anean and the Central Paratethys, was still open in the beginning of the late Badenian (Fig. 1).

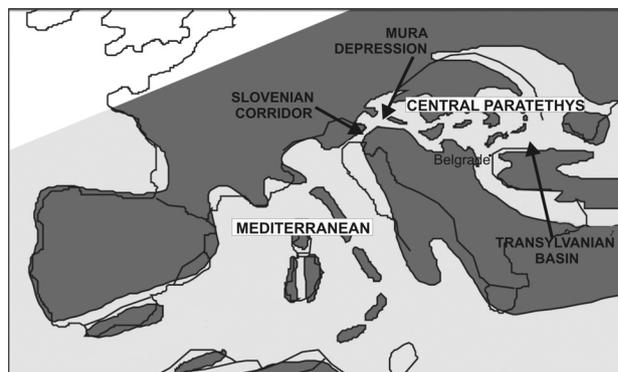


Figure 1: Paleogeographical sketch of the Mediterranean and the Central Paratethys in the early late Badenian (modified after Rögl, 1998)

In the oldest nannoplankton assemblages (NN4), a deepening trend was observed, reflecting a transgression at the beginning of the Badenian. Younger assemblages from this interval are more diverse and contain several pelagic species, which are absent in the oldest assemblages. Throughout the entire biozone NN5, the high species diversity, abundance of *Helicosphaera* spp. coccoliths, and the constant presence of rare specimens of sphenoliths and discoasters indicate relatively warm water. Some assemblages from the middle part of biozone NN5 and the ones from the youngest strata (the upper part of NN5 and the bottom part of NN6) contain several dominant species (*Helicosphaera carteri*, *Coccolithus pelagicus*, *Reticulofenestra minuta*, *R.* spp.) as well as *Reticulofenestra pseudumbilica* and *R. gelida* (summer and winter variety of the same species). This suggests increased seasonality towards the top of the studied interval, which is in agreement with some published reports (Syabraj *et al.*, 2007; Bojar *et al.*, 2004). Surprisingly, the warm-water character of the youngest nannoplankton assemblages is very pronounced. An interval characterised by high diversity, enriched in the warm-water genera *Discoaster* and *Sphenolithus*, was observed at the transition between biozones NN5 and NN6 at approximately 13.5 Ma. This is well after the beginning of the drop in temperatures at the end of the MCO, which started at 14 Ma (Bojar *et al.*, 2004; Syabraj *et al.*, 2007; Böhme, 2003). The enrichment in *Discoaster* spp., followed by an increase in abundance of *Sphenolithus* spp., closely resembles the pattern described in the upper Badenian near Belgrade (Mihajlovic & Knezevic, 1989), and probably reflects the same event. The nannoplankton assemblages from the Transylvanian Basin

(Chira, 2001), belonging to the same interval, also show a pattern similar to that recorded in Slovenia.

Late Badenian pollen and other terrestrial fossil plants from the southernmost sites in Romania, Serbia and Hungary are characterized by thermophilous flora and indicate subtropical climatic conditions, while a general cooling trend appears in other Central Paratethys sites (Kvacek *et al.*, 2006). The pattern of paleoclimatic changes in the Central Paratethys region at the end of the MCO has a regional character. Perhaps, this was the result of a gradual termination of the connection between the Central Paratethys and the Mediterranean that persisted in the westernmost and the south-western parts of the region after it ended in the others.

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