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# FROM THE PARATETHYS SEA TO LAKE PANNON: THE DEVELOPMENT OF LATE OLIGOCENE AND MIOCENE MOLLUSC FAUNAS IN A FRAGILE AQUATIC SYSTEM

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The reconstruction and interpretation of terrestrial ecosystems and vegetational patterns in the Central European Miocene have to take into account the influence of a vast landlocked water body, namely the Paratethys Sea. As northern pendant of the early Mediterranean Sea, it spans a north-south gradient of at least 4° latitude and is suggested to represent some kind of "paleothermometer", which reflected slight expansions or restrictions of climatic belts. Due to its vulnerable marine connections it was also highly susceptible to major (global) sea-level drops which are indicated by phases of endemism. Hence, a fairly continuous record of marine nearshore Mollusc assemblages throughout the Miocene reflects an extraordinary interplay of sea-level fluctuations, changes in climate, immigrations, and blooms in autochthonous elements. Whilst biostratigraphic implications of these patterns have been recognised early in paleontology, a biogeographic model is still missing. The intermingling of paleogeographic terms with those restricted to biogeography is still commonly used - a situation which has to be overcome by integrating data from different biota into a new paleobiogeographic scheme. Herein, a data-set of 1384 species-level taxa (Gastropoda) serves as base for interpretations. Gastropods in particular turned out to be of greatest value for the differentiation of paleobiogeographic units due to sensitive reactions to all environmental parameters and occupying a wide range of ecological niches. Based on the excellent gastropod record the Proto-Danubian Province, Early Danubian P., Danubian P., Balatonian P. and a Proto-Caspian Subprovince are defined. The biogeographic reorganisations are associated with five major biotic events within the gastropod faunas. These "big fives" comprise four extinctions – late Ottnangian extinction event (LOEE), mid-Badenian-extinction-event (MBEE), Badenian-Sarmatian-extinction event (BSEE), Sarmatian-Pannonian-extinction event (SPEE) – and one exceptional immigration/origination event termed early Badenian Build-up event (EBBE). The fairly well calibrated marine biostratigraphy of the Central Paratethys serves as stratigraphic backbone for the presented data and allows control for the continental stratigraphy.

For the Early Miocene, species-richness plotted as total numbers of taxa per time-slice shows a general increase for gastropods with a minor retreat in the Late Eggenburgian. The comparison of LOD and FOD data in Fig. 1 gives a rough impression of the fate of the Paratethyan gastropod faunas. The Egerian to Karpatian pattern is rather unspectacular with a slight positive balance for originations or immigrations versus extinctions. The Ottnangian crisis is poorly reflected as an extinction event, because many species which vanish from the Paratethys re-appear in the Karpatian. Hence, the Egerian to Karpatian trend of decreasing extinction rates from 67% towards 7% is only slightly interrupted during the Ottnangian.

Instead, the crisis is better reflected as a "positive" event of increased originations due to the evolution of endemic species, especially within the genera *Staliopsis* Rzehak, *Nematurella* Sandberger and *Ctyrokya* Schlickum. This rather gradual Early Miocene development is strongly contrasted by the Early Badenian build-up event (EBBE) indicated by 505 newly arriving or originating gastropod species. As documented by HARZHAUSER et al. (2003) some of the gastropod species, displaying their Paratethyan FOD in the Early Badenian, are rooted in the Burdigalian of the Proto-Mediterranean-Atlantic Region. These species extend their distribution area towards the north following the increasing SST values during the Langhian climatic optimum. Typical examples are the gastropods *Strombus (Euprotomus) schroeckingeri* Hörnes, *Rimella decussata* (Grateloup) and *Pereiraea gervaisii* Vezian. Others develop mass-occurrences [e.g. *Tibia dentata* (Grateloup), *Tudicla rusticula* (Basterot)] or display a remarkable diversification (e.g. the nassariid genus *Cyllenina* Bellardi and the rissoiid genus *Alvania* Risso). Parallels within the bivalves are found in the carditiids, isognomids or plicatulids (HARZHAUSER et al., 2003). However, due to the generally poorer knowledge of the Late Burdigalian and Langhian faunas in the Proto-Mediterranean-Atlantic Region, the potential Burdigalian origin of many Early Badenian FODs remains enigmatic. This lack of information was also stated for the bivalve faunas by STUDENCKA et al. (1998). For the same reason Middle Miocene migrations from the Central Paratethys into the Mediterranean such as shown by JANSSEN (1993) for the turrid genus *Spirotropis* Sars are hard to recognise.

A plot of the total numbers of species recorded per time-slice visualizes this peak in Early Badenian species-richness within gastropod faunas (EBBE). Putting these total-number values in scale with the global deep-sea oxygen isotope record of ZACHOS et al. (2001) reveals a surprising relationship. During the Badenian, the number of new arrivals or originations is lowered to 143 in the Late Badenian. The number of LODs reaches a first peak of 297 species for gastropods. This negative balance for the gastropods coincides conspicuously with the onset of the Middle Miocene climate transition (SHEVENELL et al., 2004). A slight cooling during the Late Badenian is reflected by the retreat and/or decline of thermophilic mollusc taxa. This is reflected e.g. by a decrease of the strombid diversity (HARZHAUSER et al., 2003) or by the drop in the nassariid genus *Cyllenina* from 9 Early Badenian species to 3 in the Late Badenian (HARZHAUSER & KOWALKE, 2004). According to these data a drop of the minimum sea-surface temperature from at least 16-18°C during the Early Badenian optimum to 14-15°C in the Late Badenian is calculated. This Late Badenian cooling seems to succeed into the Early Sarmatian, indicated by the occurrence of diatomites and the dramatic shut down of the Badenian carbonate factory (PILLER & HARZHAUSER, 2004a,b). Whilst the Badenian development is thus probably related to a global climatic trend, the next tremendous peak in extinctions is mainly geodynamically and climatically controlled. This Badenian-Sarmatian-extinction-event (BSEE) with 588 LODs in gastropods and 121 in foraminifers is the biggest turnover in the Paratethyan history. The BSEE concerns mainly Badenian gastropod species but is also the dead-end for most old species with early Miocene roots. A hint to the still unsolved trigger mechanism for the BSEE is the obvious advantage of lecitotroph larvae opposed to planktotroph larvae. Within the nassariids HARZHAUSER & KOWALKE (2004) documented a switch from 7% lecitotroph Badenian species towards 100% Sarmatian species with direct development. This points to a crisis that had affected the zooplankton. Correspondingly, the percentage of planktic species within the foraminfers fauna drops to zero at the BSEE and they never return again in the Central Paratethys. Now a new Early Sarmatian gastropod fauna is established mainly due to the radiation of the rissoid genus *Mohrensternia* Stoliczka and the archaeogastropod *Gibbula* Risso. The mid-Sarmatian extinction of these endemisms again causes a high extinction rate of 65%. This event corresponds to a change in depositional environments and the subsequent loss of ecosystems to which the highly specialized Early Sarmatian gastropod species have been adapted. The

Upper Sarmatian carbonate sequences reflect a highly productive carbonate factory of subtropical climate. The formation of thick oolite sequences with Persian Gulf-type ooids as well as the mass occurrences of thick-shelled shell beds require normal saline to hypersaline, subtropical conditions. This warming is also indicated by the negative peak of the oxygen isotope curve between MSi-3 and MSi-4 of ABREU & HADDAD (1998).

The last big leap is represented by the Sarmatian-Pannonian-extinction-event (SPEE). Although for gastropods only little impressive in absolute numbers (49 LODs versus 63 FODs), the extinction-rate climbs up to 93%. Like the BSEE the SPEE is rather a geodynamically controlled story, triggered by the isolation of Lake Pannon from the Eastern Paratethys Sea.

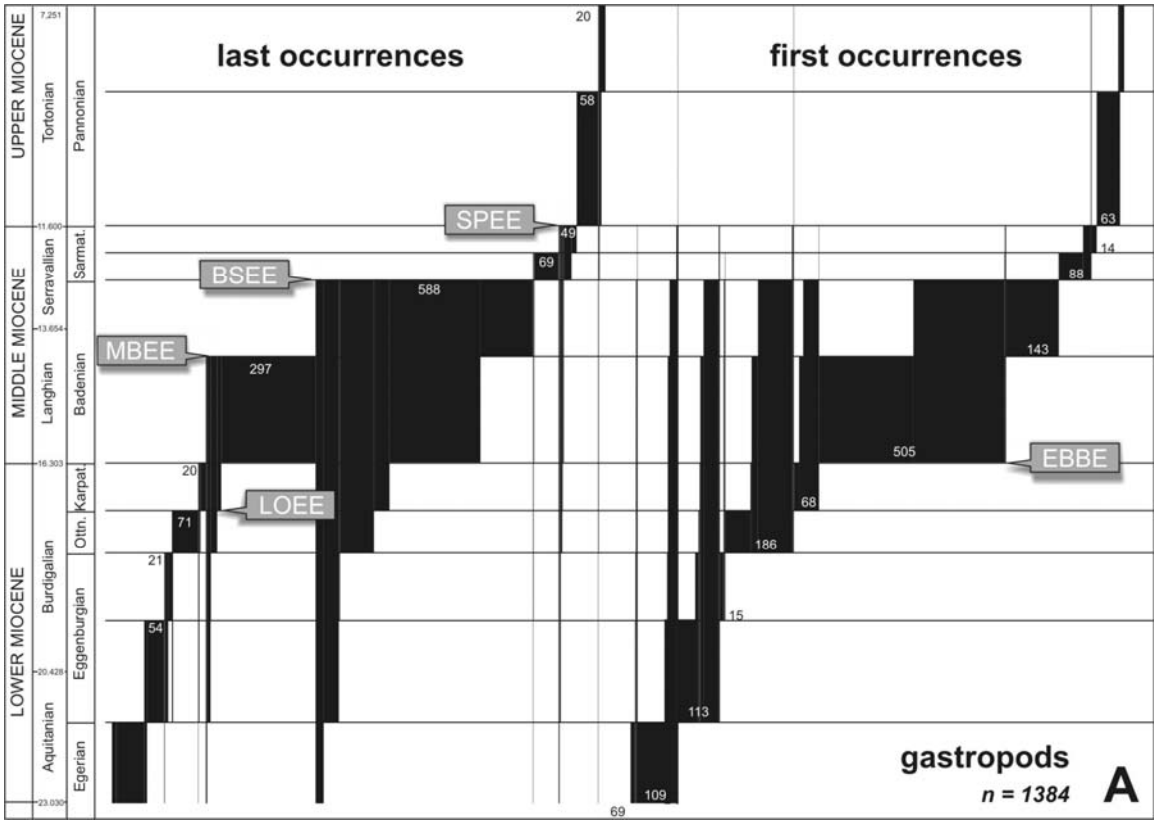


**Figure 1:** Literature-based stratigraphic ranges of 1384 gastropod species in the Central Paratethys Sea. Last occurrences on the left graphs, first occurrences on the right. The Paratethyan "big five" as based on the gastropod record are indicated: LOEE – late Ottnangian-extinction-event, EBEE – early Badenian-build-up-event, MBEE – middle Badenian-extinction-event, BSEE – Badenian-Sarmatian-extinction-event, SPEE – Sarmatian-Pannonian-extinction-event. The burst of species-richness in the Early Badenian is most eye-catching.

## CHARAKTERISIERUNG VON LAGUNENZONEN ANHAND REZENTER BIVALVEN AUF DREI ATOLLEN VOR DER KÜSTE VON BELIZE (ZENTRALAMERIKA)

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Die drei Atolle Glovers Reef, Lighthouse Reef und Turneffe Islands vor der Küste von Belize unterscheiden sich in Geomorphologie, Lagunentiefe, Sedimentbeschaffenheit,