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The water-chemistry of the Miocene Dinarid Lake System revealed by stable isotopes of mollusc aragonite

M. Harzhauser (1), O. Mandic (1), C. Latal (2)

(1) Natural History Museum Vienna, Austria, mathias.harzhauser@nhm-wien.ac.at

(2) Institute of Applied Geosciences, Graz University of Technology, Austria

The Dinarid Lake System (DLS) formed during the late Oligocene and Miocene in today NW-SE trending intra-mountain basins between the slowly rising Dinarid mountain chains (Pavelić, 2001). Early to Middle Miocene transtensional tectonics generated elongated pull-apart basins that got subsequently filled by thick lacustrine deposits. The comparatively low terrigenous input supported the diversification of lacustrine environments, including both deep- and shallow-water habitats. This habitat diversification sparked the spectacular Miocene radiation of the benthic fauna. Subsequent rifting in the Pannonian Basin System triggered the marine flooding of the northern DLS area and reduced its extension to the External Dinarides. Geographically, the deposits of the DLS cover parts of Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Hungary and Slovenia. During its maximum extent, the lake system covered an area of c. 75,000 km^2.

The most eye-catching radiations of molluscs are represented by the gastropod genera *Melanopsis* and *Prososthenia*. These radiations and the represented morphologies have striking counterparts in the much younger faunas of Lake Pannon. Similar convergences have been documented by Harzhauser and Mandic (2008) within the dreissenid bivalves which developed unrelated morpho-pairs in the Dinarid Lake System and Lake Pannon. Even more astonishing is the convergent evolution of large-sized, limpet-like, deep-water-dwelling gastropods in these lakes. In the Dinarid Lake system, *Clivunella* and *Delminiella* represent this type. The origin of these taxa is unknown. The lymnaeid protoconch and earliest teleoconch of *Delminiella* point to an

affiliation with the Lymnaeoidea. *Clivunella* lacks these conchological features and its ancylid early shell may point to a relation to the Planorboidea. These derived gastropods settled the deep lake habitats but were unable to spread into any other Early and Middle Miocene lakes. During the Late Miocene, Lake Pannon saw a near-identical development, which led to the large-sized *Valenciennius*. In this case a good fossil record documents the evolution from inflated lymnaeids via various intermediate stages (e.g. *Provalenciennesia, Velutinopsis*) to the depressed deep-water limpet *Valenciennius*. Some genera such as *Orygoceras* are even endemics to both lake systems.

Lake Pannon was documented recently by Harzhauser et al. (2007) to be a marine-derived brackish water lake with high alkalinity and a pH value of about 9. Due to the extreme morphological convergences in the mollusc faunas of both systems it was very tempting to postulate similar water chemistries in both lake systems. Typical δC^{13} values of mollusc aragonite in Lake Pannon range between -3 and +3 and δO^{18}values range from -2 to +1. To compare both systems we have chosen more than 15 different DLS species to cover a broad range of paleo-environments from riverine influenced deltaic areas via the littoral zone down to the deeper sublittoral. Our results document a main range of δO^{18}values between -2 and -6 as typical for freshwater settings. Moreover, the carbon signatures, with negative δC^{13}values between -2 and -10 differ strongly from those of Lake Pannon.

Nevertheless, the sedimentology and coal petrology data of DLS sections clearly point to enhanced lake water alkalinity (Mandic et al., submitted). Hence, based on δO^{18}values we interpret the DLS as a pure freshwater system in contrast to the brackish Lake Pannon. The trigger mechanism for the striking similarities in mollusc morphologies in Lake Pannon and the DLS may thus be linked with elevated lake water alkalinity.