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Palaeoecology of Late Glacial and Holocene profundal Ostracoda of pre-Alpine lake Mondsee (Austria) — A base for further (palaeo-) biological research

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ABSTRACT

Succession of profundal ostracod palaeoassemblages in response to environmental changes during the Late Glacial and Holocene was studied in a ~ 15-m-long sediment sequence from pre-Alpine lake Mondsee (Austria). First local ostracod assemblage zone LOAZ-1 (prior to 15,700 a BP), with low abundances of *Leucocythere mirabilis* and *Limnocytherina sanctipatricii* followed by *Cytherissa lacustris*, corresponds to the Pleniglacial phase of clastic-detrital sedimentation at relatively high rates. Most of the key species of LOAZ-2 (15,590 to 13,940 a BP, including the Pleniglacial–Late Glacial transition), i.e. limnocytherids, *Fabaeformiscandona* cf. *harmsworthi*, *F. tricicatricosa*, *C. lacustris* and *Candona candida*, reveal the significant association with high Al contents and low sedimentation rates and are classified as preferring low-productivity conditions. In contrast, *Candona neglecta*, dominant in LOAZ-3 (13,820 to 9960 a BP, palynologically defined as Bölling–Early Holocene) and in the last LOAZ-4 (9780 a BP to present) as well as *Cypria ophtalmica* (second key species in LOAZ-4) show relationship with higher productivity, elevated sedimentation rates and decreasing Al contents.
Furthermore, valve biodegradation and shape disparity at different time periods and in relation to sedimentation rate changes were investigated in A-3 juveniles of *Candona neglecta*. The highest percentage of valves biodegraded by Actinobacteria was recorded during the Allerød, Younger Dryas and Early Holocene, when the lowest sedimentation rates occurred, whereas significantly lower frequencies of biodegraded valves were recorded during the mid-Holocene and Late Holocene, when sediment accumulation was much higher. It is also hypothesised that the degree of the valve shape variation was related to the lake productivity. During the Allerød, Younger Dryas and Early Holocene a valve shape variation significantly lower than that recorded during Late Holocene intervals, characterised by intensified lake productivity, was observed. Additionally, an agenda of potential questions and approaches that should be considered and form the core of further (palaeo-)biological research projects is offered.

1. Introduction

Being common in non-marine waters, small bivalved ostracod crustaceans are nowadays used almost routinely as versatile palaeo-proxies in environmental reconstructions alongside other indicators. Their low-magnesium calcitic valves, often abundant and well-preserved in lacustrine Quaternary sediments, are valuable objects for palaeoenvironmental studies on the habitat type and succession as

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well as on chemical composition of past ambient water and provide a source for chemical analysis of trace elements and stable isotopes, which are known to reflect water and air temperature, chemistry and productivity (Holmes, 2001; De Deckker, 2002; von Grafenstein, 2002; Boomer et al., 2003; Curry, 2003; Ito et al., 2003; Horne et al., 2012).

The multi-disciplinary project DecLakes (Decadal Holocene and Lateglacial variability of the oxygen isotopic composition in precipitation over Europe reconstructed from deep-lake sediments) was primarily aimed at the reconstruction of European decadal climate variability as expressed in the stable oxygen isotope composition of past precipitation derived from ostracod valves recovered from the profundal sediments of deep pre-Alpine and lowland lakes. As a part of the DecLakes project, the present study focused on two aspects of the ostracod material obtained from a deep pre-Alpine lake Mondsee in Austria. The first one addressed the ostracod assemblage succession in relation to environmental changes in the deep lacustrine habitat during the Late Glacial to Holocene and the link between the ostracod sequential distribution and other limnological proxies. The second aspect of this study had arisen from the need of searching and testing ostracod-inferred palaeoenvironmental methods (Horne et al., 2012). It dealt with the palaeoecological information that can be extracted from the morphological variation and the preservation state of ostracod valves. In this context, we studied traces of biodegradation of the valves as well as disparity in valve shape using geometric morphometrics at different time periods and in relation to sedimentation rate changes.

2. Study site

Lake Mondsee (47°49′ N, 13°24′ E; 481 m above sea level) is located ca. 25 km east of Salzburg in the Salzkammergut lake district of the Upper Austrian Alpine Foreland (Fig. 1). It is a reasonably large (surface area 13.8 km^2, volume 0.51 km^3) and deep lake (maximum water depth 68 m, mean water depth 37 m) with a moderately developed shore line (28.3 km in length) and a water retention time of about 1.7 years (Müller, 1979; Jagsch and Megay, 1982; Dokulil and Teubner, 2012). The bathymetry is characterised by a shallower north-western basin (up to 48 m deep) and a deeper southern basin (maximum depth 68 m, Jagsch and Megay, 1982). The lake is holomictic and stratifies regularly during summer and sporadically in winter, thus switching between dimictic and monomictic mixing regimes (Dokulil and Teubner, 2012). As many other lakes, lake Mondsee underwent anthropogenic eutrophication in the late 1960s and early 1970s but considerably improved since then and can presently be classified as oligo-mesotrophic (Dokulil and Teubner, 2012). Three main streams (the Fuschler Ache, Wangauer Ache and Zeller Ache) discharge into the north-western basin, whereas only some smaller creeks (e.g. Kienbach) flow into the southern lake basin. There is one outflow (Seeache), which discharges (average outflow 9.2 m^2 s^{-1}) into lake Attersee, the last in a chain of lakes within the catchment area (Jagsch and Megay, 1982).

About half of the catchment area (~247 km^2) is covered by forests; the remaining part is mainly used for agriculture (meadows, pastures and arable land) and touristic recreation (Beiwl, 2008; Klug and Jenewein, 2010). The southwestern shoreline of lake Mondsee mainly follows a thrust zone dividing the catchment into two geological units: the steeply sloped Northern Calcareous Alps (Mesozoic limestones and dolomites) in the south and the gently sloped hills of the Flysch Zone (siliciclastic Cretaceous sediments, partly covered by Quaternary deposits) in the north (Fig. 1; van Husen, 1989). At present, the local climate is temperate with warm summers (mean annual, January and July air temperatures of 8.7 °C, 0.5 °C and 17.8 °C, respectively) and relatively high precipitation (annual average of 1550 mm with a maximum in spring/summer) (climate data for the period 1971–2000, Central Institute for Meteorology and Geodynamics (ZAMG), Vienna, Austria).

Previous work on lake Mondsee ostracods dates back to the 1980s when intensive studies on recent and fossil distribution and autecology of ostracod species in the littoral and profundal have been undertaken (Danielopol et al., 1985, 1988, 1990a, 1993; Geiger, 1993). These studies focused on *Cytherissa lacustris*, an endobenthic indicator species of environmental changes related to eutrophication processes at the sediment–water interface in recent and historical times. Investigations of the fossil record were mainly based on short sediment cores (mostly

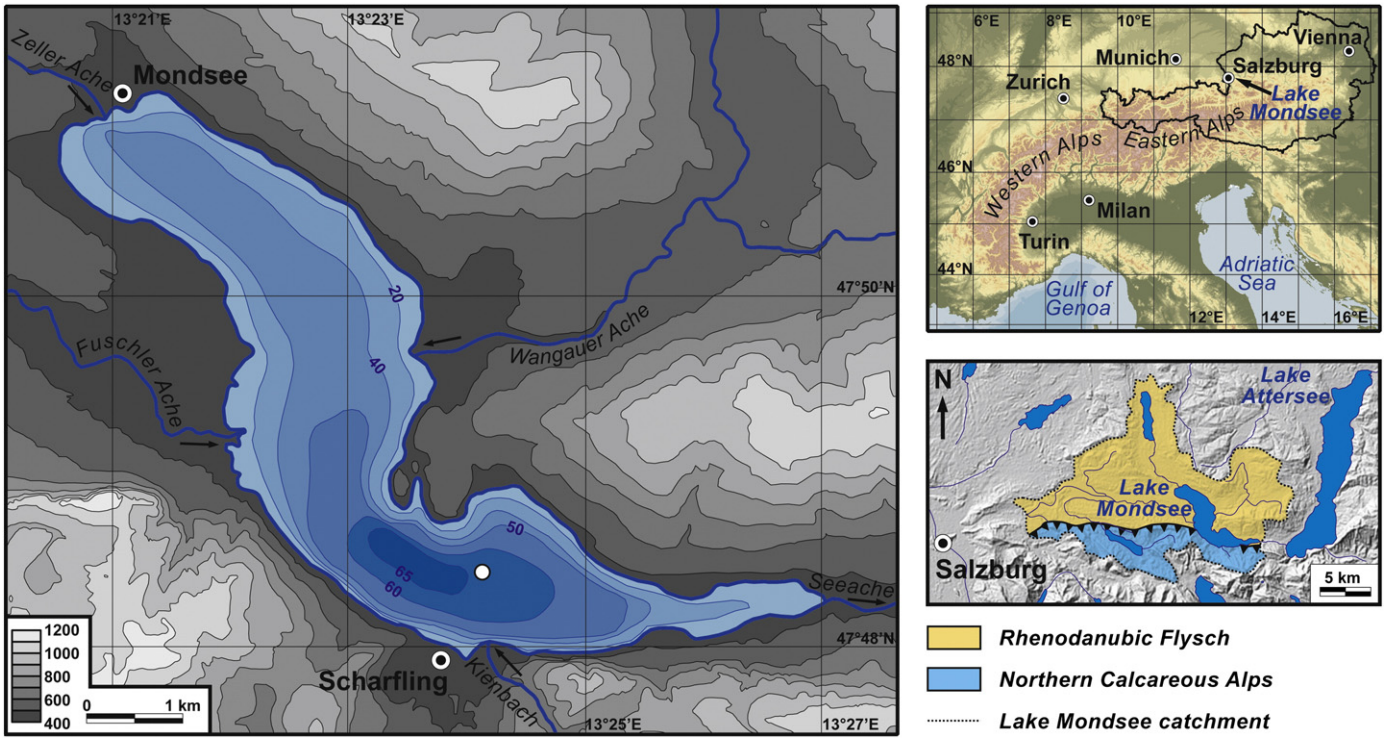

Fig. 1. Bathymetric map of lake Mondsee (coring location indicated by a white point) as well as location of Mondsee in Europe and simplified catchment map with the two major geological units.