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Invited research article

Late Burdigalian sea retreat from the North Alpine Foreland Basin: new magnetostratigraphic age constraints

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ABSTRACT

Accurate reconstruction of the final sea retreat from the North Alpine Foreland Basin (NAFB) during the Burdigalian (Early Miocene) is hampered by a lack of reliable age constraints. In this high resolution magnetostratigraphic study we try to solve a significant age bias for the onset of the Upper Freshwater Molasse (OSM) deposition in the neighboring S-German and Swiss Molasse Basins. We measured >550 samples from eleven drill cores covering the transition from marine to brackish to freshwater environments in the S-German Molasse Basin. Based on combined bio-, litho- and magnetostratigraphic constraints, the composite magnetostratigraphic pattern of these cores provides two reasonable age correlation options (model 1 and 2). In model 1, the base of the brackish succession lies within Chron C5Cr (~16.7–17.2 Ma), and the onset of OSM deposition has an age of ~16.5 Ma. Correlation model 2 suggests the transition to brackish conditions to be within C5Dr.1r (~17.7–17.5 Ma), and yields an age around 16.7 Ma for the shift to the OSM. Most importantly, both models confirm a much younger age for the OSM base in the study area than previously suggested. Our results demonstrate a possible coincidence of the last transgressive phase (Kirchberg Fm) with the Miocene Climatic Optimum (model 1), or with the onset of this global warming event (model 2). In contrast, the final retreat of the sea from the study area is apparently not controlled by climate change.

1. Introduction

The North Alpine Foreland Basin (NAFB) formed during the Eocene as a result of gravitational loading by the advancing Alpine orogenic wedge (e.g., Sissingh, 1997; Hinsch, 2008). The paleogeographic and sedimentary evolution of the NAFB is closely related to uplift and erosion caused by Alpine tectonics and relative sea-level changes (e.g., Lemcke, 1988; Kuhlemann and Kempf, 2002). The Molasse Basin largely covers the area of the NAFB and belongs to the biogeographic provinces of the Western and Central Paratethys Seas (Fig. 1). It extends from Lake Geneva in the west via northern Switzerland and southern Germany to Lower Austria in the east. The oldest Molasse sediments date from the Late Eocene/Early Oligocene, while the youngest deposits are Late Miocene in age (e.g., Schlunegger et al., 1996; Doppler et al., 2005; Grunert et al., 2015). The Molasse sediments largely originate from erosional debris of the uplifting Alps, with lesser amounts of material deriving from sources to the North and axial and radial directions of sediment transport respectively (e.g., Lemcke, 1988; Kuhlemann and Kempf, 2002). Sedimentary thicknesses range from a few tens of meters in the distal areas to >5000 m nearby the Alps (e.g., Lemcke, 1988).

Key features of the Oligocene to Miocene infill are two transgressive-regressive megacycles, each consisting of a succession of marine, brackish and freshwater sediments (Bachmann and Müller, 1992; Schlunegger et al., 1996; Berger et al., 2005a,b; Grunert et al., 2015). Six main lithostratigraphic groups have been established in the S-German Molasse Basin, comprising (from bottom to top) the Lower Marine Molasse, the Lower Brackish Molasse, the Lower Freshwater Molasse, the Upper Marine Molasse, the Upper Brackish Molasse, and the Upper Freshwater Molasse. Flora and fauna of the semi-enclosed Paratethys environments contain many endemic elements, while index species of the Tethys are often absent. This makes biostratigraphic correlation to the global ocean record difficult and resulted in the development of regional stratigraphic schemes for the Paratethys domains (e.g., Piller et al., 2007; Hilgen et al., 2012). In addition, the sequence stratigraphy of the Molasse Basin and possible correlations to global

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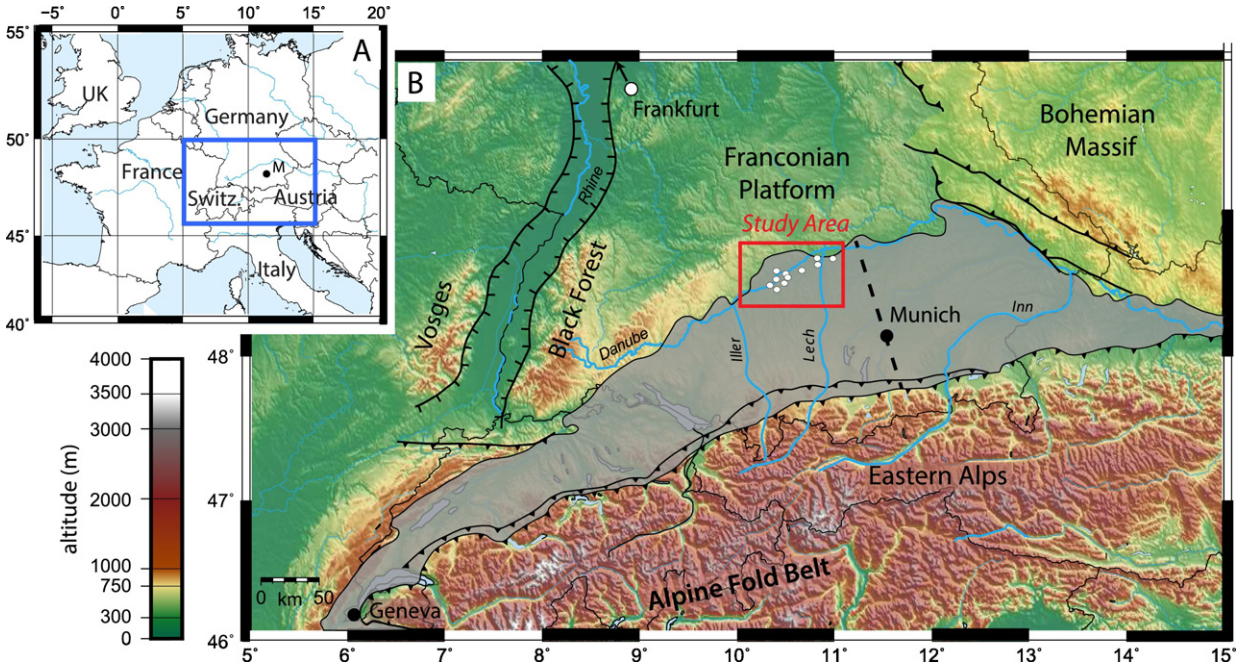

Fig. 1. Geographic location of the study area indicated in a topographic map of the North Alpine region (B) in Europe (A). Schematic outline of the Molasse Basin (in gray) modified after Jin et al. (1995). Coordinates of drill cores (white dots) are stated in Table 1. The dashed line through Munich indicates the boundary between the Western and Central Paratethys regions (Senes, 1973).

sea level changes were discussed intensively (e.g., Jin et al., 1995; Zweigel et al., 1998; Hinsch, 2008; Frieling et al., 2009; Grunert et al., 2013). As a result, most of the current regional time scales rely on biostratigraphy combined with basin sequence stratigraphy and 3rd order global sea level variations (sensu Hardenbol et al., 1998), whereas absolute age constraints on the sequence boundaries are often absent.

In this paper, we will focus on part of the second transgressive-regressive megacycle developing in the NAFB from the Early Miocene (late Aquitanian-to-Burdigalian) to the Late Miocene (Tortonian). The shift from marine conditions, represented by the Upper Marine Molasse (OMM),[1] via mainly brackish environments termed the Upper Brackish Molasse (OBM), to fluvial and lacustrine depositional settings recorded by the Upper Freshwater Molasse (OSM), marks an important change in Paratethys paleogeography. At the onset of OSM sedimentation, the marine connection between the NAFB and the western Mediterranean via the Rhône Basin was restricted or closed (Sissingh, 2001). Uplift between the Eastern Alps and Bohemian Massif separated the western NAFB (Switzerland and S-Germany) from the rest of the Central Paratethys (Kuhlemann and Kempf, 2002) (Fig. 1).

A detailed understanding of the final sea retreat from the central and northern NAFB during the Burdigalian, however, is hampered by an age bias (up to 0.7 Myr) for the onset of freshwater deposition (OSM) in the S-German and Swiss Molasse Basins. According to Abdul Aziz et al. (2010), the base of the OSM in the central Molasse Basin in S-Germany is >17.5 Ma based on correlation of magnetostratigraphy, small mammal biostratigraphy and Ar/Ar ages of two bentonites. In contrast, it was defined to be at around 16.8 Ma in the southern Molasse Basin in Switzerland, based on mammal stratigraphy, magnetostratigraphy and U/Pb ages of bentonites (Kälin and Kempf, 2009). Some diachrony can be expected, even in neighboring regions such as the Swiss and S-German Molasse Basin, but a difference of about 0.7 Myr is difficult to understand, mainly because the small mammal assemblages at the base of the OSM are similar (MN 4/MN 5 transition) in both regions. Furthermore, it is unlikely that the sea retreat would occur much earlier in the central part than in the alluvial fan-dominated proximal part of the basin.

Recently, Reichenbacher et al. (2013) tried to resolve this age controversy. They performed a magneto-litho-biostratigraphic study on four sections and three boreholes of the Swiss and S-German Molasse Basins and suggested that the base of the OSM is ~16.7 Ma in S-Germany and ~16.5 Ma in Switzerland (Fig. 2). The new data and revised correlation largely solve the age difference between the Swiss and German regions. However, the magnetostratigraphy of the S-German cores was based on a rather low sampling resolution with several polarity intervals only based on 1 or 2 samples.

The objectives of this study are to refine the chronostratigraphy of the Upper Brackish to Upper Freshwater Molasses by applying high-resolution magnetostratigraphy and to test if the new age model of Reichenbacher et al. (2013) can be supported. Our new database comprises >550 samples from eleven drill cores covering the marine to brackish to freshwater transition in the western S-German Molasse basin (Fig. 1, Table 1). The new age constraints will allow better correlation between the S-German and Swiss Molasse Basins and improve understanding of the final sea retreat from the Molasse Basin during the Early Miocene.

2. Geological setting

2.1. Overview

The OMM in the S-German Molasse Basin is dominated by glauconitic sands and marls, and is generally rich in foraminifers and other marine fossils. Biostratigraphy is based mainly on mollusks and benthic foraminifers, and correlation to global biostratigraphy based on planktonic foraminifers and nannoplankton is limited due to rarity of index fossils (e.g., Steininger et al., 1976; Cicha et al., 1998; Pippèrr, 2011). In the regional Central Paratethys stratigraphic framework, the OMM consists of an Eggenburgian and Ottnangian part; in the central S-German

[1] To avoid confusion with the classic German terminology, the German abbreviations will be used for the lithostratigraphic units of the Molasse Basin, being the Obere Meeresmolasse (OMM), Obere Brackwassermolasse (OBM) and Obere Süβwassermolasse (OSM).