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Late Early Miocene palaeoenvironmental changes in the North Alpine Foreland Basin

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ABSTRACT

The North Alpine Foreland Basin (NAFB) experienced rapidly changing palaeoenvironmental conditions at the end of the Early Miocene (middle-to-late Burdigalian, Paratethys stages Ottnangian and Karpatian), with transformation of fully marine settings into brackish and eventually freshwater environments. These changes were related to global sea-level fluctuations, climate oscillations, and tectonic processes associated with the uplift of the Alps. This study presents a new and comprehensive data set, derived from 13 boreholes and 491 core samples from the Molasse Basin of southwest Germany, that provides a significantly better understanding of late Early Miocene palaeoenvironments in the NAFB. Based on lithostratigraphy, biostratigraphy, and palaeoecological interpretation of rich fauna and flora assemblages, we show that the upper Burdigalian sediments comprise a regressive lower segment (Grimmelfingen Formation and equivalents), as indicated by the occurrence of the bivalve *Rzehakia*, and a transgressive upper component (Kirchberg Formation and equivalents) characterized by the advent of new fish and mollusc assemblages. Furthermore, we present a new lithostratigraphic concept for the Kirchberg Formation, which forms an important part of the Upper Brackish Molasse (OBM). Based on biostratigraphic constraints and recently published magnetostratigraphic data, it appears that the regressive segment of the upper Burdigalian OBM sediments correlates with the end of the global third-order sea-level cycle Bur 3, while the transgressive component reflects the Karpatian transgression at the beginning of sea-level cycle Bur 4. This implies that the Karpatian transgression actually affected the Molasse Basin of southern Germany and Upper Austria, whereas previous studies had considered this part of the NAFB as terrestrial during that time span. The new results are depicted in three palaeogeographic maps for the NAFB at 18 Ma, 17.5–17.1 Ma and 17 Ma, respectively.

1. Introduction

The North Alpine Foreland Basin (NAFB, Fig. 1A), also referred to as Molasse Basin, formed in the Late Eocene/Early Oligocene and existed until the Late Miocene. It was part of the Western and Central Paratethys, which developed in the course of the Alpine orogeny through isolation from the northern Tethys (e.g. Rögl and Steininger, 1983; Rögl, 1999; Popov et al., 2004). However, the presence of numerous endemic species among the Oligo-Miocene fauna and flora of the Paratethys and NAFB renders stratigraphic correlation with the Tethys realm difficult (see Piller et al., 2007). As a result, regional chronostratigraphic stages have been introduced for the Oligocene and Miocene Series in the Central Paratethys realm, and are also widely used for the Molasse sediments of the NAFB (Fig. 2).

The NAFB extends from the Rhône Basin in the west via Switzerland and southern Germany to Lower Austria in the east (Fig. 1A). The Swiss and SW German sectors of the NAFB correspond to the area of the Western Paratethys, while the SE German and Austrian portions represent the western zone of the Central Paratethys. The sedimentary fill of the NAFB Basin, which reaches thicknesses of over 5000 m in places, includes largely siliciclastic marine, brackish and terrestrial sediments and represents one of the most continuous Oligocene-Miocene archives in Europe (e.g. Schlunegger et al., 1997; Kuhlemann and Kempf, 2002; Abdul Aziz et al., 2010). In the Swiss and SW German segment of the NAFB, the sedimentary succession as a whole is divided into two transgressive-regressive megacycles, which are separated by an extensive unconformity (e.g. Lemcke, 1988; Bachmann and Müller, 1992). The first megacycle (Oligocene to lowermost Miocene) comprises the lithostratigraphic groups of the Lower Marine Molasse, Lower Brackish Molasse and Lower Freshwater Molasse, while the second megacycle (lower Miocene to upper Miocene) consists of the Upper Marine Molasse, Upper Brackish Molasse and Upper Freshwater Molasse (e.g. Doppler et al., 2005).

An especially interesting time span in the geological history of the NAFB is the late Early Miocene (middle to late Burdigalian, Central Paratethys stages Ottnangian and Karpatian) because this interval saw significant changes in palaeoenvironmental conditions in the region (e.g. Lemcke, 1988; Kuhlemann and Kempf, 2002). Lower Ottnangian sediments are usually fully marine, middle Ottnangian successions are dominated by restricted marine conditions, upper Ottnangian sediments

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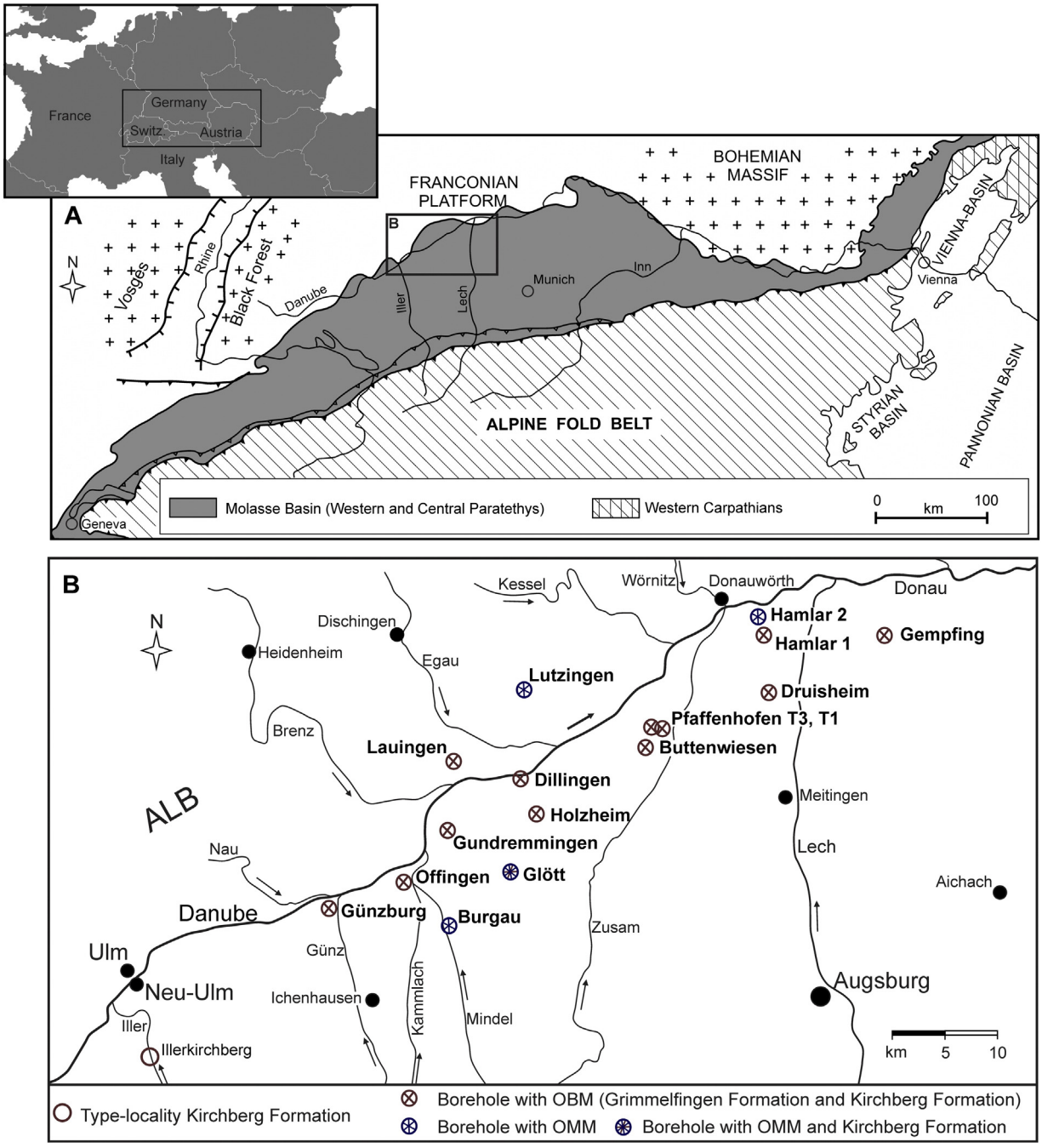

Fig. 1. (A) Schematic map of the North Alpine Molasse Basin. (B) Locations of the boreholes Glött (succession with OMM – OBM/Kirchberg Fm – OSM), Günzburg, Offingen, Gundremmingen, Lauingen, Holzheim, Dillingen, Buttenwiesen, Pfaffenhofen T1 and T3, Druisheim, Hamlar 1, and Gempfing (successions with USM or Jurassic limestone – OBM/Grimmelfingen and Kirchberg Fms. – OSM). In addition, we refer to the boreholes Burgau, Lutzingen, Hamlar 2 (Pippèrr et al., 2016; successions with OMM and without OBM) and the outcrops near Illerkirchberg, the type locality of the Kirchberg Fm (Reichenbacher, 1989). OMM = Upper Marine Molasse, OBM = Upper Brackish Molasse, OSM = Upper Freshwater Molasse.

are characterized by a brackish facies, and the Karpatian deposits are generally thought to reflect the presence of freshwater environments (e.g. Wenger, 1987; Doppler et al., 2005; Piller et al., 2007; Rupp et al., 2008; Pippèrr, 2011). Abundant shells of the bivalve *Rzehakia* (formerly *Oncophora*) often characterize the brackish deposits; this conspicuous *Rzehakia* facies can be traced across the entire Paratethys and is considered to denote the final regressive phase of the Ottnangian Paratethys sea (e.g. Čtyroký, 1968; Čtyroký et al., 1973a; Steininger et al., 1976; Harzhauser and Piller, 2007). However, whether the emergence of this noticeable *Rzehakia* facies was related to global sea-level fluctuations, climate oscillations or the Alpine orogeny has not yet been resolved.

The objective of this study is to present comprehensive new data based on 13 boreholes and 491 core samples from the SW German sector of the NAFB (= SW German Molasse Basin), which significantly enhance our understanding of the middle and late Burdigalian (Ottnangian–Karpatian) palaeoenvironments in the NAFB and western Paratethys, respectively. We show that what has previously been identified as the *Rzehakia* facies in the SW German Molasse Basin actually comprises a regressive plus a transgressive sedimentary unit. Based on biostratigraphic constraints and recently published magnetostratigraphic data (Reichenbacher et al., 2013; Sant et al., submitted), we conclude that the transgressive sediments represent the Karpatian transgression at the beginning of the global third-order sea-level cycle Bur 4. This implies

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