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Late orogenic rebound and oblique Alpine convergence: New constraints from subsidence analysis of the Austrian Molasse basin

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Abstract

Subsidence analysis of 16 wells in the Austrian Molasse basin documents major spatial and temporal changes in tectonic subsidence as well as a late-stage surface uplift. The timing of the main phase of tectonic subsidence shifted from early Oligocene in the western part of the peripheral foreland to the early Miocene in the eastern part. These temporal and spatial changes in tectonic subsidence reflect a change from oblique dextral to sinistral convergence between the Alpine nappe stack and its foreland. The main phase of sediment accumulation was delayed to the early Miocene and led to the infill of the basin and a major second, sediment-load driven phase of basement subsidence. Sediment accumulation rates in the basin reflect the build-up of topography in the Alpine mountain chain. Since approximately 6 Ma a pronounced regional uplift of the entire Molasse basin has taken place, marking the transition from lateral extrusion to orthogonal contraction within the Alpine system and deep-seated changes in geodynamic boundary conditions, possibly due to delamination of previously thickened lithosphere. Surface uplift is contemporaneous with similar processes in extra-Alpine Central Europe, where it is interpreted to reflect intra-plate stress changes.

Keywords: basin inversion; surface uplift; delamination; flexural basin

1. Introduction

Foreland basins develop in response to the bending of an elastic lithosphere due to loading by the advancing orogenic wedge and/or additional loads, e.g. slab pull forces and thickened mantle lithosphere, operating on the lithosphere (Beaumont, 1981; Royden, 1993). Modeling of foreland basins so far has mostly focused on the constructive stage of basin evolution, with relatively minor attention being paid to their late-stage inversion of subsidence, as observed in the Austrian Molasse basin.

The Austrian Molasse basin provides a detailed stratigraphic response, from the late Eocene onwards, to the configuration of the Eastern Alpine orogenic wedge, allowing the imposition of time constraints on the main young tectonic phases of the Alpine orogen. This is particularly important, as data on the timing of brittle deformation phases within the Alps are difficult to assess in the absence of related sediments. There are almost no other data on the uplift history of the Eastern Alps, apart from limited geodetic data on the present stage (e.g., Meurers, 1992) and exhumation histories from fission track data (Grundmann and Morteani, 1985; Staufenberg, 1987; Hejl, 1997). Recently, Cederbom et al. (2004) interpreted late-stage orogenic uplift in Central Western Alps as climate-induced rebound. Cloetingh et al. (2005)

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discussed late Neogene lithospheric-scale folding including surface uplift in the northern foreland of Alps to reflect intra-plate stresses due to plate collision in Alps.

The Molasse basin stretches from Lake Leman to the Bohemian spur west of Vienna and extends further NE towards the Carpathians (Fig. 1A). Below we will demonstrate that the stratigraphic record of the Austrian Molasse basin over the last 6 Ma can be explained by delamination of over-thickened lithosphere. We limit our study to the eastern, Austrian Molasse basin from the longitude of Salzburg towards east because of the availability of borehole data.

2. Stratigraphic framework

The Molasse basin of the Alps (Fig. 1) is a classical foreland basin, which developed from the late Eocene to the Present in response to the loading of the southern margin of the European plate after the final continent–continent collision (Lemcke, 1984; Bachmann et al., 1987; Wessely, 1987; Malzer et al., 1993; Wagner, 1998; Zweigel et al., 1998; Allen et al., 2001; Pfiffner et al., 2002; Kempf and Pfiffner, 2004; Deville and Sassi, 2006). An overview on stratigraphy and evolution of the entire Molasse basin is given in Kuhlemann and Kempf (2002).

The Austrian Molasse basin displays strong lateral changes in shape with a decrease in width from about 150 km in the German Molasse basin to less than 10 km at the spur of the Bohemian Massif (Fig. 1). To the east, the basin widens again and changes its strike from E–W to NE–SW. The basement depths of the basin at its southern margin decrease from about 3500 m in the west to about 500 m in the east. In the same direction, the ages of the oldest Molasse strata get increasingly younger (Malzer et al., 1993; Meulenkamp et al., 1996). The overriding Alpine nappe complex comprises, going from bottom to top, units derived from the outer shelf to slope of the European continental margin (Helvetic nappes), followed by the Flysch nappes, and finally the Austro–Alpine complex in an upper plate position. The youngest sediments of these units are of lower Eocene age. Reflection seismic profiles and well data support a post-Eocene shortening of more than 200 km (Wagner et al., 1986; TRANSALP Working Group, 2002).

The Molasse sequence started in the late Eocene with the subsidence of the European plate, deepening

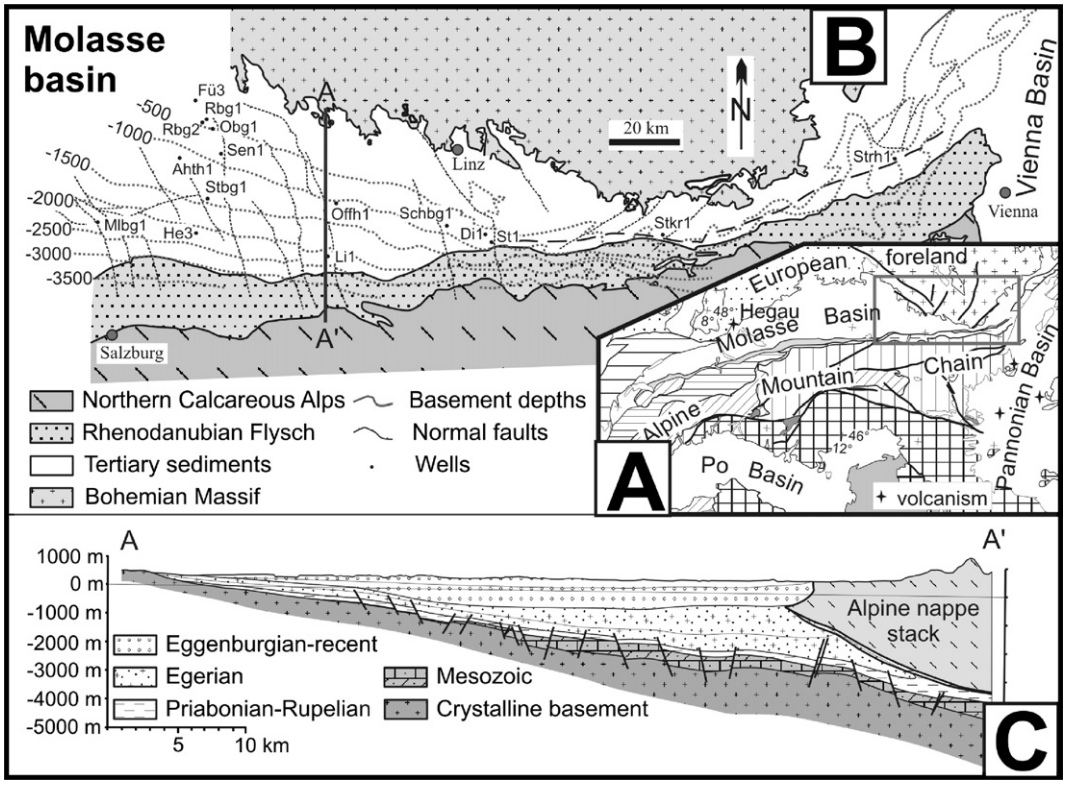

Fig. 1. A. Location of the Northalpine Molasse basin within Central Europe. B. Tectonic map of the eastern Molasse basin and its surroundings, showing basement depths and location of analyzed wells. Inset shows setting of the investigated basin in the Alpine arc. C. N–S section displays the basin geometry and main depositional units of the basin.