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Low temperature thermochronology in the Eastern Alps: Implications for structural and topographic evolution

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ABSTRACT

According to new apatite fission track, zircon- and apatite (U–Th)/He data, we constrain the near-surface history of the southeastern Tauern Window and adjacent Austrolapine units. The multi-system thermochronological data demonstrate that age-elevation correlations may lead to false implications about exhumation and cooling in the upper crust. We suggest that isothermal warping in the Penninic units that are in the position of a footwall, is due to uplift, erosion and the buildup of topography. Additionally we propose that exhumation rates in the Penninic units did not increase during the Middle Miocene, thus during the time of lateral extrusion. In contrast, exhumation rates of the Austroalpine hangingwall did increase from the Paleogene to the Neogene and the isotherms in this unit were not warped. The new zircon (U–Th)/He ages as well as zircon fission track ages from the literature document a Middle Miocene exhumation pulse which correlates with a period of enhanced sediment accumulation during that time. However, enhanced sedimentation- and exhumation rates at the Miocene/Pliocene boundary, as observed in the Western- and Central Alps, cannot be observed in the Eastern Alps. This contradicts a climatic trigger for surface uplift, and makes a tectonic trigger and/or deep-seated mechanism more obvious to explain surface uplift in the Eastern Alps.

In combination with already published geochronological ages, our new data demonstrate Oligocene to Late Miocene fault activity along the Möll valley fault that constitutes a major shear zone in the Eastern Alps. In this context we suggest a geometrical and temporal relationship of the Katschberg-, Polinik–Möll valley- and Mur–Mürz faults that define the extruding wedge in the eastern part of the Eastern Alps. Equal deformation- and fission track cooling ages along the Katschberg–Brenner- and Simplon normal faults demonstrate overall Middle Miocene extension in the whole alpine arc.

1. Introduction

Crustal scale fault zones play an important role in the evolution of orogens, both during continental collision and subsequent extension (e.g. Selverstone, 2005). In the Eastern Alps, northward oblique indentation of the European continent by a semi-rigid crustal block (the so-called Adriatic indenter) (Ratschbacher et al., 1991a,b; Rosenberg et al., 2007) caused lateral extrusion of the orogen during the collisional stage, accommodated along major faults. However, it is not clear if this extrusion occurred in a regime of extension or compression (Robl and Stüwe, 2005a,b) and the fault zones provide evidence for both: Major west–east striking conjugate strike slip zones apparently formed in a regime of compression (Fig. 1) and north–south striking detachments around the tectonic windows formed in a regime of east–west extension. Unfortunately, the temporal relationship between the west–east oriented strike slip zones and north–south detachments is not very well resolved. Some of the west–east striking fault zones were activated by at least Middle Oligocene times (Glodny et al., 2008) and continued to be active throughout the Neogene (Reinecker and Lenhardt, 1999) when the detachments were active (e.g. Fügenschuh et al., 1997; Wölfler et al., 2008). However, the geochronological data that document this activity are from exhumed mylonitic shear zones (e.g. Glodny et al., 2008 and references therein) and therefore reflect displacements under ductile conditions. Data related to the cataclastic shear zones that form the majority of the fault zones in the Eastern Alps are rare. These data demonstrate Oligecene to Early Miocene fault activity to the southeast of the Tauern Window (Kralik et al., 1987) and Late Miocene to Pliocene fault activity along the Pöls–Lavanttal fault system (Fig. 1) in the eastern part of the Eastern Alps (Wölfler et al., 2010).

1.1. Fault zones bounding the Tauern Window

The Tauern Window plays a critical role in the recent evolution of the Eastern Alps. The Tauern Window is bound by the north–south

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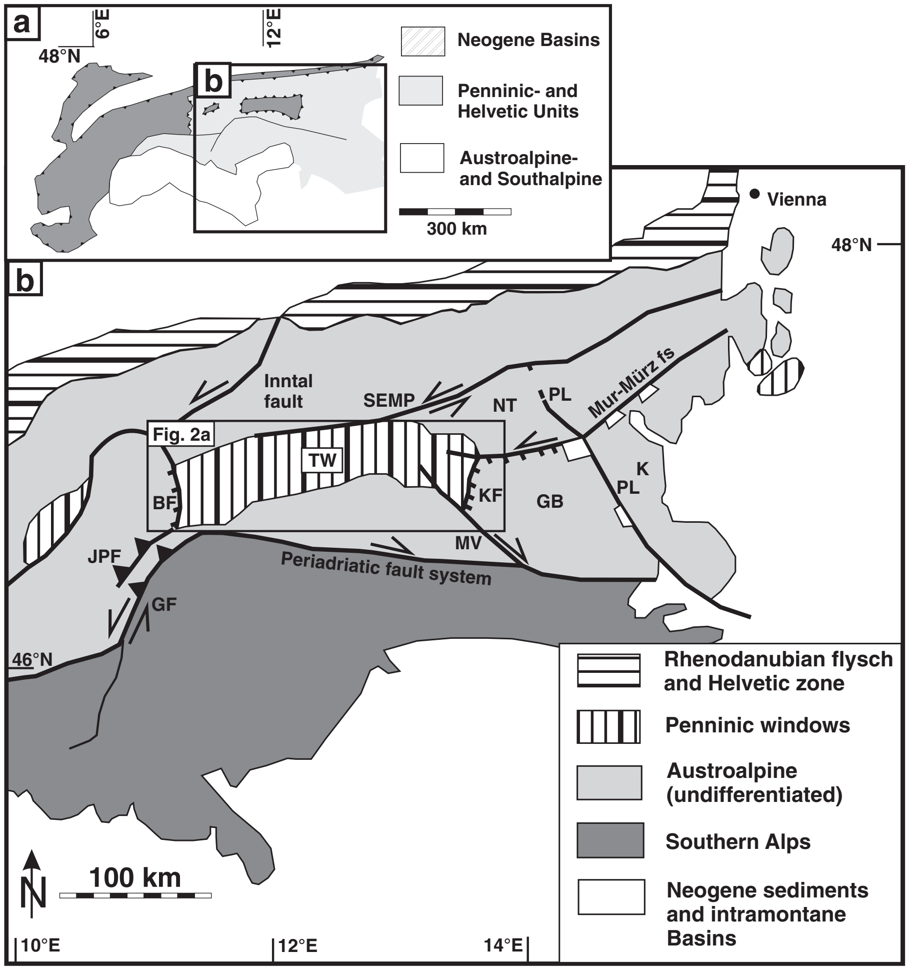

Fig. 1. (a) Simplified tectonic sketch map of the European Alps. (b) Geological sketch map of the Eastern- and Southern Alps. BF: Brenner normal fault; KF: Katschberg normal fault; GF: Giudicarie fault; JPF = Jaufen–Passeier fault; SEMP: Salzach–Ennstal–Mariazell Puchberg fault system; PL: Pöls–Lavanttal fault system; Mur–Mürz fs: Mur–Mürz fault system; MV: Möll valley fault; TW: Tauern Window; NT: Niedere Tauern; GB: Gurktal Block (Gurktal Alps); K: Koralpe.

striking Brenner normal fault (or detachment) (Selverstone, 1988) in the west and the Katschberg normal fault (Genser and Neubauer, 1989) in the east and exposes rocks from the Penninic domain of the Alps (Fig. 1). To the north the Tauern Window is bordered by the Salzach–Ennstal–Mariazell Puchberg fault zone (termed SEMP) (Fig. 1). Recent studies demonstrate that the SEMP truncates into the western part of the Tauern Window within a 50 km long mylonitic belt (Rosenberg and Schneider, 2008). Detailed kinematic analysis reveals sinistral slip (Decker and Peresson, 1996; Linzer et al., 1997; Wang and Neubauer, 1998) accommodating a displacement of 60 km (Linzer et al., 1997, 2002) during Oligocene and Miocene times.

The southern boundary of the Eastern Alps is represented by the Periadriatic fault system (Fig. 1). This is the most prominent fault zone in the European Alps, separating the Soutalpine form the Austroalpine units (Fig. 1). While the Periadriatic fault system to the south of the Tauern Window generally strikes E–W, it forms a complex system of SW–NE striking strike slip-, normal- and reverse faults to the SW of the Tauern Window (Fig. 1) (e.g. Schmid et al., 1989; Viola et al., 2001).

Between the Tauern Window and the Periadriatic fault system, a series of major fault zones form an anatomising network of faults with different senses of displacement. Northwest striking faults with dextral displacement include the Möll valley fault and the Polinik fault to the southeast of the Tauern Window (Fig. 2a). Northeast striking faults with sinistral displacement include the Defereggen–Antholz–Vals fault system and the Zwischenbergen–Wöllatratten fault and its eastern continuation, the Moser fault (Fig. 2a). The Defereggen–Antholz–Vals fault represents a ~80 km long northeast striking fault with sinistral displacement during the Oligocene (Mancktelow et al., 2001; Müller et al., 2000). It consists of mylonites that are, particularly in the eastern part, accompanied and overprinted by semi-brittle and cataclastic shearing (Schulz, 1989). The Zwischenbergen–Wöllatratten fault acts as a synthetic riedel to the Defereggen–Antholz–Vals fault system (Linner et al., 2008). The Möll valley fault forms a subvertical topographic and structural lineament with a total length of ~100 km (Fig. 1) that was mainly active in the Early to Middle Miocene (Wölfler et al., 2008). The Polinik fault is characterized by both ductile strike slip and brittle dip slip displacement (Hoke, 1990) (Fig. 2a).

Selverstone (2005) argued that the exhumation of the Tauern window along its western bound — the Brenner normal fault — is mechanically implausible, unless the Brenner normal fault is directly connected with the west–east striking strike slip zones to the north and south of the window (Fig. 1) — the Inntal fault in the north and the Periadriatic fault system in the south. This suggestion was confirmed by Robl et al. (2008) using numerical modeling. Within this interpretation, the Brenner detachment itself may not necessarily indicate horizontal extension and may simply relate to the compressive tectonically forced extrusion regime. A similar situation exists along the eastern margin of the Tauern Window: The north–south striking Katschberg normal fault is geometrically linked with the Möll valley fault in the south and possibly with the Mur–Mürz fault system in the north (Wölfler et al., 2011) (Fig. 1). This geometric association nourishes the suspicion that the extensional detachment