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Thermal evolution of an extensional detachment as constrained by organic metamorphic data and thermal modeling: Graz Paleozoic Nappe Complex (Eastern Alps)

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Abstract

Following Early Cretaceous nappe stacking, the Eastern Alps were affected by late-orogenic extension during the Late Cretaceous. In the eastern segment of this range, a Late Cretaceous detachment separates a very low- to low-grade metamorphic cover (Graz Paleozoic Nappe Complex, GPNC) above a low- to high-grade metamorphic basement. Synchronously, the Kainach Gosau Basin (KGB) collapsed and subsided on top of the section.

Metamorphism of organic material within this section has been investigated using vitrinite reflectance data and Raman spectra of extracted carbonaceous material. In the southern part of the GPNC, vitrinite reflectance indicates a decrease in organic maturity towards the stratigraphic youngest unit. The remaining part of the GPNC is characterized by an aureole of elevated vitrinite reflectance values and Raman R2 ratios that parallels the margins of the GPNC. Vitrinite reflectance in the KGB shows a steep coalification gradient and increases significantly towards the western basin margin. The observed stratigraphic trend in the southern GPNC is a result of deep Paleozoic to Early Cretaceous burial. This maturity pattern was overprinted along the margins by advective heat and convective fluids during Late Cretaceous to Paleogene exhumation of basement rocks.

During shearing, the fault zone was heated up to ca. 500 °C. This overprint is explained by a two-dimensional thermal model with a ramp-flat fault geometry and a slip rate of 1 to 1.5 cm/year during 5 Ma fault movement. The collapse basin above the detachment subsided in a thermal regime which was characterized by relaxing isotherms.

Keywords: Eastern Alps; Graz Paleozoic Nappe Complex; Thermal maturity; Exhumation; Thermal modeling

1. Introduction

The orogenic evolution of the Eastern Alps was driven by two collisional events that occurred during Cretaceous and Paleogene times (Genser et al., 1996; Neubauer et al., 2000). Both events were followed by orogen-parallel extension which resulted in the exhumation of deeper crustal rocks to higher crustal levels (Ratschbacher et al., 1989; Neubauer et al., 1995; Froitzheim et al., 1994, 1997; Fügenschuh et al., 1997, 2000; Kurz and Fritz, 2003; Sölva et al., 2005). At the eastern margin of the Eastern Alps, the kinematics of

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Cretaceous exhumation along low-angle normal faults and strike-slip faults are well-studied (Krohe, 1987; Ratschbacher et al., 1991; Krenn, 2001; Kurz et al., 2002; Kurz and Fritz, 2003; Fig. 1). In this area, thermochronologic (Neubauer et al., 1995; Hejl, 1997) and thermobarometric (Tencer and Stüwe, 2003) data constrain the cooling path of the exhumed basement. However, the thermal evolution of the hangingwall rocks remains ill-constraint as no detailed data about the Cretaceous heat flow history exist. In this paper, metamorphic data along an extensional detachment are presented which constrain a numerical model of Late Cretaceous normal faulting in the Eastern Alps.

Organic metamorphic parameters can be used to construct detailed and meaningful metamorphic maps in regions where very low- to low-grade metamorphic rocks are exposed (e.g. Petschick, 1989; Uysal et al., 2000; Ferreiro Mählmann, 2001; Rantitsch, 2001; Rantitsch and Rainer, 2003; Beyssac et al., 2004; Rantitsch et al., 2004). Moreover, the sensitive and irreversible response of organic matter to subtle temperature variations (Taylor et al., 1998) and the well-known kinetics of organic maturation (e.g. Sweeney and Burnham, 1990) allow the calibration of thermal models which give a closer insight to thermal processes in higher crustal levels (e.g. Littke et al., 1994; Ferreiro Mählmann, 2001; Rantitsch, 2001; Rantitsch and Rainer, 2003). In this contribution, we describe the pattern of organic metamorphism by vitrinite reflectance data and Raman spectroscopy of carbonaceous material. Raman spectroscopy in particular can provide reliable estimates of peak metamorphic temperatures (Beyssac et al., 2004; Rantitsch et al., 2004). Numerous studies (e.g. Grasemann and Mancktelow, 1993; Ketcham, 1996; Bertotti and ter Voorde, 1994; Dunkl et al., 1998; Bertotti et al., 1999; Zeffren et al., 2005) demonstrated the usefulness of numerical models to calculate the depth–temperature–time paths in extensional settings. Therefore, we apply 1D and 2D thermal models to explain the pattern of metamorphism by the thermal regime before and during the collapse of the overthickened crust.

Previous work (Koons, 1987; Dunkl and Demény, 1997; Mancktelow and Grasemann, 1997; Dunkl et al.,

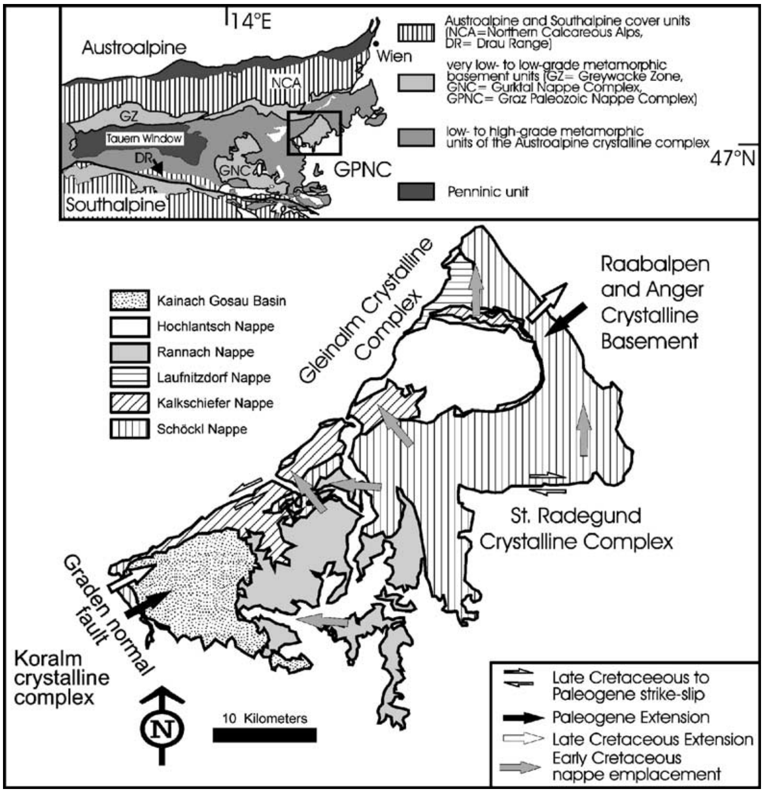

Fig. 1. Location and tectonic structure of the study area (Graz Paleozoic Nappe Complex GPNC) within the Eastern Alps. Arrows indicate the direction of Early Cretaceous nappe emplacement (compiled from Fritz, 1991; Neubauer et al., 1992) and subsequent extension (Ratschbacher et al., 1991; Krenn, 2001).