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Climate and tectonic controls on Pleistocene sequence development and river evolution in the Southern Vienna Basin (Austria)

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ABSTRACT

The impact of climate and tectonism on sedimentation and lithofacies development is demonstrated for Austria's largest Pleistocene sedimentary basin situated within the Vienna Basin. The coarse grained, massive facies is associated with high-energetic flood events reflecting a distinct seasonality effect of discharge during glacial times. In contrast, fine grained, well stratified sediments mark periods of rather high discharge to sediment supply ratios during warmer periods. Preservation of depositional sequences was facilitated by subsidence rates of approx. 0.5–1 mm/a. High subsidence rates in the basin preserve a relatively large record of sequences compared to fluvial terraces which reflect mainly sediments deposited during and shortly after glacials. ^{14}C and relative ages demonstrate the strong impact of oscillations in climate on fluvial stratigraphy covering times from the upper period of MIS 3 to MIS 1.

Abundant sediment supply and the associated increase in accumulation space as well as tectonic factors affect not only the sequence development but also the geomorphology of two mountain front alluvial fans which toe out into the Mitterndorf Basin. High discharge to sediment supply ratios leads to fan incision and to abandonment of fan surfaces. During phases of reduced sediment supply the effect of subsidence results in headcut erosion, and, if sufficient time is available, may lead to complete through trenching. Abandoned fan surfaces are exposed to widespread soil formation which mark sequence boundaries to the following coarse grained, massive facies reflecting high sediment supply to discharge ratios.

1. Introduction

The main factors controlling erosion and deposition of alluvial–fluvial sediments are changes in precipitation behaviour, the vertical shift of vegetation zones and related influence on weathering (e.g. Bull, 1996; Leeder et al., 1998). Long term preservation of alluvial depositional sequences is generally associated with tectonic forcing (Blum and Törnqvist, 2000; Starkel, 2003) preventing possible incision and sediment removal either through uplift or subsidence. Relation between climate and terrace formation has long been recognized (e.g. Penck and Brückner, 1909). Climatically controlled terrace sediments are well developed in uplifted mountainous areas of central Europe (e.g. Penck and Brückner, 1909; Fink, 1966; Amorosi et al., 1996; Krzyszkowski and Stachura, 1998; Mol et al., 2000; Starkel, 2003). Terraces have a typically rather coarse-grained nature representing high energy (braided) conditions related to glacials (e.g. Van Husen, 2000; Vandenberghe, 2002). Lithofacies of interglacial or interstadial periods are generally known to be finer-grained and less massive, representing higher discharge to sediment supply ratios, i.e. dominantly overbank fines. River patterns tend to be meandering during these periods. Deposits of warm periods are generally minor in thickness and are more prone to erosion. The switch to braided conditions during glacials and associated lateral stream erosion may cause removal of most traces of previous (meandering) systems (Vandenberghe, 2008) if uplift rates are not sufficient to prevent fluvial erosion. As a consequence, most terraces lack significant fluvial deposits of warm periods.

One possibility to preserve these strata from mechanical and chemical erosion is prolonged subsidence of the depositional area. As subsidence rates directly control the chance of sequence preservation (Blum and Törnqvist, 2000), relatively high subsidence rates accomplished in central European Quaternary basins (e.g. Rheingraben, Pannonian Basin, Mitterndorf Basin, Zohor Basin) may preserve a more complete record of sequences compared to alpine fluvial terraces which are more prone to erosion. Subsidence rates which exceed 1 mm/a, determined by precise levelling (Joó,

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1992; Decker et al., 2005; Demoulin et al., 2005; Ruszkiczay-Rüdiger et al., 2005) are not uncommon for these basins.

This study presents a climate and subsidence controlled depositional model for fluvial lithofacies in an actively subsiding Quaternary pull-apart basin of Eastern Austria (Fig. 1). Sequence stratigraphic concepts are applied in this purely fluvial setting (e.g. Aitken and Flint, 1995; Amorosi et al., 1996; Blum and Price, 1998; Weissmann et al., 2002). The significant impact of Quaternary glacial–interglacial cycles on alluvial sequence development in a basin-scale has been described by Shanley and McCabe (1994) and Weissmann et al. (2005). In the model, sediment supply and stream discharge control the characteristics of lithofacies and sedimentary structures in the short term. Subsidence is considered to act as a long term effect. The presented model is mainly based on new ^{14}C ages and biotic climate signals (pollen and terrestrial snails) covering MIS 3–1 (Middle Pleniglacial to Holocene). Thus, fluvial facies are shown to be deposited in stratigraphic cycles controlled by the impacts of glacials and interglacials.

2. Regional setting and study area

Several Quaternary sub-basins formed during the youngest kinematic history of the Miocene Vienna Basin (Fig. 1). These sub-basins are linked to releasing bends along the active sinistral strike-slip Vienna Basin Transfer fault (Mitterndorf Basin, Lassee Basin, e.g. Hinsch et al., 2005; Fig. 2) and to normal faults, which splay off from this fault system which extends into the Western Carpathians. Active faulting is indicated by earthquake data (Reinecker and Lenhardt, 1999), geodetic data (Höggerl, 1980; Grenerczy et al., 2000, 2006) and growth faults. The largest of these Quaternary sub-basins is the Mitterndorf Basin (Fig. 2) covering an area of approximately 270 km^2. The Mitterndorf Basin is a narrow, elongated strike-slip

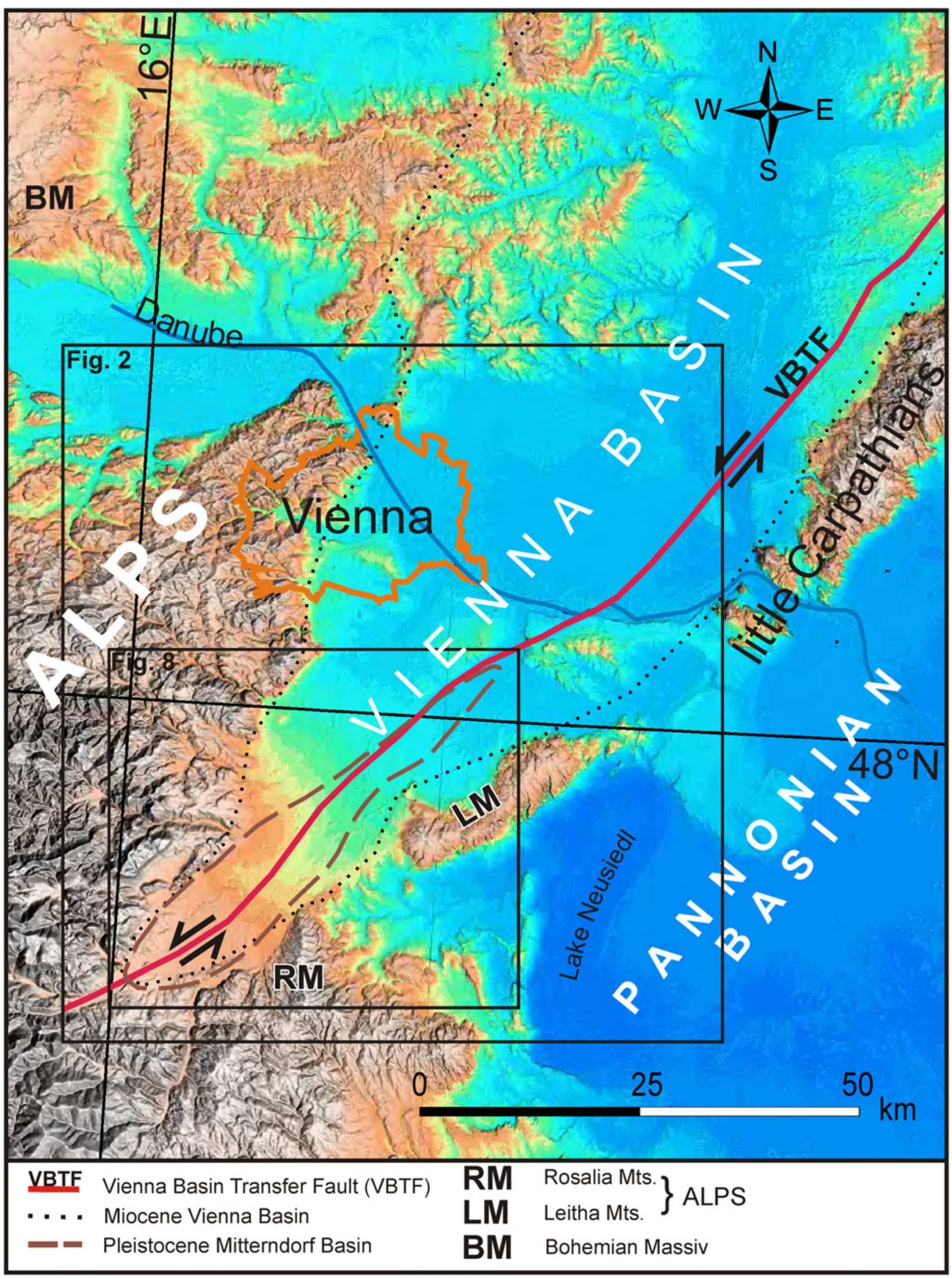

Fig. 1. Topographic map of the Vienna Basin and its surroundings.