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Late Quaternary tectonic switching of siliciclastic provenance in the strike-slip-dominated foreland of the Western Carpathians; Upper Morava Basin, Bohemian Massif

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A B S T R A C T

This study is focused on the lithology and provenance of late Quaternary fluvial deposits of the Upper Morava Basin a pull-apart basin situated at the contact of the Bohemian Massif and Western Carpathians. Late Cenozoic tectonic convergence between these two units caused differential subsidence along strike-slip faults of the Elbe-Odra zone, leading to a distinct horst-and-graben morphology of the Upper Morava Basin. The Pleistocene fluvial deposits are preserved in several terrace levels and partly buried under the present-day floodplain of the Morava River. This study is based on four cores (11–25 m deep) drilled in the floodplain of two major depocentres of the basin, the Lutín Graben, and the Upper Morava Basin *sensu stricto*. The drill cores were analysed for grain size, pebble- and heavy-mineral composition, chemical composition of detrital garnets, bulk magnetic susceptibility, sediment colour (visible-light spectral reflectance) and bulk element geochemistry. Age interpretations are based on eight optically stimulated luminescence (OSL) analyses. The Upper Pleistocene sediments were deposited in a gravelly braided to transitional braided-meandering river in both the Upper Morava Basin *s.s.* and the Lutín Graben (the oldest OSL age is 161.5 ka, corresponding to the late Saalian). Between the end of the Saalian and late Weichselian glaciations, the Morava River abandoned the Lutín Graben for the Upper Morava Basin *s.s.* where it flows up to the present day. The Pleistocene fluvial style contrasts with the present-day meandering to anastomosing fluvial style of the Morava River. The Pleistocene deposits were sourced from areas corresponding to the present-day Morava River catchment including crystalline units of the eastern Bohemian Massif and the Moravo-Silesian Carboniferous Basin. They also contain a considerable input from the Bohemian Cretaceous Basin. The composition of late Weichselian deposits from the Dub nad Moravou core (34.53 ± 3.42 ka and younger) differs from the older fluvial deposits representing the other cores. It indicates that a major provenance change occurred between the latest Saalian and the late Weichselian. In the late Weichselian, the Morava River started to recycle loess deposits, which cover large areas of its catchment. Based on OSL dating, it may be assumed that the Morava River turned from degrading (between 92.6 ± 8.03 and 34.53 ± 3.42 ka) to aggrading in style (from 34.53 ± 3.42 ka to the present day) due to coeval tectonic movements in the UMB, which are indirectly indicated by present-day seismicity, geomorphic faults and palaeoseismic evidence. Both the tectonic context and fluvial deposition styles of the Upper Morava Basin show similar features to the Upper Rhine Graben of the Alpine foreland.

1. Introduction

Cenozoic plate convergence between Africa and the northern European Platform resulted in a strong tectonic response in the foreland of the Pyrenees, Alps and Carpathians, with many associated geomorphic and geological phenomena. The most prominent feature is the European Cenozoic Rift System (ECRIS), which covers a wide area from the coast of the North Sea to the Mediterranean Sea in a N–S direction, and from France to the Czech Republic in a W–E direction (Ziegler, 1992). The evolution of ECRIS was associated with asthenospheric upwelling (Špičák et al., 1999; Wilson and Bianchini, 1999) that caused crustal processes such as intraplate volcanism, faulting and seismic activity, the formation of sedimentary grabens with accelerated Cenozoic subsidence and the accumulation of continental sediments (Dezes et al., 2004; Špaček et al., 2015). One of the most prominent sedimentary basin of ECRIS is the Upper Rhine Graben (Boenigk and Frechen, 2006; Erkens et al., 2009; Gabriel et al., 2013). It is filled with the Quaternary fluvial terraces on the slopes of the graben and their counterparts buried in the main basin depocentres such as the Heidelberg Basin (Lauer et al., 2010; Gabriel et al., 2013). The well-preserved terrace sequences in the Rhine catchment are mainly

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controlled by allogenic processes such as tectonic activity and climatic variations (Peters et al., 2005; Peters and van Balen, 2007; Erkens et al., 2009). The Upper Rhine Graben hosts mutually overlapping bodies of sediments derived from different source areas. For example, sediments derived from local sources are identified by the dominance of associations of stable heavy minerals; whereas distal sources derived from the Alps are characterised by unstable heavy minerals and an abundance of carbonate clasts (Lauer et al., 2010; Gabriel et al., 2013). In contrast to the Alpine/Pyrenean foreland, much less is known about the foreland of the Western Carpathians (*cf.*, Jarosiński et al., 2010; Widera and Hałuszczak, 2011; Špaček et al., 2015). Here, the Nysa-Morava Zone located at the eastern margin of the Bohemian Massif is the most important tectonic domain in the Czech Republic. The Nysa-Morava Zone shares common features with the Upper Rhine Graben, including present-day seismicity, late Cenozoic fault deformation, prominent faults, Pliocene-Quaternary sedimentation in small-scale grabens and coeval volcanism (Danišík et al., 2012; Havíř et al., 2012; Špaček et al., 2015). This zone is developed at the intersection of the upper Elbe Fault System with the uplifted foreland of the Western Carpathians (Scheck et al., 2002; Špaček et al., 2006). The Nysa-Morava Zone is interpreted as a transfer zone developed between two major non-coalescing, WNW–ESE-trending faults of the Elbe Fault Zone in a right lateral transpressional setting (Špaček et al., 2015). The Nysa-Morava Zone evolved into a system horsts and grabens, which are generally controlled by NW–SE-trending strike-slip faults. The largest graben-like basin of the Nysa-Morava Zone is the Upper Morava Basin, which is filled by uppermost Miocene to Holocene fluvial and lacustrine sediments with a maximum thickness of ~300 m (Růžička, 1989; Brzobohatý and Cicha, 1993; Zapletal, 2005). The Quaternary sediments of the Upper Morava Basin are mainly fluvial, partly preserved in a system of terraces on the slopes of the present-day basin valley and partly buried beneath the present-day floodplain of the Morava River, the major water course draining the study area. These complex patterns of sediment preservation suggest an important role of differential subsidence/uplift, which controlled river aggradation and degradation. These patterns are very similar to those of the Upper Rhine Graben, but they developed on a much smaller scale and are primarily driven by strike-slip tectonics (Fig. 1).

The stratigraphy of the terrace levels is based partly on their morphology (relative height above the valley floor) and superposition, and partly on the sediment provenance (pebble composition and heavy-mineral spectra) (Růžička, 1973). However, the age of the terrace levels is uncertain, being largely inferred from rare fossil finds, buried soil complexes and correlation with glacial deposits at the northern margin of the Bohemian Massif (Macoun and Růžička, 1967; Zeman, 1971). In fact, no numerical age data have so far been available for these deposits.

The present-day Morava River has many tributaries, which drain numerous units of the geologically diversified eastern margin of the Bohemian Massif. These units comprise, among others, Variscan high- and medium-grade metamorphic rocks and metaophiolite complexes (Lugicum and Silesicum), Proterozoic to lower Palaeozoic low-grade metamorphosed volcano-sedimentary complexes (Zábřeh Crystalline Unit), Palaeozoic deep-marine siliciclastics (Moravo-Silesian Culm Basin), marine sediments of the Bohemian Cretaceous Basin and the Carpathian Foredeep, and the Quaternary loessic sequences (*cf.*, Macoun and Růžička, 1967; Zapletal, 1985, 2005; Brzobohatý and Cicha, 1993; Nehyba and Šikula, 2007; Klomínský et al., 2010). This complex bedrock geology contributes to the varied provenance patterns of Quaternary fluvial infill of the Upper Morava Basin. Siliciclastic provenance therefore offers a useful tool for regional stratigraphic correlation and interpretation of sedimentary dynamics of the basin (*cf.*, Van Balen et al., 2000; Nádor et al., 2007; Gabriel et al., 2013).

The aim of this paper is to give an insight into the late Quaternary degradation and aggradation history of fluvial sediments filling the Upper Morava Basin. The study is based on stratigraphic analysis of terrace levels, which is inferred from high-resolution quantitative petrophysical and geochemical data from four drill cores and several outcrops, supported by detailed mineralogical and geochemical provenance analysis as well as several new optically stimulated luminescence (OSL) dates.

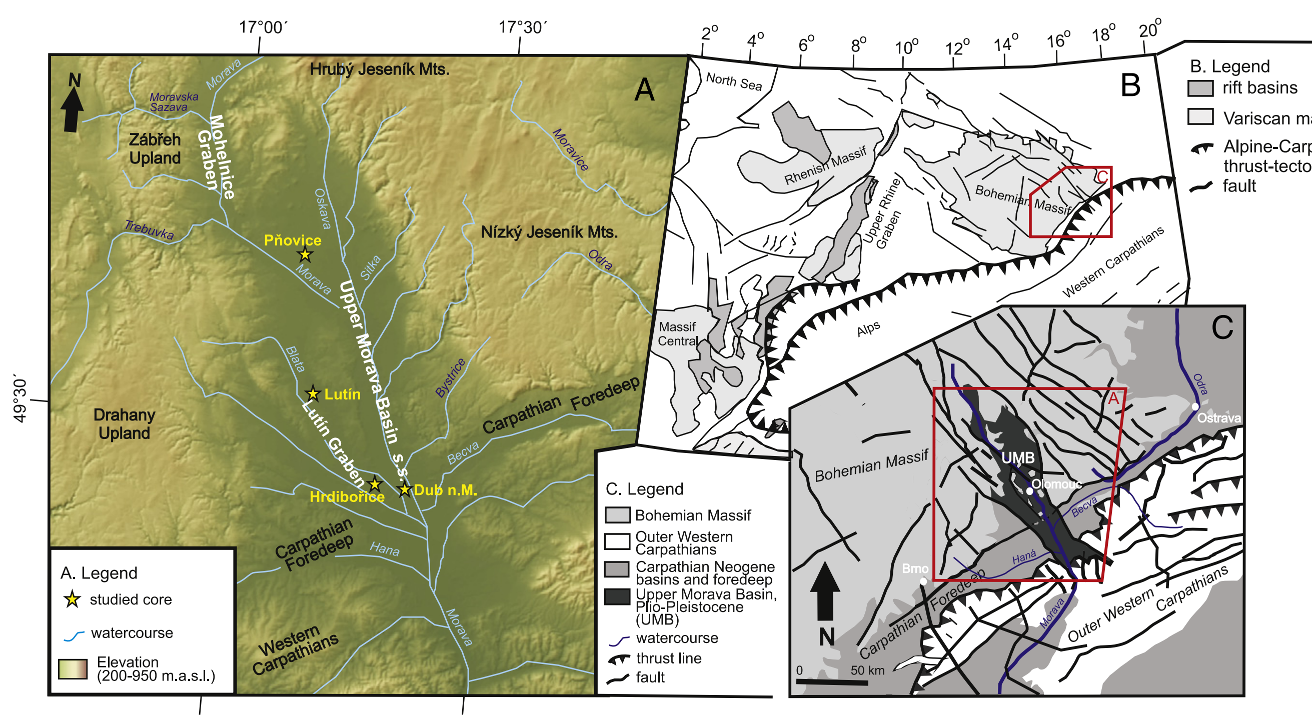

Fig. 1. Simplified maps showing the main Cenozoic tectonic features in the Central Europe and the Alpine-Carpathian foreland, with the position of the Upper Morava Basin at the contact of the Bohemian Massif and Outer Western Carpathians.
(Redrawn from Špaček et al., 2015.)