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Paleoenvironmental conditions and sedimentation dynamics in Central Europe inferred from geochemical data of the loess-paleosol sequence at Süttő (Hungary)

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ABSTRACT

This study provides a detailed geochemical record of one of the best studied loess-paleosol sequences (LPS) in Hungary covering Marine Isotope Stage (MIS) 6 to MIS 2. Süttő is situated in the northwestern Carpathian Basin at the transition between oceanic and continental climate. We investigated weathering intensity, dust provenance and sedimentation dynamics by high-resolution X-ray fluorescence (XRF) scanning of discrete samples in comparison with quantitative XRF and other published proxy data such as grain-size, magnetic susceptibility and micromorphology. Multivariate statistics unravel pedogenesis in terms of decalcification and grain-size dynamics as processes controlling the elemental composition. Furthermore, high-resolution chemostratigraphy indicates geochemical homogeneity for mature MIS 5 paleosols and the modern soil. Together with the A-CN-K plot providing no hint for K-feldspar weathering, semi-arid continental paleoenvironmental conditions are considered as prevailing. Dust provenance is studied by geochemical reference literature data from potential ultimate dust source areas, Th/metal ratios and comparison with the composition of the upper continental crust (UCC). Results indicate a felsic rock composition and a stable dust source, albeit immediate (adjacent Danube floodplains) and ultimate dust sources (surrounding mountain belts) need to be distinguished. According to the Sr-K-Rb plot, the Austroalpine cover nappes area northwest of Süttő might be the dominant ultimate dust source. The weathering-resistant elements Al, Ti and Zr as well as Zr/metal ratios indicate Zr addition and thus strongest sediment sorting and/or recycling during MIS 6. Since Al, Ti and Zr show minimal correlations with grain-size, we suggest a cascade-alike transport pathway from ultimate source to sink involving multiple sediment recycling and sorting cycles in both fluvial and eolian domains. Therefore, this study highlights how high-resolution qualitative geochemical data contributes to a better understanding of paleoenvironmental and sedimentation dynamics at LPS. Application of such a versatile geochemical screening tool is of broad interest to the scientific community working on (terrestrial) paleoenvironmental archives that are commonly discretely sampled.

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1. Introduction

Loess, a silt-sized, calcic material, often associated with periglacial environments during cold climatic periods, covers more than 10% of the Earth's surface (Pécsi, 1990). Loess-paleosol sequences (LPS) are important terrestrial paleoenvironmental

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archives characterized by an alternation between the predominance of dust deposition or paleosol formation. Chemical weathering, dust source and dust availability changes as well as grain-size and sedimentation dynamics leave behind specific signals in the elemental composition (Chen et al., 2006, 2013; Buggle et al., 2008, 2011; Újvári et al., 2008, 2014; Ahmad and Chandra, 2013; Liang et al., 2013; Profe et al., 2016). Consequently, geochemistry is able to track sedimentological variations of LPS associated with changing paleoenvironmental conditions (e.g. Buggle et al., 2008, 2011; Újvári et al., 2008; Profe et al., 2016).

The unique geological setting of the Carpathian Basin resulted in the development of numerous LPS that cover several glacial-/interglacial cycles (Horváth and Bradák, 2014; Marković et al., 2016). The Süttő LPS (Fig. 1) is located in the northwestern Carpathian Basin at the western foothills of the Geresce Mountains (Novothny et al., 2011). It is regarded as a key site due to its location at the transition between western European LPS (dominated by oceanic climate), central European LPS (dominated by continental climate), and south-eastern European LPS (dominated by Mediterranean climate). Sprafke et al. (2014), Hošek et al. (2015) and Terhorst et al. (2015) describe transitions from North Atlantic-dominated to continental climate for Austrian and Czech LPS whereas Obreht et al. (2017) highlight the confluence of all three climatic modes in south-eastern Europe, especially during Marine Isotope Stage (MIS) 3 (Lisiecki and Raymo, 2005). Süttő covers the time period from MIS 6 to MIS 2 (Novothny et al., 2010, 2011) and represents one of the best studied LPS in Hungary (Horváth and Bradák, 2014).

Previous studies comprise grain-size (Novothny et al., 2011), magnetic susceptibility, paleomagnetic properties (Novothny et al., 2011; Rolf et al., 2014), secondary carbonate morphology (Barta, 2014), stable carbon and oxygen isotope analyses (Koeniger et al., 2014), and malaco-thermometry (July temperature reconstructions) for MIS 3 and MIS 2 (Novothny et al., 2011). Luminescence ages (Novothny et al., 2010, 2011), together with amino-acid racemization (Novothny et al., 2009) and relative paleo-intensity of magnetic remanence (Rolf et al., 2014) provide robust time control. In contrast to many other LPS, especially to those from Western Europe, the deposited loess material is very coarse. There is a trend towards decreasing grain-size from MIS 6 to MIS 2 with a considerable sand content in the well-developed paleosols attributed to MIS 5e and MIS 5c. Novothny et al. (2011) attribute the high sand content to the vicinity of the sediment source, the floodplain of the Danube and its tributaries. However, despite showing the lowest sand content along the LPS, MIS 2 loess reveals highest sedimentation rates for the considered time period MIS 6 to MIS 2. Such grain-size variations together with changes in $CaCO_3$ tentatively point to alterations in either paleo-wind intensity and direction or varying contribution of the Bikol Creek as local dust source (Novothny et al., 2011; Barta, 2014). According to preliminary micromorphological results, the last interglacial period was characterized by an aridization trend with the development of a wetter MIS 5e and steppe-like vegetation at the time of MIS 5c (Novothny et al., 2010, 2011). Lacking secondary carbonates indicate climatic conditions favorable for strong leaching during MIS 5a while hypocoatings, which may represent evaporation-based $CaCO_3$ impregnations and thus semi-arid steppe conditions, characterize MIS 3 (Novothny et al., 2011; Barta, 2014). Mollusc fauna supports this interpretation with July temperatures (20.9 °C, Novothny et al., 2011) comparable to those of today (21.6 °C, Szalai et al., 2005).

Although Süttő is among the best studied LPS in Hungary (Horváth and Bradák, 2014), a detailed geochemical record is still missing for a better understanding of paleoenvironmental conditions and sedimentation dynamics (cf. Újvári et al., 2008, 2014). Hence, we acquired qualitative element data time- and cost-efficiently via XRF scanning of discrete samples (Ohlendorf, 2018; Profe et al., 2018). For the first time, a multivariate statistical approach (e.g. Martin-Puertas et al., 2017) was applied to geochemical data of a Hungarian LPS aiming at establishing a high-resolution chemostratigraphy (e.g. Raczyk et al., 2015; Sial et al., 2015). Furthermore, we investigated and evaluated the suitability

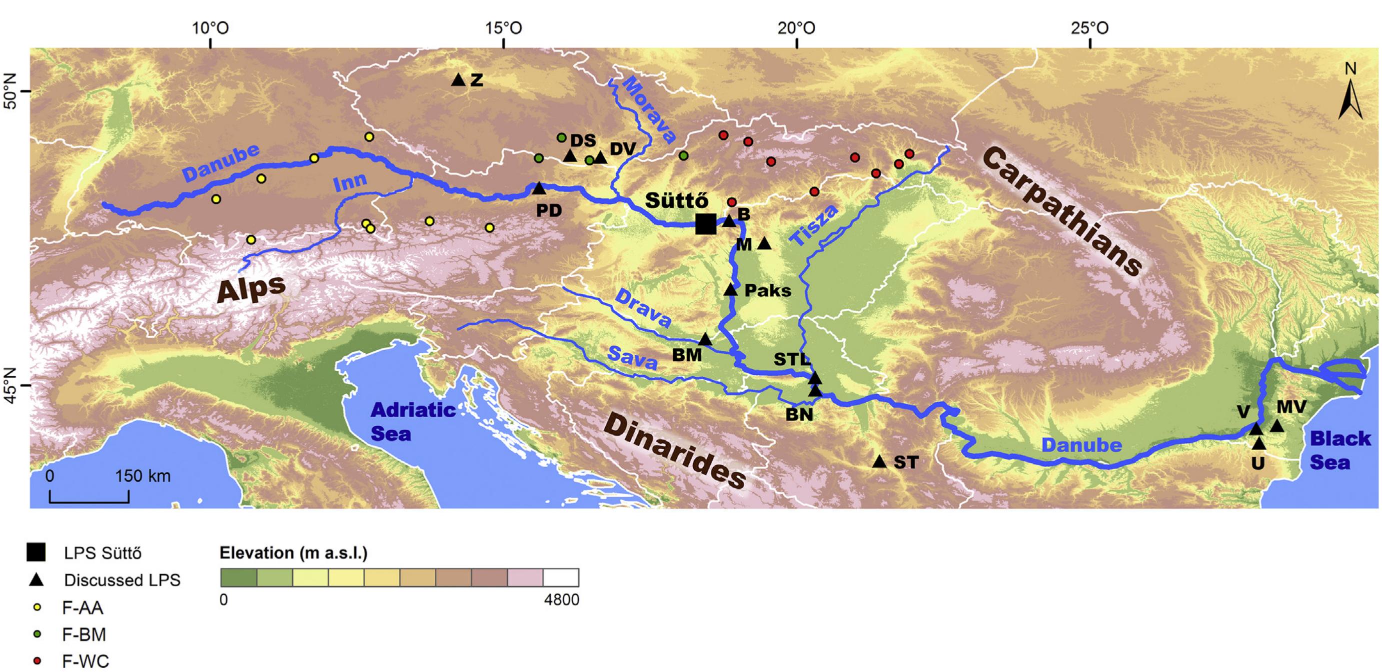

Fig. 1. Map of Central Europe showing the discussed loess-paleosol sequences (LPS), the Danube and its major tributaries. In addition, dust provenance at the Süttő LPS is inferred from floodplain sediments (F-AA: Austroalpine cover nappes area, F-BM: Bohemian Massif, F-WC: Western Carpathians). Discussed LPS: B: Basaharc, BM: Beremend, Majs, Nagynyárád, Töttös, BN: Batajnica, DS: Dobšice, DV: Dolní Věstonice, M: Mende, MV: Mircea Voda, PD: Paudorf, ST: Stalać, STL: Stari Slankamen, U: Urluia, V: Vlasca, Z: Zeměchy. GCS ERTS 1989. Data base: Shuttle Radar Topographic Mission (USGS, 2003), administrative boundaries (GADM, 2015), rivers (WISE, 2012).

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