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# Tracing the origin of loess in Hungary with the help of heavy mineral composition data

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A B S T R A C T

Heavy mineral composition of the fine sand fraction in the Hungarian loess sediments provides important data about the closer sources of the loess in the Carpathian Basin. Quantitative detrital heavy mineral compositions of 216 loess, loess-like sediment, and paleosol samples were compared to each other, and to recent fluvial sands and different Cenozoic sands and sandstones of Hungary using statistical methods: cluster analysis, principal component analysis and discriminant analysis.

Usually, garnet is the most frequent detrital heavy mineral in the studied loess sections, followed by chlorite, magnetite, epidote, and amphiboles. Old Loess and Young Loess have similar compositions, indicating uniform or similar sources. Based on the similarities, the garnet-rich loess sediments could originate from aeolian reworking of the floodplain sediments of the Danube and other rivers of Transdanubia, and the local Cenozoic sands of the uplifting Transdanubian Central Range and Transdanubian Hilly Region. The biotite- and tourmaline-rich loess in South Transdanubia, and the loess with high pyroxene content in the North Hungarian Range, had some material from nearby sources: weathered granitoids and volcanic rocks, respectively, or sediments of local rivers, which carried detritus of these rocks. The new results presented in this paper confirm numerous earlier ideas about the origin of loess in the Carpathian Basin, but also suggest newly identified sources of the loess particles at several locations.



## 1. Introduction

Origin or source of the material of loess sediments is an important question and has been among the main scopes of the loess studies for a long time. The mineralogy of the loess gives very important information about its source rocks. Hungary has a significant loess region in the Carpathian Basin, and the mineralogy of the loess and loess-like sediments here has been studied by different methods, mainly by X-ray diffraction (XRD) and thermoanalysis, more rarely by optical microscopy, scanning or transmission electron microscopy, and measurements of magnetic properties (e.g. Pécsi-Donáth, 1979, 1985; Gerei et al., 1985; Hum and Fényes, 1995; Sartori et al. 1999; Nemecz et al., 2000; Földvári and Kovács-Páffy, 2002; Hum, 2002; Marsi et al., 2004; Varga et al., 2011). Traditional heavy mineral analysis in Hungary started in the early 20th century. From the 1960s, micromineralogy, or heavy mineral analysis, was also applied on the fine sand fraction of the Hungarian loess sediments. Until 1984, about 20,000 Cenozoic sedimentary rocks (sands, sandstones, and sand fractions of gravel, silt, clay, bauxite, loess sediments, and volcanic tuffs were studied by heavy mineral analysis, reflecting an intensive use of the technique (Sallay, 1984). Results of heavy mineral analysis helped to determine provenances or source rocks, reconstruct depositional conditions, palaeoclimate and diagenesic processes, recognise reworking of older sedimentary rocks, identify volcanic ash falls, subdivide thick clastic successions by their distinctive heavy mineral associations, and delineate heavy mineral provinces (e.g. Molnár, 1964, 1965, 1970; Gedeonné Rajetzky, 1973, 1976).

Systematic heavy mineral analysis is a useful technic in the reconstruction of fluvial history and correlation of fluvial sediments and fluvial terraces. In the case of the European Quaternary sediments it is very well established for the Rhine and Rhine-Meuse river systems (e.g. Kemna, 2005; Boenigk and Frechen, 2006; Hagedorn and Boenigk, 2008). On the Hungarian Plain, based on the heavy mineral data of 590 sand and sandy silt samples from ten

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cored boreholes, penetrated into 40–700 m thick Quaternary fluvial successions complemented by data from modern river sediments, the Quaternary fluvial network and sediment provenance were reconstructed (Thamó-Bozsó and Kovács, 2007). Heavy mineral composition data of more than 120 sands in the Körös sub-basin of Hungary also helped to determine the changes in palaeotransport directions of Quaternary fluvial sediments due to tectonic activity (Thamó-Bozsó et al., 2002, 2007a,b; Nádor et al., 2007, 2011). Based on the systematic heavy mineral analysis of some loess sections in Hungary, the source areas and the alternations of climate or weathering conditions were reconstracted at Paks, Kulcs, Dunaújváros, Dunakömlőd, Üveghuta, and Cérnavölgy (Szebényi, 1954, 1979; Rónai et al., 1965; Molnár, 1971; Codarcea, 1979; Gerei et al., 1979, 1985; Marsi et al., 2004; Bradák et al., 2011).

The aim of this study is to collect and evaluate the archive heavy mineral data and compare them to each other, as well as to the recent fluvial sands, and different Cenozoic sands and sandstones of Hungary. Although the studied fine sand fraction is quantitatively subordinate in the loess, it carries important information about the origin of the loess, and the new results provide additional knowledge about the loess, loess-like deposits and paleosols in the Carpathian Basin.

## 2. Study area, samples and data

The study area is situated in the large intermontane Pannonian Basin (Fig. 1), which is surrounded by the Alps, Carpathians and Dinarides, and started to form in the Early-Middle

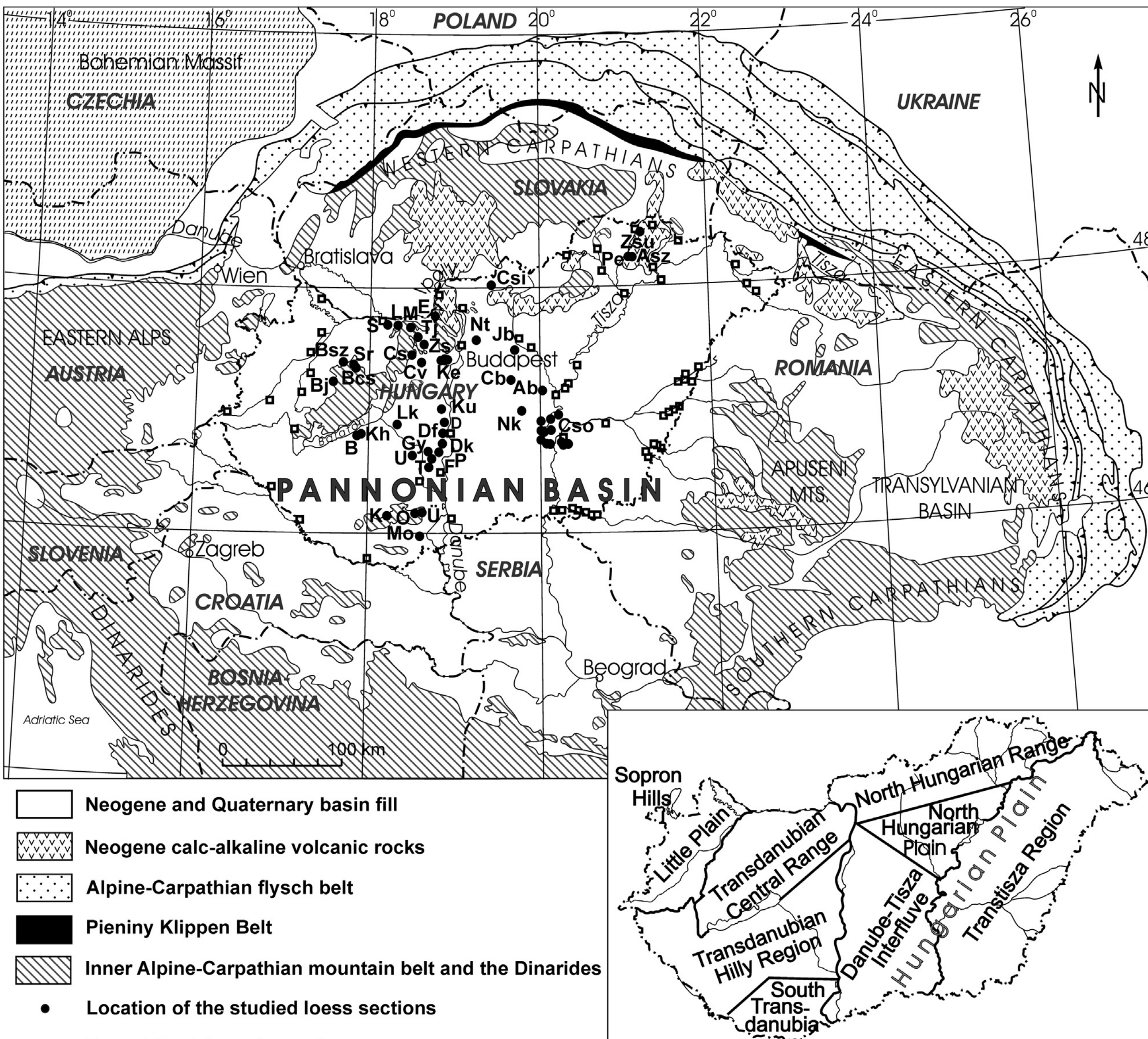


**Fig. 1.** Geological sketch map of the Carpathian–Pannonian region (after Horváth and Cloetingh, 1996) and the locations of the studied loess sections with heavy mineral data. Index map shows the main areas of Hungary. Legend: Ab: Abony (3), Asz: Abaújszántó (5), B: Balatonszárszó (1), Bcs: Bakonycsernye Bct-2 (1), Bj: Bakonyjákó Bj-23 (1), Bsz: Bakonyszentkirály Bsz-41 (1), Cb: Ceglédbercel (1), Cs: Csákvár-9, -11, -18, -32 (6), Csi: Csitár (1), Cso: Csongrád (16), Cv: Cérnavölgy Vértesacsa (15 + *4*), D: Dunaújváros H-3 (4), Df: Dunaföldvár (2), Dk: Dunakömlőd 1977/1 (6 + *9*), E: Esztergom E-30 (2), F: Földespuszta (1), Gy: Györköny (9 + *3*), Jb: Jászberény (2), K: Komló K-151 (1), Ke: Kamaraerdő (16), Kh: Körös-hegy (1 + *1*), Ku: Kulcs (20 + *8*), L: Lábatlan Lá-3, -4 (1 + *1*), Lk: Lajoskomárom Lk-1 (1), M: Mogyorósbánya M-75, -93 (2), Mo: Mohács (*4*), Nk: Nagykörös (1), Nt: Nagytarcsa Nt-6, -28 (2), Ó: Ófalu Ó-4 (6 + *6*), P: Paks (7 + *4*), Pe: Pere (1), S: Süttő (1), Sr: Súr Sr-3 (1), T: Tengelic (4 + *2*), Tj: Tarján Tj-9 (2), U: Udvari-2/a (6 + *1*), Ü: Üveghuta Üh-2,-5,-30,-37 (4 + *17*), Zs: Zsámbék Zs-5 (1), Zsu: Zsujta (1). Numbers of the loess (with loess-like sediment) samples and paleosols (in italics) are in brackets.