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On possible sources of loess deposits in the Carpathian Basin: an isotopic approach

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Origin and formation characteristics of loess deposits in the Carpathian Basin have long been debated and remain unresolved. Previous work [1, 2] identified 3 main sources of loess deposits in this region: (I) glacial materials carried through the Moravian Depression by glacial floodwaters, (II) weathering products of the Carpathian Flysch deposits, and (III) glacial materials from the Alpine region. In addition, Pannonian deposits (ca. 1.8 to 12 Ma age) could theoretically contribute materials to loess deposits in Hungary [3]. Most recently, some [4] have emphasized the significance of fluvial action in loess formation, although aeolian entrainment played an essential role as well and provides material (large dust, coarse and very coarse silt: 16-62 μm) from the Alps and Carpathians to loess deposits in the basin. Others [5] have gone further and suggest that small dust (fine and very fine silt: 2-8 μm), originating from North Africa, could provide a silty admixture to the soil/loess system in this region.

We measured Sr isotopes on several loess samples (bulk loess and grain size fractions: 63-31 μm, $<$30 μm and $<$5 μm) collected along a north-south transect of about 250 km, parallel to the River Danube. TIMS isotopic measurements were also undertaken on Pannonian (late Miocene and Pliocene) and upper Pleistocene fluvial sand samples (fractions: 63-31 and $<$30 μm), as well as, on a bulk suspended load sample of the Danube. Detrital zircon ages of 4 loess and 2 sand samples use U-Pb isotopic analyses of 100 grains from each obtained by LA-ICP-MS.

$^{87}Sr/^{86}Sr$ ratios of 7 bulk loess samples range between 0.71256 and 0.71542, and from 0.71371 to 0.71752 for the three analyzed grain size fractions with the $<$5 μm population having the most radiogenic compositions. Size fractions from one Pliocene sand sample retained less radiogenic (0.71216 and 0.71265) and another more radiogenic signatures (0.716723 and 0.719913) than loess samples of the same size fractions (63-31 and $<$30 μm). $^{87}Sr/^{86}Sr$ ratios of these two fractions of the upper Pleistocene fluvial sand sample were 0.71263 and 0.71716. Suspended load of the River Danube retains the most radiogenic signature (0.72046) among all analyzed samples. Major age populations of detrital zircons are ca. 13-30 Ma, 260-340 Ma, 420-480 Ma, 520-600 Ma, 640-700 Ma, 0.9-1.15 Ga, 1.5-1.8 Ga, and 2.0-2.15 Ga, with some older grains up to 3.4 Ga. U-Pb age groups (mostly $^{206}Pb/^{238}U$ ages) of the two sand samples are ca. 13-35 Ma, 260-360 Ma, 420-460 Ma, 580-660 Ma, 1.4-1.6 Ga, 1.8-1.9 Ga, and 2.0-2.1 Ga (oldest grains: 2.7 Ga). The three most significant age populations of both loess and sand are Paleozoic, and partly Neoproterozoic age groups (ca. 260-360 Ma, 420-480 Ma, and 520-600 Ma).

Regarding $^{87}Sr/^{86}Sr$ ratios and reproducibility, measured ratios of the $<$30 μm fractions of one loess and one fluvial sand sample of the Danube are similar, while data of other loess and sand samples differ significantly between both bulk samples and the three size fractions. Studies [6, 7] on Variscan granitoid rocks of the Western Carpathians documented $^{87}Sr/^{86}Sr$ ratios ranging from 0.70768 to 0.87094, many clustering around 0.71100-0.71500, signatures that overlap those of our loess samples. Detrital zircon age distribution patterns of loess and sand samples showed remarkable similarity characterized by the predominance of the 260-360 Ma population, ages that overlap those of zircons originating from igneous and metamorphic rocks of the Bohemian Massif and the Western Carpathians [8, 9, 10]. This latter observation suggests a source associated with Hercynian/Variscan igneous or metamorphic rocks for many of the zircons. Thus main protosources of the studied loess (and sand) deposits must have been Variscan terrains and granitoids located on the catchment of the River Danube like the Bohemian Massif or intra-Alpine and intra-Carpathian Variscids. Our results suggest that the Danube and its tributaries might have entrained mate-

rials from these terrains and accumulated on floodplains. Besides, westerly north to westerly paleowinds may be responsible for transporting dust from these floodplains and, to a smaller extent, from the aforementioned provenance terrains. Our study confirms previous speculation that the role of rivers like the Danube is critical to loess formation in the Carpathian basin.

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