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Origin of Loess in the (Middle/Lower) Danube Basin (and Dnieper Area)

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1 Text-Figure

Serbien
Rumänien
Ukraine
Donaubecken
Löss
Paläoboden

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Herkunft des Lösses im (mittleren/unteren) Donaubecken und im Dnjepr-Gebiet

Zusammenfassung

Anhand einer geochemischen Charakterisierung serbischer, rumänischer und ukrainischer Löss-Paläobodensequenzen und einer Rekonstruktion der Paläowindrichtung konnte für die Lösse im mittleren und unteren Donaubecken gezeigt werden, dass alluviales Material der Donau die wichtigste Staubquelle darstellt. Im westlichen Teil des unteren Donaubeckens deuten die Ergebnisse auf eine zusätzliche Staubquelle hin, vermutlich die glaziofluvialen Sedimente der Ukraine bzw. Weißrusslands, die sich zugleich als Hauptquelle der Lösse im Dnjeprgebiet erweisen.

Hinsichtlich seiner geochemischen Zusammensetzung können die Lösse im Donaubecken als mittlere Probe der oberen kontinentalen Kruste angesehen werden.

Abstract

Based on a geochemical characterization of loess paleosol profiles in Serbia, Romania and Ukraine and by considering the geomorphodynamic setting i.e. paleowind reconstructions, it is shown that the loess in the Danube Basin predominantly derives from Danube alluvial material. However, for the western part of the lower Danube Basin an additional dust contribution from the glaciofluvial sediments of the Fennoscandinavian ice sheet in the Ukraine and Belarus is indicated. These sediments can also be regarded as the main source of the loess in the Dnieper area.

With respect to its element composition the Danube Basin loess can be regarded as an average sample of the upper continental crust (UCC).

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1. Introduction

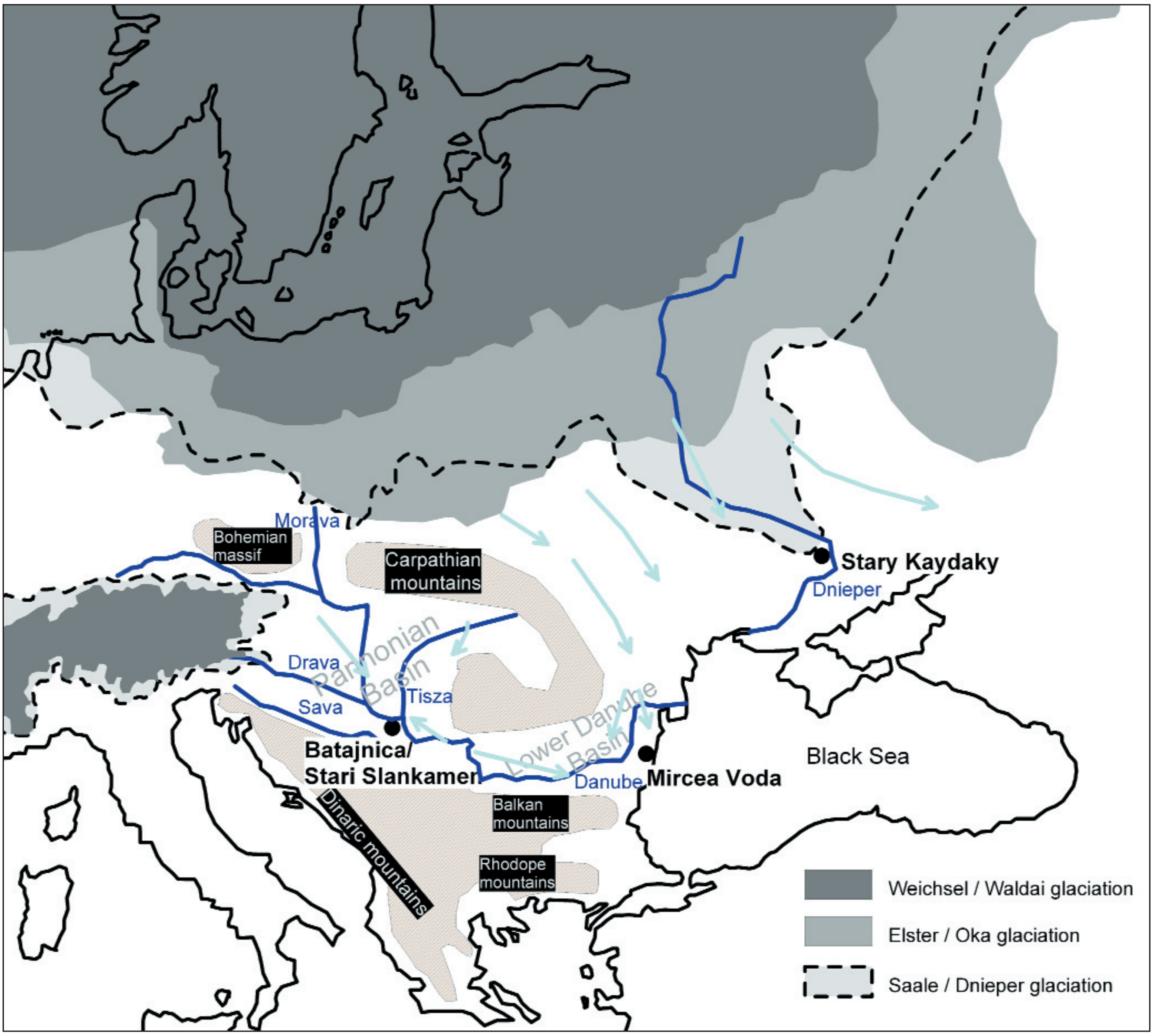
Loess paleosol sequences (LPSS) are valuable terrestrial climate/environmental archives. In Europe, extended loess plateaus can be found especially in the Southeast and East, as for example in the middle and lower Danube Basin (Hungary, Serbia, Romania, Bulgaria) and in the Dnieper area (Ukraine), respectively. However scientific knowledge about the dust provenance is scarce.

In the following, we give a (extended) summary of the latest study of our working group published in the "Quaternary Science Reviews" (Buggle et al., 2008). The objective of this study was to identify different loess facies areas and to clarify the provenance of the loess in the Vojvodina (southern part of the Pannonian Basin, Serbia), the Dobrudja plateau and the lower Danube Basin (Romania) and the Dnieper area (Ukraine).

2. Material – Methods

As key sections of these areas, we sampled the loess-paleosol sequences Stary Kaydaky (48° 22' 42" N, 35° 07' 30" E, Ukraine), Mircea Voda (44° 19' 15" N, 28° 11' 21" E, Romania) and the stacked LPSS Batajnica/Stari Slankamen (44° 55' 29" N, 20° 19' 11" E and 45° 7' 58" N, 20°18' 44" E, Serbia, Text-Fig. 1). About 60 to 70 samples of loess and paleosol units for each section were analyzed for their element composition by XRF. To identify the geochemical characteristics of the loesses and to distinguish different loess facies areas, we applied a discriminant analysis of the element composition and the Al-Na+CaO*-K (A-CN-K) ternary diagram according to Nesbitt and Young (1984) with CaO* referring to silicatic bound Ca. Furthermore, we investigated the element enrichment/depletion relative to the composition of the upper continental crust.

On basis of the geochemical fingerprints of the loesses and possible source areas, we evaluated the origin of the dust. Since no representative datasets of source rocks were available, we compared the geochemical composition of the loess with that of floodplain sediments of Danube tributaries (FOREGS dataset, see Salminen et al., 2005), representing mean samples of possible source areas. The following source areas were defined (see Buggle et al., 2008).



Text-Figure 1.
Location of the studied sections in a schematic map (Buggle et al., 2008, modified). The limits of the ice sheets were taken from Eissmann (2002). The paleowind directions, as reconstructed by Buggle et al. (2008) and Rozycki (1967) are indicated by arrows.

- The “Austroalpine cover nappes area” i.e. with floodplain sediments deriving from the Austroalpine cover nappes (not including sediments of the Inn River).
- The “Drava source area” i.e. with floodplain sediments deriving from the metamorphic and crystalline rocks of the Austrian penninic nappes and Austroalpine basement nappes, respectively.
- The “Bohemian Massif area” i.e. with floodplain sediments deriving from crystalline and metamorphic rocks of the Bohemian Massif.
- The “Western Carpathian area” i.e. floodplain sediments derived from the Western Carpathian Mountains.

Our provenance study also considers the geomorphodynamic setting, especially the paleowind direction, as reconstructed by the geographic distribution of sandy deposits / dunes.

3. Results – Discussion

In the following we give a short overview about the findings of Buggle et al. (2008). For the corresponding artworks and a more detailed discussion of the results we refer to the mentioned publication in Quaternary Science Reviews.

3.1. Origin and Characteristics of the Loess in the Dnieper Area

At its southernmost extension in the Ukraine, the Fennoscandinavian ice sheet was at about 50 km distance from the Stary Kaydaky section. Thus, one can assume its glaciofluvial sediments as major dust source. This proposal is confirmed by the discriminant analysis, which shows significantly higher Si and Zr contents for the material of the Stary Kaydaky site compared to the sections in the Danube Basin. Normalizing the element contents on the average composition of the upper continental crust, reveals also significantly higher Hf contents. A similar factor group was identified by the factor analyses of Batista et al. (2006) on European floodplain sediment, stream sediment and soil data, with high scorings of Si, Zr and Hf, typical in the area of glaciofluvial sediments of the Fennoscandinavian ice sheet. The reconstruction of the paleowind direction, based on the distribution of sandy deposits in relation to river courses, yields predominantly northerly and northwesterly winds. Thus, besides the Dnieper River, katabatic winds from the Fennoscandinavian ice sheet are seen as responsible for the southward transport of glaciofluvially derived material in the Ukraine.

3.2. Origin and Characteristics of the Vojvodina Loess

Compared to the Dnieper loess area the discriminant analysis reveals higher Al, Ga, Rb, Fe and lower Si, Zr contents in the Vojvodina loess area, indicating less coarse material with a supposably higher content of clay (Chapman & Horn, 1968; Reeder et al., 2006; Yang et al., 2006). The element fingerprint normalized to the UCC shows that the average contents of all elements, except for Si, Zr, and Hf, are higher in the Vojvodina loess. This points to a smaller dilution effect by quartz than in the Dnieper loess area. The element fingerprint of the Vojvodina loess and the lower Danube Basin/Dobrudja loess are very similar, confirming that both originated predominantly from Danube alluvium, as proposed already by Smalley & Leach (1978).

On the basis of the geochemical composition of the respective floodplain sediments, only the northern Austroalpine cover nappes area and the area of the northern Alpine foreland glaciations (without the Inn area) may be ruled out as major provenance region for the alluvial loess source material (Buggle et al., 2008). From the geomorphodynamic point of view, major sources of the silt sized material in the Vojvodina are weathering products of the Carpathian Mountains brought by the Tisza River and glaciofluvial sediments of the Alpine brought by the Drava and Inn River. This is in accordance to the concept of Smalley & Leach (1978).

3.3. Origin and Characteristics of the Lower Danube Basin Loess

The material of the Mircea Voda section shows a similar geochemical fingerprint and element ratios as the Batajnica/Stari Slankamen section, in general. This suggests also the Danube alluvium as major dust source. The higher Ca, Mg and Sr content of the lower Danube Basin section, as revealed by the discriminant analysis, is thought to reflect the aridity trend between the sites. The tendency of higher Zr and Hf contents, significantly elevated Si contents and some other minor differences in element composition suggest an additional, geochemically significant dust source, most likely the glaciofluvial sediments in the Ukraine or Belarus. This is supported by the N–NE paleowind direction, which was reconstructed for the Eastern part of the lower Danube Basin and Dobrudja region. For the western part of the lower Danube Basin, such a contribution is unlikely due to a prevailing WNW paleowind direction.

3.4. Geochemical Comparison with Upper Continental Crust Composition

The A-CN-K plot reveals that the initial ratio $K_2O/(CaO^*+Na_2O)$ of the unweathered Vojvodina and lower Danube Basin/Dobrudja loess was similar to the average upper continental crust composition. For the loess of the Dnieper area, no clear initial composition can be derived from the A-CN-K plot, due to mineral and grain size sorting effects. However, applying a Fe/Ti vs. Al/Ti plot, Buggle et al. (2008) deduced also an initial UCC-like composition for the studied loess in the Ukraine. Furthermore, the element fingerprint normalized to average UCC-composition shows similar patterns for the loesses of all three sites. The element contents were close to the UCC values with relative enrichment – or depletion – factors mostly between 0.5 and 2. Biases from the UCC composition can be addressed to mineral and grain size sorting as well as weathering effects, since observed patterns in element distribution reflect mostly element mobility and the weathering resistance of the respective host minerals. For instance, the concentration of the elements Si, Ti, Zr and Hf indicates selective enrichment of the weathering-resistant minerals quartz, rutil and zircon (Reeder et al., 2006). High content of Ca and Mg in the loesses is attributed to the accumulation of secondary carbonates, leached from the soil on top of them.

The relatively high preweathering of the loess, revealed in the A-CN-K plot, indicates at least one previous sedimentary recycling phase of the source material. The weathering in the fluvial and especially glaciofluvial systems of the cold stages seems not to be strong enough to account for this. Thus, we assume that the weathering signal is inherited already from sedimentary source rocks. These findings are in accordance to the results of Gallet et al. (1998) and Jahn et al. (2001) for other loess regions of the world.

4. Conclusions

1) A geochemically defined “Danube-Basin” loess facies region can be identified and distinguished from the loess of the Dnieper area (Ukraine).

2) We could confirm that the loess of the Dnieper region predominantly derives from glaciofluvial sediments in the Ukraine or Belarus, whereas the loess in the southern Pannonian Basin (Vojvodina, Serbia) and the lower Danube Basin/Dobrudja derives from alluvial material of the Danube River.
3) For the eastern part of the lower Danube Basin/Dobrudja an additional dust contribution from the glaciofluvial sediments in the Ukraine or Belarus is evident. The predominant paleowind direction in this area was N to NE, whereas in the western part of the lower Danube Basin WNW winds prevailed.
4) The loess of the Danube Basin represents an average sample of the upper continental crust. However, due to its preweathering state it shows evidences of previous sedimentary recycling. Further deviations from the composition of the upper continental crust can be attributed to mineral dilution effects, essentially caused by quartz and secondary carbonate, as well as mineral and grain size sorting.

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