Cyclic Climatic Records in Loess-Paleosol Sequences in Southeastern Transdanubia (Hungary) on the Basis of Sedimentological, Geochemical and Malacological Examinations

Laszlo HUM and Pal SÜMEGI

Department of Geology and Paleontology, University of Szeged, Egyetem u. 2-6., H-6722 Szeged, Hungary

ABSTRACT. The paper discusses the relation between geochemical characteristics of loess-paleosol sequences and paleoclimate in southeastern Transdanubia, Hungary. Geochemical properties of the sediments reflect the intensity of weathering and pedogenesis, thus nine sediment types could be distinguished upon this basis. Analyses of the geochemical character of different stratigraphic horizons allowed to reconstruct paleoclimatic trends. With the help of Quaternary-malacological investigations we managed to identify several changes in the paleoecology and paleoclimate. The paleoclimatic trends reconstructed on the basis of geochemical investigations show a good coincidence with the paleotemperatures calculated by malacothemometry for the last 300,000 years.

KEY WORDS: loess, paleosol, geochemistry, climate, paleoecology.

Introduction

Quaternary sediments reflect environmental effects, which played a crucial role in their development. Paleoenvironmental conditions determined the mineral composition and the distribution of chemical elements in loesses and in paleosols. Consequently, the changes in mineral composition and geochemistry of sediments allowed the reconstruction of the dynamic changes of the paleoclimate and the environment.

As the climate becomes warmer and more humid, the intensity of weathering and pedogenesis increases. In warm-humid periods the dissolution of carbonates increases, and so do the formation of clay minerals, the accumulation of Fe_2O_3, Al_2O_3, and the enrichment of several main components and trace elements.

On the basis of their lithological features, the loesses in Hungary can be divided into two contrasting units: the "young loess" and the "old loess" series. The upper part of the young loess series is designated "Dunaújváros–Tápiósüly subseries", while the lower part is known as "Mende–Basaharc subseries" (Pecsi and Richter, 1996)

Loess and paleosol profiles belonging to the young loess series are exposed in a number of outcrops in southeastern Transdanubia. The Dunaújváros-Tápiósüly subseries contains two humic horizons (h_1, h_2), while the two chernozem-like forest steppe soil complexes (Mende Upper I and Mende Upper II; Basaharc Double I and Basaharc Double II) and one well-developed forest steppe soil horizon of considerable thickness (Basaharc Lower) are interlayered in the Mende–Basaharc subseries.

The aim of the systematic analysis of the Pleistocene sequences belonging to the "young loess series" of southeastern Transdanubia was to provide an accurate reconstruction of their various depositional environments.

Methods

Sampling interval was 0.25 m in the sections, but thinner layers were also sampled. After the determination of grain-size distribution and carbonate content, we selected nearly 150 samples for mineralogical and elemental analyses. The fraction under 71 μm was analysed. X-ray measurements were used for the determination of mineral composition. In case of 25 samples, the fraction under 5 μm was also examined; these samples were treated with ethylene-glycol for determination of clay minerals. The calcite/dolomite ratios were determined using XRD. Determination of carbonate and clay minerals was promoted by thermoanalytical examinations. Inorganic carbon was removed with HCl, and then organic carbon content was determined using LECO Carbon-Sulphur Determinator. For the determination of trace and major elements, destructive attack was performed using HF-$HClO_4$-HNO_3 mixture in a Teflon bomb under high pressure. Al, Fe (total), Mn, Mg, Ca, Na, K, Li, Zn, and Sr were analysed using flame AAS (Perkin Elmer 4100). Cr, Rb, Ni, Co, Pb and Cu were determined using graphite-tube AAS (ZEISS). Si was measured by RFA, while Ti and P were analysed spectrophotometrically (using the Tiron-method and the molybdenum yellow method). Ba was determined using ICP-AES. The AAS measurements were tested by the results of RFA and ICP-AES measurements for several elements.

Results

On the basis of their mineral and chemical compositions determined by paleoclimatic conditions, it is possible to make distinction between loess and paleosol types that suffered different degrees of weathering and pedogenesis (Hum and Fenyes, 1995; Hum, 1997, 1998).

As weathering and pedogenesis intensify, the grain-size distribution significantly shifts towards finer fractions at the expense of silt fraction. At the same time carbonate content decreases; it is high in weakly weathered loess, but has been nearly entirely dissolved from well-developed paleosols. Clay fraction of the loesses is characterized by illite, chlorite and montmorillonite content with a relatively low variation, while the clay fraction of the paleosols is characterized by higher contents of montmorillonite (smectite) and kaolinite relative to that of the loesses. Along with the decrease in originally high carbonate content, the low calcite/dolomite ratio (1:2) of the loess chang-

es significantly and increases to 2:1 to 3:1 in paleosols, the overall carbonate content of which being very low.

Due to weathering and pedogenesis, the CaO, MgO, and Sr contents in the sediments decrease, while those of SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, Na_2O, K_2O, P_2O_5, and Li, Cr, Co, Ni, Cu, Zn, Rb, Pb, and Ba increase. When weathering intensifies, the CaO/MgO and $CaO+K_2O+Na_2O/Al_2O_3$ ratios fall, and the K_2O/Na_2O ratio keeps growing. Geochemical properties of the sediments reflect the intensity of weathering and pedogenesis, thus nine sediment types could be distinguished upon this basis.

The *weakly weathered loess* formed under cold and arid climate. This is the group the least affected by weathering. The *weathered loess* was deposited under milder and more humid conditions, thus weathering did influence its formation. More intense weathering, however, led to the formation of *strongly weathered loess*, which can be interpreted as *humic loess* or embryonic soil as well. In these cases, however, pedogenesis was not strong enough to develop real soil horizon. The strongly weathered loess displays intermediate geochemical and developmental character between loess and paleosol. The *carbonate accumulation horizons* belong to the loess-like deposits. The *Mende Upper* (MF) and *Basaharc Double* (BD) soil complexes were formed due to strong pedogenesis under mild and humid climate. The *Basaharc Lower* (BA) and the *Mende Base* (MB) paleosols witness the most intense pedogenesis and weathering, and are associated with even warmer and more humid paleoclimate than the Mende Upper and Basaharc Double soil complexes.

Geochemical investigation of loess-paleosol series renders reconstruction of paleoclimatic trends possible. The loess under the Mende Base paleosol-complex belongs to the weathered loess group. The Mende Base paleosol represents the strongest weathering and pedogenesis among the nine studied sediment types. The loess underlying the Basaharc Lower paleosol belongs to the weakly weathered loess group. The cold period, favourable for loess accumulation, was interrupted by a warm, humid period, resulting in the formation of the Basaharc Lower soil horizon. The overlying weathered loess was deposited during a period characterized by cooling. Geochemical data from the two soil horizons of the following Basaharc Double soil complex argue for the same degree of pedogenesis which was less intense than that of BA paleosol. The weathered loess interlayered between the Basaharc Double I and Basaharc Double II soil horizons indicates that the cooling between the two mild and humid periods forming the soils was not significant. The soil complex is overlain by strongly weathered loess, indicating graduate cooling in the profile. When the climate became cold and dry again, weakly weathered loess accumulated. During the following mild and humid period, two chernozem-like forest steppe soil horizons formed (Mende Upper soil complex). The upper horizon of the complex (Mende Upper I) suffered more intense weathering than the lower one (Mende Upper II). Again, the paleosol complex is overlain by strongly weathered loess, formed under cooler, still mild climate. The overlying, weakly weathered loess hallmarks the last cold and arid period, which was interrupted by two milder intervals, as indicated by two humic loess horizons (h_1 and h_2).

With the help of Quaternary-malacological investigations we managed to identify several changes in the paleoecology and paleoclimate of the area of the "young loess series" deposits. The mean July temperatures were determined by means of malacothermometry. Paleoclimatic trends reconstructed on the basis of geochemical investigations show a good coincidence with the paleotemperatures calculated by malacothermometry for the Middle and Upper Pleistocene (Fig. 1). Besides species living in bushy areas, typically forest species (*Aegopinella ressmanni, Ena montana, Discus rotundatus, Discus perspectivus*) could be identified in the area. The relative abundance of warm-requiring species is a common feature of the SE Transdanubia and the southern part of the Danube–Tisza Interfluve. The average values of the mean July temperatures determined by malacothermomtry were around 15–16 degrees Celsius in the cooling periods. The climate reconstructed on the basis of malacological investigations was milder and more humid than that identified for the northwestern areas of Hungary. The average values of the mean July temperatures were generally 2–4 °C higher than those in NW Hungary. The loess and loess-like deposits of the area developed under milder and more humid conditions than those of the central and northern part of the Carpathian Basin. The vegetation cover in the area was generally much more closed, with bushy and forest surfaces in the rainy steppe environment. Because of the milder climate and the higher vegetation cover, traces of the significant cooling periods of the Upper Würmian (*Pupilla sterri* zonula) could not be detected.

References

HUM L., 1997. Paleoenvironmental changes and geochemistry of loesses and paleosols in SE-Transdanubia, Hungary. *Z. Geomorph. N. F. Suppl.*, 110, 69-83.

HUM L., 1998. Geochemical investigations of the Dunaszekcső loess-paleosoil sequence. *Acta Min. Petr.*, 39: 139-150.

HUM L. and FENYES J., 1995. The geochemical characteristics of loesses and paleosols in the South-Eastern Transdanube (Hungary). *Acta Min. Petr.*, 36: 89-100.

PECSI M. and RICHTER G., 1996. Löss. Herkunft-Gliederung-Landschaften. *Z. Geomorph. N. F. Suppl.*, 98.