An Introduction to the Late Pleistocene Loess-paleosol Sequence at Susek (Vojvodina, Serbia)

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Abstract

The Susek loess-paleosol sequence is located in the western part of the north slope of the Fruška Gora mountain, in the Vojvodina region, Serbia. Three loess units and two fossil pedo-complexes, and recent soil are preserved in the ~7.5-m thick Susek exposure document about the environmental changes during the Late Pleistocene and Holocene. Detailed magnetic susceptibility and sedimentological evidence of the Susek loess-paleosol sequence are used for correlation with the SPECMAP paleoclimatic record, as well as, with other Late Pleistocene loess sites in the Vojvodina region. Primary climatic and environmental records of the loess unit L1L2 are disturbed by post-depositional hydromorphic processes. Our investigations confirm previous malacogical results from the northern slope of Fruška Gora mountain which demonstrated significant similarities to the Paleopreillyrian fauna of the southern Transdanubia region in Hungary and suggested that the Susek site also has a refugial character during the last glacial.

Key words: paleoclimate, paleoenvironment, Late Pleistocene, loess, Serbia, Susek, grain size, magnetic susceptibility

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Introduction

The rich loess records from the Vojvodina region (Northern Serbia) (Marković, 2000, 2001; Marković et al., 2003, 2004a, 2006), located in the southeastern part of the Carpathian (Pannonian) Basin (Fig. 1), provide important information for the comparison of the European loess stratigraphies. Loess accumulation in the Vojvodina province started in the late Lower Pleistocene (Marković et al., 2003) and culminated during the Late Pleistocene. Due to the high accumulation rates and widespread occurrence, the last glacial-interglacial loess-paleosol sequences in the Vojvodina region have preserved a detailed record of Late Pleistocene climate dynamics and environmental changes (Marković, 2000, 2001; Marković et al., 2003, 2004b, 2005, 2006).

The Susek loess exposure (45013'37" N and 19030'37" E) is located on the right bank of the Danube River, in the western part of the northern loess slope of the Fruška Gora mountain (Vojvodina, Serbia) (Fig. 1 and 2). Initial investigations focus on the two loess layers and two paleosols preserved in the ~7.5-m thick exposure. This study presents high resolution changes in the low field magnetic susceptibility (MS), grain size (GS) distribution, pedology, lithology, and mollusk assemblages of these Late Pleistocene deposits to compare the Susek stratigraphy with other European loess records.

Material and Methods

Investigations into the loess-paleosol sequences of the Susek exposure began in 2004. Samples were collected at 5-cm intervals for MS measurements and sedimentological analysis, and at 10-cm intervals for malacological studies.

Dry and moist colors were recorded using Munsell Soil Color Charts.

Grain size (GS) fractions (<2, 2-20, 20-200, >200 μm) were measured by sieving and pipetting, carbonate content was analyzed by gas volumetry.

The measurements of the low-field magnetic susceptibility (MS) were performed at the paleo- and rock-magnetic laboratory of the Chair of Geomorphology, University of Bayreuth, using a KLY-2 susceptibility bridge (AGICO, Brno, Czech Republic).

10-kg bulk sediment samples for malacological investigations were sieved through a 0.7 mm mesh. After fossil gastropod shells were identified, paleoenvironmental classification and interpretation were done and they are based on the methods of Ložek (1964), but also extended with some local variants defined by Krolopp and Sümegi (1995) and Sümegi and Krolopp (2002).

Results

Litho- and pedostratigraphy and correlations

The loess stratigraphy is quite uniform in the Vojvodina region because of mostly

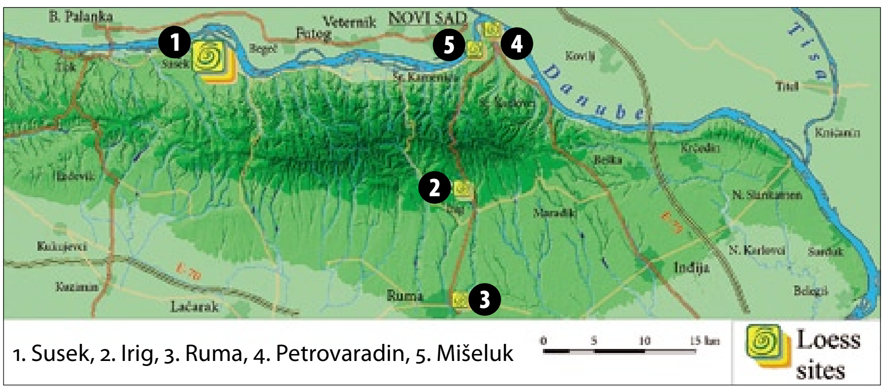

Fig. 1 Geographic position of the Susek loess-paleosol sequence and other relevan loesst sites in the Fruška gora area

plateau depositional conditions (Marković, 2000, 2001; Marković et al., 2003, 2006) similar to the ones in the central Chinese loess plateau (e.g. Liu et al., 1985; Kukla, 1987; Kukla and An, 1989). Recent stratigraphic studies of loess and paleosols at various exposures in this area region have used lithologic and pedogenic criteria and MS variations as the primary bases for correlation. Marković et al. (2003; 2004a; 2004b; 2006) designated the Vojvodinian loess-paleosol chronostratigraphic units as the labels that follow the Chinese loess stratigraphic system (e.g. Liu et al., 1985; Kukla, 1987; Kukla and An, 1989).

According to the current chronostratigraphic model (Marković et al. 2004b, 2005) of the Late Pleistocene loess–paleosol sequences in the Vojvodina region, the last interglacial – early glacial paleosol S1 correlates with MIS 5. This palaeosol is overlain by composite loess unit L1, correlated with MIS 4-2. The structure of the last glacial loess L1 varies in different loess localities across the Vojvodina region (Marković et al., 2004a, 2005a, 2006). The lower sub-horizon of the upper loess, L1L2, accumulated above palaeosol S1. The middle pleniglacial is represented in the area by a weakly developed soil complex L1S1. The youngest loess layer L1L1 accumulated during the upper pleniglacial period.

Loess-paleosol sequences distinguished at the Susek exposure are presented in fig. 3. Table 1 shows the morphological description of the loess and paleosol units.

The oldest pale yellow (5Y 7/3, 5/4) loess unit L2 is uncovered only at lowest 10 cm of the profile. Many carbonate concretions (3-10 cm diameter) and humus infiltrations appear near the contact of the S1 soil complex and the underlying L2 loess. The reddish-brown fossil soil S1 is 135 cm thick. The lower darker transitional A(B) horizon (7.5YR, 10YR 4/4) is darker than the middle Ah horizon (10YR 6/4,4/4) that contains some preserved carbonate pseudomycelia. The boundary between paleosol S1 and loess unit L1 is sharper than in other investigated at loess sites in Vojvodina (Marković, et al., 2004a, 2004b, 2005, 2006).

The composite loess unit L1 is 560 cm thick and contains three loess layers (L1L1, L1S1L1 and L1L2) separated by pedocomplexes L1S1S1 and L1S1S2. The 230 cm thick loess layer L1L2 is accumulated above the S1 paleosol. This light yellow grey (5Y 7/3 5/3), porous, loosely cemented loess shows its primary characteristics only in the uppermost part. From 4.15 to 5.95 m depth strongly developed hydromorphic features, such as manganese nodules, iron coatings, iron oxide patches, and carbonate concretions are exposed.

The superimposed paleopedocomplex horizon L1S1 is 140 cm thick and contains

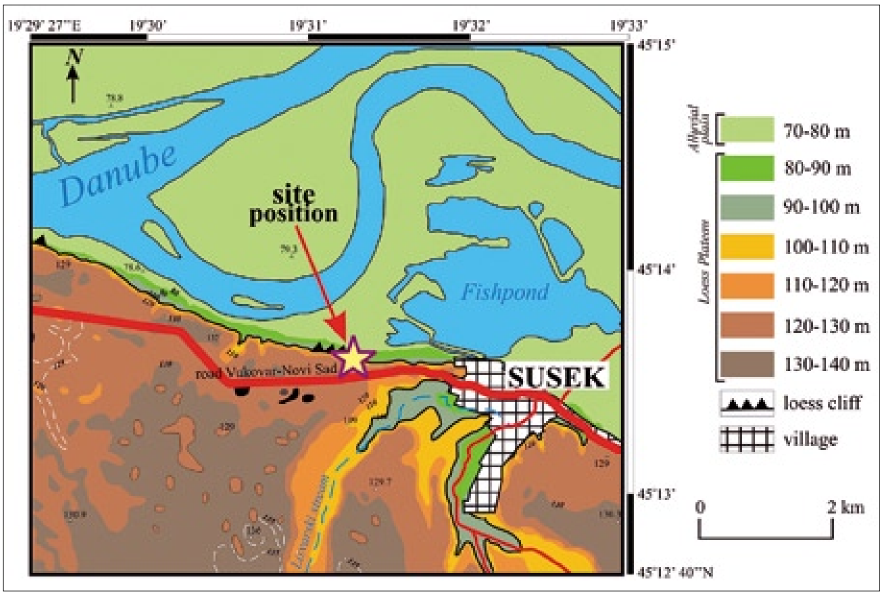

Fig. 2 Topographic map of the area surrounding the Sussek site

a lower chernozem-like pedological horizon L1S1S2 with carbonate pseudomycelia, loess inter-stratum L1S1L1 (10YR 6/3 4/2) with many carbonate concretions 1-3 cm in diameter, and an upper weak incipient pedohorizon L1S1S1 (10YR 5/4 4/4) with the granular structure and small soft carbonate spots.

Loess layer L1L1 is 195 cm thick, very porous and in some parts intensively bioturbated. Many spherical, relatively soft carbonate nodules and humus infiltrations in old root channels are found at the contact zone with the modern soil V-So.

The Holocene soils developed on the loess plateau surface in the area surrounding the Susek exposure are micelar and calcareous chernozem, and slightly melanized chernozem. At the top of the investigated section, the modern soil is a 55-cm thick slightly melanized chernozem. The lower Ck horizon contains many $CaCO_3$ nodules of 2-5 cm in diameter and numerous krotovinas and root channels filled with humic material. A transitional AC horizon (10YR 5/1-3/3) is 15-cm thick, very porous silt loam with fine blocky structure. The A(B) horizon is 20 cm thick, reddish-

***Tab. 1** Morphological description of loess-paleosol sequences at the Susek exposure*

Unit / subunit	Thickness (cm)	Depth (cm)	Description
So	55	0-55	Modern soil, 55-cm thick chernozem slightly melanized with weak blocky structure
L1	560	55-615	
L1L1	195	55-245	Very porous, pale yellow loess (10YR 7/4-5/3) with many humic infiltrations and carbonate concretions (ø 2-5 cm), intensively bioturbated.
L1 S1	160	245-385	L1S1S1: the upper lighter (10YR 5/4-4/4) part is a weakly developed incipient (A) horizon with granular structure. L1S1L1: thin loess layer (10YR 6/3 4/2) with carbonate concretions (ø 1-3 cm). L1S1S2: the lower darker (10 YR 6/3-4/2) mollic Chernozem-like A horizon with carbonate pseudomycelia.
L1L2	230	385-615	Yellowish brown (10YR 5/3, 4/3) porous, loosely cemented calcareous loess only upper 20 cm, bellow are strongly developed hydromorphic features (manganese, iron coatings, iron oxide patches)
S1	135	615-740	Thick transitional Cambisol-Chernozem pedocomplex: the lower transitional AB horizon has weak platy structure (10YR 5/2-3); the upper mollic Ah horizon with brighter colour (10YR 6/2-4) and carbonate pseudomycelia..
L2	10 ?	740- ?	Porous yellow (5YR 7/3, 5/4) loess with many humus infiltrations and carbonate concretions (ø 3-7 cm).

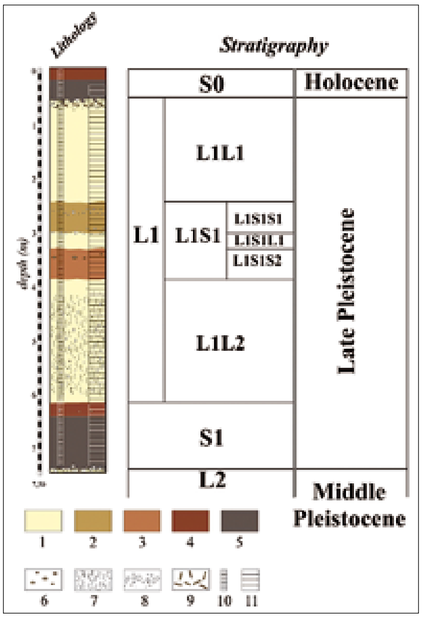

Fig. 3 Description and stratigraphy of the Susek loess-paleosol sequence.

- **1.** Loess;
- **2.** Embryonic pedogenetic layer (incipient soil horizon);
- **3.** Chernozem-like A horizon;
- **4.** Ah horizon;
- **5.** Transitional AB horizon;
- **6.** Krotovinas;
- **7.** Hydromorphic features;
- **8.** Carbonate concretions;
- **9.** Humus infiltrations;
- **10.** Position of samples for sedimentological and rock magnetic measurements;
- **11.** Position of samples for malacological investigations.

brown (10YR 6/3, 7.5YR 4/2), and porous with blocky structure. The Ah horizon (10YR 6/3-4/4) is a 20 cm thick silt loam with the granular structure and carbonate pseudomycelia in the lower part.

Low-Field Magnetic Susceptibility (MS)

According to our investigations, the variations in the low-field MS are related to the pedostratigraphy in the Susek section. MS values observed in soils So (average 62.3 x $10^{-8}m^3kg^{-1}$), L1S1 (average 50.1 x $10^{-8}m^3kg^{-1}$), and S1 (average 105.7 x $10^{-8}m^3kg^{-1}$) are higher than in the loess units L1L1 (average 28.2 x $10^{-8}m^3kg^{-1}$)), L1L2 (average 45.6 x $10^{-8}m^3kg^{-1}$), and L2 (average 47.4 x $10^{-8}m^3kg^{-1}$) (figure 5). This type of MS pattern that reflects magnetic enhancement via pedogenesis is similar to the one in Chinese and Central Asian loess deposits (e.g. Heller and Liu, 1986; Maher and Thomson, 1999).

The basal penultimate glacial loess unit L2 shows relative high MS values: close to 50 x $10^{-8}m^3kg^{-1}$. MS values in the middle part of the paleosol S1 increase to 140.4 x $10^{-8}m^3kg^{-1}$ where it is the highest in the whole column. Above that MS values continuously decrease to relatively low values in loess subunit L1L2: ~ 45 x $10^{-8}m^3kg^{-1}$. The L1S1S1 shows higher, also stable values (range of 41.6 x $10^{-8}m^3kg^{-1}$ to 56.3 x $10^{-8}m^3kg^{-1}$). MS of the youngest loess layer L1L1 is the lowest with a minimal value of 19.5 x $10^{-8}m^3kg^{-1}$. The Holocene soil So shows an increasing trend from ~ 50 x $10^{-8}m^3kg^{-1}$ units at the base to more than ~ 65 $10^{-8}m^3kg^{-1}$ in its middle part (fig. 4).

Grain-size (GS) Distribution and Carbonate content (CC)

Measured variations in GS distribution also coincide well with the pedostratigraphy of the Susek loess-paleosol sequence. Generally, the pedogenic horizons have a lower proportion of coarse material than the loess layers (e.g. Vandenberghe and Nugteren, 2001). Variability in clay content (< 2µm) mostly parallels the MS record. The highest value of clay content is observed in lower part of paleosol S1 (more than 30 %) in contrast to relatively low values detected in loess layer L1L1 (less than 10 %). Loess horizon L1L2 with strongly developed hydromorphic features shows stable values of clay content from 20 to 25 %. Within the section, the middle part shows the highest variability of clay content: the lower part of loess L1L1 (9-27 %) and fossil soil L1S1S2 (11-32 %). Contribution of the clay fraction continuously increases from the middle part of loess L1L1 (about 20 %) to the recent soil So (more than 25 %) (fig. 4).

The coarse material (>20 µm) content shows many abrupt small amplitude fluctuations. High values of >20 µm content are also associated with the several peaks of coarse sand (>200 µm) deposition indicating periods associated with the dynamic environments typified by strong winds and cold climatic conditions (fig. 4).

Higher values of CC are detected in the upper part of profile: the recent soil So contains 15 to 25 %, the upper part of the loess unit L1L1 has higher values (33-20 %) than the lower part (20-10 %), and upper part of paleosol L1S1 has more than 5 %. However, very low values of carbonate (less than 5 %) are registered in the middle and lower parts of the section (fig. 4). This is a consequence of post-depositional gleyification in the loess layer L1L2 and strong pedogenesis of the paleosol S1.

Malacology

Shells of 13.444 individuals of land snails representing 31 species (29 genera) were found in 75 samples taken from the Susek section. Generally, the terrestrial malacological assemblages reflect humid and relatively cold environmental conditions with mosaic vegetation.

No land snails were recovered from the loess horizon L1L2 and from paleosol S1. Because of intensive gleyification in loess layer L1L2 and poor preservation and leaching in the fossil soil S1, these units were not valuable for malacological investigations.

The snail assemblages of the youngest paleosol L1S1S1 and loess L1L1 provided different environmental conditions. Domination of woodland environmental conditions represented by the presence of the forest snails such as *Aegopinella ressmanni*, *Orcula dolium* and *Clausilidae* detected in the palaeosol L1S1S1 and in upper part of loess L1L1 indicates relative humid climatic conditions. However, in the lower part of loess unit L1L1 dominance of steppe environmental conditions characterized by the presence of aridity-tolerant snails such as *Pupilla triplicata, P. muscorum, Chondrula tridens*, and *Granaria frumentum* is observed.

During the last glacial period we note the presence of several relatively cold episodes. The coldest one was during the accumulation of loess layer L1L1 indicated by the presence of the cryophilous species *Columella collumella* and *Vallonia tenu-*

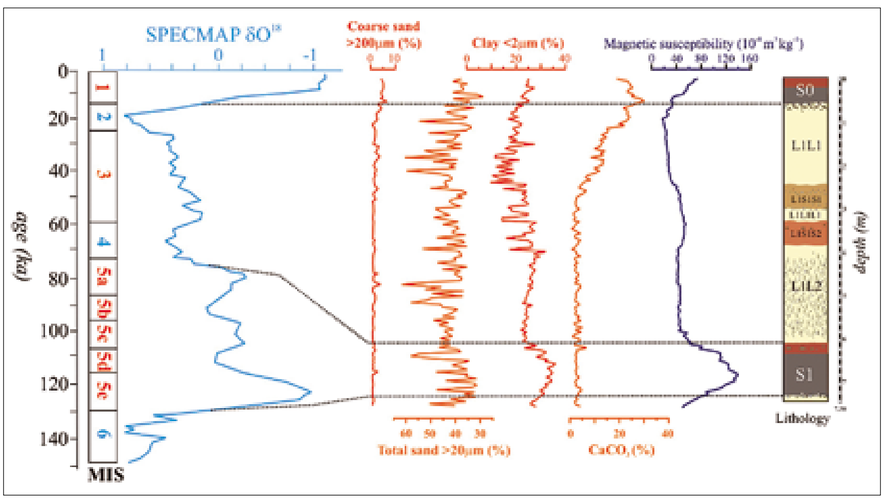

Fig. 4 Depth plots of magnetic susceptibility, clay content, particle size fractions >20µm, and carbonate content at the Susek exposure related to SPECMAP paleoclimatic model (Martinson et al., 1987). Pedostratigraphy is same as in Figure 3.

ilabris. The earlier cold periods occurred during the deposition of loess layers L1L2 and L1S1L1, and the weakly developed soil L1S1S1 is characterized by increasing cold-resistant species and a very low frequency of cryophilous snails.

Discussion

The stratigraphic pattern of the Susek site is generally similar to other Late Pleistocene loess-palaeosol sequences in Europe (e.g. Kukla, 1975; Vandenberghe et al., 1998; Rousseau et al., 1998, 2001; Antoine, et al., 1999, 2001; Horvath, 2001). However, all analysed proxies at Susek and other loess exposures in the Vojvodina region (Gaudenyi et al., 2003; Marković et al., 2004b, 2005, 2006) indicate that the Late Pleistocene palaeoclimatic and palaeoenvironmental evolution was relatively uniform compared to equivalent central, western and eastern European loess records (e.g. Kukla, 1975; Vandenberghe et al., 1998; Rousseau et al., 1998, 2001; Antoine et al., 1999, 2001; Horvath, 2001).

The multi-proxy data set and identified pedostratigraphy in the Susek sequence indicate the following climatic and environmental changes. Pedological interpretation of pedocomplex S1 shows a paleoenvironmental succession from interglacial forest-like to steppe conditions during the early peniglacial. Intensive post-depositional hydromorphic conditions disturbed the primary climatic record of loess unit L1L2. Similar hydromorphic features are not observed in any other investigated Late Pleistocene loess sequence in the Vojvodina region (Marković, et al, 2004a, 2004b, 2005, 2006).

Detailed evidence of middle and upper pleniglacial environmental changes is preserved in the pedocomlex L1S1 and loess L1L1. At the Susek loess sequence, the first phase of climatic improvement of the middle pleniglacial is indicated by the pedogenesis of chernozem-like fossil soil L1S1S2. During deposition of the loess subunit L1S1L1, the mean rate of dust deposition was relatively high, and the intensity of pedogenic activity was restricted. The weakly developed paleosol L1S1S1 provides mostly dry steppe environment.

Data from the youngest loess layer L1L1 indicates the coldest conditions during the last interglacial-glacial cycle. The rich upper pleniglacial snail fauna witnesses humid forest-steppe-like environmental conditions. The lower part of loess L1L1 represents a steppe-like environment. By contrast, the upper part of this loess unit shows an increase of woodland elements and coldest climatic conditions. The increase of cryophilous and cold-resistant snails in the upper part of loess L1L1 agrees with other interpretations of the last glacial maximum recorded in the European loess sediments (e.g.; Antoine et al., 1999; Ložek, 2001; Sümegi and Krolopp, 2002). Finally, the Holocene soil S0 indicates the return to an interglacial climatic mode.

Generally, the snail assemblage of Susek's loess sequence is similar to other investigated sections on the northern slope of Fruška Gora mountain (Marković et al., 2004b, 2005). All of these mollusc records show more humid and relatively colder environments than in other investigated sites in the Vojvodina region (Marković et al., 2000, 2006; Gaudenyi et al., 2003). Therefore, we think that it was perhaps a refuge, i.e. one of those rare places in the southeast part of the Carpathian Basin where the Palaeopreillyrian snail assemblage (e.g. Aegopinella ressmanni, *Ena Montana, Macrogastra ventricosa* and *Trichia edentula*) survived (Sümegi and Krolopp, 2002). Paleoclimatic gradients were similar as under actual climatic conditions. Present mean annual rainfall is approximately 10% higher on the north-western slopes of Fruška Gora mountain than the average precipitation in the other parts of the Vojvodina region.

Conclusions

The multidisciplinary study of the loess-paleosol sequence reveals a detailed Late Pleistocene record at the Susek section. The soil complex S1 shows a stable pedo-sedimentary evolution similar to other investigated loess sites in the region. Intensive post-depositional processes disturbed the primary environmental record of loess layer L1L2. By contrast, paleosol L1S1 and loess L1L1 preserved high-resolution evidence of paleoclimatic changes. These results have established the importance of this site as a record of the last interglacial-glacial palaeoclimate and palaeoenvironment in the southeastern part of the Carpathian Basin.

The identified mollusk record provides several rhythmic changes of the environmental conditions characterized by alternating domination of steppe and woodland elements. These fossil snail assemblages indicate more humid environmental conditions in this area than in other parts of the Vojvodina region (Northern Serbia) during the last glacial. Because of that the northern slope of the Fruska Gora mountain was a biogeographical "island" during the last two glacials; i.e. a refuge where the Palaeopreillyrian snail assemblage survived.

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References

Antoine P., Rousseau D.D., Lautridou J.P., Hatté C. 1999. Last Interglacial-Glacial climatic cycle in loess-paleosol successions of north-western France. *Boreas* 28, 551-563.

Antoine P., Rousseau D.D., Zöller L., Lang, A., Manau, A.V., Hatté, C., Fontugne, M. 2001. High resolution record of the last interglacial-glacial cycle in loess palaeosol sequences of Nussloch (Rhine Valley–Germany). *Quaternary International* 76/77, 211-229.

Gaudeny T., Jovanović M., Sümegi P., Marković S.B. 2003. The north boundary of the Mediterranean paleoclimate influences during the late Pleistocene at South-eastern part of Carpathian Basin based on assemblages of mollusca (Vojvodina, Yugoslavia) In: Zapata M.B.R., Valino M.D., Rodriguez A.V., Garcia J.G., Azcarate T.B., de Bustamante Gutierrez I. & Mendizabal I.M. (Eds.): Quaternary climatic changes and environmental crises in the Mediterranean Region. *Univerzidad de Alcala, Alcala de Heneras*, Madrid, 41-47.

Heller F., Liu T.S. 1986. Paleoclimatic and sedimentary history from magnetic susceptibility of loess in China. *Geophysical Research Letters* 13, 1169-1172.

Horvath E. 2001. Marker horizons in the loesses of the Carpathian Basin. *Quaternary International*. 76/77, 157-163.

Krolopp E., Sümegi P. 1995. Paleoecological Reconstruction of the Late Pleistocene, based on Loess Malacofauna in Hungary. *GeoJournal* 36, 2/3, 213-222.

Kukla G.J. 1975. Loess Stratigraphy of Central Europe. In: *After Australopithecines*. Butzer, K, W. and Isaac, L., I. eds. Mouton Publishers, The Hague, 99-187.

Kukla G.J. 1987: Loess Stratigraphy in Central China. *Quaternary Science Reviews* 6, 191-219.

Kukla G.J., An Z. 1987. Loess Stratigraphy in Central China. *Palaeogeography Palaeoclimatology, Palaeoecology* 72: 203-225.

Liu T.S. (eds.) et al. (unnamed) (1985): Loess the Environment. China Ocean Press. Beijing.

Ložek V. 1964. Quartärmollusken der Tschechoslowakei., *Rozpravý Ustrediniho Ústavu Geologické* 31, Praha, 374 pp.

Ložek V. 2001. Molluscan fauna from the loess series of Bohemia and Moravia. *Quat. Int.* 76/77, 141-156.

Maher B.A., Thompson R. (eds.) 1999. Quaternary Climates, Environment and Magnetism. Cambridge University Press, Cambridge, 390 pp.

Marković S.B. 2000. Paleogeography of Vojvodina region during the Quaternary. Ph.D. thesis. Institut za geografiju, University of Novi Sad. (in Serbian, unpublished)

Marković S.B. 2001. Paleosols of Srem region. In: *Soils of Srem region (Vojvodina, Yugoslavia)* (eds.: Miljković, N. & Marković, S.B.): 133-155.

Marković S.B., Heller F., Kukla G.J. P, Gaudenyi T., Jovanović M., Miljković, LJ. 2003. Magnetostratigrafija lesnog profila Čot kod Starog Slankamena. Zbornik radova Instituta za geografiju 32: 20-28.

Marković S.B., Kostić N., Oches E.A. 2004a. Paleosols in the Ruma loess section. *Revista Mexicana de Ciencias Geológicas* 21, 79-87.

Marković S.B., Oches E.A., Gaudenyi T., Jovanović M. Hambach, U., Zöller, L., Sümegi P. 2004b. Paleoclimate record in the Late Pleistocene loess-paleosol sequence at Miseluk (Vojvodina, Serbia). *Quaternaire* 15: 361-368.

Marković S.B., McCoy W.D., Oches E.A., Savić S., Gaudenyi T., Jovanović M., Stevens T., Walther R., Ivanišević P., Galić Z. 2005. Paleoclimate record in the Late Pleistocene loess-paleosol sequence at Petrovaradin Brickyard (Vojvodina, Serbia). *Geologica Carpathica* 56, 545-552.

Marković S.B., Oches E.A., Sümegi P., Jovanović M., Gaudenyi T. 2006. An introduction to the Upper and Middle Pleistocene loess-paleosol sequences in Ruma section (Vojvodina, Yugoslavia). *Quaternary International* 149, 80-86.

Martinson D., Pisias M.G., Hays J.D., Imbrie J., Moore T.C., Shackleton, N.J. 1987. Age dating and the orbital theory of ice ages: development of a high-resolution 0 to 300,000-year chronostratigraphy. *Quaternary Research* 27, 1-30.

Rousseau D.D., Zöller L., Valet J.P. 1998. Climatic variations in the Upper Pleistocene loess sequence at Achenheim (Alsace, France). Analysis of magnetic susceptibility thermoluminescence chronology. *Quaternary Research* 49, 255-263.

Rousseau D.D., Gerasimaenko N., Matvviishina Z.N., Kukla G.J. 2001. Late Pleistocene Environments of the Central Ukraine. *Quaternary Research* 56, 349-356.

Sümegi P., Krolopp E. 2002. Quatermalacological analysis for modeling the Upper Weichselian palaeoenvironmental changes in the Carpathian Basin. *Quaternary International* 91, 53-63.

Vandenberghe J., Nugteren G. 2001. Rapid changes in loess successions. *Global and Planetary Change* 28, 1-9.

Vandenberghe J., Hujizer B., Mücher H., Laan W. 1998. Short climatic oslilations in a western European loess sequence (Kesselt, Belgium). *Journal Quaternary Science* 13, 35-38.