ABHANDLUNGEN DER GEOLOGISCHEN BUNDESANSTALT
Abh. Geol. B.-A. | ISSN 0378-0864 | ISBN 978-3-85316-043-5 | Band 62 | S. 15–19 | Wien, August 2008
Veränderter Lebensraum – gestern, heute und morgen
Hauptversammlung der Deutschen Quartärvereinigung e.V. (DEUQUA) in Wien: 31. August – 6. September 2008

Long-Term Paleoclimate Records in SE-Europe – The Loess Paleosol Sequences Batajnica/Stari Slankamen (Serbia) and Mircea Voda (Romania)

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Zusammenfassung

Für die Löss-Paläoboden-Sequenzen Stari Slankamen/Batajnica (Serbien) und Mircea Voda (Rumänien) werden Chronostratigraphie und erste paläoklimatische Interpretationen vorgestellt. Es kann gezeigt werden, dass die genannten Profile wertvolle Paläoklimaarchive für das Quartär (mindestens bis zum MIS 17) in SE-Europa darstellen. Um paläoklimatische Aussagen abzuleiten, wurde ein Bodenfarb-Index zur Quantifizierung der Rubefizierung angewendet sowie ein geochemischer Verwitterungsindex zur Charakterisierung der Mineralverwitterung in Löss-Paläobodensequenzen entwickelt. Anhand der Ergebnisse lässt sich ein paläoklimatischer Trend von den älteren zu den jüngeren Interglazialen feststellen. Während für die älteren Paläoböden (MIS 13 und älter) auf relativ feuchte, subtropische Bedingungen geschlossen werden kann, sind den jüngeren eher kühlere, trockenere, steppenhafte Verhältnisse zuzuweisen.

Abstract

We present the chronostratigraphy and first paleoclimatic interpretation of two key archives of the Quaternary in SE-Europe: the loess paleosol sequences (LPSS) Stari Slankamen/Batajnica (Serbia) and Mircea Voda (Romania). Our chronostratigraphic work shows that these sections represent paleoclimate archives of the last 17 Marine Isotope Stages (MIS), at least. To derive paleoclimatic information, we applied a soil color index of rubification and developed a geochemical weathering index as proxy of mineral weathering in LPSS. Our results suggest a gradual climate shift from relatively wet, subtropical conditions for the older paleosoils (MIS 13 and older) to cooler, dryer, steppe-type conditions for the younger interglacials.

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1. Introduction

In the middle and lower Danube Basin, loess paleosol sequences (LPSS) of several decameter thickness are widely distributed. They provide valuable long-term archives for the Quaternary climate development of the region and possibly for SE and Central Europe, in general. In the following, we develop a chronostratigraphy for two key sections of the area and derive first paleoclimatic information from the paleosols of the profiles. The presented results are a summary of two studies, submitted to Quaternary international (BUGGLE et al., submitted a) and Geochimica et Cosmochimica Acta (BUGGLE et al., submitted b).

2. Material and Methods

As key sections of the Vojvodina (southern part of the Pannonian Basin) and the lower Danube Basin – Dobrudja loess plateau, we studied the loess paleosol sequences Batajnica/Stari Slankamen (Serbia; 44°55´29´´N, 20°19´11´´E and 45°7´58´´N, 20°18´44´´E) and Mircea Voda (Romania, 44°19´15´´N, 28°11´21´´E). Regarding the potential vegetation, the sites are situated in an area of present day forest steppe and feather grass steppe. Each sequence contains at least six interglacial pedocomplexes, which were sampled in 10 to 50 cm intervals according to horizontation and thickness. Three representative samples were taken from each loess layer to determine background values for the applied parameters. Soil color, magnetic susceptibility and element composition (by XRF method) of the samples were determined. A chronostratigraphy of the section was developed (BUGGLE et al., submitted a) correlating our magnetic susceptibility curve with the astronomically tuned stacked records of Lingtai and Zhaojiachuan of the Chinese Loess Plateau (SUN et al., 2006) and the benthic $\delta^{18}O$ values of ODP site 677 (SHACKLETON et al., 1990). Using pedostratigraphic correlations we validated the obtained chronostratigraphy against existing chronostratigraphic models and numerical dating results at other LPSS in the region such as Ruma (Serbia, MARKOVIĆ et al., 2006), Koriten (NE Bulgaria, JORDANOVA & PETERSEN, 1999) and Mostistea (SE Romania, PANAIOTU et al., 2001).

To derive paleoclimatic information from the profiles, the rubification intensity (RI) as proxy of the hematite content was quantified using the rubification index according to HARDEN (1982).

Furthermore, we (BUGGLE et al., submitted b) developed a geochemical proxy of mineral weathering for loess paleosol sequences. Weathering indices rely on the different behavior of elements under weathering conditions i.e. the ratio of immobile to mobile elements (e.g. SMYKATZ-KLOSS, 2003). As mobile elements one can generally consider those with a low ion potential i.e. the alkali and earth alkali elements. However, with increasing ionic radius the tendency of elements for being adsorbed to clay minerals increases and the mobility in the weathering profile decreases again (e.g. RAILSBACK, 2003; SMYKATZ-KLOSS, 2003). Therefore, weathering indices relying on the mobility of elements such as K, Rb and Ba may be less sensitive indicators of weak pedogenesis. Also indices relying on Ca, Mg, Sr and Fe, Mn should not be applied to loess paleosol profiles. They might be biased by the dynamics of secondary carbonate and changing redox conditions, respectively. Thus, Na is regarded as the mobile element of choice. Immobile elements are generally those of an intermediate ion potential between three and ten e.g. the elements Al, Ti, Si, Zr (e.g. MASON & MOORE, 1985; RAILSBACK, 2003). The elements Ti, Si and Zr can reside to substantial proportions in host minerals like rutile, anatase, quartz or zircon, which may occur at variable amounts within the loess. To minimize biases due to changing parent material composition, we choose Al as immobile element. The main host mineral group of both, Al and Na, is the feldspar group, which forms clay minerals and aluminous oxides in the course of weathering. Therefore, we defined the Al/(Al+Na)*100 ratio as the chemical proxy of alteration (CPA), indicating the silicate and especially the feldspar weathering intensity of loess paleosol profiles. For more details on the deduction of the CPA and for an evaluation of other commonly used weathering indices, we refer to BUGGLE et al. (submitted b).

To avoid biases from down profile variation in loess composition and to evaluate the pedogenic weathering enhancement, paleoclimatic interpretation was deduced from ΔCPA values defined as the difference between CPA values of the paleosols and the respective background values of the underlying loess units.

3. Results – Discussion

3.1. Stratigraphy

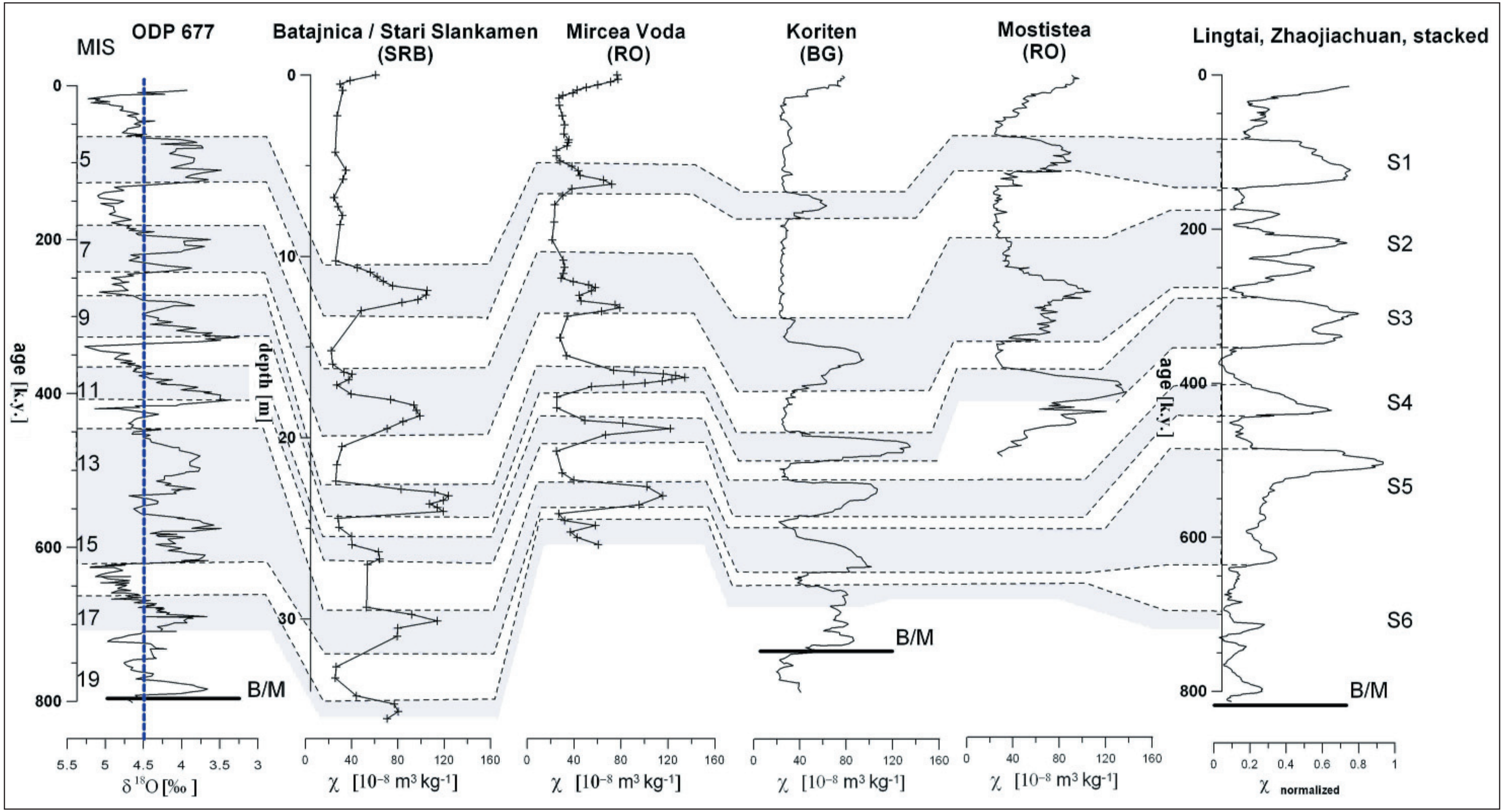
Similar to the Chinese loess records, the magnetic susceptibility of the LPSS in the Danube Basin is enhanced in the paleosols compared to the loess indicating pedogenesis. Though having a relatively low resolution for a stratigraphic work, comparison with other, high resolution records of the Batajnica and Mircea Voda sections (MARKOVIĆ et al., submitted, http://ns.geo.edu.ro/~paleomag/loess-MV.htm) confirms that our dataset reveals the characteristic magnetic susceptibility patterns. These allow the correlation to the astronomically tuned magnetic susceptibility records of the Chinese loess plateau. We can show that the studied part of the sections comprises the last 17 MIS stages. In even lower parts of the Stari Slankamen section, earlier investigations (MARKOVIĆ et al., 2004) identified also the Brunhes-Matuyama (B/M) boundary in a similar stratigraphic position as found in Chinese LPSS (ZHOU & SHACKLETON, 1999).

Besides the B/M boundary in Stari Slankamen, our chronostratigraphic model (Text-Figure 1) is also supported by IRSL dates and the amino acid racemization chronology of the respective pedostratigraphic units in nearby sections (e.g. FUCHS et al., 2008; MARKOVIĆ et al., 2006). Furthermore, it is basically in line with the chronostratigraphic models for the LPSS Koriten and Mostistea (JORDANOVA & PETERSEN, 1999; PANAIOTU et al., 2001).

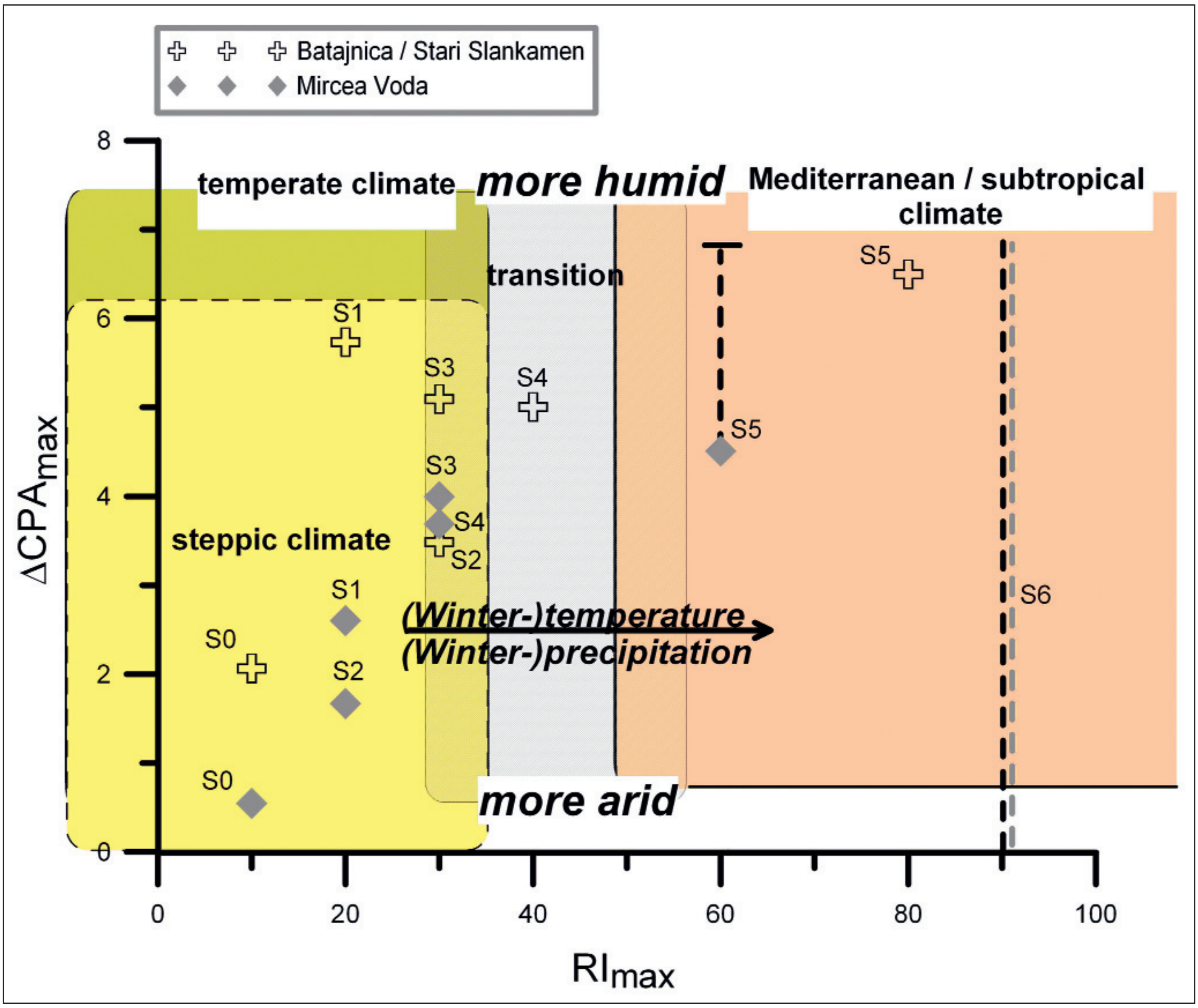
In the following, our nomenclature differences between paleosols (S) and loess layers (L) as correlatives for the respective stratigraphic units in the Chinese stratotype sections of the Quaternary (KUKLA & AN, 1989; see Text-Figure 1).

3.2. Paleoclimatic Interpretation

The maximum RI (RI_{max}) and ΔCPA values (ΔCPA_{max}) obtained for each interglacial pedocomplex are presented in Text-Figure 2. For both, the Serbian and Romanian LPSS, an increase of the rubification intensity to the older pedocomplexes is indicated. This is in line with our field observations, in which the younger pedocomplexes S1 to S3 have been identified as fossil steppe soils. The older ones however, are more reddish, indicating a Mediterranean and subtropical type of climate. In Text-Figure 2, we also show, how we suggest to transfer the applied mineral weathering proxy and rubification proxy into qualitative paleoclimate proxies. Hematite formation is strongly promoted by warm, alternating wet and dry climatic conditions, as they can be found in the Mediterranean and subtropic climate zone, respectively. The present steppe climate conditions are already charac-



Text-Figure 1.
Correlation of the magnetic susceptibility records of the profiles Batajnica / Stari Slankamen (Serbia) and Mircea Voda (Romania) with the astronomically tuned benthic oxygen isotope record from ODP site 677 (SHACKLETON et al., 1990) and with the stacked, normalized magnetic susceptibility curve of Lingtai and Zhaojiachuan (Chinese loess plateau). Data and astronomical tuning of the latter record are taken from SUN et al. (2006). Furthermore the correlation to loess paleosol records in the region i.e. Koriten (Bulgaria; JORDANOVA & PETERSEN, 1999) and Mostistea (Romania; PANAIOTU et al., 2001) are shown. The figure is redrawn and modified after BUGGLE et al. (submitted a).



Text-Figure 2.
ΔCPA_{max} vs. RI_{max} plot, modified after BUGGLE et al. (submitted b). See text (chapter 3.2) for the interpretation of this diagram. Dashed bold lines indicate uncertainty ranges of the ΔCPA_{max}, since the CPA values of the parent loess unit for the Mircea Voda S5 may be biased by pedogenetic overprint and for the S6 no data at all were available to derive background CPA values.

terized by such a wet/dry cycle. However, temperature, especially winter temperature, and (winter) precipitation are lower. Low winter temperatures hinder the decomposition of organic material and the hematite formation in favor of the goethite formation, whereas low (winter) precipitation hamper the formation of the hematite and goethite precursor ferrihydrite (CORNELL & SCHWERTMANN, 2003; BUGGLE et al., submitted b). Thus, increasing values of RI_{max} should in the first line indicate increasing (winter) temperature and in the second line increasing (winter) precipitation. At a given temperature regime i.e. in about the same range of RI, the silicate weathering intensity (ΔCPA) is expected to reflect mainly the humidity. Applying this paleoclimatic transfer of the pedogenesis proxies reveals that temperature and probably also precipitation of the interglacials, especially concerning the winter months, decreased during the Quaternary, at the Serbian as well as the Romanian section. The transition between Mediterranean/subtropical and steppe climate conditions probably occurred during MIS 11, since the Serbian S4 is the youngest pedocomplex having a hue of 7.5 YR, indicating significant amounts of hematite, whereas the Serbian and Romanian S5 fulfill already the criterion for the chromic qualifier. Regarding the humidity conditions, the ΔCPA_{max} indicates that during the past interglacials the Romanian site was more arid than the Serbian one, similar as it is also today.

4. Conclusions

The loess paleosol sequences Mircea Voda (Romania) and Batajnica/Stari Slankamen (Serbia) represent long-term archives of the middle and late Pleistocene climate evolution in SE Europe. The oldest units at the studied part of the sections can be attributed to MIS 17 (~700 ka).

The combination of a silicate weathering proxy and a proxy of hematite may provide valuable paleoclimatic information, also with respect to seasonality.

For the middle and lower Danube Basin, the applied weathering and rubification proxy confirms a transition from a Mediterranean/subtropical climate during the warm stages of MIS 13–15 and MIS 17 to cooler and dryer steppe climate conditions during the younger warm stages. The climate deterioration occurred gradually from one interglacial to the other. The essential change-over between the two different climate systems appeared between MIS 13–15 and MIS 9. There is no evidence that regional climatic trends i.e. higher aridity of the Romanian sites were significantly different from today.

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Manuskript bei der Schriftleitung eingelangt am 5. Juni 2008