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Late Pleistocene and Holocene Climatic Variability in the Carpathian-Balkan Region

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Towards mineral magnetic based millennial time scales in Late Pleistocene Danubian Loess-Palaeosol Sequences

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The understanding of the climate system of the Earth's, its present day state, and the prediction of its future states requires the detailed knowledge of its history. Sedimentary archives are the base of almost any historical approach to the Earth's climate system – the palaeoclimate research. Aeolian dust sediments (loess) are beside marine/lacustrine sediments, peat bogs and arctic ice cores the key archives especially for the reconstruction of the palaeoclimate in the Eurasian continental mid-latitudes. The Eurasian loess-belt has its western end in the Middle Danube (Carpathian) and the Lower Danube Basin. Like in the Chinese Loess Plateau and in the steppe areas of Central Asia and in the regions around the Caspian and the northern Black Sea one can find here true loess plateaus dating back more than one million years and comprising a semi-continuous record of the Quaternary palaeoclimate (Marković et al. 2011, 2012).

In Eurasia, unweathered loess consists predominantly of common silicates and a varying amount of detrital carbonate and reflects the average geochemical composition of the upper continental crust. Large proportions of the poorly sorted medium to coarse silt from which the loess forms has been transported relatively short distances (≤100 km) in contrast to fine grained, long-range-transported or aerosolic dust (cf. Muhs 2013). After deposition the medium to coarse silt undergoes a special diagenetic process called "loessification" which comprises initial silicate weathering, partial carbonate dissolution and re-precipitation as well as the neo-formation of clay minerals. It also controls the complex geochemical dynamic of Iron (Fe) which in turn is responsible for the colour and magnetic properties of the loess. Because all these processes are typical for pedogenesis, "loessification" can be regarded as a weak soil-forming process which is also influenced by microbiological communities (biological soil crusts) (Svirćev et al. 2013, Smalley et al. 2011). Therefore no sharp limit can be drawn between "loessification" and soil formation as long as the detrital carbonate is not completely dissolved and subsequently intense silicate weathering starts.

Following the widespread conventional wisdom in loess research, cold and more importantly dry conditions are generally assumed to lead to relatively high accumulation rates of loess, whereas during warmer and more humid environmental conditions vegetation cover prevents clastic silt production as well as ablation. When more humid conditions predominate, synsedimentary pedogenesis prevails and (embryonic) soil horizons are formed which are rapidly buried by loess as soon as the climate returns to drier conditions. These buried soil horizons are referred to as palaeosols and developed during the humid and warm interglacial phases of the Pleistocene as mature soils, when aeolian silt deposition – as generally assumed – dramatically decreased or even ceased in most parts of western Eurasia. Loess deposits with intercalated palaeosols, so-called loess-palaeosol sequences (LPSS), represent in Eurasia – apart from ice cores and lake sediments – one of the best and most widespread terrestrial archives of Quaternary climatic fluctuations (Hosek et al. in revison, Marković et al. 2012, Muhs 2013).

The LPSS of the Lower Danube and the Carpathian Basin allow inter-regional and trans-regional correlation and, even more importantly, the analysis of temporal and spatial trends in Pleistocene palaeoclimate, even on hemispheric scales (Fitzsimmons et al. 2010, Marković et al. 2011, 2012). However, the general temporal resolution of the LPSS seems mostly limited to (sub)deca-millennial (orbital) scales enabling the correlation of their well documented palaeoclimate record to the marine isotope stages (MIS) and thus to the course of the global ice volume with time (cf. Basarin et al. 2014).

Since the seminal work of Heller & Liu (1984) mineral magnetic parameters became fundamental palaeoclimate proxies in loess research. Magnetic susceptibility (χ) and its dependence on the frequency of the applied field (χ_{fd}) turned out to be beside grain size (GS) and geochemical indices a highly sensitive proxy for temperature and humidity during loess accumulation (cf. Buggle et al. 2014). The application of χ and χ_{fd} as palaeoclimatic proxy in the Eurasian loess steppe environments is based (1) on the mineralogical homogeneity of the loess and (2) on the neo-formation of ferrimagnetic minerals in the course of silicate weathering and pedogenesis. The latter obviously depends largely on the temporal variation of soil humidity and thus the temporal course of palaeoclimate. Thus, increasing pedogenesis goes along with the enhancement of the mineral magnetic signals. However, the properties of a given magnetic assemblage in loess do not only depend on the concentration and mixture of the minerals, but largely on the grain size distribution of the magnetic particles. For a given mineral, χ varies over orders of magnitude depending only on grain size, being largest for very fine so-called superparamagnetic (SP) particles. These SP-particles mainly precipitate from weathering solutions and provide therefore a sensitive soil humidity proxy.

Recent studies on GS trends across the Chinese Loess Plateau (CLP) revealed palaeoclimatic fluctuations on millennial scale which were correlated to the Dansgaard-Oeschger (D-O) events known from the Greenland Ice Cores (GIC) (Yang & Ding 2014). Similar GS trends were already observed more than a decade ago for intervals of the Upper Pleistocene loess from Nussloch (Germany) (Antoine et al. 2001, Gocke et al. 2014). However, a mineral magnetic record of intervals from Upper Pleistocene loess showing D-O scale palaeoclimate variability is – to our knowledge – only documented for the Krems-Wachtberg site (Lower Austria) (Hambach 2010, Terhorst et al. in press).

In order to investigate the potential of Danubian loess in recording millennial palaeoclimate variability, Upper Pleistocene and pre-last glacial LPSS from the southern Carpathian Basin (Titel-Plateau) and the eastern Lower Danube Basin (Dobrogea, Urluia quarry) were sampled in high resolution (5 to 2 cm spacing).

LPSS preserved in these regions are exceptionally complete and as such represent one of the most detailed European terrestrial climatic records available, made especially valuable by their spatial extent. The better preservation of Danubian loess in comparison to that to the North and West is – as generally assumed– most likely related to the continuous presence of much drier climatic conditions in this region and the persistence of stable 'plateau-facies' of accumulation. This relatively dry climate may also further explain why the loess climate record there shows some similarities to Chinese and Central Asian records. Climate is a key factor of any environment and has extensive influence also on human evolution. Hence, the loess in the Danube Basin is not only an outstanding archive of palaeoclimate but also of the record of Palaeolithic cultures. As the lower and middle Danube River valley and its major tributaries has long been proposed to represent one of the major migration routes for humans into Europe, the Titel loess plateau at the confluence of Tisza into the Danube and the southern Dobrogea situated between Danube and Black Sea coast represent key sites for the documentation of possible human-environmental interaction and Pleistocene environmental change.

In April 2013, we drilled a 22 m deep core in the northern Titel loess plateau (Vojvodina, Serbia; see figure 1) and beginning of May 2014, a more than 15 metres thick LPSS in the southern Dobrogea (Romania) was contiguously sampled. Both sides will provide us deep insight into the palaeoclimate of the regions down to MIS 7/MIS 6, respectively.

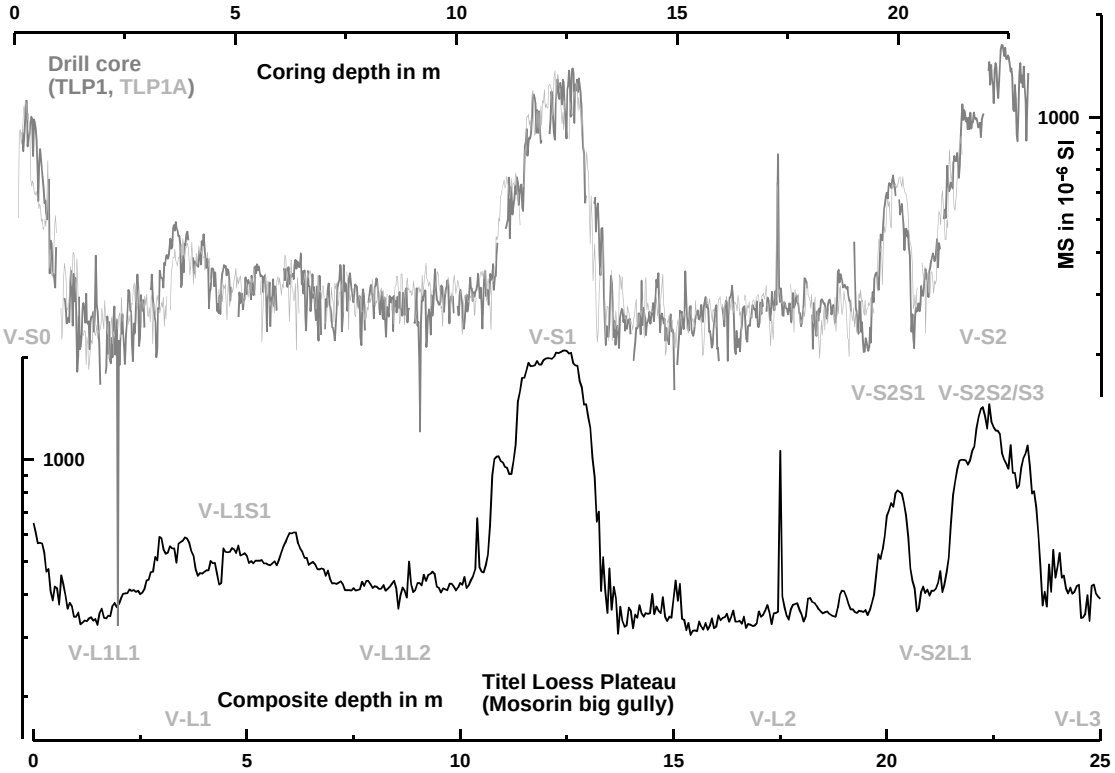

Fig. 1 Ms record of the last two climatic cycles (MIS 0 to MIS 7) from the Titel-Plateau (Serbia). Data from an outcrop (5 cm spacing) are displayed below. Data from two overlapping cores (2 cm spacing) drilled nearby are shown above. Though, the data from the two cores are not perfectly adjusted variations on dm-scale (≅ kyr) are evident.

Here, we shall discuss the down-core/down-section variability (temporal) of χ and χfd as palaeoclimatic proxy parameters. Based on these mineral magnetic proxies we can already draw the following astonishing conclusions:

1) The dust accumulation rates in both regions were relatively constant over the past 130 kyrs, even during full interglacial conditions.

2) In the studied sections, the pedo-complex S1 represents the Eemian and NOT the entire MIS 5, as previously thought.

3) There are a lot of similarities between the mineral magnetic records of the Vojvodina and the Dobrogea and also between these records and those from the Chinese Loess Plateau, but also fundamental differences.

Sedimentological, geochemical, geochronological and palaeomagnetic investigations are in progress. They will hopefully provide further high quality data sets leading to an improved understanding of the Late Pleistocene environmental evolution in the Danube Basin.

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