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The Mono Lake geomagnetic excursion recorded in loess: Its application as time marker and implications for its geomagnetic nature

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One of the youngest and worldwide documented geomagnetic excursions in the Brunhes Chron is the Mono Lake excursion (MLE). It has been detected in marine and terrestrial sedimentary archives as well as in lavas. Recent age determinations and age estimates for the MLE centre around an age interval of approximately 31 – 34 ka. Likewise the Laschamp excursion the MLE goes along with a distinct peak in cosmogenic radionuclides in ice cores and sedimentary archives. It provides therefore an additional geomagnetic time marker for various geoarchives to synchronise different climate archives.

Here we report on a detailed record of the MLE from a loess site at Krems, Lower Austria. The site is situated on the southern slope of the Wachtberg hill in the vicinity of the old city centre of Krems. The archive comprises Middle to Upper Würmian (Late Pleistocene) loess in which an Upper Palaeolithic (Early Gravettian) cultural layer is embedded. The most spectacular finds are a double infant burial found in 2005 and a single burial discovered in 2006 (Einwögerer et al., 2006). Generally, archaeological findings show an extraordinarily good preservation due to embedding in rapidly sedimented loess (Händel et al., 2008).

The about 10 m thick loess pile consists of calcareous sandy, coarse silt which is rich in mica indicating local sources. It is well stratified with brownish horizons representing embryonic soils pointing to incipient pedogenesis. Some of the pedo-horizons show occasionally indications of minor erosion and bedding-parallel sediment transport, but no linear erosional features. Pale greyish horizons are the result of partial gleying under permafrost conditions. No strong pedogenesis including decalcification and clay formation is present. The cultural layer is still covered by more than 5 m of loess, and dated by radiocarbon to $\sim$27 ka 14C BP (Einwögerer et al., 2006). Below this layer up to 2.5 m of loess resting on Lower Pleistocene fluvial gravels are preserved. Thus, the loess section represents a palaeoclimatic record of alternating cold-dry and warm-humid conditions on millennial scale. Optical stimulated luminescence dating of aeolian loess around the cultural layer reveals ages of 30 to 32 ka which is supported by thermoluminesence dating of burnt loess from a hearth belonging to the archaeological living floor.

In summer 2005 and 2006, two overlapping sections were continuously sampled in for palaeomagnetic investigations. The sampled sections are located outside the centre of the main archaeological occupation in the northwestern corner of the excavation pit. Sample spacing is strictly 2.1 cm, measured from centre to centre of the specimens. In total, 432 individually oriented specimens were recovered from the almost 8 m thick section.

Magnetic susceptibility (MS) as function of depth resembles generally the lithology. Low MS-values represent pure unaltered or weakly gleyed loess, whereas higher values represent the enhancement of magnetic minerals caused by incipient soil formation. Anhysteretic remanent magnetisation (ARM) versus MS reveals an enhancement of super-paramagnetic particles where MS is increased. Consequently, the rock magnetic variations with depth can be taken as a palaeoclimatic record representing the climatic variations between drier and slightly more humid conditions at the transition from Middle to Upper Pleniglacial. Based on the ARM/MS record a correlation of the geoarchive at the Krems-Wachtberg site with the NORTH-GRIP isotopic record (NGRIP Members, 2004) and with sedimentological data from Maar-lake sediments of the Eifel area (ELSA; Schaber and Sirocko, 2005), Germany can be established. The general correlation suggests the dating of the loess at the excavation site to a time interval between approx. 20 to 40 ka, covering Greenland interstadials (GI) 2 to 8 and Heinrich Events 3 and 4 (top). The Gravettian living floor is assigned to the base of GI 5 and thus to an age of 32 to 33 ka.

The directional palaeomagnetic record is of high quality and shows variations in the bandwidth of secular variation in the upper and in the lower part of the section, whereas in the central part shallow ($\leq 30^\circ$) and oversteep inclinations reveal the record of a geomagnetic excursion just above the find horizon. The shallow inclinations are preceded by and go along with westerly declinations, whereas the steep inclinations are preceded by easterly declinations. This directional pattern is similar to what was found at the Mono Lake in California (e.g. Liddicoat and Coe, 1979; Lund et al., 1988). A relative palaeointensity (RPI) record was constructed by using MS and ARM as normalisers. This record corresponds quite well to the GLOPIS (Laj et al., 2004) and thus provides additional dating. The peak of the directional excursion coincides with a relative minimum of RPI. The average RPI during the excursional interval, however, is significantly higher than during normal periods, contrary to what is usually reported. Furthermore, just before and after the directional excursion the highest values of RPI occur. The largest amplitude of the directional excursion does not correspond to the well defined minimum in RPI preceding this interval which is usually taken for the MLE in the marine RPI records. This offset between the RPI and the directional record may indicate the presence of strong non-dipole components and may also explain the blur in dating of the MLE. The calculated VGPs of the directional excursion lie over North America but do not correspond to the looping behaviour as reported from the Mono Lake VGPs itself (Liddicoat and Coe, 1979).

The cultural layer at the Krems-Wachtberg site is located in the centre of the RPI minimum which is slightly older than the peak of the directional excursion. The radiocarbon ages from the cultural layer ($\sim$27 ka 14C age BP = $\sim$32 ka calendric age calBP) fit well to the age estimates of the MLE at the Mono Lake based on radiocarbon dating and tephrochronology (31.5 – 33.3 ka; Benson et al., 2003). Furthermore, the recently published 40Ar/39Ar ages of one excursional group (Auckland cluster 1: 31.6 $\pm$ 1.8 ka) from the Auckland volcanic field, New Zealand correspond to the ages discussed above. Thus, the MLE is a perfect time marker occurring globally but is probably dominated by strong non-dipole components.

Benson et al. (2003). Quaternary Science Reviews, 22,135–140; Cassata et al. (2008). Earth and Planetary Science Letters, 268, 76–88; Einwögerer et al. (2006). Nature, 444, 285; Händel et al. (in press). Quaternary International; Laj et al. (2004). Geophysical Monograph Series, 145, 255-265; Liddicoat and Coe (1979). Journal of Geophysical Research, 84, 261–271; Lund et al. (1988). Geophysical Research Letters,15,10, 1101-1104; North Greenland Ice Core Project Members (2004). Nature 431, 147-151; Schaber and Sirocko (2005). Mainzer geowiss. Mitt., 33, 295-340.