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Magnetic Dating of an Upper Palaeolithic Cultural Layer Bearing Loess from the Krems-Wachtberg Site (Lower Austria)

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Niederösterreich
Paläolithikum
Löss
Paläomagnetismus
Magnetische Suszeptibilität
Magnetische Datierung

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Magnetische Datierung eines jungpaläolithischen Lösses mit Kulturhorizont von Krems-Wachtberg (Niederösterreich)

Zusammenfassung

Paläo- und gesteinsmagnetische Datierungsverfahren wurden auf das Lössarchiv am Wachtberg in Krems (Niederösterreich) angewandt, das einen jungpaläolithischen Kulturhorizont birgt. Dieser Datierungsansatz ergibt ein Sedimentationsalter von 20–40 ka für den Löss und ein Alter von 32–34 ka für den Begehungshorizont des Gravettien. Die geomagnetische Mono-Lake–Exkursion ist zur Gänze aufgezeichnet und ermöglicht die Korrelation zwischen dem Lössarchiv am Wachtberg und einer großen Bandbreite von zeitgleichen Paläoklimaarchiven.

Abstract

Magnetic dating techniques were applied to the loess archive at the Wachtberg in Krems (Lower Austria) in order to assess the age of the loess itself and to date the Upper Palaeolithic cultural layer which is preserved in the loess. This dating approach results in an age interval of about 20 to 40 ka for the loess and of 32 to 34 ka for the Gravettian living floor. The Mono Lake geomagnetic excursion is fully recorded and provides correlation between the loess archive at the Wachtberg and a wide range of contemporaneous palaeoclimatic archives.

1. Introduction

The loess archives on the Wachtberg in Krems contain Upper Palaeolithic cultural layers which can be assigned to the Aurignacian and Gravettian cultural stages. Since 2005, a Lower Gravettian cultural layer is investigated on the southern slope of the Wachtberg in the vicinity of the old centre of the city of Krems. The excavations are conducted by the Prehistoric Commission of the Austrian Academy of Sciences under the lead of Dr. Christine

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NEUGEBAUER-MARESCH. The archive comprises Middle to Upper Würmian loess in which the Lower Gravettian find horizon 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, findings show an extraordinarily good preservation due to embedding in rapidly sedimented loess (HÄNDEL et al., 2008).

Here we applied magnetic dating techniques in order to establish an independent age model for the loess and for the archaeological horizon therein. Magnetic dating comprises all approaches dealing with the temporal variation of the Earth's magnetic field (EMF) as well as with the application of climate dependent variations of rock magnetic properties of sedimentary sequences and their correlation to independently dated palaeoclimatic archives. Palaeomagnetic dating employs the temporal variation of the direction as well as the intensity of the EMF on time scales from 10^2 to 10^7 years. The well-known temporal pattern of reversals of the EMF on time scales from 10^4 to 10^7 years and the shorter secular variation (amplitude 10–30°, time scale 1 to 10^3 years) provide an excellent tool for stratigraphic subdivisions and correlations. Records of the intensity variations of the EMF also serve as dating tools (HAMBACH et al., 2008).

Short-lived changes of the EMF (in the order of 10^3 years) in direction and intensity are called geomagnetic excursions. If their chronology is known, they are perfect time markers, especially in sequences that are hardly datable by other methods. Between 20 and 50 ka two excursions seem to occur globally. The Mono Lake (32–34 ka) and Laschamp (40–42 ka) geomagnetic excursions have been recorded in marine and terrestrial sedimentary archives as well as in lavas from Hawaii. The Mono Lake geomagnetic excursion (MLE) is among the youngest and one of the earliest found and better-documented excursions in the Brunhes Chron. Recent age determinations and age estimates for the MLE centre around an age interval of approximately 32–34 ka.

Our magnetic dating approach can not only date the cultural layer but the complete loess sequence itself. Furthermore, the palaeomagnetic record implies direct consequences for the calibration of radiocarbon dating, as the magnetic field is the main factor controlling the production of ^{14}C in the atmosphere.

2. Setting, Sampling and Methods

The city of Krems is located in the Danube valley upstream Vienna. The archaeological excavations at Krems are situated on a ridge called Wachtberg near the confluence of the rivers Krems and Danube at ~250 m asl. The cultural layer is imbedded in about 8 m thick loess, and dated by radiocarbon to ~27 ka (uncal.) BP (EINWÖGERER et al., 2006). It is still covered by more than 5 m of loess. Below the layer up to 2.5 m of loess resting on fluvial gravels are preserved. The loess consists of sandy, coarse silt rich in mica, indicating local sources. It is well stratified with brownish horizons representing "embryonic soils" pointing to incipient pedogenesis. Some of the pedohorizons show occasionally indications for minor erosion and bedding-parallel sediment transport, but no linear erosional features. Pale greyish horizons are the result of partial gleying during permafrost conditions. Thus, the loess section represents a palaeoclimatic record of alternating cold-dry and warm-humid conditions on millennial scale.

The almost 8 m thick loess pile was continuously sampled in two overlapping sections using brass tubes with quadratic profile of 2 cm width. The sharpened brass tubes could be easily pushed into the loess without any deformation of the sediment. The recovered loess-prisms were then carefully pushed out of the tube and inserted into a cubic plastic box. Sample spacing is strictly 2.1 cm, measured from centre to centre of the specimens. Full spatial orientation is provided by magnetic compass measurements. In total, 432 individually oriented specimens were recovered from the section.

All specimens were subjected to standard rock and palaeomagnetic laboratory procedures in order to reveal their rock magnetic characteristics and to decipher the directional trends of the past Earth magnetic field stored in the sediment. For the isolation of the characteristic remanence, showing the direction and intensity of the EMF at or shortly after deposition, we used standard step-wise alternating field demagnetisation. The course of initial volume susceptibility (?) and so-called anhysteretic remanent magnetisation (ARM) with depth is discussed here. These data are used as first order proxies for pedogenesis and thus as proxies for the palaeoclimatic trend recorded in the loess. A relative palaeointensity record was constructed by using the ARM as normaliser of the determined intensity of the characteristic remanence.

3. Results and Discussion

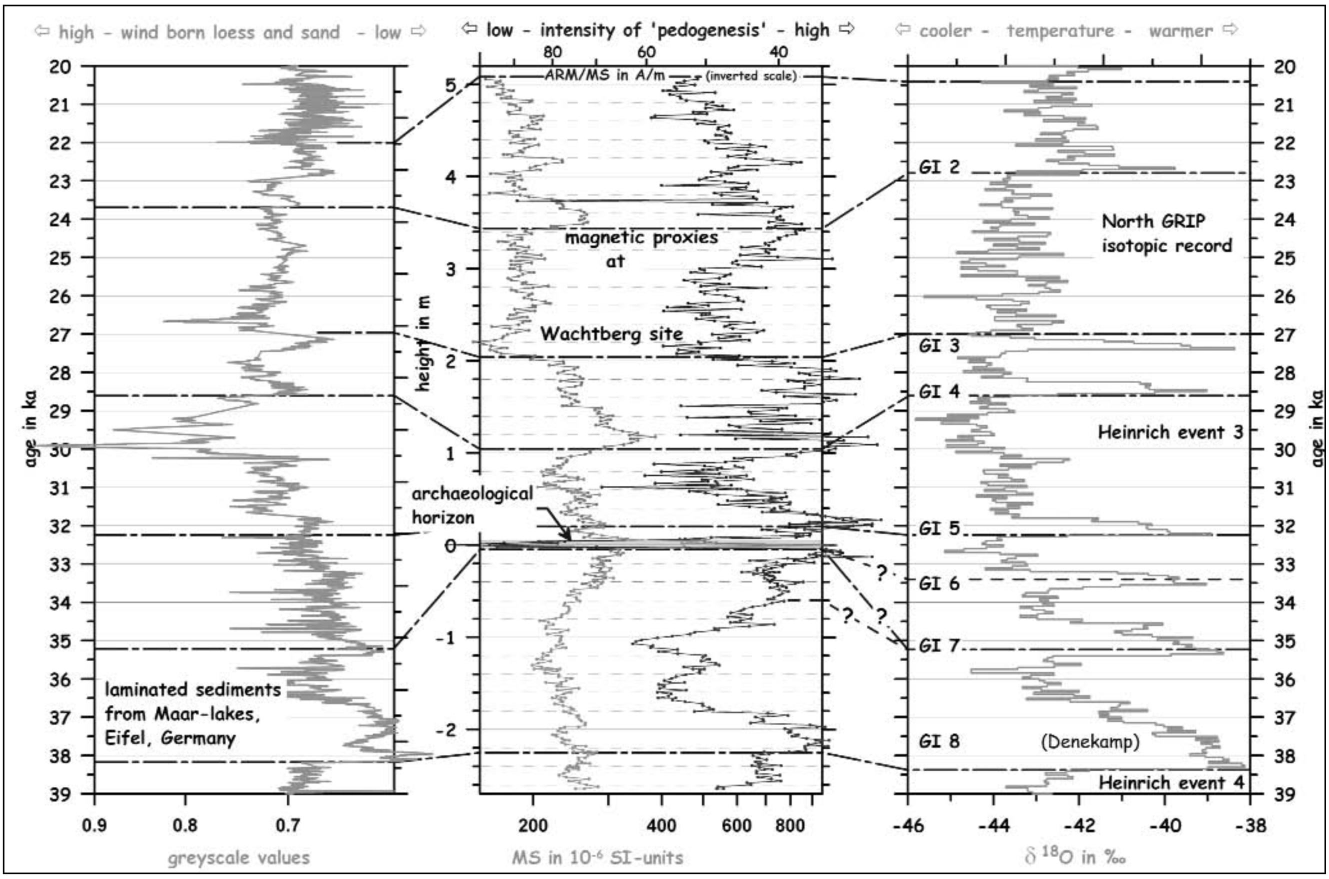
The sampling 2005 started about 0.4 m below the archaeological horizon. In the 1.5 m just above the living floor a geomagnetic excursion is recorded, which is a probable representation of the MLE. The depth interval containing the excursion was sampled at two different walls (2005 and 2006) of the excavation pit. The results show an almost identical rock magnetic and palaeomagnetic signal. Details of the palaeomagnetic directional record will not be discussed here. These results are the topic of a future paper.

3.1. Environmental Magnetism

Environmental magnetism is rock and mineral magnetism applied to environmental questions. It deals with the magnetism of sediments and soils and describes the occurrence, abundance and properties of iron-bearing minerals in the environment: When we study the magnetic properties of sediments and soils as proxies for environmental change, we study the physical (magnetic) properties of the sedimentary recorder of our palaeomagnetic signal.

The magnetic susceptibility (κ) as function of depth resembles generally the lithology. Low κ-values represent pure unaltered loess, whereas higher values represent the enhancement of magnetic minerals caused by incipient soil formation. The record shows quasi-periodic variations and decreasing values towards the top of the section indicating decreasing concentration of magnetic minerals probably caused by increasing aridisation with time (Text-Fig. 1).

Anhysteretic remanent magnetisation (ARM) versus κ reveals an enhancement of superparamagnetic particles. Consequently, the κ-variations together with ARM/κ (inverted scale) are 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 κ-record a correlation of the loess pile at the Krems-Wachtberg site with the North-GRIP isotopic record (NORTH GREENLAND ICE CORE PROJECT MEMBERS, 2004) and with sedimentological data from Maar-lake sediments of the Eifel area (ELSA; SCHABER & SIROCKO, 2005), Germany, can be established. The greyscale record from the Eifel Maar-lake sediments are interpreted as a measure for the dust input and thus for dry and cold climatic conditions. This record correlates well with the temperature record derived from the North-GRIP ice cores. Text-Fig. 1 shows the much clearer correlation of the environmental magnetic parameters to the North GRIP



Text-Fig. 1.
Correlation of the environmental magnetic record of the Krems-Wachtberg loess section to independently dated palaeoclimatic records from the Eifel Maar-lakes (left; SCHABER & SIROCKO, 2005; http://www.uni-mainz.de/FB/Geo/Geologie/sedi/) and from the Greenland ice shield (right; NORTH GREENLAND ICE CORE PROJECT MEMBERS, 2004). Volume susceptibility (κ) and ARM/κ (note the inverted scale) serve as proxies for the intensity of pedogenesis and thus for change of palaeoclimate with time.
The correlation of the environmental magnetic parameters to the North GRIP isotopic record is much clearer than to the Eifel Maar-lakes greyscale record. The possibility of an erosional gap below the archaeological horizon leads to alternative correlations. For further details see text.
Modified after HAMBACH (submitted).

isotopic record than to the Eifel Maar-lakes greyscale values. The general correlation suggests the dating of the loess at the excavation site to a time interval between 20–40 ka, covering Greenland interstadials (GI) 2–8 and Heinrich Events 3 and 4. The Gravettian living floor is assigned to the base of GI 5 and thus to an age of 32–33 ka. However, the possibility of an erosional gap below the archaeological horizon leads to alternative correlations for the loess below (HAMBACH, submitted).

3.2. Palaeomagnetic Directions

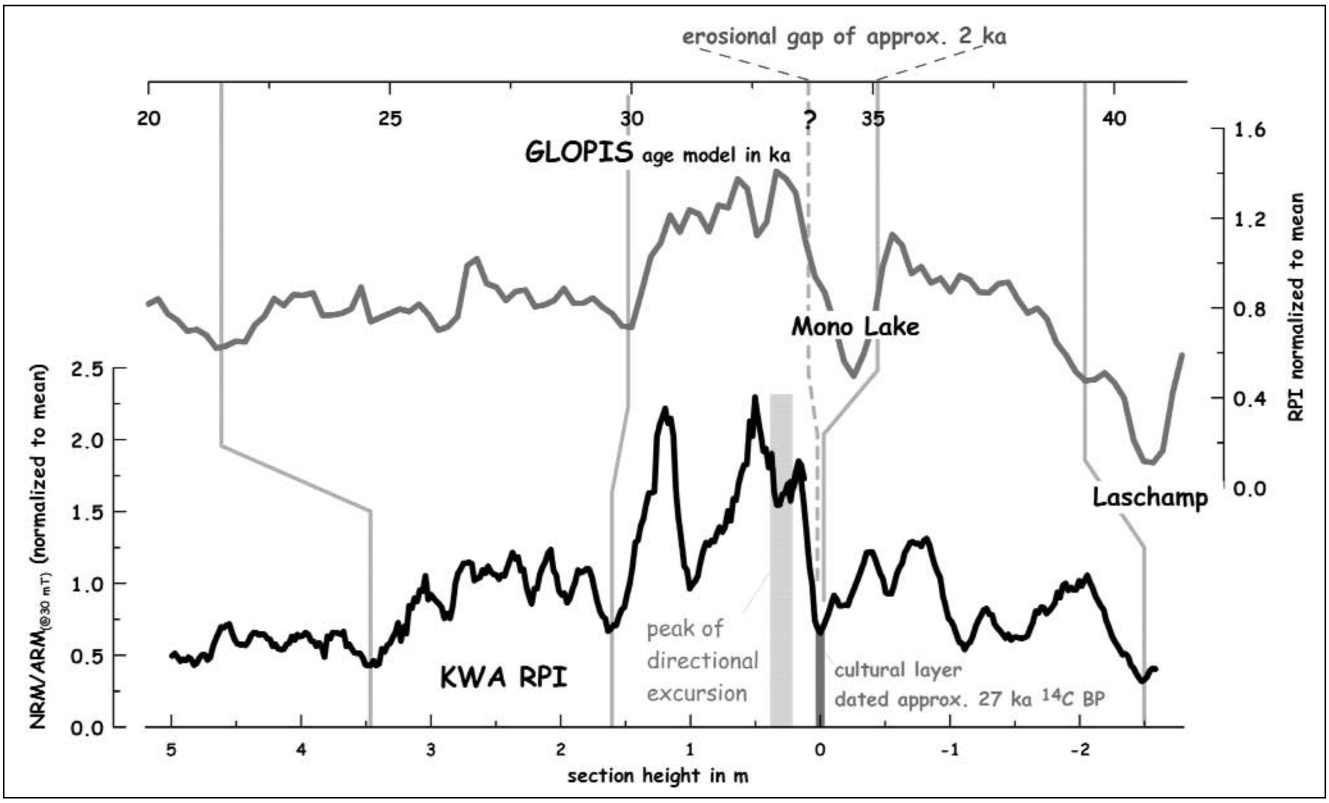
The directional palaeomagnetic record is of high quality and shows variations in the bandwidth of secular variation in the upper and in the lower part of the section, whereas in the central part shallow and oversteep inclinations reveal the record of a geomagnetic excursion. The shallow inclinations are preceded by and go along with westerly declinations, whereas the steep inclinations are preceded by easterly declinations. This looping behaviour is a typical feature for the MLE which was found almost worldwide. The directional anomaly of the MLE covers a few thousand years but culminates in its older part which is dated to 32–34 ka (LAJ & CHANELL, 2007). As the archaeological horizon lies immediately beneath the loess containing the excursion, its age is only slightly higher.

3.3. Relative Palaeointensity

A relative palaeointensity (RPI) record was constructed by using ARM as normaliser. This record corresponds quite well to the marine RPI stacks and thus provides additional dating. The correlation of this record to the global palaeointensity stack (GLOPIS; LAJ et al., 2004) yield a time interval from approximately 20–40 ka for the formation of the loess at the excavation site (Text-Fig. 2). The loess containing the archaeological horizon as well as the loess below and above reveal a minimum in RPI which is correlated to the intensity minimum assigned to the MLE which in turn centres in North Atlantic marine sediments on Greenland interstadial 6 (33–34 ka in North-GRIP time scale). All in all the Wachtberg RPI record shares considerable similarity with the GLOPIS, indicating onset of loess sedimentation just after the Laschamp geomagnetic excursion and revealing ages around 20 ka for the youngest loess (HAMBACH et al., submitted).

4. Conclusions

Unlike the situation in western Central Europe, where interstadial palaeosols interrupt the loess sequences, the loess in Lower Austria yields a quasi-continuous sedimentary archive of the upper Middle to the Late Würmian. A similar loess facies can be found further to the East in the Middle and Lower Danube basins (Hungary, Serbia, Romania, Bulgaria [MARKOVIĆ et al. 2008]). There, Middle Würmian interstadial palaeosols are developed only in relatively humid settings (windward position of mountain regions), whereas in most of the area contemporaneous palaeosols are hardly developed. Even quite pronounced interstadials



Text-Fig. 2.
The relative palaeointensity (RPI) record from the loess section at the Wachtberg in Krems and the global palaeointensity stack (GLOPIS; LAJ et al., 2004). The Mono Lake and Laschamp geomagnetic excursions are characterised by pronounced intensity lows. Age (GLOPIS) and depth (from left: shallow, young to right: deep, old) are plotted on the abscissa vs. the RPI. Light grey lines indicate suggested correlations; the cultural layer dated by radiocarbon is indicated. Modified after HAMBACH et al. (submitted).

like GI 8 which is seen as the correlative of the Denekamp (HAMBACH, submitted), are only recorded as incipient pedohorizons.

Our magnetic dating approach revealed three independent age estimates for the archaeological horizon:

* The general correlation of the environmental magnetic signal to independently dated palaeoclimatic records suggests the dating of the loess at the excavation site to a time interval between 20 to 40 ka. The Gravettian living floor is assigned to the base of GI 5 and thus to an age of 32 to 33 ka.
* The directional signal of the past Earth's magnetic field revealed just above the archaeological layer the record of the MLE which is dated to 32–34 ka. Thus, the age of the Gravettian living floor is only slightly higher (<1 ka).
* The investigation of the intensity of the palaeomagnetic signal results in a reliable and comparable RPI record with a characteristic pattern correlable to the GLOPIS in the time interval from approximately 20 to 40 ka. The loess containing the archaeological horizon as well as the loess below and above reveal a minimum in RPI which is correlated to the intensity minimum assigned to the MLE which in turn centres in North Atlantic marine sediments on Greenland interstadial 6 (33–34 ka in North-GRIP time scale).

The environmental magnetic and the RPI record allow for the construction of independent age models. Both models see the onset of sedimentation just after 40 ka and the cessation around 20 ka. Sedimentation rates calculated on the basis of these models range from 0.2 to 0.7 m/ka with average values of 0.41 m/ka for the age model based on the environmental magnetic record and of 0.34 m/ka for the age model derived from the RPI record.

The calibration of the available radiocarbon dates from the archaeological horizon (EINWÖGERER et al., 2006) using "Calpal-Online" (http://www.calpal-online.de/) leads to ages ranging from 31 to 32 ka. These ages are still slightly younger than the age interval of 32 to 34 ka derived from magnetic dating. This difference might be explained by an offset between the age models used in "Calpal-Online" and in our magnetic dating approach.

The high-resolution environmental magnetic and palaeomagnetic record from the Krems-Wachtberg excavation site clearly emphasises the yet largely undiscovered but high potential of archaeology bearing quasi-continuously deposited loess sites for palaeo- and rock magnetic studies.

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