

**THE COMPARATIVE ANALYSIS OF THE MAGNETIC FABRIC OF HUNGARIAN
LOESS AND THEIR ROLES IN THE PLEISTOCENE ENVIRONMENT
RECONSTRUCTIONS**

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Ph.D. Theses

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2014

1. Introduction

In my dissertation Hungarian loess and paleosol samples were investigated by anisotropy of magnetic susceptibility (AMS) measurements; a well spread method in palaeomagnetic studies. The AMS measurements were completed by isothermal remanent magnetization, frequency dependence of magnetic susceptibility, and scanning electron microscope studies. The investigation of the magnetic fabric of Hungarian loess was a new method in Hungarian Quaternary studies and the first results were followed by lot of questions connected to classification of loess or environment reconstructions (Bradák, B. 2009; Bradák, B. et al. 2011; Bradák, B. – Kovács, J. 2013 in press).

2. Investigated profiles

In the first period the overlaying loess of Bag Tephra were sampled to determine the wind direction or the direction of accumulation of dust during the deposition of tephra (Bag Basaharc, Dunaszekcső, Galgahévíz, Hévízgyörk, Isaszeg Sióagárd). (Bradák, B. 2009). In the second period the research focused on the separation of the magnetic fabric of typical and reworked loess (Hévízgyörk, Lovasberény, Vácbotyán, Verőce). In the third phase of the investigation the main goal was to reveal the connection between the magnetic fabric of different kind of layers sampled in the same section (Cérnavölgy) (Bradák, B. et al. 2011; Bradák, B. – Kovács, J. 2013 in press)

3. Sampling and methods

A 'brick size' of loess samples were cut out from loess walls and inclination and declination were measured by compass during sampling. In a laboratory 'loess sample cubes' (2×2×2 cm) were created from bigger samples and the direction of sampling was marked in every cube. The magnetic mineralogical studies were conducted on the samples originated from cérna Valley profile collected in cylindrical plastic boxes.

Magnetic susceptibility of the sample-cubes was determined by KLY-1 and KLY-2 Kappabridge instrument. Fifteen measurements were performed on all samples following the Jelinek-method. The value and direction (inclination and declination) of the principal susceptibilities (κ_{\max} , κ_{int} , κ_{\min}) were determined by computer analysis (Aniso — anisotropy

program package for IBM PC. ELGI, Budapest, Bordás R, 1990). The magnetic foliation, lineation and the degree of anisotropy were defined by the formula of NAGATA, T. (1961; $P = \kappa_{\max} / \kappa_{\min}$), BALSLEY, J. R. – BUDDINGTON, A. F. (1960; $L = \kappa_{\max} / \kappa_{\text{int}}$), STACEY, F. D. et al, (1960; $F = \kappa_{\text{int}} / \kappa_{\min}$) and HROUDA, F. ET AL. (1971; $\kappa_{\text{int}}^2 / (\kappa_{\max} \times \kappa_{\min})$)

To complete the AMS measurements, pilot sample from Hévízgyörk profile was chosen to determine the magnetic mineral composition by isothermal remanent magnetization (IRM). To determine the multi- (MD) or single-domain (SD) character of ferromagnetic minerals, the IRM study of samples is completed by the Cisowski-test (Cisowski, 1981). One Hévízgyörk1 pilot sample is demagnetized on 70 mT by LDA-2A alternating field demagnetizer. In the first part of the experiment this sample is magnetized again in 18 steps by pulse magnetizer (fields from 20 to 1000 mT). The intensity of the sample is measured in every step by JR4 magnetometer. In the second part of the experiment the magnetized sample is demagnetized in alternating field from 3 to 70 mT by a LDA-2A demagnetizer and the intensity is measured again.

The frequency dependence of magnetic susceptibility is the rate of the magnetic susceptibility of the sample measured at low (460 Hz; κ_{LF}) and high (4.6 kHz, κ_{HF}) frequency ($\kappa_{\text{FD}} = 100(\kappa_{\text{LF}} - \kappa_{\text{HF}}) / \kappa_{\text{LF}}$). A Bartington MS2 was used to determine the low and the high field susceptibility of the samples. The frequency dependence of samples with lower susceptibility than $\kappa_{\text{LF}} = 20 \times 10^{-5}$ SI unit was not determined due to the high probability of error. The different rate of frequency dependence of susceptibility is indicative of fine grained superparamagnetic minerals which formed during pedogenesis in soils.

4. Thesis

Thesis 1. The possibility of the application of the method on samples originated from „spot like” sampling. The first measurements were elaborate to test the possibilities of the method on the Hungarian loess samples. The possibility of the application of the AMS measurements on different kinds of loess was revealed during the test measurements. **The magnetic fabric of loess samples are anisotrop, can be analysed and the results can be used during the further environmental reconstructions**

Thesis 2. The possibilities and critics of the application of statistical-analytical methods applied on the AMS results of the Hungarian loess. The magnetic fabric of different kinds of materials was characterized by P (degree of anisotropy), F (foliation), L (lineation) and E

(shape of susceptibility ellipsoid) parameters (calculated from the κ_{\max} , κ_{int} , κ_{\min} values). Different kinds of statistical analysis were elaborated based on the calculated parameters. Numerous methods have been elaborated since the 1960s (e.g. histogram analysis, Flinn-, Jelinek- or Tauxe diagram) on the analysis of AMS parameters, however the different kinds of Chinese loess versions were classified only by Liu, X. et al, (1988). Opposite to the analysis of Chinese loess variation, which focused only on two different version of loess like sediments, the statistical analysis of Hungarian loess elaborated on numerous kind of loess variations. **The statistical analysis of the loess focused on the classification of Hungarian loess variation. Some main type (typical loess, redeposited loess) can be separated by the statistical analysis, but there are overlapping between the groups and the characterization was not convincing.**

Thesis 3. The role of the AMS results and analytical methods in the environmental reconstruction. Beyond the statistical analysis of the AMS parameters the most important analytical method is the stereographical projection of the direction of principal susceptibilities. This method was the most adaptable during the analysis of the magnetic fabric of Hungarian loess samples.

The parameters of the magnetic fabric can be characterized by the arrangement of the directions of principal susceptibilities or the grouping of directions. Beyond the characterization of the AMS parameters the environment of dust deposition (palaeowind directions, directions of depositions, palaeogeomorphology), the post depositional effects (redeposition, reworking by biological processes or pedogenesis) are revealed by the detailed analysis of stereoplots. **The complex environment reconstructions based on the analysis of the directions of the texture of different kind of Hungarian loess or paleosol layers go beyond the previous studies** (e.g. BEGÉT, J. E. et al 1990; LAGROIX, F. - BANERJEE, S. K. 2002, 2004a, b; MATASOVA, G. et al. 2001; MATASOVA, G. - KAZANSKY, A. Y. 2004; NAWROCKI, J. et al. 2006). These studies mainly focused on the determination of palaeowind directions.

Thesis 4. The determination of the magnetic composition of Hungarian loess and paleosol samples. One of the most important parts of the AMS measurements is the determination of the magnetic mineral component of the fabric. **The main component of the magnetic fabric of the Hungarian loess is the ferromagnetic, coarser grain, multidomain magnetit based on the magnetic mineralogical experiments (e.g. isothermal remanent magnetisation, saturation remanent magnetization, frequency dependence of magnetic susceptibility, Cisowski-test).** In the fabric of the paleosols an increasing amount of fine grained, single

domain magnetite was detected. The appearance of this component was connected to pedogenic processes.

Thesis 5. Complex analysis of the development of the magnetic fabric based on the investigation of the different layers of a profile. Beyond the statistical analysis of the samples from “spot like” sampling a detailed investigation of a loess/paleosol sequence (Cérna Valley, Vértesacska) was elaborated to reveal the possible connection between the magnetic fabric of loess, redeposited loess and paleosol layers. Two different kind of new magnetic fabric were identified in Cérna Valley loess and paleosol samples. These kind of magnetic fabric haven't been identified in loess or paleosols yet. Higher degree of redeposition and higher energy of the paleocurrents were identified by the pencil fabric of redeposited loess and vertical pedogenic processes were revealed by the inverse fabric of some paleosol layer.

A complex model of the different palaeoenvironments during the glacial (or stadial), interglacial (or interstadial) and the transition period were generated based on the different parameters of magnetic fabric and magnetic mineral composition of the layers of Cérna Valley. A dynamic approach during the analysis of magnetic fabric was revealed by creating the model which point out the next direction in the analysis of magnetic fabric of Hungarian loess/paleosol sequences.

Thesis 5. The dynamic approach versus the classification viewpoint during the analysis of the magnetic fabric – future perspectives. From the simple statistical analysis of AMS parameters to the detailed interpretation of the magnetic fabric a complex nature of the magnetic fabric of Hungarian loess and paleosol samples were revealed.

The really clear classification of the Hungarian loess variation was not possible by different kind of the statistical analysis, only some main group could be separated. Before a really detailed classification a dynamic approach would be useful to understand the development of magnetic fabric from the deposition to the redeposition or pedogenesis. The main groups of the statistical analysis revealed the “states” of magnetic fabric (e.g. degree or level of redeposition or pedogenesis). The connection between the “states” could be characterized by the overlapping groups or “transient fabrics” during the classification. Detailed description of the processes and the different palaeoenvironments are revealed by the complex and “dynamic” analysis of these fabrics.

Thesis 5a. Characterization of the fabric of typical loess from Hungary

The dust was deposited in arid/semiarid steppe environment (~350-400 mm/year) based on the results of the frequency dependence susceptibility analysis) (**Fig. 1**).

The palaeoenvironments are well indicated by the magnetic fabric of the investigated material.

Deposition on horizontal plane is well indicated by the position of the direction of principal susceptibilities: the directions of maximum and intermedier susceptibilities gathered on the „edge” of the stereoplot (different declination with some degree of inclination) and the directions of minimum susceptibilities located on the centre of the stereoplot (**Fig. 1**).

The determination of paleowind direction or the direction of deposition was possible by the analysis of the maximum direction of higher amount of samples (more than 6-10 sample/layer), because of the scattered position of the directions.

Based on the investigation of the magnetic fabric of the overlaying loess of Bag Tephra the following palaeowind directions or directions of deposition can be determined: a primer NE-SW angle and a secondary NW-SE angle of the deposition were identified in the magnetic fabric of typical loess. These directions are similar to the recent dominant directions, but during the glacial (or stadial) periods become stronger, possibly the NE-SW angle (**Fig. 1**).

The deposition on slope possibility was indicated by the deviation of the directions of minimum susceptibilities from vertical (**Fig. 1**).

Thesis 5b. Characterization of the effect of pedogenesis on magnetic fabric

The pedogenic processes are indicated by the higher amount of superparamagnetic component of magnetic fabric during the more humid period of Pleistocene (~650 mm/year estimated precipitations). The vertical pedogenic processes (e.g. vertical migration) were identified by the alteration of the magnetic fabric. The rate and the environment of pedogenesis is indicated by the degree of the development of inverse magnetic fabric (the directions of maximum susceptibilities situated in the centre of the stereographic projection)

The reworking of magnetic fabric by biogenic processes was less than it was expected.

The fabric of the macroscopically reworked samples (full of with krotovinas or biogalleries) was similar to the fabric of typical loess, but the directions of maximum or intermedier susceptibilities were a bit scattered on stereographical projections (**Fig. 1**).

Thesis 5c. Characterization of the transition periods between the climatic cycles of pleistocene – the magnetic fabric of redeposited loess and the changing of the energy of paleocurrents

The pedogenic periods were not followed directly by a glacial, cold, dry period. Between the climatic phases of Pleistocene a transition period was identified. These periods are characterised by high, but more rhapsodic precipitation events (e.g. heavy rains).

The extreme weather at the end of the pedogenic period or at the start of glacial phase was well identified by the magnetic fabric of redeposited loess.

The alteration of the magnetic fabric of typical loess by the different kind of paleocurrents and different transport energies can be characterized by different fabrics:

The magnetic fabric affected by low level transport (energy) was characterized by the gathering of the maximum and intermedier directions, increasing of lineation and the decreasing of foliation. The oblate susceptibility ellipsoid becomes triaxial and prolate then.

There was not any identified macroscopically sedimentary structure in the samples, the redeposition was only identified by the alteration of the magnetic fabric. The fabric was possibly developed by low energy sheet wash, laminar flows or processes connected to solifluction.

The mixing of the magnetic fabric (the directions of principal susceptibilities) was described by the increasing of the transport energy. The groups of the principal susceptibilities dissolved and the identification of the direction of the redeposition is difficult. Higher transport energy than the previous group was identified by the sedimentary structure of sampled layers (macroscopically laminated).

Complex magnetic fabric can be developed by the rhapsodic change of the transport energy and directions. this fabric is characterized by separated maximum susceptibility directions in different degree and different number of groups. The degree of anisotropy is decreasing because of the different numbers of separated groups. this group is characterized by laminas including different kind of materials from paleosol to fine sand.

The maximum susceptibilities were gathered well and the direction of transport becomes clear by the increasing of the transport energy (e.g.. Lovasberény – Verőce áth. – Vácbotyán áth. group) (**Fig. 1**).

The highest transport energy during loess redeposition was identified by the pencil structure of the fabric. This kind of fabric was possibly created by turbulent flows. The elongated grains was not oriented to the direction of transport, but rolled perpendicular to the transport direction.

Based on the results of the analysis of the magnetic fabric of loess the following conclusions can be summarized.

The groups of the Hungarian loess variation had not been separated clear by the statistical analysis of the main parameters of the magnetic fabric. However, typical loess reworked or redeposited loess groups were created by statistical analysis.

More detailed palaeoenvironment informations can be described by the analysis of the position and directions of the principal susceptibilities on stereographical projections (stereoplots) (**Fig 1.**).

The described(!) part of a climatic cycle is well described(!) by the layers of the Cérna Valley section and the environmental model based on it. The directions of transports, the effect of the palaeogeomorphology or the pedogenesis is well identified in the fabric of layers originated from Cérna Valley section. **Beyond the analysis of the magnetic fabric of the layers the model of the Cérna Valley section is well symbolizing the aim of the dissertation: to change the “statistical” viewpoint of the analysis into a more complex “dynamic view” during investigation of the magnetic fabric of Hunagrian loess and paleosol sequences.**

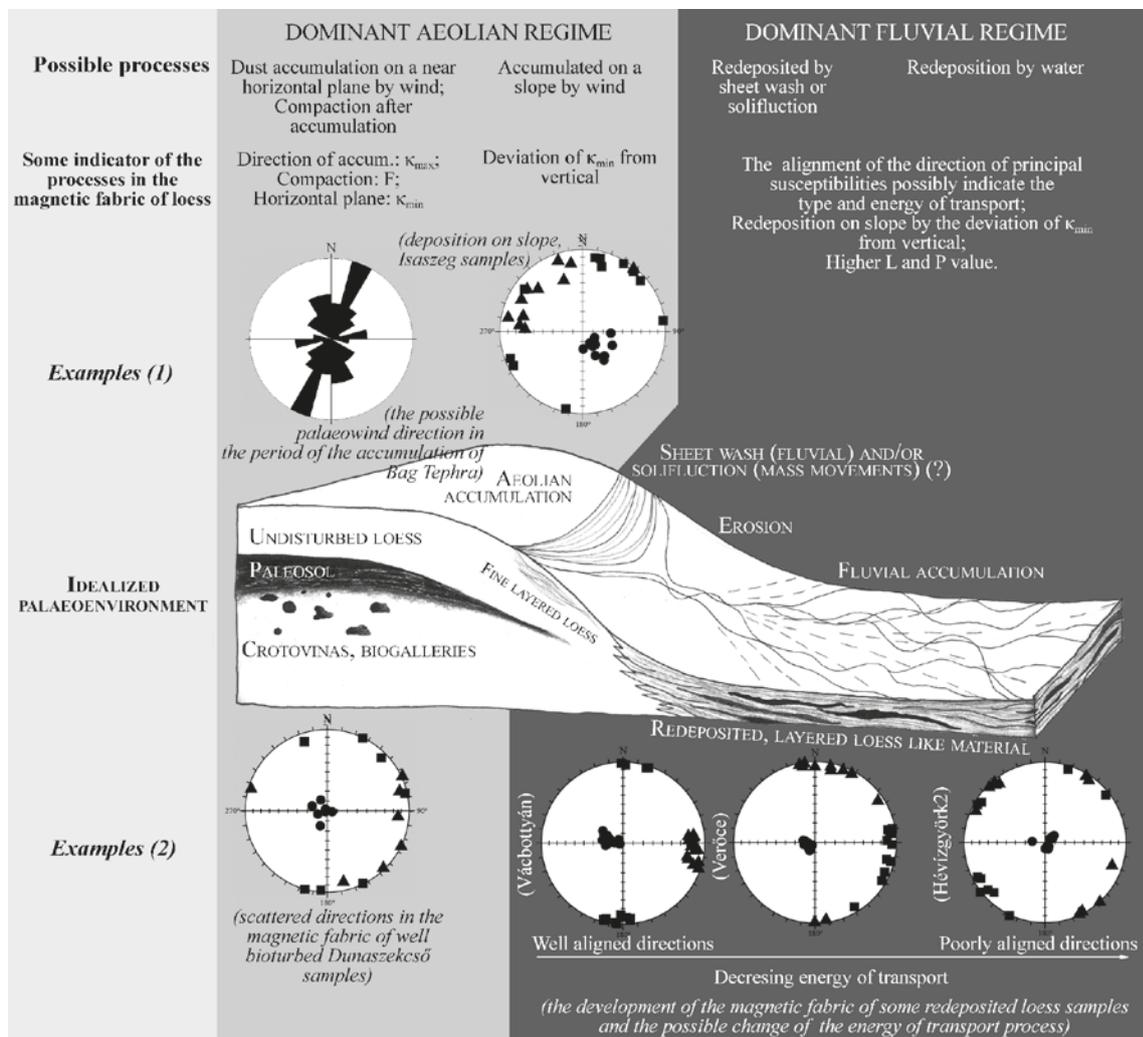


Figure 1. Possible surface processes and indicators in magnetic fabric

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