Quaternary International 319 (2014) 76–87

Contents lists available at SciVerse ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Quaternary surface processes indicated by the magnetic fabric of undisturbed, reworked and fine-layered loess in Hungary

Balázs Bradák*, József Kovács

Department of Applied Geology, Institute of Geography and Earth Science, Eötvös Loránd University, Pázmány P. 1/c, H-1117 Budapest, Hungary

ARTICLE INFO

Article history:
Available online 14 February 2013

ABSTRACT

Statistical analytical methods were applied to classify the magnetic fabric of samples from different Hungarian loess profiles. A previous study of the anisotropy of magnetic susceptibility (AMS) of Hungarian loess suggested that 'typical' (wind-blown or undisturbed) and 'redeposited' loess were well differentiated by known statistical methods. The analyses of new samples require a review of previous results and the terms like 'typical' (wind-blown), 'reworked' and 'redeposited' loess.

The type of magnetic fabric of fine-layered loess is classified by a new mathematical method in AMS study of loess: hierarchical cluster analysis. The following Quaternary surface processes were revealed by characteristics of the magnetic fabric of Hungarian loess:

The primary magnetic fabric preserves the possible transport or accumulation direction of dust (direction of maximum susceptibility, NE/SW axis) and the structure of the fabric was affected by compaction. In the case of loess, the deviation of the inclination from vertical indicates the accumulation of dust on a sloping surface.

The secondary magnetic fabric (fabric of the material after reworking or redeposition) of loess shows the magnetic fabric characteristics of reworked or redeposited material. Scattered values of the principal susceptibilities indicate the effect of bioturbation. Redeposition (fine-layered loess samples) is indicated by the alignment of the direction of maximum and intermediate susceptibilities on a stereographic plot and the degree of alignment possibly indicates the energy of the surface process (lower or higher degree of energy connected to different kind of surface process can produce different kind of magnetic fabric).

The magnetic mineralogy of the pilot samples is determined by isothermal remanent magnetisation (IRM) measurements. No differences between loess samples with different sedimentary structure could be shown. The dominant phase in the magnetic fabric that determined the magnetic character of samples was magnetite/maghemite.

1. Introduction

Anisotropy of magnetic susceptibility (AMS) was first mentioned as a good tool to determine the paleodirection of deposition by Graham (1954). This geophysical method was first applied by Fuller (1963), Uyeda et al. (1963) and Rees (1965). The first investigations of loess magnetic fabric on the Chinese Loess Plateau (Liu et al., 1988; Zhu et al., 2004) were followed by AMS studies in Alaska (Begét et al., 1990; Lagroix and Banerjee, 2002, 2004), in Siberia (Matasova et al., 2001) and in Poland and Ukraine (Nawrocki et al., 2006). Hus (2003) compared the anisotropy parameters of numerous loess–paleosol sequences from Europe [Remicourt and Kesselt sections (Belgium), Roxolany (Ukraine)], Siberia (Kurtac section) and China (Huangling).

According to Derbyshire et al. (1988), a 'true aeolian dust deposit' is isotropic and any anisotropy found in loess is secondary, created after deposition. However, AMS studies showed that elongated grains adjust to the direction of the paleocurrent during dust deposition (e.g. Lagroix and Banerjee, 2002; Zhu et al., 2004). During diagenesis, the grains preserve their original orientation in the loess fabric. This may be influenced by numerous processes (e.g. redeposition on a slope, rate of compaction, bioturbation, etc.), which generate a secondary magnetic fabric (Hrouda, 1982; Ellwood, 1984; Liu et al., 1988; Hus, 2003).

The direction of paleocurrents is reflected by the direction of maximum susceptibilities (Hrouda, 1982; Begét et al., 1990; Matasova et al., 2001; Lagroix and Banerjee, 2002; Nawrocki et al., 2006; Bradák, 2009; Bradák et al., 2011). The foliation plane (the

---

* Corresponding author.
E-mail address: bradak.b@gmail.com (B. Bradák).

1040-6182/$ – see front matter © 2013 Elsevier Ltd and INQUA. All rights reserved.
http://dx.doi.org/10.1016/j.quaint.2013.02.009

direction of minimum susceptibilities, $\kappa_{\min}$) mirrors the slope angle (Rees, 1966; Rees and Woodal, 1975; Ellwood and Howard, 1981). Scattered direction of the principal susceptibilities may indicate bioturbation (Ellwood, 1984). Subaerial and subaqueous loess was separated by detailed magnetic mineralogical experiment by Wang and Løvlie (2010). This investigation attempts to reconstruct these processes by characterising the magnetic fabric of loess in numerous Hungarian profiles and to control the possibility of the application of the statistical methods by Liu et al. (1988) on Hungarian loess.

2. Methods

'Brick size' loess samples were cut out from loess walls, and inclination and declination were measured by compass during sampling. In a laboratory 'loess sample cubes' ($2 \times 2 \times 2$ cm) were created from bigger samples and the direction of sampling was marked in every cube. A Munsell Color Chart was used to describe the colours of the sample (see results at field description part, Table 1).

Table 1

The results of field observation and the average of the basic susceptibility values

Profile	Number of sample	Field observation		Anisotropy of magnetic susceptibility parameters						
		Field description	Munsell colour	MS [10-6 SI]	Average of principal susceptibilities			Average of *P*, *L*, *F* values		
					Max	Inter	Min	*P*	*L*	*F*
Bag	4	Poorly compacted, laminated, redeposited infill of a paleovalley, the outcrop is covered by plants	10YR7/6	403.254	1.009	1.006	0.985	1.025	1.004	1.021
Basaharc	11	Light yellow, calcium carbonate cemented, homogeneous, well compacted	2.5Y8/4	475.109	1.005	1.001	0.994	1.011	1.004	1.007
Dunaszekcső	7	Gleyed, contained calcium carbonate concretions, showed evidence of being reworked by roots and had biogalleries filled by grey coloured silty sand	2.5Y7/2	406.893	1.008	1.004	0.988	1.020	1.004	1.015
GalgahévÍz	9	Light yellow, calcium carbonate cemented, homogeneous, well compacted	2.5Y8/4	419.046	1.005	1.003	0.992	1.013	1.002	1.011
Hévízgyörk 1	7	Light yellow, calcium carbonate cemented, homogeneous, well compacted	2.5Y8/4	438.491	1.004	1.002	0.994	1.010	1.003	1.007
Hévízgyörk 2	9	Fine layered, mixed with paleosol, paleosol lentils and laminas	10YR7/6	312.104	1.007	1.002	0.990	1.017	1.005	1.012
Isaszeg	11	Light yellow, calcium carbonate cemented, homogeneous, well compacted	2.5Y8/4	564.022	1.006	1.003	0.991	1.014	1.003	1.011
Sióagárd	10	Light yellow, calcium carbonate cemented, homogeneous, well compacted	2.5Y8/4	318.157	1.007	1.002	0.991	1.016	1.005	1.011
Vácbottyán	11	Fine-layered material below the homogeneous loess, separated by a sharp boundary from the undisturbed loess, effect of sheet wash, mass movements	2.5Y7/4	376.495	1.015	1.006	0.980	1.036	1.009	1.027
Verőce	11	Fine layered material, loess–sandy loess, possibly paleovalley infill bearing a paleosol, which reflects the shape of the depression	10YR7/4	376.495	1.015	1.006	0.980	1.036	1.009	1.027

Magnetic properties of rocks are generally characterized by crystals with anisotropic magnetic behaviour (crystallographic anisotropy) or anisotropic elongated grains (shape anisotropy). Magnetic susceptibility of the sample-cubes was determined by KLY-1 a Kappabridge instrument. Fifteen measurements were performed on all samples following the Jelinek-method (Jelinek, 1981; Tauxe, 2005). The value and direction (inclination and declination) of the principal susceptibilities ($\kappa_{\max}$, κ_{int}, $\kappa_{\min}$) were determined by computer analysis (Aniso—anisotropy program package for IBM PC. ELGI, Budapest, Bordás R, 1990). Results with negative *F* statistic were excluded. The magnetic foliation, lineation and the degree of anisotropy were defined by the formula of Balsley and Buddington (1960), Stacey et al. (1960) and Nagata (1961), (Table 1):

$$\text{Magnetic foliation } (F) = \kappa_{\text{int}}/\kappa_{\min};$$

$$\text{Magnetic lineation } (L) = \kappa_{\max}/\kappa_{\text{int}};$$

$$\text{Degree of anisotropy } (P) = \kappa_{\max}/\kappa_{\min};$$

In most cases the direction of paleocurrents (or tectonic activities) is reflected by the direction of maximum susceptibilities ($\kappa_{\max}$) (Hrouda, 1982; Begét et al., 1990; Rochette et al., 1992; Matasova et al., 2001; Lagroix and Banerjee, 2002). The foliation plane (direction of minimum susceptibilities, $\kappa_{\min}$) mirrors the slope angle (Rees, 1966; Rees and Woodal, 1975; Ellwood and Howard, 1981). The position of the directions of the $\kappa_{\max}$ and of the intermediate susceptibility (κ_{int}) may indicate bioturbation or lamination (Ellwood, 1984).

The discrimination between undisturbed (wind-blown) and redeposited/reworked loess is followed the analysis described by Liu et al. (1988). In this work *a*, *b*: coefficients of the trend equation ($y = ax + b$) by the trend in the *P* vs. *L* and *P* vs. *F* correlation and *r*: correlation coefficient were used (Liu et al., 1988).

In a previous work, hierarchical cluster analysis was applied on non-disturbed, reworked and redeposited loess sample group originated from a same profile (Cérna Valley, Bradák et al., 2011). In this study, magnetic anisotropy data of redeposited loess samples (above Bag Tephra layer, published in Bradák, 2009) was completed by new samples to reveal the efficiency of hierarchical cluster analysis on data originating from a different redeposited profile.

One of the most preferred multivariate methods is cluster analysis. Its scope is to group and compare the loess samples, based on their similarity and common properties. Eventually, statistics of parameters in each group are illustrated, most frequently with box-and-whiskers plots (Norušis, 1993) and the separation of the groups on a dendrogram. Clustering is a kind of coding, in which a certain sample – originally described with many parameters (in this case values and directions of principal