PALEOMAGNETIC RECORD OF KARADJA LATE PLEISTOCENE SECTION REFLECTS GLOBAL VARIATIONS OF THE GEOMAGNETIC FIELD AND PALEOENVIRONMENTAL CHANGES

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Abstract. New detailed rock magnetic and paleomagnetic investigations of the lagoon/marine loess-like loams samples from the Karadja range section equals Khvalynian horizon (ca. 45-20 ka B.P.) are presented. Karadja range is located in Azerbaijan not far from the town Mingechaur (Mingechaur Reservoir, 47°E, 40°N). By means of the standard methods of paleomagnetism and a high-resolution environmental magnetic study the object was to test whether a clear magnetic signature is associated with the geomagnetic field variations or climatic changes. The variability of the scalar magnetic parameters were examined and reflect the rhythmic character of transgression and regression of the Caspian paleobasin. The composition of the magnetic minerals was determined by thermomagnetic analysis and isothermal remanent magnetization experiments. Rock magnetic properties showed that there is no uniformity in terms of magnetic mineralogy, concentration and grain size of the main carriers of the NRM. Determination of the angle elements of the geomagnetic field (declination and inclination) gave information about intervals of abnormal behavior of magnetization. Some of these diagnostic intervals can be associated with the existence of anisotropy of magnetic susceptibility (AMS). The AMS indicates movements of deposited layers down the core which was the cause of the ChRM vector turn. The paleomagnetic study showed that there are intervals of abnormal behavior of the NRM during about ~25, ~29 and ~39 ka B.P. which are not connected with the AMS. These diagnostic intervals probably reflect global geomagnetic field changes during the deposition and may be associated with the Mono Lake and Laschamp geomagnetic excursions.

Introduction

Differences in formation of sedimentary rocks may be reflected in the content of main magnetic minerals. The present work is devoted to a paleomagnetic and rock magnetic study of the Karadja range marine terrace deposits. Karadja range is located in Azerbaijan not far from the town Mingechaur (Mingechaur Reservoir, 47°E, 40°N). This section is classical and has many times been subjected to various geological, stratigraphical and paleomagnetic investigations. The upper part of the Pleistocene deposits of the Karadja range section are horizontal and form a marine terrace. This terrace corresponds to the so-called Khvalynian transgression of the Caspian paleobasin the age of which is associated with the middle and late Valdai interstadials (~50-10 ka BP).

The Pleistocene transgression of the Caspian paleobasin had a glacial-eustatic nature and a rhythmic character. In the cold climatic periods the water in the world oceans were stored in the acecaps and glaciers, and the sea water level was reduced (regression). During the warmer periods there was a reduction of the glaciers and this led to an increase in the water level. It was a gradual and slow process. The surpluses of water from the Caspian paleobasin ran out through the Manych strait. A tectonic activity in the Kaukasian region shut off the Manych strait and the sea level increased locally up to the ~70 m. When this barrier was eroded the sea level again fell down to the ~30 m level.

These periods of transgression and regression of the Caspian paleobasin were reflected in the structure of the marine terrace. Two sections were formed corresponding to the transgression of the Caspian paleobasin (worm periods) separated by a section corresponding to the period of regression (cold period). The low part of the terrace was made of the marine deposits in the form of carbonate loess-like loam sediments. During the second later stage of the transgression subaerial deposits were deposited in the form of sandy loess-like loam sediments. These two parts are separated by a sand layer which corresponded to the decreasing sea level. The thickness of the sequence is about 13 m.
The age of two levels in the section can be obtained by correlation. The transgressions of the Caspian and Black sea paleobasins had a glacial-eustatic nature and should be synchronous. The Khazarian deposits of the Caspian paleobasin is synchronous with the Karangatian deposits of the Black sea paleobasin, which were established reliably from unstable uranium [Dodonov et al., 2000]. These deposits correspond to the oxygen-isotope stage 5, revealing an age of the base of the Khvalynian deposits of the marine terrace as ~45 ka. The upper part of the marine terrace coincides with the regression of the Paleocaspiy in the middle Valdai and to the oxygen-isotope stage 3, corresponding to an age of ~ 20 ka.

**Selection of the collection**

Loess-like loam hand blocks of the Karadja section were collected by the method of continuous sampling from the two parts of marine terrace corresponding to two parts of the transgression of the Caspian paleobasin. Hand blocks oriented after the magnetic meridian were sawed into horizontal plates. The latter were used to prepare oriented 2-cm cubic samples with three duplicates for each level. The number of levels of the marine terrace amounted to 406.

**Methods**

A complex of methods well established in rock magnetism was applied to examine the ferromagnetic composition of the loess-like loam deposits from the Karadja section by construction of saturation isothermal remanent magnetization (SIRM) curves, determination of the values of coercivity of remanence ($B_{cr}$), the temperature dependence of the saturation magnetization and the blocking temperatures. The experiments were conducted at the Paleomagnetic laboratory at the University of Aarhus (Denmark) and at the “Laboratory of main geomagnetic field and petromagnetism” of Institute of physics of the Earth RAS, Moscow (Russia). The composition of the magnetic minerals (magnetite, maghemite and hematite) was determined by thermomagnetic analysis and isothermal remanent magnetization experiments.

The main magnetic parameters such as low-field magnetic susceptibility ($K_{lf}$), natural remanent magnetization (NRM), SIRM, anhysteretic remanent magnetization (ARM), $B_{cr}$ were measured in 2-cm intervals throughout the profile. The variation in the concentration of magnetic minerals typically can be monitored by measuring the susceptibility $K_{lf}$ and the SIRM. For the marine terrace sediments both ratios of maximum to minimum values of $K_{lf}$ and SIRM are around ~ 15. The high values of $K_{lf}$ and SIRM belong to the sandy horizons which correspond to the phases of Caspian paleobasin regressions. The water of the basin was redrawed and the deposition of a coarse ferromagnetic fraction was increased.

The magnetic mineralogy of selected samples from each stratigraphic level was inferred from isothermal remanent magnetization (IRM) experiments. Stepwise acquisition of IRM in fields up to 1.5 T shows that 90% SIRM is acquired by samples in a field up to 0.3 T. This suggests that the main NRM carrier is a low coercivity mineral such as magnetite or maghemite. In some samples there is a permanent increase up to 1.5 T which indicates the existence of grains of high coercivity minerals, such as hematite.

By the measurements of the S-ratios ($S=IRM_{0.3T}/SIRM$) (King and Channell, 1991) this provide a fair estimate of the relative importance of antiferromagnetics versus ferrimagnetics. In various parts of the section the value of the S-ratio changes in the range -0.5 to -0.95. The majority of the samples had values around $S$~0.9. This indicates a dominant role of low coercivity minerals such as magnetite or maghemite. But in the sand horizons which coincide with the regression phases of the Caspian paleobasin the $S= -0.5$ to -0.6 which reflects a majority of a high coercivity mineral such as hematite. This conclusion is supported by measurements of the coercivity of remanence $B_{cr}$. In the same samples $B_{cr}$ varies between ~60 and ~90 mT. For the main part of the collection $B_{cr}$ typically falls between ~30 and ~40 mT.

IRM experiments using the method of Lowrie (1990) were also made on 34 samples of a pilot collection. An IRM in 1.5 T was induced along the sample X orthogonal axis, 0.5 T field along Y-axis and finally 0.2 T field along the Z axis and thereafter stepwise thermally demagnetized, with measurements of the resultant remanence performed after each step. The thermal unblocking characteristics of the IRM show the presence of a dominant low coercivity magnetic phase (0.2 T) with
unblocking temperatures of 580-620°C on all representative samples. These results indicate that magnetite and slightly oxidized magnetite is the dominant magnetic mineral. In all curves there is also an inflection between 300° and 400°C. This can be attributed to the presence of maghemite, which transforms to hematite on heating. The presence of a hematite phase is also indicated by a higher coercivity unblocking temperature (675°-700°C).

Hence the various experiments show that magnetite, magemite and hematite are the dominant magnetic carriers of the remanence.

The ARM/SIRM, SIRM/k_{if} and ARM/k_{if} ratios were applied as grain size indicators for magnetite. In the Karadja range section the ratios vary ~3 to 4 times indicating that the grain size variations in general are not very strong in the section. For the sandy horizons the values ARM/SIRM and ARM/k_{if} show larger values which can be associated with the growth of the super-paramagnetic
particle concentration. At the same intervals the values of the frequency-dependent susceptibility $K_{fd} = (K_{lf} - K_{hf}) \times 100\% / K_{lf}$ are higher than 8%. That means that the percentage of the super-paramagnetic particles is more than 50% (Dearing, 1999).

The anisotropy of magnetic susceptibility (AMS) was used for checking of reliability of the NRM directions. When the AMS results show any tilting or deformation of the sedimentary layers, the orientation of the remanence carriers can also be effected. Prior to AF-demagnetisation of the samples, AMS was measured on 3 samples from the level. An increasing trend of $F = K_y / K_z$ with depth is observed beginning from ~10 m. This may relate to compaction of the loams. More over a sharp fall of $F$ is seen at the interval 8.4-8.8 m.

Stepwise alternating field demagnetization (AF) was carried out on representative samples in order to extract the component parallel and proportional to the geomagnetic field coeval with accumulation and fixation of magnetic grains in the sediments. To determine the range of AF demagnetization values required to extract the primary magnetization component, representative 34 samples were subjected to a full stepwise AF demagnetization (5-90 mT) in steps of 5 mT.

The majority of samples exhibit a secondary VRM overprint which was easily removed by moderate AF-demagnetization, and the stable ChRM isolated at 25 mT. Seldom after removing of the secondary VRM there were two very close directional low coercivity and high coercivity components. On the base of full AF-demagnetization of the pilot collection, the collection of two duplicate samples from each of the 375 levels was AF-demagnetized in the interval 15-35 mT when the main carrier was a low coercivity mineral and 15-60 mT in case of a high coercivity carrier.

### Results

Using the principle component analysis (PCA), variations in the inclination $I$ and declination $D$ were plotted as a function of the section depth. The mean direction calculated after AF demagnetization may be compared to the present day value for the geomagnetic field at the sampling site ($I_0 = 59^\circ, D_0 = 5.5^\circ$). For the depth intervals 3.65-3.74, 5.15-5.24, 8.58-8.69 and 11.14-11.38 m in the section the values of $D$ and $I$ deviate significantly from the average.

The first diagnostic interval 3.65 to 3.74 m covers 5 levels of the layer 19 in the upper part of the terrace and show inclination values $I = -7^\circ$ to $-54^\circ$ and the declination $D = 101^\circ$ to $119^\circ$. The main carrier of magnetization is hematite. Low coercitivity and high coercivity components have similar direction of magnetization. The AMS measurements showed that this interval of the section has a normal sedimentary fabric.

The next diagnostic interval (5.15 to 5.24 m) demonstrates abnormal directions of magnetization on 3 levels of the layer 17 when inclination fall down to $I = 27^\circ$ and the declination $D = 190^\circ$. The main carrier of magnetization is hematite. The AMS results show that there is no tilting or deformation of the sedimentary layers.

The third interval (8.58 to 8.69 m) comprise 6 levels in layer 13. Values of $I$ varies between 39$^\circ$ and 57$^\circ$ and $D$ between 166$^\circ$ and 187$^\circ$. The scalar magnetic parameters show values characteristic for the low coercitivity minerals such as magnetite or magemite. The deviations of angle elements coincide with sharp variations of the parameters $F = K_y / K_z$ and $L = K_x / K_y$. Stereographic projections of the main axes of AMS ellipsoid show linear anisotropy which was caused by sedimentary layers movements down slope. This could cause a rotation of the ChRM vector.

The forth diagnostic interval (11.14 to 11.38 m) is found in layer 7 and covering 11 levels, where $D$ deviates up to 167$^\circ$. Thermomagnetic analysis indicates that hematite is the main carrier of the magnetization. There is an increasing trend of $F$ with depth up to the 10 % . This may be related with compaction of the loams and it is natural for a normal sedimentary fabric.

### Discussion

The samples which show an abnormal behavior of the NRM except the interval of 8.58 to 8.69 m have the hematite like a main carrier of NRM. These intervals can be associated with chemical oxidation processes in the deposits and reflect the environmental and climate changes during the deposition process. However, these samples had the abnormal direction from elementary measurements of NRM only. After AF-demagnetization the RM did not show the direction of the dipole field characteristic for the given geographic site. The Zijderveld diagrams demonstrated two very close directional components: low and high coercivity components. That is why one can conclude that these
grains of magnetite and hematite were magnetized before a transport and compaction of the sediments. During deposition and eventual lithification, the detrital magnetic particles became aligned parallel to the Earth’s magnetic field and acquired a detrital remanent magnetization. If we take into account the data described above, we obtain the following age estimates for the diagnostic intervals: 3.65 to 3.74 m: ~25 ka B.P., 5.15 to 5.24 m: ~29 ka B.P., 11.14 to 11.38 m: ~39 ka B.P. These directional anomalies may be interpreted as evidence of reduced Mono Lake and Laschamp excursions recorded in the Karadja section. Hence the magnetic characteristics of the Karadja deposits appear to carry information not only about environmental conditions which took place during accumulation and lithification of the sediments but probably also about global changes in the geomagnetic field recorded elsewhere.

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**References**


