GEOMAGNETIC FIELD BEHAVIOR IN THE PAST AS DERIVED FROM PALAEOMAGNETIC INVESTIGATIONS OF SEDIMENTS OF ARCHAEOLOGICAL PALEOLITHIC SITES

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Abstract. Palaeomagnetic studies of sediments of two paleolithic sites Kostenki14 (Markina Gora) and Kostenki 16 (Uglyanka) situated at a distance of 500 meters from each other in Voronezhskaya region (Russia) have been carried out. Magnetic characteristics of the samples were measured in the Laboratory for Magnetostratigraphy and Palaeomagnetic Reconstructions of VNIGRI. The palaeomagnetic studies of 100 samples of the Kostenki 14 site (Markina Gora) and 17 samples of the Kostenki 16 site (Uglyanka) have revealed the geomagnetic field Kargopolovo and Mono excursions in both cases, which allows us to date the sediments of each of the paleolithic sites as about 42000–24000 years BP.

Introduction

During the entire period of historical evolution of the science dealing with early humans, materials from the Kostenki group of palaeolithic monuments were corner stones for development of cultural-historical schemes of the Upper Paleolithic Age in Eastern Europe. The first early man site at Kostenki was discovered more than 130 years ago, in 1879, by a well-known Russian natural scientist I.S. Polyakov. The basic direction of the modern stage of research into the Palaeolithic age at Kostenki is to study multilayer monuments. The works are carried out in close cooperation with natural scientists: series of new radiocarbon and OSL datings and data (first of all, palynological) for reconstruction of dynamics of the ancient natural environment in the Middle Valday age have been obtained. Of great importance is the use of the entire range of methods of dating of archaeological sections of the monuments. One of them is the palaeomagnetic method based on revealing geomagnetic field excursions with known datings in the archaeological monument section [Petrova et al., 1992]. Particular attention at Kostenki is paid now to the materials from the lower horizons of the multilayer sites dated as 37-42 kyr ago. At the moment these are the most ancient complexes of the Upper Palaeolithic Age in Eastern Europe associated with the appearance of modern humans (*Homo sapiens sapiens*).

Fig. 1 shows a chronostratigraphic scale of evolution of the geomagnetic field excursions in the late Brunhes chron (Petrova et al. 1992). Several geomagnetic excursions were revealed in the section of the stratigraphic borehole at Kostenki in the late 1970s – early 1980s (Zubakov, 1986; Sinitsyn and Hoffecker, 2006). During the last decade palaeomagnetic investigations at Kostenki have been carried out by a number of researchers (Gernik, Guskova, 2002; Pospelova, 2005; Pospelova et al., 2008; Løvlie, 2006). Of major importance is the discovery of the Kargopolovo (Laschamp) and Mono excursions which developed around 42 and 28 kyr ago, respectively.

In our study we summarized and generalized the results of palaeomagnetic investigations of archaeological monuments Kostenki 14 (Markina Gora) and Kostenki 16 (Uglyanka) (51.5°N, 39.0°E), the age interval of which embrace the interval of 20 kyr.

The goals of the investigations were

- To reveal geomagnetic excursions in the sections;
- To perform dating of cultural layers by using the excursions (in addition to the radiocarbon and palynological methods);
- To reveal time links between geomagnetic excursions and changes in the environment.

Fig. 2 shows locations of the palaeolithic monuments Kostenki 14 and Kostenki 16. Note that on the scale of geological history a geomagnetic excursion is a short-term event during which the virtual palaeomagnetic pole deviates from its initial position by 60-120 degrees in latitude and then returns to the initial position.
The geomagnetic field intensity during the excursion typically falls. It is extremely difficult to reveal excursions because of their shortness. Careful analysis of the initial data is needed.

**Detection of geomagnetic field excursions at Kostenki 14 (Markina Gora)**

In accordance with the stratigraphy of cultural layers of the monument, correlation of geological sediments and available radiocarbon datings (Sinitsyn and Hoffecker, 2006), samples in the form of cubes 5x5x5 cm in size were collected in a continuous manner along the vertical profile of the Eastern wall of the Kostenki 14 section. Large cube sizes were due to soil looseness. All in all, 100 samples were collected and measured. Sample No. 100 was collected near the section bottom at a depth of about 7 m. The first measurements of the samples from Kostenki-14 were carried out at an astatic magnetometer MAL-26 at Laboratory for Magnetic Properties of St.Petersburg Filial of Institute of Terrestrial Magnetism, Ionosphere and Radiowave Propagation at Voeykovo (Leningrad Region). Vector of natural remanent magnetization $J_n$ characterized by its magnitude and two angles (inclination $I$ and declination $D$) was measured for each of the samples.

The next stage was estimation of the possibility of manifestation of a geomagnetic field excursion along the trajectory of motion of the virtual palaeomagnetic pole (VPP) for Kostenki 14. To this end, coordinates (latitude $\Phi$ and longitude $\Lambda$) of the virtual palaeomagnetic pole for each sample were calculated and the pattern of VPP motion at the Earth’s surface was obtained. The results of VPP calculations are summarized in Table 1.

It follows from Table 1 that for samples No. 85 ($\Phi=0^0, \Lambda=154^0$), No. 71 ($\Phi=-29^0, \Lambda=46^0$), and No. 61 ($\Phi=8^0, \Lambda=13^0$) the latitude of the virtual palaeomagnetic pole decreases, which can be the indication of a geomagnetic excursion.

Comparison of the locations of the sites in the section where palaeomagnetic field behaves anomalously with radiocarbon and palynological datings shows that the anomalous magnetic field behavior corresponds appr. to 42-40 kyr BP and 29-27 kyr BP [Sinitsyn and Hoffecker, 2006]. In these time intervals, geomagnetic Kargapolovo and Mono excursions were detected, the development of the Kargapolovo excursion occurring in two stages. The evidence of the second stage is sample No. 71, the VPP coordinates of which are in the Southern Hemisphere. This yields dating of the archaeological object as $\sim 42000$ BP.

Investigations of the VPP behavior from the data of numerous geological objects have shown that motion of the virtual geomagnetic pole occurred in a clockwise fashion around (or near) the north magnetic pole, and during an excursion the motion became counterclockwise.

Fig. 3 shows trajectories of the virtual palaeomagnetic pole for the first (samples Nos. 88-81 in Table 1) and second (samples Nos. 81-71) stages of the Kargapolovo excursion. In both cases the VPP motion during the excursion was counterclockwise. An analogous picture of the VPP motion is observed for the Mono excursion (samples Nos. 63-58).
Detection of geomagnetic field excursions at Kostenki 16 (Uglyanka)

Seven samples in the form of cubes 2×2×2 cm³ in size were collected in the section of the western wall of the excavation of the archaeological site Kostenki 16 (Uglyanka) at the cultural layer level with radiocarbon datings 28-29 kyr BP (Fig. 4). Magnetic characteristics of the samples were measured using a commonly accepted method at the Laboratory for Magnetostratigraphy and Palaeomagnetic Reconstructions of VNIGRI. Results of studies of changes in magnetic characteristics of seven samples from the western wall of the section at Kostenki 16 including primary measurements \((D^0,20; I^0,20)\) and those after a temperature cleaning to 120°C \((D^0,120, I^0,120)\) and also calculated positions of the virtual palaeomagnetic poles (latitude \(\Phi\) and longitude \(\Lambda\)) are given in Table 2.

Table 1

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Fig. 3. Motion of the virtual palaeomagnetic pole during development of the first stage (left) and second stage (right) of the Kargapolovo excursion from the data of the section at Kostenki 14.
As Table 2 shows, for sample No. 6 the VPP displaced to the Southern Hemisphere, which indicates that the VPP behavior is typical of the second stage of the Kargapolovo excursion. Fig. 5 presents the VPP trajectory derived from the seven samples from the western wall of the section at Kostenki 16. It can be seen that the VPP motion is counterclockwise, which is characteristic of development of a geomagnetic excursion.

To reveal the Mono excursion, which, as mentioned above, manifested itself in the section of Kostenki 14, 10 samples were additionally collected and placed into glass ampoules (2x2x2 cm³ in size). They were supposed to embrace a less ancient time interval as compared with the first seven samples. Fig. 6 shows changes in palaeomagnetic characteristics of 10 samples from the western wall of the section at Kostenki 16 and changes in the positions of the virtual palaeomagnetic pole (latitude $\Phi$ and longitude $\Lambda$). For sample No. 6, VPP is seen to displace to low latitudes, which can be the indication of development of the Mono excursion (~22,000 BP). Radiocarbon dating of the soil layer from which the samples for palaeomagnetic investigations were taken yielded 28,000-29,000 BP, which confirm magnetic dating.

Fig. 7 presents the VPP trajectories for 10 samples from the western wall of the section at Kostenki 16. The VPP moves counterclockwise, which confirms the Mono excursion development.
Fig. 5. VPP motion for the Kargapolovo excursion according to the data of 7 samples from the western wall of the section at Kostenki 16.

Fig. 6. Variations in magnetic characteristics of 10 samples from the western wall of the section at Kostenki 16 and changes in the virtual palaeomagnetic pole position (latitude $\Phi$ and longitude $\Lambda$).

Fig. 7. VPP for 10 samples from the western wall of the section at Kostenki 16. The VPP displaces counterclockwise, which confirms the excursion development.
Conclusion

Results of palaeomagnetic investigations of archaeological monuments Kostenki 14 and Kostenki 16 (51.5°N, 39.0°E) have been generalized for the first time.

- Analysis revealed the geomagnetic Kargapolovo excursion, the development of which occurred in two stages, and the Mono excursion.
- The excursions thus revealed allowed dating of the layers of the section (in addition to the palynological method and radiocarbon dating).
- Additional analysis combined with treatment of the palynological data revealed a time correlation in the development of geomagnetic excursions and changes in the environment.

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References


