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Behavior of paleointensity during the Paleogene

A.Yu. Kurazhkovskii *, N.A. Kurazhkovskaya, B.I. Klain

Geophysical Observatory Borok, Schmidt Institute of Physics of the Earth of the Russian Academy of Sciences, Borok, Yaroslavl Region 152742, Russian Federation

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ABSTRACT

Behavior of the intensity of geomagnetic field in the Paleogene was studied by the analysis of the sedimentary rocks of the Russian Plate. It is revealed that in the beginning of the Paleogene the variations of little-amplitude paleointensity (about $0.5H_0$, where H_0 is the value of modern geomagnetic field taken as 40 μT) were alternating with bursts of large amplitude (up to $5H_0$). By the end of the Paleogene only the paleointensity variations with a little amplitude were revealed.

The relation between behavior of the paleointensity and the polarity regime is analyzed. On the basis of the behavior of the reversal frequency and asymmetry of the polarity and according to Molostovskii et al. (2007) the Paleogene was divided into two hyperchrons. In the first hyperchron (66–40) Ma the polarity of the geomagnetic field was predominantly reverse. In the second hyperchron (40–22) Ma the intervals of normal and reverse polarity alternated. The bursts of the paleointensity were revealed only in the beginning of the first hyperchron. In addition, during the first hyperchron both the average values (for the geological age) and the amplitude of the paleointensity variations decreased; within the interval of (40–22) Ma both the amplitude and its mean values were changing inconsiderably.

1. Introduction

Until recently, the conceptions on the geomagnetic field intensity in the Paleogene were based mainly on the data obtained by analyses of thermomagnetized rocks. These data allowed for rather rough conception on changes in the intensity of geomagnetic field in the Paleogene. It has been shown that in the beginning of Paleogene the paleointensity was on average slightly higher than by the end of this period. For instance, Solodovnikov (1998) suggested that at the boundary between the Early and Middle Eocene (about 50 Ma) the abrupt (twofold) decrease in paleointensity took place. According to the more recent papers (Valet, 2003; Biggin and Thomas, 2003; Heller et al., 2003; Tauxe and Yamazaki, 2007), the paleointensity in the Paleogene really decreased, but this change was neither abrupt nor considerable.

The sedimentary rocks are the preferable substratum for study of the behavior of paleointensity. Attempts to study in detail the behavior of paleointensity in the Late Paleogene using the analysis of sedimentary rocks (in the interval 34–23 Ma) were made in papers (Tauxe and Hartl, 1997; Constable et al., 1998). The referred authors concluded that in the Late Paleogene the paleointensity variations with characteristic times of an order of million (a few million years) took place. The intensity of geomagnetic field in the Early and Middle Paleogene by sedimentary rocks has not been studied yet.

This paper sets to study the paleointensity behavior in the Early – Late Paleogene by analysis of the sedimentary rocks from the southern part of the Russian Plate.

2. Analyzed data

The behavior of geomagnetic field intensity in the Paleogene was studied by analysis of two sedimentary layers. One layer situated north of the Big Caucasian Ridge (coordinates 43°22′ N and 43°41′ E) and was disclosed by geomapping borehole (hereinafter mentioned as the deposits or the sediments of North-Caucasian region). Another layer was situated in the south of the Saratov Oblast (coordinates 50°42′ N and 45°39′ E). The samples of the later sedimentary layer were collected from the natural outcrop on the bank of the Volga River (the Saratov region sediments).

2.1. Sedimentary rocks of the North-Caucasian region

The formation of sedimentary layer of the North-Caucasian region took place during the period from the Maastrichtian (end of the Cretaceous) to the Chattian (end of the Paleogene). The thickness of the Paleogene sediments was 530 m. The results of stratigraphic – paleontological studies of this sedimentary layer were given earlier (Bugrova et al., 1988). According to the studies performed later (Bogachkin, 2004), the following stages present in this sedimentary layer:

Danian stage: The thickness of this stage was 20 m. At the base of the interval the nanoplankton of *Cruciplacolithus tenuis* zone

* Corresponding author. Tel.: +7 4854724763.
E-mail address: ksasha@borok.yar.ru (A.Yu. Kurazhkovskii).

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corresponding to the zones of the scale (Martini, 1971) NP1–NP2 and planktic foraminifers of *Globigerina taurica* and *Globoconusa daubjergensis* zones were found. The border between the Danian and the Selandian stages corresponds to the roof of *Acarinina inconstans* zone. *Selandian stage*: Its total thickness was 40 m. The border between the Selandian and the Thanetian stages lies on the border between the following biozones: foraminifers *Acarinina djanensis* and *Acarinina subsphaerica*; nanoplankton *Fasciculithus tympaniformis* (NP5) and *Heliolithus kleinpelli* (NP6). *Thanetian stage* : The thickness of the stage is 65 m. The stage is characterized faunistically by the zones of *A. subsphaerica* and *Acarinina acarinata* and nanoplankton of the zones of *H. kleinpelli* and *Discoaster multiradiatus* (zones NP6 and NP9, respectively). *Ypresian stage*: This stage is characterized faunistically by the zones foraminifers *Globoratalia* (*Morozovella*) *subbotina*, *Globoratalia aragontnsis* and nanoplankton of the NP10, NP11, NP12, NP13 zones. The roof of the Ypresian stage corresponds to the base of foraminiferal *Acarinina bullbroki* zone and to the border between NP13 and NP14 zones. The thickness of sediments attributable to the Ypresian stage is 51 m. *Lutetian stage*: The total thickness of this stage is 44 m. The nannofossils attributable to the zones of *Acarinina bolbroki*, *Acarinina rotundimarginata*, *Hantkenina alabamensis* and *Globigerina turcmenica* foraminiferal (at the foundation) and NP14, NP15 and the lower part of NP16 zones present in this stage. *Bartonian stage*: The stage is characterized faunistically by foraminifers of *G. turcmenica*, NP16 (upper part) and NP17 zones. The thickness of the stage is 45 m. *Priabonian stage*: The deposits are characterized paleontologically by findings of foraminifers of the zone of *Globigerapsis tropicalis* and nanoplankton of *Discoaster bsrbadiensis* (NP18, NP19, NP20 zones according to Martini (1971)scale). The thickness of the Priabonian stage is 114 m. *Rupelian stage*: The zone of *Globigerina officinalis* is distinguished here by the planktic foraminifers; near the sole the nanoplankton of the zone of *Cocolithus subdistichus* (NP21) was detected. The roof of the sediments is conditionally drawn in ostracoda layer with nanoplankton of the zones of *Sphenolithus predistetus* and *Sphenolithus distentus* (NP23–NP24). The total thickness of the stage is 64 m. *Chattian stage*: The stage was not characterized paleontologically. The border with clays of the Miocene age is drawn at the basis of appearance in the section of layers of strongly magnetic siderite nodules of the Caucasian regional stage.

The magnetic and petromagnetic properties of this sedimentary layer were studied in order to draw the magnetostratigraphic scheme of the Pre-Caucasian deposits. Earlier, these studies were used for drawing the regional magnetostratigraphic scheme of the southern regions of the European part of Russian Federation (Bogachkin, 2004) and for specification of the Cenozoic part of the magnetostratigraphic scale of the Phanerozoic (Molostovskii et al., 2007). The present study continues the above mentioned examin ations.

The samples of the Paleogene were collected from 280 stratigraphic levels with 1–2 m interval between the layers. For paleomagnetic studies two samples from each layer were selected. The time of the sediments accumulation between the two nearest levels from which the samples were collected averaged 100–200 thousand years. This estimate is rather conditional. It is unlikely that the sediments of the region situated near the tectonically-active area of Caucasus were accumulated evenly. However, the resolution of the sampling is sufficiently small-scaled allowing for the detection of the variations of geomagnetic field intensity with the characteristic times of a million years' order. According to Bogachkin (2004) and Molostovskii et al. (2007), the examined sediments had predominantly reverse polarity. Totally 18 intervals of the normal polarity were found against the background of the above polarity. This suggests that the deposits of the North-Caucasian region are appropriate for the reconstruction of the geomagnetic events in the Paleogene in good fullness.

The measurement of the magnetic parameters of these deposits' NRM, saturation isothermal remanent magnetization (SIRM), magnetic susceptibility (K) and the magnetic susceptibility after the heating at a temperature above 500 °C (TK), and thermal cleaning NRM were determined in the Paleomagnetic Laboratory of Scientific-Research Institute of Geology of Saratov State University.

The sedimentary layer consists of marine, mainly grey-colored carbonate and terrigenic deposits. The results of separation of the grains of the magnetic minerals in conjunction with the thermomagnetic analysis suggested that terrigenic magnetite is the main carrier of magnetization of the sediments (Bogachkin, 2004; Molostovskii et al., 2007). According to Guzhikov et al. (2003), the following criteria indicate the orientational nature of the sediments' NRM and, hence, their primacy: the presence of detrital grains of the ferromagnetic minerals, low values of the Königsberger factor ($Q < 0.1$) and low inter-layer concentration of distribution of the vectors of directions of remanent magnetization ($k = 5–15$). To determine the inter-layer paleomagnetic concentration of the directions of NRM five samples were collected from every tenth level.

The Lutetian deposits had weak magnetization. This is why they were not used for magnetostratigraphic studies and for the reconstruction of the geomagnetic field paleointensity. In the present study we omit the data on the Lutetian paleointensity.

2.2. Method for the determination of the paleointensity

We identified the dynamics of the paleointensity using the behavior of a parameter Rns = NRMt/SIRMt (the parameters with index t have been measured after the thermal cleaning). In the most cases the NRM of the studied samples consisted of two components. The examples of orthogonal diagrams of demagnetization of the samples during thermal cleaning (Zijdervild diagrams) are presented in Fig. 1. The given Zijdervild diagrams show that one of the NRM components was destroyed by the thermal cleaning (by heating within three-layer permalloy screen placed in the Helmholtz coils) at a temperature of 200 °C. The second component (the ancient magnetization) was isolated in a temperature range of 200–500 °C. In some samples the primary magnetization was isolated at high (more than 300 °C) temperatures. These samples were not used for determination of the paleointensity. Finally, to determine the paleointensity of the Paleogene we used the samples taken from 187 layers.

The changes in the values of Rns, K and TK are shown in Fig. 2. The data in Fig. 2 shows that the behavior of Rns differed from the dynamics of the petromagnetic parameters K and TK. The dependence of the Rns from TK and K along with the coefficients of correlation between the Rns-TK and Rns-K (−0.03 and −0.05, respectively) are shown in Fig. 3. The data given in Figs. 2 and 3 indicate the lack of connection between the behavior of Rns and the petromagnetic parameters. This was yet another argument in favor of the suitability of the sedimentary layer for studying of the paleointensity. It is worth noting that near the boundaries of geological epochs the magnetic susceptibility of the sediments increased significantly. This indicates that at the boundaries of epochs not only the replacement of biota took place but the geological processes were changed as well. However, as it seen from Fig. 2 the replacement of these processes was not reflected clearly in the behavior of Rns parameter.

We utilized two ways of the calibration of Rns values or the determining of "absolute" values of the paleointensity for the North-Caucasian deposits. In the first case, calibration of the behavior of the Paleogene paleointensity was performed using the results of the determination of paleointensity in the thermomagnetized rocks. These data were taken from the database (DB) PINT10 [http://earth.liv.ac.uk/pint/]. The description of this