ISSN 1028-334X, Doklady Earth Sciences, 2007, Vol. 414, No. 4, pp. 574–577. © Pleiades Publishing, Ltd., 2007.
Original Russian Text © A.Yu. Kurazhkovskii, N.A. Kurazhkovskaya, B.I. Klain, 2007, published in Doklady Akademii Nauk, 2007, Vol. 414, No. 1, pp. 97–100.

GEOPHYSICS

Relation between the Earth's Magnetic Field Intensity and Geotectonic Processes

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

Presented by Academician V.N. Strakhov April 5, 2006

Received May 10, 2006

DOI: 10.1134/S1028334X07040198

Investigation of the relation between cyclic geomagnetic and geotectonic processes plays an important role in estimating the rate of energy transfer from the core–mantle boundary to the Earth's surface layers and in studying mechanisms governing the dynamics of the lithosphere. The data on the magnetic polarity regime are used as a characteristic of the Earth's magnetic field. The characteristic times of the reversal of magnetic polarity regimes and associated geotectonic processes are tens and hundreds of millions of years. The spectrum of variations in paleointensity (geomagnetic field intensity) characterized by periodicities from thousands to hundreds of million years undoubtedly contains more information about the processes related to the generation of the geomagnetic field. The analysis of the correlation between paleointensity and geotectonic processes opens new opportunities in the study of processes, whose characteristic times are smaller than the reversal rate in the magnetic polarity regime. However, at present, paleointensity is the least studied characteristic of the Earth's magnetic field. This hampers the investigation of the correlation of paleointensity with processes in the lithosphere. The appearance of new determinations of paleointensity based on sedimentary rocks [1–3] and volcanogenic material presented in the database (DB) [http:/wwwbrk.adm.yar.ru/palmag/index/html] allowed us to analyze for the first time the correlation of paleointensity with the cyclicity of ash volcanism during the Pleistocene and the activity of riftogenesis in the Mesozoic–Cenozoic.

We used the data about the behavior of the geomagnetic field intensity (curve Sint 800 in [1]) to study the relation of volcanic activity with the dynamic of paleointensity during the last 800 ka (Fig. 1). The diagram of interlayer distribution of volcanic tephra in the sedimentary cover of the Pacific Ocean and related Shachleton–Opdyke oxygen-isotope diagram was adopted from [4]. According to the results in [4, 5], the Pleistocene volcanic activity at the boundaries of the Pacific increased during oxygen-isotope stages with even numbers.

It is worth noting that the cores of sediments, in which variations in the magnetic and mineralogical composition (and tephra) are minimal, are used in the investigation of the behavior of paleointensity. Thus, the behavior of paleointensity and variations in volcanic tephra are determined using different cores of sediments. At the same time, regardless of the goal of the study, sediment levels are dated using the same methods (including those based on the concentration of ^{18}O in foraminifera). This makes it possible to compare with high accuracy the time boundaries of geomagnetic and geotectonic events even if they were determined from different cores.

As seen from comparison of the data in Fig. 1, all maxima of the geomagnetic field intensity correspond either completely or partially to the even oxygen-isotope stages (positive values of δ^{18}O). In four cases (oxygen stages 2, 4, 6, and 10), the maxima of magnetic field intensity coincide exactly with the activation of volcanism. In the other four cases, the activation of volcanism occurs during an increase (stages 8 and 12) or decrease (stages 16 and 18) of the paleointensity. At the same time, the mean values of paleointensity corresponding to the even stages of the oxygen curve also appear higher than in the neighboring odd stages. Only at oxygen-isotope stage 14, i.e., 520–560 ka ago, did activation of volcanism occur at relatively low values of paleointensity.

Based on the results shown in Fig. 1, it is possible to obtain an approximate estimate (~100 ka) of the volcanic activation periodicity and corresponding intensity of the geomagnetic field. Previously, a similar periodicity (close to 100 ka) was distinguished in the spectra of time variations in δ^{18}O in the sediments of the Pacific and paleointensity (Sint 800), whose analysis was car-

---

Borok Geophysical Observatory, Institute of Physics of the Earth, Russian Academy of Sciences, Settlement of Borok, Yaroslavl Region, 152742 Russia;
e-mail: ksasha@borok.adm.yar.ru

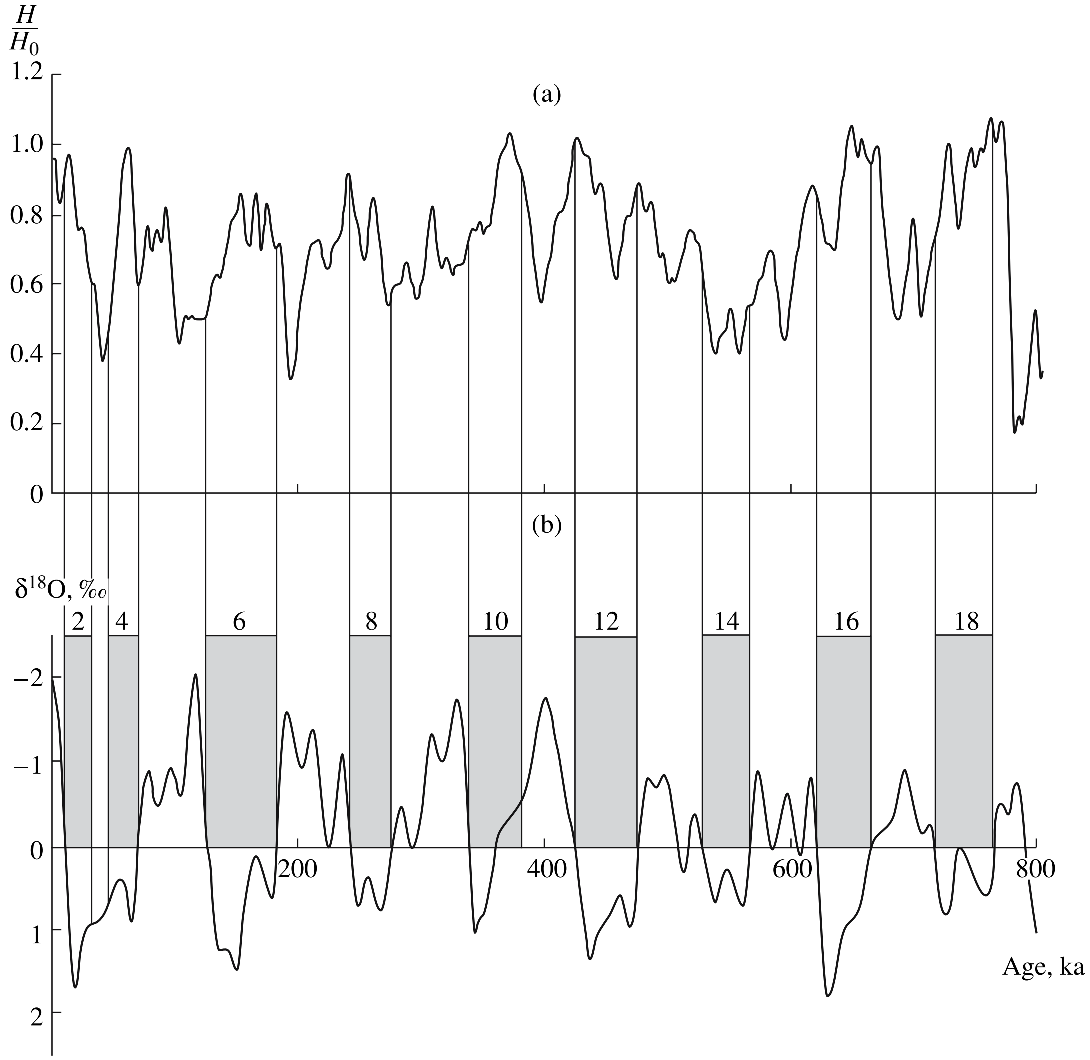

Fig. 1. Correlation between (a) the behavior of paleointensity during the last 800 ka $\left(\frac{H}{H_0}\right)$ [1] and (b) the activity of ash volcanism [4]. Even stages of the Shachleton–Opdyke oxygen-isotope diagram [6] corresponding to volcanism activation are denoted with dark boxes.

ried out to investigate the correlation between geomagnetic and climatic processes [7].

In the analysis of world data on the module of the ancient geomagnetic field [8], the authors noticed that the mean values of paleointensity in the interval of 70–800 ka B.P. based on volcanogenic material appeared to be greater than those based on sedimentary rocks. The authors did not give any explanation for this fact. The revealed coincidence between the volcanism activation and maxima of the geomagnetic field intensity allows us to explain the causes of this difference: (1) the volcanogenic material formed nonuniformly and productivity of volcanism increased at high values of paleointensity; (2) the accuracy of radiometric measurements of the age of volcanogenic material in the majority of cases does not allow us to estimate the nonuniform character of their formation. Thus, reconstructions of paleointensity based on the volcanogenic material mainly yield overestimated values. In general, these values do not adequately characterize the geomagnetic field intensity, which existed in the time interval considered here (70–800 ka B.P.).

We analyzed for the first time the data on volcanogenic and sedimentary rocks to reconstruct the dynamics of paleointensity behavior in the last 200 Ma. The results of paleointensity determination based on magnetized rocks (volcanogenic rocks) were obtained from the DB. We determined the fragments of paleointensity behavior in the Cretaceous and Jurassic periods on the basis of sedimentary rocks of the Russian Plate, Northern Caucasus, and Subpolar Ural regions [2, 3]. A fragment of the reconstruction of paleointensity behavior during the Maestrichtian (65–70 Ma B.P.) and the data on its mean values in the Callovian–Bathonian (160–

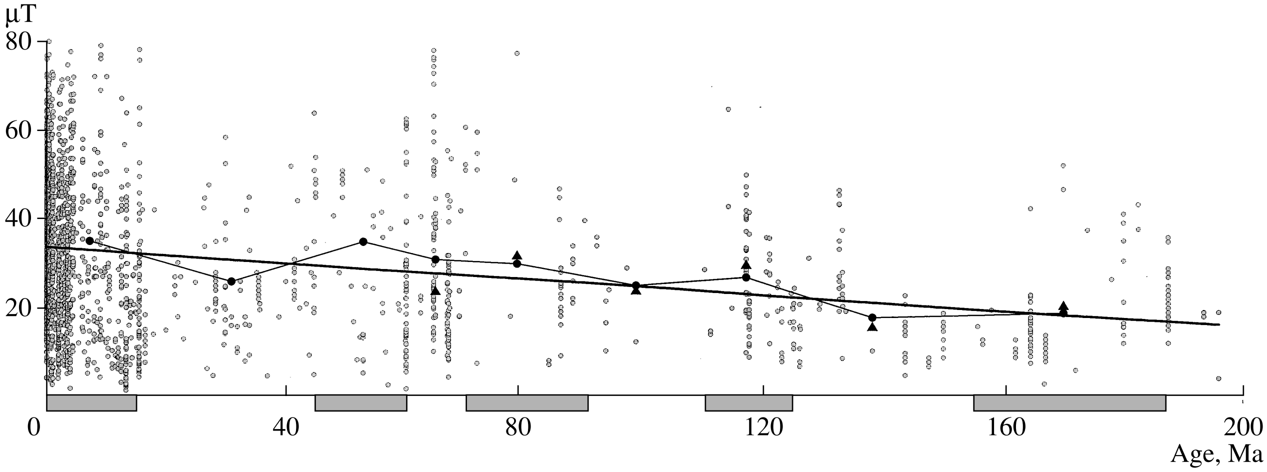

Fig. 2. Correlation between geomagnetic field intensity and riftogenesis cyclicity. Dots denote all determinations of paleointensity in the last 200 Ma based on the DB. Slope line denotes time trend of paleointensity. Average (over phases of riftogenesis) values of paleointensity determined from volcanogenic material and sedimentary rocks are shown with circles and triangles, respectively. Gray color along the abscissa axis highlights the phases of riftogenesis activation [10].

170 Ma B.P.) are published for the first time. Samples from the reference section in the Settlement of Pudovkino (Saratov region), Saratov, and Rybinsk were used to determine paleointensity during the Maestrichtian and Bathonian–Callovian. Paleointensity in the Maestrichtian and Bathonian–Callovian was reconstructed based on the method used in [2, 3].

The existence of epochs of riftogenesis and folding remains a debatable issue. However, the data on the intensity of volcanogenic material formation indicate that this was a nonuniform process consisting of cycles with different durations [9]. Figure 2 allows us to compare the data on riftogenesis cyclicity [10] with the data on paleointensity in the last 200 Ma based on the volcanogenic material (DB) and sedimentary rocks. We determined the trend in paleointensity using the DB over the entire age interval analyzed here and calculated its mean values within the time boundaries corresponding to individual phases of riftogenesis.

As seen from the graph, the geomagnetic field intensity increased during the last 200 Ma. Activation of riftogenesis occurred at relatively high mean values of paleointensity. Riftogenesis activity decreased when paleointensity decreased. A distortion from this regularity (only a decrease in the rate of decrease instead of a decrease in the mean values) was observed at the Cretaceous–Paleogene boundary (60–70 Ma B.P.).

The mean values of paleointensity based on both sedimentary rocks and the volcanogenic material were determined within the same time boundaries. Reconstruction of paleointensity in the Cretaceous based on rocks confirmed that variations in its mean values are consistent with the cyclicity of riftogenesis. Relatively high mean values of paleointensity corresponded to all stages of riftogenesis activation (Fig. 2).

As was shown above, paleointensity determined from sedimentary and volcanogenic rocks can differ for the same time intervals. However, in the time interval considered here (Jurassic–Cretaceous, 65–200 Ma B.P.), the form of the curve of paleointensity variations and its correspondence to the riftogenesis cycles did not depend on the genesis of rocks used for these purposes. During the Cretaceous and Jurassic periods (excluding the Maestrichtian), no significant differences were found between the mean values of paleointensity determined from volcanogenic and sedimentary rocks. It is likely that the phase correspondence between the volcanic activity and variations in paleointensity changed many times during the epochs of riftogenesis.

Figure 3 shows fragments of paleointensity behavior during different phases of the Cretaceous riftogenesis. Phases of active riftogenesis corresponded to the fragments of paleointensity obtained from Barremian (zone M1) [2], Albian [2], and Santonian [3] rocks. These intervals were characterized by relatively high values of paleointensity ($0.8H_0$, where H_0 is the intensity of the present-day magnetic field of the Earth). The amplitude of variations in the geomagnetic field intensity was not constant. Variations in paleointensity of relatively small amplitude alternated with bursts. During the bursts, paleointensity increased several times (up to $3H_0$).

Paleointensity of low riftogenesis activity is shown in the examples of the fragments of its behavior obtained from Hauterivian [3], Cenomanian [3], and Maestrichtian (Fig. 3) rocks. Its mean values were equal to $0.5H_0$, $0.6H_0$, and $0.6H_0$, respectively. During low riftogenesis activity, significant variations in paleointensity were always observed, but the bursts were either absent or had low amplitude (up to $2H_0$). Among the paleointensity fragments considered here, the maximal amplitude of its variation was found in the Maestrichtian rocks.

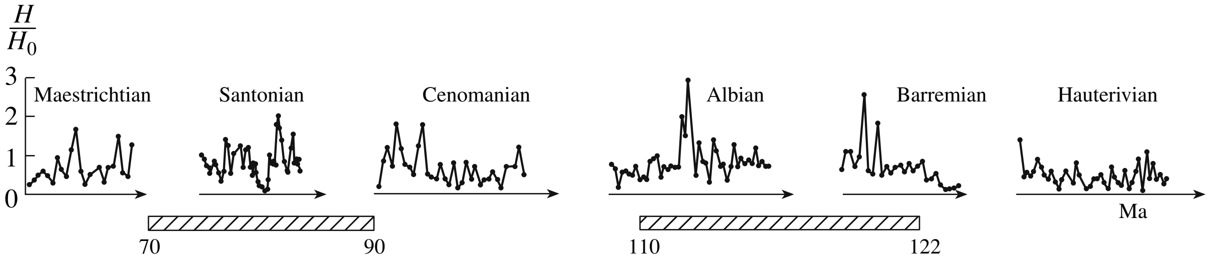

Fig. 3. Fragments of paleointensity behavior in the Cretaceous during different phases of riftogenesis obtained from sedimentary rocks. Phases of active riftogenesis with age boundaries adopted from [10] are shown below the abscissa axis.

The investigation showed the existence of general periodicities (~100 ka and 10*n* Ma long) in the geotectonic and geomagnetic processes. The character of time correlation between geomagnetic and geotectonic processes depends on the duration of their variation periods.

Variations in paleointensity and volcanic activity with a duration of ~100 ka lack permanent phase correspondence. In the time interval of 0–800 ka, activation of volcanism in most cases corresponds to increased paleointensity.

A good correlation is observed between the riftogenesis cyclicity and behavior of paleointensity (processes up to tens of million of years long). Riftogenesis cycles have different durations, but the phases of their activity coincide with the variations in the mean values of the geomagnetic field intensity. Such coincidence is a serious argument in favor of the existence of the genetic relation between the generation mode of the Earth's magnetic field and processes in the lithosphere.

ACKNOWLEDGMENTS

The authors thank A.Yu. Guzhikov, M.V. Pimenov, and O.B. Yampolskaya for the collections of sedimentary rock samples and useful remarks.

REFERENCES

1. Y. Guyodo and Y.-P. Valet, Nature **399**, 249 (1999).
2. A. Yu. Kurazhkovskii, N. A. Kurazhkovskaya, B. I. Klain, and A. Yu. Guzhikov, Dokl. Earth Sci. **390**, 729 (2003) [Dokl. Akad. Nauk **390**, 825 (2003)].
3. A. Yu. Kurazhkovskii, N. A. Kurazhkovskaya, B. I. Klain, and A. Yu. Guzhikov, in *Proc. International Seminar on Paleomagnetism and Magnetism of Rocks: Theory, Practice, and Experiment* (Kazan Univ., Kazan, 2004), p. 27 [in Russian].
4. N. I. Seliverstov, Vulkanol. Seismol., No. 5, 22 (2001).
5. J. P. Kenneth, *Marine Geology* (Englewood Cliffs, New Jersey, 1982; Mir, Moscow, 1987), Vol. 1.
6. N. J. Shachleton and N. D. Opdyke, Quatern. Res., No. 3, 39 (1973).
7. N.-A. Moerner, G. N. Petrova, O. V. Pilipenko, et al., Izv. Phys. Solid Earth **37**, 796, (2001) [Izv. Akad. Nauk, Fiz. Zemli, No. 10, 24 (2001)].
8. V. P. Shcherbakov, G. M. Solodovnikov, and N. K. Sycheva, Izv. Phys. Solid Earth **38**, 113, (2002) [Izv. Akad. Nauk, Fiz. Zemli, No. 2, 26 (2002)].
9. V. F. Belyi and A. A. Sidorov, Vulkanol. Seismol., No. 1, 12 (2002).
10. V. E. Khain and M. G. Lomize, *Geotectonics with Principles of Geodynamics* (MGU, Moscow, 2005) [in Russian].