

RESEARCH ARTICLE

On the study of anomalous variations of the geomagnetic field

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Abstract

Elucidation of the nature of anomalous variations of the geomagnetic field throughout the geological and modern periods is important for identifying local anomalies associated with the preparation of strong earthquakes. The results of detailed studies of geomagnetic field variations over the past 100 years reflect the manifestation of anomalies in a wide spatiotemporal spectrum, intensity and shape. In terms of their parameters, they are comparable to the anomalous variations caused by the processes of preparation of strong ($M \geq 5$) earthquakes. As a result of a review of the literature, it was found that the period of secular variations of the geomagnetic field according to paleomagnetic data ranges from 600 to 100 thousand years. According to the archaeomagnetic data, abnormal fluctuations of the geomagnetic field with a period of several decades to 8-9 thousand years have been revealed. Measurements of the geomagnetic field over the past 200 years have revealed abnormal fluctuations with periods from 10-15 days to 20-60 years. The main versions about the possible nature of the age-old variations manifested in the geological past and present are given.

Keywords: geomagnetic field; magnetic anomalies; abnormal fluctuations; paleomagnetic data; archaeomagnetic data

1. Introduction

Anomalous field changes according to paleomagnetic and archaeomagnetic data in the Phanerozoic and modern times were manifested both in platform areas (European, Russian, West Siberian) and in geosynclinal regions (Asia, Japan, North and South America), which indicates their planetary scale.

To date, a large number of geological and geophysical phenomena and geodetic measurements have been recorded, which manifested themselves during strong earthquakes. There are cases when earthquakes were not accompanied by precursor changes and, conversely, anomalies that are not related to earthquakes. In this regard, the task arises of determining the nature of these anomalous variations. The purpose of our review is to clarify the question of the existence of anomalies similar to modern ones in the geological past and their possible nature.

2. Review and analysis of works devoted to the geomagnetic field anomaly.

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In^[1,2], the geomagnetic field in the Paleozoic is divided into two components: the field of secular variations and the quasi-stationary paleomagnetic field. Secular fluctuations have a period from 1 to 10 thousand years;

In^[3], the results of paleomagnetic studies are presented, where it is established that over the last million years the magnetic field has undergone a number of changes in direction.

The authors of the work^[4] identified periods of 600, 1200, 1800 and about 3000 years.

In^[5], a change in the periodicity of the geomagnetic field in the Late Cambrian with periods of about 50, 34, 20 and 17 thousand years was established. Similar features are, in principle, characteristic of the entire Phanerozoic^[6-8].

Archaeomagnetic studies have been conducted in Russia, Ukraine, India, Moldova, Poland, Georgia, Mongolia, Uzbekistan and other territories. The change of inclination over the last 2000 years in Ukraine has been clarified and an inclination fluctuation with a period of 500-600 years has been revealed. The same phenomenon was observed in Moscow with a period of 500 years. Century-long changes in the intensity of the geomagnetic field of Europe, Asia, Japan, North and South America with a sliding step of 50 years using spectral analysis revealed periods of the order of 350 and 1000 years. The changes of the ancient geomagnetic field on the territory of Georgia in the interval from the third millennium BC to the first millennium AD were studied. A wide range of changes in the parameters of the geomagnetic field has been revealed, ranging from several hundred years to 1200-1800 years^[9-12].

In^[13], a study of changes in the geomagnetic field in Mongolia, Abkhazia and Uzbekistan was conducted. Changes in the tilt and intensity in the territory of Uzbekistan over the last thousand years confirmed the existence of a 500-year period. The results for Mongolia over the last one and a half thousand years showed the presence of secular variations in the tilt and intensity of the field with a period of 500-600 years.

Archaeomagnetic studies in Bulgaria are conducted to determine the inclination of the geomagnetic field in our era^[14]. As a result, a list of age-old variations in the inclination of the ancient geomagnetic field for this area was obtained. Tilt fluctuations with a period of about 700-900 years were detected.

For the territory of Central Europe (Czechoslovakia, Hungary, Poland and Turkey), changes in the intensity of the Earth's magnetic field over the past 8,500 years have been determined^[15]. As a result, there have been long-term changes with a period of about 8,900 years. Variations with a period of about 1200 years have been identified. The nature of these changes is generally similar to the variations for the territories of Central America and Japan. In^[16], slow changes in the geomagnetic field are considered based on archaeomagnetic data. In the spectrum of the geomagnetic field over the last 10 thousand years. Against the background of a period of about 8000 years, there are rapid fluctuations lasting 300-400-600 years and slow fluctuations lasting 1200 and 1800 years. In^[17], changes in the intensity of the ancient geomagnetic field over the past seven thousand years were studied. Here, fluctuations of shorter duration with a period of several hundred years and several tens of years are superimposed on a smooth change with a characteristic time of several thousand years.

The work^[18] presents the results of archeomagnetic studies of the intensity of the geomagnetic field in the 2nd-1st millennia BC. The smooth change in the geomagnetic field is superimposed by shorter-period changes with characteristic periods of 300-500 years.

In^[19] archeomagnetic studies of the Spanish monument Baeza were conducted. Data on the intensity of the geomagnetic field of the 19th - 13th centuries BC were obtained. The maximum smooth change in the

field intensity occurs in the 16th - 15th centuries BC. In the interval of the 19th - 13th centuries BC, rapid changes in the intensity of the geomagnetic field occur.

A brief review of the results of paleomagnetic studies showed that the intensity of the geomagnetic field throughout geological time was complex. Variations of the geomagnetic field with periods ranging from 600 years to 50 thousand years have been revealed. These features of geomagnetic field variations are typical for the entire Phanerozoic^[20-24].

Archeomagnetic studies have been conducted in the territories of North and South America, Europe, Asia, India, and Japan. The research covered the period over the last 10 thousand years. Changes in the intensity of the ancient geomagnetic field have been revealed with a period from several decades to 8-9 thousand years^[25, 26].

Anomalous variations of the geomagnetic field were analyzed according to the data of the world network of magnetic observatories in the modern period^[27, 28]. In a number of observatories, slow field changes are observed with periods of 15-25 years and an amplitude of up to several hundred nTl. Changes with a duration of 1-3 years and an amplitude of about 20-30 nTl were also revealed.

The author of^[29] analyzed data for three observatories Alibag, Abinger - Hartland and Tse. It was found that high-frequency irregular oscillations are observed against the background of a smooth change in low frequencies. The frequency of the low-frequency part ranges from 40-50 years. High-frequency changes with significantly shorter periods were detected in all three observatories.

The spatial structure of the 20-year variation of the geomagnetic field was analyzed using data from more than 50 observatories^[30].

The author of the work^[31] studied data from more than 30 magnetic observatories in Europe. The spatial and temporal characteristics of secular variations of the geomagnetic field for the period from 1957 to 1975 have been studied. During this period, there were three anomalous areas of age-old variations in Europe.

In the work^[32] geomagnetic studies were conducted in the Transcarpathian region during 1982-1989 to study long-period (annual, seasonal) temporal changes in the geomagnetic field. Trend components and local temporal changes with a duration of 1.5-2.5 months and an intensity of up to 5 nTl were identified.

The work^[33] analyzes the results of geomagnetic studies on the territory of the Bishkek geodynamic testing ground. Over a long period of observations, various variations (in form, intensity, duration and sign) of the geomagnetic field were recorded.

The work^[34] examines the features of the manifestation of local variations in the geomagnetic field in the territory of the Alma-Ata geophysical testing ground. As a result of annual measurements of the geomagnetic field for 16 years (1968 - 1983), long-period changes were discovered. Data from some points that differ in intensity and period of anomalous variations in the geomagnetic field were also revealed.

High-precision geomagnetic studies have been conducted on the territories of the Tashkent and Ferghana geodynamic polygons of Uzbekistan for more than 50 years. During this period, along with the previous anomalous changes, anomalous variations associated with geodynamic processes in the lithosphere were revealed^[35]. Sometimes there is an overlap of short-period anomalies with longer ones. These abnormal fluctuations of the parameters are comparable to the abnormal fluctuations caused by the processes of preparation of strong earthquakes.

Anomalous variations of the geomagnetic field found in the territories of geodynamic polygons of Uzbekistan^[36- 42] are divided by linear dimensions into local (from 1 to 5 km or more) and regional (100 km

or more). Variations of a regional and local nature manifested themselves in sinusoidal, bay-shaped and trending forms lasting from 10-15 days to 7 years or more and with an intensity from 2 to 25 nTl^[43, 44]. Long-term changes can sometimes be overlaid with shorter changes of varying intensity, shape, and sign. In terms of quantity and parameters, they are comparable to abnormal changes caused by the processes of preparing strong earthquakes. In this regard, the definition of the nature of secular and anomalous variations discussed above is of great scientific and practical importance.

There are statements in several works about the possible mechanism of manifestation of these variations. In ^[45], the maxima of secular variations with a period of 500 years or more are associated with the phenomenon of western drift.

In works devoted to the modern geomagnetic field^[46-49], it is assumed that the mechanism for the manifestation of anomalies with processes in the core, at the core-mantle, crust-mantle boundaries and currents of an electro kinetic nature at various depths in the earth's crust.

In^[50] it is assumed that under certain conditions a thin “current sheet” arises near the outer boundary of the core. The processes occurring in such a layer may manifest themselves as variations in the magnetic field. S. Runcorn^[51] suggested the possible existence of “leakage” currents from the Earth’s core on the Earth’s surface. In the work^[52] it is suggested that the 20-year cycle of solar activity may influence the Earth’s liquid core, resulting in 20-year variations in the magnetic field. In ^[53,-58] the authors explain the secular variations by some magneto-hydrodynamic interactions in the core. In^[59, 60] it is assumed that the intense secular variations near South Africa can be explained by the assumption of vortex motion in the upper layer of the core. It has been repeatedly assumed that magnetic dipoles can be placed near the core-mantle interface ^[61-65]. The authors of ^[66, 67] calculated the systems of electric currents that were assumed to be located on the surface of the core and to cause the anomalous variations observed at the earth's surface. The authors of ^[68-71] suggest that the observed field can be spatially divided into two parts: one short wave, caused by sources in the Earth's crust, and the other long-wave, the sources of which are possibly located in the core.

3. Conclusion

As a result of a review of the literature the fact of the manifestation of age-old and abnormal variations of the geomagnetic field throughout the entire geological time was established:

- The period of secular fluctuations according to paleomagnetic data ranges from 600 to 100 thousand years;
- The period of anomalous fluctuations according to archaeomagnetic data ranges from several decades to 8-9 thousand years;
- Measurements of the geomagnetic field over the past 200 years have revealed abnormal fluctuations with periods from 10-15 days to 20-60 years.

The noted variations of the geomagnetic field of an unknown nature have been revealed quite often in modern times. They are comparable in all respects to the anomalous variations caused by the processes of preparation of strong earthquakes. This fact poses an urgent task of determining the nature of these anomalies in order to identify the anomalies of the precursors of nature.

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