

OPEN ACCESS

Migration of the northern geomagnetic pole and the fall of temperature on the Earth 8200 years ago

To cite this article: V A Dergachev and S S Vasiliev 2013 *J. Phys.: Conf. Ser.* **409** 012233

View the [article online](#) for updates and enhancements.

You may also like

- [High-resolution, High-sensitivity, Low-frequency uGMRT View of Coma Cluster of Galaxies](#)
D. V. Lal, N. Lyskova, C. Zhang et al.
- [DARK MATTER SCALING RELATIONS AND THE ASSEMBLY EPOCH OF COMA EARLY-TYPE GALAXIES](#)
J. Thomas, R. P. Saglia, R. Bender et al.
- [A roadmap to achieve the global methane pledge](#)
Christopher S Malley, Nathan Borgford-Parnell, Seraphine Haeussling et al.



PRIME
PACIFIC RIM MEETING
ON ELECTROCHEMICAL
AND SOLID STATE SCIENCE

HONOLULU, HI
Oct 6–11, 2024

Abstract submission deadline:
April 12, 2024

Learn more and submit!



Joint Meeting of

The Electrochemical Society
•
The Electrochemical Society of Japan
•
Korea Electrochemical Society



Migration of the northern geomagnetic pole and the fall of temperature on the Earth 8200 years ago

V A Dergachev¹ and S S Vasiliev²

Ioffe Physical-Technical Institute of the Russian Academy of Sciences;
Polytechnicheskaya, 26, St.-Petersburg 194021, Russia

E-mail: ¹v.dergachev@mail.ioffe.ru, ²sergey.vasiliev@mail.ioffe.ru

Abstract. We have analyzed the paleomagnetic data on lake sediments. For known values of declination, inclination and the site position in the framework of a model of the geomagnetic dipole the pole position (GMP) was evaluated as a function of time for the past 10,000 years. The values obtained for the position of the geomagnetic poles were presented in the form of an expansion in the empirical modes (EMD). It is shown that the latitude and longitude do not change stochastically with time, but have regular cyclical components. Velocity of drift of the GMP has been estimated. The correlation analysis of accumulation rate of Greenland ice and of the position of GMP are carried out and it is shown that there is a significant correlation between these data. The data on changes in the latitude of GMP that taken place 8.2 thousand years ago are discussed.

1. Introduction

The magnetic field of the Earth has the complex structure including dipole, quadrupole and other components. There are numerous papers on reconstruction of the magnetic field of the Earth in the past (e.g., [1, 2]). As a rule, these reconstructions are based on axial-symmetric model of the magnetic field. This model assumes that the axis of the magnetic field coincides with the axis of rotation of the Earth. With this approach, there are difficulties in interpreting the data of the reconstructed field of the Earth [3]. In contrast, in the present paper the positions of the magnetic pole for the previous 10,000 years are investigated in detail.

Databases of parameters of geomagnetic field for past epochs now are available [4]. These data are based on the study of natural samples containing information about the spatial orientation and the degree of magnetization. The data we use include an information on the direction and intensity of magnetic field at the moment of formation of the sample. Lava of volcanoes, archaeological artifacts, and lake sediments are the samples of this type. We will base on magnetic field measurements in lake sediments for following reasons:

1. Data for lake sediments, as a rule, belong to a suitable time interval (8-10 thousand years to the past and more);
2. Measurements form chronological sequence;
3. There is an information on the direction of prehistoric field.

2. Data and processing

We have considered and analyzed paleomagnetic data on lake sediments from 30 sources [4]. These data present the measurements of magnetic declination and magnetic inclination in layers of sediment core. Dating was carried out by the radiocarbon method.

Using known values of declination, inclination, and coordinates of the site [5], on the basis of dipole model, the position of magnetic pole versus time is estimated. Because of errors in the measurement, the pole position fluctuates significantly and the deviations from the mean value are not symmetrical. By this reason for the analysis of derived data we have chosen a method based on consideration of distribution function. Data from all sources have been sorted by time. For each 200-year time span the discrete distribution function was calculated. As a result of smoothing, the continuous density of distribution was calculated. The maximum of the distribution density was accepted as the most probable value of latitude in examined time interval.

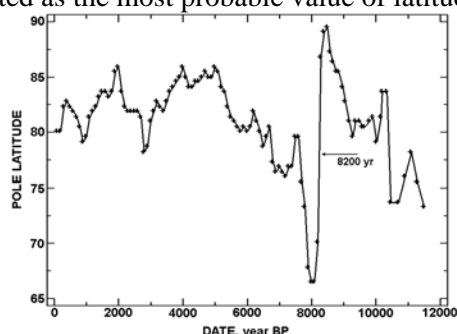


Figure 1. Data on latitude of the geomagnetic pole obtained for 10 thousand years by the maximum likelihood method. Calibrated age of sample is plotted on the horizontal axis and pole latitude is plotted on the vertical axis. The calculated values are marked by crosses

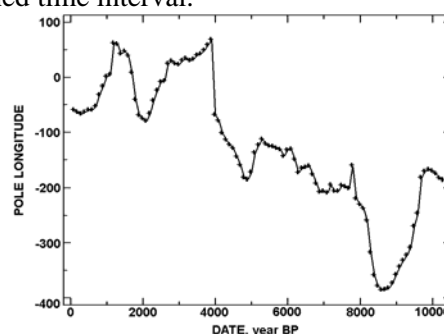


Figure 2. Data on longitude of the geomagnetic pole obtained by the maximum likelihood method for time interval of 0–10,000 years BP. Calibrated age is plotted on the horizontal axis, the pole longitude is plotted on the vertical axis. The calculated values are marked by crosses

Thus, all 200-year ranges of time for the last 10 thousand years have been considered. A 100-year displacements were used as a time step. The results are presented in Figure 1. Consideration of the time dependence of the longitude of pole has been carried out just as for the latitude. The curve for longitude was obtained by calculations (see Figure 2).

3. The EMD-analysis of data on changes in position of the geomagnetic pole

At first sight, the changes in the position of the geomagnetic pole (Figure 1 and Figure 2) are chaotic. The obtained time dependencies of latitude and longitude have non-stationary character. For analysis of similar signals the method of empirical mode decomposition (EMD) was developed [6]. The essence of the method is that the original data are decomposed into orthogonal components. Feature of this method is that orthogonal functions are not predetermined as, for example, in the Fourier-analysis. They are obtained through processing the data. Without considering the technical details of the processing (that can be found in the literature) we present below the results of changes of pole latitude and longitude in time.

Table 1. Cyclic modes in the analysis of latitude

Mode	Period ^a	Power ^b
IMF2	1876	0.15
IMF3	2737	0.30
IMF4	6185	0.30

^a in years.

^b in relative units.

Table 2. Cyclic modes in the analysis of longitude

Mode	Period ^a	Power ^b
IMF2	1240	0.10
IMF3	2200	0.43
IMF4	3690	0.46

Table 3. Spectral lines of accumulation rate of ice.

Line	Period ^a	Power ^b
1	1300	16
2	2000	11
3	3500	9

The data on the latitude and longitude contain a noise component. A cause of the noise is not clear, although much of it can be attributed to errors of measurement. The linear trend can be seen in changes of the latitude and longitude. The other modes are cyclic functions for which the Fourier spectra were calculated (see table 1 and table 2).

4. The accumulation rate of the ice in Greenland and pole position

There are studies which discuss the connection between position of the geomagnetic pole and the change of climate [7]. The temperature data [8] and the accumulation rate of ice in Greenland [9] are suitable for comparison of the changes of latitude and longitude of GMP with climate. To study of possible cyclic processes, the spectral analysis of the rate of accumulation has been made. Periods of the most powerful lines are 1300, 2000 and 3500 years. These lines correspond to lines of longitude cyclic modes (see table 2 and table 3).

The similarity of the harmonic components presented in tables 2 and 3 suggests a possible correlation of accumulation rate and pole position. After removal of trends, the correlation analysis of these data was carried out. The obtained correlation coefficient K_{cor} is equal to 0.4, and is significant at a confidence level of 0.9995 ($p = 0.0005$).

5. Climatic anomaly occurred 8.2 thousand years ago

The well-known climatic anomaly occurred about 8.2 thousand years ago [10]. Its best known manifestation is the short-term changes in the Earth's temperature. A good indicator of the temperature is the relative concentration of the natural isotopes of oxygen ^{18}O ($\delta^{18}\text{O}$). This parameter is known from studies of ice cores in Greenland. Figure 3 shows the relative concentration of oxygen ^{18}O in the Greenland ice in the last 10,000 years. A short-term decrease of the content of heavy isotope of oxygen in ice is observed at about 8200 year BP. It indicates the temperature fall in northern Atlantic about 8200 years BP.

It is known that there is a relation between the relative concentration of heavy oxygen isotope ^{18}O in the fresh snow and temperature of the air T [11]: $\Delta\delta^{18}\text{O} \propto 0.67 \cdot \Delta T$. How it follows from Figure 3, $\Delta\delta^{18}\text{O} \approx 1.75$ ‰, whence we get an estimation: $\Delta T \approx 2.6$ °C.

The change in latitude of the geomagnetic pole in the last 10,000 years is shown in Figure 1. There are peculiarities in the Figure 1: a sharp drop of the latitude of the pole about 8200 BP. Such a coincidence of displacement of the geomagnetic pole and the appearance of temperature minimum cannot be casual. A more detailed examination of the dynamics of the pole movement shows that there was a sharp decrease in the latitude of the pole about 8200 years BP, the stabilization of position and the subsequent restoration of its latitude. The additional information can be obtained from consideration of track of moving of pole (Figure 4).

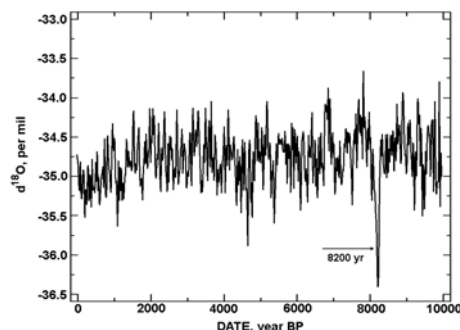


Figure 3. Temperature indicator $\delta^{18}\text{O}$ for the ice core of Greenland. The relative concentration ^{18}O is plotted on vertical axis

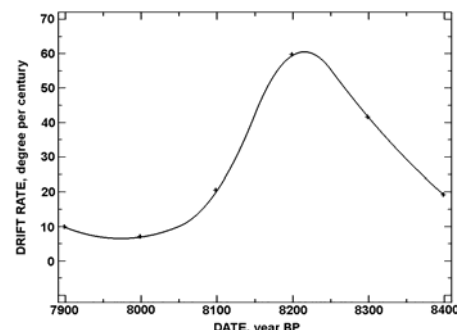


Figure 4. Velocity of drift of the pole. The velocity of pole drift is plotted on vertical axis. A degrees of arc of great circle are used as unit

6. Conclusions

We have considered and analyzed paleomagnetic data on lake sediments from 30 sources. For the dipole model, the geomagnetic pole position was found as a function of time for the last 10,000 years.. It is shown that the latitude and longitude do not change stochastically with time, but have regular cyclical components. The trend of the longitude is observed, which corresponds to the drift of the pole longitude. The velocity of drift is 3.24 degrees of longitude in the century.

We considered the correlation of one of the indicators of climate change, of the rate of the snow accumulation and the geomagnetic pole position. The obtained coefficient of correlation K_{cor} is equal to 0.4 and is significant at confidential level of 0.9995 ($p=0.0005$).

We showed that sharp fall of latitude of the geomagnetic pole took place at $t \approx 8200$ yr BP. Data on the sharp short-term changes in temperature, that have occurred 8.2 thousand years ago, were compared to the changes in latitude of GMP. The conclusion is that short-term change in the latitude of the geomagnetic pole and the temperature depression 8200 years ago are interrelated.

References

- [1] McElhinny M W and Senanayake W E 1982 Variations in the geomagnetic dipole: I. The past 50,000 years *J. Geomag. Geoelectr.* **34** 39
- [2] Knudsen M F, Riisager P, Donadini F, Snowball I, Muscheler R, Korhonen K, Pesonen L J and Jacobsen B H 2008 Variations in the geomagnetic dipole moment during the Holocene and the past 50 kyr *Earth Planet. Sci. Lett.* **272** 319
- [3] Dergachev V A, Vasiliev S S, Raspopov O M and Jungner H 2010 Long-term changes of formation rate of cosmogenic isotopes ^{10}Be for last 10 thousand years and variations of virtual dipole moment of the Earth *Problems of Geocosmos: Proc. 8th International Conference (St. Petersburg, Russia, 20-24 September 2010)* ed V. S. Semenov (St. Petersburg: Saint-Petersburg State University) pp 75-80
- [4] Donadini F, Korhonen K, Riisager P and Pesonen L J 2006 Database for Holocene geomagnetic intensity information *EOS Trans. Am. Geophys. Soc.* **87** 92
- [5] Merrill R T, McElhinny M W and McFadden P L 1996 Magnetic field of the Earth: Paleomagnetism, the core, and deep mantle (San Diego: Academic Press)
- [6] Huang N E, Shen Z, Long S R, Wu M C, Shih H H, Zheng Q, Yen N C, Tung C C and Liu H H 1998 The empirical mode decomposition and the Hilbert spectrum for nonlinear and non-stationary time series analysis. *Proc. R. Soc. Lond. A* **454** 903
- [7] Bakhmutov V 2006 The connection between geomagnetic secular variation and longrange development of climate changes for the last 13,000 years *Quaternary International* **149** 4 doi:10.1016/j.quaint. 2005.11.013
- [8] Stuiver M, Grootes P M and Braziunas T F 1995 The GISP2 ^{18}O climate record of the past 16,500 years and the role of the sun, ocean and volcanoes *Quaternary Research* **44** 341
- [9] Cuffey K M, Clow G D, Alley R B, Stuiver M, Waddington E D and Saltus R W 1995 Large Arctic temperature change at the Wisconsin-Holocene glacial transition *Science* **270** 455
- [10] Dansgaard W, Johnsen S J, Clausen H B, Dahl-Jensen D, Gundestrup N S, Hammer C U, Hvidberg C S, Steffensen J P, Sveinbjornsdottir A E and Jouzel J 1993 Evidence for general instability of past climate from a 250-kyr ice-core record *Nature* **364** 218
- [11] Jouzel J, Alley R B, Cuffey K M, Dansgaard W, Grootes P, Hoffmann G, Johnsen S J, Koster R D, Peel D, Shuman C A, Stievenard M, Stuiver M and White J 1997 Validity of the temperature reconstruction from water isotopes in ice cores *J. Geophys. Res.* **102** 26471 doi:10.1029/97JC01283