

# ON THE POSSIBILITIES OF USING GEOMAGNETIC STORMS TO STUDY THE ELECTRICAL CHARACTERISTICS OF THE EARTH

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**Abstract**

**Full Text**

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*GEOPHYSICS*

M. B. GOKHBERG

## **ON THE POSSIBILITIES OF USING GEOMAGNETIC STORMS TO STUDY THE ELECTRICAL CHARACTERISTICS OF THE EARTH**

*(Presented by Academician A. P. Aleksandrov, 14 VI 1965)*

Magnetic storms are a powerful and clearly expressed phenomenon in the Earth's electromagnetic field. It is therefore very tempting to consider the possibility of using them for the practical determination of deep geoelectrical characteristics of the Earth by the method of magnetotelluric sounding.

At present, magnetotelluric sounding (MTS) curves (<sup>1-3</sup>), from which the deep parameters of the geoelectrical section are determined, are constructed by processing variations of the natural field of the Earth, which, generally speaking, have different origins. As will be shown below, a number of important parameters of the Earth's deep structure can be obtained by processing simultaneous records of the electric and magnetic components of the initial phase of a magnetic storm with a sharp onset. The electromagnetic fields of such storms observed on the Earth's surface are naturally related to the distribution with depth of its electrical conductivity. The field components reflect the process of establishment of the electromagnetic field in the conducting Earth.

A characteristic feature of sharp onsets of both bay-like disturbances and magnetic storms is the rapid increase of the field and a clearly expressed initial stage of the process, which in magnetic storms may last 2 hours or more. The complicated character of the record in the "tail" part of the process makes it difficult to apply the usual processing techniques, in particular Fourier spectral decompositions, used in the MTS method.

The method described in (<sup>4</sup>) makes it possible to suppress the tail part of the process and to extract the information of interest to us about the geoelectrical section from its most clearly expressed initial stage. With appropriate processing of such a nonstationary process, information on the deep structure can be obtained from an initial time interval substantially shorter than in harmonic analysis of records, in particular of daily variations of the Earth's natural electromagnetic field.

Fig. 1

Figure 1: Fig. 1

Figure 1 shows a sharp nonstationary disturbance of the electromagnetic field in the region of the city of Ashkhabad, recorded on 4 XII 1962 by V. G. Dubrovsky (Academy of Sciences of the Turkmen SSR). This is one of the most favorable cases, when there is a clear onset of both the electric and magnetic fields. While the horizontal component of the magnetic field  $H_x$  reaches a certain level and remains at it for about 2 hours, the horizontal component of the electric field  $E_y$  returns to its initial value within 1 hour.

As indicated in <sup>(4)</sup>, the problem of deep sounding using nonstationary disturbances is solved on the basis of the transform

$$F(p) = \int_0^{\infty} f(t)e^{-pt} dt, \quad (1)$$

where  $p$  is a real number having the dimension of frequency, and  $f(t)$  is the dependence of the electric or magnetic field on time.

The apparent resistivity of the section is calculated by the formula

$$\rho_p = \frac{0.4\pi}{p} \left[ \frac{E_y(p)}{H_x(p)} \right]^2, \quad (2)$$

where, as is customary in the MTS method,  $E$  is expressed in millivolts per kilometer,  $H$  in gammas, and  $\rho_p$  in ohm  $\cdot$  m.

The integral transforms for the time dependences  $H_x$  and  $E_y$  were calculated by selecting simple functions of the type

$$f_1(t) = 1 - \exp(-\alpha t), \quad f_2(t) = [1 - \exp(-\alpha t)] \exp(-\beta t). \quad (3)$$

### Fig. 1

For the chosen time scale, the actual records  $H_x(t)$  and  $E_y(t)$  in Fig. 1 correspond to the representations

$$H_x(t) = 1 - \exp(-20t), \quad E_y(t) = [1 - \exp(-20t)] \exp(-3t), \quad (4)$$

indicated by the dotted line. For  $\rho_p$  we obtain:

$$\rho_p = \frac{0.4\pi}{p} M \left[ \frac{p(20+p)}{(3+p)(23+p)} \right]^2, \quad (5)$$

Fig. 2

Figure 2: Fig. 2

where  $M$  is the scale coefficient determined by the specific conditions of registration.

**Fig. 2**

Figure 2 presents the curve  $\rho_p$  on a bilogarithmic scale, constructed by formula (5). The dotted line denotes the curve obtained with the aid of the quadrature formula (14) of paper [4] from ordinates taken directly from the oscillogram.

Thus, from a single electromagnetic process an almost complete curve of deep sounding has been obtained. The initial stage of the process of establishment, in the region of large  $p$ , when the electric and magnetic fields change sharply, reflects the structure of the near-surface parts of the Earth's crust, which are characterized by the total longitudinal conductance of the sedimentary layer  $S$ . At a later stage of the process there is a significant level of magnetic-field intensity, while the electric field is practically established at its initial value,

which corresponds to the right descending branch of the sounding curve. From this part of the curve  $\rho_p$ , the depth  $h_{\text{sum}}$  to the layer of high conductivity is determined. From the abscissa of the point of intersection  $1/\sqrt{p_0}$  of the left descending branch of the curve  $\rho_p$  with the line  $\rho_p = 1 \Omega \cdot \text{m}$ , one determines  $S = 890 \frac{1}{\sqrt{p_0}}$ . Within the accuracy of the method, the value  $S = 3500 \text{ mo}$  coincides with the value of  $S$  obtained from a magnetotelluric survey at the same point. From the abscissa of the point of intersection of the right branch with the line  $\rho_p = 1 \Omega \cdot \text{cm}$ , one determines

$$h_{\text{sum}} = \frac{1}{\sqrt{0.4\pi}} \frac{1}{\sqrt{p_0}} \simeq 250 \text{ km.}$$

It should be noted that, when processing by the method of harmonic analysis, the descending branch of the curve  $\rho_k$  of analogous geoelectrical sections can be obtained only from the first harmonics of the diurnal variations of the Earth's electromagnetic field. In analyzing such a storm with a sharp onset, however, study of a time process of duration about 2 hours is sufficient to obtain the necessary information.

In the present work, the author, jointly with Z. G. Lomakina, has developed a program for computing the transform  $F(p)$  by means of an electronic digital computer. The results of processing bay-shaped disturbances with a sharp onset for the Pleshchenitsy Observatory (Minsk) agree with the data of N. V. Lipskaya (3). The computed values of  $\rho_p$  as a function of  $1/\sqrt{p}$  are plotted in Fig. 3.

**Fig. 3**

Fig. 3

Figure 3: Fig. 3

The range of reliable values of  $p$  was estimated as a function of the choice of the minimum time interval  $\tau$  for various simplest functions. It turned out that, for impulses actually encountered, one may practically take  $p \geq 4/\tau$ . For all the curves described above this requirement is satisfied.

Estimates show that, in interpreting ground observations of magnetic storms for the purpose of magnetotelluric sounding, over a sufficiently wide range of values of  $p$  one may use the plane-wave scheme without taking into account corrections for the sphericity of the Earth.

Thus, the rich spectrum of the initial stage of magnetic storms with a sudden commencement makes it possible to recommend them for broad use in deep magnetotelluric sounding.

Schmidt Institute of Physics of the Earth,  
Academy of Sciences of the USSR

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*Note: Figure translations are in progress. See original paper for figures.*

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