Reports of the Academy of Sciences of the USSR

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1965

SovietRxiv

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Abstract

Full Text

Reports of the Academy of Sciences of the USSR
1965. Volume 164, No. 3

GEOPHYSICS

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DEEP MAGNETOVARIATIONAL SOUNDINGS (M.V.S.) IN THE SOUTH OF CENTRAL SIBERIA AND IN TRANSBAIKALIA

A considerable decrease in the electrical resistivity of crystalline rocks upon heating to 800-1200° (^16) makes electromagnetic methods among the very promising ones for geothermal investigations of the Earth' s interior (^6, ^7). As a result of an analysis of geomagnetic variations for the Earth as a whole, it was established that, after extremely high values of resistivity within the Earth' s crust and somewhat deeper, a sharp decrease is observed at depths of about 200-300 km, i.e., in the Earth' s upper mantle, which is consistent with the temperature distribution in the same section according to other geophysical data (^1, ^14, ^15).

For studying geoelectrical characteristics in a local region, a method of magnetotelluric soundings (^9, ^13) was proposed, using synchronous observations at one point of variations of the horizontal components of the electric [E] and magnetic [H] fields to determine, over a broad spectrum of periods, the apparent resistivity $\rho_T = 0.2(E/H)^2$. This modification has found wide application in exploration geophysics for determining the thickness of conducting sedimentary strata overlying the consolidated Earth' s crust (^2). However, experience has shown that, in studying the upper mantle by the magnetotelluric sounding method, considerable difficulties are encountered in a number of places, associated with the influence of inhomogeneities of the sedimentary cover. Indeed, it follows from Ohm' s law that the intensity of low-frequency variations of a uniform electric field, polarized in the direction of change of the integral conductivity S of the sedimentary cover, is inversely proportional to S.

Fig. 2 and Fig. 3

Figure 2: Fig. 2 and Fig. 3

Fig. 1. Layout of observation points.
1 —Siberian Platform; 2 —folded structures of the Eastern Sayan, Baikal region, and Transbaikalia

The use of magnetic variations alone (⁀17) to a considerable extent freed the observational results from the influence of the sedimentary cover and made it possible to propose a procedure for identifying large inhomogeneities of the upper mantle.

Analysis shows that, by using certain types of geomagnetic variations, it is also possible to determine, in a local region, the variation of resistivity with depth, i.e., to carry out m.v.s. Here we have in mind geomagnetic variations with a period of 0.5–4 hours, the so-called "bays," recorded at a distance $y \geq$ 1500–2000 km from the quasi-linear polar current flowing near 70° N latitude and constituting their source (⁀5). In this case the following expression for the apparent—

of the apparent resistivity:

$$\rho_T = \frac{2}{T}\left(y\frac{z}{H}\right)^2,$$

where z is the amplitude of the variation of the vertical component of the magnetic field.

The identification of "bays," whose source is the polar current, becomes possible when a network of field magneto-variation stations is used, owing to the fact that variations of this type are characterized in middle latitudes by a regular decrease of z inversely proportional to the cube of the distance from the source, and of H inversely proportional to the square of this distance (5).

Fig. 2. Correlation of the z impulse along the profile

Fig. 3. M.V.S. curves obtained in Kachug (1), Barguzin (2), Patrony (3), Ulan-Ude (4), and Khilok (5)

By work of the Institute of Geology and Geophysics of the Siberian Branch of the Academy of Sciences of the USSR, carried out in 1962–1963 in the south of Central Siberia (the Siberian Platform) and in Transbaikalia, a number of geomagnetic bays were identified, the regularities of whose spatial distribution corresponded to the requirements given above (Figs. 1, 2, 4). At the same time it is important to emphasize that although the S of the sedimentary cover along the profile varied almost from zero (at exposures of crystalline rocks near Lake Baikal) to 500–600 mho (in the Kansk-Taseevo depression), this did not introduce substantial distortions into the intensity and form of the geomagnetic

Fig. 4. Geophysical section along the Achinsk—Irkutsk (Patrony)—Chita profile.

Figure 3: Fig. 4. Geophysical section along the Achinsk—Irkutsk (Patrony)—Chita profile.

variations. However, in moving to the southeast from Lake Baikal, an anomalous decrease of the z variations by approximately 50% is observed.

On the M.V.S. curves, constructed in the range of periods from 0.5 to 3 hours (Fig. 3), a decrease of ρ_T with increasing period of oscillations is established, i.e., with increasing depth of penetration of the field. Among the curves obtained, two types are clearly distinguished: the first, characterized by elevated apparent resistivities, is observed to the northwest of the Baikal depression; the second, with lower values of ρ_T, is distributed to the southeast of the depression. This testifies to increased geothermal activity of the upper mantle in the folded regions of the Cisbaikal area and Transbaikalia in comparison with the regions of the Siberian Platform.

Despite the limited frequency spectrum of the recorded variations, which does not allow a detailed quantitative interpretation, from the graphs in Fig. 3 it is possible to estimate the depth h, near which

the resistivity decreases most significantly as a result of heating. As is known (10), h is determined from the abscissa $\sqrt{T}$ of the point of intersection of the tangent to the right-hand part of the sounding curve, falling at an angle of $-63°25'$, with the axis $\rho_T = 1\ \Omega \cdot \mathrm{m}$ ($h = 356\sqrt{T}$). Such an estimate gives $h \simeq 180$ km for type-I curves and $h \simeq 80$ km for type-II curves, which confirms the conclusion about anomalous heating of the upper mantle in Transbaikalia.

Fig. 4. Geophysical section along the Achinsk—Irkutsk (Patrony)—Chita profile.
1 —Earth' s crust; 2 —base of the Earth' s crust (M); 3 —top of the horizon of elevated electrical conductivity;
z'_{H} —bay of 29 IX 1962; z''_{H} —bay of 18 VIII 1963.

Figure 4 shows a section along the Achinsk—Chita profile, which crosses Lake Baikal in its southwestern part. In this section, in addition to the data of magnetovariational studies (the ρ_T curves; graphs of the ratios z_{H}—the observed field to z_0—the normal field), the curves ΔT_a and Δg, the Mohorovičić surface, and the roof of the horizon of elevated electrical conductivity within the upper mantle are shown.

The interpretation of the behavior of gravity anomalies and geomagnetic fields in the region under consideration is the subject of works by A. P. Bulmasov et al. ([3,4,11,12]). The connection between the deep structure of these regions and their seismicity is considered there as well. These data reflect considerable fluctuations in the thickness of the Earth' s crust within the Baikal region and a sharp isostatic disequilibrium here of individual blocks of the crust, which move along faults and fractures of very deep origin.

The geological aspects of interpreting the connection between the geothermal heterogeneity of the upper mantle and the tectonic structure of the upper horizons of the Earth' s crust in the Baikal region and southern areas of the Siberian Platform have already been discussed earlier in general terms ([8]). It should be added that, in the same direction, the emerging regularities between the geothermal heterogeneity of the upper mantle and the composition of deep-seated material that has reached, even in altered form, the Earth' s surface in a number of areas of the territory under consideration must also be examined. Thus, the basaltic magma intrusions (traps) widely developed in the regions of the Siberian Platform correspond to the greatest depths (up to 200 km) of the horizon

of increased electrical conductivity (elevated temperatures) in the upper mantle. The rise of this horizon in Transbaikalia is accompanied by a change in the composition of the principal intrusions to trachybasaltic ones. It is evident that a more detailed study of the available geological and geophysical data will make it possible to establish new regularities and to clarify the causes that determine them.

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Received
20 I 1965

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