

**GENERALIZATION OF
DATA ON THE
ELECTRICAL
CONDUCTIVITY OF
IGNEOUS ROCKS AT
HIGH TEMPERATURES
IN CONNECTION WITH
THE STRUCTURE OF
THE EARTH' S CRUST
AND UPPER MANTLE**

GEOPHYSICS

1968

SovietRxiv

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.

Fig. 1. Regions of location of the graphs $\sigma = f(1/T)$ for rocks. 1 –granites; 2 –basalts; 3 –ultrabasic rocks; 4 –alkaline rocks of the Lovozero massif

Figure 1: Fig. 1. Regions of location of the graphs $\sigma = f(1/T)$ for rocks. 1 –granites; 2 –basalts; 3 –ultrabasic rocks; 4 –alkaline rocks of the Lovozero massif

Abstract

Full Text

UDC 552.1:53

GEOPHYSICS

A. T. BONDARENKO

GENERALIZATION OF DATA ON THE ELECTRICAL CONDUCTIVITY OF IGNEOUS ROCKS AT HIGH TEMPERATURES IN CONNECTION WITH THE STRUCTURE OF THE EARTH' S CRUST AND UPPER MANTLE

(Presented by Academician M. A. Sadovskii, 18 IV 1967)

Laboratory investigations of the temperature dependence of the electrical conductivity σ of rocks, and the values calculated from it for the activation energy of the current carriers E_0 and the pre-exponential coefficient σ_0 , are used in calculations of thermodynamic conditions and processes in the deep layers of the Earth' s crust, as well as in the upper mantle ^(1,2). Rocks, in composition and structure even within a single type, are very diverse, and the magnitude of their electrical conductivity may differ greatly. Therefore it became necessary to generalize the experimental data obtained and to derive average electrical-conductivity curves as a function of temperature for different types of rocks.

Fig. 1. Regions of location of the graphs $\sigma = f(1/T)$ for rocks. **1** –granites; **2** –basalts; **3** –ultrabasic rocks; **4** –alkaline rocks of the Lovozero massif.

Average values of the electrical parameters were obtained on the basis of measurements of about 200 samples of various rocks, selected

mainly on the Kola Peninsula. The basalts were taken from other deposits, including islands of the rift zone of the Indian Ocean. In addition, for comparison, several samples of igneous rocks from other regions were studied. The method for measuring the electrical conductivity of rocks under high-temperature conditions is described in ⁽³⁾. It was determined from the mean value of the initial

current recorded in two directions.

A large number of measured samples of various types of igneous rocks made it possible to determine average data for electrical conductivity, activation energy, and the pre-exponential coefficient (see Table 1).

As a result, for dry rocks, regions of the positions of the graphs were constructed in the coordinate system logarithm of electrical conductivity—reciprocal absolute temperature (Fig. 1). In the centers of these regions, the mean values of electrical conductivity are shown by a solid line.

Table 1

Mean values of electrical conductivity σ , activation energy E_0 , and pre-exponential coefficient σ_0 of igneous rocks

| Rock | Temperature interval, °C | σ , ohm ⁻¹ · cm ⁻¹ | E_0 , eV | σ_0 , ohm ⁻¹ · cm ⁻¹ |
|--------------------------------------|--------------------------|---|------------|---|
| Granites | 100–275 | $3 \cdot 10^{-14} 8.4 \cdot 10^{-12}$ | 0.56 | $4 \cdot 10^{-6}$ |
| Granites | 275–900 | $5 \cdot 10^{-7}$ | 0.92 | $5 \cdot 10^{-3}$ |
| Granites | 900–1200 | $1 \cdot 10^{-4}$ | 4.0 | $5 \cdot 10^9$ |
| Gneisses | 100–850 | $4 \cdot 10^{-10} 2 \cdot 10^{-4}$ | 0.6 | 0.5 |
| Gneisses | 850–1200 | $5 \cdot 10^{-2}$ | 2.4 | $6 \cdot 10^7$ |
| Basalts | 50–550 | $1 \cdot 10^{-11} 1 \cdot 10^{-6}$ | 0.56 | $4 \cdot 10^{-3}$ |
| Basalts | 550–900 | $8 \cdot 10^{-3}$ | 0.9 | 0.5 |
| Basalts | 900–1200 | $4 \cdot 10^{-3}$ | 2.3 | $6 \cdot 10^3$ |
| Diabases | 50–450 | $1 \cdot 10^{-11} 3 \cdot 10^{-7}$ | 0.5 | $2 \cdot 10^{-3}$ |
| Diabases | 450–800 | $1 \cdot 10^{-4}$ | 1.12 | $1 \cdot 10^{-1}$ |
| Diabases | 800–1200 | $1 \cdot 10^{-2}$ | 1.7 | $9 \cdot 10^1$ |
| Gabbro | 150–900 | $3 \cdot 10^{-12} 5 \cdot 10^{-6}$ | 0.8 | $9 \cdot 10^{-3}$ |
| Gabbro | 900–1200 | $2 \cdot 10^{-3}$ | 3.3 | $5 \cdot 10^7$ |
| Ultrabasic rocks | 100–450 | $3 \cdot 10^{-13} 1 \cdot 10^{-8}$ | 0.79 | $1 \cdot 10^{-3}$ |
| Ultrabasic rocks | 450–850 | $6 \cdot 10^{-6}$ | 1.2 | $5 \cdot 10^{-1}$ |
| Ultrabasic rocks | 850–1200 | $2 \cdot 10^{-3}$ | 2.3 | $6 \cdot 10^{-4}$ |
| Dunite | 100–700 | $1.6 \cdot 10^{-12} 1 \cdot 10^{-7}$ | 0.7 | $9 \cdot 10^{-4}$ |
| Dunite | 700–1200 | $2 \cdot 10^{-4}$ | 2.0 | $5 \cdot 10^2$ |
| Alkaline rocks of the Khibiny massif | 20–700 | $3 \cdot 10^{-12} 1.6 \cdot 10^{-8}$ | 0.62 | $7 \cdot 10^{-4}$ |

| Rock | Temperature interval, °C | σ , ohm ⁻¹ · cm ⁻¹ | E_0 , eV | σ_0 , ohm ⁻¹ · cm ⁻¹ |
|---------------------------------------|--------------------------|---|------------|---|
| Alkaline rocks of the Khibiny massif | 700–1200 | $1 \cdot 10^{-2}$ | 2.8 | $1 \cdot 10^5$ |
| Alkaline rocks of the Lovozero massif | 20–800 | $1 \cdot 10^{-10} \cdot 2.6 \cdot 10^{-5}$ | 0.45 | $5 \cdot 10^{-3}$ |
| Alkaline rocks of the Lovozero massif | 800–1200 | $1 \cdot 10^{-2}$ | 2.3 | $5 \cdot 10^5$ |

It is evident from the figures that the electrical-conductivity graphs of individual types of rocks (not plotted in the hatched areas) occupy a definite region. For granites and gabbro (data for gabbro are not given in the figures), these regions are narrow bands with a large angle of inclination to the horizontal axis. Basalts at low and high temperatures have high electrical conductivity in comparison with granites; therefore the region in which the graphs $\sigma = f(1/T)$ for basalts are located is shifted upward and occupies a wide band.

Ultrabasic rocks are very diverse in their composition; therefore, the graphs of their electrical conductivity in the low-temperature interval occupy a wide zone. However, in the inclination of this region and in the values of electrical conductivity in the temperature interval 50–1200° C, they differ from other types of igneous rocks. Alkaline rocks, in their electrical parameters, differ even more sharply from rocks of acidic and ultrabasic composition.

When considering the graphs, as well as the activation energy, attention is drawn to the fact that, first, in the high-temperature region, E_0 for rocks of different composition has high and approximately identical

values; second, all regions of $\sigma = f(1/T)$ coincide. These experimental data indicate an ionic mechanism of conductivity, carried out by ions of the crystal lattice, as well as by defect ions. The conductivity of the low-temperature segment, judging by the low activation energy, is effected by impurity ions.

Fig. 2. Distribution of electrical conductivity in the Earth's crust and upper mantle, constructed from experimental data: 1—sedimentary layer; 2—granite-gneiss layer; 3—granulite-basite layer; 4—granulite-eclogite layer

Averaged electrical-conductivity data made it possible to construct a general

Figure 2. Distribution of electrical conductivity in the Earth' s crust and upper mantle, constructed from experimental data: 1—sedimentary layer; 2—granite-gneiss layer; 3—granulite-basite layer; 4—granulite-eclogite layer

Figure 2: Figure 2. Distribution of electrical conductivity in the Earth' s crust and upper mantle, constructed from experimental data: 1—sedimentary layer; 2—granite-gneiss layer; 3—granulite-basite layer; 4—granulite-eclogite layer

experimental curve for the distribution of the electrical conductivity of the continents down to a depth of 100 km (Fig. 2). The scheme of the structure of the Earth' s crust and the upper mantle of the continents is taken from (4). From Fig. 2 it is seen that σ , from the sedimentary to the granite-gneiss layer, decreases sharply down to a depth of 15 km, and with a further increase in depth and temperature begins to increase. Within the crust and in the granulite-basite and granulite-eclogite layers at depths of 20–35 km, and in the upper mantle at a depth of 45 km, the sharp increase in electrical conductivity slows. A rapid increase in σ is again observed at a depth of 75 km. At a depth of 100 km, according to experimental data for peridotites, the electrical conductivity takes an average value of $10^{-3} \text{ ohm}^{-1} \cdot \text{cm}^{-1}$; for dunites, $10^{-4} \text{ ohm}^{-1} \cdot \text{cm}^{-1}$, i.e., these values are close to the data obtained from variations of the Earth' s electromagnetic field.

The distribution of electrical conductivity with depth probably corresponds to reality, since it was constructed on the basis of experimental data for rocks occurring at definite depths. When measurements of electrical conductivity are carried out not only at high temperatures, but also at high pressures, the distribution curve of σ with depth may shift somewhat. The sharp increase in electrical conductivity at depths of 50–60 km, recorded from variations of the electromagnetic field (5), may occur because of a local increase in alkaline oxides in the composition of the mantle (6).

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

Received
10 IV 1967

CITED LITERATURE

1. V. N. Zharkov, *Izv. AN SSSR, ser. geofiz.*, No. 9 (1959).
2. V. N. Zharkov, *Izv. AN SSSR, ser. geofiz.*, No. 4 (1958).
3. A. T. Bondarenko, *Tr. Inst. fiz. Zemli AN SSSR*, No. 37 (1966).
4. V. V. Belousov, *The Earth' s Crust and Upper Mantle of the Continents*, "Nauka," 1966.

5. A. Adam, *Gerlands Beitr. Geophys.*, No. 1, 74 (1965).

6. M. P. Volarovich, E. P. Parkhomenko, A. T. Bondarenko, *Tr. Inst. fiz. Zemli AN SSSR*, No. 37 (1966).

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

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.