GEOPHYSICS

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1964

SovietRxiv

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Abstract

Full Text

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CHANGE IN THE SPECIFIC ELECTRICAL CONDUCTIVITY OF MINERALS AND ROCKS WITH THEIR AGE

(Presented by Academician D. I. Shcherbakov on 10 XI 1962)

In studying gases contained in micas and feldspars of various ages, we discovered a dependence of the amount of gases released on the age of the mineral. Work carried out in 1955-1958 showed, in particular, that the specific electrical conductivity of minerals and rocks at high temperature depends on age, namely: the older the minerals and rocks, the lower their electrical conductivity. On the basis of a study of more than 200 samples, it may be asserted that this phenomenon is associated with the accumulation of valency and β-radiation occurring as a result of the radioactive transformation of K^{40} and Ca^{40}.*

1. **Heating of the samples under study** was carried out in a two-stage furnace mounted on porcelain tubes (Fig. 1). The sample was placed in the center of the furnace between two sillimanite electrodes ground flat at the ends. To eliminate edge effects, a porcelain tube in the form of a truncated cone was placed over the electrode. To ensure reliable contact, the electrodes were pressed against the sample under a load of 3 kg. Electrical resistance was measured with an A4-M2 cathode voltmeter. Temperature was measured with a Pt/PtRh thermocouple introduced into the heating zone of the sample. Both sheet and fine fractions of mica were studied, as well as powdered feldspars and rocks. For each sample the experiments were performed 3-5 times. The measurement error was 0.5-1%. The results we obtained agree with data obtained by the potassium-argon method, with a discrepancy of 5-10%, predominantly in the direction of overestimation. Sample weights were taken as 0.4-0.3 g for rocks and 0.2-0.25 g for minerals.

Fig. 1. Furnace in which the samples under study were heated. 1 —electrodes, 2 —porcelain tube in the form of a truncated cone, 3 —platinum-platinum-rhodium thermocouple, 4 —two-stage furnace

2. **Calculation of electrical conductivity and age.** Starting from the equations

$$R = \rho \frac{l}{S},$$

$$p = \vartheta \cdot d = lS_1 d,$$

we find

$$\rho = \frac{RSS_1 d}{p}.$$

Taking into account the potassium content,

$$\rho_1 = \rho \frac{8}{x} = \frac{8RSS_1 d}{px}$$

and

$$\sigma = \frac{1}{\rho_1} = \frac{xp}{8RSS_1 d},$$

where x is the potassium content, R is the resistance of the sample according to the instrument reading, p is the weight of the sample, S is the cross section of the electrodes, S_1 is the mean cross section of the porcelain tube, and d is the specific gravity of the sample studied.

Using the obtained conductivity values and a graph compiled from reference samples in which the potassium content was 8%, we calculated the absolute age of the samples studied.

* The work was reported in January 1961 at a methodological seminar of the Commission for Determining the Absolute Age of Geological Formations.

Table 1

Specific resistivity of same-age samples and the potassium content in them

No.	Sample	K content, %	Specific resistivity, ohm/mm	Abs. age, million years	Place where sample was taken
1	Tuffite, No. 330	1.37	$4.0 \cdot 10^6$	260	Dergamysh deposit
2	Gabbrocarbonate, No. 108	1.4	$3.92 \cdot 10^6$	260	Same
3	Quartz albito-phyre, No. 6004	2.1	$5.65 \cdot 10^6$	260	Uchalinsky quarry
4	Sericite-quartz rock, No. 7032	2.32	$6.61 \cdot 10^6$	260	Same
5	Quartz-sericite rock, No. 7018	3.17	$8 \cdot 10^6$	260	Same
6	Muscovite, No. 3	5.85	$1.56 \cdot 10^7$	250	Southern Urals, Ufaley district
7	Muscovite, No. 5001	1.19	$4.76 \cdot 10^6$	400	Southern Urals, Maksyu-tovo district
8	Muscovite, No. 1208	6.6	$2.62 \cdot 10^7$	400	Same
9	Muscovite, No. 42	7.5	$3.3 \cdot 10^7$	400	Southern Urals, Tubin-sky district

In studying the dependence of the amount of gases released from micas upon heating on the age of the minerals, we found that the observed relationship must be attributed to the hydrogen content.

To determine the cause of this dependence, we extracted gases from micas at various stages of heating, with continuous removal of the evolved gas from the heating zone. It was thereby established that the amount of gases extracted from micas by heating in a vacuum to a temperature of 600° is directly dependent on the age of the minerals.

Next, the change in the specific electrical conductivity of micas was studied during their heating from room temperature to 1150°. The measurement results showed that the rate of change of specific resistivity at a temperature of 700° differs for different samples. Ionic conductivity at the indicated temperatures apparently depends on imperfections in the crystal structure or on the presence of impurities in it. Upon heating above 700°, the presence of a temperature region was noted in which the change in specific resistivity proceeds at the same rate in all samples. On the curves of the dependence of specific resistivity on temperature, a sharp bend appears. In the conductivity region in which the specific resistivity changes at the same rate in all samples, the current carriers apparently are ions entering the sites of the crystal lattice, and the activation energy of these ions is associated with the lattice energy (1-7). We established experimentally that in this temperature region the current carriers are monovalent potassium and sodium ions. It was also found that potassium ions become mobile at higher temperatures than sodium ions; with a further increase in temperature, divalent ions become mobile, the rate of change of conductivity assumes a different value, and another bend appears on the curve of the dependence of specific resistivity. It may be supposed that, in this case, the monovalent ions fully participate in the conduction process. The value of the specific resistivity at the second bend point on the curve of the dependence of resistivity on temperature proved to be related to the age of the investigated samples containing the same amount of potassium: the older the investigated sample, the greater its specific resistivity. Samples in which the potassium content is less than 1% cannot be studied, since it is difficult to determine the conductivity region of potassium ions.

Because among the micas we studied there were both sheet and crushed samples, and the rocks and feldspars were powdery (consequently, the crystallites could be located between the electrodes at any angle), we investigated the electrical conductivity of some mine-

Table 2

Absolute age of some minerals and rocks, determined from the change in their electrical conductivity

No.	Sample	Place where sample was taken, author' s code	Absolute age, million years	Author of samples
1	Glauconite	Shikhanskoe, 5/20	1070	K. R. Timergazin

No.	Sample	Place where sample was taken, author' s code	Absolute age, million years	Author of samples
2	Muscovite	Maksotovskoe, 5001m	400	V. I. Lennyh
3		Maksotovskoe, 1208	400	»
4	Biotite	60925-6	1000	M. A. Garris
5	»	20-yu-6	275	»
6	Feldspar	Adamovskoe, 7/7	285	»
7	» »	Adamovskoe, 10/12	285	»
8	Quartz albite porphyry	Uchalinskoe, 6004	260	G. S. Ilyasov
9	Sericitic quartz with sulfide inclusions	Uchalinskoe, 7002	260	»
10	Hornblende porphyrite	Deposit named after the 19th Party Congress, 5703	275	»
11	Gray albitophyre tuff	Same, 5522/1	270	»
12	Altered spilite	Buribaevskoe, 931	400	»
13	Quartz-sericite rock	Kurpalinskoe, 7090	220	»
14	Felsite-albitophyre	Tubinskoe, 6068	280	»
15	Serpentinite	Dergamyshskoe, 150	150	»

minerals along different axes of symmetry: micas (biotites and muscovites) and feldspars along two axes, quartz along four axes. The results showed that the electrical conductivity of each of these minerals at temperatures from 700 to

1000° is the same along all axes of symmetry.

Some data on determining the age of minerals and rocks are given in Table 2.

Taking into account the relation between electrical conductivity and potassium content, and the exponential course of the change in electrical conductivity with the age of the samples, it may be assumed that the change in electrical conductivity at high temperature as a function of age is the result of the radioactive decay of K^{40}, during which, as is known, Ca^{40} is formed. With time, with the formation of Ca^{40}, valence accumulates in the crystal, since the sites of monovalent potassium will be occupied by divalent calcium. This leads to a change in the physical properties of the crystal, to an increase in the activation energy (8–11), and thus to a decrease in electrical conductivity (12). At the same time, during the β-decay of K^{40}, the rocks under study are subjected to β-irradiation over geological time. Taking into account the known data on the increase in activation energy and the increase in specific resistance (13–15) under the influence of β-irradiation of a substance, it may be assumed that natural β-irradiation, which occurred as a result of the β-decay of K^{40}, also led to an increase in the activation energy in the samples we studied.

Received
10 IX 1962

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