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Studies on the Electrical Conductivity of a few Samples of Granite and Andesite

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Abstract

The measurements of the change in the electrical conductivity against the temperature variance to the melting point of samples were carried out about a few samples of granite and andesite.

According to the results of experiments, it was found that the change of electrical conductivity with temperature would be devided into three or four processes, that is, up to 500°C, from 500°C to 900°C, from 900°C to 1100°C and above 1100°C.

At lower temperatures, the activation energies of all samples were of small values and the changes of electrical conductivity with temperature were affected mainly by Fe_2O_3 and Al_2O_3 contained in the samples. At high temperatures, it seemed that the phenomena were the same as that of silicate minerals.

1 Introduction

With the progress of the theory of matters, a study of the electrical conductivity of rocks has been developed from the new standpoint. In order to investigate the properties of materials in the interior of the earth, it is desirable to make various investigations on the basic rocks constructing the crust of the earth. Recently, RUNCORN and TOZER [1] reported that the change of electrical conductivity of basic minerals with temperature could be devided into three processes, viz, up to 600°C, from 600°C to 1100°C and above 1100°C. Each process indicates respectively impurity semiconduction, intrinsic semiconduction and ionic conduction. The authors have been carrying out various experiments on the electrical properties of silicate minerals. [2] [3] [4]. In the present paper, the studies on the electrical conductivity of a few samples of grainte and andesite were reported.

The first purpose of this experiment was to measure the change of the electrical conductivity of these samples against the temperature variance to the melting point of samples, the second was to compare the results of these samples with each other for the same temperature range and to investigate what elements composing the samples play the main role of charged carrier.

2 Method of the Experiment

In order to attain our object as mentioned above, we adopted the following method. A massive salmple was ground into powder and stuffed between two con-

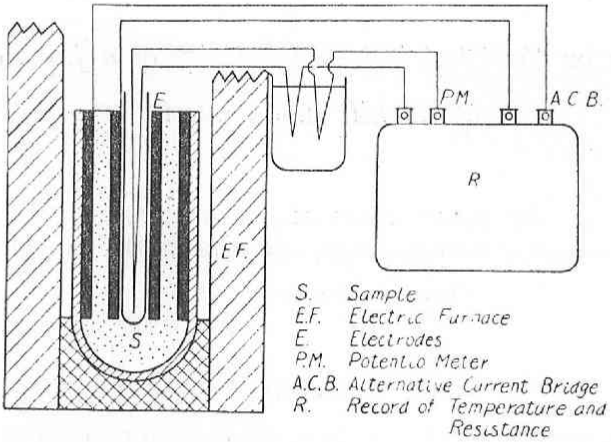

Fig. 1. The equipment used in measurement.

centric iron cylinders which function as the electrods. In this case, we determined the dimension of cylindrical electrods as the end effects were negligible. The equipment is shown in detail in Figure 1. The temperature of specimen was measured by use of the thermojunction, which was put in the inside electrode. With this equipment, the resistance of specimen were measured by using an A. C. bridge of 50 cycles.

In reality, it is desirable to measure about the block sample instead of the powdered one, because the block and the powder indicated different conductivities with each other. However, for example, in the case of a block of granite, the measurement was disturbed by growth of cracks within the sample at higher temperatures. Moreover, the representative phenomena may not be observable on account of irregular distribution of rock-forming crystals within the sample.

On the other hand, the measurements for the block and the powder samples of quartz diorite were carried out in order to estimate the difference of the electrical conductivity for the temperature change. According to the results as seen in Figure 2, both cases indicated the

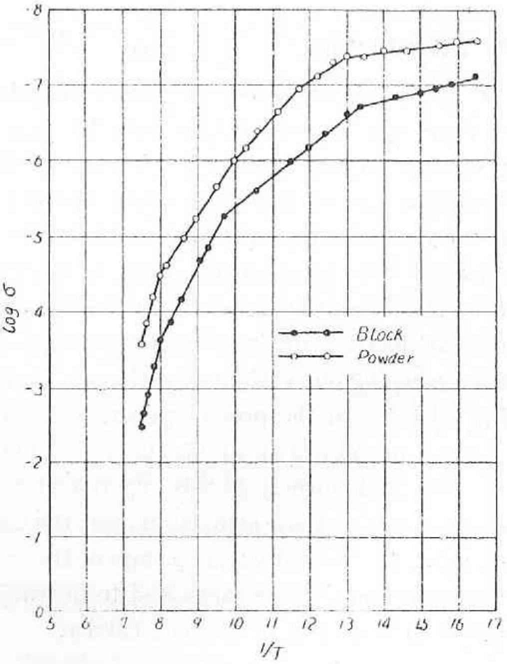

Fig. 2. The electrical conductivities as a function of reciprocal absolute temperature in cases of the block and the powdered specimens in quartz diorite.

same relative changes with temperature, but for the absolute value of conductivity, the values of block samples showed 10∼10² times as large as those of the powdered. Therefore, it may be concluded that the relative changes of the electrical conductivities for the both cases of block and powder are equal at any temperatures.

3 Results of Experiment

The samples and their localities are as follows,

Quartz : Nishida village Fukushima Prefecture, Japan.
Perthite : Suisyoyama, Fukushima Prefecture, Japan.
Granite 1,2,3, : Tanobata, North eastern parts of Iwaizumi Town, Iwate Prefecture, Japan.
Andesite : Fumoto, Nishi-Monai Town, Hiraga District, Akita Prefecture, Japan.

Table. 1. Chemical composition and Norm. of the samples. Analyst: Y. UEDA * I. KATO)

Constituent	Granite 2	Granite 2	Granite 3	* Andesite	Augite hyperthene andesite	Quartz diorite	Basaltic andesite
SiO_2	67.50	63.15	76.95	58.24	64.78	61.01	49.71
Al_2O_3	15.77	17.01	12.59	16.59	14.91	14.41	21.30
Fe_2O_3	2.61	3.30	1.31	3.68	5.56	4.39	3 30
FeO	2.25	2.53	0.12	3.39	0.78	3.23	5.97
MgO	1.82	2.60	0.22	3.27	0.54	3.16	2.80
CaO	4.47	5.09	1.08	5.80	3.82	3.82	12.59
Na_2O	1.99	1.59	1.02	3.97	4.62	3.28	1.58
K_2O	2.80	3.74	5.99	1.50	2.00	2.66	0.45
H_2O_+	0.14	0.40	0.10	0.22	0.68	0.48	1.08
H_2O_-	0.06	0.10	0.06	0.98	1.10	0.84	0.75
TiO_2	0.25	0.41	—	1.50	0.82	0.19	0.73
P_2O_5	0.02	0.02	0.03	0.57	0.27	0.10	0.24
MnO	0.10	0.07	0.02	—	—	—	0.20
Total	99.78	100.01	99.49	99.42	99.88	100.75	100.70
Quartz	31.86	24.36	45.42	14.82	22.80	18.00	7.50
Orthoclase	16.68	21.68	35.58	8.90	11.68	15.57	2.78
Albite	16.77	13.62	8.38	34.60	39.30	27·77	13.10
Anorthite	22.24	25.30	5.56	32.80	13.90	16.68	49.76
Corundam	1.33	1.12	2.48	—	—	—	—
Diopside	—	—	—	0.68	1.28	5.03	9.22
Hyperthene	6.71	7.82	0.60	7.25	0.02	6.59	9.82
Magnetite	3.71	4.87	0.23	5.34	0.23	6.50	4.87
Ilmenite	0.45	0.46	—	2.89	1.52	1.52	1.00
Hematite	—	—	1.12	—	5.44	—	—
Normative Plagioclase	Ab_{29} An_{71}	Ab_{22} An_{78}	Ab_{56} An_{44}	Ab_{31} An_{69}	An_{40}	Ab_{62} An_{38}	An_{93-95}

Augite hyperthene Andesite ; Mizusawa, Western parts of Niiyama, Yasawagi Village, Mogami District, Akita Prefecture, Japan.
Quartz diorite ; Upper stream of the Tsuchiuchi River, Hagino Village, Mogami District, Yamagata Prefecture, Japan.
Basaltic andesite : Mitaki, Sendai, Miyagi Prefecture, Japan.

The chemical and mineral compoistion of the granite and the andesite groups are shown in Table 1. The results obtained from the experiments for quartz, perthite and

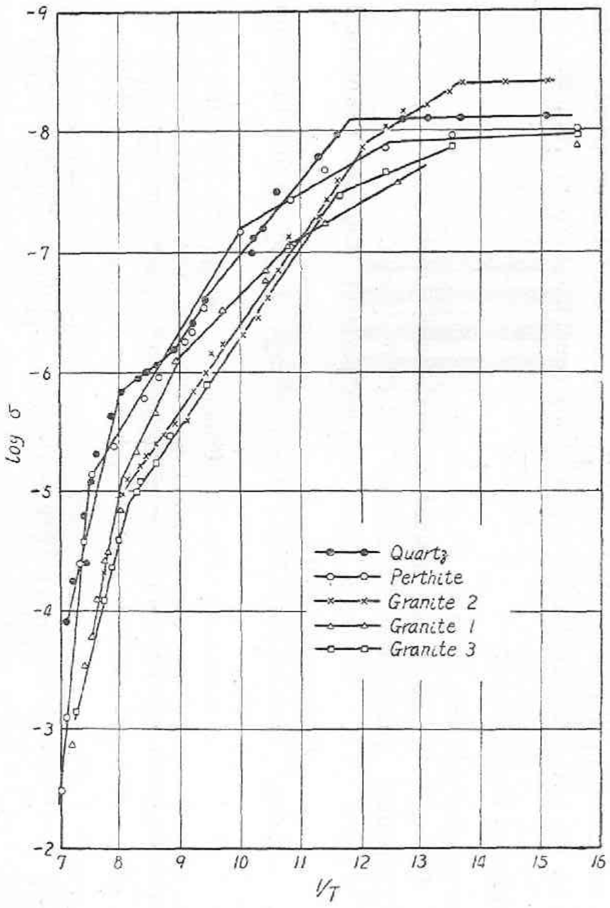

Fig. 3. The relations between the electrical conductivity and temperature for silicate minerals and granite group.

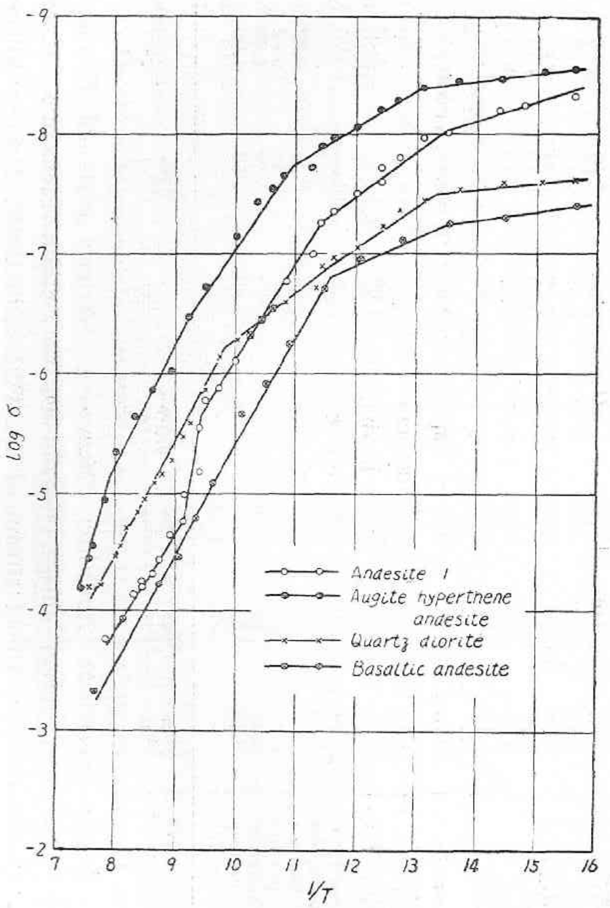

Fig. 4. The relations between the electrical conductivity and temperature for andesite group.

Table: 2. The values of ΔE and σ_0 at the different temperature ranges. The hatching parts show the temperature region in which the conductivity changes irregularly.
The values of ΔE are shown in the unite of eV,
The values in the blacket show $\log_{10}\sigma$.

	400	500	600	700	800	900	1000	L100	1200
Granite 1		0.75 (−3.1)	▤	2.2 (88.8)			5.5 (226)		
Granite 2		0.9 (−2.4)			1.4 (0.8)			4.5 (165)	
Granite 3		0.6 (−4.2)			1.4 (0.8)			4.3 (171)	15.6 (610)
Andesite	0.7 (−2.2)	▤	1.4 (1.1)		▤		1.6 (48)		
Augite hyperthene andesite		0.6 (−4.3)	1.1 (−1.5)		1.7 (56)	1.3 (−0.4)	3.7 (137)	16.4 (606)	
Quartz diorite (Powder)		0.8 (−2.7)		0.9 (−1.7)		1.6 (71)		8.0 (316)	
Quartz diorite Block	0.4 (−3.9)		0.7 (−2)	0.9 (−0.8)		1.6 (67)		11.1 (6.1)	
Basaltic andesite	0.1 (−6.5)	0.3 (−4.0)	1.5 (65)	1.1 (4.3)		0.9 (−0.5)			
Quartz			0.9 (−3.6)		1.6 (1.1)		4.7 (173)	12.5 (453)	
Perthite			1.3 (−0.6)		1.6 (1.1)	0.7 (−2.4)		5.6 (201)	

granite group are shown in Figure 3, and for andesite group in Figure 4. In the figures, the ordinate and the abscissa demonstrate respectively logarithm of electrical conductivity and reciprocal of the absolute temperature. As seen in Figures 3 and 4, each curve consists of a few straight lines having the different gradients, which increases with the rise of temperature. Therefore, these curves are expressed by the equation as follows ;

$$\sigma = \sigma_1 e^{-\frac{\Delta E}{kT}} + \sigma_2 e^{-\frac{\Delta E_2}{kT}} + \cdots\cdots ,$$

where ΔE activation energy and k is BOLTZMAN's constant. The values of σ and ΔE for each sample are show in Table 2. As the values for σ are concerned with powder samples, they are not always unique in the present case, but they may be useful to decide the approximate conditions of the samples.

From Figure 3, Figure 4 and Table 1, it may be said that the changes of the electrical conductivity with temperature can be devided into three or four processes, that is, up to 500°C, from 500°C to 900°C, from 900°C to 1100°C and above 1100°C. Above 800°C, the processes for different rocks are similar to that for quartz. This fact means that the phenomena in these temperature ranges are influenced mostly by silica contained within the samples. On the other hand, at lower temperatures from 500°C

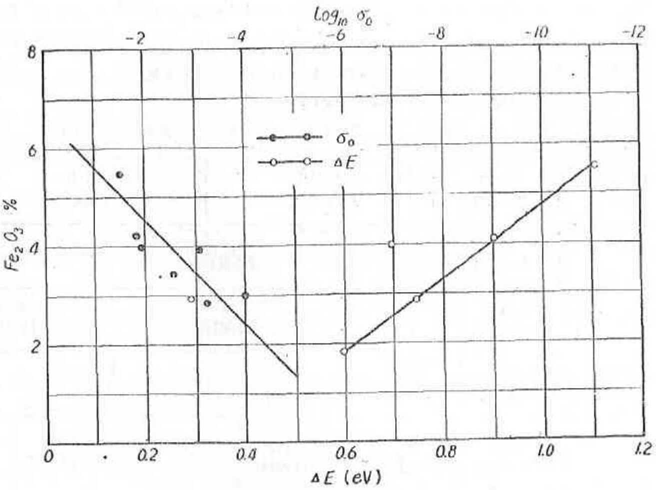

Fig. 5. The relations between the values of ΔE (and σ) and the temperature in the lower temperature region.

to 800°C the curves are somewhat different from one another. These departures seem to depend upon the elements of Fe_2O_3, Al_2O_3 and FeO, especially of Fe_2O_3 contained within the samples. For example, Figure 5 indicates the relation between ΔE (and σ) and the amount of Fe_2O_3 contained within the sample. But, the result of basaltic andesite is an exception of this relation. It may be caused by the character of the basic rock. A marked change is observed near the melting point of the samples and no considerable change in the conductivity can be seen in the higher temperature ranges above the melting point, up to about 1500°C. In general, the conductivity of the melting sample seems to be not so much dependent upon temperature. Finally, in the whole range of temperature, the changes in the electrical conductivity of most samples are similar to that of quartz.

4 Conclusion

The electrical conductivities of the granitse and the andesite groups seem to depend upon that of silicate mineral. At lower temperatures, however, σ and ΔE of samples depends upon Fe_2O_3 and Al_2O_3, that is, the process at lower temperatures is considered to be a sort of semiconduction caused by the element having relatively small activation energy.

At high temperatures, the changes of the electrical conductivities of all samples are nearly equal. This signifies that the phenomena in the samples containing abundant silica are controlled by the properties of silica.

Near the melting point, remarkable changes are found in the conductivity of samples.

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