Bulletin of Shimane University (Natural Science), No.13, pp. 139—143.
December, 1963.

A Supplement to the Palaeomagnetic Study on the Kawajiri Basalt Lavas

By Eizo Asami

Physical Institute, Faculty of Arts and Science, Shimane University

Matsue City, Japan

1 Positional intermixing of the normal and the reverse magnetization in the same lava

It was already reported[1] that the basalt lava at Cape Kawajiri, Japan, possesses the positionally intermixed normal and reverse natural remanent magnetism (N.R.M.) and this fact would have been caused by the self-reversal mechanism of magnetization due to an exsolution of titanomagnetite which has been proposed by N. Kawai and others.[2]

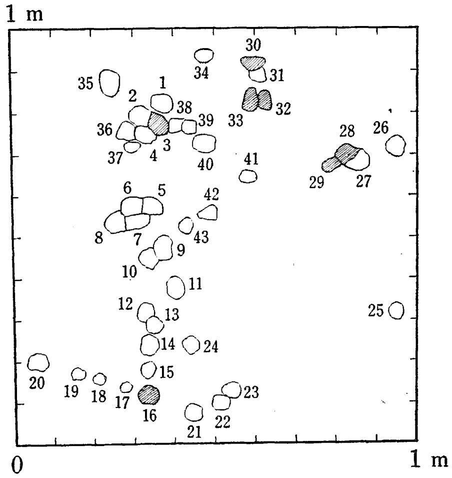

Fig. 1. The arrangement of 43 specimens sampled.
No. 3, 16, 28, 29, 30, 32, 33: normal
No. 27, 31 : intermediate
The remaining 34 specimens : reverse

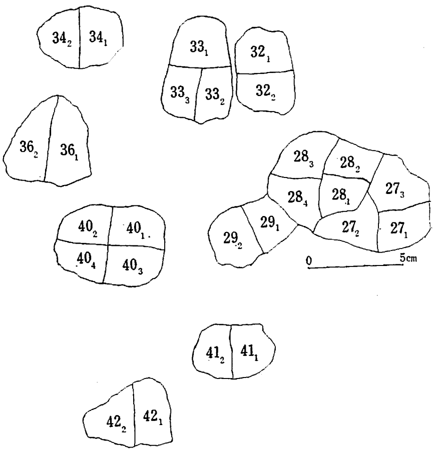

Fig. 2. The schematic view of division of specimens.

In Fig. 1 is shown a good example of the positional close intermixing of the normal and the reverse N.R.M. of 43 specimens within an area of one meter square of the outcrop of an entirely one block of the Kawajiri basalt lava. This figure is the reproduction from the author's previous paper.[3] Of these 43 specimens, ten were selected of which four (No. 28, 29, 32, 33) are normal, five (No. 34, 36, 40, 41, 42) reverse and one (No. 27) has the N.R.M. of intermediate direction. Each of them was cut into a few smaller parts of nearly equal size and the N.R.M. of each divided parts was measured. The schematic view of division of these specimens is represented in Fig. 2. Employing the masses of the divided parts as the weights, the vectorial weighted sum of the N.R.M. of these divided parts belonging to their original specimen was computed and then was compared with the original N.R.M. The results are shown in Table 1 and Fig. 3.

Table 1. Numerical values of the directions and intensities of N.R.M.
In the fourth column under the heading of corrected mass is given the mass of the divided parts corrected for the loss of mass due to the sawing process.

	Specimen No.	Mass	Corrected Mass	Declination	Dip	Intensity $\left(J_n \times 10^4 \frac{\text{e.m.u.}}{\text{g}}\right)$	Normal or Reverse
N.R.M. of original specimen	27	134.0^g	134.0^g	+ 100°	−34°	1.7	Intermediate
N.R.M. of divided specimens	27_1	42.7	45.5	− 157	−62	3.6	R
	27_2	44.0	46.9	+ 66	−30	1.0	Intermediate
	27_3	39.1	41.6	+ 35	+ 6	1.3	N
Vectorial weighted sum of N.R.M. of divided specimens	27′	125.8	134.0	+ 106	−77	1.3	Intermediate
N.R.M. of original specimen	28	129.3	129.3	+ 48	+16	1.3	N
N.R.M. of divided specimens	28_1	35.1	37.0	± 0	+40	2.1	N
	28_2	25.4	26.8	+ 17	+11	1.4	N
	28_3	27.2	28.8	+ 62	+16	1.4	N
	28_4	34.8	36.7	+ 42	+27	1.6	N
Vectorial weighted sum of N.R.M. of divided specimens	28′	122.5	129.3	+ 28	+29	1.3	N
N.R.M. of original specimen	29	35.3	35.3	+ 24	+ 4	1.2	N
N.R.M. of divided specimens	29_1	14.1	14.5	− 18	+32	1.5	N
	29_2	20.2	20.8	+ 57	− 6	1.5	N
Vectorial weighted sum of N.R.M. of divided specimens	29′	34.3	35.3	+ 30	+12	1.2	N
N.R.M. of original specimen	32	57.6	57.6	+ 25	+26	2.1	N
N.R.M. of divided specimens	32_1	35.2	36.5	+ 12	+42	2.1	N
	32_2	20.3	21.1	+ 27	+39	2.2	N
Vectorial weighted sum of N.R M. of divided specimens	32′	55.5	57.6	+ 18	+41	2.1	N
N.R.M. of original specimen	33	94.5	94.5	+ 51	+12	2.1	N
N.R.M. of divided specimens	33_1	33.1	35.2	+ 20	+21	1.6	N
	33_2	28.1	29.9	+ 29	+14	2.6	N
	33_3	27.6	29.4	+ 60	+46	2.1	N
Vectorial weighted sum of N.R.M. of divided specimens	33′	88.8	94.5	+ 34	+29	2.0	N

N.R.M. of original specimen	34	53.6	53.6	± 180	−61	5.6	R
N.R.M. of divided specimens	34_1	25.6	26.5	+ 178	−59	5.3	R
	34_2	26.2	27.1	+ 179	−60	6.1	R
Vectorial weighted sum of N.R.M. of divided specimens	34′	51.8	53.6	+ 179	−60	5.8	R
N.R.M. of original specimen	36	59.5	59.5	+ 149	−51	7.5	R
N.R.M. of divided specimens	36_1	29.8	30.8	+ 132	−57	9.2	R
	36_2	27.7	28.7	+ 150	−54	8.9	R
Vectorial weighted sum of N.R.M. of divided specimens	36′	57.5	59.5	+ 140	−56	8.9	R
N.R.M. of original specimen	40	124.5	124.5	+ 151	−40	7.9	R
N.R.M. of divided specimens	40_1	38.2	40.3	− 165	−47	8.0	R
	40_2	33.8	35.6	+ 159	−49	7.7	R
	40_3	26.8	28.2	+ 168	−38	8.4	R
	40_4	19.3	20.4	+ 145	−42	8.7	R
Vectorial weighted sum of N.R.M. of divided specimens	40′	118.1	124.5	+ 170	−46	7.9	R
N.R.M. of original specimen	41	31.3	31.3	+ 167	−69	7.2	R
N.R.M. of divided specimens	41_1	13.7	13.8	+ 164	−70	6.4	R
	41_2	17.3	17.5	+ 162	−70	8.6	R
Vectorial weighted sum of N.R.M. of divided specimens	41′	31.0	31.3	+ 163	−70	7.6	R
N.R.M. of original specimen	42	52.5	52.5	+ 169	−58	8.3	R
N.R.M. of divided specimens	42_1	20.2	21.2	± 180	−64	9.7	R
	42_2	30.1	31.4	+ 148	−64	9.4	R
Vectorial weighted sum of N.R.M. of divided specimens	42′	50.3	52.5	+ 161	−65	9.4	R

As can be seen from Table 1 and Fig. 3, the vectorial weighted sum of N.R.M. of the divided specimens is nearly equal to the N.R.M. of the original specimen prior to the division. Thus, the fact of the positional intermixing of the normal and the reverse N.R.M. in the same rock block has been more completely clarified. This field evidence strongly suggests that the self-reversal of magnetization took place in the Kawajiri basalt lavas.

2 Chemical composition of the ferromagnetic minerals contained in the Kawajiri basalt lavas

The present author has carried out the chemical analysis of ferromagnetic minerals contained in the Kawajiri rocks. Rock specimens were sampled from three representative parts of the Kawajiri basalt lavas; i.e. the first is the normally magnetized lava with the intensity of the order of 10^{-2} c.g.s.e.m.u./g., the second the reversely magnetized one of the intensity about 10^{-3} and the third the positionally intermixed part of normal and reverse magnetization of the

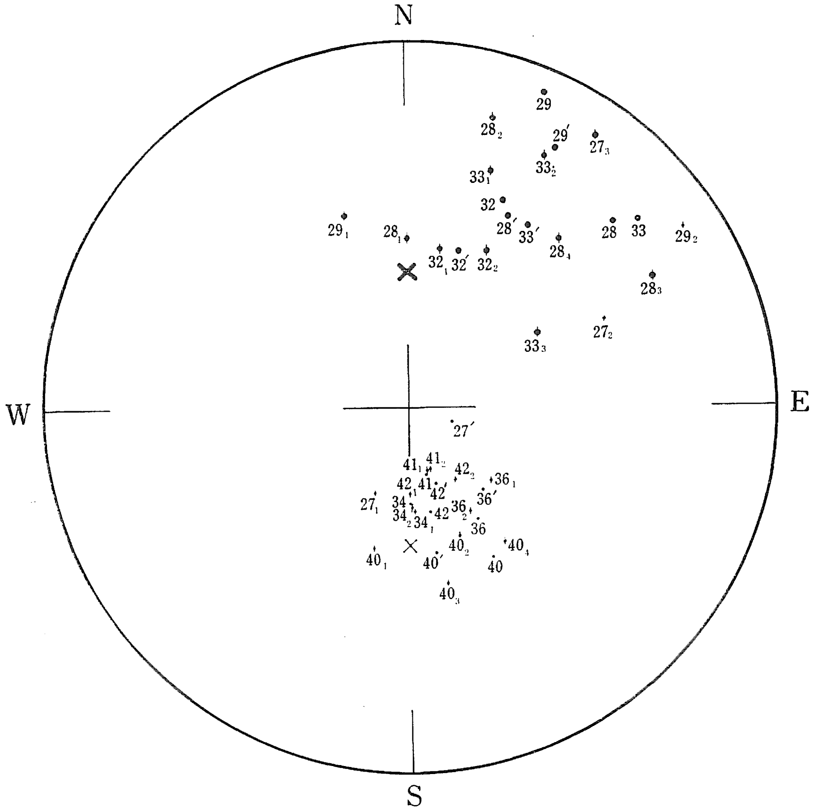

Fig. 3. Wulff's projections of the directions of N.R.M.

intensity about 10^{-4}. For the purpose of extracting ferromagnetic minerals, the rocks were ground into fine powder. The powder was steeped in alcohol in order to prevent oxidation and this was further pulverized fully in an agate vessel and ferromagnetic minerals were separated from other non-magnetic constituents and extracted by an electromagnet. As the separation is not complete by one procedure, the process was repeated very many times. Thus, ferromagnetic minerals were extracted from the rocks of the above three parts of the Kawajiri lavas; that is, normal, reverse and intermixed. The author asked the chemical analysis of the stuffs to Dr. M. Yoshida, Dept. of Geochemistry, Tokyo Institute of Technology, and he kindly has done it for me. The results are shown in Table 2 and Fig. 4.

As seen from Table 2 and Fig. 4, the observed values of chemical compositiion of Kawajiri rocks indicate those of the oxidized phases of titanomagnetite, being not situated on Fe_3O_4 —$TiO_2 Fe_2 O_2$ line. This result seems to be not consistent with the already reported one.[1] Therefore, a mechanism most appropriate to accounting for the fact must be discussed.

Recently, Akimoto[4] proposed a new idea that the self-reversal of magnetization is possible to occur in the process of oxidation of titanomagnetite into titanomaghemite. He considers in such a way that the chemical remanent magnetism (C.R.M.) due to the newly oxidized phase has the direction of magnetization antiparallel to that of the original unoxidized phase of titanomagnetite. Accordingly, it may be also very probable that the reverse N.R.M. of Kawajiri

Table 2. Chemical composition of the ferromagnetic minerals contained in the Kawajiri basalt lavas.

	Normal	Reverse	Intermixed
Weight%			
FeO	20.43	14.39	24.37
Fe_2O_3	44.38	51.85	50.83
TiO_2	6.96	10.99	10.87
Total	71.77	77.23	86.07
Mol%			
FeO	43.79	30.23	42.74
Fe_2O_3	42.80	49.01	40.10
TiO_2	13.41	20.76	17.16
Total	100.00	100.00	100.00

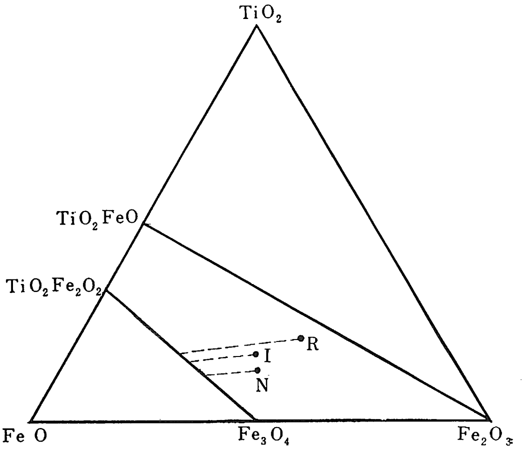

Fig. 4. Chemical composition represented on FeO-Fe_2O_3-TiO_2 diagram in mol percent. N: normal, R: reverse, I: intermixed.

rocks is attributed to the effect of the self-reversal of magnetization due to the oxidation during the formation of the lavas.

However, it should not be neglected that as already reported[1] the Kawajiri rock specimens possess the same characteristics that the sudden inversions of the direction of magnetization of the specimen take place when it is continuously heated as demonstrated by N. Kawai's experiments[2] to prove the exsolution of titanomagnetite. On the other hand, it seems to be not impossible to explain the above data of the chemical composition as the result of oxidation which happened during the experimental process of the extraction of ferromagnetic minerals from the rocks in the laboratory. Because, since the ferromagnetic phases have both the very small grain size and the weak magnetic intensity, it took a long time to extract them from the rock specimens, i.e. first the rock being pulverized into grains of the size of about 10 μ and secondly gathered by using electromagnet. Hence, these pulverized minerals may have been exposed to the air, on account of imperfect steeping in alcohol, for a sufficiently long time that the original phase has been oxidized by the heat of friction in the agate vessel into the phase of titanomaghemite as revealed in the chemical analysis. For the purpose of clarifying this, it seems to be most required to make a good extraction of the ferromagnetic minerals so as the oxidation is perfectly prevented and then to carry out the chemical analysis once more.

In conclusion, the author is very thankful to Emeritus Prof. N. Kumagai and Prof. Y. Tamura of Kyoto University for kind encouragements and also to Prof. N.Kawai of Osaka University and Dr.S. Akimoto of Tokyo University for valuable discussions.
(Read at the Symposium on Rock Magnetism, Aug. 25, 1959 and Nov. 15, 1962)

Reference

[1] E. Asami; Journ. Geomag. Geoele., **6**, 145 (1954), **8**,147 (1956).
[2] N. Kawai, S. Kume and S. Sasajima; Proc. Jap. Acad., **30**, 588, 864 (1954).
[3] E. Asami; Journ. Geomag. Geoele., **9**, 162 (1957).
[4] S. Akimoto; Read at the Symposium on Rock Magnetism, Nov. 14-15 1962.