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The Reliability of Natural Remanent Magnetization observed at Several Sites in a Rock Unit

by

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1) Introduction

Results of palaeomagnetic observations are discussed on the assumption that rocks were magnetized along the direction of the geomagnetic field at the time of formation. It is a matter of great importance that the natural remanent magnetization (NRM) of rocks has stably been preserved against the later change of the geomagnetic field or other physico-chemical influences. Stability of the NRM is examined either by field or laboratory tests (Graham, 1949 ; Nagata, 1961 ; Irving, 1964). However, although the NRM of a rock unit is shown to be stable, it is often unknown whether the direction of the NRM is a primary one of the rock unit or not. For example, the directions of magnetization obtained from rocks of the same time or a single rock mass must closely coincide with one another, but inconsistent examples are rarely observed in such rocks. The inconsistent example suggests that the direction of the stable magnetization of samples collected at a site in a single mass is not always representative of the primary magnetization of the rock unit. Especially, the Japanese Islands are in a zone of active tectonic movement in the Tertiary or Quaternary, and it is of a great importance to confirm that a rock mass has not been deformed by such tectonic movement, and to find out the direction of the original NRM.

2) Examples of good consistency of directions of NRM in different sites

In general, it is difficult to know whether a lava flow had suffered from some tectonic movements after its solidification, but if sedimentary rocks have been found on or under the lava, deformation of the lava can be estimated by the observation of bedding plane of the sedimentary rocks. In the case when an amount of deformation in a lava flow is small, the directions of the NRM obtained from different sites must be consistent with one another. Similarly, if rocks possess a stable magnetization, the NRM of lavas of the same age must have the same directions regardless of rock kinds. If the directions of the NRM obtained from several sites in the same lava or group are stable and well-grouped one, it is said that the lava has not been deformed and the direction of the NRM is the primary magnetization of the rock unit. The directions of the NRM of this kind are shown in Fig. 1 (a) to (d). The geology and collecting sites of each locality are as follows.

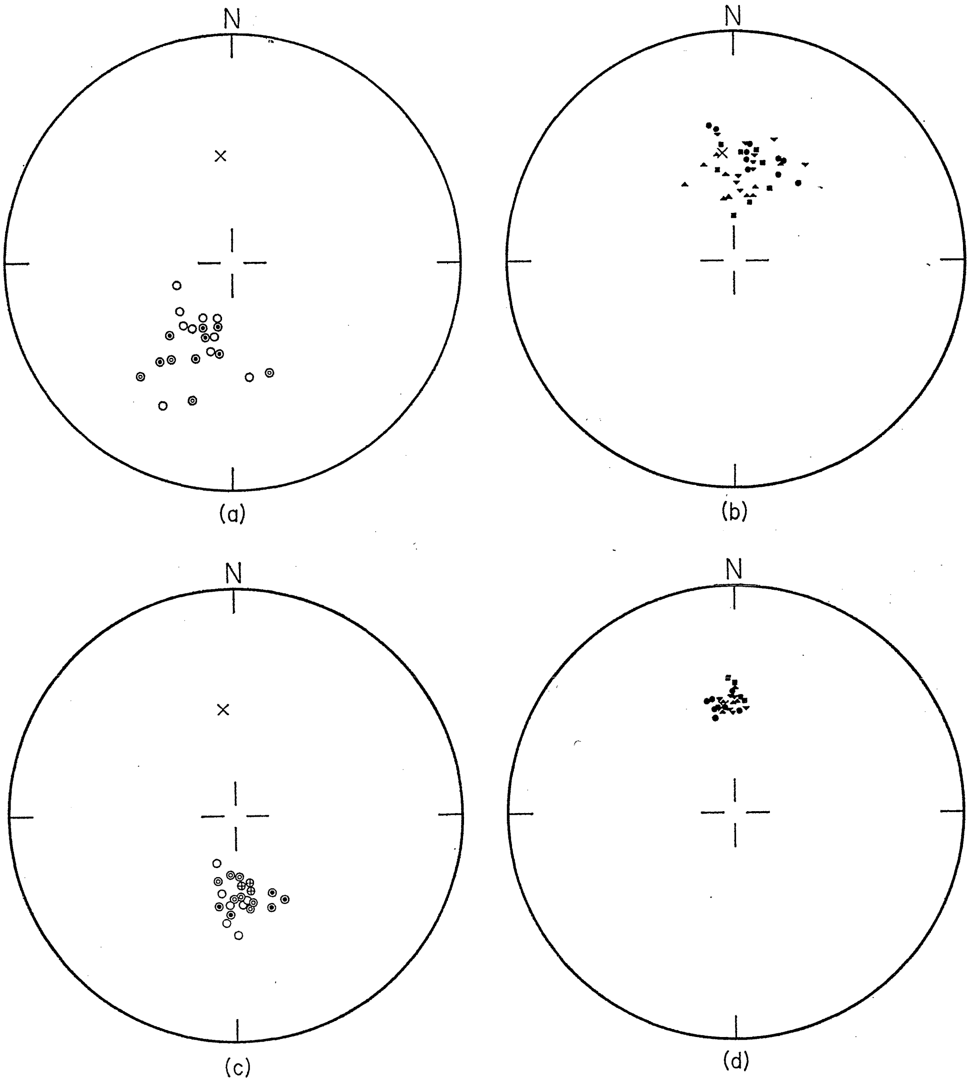

Fig. 1. Directions of NRM obtained from four rock units showing the good consistency. Closed symbols show to be the lower hemisphere and open symbols upper hemisphere. Schmidt's equal area net is used.

(a) Agei District
○ : A site ◎ : B site ◉ : C site

(b) Saigo District
● : D site ■ : E site ▲ : F site ▼ : G site

(c) Tara-dake District (I)
○ : H site ◎ : I site ◉ : J site ⊕ : K site

(d) Tara-dake District (II)
● : L site ■ : M site ▲ : N site ▼ : O site

× : Direction of the present geomagnetic field

(a) Agei District

Volcanic rocks collected in this district (Tottori Prefecture) are of Hachibuseyama andesite belonging to the Pliocene (Murayama and Ozawa, 1961). Samples were taken from three sites in the andesite mass. The distance between A and B sites is about 1.5 km and that of B and C is about 10 km. The directions of the NRM are plotted in the Schmidt's equal area projection as seen in Fig. 1 (a).

(b) Saigo District

Samples collected in this district are trachy basalt of the late Miocene in Oki Islands, Shimane Prefecture, reported by Tomita (1927). However, the age of the trachy basalt has recently been concluded to be of the lower Pleistocene from the radiometric dating (Hirooka, private communication). According to the geological observations (Tomita, 1927), the trachy basalt is covered by a few lava flows showing the reverse NRM. Collecting sites are four of (D, E, F, G). The distance between these sites is about 2 km. The directions of the NRM are shown in Fig. 1 (b).

(c) Tara-dake District (1)

Basaltic rocks lying in a base of Tara-dake volcanic rocks, which were erupted in the Pliocene or Pleistocene, are distributed in the east side of Tara-dake, Saga Prefecture (Takahashi and Kurasawa, 1960). The basaltic rocks are separated into two parts from the stratigraphic sequence and the results of palaeomagnetic measurements. The lava belonging to the lower part was normally magnetized, but the upper part reversely. Samples were collected from four sites of H, I, J and K in the several lava flows of the upper part. The distance between H and K is about 2 km. The directions of the NRM are shown in Fig. 1 (c).

(d) Tara-dake District (11)

Basaltic andesite in this region is likely to be erupted in the Pleistocene (Takahashi and Kurasawa, 1960). Samples were collected from four sites of (L, M, N, O). The distance between L and O sites is about 4 km. The directions of the NRM are shown in Fig. 1 (d).

As seen in Fig. 1, the directions of the NRM obtained from these districts show a good consistency in a rock unit. This seems to show that these rock units are not affected by local tectonic movement and the NRM has stably been preserved against the various disturbances.

3) An inconsistent example of NRM

An inconsistent typical example is a Wakurayama andesite erupted in some time during the Pliocene to Pleistocene times (Tomita and Sakai, 1938). However, the andesite mass is concluded to have been erupted in the middle Pliocene by the radiometric dating (Hirooka, private communication). At Ōmisaki, which lie in the east side of Wakurayama in Matsue City, Shimane Prefecture, rock samples being a part of the Wakurayama andesite were collected from four sites of A, B, C and D lined up on the same level. The distance between A and B sites is about 0.2 km, B and C is 0.3 km and C and D is 1 km. These outcrops are quarries being dotted from place to place without successively exposed site. All samples collected from the outcrops appear to belong to the same lava or group from the geological or petrological observations. The directions of the NRM of all sites are shown in Fig. 2 and the results of measurements are summarized in Table 1.

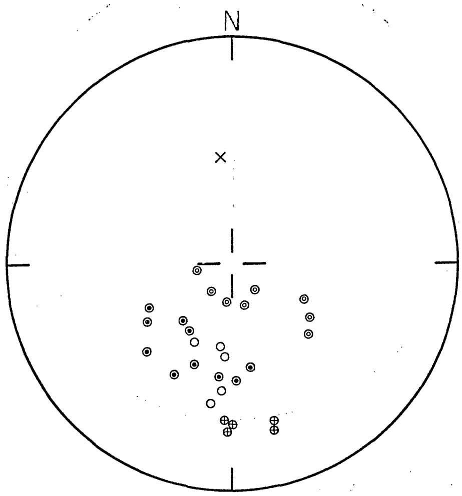

Fig. 2. Directions of NRM of Wakurayama andesite showing the inconsistency. Schmidt's equal area net is used.
○ : A site
◎ : B site
◉ : C site
⊕ : D site
× : Direction of the present geomagnetic field

Tab.e 1

Locality	Number of samples	Present latitude and longitude of site		Mean direction		Intensity of NRM (e.m.u./g)	I_i/I_n	Mean direction in all sites		Pole Position	
		Lat.	Long.	D	I			D	I	Lat.	Long.
A	5			SW 9°	−51°	$2.01\times10_{-4}$	0.22				
B	8	35°28′ N	133°09′E	SE 36°	−73°	7.48	0.10	SW 5°	−56°	86°S	26°E
C	10			SW 27°	−55°	1.45	0.68				
D	5			SE 6°	−28°	2.59	0.10				

One or two specimens from each site were demagnetized by A. C. method. The stability of their NRM was examined by heating process or storage in the laboratory and the NRM was confirmed to be reasonably stable. An example of the A. C. demagnetization is shown in Fig. 3.

As seen in Table 1, both of declination D and inclination I show a maximum discrepancy of about 40° between B and D sites. The discrepancy is not considered to be due to inadequate sampling, so that it seems to be due to an extremely local phenomenon which occurred in the rock unit at the time of eruption or after the formation. This fact suggests that the direction of magnetization of samples collected at only one place in a single mass does not always represent that of the primary NRM as described in the forgoing chapter, although the samples have possessed a stable magnetization as seen

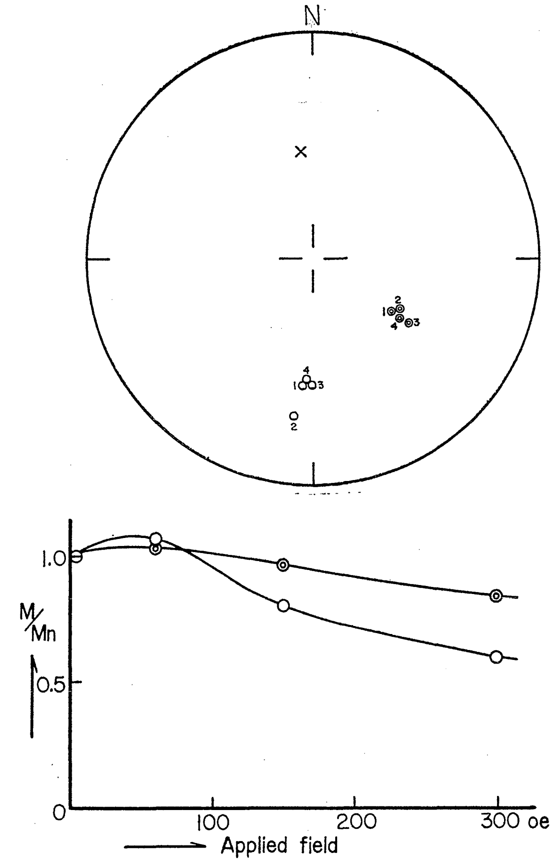

Fig. 3. Demagnetization of NRM by alternating magnetic field.
(a) : Change in direction of NRM
1 : 0 oe 2 : 60 oe 3 : 150 oe 4 : 300 oe
(b) : Demagnetization curves
○ : A site
◎ : B site

from the various tests.

The cause of the discrepancy among the directions of the NRM in each site is assumed as follows : (1) B site inclined toward the north by some local movement after the

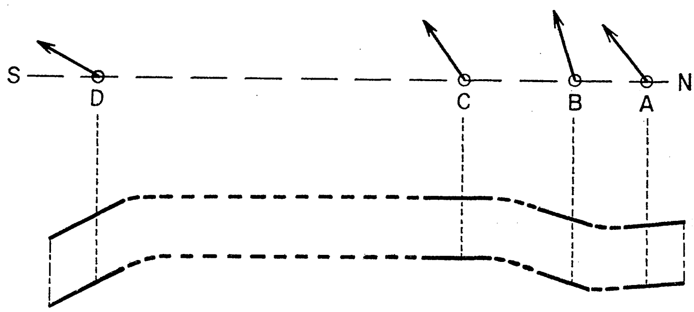

Fig. 4. Deformation of the lava flow which can be deduced from the directions of NRM.

eruption and D site toward the south, and the rock mass formed an anticlinal structure with an axial line passing through the C site as shown in Fig. 4. (2) The direction of the primary magnetization may be modified by secondary components which were different in localities. (3) The discrepancy of the NRM among the sites is due to a secular variation during the eruption.

At present, the deformation of the lava flow cannot be confirmed distinctly by the field survey, but it is observed that the sedimentary rocks underneath the lava are subjected to a certain deformation (Mii, private communication). An existence of the secondary component of magnetization could not be confirmed from the laboratory tests of stability, and also the influence of the secular variation cannot be clarified from the geological and the palaeomagnetic observations. Consequently, the discrepancy of the NRM in this region can be explained by a local folding which occurred in the lava flow, as mentioned in the case (1).

4) Conclusion

From the examples of the good consistency described in the chapter (2), it is concluded that the majority of volcanic rocks in the Tertiary or Quaternary has preserved the direction of the original magnetization. On the other hand, the existence of the inconsistent example introduces an ambiguity in the directions of the NRM of samples if they were collected at one site in a rock unit. In order to avoid the ambiguity, it is necessary to collect samples from at least two or three sites in a rock unit.

If the discrepnacy among the directions of the NRM is proved to be due to certain deformation in rock unit, then a correction of the folding has to be carried out on the directions of the NRM. If the cause of the discrepancy cannot be detected by geological or palaeomagnetic observations, the direction of the NRM in all sites should be averaged to obtain the primary direction of magnetization of the unit, or the data should be omitted from the discussion on palaeomagnetic observations. The discrepancy of the NRM obtained in the Wakurayama andesite is probably one of the typical examples of inconsistency, and the direction of the primary magnetization of this rock unit may be reasonable to be shown by a value averaged in all sites, because the cause of the discrepancy cannot be exactly confirmed by the geological observations on the rock unit. However, if the directions of the original magnetization in rocks were parallel to that of the present geomagnetic field, the discrepancy may indicate that the rock mass was disturbed by local folding as has been pointed out.

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References

Graham, J. W. ; J. Geophys. Res., **54**, 131, 1949.

Irving, E. ; Paleomagnetism, John Wiley and Sons, New York, 1964.

Murayama, M. and Ozawa, A. ; Explanatory Text of Geological Map of Japan "Aoya and Kurayoshi", 1961 (in Japanese).

Nagata, T. ; Rock Magnetism (Revised editions), Maruzen, Tokyo, 1961.

Takahashi, K. and Kurasawa, H. ; Bull. Geol. Surv. Japan, **11**, 19, 1960 (in Japanese).

Tomita, T. ; J. Geol. Soc., **34**, 321, 1927 (in Japanese).

Tomita, T. and Sakai, E. ; J. Geol. Soc., **45**, 529, 1938 (in Japanese).