Bull. Shimane Univ. (Natural Sci.) No. 15, pp. 19–25. December, 1965.

Palaeomagnetic Researches for the Plio-Pleistocene Volcanic Rocks in Mishima and Oki Islands

by

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1) Introduction

In recent years many workers have a great store of the information on reversals of the geomagnetic field during the late Tertiary. The age or the time interval of the field reversal in the late Pliocene and the early Pleistocene are minutely obtained by using the radiometrically dated rocks (Cox et al, 1963, 1964 ; Gromme and Hay, 1963 ; McDougall and Tarling, 1963). According to these results, it seems that the change of the geomagnetic field direction from the normal to the reverse or in the opposed way abruptly took place and a transition occurred in a short interval of time. On the other hand, one of the present authors reported that there exists the positional intermixing of the normal and the reverse magnetization in the same lava (Asami, 1954, 1956). This fact strongly suggests that the natural remanent magnetization (NRM) in some rocks was acquired by a self-reversing process of ferromagnetic minerals in the rock during or after the formation.

For the purpose of clarifying these two questions, the present authors searched localities containing both lavas of the normal and the reverse NRM and carried out their palaeomagnetic researches.

2) Sampling locality and results of measurements

In the San-in Province occupying the Japan Sea side of west Japan from Genbudo to Kawajiri-misaki (Cape Kawajiri), volcanic rocks of the Plio-Pleistocene are widely distributed (Fig 1.). Islands of Mishima and Oki consist mainly of such volcanic rocks and the lava flows lie in nearly horizontal plane. Moreover, the vertical distribution of the lavas was conveniently observed on the cliffs of coastline in their islands.

Mishima is composed mostly of the basaltic lavas of the alkaline rocks which were erupted in the Pleistocene (Oji, 1960). The tholeiitic basalt which were erupted in the Miocene is partly exposed in the lowest part of these lavas. Rock samples were collected from five main lavas belonging to the alkaline rock series in the Pleistocene (Fig. 2). The directions of the stable magnetization were plotted on the Wulff's net in Fig. 3. The lavas in Mishima, as seen in Fig. 3, are fairly classified into the lower and upper parts from the results of this palaeomagnetic measurement and geological sequence. Namely, all of lavas in the lower part become normally magnetized, while those in the

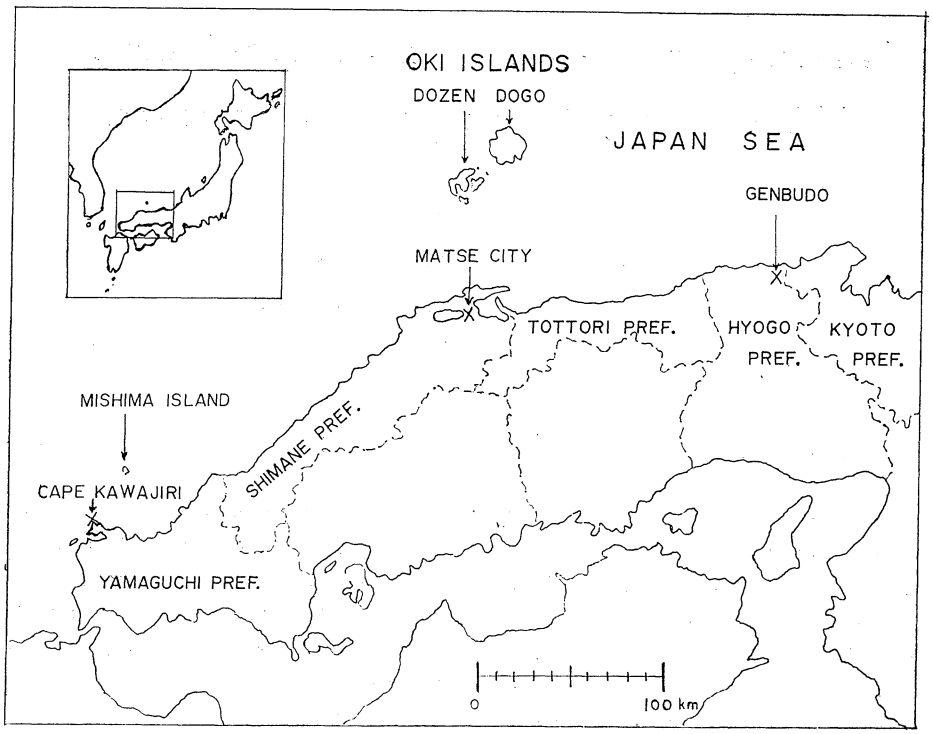

Fig. 1. A map of the San-in Province.

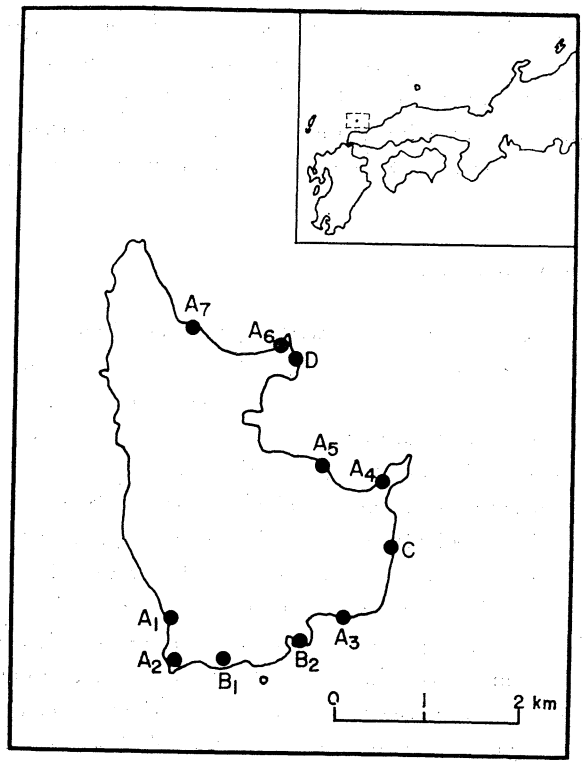

Fig. 2. A map of Mishima District in which collecting sites are shown.
A : Lower part.
B : Upper part.
C : A site being in contact with lower and upper part.
D : Another contact zone where baked rock is observed.

upper reversely.

Dozen district of Oki Islands consists of four kinds of the alkaline rock series and quartz syenite which were erupted in the Pleistocene (Nishiyama and Miura, 1963). Samples were taken from several outcrops in each rock (Fig. 4). The NRM of the samples with stable magnetization are shown in Fig. 5. Quartz syenite and trachyte lying

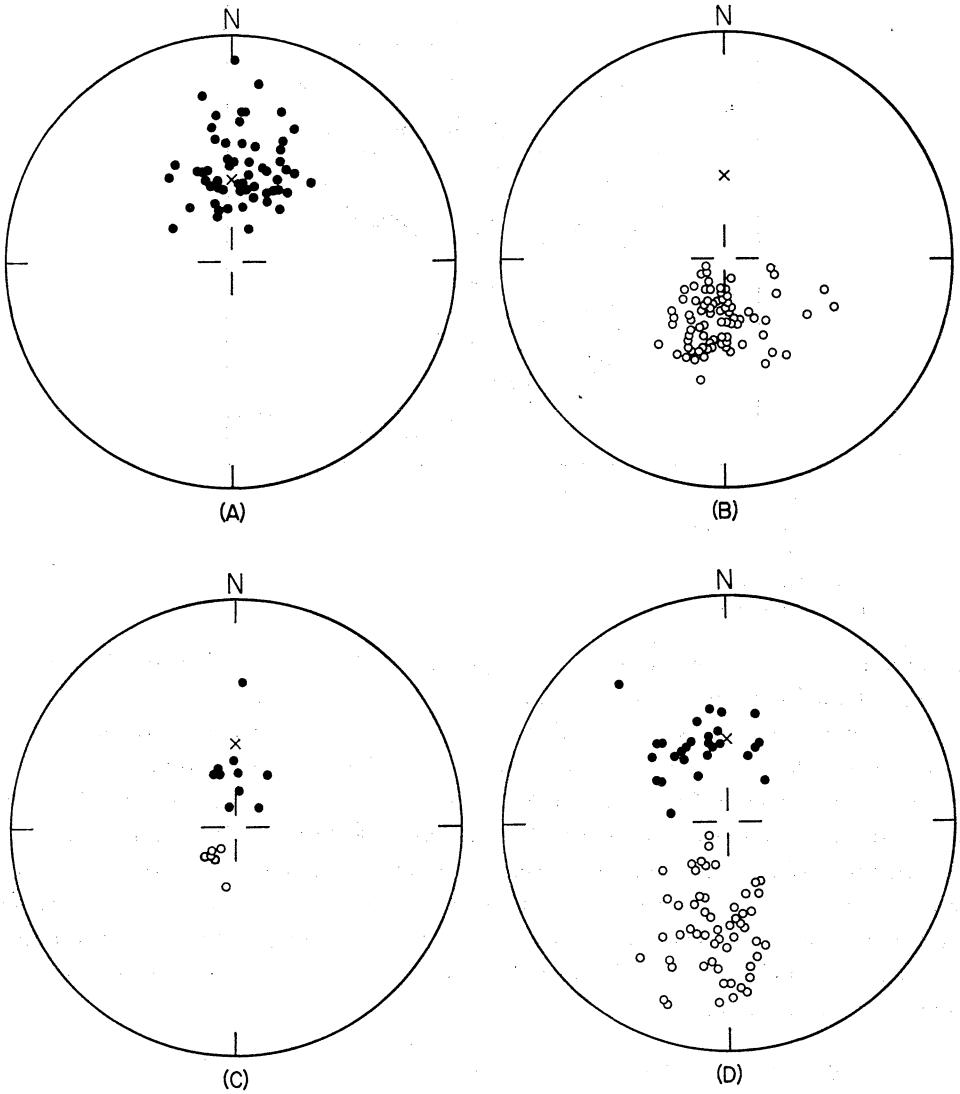

Fig. 3. Directions of NRM in Mishima District. The Wulff's net is used.
A : Lavas of lower part
B : Lavas of upper part
C : Contact zone of normal and reverse rocks
D : Another contact zone where baked rock is observed
● : Lower hemisphere
○ : Upper hemisphere
× : Direction of the present geomagnetic field

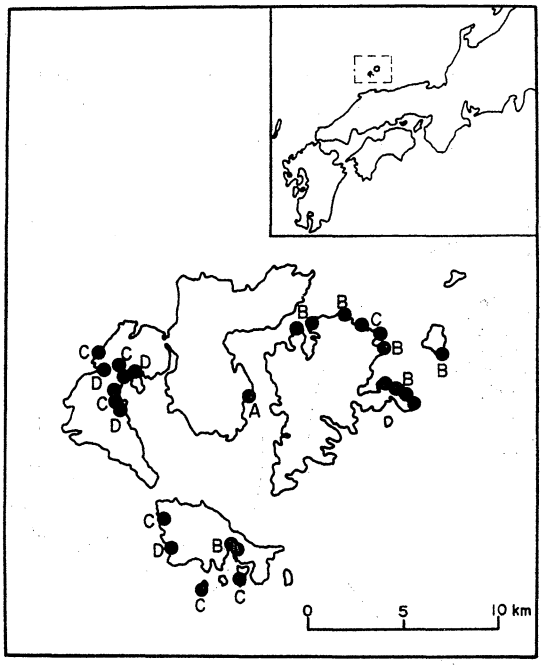

Fig. 4. A map of Dozen District in Oki Islands and collecting sites of each group.
A : Quartz syenite.
B : Trachyte.
C : Trachy basalt.
D : Trachyte dyke.

the lower part in rock formation and trachyte dyke which was poured out finally were normal, but trachy basalt of middle part was reverse to the contrary.

Thus, although the rock series with the normal and the reverse magnetization was obtained from place to place, we could not collect the samples continuously from the normal to the reverse or the reverse to the normal even at several sites where a boundary between the normal and the reverse rocks was observed. Namely, the directions of NRM of the samples collected from some contact zones have shown only those of magnetization parallel or anti-parallel to the present Earth's field having no intermediate direction. However, it is unknown from the observation obtained so far whether the direction of the geomagnetic field has abruptly changed throughout 180° or the rocks were not formed at the time of transition.

3) NRM of the baked rock at the contact zone

In the Mishima District, the basaltic rocks baked by the intrusive sheet are found at one outcrop as shown in Fig. 6. We collected samples in succession from a lower basalt to an upper basalt in order to observe the NRM of the baked rock and a variation of the geomagnetic field from the normal to the reverse polarity. The basaltic flow of the lower part and basaltic tuff breccia were normal, while the basalt sheet of the middle part was reverse. All of the other intrusive lavas were reversely magnetized. The

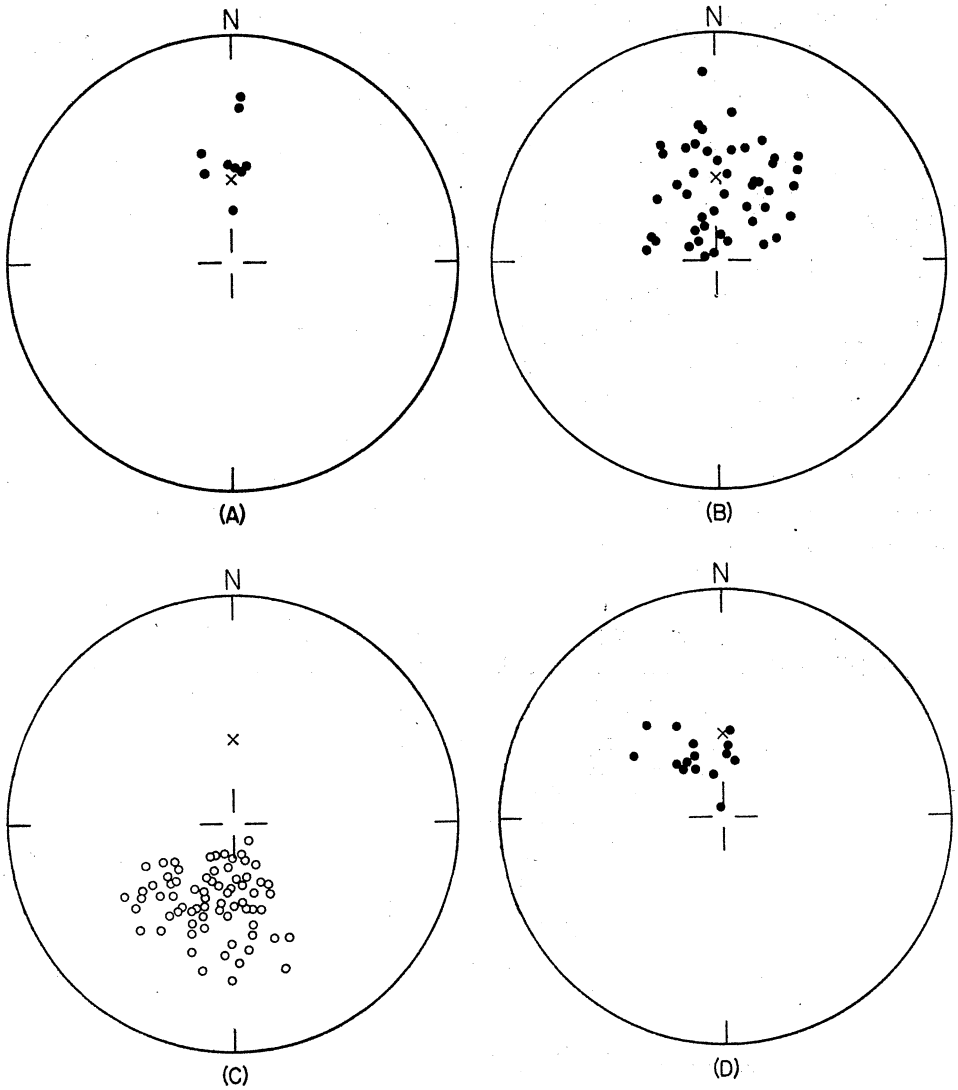

Fig. 5. Directions of NRM in Dozen District. The Wulff's net is used.
A : Quartz syenite
B : Trachyte
C : Trachy basalt
D : Trachyte dyke
● : Lower hemisphere
○ : Upper hemisphere
× : Direction of the geomagnetic field

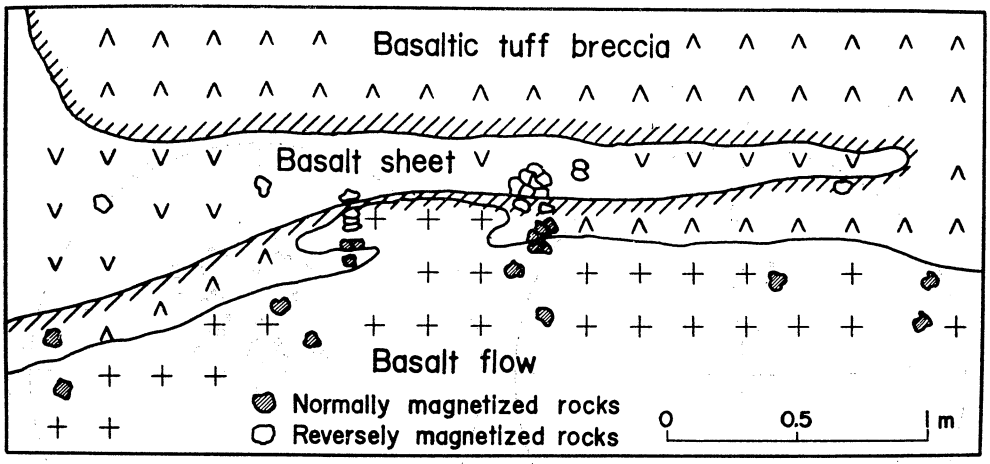

Fig. 6. A typical contact place where baked rock was observed. The shaded portion is metamorphosed rock about 1 cm in thickness.

directions of magnetization at this site are shown in Fig. 3. (D). The NRM of the baked rock has shown the same direction as that of the intrusive sheet, and the directions of magnetization in this outcrop were distinctly separated into two groups of the normal

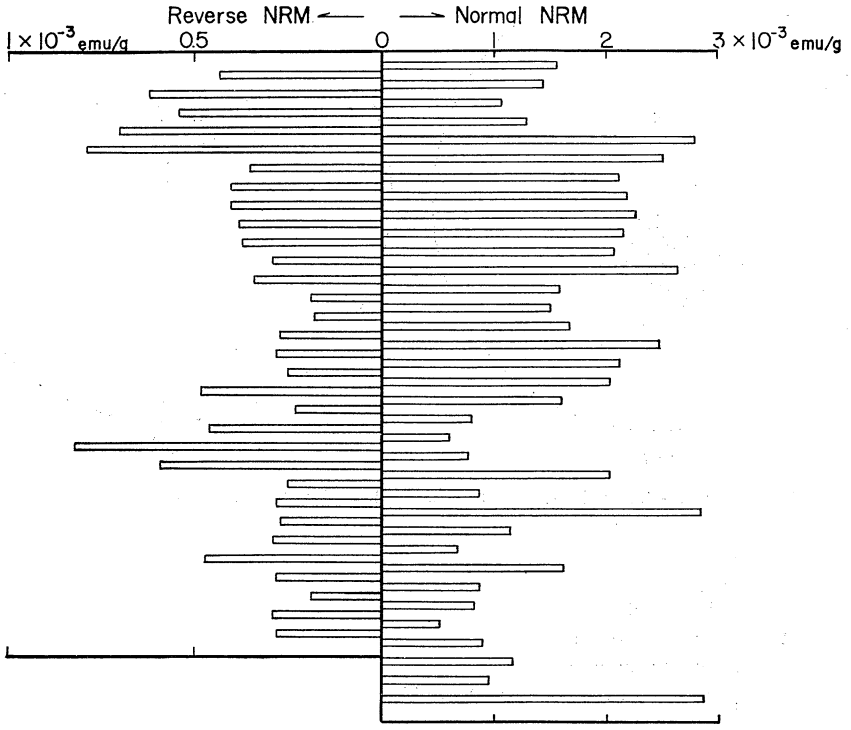

Fig. 7. Intensities of NRM obtained at place being in contact with normal and reverse rocks in Mishima District.

and the reverse. Results obtained at other sites were also definitely classified into the same two groups as those of this site. As seen in Fig. 7, the intensity of the NRM of the normal rocks is the same order to that of the reverse rocks and there is no significant difference between both intensities and they are fairly uniform. On the contrary, it is worth while to note here that the intensities of the NRM at Kawajiri-misaki lavas are not uniform, ranging from 10^{-2} to 10^{-4} c. g. s. e. m. u./g. (Asami, 1954, 1956).

4) Discussion and conclusion

Palaeomagnetic studies on the volcanic rocks in Yamaguchi Prefecture are reported by Asami (1954) and Domen (1960). The rocks with reverse magnetization belong to the Pliocene or Pleistocene, and the reverse lavas are situated on the same level in the geological sequence (Oji, 1960 ; Okamoto and Imamura, 1963). In the Mishima and Dozen Districts, the reverse NRM was generally observed in rocks of the same group in the stratigraphic sequence, but they do not always belong to the same lava. The directions of the reverse NRM are exactly anti-parallel to that of the present geomagnetic field. Besides, although the geological sequence or rock type in these regions are similar to those at Kawajiri-misaki, the same intermixing phenomenon in a single lava flow as observed on the basalt lavas at Kawajiri-misaki was not found in the volcanic rocks or the baked rocks in these districts. Hence it is concluded that the reverse rocks had been formed at the time of field reversal having no self-reversing process.

From the results of our observations, the following explanations for the change in polarity of the geomagnetic field of the Pliocene or Pleistocene can be suggested : (1) If the lava flows were extruded in a regular succession over a period of the change in polarity, the geomagnetic field in this period had abruptly changed its direction. (2) Although the direction of the geomagnetic field had changed continuously and gradually, the lava flows were not extruded in a regular succession. In these regions, we could not find palaeomagnetic evidence that the geomagnetic field changed its direction continuously. However, from the geological standpoint of view, it is expected that the transition of the geomagnetic field in this period had occurred in a very short interval of time relative to the geological time scale.

Finally, this work was done under the Japan-U. S. Co-operative Scientific Programme administered by the Japan Society for the Promotion of Science.

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