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Paleomagnetic Study on Some Pliocene and Pleistocene Volcanic Rocks in Southwest Japan

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Abstract

The directions of natural remanent magnetization of about 300 volcanic rock specimens collected from Southwest Japan of which ages range from Pliocene to Pleistocene were measured. The mean pole positions calculated from the results agree with the present geographic north pole within an oval of 95% confidence. This fact suggests that there were no considerable movement of paleomagnetic pole position during Pliocene and Pleistocene in Southwest Japan, and that Southwest Japan did not change its geographical situation since Pliocene epoch.

Furthermore, the volcanic rocks of remote localities used in the study can be correlated much more exactly with one another by the aid of comprehensive knowledges, such as their stratigraphy, absolute age determined by isotope method and the paleomagnetic polarity change of their remanent magnetization.

Introduction

It is a well known fact that volcanic rocks acquire the thermoremanent magnetization in parallel with the direction of the ambient geomagnetic field when they are cooled down through their Curie temperature. Basing on the fact, many investigators have tried to elucidate the nature of the past geomagnetic field by measuring directions of the magnetization of rocks.

Many studies on post-Pliocene rocks, particularly, have been reported all over the world. Recently, Cox *et al.* (1966, 1967) reported the reverse-normal chronology of past geomagnetic field combining paleomagnetic results with the data of K-A age determination on Pliocene and Pleistocene rocks.

In Japan, many investigators such as ASAMI (1954), NAGATA *et al.* (1959), KAWAI *et al.* (1961), ITO (1963) and MOMOSE (1963) reported the results on Neogene volcanic rocks. The present authors have intended to estimate from Southwest Japan the movement of paleomagnetic pole position ranging from Paleozoic to Recent. As a part of the study, more than 300 volcanic rock specimens which

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range from Pliocene to Pleistocene in age were collected from various parts of Southwest Japan. In this paper, the paleomagnetic results obtained from these rocks are reported and their geological application is also discussed.

Sampling sites and geological descriptions

About 300 rock specimens were collected from several localities in Southwest Japan. The index map of sampling localities is shown in Fig. 1.

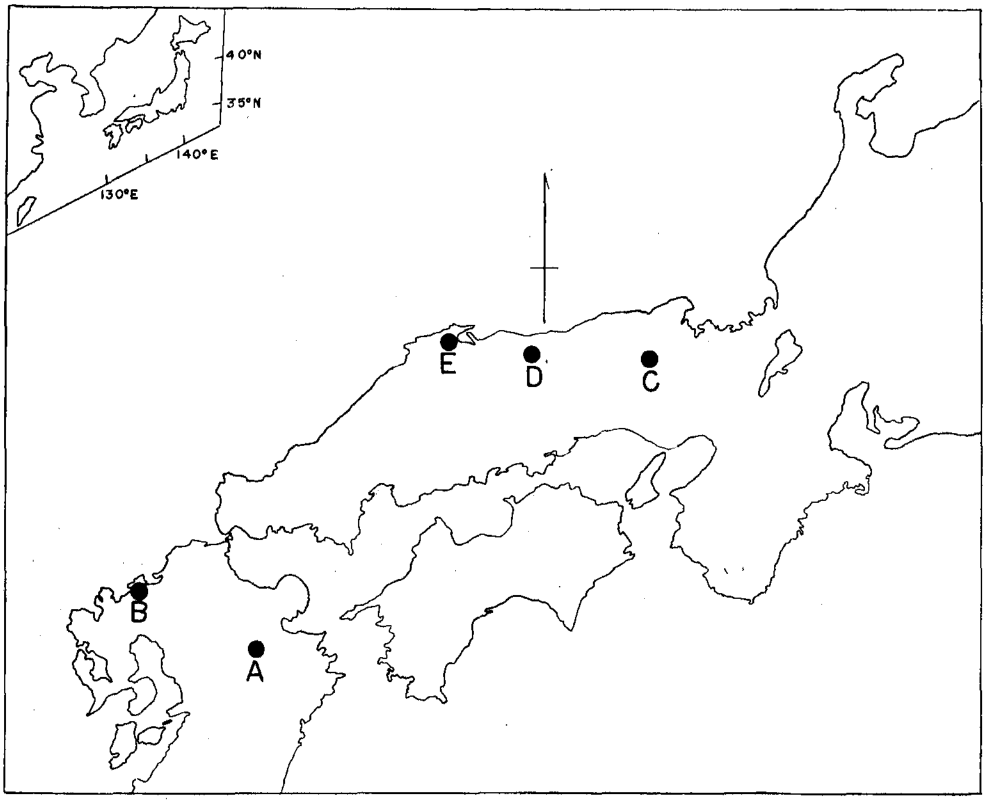

Fig. 1. The index map of sampling localities.
A Kuju, Central part of Kyushu.
B Yobuko and Karatsu, Northern part of Kyushu.
C Genbudo, Northern part of Hyogo.
D Kurayoshi, Northern part of Tottori.
E Wakurayama, Northern part of Shimane.

Geological and petrological studies of these rocks were performed in detail by many investigators, and those reviews are briefly described as follows.

a) Kuju, Central part of Kyushu

Kuju district is one of the typical Cenozoic volcanic regions in Japan. Geological study of this region has been performed by ONO (1963). According to his study, the volcanic rocks of this region can be classified into four groups regarding their eruption times, *i.e.* Upper Miocene to Lower Pliocene, Lower Pliocene to Upper Pliocene, Upper Pliocene to Lower Pleistocene and Recent. 30 series of lava flows are found in this region, of which 15 flows were collected.

b) Yobuko and Karatsu, Northern part of Kyushu

In the northern part of Kyushu, basic rocks generally called Matsuura basaltic rocks are widely developed. Geological and petrological studies on these rocks were extensively worked by MATSUMOTO (1961) and KOBAYASHI *et al.* (1955, 1956). According to them, these lava flows are considered to have erupted in Pleistocene epoch. Successive rock samples were collected from several sites.

c) Genbudo, Northern part of Hyogo

In the northern part of Hyogo Prefecture, there is some distribution of basic lava flows summarized as Genbudo basalts. Geological and petrological studies on these basalts were performed by KOKAWA (1956), MATSUMOTO and WADATSUMI (1958, 1959), whose estimates of eruption times were in early Pleistocene.

d) Kurayoshi, Northern part of Tottori

In the northern part of Tottori Prefecture, there are several lava flows whose geological studies were made by MURAYAMA *et al.* (1963). According to these investigators, the lava flows collected in the present study are presumed to be Pliocene ones.

e) Wakurayama, Northern part of Shimane

Wakurayama andesite is found around Mt. Wakurayama of Matsue city, Shimane Prefecture. HIROOKA and KAWAI (1967) determined the age of this andesite to be 6.34 ± 0.19m.y. by K-A method.

Result and consideration

The directions of magnetization of the specimens were measured with an astatic magnetometer. The stability of the remanent magnetization was examined by a.c.- and thermal demagnetization. Prior to the paleomagnetic use, the direction of n.r.m. has to be considered from the following criteria:

1) The number of specimens in each site is at least more than 4 and a radius of the circle of 95% confidence obtained from each site does not exceed 20°.

2) The data are adopted when the direction of n.r.m. is proved to be stable

by the stability tests and gives better precision after the removal of soft component.

3) There is no evidence of possible self-reversed magnetization.

The directions of n.r.m. of Pliocene and Pleistocene rocks with the circle of 95% confidence (α), the precision parameter (k), and their corresponding virtual pole positions are shown in Table 1 and Table 2 respectively. The mean directions of n.r.m.s and their corresponding pole positions for Pliocene and Pleistocene epochs are given in Table 3. In Fig. 2, these results are also shown together with the Cretaceous paleomagnetic pole position estimated from Southwest Japan (SASAJIMA and SHIMADA, 1966).

As shown in this figure, the pole positions for Pliocene and Pleistocene epochs obtained from the present study show a good agreement with the present north pole within an oval of 95% confidence, whereas the pole position for Cretaceous period is significantly deviated from the present pole. The latter fact was already discussed in detail by SASAJIMA and SHIMADA (1966). However, the former result suggests that the directions of the geomagnetic field in Pliocene and Pleistocene may be almost the same as that of the present day.

There are many investigators such as BLUNDELL (1961), COX and DOELL

Table 1. The direction of n.r.m. of Pliocene rocks in Southwest Japan.

Reference Number	Rock unit studied		N	Direction of Magnetization		k	α_{95}	V.P.P		δ_p	δ_m
	Location	Name (Age)		D_m	I_m			φ	λ		
201	Kyushu Kuju	H_4	10	358.6	65.5	72	6.0	N77	W134	8.0	9.8
202		H_2	10	6.9	45.3	75	5.8	N81	W 88	4.8	7.2
203		H_1	10	348.7	32.6	17	12.1	N70	W 14	7.7	13.6
204		Y	10	357.6	46.0	30	9.0	N87	W 10	7.5	11.4
205		Rw	10	177.5	−59.6	32	8.7	S 84	W 69	9.7	13.3
206		R_1	10	184.1	−41.0	23	10.4	S 78	W117	7.6	12.6
207		P_1(R)	10	154.5	−40.3	97	4.9	S 65	W159	3.6	5.9
208		P_1(N)	6	19.1	55.8	69	8.1	N74	W145	8.3	11.7
209		I_3	9	345.9	37.0	14	14.1	N71	W 1	9.6	16.4
210		Tp	9	5.4	55.7	58	6.5	N85	W155	6.6	9.4
211	San'in Kurayoshi	Kurayoshi basalt V-1	7	125.3	−42.5	90	6.4	S 43	W133	4.8	7.9
212		V-2	4	190.6	−66.6	253	5.8	S 75	E 72	7.8	9.7
213		V-3	5	248.0	−14.1	25	15.6	S 22	E 52	8.1	15.9
214		V-4	4	354.2	8.0	1286	2.6	N58	W 34	1.3	2.6
215		V-5	8	165.0	− 1.5	9	19.7	S 54	E 161	9.9	19.7
216	San'in Wakurayama	Wakurayama andesite (6.34 m.y.)	8	182.3	−39.6	7	22.4	S 67	E 73	15.9	27.1

Table 2. The direction of n.r.m. of Pleistocene rocks in Southwest Japan.

Reference Number	Rock unit studied		N	Direction of Magnetization		k	α_{95}	V.P.P		δ_p	δ_m
	Location	Name (Age)		D_m	I_m			φ	λ		
101	Kuju	A	14	355.4	48.2	35	6.7	N83	W 8	5.7	8.7
102	,,	Kp	9	338.3	32.8	28	10.3	N65	E 11	6.6	15.6
103	,,	Dh	7	241.7	−51.2	140	5.3	S 39	E 30	4.9	7.1
104	,,	D_4	6	355.2	43.8	58	9.1	N80	W 23	7.1	11.5
105	,,	D_2	6	355.2	26.8	53	9.3	N69	W 32	5.5	10.0
106	,,	K_7	7	323.7	34.4	38	10.1	N54	E 29	6.7	11.5
107	,,	K_6	10	350.4	51.6	16	12.3	N83	E 34	11.3	16.9
108	,,	K_4	4	340.1	29.1	76	10.6	N64	E 3	6.4	11.7
109	,,	K_2	4	19.6	56.3	144	7.7	N74	W145	7.7	11.0
110	San'in	Genbudo basalt (1.6 my)	8	228.4	−48.5	18	14.5	S 49	E 39	12.4	19.3
111	,,	Yakuno basalt	6	15.7	52.2	138	5.7	N77	W127	5.4	6.1
112	,,	Kannabeyama basalt	7	4.3	61.7	80	6.9	N83	E 154	8.3	10.4
113	Kyushu Yobuko	Yobuko basalt B_7	6	0.3	57.7	343	4.2	N88	E 140	4.5	6.2
114		B_6	7	312.4	48.2	38	10.0	N50	E 50	8.5	13.0
115		B_4	13	13.6	54.5	33	7.6	N78	W143	7.6	10.8
116		B_3	11	355.1	54.9	27	9.2	N87	W 48	9.1	13.1
117		B_2	10	169.9	−40.4	26	9.8	S 76	E 177	7.1	11.2
118		B_1	10	318.9	59.0	60	6.3	N57	E 67	7.1	9.3

Table 3. The mean directions of n.r.m.s calculated from the data, and their corresponding mean pole positions.

Age	Mean direction		α_{95}	k	Pole position		δ_p	δ_m
	D	I			φ	λ		
Pleistocene	351.7	48.1	7.7	25	N 82.0	E 2.0	6.6	10.0
Pliocene	358.0	49.3	7.5	34	N 85.5	W35.0	6.6	8.6

(1960) and KAWAI *et al.* (1961), who tried to apply paleomagnetic results to solve some geological problems. Considering from knowledges so far obtained about the nature and direction of Pliocene and Pleistocene geomagnetic field, it might be said that the geomagnetic field changed its polarity periodically during the epochs (COX, DOELL and DALRYMPLE; 1966, 1967). Supposing the above mentioned feature of

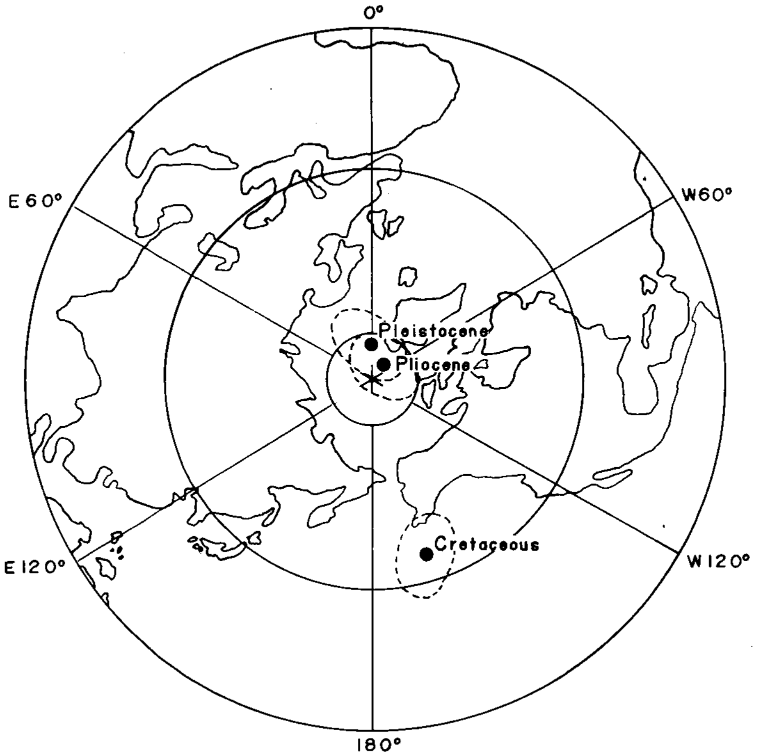

Fig. 2. Mean virtual geomagnetic pole obtained from Southwest Japan.

the past geomagnetic field, the volcanic rock series of far different localities can be better correlated with one another by the aid of combined knowledges, such as their stratigraphy, absolute age determinations on some rocks and the paleomagnetic polarity changes of the remanence.

In fact, so far as Upper Pliocene to Pleistocene time concerns, it is safer to adopt as a standard, the normal-reverse polarity time scale proposed by Cox *et al.* (1967).

There is a series of lava flows in Kurayoshi, most of which are reversely magnetized, and these lava flows are considered to be Middle Pliocene in age. Some of Kuju lava flows in Middle Pliocene are also reversely magnetized. These reversals may possibly be correlated with each other.

On the basis of the above mentioned method, the present results on some Pliocene and Pleistocene volcanic rocks with different localities in Southwest Japan could be well ranked on the geological chronology. Thus obtained result is summarized in Fig. 3.

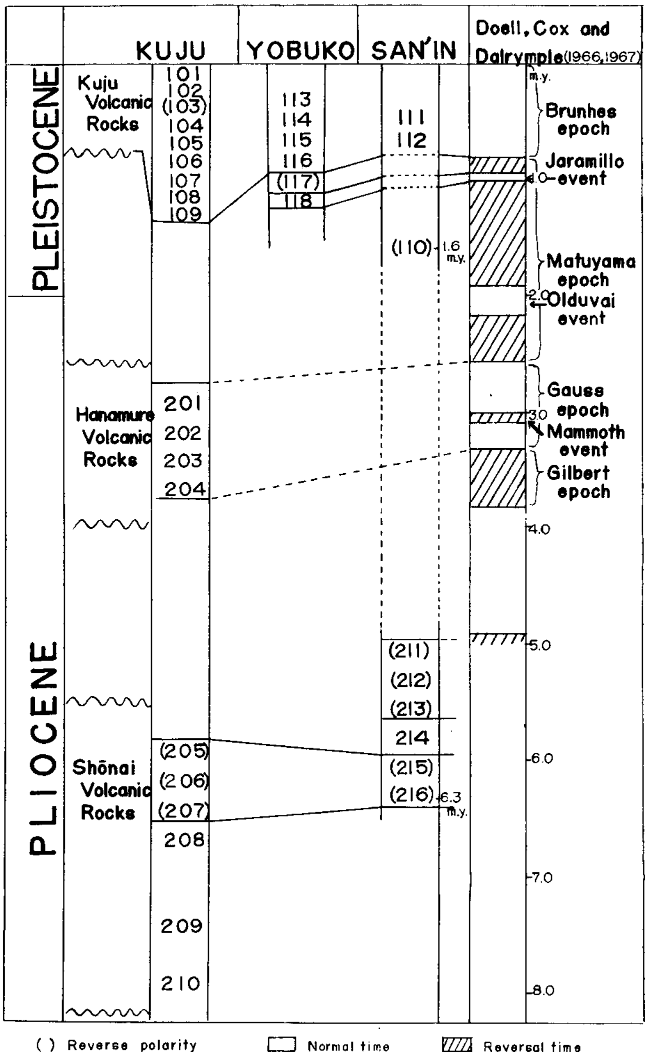

Fig. 3. Correlation of volcanic rocks of southwest Japan.

Conclusion

From our present study, following conclusions may be led in final.

1) The pole positions of Pliocene and Plcistocene epochs agree well with the present north pole, and it strongly suggests that there were no movement of Southwest Japan during and after those epochs.

2) The volcanic rock series of remote localities can be better correlated

by comprehensive knowledges of their stratigraphy and paleomagnetic polarity changes of their remanence, together with some data of absolute age determination among them.

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