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Paleomagnetism and Radiometric Age of Trachytes in Jeju Island, Korea

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Abstract: The geology of the Jeju island is characterized by the occurrence of thick voluminous basaltic lava flows and minor trachytic lavas. The land form can be divided topographically into the lava plateau, the shield-shaped Halla volcanic edifice and the parasitic cones whose number is more than 360, which is closely related to the cyclic volcanism of the island. Especially, the trachytic lavas seem to be the latest differentiation products of the cyclic activities and largely classified into two groups (Backlokdam group and Sanbangsan group) on the basis of the occurrence and the petrography.

The paleomagnetism and the radiometric age on the two groups of trachyte suggest a lower and an upper time limits of the volcanic stratigraphy of the island. An average age of the trachyte of the Sanbangsan group is 0.733 ± 0.056 m.y., and is correlated to a horizon a little lower than the boundary (0.69m.y.) between the Brunches normal epoch and Matuyama reversed epoch. An average age of 0.025 ± 0.008 m.y. determined from the Backlokdam trachyte may be corrected to any one horizon of the Laschamp, or the Lake Biwa, or the Lake Mono excursion.

The two groups of trachytes are distributed with the latitude difference of 9′(0.15°), and with age difference of about 0.71 m.y. Assuming that the two trachyte groups were erupted from the same stationary hot spot, the lithosphere comprising the Jeju island is considered to have moved southward with a rate of about 2.3 cm/year.

INTRODUCTION

Jeju island, which rises to a maximum elevation of 1,950m above sea level, is situated about 90km south of the Korean Peninsula. Its shape is an ellipse with size of 80×40km.

The geology is characterized by occurrence of thick voluminous basaltic lava flows, minor pyroclastic rocks, and numerous parasitic cones. Volcanic rocks of the island form a continuous series which belong to a alkali basalt-trachyte association. Since 1925, many geologists have studied the geology and petrology of the island (Nakamura, 1925; Haraguchi, 1928~31, 1960; Lee, 1966; Matsmoto, 1969; Kim, 1969, 1974; Taneda et al., 1970; Lee, 1981; Won, 1975; Lee, 1982a, b). However, the study concerning the paleomagnetism and the radiometric age of the island have rarely been carried out.

The purpose of this study is to determine the paleomagnetism and the radiometric age of trachytes and to discuss the volcanic rocks in this island from the following two reasons.

1) The trachytes of the island can be classified into two groups on the basis of petrography and occurrence. They seem to be the final eruptions of the early stage and the late stage in volcanic activities of the island.

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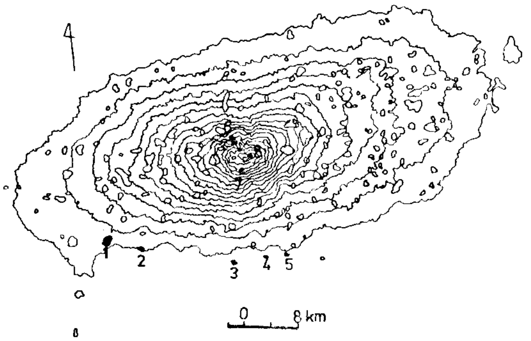

Fig. 1 Contour map showing the topographical features of Jeju island and sampling sites.
● ; trachytes
○ ; parasitic cones
1. Sanbangsan, 2. Whasun, 3. Beomseom, 4. Munseom, 5. Supseom, 6. Cheonwangsa, 7. Yeongsil, 8. Backlokdam

2) Trachytes have high K_2O content, which means that radiometric ages of trachytes by K-Ar method have high accuracy.

GEOLOGY AND PETROGRAPHY OF TRACHYTES

Jeju island forms a shield-shaped volcanic edifice, about 2,000m in height in the central part of the island. It is characterized by a symmetrical form whose peak is the Mt. Halla (1,950m). The land form, which is closely related to the volcanism, can be divided topographically into the lava plateau, the shield-shaped Halla volcanic edifice, and the parasitic cones whose number is more than 360.

Won(1975) and Lee(1982) classified the process of growth of the island into 4 stages on the basis of geology and topographic features as follows;

1) the first stage which formed the base of the island under sea level.

2) the second stage which formed the lava plateau of the island above sea level.

3) the third stage which formed the Halla volcanic edifice in the central part of the island.

4) the fourth stage which formed the parasitic cones along the long axis of the island.

The geology of the island is characterized by the occurrence of thick voluminous basaltic lava flows and small amounts of trachytic lavas. The latter seems to be the latest differentiation products of the cyclic activities and is largely classified into two groups on the basis of occurrence and the petrography; one is distributed along the south coastal line and shows aphyric texture, while the other is at around the summit and shows porphyritic texture. The former, what is called Sanbangsan group, seems to be the latest eruption of the lava plateau stage and the latter, what is called the Backlokdam group, is the latest eruption of the Halla volcanic edifice stage.

The paleomagnetism and the radiometric age of the two trachytes group will suggest a lower and an upper time limit of the volcanic stratigraphy of the island.

The analyes and norms of the trachytes are presented in Table 1.

aphyric trachytes

Included here are Sanbangsan, Beomseom, Supseom, and Munseom trachytes. In hand specimens, they are green-gray or light purple and compact. In thin section, it has an interstitial texture with oligoclase and alkali feldspar, accompanied by minor ferrosilite. Oligoclase is surrounded by alkali feldspar with a distinct chemical gap at the contact.

porphyritic trachytes

These rocks include Yeongsil, Backlokdam and Cheonwangsa trachytes. In hand specimen, trachytes from lava domes are white-gray porphyritic rocks, while trachytes from lava flows are brown or gray-black porphyritic.

In thin section, the phenocrysts of the two rocks consist of anorthoclase, oligoclase, olivine, magnetite, ferroaugite, hedenbergite and apatite. The olivine phenocrysts are usually brownish colored and rounded up to 1 mm across, with normal zonning. Most have been altered around

Table 1 The composition of trachytes in Jeju island.

	Sanbang-san	Yeongsil	Cheon-wangsa	Backlok-dam
SiO_2	62.38	62.84	61.98	65.54
TiO_2	0.50	0.46	0.64	0.28
Al_2O_3	17.73	17.84	17.51	16.73
Fe_2O_3	1.89	1.90	5.67	2.50
FeO	1.98	2.75	0.93	0.94
MnO	0.25	0.14	0.12	0.12
MgO	0.19	0.28	0.62	0.13
CaO	2.69	1.78	1.57	1.07
Na_2O	6.39	5.98	5.51	6.04
K_2O	4.26	5.03	4.47	5.63
H_2O^+	1.48	0.29	0.45	0.54
H_2O^-	0.17	0.32	0.35	0.08
P_2O_5	0.25	0.22	0.47	0.03
Total	100.16	99.83	100.29	99.63
Ni	6	—	7	4
Cr	6	8	—	6
Co	—	—	—	—
Sc	2	10	—	7
Sr	620	218	221	18
V	8	42	10	10
F	285	351	1,415	290
Ba	1,246	1,533	—	—
Y	41	29	—	31
Zr	713	768	—	718
Rb	106	96	—	123
Nb	118	91	—	100
Ce	170	126	—	125

Major elements in wt.%, and trace elements in ppm.

the margin and along fractures to red or brownish iddingsite. In certain thin sections, the Phenocrysts are glomerocrysts, consisting of interlocking, anhedral crystals of anothoclase. Pyroxene is rarelyfound. Some partially resorbed pyroxene has been replaced by unidentifiable ferromagnesian materials. The plagioclase is zoned from An_{40} to An_{30} with alkali feldspar around its margins. Magnetite and colorless apatite, often in close association, also occur as euhedral microphenocrysts. The groundmass consists of abundant laths of simple twinned alkali feldspar, magnetite, olivine, pyroxene, apatite and rare cristobalite. Between the alkali feldspar laths are small granules of magnetite, olivine and irregular patches of alkali feldspars. Most of the olivine with composition of Fo_{32-4} is altered to brownish iddingsite. Pale yellow-brown hedenbergite (Wo_{46-45} En_{8-7} Fs_{46}) are also found.

PALEOMAGNETISM AND RADIOMETRIC AGES OF TRACHYTES

Measurements

Block samples were collected from the trachytes of the Sanbangsan group and the Backlockdam group. Total 70 samples were obtained from eight sites; three sites from the Backlokdam group and five sites from the Sanbangsan group. The block samples were drilled into 2.4cm diameter cores and cut into specimens of 2.4cm long. One or two specimens were obtained from each block sample.

NRMs of specimens were measured with the spinner magnetometer constructed at Department of Earth Science, Kobe University, Japan, and with the astatic magnetometer constructed at the Department of Earth Science Education, Chonbuk National University, Korea.

One or two pilot specimens from each site were progressively demagnetized in alternating field (a.f.) in steps of 50 Oe up to a maximum field of 500 Oe to determine optimum fields for demagnetization.

Thermal demagnetization experiment was done in nitrogen gas with a non-inductive electronic furnace shielded by u-metal tube, holding the specimens at a maximum temperature during each run for 30 minutes. One or two pilot specimens from each site were subjected to progressive thermal demagnetization at the temperature of every 100 degrees from 200°C up to 500°C or 600°C in nitrogen gas. Thermal demagnetization experiments on pilot specimens displayed blocking temperatures somewhat below

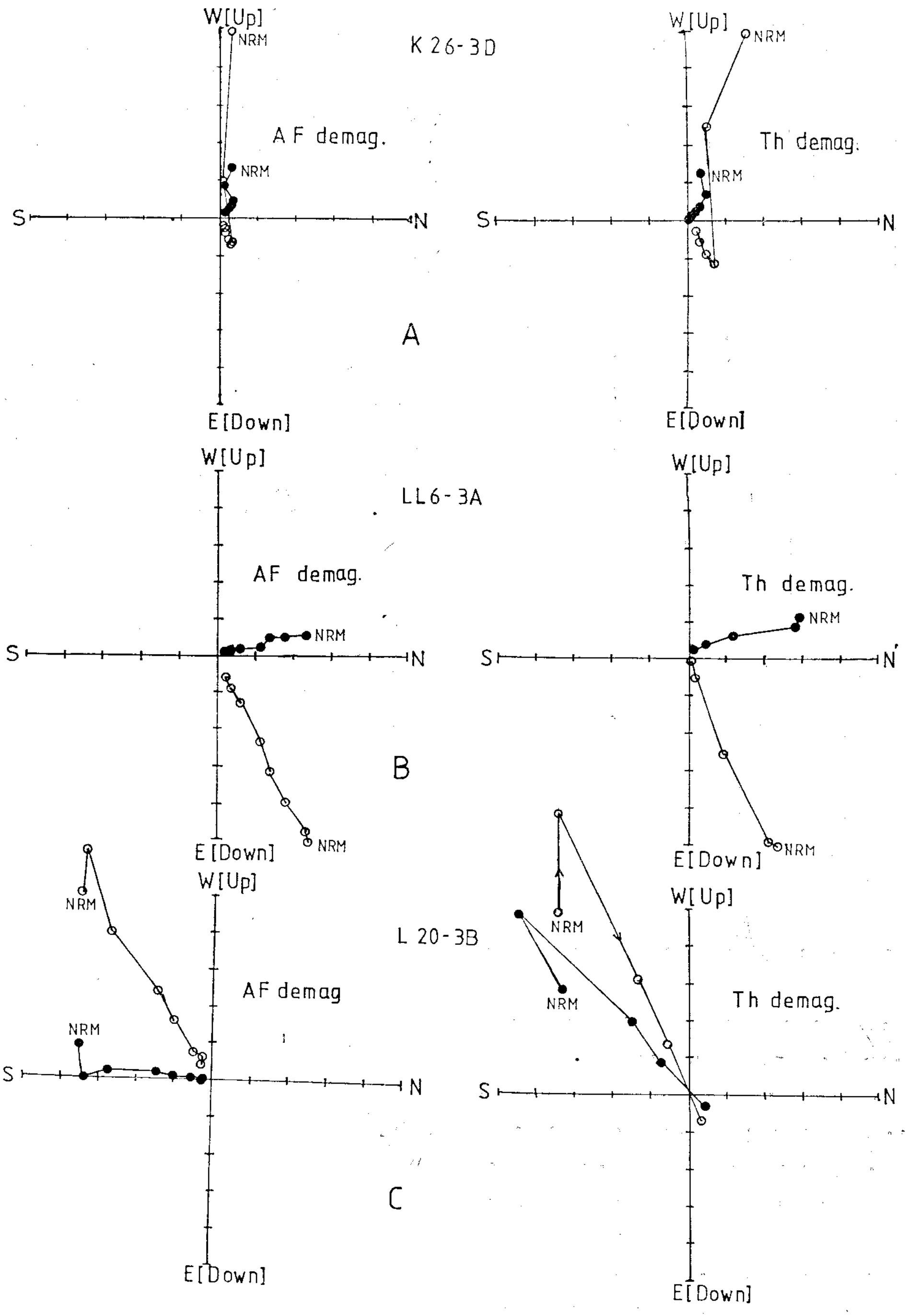

Fig. 2 Direction change during progressive alternating field (AF) and thermal demagnetization (Th).
Orthogonal projections of magnetization vectors of specimens from trachytes of (A) Backlokdam (B) Yeongsil (C) Sanbangsan following the method by Zijderveld(1967).
Solid (open) circles refer to projection on X-Y (X-Z) plane, respectively.

Table 2 Mean directions of remanent from sites of trachytes in Jeju island.

Names of sites	N	NRM					RM					Remarks
		Jo	D	I	K	a95	J	D	I	K	a95	
Cheonwangsa	4	75.1	6.4	37.6	191.8	7	56.6(100)	5.0	35.9	227	5.5	Backlokdam Gr.
Yeongsil	7	20.0	−21.8	61.7	83.6	8	11.4(200)	−22.9	62.1	78	8.6	
Backlokdam	10	25.3	−76.6	−58.2	1.9	55	2.2(200)	−50.8	61.8	70	6.6	
Sanbangsan	8	7.8	197.2	−61.0	20.9	15	6.9(150)	187.3	−56.9	19	15.5	Sanbangsan Gr.
Whasun	4	29.5	181.4	−58.9	146.1	7	13.5(150)	168.3	−55.3	164	7.1	
Munseom	6	3.9	160.1	−57.6	10.9	21	3.7(100)	164.6	−55.0	71	8.0	
Beomseom	7	3.9	59.7	73.6	4.4	36	2.2(100)	171.7	−39.7	39	10.9	
Supseom	10	12.3	205.2	−56.2	97.3	6	10.6(100)	192.7	−59.8	13	16.2	
Mean			178.9	−52.9	2.0	73		176.0	−53.8	59	10.0	

N: number of block sample; D: mean declination (degree)
I: mean inclination (degree); Jo, J: mean intensity of magnetization ($\times 10^{-4}$emu) before and after a.f. demagnetization, respectiviely.
K: Fisher's precision parameter; a95: radius of 95% confidence circle (degree). number in parenthesis: optimum field intensity (Oe) for a.f. demagnetization.

580°C, indicating that magnetite is the magnetic carrier (Fig. 2).

To determine a stable direction of magnetization for each site, Zijderveld component plots were used to identify the characteristic direction of each specimen (Zijderveld, 1967).

At nearly all sites the plots revealed that an overprint of unstable components had been-removed. Both a.f. and thermal demagnetization generally gave the same characteristic directions. Directions judged to represent the characteristic direction of each specimen were averaged to determine a single direction for the site.

Paleomagnetic direction

Characteristic directions from the trachytes of Sanbangsan group appear to have reversed direction (Fig. 3). After determining the characteristic direction of each specimen, the specimen direction were averaged using Fisher statistic to obtain a mean magnetic direction for the site (Table 2). Overall mean direction obtained from the five site means is D=176.0, I=−53.8 with precision parameter (Fisher, 1953) I=59 and radius of 95% confidence circle a95=10.0.

Characteristic directions from trachytes of Backlokdam group appear to have normal directions (Yeongsil and Cheonwangsa trachytes), and excursion (Backlokdam trachyte) (Table 2, Fig. 3). The Yeongsil and the Cheonwangsa trachytes were found to be magnetically very stable and did not change their direction by the a.f. and thermal magnetizations, while the Backlokdam trachyte was found to be magnetically unstable (Fig. 2). Intermediate NRM directions with negative values of inclination obtained from Backlokdam trachyte changed to abnormal directions(excursion?) after a.f. demagnetization, but unchanged in thermal demagnetization (Fig. 2).

K-Ar ages of the trachytes

Four samples were radiometrically dated by K-Ar method. One was from the Backlokdam trachyte which crops out at the summit of the Mt. Halla, the other three were from trachytes of Sanbangsan group; one was from Sanbangsan, the other two were from islands of the Munseom and the Supseom, off the southern coast line of the main island.

The K-Ar ages were determined twice for

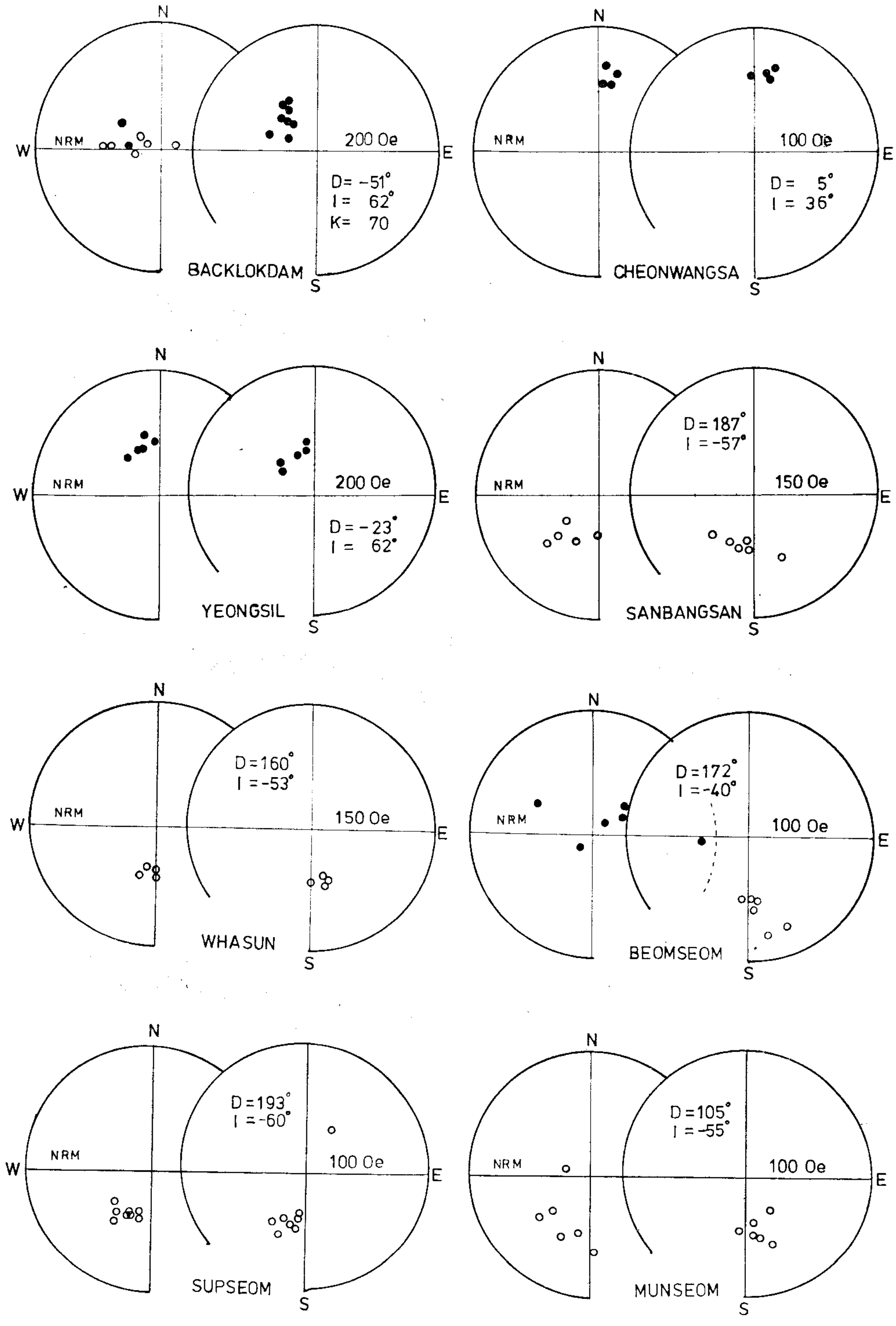

Fig. 3 Directions of the magnetic vector's plotted on equal area net.
Solid (open) circles refer to projections on lower (upper) hemisphere, respectively.

Table 3 K-Ar ages of trachytes from Jeju volcanic island, Korea.

Sample	Sample weight (g)	^{40}Ar rad. ($\times 10^{-8}$cc/g)	$\frac{^{40}Ar\ rad}{^{40}Ar\ total}$(%)	K_2O(wt %)	Age (m.y.)	
Backlokdam tra.	0. 4488	0. 37±0. 16	96	4. 26±0. 11	0. 023±0. 010	0. 025±0. 008
	0. 3118	0. 44±0. 20	97		0. 027±0. 013	
Sanbangsan tra.	0. 2666	11. 45±0. 30	56	3. 96±0. 14	0. 745±0. 033	0. 747±0. 023
	0. 2647	11. 51±0. 33	56		0. 749±0. 034	
Munseom tra.	0. 3126	12. 33±0. 84	72	4. 48±0. 11	0. 710±0. 052	0. 728±0. 034
	0. 2908	12. 96±0. 34	53		0. 746±0. 027	
Supseom tra.	0. 1992	11. 10±0. 52	73	3. 81±0. 11	0. 751±0. 042	0. 725±0. 038
	0. 2349	10. 33±0. 46	70		0. 699±0. 037	

each sample, and were calculated for each Ar measurement, using same K_2O content (Table 3). The ages obtained agree very well and quite reliable even for their young ages. Average age of trachytes of the Sanbangsan group is 0. 733 ±0. 056 m.y., and is correlated to a horizon a little lower than the boundary (0. 69 m.y.) between the Brunches normal epoch and Matuyama reversed epoch.

An average age of 0. 025±0. 008 m.y. determined from Backlokdam trachyte may be correlated to any horizon of the Laschamp excursion. Huxtable et al. (1978) determined the ages of the Laschamp excursion as about 25800BP, Valladas et al. (1977) gave the ages of 33000±4000BP, while Gillot et al. (1980) gave the ages of 36000±4000BP for the Laschamp flow. The ages of Lake Biwa excursion (Nakajima et al., 1973) and Lake Mono excursion (Denham, 1974) were reported to be about 18000BP and 25000BP, respectively.

RESULTS AND DISCUSSIONS

Sanbangsan group trachytes, which crop out around the south coastal line of Jeju island, appear to be occurred in a reversed polarity epoch. The paleomagnetic directions of these trachytes, the Sanbangsan, the Whasun, the Beomseom, the Munseom, and Supseom trachytes, are considered to be nearly similar within error

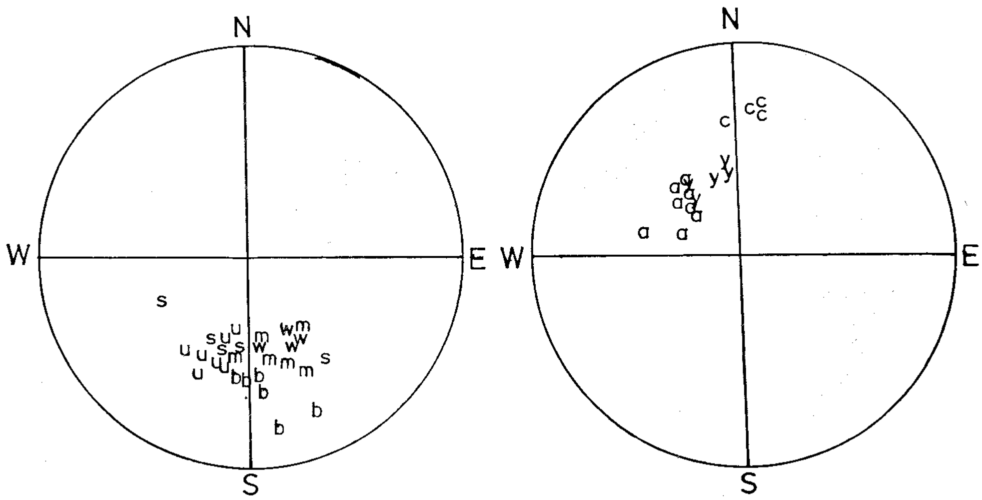

Fig. 4 Simultaneous plots on equal area net of paleomagnetic directions of the two groups.
a: Backlokdam s: Sanbangsan y: Yeongsil w: Whasun
c: Cheonwangsa m: Munseom b: Beomseom u: Supseom

limits (Fig. 4). The mean paleomagnetic direction of each of the five trachytes are D=176.0, I=−53.8, and a95=10.0.

K-Ar ages of the trachytes were also determined. Ages of the trachyte samples from Sanbangsan, Munseom, and Supseom, are also nearly equal. An average age of these three is 0.733±0.056 m.y., and is correlated to a horizon a little lower than the boundary between the Brunches normal and the Matuyama reversed epochs. The trachytes of the Sanbangsan group were, therefore, errupted at the latest time span of the Matuyama reversed polarity epoch; a little earlier than the Brunches normal epoch.

Backlokdam trachyte, which crops out around the summit of the Mt. Halla, has paleomagnetic direction D=−51, I=62, and is considered to be errupted when the geomagnetic field was changing from normal to abnormal (vice versa), but further studies are required why this trachyte has an abnormal magnetic direction. K-Ar age of Backlokdam trachyte was also determined to be 0.0025±0.008 m.y. This might be correlated to any horizon of the excursions of the Lake Biwa, or the Lake Mono, or the Laschamp. The Yeongsil and Cheonwangsa trachytes gave normal magnetic directions.

The Sanbangsan group of trachyte is distributed on the southern coastal line of Jeju island of average latitude 33°13′N, and the Backlokdam group of trachyte is cropped out around the summit of the Mt. Halla of average latitude 33°22′N with the latitude difference being 9′ (0.15°). The average ages of the trachytes of the Sanbangsan group and the Backlokdam group are 0.733 m.y., respectively, the age difference being about 0.71 m.y. When assuming the magmas, with which two trachyte groups were supplied, errupted from the same stationary hot spot, the lithosphere comprising the Jeju island is considered to have been moved southward with the rate of about 2.3 cm/year. Kim (1985) reported that the Korea land mass has been rotated clockwise or moved southward since Cretaceous. The result of our study also confirms the southward movement of Korean land mass since late Quaternary.

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韓國, 濟州島에 產出하는 粗面岩類의 古地磁氣 및 絕對年齡에 關한 硏究

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요약 : 제주도의 지질은 다량의 현무암질 용암과 소량의 조면암질 용암으로 특징지워진다.

제주도는 지형적인 특징에 따라서, 용암대지, 순상형의 한라산 화산체 및 360여개 이상의 기생화군으로 구분된다. 이와같은 지형적인 특징은 제주도의 화산활동과 밀접한 관계를 갖는다.

조면암질 용암은 암석기재학적 및 산출상태의 특징에 따라서 백록담 구룹과 산방산 구룹으로 구분되며, 이들은 제주도의 화산층서 상, 하한선을 규정할 수 있는 것으로 생각된다. 따라서 이 연구에서는 두 구룹의 조면암질 용암의 연대측정 및 고지자기 연구를 하였다.

산방산 구룹 조면암의 평균 연령은 0.733±0.056 M.Y.을 나타내며, 이는 Brunches 정자극기와 Matuyama 역자극기 사이의 경계의 약간하부와 (0.69 M.Y.) 대비된다. 반면 백록담 구룹 조면암의 평균연령은 0.025±0.008 M.Y.를 나타내며, Laschamp excursion, Lake Biwa excursion 또는 Lake Mono excursion 중 어느 horizon과 대비된다. 이들 두 조면암구룹은 위도 9′(0.15°)의 차이를 두고 분포하며, 연대는 0.71 M.Y.의 차를 나타낸다. 이러한 결과는, 두 구룹의 조면암류 용암이 같은 원천의 hot spot에서 분출된 것으로 가정한다면, 제주도를 포함한 lithosphere는 신생대 제 4 기 동안에 약 2.3cm/y의 속도로 남쪽으로 이동하고 있는 것으로 사료된다.

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