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Paleomagnetism and K-Ar Age of Volcanic Rocks from Guryongpo Area, Korea

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Abstract: Samples of porphyries, andesites, decites and sandstones were collected from 14 sites in order to study paleomagnetism and to determine K-Ar age in Guryongpo area.

K-Ar age dating indicates that porphyries and volcanic rocks formed 41.7 and 22.7~19.4Ma, respectively.

The mean direction of remanent magnetization for each site was generally well grouped after alternating field demagnetization. Both normal and reversed directions are present. The mean magnetic direction of the porphyries of Late Eocene and that of the volcanic rocks of Late Oligocene to Early Miocene have similar, easterly declinations. Overall magnetic direction is Dm=43.8°, Im=53.5°, $\alpha 95$=12.2°. the reliability of the observed paleomagnetic directions is ascertained by the presence of normal and reversed polarities. This is also conformed by the similarity of the declinations of the normal and reversed polarities. Observed easterly declinations in this area are attributed to local clockwise rotation of the land mass by approximately 40~50 degrees since early Miocene.

INTRODUCTION

The study area is situated in the south-eastern part of the Korean Peninsula, and is in the north-eastern perimeter of the Pohang Basin of the Tertiary. The geology in and around this area was first surveyed by Taeiwa(Yonil, Guryongpo, and Choyang Sheets, 1924). This area was the center of volcanic activity in the Tertiary, and the strata of the area, therefore, show quite a different aspect from that of the other Tertiay strata in Korea. Especially, tuffaceous rocks, which might be related to volcanic activity, are distributed on a large scale. Zeolites of economic value are produced from them(Kim et al., 1978). Studies on mineralogical properties of zeolites and smectites, and on their origins were made by Kim et al. (1983). Petrological study on volcanic rocks, especially mineralogical study on tuffaceous rocks, were made by Won et al. (1985) and by Noh (1982, 1984), respectively. Petrological study on the Nuldaeri volcanic rocks was made by Lee et al. (1986).

A quantitative study on the time of volcanic activity in this area was not made yet. And the geological sequence between each volcanic rock type is not known cleary, therefore, it is difficult to interprete the volcanism in this area without a quantitative study on the time of volcanic eruption. This study aims at elucidating the time of volcanic activity and paleomagnetism in this area.

GENERAL GEOLOGY

The present study area consists of porphyries,

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felsites, and hornfels as basement rocks, sedimentary rocks of Janggi Group and volcanic rocks.

Tateiwa (1924) assigned the basement rocks to the Crectaceous, and the sedimentary and the volcaic rocks to the Tertiary. He subdivided the Tertiary strata into the Janggi, the Beomgogri and the Yonil Group based on unconformity in ascending order. He described the Janggi and the Beomgogri Groups as continental deposits, and the Yonil Group as Marine deposits. Later, Kanehara (1936) and Huzioka (1972) interpreted the age of the Janggi and the Beomgogri Groups as the Miocene based on plant fossils discovered from the Janggi Group.

The Tertiary volcanic rocks, which are called Nuldaeri volcanic rocks, are the main rock types in this area. They intruded or extruded the sedmentary rock formations, and form relatively high hills and are widely distributed in this area. They are classified to perlites, perlitic dacites, brecciated dacites, rhyolites, andesites and basalts based on petrography, and from a circular distribution on the whole whose center may be Guryongpo town (Fig. 1). Rock sequence between these rock types was not revealed from field surveys. In the outer-most part of the circular distribution, the Nuldaeri tuffs, which is the uppermost layer in this area, are widely distributed intermittently. In contact with the Nuldaeri tuffs, perlitic dacites, brecciated dacites, andsites and rhyolites are distributed in the direction to Guryongpo town. Perlites produce from the perlitic dacites at several sites. Near the Pyongpo Bridge in Guryongpo town, there is an outcrop which has rhyolitic groundmass and contains angular fragments of granites, shaly shist, gne-

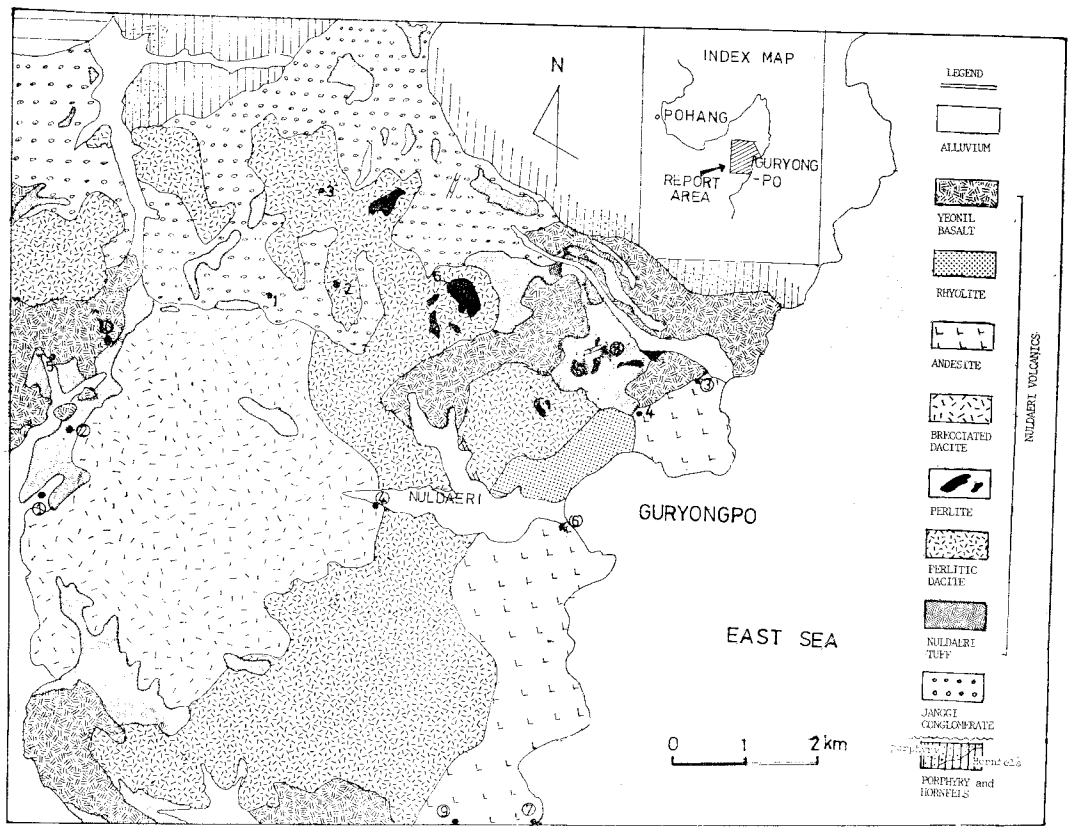


Fig. 1 General geological map of Guryongpo area. Numbers show sampling sites for the determination of K-Ar ages and paleomagnetism (○ is for that of paleomagnetism.)

Table 1 Bulk chemical composition of the typical volcanic rocks from Guryongpo area.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	50.89	57.23	59.76	60.13	60.72	64.42	67.94	68.04	69.88	70.22	71.12	73.86	74.81	76.76
TiO_2	1.29	0.82	0.15	0.66	0.59	0.49	0.12	0.18	0.30	0.07	0.07	0.07	0.15	0.05
Al_2O_3	18.33	17.47	19.38	17.11	16.45	16.05	15.82	16.40	15.80	12.84	17.02	14.08	13.15	13.46
Fe_2O_3	9.10	7.58	2.32	5.84	5.49	3.77	3.13	2.43	2.20	0.33	0.57	1.03	0.98	0.73
FeO	—	—	3.00	—	—	—	1.13	0.78	—	0.21	0.51	0.22	—	0.27
MnO	0.20	0.17	0.12	0.12	0.80	0.92	0.10	0.08	0.06	0.03	0.09	0.10	0.08	0.02
MgO	3.47	3.30	2.25	2.70	2.25	1.28	0.50	0.84	0.48	0.10	0.37	0.41	0.31	0.10
CaO	8.55	6.35	4.97	5.28	4.44	4.00	3.86	3.33	1.89	1.92	0.90	0.68	1.04	0.85
Na_2O	3.43	3.61	3.98	3.26	3.46	4.56	3.75	3.92	4.32	3.07	3.38	3.75	3.47	3.81
K_2O	0.70	1.34	1.47	1.79	2.19	1.85	1.93	2.20	3.13	1.42	3.29	3.20	3.46	3.16
H_2O^+	3.57	1.95	2.11	1.19	3.93	3.35	2.05	1.59	1.87	6.74	1.61	1.41	2.51	0.87
H_2O^-	—	—	0.39	—	—	—	—	0.40	—	3.04	0.34	0.39	—	—
P_2O_5	0.45	0.18	0.22	0.13	0.13	0.14	0.15	0.22	0.07	0.04	0.06	0.06	0.04	tr
Total	100.00	100.00	100.45	100.00	100.00	100.00	100.48	100.32	100.00	100.05	99.38	99.88	100.00	100.08

Table 2 K-Ar ages of volcanic rocks from Guryongpo area. Sampling sites shown in Fig. 1.

Sample No.		Weight(mg)	K(wt%)	40Ar air($\times10^{-8}cm^3/g$)	Ar air(%) / Ar total	Age(m.y.)
*Quartz dorphyry (840215-3)	1	253.4 335.6	4.11	654±8 692±8	23 21	40.5±2.1 42.9±2.2 } 41.7±1.9
Two Pyroxene Andesite (840215-2)	2	272.7 334.2	0.556	48.7±0.8 49.1±0.7	45 39	22.4±1.2 22.6±1.2 } 22.5±0.8
Trachyte(Dacite) (841002-2)	3	209.8 311.3	2.87	267±4 243±3	24 22	23.8±1.2 21.7±1.1 } 22.7±1.3
Andesite(KR3)	4	311.4 344.2	1.67	147±2 149±2	35 41	22.5±1.2 22.9±1.2 } 22.7±0.8
Basalt(KR7)	5	289.2 376.2	1.06	83.7±0.9 85.7±0.8	15 18	20.2±1.0 20.7±1.0 } 20.5±0.8
Perlite(KR8)	6	334.4 250.3	2.91	246±4 224±3	45 36	21.6±1.1 19.7±1.0 } 20.7±1.2

* Quartz porphyry is the boulder of conglomerate.

isses and andesites, the diameters of which are in the range of 3-50cm,

Chemical compositions of the typical volcanic rocks in this area are as in Table 1. The volcanic rocks are classified to basalts (SiO_2 : 50~51%), andesites(SiO_2 : 57~60%), dacites(SiO_2 : 64~70%) and rhyolites(SiO_2 : 70%~) based on SiO_2 content. The volcanic rocks are belong to calc-alkali rock series in chemical composition, and show the differentiation trend of basalts-andesites-dacites-rhyolites. The characteristics of chemical compositions, constituent minerals and differentiation trend of the volcanic rocks are similar to those of the calc-alkali rock series of the Ido Peninsula-Hakone district of Japan.

K-Ar AGE DETERMINATION

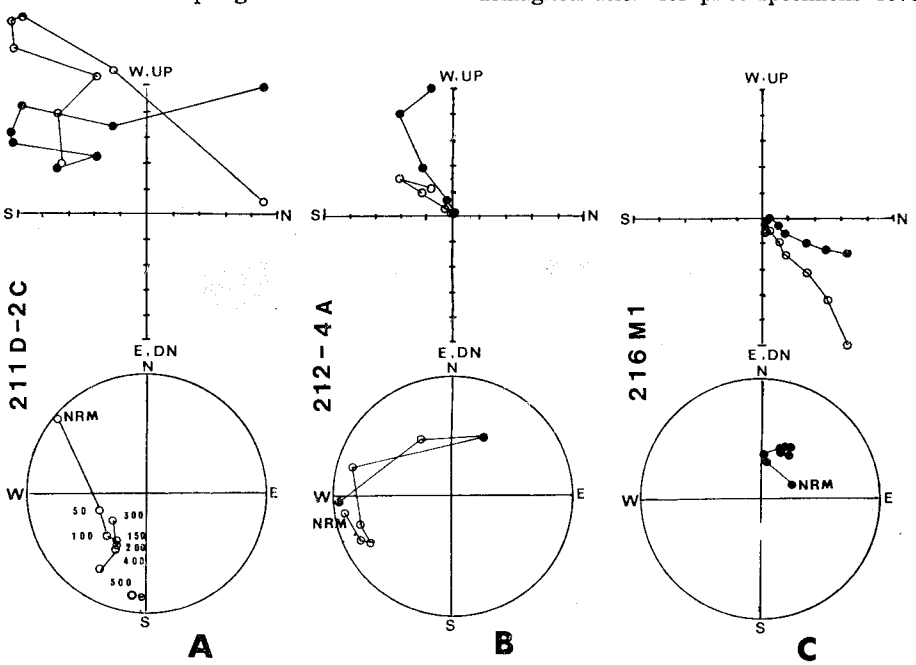
Typical rock samples were collected from each rock type in the area to determine the age of them. Sampling sites are shown in Fig. 1. Measurement was made twice for each sample and the two values obtained agree very well each other. The age of porphyry is 41.7 Ma, these of the Nuldaeri volcanic rock are in the range of 22.7~19.4Ma. Result of K-Ar age determin-

ation is in Table 2.

PALEOMAGNETISM

More than 120 oriented hand samples were collected from 14 sites using a magnetic compass. These sites include the sampling sites for K-Ar age dating(Fig. 1). Paleomagnetic measurement was made at Kobe University of Japan and Chonbuk National University of Korea using the spinner and the astatic magnetometer, respectively.

Treatment in progressive alternating field(AF) demagnetization for pilot specimens reveals that



Fig, 2 Alternating field demagnetization of pilot specimens from Guryongpo samples. Orthogonal and equal area projections, solid(open) circles in the case of orthogonal projections refer to horizontal(vertical) projection and those of equal area projections refer to lower (upper) hemisphere.
(A) and (B); from andesites (C); from porphyries

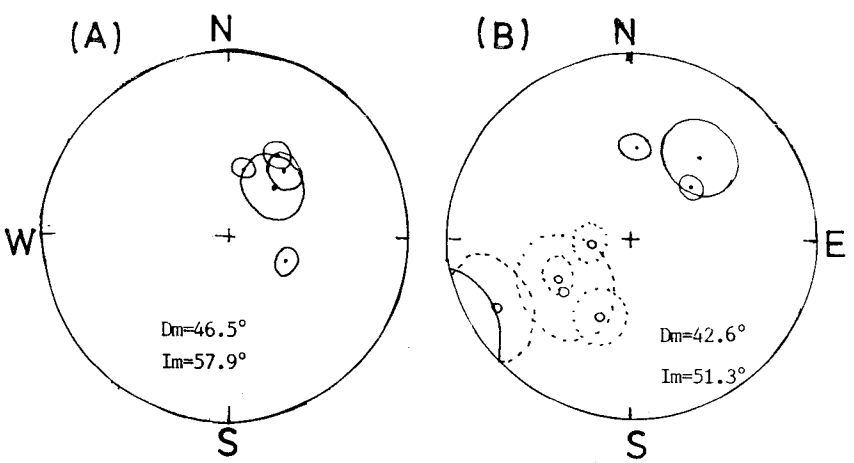


Fig. 3 Site mean magnetic directions from Guryongpo rocks. A; porphyries of late Eocene age, B; volcanic rocks and red sandstones of late Oligocene to early Miocene age.

Table 3 Result of magnetic measurement of rocks distributed in Guryongpo area. Sampling sites shown in Fig.1. N; number of block samples, I; mean inclination(degree), k; Fisher's precision parameter, $\alpha 95$; redius of 95% confidence circle (degree).

	Samling site (sample No.)	N	Before AF cleaning				After AF cleaning				rock type
			D(°)	I(°)	k	$\alpha 95$(°)	D(°)	I(°)	k	$\alpha 95$(°)	
①	Chuksil(216M)	10	29.7	46.4	136.0	4.2	34.8	44.1	240.8	3.1	porphyry
	Chukha(216-2)	5	98.7	48.7	5.5	36.0	11.5	60.1	482.0	3.5	porphyry
	Chukha(216-1)	6	15.6	57.5	464.5	3.1	18.3	59.5	476.3	3.1	porphyry
②	Kongdangdong(215-7)	6	32.1	49.8	39.8	10.1	41.4	49.3	28.1	12.9	porphyry
	Mean						46.5	57.9	12.2	27.2	
③	Samjongri(212-10-13)	8	8.8	47.5	21.3	12.2	4.9	48.4	66.3	6.8	andesite
④	Hudongri(211B)	6	51.4	42.9	2.6	58.4	41.4	38.9	17.8	18.5	dacite
⑤	Samjongri(212-8)	4	46.6	60.3	251	3.5	47.6	52.4	241.2	3.6	red s.s.
⑥	Pyongpori(211A)	3	197.7	−39.0	4.2	69.7	200.5	−43.2	12.0	24.7	andesite
⑦	Changkilri(211D)	3	−44.2	18.0	4.9	62.7	207.5	−62.9	349.0	6.6	andesite
⑧	Maeamsan(212-4-4)	4	−81.1	21.0	3.1	85.3	−115.3	−17.8	32.1	22.1	andesite
⑨	Taejinri(214-2)	4	−94.8	−6.2	22.4	19.8	−116.3	−52.6	210.3	6.3	andesite
⑩	Chungsandong(215-3)	4	−89.9	−72.5	94.9	9.4	−92.5	−75.1	212.9	6.3	andesits
	Mean						42.6	51.3	12.6	16.2	
	Overall mean						43.8	53.5	13.4	12.2	

natural remanent magnetizations(NRM) of porphries show little directional change, while NRMs of andesites and dacites show unstable directional change (Fig.2). Optimum AF demagnetization field to produce minimum dispersion for each site was determined from both orthogonal and equal area projections of magnetization vectors. Only the intrasite-mean directions whose precision parameter(k) is greater than 10 were used for this study.

Tilting angles of the volcanic strata could not be determined, but the dip angles of sedimentary strata in the vicinity of this area are negligible.

Table 3 summarizes the mean characteristic directions of each site. Porphyries, dacites, and red sandstone reveal normal polarities, while andesites reveal normal and reversed polarities. k values become relatively larger for each-site after AF demagnetization, but that for overall site-mean direction decreases much, which may mean tectonic disturbance in this area. The site-mean direction of porphyries with age of 41.7Ma is Dm=46.5°, Im=57.9°, $\alpha 95$=27.2°. Nuldaeri volcanic rocks with ages between 22.7 and 19.4 Ma reveal normal and reversed polarities, and their site-mean direction is Dm=42.6°, Im=51.3°, $\alpha 95$=16.2° (Fig. 3).

DISCUSSION AND RESULT

Nuldaeri volbanic rocks consist of various rock types ranging from basalts to rhyolites. The distribution of acidic rocks show roughly ring structure, the center of which is Guryongpo town. Although the geologic sepuence is not apparent from field survey, it is suggested that each rock type is a series of fractional crystallization of magma which belongs to calc-alkali rock series.

The age of the Nuldaeri volcanic rocks by K-Ar method is within the range of 22.7—19.4Ma, which indicates that the volcanic activities in

this area were between late Oligocene and early Miocene and the Nuldaeri volcanic rocks are a series of differentiation from cognate magma.

The remanent magnetization of the porphyries and the Nuldaeri volcanic rocks after AF demagnetization is characterized by easterly declinations with overall mean direction of Dm=43.8°, Im=53.5°, $\alpha 95$=12.2°. The reliability of the NRM is supported by the following facts; (1) Both normal and reversed polarities appear from different rock types. (2) Rocks with both polarities have similar, easterly declinations. (3) The precision for each site increase remarkably after AF demagnetization (see Table 3).

The rock samples collected at ten sites consist of six different rock types of different ages in Tertiary. And the number of samples are sufficient so that it can be presumed that the secular variation is averaged out.

Paleomagnetic and K-Ar age data suggest that the magnetic vectors of porphyries of late Oligocene and those of andesites of early Miocene have similar directions, which means that there were not any appreciable tectonic movement of land mass before early Miocene in this area. The magnetic direction in the other Tertiary strata in Korea is similar to that of the present magnetic field (Kim, 1964; Lee, 1984; Kim, 1985). Thus the easterly deflected declinations in this area can be attributed to local, clockwise rotation of land mass by approximately 40~50 degrees since early Miocene. Detailed geologic survey is required for the geological evidences of tectonic rotation in this area.

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구룡포에서 産出되는 火山岩에 對한 古地磁氣와 K-Ar年齡

金光浩・元鍾寬・松田准一・長尾敬介・李文遠

요약 : 구룡포지역을 고지자기학적으로 연구하고 또한 분포된 암석의 K-Ar연대를 결정하기 위하여 14개지점으로부터 반암류, 안산암류, 석영안산암류 및 적색사암등의 시료를 채취하였다.

K-Ar연대 측정결과 반암류와 화산암류는 각각 42.7Ma 및 22.7—19.4Ma에 형성되었음을 나타냈다.

각지점별로 이들 시료를 최적자기장에서 교류소자한 후에는 자화방향이 한방향으로 집중되었다. 후기마이오세의 반암류들은 모두 정자화를 하고 있었고 후기올리고세에서 초기마이오세에 걸쳐서 분출된 화산암류들은 정자화를 한 것과 역자화를 한 것으로 나뉘어 나타났다. 반암류와 화산암류의 평균 자화방향은 서로 유사한 방향이었으며 또한 동쪽 편각을 보여주었다. 암석전체의 평균자화방향은 평균편각 Dm=43.8°, 평균복각 Im=53.5°, 95%의 신뢰도를 나타내는 원의 반경α 95=12.2°이다. 연구지역의 암석들에서 정자극과 역자극이 동시에 나타난점과 또한 이들이 서로 비슷한 편각을 갖고 있다는 점들로 미루어 측정된 고지자기 방향의 신뢰도가 크다고 판단되었다. 측정된 동쪽편각 43.8°는 이 지역이 동쪽으로 약 40°～50°정도 회전한 결과라 해석하였다.