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$^{40}Ar/^{39}Ar$ and K-Ar Age Datings on the Volcanic Rocks in Northern Coast of King George Island, West Antarctica

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Abstract: Isotopic ages of the volcanic rocks along the northern coast of King George Island, West Antarctica have been systematically measured by $^{40}Ar/^{39}Ar$, K-Ar and laser microarea isochron age dating techniques. The results indicate that ages of volcanic activity in the island began at Late Cretaceous and continued to the end of Eocene and the major eruptive epoch was in Eocene. Also volcanic centers migrated from southwest to northeast. This is consistent with the regional volcanic distribution in time and space. Acquirement of the present date with good quality will provide a strong foundation for determining the ages of regional volcanic strata and studying tectonic-magmatic evolution.

Key words: $^{40}Ar/^{39}Ar$, K-Ar, volcanic rock, King George Island, West Antarctica

INTRODUCTION

Accurate age dating on volcanic rock is the foundation to understand volcanic activity correctly and to approach the tectonic-magmatic evolution. A lot of studies on the volcanic rocks in King George Island of West Antarctica had been carried out and many age data published (Birkenmajer *et al.*, 1982; Grikurov *et al.*, 1970; Pankhurst and Smellie, 1983; Valencio *et al.*, 1979; Watts, 1982; Smellie *et al.*, 1984; Zhu Ming *et al.*, 1991). For the rocks collected from the same outcrop or same layer, the ages determined by K-Ar dilute technique are sometimes rather discrepant. In addition, all the previous studies were concentrated on the southern coast of the island due to the limitation of natural geographic conditions, while the northern coast remained blank in geochronology. Therefore, we report 7 ages of the volcanic rocks from the northern coast, which were yielded by $^{40}Ar/^{39}Ar$, K-Ar, and laser microarea isochron age dating techniques, as a result of the Sino-Poland joint research on Antarctica geology.

GEOLOGICAL SETTING AND SAMPLE DISTRIBUTION

The South Shetland Islands, West Antarctica is a post-Mesozoic, subduction-related calc-alkaline magmatic arc. Volcanic activities begun in Late Jurassic and continued till Quaternary (Pankhurst and Smellie, 1983; Smellie *et al.*, 1984). King George Island, the largest one in the South Shetland Islands, is almost all covered by Cenozoic volcanic rocks, composing of basalt, basaltic-andesite, andesite with their corespondent pyroclastic and pyroclastic sedimentary rocks (Birkenmajer and Narebski., 1981; Smellie *et al.*, 1984; Smellie, 1990; Zheng Xiangshen *et al.*, 1988, 1991; Li Zhaonai *et al.*, 1992). The majority of volcanic rocks were formed in Tertiary (Birkenmajer, 1989; Birkenmajer and Narebski., 1981, Birkenmajer *et al.*, 1982; Zhu Ming *et al.*, 1991) with a few exception of Late Cretaceous pyroclastic sedimentary rocks outcropped at the southwest tip of the island (Shen Yanbin, 1989; Cao Liu, 1989, 1990).

King George Island has been subdivided into two major tectonic units: both northern and south-

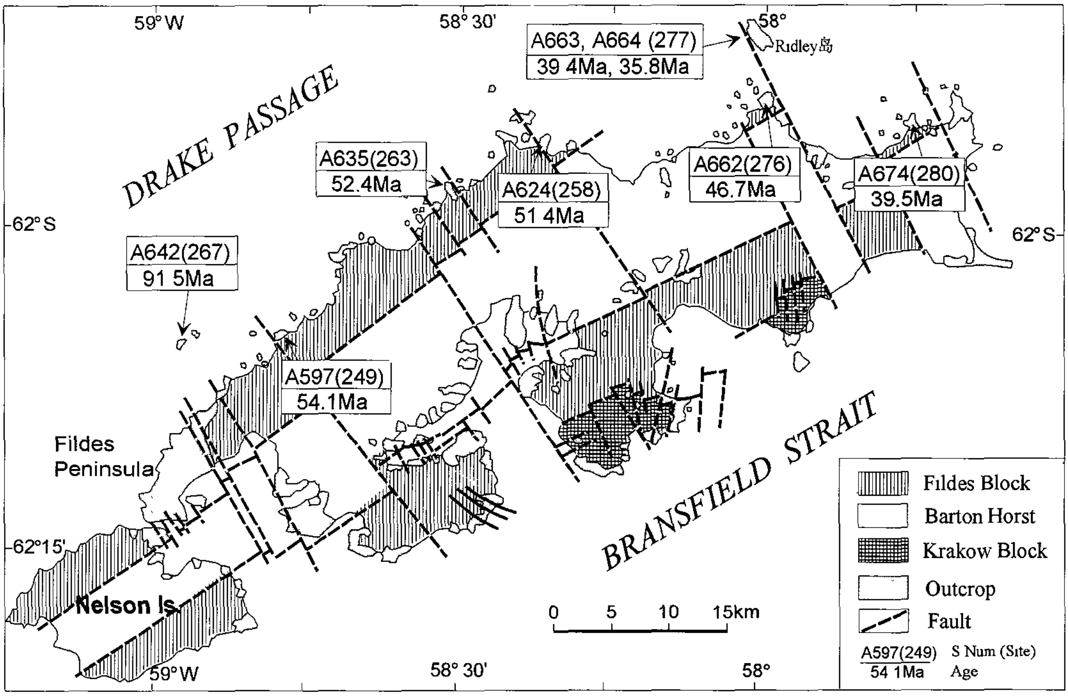

Fig. 1. Sampling site of the volcanic rocks in King George Island

ern sides are named Fildes Downthrow Block and Barton Uplift Horst is located in the middle. The units are separated by two strike-slip fault zones, the majority is the fults running parallel with elongation of the island (NE-SW) and the other is the younger, transverse strike-slip faults trending in NW-SE direction (Birkenmajer, 1992). Another small block, Karakow Block, is only confined to a part of southern coast. The eastern part of the northern coast belongs to Fildes block, where volcanic rocks arc mainly composed of basalt-andesite lava (Fildes peninsular Group, FPG) and basaltic-andesitic rocks (Admiralty Bay Group, ABG). In the western part of northern coast, altered volcanic rocks (Martel Formation), and intruded trachybasalt and granodiorite (Wegger Peak Formation) belong to Barton Horst. Dated samples in this study are chiefly of Fildes Block and partly of Wegger Peak Group (WPG), which were collected by Prof. Birkenmajer from onshore and offshore exposures between Fildes Peninsula and North Foreland in 1980/81 (Birkenmajer, 1984; Fig.1).

EXPERIMENTAL PROCEDURE

After careful petrographic study, six fresh and almost unaltered whole-rock samples were selected and used for $^{40}Ar/^{39}Ar$, K-Ar and laser microarea age dating.

$^{40}Ar/^{39}Ar$ age dating

Four samples were measured by $^{40}Ar/^{39}Ar$ age dating method. The samples, ground into 60-80 mesh firstly, were wrapped with aluminum foil and sealed hermetically in a quartz ampoule together with monitor sample for neutron flux. The monitor samples include ZBJ hornblende of 132.8±3.1Ma age, ZBH-25 biotite of 132.7±2.8Ma and international standard sample BSP-1 hornblende (2060±17.5Ma). K_2SO_4 and CaF_2 were used in experiment in order to correct K and Ca interfering Ar isotopes. Sample was put in H_4 channel of 49-2 Reactor of Institute of Atomic Energy, Chinese Academy of Sciences (CAS) for 4490 minutes irradiating with instantaneous fast neutron flux of 0.6 $\times 10^{13}$n/cm^{2}s, thus the integrated total amount of the fast neutron flux is 1.43×10^{18}n/cm^2. The cadmium foil with 0.5 mm in thickness was used as a shield to prevent the interference of slow neutron. During irradiation, the sample box was circulated by cooling water, which has the temperature of 42°C at outlet, and being rotated in 2 to 8 r.p.m to eliminate the transverse gradient of neutron flux.

After cooling to safe dosage, the irradiated sample was put in an Ar-extraction system to carry out stepping analysis. A high-frequency oven was used for melting sample and the high temperature of each step should keep in 20 minutes. The extracted argon was purified by CuO and sponge titanium and then, introduced directly to RAG-10 mass spectrometer for argon isotope analysis. Every calculation of apparent ages should make corrections of mass discrimination, memory effect, K and Ca interfering Ar isotope and ^{37}Ar radioactive decay. The measured correction factors of K and Ca interfering Ar isotope are $(^{40}Ar/^{39}Ar)_K = 7.15\times10^{-3}$; $(^{36}Ar/^{37}Ar)_{Ca} = 2.64\times10^{-4}$; $(^{40}Ar/^{39}Ar)_{Ca} = 6.87\times10^{-4}$ (Hu Shiling *et al.*, 1985). A half life of 35.1 days was adopted for correcting the radioactive decay of ^{37}Ar.

Laser-mass spectrometers microarea $^{40}Ar/^{39}Ar$ age dating

This method was only used to date the A635 basalt (Hu Shiling *et al.*, 1995).

The polished section with $6\times6\times2$ mm in dimensions of the sample was irradiated in the E-5 channel of reactor for 50 hours with 1.8×10^{18}n/cm^2 of fast neutron flux totally. The K-Ar standard biotite sample with age of 132 Ma from Zhoukoudian, Beijing was used as monitor of neutron flux. Then, the sample was undergone continuous laser melting by a device of laser-mass spectrometer built by The Isotopic Laboratory of Guangzhou Geochemistry Institute, CAS. Heating source is a Nd: YAG solid laser which outputs interference laser beam of near-infrared radiation with 1064 nm wavelength and with the facula about 250 μm in diameter. When the current in the krypton lamp of krypton pump had being continuously regulated up to 14A, it would be produced a laser beam with enough energy to melt the sample instantaneously. A He-Ne collimated laser which is a low energy (1mv) visible light with 632 nm wavelength was used to guide the invisible Nd:YAG laser beam through the glass window over the sample stage of microscope to focus the surface of sample on the stage. After radioactive cooling, the sample was put in a pan on the object stage of microscope which is adjustable in X-Y-Z directions. A corrugated pipe connected the sample pan at its margin to a ultravacuum system (10^{-9} torr), a Zr-Al getter purified system. Four microareas of the sample were chosen for melting separately and the released and purified gas was put into MM-1200 mass spectrometer. The peak values of argon isotopes were measured with a 17 cascade Cu-Be high gain electronic multiplier. For age calculation the constant $\lambda^{40}K=5.543\times10^{-10}$/a (Steiger and Jäer, 1977) is used.

K-Ar age dating

Only two ages were obtained by K-Ar dilute method. Extraction of argon is carried out in ultra-high vacuum system which has a static vacuum of 10^{-8} torr. Sample would melt at 1450°C to 1500°C and in 30 minutes. CuO and sponge titanium are used as purifier and ^{38}Ar spike is added during purification process. The purified argon is directly introduced into RAG-10 mass spectrometers for isotopic analyses. K content is measured by a flame photometer.

For age calculation of all above three methods, constants $\lambda^{40}K=5.543\times10^{-10}$/a and $^{40}K/K=1.167\times10^{-4}$ (Steiger and Jäer, 1977) are adopted and the error of age is 1σ.

AGE DATING RESULTS

Four samples measured by $^{40}Ar/^{39}Ar$ method are belong to FPG (A597, A624, A674, A662) and two samples (A642 and A635) by K-Ar age dating belong to ABG.

$^{40}Ar/^{39}Ar$ age spectrum of A597 andesite

The sample, location number 249, was collected from a lava bed located in western margin of Joannes Poulus II coast, west part of northern coast. The rock is dark-gray in color, dense and fine-crystalline, with sparse porphyritic texture. Only several small, euhedral plagioclase phenocrysts and seldom little, anhadral clinopyroxene phenocrysts are found in thin section. The matrix is with hyalop-

Table 1. Argon isotopic data of A597 andesite

J = 0.02076, W = 0.30g

Step	Tem. °C	$(^{40}Ar/^{39}Ar)_m$	$(^{36}Ar/^{39}Ar)_m$	$(^{37}Ar/^{39}Ar)_m$	$(^{38}Ar/^{39}Ar)_m$	$^{39}Ar_K$ 10^{-12} mol	$(^{40}Ar^*/^{39}Ar_K)$ $\pm 1\sigma$	$^{39}Ar_K$ %	Apparent age t±1σ(Ma)
1	450	165.938	0.5	8.956	0.406	0.45	19.70±0.88	0.12	618.5±22.3
2	650	9.753	0.0265	0.531	0.0228	22.71	1.98±0.10	6.16	72.7±3.7
3	800	2.523	0.00341	0.923	0.0225	123.4	1.59±0.03	33.48	58.4±1.1
4	950	6.988	0.0188	1.225	0.0153	119.2	1.54±0.071	32.34	56.8±2.6
5	1050	18.770	0.0605	0.742	0.0233	43.32	1.02±0.23	11.75	37.9±8.3
6	1200	3.213	0.00601	0.947	0.0135	46.69	1.51±0.032	12.67	55.8±1.3
7	1300	5.904	0.0160	4.743	0.0195	7.91	1.58±0.06	2.15	58.2±2.2
8	1450	15.0	0.0402	3.294	0.0259	4.88	3.43±0.16	1.33	123.5±5.7

Ar*: radiogenic Ar.

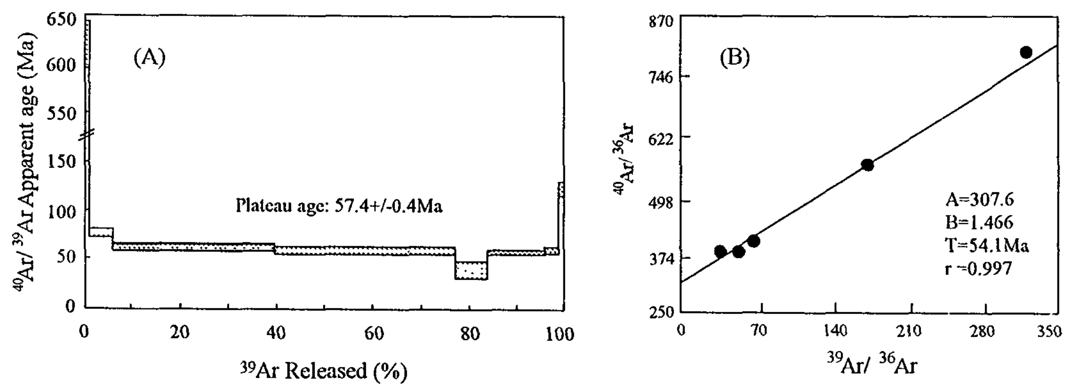

Fig. 2. $^{40}Ar/^{39}Ar$ age spectrum (A) and $^{40}Ar/^{36}Ar$-$^{39}Ar/^{36}Ar$ isochron (B) of A597 Andesite

ilitic texture composed of fine lath-shaped feldspar, anhedral pyroxene, ferruginous grain, little volcanic glass and interstitial quartz. The rock contains 60% of SiO_2 content (andesite).

Eight temperature points of $^{40}Ar/^{39}Ar$ step heating were measured on A597 andesite sample and the Ar isotopic data and age spectrum yielded are shown in Table 1 and Figure 2A.

As a rule, the apparent age of the lowest temperature is commonly meaningless geologically because it was effected by nuclear recoil in irradiation, so does the apparent age of the high temperature due to the high background contribution of apparatus. On Figure 2A, all apparent ages construct an even line of age spectrum from 800°C to 1300°C, except step 5. A $^{40}Ar/^{39}Ar$ plateau age of 57.4±0.4 Ma was obtained by calculating the apparent ages of step 3, 4, 6 and 7 of the plateau and released 39Ar is 80.6% of total Ar released. Furthermore, $^{40}Ar/^{36}Ar$-$^{39}Ar/^{36}Ar$ isochron calculation was made by using the Ar isotopic ratios of above mentioned 4 steps of the plateau age. The good fit isochron line is with $^{40}Ar/^{36}Ar$ initial ratio of 307.6, which is slightly higher than the ratio of atmospheric argon (Neir value = 295.5), and $^{40}Ar/^{39}Ar$ isochron age of 54.1 Ma, slightly lower than the plateau age of the sample (Fig. 2B). So, it is even more applicable to take the isochron age yielded from the initial ratio value of $(^{40}Ar/^{39}Ar)_i$ = 307.6 as the forming age of the sample. We consider the forming age of A597 andesite should be 54.1 Ma., the early Eocene.

$^{40}Ar/^{39}Ar$ age spectrum of A624 basaltic-andesite

The lava sample was collected from an outcrop in Pottinger Cape, middle part of the northern coast

Table 2. Argon isotopic data of A624 basaltic andesite

J = 0.02076, W = 0.30g

Step	Tem. °C	$(^{40}Ar/^{39}Ar)_m$	$(^{36}Ar/^{39}Ar)_m$	$(^{37}Ar/^{39}Ar)_m$	$(^{38}Ar/^{39}Ar)_m$	$^{39}Ar_K$ 10^{-12} mol	$(^{40}Ar^*/^{39}Ar_K)$ $\pm 1\sigma$	$^{39}Ar_K$ %	Apparent age t±1σ(Ma)
1	450	82.256	0.226	2.257	0.333	0.04	16.04±1.94	0.37	518.6±54.8
2	650	14.370	0.0420	2.764	0.0395	0.568	2.24±0.16	5.32	81.9±5.6
3	900	4.867	0.015	20.991	0.58	0.421	2.11±0.049	3.94	77.4±1.9
4	1090	4.098	0.00976	5.120	0.134	0.575	1.63±0.041	5.39	59.9±1.6
5	1130	2.194	0.00347	1.263	0.0241	3.028	1.27±0.022	28.36	46.8±0.92
6	1180	2.341	0.00372	0.737	0.0149	2.264	1.30±0.023	21.2	48.0±1.0
7	1260	2.246	0.00204	1.272	0.0187	2.622	1.55±0.02	24.55	57.2±1.0
8	1350	5.079	0.0113	1.745	0.0181	0.618	1.88±0.051	5.79	68.9±2.0
9	1450	4.729	0.00473	1.989	0.0207	0.543	2.60±0.047	5.08	94.8±1.9

Ar*: radiogenic Ar.

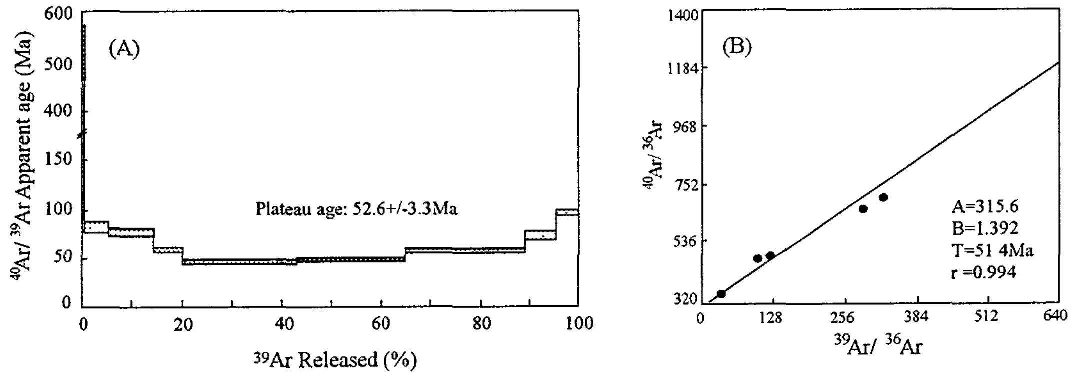

Fig. 3. $^{40}Ar/^{39}Ar$ age spectrum (A) and $^{40}Ar/^{36}Ar$-$^{39}Ar/^{36}Ar$ isochron (B) of A624 basaltic andesite

of King George Island (location number 258, Fig. 1). The rock is dark-gray, massive and with phaneritic and porphyritic texture, The phenocrysts include mainly euhedral-subhedral, lath-shaped plagioclase and anhedral clinopyroxene, and the matrix with intergranular texture is composed of lath-shaped feldspar, anhedral pyroxene and ferruginous grain. The sample had experienced very weak alteration, that is, a few pyroxene in matrix are partly replaced by chlorite. The rock is basaltic-andesitic in composition with 53.8% of SiO_2.

Nine points of $^{40}Ar/^{39}Ar$ step heating were measured on A624 basaltic-andesite and the Ar isotopic data and age spectrum are shown in Table 2 and Fig 3A. Similarly, the apparent age 518.6 Ma of the first step is meaningless geologically, because it should be effected by nuclear recoil. A saddle-like age spectrum is constituted by 8 apparent ages of the 2-9 steps, with the lowest apparent age of 46.8±0.9 Ma and the highest one of 94.8±1.9 Ma. If we choose the step 4 to 8 as an age plateau, a plateau age of 52.6±3.3 Ma will be yielded, with released ^{39}Ar up to 85.3% of total. $^{40}Ar/^{36}Ar$-$^{39}Ar/^{36}Ar$ isochron was calculated by the isotopic ratios of above 5 steps (Fig. 3B), from which an isochron age of 51.4 Ma was yielded. This isochron age is almost identical with the plateau age indicating the forming age of A624 basaltic andesite must be 51.4 Ma, namely, the early Eocene. The $^{40}Ar/^{36}Ar$ initial ratio from the isochron diagram is slightly higher than Nier value implying that there was no excess argon in step 4-8 of the saddle-like age spectrum, while the rather high apparent ages of steps 2, 3 and 9 may be resulted from excess

Table 3. Argon isotopic data of A674 andesite

J = 0.02076, W = 0.25g

Step	Tem. °C	$(^{40}Ar/^{39}Ar)_m$	$(^{36}Ar/^{39}Ar)_m$	$(^{37}Ar/^{39}Ar)_m$	$(^{38}Ar/^{39}Ar)_m$	$^{39}Ar_K$ 10^{-12} mol	$(^{40}Ar^*/^{39}Ar_K)$ $\pm 1\sigma$	$^{39}Ar_K$ %	Apparent age t$\pm 1\sigma$(Ma)
1	450	300	1	13.991	0.286	0.01	7.05±0.35	0.02	246.4±11.3
2	600	16.151	0.0464	0.841	0.0292	0.816	2.57±0.18	2.09	93.7±6.4
3	800	2.603	0.00452	0.443	0.0115	10.23	1.30±0.026	26.22	48.1±1.1
4	950	2.637	0.00577	1.195	0.0129	12.75	1.03±0.026	32.68	38.1±1.0
5	1050	2.589	0.00536	0.583	0.0125	2.355	1.05±0.026	6.04	39.0±1.0
6	1200	2.830	0.0060	1.245	0.0134	5.846	1.06±0.028	14.98	42.8±1.1
7	1350	2.737	0.00632	3.574	0.0140	3.996	1.15±0.027	10.24	42.7±1.1
8	1450	5.488	0.0135	5.330	0.0149	3.014	1.94±0.055	7.73	71.1±2.1

Ar*: radiogenic Ar.

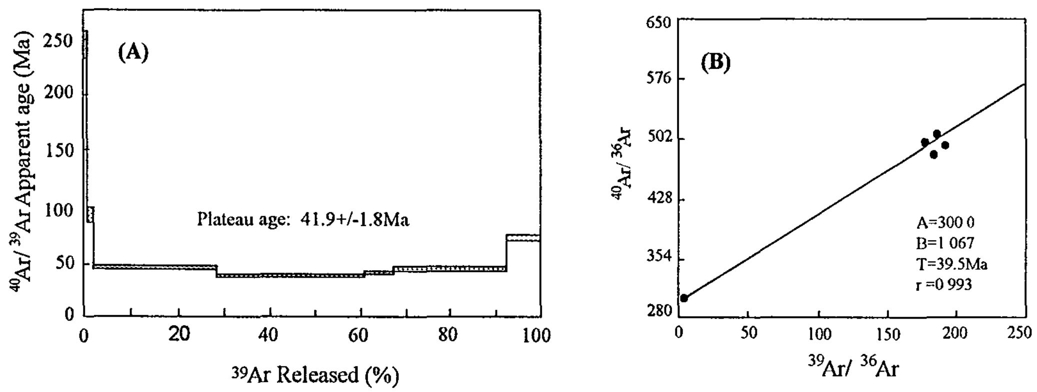

Fig. 4. $^{40}Ar/^{39}Ar$ age spectrum (A) and $^{40}Ar/^{36}Ar$-$^{39}Ar/^{36}Ar$ isochron (B) of A674 andesite

argon. However, the excess argon contained in the sample would be very limited because the apparent ages of both sides of the saddle-like age spectrum were only about 35-42 Ma higher than the isochron age.

$^{40}Ar/^{39}Ar$ age Spectrum of A 674 andesite

A 674 andesite sample was collected from a lava crop located between Venrs Bay and North Cap of the northern coast (Fig.1, location 280). The massive rock is characterized by dark-gray color and porphyritic. There are many (>30% of whole rock) phenocrysts of euhedral-subhedral lath-shaped plagioclase and minor subhedral-anhedral clinopyroxene found under microscope observation. The pyroxene crystals usually cumulate together forming glomerocryst. Few hornblende porphyroclasts are observed. Matrix is of hyalopilitic texture and minor small lath-shaped feldspar crystals scattered in brownish glass groundmass. Rock is fresh and contains 56.84% of SiO_2 (andesite).

Eight points of $^{40}Ar/^{39}Ar$ step heating were measured on A674 andesite, Ar isotopic data and age spectrum are shown in Table 3 and Fig. 4A.

For the same reason, the high apparent ages of the first and last steps are rejected. The apparent ages yielded from 3-7 steps of the age spectrum are close each other constructing an even age plateau. The plateau age constituted by above 5 steps is 41.9±1.8 Ma with 90.2% released 39Ar. $^{40}Ar/^{36}Ar$-$^{39}Ar/^{36}Ar$ isochron calculation was made with the isotopic ratios of the middle 5 steps of age spectrum and a good fit isochron line was obtained (Fig. 4B) with 39.5 Ma isochron age and $^{40}Ar/^{36}Ar$ initial ratio of 300. The plateau age is almost consistent with the isochron age within error bar, hence, it

Table 4. Argon isotopic data of A662 basalt

J = 0.02076, W = 0.25g

Step	Tem. °C	$(^{40}Ar/^{39}Ar)_m$	$(^{36}Ar/^{39}Ar)_m$	$(^{37}Ar/^{39}Ar)_m$	$(^{38}Ar/^{39}Ar)_m$	$^{39}Ar_K$ 10^{-12} mol	$(^{40}Ar^*/^{39}Ar_K)$ $\pm 1\sigma$	$^{39}Ar_K$ %	Apparent age $t\pm 1\sigma$ (Ma)
1	460	94.211	0.263	6.651	0.211	0.027	17.41±2.57	0.34	556.5±70.9
2	650	23.12	0.0611	11.576	0.0534	0.184	6.11±0.27	2.32	215.5±9.0
3	800	10.459	0.0220	6.493	0.248	1.528	4.50±0.11	19.26	161.2±3.9
4	950	11.271	0.0339	6.533	0.0636	1.654	1.81±0.12	20.84	66.6±4.4
5	1150	2.35	0.0045	3.096	0.0145	2.804	1.26±0.024	35.34	46.7±0.97
6	1200	8.371	0.0210	11.007	0.0210	0.869	3.08±0.085	10.95	111.7±3.2
7	1300	15.925	0.0482	34.024	0.0256	0.547	4.34±0.18	6.89	155.5±6.3
8	1450	46.414	0.131	21.595	0.0380	0.322	9.76±0.75	4.05	332.9±23.6

Ar*: radiogenic Ar.

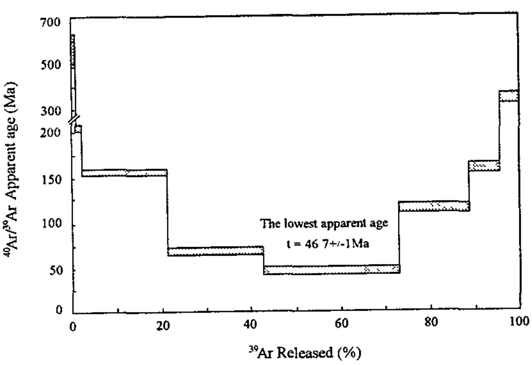

Fig. 5. $^{40}Ar/^{39}Ar$ age spectrum of A 662 basalt

may be considered that the plateau age of 41.9±1.8 Ma is the forming age of the andesite, that is, the later Eocene.

$^{40}Ar/^{39}Ar$ age spectrum of A 662 basalt

This sample was collected from a basaltic lava layer at False Round Cape of Corsair Bay, which has location number of 276 (Fig. 1). The rock is block-dense massive and with porphyritic texture. The phenocrysts in rock include large euhedral plagioclase and euhedral-subhedral clinopyroxene. The latter always forms glomerocryst. Matrix texture is intergranular and composed of coarser mineral grains of short-prismatic to lath-shaped feldspar, anhedral pyroxene and minor ferruginous grains. The rock had experienced slight alteration and contains 52.71% of SiO_2.

Eight points of $^{40}Ar/^{39}Ar$ step heating were measured on A662 basalt, the Ar isotopic data and age spectrum are shown in Table 4 and Figure 5.

This basalt yields a typical saddle-shape age spectrum with the lowest apparent age of 46.7±1.0 Ma and the highest apparent age of 556.5±70.9 Ma. It is impossible to get an isochron age, because the isotopic ratios of different heating steps are scattered on the isochron diagram. Dalrymple and Lanphere (1976) had obtained a typical saddle age spectrum in their study on the known excess argon-fearing mineral and on $^{40}Ar/^{39}Ar$ age dating. They reported that "Saddle-shape age spectra appear to be diagnostic of excess ^{40}Ar in igneous rocks and minerals, however the minima in such spectra approach the crystallization ages, and in some samples may even reach the correct age." So we consider that the apparent age of 46.7±1.0 Ma, the lowest apparent age on of the saddle-shape age spectrum of A662 basalt would be the forming age of A662 basalt.

K-Ar age of A642 andesite

This sample was collected from Atherton Isle, west of the northern coast of King George Island (Fig. 1, site 267). The rock, from a subvolcanic neck, is black, dense massive and porphyritic with some phenocrysts of euhedral-subhedral lath-shaped plagioclase and anhedral clinopyroxene. Matrix is characterized by pilotaxitic texture and mainly composed of euhedral lath-shaped feldspar and minor pyroxene grain. The rock contains 57.2% of SiO_2.

Dating result lists in Table 5. The K-Ar age of

Table 5. K-Ar age dating result

S.Num.	Rock	Weight(g) (g)	K(%) (%)	^{40}Ar ($\times 10^{-8}$ mol/g)	$^{40}Ar^*$ (%)	$^{40}Ar/^{40}K$ (Ma)$\pm 1\sigma$	Apparent age
A635	Basalt	0.3352	0.69	0.0205	59.2	0.00994	163.5±4.9
A642	Andesite	0.3643	0.99	0.0161	68.0	0.00545	91.5±2.3

Ar*: radiogenic Ar.

the measured sample is 91.5±2.3 Ma, higher than all plateau ages and isochron ages of above described four samples, obtained by $^{40}Ar/^{39}Ar$ age dating technique. This K-Ar age is reasonable, because the K content of A642 andesite is about 1% close to that of common andesite, and the $^{40}Ar^*$ (radiogenic Ar) content of the sample is as high as 68%.

K-Ar age of A635 basalt

The sample was collected from David Cape of Joannes Paullus Coast and the number of sampling site is 263 (Fig. 1). The rock is black, dense massive, and porphyritic. Phenocrysts in rocks are euhedral-subhedral lath-shaped plagioclase and subhedral-anhedral clinopyroxene which sometime builds up glomerocryst. Matrix is with intergranular texture and composed of small lath-shaped feldspar, minor pyroxene and ferruginous grains. Devitrification partly occurred in dark brown volcanic glass matrix. Rock contains 53.84% of SiO_2.

The K-Ar apparent age of 163.5±4.9 Ma (Table 5) for A635 basalt is obviously higher than $^{40}Ar/^{39}Ar$ plateau age and K-Ar ages of other volcanic rocks from the same region. This leads us to consider A635 basalt being a excess argon-bearing sample. For solving the problem properly, the sample has been redetermined by laser microarea $^{40}Ar/^{39}Ar$ isochron age dating.

Laser microarea $^{40}Ar/^{39}Ar$ isochron age dating

The result of laser microarea $^{40}Ar/^{39}Ar$ isochron age dating for A635 sample is listed in Table 6.

It can be seen from Table 6 that full fusion $^{40}Ar/^{39}Ar$ apparent age by laser-mass spectrometer of 4 points (1-4) of A635 basalt vary from 155.8 Ma to 445.3 Ma. An isochron line with rather high goodness of fit, slope B = 0.962, was obtained by plotting the 4 isotope ratios of $^{40}Ar/^{36}Ar$-$^{39}Ar/^{36}Ar$ of the 4 points (Fig. 6) and an isochron age of 52.4

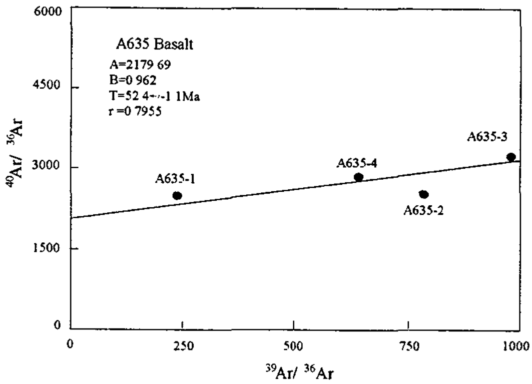

Fig. 6. $^{40}Ar/^{36}Ar$-$^{39}Ar/^{36}Ar$ isochron of A635 basalt

±1.1 Ma was resulted. This value is far lower than above 4 apparent ages, while the initial ratio of $^{40}Ar/^{36}Ar$ is much higher than Nier Value. The result strongly supports that the A635 basalt does contain excess argon and it causes each of 4 apparent ages much higher. The isochron line was resulted by using $^{40}Ar/^{36}Ar$ initial ratio, which was acquired during basalt forming, to deduct nonradioactive Ar component. Therefore, the isochron age should represent the real forming time of the basalt (Hu Shiling *et al.*, 1995).

DISCUSSION

All of the measured ages of the volcanic rocks from northern coast of King George Island are summarized in Table 7.

It can be found that the 4 volcanic rocks of FPG vary in age value from 54.1 Ma to 39.5 Ma and the laser microarea $^{40}Ar/^{39}Ar$ isochron age of A635 basalt of ABG is 52.4 Ma. This indicates that the volcanic activity in the region mainly occurred in Eocene. Furthermore, the distribution of the age values and the sample locations (Fig.1) represents a successive decrease of ages from the west to east

Table 6. ^{40}Ar-^{39}Ar isochron data for A635 basalt

S. Num.	Tem. (°C)	^{39}Ar (%)	^{40}Ar (%)	$^{40}Ar^*$ (%)	$^{40}Ar/^{36}Ar$ (Ma)±1σ	$^{39}Ar/^{36}Ar$	Apparent age
A635(1)	1500	100	100	87.9	2452.44	235.967	445.3±0.4
A635(2)	1500	100	100	88.4	2591.73	781.59	155.8±0.1
A635(3)	1500	100	100	90.8	3308.35	979.66	162.8±0.2
A635(4)	1500	100	100	89.6	2878.42	640.33	210.4±0.5

Ar*: radiogenic Ar.

Table 7. Age dating result of the volcanic rocks from Northern Coast of King George Island

S.Num	Site	Rock	$^{40}Ar/^{39}Ar$ P. age (Ma)	$^{40}Ar/^{39}Ar$ I. age (Ma)	K-Ar A. age (Ma)	$^{40}Ar/^{39}Ar$ L. age (Ma)
A642	267	Andesite			91.5±2.3	
A597	249	Andesite	57.4±0.4	54.1		
A624	258	B. Andesite	52.6±3.3	51.4		
A635	263	Basalt			163.5±4.9	52.4±1.1
A662	276	Basalt	46.7±1.0			
A674	280	Andesite	41.9±1.8	39.5		
A663	277	Granodiorite			39.4±1.2	
A664	277	Granodiorite			35.8±1.1	

The ages of A663 and A664 are from Birkenmajer et al. 1986, others were dated in Institute of Geology, CAS. P.age = Plateau age, I. age = Isochron age, A. age = Apparent age, L. age = Laser microarea 40Ar/39Ar Isochron age.

along the northern coast of King George Island: that is, volcanic activity migrated gradually eastwards (Table 7, Fig. 1). Regionally, the formation of South Shetland magmatic arc is closely related to the continuous subduction of proto-pacific oceanic crust beneath the Antarctic continental margin and the volcanic activity there began in Late Jurassic and lasted till the end of Tertiary. So, the volcanic rocks from Late Jurassic to Tertiary are gradually younging from southwest to northeast in South Shetland Islands. (Pankhurst and Smellie, 1983; Smellie *et al.*, 1984). The age of volcanic rock on Byers Peninsula in the west end of Livingston Island, for instance, is 132±5 Ma (Pankhurst *et al.*, 1979) and, to eastern of the island, it is about 70 Ma (Pankhurst *et al.*, 1979; Smellie *et al.*, 1984). The volcanic rocks in Fildes Peninsula of southwest King George Island mainly formed in Paleocene to Eocene (Grikurov *et al.*, 1970; Valencio *et al.*, 1979; Watts, 1982; Smellie *et al.*, 1984; Birkenmajer, 1989; Zhu Ming *et al.*, 1991). All of the volcanic rocks discussed here distribute geographically in the east to northeast of Fildes Peninsula. So their age values of Eocene are consistent with the previous studies. These results show the migration and evolution of South Shetland magmatic arc in time and space clearly.

A642 andesite, also belonging to ABG, has an apparent age of 91.5Ma which is of Late Cretaceous and older than others in above table. According to experiment, the age value is convincible because of no excess argon in the sample. Considering the regional migration of volcanic activities, the occurrence of such a large age value is reasonable too.

Both A663 and A664 granodiorites are intrusive rock of WPG collected from Ridley Island of the east terminal of northern coast (Fig.1, site 277). The apparent ages of them are 39.4±1.2 Ma and 35.8±1.1 Ma, respectively (Birkenmajer *et al.*, 1986), belonging to later Eocene. Both age values slightly lower than plateau age of A674 andesite and the lowest apparent age of A662 basalt occurred in the adjacent area. This result can be explained, combining with the age variation of volcanic rocks, as that intrusive activity in the area is also consistent with the regional development of volcanism. The intrusive rock formed later and more acidic than the volcanic rocks indicating that they would be the comagmatic differentiated products.

It was discovered that some much high age values measured by K-Ar method might be due to the excess argon in some rocks, resulting in different ages of the rocks collected from the same outcrop or layer. For this reason, $^{40}Ar/^{39}Ar$ age dating was adopted in the present study. The results from systematical age dating show that $^{40}Ar/^{39}Ar$ plateau age and isochron age in andesite are basically identical, indicating that almost no excess argon has involved. But the basalt with saddle age spectrum does contain excess argon which is due to the lower contents of Si and K. Advanced laser-mass spectrometer microarea $^{40}Ar/^{39}Ar$ isochron age dating technique was chosen for A635 basalt which shows much higher K-Ar apparent age. Since the technique possibly eliminated the influence of excess argon, the isochron age provides a real forming age. In short, in chronology research on young volcanic rocks both conventional $^{40}Ar/^{39}Ar$ and laser-mass spectrometer $^{40}Ar/^{39}Ar$ isochron age dating techniques are more efficient in overcoming the influence of excess argon contained in rock than K-Ar technique.

CONCLUSION

1. Systematic chronological study proves that the volcanic activities in northern coast of King George Island began in Late Cretaceous and continued till the end of Eocene, while the major eruptive epoch was Eocene. The formation of the volcanic rocks became successively younger from southwest to northeast, showing the continuous migration of volcanic centers. This is consistent with the temporal and spatial evolution of South Shetland magmatic arc.

2. Similarly, intrusive activity is also consistent with volcanic activity. However, comparing to volcanic rock, the intrusive rocks usually formed later and is much acidic in composition, implying that they would be the comagmatic differentiated products.

3. Systematic age dating shows that there is basically no excess argon in andesite, but the effect of excess argon was appeared in basalt.

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