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ISOTOPIC AGE AND STRATIGRAPHYCAL CORRELATION OF VOLCANIC ROCKS IN FINDES PENINSULA, KING GEORGE ISLAND

Zhu Ming, E Molan, Liu Xiaohan, Zheng Xiangshen

Institute of Geology, Academia Sinica, Beijing 100029, China

Abstract The ages of volcanic rocks from the Fildes Peninsula of King George Island, West Antarctica, have been determined with K－Ar, ^{39}Ar－^{40}Ar, Rb－Sr methods by the authors. The results show that:a. The volcanism on the Fildes Peninsula has been from later Paleocene to early Middle Miocene; b. The formation time of the volcanic rocks of Jasper Hill Member belongs to later Paleocene becarse of the isotope age being 54Ma and 55Ma determined with Rb－Sr and ^{39}Ar－^{40}Ar methods, respectively. c. The volcanic rocks of Agate Beach Member are the products of the volcanic activities during Early Eocene according to K－Ar isochron(45－50Ma); d. The geological age of fossil Hill member is about Middle Eocene to Early Oligocene; e. the formation time of Block Hill member is probably early Middle Miocene.

These data combining with the geological adn palaeontological evidenees strongly support to best understand the stratigraphical correlation adn reveal the volcanism in studied area.

Key words Fildes Peninsula, isotopic age, stratigraphical correlatiopn.

Introduction

King George Island is the largest one in the South Shetland Island. During 1984－1987, Antarctic Research Expidition has carried out geological investigations four times in Fildes and hence established a stratigraphical sequence of volcanic rocks, made a great amount of petrological and geochemical studies and revealed the geological history of the study area in detail(Liu and Zheng 1988; Zheng and Liu, 1989; Zheng and Liu, 1989).

The stratigraphical division, correlation, and timing of the volcanic rocks have been long conducted. Hawkes(1961) concluded that the volcanic rocks on the peninsula is early Miocene. Baton (1965) proposed that the volcanic rocks on Fildes Peninsula stratigraphically is composed of two suites of volcanic groups. One of them belongs to th upper Jurrassic distributed in the southern part of Fildes Peninsula and Ardley Island. The other is considered to be late Cretaceous to Miocene, distributed in the north－western and

central parts of the peninsula, and is called "Fildes Peninsnla Group". But the recent results of isotopic dating raise a question, exists the Jurrassic system? Birkenmajer *et al.* (1982) proposed that the so—called "upper Jurrassic" volcanic rocks distributed in the southern and other areas should belong to Cretaceus to Pliocence, which were named "Fildes Group", Smellie et al. (1985) published a set of isotopic age data of volcanic rocks on the whole Shetland Archiplago, discussed their ages, magration and evolution, and suggested that all of the volcanic rocks on Fildes Island belong to the Oligence.

Analytical Techniques

In this paper the isotopic dating of the volcanic rocks was proformed by K—Ar, ^{39}Ar—^{40}Ar, and Rb—Sr methods.

K—Ar method: Argon is extracted in the ultra—high vaccum system with static vaccum of 10^{-8} Torrs before melt of samples. Melting sample is taken 40 min. at temperature of 1400—1500℃, during which ^{38}Ar diluent is added and mixed with gas to be extracted, then the mixed gases is purified with sponge titanium. The isotopic mass is determined on a mass spectrometer ZhH—1301 at static operation. ^{38}Ar dilunt is shared by to branch pipe system in our lab. and content of K is determined on flame photometer.

^{39}Ar—^{40}Ar method: The samples are put on aluminium foil. The Cadmadium foil is used for screening the thermal neutron. The samples are radiated in the centre of channel H_4 of the 49—2 reactor in the Institute of Atomic Energy, Acdemia Sinica for 85 hours and 53 min. The flux of fast neutron reaches $5.8 \cdot 10^{12}/(cm^2s)$ and the amount of accumulated fast neutrons is about $3 \cdot 10^{18}/cm^2$. The correlation factor $(^{40}Ar/^{39}Ar)_K = 0.715 \cdot 10^{-2}$; $(^{36}Ar/^{37}Ar)_{Ca} = 2.644 \cdot 10^{-4}$, $(^{39}Ar/^{37}Ar)_{Ca} = 6.868 \cdot 10^{-4}$. The monitoring standard is a Franceh standard sample B600 biotite, $t = 322.0 \pm 4.3$Ma; and a Chinese standard sample ZBH—25, $t = 132.7 \pm 1.9$Ma; a ZBT hornblende, $t = 132.8 \pm 3.4$ Ma. Cooling the radiated samples, then sample they are heated and purified and determined on mass spectremeter MS—10.

The Constants: $\lambda_e = 0.581 \times 10^{-10}/a$; $\lambda = 4.96 \times 10^{-10}/a$; $^{40}K/K = 1.167 \times 10^{-4}$mole/mole.

Geological Outline and Sampling Sites

The volcanic strata on Fildes Peninsula can be divided into two suites from bottom to top. The lower suit is the Great Wall Formation and the upper Fossil Hill Formation (Lu and Zheng, 1988; Zheng and liu, 1988; Zheng and Liu, 1989). Every suit of the volcanic rocks is composed of two members. For example, the lower part of the Great Wall Formation is called Jasper Hill member and the upper part is called Agate Beach member,

whereas the Fossil Hill Formation is composed of Fossil Hill member in its lower part and Block Hill member in its upper part. The Great Wall Formation is covered unconformally with the Fossil Hill Formatiom, showing a sedimentary hiatus with the Fossil Hill Formation, a larger depositional break between the Great Wall Formation and the Fossil Hill Formation. All the volcanic strata could correlated in the whole study area including not only that in the southern and central parts of Fildes Peninsula, but also that on the Northern Terres and Northwestern Platform.

The samples for Rb—Sr and $^{40}Ar-^{39}Ar$ dating were collected from Jasper Hill member. Among them samples XN—13 and XN—17 for $^{40}Ar-^{39}Ar$ datings were taken from south of 117 highland of Jasper Hill and samples for K—Ar dating were from Agate Beach member and Block Hill member. Among them samples 2602, 2603, 2604, 2605 and C—2—1 were collected around Lava Hill. Samples C—1—21 and C—1—13 from the North Horatio; samples HS—4 and C—1—2 from Horatio; sample FTPP from Plat Top Peninsula; D130 and D131 from Northwest Platform; D142 from North Terras; D122 from the southern end of Fildes; D165 from the northwest Uruguay Station; EF—78, EF—78—1 and ZF—84 from Suffield point.

In addition, the samples 2504 and 2601 are subvolcanic rock.

Result and Discussion

The age of Jasper Hill member is 54Ma obtained by Rb—Sr method (Zheng *et al.*, 1991). $^{40}Ar-^{39}Ar$ dating of sample XN—13 from Jasper Hill member shows that the plateau age well reflects the mid—high temperature, which offers a value of 44.9±0.5Ma (Table 1, Fig. 1), except the age value below 600℃ being rather youth. But at above 1450℃, the 5% of ^{40}Ar content still gives its age of 55.4±5.9 Ma, showing still a record of crystallization time of volcanic rock having undergone geological heat event. Although the plateau age of 44.9±0.6 Ma has obtained, a comparison with the result of Rb—Sr dating shows that it seems to be a result of heat event in geological history about 44.9Ma ago.

Table 1. Analytical data of $^{40}Ar/^{39}Ar$ in basalt No. XN—13. at step—heating

Step heating	t (℃)	$(\frac{^{40}Ar}{^{39}Ar})_m$	$(\frac{^{36}Ar}{^{39}Ar})_m$	$(\frac{^{37}Ar}{^{39}Ar})_m$	^{39}Ar (10^{-12}mol)	^{39}Ar (%)	$\frac{^{40}Ar}{^{39}Ar}$	t(Ma)
1	600	40.4	0.137	9.134	0.32	3.1	1.03±0.4	30.3±4.8
2	720	15.2	0.050	13.86	1.30	12.7	1.65±0.2	48.2±5.9
3	900	3.85	0.012	14.41	3.90	37.9	1.52±0.04	44.5±1.2
4	1050	3.64	0.009	7.434	3.10	30.2	1.56±0.04	45.6±1.2
5	1200	9.69	0.034	21.61	1.10	10.7	1.45±0.09	42.4±2.7
6	1450	17.3	0.058	21.18	5.5	0.56	1.9±0.2	55.4±5.9

$^{40}Ar/^{39}Ar$ Plateau age = 44.9±0.6Ma

Sample weight 0.4g; Radiated Parameter 0.01642

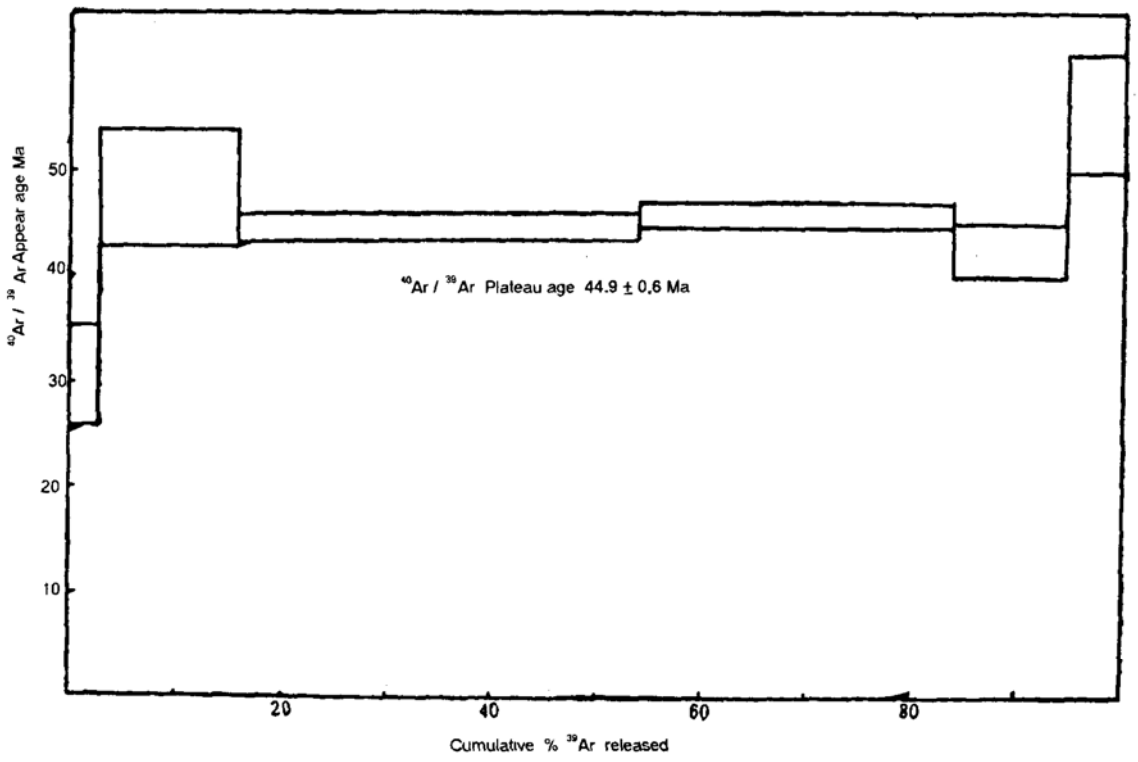


Fig. 1. $^{40}Ar/^{39}Ar$ age spectrum of basalt XN—13.

The result (Table 2, Fig. 2) of $^{40}Ar-^{39}Ar$ dating of plagioclase sample XN — 17 suggests that the spectrum is characterized by a saddle. The age value of which is 46. 8± 14. 8Ma. It appeared at a middle—temperature of 900℃. But 49% of argon is released at high tempreature above 1050℃ and gives a higher appearant age of 326. 9 — 432. 5Ma, which is a good evidence of excess argon. The result would suggest that the plagioclase phenocryst in volcanic rock has trapped rather high excess argon in this area, which is

Table 2. Analytical data of $^{40}Ar/^{39}Ar$ in plagioclase No. XN — 17 by stepheating.

Step heating	t (℃)	$(\frac{^{40}Ar}{^{39}Ar})_m$	$(\frac{^{36}Ar}{^{39}Ar})_m$	$(\frac{^{37}Ar}{^{39}Ar})_m$	^{39}Ar (10_{-12}mol)	^{39}Ar (%)	$\frac{^{40}Ar}{^{39}Ar}$	t(Ma)
1	600	217. 9	0. 585	11. 03	0. 37	5. 3	40. 2±2. 2	1051. 8±64. 0
2	720	364. 6	1. 481	44. 54	0. 76	10. 9	23. 6±3. 8	590. 9±89. 7
3	900	50. 48	0. 171	29. 69	2. 40	34. 3	1. 6±0. 5	46. 8±14. 8
4	1050	191. 40	0. 619	19. 19	1. 086	15. 5	12. 1±1. 9	326. 9±55. 4
5	1200	113. 66	0. 351	12. 687	1. 180	16. 9	12. 5±1. 1	336. 8±32. 3
6	1450	240. 2	0. 768	7. 072	1. 20	17. 2	16. 5±2. 4	432. 5±69. 7

$^{40}Ar/^{39}$ Ar Plateau age = 44. 9±0. 6Ma

Sample weight 0. 4g; Radiated parameter 0. 01642

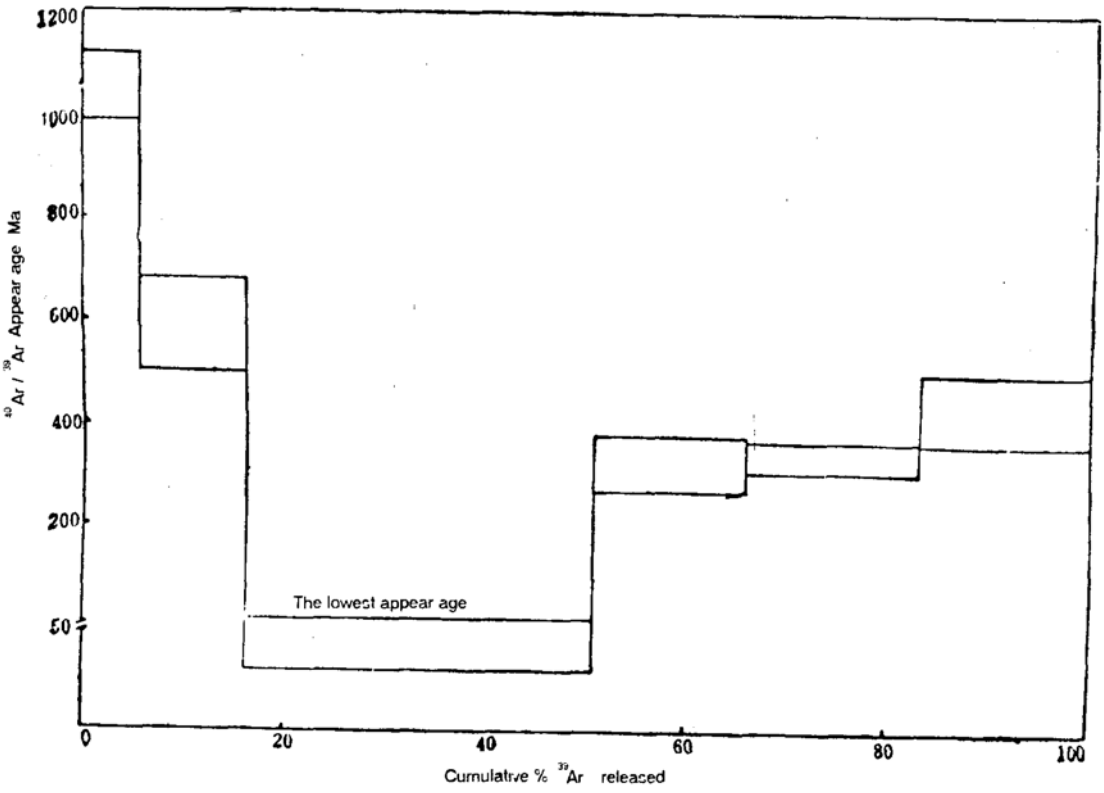


Fig. 2. $^{40}Ar/^{39}Ar$ age spectrum of plagioclase from basalt No. XN－17.

possible to account for higher apparent age detected by K－Ar method. It is worthy to note that the age value of 46. 8Ma of sample XN17 at the saddle is quite coincident with the plateau age of sample XN－13, indicating the end of the heat event.

If we link the age of 54Ma of Jasper Hill member by Rb－Sr method with the age of 55Ma at high temperature by $^{40}Ar-^{39}Ar$, we could determine formation age of the volcanic rock to be about 55Ma ago of Jasper Hill member located in the southern part of Fields Peninsula, and the plateau age of 44. 9±0. 5Ma and the saddle age 46. 8±14. 8 Ma only represent the end of a geological event.

Thirteen samples from Agate Beach member were analysed (Table 3).

In the zone from Plat Top Peninsula, Horatio, Lava Hill to the Great Wall Station, the apparent age values of volcanic rocks, except for individual giving its 33. 7Ma, are mostly in a range from 42Ma to 55Ma. For the Northwest Platform and North Highland the apparent age values are rather higher than in the central part of Fildes Peninsula and are 51－62 Ma. But when we plot the K－Ar isochron of the samples from the same stratum at the adjacent locations, the advantage of $^{40}Ar/^{36}Ar-^{40}K/^{36}Ar$ isochron is obviously revealed. For example, the isochron of samples 2602, 2603, 2604, and C－2－1 is obtained to 49. 65Ma

Table 3. K—Ar ages of volcanic rocks on Fildes Peninsula, King George Island, West Antarctica.

Samples No.	No. in Lab.	stratum	Location	^{40}K, %	$^{40}Ar_r$ 10^{-10}mol/g	$^{40}Ar_a$, %	apparent age, t Ma	$\frac{^{40}Ar}{^{36}Ar}$	$\frac{^{40}K}{^{36}Ar}$	isochron age, t Ma
2602	C85064	Agate Beach member	Lava Hill Zone	0.291	2.532	91.04	44.85±5	324	11017	49.65
2603	C860112			0.548	4.079	65.13	42.3±	153	63470	
2604	C86013			0.515	4.560	53.63	50	550	86076	
CC—2—1	C86014			0.350	2,692	78.43	42.8±2.0	376	31547	
C—1—21	C88012		Plat Top Pen. —Horatio	0.520	4.965	92.22	52.3±6.6	320	8229	50.79
C—1—13	C88021			0.270	2.236	87.79	55.1±4.5	336	12617	
FTPP	C88019			0.660	5.974	82.65	55.5±2.9	357	20427	
2605	C88068			0.432	2.55	84.06	33.7±2.0	351	28348	
D142	B88009		Northwest Platform —North Highland	0.24	2.498	70.34	59.0±2.0	420	35735	45.64
D130	C88017			0.34	4.857	57.46	51.1±1.2	514	72252	
D139	B88008			0.90	9.612	65.44	60.5±1.7	451	43542	
D165	C88017			0.94	10.041	77.27	62.8±2.8	381	23382	
ZF78	C88029	Block Hill member	Suffied cape	0.651	3.816	78.21	33.06±1.5	377	41929	22.06
ZF78—1	C88030			0.651	3.108	72.01	27.29±1.0	410	71855	
ZF81	C88031			0.252	2.190	88.29	49.45±4.7	334	11095	
ZF84	C88032			0.352	3.706	88.29	59.91±0.5	334	13449	
D167	C88015			1.31	5.347	81.59	23.38±1.3	361	48698	
HS—4	C88020	Subvolcanic rock	Horatio Plug	0.55	7.406	80.02	76.02±0.3			
C—1—21	C88013		Horatio Plug	0.22	3.049	88.97	76.29±7.5			
1816	C85070		Fossil Hill	0.341	0.629	89.02	19.03±1.8			
2504	C85071		North—West of G.W.S.C	0.224	2.072	61.00	73.97±1.9			
2601	C88010			0.180	3.32	66.40	103.0			

around Lava Hill (Fig. 3a); For the zone of North Horatio and Plat Top Peninsula the K—Ar isochron of samples is 50.79 Ma (Fig. 3b); and for the Northwest Platform and North Highland the samples give their isochron value of 45.64 Ma and their initial ratio $^{40}Ar/^{36}Ar = 324$. It indicates the excess argon in these samples and hence makes the apparent age for North Peninsula rather higher than that for the southern part.

The above mentioned K—Ar isochron (Table 3, Fig. 3) shows that the Agate Beach member might be formed about 50—45Ma ago. From to the isotopic ages of Jasper Hill member and Agate Beach memeber we can determine the lower limit age of the Great Wall Formation to be no later than 55Ma ago and the upper limit age no earlier than 50—45 Ma ago.

The Fossil Hill member above the Great Wall Formation is abundant in paleoflora and a discordence exists between them, which show that a relative quiscent period in this area.

The Cenozoic Paleoflora on Antarctica have been studied for a long time. For example, the history of study of paleoflora in Seymour Island is as long as a hunderd years (Dusen, 1908), and the fossils on the island always serve as a correlation scale. Dusen (1908) considered the flora on the island to be Oligocene—Miocene, but Granwell (1959) proposed it only to be Tertiary. Gase (1988) detailedly researched the flora at different levels and suggested that there are two units of plant fossil. One of them, the paleoflora in Gross Valley Formation, corresponds with the Dusen's (1908) description to be Paleocence in time, but two paleofloras of La Meseta Formation belong to middle and late Eocene, respectively. All of these studies offer a good basement for research of flora on King George

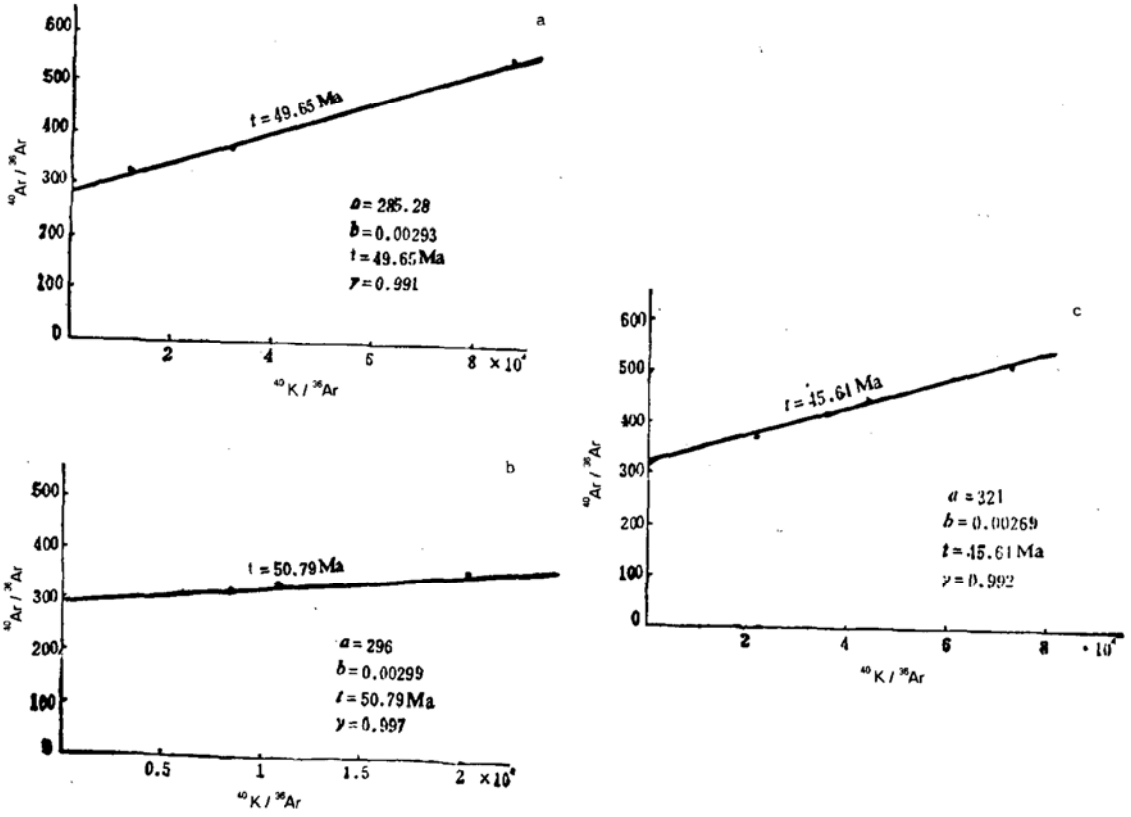


Fig. 3. K—Ar isochron plots of Agate Beach member on Lava Hill(a), on Plat Top Peninsula Horatio(b), and on Northwest Platform(c). a: Agate Beach member in Lava Hill. b: Agate Beach member in plat top pen. Horatia. c: Agate Beach member in Northuest Platform.

Island and Fildes Peninsula.

Studies by many authors studies show that the paleoflora on King George Island is not synchronous. Barton (1964) put all of the flora into Tertiary. Orlando (1964) considered that the flora on Adley near King George Island is the same as on Seymour Island, but its time is identified to be early—middle Miocene. Zestawniak (1981, 1985) researched the flora near admiralty inlet of King George Island and determined the age to be late Oligocene, but the isotopic age of it was determined to be early Eocene or late Paleocene to early Eocene.

The veiw on the time of the flora on Fossil Hill of Fildes Peninsula is getting advanced. For example, Torres (1984) considered it to be Miocene. Later, Czajkowski and Kosler (1986) concluded that it is very similar to that on Seymour Island. Li and Song (1988), Shen (1988) proposed that it could be possible to Eocene. According to Case's research (1988), the size of leaf on Seymour Island during Paleocene to early Eocene are rather

smaller; and is classfied into the small—leaf type, but in the period of middle Eocene the size of leaf is generally larger than in the period of Paleocene to early Eocene, and is classified into the mid—leaf type. So Case (1988) considered that the difference above mentioned may indicate that the favourable climatic condition in the period of middle—Eocene could promote the plant growth. On the basis composition of flora and size of leave, the flora on Fossil Hill is close to that of middle Eocene on Seymour Island.

Comparison of the fossils on Fossil Hill and at admiralty inlet shows that the fossil—bearing layers on King George Island during the Cenozoic are not synchronous. The age of fossil—bearing layer on Dufayel Island of Admiralty inlet belongs to early Eocence, or late Paleocene — early Eocene, with an isotopic age of 51. 9 — 56. 8 Ma (Birkenmajer and Zastawniak, 1986), and the paleoflora on Point Hennequin Island can be identified to be late Oligocene with an isotopic age of 24. 5±0. 5Ma (Zastawniak, 1981, 1985). the later flora is obviously different from that on Fossil Hill (Li, Shen, 1990).

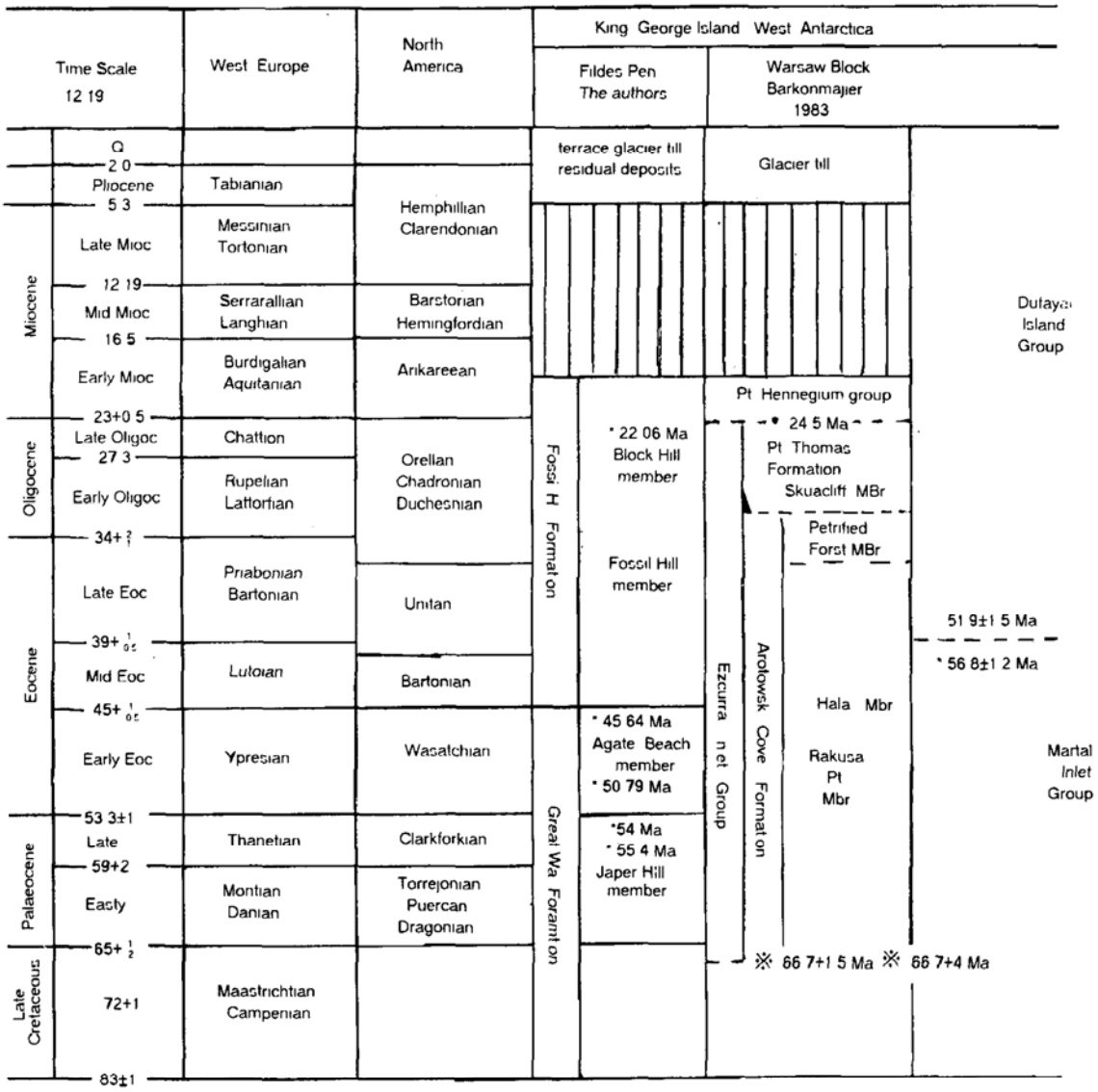
As the isotopic age of volcanic rock of Agate Beach member is 50. 79—45. 66Ma, the age of Fossil Hill member is no older than 45. 66Ma ago, There is enough reason to consider the lower limit of its age of it is no earlier than middle Eocene, since the results of isotopic dating is identical with the result of biostatigraphical.

The upper limit of time of flora in Fossil Hill member was determined by by Satanglera (1986) to be Oligocene, but Li and Shen (1990) limited the flora in Fossil Hill member to be Eocene. Due to no any isotopic age data of the upper time limit of fossil Hill member (or lower time limit of Block Hill member), it is difficult to decide the lower limit age of Block Hill member, But according to Satanglera (1986) opinion, the upper time limit of Fossil Hill should be early Oligocene.

There is a latest volcanic activity in the area investigated in Suffield Point and its apparent K—Ar age values are rather dispersed (Table 3), but its isochron age is 22. 06 Ma (Fig. 4), which may be determined to be the upper limit of formation time of Block Hill member. Thus the Block Hill member was formed about in late Oligocene — early Miocene. According to the above—discussed, a correlation of Cenozoic strata on Fildes Peninsula of King George Island is shown in Table 4. The time scale in Table (Table 4) is cited from Carry and Odin(1982). The boundry between Cretaceous and Tertiary is 65 Ma. Paleocene is divided into two stages. The boundary between early and late Paleocene is $59\ ^{+1}_{-2}$Ma; the boundary between Paleocene and Eocene is 53±1 Ma. The Eocene is divided into three parts with their internal boundaries of $45\ ^{+1}_{-0.5}$Ma and $39\ ^{+1}_{-0.5}$Ma, respectively. The boundary between Eocene and Oligocene is 34±2 Ma, and the boundary between Paleogene and Neogene is 23±0. 5 Ma.

On the basis of above time scale the isotopic age of Jasper Hill member is 54. 35 and 55 Ma by Rb—Sr, and ^{40}Ar—^{39}Ar method (at high—temperature step), which indicate that the volcanic activity in this area has begun in late Paleocene. As the Agate Beach member covering on the Jasper Hill member and its K—Ar isochron age is 45—50 Ma, the boundary between these two members should be 50—55 Ma that approximately corresponds with the time between late Paleocene and early Eocene. The Agate Beach member began to form in early Eocene and its upper time limit would be no younger than 45 Ma, because it lies under the Fossil Hill member belonging to middle—Oligocene, It suggests that after 45Ma ago,

Table. 4. The division and correlation of strata in Fildes Peninsula, King George Island.



at the end of the Agate Beach member the extensive volcanic eruption events ceased and a period of cooling and deposition atarted. The time limit value 45 Ma is very close to the time of the boundary between the early and middle Eocene. The isochron age of Block Hill member is 22. 06 Ma, indicating that the upper limit of volcanic rock has stepped in early stage of early Miocene.

It should be noted that rather higher apparent age values are always obtained on the samples near the volcanic craters. For example, the apparent age of samples H—1, C—1—21 from Horatio Plug is about 76 Ma, the apparent age of subvolcanic rock is 103 Ma as sample 2601 taken from the volcanic crater northwest of the Great Wall Station and 73 Ma of sample 2504 from Fossil Hill. Stratigraphically, these samples are not significant. The higher age values may be produced by the magma trapping the relict components of the basement or the rock having had not degassed. For this a best evidence is the finding of

diorite rubble near a volcanic plug by Liu Xaihan.

The study result shows that the volcanic strata on Fildes Peninsula have mainly deposited in the Paleocene. Recently, Cao (1990) and Shen (1990) have found Cretaceous sporopollen compolex at the Half Triangle in the Southeast of the Peninsula indicating the existence of Cretaceous strata.

The South Shetland Archipelago is one part of the northern Antarctic Peninsula during the Cretaceous, numerous volcanic activities developed during the Cretaceous to the Cenozoic. Subduction of Pacific Plate has ceased back—arc spreading which led the South Shetland to depart from the Peninsula and to formation of Bransfield Strait. Therefore there is a syngenetic Mesozoic basement for the South Shetland and Antarctic Peninsula, Thus it is possible to find the late Cretaceous strata. But, isotopic dating is needed to do in Half Triangle area yet.

Conclusion

The result of the isotopic dating of volcanic rocks on Fildes Peninsula enables us to draw the following conclusions:

1. The time of volcanic activity on Fildes Peninsula is from late Paleocene to early Miocene. The isotopic age of Jasper Hill member of the lowest part of volcanic strata is 51—55Ma. K—Ar age of Agate Beach member is 45—50 Ma belonging to the Eocene. The fossil Hill member biochronologically belongs to middle Eocene to early Oligocene. The Block Hill member has ended in early Miocene. However, it should be noted that a possiblity to find Cretaceous stratum.

2. The apparent ages detected for the study area are dispersed and tend to be higher. It is related with the excess (and inherited) argon in the rocks detected by K—Ar method.

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