Antarctic Research, Vol. 4, No. 1, 12~25, June 1993

CHARACTERISTICS OF Nd AND Sr ISOTOPES AND TRACE ELEMENTS FOR LATE CRETAEOUS VOLCANIC ROCKS IN KING GEORGE ISLAND, ANTARCTICA: IMPLI-CATIONS FOR SOURCE OF THE VOLCANICS FROM DEPLETED MANTLE*

Wang Yinxi[1](王银喜), Shen Yanbin[2](沈炎彬) and Yang Jiedong[1](杨杰东)

[1] *Modern Analytical Center, Nanjing University, Nanjing 210008, China*

[2] *Nanjing Institute of Geology and Palaeontology, Academia Sinica, Najing 210008, China*

Abstract Rb—Sr isotopic isochron dating of the volcanic rock samples from the Upper Cretaceous Half Three Point Formation on the King George Island is 71. 33±0. 3 Ma. Correlative study of $\epsilon_{ND}(T)-{}^{147}Sm/{}^{144}Nd$, ${}^{143}Nd/{}^{144}Nd-{}^{87}Sr/{}^{86}Sr$, ${}^{87}Sr/{}^{86}Sr-Sr$ and ${}^{87}Sr/{}^{86}Sr-K_2O/(K_2O+Na_2O)$ indicated that the volcanic rocks were chiefly derived from the depleted mantle source and generally were not mixed crust materials. Of the samples 6 were given the mean Sm—Nd model age (T_{DM}^{Nd}) of 443. 3±20. 6 Ma possibly indicating the age of chemical variation event in the magma source of the study area. Features of the trace elements indicated that the rocks from the Half Three Point Formation are of typical calc-alkaline volcanic suite and similar to those from the Tertiary volcanic rocks of the Fildes Peninsula, being the same products of the island-arc volcanic activity.

Key words Late Cretaceous Rb—Sr dating, Nd—Sr isotopes, trace elements, petrgenesis

There are many reported on the isotopic dating and geochemical studies of the volcanic rocks from the Fildes Peninsula, King Geoge Island (Grikurov *et al.*, 1970; Fleming, 1979; Watts, 1982). In particular, the Chinese Antarctic Expedition has intensively inquired into the petrology of the volcanic rocks and the magmatic senesis and evolution in this area (Li and Liu, 1987; Zheng *et al.*, 1991; Zhu *et al.*, 1991). The present paper deals with the isotopic dating of Rb—Sr and Sm—Nd and trace elements in the volcanic rocks from the Half Three Point Formation. The samples used in this study were all colllected from a small islet near Half Three Point of the Fildes Peninsula and were attributed to the Upper Cretaceous Half Three Point Formation (Shen, 1990, 1992) (Fig. 1).

* The project supported by the State Antarctic Committee and the National Natural Science Foundation of China.

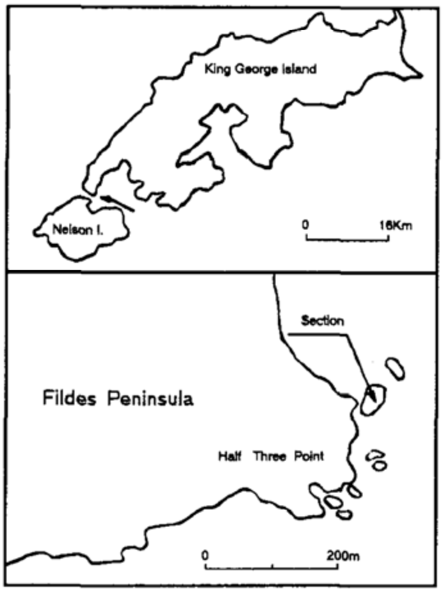

Fig. 1. Showing the sample site.

Method of analysis and results of measurement

Rb, Sr, Sm and Nd elements and isotopes were all analysed in the Modern Analytical Center, Nanjing University and by using the VG354 Isotope Mass spectrometer made in England. In this laboratory, the analysis of contents of Rb, Sr, Sm and Nd elements with dilution and the isotopic ratio determination of Sr and Nd with non dilution were carried out separately. The results of measurement of NBS 607 Rb — Sr standard sample in this experiment are: Rb=524.6±1.2 $\mu g/g$; Sr=66.34±0.78 $\mu g/g$; $^{87}Sr/^{86}Sr$=1.20014±10)(2σ), taking $^{86}Sr/^{88}Sr$ = 0.1194 as standard ratio; the standards of Sr isotope were determined as $^{87}Sr/^{86}Sr$=0.71022±4 (2σ), with the standardized value the same as above. Taking $^{146}Nd/^{144}Nd$ as the standardized value, in the standard samples the American LaJolla Nd isotope was determined as $^{143}Nd/^{144}Nd$=0.511860±6(2σ); in the American CIT Nd standard solution (Ndα), the Nd isotope in the sardard sample as $^{143}Nd/^{144}Nd$=0.511901±5(2σ); $^{143}Nd/^{144}Nd$=0.512662±8 (2σ) in the standard rock sample (BCR—1) from the American Geological Survey; $^{143}Nd/^{144}Nd$ = 0.513009±13 (2σ) in the standard samples (BHVO—1); Sm=6.83±0.02$\mu g/g$, Nd=29.37±0.1$\mu g/g$ in the standard rock sample (BCR—1); Sm=6.62±0.02$\mu g/g$, Nd=25.0±0.1 $\mu g/g$ in the standard rock sample (BHVO — 1). The determined values of the above-mentioned standard samples are all identical to those determined abroad or within the range of change. Chemiacl preparation procedures, methods of mass spectrum analysis for Sm — Nd and Rd — Sr and detailed results of various standard samples have been reported in the related literature (Wang *et al.*, 1988; Yang *et al.*, 1986)

Table 1. Rb—Sr isotope data and Sr isotope parameter of the tuffites.

Sample No.	Name of rock	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$(^{87}Sr/^{86}Sr)_S$	T (Ma)	$(^{87}Sr/^{86}Sr)_T$	$f_{Rb/Sr}$	$\varepsilon_{Sr}(0)$	$\varepsilon_{Sr}(T)$
No. 1	grey tuffite	22.43	446.7	0.1431	0.703291±16	71.33	0.703148	0.73	−17.2	−18.0
Gwp6	tuffaceous greda	28.13	443.4	0.1808	0.703320±8	71.33	0.703139	1.18	−16.7	−18.1
Gwp7	grey tuffite	20.75	424.9	0.1392	0.703285±15	71.33	0.703146	0.68	−17.2	−18.1
Gwp8	tuffite	8.012	487.3	0.04686	0.703187±10	71.33	0.703140	−0.43	−18.6	−18.1
No. 4	grey tuffite	18.66	481.3	0.1.25	0.703249±12	71.33	0.703146	0.24	−17.7	−18.0
Gwp9	grey tuffite	25.73	489.6	0.1498	0.703295±14	71.33	0.703145	−0.81	−17.1	−18.1
No. 6	grey tuffite	13.23	527.7	0.07145	0.703215±11	71.33	0.703143	−0.13	−18.2	−18.0
Gwp10	grey tuffite	26.26	490.8	0.1525	0.703299±9	71.33	0.703146	0.84	−17.0	−18.0
Gwp8	enriched heavy materials	3.056	432.6	0.02013	0.703162±15	71.33	0.703142	−0.76	−18.9	−18.0
No. 6	enriched heavy materials	4.329	352.7	0.03498	0.703176±10	71.33	0.703141	−0.58	−18.8	−18.1
Gwp10	enriched light materials	50.65	310.9	0.4642	0.703606±9	71.33	0.703144	4.61	−12.7	−18.2
Gwp6	enriched light materials	64.37	209.5	0.8756	0.704032±11	71.33	0.703142	9.59	−6.64	−17.9

Table 2. Sm—Nd isotope data and Nd isotope parameter.

Sample No.	Name of rock	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$(^{143}Nd/^{144}Nd)_S$	T (Ma)	$(^{143}Nd/^{144}Nd)_i^T$	$f_{Sm/Nd}$	$\varepsilon_{Nd}(0)$	$\varepsilon_{Nd}(T)$	T_{DM}^{Nd} (Ma)
Gwp6	grey tuffite	5.322	23.48	0.1371	0.512923±12	71.33	0.512068	−0.303	5.55	6.08	455.1
Gwp7	grey tuffite	4.795	20.06	0.1446	0.512938±14	71.33	0.512079	−0.265	5.84	6.31	471.3
Gwp8	tuffite	5.410	23.36	0.1401	0.512954±16	71.33	0.512097	−0.288	6.15	6.66	409.3
Gwp8−1	grey tuffite	4.985	21.04	0.1433	0.512945±10	71.33	0.512087	−0.271	5.99	6.46	447.4
Gwp9−1	grey tuffite	5.212	22.32	0.1413	0.512950±15	71.33	0.512083	−0.282	5.88	6.38	445.5
Gwp10	grey tuffite	5.815	25.15	0.1399	0.512922±18	71.33	0.512066	−0.289	5.53	6.04	437.1
BCR−1	basalt(U.S)	6.83	29.37	0.1407	0.512662±8			−0.284	0.47		1020
BMVO−1	basalt(U.S)	6.22	25.01	0.1505	0.513009±13			−0.235	7.23		343.7

Table 1 shows the element contents of Rb and Sr in 12 samples, their Sr isotope data and related isotope parameters. Table 2 shows element contents of Sm and Nd in 6 samples, their Nd isotope data and related isotope parameters. For the convenience of comparison, the Sm—Nd isotope data of two American baselt samples and related parameters are listed in Table 2.

In table 1 and 2, T represents the age of rock-forming; $(^{87}Sr/^{86}Sr)_s$ and $(^{143}Nd/^{144}Nd)_s$ are the measured values given by instruments $^{87}Rb/^{86}Sr$ and $^{147}Sm/^{144}Nd$ are the present measured values of the samples; $(^{87}Sr/^{86}Sr)_i^T$ and $(^{143}Nd/^{144}Nd)_i^T$ are the initial ratio of the samples during the T time.

Discussion

1. Geochronology of Rb—Sr isotopes

The difference between the Rb and Sr contents of the former eight samples and the $^{87}Sr/^{86}Sr$ ratio error are only 0.0001 in table 1. Because the Sr isotopes ratio error of NBS 987 measured by our intruments in the past many year is 0.0005, the ratio difference of the samlpes measured in this study is practicable. The calculated isochron age Rb—Sr is 70.44 ±1.93 Ma, the initial of Sr is I=0.70314±0.0001, and the correlation coefficient is R= 0.998. For the sake of making the age data more reliable, four powder samples were chosen from the eight samples that have been measured and treated by repeated magnetic separation. Ralatively enriched heavy materials were chosen from the GWP 8 and No. 6 whole rocks and relatively enriched light materials from the GWP 10 and GWP 6. Through the test, the Rb/Sr and $^{87}Sr/^{86}Sr$ ratios with difference greater than those of the original eight samples are obtained, the difference being 0.0008.

Fitting together of Rb—Sr isochron dating of the samples measured twice gives the results of t=71.33±0.3 Ma. I=0.70314±0.0001, R=0.999. Thus, the age data are reliable, which indicate the stratigraphic age of the volcanic sedimentary rocks from the Half Three Point Formation, coinciding with that of data indicated spore pollen (Shen, 1989, 1990; Cao, 1990). It is further proved that the activity of the volcanic eruption in Fields Peninsula began at least in the Late Cretaceous and not in the Tertiary age (Li and Liu, 1987).

2. Sm—Nd isotopic features

Judging from table 2, the change in Sm/Nd ratios and Nd isotopes ratios from the volcanic rocks is very small; $\varepsilon_{Nd}(O)$ value is +5.53—+6.15 approaching the $\varepsilon_{Nd}(O)$ value (+7,23) of the Hawaii basalt BHVO—1 the $^{147}Sm/^{144}Nd$ is similar to that of the basalt BCR—1, but the ratio of basalt BHVO—1 is relatively higher. The $^{143}Nd/^{144}Nd$ ratio in the samples is closed to that basalt BHVO—1. If the $\varepsilon_{Nd}(0)$ values against $^{147}Sm/^{144}Nd$ ratios are plotted in figure 3, the sample spots all fall within the range of oceanic island alkali basalts and situated below the evolution line of T=2000 MYr, near one end of the depleted mantle end-member and far away from the enriched mantle end-member. As a whole, the

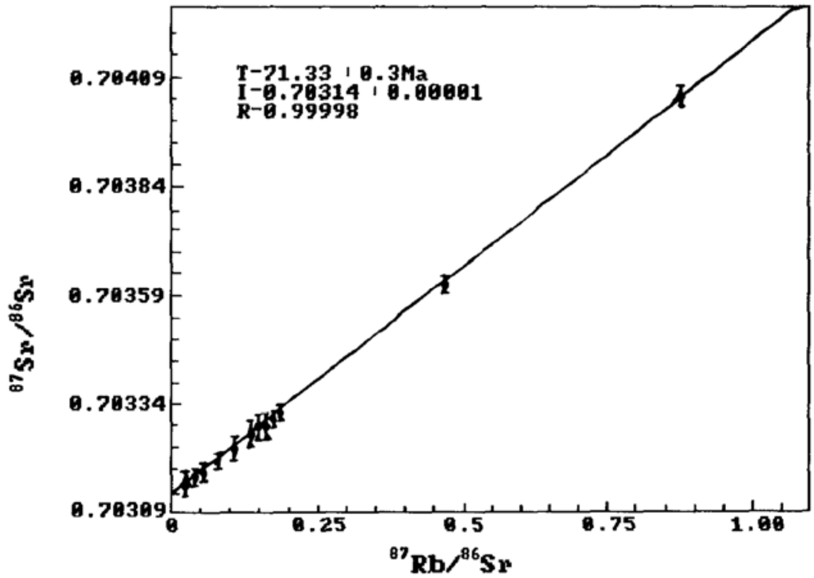

Fig. 2. Rb—Sr whole—rock isochron diagram of the valcanic rocks of Half Three Point Formation.

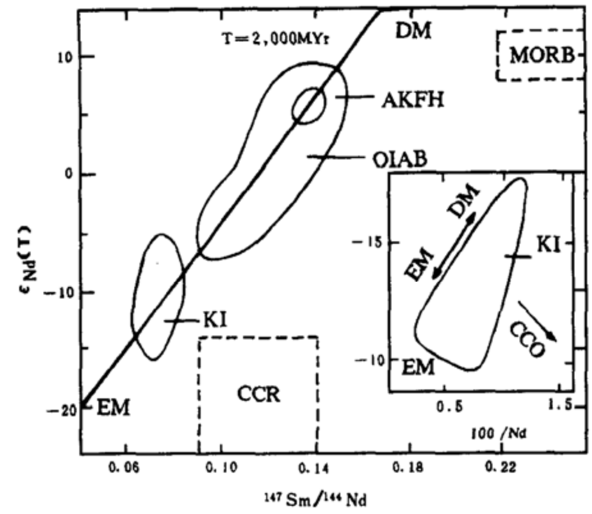

Fig. 3. $\epsilon_{Nd}(T)$ plotted against $^{147}Sm/^{144}Nd$ diagram for the samples (after McCulloch *et al.*, 1983) OIAB: Mid-Ocean island alkali basalts; MORB: Mid-Ocean ridge basalts); KI: Kimberlites and lamproites; EM: Enriched mantal; DM: Depleted mantal; CCO: Crustal contamination; CCR: Continental crust; AKFH: This papaer.

oceanic island basalt $\epsilon^{Nd}(T)$ value has a positive correlation with $^{147}Sm/^{144}Nd$ ratio.

3. Sr isotope

The identity of the initial Sr isotope value of $(^{87}Sr/^{86}Sr)_i^T$ (0.703139—0.703148) in table 1 reflects the features of the samples from the same source region with Sr isotope homogenization, i. e., the depleted mantle source of low $^{87}Sr/^{86}Sr$ and high $^{143}Nd/^{144}Nd$ ratios. $^{87}Sr/^{86}Sr$ ratio in the rocks is higher than the lower limit of some mid oceanic ridge basalt ratio (0.7022—0.7032) and close or identical to the upper limit of it. When we compare $^{87}Sr/^{86}Sr$ ratio in the samples with the oceanic island basalts ratio (0.703—0.706), we may see that its lower limit is identical to that of the latter and evidently lower than the upper limit value of the latter.

As show in Fig. 4, there is roughly an inverse proportoin between the Sr contents and the $^{87}Sr/^{86}Sr$ ratios in different valcanic rocks (Faure and Powell, 1972). Putting all the data of the samples in the superposed range of oceanic island and oceanic floor basalts. All $(^{87}Sr/^{86}Sr)$ measured and the data spots of the coresponding $K_2O/(K_2O+Na_2O)$ near the juncture of the Hawaii basalts, but evidently inclined to the sea-ridge tholeiite region (Fig. 5). The samples from this region are identical with oceanic island basalts, and have a positive correlation between $^{87}Sr/^{86}Sr$ ration and the K contents i. e. $K_2O/(K_2O+Na_2O)$.

Othewise, the $^{87}Sr/^{86}Sr$ ratio may judge whether there were effects of the sea water interaction and indicates whether the volcanic rocks were of maine or of continental origin. In the study of $^{87}Sr/^{86}Sr$ ratios of the Cretaceous mid-ocean ridge basalts from the Atlantic, Borming *et al.* (1980) found that the ratios are comparatively high, being 0.70355—0.

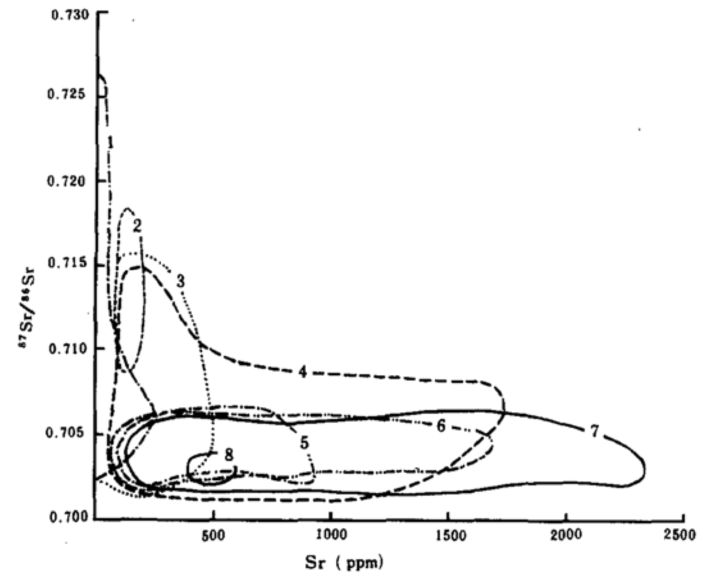

Fig. 4. $^{87}Sr/^{86}Sr$ plotted against Sr (ppm) diagram for the samples (after Faure and Powell, 1972) 1. Olivinfels and Pure; 2. Jurassic dolerite of Antarctica and Tasmania; 3. Continental Felsic volcanic rocks; 4. Continental bassaltic rocks; 5. Sea—floor basalts; 6. Circum-oceaanic andesites; 7. Oceanic-Island basalts; 8. This paper.

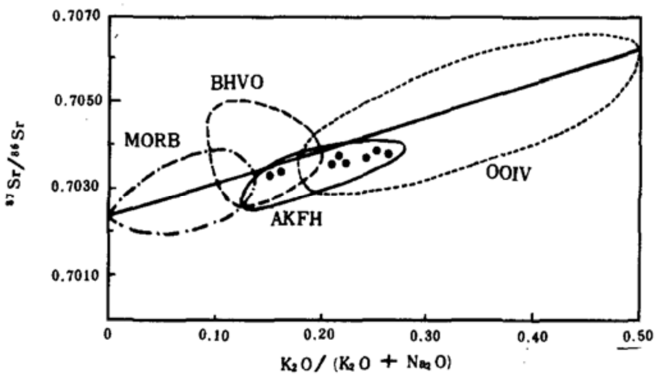

Fig. 5. $^{87}Sr/^{86}Sr$ plotted against $K_2O/(K_2O)+Na_2O)$ diagram for the Formation (after Faure and Powell, 1972) MORB: Mid-ocean ridge basalts; BHVO: Hawaii basalts; OOIV: Other ocan island volcanic rocks; AKFH: This paper.

70470. and considered that this results from the effect of exchange action from sea water and the rocks. The Cretacous sample dealt with in this paper have the comparatively low $^{87}Sr/^{86}Sr$ ratios(0. 703189—0. 703320). If inferred from the study results of Borming *et al.* (1980), the volcanic rocks of the Half Three Point Formation were possibly not affected by the sea water exchange action.

4. Nd—Sr isotope correlation

$^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ ratios from the volcanic rocks are plotted in figure 6, and data point of the samples fall on the distribution region of Hwaii basalts and also on the margins between the distribution regions of the mid-ocean ridge basalts, Azores Island basalts (Hawkesworth *et al.*, 1979) and the continental basalts of East China (CEB) (Chen *et al.*, 1990); and it is evident that the distribution region of the Kerguelen Island basalts is far away (Dosso and Murthy, 1980). Excepting the mid-ocean ridge basalts, in which there are little changes, there are great changes in the correlation diagram between AKFH of the present paper, other oceanic island baslts and continental basalts of East China (Fig. 6). These features show that they are different in composition, but their Nd and Sr isotopes are distribution in the state of overlapping in diagram. Judging from figure 6, the negative correlation of Nd—Sr of the mid-ocean ridge basalts (MORB) is more evident than that of the ocean island basalts (OIB). This is because the materials, of which the MORB were composed, were (Fig. 6) undoubtedly derived from the depleted mantle and were single in composition. But the materials source region of the OIB includes many sorts of compositions, which lessens the negative relation. Owing the long term evolution of the subcontinental mantle, the diversits of the composotion of the subcontinental lithosphere mantle, the formative of the old continental crust and the subseqent material exchange beteen crust and mantle, this relation became more complicated (Hawkesworth *et al.*, 1979). This is the chief reason for making the great Nd—Sr correlation change of the ocean islands and continental basalts in figure 6. However, it is worth noting that the samples in this study all full within the area of Hawaii basalts (known as the ocean island type) and, some of samples fall within the Azores basalts and continental basalt region of East China, too. The overlapping data results in many interpretions of problems. Besides, the authors noted the $^{87}Sr/^{86}Sr$ and $\varepsilon_{Nd}(T)$ are 0.70270—0.70424 and +2.0—+9.1 respectively in the volcanic rocks (ocean island type) from the central to northorn parts of Japanese islands and $^{87}Sr/^{86}Sr$ and $\varepsilon_{Nd}(T)$ are 0.70320—0.70348, and +8.3—+9.3 respectively in the nearby Isu island arc volcanic rocks (Susumu and Wasserbury, 1981). The Nd and Sr istope data of the ocean island and island arc types are over lapped. Thus, the authers, on the basis of the above-mentioned examples, considered that there are some limitation in the use of Nd—Sr isotopic correlation diagram for judging the tectonic setting of the volcanic rocks. Because these volcanic racks are characterized by the overlapping Nd—Sr isotope data. But some trace element combinatoins are useful in the judgement of tectonic setting of the volcanic activities (Pearce and Cann, 1973).

5. Model age of Sm—Nd

Model age (T^{Nd}_{CHUR} and T^{Nd}_{DM}) was first proposed by Depaolo and Wasserburg in 1976.

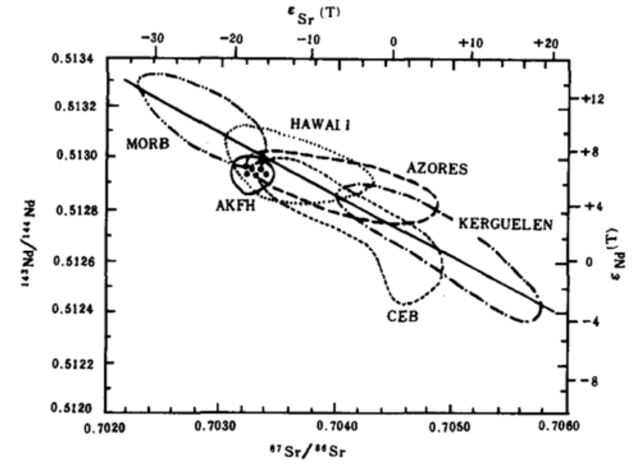

Fig. 6. $^{143}Nd/^{144}Nd-^{87}Sr/^{86}Sr$ diagram for the samples (after Peng *et al.* ,1986) MORB:Mid-oceam ridge basalts; HAWA I I : Hawaii basalts; AZORES: Azores island basalts; KERGUELEN: Kerguelen island basalts; CEB: Basalts of E. China; AKFH: This paper.

The T_{CHUR}^{Nd} age is the time derived from the mantle consisting of aschistic chondrities. It represents the time of crustal rocks derived from the light rare-earch deplete source (i. e. , depleted mantle).

The time of continental crustal samples when separated from mantal may be often repressed by model age of Sm—Nd, hence, in the latest years, model age of Sm—Nd has been extensively used. However, model age od Sm—Nd may be given two interpretations. Thus, if the model ages of Sm—Nd and th U—Pb age data of zircon are identical with the evidence for some orogenic events or events of magmatic activity in mantal (Rb—Sr and Ar—Ar age), the model age of Sm—Nd may be used for interpreting the age of crust forming (or called the age of crust-mantle differentiation) (Arndt and Goldstein, 1987).

As shown in table 2, th T_{DM}^{Nd} of the sample sudied in this paper averages 443. 3±20. 6 Ma, equivalent to the time from Ordovician to Silurian. Judging from the model age of Sm—Nd, this value is evidently higher than 71. 33 Ma, the diagenetic age of the rocks containing the samples (or called the age of volcanic eruption). In the light of principal and empirical standard ($^{147}Sm/^{144}Nd \leqslant 0.15$) used for judging the significance of model age (Wang *et al.* , 1991), the model ages of those samples can be interpreted as the ages of crustal formation. It is evidently not suitable also to interpret this model age as the average of the mixed source region, because this suite of volcanic rock of the Half Three Point Formation has been determined to be derived directly and chiefly from the upper mantle source region by the study of Nd and Sr isotope and to result from volcanic eruption. Thus, this model age may be chiefly related with the event of magmatic chemical differentiation taking place in the upper mantle region (Borming *et al.* , 1980). We also can not exclude the possibility that a very small number of crustal matters were added because the values of these samples are a little higher than that of the standard MORB, and the $\varepsilon_{Nd}(T)$ value are a little lower than that of the latter. These features indicate that these samples, compared with the standard MORB are mixed with a very small number of crustal matters. This conclusion is not in contraction with the forgoing one that these sample matter are chiefly derived from the depleted mantle. It is interesting that some gneisses on the eastern Graham Land of the Antarctic Peninsula deduced by Walton (1987) to be precambrian or lower Paleozoic in age.

6. Geochemical Characteristics of elements and the significants of tectonic setting

The geochemical characteristics of major elements, trace elements and rare earch elements in the volcanic rocks of the Half Three Point Formation have been discussed in another paper (Wang Yinxi and Shen Yanbin, in press*). Based on the measured data (see literature cited in the following note). We only make some diagrams in this paper, and from different Points of view further discuss the geocemical characterics of these elements and the significance of tectonic setting in which they were produced.

Fig. 7 is a coorelation diagram of Ni, V, Cr, T_iO_2, CO, Cu and MgO_2 in which Ni, V and TiO_2 have a positive correlation, but Cr and Co are unclear correlativity, indicating a comparatively weak fractionating crystallization of magma before the condensation of the rocks.

From figure 8 the correlation relation between some in compatible elements and MgO (wt%) may be seen, i. e., a basic positive correlation between Pb, Sr, Li, Nb, Hf and MgO (wt%); Y, Th, Ta, U and Bi have a negative correlation basically and the correlation between Ba and Rb and MgO (wt%) is not very distinct. Figure 9 shows the correlation relation between some in compatible elements and K_2O (wt%). Y, Pb, Th, Rb, U and Bi generally have positive correlation, and Li, Nb and Hf generally have negative correlation. The correlation relation of Ta, Ba, Sr and Zr is not distinct.

In Hf-Th-Ta diagram (Fig. 10), the samples are plotted on the destructive plate margin basalts, and in D region are chiefly within the calc-alkalina basalt region and with a minority within the primitive arc tholeiite region. All of the above-mentioned rocks are of plate-margin volcanic are basalt type.

In Ti/100—Zr—Sr/2 diagram (Fig. 11), the samples are plotted in the B region of calc-alkaline basalts. When using F_1-F_2 diagram (Pearce, 1973) to discriminate the basalts of different magma types (Figure 12), the samples are all plotted in the CAB+LKT

* Wang Yinxi and Shen Yanbin, Rb—Sr and Sm—Nd isotopic evidence for genesis and dating of the Late Cretaceous volcanic rocks from the King George Island, Antaarctiac in Shen Yanbin (ed.); Stratigraphy and Palaeontology of the Fields Peninsula, King George Island, Antarctica.

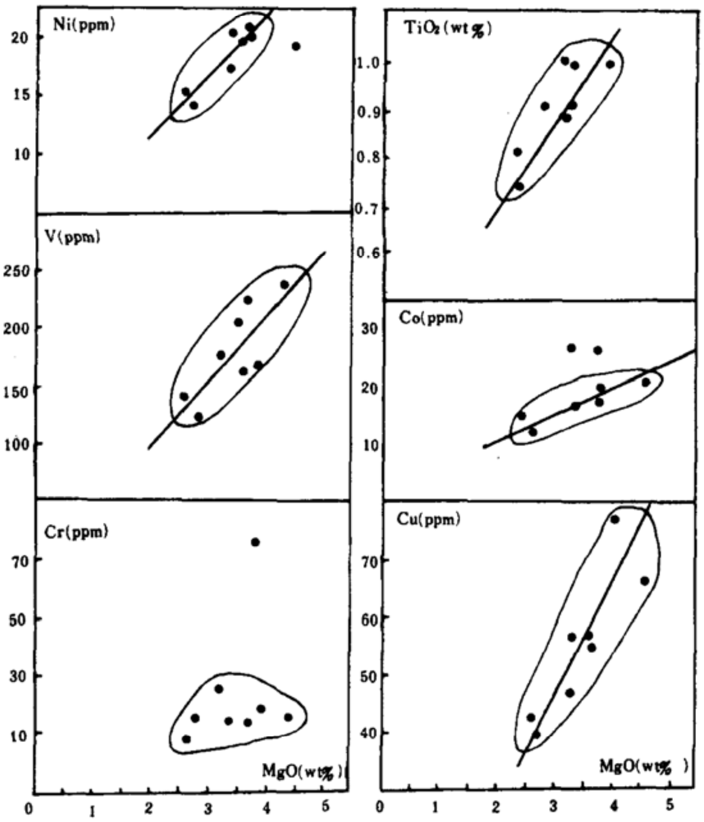

Fig. 7. MgO vs. the first interim clan element diagram for the samples.

region, indicating the characteristics of both the calc-alkaline basalts and the low-Potassium tholieiite. In order to discriminate CAB from LKT, using F_2-F_3 diagram, the samples are all plotted in the CAB region . Basaed comprehensively on the above-mentioned diagrams, the samples are chiefly characterized by calc-alkaline volcanic rocks and also by some low-potassium tholeiites. They are differnt from the Early Tertiary volcanic rocks from the Fields Peninsula, which are characterized chiefly by low-potassium tholeites (island-arc tholeiites and also by calc-alkaline basalts (Zheng *et al.*, 1988). It is possible that this resulted from the chemical evolution of magma chambers of different ages and the difference between tectonic setting. They are all the convergent plate-margin volcanic arc basalts, being typical calc-alkaline volcanic rock series and resulting from the island arc volcanic activity.

Conclusion

(1) The Rb—Sr isochron dating in 12 volcanic rock samples from the Half Three Point Formation gives an age of 71. 33±0. 3 Ma, which is fundamentally the same as the age given by sporo-pollen fossiles in the rocks, indicating that the volcanic eruption activity in

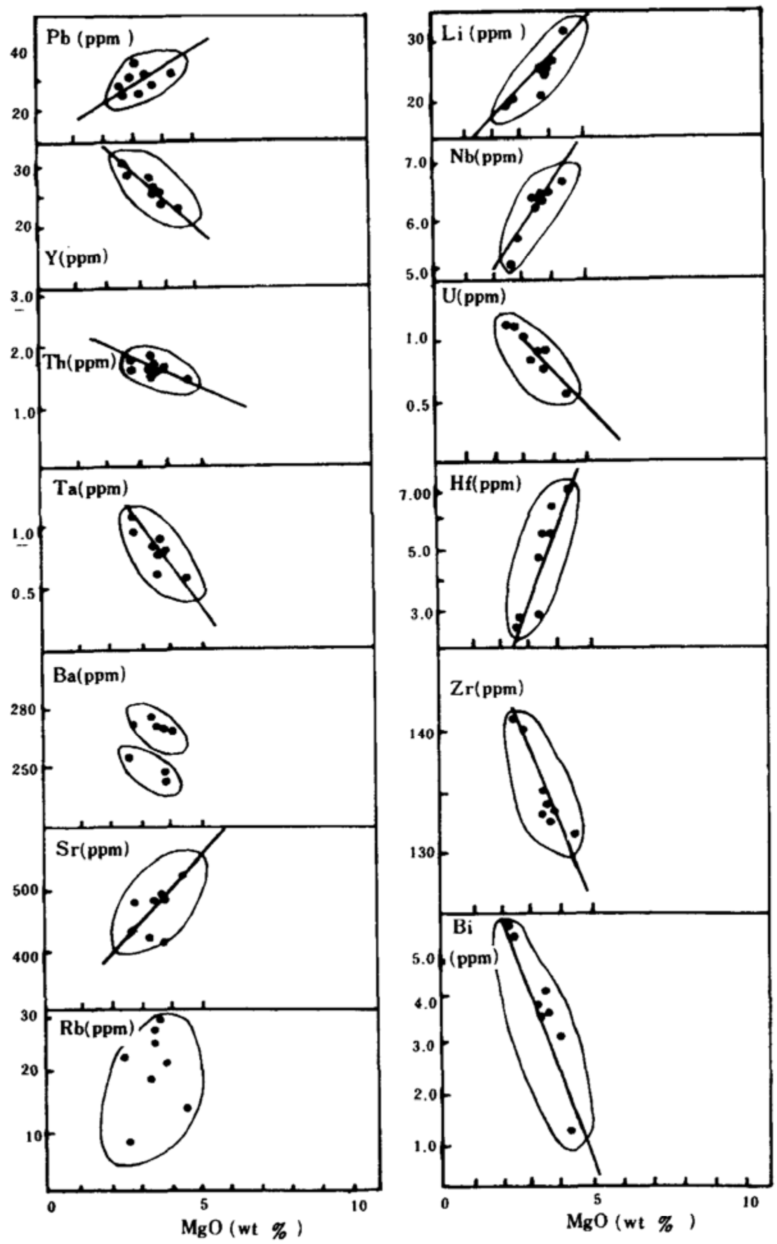

Fig. 8. MgO-some trace elements plots for the samples.

the Fildes Peninsula at least began in the Late Cretaceous and not in the Tertiary.

(2) The sample have $\varepsilon_{Nd}(T)$ positive values (+6.04—+6.66) and low ratio vlaue of $^{87}Sr/^{86}Sr$, generally indicating the isotopic chracteistics of Nd and Sr in the asthenosphere. The matters were chiefly derived from the depleted mantle.

(3) The negative correlation characteristics of $^{143}Nd/^{144}Nd-^{87}Sr/^{86}Sr$ in the samples are similar to those of Nd—Sr in most basalts of marine environments, using Nd—Sr isotope

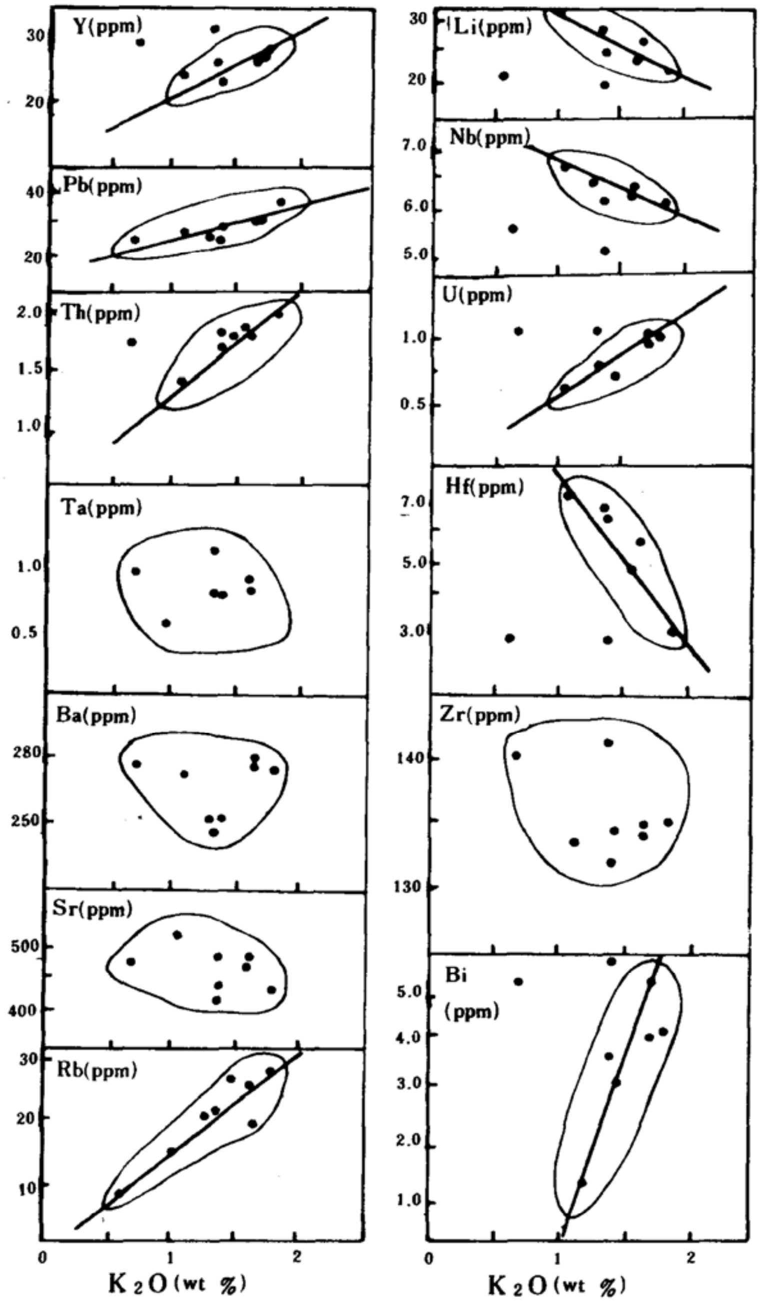

Fig. 9. K_2O—some trace elements plots for the samples.

may discriminate MORB from other volcanic rocks, but compared with trace elements, they can not more effectively discriminate the valcanic rocks other than MORB from the techtonic settings of other volcanic rocks.

(4) The ratio values of $^{87}Sr/^{86}Sr$ and related oxides or elements indicated that the volcanic rocks in this area have not been contaminated by crustal matters fundamentally or slightly. The low ratio values of $^{87}Sr/^{86}Sr$ indicates no exchange action of sea water.

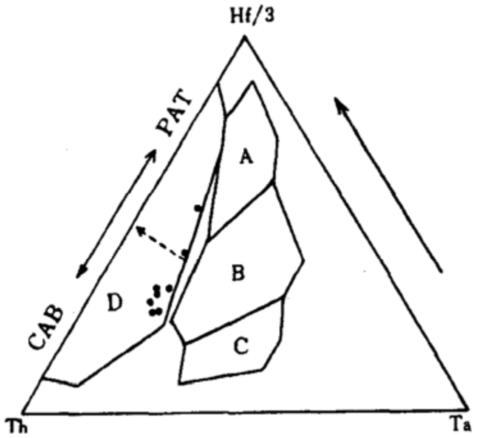

Fig. 10. Th-Hf-Ta discrimination diagram with revised fields for different tectonic environment (after Wood, 1980) A: (N-type MORB; B: E-type MORB + WPS(whthin-plate-basalt); C: (Alkline within-plate basalt; D: Destructive plate-margin basalt; CAB: Calc-alkaline basalt; PAT: Ca Primitive arc tholeiite.

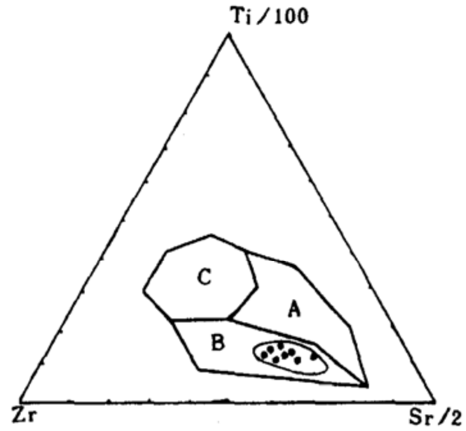

Fig. 11. The samples plotted on the Ti/100 — Zr — Sr/2 discrimination diagram (after Pearce and Cann, 1973). A: Low-kotassium tholeiite; B: Calc-alkaline basalt; C: Ocean-floor basalt.

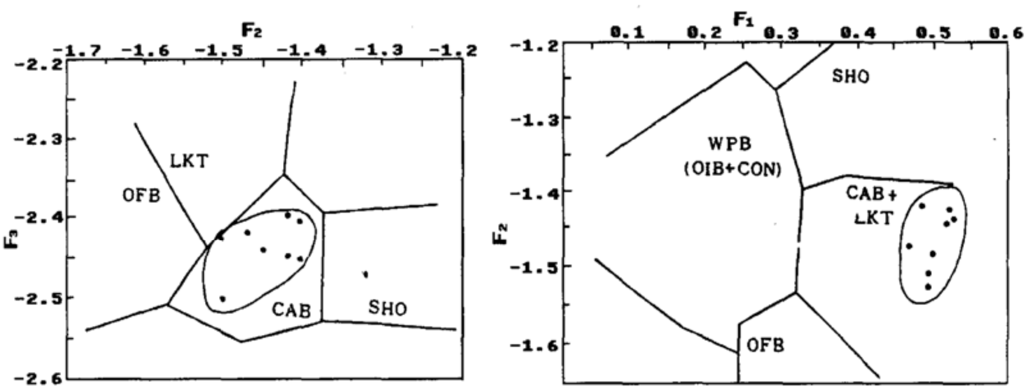

Fig. 12. $F_1 - F_2$ and $F_2 - F_3$ diagram to determine tectonic setting of volcanic rocks. CAB: Calc—alkali basalts; LKT: Low K basalts; OLB: Ocean island basalts; OFB: Ocean floor basalts.

(5) Model age of Sm—Nd (409.3—471.3 Ma)with not very wide range very possibly indicates the age of chemical differentiation event in the magma source region.

(6) Study of trace elements indicated that the sample assembages of the Half Three Point Formation belong to the calc-alkaline volcanic rock series and are products of the island are volcanic acitvities. The correlation relations betweem MgO and some in compatible elements indicate that there is the continuous evolution between these rocks.

References

Aarndt, N. T. and Goldsten, S. L. (1987): Use and abuse of cust formation ages, *Geology*, 15(10), 893—895.

Barton, C. M. (1964): Significance of teriary fossil floras of King George Island. In Adie, R. J. (ed), Antarctic Geology, 603—608.

Borming, J., Bernard — Griffiths. J., Chardot, R., Cornichet J., and Vidal, P. (1980): Nd and Sr isotopic compositions and REE abundances of Cretaceous MORB (Holes 417 and 418A. Legs 51, 52 and 53), *Earth Planet Sci Lett.*, 48, 171—184.

Cao Liu(1990):南极乔治王岛菲尔德斯半岛晚白垩世孢植物群的发现及其意义,古生物学报,29(2),140—146.

Chen Daogong, Yang Jiedong and Wang Yinxi (1990):苏皖鲁某些新生代火山岩的同位素组成及意义,科学通报,35(12),925—927

De Paolo, D. J. and Wasserbury, G. J. (1976): Inferences about magma sources and mantle structure from variations of $^{143}Nd/^{144}Nd$, *Geophys. Res. Let.*, 3, 743.

Dosso, L. and Murthy, V. R. (1980): A Nd isotopic study of the Kerguelen Island: inference on enriched oceanic mantle sources, *Earth Plant Sci. Lett.*, 3, 743

Faure, G., and Powell, J. L. (1972): Strontium isotope geology, Spring Verlag.

Fleming, E. A. (1979): British antaactic teritory geological map 1:500000 Northern Graham Land and South Shetland Island, ed. by Brithish Antarctic Survey.

Golesm, G. E. and Lambert, R. J. (1990): A Strontium isotopic study of Newberry volcanno, Central Orgon: structural and thermal implication, *J. Volcanology and Geothermal Research*, 43, 1—16.

Grikurov, G. E., Krylov, A. Ya., Polyalov, M. M. and Tsovbun, Ya. N. (1970): Age of rocks from the northern part of the Antarctic Peninsula and the South Shetland Island (from data of the potassium method), *Bull. Sov. Antac. Expad.*, 8, 61—63.

Hawkesworth, C. J., Norry, M. J., Roddick, J. C,. and Vollmer, R. (1979): $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ rations from the Azores and their significance in LIL-element enriched mantle, *Nature*, 280, 28—31.

Jacobsen, S. B. and Wasserburg, G. J., (1984): Sm—Nd isotopic evolution of chondrites and and achondrites. II, *Earth Planet Sri. Lett.*, 67, 137—150.

Keto, L. S. and Jacobsen, S. B., (1987): Nd and Sr isotpic variations of Early Paleozoic oceans, *Earth Planet Sci,. Lett.*, 84, 27—41.

Li Zhaonan and Liu Xiaohan (1987):南极乔治王岛菲尔德斯半岛长城站地区火山岩系的地质特征,地质论评,33(5),484—487.

McCulloch, M. T., Jaques, A, L., Nelson, D. R. and Lewis, J. D. (1983): Nd and Sr isotopes in Kimberlites and lamproites from Western Australia: an enriched mantle origin, *Nature*, 302(31), 400—403.

Obermiller, W. A. (1987): Geologic, structural and geochemical features of basaltic and rhyolitic volcanic rocks of the Smith Rock/Gray Butte area, Central Oregon, Master of Science (M. Sc.) dissertation, University of Oregon, 1—189.

O'Nions, R. K., Hamilton, P. J. and Evensen, N. M. (1977): Variation in $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ ratios oceanic bassalts, *Earth Planet Sci. Lett.*, 34, 13—22.

O'Nions, R. K., Hamilton, P. J. and Hooker, P. J. (1983): A Nd istotope investigation of sediments related to crustal development in the British Isles, *Earth Planet Sci. Lett.*, 63, 229—240.

Pearce, J. A. and Cann, J. R. (1973): Tectonic setting of basic volcanic rocks determined using trace element analysis, *Earth Planet Sci. Lett.*, 19, 290—300.

Peng, Z. C., Zartman, R. E., Fut, K. and Chen, D. G. (1986): Pb—Sr— and Nd—isotopic systematices and chemical characteristics of Cenozoic Basalts, Eastern China, *Chemical Geology (Isotope Geoscience Section)*, 59, 3—33.

Shen Yanbin (1991): A nonmarine Late Cretaceous deposit — Half Three Point Formation, For the sixth international symposium on Antarctic earth science, abstracts, ed. by Japan National Institute of Polar Research, 519.

Shen Yanbin (1989):南极乔治王岛菲尔德斯半岛晚白恶世火山岩地层的古生物证据,南极研究(中文版),2(1),27—33.

Shen Yanbin(1990):南极乔治王岛菲尔德斯半岛地层古生物研究新见,古生物学报,29(2),129—139.

Shen Yanbin(1992):南极乔治王岛菲尔德斯半岛有关地层划分、命名问题之商榷.南极研究(中文版),4(2).

Susumu Nohda and Wasserbury, G. J. (1981): Nd and Sr Isotopic study of volcanic rocks from Japan, *Earth Planet Sci. Lett.*, 52, 264—276.

Walton, D. W. H. (1987): Antarctic Science, chaper 13, Keystone to Gondwana, 174—187.

Yang Jiedong, Wand Yinxi, Tao Xianchong, Li Huiming and Wang Zongzhe (1986): Rb—Sr dating on the Cambrian—Ordovician boundary interval, In Chen Junyuan (ed.)., Aspects of Cambrin—Ordovician Boundary in Dayangcha, China, 72—82. China Prospect, Wuhu.

Wang Yinxi, Yang Jiedong, Tao Xiancong and Li Huimin (1988):化石,矿物和岩石样品的 Sm—Nd 同位素实验方法研究及其应用,南京大学学报(自然科学版),2,297—308

Wang Yinxi, Li Huimin, Tao Xiancong, Yanghao, Gu Lianxin and Guo Jeichun (1991):中天山东投花岗岩类 锶氧同位素及地壳形成年龄,岩石学报,3(3),19—26

Wang Yinxi, Yang Jiedong, Wang Jianmin and Yang Nianqiang (1991):苏州迂里多金属矿床 Sm—Nd Rb—Sr 成矿年龄及地质意义,科学通报,36(17),1326—1328

Watts, D. R. (1982): Potassium—Argon age and paleomagnetic results from King George Island, South Shetland Isalnds, In Craddock, C. (ed.), Antarctic Geoscience, 255—262.

ZhenXiangshen, Liu Xiaohan and Yang Ruiyin (1988):西南极长城站地区第三系火山岩岩石特征,岩石学报,1(1),34—47.

ZhenXiangshen, E Molan, Liu Xiaohan, Zhu Min and Li Jiaju (1991):西南极乔治王岛长城站地区第三系火山岩地质、岩石学特征及岩浆生成演化,南极研究(中文版), 3(2).

Zhu Min, E Molan, Liu Xiaohan and Zheng Xiangshen (1991):西南极乔治王岛菲尔德斯半岛火山岩同位素年代及地层对比,南极研究(中文版),3(2),126—135

Zindler, A. (1986): *Ann. Rev. Earth Planet. Sci.*, 14, 493—570.