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Paleomagnetism of Early Tertiary volcanics in the South Shetland Islands and its tectonic implications*

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Abstract A total of 334 oriented volcanic samples of Early Tertiary were collected for a paleomagnetic study from 43 sampling sites in the South Shetland Islands, Antarctica. Paleomagnetic study indicates that the South Shetland Islands and Antarctic Peninsula were situated in or close to their present position in Early Tertiary. Furthermore, it is also suggested that a counterclockwise rotation about 15 degrees related to the relative movement between South America and Antarctica took place in north of Antarctic Peninsula since Paleocene.

Key words South Shetland Islands, Early Tertiary, volcanics, paleomagnetism.

1 Introduction

The South Shetland Islands(SSI) lying on the northern margin of Antarctic Peninsula and extending about 550 km with the direction of NE－SW, consist of fifteen islands, among them the King George Island is the largest one. Tectonically, the islands are located at the conjunct place where Antarctica, South America and Scotia Plate are met together. South Shetland Islands, South Shetland Trench and Bransfield Strait constitute a perfect tectonic-morphologic system, i.e. trench-arc-basin system.

During 1990～1991 austral summer, the 7th Chinese National Antarctic Research Expedition carried on a cruise in China by RV “Haiyang Ⅳ” from MGMR(Ministry of Geology and Mineral Resources) to investigate comprehensive geoscience in West Antarctica and South Pacific Ocean. A large number of geological and geophysical data and samples were obtained. The present paper aims at explaining the tectonic movement of the area during Cenozoic based on the paleomagnetic study of Early Tertiary volcanic rocks of the isles together with previously-published geological and geophysical data.

2 Geologic setting of the South Shetland Islands

The Antarctic Peninsula(AP) with SSI on its north margin has gradually developed into Andean type magmatic arc since the breakup of Gondwanaland in Jurassic. It is one

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of the four crustal blocks, which comprise West Antartica, and the other three are Thurston Island-Eights Coast(TI), Ellsworth-Whitemore Mountains(EWM) and Marie Byrd Land(MBL)(Jankonski and Drewry, 1981; Dalziel and Elliot, 1982)(Fig. 1). SSI was separated from AP due to the opening of Bransfield Strait, a back-arc spreading center, at 1.5~2 Ma(Baker, 1982; Roach, 1978).

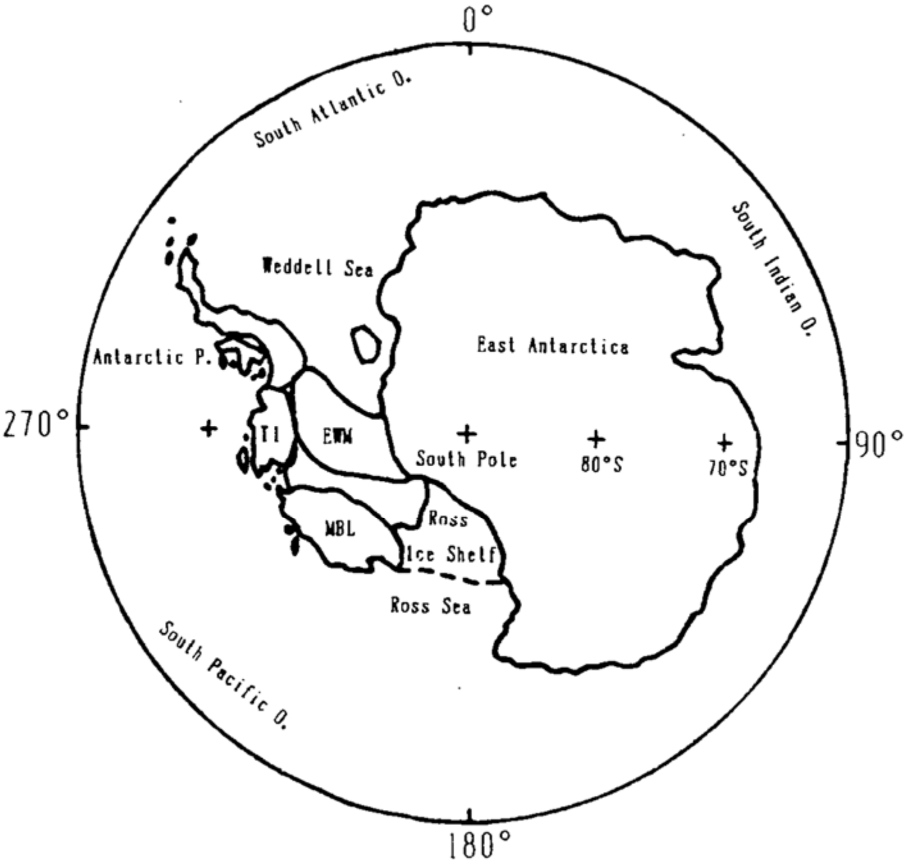

Fig. 1. The West Antarctica crustal blocks in their present day positions with respect to East Antarctica (from Grunow, 1993).

SSI is mainly composed of Mesozoic-Cenozoic volcanics. The volcanic activity could be traced to Early Cretaceous(Tomson *et al.*, 1983; Baker *et al.*, 1991). The accumulations known as Andean fore-arc sediments can be found in Snow Island and Livingston Island, where they are mainly composed of plant-bearing sandstone and shale intercalated with ammonite-bearing marine beds with the age being Late Jurassic-Early Cretaceous. The uncomformity with an age of pre-Middle Jurassic is a sign of the most important geological event in this area.

Mesozoic-Cenozoic volcanics are distributed widely in SSI. The volcanic activities are almost recorded completely. According to Hawkesz(1961), four groups of volcanic sequences could be divided. They are Mesozoic basalt-rhyolite suite on Byers Peninsula and Livingston Island, Early Tertiary basalt on Fildes Peninsula, King George Island, Pliocene-Peistocene basalt on the south coast of King George Island and Quaternary volcanics on Bribgeman Island and Penguin Island. Except Quaternary volcanics, Mesozoic-

Cenozoic volcanics are all calc-alkaline volcanic suite characterized by low content of K_2O and high value of Na_2O/K_2O(Tomson and Pankhurst, 1983). It is believed that they are formed due to the underthrust of Pacific Ocean crust and their source rocks are the partly molten mass of upper mantle wedge in undertrust zone(Kang, 1991). Tertiary volcanics on Fildes Peninsula and Navy Bay,King George Island have been studied more detailed relatively to the others. The Upper Cretaceous-Pliocene volcanic rocks in this area could be divided into six formations by Shen (1992)(Table 1).

Table 1. Stratigraphic division of the volcanic series in Fildes Peninsula (from Shen, 1992)

Fildes Peninsula Group	Mio.	Suffied point volcanics
	$E_{2\cdot3}$	Block Hill Formation, Fossil Hill Formation
	E_1	Agate Beach Formation, Jasper Hill Formation
	K_2	Half Three Point Formation

3 Sample source and laboratory procedure

A total of 334 oriented samples were collected from 43 sampling sites in King George Island, Greenwich Island and Lunar Island, SSI(Fig. 2). But oriented core samples were obtained with portable sample drill at sixteen sites in the area of Fildes Peninsula, King George Island,and oriented hand samples were collected at the other sites. All the samples were oriented by using magnetic compass after correction for local magnetic variation.

The samples were analyzed in the paleomagnetic laboratory at Guangzhou Marine Geological Analysis Center. Measurements were made using a computerized flux gate spinner magnetometer with a sensitivity of 10^{-4} A/m. The natural remanent magnetization(NRM) of the specimens is from 0.1 to 1 A/m. To avoide the effection of viscous magnetization, all the samples were measured in the space shielded by coils in electric currents, in which magnetic field intensity converges to zero.

All the samples are demagnetized progressively by using stepwise thermal techniques (TH) or alternating field (AF) to determine the best demagnetization procedure. Twelve-fourteen steps of generally 100 C up to 630 C were used during TH demagnetization, while steps of 5 mT up to a peak of 80 mT were used in AF demagnetization.

The measurement results show that remanent magnetization components of samples are generally simple. Most samples have only one single remanent magnetization component. In demagnetization procedure, the specimen's magnetization intensity decreases slightly from ordinary temperature to 550 C and drops down rapidly up to 600 C (Fig. 3a. A). It is believed that the Curie point is between 550 C and 600 C and the magnetic carriers are magnetite and titanomagnetite. It is showed that there is no obvious change in directions of declination and inclination during demagnetization procedure in orthogonal projection(Fig. 3a. B) while magnetized vectors are projected together in equal area projection (Fig. 3a. C). Fig. 3b shows the characters of another kind of samples with two magnetization components. In demagnetization procedure, magnetization intensity of the

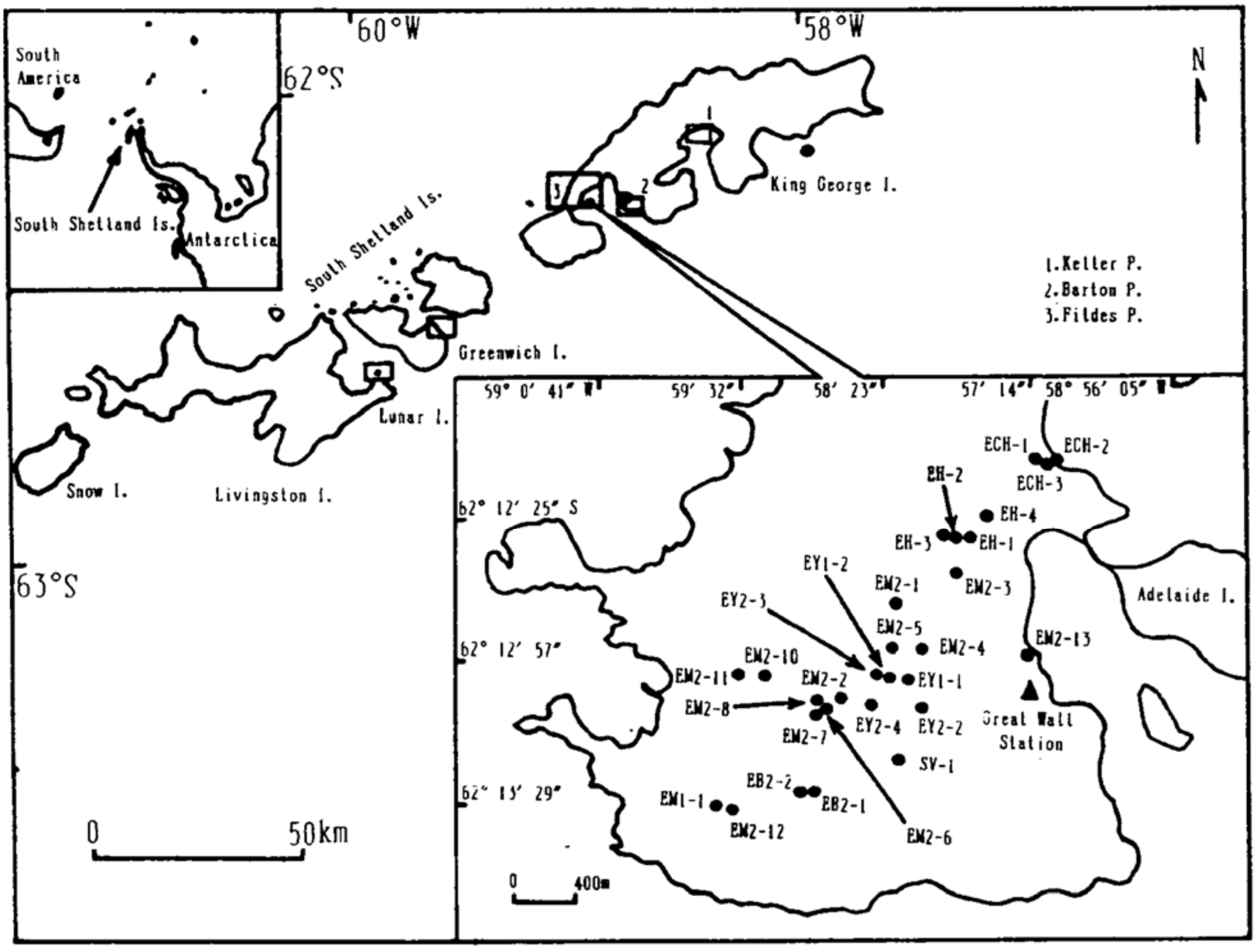

Fig. 2. Sketch map of the South Shetland Islands, showing the paleomagnetic sampling sites.

specimen decreases slowly but obviously from ordinary temperature to 200 C, and then keeps stably up to 550 C and decays rapidely down to the noisy level at 600 C (Fig. 3b. A). In orthogonal projection, it is showed that declination gradually changes from the first to the second phase (Fig. 3b. B). The projected points of magnetized vectors are dispersed in low temperature stage and concentrated relatively in high temperature stage (Fig. 3b. C). It is also indicated by linearity spectrum analysis and multicomponent analysis for the specimen that there are two magnetization components with higher linearism and greater colinear precision during demagnetization procedure and the higher unblocking temperature component converges toward coordinary origin. It is reflected that an unstable magnetization component with lower unblocking temperature is cleaned in low temperature stage. The component with higher unblocking temperature yields a similar direction with the samples characterized by single magnetization component and is believed to be the characteristic magnetization.

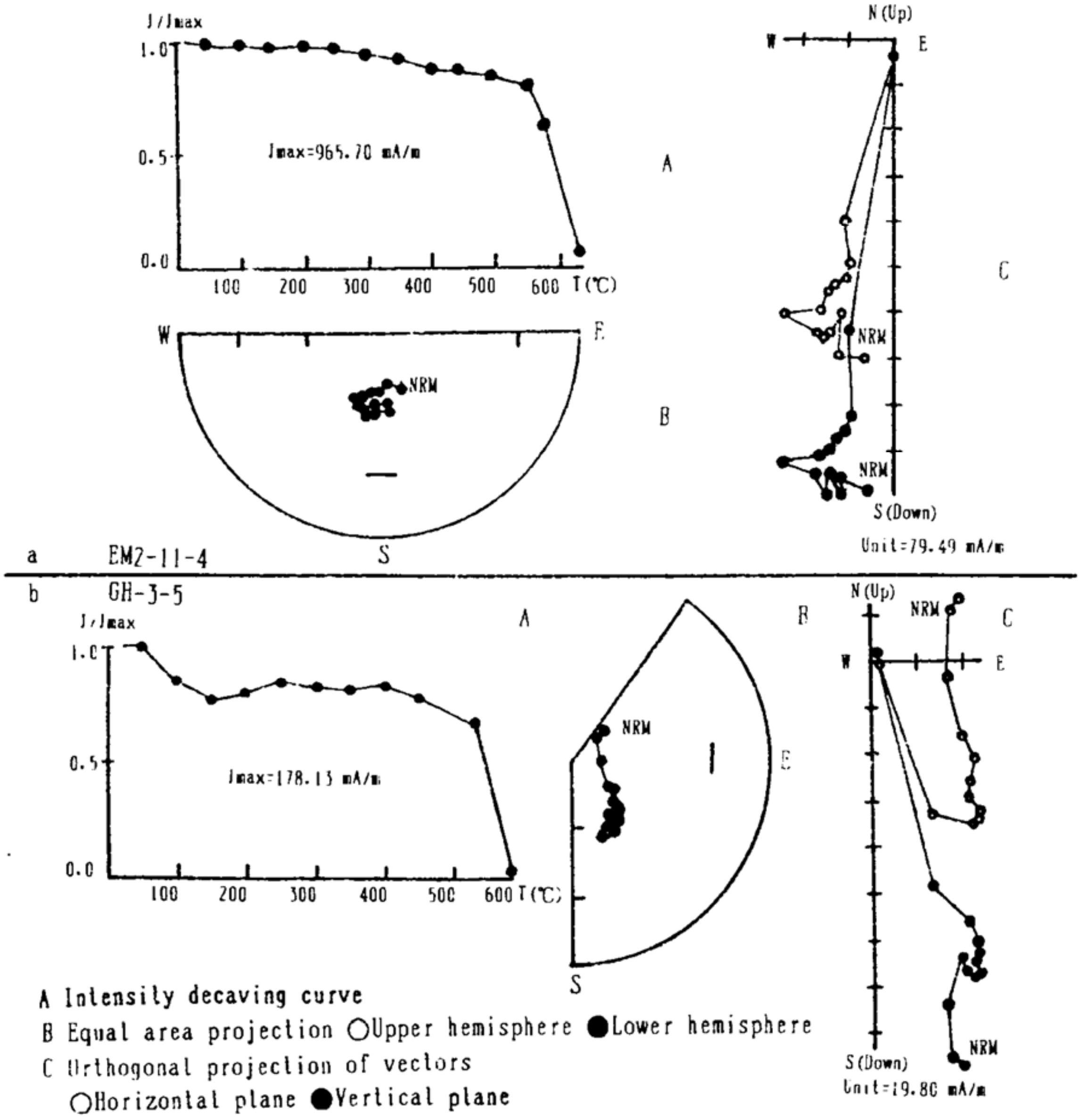

Fig. 3. Remanent magnetization analysis of the Early Tertiary volcanic rocks from the South Shetland Islands.

4 Paleomagnetic results

Mean directions for each locality are based on combining sample means to site mean and then site means to a unit mean using two-tier analysis(McFadden, 1982). Location mean poles are calculated using site mean virtural geomagnetic poles(VGPs).

Paleomagnetic data for each site are listed in Table 2. Data from thirty sites are used to calculate mean pole, while those of other thirteen sites are excluded due to various reasons as described below:

Table 2. Site mean directions and virtual geomagnetic poles from South Shetland Islands

Site	Locality		Lithology *	Samples	D	I	α95	K	VGP	
	Lon°W	Lat°S		n/N	(°)	(°)	(°)		Lon°E	Lat°S
Fildes Peninsula, King George Island										
ECH-1	58.953	62.203	Andesit basalt	5/5	331.6	-76.4	5.5	197.1	9.9	77.1
ECH-2	58.950	62.203	basalt	8/11	110.0	73.9	3.6	231.4	3.0	57.7
ECH-3	58.951	62.203	basalt	5/6	117.9	77.8	3.5	467.4	354.2	63.9
EM1-1	59.000	62.225	basalt	4/6	307.3	−57.8	8.8	110.9	42.8	50.5
EM2-1	58.972	62.213	porphyritic basalt	4/7	41.7	−70.1	2.5	1321.6	209.7	67.1
EM2-2	58.980	62.218	diabase	8/8	353.3	−63.1	2.2	633.3	105.4	71.9
EM2-3	58.963	62.210	basalt	9/9	17.9	−83.1	2.3	517.4	285.4	74.5
EM2-4	58.968	62.215	altered basalt	8/8	348.4	−67.6	1.5	1333.7	87.3	76.7
EM2-5	58.972	62.215	amygdaloidal tuff	11/11	356.8	−81.6	2.8	259.4	305.5	78.5
EM2-6#	58.982	62.218	basalt	5/5	31.2	18.3	4.3	317.9	332.9	14.4N
EM2-7#	58.982	62.220	basic breccia lava	7/7	57.8	44.7	8.2	55.7	351.3	9.8N
EM2-8#	58.983	62.218	basalt	10/10	196.7	46.0	6.4	58.4	146.4	53.5
EM2-10	58.990	62.217	basalt	3/4	328.3	−71.7	11.7	113.0	36.2	73.1
EM2-11#	58.993	62.217	basalt	8/8	212.3	62.1	2.6	450.7	181.1	63.4
EM2-12	58.995	62.225	basalt	4/5	280.3	−77.1	10.7	74.7	350.0	57.0
EM2-13#	58.955	62.215	basalt	5/5	154.2	−1.6	4.0	375.3	272.5	24.0N
EY1-1	58.972	62.217	basic agglomerate lava	8/8	29.3	−68.8	3.2	303.4	191.7	71.5
EY1-2	58.973	62.218	basic agglomerate lava	10/10	29.4	−72.6	1.9	666.9	208.0	74.8
EY2-2	58.968	62.218	basalt	10/10	14.4	−65.8	1.8	706.1	157.2	73.7
EY2-3	58.973	62.217	basalt	8/8	15.2	−65.3	3.6	239.5	158.0	72.9
EY2-4	58.975	62.218	andesit basalt	3/8	295.4	−79.1	10.9	129.9	348.2	63.2
EH-1	58.962	62.208	breccia tuff	9/11	286.2	−73.7	3.8	181.5	1.1	56.0
EH-2	58.963	62.208	breccia tuff	6/6	339.7	−62.8	6.7	101.6	78.4	68.5
EH-3	58.963	62.206	breccia tuff	9/9	324.4	−73.6	1.1	2254.4	23.9	72.7
EH-4#	58.960	62.206	diabase	3/3	242.5	87.2	1.3	9446.6	289.5	64.3
EB2-1#	58.983	62.223	basic breccia lava	6/7	311.4	−27.0	28.7	6.4	62.8	31.1
EB2-2	58.984	62.223	basic breciaa lava	9/10	189.7	68.7	4.2	178.9	152.7	78.6
SV-1	58.972	62.222	basalt-porphyrite	9/12	340.4	−60.2	3.2	256.1	82.8	65.8
Keller Peninsula, King George Island										
GH-1#	58.427	62.083	andesit basalt	11/11	168.0	43.3	3.6	160.7	103.7	52.3
GH-2	58.428	62.083	andesit basalt	6/6	152.3	51.9	5.2	165.0	77.8	55.5
GH-3	58.417	62.082	basalt	8/8	151.9	73.8	4.1	182.9	28.8	76.3
GH-4	58.408	62.082	andesit basalt	4/6	144.1	73.2	8.5	118.5	25.8	72.3
GH-5	58.412	62.078	andesit basalt	6/6	231.1	80.0	9.5	51.0	256.2	68.6
Barton Peinisula, King George Island										
B-1#	58.773	62.237	diorite	4/4	353.5	71.4	3.7	631.0	297.1	28.4
B-2	58.767	62.235	tuff	10/10	209.6	72.6	2.9	271.3	208.3	74.8
Greenwich Island										
F-1	59.623	62.483	breccia andesite basalt	4/7	115.6	73.0	3.8	579.5	7.9	59.4
F-2	59.618	62.483	breccia dacite	8/8	145.3	77.0	7.3	58.7	5.2	74.7
F-3#	59.615	62.485	amygdaloidal andesit andesite basalt	8/8	185.1	29.9	3.2	291.9	127.2	43.4
Lunar Island										
ML-1	59.917	62.583	breccia andesite	8/8	193.0	65.5	3.1	323.5	152.1	73.4
ML-2#	59.917	62.583	andesite	8/8	123.6	21.3	1.4	1537.2	55.9	24.8
ML-3	59.917	62.583	diorite	9/9	208.2	76.2	1.5	1115.1	228.2	77.3

n/N: number of samples used for site mean calculation/total number of samples; D: declination in degrees; I: inclination in degrees; K: estimate of precision parameter; α95: radius of error circle at the 95% confidence level for site mean direction; VGP: virtual geomagnetic pole; *: field designation; #: site rejected.

Sites EM2-9 and EY2-1 from Fildes Peninsula are rejected because no significant site mean directions can be concluded due to various magnetization directions of the samples. Data from sites EM2-6, EM2-7, EM2-13 in Fildes Peninsula, B-1 in Barton Peninsula, F-3 in Greenwich Island and ML-2 in Lunar Island are in disagreement with the model of axial geomagnetic dipole field or are in conflict with some conclusions about austral plates evolution based on a quantities of geological and geophysical data published. This is because of secular variation or uncorrect tectonic tilt correction. Sites EM2-8, EM2-12, EH-4 in Fildes Peninsula and GH-1 in Keller Peninsula are rejected due to unclear strata occurrence in the field. Site EB2-1 in Fildes Peninsula is refused because of its too great α95(28. 7°). Paleomagnetic data from thirty sites used are listed in Table 3.

Table 3. Location mean directions and paleopoles from the South Shetland Islands

Strata and rock	Time	Sample n/N	Polarity	D (°)	I (°)	α95 (°)	K	Paleopole Lon. °E	Paleopole Lat. °S	PLAT (°S)
Fildes Peninsula, King George Island (59. 0°W, 62. 2°S)										
Jasper Hill Fm.	E_1	1/8#	R	189. 7±8. 9	68. 7±3. 2	4. 2	178. 9	152. 7±7. 0	78. 6±6. 0	52. 1
Agate beach Fm.	E_2	9/58	N	339. 1±26. 1	−75. 0±6. 8	8. 5	37. 3	24. 0±15. 6	80. 2±14. 2	61. 8
		2/13	R	113. 4±27. 4	75. 9±6. 6	9. 5	696. 2	358. 9±17. 5	60. 9±16. 1	63. 3
		11/71				7. 3	40. 4	14. 2±13. 4	77. 0±12. 3	63. 2
Fossil Hill Fm.	E_{2-3}	3/24	N	321. 2±39. 5	−71. 4±12. 6	16. 9	54. 8	30. 7±29. 5	69. 5±25. 8	56. 1
Block Hill Fm.	E_{2-3}	5/39	N	14. 0±26. 9	−72. 2±8. 2	10. 7	52. 6	182. 8±18. 8	81. 5±16. 7	57. 4
Fildes Peninsula Group	E_1-E_3	21/151				5. 1	40. 0	37. 3±9. 2	81. 9±8. 3	60. 3
Keller Peninsula, King George Island (58. 4°W, 62. 1°S)										
Basalt	E_2	4/24	R	158. 3±44. 0	71. 7±13. 8	18. 2	26. 5	48. 4±32. 0	77. 7±28. 1	56. 5
Barton Peninsula, King George Island (58. 8°W, 62. 2°S)										
Tuff	E_{2-3}	1/10#	R	209. 6±7. 8	72. 6±2. 3	2. 9	271. 3	208. 3±5. 2	74. 8±4. 6	57. 9
Greenwich Island (59. 6°W, 62. 5°S)										
Andesite	E_2	2/12	R	128. 5±52. 2	75. 5±13. 1	18. 7	180. 3	7. 0±34. 3	66. 9±31. 5	62. 6
Lunar Island (59. 9°W, 62. 6°S)										
Andesite	E_2	2/17	R	199. 5±55. 5	71. 0±18. 1	25. 8	95. 7	181. 5±45. 0	78. 1±39. 2	55. 4

n/N: number of sites/number of samples; N: normal polarity; R: reversed polarity; PLAT: paleolatitude; #: paleopole calculated using sample means.

4. 1 *Fildes Peninsula, King George Island*

4. 1. 1 *Jasper Hill Formation (JF)*

Samples were obtained by drilling from one site. The site mean direction for eight samples reversely magnetized is: D=189. 7°, I=68. 7°(α95=4. 2°). As compared with the data published by Liu *et al.* (1991) (D=323. 6°, I=−75. 8°, α95=10. 6°, n/N=1/6) they are different in declination and in the opposite polarities. Thus, these data were not used by the statistic analysis to calculate a mean pole. Therefore, the unit pole listed in Table 3 can't be treated as an independent reliable mean pole, but only as a VGP used to calculate the location mean pole.

4. 1. 2 *Agate Beach Formation (AF)*

Samples from this formation yield normal and reversal remanences. The unit mean direction for the nine sites with a total of fifty-eight specimens normally magnetized is: D=339. 1°, I=−75. 0°(α95= 8. 5°). The unit mean direction for the two sites with thirteen specimens reversely magnetized is: D=113. 4°, I=75. 9°(α95=9. 5°). The two unit data can pass reversal test roughly. The large difference in their declinations is due to the special geographic position, which is close to geomagnetic pole in such a high latitude area. The unit mean pole calculated on the mean direction of eleven sites is: 14.2°E, 77.0°S(A95=7.3°).

4.1.3 *Fossil Hill formation (FF)*

Twenty-four specimens normally magnetized are measured. The unit mean direction for three sites is D=321.2°, I=−71.4° (α95=16.9°) and is similar to the mean direction of AF. The geological data show that FF lies unconformably over AF with a gentle dip angle (Zhen and Liu, 1990). There is a transient lacuna of accumulation between them. It is also comfirmed that the ages of the two formations differ slightly by isotopic dating(Zhen and Liu, 1990). Therefore, it is also confirmed that the mean directions for the two formations are similar. The unit mean pole is calculated to be 30.7°E, 69.5°S.

4.1.4 *Block Hill Formation (BF)*

Thirty-nine specimens measured are normally magnetized. The unit mean direction for five sites is: D=14.0°. I=−72.2° (α95=10.7°). As compared with underlying AF and FF, there is obvious difference in their declinations. The unit mean pole is 182°E, 81.9°S.

4.1.5 *Subvolcanics*

Twelve samples were collected by drilling from one site (basalt-porphyrite dike). The mean direction is: D=340.4°, I=−60.2° (α95=3.2°, N=9). It is similar to the directions of AF and FF.

Based on the mean directions of twenty-one sites mentioned above, the mean pole of Fildes Peninsula, King George Island is calculated to be 37.3°E, 81.9°S, α95=5.1° during Paleocene-Oligocene(Tab. 3).

4.2 *Keller Peninsula, King George Island*

All the samples from Admirlty Bay Group are reversely magnetized. The unit mean direction of four sites is: D=158.3°, I=71.7°(α95=18.2°). Based on the site mean the unit mean pole is calculated to be 48.4°E, 77.7°S. It is consistent with the mean pole of Fildes Peninsula.

4.3 *Barton Peninsula, King Geore Island*

Fourteen samples were collected from two sites. But only the data of ten samples from one site were used to make a statistic calculation. A reversal magnetization component pointing steeply downward to the south-southwest is consistently found. The site mean direction is: D=209.6°, I=72.6° (α95=2.9°). Obviously it differs from the mean directions of Fildes Peninsula and Keller Peninsula especially in declination. It can't be confirmed whether the site mean direction characterized a regular geomagnetic field or a paleosecular variation. Since no reliable paleomagnetic data of Baton Peninsula has been seen at present, it is obtained here and used as a VGP to calculate the location mean pole.

4.4 *Greenwich Island*

Twelve samples measured from two sites are reversely magnetized. The unit mean direction is: D=128.5°, I=75.5° (α95=18.7°) and the unit mean pole is 70°E, 66.9° S. They are consistent with the data of Fildes Peninsula and Keller Peninsula, King George Island.

4.5 *Lunar Island*

Seventeen samples from two sites are reversely magnetized with a consistent magnetization component pointing to south-southwest steeply downward. The unit mean direction is: D=198.5°, I=71.0° (α95=25.8°). It is similar to the data of Barton Peninsula but different from the data of Greenwich Island and Livingston Island (Dalziel *et al.*, 1973). The isotopic ages of sites ML-2 and ML-3 are dated at 49.6 Ma and 43.0 Ma respectively, that of site F-3 in Greenwich Island at 47.5 Ma and that of Livingston Island at 46.1 Ma. The ages of these volcanics seem to coincide roughly. The various directions may be due to the fact that volcanics were magnetized rapidly by paleogeomagnetic field while cooling.

Based on the paleomagnetic data mentioned above, a mean pole for SSI during Paleocene-Oligocene is calculated to be 37.0°E, 82.5°S (A95=4.2°, N=30 VGPs). Its paleolatitude is 60.2°±5.5°. It can be seen that this mean pole is consistent to what has been previously published (Table 4).

Table 4. Early Tertiary paleopoles of Antarctic Peninsula

Locality	Age (Ma)	Plaoepole		A95 (°)	Basis for poles
		Lon°W	Lat°S		
South Shetland Island	55～22#	37.0±7.6	82.5±6.9	4.2	this paper; N=30 VGPs from Barton Peninsula (1), Keller Peninsula (4), Filds Peninsula (21), Lunar Island (2), and Greenwich Island (2)
Livingston Island	46±1	21	81	9.0	Daziel *et al.* (1973)*
Snow Island	54	17	70	8.2	Watts *et al.* (1984)*
King George Island	49	48	79	8.0	Watts *et al.* (1984)*
Moot Point	～55	359	64	5.9	Grunow (1993); N=13 VGPs
Snow Island	～55	357	81	8.1	Grunow (1993); N=3 VGPs
South Shetland Islands	50	21	78	7.5	Grunow (1993); N=4 poles

A95: radius of error circle at 95% confidence level for the mean pole based on the site mean VGP; #: from Zhu *et al.* (1991); *: calculated by Grunow (1993).

5 Interpretation of paleomagnetic results and their tectonic implication

When studing the tectonic evolution of AP Block, It is necessary to review the history of Gondwanaland breakup at first. Based on interpretation of marine magnetic anormalies (Norton and Sclater, 1979; Lawver *et al.*, 1985), Gondwanaland broke along faults paralleled to the present East African coast in Late Triassic—Early Jurassic. Africa and South America were separated from each other in Early Cretaceous, while South Atlantic Ocean opened due to sea-floor spreading. Simultaneous separati on is possible between India and Australia-Antarctica. In Late Cretaceous, India was separated from Madagascar. It is also confirmed that in Eocene Australia was separated from Antarctica and joined with the Indian Plate.

It is believed that East Antarctica has yielded a dextral movement characterized by clockwise rotation since Gondwanaland breakup according to geological and geophysical data published. This view has been accepted by most researchers. But paleomagnetic results listed in Table 3 and Table 4 indicate that northen AP rotated counterclockwisely in about fifteen degrees since Paleocene. It is believed that this counterclockwise rotation is suited to the conditions of the boundary between South America and Antarctica, and a disscusion is made in the following. Paleomagnetic results also show that AP Block was roughly in its present position during Paleocene and no obvious north-south displacement has taken place since then.

Geological data existng show that SSI was once connected with AP. It was separated from AP due to the opening of Bransfield Strait at 1. 5～2 Ma (Baker, 1982; Roach, 1978). AP Block and other blocks comprised West Antarctica, which together with East Antarctica might be at or near their present position in Late Cretaceous. Lawver *et al.* (1985) indicated that MBL Block joined East Antarctica at 135 Ma. Paleomagnetic data (Grunow *et al.* 1991; Grunow, 1993) show that AP Block and TI Block coincide in magntic pole with East Antarctica in Late Cretaceous. It is believed that West Antarctica joined East Antarctica during mid-Cretaceous. The closure of Rocas Verds Basin in mid-Cretaceous (Dalziel *et al.*, 1974) and the compression deformations distributed widely in the sediments in fore-arc and back-arc basins in the area of AP (Baker *et al.*, 1991) could be caused by the joining. It is due to the continuous clockwise rotation of East Antarctica since GondwanaLand breakup that AP Block and the others in West Antarctica joined East Antarctica in mid-Cretaceous. This fact shows that AP Block has been a part of Antarctica since Late Cretaceous.

A large quantities of existing geological data indicate that AP was part of Andean magmatic arc, being close to Pacific margin during Mesozoic (Tomson *et al.*, 1983; Baker *et al.*, 1991). AP was connected with South America before Miocene which is evidenced by the Ankylosauria found in Campanian marine strata from James Ross Island (Olivero *et al.*, 1991) and by Polydolopidae found in Oligocene strata from Seymour Island (Woodburne and Zinsmeister, 1983). Therefore, the AP Block moved only with South America before it closed to East Antarctica. After the closure of West Antarctica to East Antarctica and before the opening of Drake Passage (Baker and Burrell, 1977; Baker *et al.*, 1991), AP may be a continental bridge connecting South America and Antarctica just like the presen isthmus of mid-America.

Before the closure, AP Block was located at the south end of South America and separated from the other blocks in West Antarctica and East Antarctica. It moved westwards with South America due to the opening of Weddell Sea in Late Jurassic-Early Cretaceous (LaBrecqu and Baker, 1981) and the spreading of South Atlantic in Early Cretaceous (Baker *et al.*, 1991).

After the closure, the south boundary of AP greatly changed, as it was connected with Antarctic continent. Relatively, South America drifted westwards faster than its does at present. It moves in a speed of 20～24 mm/a(Chase, 1978; Minster and Jordan, 1978) due to the continuous spreading of South Atlantic since Early Cretaceous. Because AP Block was restricted by Antarctic continent on south, it could not move freely with South America as it did before the closure. Therefore, the northern AP Block rotated counterclockwisely drived by the westward drifting of South America partly due to its strip solide shape, which colud be narrower than at present. The westward motion of South America relative to Antarctica furtherly led to a sinistral strike-slip in the most frail area between South America and Antarctica so that a series of sinistral strike-slip faults, such as magellan-lago Fagrano Fault were formed. It perhaps resulted in the spreading of Scotia Plate. It is believed that the continental segments, such as South Georgia Island and South Orkney Islands disperse in Scotia Sea due to the combination of the westwrad motion of South America, the sinistral strike-slip and the spreading of Scotia Sea. Baker *et al.* (1991) revealed that the continental segments dispersing in Scotia Sea now were located at a position close to the north end of AP before 30 Ma.

Counterclockwise rotation discussed in this paper might range be from Late Cretaceous to late Oligocene when Scotia Plate was spreading. It seemed that the spreading of Scotia Plate would lead to clockwise rotation of AP.

Considering that the blocks in West and East Antarctica were close to their present positions in Late Cretaceous(Grunow, 1993) and the geological and geophysical data show that no tectonic movement took place between AP and Antarctica continent in Cenozoic, paleomagnetic data in this paper sign a motion restricted in a partical area of AP. This rotation is related directly to its special solid shape. It is thought that the south boundary of the area rotated may be near the southern protrusion of the "S" shape of AP. It protruded eastwards due to the counterclockwise rotation of northern area. Further detailed researches are needed to prove it.

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