Antarctic Research, Vol. 3, No. 1, 40～49, June 1992

PALEOMAGNETISM OF THE LATE CRETACEOUS AND EARLY TERTIARY ROCKS FROM FILDES PENINSULA, WEST ANTARCTICA, AND ITS GEOTECTONIC SIGNIFICANCE

Liu Chun[1], Zhu Rixiang[2], Zheng Xiangshen[1], Liu Xiaohan[1]

Jin Zengxin[1], Feng Yu[1]

[1] *Institute of Geology, Academia Sinica, Beijing, 100029*

[2] *Institute of Geophysics, Academia, Sinica, Beijing, 100101*

Abstract The paleomagnetis m of 109 oriented samples collected from drill cores through 5 rock units of Late Cretaceous and Early Tertiary on Fildes Peninsula were systematically studied. According to the study, the paleomagnetic pole position of this area is different from the position of Australia during the 55 — 45 Ma period. This means that when the break — up of the Gondwanaland at 55 — 45 Ma ago, Australia was separated from the Gondwanaland, drifting southward 20° — 30° Lat. and rotating 70° — 80° westward and then gradually arriving at recent position . The paleolatitudinal data indicate that it is not impossible that the area studied was covered with land glacier at that time. The apparent polar wander path of Antarctica through the geological time are also roughly worked out.

Key words Fildes Peninsula, paleomagnetic pole position, tectonic displacement, apparent polar wander path.

Introduction

According to the geotectonic and geograhic features, Antarctica can be divided into two parts, East Antarctica and West Antarctica. Most area of Antarctica land is covered with glaciers. In the early Paleozoic era, Antarctica was combined with the other continents of the Southern Hemisphere and formed the Gondwana land. At the late Triassic period and early Jurassic of the Mesozoic era, the Gondwana land began breaking up and then was gradually dissociated into the continental plates: South Africa, South America, India, Australia, New Zealand and Antarctica (McElhinny. 1973).

The paleomagnetism study on Antarctica started from the early 1960s. Tumbull reported the paleomagnetic result of the Jurassic trachybasalt in 1959. Then Scharon *et al.* (1969, 1970) made some paleomagnetic measurements of Cambrian and Ordovician rock in the area. In 1973, McElhinny reported some limited paleomagnetic data on Antarctica. Later, some researchers reported more paleomagnetic results on Mesozoic and Cenozoic volcanic rocks successively (Valencio, 1979; Watts, 1982, 1984). In China, the paleomagnetism study work on Antarctica started from 1985. Zhu Zhiwei and Li Huamei made some paleomagnetic measurements of Cambrian metamorphic rock, Jurassic igneous rock on the Cross Mountain, and Quarternary sediments in the Fildes'lowland area of East Antarctica at 1985 and 1990. But so far, all the paleomagnetic data about Antarctica were incomplete and hard to be used in explanation of geologic evolution history of Antarctica and its adjacent continents.

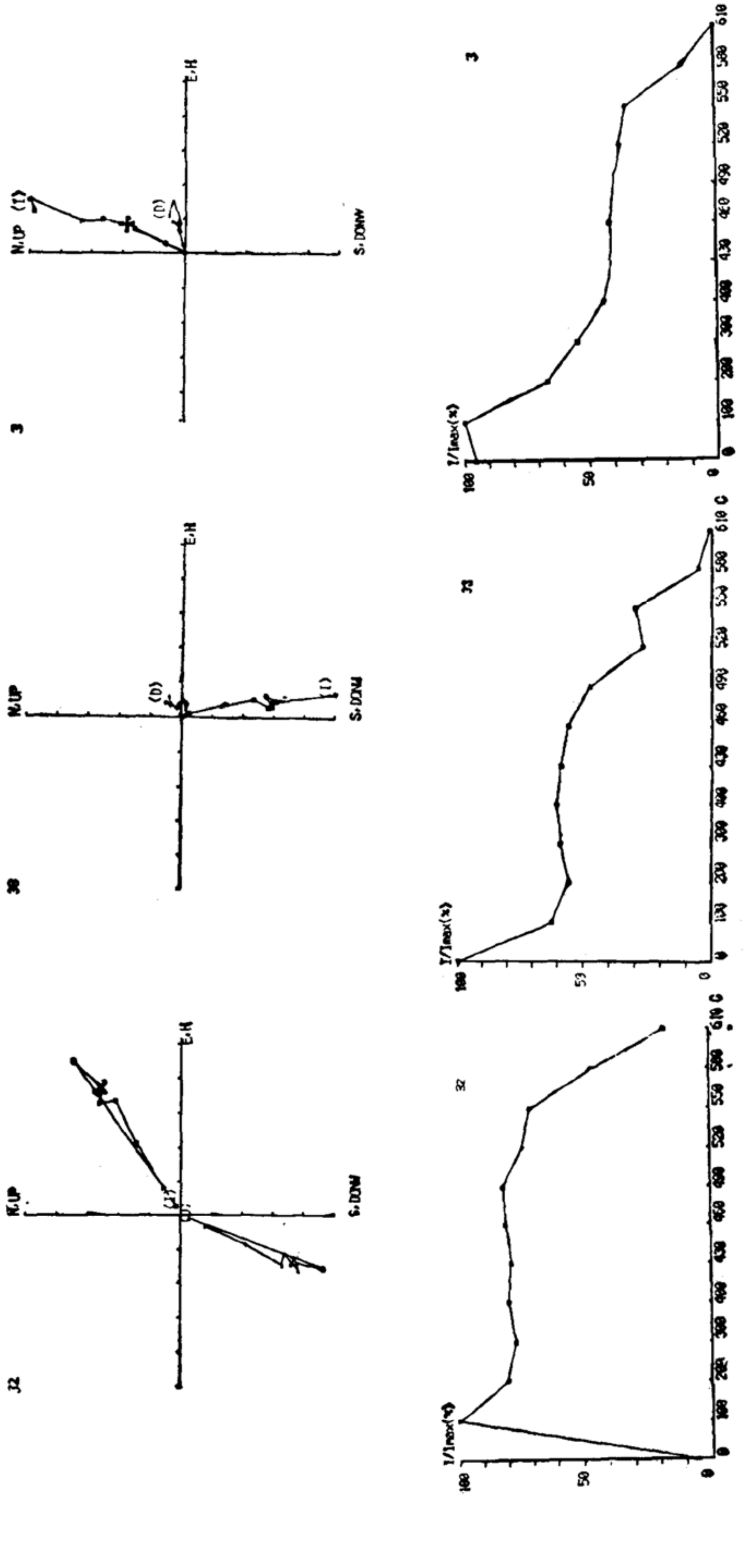
The purpose of this paper is to report the paleomagnetic results of Late Createaceous and Early Tertiary rocks on Fildes Peninsula of West Antarctica, study the location of Antarctica at that time and its geodynamic relationship with its adjacent continents, and clarify their geotectonic evolution features.

Geological Background and Sampling

the Fildes Peninsula is located on West Antarctica, and is one part of the King George Island of the South Shetland Islands. Its area is about 40 km^2. Basaltic lava and pyroclastic —sedimentary rocks are exposed there. The rock formations occour as gentle monocline with its dip to ENE or NNE at an angle generally of 10°—20°, and 30° in maximim. Their total thickness is 300—400m. With reference to the age of these formations, including the Late Cretaceous age of the pyroclastic — sedimentary layers in the semitriangle area determined by Shen Yanbin from his sporo—pollen analysis data of *Deltoidospora hallii*, *D. Microleoides*, *D. Regularis*, *d.* Sp., *Cyathidites minor*, *C.* Sp., *Osmundacidites* Sp., *Ornatisporites*; Sp., *Asterisporites* Sp., *Gleicheniidites senonicus*, *G.* Spp., *Polypodiisporites favus*, *P.* Sp., *Araucariacites* Sp., *Nothofagidites* Spp., *N. senectus*, *N. nonus Tricolporollenites* Sp., and the former isotope data of 106. 0±1. 2Ma; 64. 4±0. 8Ma and 79. 2±2. 6Ma, the Chinese researches have classified all volcanic rock formations in Fildes Peninsula into four suits of stratigraphic units. They are Jasper Hill Member, Agate Beach Member, Fossil Hill Member and Block Hill Member. Their isotope ages are 44. 9±0. 6Ma, 55. 4±5. 9Ma, 50—45Ma and 19—23Ma, respectively. From these data we can know the volcanic activities were mostly concentrated in a period from the Late Paleocene to Oligocene, and some are in the early Miocene (Liu Xiaohan, Zhen Xiangshen, 1988; Zheng Xiangshen *et. al*, 1989).

Table 1. Paleomagnetic data of Late Cretaceous and Early Tertiary rocks from Fildes Peninsula.

data No.	rock unit	site	samp.	locality	mean remanence D	mean remanence I	K	α_{95}	Paleomagn. Pole λ	Paleomagn. Pole φ	δ_p	δ_m	Paleo Latitude
1	Half Triangle Pyroclastic Sediment. rock	1	5	Half Triangle	347.07	−73.65	107.27	6.05	107.82	−83.21	9.77	10.87	59.60
	Jasper Hill Member												
5	Basaltic Andesite	1	6	by the Fildes Passage of Jasper Hill	323.60	−75.84	29.03	10.61	11.31	−73.51	17.99	19.53	63.23
	Agate Beach Member												
3	Basaktuc andesite	1	7	Oil Reservoir Beach	340.01	−75.41	33.05	9.20	201.00	−80.78	15.47	16.87	62.50
4	Basaltic andesite	1	10	West Lake	347.06	−73.57	24.69	8.91	229.45	−83.11	14.37	16.00	59.47
10	Basaltic andesite	1	4	South Part of Ardley Island	54.36	−70.63	18.82	16.14	221.40	−61.63	24.26	27.98	54.88
11	Basaltic andesitic Lava	1	5	North Part of Ardley Island	18.20	−74.61	23.47	12.92	212.39	−81.34	21.34	23.49	61.17
12	Andesitic dacite	1	11	North Height (Davies)	359.52	−72.29	22.90	8.82	297.98	−85.22	13.81	15.61	57.43
6	Basalt	1	4	Long Hill	34.84	−76.96	37.80	11.39	237.14	−74.50	19.75	21.21	65.15
	mean	6	41		12.82	−75.55	98.75	5.75	221.99	−81.06	9.69	10.56	62.74
	Fossil Hill Member												
8	Pyroclastic sediment. rock	1	6	North Bank of Glubok Lake	10.95	−79.09	16.40	11.11	272.02	−81.92	25.49	26.[illegible]	68.92
9	Tuffaceous Sandstone, siltstone	1	17	Fossil Hill	17.55	−70.63	6.76	13.06	180.22	−78.35	19.63	22.64	54.89
	Mean	2	23		15.15	−74.88	176.78	7.45	209.02	−82.86	12.37	13.57	61.62
	Block Hill Member												
2	Agglomeratic lava	1	7	Panlong Hill	353.57	−68.81	55.53	7.10	279.08	−79.43	10.2[illegible]	12.04	52.21
7	Basaltic andesite	1	6	[illegible]	[illegible]	[illegible]	[illegible]	11.79	277.[illegible]	−62.[illegible]	21.25	22.38	68.72
	Mean	2	[illegible]		[illegible]	[illegible]	[illegible]	9.[illegible]	[illegible]	[illegible]	15.27	16.92	60.17


N,UP
S,DOWN
E,H
I/Imax(%)

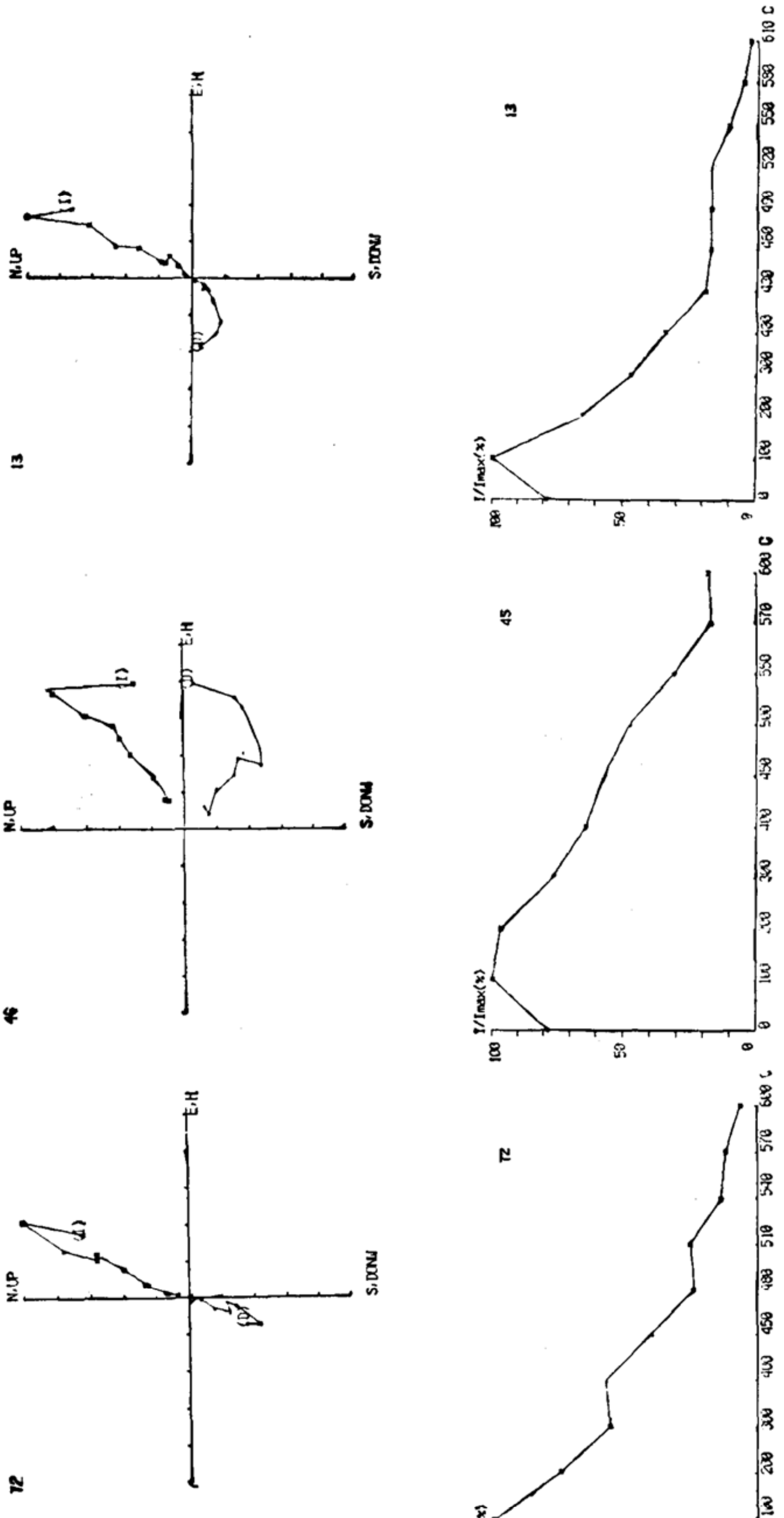


Fig. 1. Thermal demagnetization Curves of some rock specimens.

From November 1986 to March 1989, Zhen Xiangshen carried out the field works twice on the Fildes Peninsula area and sampled paleomagnetically oriented cores with compass and portable drill. Totally 105 samples at 12 sampling sites are 5 Late Cretaceous Liparite samples at the Semi—Triangle, 6 samples from Jasper Hill Member near the Fildes Channel, 41 samples from the Agate Beach Member at the Oil Warehouse Beach, Weat Lake, North Platform and the North of Adelay Island and the Esat German Haven, 23 samples from the Fossil Hill Member at the Gluboko Lake and the Fossil Hill, and 13 samples from the Block Hill Member at the Wind Dragon Mountain. All samples were transported to lab and processed into 250 specimens(2—2. 2×2. 54cm).

Paleomagnetic Measurement and Result

The laboratory work on all paleomagnetic specimens were made at the paleomagnetic laboratory of the Institute of Geology, Academia Sinica. The remnant magnetization of the specimens were measured on a Minispin with high precision and zero—magnetization space. This kind of zero magnetic space is made of HCM 3—2 triaxial—square Helmholtz coil. fitting with electric current feedback and automatic compensation equipment. The magnetometer has four meassuring ranges, from 0.1×10^{-6} to 2500×10^{-6} emu. cm^{-3}. For a specimen of 12. 87 cm^3 cube. when the integral time is 6 second, the noise level is 0.2×01^{-6} emu. cm^{-3}; when the integral time is 24 second (24 circle), the noise level is higher than 0.1×10^{-6} emu. cm^{-3}, The magnetization strength is 8.8×10^{-5} emu. cm for the samples from sedimentary rock at the Semi—Triangle area 229.0×10^{-4} emu. cm^{-3} for the andesite samples from Jasper Hill Member, 196.9×10^{-4} emu. cm^{-3} for the black samples from the Agate Beach Member, 574.7×10^{-4} emu. cm^{-3} for the basalt—andesite samples, 87.6×10^{-4} emu. cm^{-3} for the samples from phyroclastic—sedimentary rocks of the Fossil Hill Member, and 1145.2×10^{-4} emu. cm^{-3} for the samples of basalt—andesite and volcanic massive lava from the Block Hill Member. All specimens were demagnetized by the TSD—1 thermodemagnetometer by gradual thermodemagnetization at temperature steps of 100℃, 200℃, 300℃, 350℃, 400℃, 430℃, 460℃, 490℃, 510℃, 540℃, 570℃, and 600℃.

From the amalysis result of relative strength attenuation carves in the demagnetization process. we can find two kinds of magnetization carriers in rocks, one is the carrier with single component, its Curie temperature is 550—600℃ and block temperature is 500—600° C. Obviously this magnetic mineral is magnetite (Fig. 1, Specimen No. 32, No. 38,No. 3). The other one is the carrier with complex components. Their block temperature is 400—430℃, 510—520℃, and 550℃, respectively. The magnetic mineral is a transition mineral of magnetite—titanomagnetite series. (Fig. 1 Specimen No. 72, No. 46, No. 13).

Table 2. Paleomagnetic Data of Late Cretaceous and Early Tertiary Rocks from West Antarctica, Australia and South America.

Lacality	Age	Paleomagn. Pole		eference
		φ	λ	
West Antarctic	K—J	86S	164E	MeElhinny, M. W., 1973
	K_1	56S	172E	Watts, D. R., 1982
		47S	120E	Watts, D. R., 1982
	102±5Ma	73S	104E	Valencio, D. A., 1979
	94±6Ma	84S	138E	Valencio, D. A., 1979
	110—61Ma	85S	192E	Valencio, D. A., 1979
	58—49Ma	77S	78W	Watts, D. A., 1982
	45Ma	86S	126E	Valencio, D. A. *et al.*, 1969
Australia	K2	56S	138E	McElhinny, M. W., 1973
	100Ma	66S	197E	Klootwijk, C. T. *et al.*, 1979
	98Ma	71S	200E	Klootwijk, C. T. *et al.*, 1979
	93Ma	82S	187E	Klootwijk, C. T. *et al.*, 1979
	93Ma	74S	206E	Klootwijk, C. T. *et al.*, 1979
	63Ma	63S	140E	MeElhinny, M. W., 1973
	57Ma	84S	88E	MeElhinny, M. W., 1973
	55Ma	80S	191E	MeElhinny, M. W., 1973
	52Ma	86S	293E	MeElhinny, M. W., 1973
	52Ma	70S	126E	MeElhinny, M. W., 1973
South America	K	63S	30E	MeElhinny, M. W., 1973
	K	78S	56E	MeElhinny, M. W., 1973
	Tr	75S	286E	MeElhinny, M. W., 1973
	Tr	73S	191E	MeElhinny, M. W., 1973
	Tr—θ	87S	312E	MeElhinny, M. W., 1973

Using a main vector analysis method, we know the remanent magnetization got at the thermodemagnetization temperature of 500 — 550°C is the characteristic remanent magnetization of rocks. The declination is ENE or WNW, inclination is —70°, Putting these values into the equation of sinusoid law in spherical trigonotry and calculating test data on computer, we can get various paleomagnetic pole positions of different stratigraphic units: 83.21°S and 107.82°E for the pyroclastic—sedimentary rocks at the Semi Triangle, 73.51°S and 11.31°E for the Jasper Hill Member, 84.06°S and 221.99°E for the Agate Beach Member, 82.86°S and 209.02°E for the Fossil Hill Member and 87.86°S, 219.41°E for the Black Hill Member. From these data we can calculate the average paleolatitudes for the corresponding sampling sites. They are 59.60°S in the late Cretaceous and 63.23—60.17°S in the Early Tertiary.

Discussion and Conclusions

According to the paleomagnetic results shown in this paper, the authors try to discuss

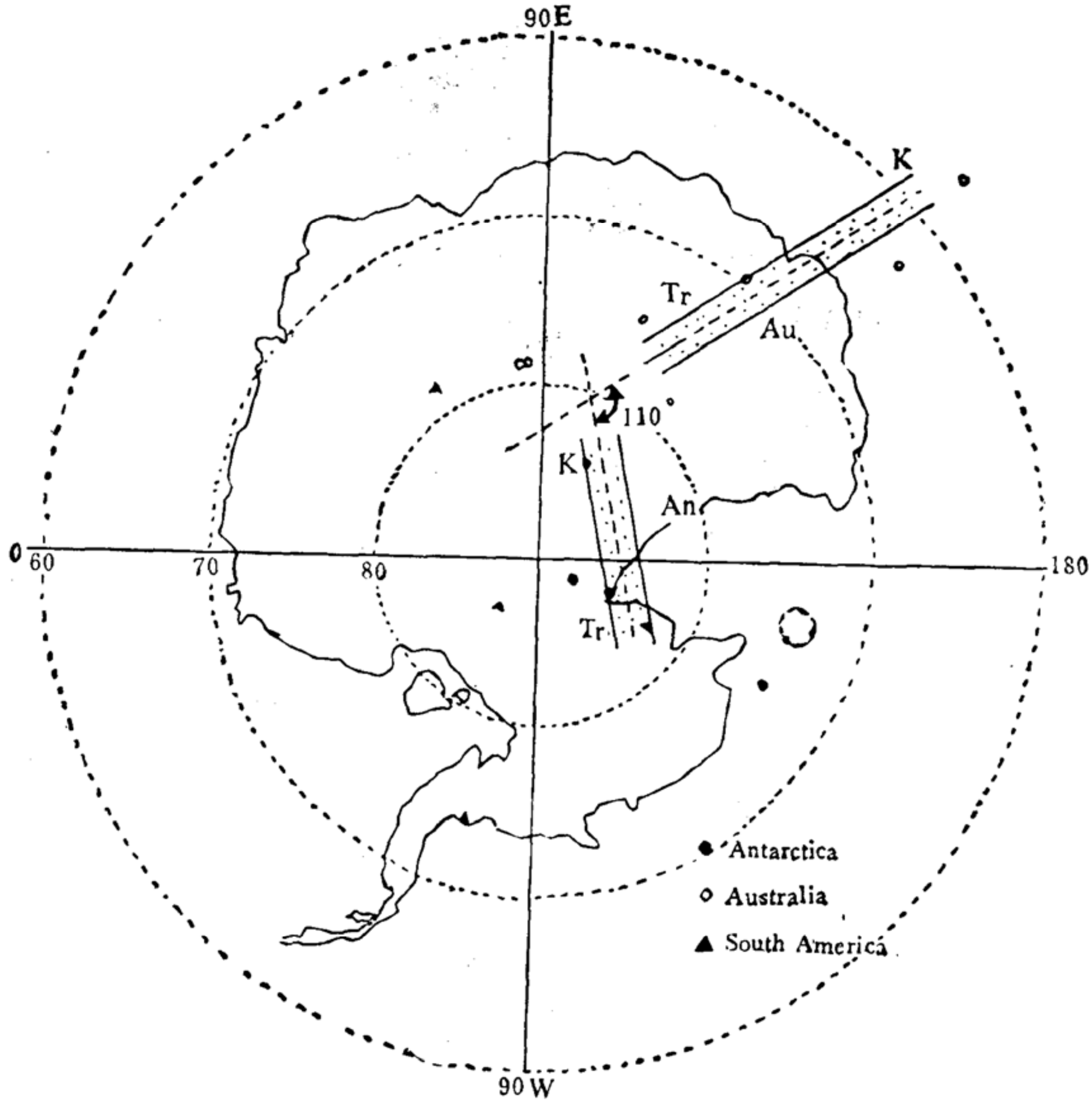


Fig. 2. The paleomagnetic polar positions for West Antarctica, Australia and South America in the Late Cretaceous and Early Tertiary.

the following problems:

(1) About the reliability of the data: Comparing our paleomagnetic data of the Late Cretaceour and Early Tertiary at the Fildes peninsula with the former previous paleomagnetic data of rocks of the same period in West Antarctica, we can see they are almost similar (Table 2). So the similarity tells us our data are reliable.

(2) About the breakup of Gondwana Land: Comparing these results with the data got for Australia and South America, we find the paleomagnetic pole position of Australia in the Cretaceous determined by Klootwijk and Peirce (1979) is 50°—82°S and 138°—208°E. It is not only close to the data obtained by McElhinny for Antarctica, but also close to our results. But the paleomagnetic pole position of the Cretaceous rock in South America is 78°

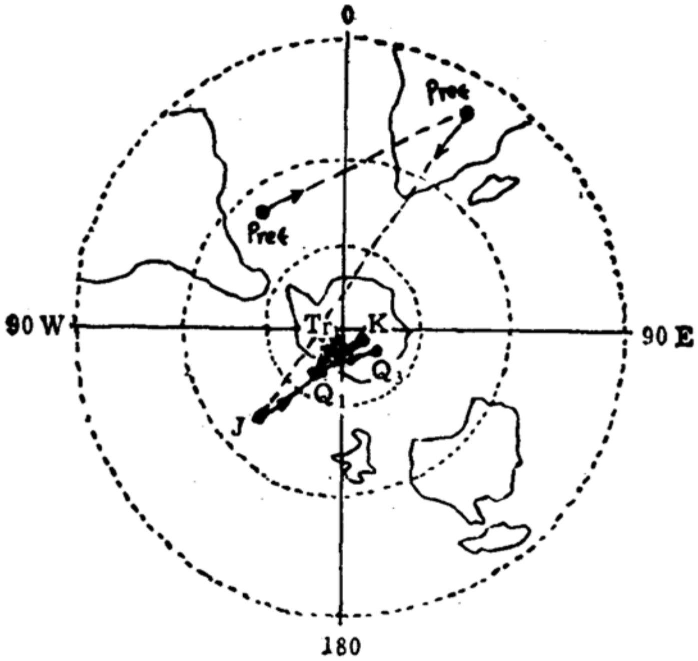


Fig. 3 The paleomagnetic apparent polar wander path of Antarctica.

—63°S and 56°—30°E, obviously different from the data for Australia and Antarctica. The paleomagnetic pole position from West Antarctica, Australia and South America in the Early Tertiary are different, in particular, for West Antarctica and Australia, their paleomagnetic apparent pole wander paths are reverse in direction, one is in the west, the other is in the east. The angle between them is about 110°E (Fig. 2). This phenomenon reflects the different geotectonic displacement of Australia and Antarctica during the process of breakup of Gondwana Land from the Cretaceous to Early Tertiary. Furthermore, Australia have moved about 20°—30°southward and turned 70° westward during this time, relative to the recent position of Antarctica and its adjacent continents. Hence a framework of the relative positions was formed.

(3) The paleomagnetic location of Fildes Peninsula: Some researchers suggested that the formation time of the glaciers covering the Antarctica Land is Oligocene (Zhang Qinsong, 1988). The paleomagnetic results in this paper show that the paleolatitude of Fildes Peninsula in the Early Tertiary is about 63.23°—60.17°S. The position is similar to that of today. Geological data tell us that the volcanic activity on the Fildes Peninsula was very strong in the period of 55Ma—45Ma at the Early Eocene. Thus the land glacier the Fildes Peninsula was formed after the Oligocene.

(4) Drawing of the paleomagnetic apparent polar wander path of Antarctica: In order to study the geotectonic evolution history of Antarctica, construction of the paleomagnetic apparent wander path of Antarctica Land is very important. According to the necessary conditions — samples' geographic units, the reliability of the geological time, the

paleomagnetic measurement method' correctness and the data processing reliability, the authors inspected all paleomagnetic data on Antarctica and selected reasonable data. Combining with this result, the authors draw out roughly the paleomagnetic polar wander path of Antarctica in different geologic periods(Fig. 3).

Acknowledgement We are grateful to Professor Er Molan for his support and help in this research program. Thanks are also to the National Scientific Foundation Committee.

References

Liu Xiaohan, Zhen Xiangshen (1988): The preliminary study the volcanic rock geology at the Fildes Peninsula, King George Island, West Antarctica, *Antarctica Research (Chinese Edition)*, Vol. 1, No. 1, 25—35.

Zhu Zhiwen (1985): The paleomagnetic study about the Late Pleistocene sediments at the Weisteflde Downland, Antarctica, The study of Late Quarternary geology and geomorphic feature, at the weiteflde Downland, Antarctica, Scientific Press, 47—52.

Zhu Zhiwen (1985): The paleomagnetic measuring results about the Precambrian rock at the at the Weisteflde Downland, Antarctica, The study of Late Quarternary geology and geographic feature, at the weiteflde Downland, Antarctica, Scientific Press, 211—217.

LI Huamei, Wang Shengyuan (1989): Geology and Geochemistry at the Cross Mountain and Rose Island area, Antarctica, Scientific Press.

Li Zhaonai, Li Xiaohan (1987): The geological feature about the volcanic rock series at the Great Wall Station, Fildes peninsula, King George Island, Antarctica, *Review of Geology*, Vol. 1, 33, No. 55, 484—487.

Shen Yanbin (1989): The evidence of paleontology about Late Cretaceous volcanic stratigraphic formation at the Fildes Peninsula, King George Island, *Antarctic Research (Chinese Edition)*, Vol. 1, No. 3, 27—33, *Review of Geology*, Vol. 1, 33, No. 55, 484—487.

Zhang Qinsong (1988): The Antarctic paleogeography and glacial sheet at the Pre—Tertiary, *Antarctica Research (Chinese Edition)*, Vol. 1, No. 1, 3—12.

McElhinny, M. W. (1973): Paleomagnetism and plate tectonics, Cambridge University Press 357p.

Valencio, D. A., Mendia, J. E., Vilas, J. F. (1979): Paleomagnetism and K—Ar age of Mesozoic and Cenozoic igneous rocks from Antarctica, *Earth and Planetary Science*, No. 45, 61—68.

Watts, D. R. (1982): Polassium—Argon ages and paleomagnetic results form King George Island, South Shetland Islands, Antarctic Geoscience, University of Wisconsin Press, Wis, 2550261.

Watts, D. R., Watts, G. C., Bramall, A. M. (1984): Cretaceous and Early Tertiary paleomagnetic results from the Antarctic Peninsula, *Tectonics*, Vol. 3, No. 3, 333—346.

Scharon, L., Scharnberger, C., Early, T. and Shimoyama, A. (1970): international Co—operation for paleomagnetic insight into Antarctic tectonic history, *Antarct. Jul. U.S.*, 5, 219—224.

Turnbull, G. (1959): Some paleomagnetic measurements in Antarctica, *Arctic*, 12, 151—157.

Zheng Xiangshen, Liu Xiaohan (1989): Tertiary volcanic stratigraphy and volcanism in Fildes Peninsula, King George Island, West Antarctica, Advances in Geoscience (I), China Ocean Press, Beijing, 239—246.