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THE ENVIRONMENTAL EVENTS ON KING GEORGE ISLAND SINCE THE LAST GLACIATION

Xie Youyu[1] and Cui Zhijiu[2]

[1] *Institute of Geography, Chinese Academy of Sciences, Beijing 100101*
[2] *Department of Gorgraphy, Peking University, Beijing 100871*

Abstract The extension of ice sheet on King George Island during the last glaciation was an environment event since the last glaciation. At that time South Shedlands Islands were a large unified island and the ice mass on King George Island might come from the Antarctic Peninsula. The model of ice retreat and ice advance events in the Holocene show that the ice sheet was separated into three small ice caps and then dispeared gradually. At present the retreating velocity of glacier is about 1.3m each year. After the retreat of ice sheet the isostatic compensation appeared in the crust there, and then 5—6 steps of the uplifted marine terraces have been developed along the coast. The uplift rate of the crust may be 6—10mm/a.

Key words Ice advance, ice retreat, isostatic compensation uplift

Introduction

Located between latitude 61°50′—62°15′S and longitude 57°30′—59°00′W, King George Island is the largest island (64km long and 24km wide) of South Shedland Islands. South Shedland Islnads, which consist of nine big islands, are separated from the Antarctic Peninsula by the Bransfield Strait, belonging to a subantarctic zone. Covering an area of 1338km2, 95% of King George Island is covered with glacier. Only the coastal area and the individual island mountains among ice caps are ice—free. Their highest elevation is 668m. The averge thickness of Collins ice cap is 100m and the thickest one is 350m.

Originally, King George Island was a component part of volcanic island of the Antarctic Peninsula. During the Pleistocene period was separted from the latter due to spreading of Bransfield rift and moved 70 km to west. From the Eocene Epoch, at least, King George Island as the western margin of magmatic arc of the Antarctic Peninsula was raised up on the sea surface by tectonic uplift and volcanism. And a set of basaltic lava, volcanicelastic—sedimentary rocks and subvolcanic rocks of continental facies was developed. The volcanic activity on this island lasted from Eocene to Oligocene. By the end of Tertiary the movement along both systems of NWW and NE groups faults was

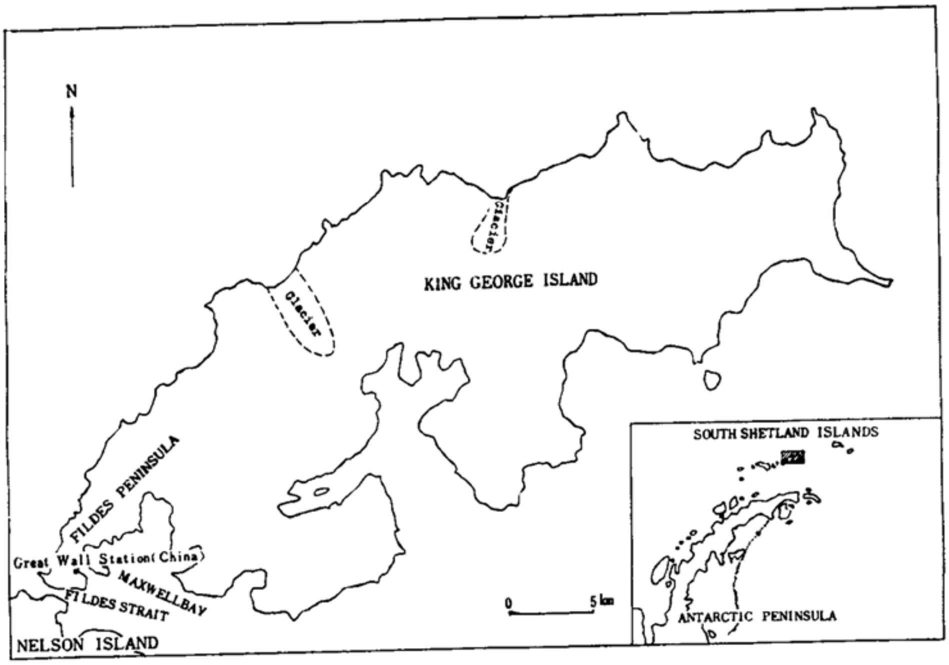

Fig. 1. A map showing geographic location of King George Island.

strengthened due to spreading of Bransfield rift, which established the tectonic framework of the island and provided a basis for later glaciation. The rocks in this area are basaltic andesite, breccia (agglomerate) lava, subvolcanic rocks, agglomerate, tuff breccia, tuff sandstone, etc(Liu Xiaohan and Zheng Xiangshen, 1988).

The Last Glaciation Event

Although a large amount of studies on Antarctic were carried out in last 30 years, the beginning and retreating time of glacier in the area has not fully been understood. For example, Denton and Hughes (1981) provivded detail data about Dry Valley area of Antarctica(the McMurdo Sound and Victoria areas)and compared them with some areas of West Antarctica. However, their conclusion are not completely coinsident with some scholars' viewpoints. The reason is that the exact position of the maximum extension of the late Pleistocene ice sheet is unknown(Mausbacher et al. ,1989)

Chalmers and Clapperton(1971), held that the sea level during the prevailing stage of the last glacition, 18000 a B. P. was 100—200m lower than that at present. On the basis of the submarine isobathic map of South Shedland Islands compiled by the Antarctic Institute of Argentina, the authors have drawn isobathic contours 100m and 200m (Fig. 2). Taking these isobathes as a standard, we can see that South Shedland Islands were a large unified island rather than islands at that time(Xie Youyu, 1987). The whole island was covered with ice mass and long and narrow trough was formed in the marginal zone, indicating that ice tougue extended continuously into the present sea. A large amount of moraine debris was left on the present seafloor, and only less drift boulser might remain on the present islands. Gravels of granite angen — gneiss, quartzite and other rocks scattered on the Fildes Peninsula have come from the Antarctic Peninsula, since these rocks do not occer on the Fildes Peninsula area, but on the most areas of the adjacent Antarcic Peninsula there are granite, gneiss and other metamorphic rocks(Lovering and Prescott, 1979). Furthermore, the found 22 drift boulders with a long diameter more than 1m all have an excellent polished surface and a certain roundness, showing that the boulders came from a far place. Most of these boulders are disfributed in the beach zone below an elevation of 10m a. s. l. and some in the tidal zone. That can be found only at low tide, and mainly conccntrated at the castern Fildes Channel and the western beach of Collins ice cap. Even in the present terminal moraine ridge at the western Collins ice cap the drift boulders of gneiss are found. And a few boulders is distributed on the platform at an elevation of 50m a. s. l. All of the facts indicate that there are at least two origins for these aullogenic boulders. First, the the sea level was 100—200m lower than that at present during the prevailing time of the last glaciation. Ice flow carrying drift boulders dominated by granite might come from the Antarctic Peninsula. During Holocene ice retreat, a part of the large ice flow remained on King George Island and become the original component part of Collins ice cap,etc. Second, the drift boulders wre carried by iceberg from the Antarctic Peninsula during ice retreat of the last glaciation. The present beach zone retaining the boulders was at least at 100—200m below sea level at that time. As iceberg is stranded, the drift boulders of its bottom a left. That is to say, the most part of the Fildes Peninsula was then below sea level. Sea geomorphic features well present on the peak of the Breccia Mountain (also called the Friendship Peak) should be formed at that time.

The enormous NW-SE-trending ice—scoured relict mounds, sheepbacks, troughs, inderntations, etc. can be found on the ice—free area of the Fildes Peninsula and the Nelson Island whether through on-the-spot observation or in an aerial photography. This trend corresponds to the fact that ice flow might come from Palmer and Grahan ice caps on the Antarctic Peninsula across the Bransfield Strait during the last glaciation. Since the small ice caps developed on King George Island during Neoglaciation after the last glaciation or Little Ice Age covered by Fildes Peninsula, the ice caps were more than one. The polished surface and strial formed by them have many treends, dominated by NE, indicating that these small ice caps can not change the ice — erosion geomorphical framework established during the last glaciation.

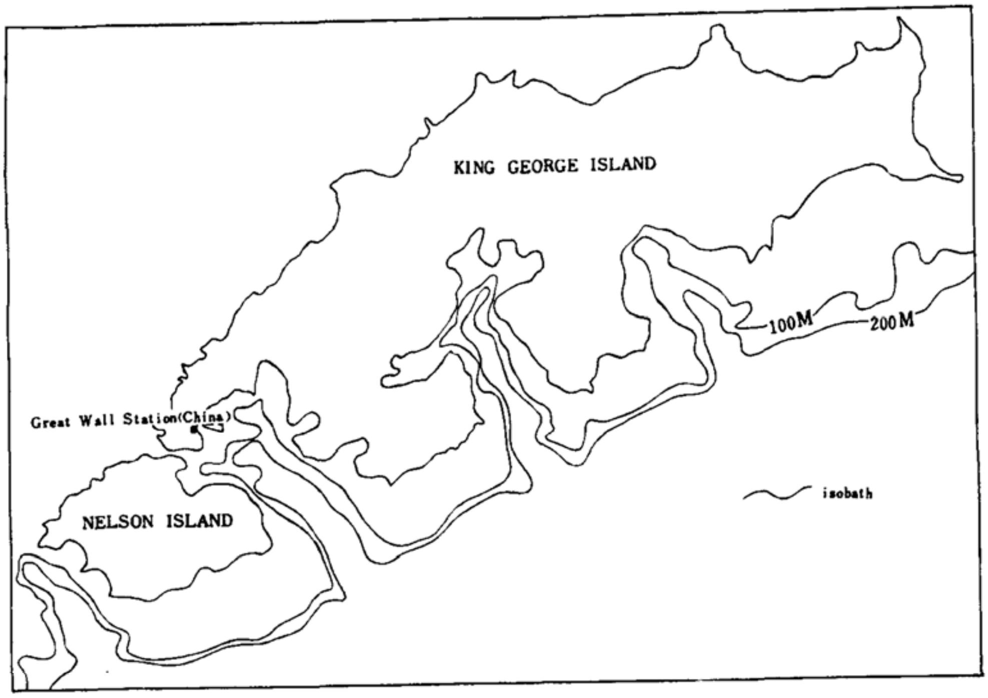

Fig. 2. A submarine isobath map of King George Island.
(from the Antarctic Institute of Argentina)

Besides, on the Fildes Peninsula of King George Island no real moraine zone had been developed. Whether during the last glaciation, Neoglaciation, or Little Ice Age the moraine zones were in the sea below present sea level. As far as the last glaciation concerned, the moraine zone was at about 80—160km outside the Antarctic continent, with a height of about 100m. During Neoglaciation very little sporadic moraine was left in this area. It was scattered on ice—erosion hills, and the real moraine layer was never formed.

In this paper, the model that ice flow in this area came from the Antarctic Peninsula in the southeast during the last glaciation is inferred on the basis of the Antarctic Peninsula being the most possible land—source area for the external drift boulders and of the ice — scour geomorphic features of this area. This is cotrary to the hypothesis suggested by John (1971), there was a large ice cap on the northwestern King George Island. He held that the ice flow on this Peninsula came from the northwestern sea, but there is no a reliable evidence to support his idea.

A Model of Ice Retreat and Ice Advance Events of Neoglaciation and Little Ice Age During Holocene

After the prevailing stage of the last glaciation global climate started to get warm and the ice cap of King George Island began to be broken. Denton and Hughes suggested that in the Ross ice shelf area the main period of ice retreating began at 12 330a. B. P. and ended at 4 620 a. B. P. These ages were determined from marine sedimendts (Mausbacher and Muller, 1989). ^{14}C ages of the sediments of lake facies from the West Lake sampled by us are 1445±70a B. P. for 0—0. 21m (Zhao Junlin, 1989), 2265±75a B. P. for 0. 63—0. 87m (Zhao Junlin, 1989), 2170±180a B. P. for 1m (Liu Xiaohan and Zheng Xiangshen, 1988), 3930±80a B. P. for 1. 93—2. 14m (Zhao Junlin, 1989) and 3200±400a B. P. for 2—2. 6m (Liu Xiaohan and Zheng Xiangshen, 1988) repectively. Although there is some differences in age determinations, it indicates at least that the large ice cap had retreated from the Fildes Peninsula and the ice—thawed water occupied the ice—scour depreession to form a lake at 3 900—3 500 a. B. P. Comparing the records of King George Island, Mausbacher, *et al.* (1989) suggested that the last stage of ice retreat was the same as that in Ross ice shelf area and that the beginning stage of ice retreat for both areas differs. During 1986 and 1987 Mausbacher, *et al.* sampled the sediment from three lakes, the Tiefersee, Kiteschseee and Jurasee Lakes by drilling at different distances from Collins ice cap on the Fildes Peninsula, providing an information of ice retreat, sea level and cilmatic changes on South Shedland Islands during Holocene.

According to ^{14}C dating of cores from these three lakes, Mausbacher suggested that ice retreat began at 8000a B. P. since ^{14}C dating of the sediments from the Kiteschsee Lake showed that the ice—free area was exposed after 8000a B. P. and before 6000a B. P. The age of ice retreating and formation of fresh—water environment for the Tiefersee Lake was at 5500 and 5000a B. P. During this period the ice cap migrated from the Tiefersee Lake basin and the maximum extent of the ice cap margin was the same as that at prsent time. It does not mean, however, that Collins ice cap has always been at this location during last 5000 years, but with advance and retreat. In the Jurasee Lake furthest from Collins ice cap till gravel bed lies at 4m depth in drill. ^{14}C age of silt at 360cm is 8700 ±300a B. P., 5190±125 a B. P. at 320 cm and 4320±105 a B. P. at 70 cm. These are all the sediments of lake facies. Thus, it can be deduced that ice cap breakup in the Fildes Peninsula area started from the Fildes Channel area. At 9000 a B. P. the extent of ice cap had reached around the Fildes Channel. Since the time 8000 years ago the Jurasee Lake began to be formed and ice cap has retreated to the neighborhood of the Great Wall Station. At 6000a B. P. the Kiteschsee Lake was formed, and at 5000 a B. P. Collins ice cap had been at the present site (Fig. 3) (Mausbacher *et al.*, 1989).

According to the data we have learned, however, the history of Holocene ice cap retreat from the Fildes Peninsula is more complex. Take the Jurasee Lake remarked by Mausbacher, etc. as an example. It is only at 2. 1 km away from the present Nelson ice

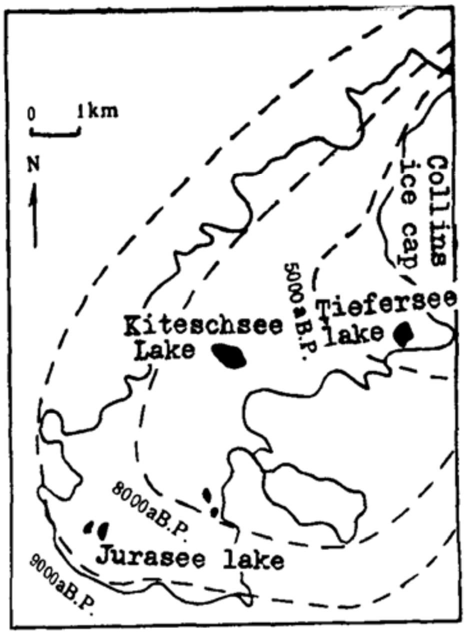

Fig. 3. Ice cap breakup and ice retreating prosess in the Fildes Peninsula area(Mausbacher *et al.*, 1989).

cap, but at about 6 km from Collins ice cap. The Fildes Channel between the Jurasee Lake and Nelson ice cap is only 400 m wide, with a serial of isles and reefs and shallow water. It seems more reasonable that if the Jurasee Lake and another small one in the west were produced by Nelson ice cap as the ice retreats, or it was an ice margirnal lake among the small ice caps on the central highland which do not exist at present. In addition, all of water systems on the central highlsnd of the Peninsula (nearby the northen Jurasee Lake) are radial. There are a series of ice—scour lakes and NE—SW—trending secondary though, sheepbacks and strin which is perendicular to NW— SW flow dirrection of the last glaciation, on the central highland, showing that the highland was occupied by small ice caps. That is to say, as the ice cap separating the Fildes Peninsula was occupied by two individual small ice caps at least, and plus Collins ice cap in north and Nelson ice cap in south there were totally four ice caps. Currently, the northern and southern highlands have been completely exposed because of lower elevation (below 150m a.s.l). But both Nelson and Collins ice caps are higher than 200—300 m and the ice caps remain. Therefore, the model of ice retreat on the Fildes Peninsula is not that ice fairly retreated to the present site from the mariginal Jurrasee Lake centered at Collins ice cap at 8 000a B.P. but as the ice cap break up it was firstly separated into several individual small ice caps centered at highland at 8 000 a. B. P. On the Fildes Peninsula, there were at least two small ice caps centered at the central and northern highlands, and these ice caps might last to 3 000 a B. P. i. e. to the Neoglaciation. In the Great Wall Station area ice flow from the central highland could yet arrive at the coast at that time, leaving a large area of glacial polish and strial on the bedrock platform at a

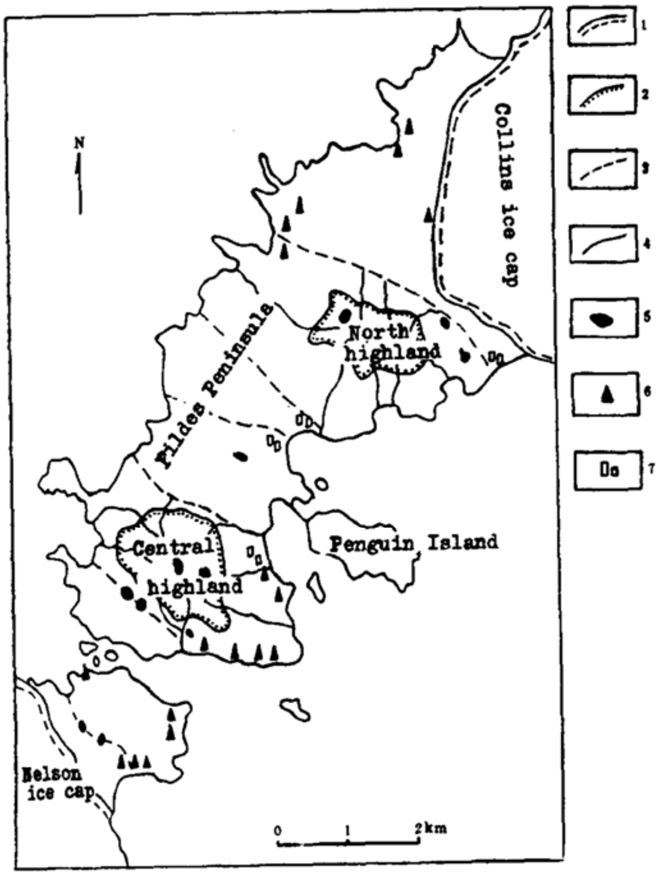

Fig. 4. Distrbution of major glacier traces on the Fildes Peninsula. 1. Ice cap; 2. Ice—scour highland; 3. Drainage depression; 4. Valley; 5. Ice—scour lake; 6. Exogenic drift boulder; 7. Station Site.

present elevation of 24m a. s. l. (Fig. 4).

During the Neoglaciation between 3 000 and 2 000 a B. P., with a worsened global climate, the ice cap on King George Island had somewhat expanded, and led the uplighted coastal terraces formed by ice sheet dissipation and isostatic compensation to suffer glacialaction in the Neoglaciation period. Most obviously, on the fifth — step terrace (at elevation of 40— 50m a. s. l.) formed during high sea level period almost whole marine sediments were replaced by till, and terminal moraine dam and groups of sheepbacks of Neoglacition were left on the margin of Collins ice cap.

During the Neoglaciation period small ice caps had been developed on the Fildes Peninsula. The small ice caps, centered at the Shanhaiguan Peak and the Monster Mountain (i. e. central and northern highland), moved from the high to the low, with a certain scouring, forming a vast amount of sheepbacks, polished surface, small ice — scour troughs and silt material. Larger troughs formed during the last glaciation were mostly intersected by these small ones, and the till at that time could arrive directly at the sea front. Calculating from this, the distance from the margin of the ice cap to the center of the small ice cap is about 1.5 km. According too J. E. Nye's fromula

$$H = 4.76\sqrt{R}$$

(where R is the distance) the thickness of the small ice cap on the Fildes Peninsula during the Neoglaciation period is about 184m.

In the marine sediments on the first-second-and third-step uplift coastal terraces the banded till has been found, indicating that as these terraces form there is a small glacier in the form of trough developed in this area, which moved from the center of the ice cap to the coast. Thus both marine deposit and till are intercalated each other. It also indicates that there existed small ice cap yet as the fouth-and fifth-step sea terraces are developed. And there was still a little valley glacier until the third-step accumulational terrace formed.

The history of glacier advance and retreat at the margin of Collins ice cap has been studied by Polish scholars in detail. Studying on glacial deposit on Cape Hennequin opposite to the Polish Arctowski Station in the Maxwell Bay, B. Krzystof suggested that in this area till covered the uplifted coastal terrace over 5m, the age of till formation dated by lichenometry is 1780 years, called the Red Cirque moraine, corresponding to the cold period of 18th century. Another much younger glacial event is that all of the coastal terraces were overlapped by Loggia Cirque glacier, corresponding to the cold period of the first half of 19th century, called Loggia Cirque glacial event, and its age is 1825 years. Before this, the maximum glacier advance stage existing for 1 240 years, is called the Ferguson glacier event. That is to say, after ice cap breakup in the Neoglaciation there little glacier advance progress look place (Birkenmajer, 1979).

As to the velocity of glacier retreat, the Polish scholar suggsted that glacier was in a relatively stable stage for some 500 years from the first half of 13th to 18th century and then in a rapid retreat stage from late 18th to the first half of 19th century. During 100 years from the mid — 19th to the mid — 20th century glacier retreat had decreased, and it has obviously increased in last 20 years.

Particularly, it follows:

(1) For about 500 years from the first half of 13th to 18th century glacier was in a relatively stable stage, with a retreating rate of 7.4m/100a;

(2) Glacier was in a rapid retreat stage from the late 18th to the first half of 19th century, with a retreating rate of 163.5m/100a;

(3) Over 100 years from the middle 19th to the middle 20 century the velocity of glacier retreat decreased, with a rate of 30m/100a.

(4) In last 20 years the velocity of glacier retreat has obvioursly increased, with a rate of 133.3m/100a.

The last ice retreat stage has been verified by a England glacierist. In the 12—year observation period from 1948 to 1960 the Flagstaff glacier was in a negative balance on the whole and in a slow retreat state, and in the negative balance year the water amount lost was more than increased in the positive balance year (Birkenmajer, 1979).

The Isostatic Compensation Uplift Event Resulted From the Holocene Ice Retreat

It is incvitable to lead to sea level rist after retreat and breakup of ice cap. Due to the decrease of ice load the crust bounces back and uplifts relative to sea level, and this is called an isostatic compensation uplift. Obviously, the amount of the isostatic compensation uplift is more than that of sea level rise, which can be verified by the fact that there occur at lease 5—6 steps of the elevated coastal tereaces in this area.

The authors consider that the fifth—step sea terrace at elevation of 45—50m. a. s. l. extensively distributed on the Fildes Peninsula can represent the globe warmest high sea level in the middle and late Holocene. The distribution of this terrace on the western coast is very extensive. The airport runway of the Marsh Base was built just on this terrace. On the terrace a gravel layer of marine facies is accidentally found. From topogrphic contour it can be seen that the Fildes Peninsula become three separated small islands at that time. From south to north, that is from north of the Fildes Channel to vicinity of the Shanhaiguan Peak near the Great Wall Station, it is a larger area of islands. The Fossil Mountain in the north is separated from the hilly area around the Shanhaiguan Peak by the giant fault valley—the Wind Valley to north of the Great Wall Station. The Fossil Mountain is also a small individual island. The area aroud the Bellingshousen Station and the Marsh Base of Chile was a vast sheet of water. The third one is the northern highland to north of these two stations (Fig. 5). The flat coastal platforms in its western flat were all on the sea floor at that time. Also, according to the beach sediments and wave — cut shapes, John and Birkenmajer put forward that the Holocene high sea level was 45m higher than the present sea level (Birkenmajer, 1981). As for marine graval, sea cave and so on found at the Friendship Peak (the Breccia Mountain) at 90—99m above sea level on the northern highland, they are the evidence for oceanic process, whose age ranges from the last glaciation to the early Holocene.

From ^{14}C age of the Jurasee Lake (47m above sea level), M. Roland concluded that there was no marine deposite at that time. The evidence for oceanic state obtained by

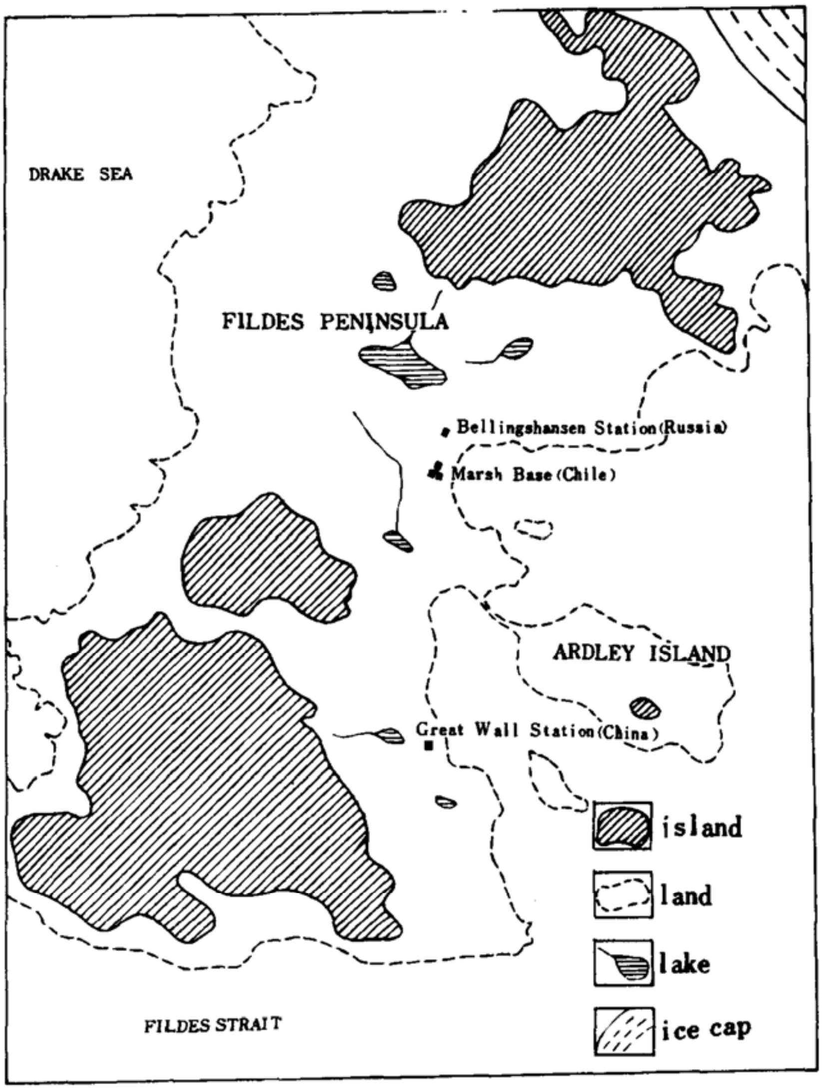

Fig. 5. A sketch map of geomorphic landscape of Fildes Peninsula in the middle Holocene (high sea level period). 1. Island; 2. Land; 3. Lake; 4. Icce cap.

them from the beach margin and wave—worn shape is only found at the sites over 18m above sea level near the Jurasee lake area. From these two elevation heights (47 and 18m) it follows that the maximum high sea level was 47m above sea level and the minimum one 18m on the Fildes Peninsula during the postglcial age. However, on the basis of diatom assemblage in the fresh and salt water in the marine sediments of the Kiteschsee Lake it can be concluded that the water in this lake changed from the salt to the fresh at 6000 a B. P. Thus the deduced sea level at 6000 a B. P. was lower than the recent height of the Kiteschsee Lake (16m). After correction the sea level fell below 16m above sea level at 5900 a B. P. (Mausbacher *et al.* 1989).

The maximum uplift amount of Cape Harrnory of the Nelson Island close to King George Islsnd, reported by Roberto, is 22. 6 m. He also point out that it seemed to be that the relative uplift of the whole South Shetlands increaced more and more during the postglacial period(Robero, 1972).

It can be said that the uplift coast can be found on every marginal area of Antarcitic continent, such as sea platform, sea cave, sea stack and wave—worn surface. Most of them were formed at 60m below sea level, but 80% is 30m higher than the present sea level. The oldest forms is the late Pliocene and the youngest is the late Holocene, younger than the latest glaciation(Calkin, 1970).

In Cape Mabo area of the McMurdo Strait the marine fossils were buried in the elevated coastal terrace at an elevation of 13m, and their ^{14}C age is 4450±150a B.P. The sea level at that time was almost 3m lower than the preesent one on average. The Cape Mabo area was uplifted by about 16m at 4 450±150a B.P(Poter and Stuiver, 1984).

The ages of the elevated coastal terraces on the Fildea Peninsula, obtained by Birkenmajer(1981), through studying on lichen, are listed in Table 1.

Table 1. Dating of the elevated coast.

Geologic form of the elevated coast		Height(m a.s.l.)	Diameter of lichen(mm)	Age(a B.P. 1979)	A.D. (a)
A	The elevated coast	0—1.5	—	—	
B	Strong storm ridge	1.5—2	33、30、30、23、20	244	1735
C_1	Coast	2—2.5	(80)、55、50、40	(539) 407	(1386) 1572
C_2	Strong storm ridge	4	55、50、40	407	1572
D	Coast+storm ridge	5	45、45、45	333	1646
E	Storm ridge+coast	6,7.5	40、40、38	296	1683
F	Coast	6—16.5	70、40	518	1461

F level in Table 1 corresponds to T3 divided by us, E level to T2, D, C and B levels to T1, and A level to the present beach. Also, the sea terraces types of T4 and T5 are divided.

^{14}C age at the rised beach at elevation of 9m on Hafe Three Point, dated by Cui Zhijiu and Liu Gengnian of The Fourth Chinese Antarctic Research Expedition, is 1 310 ±90 a B.P. that is the age of the third—step marine terrare is 2180—1310 a B.P. And ^{14}C age of the shell fossil from the rised beach at elevation of 14m on the side of the Tern Lake has been dated to be 2 180±95 a B.P. They are older than the age measured from lichenometry by a Polish scholar.

On the basis of the research results the uplift rate of crustal rebound is about 6—7 mm/a.

According to Birkenmajer's data, the ages of terraces on the Maxwell Bay of King George Island are 250 a B.P. for 2m above sea level, 550 aB. P. for 6m above sea level, 800 a B. P. for 10m above sea level, and 1 000 a B. P. for 14m above sea level respectively (Birkenmajer, 1981). The age of the terrace at elevation of 45m, measured by Tatur (1986), is 5000a B. P. and the uplift rate of the crust ranges from 8 to 14 mm/a.

Using geomorphic — stratigraphic method, Xie Youyu has deduced that the extensively distributed fifth—step marine terrace was produced during the Holocene high sea level stage, about 5000 a B. P. The height of the terrace is 40—50m above sealevel, and the isostatic uplift rate calculated is 10 mm/ a. This conclusion corresponds to Tatur's suggestion and is also closer to that suggested by B. Krzysztof, who has dated the ^{14}C age of 420±65 a B. P. and 500±50 a B. P. for the terrace at elevation of 6m in Potter Cove area and uplift rate of the isostatic rebound was calculated to be 3 mm/ a.

Study on the coasts of the Magellan Strait and the Beagle Strait in the southern most part of South America (Poter and Stuiver, 1984), has shown that the highest sea level was 3. 5 m higher than the present one at 5 000 a B. P. And it has been considered that the coasts subsided in the early Holocene, the sea level rose and was higher than the present one in the middle Holocene and the coasts uplifted and the sea level fell in the Late Holocene. At −7. 7m below sea level ^{14}C age of peat is 15800±200 a B. P. The sea level in this area was 3m higher than the present one at 3860±40 a B. P. and 0. 65m higher at 1 470±30 a B. P (Calkin, 1970).

At Ushuaia (the southern most pat of Argentina) ^{14}C age of peat layer at 4. 5m above sea level is 7 450±100 a B. P. and the sea level rose by 2—3m at 7 850 ± 110 a B. P (Poter and Stuiver, 1984).

A curve of relative sea level changes during most of Holocene can be established from the data gained at 5 sites along the coasts of the Magellan Strait and the Beagle Strait. The curve shows that the sea level rose to the present height during the early Holocene, rose by 3. 5m during the middle Holocene, 6 000—5 000 a B. P. and fell to the prsent height during the Late Holocene (Tatur, 1986).

From the above — mentioned study, it is an objective fact that exist the uplifted coasts in Antarctic region. However, the uplift amounts differ greatly in different periods, it may be a problem remaining to be studied from geochronology.

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