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Magnetotelluric sounding study in the region of Zhongshan Station, East Antarctica

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Abstract This paper deals with the results of the MT observations in the region of Zhongshan Station, Larsemann Hills area, East Antarctica and points out that the lithosphere thickness of the Larsemann Hills is 140 km and the crustal high conductivity layer is situated in 22 km.

Key words Zhongshan Station, magnetotelluric deep sounding, electrical conductivity structure.

1 Introduction

Geophysical study in Antarctica is one of the most economical and the most effective ways to find out geologoical structure, the evolution and the material components of the surface and the deep in the Antarctic continent and surrounding sea area. Different from other branches of geosciences, geophysical study can help us more understand the deep structure in the Antarctic continent and develop our knowledge about the general geological characteristics in Antarctica. Because of harsh condition, little deep geophysical study was carried out there. In 1962, American scientist Woolard pointed out that the crustal thickness is 30 to 35 km in Antarctic seashore from the seismic and gravity data and the crustal thickness is 48 km in Antarctic pole(Fifield, 1987). In 1967, the Ex-Soviet researchers pointed out that the crustal thickness in the middle of East Antarctica and Transantarctic Mountains area is 50 km and that the crustal thickness on the edge of the Antarctic continent is 20～25 km from the seismic and gravity anomaly data (Fifield, 1987). Kogan(1972) calculated the crustal thickness in the East Antarctica from the reflective seismic data and Kadmina *et al.* (1983) pointed out that the crustal thickness in the East Antarctica is 34 km from the refractive seismic data. Chinese researchers (Shu and Zhu, 1992) pointed out that the crustal thickness is 43 km nearby Japanese Syowa Station of Antarctica from the seismic data acquired in this station. We carried out the first magnetotelluric sounding (MT) in West Antarctica in 1993 and gave the deep electric conductivity structure in the Fildes Peninsula (Kong and Zhang, 1994). Soon afterwards, we carried out 2 MT sounding sites near the Zhongshan Station area, East Antarctica. Although the data we got are too limited to analyze detailed electrical conductivity structure in this area, they may be very important as the reference to the future measurements and the analysis of geomagnetism, natural and explosive sounding and earthquake, gravity and geotherm.

2 Geological setting and field work

Zhongshan Station is situated in Larsemann Hills, east Antarctica. Larsemann Hills (69°12′～69°28′S, 76°00′～76°30′E) covers four peninsulas (Stornes, Broknes, Mirror and Little Peninsula) and more than 130 islands. Broknes Peninsula and Stornes Peninsula, as the host parts, trend in a NW-SE direction, being surrounded by tens of islands such as Manning and others. Broknes Peninsula lies in the east of Larsemann Hills. It is divided into the east and the west parts by Naila gulf. The east part is also called Mirror Peninsula, where Zhongshan Station (69°22′24″S, 76°22′40″E) is situated.

Larsemann Hills is part of ancient crystalline structure in East Antarctica. It was formed 1.2～1.4 billion years ago. Its basement encountered mixed-metamorphism many times (Stüwe, 1989). The metamorphic rock is mainly composed of garnet gneiss with abundant FeO and TiO_2 and cordierite gneiss. Twogroups of structure lines (NE and

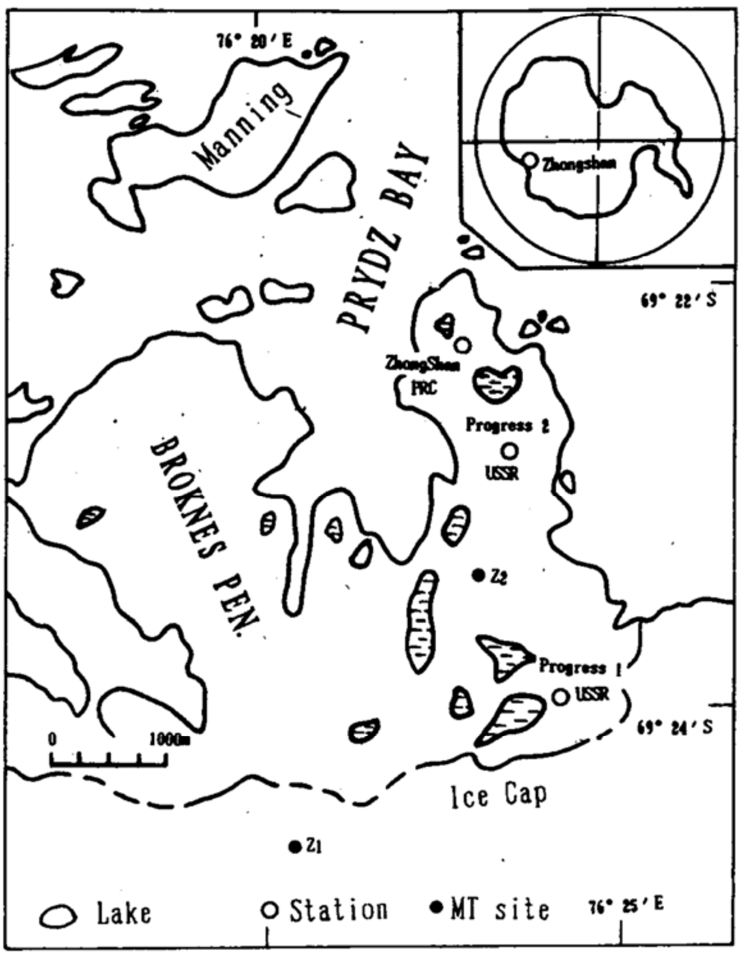

Fig. 1. The location of the MT sites near Zhongshan Station (Z_1 and Z_2) in the Lasemann Hills.

NW) controlled the geomorphologic pattern of this area. New tectogenesis is weaker in this area. The facts that two levels of marine-cut platforms exist in Larsemann Hills seashore and marine sedimentary rock exists in some lake basins manifest that this area encountered eustatic movement at least twice since Holocene epoch(Li ,1993).

The MT sites are located on the south of Zhongshan Station. Z_1(69°24′38″S,76°20′23″E) is near periglacier with a sea-level elevation of 36 m. The ground is covered by snow (0.01～1 m thick). There is an ice layer (20 m thick) under snow. Z_2(69°23′21″S,76°22′51″E) lies at Australian Law Base with a sea-level elevation of 64 m. It is a flat ground 300 m long and 100 m wide. This flat ground is surrounded by mountains in three directions but faces lake in one direction. Its surface is weathering granulite with more stones and sands(Fig. 1). The electrodes used in Z_1 site are Pb plate. While the electrodes used in Z_2 site are saturated $CuSO_4$ solution. The four electrodes were displayed along NS and EW. The electrode distance is 30 m. The magnetic declination is −75°40′ W.

The magnetotelluric measurement system MMS-02 was made in Germany. The observation coordinate system is composed of *X* axis(magnetic North), *Y* axis (magnetic East) and *Z* axis (the earth's core). Recorded signals include two channels of electric field(E_x and E_y) and three channels of magnetic field (H_x , H_y and H_z). Signal's period range is from 2.5 s to 4096 s.

Fig. 2 shows the five components of natural electromagnetic field records in site Z_2

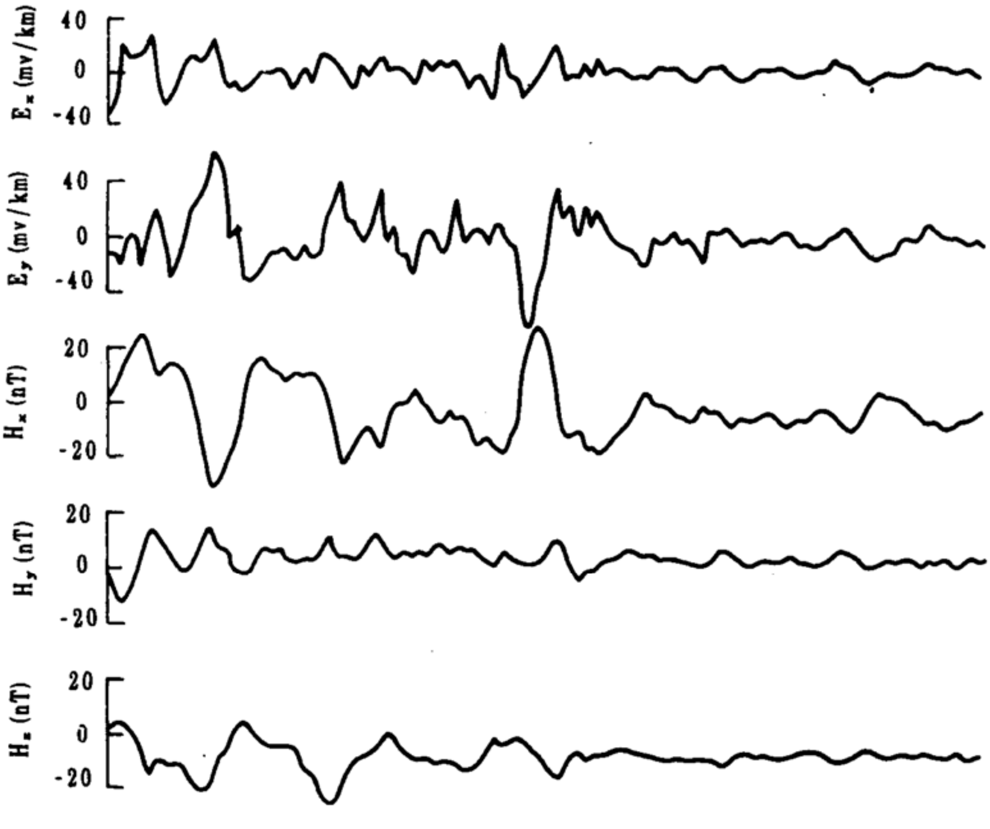

Fig. 2. The natural electromagnetic field signals in site Z_2

with the sample period of 4 s. E_x and E_y are the NS and EW electric components respectively, H_x, H_y and H_z are the NS, EW and vertical magnetic field components respectively. It can be seen from the recorded curves that the vertical component H_z has the higher changeable amplitude than the horizontal components H_x and H_y in Zhongshan Station area. This fact is one of geomagnetic field's characteristics in the polar area. In low latitude area of China, the amplitude of H_z is only from one-tenth to one-twentith of that of H_x and H_y components.

3 MT results and geological interpretation

3.1 MT results

Fig. 3 shows the apparent resistivity and phase curves of site Z_2. The apparent resistivity curve implies that there are several resistivity layers in this area and there is a high electrical conductivity layer in upper mantle.

Fig. 4 shows the dimensional parameters of D_1, D_2 and D_3. We can see that D_1 is larger than 50%, D_2 is about 40% and D_3 is less than 5%. It indicates that the survey area is mainly a two dimensional structure. Considering of the calculated tipper value, it can be said that this area is tectonically in a N-S direction.

According to 1D Marquart inversion with the apparent resistivity and phase curves

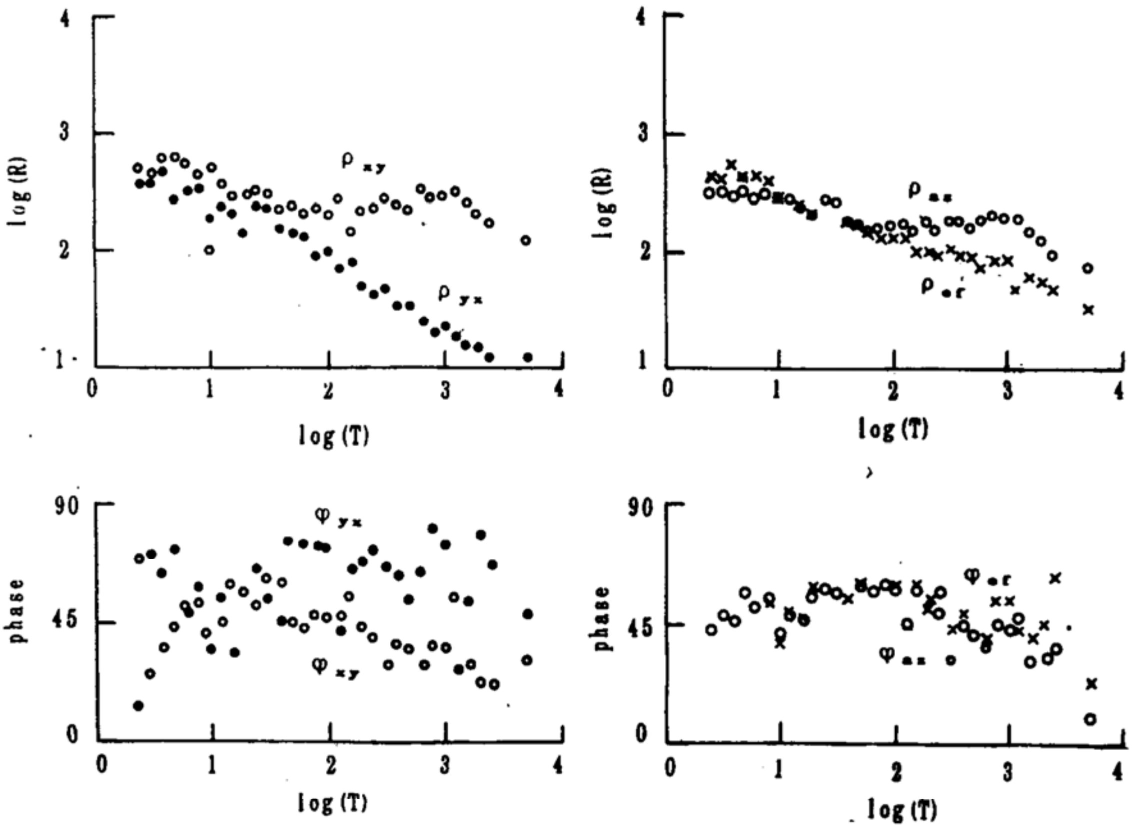

Fig. 3. The apparent resistivity and apparent phase in site Z_2.

in site Z_1 and Z_2 , the electrical conductivity structure of this area is showed in Fig. 5.

3. 2 Geological interpretation

The East Antarctica is in a stable shield. It is composed of basement rock and caprock. The basement rock includes sedimentary, volcanic and intrusive rock formed by strong deformation since Archezoic era. While the caprock includes sedimentary and volcanic rock formed after Ordovician period. The ancient basement rock of East Antarctic shield crops out along the whole seashore with the thickness of 15～20 km. It is composed of gneiss, schist and migmatite, generally these components were transformed into granulite facies and amphibilite facies after metamorphism. The margin of the Antarctic continent mainly is passive. Modern deposition is extremely not developed. The basement rock outcrops in Larsemann Hills while the caprock formed in Devonian-Jurassic period is absent. According to limited explosive sounding and gravity data, the average crustal thickness is 40 km in east Antarctica and V_p is 7. 9 km/s in upper mantle. MT sounding in Zhongshan Station, which indicate that there are 5 resistivity layers in the Larsemann area.

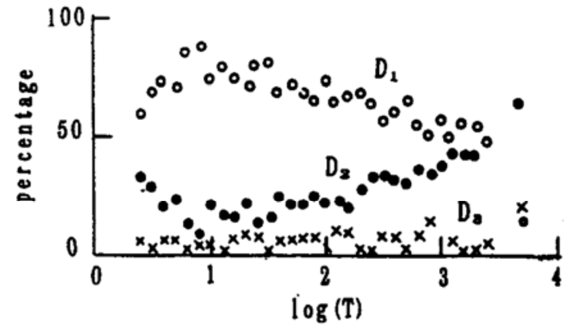

Fig. 4. The percentages of D_1 ,D_2 ,D_3 in site Z_2.

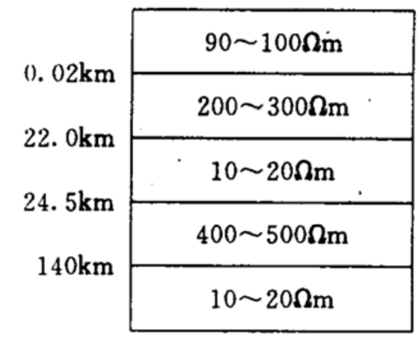

Fig. 5. The resistivity structure drift map in the Larsemann Hills.

The first layer has a resistivity of 90～100 Ωm and a thickness of 10～20 m, belonging to Cenozoic glacier sedimentary layer.

The second layer has a resistivity of 200～300 Ωm and a thickness of 6. 7 km, belonging to hypometamorphic rock.

The third layer has a resistivity of 10～20 Ωm and a thickness of 2. 5 km. The top depth of this layer is 22 km. The occurrence of the high electrical conductivity layer may be due to phase change and dehydration of rocks or hydrous crush rock belt. In Mac Robertson Land and Princess Elizabeth Land, deep seismic sounding, gravity and airmagnetic survey carried out by Ex-Soviet researchers indicate that the deep structure mainly are faults along NS. These faults dislocates the two main seismic boundaries and some secondary boundaries. The upper boundary can be compared with the boundary above the crystalline basement in Lambert graben, Mac Robertson Land. It is hidden 8 ～10 km beneath sea level and covered by low density rock(2. 4～2. 5 g/cm^3). It is confined in Lambert glacier and Beaver Lake. The lower boundary is Moho. The crustal high conductivity layer discovered by MT survey indicates that there is also an upper boundary. It may be the boudary of crystaline basement in ancient shield.

The fourth layer, with a resistivity of 400～500 Ωm and a thickness of 110 km, includes the upper mantle and the lower crust above the asthenosphere. It must be pointed out that Moho can not be discovered because the resistivity changes gradually in crust-mantle boundary.

The fifth layer, with a resistivity of 10～20 Ωm, is the asthenosphere. The top depth of this layer is 140 km.

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