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Topographic features around Zhongshan Station, southeast of Prydz Bay*

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Abstract Considering the complex topographic features of the southeast of Prydz Bay where China's Zhongshan Station is located, three types of geomorphologic units can be identified, i.e., submarine slopes, canyons, and terrains. The major topographic features in the study area are the submarine canyon and trough system outside the calving ice front of Dalk Glacier. A 3.8 km × 80 m fissure is found on the submarine terrain at Zhongshan Anchorage, which, once triggered by geological hazards such as earthquakes and ice falls, would be a threat to the usage and maintenance of the anchorage.

Keyword: Prydz Bay; Zhongshan Station; Zhongshan Anchorage; topography feature

1 INTRODUCTION

Prydz Bay, as the largest shelf sea of the East Antarctic, has drawn intensive interests of researchers from Russia, Japan, Australia, U.S., and China etc. ever since the early 1900's. The majority of these studies were based on ODP program concentrating mainly on the central or outer part of the bay. Studies related to the sedimentary, geological and topographic features of the area where several Antarctic Research Stations are located, are rather limited.

China's Zhongshan Station (69°22′24″S, 76°22′40″E) was built in February 1989. Because of the lack in bathymetric and topographic data, research vessels had no fixed anchorage around the Zhongshan Station in the following 10 years, which increased the difficulty and risk of scientific investigation in Prydz Bay area. Based on the *in-situ* survey data collected in January 1999, the topographical features of the study area around Zhongshan Station and Zhongshan Anchorage were reviewed. The preliminary results present in this paper shall be helpful for the future investigation, engineering construction, and maintenance of the Zhongshan Anchorage, and transportation in the bay area as well.

2 MATERIALS AND METHODS

2.1 Background

Prydz Bay is referred as an embayment caused by a crustal structure named as Lambert Graben in tectonics, which extends 700 km inland. As the geology of the Pre-Mesozoic shows, the east boundary of Prydz Bay, where Zhongshan Station is located, was formed mainly during the late Proterozoic metamorphism (O'Brien et al., 2001). According to the study on lithofacies distribution in more than 250 grab and core sediment samples (Harris et al., 1998), the southeast part of Prydz Bay is described as a "rough basement outcrop zone".

Zhongshan Station sits on Larsemenn Hills, the Mirror Peninsula. The average altitude of Zhongshan Station is about 10 m. The Mirror Peninsula is embraced by sea in three directions with many islands with complex submarine topographic features. The majority of the coastline is erosional under sea ice scouring. Clastic sedimentation is developed in the bay areas that are constantly covered by ice and snow.

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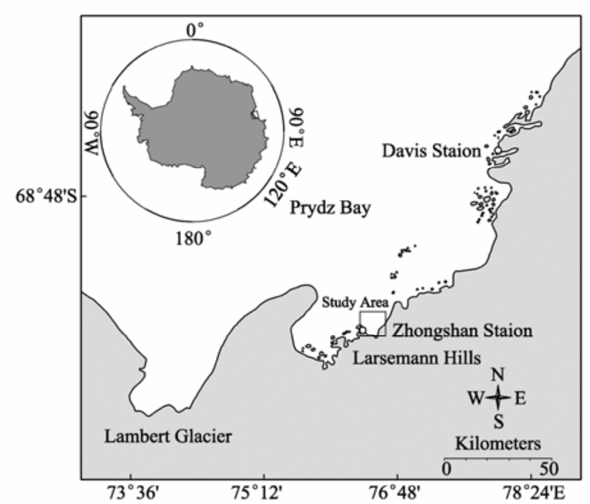

Fig.1a The study area

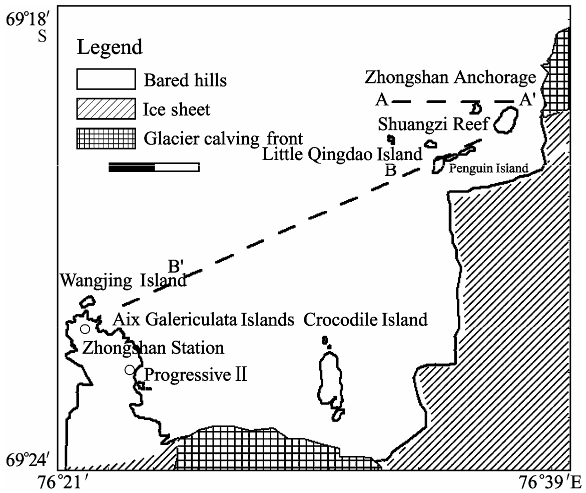

Fig.1b Bathymetric profile position

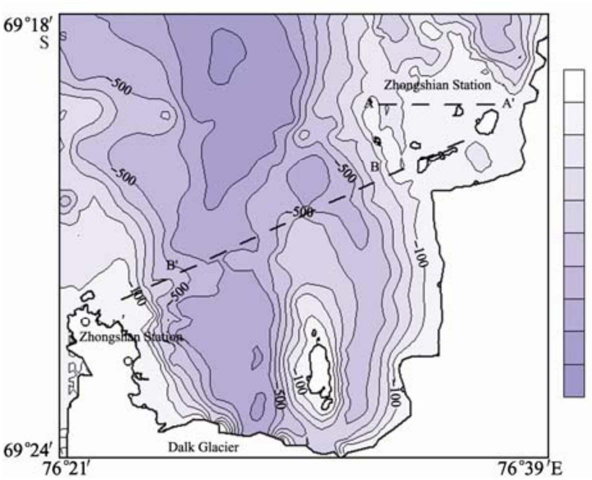

Fig.2 Sea-bottom topography near Zhongshan Station

Zhongshan Anchorage ground is located on the submarine terrain at the northeast part of the study area. The main topographic feature of the area between Zhongshan Anchorage and Zhongshan Station is a large depression, with a 400–800 m deep submarine canyon lying N-S direction and extending beneath the bottom of ice sheet (Fig.1a) (Feng, 2004).

2.2 Methodology

Bathymetric data (3.50×2.65 km^2 in area) was collected using a CS-500 single beam digital echo sounder in precision of <±Z×0.5% m (Shanghai, China) during the China's 15th Antarctic Investigation from December 1998 to February 1999. The collected bathymetry data were processed and analyzed by software MapInfo Professional 7.8 and Surfer 8.0. Together with the background data of Prydz Bay area, a 1:5 000 scale topographic map was generated. To better understand the topographic feature, two profiles, A-A′ and B-B′ as shown in Fig.1b, were selected and discussed in detail in the section followed

3 RESULTS

In general, the bathymetry of the study area becomes shallower from the south to north with the deepest area around the submarine canyon. The seafloor is categorized into three major zones as submarine slopes, canyons, and terrains. Scouring troughs, mounds and depressions as secondary geomorphologic features are also identified and described in the following sections (Figs.2 & 3).

Submarine slopes: The term "submarine slope" is mainly referred to the area between the low-water line and the wave base. Its outer boundary is less than 20 m with a high-gradient slope. Considering the dominance of erosion or deposition, submarine slopes could be categorized as erosional, erosion-depositional and depositional ones. In the study area, erosion-depositional submarine slopes are found between 10 and 20 m water depths on both sides of the submarine canyon east of Zhongshan Station; erosional slopes are found in the nearshore area north of Zhongshan Station and is part of the south anchorage. The sediments on the erosion-depositional slopes are mainly river delivered materials including sands and pebbles. Sediments on the erosional slopes are mainly originated from the cliffs reformed by waves, iceberg keels and currents. As a result, they are in mobile status because of hydrodynamics dominated by wave action. No depositional slopes are found in the study area.

The east coast of the submarine canyon is covered by either ice or glacial tongue, so these areas are dominated by the scouring or plowing of ice erosion. For areas near the anchorage ground in the northeast and Crocodile Island in the south, a large area of slope has been broken into scoured troughs, depressions and mounds under the activity of ice keels. On the northeast side of the anchorage, where the ice sheets collapse into the sea, the deepest depth of the submarine depression reaches up to 461 m. Near Crocodile Island, because of the ice keels plowing, its north side is much steeper than the south, so a submarine mound flank is reformed into depressions. As for the middle part of the coasts, the slopes are narrow and steep with even more complex topographic variations. The water depths generally vary from 100 to 400 m. There is a sharp fall out of the 100 m isobath which is a trough contributed as a main branch through which icebergs entering the open sea.

The coast west of the submarine canyon shows a concave shape toward inland with caves on it. Under the influence of landslides from the Mirror Peninsula, the coastline is meandering and has a large number of islands, for example, Wangjing Island and Aix Galericulata Islands (Fig.1b), and submarine mounds and troughs as well. Passing by flowing icebergs are usually detained here because of the sharp elevation variations of the sea floor. There is only a narrow submarine slope between the steep shore and the submarine canyon.

Submarine canyons: Submarine or subaqueous canyon is a typical geomorphologic feature on the bedrock of land slopes or island slopes. Generally submarine canyons are related to the tectonic fault, turbidity currents and glacier activities. Cross-shore faults are usually accounted for the origin of a submarine canyon, which is reformed by turbidity currents or glacier activities later. In the area between Zhongshan Station and the anchorage, a large submarine canyon and trough system is found out side of the Dalk Glacier calving ice front(bathymetric profile named B-B′ in Fig.4, position see Fig.1b and Fig.2). Both walls of the canyon are steep with an average slope gradient of 45.75% on the east wall and 33.4% on the west wall, respectively. At the central bottom there is a mound on the uneven seafloor which is believed to be the relicts of Crocodile Island at the south.

The irregular canyon boundary lies from the north to south where ice sheets collapse, making the canyon a main route through which the icebergs flow heading to the open sea. At the same time, ice keels plowing also plays an important role in canyon

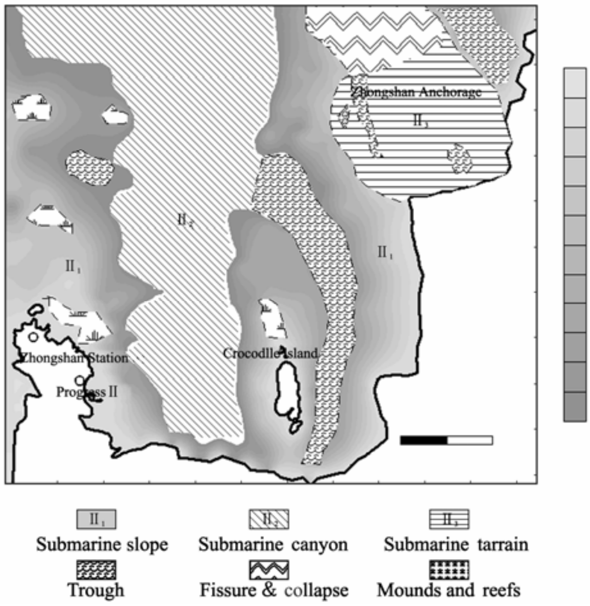

Fig.3 Topographic features of the study area

topographic reformation. The sidewalls receive reformation from not only the icebergs of different volumes and shapes, but also the sharp hydrodynamic changes brought by their movements. Specifically, slow-moving iceberg keels are main reason for the irregular-shaped sidewalls. All above mentioned activities make the canyon under intensive erosion.

Submarine terrains: Zhongshan Anchorage sits right on the shallow part of the submarine terrain northeast of the submarine canyon. The seafloor here is generally flat with few variations. The only exception is the terrain edge where bathymetry changes sharply because of the distribution of islands, reefs, and depressions (Fig.3). A series of troughs and grooves are formed among the islands and reefs surrounding the submarine terrain (Fig.5). There is also a 1 km^2 depression with a mean water depth of 110m at the crossing of the south anchorage and the east Penguin Island. Meanwhile, a large mound is found about 1 200 m northwest of the Penguin Island and 400m north of the Little Qingdao Island.

The anchorage ground has an average water depth of less than 50 m. The bathymetry drops sharply after 50 m. There is a tongue-shaped relict in the north of the terrain which is believed to be generated by fissure collapses. The largest fissure, which is roughly 3.8 km × 10 m in area, is found right under the south boundary of the anchorage.

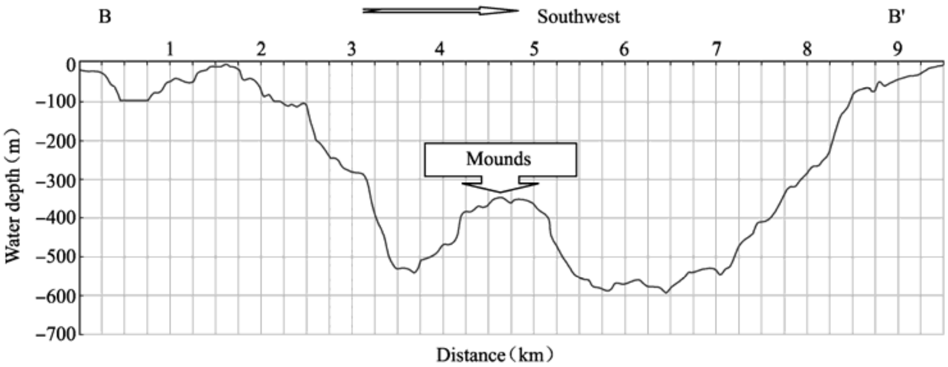

Fig.4 Bathymetric profile of B-B′

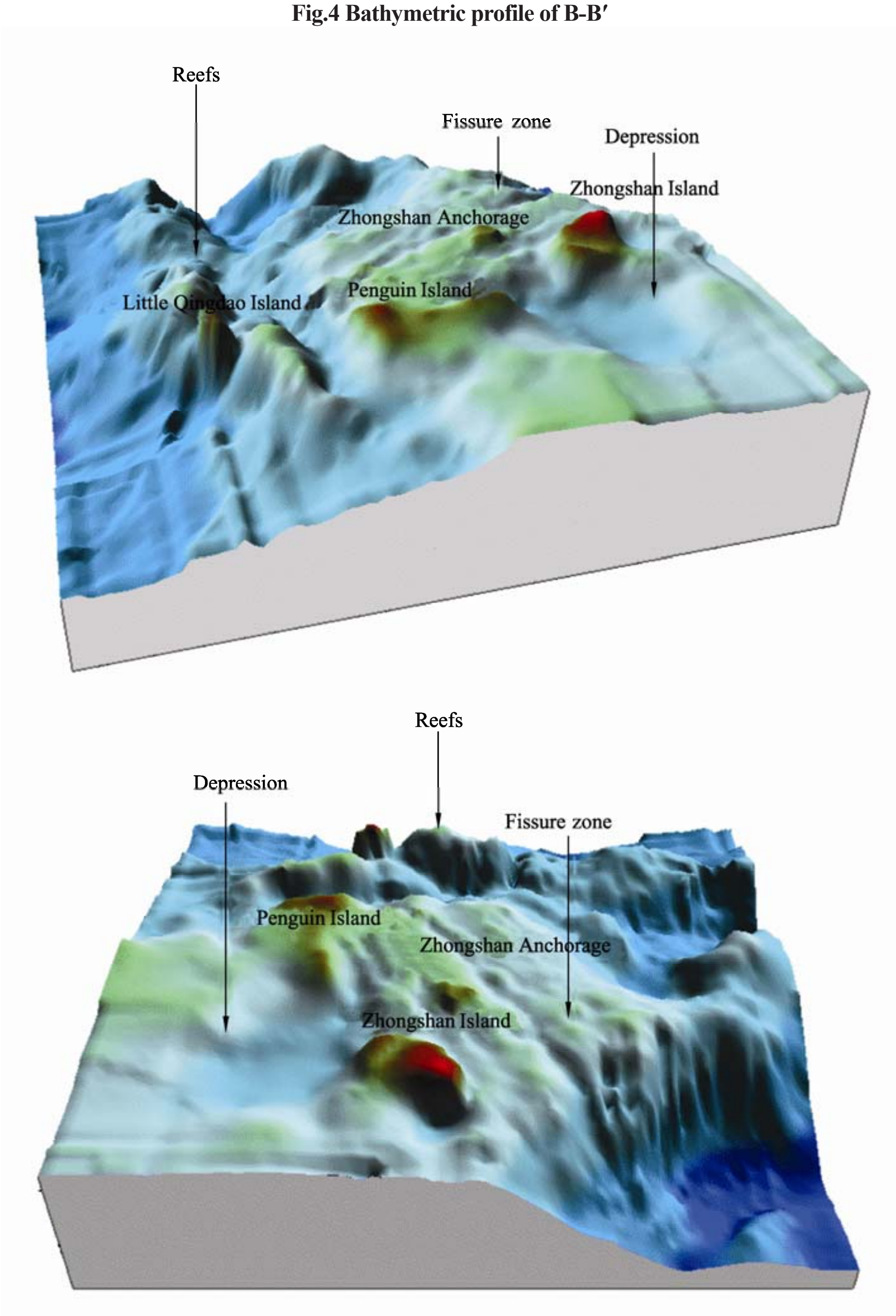

Fig.5 Three dimensional view of the submarine terrain (up: rotation 15; down, rotation 270°)

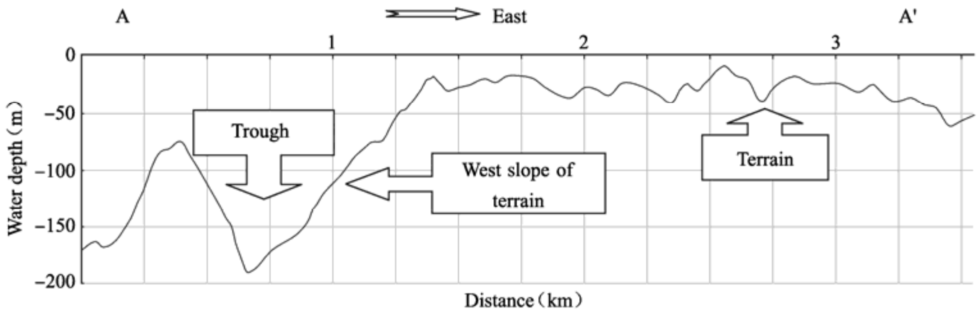

Fig.6 Bathymetric profile of A-A′ (position showed in Fig.2)

Profile A-A′ in Fig.6 shows the combination morphology of general flat terrain and rapid drop slopside. Surrounding the submarine terrain, there are broken slopes with parallel ridges and grooves, which have 50—300 m elevation variations. Profile A-A′ is right crossing the south part of the anchorage, where the water depth on the terrain is between 20 and 40 m with variations of 10 m. While the western slope shows gradient of 23% and a 190 m deep depression, the eastern part is occupied by series of reefs including Shuangzi Reef with shallowest area only 10.1 m deep. To the southwest of anchorage the bathymetry is even more variable. Large-scale ice bodies are frequently formed in the northeast boundary of the terrain calving from ice sheet, making this place anther route through which icebergs enter the open sea.

4 DISCUSSION

4.1 Geomorphology and topography

Larsemenn Hills, an ice-free oasis on the Ingrid Christensen Coast, is in continuous permafrost with intensive wind action. Periglacial process is the main factor determining the local modern geomorphology. Large quantities of garnet crystals are found on the erosion surface of bedrocks and bare hills. According to Li (1995), gneiss is the main rock type in this area. The high level of petrofabric structure and particle arrangement uniformity of gneiss weaken both the porosity and glacial agents, especially the expanding and shrinking function brought by temperature changes. However, structure fissures caused by metamorphism would enhance frost wedging, wind erosion and snow erosion as well. As a result, more than half of the Mirror Peninsular is covered by the Holocene unconsolidated sediments, providing large amount of clastic material to the study area (Gasparon and Matschullat, 2006).

As for subaqueous topography, the most obvious feature of this area is the submarine canyon and trough system, separated by Crocodile Island, outside the calving ice front of Dalk Glacier. As a main route of icebergs, this canyon and trough system could be the result of either ice keel ploughing or cross shore tectonic fault. To fully understand its formation, more information on the evolution and dynamic of Dalk Glacier and local tectonic activities is certainly needed.

4.2 Modern sedimentation

Prydz Bay receives large amount of sediments-laden ice from Lambert Glacier system, which drains 14% of the grounded ice area of East Antarctica (Harris et al., 1998). As a result, most area of the Prydz Bay is covered by 5 km thick sediment with alternating clastic-rich and biogenic-rich intervals that reflect alternations of glacial and interglacial conditions (Taylor et al., 1997). Yet, the whole shelf area has been under erosion by grounded ice since the Middle Miocene. Although the area of 60º east of Prydz Bay is mainly controlled by the Lambert Glacier, there are almost no seismically visible sediments covering the southeast boundary of Prydz Bay (Stagg, 1985; Harris et al., 1998).

In the anchorage area, four surface samples have been documented by Feng and Xu (1999). Urchins and kelp are found in two of the four surface samples. However, for lacking detail seismic survey and sampling from this area, no conclusion has been made on the local sedimentation.

4.3 Anchorage stability

Zhongshan Anchorage is located at the submarine terrain in the northeast of the study area. The terrain is general flat with the shallowest water depth, average 20–40 m, in the study area. The terrain slope with maximum gradient of 50% drops rapidly to the surrounding submarine slope and canyon. A fissure near the south boundary of the terrain, roughly 3.8 km×10 m in area as described above, could be a threat to the anchorage stability. According to Yang and Wang (1996), thousands of ice fall signal (> 1mv) have been collected by seismic geophone in a single year around Zhongshan Station. Once trigged by ice falls or other factors, for example, earthquakes, it is highly possible that the fissure would lost its stability and make the south edge of the terrain fall into deep sea in approximately NWN (Northwestnorth) direction.

Antarctic sea ice consists mostly of young or first-year formed ice since most of the ice melts during the first summer after it forms (Allison et al., 1993), which means that seasonal sea ice covers the region throughout autumn, winter and spring. In the study area, besides sea ice, Dalk Glacier is the main source of icebergs. Considering the dominant westward flow and wind in the southeast Prydz Bay (Nunes Vaz and Lennon, 1996), icebergs from Dalk Glacier should not be a threat to the usage of anchorage in the east. Yet, ice drifting from the northwest of the study area, for example, Sørsdal Glacier southwest of Davis Station, should be taken into consideration during the usage of Zhongshan Anchorage.

5 CONCLUSION

Zhongshan Station is located in a continuous permafrost zone and periglacial process is the main factor determining the local modern geomorphology. The up to 700 m deep canyon is the dominant feature of the seafloor between Zhongshan Station and Zhoangshan Anchorage. Around the submarine terrain are submarine mounds, troughs and depressions with 200 to 300 m depth variation. The fissure on the south terrain is a threat to the anchorage stability. To better understand the origin of the submarine canyon and trough system as well as the drifting ice in the study area, more investigations on the local tectonic, sedimentation and the evolution of Dalk Glacier are needed.

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