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Heat Flow Measurements in the Antarctic Peninsula Region

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Abstract: Data from 250 heat flow measurements were compiled for the southern ocean and the Antarctic continent. However, only few data were available on the ground such as around McMurdo Station (77°S, 165°E) and Syowa Station (69°S, 39°E). Japanese R/V Hakurei-maru was responsible for measuring about 40% of the heat flow data in the southern ocean surrounding the Antarctic Continent. Other measurements were concentrated mostly in the Weddell and the Ross Seas. Around the South Shetland Islands and the Antarctic Peninsula, 91 heat flow measurements were gathered. Heat flow values around the Antarctic Continent are about 10 to 30% higher than those expected for a given age of the seafloor by the plate cooling theory. As the seafloor surface temperature is controlled by the bottom water, one possible explanation of this high heat flow may be due to the temperature change of bottom water.

Key words: heat flow, southern ocean, South Shetland Islands, bottom water.

INTRODUCTION

The nember of heat flow measurements from the southern ocean around the Antarctic Continent are few compared with those in other areas of the world. The heat flow measurements in the southern ocean are disturbed frequently by sea ice and ice bergs. The heat flow data from the continental shelf are sparse because the area is mostly covered by sea ice through out the year. On land, the heat flow measurements were tried at only two stations; one was around McMurdo Station and the other was around Syowa Station. Because more than 95% of the Antarctic Continent is covered by ice sheet and it is also very hard work to dig a deep hole for measuring heat flows. Data representing 250 heat flow measurements were compiled for the Antarctic Continent and surrounding southern ocean by 1992.

In the view of platetectonics, the South Shetland Islands and its surrounding ocean are the most active/interesting area in and around the Antarctic Plate. The South Shetland Trench located along the south-west side of the South Shetland Islands is the only trench topography recognized clearly along the Antarctic Plate margin. The Bransfield Rift in the Bransfield Strait also represents the only rift in the Antarctic Plate boundaries.

The region at the tip of the Antarctic Peninsula, including the South Shetland Trench is considered to be the last remnant of a subduction zone that has been active along the Pacific margin of Gondwana (Pankhurst, 1990).

Earthquakes are located around two active volcanic islands, Deception and Bridgeman Islands at both ends of the Bransfield rift, however, no seismic activity is recognized along the rift at present. (Kaminuma, 1995).

In this paper, the present status of the heat flow measurements in the Antarctic is summarized with a focus on heat flow data around the South Shetland Islands. Heat flow values are discussed in terms of platetectonics.

PRESENT STATUS OF DATA IN THE ANTARCTIC

International Heat Flow Commission (IHFC) compiled a heat flow (HF) database in 1991, and 72 HF measurements from the southern hemisphere (greater than 45°S in latitude) were included in the database (Pollack *et al.*, 1991). Most of the data were measured in the Southern Ocean. Some HF measurements on land were made in and around McMurdo Station and Dry Valleys in the Victoria Land using the boreholes of The Dry Valley Drilling Project (DVDP) (Decker and Bucher, 1982). HF values on land were also obtained using shallow holes at Syowa Station (Nagao and Kaminuma, 1983 a and b, 1985). Thus at these above mentioned measurement sites are only HF measurements for the land area in Antarctica. Nagao *et al.* (1985) and Nagao and Kaminuma (1986) reported a result of the long-term underground temperature measurements at Syowa Station threughout the year.

This is the first mesurement of the long-term undergound temperature throughout the year in Antarctica. A Japanese research vessel Hakurei-maru has been conducting geophysical surveys in the Southern Ocean surrounding the Antarctic Continent since 1980. Her survey tracks during the period 1980-1990 are shown in Fig. 1. She made 102 HF measurements during the 11 year period of 1980-1990 (Okuda *et al.*, 1983, Sato *et al.*, 1984, Tsumuraya *et al.*, 1985, Mizukoshi 1986, Saki *et al.*, 1987, Yumaguchi *et al.*, 1988 and Shimizu *et al.*, 1989).

Another 76 HF measurements were done, mostly in the region around the tip of the Antarctic Peninsula and Weddell Sea. The first heat flow measurments in the Scotia and Weddell Seas were reported by Zlotnicki *et al.* (1980). Thirty-five of the 76 HF measurements were made in the Jane Basin by Lawver *et al.* (1991).

A total database of 250 HF measurements is therefore available in the southern hemisphere at latitude greater than 45°S. All data are shown in Fig. 2.

HF values offshore of Queen Maud Land range from 43 to 57 mW/m2 and those offfshore of Enderby Land and Wilkes Land are from 41 to 91 mW/m^2. All these values off East Antarctica shore were measured by the Hakureimaru cruises.

HF data in the Ross Sea and north of the Ross Sea show high and scattered HF values ranging from 10 to 113 mW/m^2. In the Bellingshausen Sea,

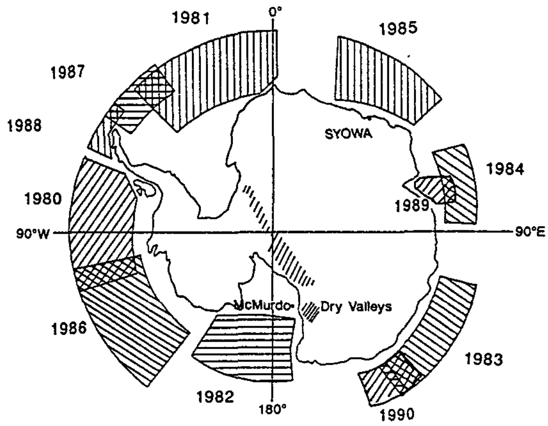

Fig. 1. The survey areas by Hakurei-maru in 1981-1990 currently.

HF values range from 43 to 72 mW/m^2.

BRANSFIELD STRAIT

Figure 3 shows the location of HF values measured around the tip of the Antarctic Peninsula and the north-western part of Weddell Sea. The HF values in this area seemed to be important because the HF measurements have been made along the Antarctic Plate margin. HF values in the Jane Basin ranged from 67 mW/m^2 to 92 mW/m^2 (Lawver *et al.*, 1991). Interesting HF measurements were made by Hakurei-maru in 1983. Two low HF values of 16.5 and 12.9 mW/m^2 were measured at 69.2°S, 51.7°W, 1794 m in depth and 69.3°S, 52.0°W, 1844 m in depth; and of 85.0 mW/m^2 and 91.3 mW/m2 at 69.5°S, 34.1°W, 4360m in depth and 69.5°S, 34.1°W, 4364 m in depth respectively.

HF values around Bransfield Strait are shown in Fig. 4. Open circles in Fig. 4 were measured in the north-west side of the Peninsula by Dougherty *et al.* (1986), and shaded ones were by Hakurei-maru. Dougherty *et al.* mentioned that HF values measured on the continental margin are about 75 mW/m^2, and those along the trench are over 100 mW/m^2, and the general pattern of these high HF values may be due to the presence of a young plate in the extinct subduction zone.

HF values measured at six locations by Hakurei-maru are all over 100 mW/m^2 and the value of 66 mW/m^2 was measured at another location.

Three HF measurements were made by Hakurei-

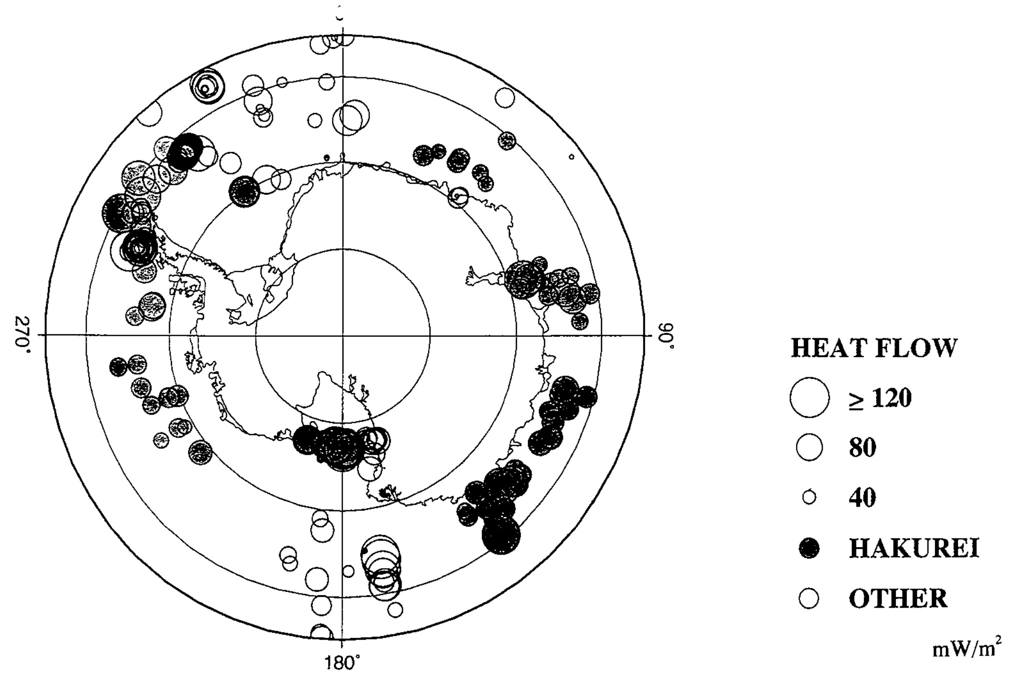

Fig. 2. Heat flow data in southern part of 45°S.

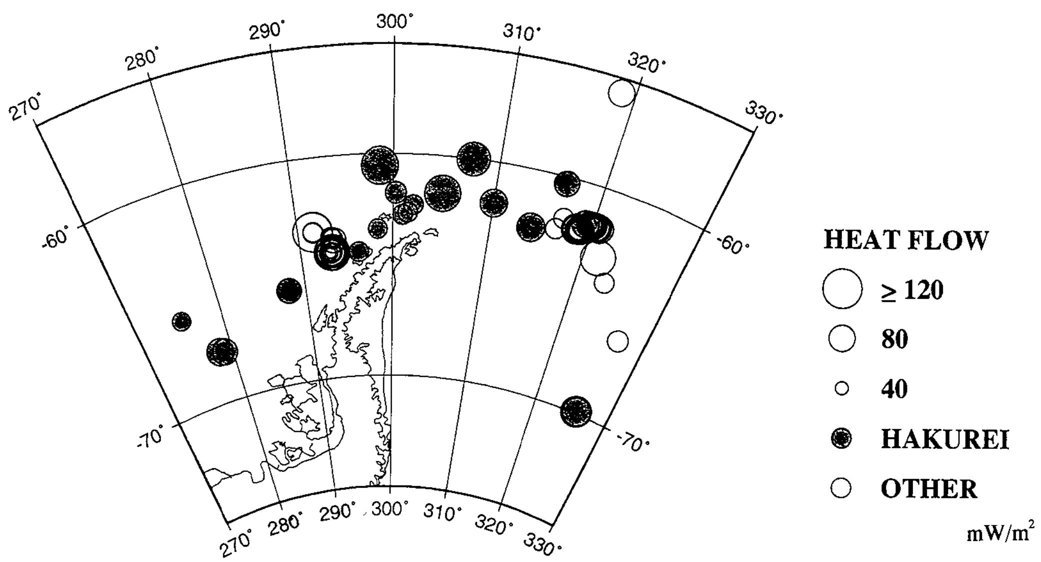

Fig. 3. Heat flow data in the tip of the Antarctic Peninsula and the northwest of Weddell Sea. The unit is mW/m2.

maru in The Bransfield Strait. These values are very high and scattered as 413, 164 and 140 mW/m^2.

Exempting the abnormally high value of 413 mW/m^2, the HF values measured by Hakurei-maru have been similarly obtained by Dougherty *et al.*

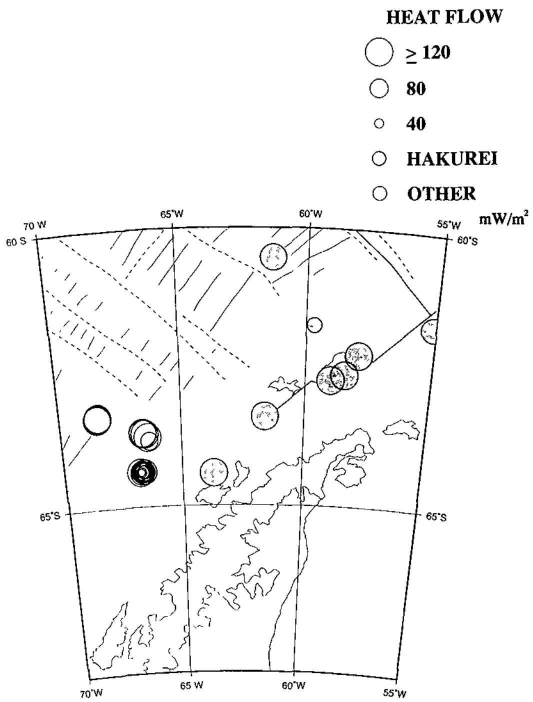

Fig. 4. Heat flow data around the South Shetland Islands. The unit is mW/m^2.

(1986).

The distribution of high HF values seen in Fig. 4 is probably the general pattern of HF values in the north-west area of the Antarctic Peninsula.

DISCUSSION AND CONCLUSION

In general HF values measured in the deep ocean according to the plate cooling theory is proportional to $1/\sqrt{t}$, where t is the age of sea floor. As shown in Figs 2, 3 and 4 the HF values in the southern ocean especially in the continental margins are relatively high in comparison with the expected values from the age of sea floor. The measured HF values are about 10~30% higher than thouse expected (eg. Lister, 1977, Persons and Sclater, 1977). One possible explanation for this relatively high HF is sudden temperature decrease of bottom water, which is caused by rapid inflow of melting water from glaciers/icesheet and icebergs.

By this temperature decrease, the surface temperature of the sediment becomes lower and apparent thermal gradient in the sedimen layer of sea floor become larger, therefore HF values appear larger, and HF values exceed expectations.

The HF values from the continental shelves, especially in Ross Sea, show anomalously high and low HFs. If these scattered HF values are true, several mechanisms may be causative: (1) pore water convection through sediments: (2) effects of sea bottom water change: and (3) topographic effect (heat flow refraction). Mechanism (2) is proposed in this paper and mechanism (3) was also proposed by Zlotnicki *et al.* (1980). Unfortunately a comprehensive scientific study of the nature of HF in the ocean proximate to the Antarctic Continent has not been undertaken. Therefore the HF values are less than highly reliable. If we have a chance to visit the Antarctic region, we have to get not only HF data but also detailed geophysical (topography, magnetic and seismic data) and geochemical (pore water chemistry, pore water pressure and so on) data simultaneously to know the nature of polar region and there-by assess the nature of the HF data.

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