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PRELIMINARY STUDY ON THE OXYGEN-MINIMUM LAYER IN WATER AREA ADJACENT TO SOUTH SHETLAND ISLANDS AND NORTH OF ARDLEYD ISLAND, ANATRCTICA, IN SUMMER

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Abstarct In this paper, a distribution of the oxygen-minimum layer in the sea area adjacent to the South Shetland Islands and north of the Ardleyd Island, Antarctica, in summer is discussed.The vertical distribution of oxygen in oxygen-minimum layer has the following features: 1). The depth at which the oxygen content greatly decreases is coincident with the depth of pycnocline; 2). There is a thick water layer with low oxygen content; 3). The oxygen-minimum layer occurs below the thermocline and coincides with the depth at which the temperature mostly increases. According to preliminary result of correlation analysis, the variation of oxygen-minimum layer is related to physical preperties of the circulation and biochemical process in deep layer of the ocean.

Key words Dissolved oxygon, Oxygen-minimum layer, South Shetland Island

1. Introduction

The occurence of oxygen-minimum layer in deeper layer of the ocean is an important and widespread feature of the oceanic environment. The oxygen content at a certain depth of the ocean is lower than that in its nearby upper and lower layers and reaches a minimum value, so the layer is called the oxygen-minimum layer. Early, Wust (1936) and Seiveil (1937). have studied the oxygen-minimum layer. Afterwards, not a few oceanographers, such as Okeyen (1961). Weyl (1965) and Decon (1984) also studied the distribution features of oxygen-minimum layer and its formation mechanisum in the world ocean. These studies have a practical significance for detecting the circulation features and life condition for biotic realm in deep sea. In this paper, the author studies preliminarily the oxygen-minimum layer in the Antarctic water by using data of dissolved oxygen obtained during the Chinese South Ocean Expedition in January to February of 1985 (Location of observation stations is shown in Fig. 1).

2. Horizontal distribution feature of oxygen-minimum layer

It can be seen in Fig. 1 that the existence of oxygen-minimum layer at the depth of 150 m to 470 m in the Bransfield Strait, northwest of the South Shethand Islands, north of the Ardleyd island as well as in southern bay of the Liwinston Island and the Gerlache Strait. Among all these areas, the oxygen content in oxygen-minimum layer at Station No. 11 northwest of the South Shetland Islands is the lowest (4.00ml / L) and depth of this layer is the deepest (470m).

Figs. 2,3 show the horizontal distribution of oxygen content in the oxygen-minimum layer and its depth.

It can be seen in Fig. 2 that the general distribution tendency of oxygen-minimum layer is that

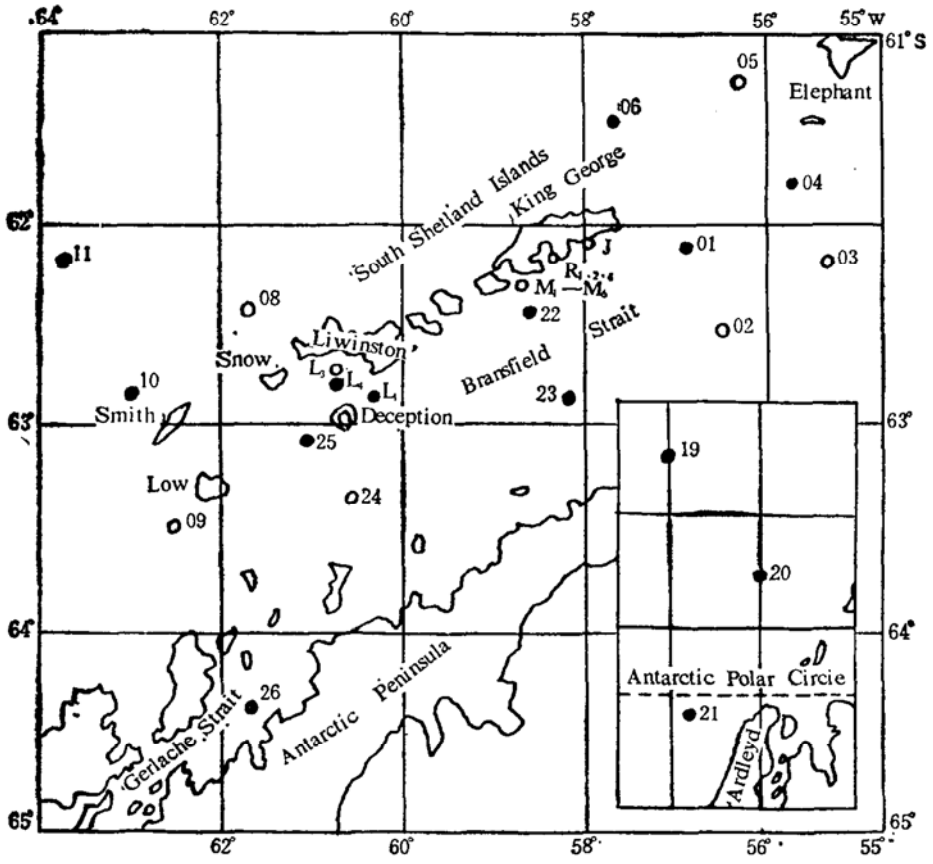

Fig. 1. Map of the studied Antarctic area showing Locations of observation stations. Black circle indicates stations at which the oxygen-minimum layer was observed.

the oxygen content in the sea northwest of the South Shetland Islands, the western Bransfield Strait and sea area north of the Ardleyd Island is the lowest, in a range from 4.00ml / L to 5.20 ml / L. But, in the middle part of the Bransfield Strait the Oxygen content is the highest, in a range from 5.77 ml / L to 6.43 ml / L. The oxygen content in the area between King George Island and Elephant Island is 5.45 ml / L to 5.80 ml / L, in a range between both of formers.

In the western Bransfield Strait, an oxygen contour line of 5.60 ml / L in the form of tongue enters into the Strait from west to east. The front of tongue reaches to about 59°50′ W. To the west of the contour line, the oxygen-minimum layer is evident and its oxygen content ranges from 4.00 ml / L to 5.60 ml / L, and increases gradually from west to east. In addition, oxygen contour lines appears to be densely concentrated (Fig. 2). As shown in Fig. 3, the depth of oxygen-minimum layer is shallowed gradually from 470 m to 300 m from Station No. 11 in the sea area northwest of the South Shetlands to near Deception Island. These variations of oxygen and depth are related to the influence of the Antarctic Circumpolar Water from the Bellingshausen Sea.

Under the influence of the Weddell Bottom Water, oxygen content in the eastern Bransfield Strait is the highest. Oxygen contour line of 6.40 ml / L in the form of tongue stretches to near the King George Island. At station No. 22 south of King George Island, oxygen content is as high as 6.43 ml / L and its depth increases to 150–200m from south to north. In the sea area northeast of the King George Island, oxygen content increases gradually from north to south and its

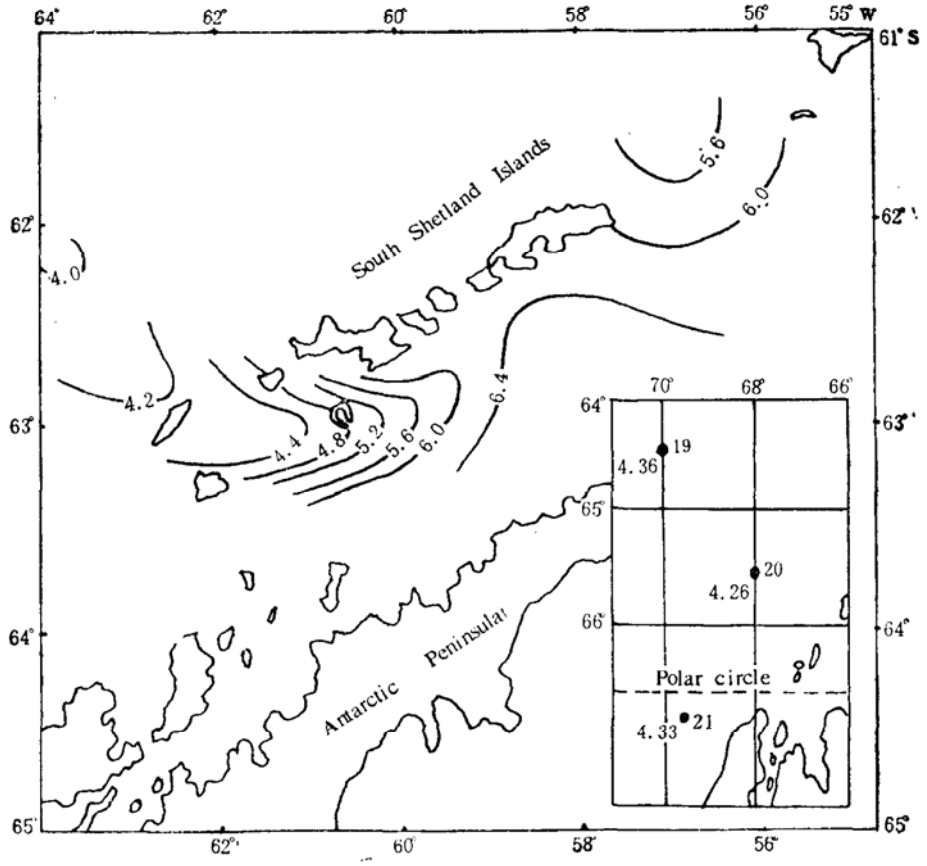

Fig. 2. Horizontal distribution of oxygen content in the oxygen-minimum layer. Numbers by Stations 19, 20, 21 are oxygen content (ml / L) in the oxygen-minimum layer.

depth increases also from north to south. At station No. 1 southeast of the King George Island, the depth declines down to 404 m because of setting of oxygen-rich surface water. As the water in the baies of Liwinston Island and the Gerlache Strait has the nature of mixed water, so the oxygen content and depth of oxygen-minimum layer at Station L1, L4 and S20 range from 5.20 to 5.77 ml / L and 180m–300 m, respectively. In the area north of the Ardleyd Island, oxygen content is lower (4.26—4.36ml / L)and the depth of the layer at Station No. 19 off northern coast of Ardleyd is the deepest (448m), but at Station No. 21 near the Addleyd Island is the shallowest (227 m). In general, the oxygen content and depth of oxygen-minimum layer are different in the Antarctic area in observation with the different characteristics of water mass and its influence on the oxygen-minimum layer. The horizontal distribution of the oxygen-minimum layer is related with the flow direction of the Antarctic Circumpolar Water and Widdle Bottom Water.

3. Vertical distribution features of oxygen-minimum layer

According to analysis of data on oxygen content, density and temperature obtained in the Antarctic water area, the following vertical distribution features of oxygen-minimum layer are found:

1) The depth at which the oxygen content greatly decreases is coincident with the depth of pycnocline.

2) There is a thick water layer with low oxygen content.

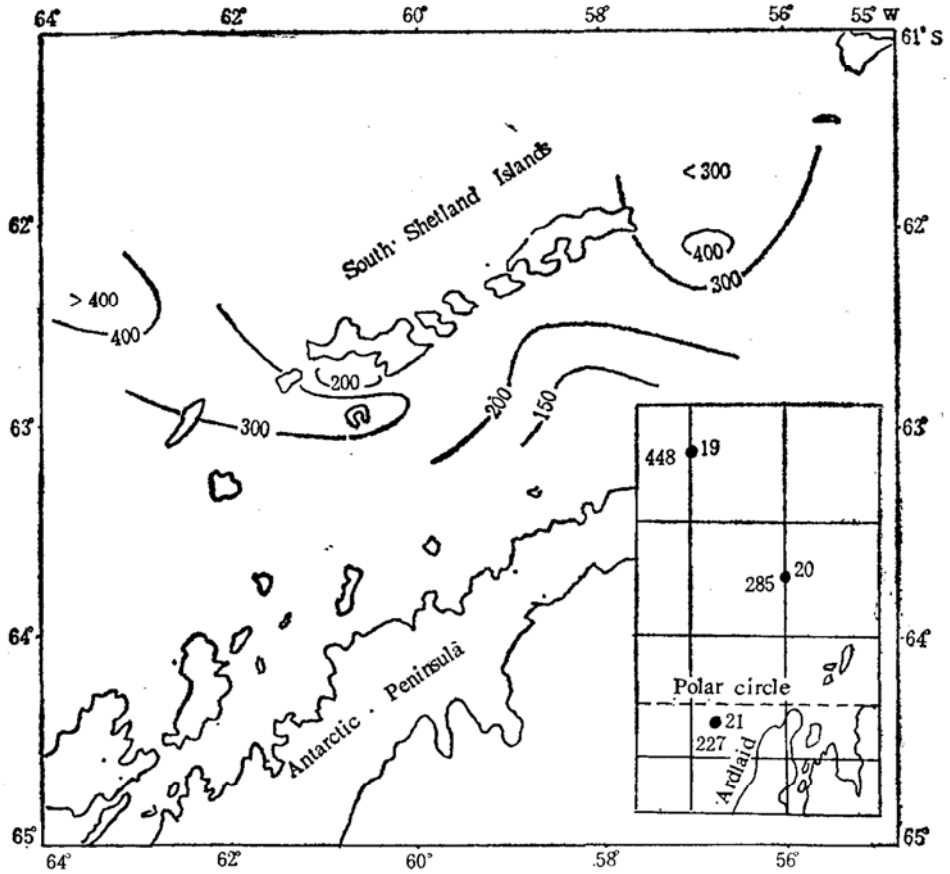

Fig. 3. Horizontal distribution of the depth (m) of oxygen-minimum layer. Numbers by Stations 19, 20, 21 are depth (m) of oxygen-minimum layer.

3) The oxygen-minimum layer occurs below the thermocline and coincident with the depth at which the temperature mostly increases.

Fig. 4 shows a representative example of the vertical distribution of oxygen, temperature and density at Station No. 10 in sea area northwest of the South Shetland Islands.

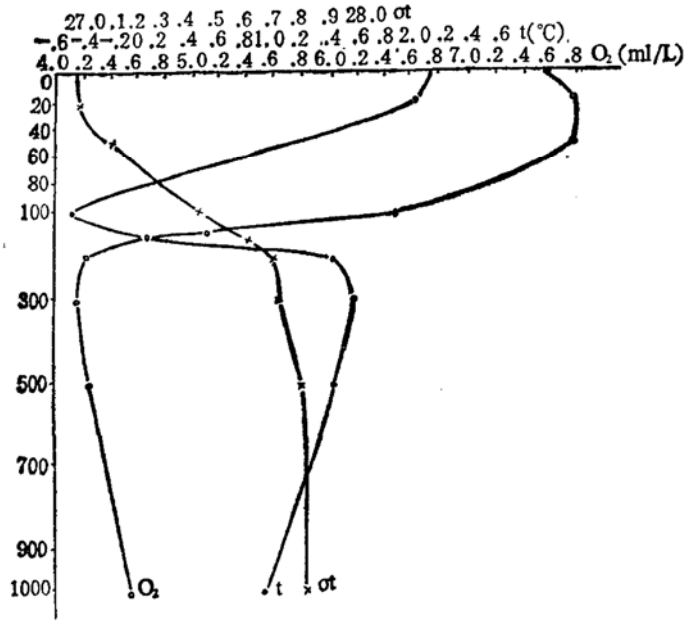

Fig. 4 Vertical distribution of oxygen, temperature and density at Station 10 (1985).

It can be seen in Fig. 4 at the depth of 20m to 50m below the surface, there exists an Antarctic Surface Water with high temperature, high oxygen and low density. At the depth of 50m to 100m, there is an Antarctic Cold Water with low temperature. Within the range of above-mentioned depth, the temperature decreases rapidly with the increasing depth. but the density increases. Thus, thermocline and pycnocline are formed. Owing to the increasing stability of sea water, the thermocline and pycnocline prevent the underlying water from the replenishment of oxygen from the surface. Therefore, the dissolved oxygen is lost without retrieval beneath spring layer, due to oxidation-decomposition of organic matter and little or no supply of oxygen, and then a large spring layer of oxygen occured with the increasing depth. The upper depth of pycnocline (50m) is just the depth of greatly decreasing oxygen content. Below 100m depth the temperature increases gradually with the depth due to the effect of the Antarctic Circumpolar Water. At the depth of 300m, the temperature raised to the highest (1.60°C), but oxygen content reduces to the lowest (4.18 ml/L), and then it increases slowly with the depth. The depth of oxygen-minimum layer is coincident with the depth at which temperature mostly insreases and it occurs below the thermocline. Although the thermocline, halocline and pycnocline in the Antarctic Water are not evident than that in the world ocean, the relationship between the oxygen content and temperature as well as density would appear when the nutrient-rich surface layer with high productivity and the distinct thermocline, halocline and pycnocline coexist in summer.

In the studied at the stations where the oxygen-minimum layer exists, a thick water layer with low oxygen appears beneath the oxygen-minimum layer. It is 400–500m thick in maximum, and some dozens of metres in minimum. For example, oxygen-minimum layer at Station No. 11 northwest of the South Shetlands was found at the depth of 470m, and below 470m to 939m there is a low oxygen layer, the thickness of which is 469 m. In the low-oxygen layer, oxygen content is almost the same as that in the adjacent upper and lower layers (see Fig. 5).

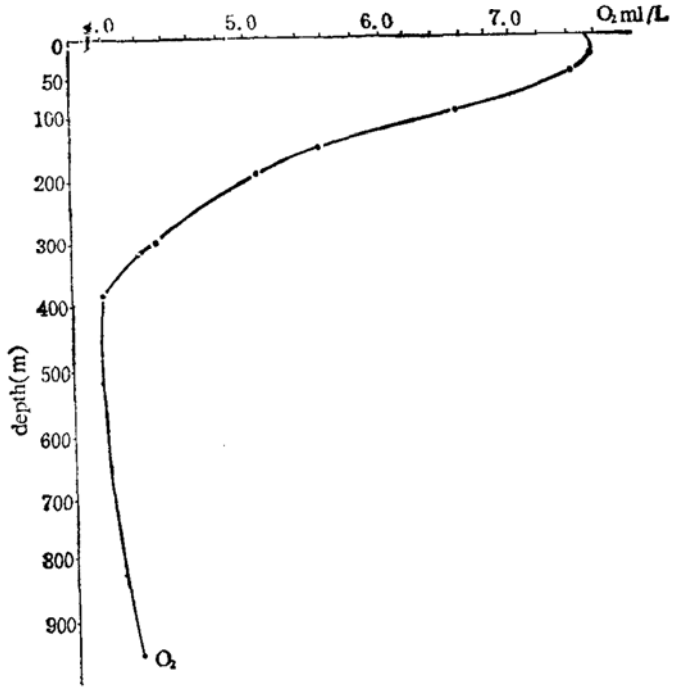

Fig. 5. Vertical distribution of oxygen content in the water at Station No. 11.

We can see in Fig. 5 that the oxygen content in the water at station No. 11 is 4.00ml / L and 4.21 ml / L at the depth of 470m and 939m, respectively. and it differs by 0.21 ml / L. Again, at Station No. 19 north of Polar Circle, oxygen-minimum layer was found at the depth of 448m, and thickness of low-oxygen layer reaches 452m. Difference in oxygen content between both these layers is only 0.05 ml / L. It indicated that the water beneath the oxygen-minimum layer is controled by a homogeneous water mass with low oxygen. In the water northwest of the South Shetland Islands and north of the Ardleyd Island, the thickness of low-oxygen layer becomes larger due to the influence of the deep Antarctic circumpolar water. As the depth of the Antarctic circumpolar water is shallow from west to east, the thickness of low-oxygen water is only some dozens of metres at Station No. 10. The thickness of the water is generally 100m to 200m in the western the Bransfield Strait near Deception Island due to the influence of water from the Strait.

4. Discussion

The studied Antarctic area belongs to the high-latitude cold region, here the circulation features and biochemical process are different from those in the world ocean. Thus the oxygen content and depth of the oxygen-minimum layer are different from those in the world ocean.

Table 1. Oxygen—minimum layer in the studied area in comparisor with that in the oceans.

sea area	oxygen (ml/l)	depth (m)	sigma—t	A. O. U (ml/l)	number of oxygen—min. layers
Antarctic sea	4. 00—6. 43	150—470	27. 68—27. 8	3. 3—3. 5	1
South of 68°S	4. 02—4. 33	400—600	—	—	1
Subarctic area	0. 50	600	27. 20—27. 3	—	2
Equtorial Pacific	2. 00	400—500	26. 80—27. 0	—	2
North Pacific	0. 24—0. 46	800	—	—	2
South and North subtropic Pacific	0. 10—0. 90	300	—	—	2
Coast of central American	0. 0	100	—	—	1
Kuroshio	1. 00	1000	—	—	1
Japan Sea	0. 50—5. 00	1000—3000	—	—	2
Atlantic ocean	3. 00—4. 00	300—800	—	—	2
Indian ocean	1. 50	300—800	—	—	2

* Other data from A. M. Муромчев, 1959.

It can be obviously seen in Table 1 that oxygen content in the oxygen-minimum layer in the Antarctic area ranges from 4.00 ml / L to 6.43 ml / L, which is higher than that in the world ocean. Oxygen content and depth of the layer west of the South Shetlands and north of the Ardleyd Island are 4.00—4.36 ml / L and 227 to 470m, respectively, Oxygen content in above-mentioned areas is close to the result (4.02 ml / L to 4.33 ml / L) obtained from the water south of 68° S. But the depth of the layer is shallower than that in the later. This is because a number of observation stations located in the shelf area. The density of oxygen-minimum layer (27.68—27.80) in the inves-

tigated Antarctic area is higher than that in the Indian Ocean(25.00—26.50)and the Subarctic Ocean (27.20—27.30), but the apparent oxygen utilization (A.O.U) (3.3—3.5ml / L) is lower than that in the Subarctic Ocean and Pacific Ocean (4.00—6.00ml / L). In addition, only an oxygen-minimum layer was found in the Antarctic area. According to the calculation of correlation coefficient between oxygen content and other factors such as temperature, salinity, density, pH and A.O. U at the depth of oxygen-minimum layer, the liner regression equations for them are obtained as follows:

$$02\ (ml/L) = 6.406 - 1.65\ T(C^\circ)\quad (n=11,\ r=-0.9688)$$

$$02\ (ml/L) = 135.19 - 3.767\ S\ (\times 10^{-3})\quad (n=11,\ r=-0.5399)$$

$$02\ (ml/L) = -290.5 + 10.647\delta_t\quad (n=11,\ r=0.4766)$$

$$02\ (ml/L) = 3.993 + 0.1394\ pH\quad (n=11,\ r=0.3638)$$

$$02\ (ml/L) = 8.178 - 1.108\ AOU\ (ml/L)\quad (n=11,\ r=-0.9945)$$

From the above regression equations, the correlation between oxygen and temperature is good negative. The correlation between oxygen and apparent oxygen utilization (A. O. U) is also good. It indicates that temperature and process of oxidation-decomposition of organic matter are the important factors for controlling the variation of oxygen-minimum layer.

5. Conclusion

As a result of above comprehensive study, the author draws the following conclusions:

1. The oxygen-minimum layer in the northwestern sea area of the South Shetland Islands, Western Bransfield Strait and sea area north of the Ardleyd Island is evidently present . The oxygen content in oxygen-minimum layer is the lowest (4.00ml / L) and the depth of the layer is the deepest (470m). The oxygen content is higher at the other stations. The density of oxygen-minimum layer is found to be 27.68 to 27.80 and salinity is more than 34.60. The distribution of oxygen-minimum layer corresponds with the direction of the circulation in deeper layer.

2. The oxygen content in oxygen-minimum layer in the studied Antarctic area is higher than that in the world ocean. Only an oxygen-minimum layer was found in the Antarctic area as the coexistence of the nutrient-rich surface layer with the high productivity and the distinct thermocline, halocline and pycnocline appears.

3. The correlations of oxygen content with temperature and apparent oxygen utilization at the depth of oxygen-minimum layer are good negative. It indicates that temperature and biochemical process are the important factors for control on the distribution and variation of oxygen-minimum layer.

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References

Deacon, G. E. R. (1984) Oxygen in Antarctic Water, *Deep-sea research,* Vo.l. 31; No. 11.

Kawamoto, T. (1956): On the distribution of the dissolved oxygen in the Pacific Ocean, Umi to Sora (Sea and Sky) 32; 92—98.

Miyake, Y and Saruhasht, K. (1956): On the vertical distribution of the dissolved oxygen in the ocean. Deep-sea research. 13: 242—247.

Yoshio, S. (1969) On the oxygen-minimum layer in the Ocean, La mer Tome 7; No. 2; pp 84—89.

Stein, M. (1981): The distribution of water masses in the South Shetland Islands area During FIBE, *Antarctic ocean,* No. 23, pp 22—23.

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