

Plankton Ice in the Antarctic Ocean

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南極海のプランクトンアイスについて

目 黒 熙*

要 旨

プランクトンアイスは南極海のパックアイス中で広く見られる、プランクトンの繁殖により著しく着色された海氷である。海氷の面から見れば、この現象はプランクトンの増殖により着色した部分が選択的にとがされ、海氷の積雪層と海氷層とがサンドイッチをはがすように上下2層に分別する、融氷の1形式であり、生物学的には、ケイソウ (diatoms) を主とする1群の植物性プランクト

ン生活環の1形式である。すなわち、海氷上の積雪層で水面下にある部分にプランクトンが侵入増殖して、これを着色せしめるほどの量にまでなる。このプランクトンの数は通常の海水中のその10倍以上にも達する。生活環境としてのプランクトンアイスは、温度、日光の供給、空気、栄養塩の諸点からみて、一般に考えられている程きびしい異常のものではない。

Introduction

In the pack ice area of the Antarctic Ocean a great deal of brown sea ice can be seen during the summer. This brown colour is caused by the growth of some planktons in the sea ice.

Calling this brown sea ice a plankton ice may give rise to discussion, but for convenience' sake this term will be used in this paper.

The biologists of our expeditions have already observed it and took a great interest in this phenomenon.

YOSHII¹⁾ called this phenomenon a coloured ice, and reported that the coloured ice is formed by growing planktons and that it is divided into two layers, upper and lower.

FUKUSHIMA²⁾ called this ice a brown ice and reported that these planktons comprise a large number of diatoms and a smaller number of Chrysochyta.

MATSUDA³⁾ told me in his personal communication that some of the planktons can be cultured in an artificial medium and that they are possibly growing and dividing in the ice.

He called this ice a plankton ice and mentioned briefly that the plankton ice was formed in the sea in the course of freezing. Ecological observations on the plankton ice were carried out in Antarctica, although the details have not been published yet.

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In the fifth Expedition surveys of the plankton ice were carried out by the author (chemist) and FUKUSHIMA (biologist). The details of the flora and biological aspects of the plankton ice will be reported by FUKUSHIMA in other paper. This report deals with the following.

1. Structure of plankton ice
2. Mechanism of plankton ice formation
3. Plankton ice as biological environment
4. Photosynthetic pigments of phytoplanktons in plankton ice

The structure of plankton ice

The vertical section of the plankton ice is illustrated in Fig. 1. This sample, collected at the end of January, is a representative type of plankton ice.

The plankton ice consists of three layers;

1. Upper layer or snow layer
2. Middle layer or plankton layer
3. Lower layer or sea ice layer

1. The upper layer or snow layer consists of snow. The colour is white. Thickness is about 30 to 40 cm. The specific gravity is estimated at about 0.4 according to MORITA. Snow crystals are coarse due to partial melting.

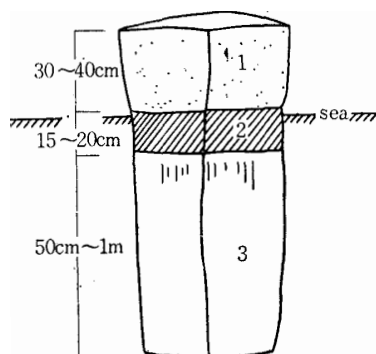
This layer occurs above the sea level and the sea water is not absorbed. Few planktons are seen in this layer.

2. The middle layer or plankton layer is the essential part of the plankton ice. Thickness is about 15 to 20 cm. The colour is yellow to brown due to a surprisingly large number of phytoplanktons. Many colonies of diatoms are seen. This layer consists of sea-water-absorbed snow just like sherbet and is quite different from the hard sea ice as was formerly considered.

This layer is located just above and below the sea level. The specific gravity is about 0.9 according to MORITA.

3. The lower layer or sea ice layer consists of sea ice resulted from freezing of sea water. It is hard and has a vertical-lined crystal structure characteristic of common sea ice. Chlorinity is very low. Few planktons are found. Semitransparent

Fig. 1. The vertical section of the plankton ice.



1. Upper layer or snow layer
2. Middle layer or plankton layer
3. Lower layer or sea ice layer

Collected on Jan. 25, 1961.

and no brown colour. Specific gravity is about 0.9. Thickness is about 50 cm to 1 m. Located below the sea level.

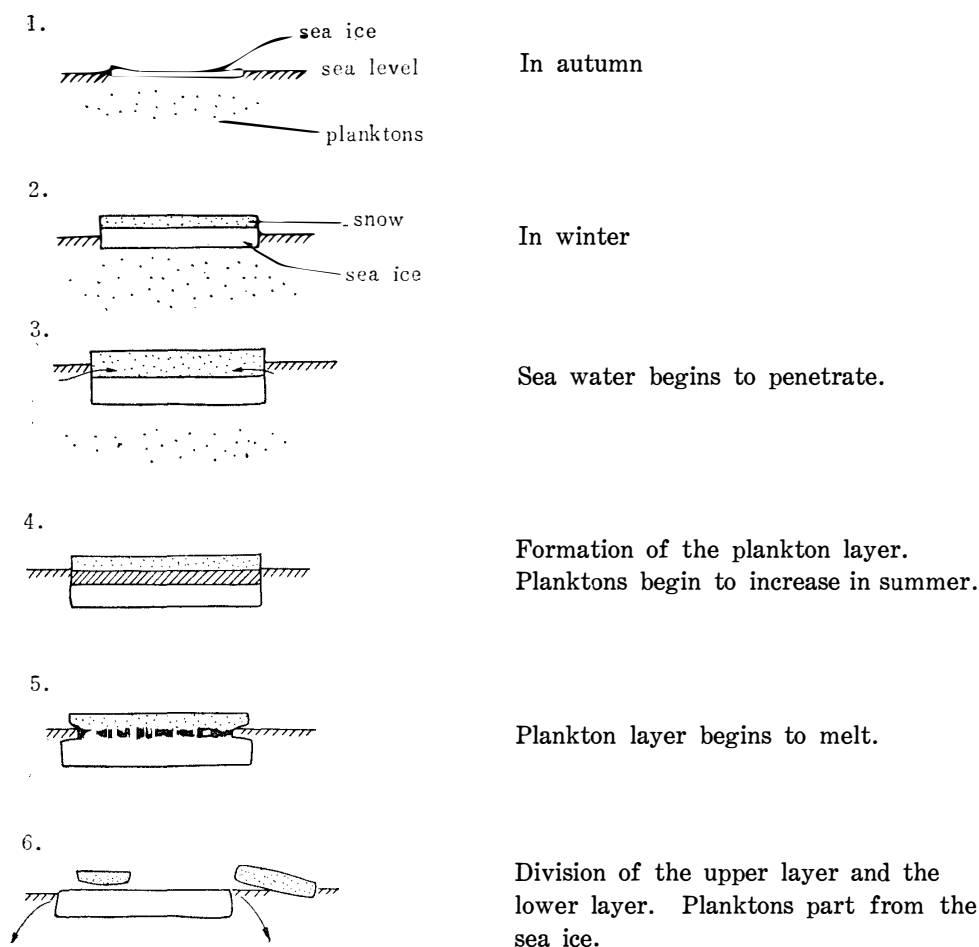
The mechanism of plankton ice formation

The process of the formation of plankton ice is considered to comprise the following stages. It is a process of mutual influence between the melting of sea ice and the growth of phytoplanktons.

Fig. 2 shows every stage of the plankton ice formation. The first 3 stages have been assumed from the formation of the common sea ice, and the colour photographs show the stages 5 and 6.

1. In autumn, the sea begins to freeze. Planktons are drifting in the sea water.
2. In winter, the sea ice becomes thicker and falling snow covers the sea ice. Planktons are in the sea water and no sunlight is supplied.
3. By the weight of snow the sea ice sinks to such depth that sea water can penetrate into the snow layer accompanied by some planktons.
4. In summer, when the sun comes to shine and the sea ice begins to melt and split, planktons start to grow and increase in the snow layer of the plankton ice

Fig. 2. The process of the formation of plankton ice.



Colour Photographs of Plankton Ice

Fig. 3. Plankton ice of Stage 5. The typical plankton ice.

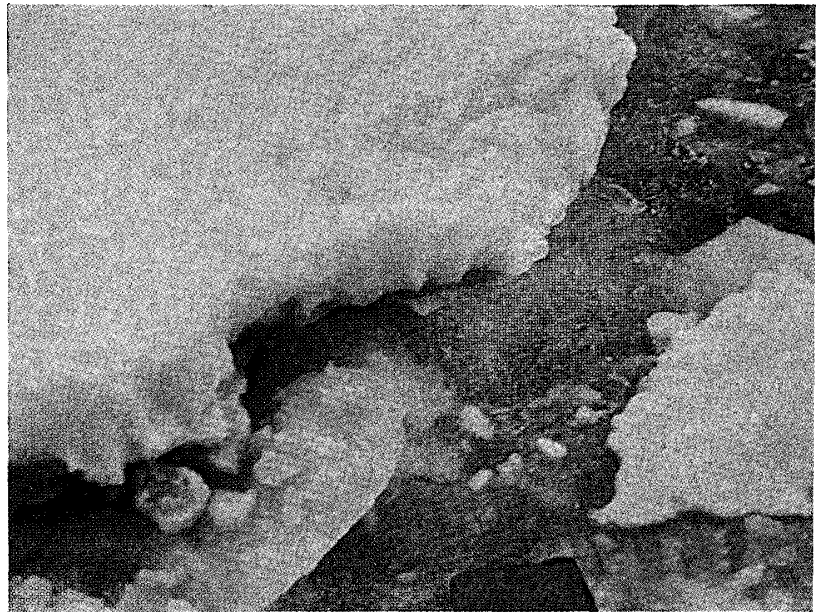
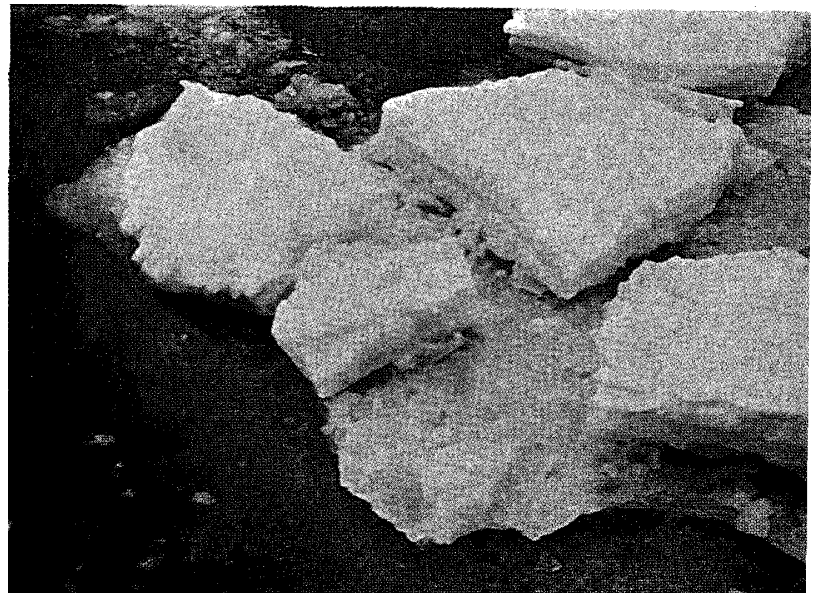


Fig. 4. Plankton ice of Stage 6. Division of the plankton ice.



below the sea level. In this stage the plankton ice illustrated in Fig. 1 is formed.

5. As the planktons grow, the plankton layer becomes brown and preferably absorbs the sunlight. As the result only the plankton layer is melted and becomes sherbet-like. On the other hand, the upper layer and the sea ice layer remain frozen. In this stage the sea water can penetrate more and more freely into the plankton layer with the nutrient material.

There is another effect promoting the plankton layer melting. Sea waves mechanically wash the plankton ice just on the sea level.

6. At the end of the summer the plankton layer is melted so much that the upper snow layer and the sea ice layer begin to separate, looking like sandwiches.

The planktons are again set free into the sea. At this stage even some zooplanktons such as *Euphausia* are seen in the room or small holes of the plankton layer.

Plankton layer as biological environment

1) Temperature

The temperature of the plankton layer is much more stable and milder than we had expected first. In the last two stages (stages 5 and 6) the plankton layer is a kind of seawater-snow-coexistent system, therefore it maintains a constant temperature almost the same as that of the surrounding sea water (-1.7°C).

The upper snow layer acts as a protector against the temperature change of the atmosphere. Fig. 3(a) shows that the temperature below the depth of 40 cm is not affected by the temperature change of the atmosphere, and that the layer into which sea water penetrates is -1.7°C just the same as that of the surrounding sea water.

Thus, it can be said that the temperature is not so severe for diatoms to live in.

2) Air

As snow itself contains much air, the supply of air, i.e., oxygen and carbon dioxide, is enough for diatoms to live.

The oxygen content is supposed to be saturated.

3) Sunlight

As energy source of photosynthesis, the supply of sunlight is essential. According to MORITA⁴⁾, Fig. 3(b) the sunlight at the depth of 30 cm in the snow layer of the heliport decreases to one-fourth of the surface. In the case of plankton ice also, the sunlight is supposed to decrease by one-fourth before it reaches the plankton layer.

According to oceanographical data, the transparency off the pack ice area is about 7-10 m. It means that the light will decrease to 15% at this depth. Then the illumination in the plankton layer is almost the same as that of the sea at 6-8 m depth.

At any rate, the plankton layer is supplied with the sunlight much more than is the sea under the plankton ice.

4) Nutritions

Inorganic nutrient salts are supplied by penetrating sea water. The surface water of the Antarctic Ocean is rich in nutrient matters.

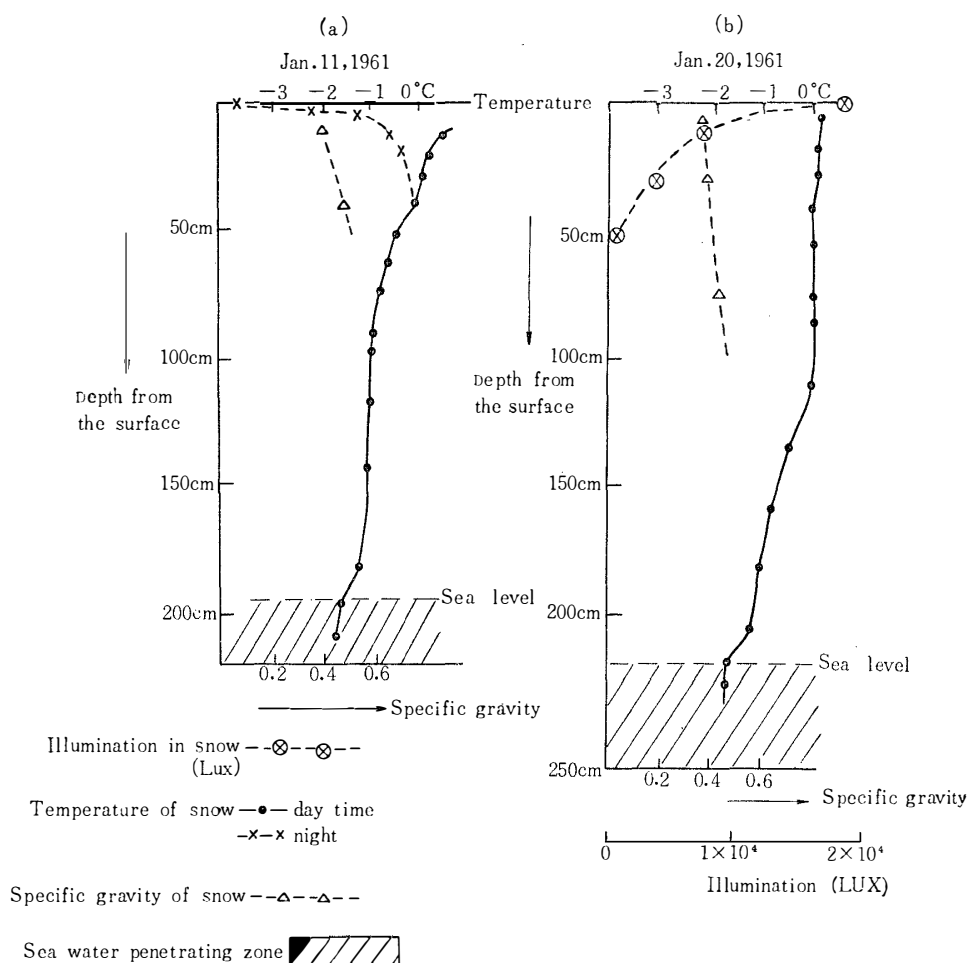


Fig. 5. Survey data of the vertical section of snow on the sea ice used for heliport by MORITA.

(According to the oceanographical data, P: 2.5-3.0 $\mu\text{g-a./l}$, $\text{NH}_3\text{-N}$: 1-3 $\mu\text{g-a./l}$, Si: 30-50 $\mu\text{g-a./l}$, $\text{NO}_3\text{-N}$: 10-20 $\mu\text{g-a./l}$, $\text{NO}_2\text{-N}$: 0.1-0.3 $\mu\text{g-a./l}$) The chlorine content of the water prepared by melting the plankton layer was 80-100 mg/l according to the author's experiments. It is about 1/200 of the chlorine content of the surrounding sea water.

According to FUKUSHIMA in his personal communication, it is about 1/100 to 1/4 of the chlorine content of the sea water.

The plankton layer is composed of snow and sea water, and biologically only the nutrient content of the water portion should be considered.

The nutrient content of the water portion is considered to range from 1/4 to 1 of the surrounding sea water.

At the last stage when the division of plankton ice takes place, diatoms are washed and get contact with sea water.

The osmotic pressure of the plankton layer is considered to be also 1/4 to 1 of that of sea water.

Photosynthetic pigments of phytoplanktons in plankton ice

1) Absorption spectrum of 80% acetone extract

In order to study the photosynthesis in the plankton layer the absorption spectrum of acetone extract of the plankton in the plankton layer was estimated by BECKMAN, D. U. spectrophotometer illustrated in Fig. 6.

The sample was collected on the 25th of January.

The contents of chlorophyll, a, b and c, were calculated by Richard Thompson⁵⁾ method

| | (I) | (II) |
|---------------|-----------------|----------------------------|
| chlorophyll a | 0.67 mg/l | 97 mg/m ² |
| b | 0.05 mg/l | 8.8 mg/m ² |
| c | 0.57 M.S.P.U./l | 86 M.S.P.U./m ² |

(I) represents the chlorophyll content of the plankton layer in one l.

(II) represents the chlorophyll content per m² of plankton ice.

The above chlorophyll content shows the extremely dense population in plankton ice. It is more than ten times denser than that of the usual sea water, though the values may differ in each stage of the plankton ice formation.

For this extraction 3 kg of plankton ice was used.

2) Absorption spectrum of cell suspension

The colour of the plankton ice is originally yellowish brown though that of acetone extract is dark green. To elucidate the colour and absorption spectrum of the plankton ice itself, the absorption spectrum of cell suspension was estimated directly by using

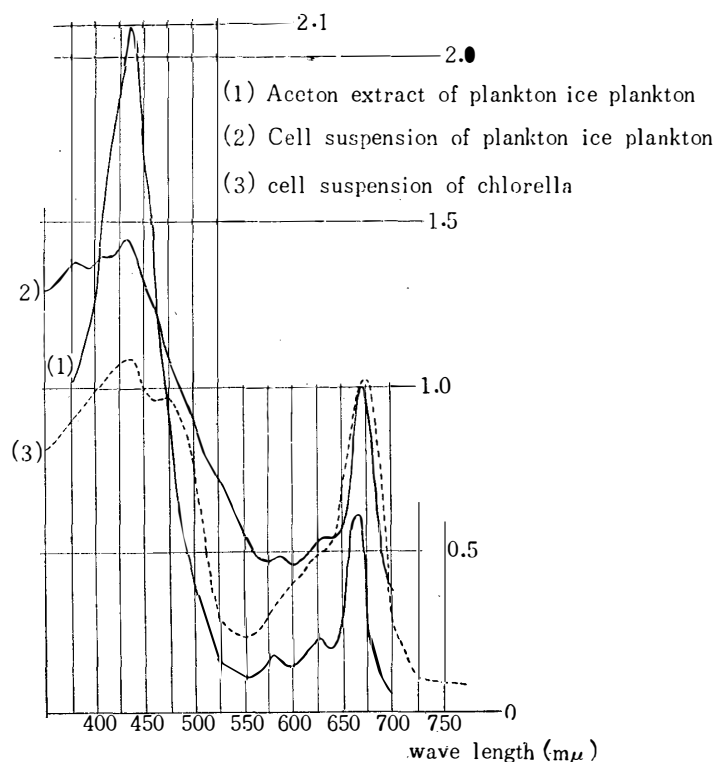


Fig. 6. Absorption spectrum of the plankton ice.

an opal glass attachment. Then, all the chlorophyll and other pigments were calculated in living state combined with protein. In this method, however, the near Ultra Violet region (below $400\text{ m}\mu$) is not so accurate due to scattering of light.

The sample collected in the Antarctic Ocean was stored in the refrigerator (-3°C – -7°C), and was melted at room temperature just before the calculation. Planktons were separated centrifugally and then suspended again in distilled water. This suspension was analysed by "Carry electric spectrophotometer" equipped with an opal glass.

The absorption spectrum of the living cell according to the content of chlorophylls and other accessory pigments is supposed to have relation to the spectrum of the light which reaches the planktons after passing through the upper snow layer.

For comparison, the absorption spectrum of the cell suspension of *Chlorella Ellipsoidea* was calculated by the same apparatus. Fig. 6 illustrates that diatoms in the plankton ice show higher absorption than that of *Chlorella Ellipsoidea* in the regions of ($350\text{ m}\mu$ – $470\text{ m}\mu$) and ($500\text{ m}\mu$ – $600\text{ m}\mu$) when their absorption of Chlorophyll ($675\text{ m}\mu$) is the same.

Discussion

Plankton ice must be discussed from the viewpoint of glaciology and ecology.

1. Glaciologically, the plankton ice is a system of melting of sea ice. It is a phenomenon of separation of sea ice horizontally into two parts by colour of the planktons, and it accelerates the melting of sea ice.
2. Biologically it is a special life cycle of phytoplanktons, not of a single species but of a group of phytoplanktons mostly diatoms, which presumably can live in usual sea water as well as in plankton ice.

As cited before, the plankton ice is not so severe as a biological environment. The main differences between sea water and plankton ice are the supply of light and the osmotic pressure. The number of planktons in the plankton ice is extraordinarily large, as large as that in an artificial medium. The photosynthesis in plankton ice is supposed to take a considerable part of the whole photosynthesis in pack ice region. The physiological adaptation of the plankton ice has not been studied yet.

It is significant that this phenomenon is not an accidental or local phenomenon in Lützow-Holm Bay but is seen everywhere in the route the SOYA has cruised through the pack ice region from 50°E to 30°E in summer.

In consideration of the mechanism of the plankton ice formation, it is inferred that plankton ice may be found in other parts of the Antarctic Ocean and perhaps in the Arctic also.

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