Echo-Sounding of Ice-Covered Waters from Surface of Ice

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氷上からの音響測深について

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要　　旨

昭和基地周辺の海岸の調査は，種々の点で興味があり，筆者はとくに大陸氷の消長との関連で注目している．今後氷海で本格的な海底地形，海底地質，地殻物理等の調査を行なう必要があるが，これに備えて，筆者は，氷上から氷を通して測深できるような音響測深機を試作し，第8次越冬観測中，海氷および湖氷上で使用してみた．これは市販の音響測深機に，極地での使用を考慮して改良を加えたものである．本体（発振および記録部），配電盤，インバーター，送受波器，バッテリーからなる一式を，カブースそりにのせて使用した．送受波器は一つは氷上より直接送受波を行なうもの　一つは氷の質や厚さが氷上からのものに適当でない場合に，氷に穴をあけて水中に挿入して送受波を行なうものの2種を用意した．結果は氷質や氷厚によって異なるが，厚さ 140cm の氷上から 405m の深さのエコーも得ることができ，テスト機としては成功だったといえよう．

1. Introduction

Geological and geophysical investigations of the sea around the Antarctic Continent have been carried out by many expeditions (LISITZIN and ZHIVAGO, 1960) They contain many interesting problems, especially with respect to the fluctuation of the Antarctic ice sheet. Japanese expeditions have performed sounding of sea bottom, sea-borne gravity measurement, and air-gun prospecting of marine deposits, aboard the expedition ship (SATO, 1964) But surveys have been insufficient, in near-shore areas obstructed by the almost perennially frozen sea (YOSHIDA *et al*, 1964). As a preliminary work for future researches, the equipment to conduct echo-sounding from the surface of ice was manufactured for trial, and some soundings were attempted at several locations on sea ice and on lake ice near Syowa Station in Antarctica in 1967. This was the first attempt in Antarctica so far as the author

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knows. The equipment and the result of echo-sounding are briefly outlined here. The equipment was designed under the guidance of Dr. Y. MANIWA, chief researcher at the Fishing Boat Laboratory, Fisheries Agency, Ministry of Agriculture and Forestry, who carried out the pioneer work of echo-sounding from the surface of lake ice in Japan. Instructive suggestions for sounding were also given by him.

2. On the Echo-Sounder

The echo-sounder on the market (manufactured by the Sanken Electronics Co., Ltd.) was remodelled for the use in the Antarctic environment of severe climatic and mechanical conditions. Special regard was paid to the design of the transducer so as to make sounding from the ice surface possible.

2.1. Type of the equipment

i) Range of depth recording: Shallow : 0–130m, 100–230m, 200–330m
Deep : 0–520m, 400–920m, 800–1,320m

ii) Transmitting : Vacuum bulb system

iii) Transducer : 20 kc Ferrite vibrator

iv) Recording : Dry paper system

v) Power source : DC 24 volts (8A)

vi) Constituents (Fig. 1)

a) Main body (transmitting, receiving, and recording), 24 kg in weight

b) Inverter, 11 kg

c) Distributor, 3.5 kg

d) Two transducers, 4 and 18 kg each

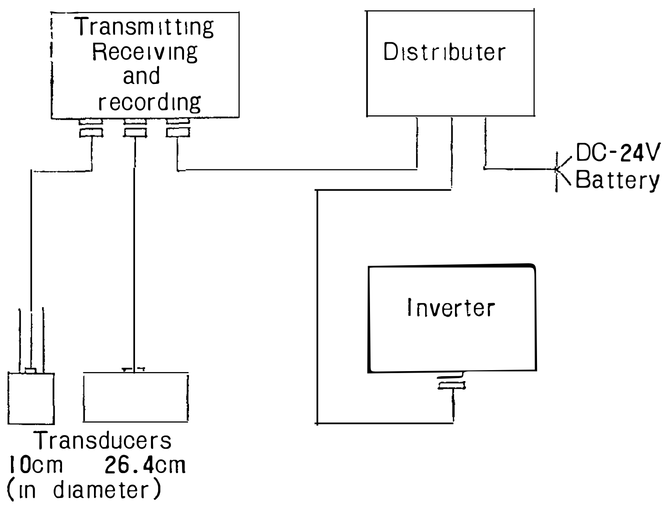

Fig 1 Constitution of the echo-sounder

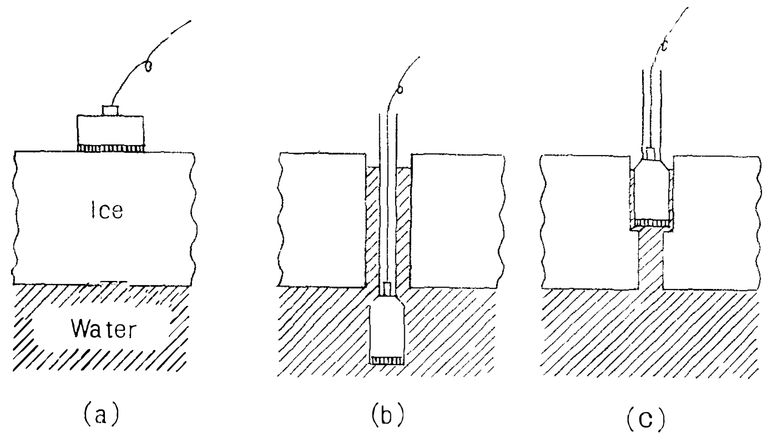

Fig. 2 Setting of transducer on and under ice.

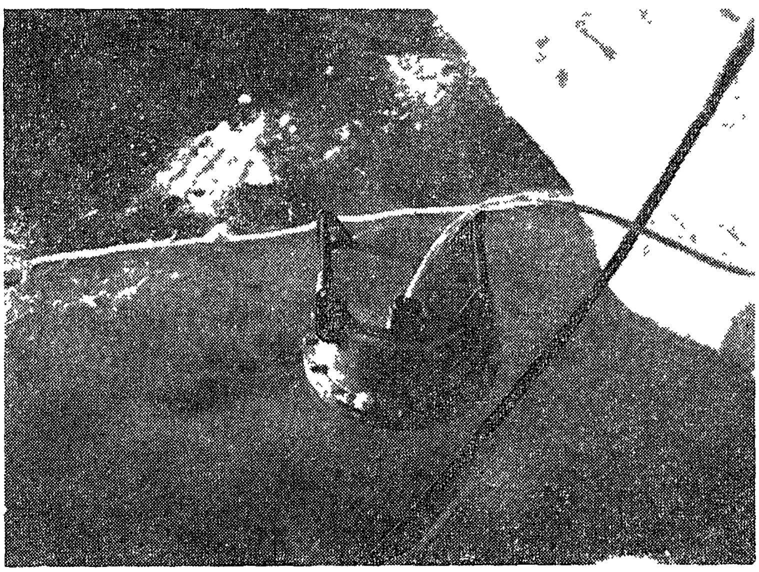

Fig 3 "Ice-surface" type transducer on lake ice in Ô-ike, West Ongul Island

2. 2. Notes on the equipment

i) Cold-resistant parts, cables, lubricant and a battery were chosen for the equipment, provided that -40°C is the minimum air temperature in operation.

ii) Frequency of ultrasonic wave is 20 kc, to minimize the loss of energy of wave by passage through ice (HASHIMOTO and MANIWA, 1962).

iii) Two transducers were prepared. One whose diaphragm is 26.4 cm in diameter has rather good directivity (half attenuation degree is 15.5°×24°), and is used on the ice surface (Figs. 2a, 3). The other with a 2m long polyester tube is used in a bored hole or a crack of ice through which it is inserted to water, when the property of ice prevents sounding from the surface (Fig 2b). The diameter of the diaphragm is 10cm and half attenuation degree is 46°×50°

iv) Dry recording paper system was used so as to avoid freezing of paper. at the sacrifice of benefit of good recording with wet recording paper system.

v) The equipment was set in a wooden box with lining, to protect it from severe impact caused by pitching of a sledge.

3. Setting and Operation of the Equipment

The equipment was set on the caboose sledge (a sledge mounted with a large tent, Fig. 4). Mattress was used as a shock absorber for the main body of the equipment. Power source was a battery of 24 volts and 120 A. H. which was laid aside and connected to the distributor all the time. An engine generator of 1 kW was set as a charger combined with a battery.

Echo-sounding through ice is performed by sticking the diaphragm of the

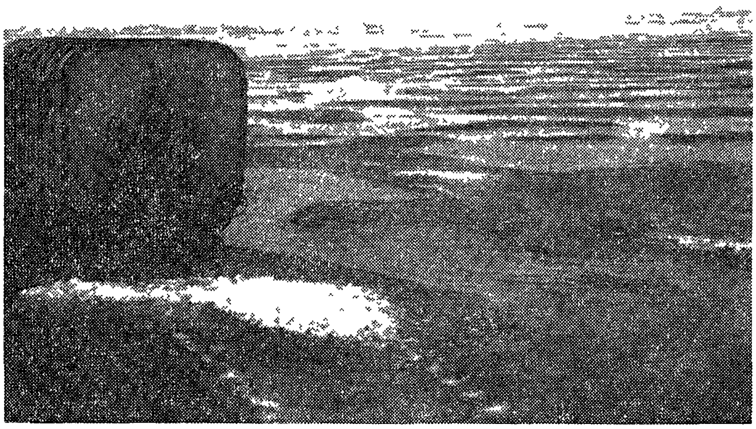

Fig. 4. "Caboose" sledge and flat sea ice near Tottuki Point

Fig 5. "Ice-surface" type transducer on ripple-marked sea ice near Shinnan Rocks.

transducer on the surface of ice closely (Figs. 2a, 3). Snow layer on the surface of ice prevents penetrating and receiving of ultrasonic wave. Properties of ice, *i. e.* amounts of included air bubbles and small cracks and ice thickness affect the sounding ability of the equipment The problem was how to contact the diaphragm of the transducer closely to the ice surface. Water and kerosene were used as the "binding agent". But they were not useful on the surface of sea ice which had ripple-marked microrelief with small cracks and was rather porous (Fig 5) The use of grease for machine, as suggested by Dr. T ISHIDA, proved most effective in our case Echo was easily obtained naturally when another transducer was inserted into the bored hole of ice (Fig 2b). Sounding with this type of transducer along a large crack of sea ice will give a continuous record of the sea bottom if a sledge can move safely near the crack.

4 Soundings

The echo-sounder was used in the period from August to October, when sea ice grew thicker. Test soundings were carried out near Syowa Station, in comparison with lead line soundings. Then, surveys were made in traverses and near Syowa Station (Fig. 6). Results are as follows.

4. 1. Testing near Syowa Station (August 12)

The sea ice was 130cm thick young polar ice (or a polar ice[2]) including

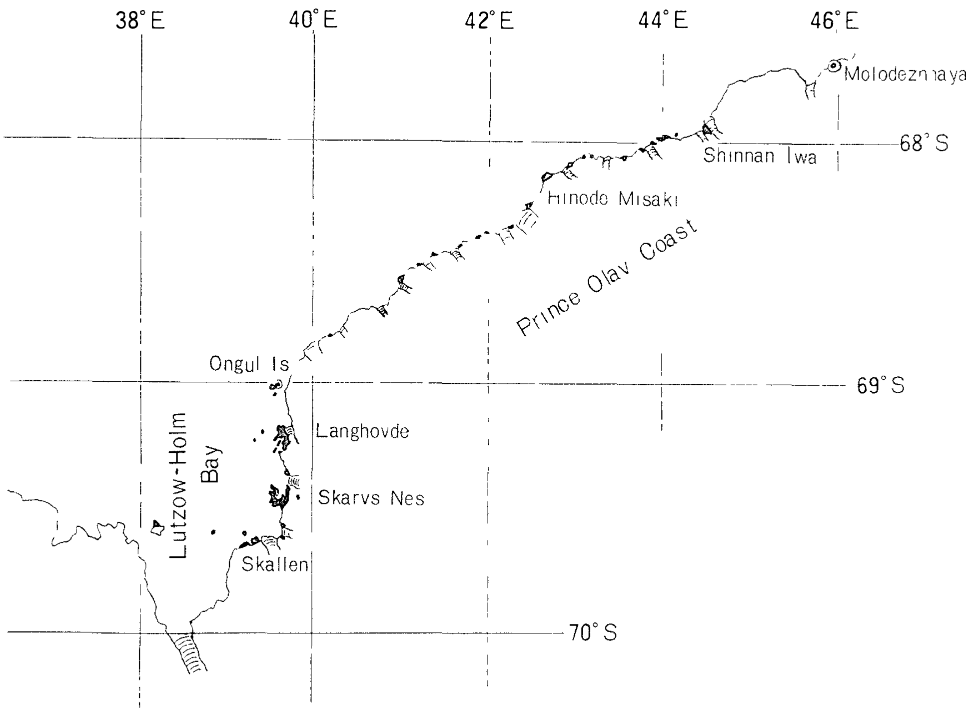

Fig 6 Sketch map of Prince Olav Coast and Lutzow-Holm Bay

considerable air bubbles. At first, sounding by the "under-ice" type transducer was tried through a hole bored into ice which had a step at the middle of the hole (Fig. 2c). But it failed to gain echo. Transmitting and/or receiving of ultrasonic wave in the sea ice seem to be disturbed by an unknown factor. This is an interesting phenomenon, though the cause is inexplicable yet After that, echo-sounding in the same place was made through a wider hole, setting the transducer under the sea ice (Fig. 2b). It gave clear echo (Fig. 7A). Echo-sounding from the surface of ice by the "ice-surface" type transducer also went on successfully, though echo was weakened due to its passage through thick ice (Fig. 7B). Echo was clear but no doubled echo appeared. Then, the deeper place was sounded by the "under-ice" type transducer. Clear echo indicating the depth of 92m was gained (Fig. 7C), though the depth was 95.5m by lead line sounding. Distance between the surface of sea and the diaphragm of the transducer was 1.5m, so that the net difference between echo- and lead line soundings was 2m.

4. 2. Near Shinnan Rocks (August 26)

Soundings were carried out in a small embayment in order to know longitudinal and transverse profiles of the bottom of the bay. Time was too short to make a detailed survey. But the tensional crack caused by thrusting of a near-by glacier tongue into the sea runs transversely at the mouth of the bay, and it

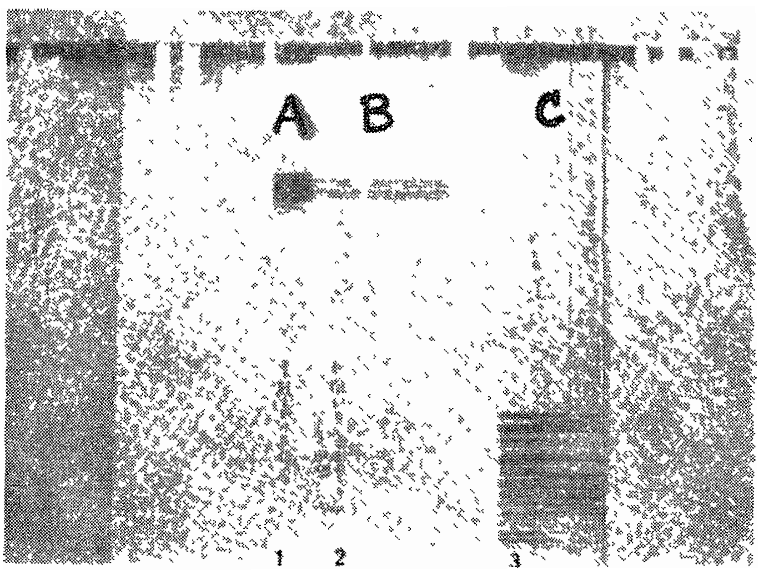

Fig 7 Record of test sounding near Syowa Station
A, C Echo obtained by the "under-ice" type transducer
B Echo obtained by the "ice-surface" type transducer.
Light color of B was caused by loss of energy of ultrasonic wave as a result of passing through sea ice A was shallower than B by thickness of ice

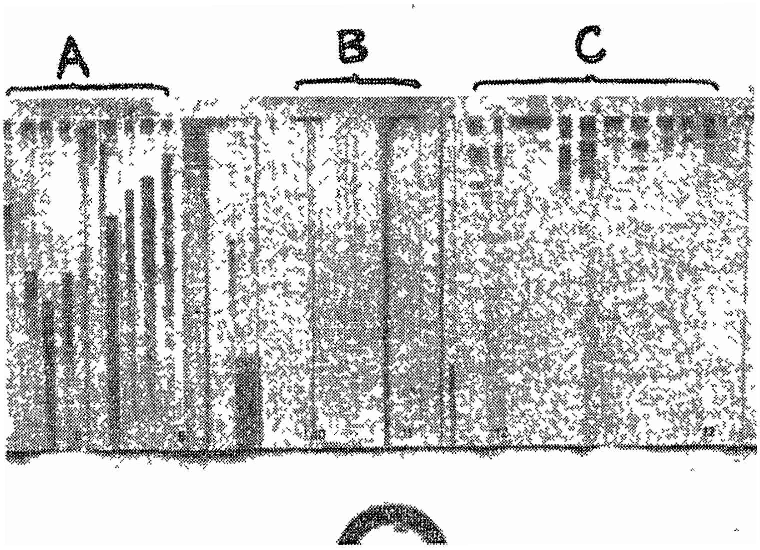

Fig 8 Record of sounding

A. Echo obtained by the "under-ice" type transducer through a crack on sea ice near Shinnan Rocks

B Very weak echo obtained by the "ice-surface" type transducer off Prince Olav Coast.

C Echo obtained by the "ice-surface" type transducer on lake ice at Ô-ike

allowed the use of the under-ice type transducer (Fig 8A) In the bay, the ice-surface type transducer was used on the 136cm thick sea ice, which was a young polar ice or an older one. Echo was clear in both cases, because of the shallow water (14 to 37m)

4. 3. Off Prince Olav Coast (August 17–30)

Sporadic soundigs were tried with two types of the transducer in areas of 1 to 10km off the coast. It is worthwhile noting that rather clear echo of a bottom 330m deep and feasible echo of 405m deep were obtained from the surface of young polar ice 140cm thick.

4. 4. Near Langpollen in Skarvs Nes District (October 10)

Depths between 87m and 127m were detected by the ice-surface type transducer through winter ice and young polar ice with inferred thickness of 160cm. Echo was weak, because ice contained so many air bubbles.

4. 5. Hamna Bay, Langhovde District (October 12)

The ice-surface type transducer was used on flat and air bubble rich winter ice 150cm thick in Hamna Bay. Though the ice character was somewhat inadequate for the sounding, rather clear echo was gained at depths of 37 to 124m.

4. 6. On Ongul Strait (October 24–26)

Soundings were made by the echo-sounder and a lead line not only for the geomorphological survey but for the navigation of the ice breaker which was to be moored to the continent for the first time. Weak but distinct echo was obtained through winter ice 130 to 160cm thick.

4. 7. On Lake Ô-ike in West Ongul Island (September 11)

Lake ice 162cm thick has many small cracks but includes less air bubbles than in sea ice (Fig. 3). Shallow water (5–12m) and scanty of air bubbles gave the very clear echo of doubled and tripled reflections (Fig. 8C).

5. Concluding Remarks

The largest difficulty in operation was to set the diaphragm of the transducer closely to the surface of ice. For catching echo it is required that almost the whole surface of the diaphragm touches the ice surface. The surface of bare sea ice has commonly micro-relief just like a ripple mark which prevents the close contact of the diaphragm. Measurements were performed after the ice was levelled by an ice bail and the diaphragm was stuck with machine grease. And yet we were often forced to start the process all over again. It is desirable to prepare an adequate grader.

Properties of ice, amounts of air bubbles and cracks affect greatly the avilability of the echo-sounder. It is difficult to catch echo when ice includes a snow layer. Hence we must use the "under-ice" type transducer together with the "ice-surface" type one.

Shock to the equipment caused by bumping of the sledge against ice did not give serious damages but made minor troubles in wiring.

On the whole, the echo-sounding from the surface of ice by the newly developed sounder was considerably successful for a test case, though some troubles were experienced. The 9th Expedition used the sounder and obtained many data on submarine topography. The availability of the equipment will increase greatly if the sledge is specially designed for oceanographic research.

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