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RADIO ECHO-SOUNDING OF SHIRASE GLACIER AND THE YAMATO MOUNTAINS AREA

by

Makoto Wada, Takashi Yamanouchi and Shinji Mae

(National Institute of Polar Research, 9–10, Kaga 1-chome, Itabashi-ku, Tokyo 173, Japan)

ABSTRACT

In 1979, the National Institute of Polar Research (NIPR) developed a 179 MHz airborne radio echo-sounder (NIPR-A), and installed it in a Pilatus Porter PC-6 aircraft. The peak power of the sounder is about 1kW and the pulse width is 0.3 μs. Soundings were carried out in Antarctica on Shirase Glacier and the Yamato Mountains in January 1980. The total flight distance over the Shirase Glacier was about 500 km in six flights, while, on the Yamato Mountains area, about 80 km long, two north-south flights and three east-west flights were carried out.

In spite of poor wave penetration, the presence of many sub-glacial uplands (1 000 to 2 000 m a.s.l.) near the Yamato Mountains area was revealed. Discussion is concentrated on the bedrock and surface topography of the bare ice area near Motoi Nunatak in the south-east Yamato Mountains, because the previous traverse party covered this area and many meteorites have been discovered here.

A high sub-ice ridge with three peaks extends east of Motoi Nunatak, and from 22 to 28 km east of Motoi Nunatak there is a short ridge with two peaks. From 12 to 20 km up-glacier from Motoi Nunatak, a long but comparatively low ridge surrounds Motoi Nunatak ridge like an arc. Finally, the sub-ice flow lines near Motoi Nunatak are deduced from new and earlier data.

1. INTRODUCTION

The Japanese Antarctic Research Expedition (JARE) used a 35 MHz Scott Polar Research Institute MK-II radio echo-sounder during glaciological oversnow traverses in Mizuho Plateau from 1969 to 1974 (JARE-10 to JARE-14) (Shimizu and others 1972, Naruse and Yokoyama 1975, Omoto 1976). However, the records were discontinuous and their interpretation by these previous investigators was not always correct as was pointed out by Mae (1978). The glaciological party of JARE-10 installed a trilateration network which was tied to Motoi Nunatak in the Yamato Mountains in December 1969. They collected nine meteorite pieces on the bare ice in the vicinity of Motoi Nunatak. This discovery led to a further search for meteorites and about 4 000 have been collected so far. The glaciological party also surveyed the western part of the Yamato Mountains, departing from the northern part of the mountains along 71°S. The trilateration network and other offset markers were resurveyed in the 1973-74 field season; surface velocity, accumulation and ablation, surface strain, ice thickness, and relevant glacial-meteorological elements were clarified. The meteorites were designated Yamato meteorites and the bare ice area was named the Meteorite Ice Field.

In 1979, NIPR designed a 179 MHz radio echo-sounder (NIPR-A) to be installed in a Pilatus Porter PC-6 aircraft owned by the institute. The sounder and the aircraft were taken to Syowa station, Antarctica, in January 1980 and were used to make a preliminary survey of the area of Shirase Glacier and the

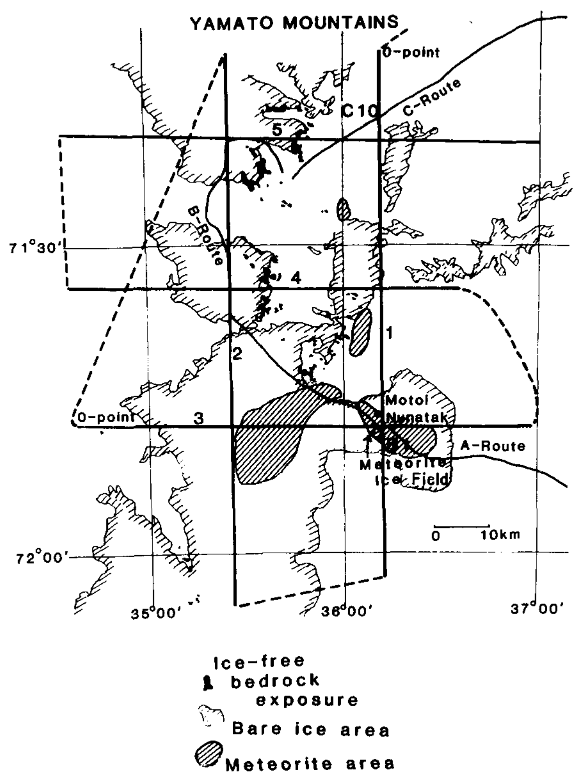

Fig.1. Radio-echo sounding tracks in the Yamato Mountains region. Lines 1 to 5 are the airborne sounding tracks in 1980. A-, B-, and C-routes were the oversnow sounding routes in 1969-74. Many meteorites were found in the hatched areas. The shaded area shows the bare ice area.

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TABLE I. SPECIFICATIONS OF NIPR-A SOUNDER

Transmitter	Carrier frequency	179 MHz
	Pulse energy duration	0.3 μs
	Rise time	0.15 μs
	Peak power	1 kW
	Pulse repetition frequency	1 kHz
	Total power consumption	DC 28 V, 2.7 A
	RF gain	39 dB
Receiver	Central frequency	179 MHz
	Band width	5 KHz
	Noise figure	3 dB
	Receiver sensitivity	-104 dBm
	Input attenuation	0 to 70 dB in 10 dB steps
Aerials: 3-element Yagi	3-element Yagi Absolute power gain	8 dB
Monitor and recorder	Oscilloscope (National VP-5260) Rise time: 35 ns 35-mm continuous recording camera	

Yamato Mountains on 28 and 29 January 1980; Wada (JARE-20) took observations with the aid of members of JARE 21. Sounding flights were limited because of the circumstances of expedition operation for both science and logistic support, and because of deterioration of the ice runway near Syowa station. Results of the sounding were reported in brief by Wada and Mae (1981).

The present report outlines first the airborne sounding of Shirase Glacier. Attention will be drawn to the glaciological features and bedrock morphology of the Yamato Mountains, because the results of oversnow traverses will help to interpret the records of airborne soundings.

2. THE NIPR-A SOUNDER AND ITS FIELD USE

This sounder was designed to be installed in the Pilatus Porter aircraft, thus limiting the available electric power and the dimensions of the aerials. The peak transmitter power was restricted to 1 kW, so the penetration depth of radio waves was about 1 500 m. The carrier frequency of 179 MHz was chosen because of the aerial length of 1 m and the Governmental frequency allocation. Details of the sounder were reported by Wada and Mae (1981) and its specifications are listed in Table I.

Since the aircraft fuselage does not allow sophisticated navigational instruments to be installed, the position of the aircraft was determined by map reading. Flights were planned to pass over as many known sites on nunataks or exposed rocks as possible, maintaining a constant altitude of about 3 000 m a.s.l. and a constant speed of about 90 knots. The errors of position were less than 3 km in the direction of flight and less than 1 km perpendicular to the flight line. On 28 January 1980, a flight of about 400 km was accomplished over the Yamato Mountains, taking two north-south and three east-west tracks (Fig.1); the next day the aircraft covered about 500 km over Shirase Glacier, taking two longitudinal and four transverse tracks. To estimate the ice thickness the wave velocity was taken as 169 m μs^{-1}. The error in the estimation of the ice surface elevation is about 70 m and the ice thickness about 50 m.

3. GLACIOLOGICAL FEATURES OF THE SHIRASE GLACIER

Figure 2 shows the flight track over Shirase Glacier and its drainage basin on 29 January 1980. Oversnow traverses in Mizuho Plateau in 1969-74 revealed that Shirase Glacier has a drainage area of 2×10^5 km^2 and an average thickness of 1 800 m (Shimizu and others 1978). Air photographs near the terminus have been taken intermittently and Landsat images covering the whole glacier have been available in recent years. Interpretation of these images showed that the width of the glacier near the coast is about 10 km, and that the ice tongue extends more than 50 km into Havsbotn in Lützow-Holm Bay; a heavily crevassed region extends about 50 km inland. Fujii (1981) estimated an average ice thickness of 550 m and an average flow speed of 2 500 m a^{-1} from air photographs.

In analysing the records of radio echo-sounding of Shirase Glacier, Wada and Mae (1981) found that no bottom echo was recorded from a heavily crevassed area up to 70°10'S and 39°00'E where the surface elevation is about 600 m. A conspicuous valley profile was observed both at the surface and sub-glacially near 70°20'S. They also discussed the absorption and

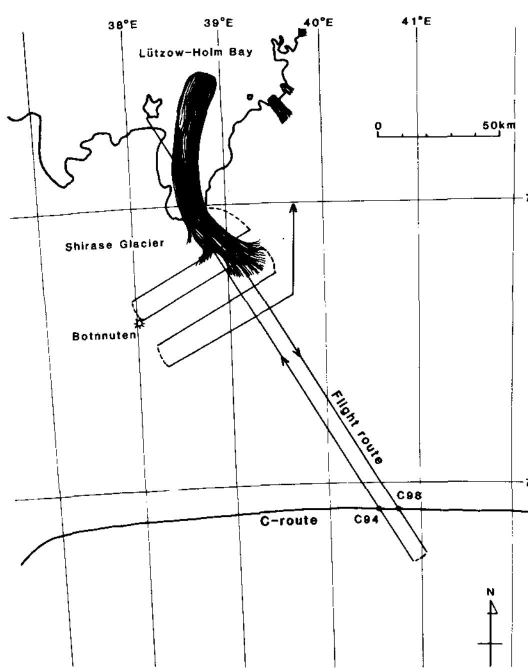

Fig.2. The echo sounding routes on Shirase Glacier and its drainage basin. C-route is the previous traverse route.

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scattering in the ice in analysing the continuous records and A-scope displays.

The airborne sounding flight crosses the C-route of the oversnow traverse by JARE-10 and JARE-14. From the results of the oversnow traverse, the ice thickness at C94 was found to be 1 794 m (surface elevation 1 800 m) and at C98 was 1 654 m (surface elevation 1 824 m). The airborne sounding results indicated that the ice thickness at C94 was 1 700 m and at C98 was 1 600 m.

4. GLACIOLOGICAL FEATURES IN THE VICINITY OF THE YAMATO MOUNTAINS

4.1. Topography of the ice sheet near the Yamato Mountains

Yoshida and Fujiwara (1963) carried out a geomorphological survey of the Yamato Mountains area and reported that the ice sheet flows from east to west between several massifs. The surface elevation and ice thickness along A-, B-, and C-routes in Figure 1 and the surface velocity of the ice flow along the A-route the east of Motoi Nunatak were surveyed by JARE-10 and JARE-14 (Naruse and Yokoyama 1975, Naruse 1978).

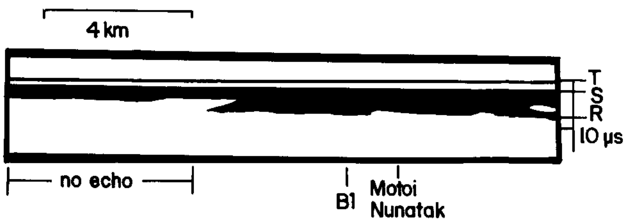

Fig.3. Continuous record near Motoi Nunatak along flight track 1 in the Yamato Mountains. B1 is shown in Figure 1. 'No echo region' shows the area where no bedrock echo was observed.

Figure 3 shows the continuous record of radio echosounding near Motoi Nunatak along route 1, which is the north-south flight in the eastern part of the Yamato Mountains where the surface elevation increases from 1 600 to 2 300 m. T, S, and R in Figure 3 indicate the transmitted wave, the echo from the ice surface, and the echo from the bedrock, respectively. Near the oversnow traverses, route 1 crosses two previously occupied sites, B1 and C 10, whose elevations were 2 242 and 1 768 m, respectively. The surface elevation deduced from the airborne sounding was 2 250 m at B1 and 1 775 m at C10. As shown in Figure 3, the echo from the bedrock was not obtained at several places where the ice thickness was assumed to be more than 1 500 m or the absorption of radio waves was large.

The surface and bedrock topography along the flight tracks is shown in Figure 4. As seen from tracks 3, 4, and 5 in Figure 4, the surface of the eastern side of the Yamato Mountains is about 500 m higher than that of the western side. In particular, the elevation of the sub-glacial topography west of 35°20'E is less than 1 000 m, but the elevation of the eastern sub-glacial uplands is more than 1 500 m. It is found that the glacier which flows between 71°25'S and 71°30'S is influenced by the bedrock elevation difference between the eastern side of 35°20'E and the western side.

4.2. Comparison of data of oversnow and airborne soundings

Figure 5 shows the bedrock and surface topography along route 5 obtained by airborne sounding. The solid circle shows the elevation of the bedrock obtained by the oversnow echo-sounding, which was reported by Shimizu and others (1972) who took the deepest echo as the reflection from the bedrock. Several echoes were tabulated by Shimizu and others (1972) and open circles indicate their shallowest positions. In a detailed examination of the airborne sounding record over B45, the reflection from the

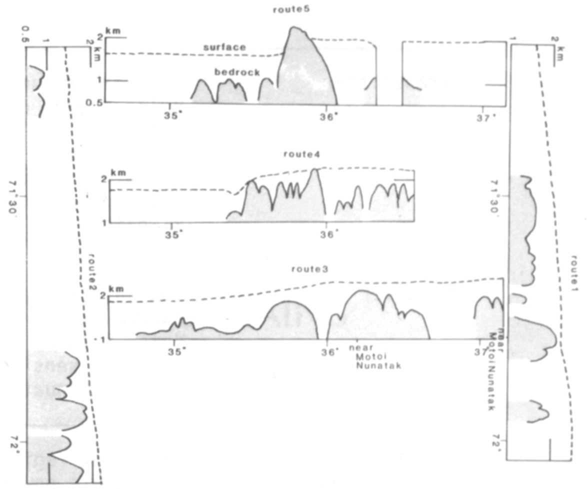

Fig.4. The surface and bedrock topography obtained by airborne soundings along flight tracks in the Yamato Mountains.

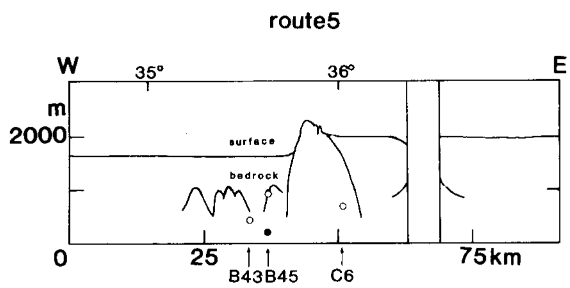

Fig.5. The surface and bedrock topography along route 5. B43, B45, and C6 are the positions of previous oversnow sounding. The solid circle indicates the elevation of the bedrock obtained from surface sounding (Shimizu and others 1972) and open circles show bedrock elevation indicated by the shallowest echo in the report of Shimizu and others (1972).

bedrock coincides with the open circle, which is the shallowest echo in the report of Shimizu and others (1972). Comparison of airborne and oversnow soundings was made for other routes; in most cases, the shallowest echo from oversnow sounding should be interpreted as the reflection from the bedrock. Exceptionally in the case of C6 in Figure 5 the shallowest echo in the oversnow sounding did not indicate the bedrock. Probably the oversnow sounding was erroneous.

4.3. Bedrock topography and ice flow in the bare ice area near Motoi Nunatak

A more detailed discussion will be given of glaciological features and bottom morphology of this area, combining data of oversnow traverses and airborne radio echo-soundings. From the airborne survey the surface elevation along routes 1 and 3 was obtained. JARE-10 and JARE-14 measured the surface elevation along A- and B-routes and the velocity vectors of surface flow along the A-route. On the basis of the surface traverses and airborne sounding data a contour map of the area near Motoi Nunatak is drawn (Fig.6). The flow lines are drawn from surface flow vectors and are perpendicular to the surface contours. In the shaded area in Figure 6 many meteorites have been collected. If the flow directions do not vary with depth, the meteorites are considered to be transported by the motion of ice sheet between flow lines L1 and L2.

Figure 7 shows the bedrock elevations deduced from the airborne sounding of routes 1 and 3 and the oversnow radio echo soundings (on the A-route by JARE-10 and JARE-14), where the ice thickness along A-route was corrected for the shortest echo time. East

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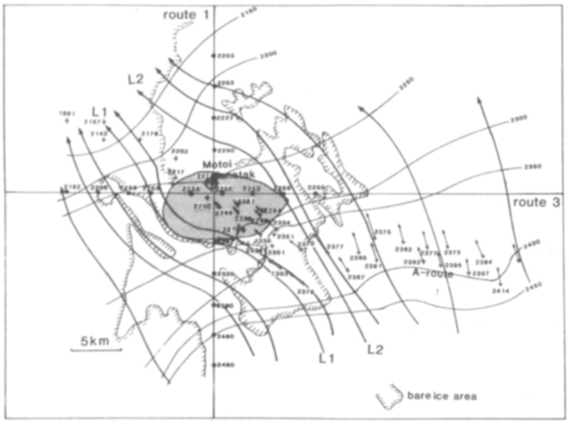

Fig.6. Contour map of ice surface elevation near Motoi Nunatak. Flow lines are shown by thick lines. Many meteorites were found in the shaded areas.

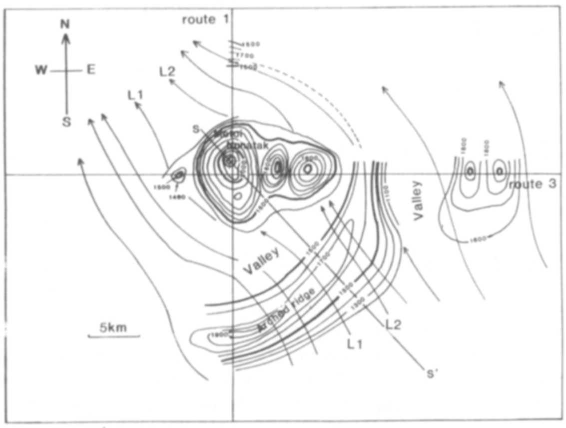

Fig.7. Bedrock elevation near Motoi Nunatak. The flow lines are shown by thick lines.

of Motoi Nunatak three peaks create a high ridge, the Motoi Nunatak ridge. There are two peaks from 22 to 28 km east of Motoi Nunatak. From 12 to 20 km up-stream of the Motoi Nunatak ridge there is an arc of a long and comparatively low ridge, called the Arched ridge. In view of the bedrock topography north of the Motoi Nunatak ridge, perhaps the Arched ridge may extend to the north-west as was shown by a dashed line in Figure 7. The depths of the valleys between the ridges was not estimated because of the sounding limitation of the NIPR-A. The flow lines in Figure 6 are also drawn in Figure 7. The area where meteorites were collected is shown by the shaded part in Figure 6 and is the up-stream part of the Motoi Nunatak ridge and under the lee of the Arched ridge.

Figure 8 shows the south-east to north-west cross-section along the line (S-S') in Figure 7. Figure 8 also shows the area where many meteorites were retrieved. The ice surface is comparatively flat near the Motoi Nunatak ridge and over the Arched ridge, but the surface inclination is large between them and also in the up-stream area of the Arched ridge. Naruse (1978) estimated a vertical velocity of about 50 mm a^{-1} at the flat surface near the Motoi Nunatak, where meteorites were found, 70 mm a^{-1} over the Arched ridge, and 30 mm a^{-1} between the two flat surface areas. It appears, therefore, that up-welling motion is governed by the presence of ridges, and flow lines shown in Figure 8 may be reasonable.

Many meteorites were found on the flat surface near Motoi Nunatak but very few on that over the Arched ridge even though the up-welling velocity is large in this area. If meteorites are distributed homogeneously in the ice mass, more meteorites should be found over the Arched ridge.

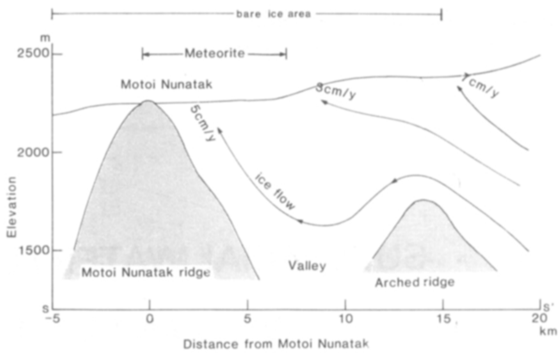

Fig.8. The south-east to north-west cross-section near Motoi Nunatak along the line (S-S') as shown in Figure 7.

5. CONCLUSIONS

The bedrock and surface topography of Shirase Glacier and the Yamato Mountains were obtained from the first airborne radio echo-sounding carried out by JARE-20 and -21. In particular the precise topography of the bedrock and surface in the area up-stream of Motoi Nunatak is investigated because previous over-snow traverses covered this area and many meteorites were found. It is planned to carry out more detailed airborne sounding in the Yamato Mountains, possibly starting in the 1982-83 field season.

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