RADIO ECHO SOUNDING IN THE AREA OF THE YAMATO MOUNTAINS

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***Abstract*:** In the bare ice area of the Yamato Mountains about 4000 pieces of meteorite were found by the Japanese Antarctic Research Expedition (JARE). The most plausible explanation of the mechanism of meteorite concentration in the area was presented by NAGATA.

In order to survey the bedrock topography in the bare ice area airborne radio echo sounding was carried out in January 1980. The new sounder (NIPR-A) was operated at 179 MHz and mounted in a Pilatus Poter PC-6. The peak power of the sounder was approximately 1 kW and the pulse width was 0.3 μs. The line of the survey consisted of 5 parts, each being 80 km long. Two of them were parallel to the north-south direction and three were parallel to the east-west direction. Their interval was about 30 km.

In this paper, the result of the survey on the topography of the bedrock and the surface is reported and especially the ice flow near Motoi Nunatak where the flow velocity and the ablation rate of ice were measured is commented. The bare ice area where a lot of meteorites were found is a flat surface area upstream of subsurface mountains.

1. Introduction

In December 1969, a glaciological party of the 10th Japanese Antarctic Research Expedition (JARE-10) found and collected nine pieces of meteorite in the bare ice area southeast of the Yamato Mountains (YOSHIDA *et al.*, 1971; KUSUNOKI, 1975). Since then about 4000 pieces of meteorite were collected in the bare ice area near the Yamato Mountains (YANAI, 1978, 1980).

A reasonable interpretation of the mechanism of concentration of meteorites was presented by NAGATA (1978). His hypothetical mechanism is as follows: Meteorites falling from cosmic space over the interior region of Antarctica are transported by ice flow inside the ice sheet which results in a horizontal convergence. Near the mountains, the meteorites ascent with an upwelling motion of ice owing to the bedrock topography and they are exposed on the surface of the bare ice area where ablation of ice is predominant. Namely, the concentration of meteorites requires the upwelling motion of ice and ablation at the ice surface. This is a very important reason why a large number of meteorites were found in the area of bare ice near the Yamato Mountains.

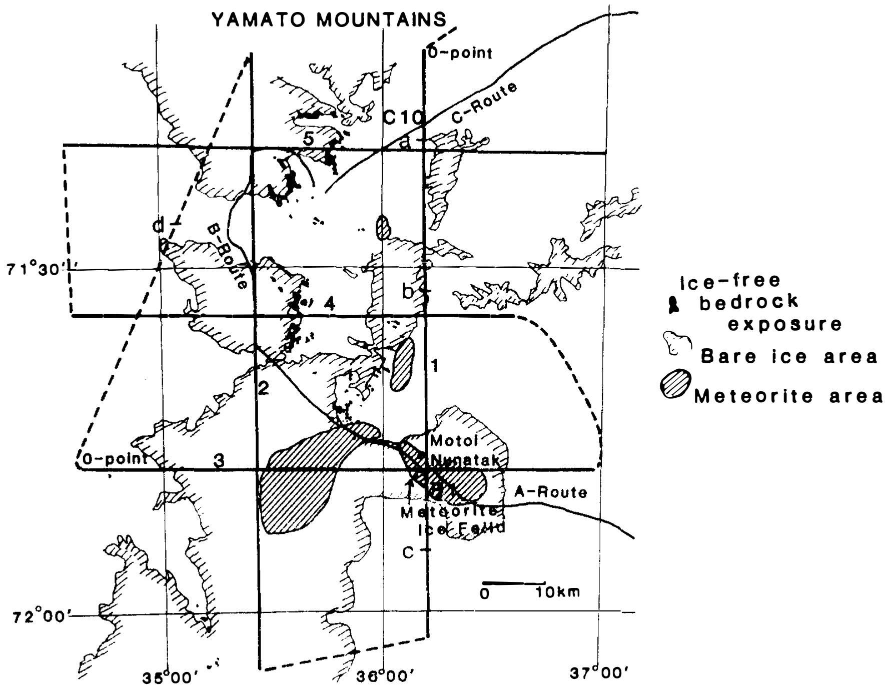

Fig. 1. The route of survey around the Yamato Mountains. Solid lines are the routes of JARE-20 and -21. Numerous meteorites were found in the hatched area.

Though the ablation rate is determined by the meteorological condition, the upwelling motion of ice is controlled by the bedrock topography. The surface elevation and the ice thickness along B and C routes were measured by JARE-10 (SHIMIZU *et al.*, 1972) and JARE-14 (NARUSE and YOKOYAMA, 1975). The flow velocities as well as the surface and bedrock elevations were measured along A route (NARUSE, 1978). The ice thickness was measured by using the SPRI (Scott Polar Research Institute) MKII radio echo sounder with a 35 MHz transmitter mounted on an oversnow vehicle. The traverse route is shown in Fig. 1. Unfortunately, the survey of the bedrock topography and ice flow is limited in a very small area so that it is difficult to study ice motion which acts to concentrate meteorites in the meteorite field shown in Fig. 1.

In order to expand the survey area of the bedrock topography the National Institute of Polar Research constructed a new radio echo sounder (NIPR-A) mounted on a small aircraft, Pilatus Poter PC-6. The sounder was operated at 179 MHz and the pulse width was 0.3 μs. The peak power was 1 kW and the sounder was designed to have the penetration depth of radio wave about 1500 m. The detailed of the sounder were described in a previous paper (WADA and MAE, 1980).

In January 1980, the survey of the bedrock topography was carried out by JARE-20 and -21 in the bare ice area near the Yamato Mountains by using the NIPR-A sounder. The result of the survey is reported in this paper.

2. Route of Operation

The route of the survey is illustrated in Fig. 1. Since a navigation system on the aircraft using ω-wave was not available, the position of the aircraft was determined by the method of terrestrial navigation. The error of position in this survey was less than 3 km in the flight direction and less than 1 km in the direction perpendicular to the flight direction. The height of flight was about 3000 m above sea level. In Fig. 1 the area where a large number of meteorites were found and the bare ice area are shown.

3. Result and Discussion

3.1. Outline of the topography in the vicinity of the Yamato Mountains

The continuous records obtained along the suvey routes, 1 and 3, are shown in Fig. 2. T, S and R marked in Fig. 2 indicate the transmitted wave, the echo from the ice surface and the echo from the bedrock. Therefore, the distance between T and S means the flight level from the ice surface and the distance between S and R is the thickness of the ice sheet. As shown in Fig. 2 the echo from the bedrock disappeared at places where the ice thickness may exceed 1500 m or the absorption of radio wave may be large.

Figure 3 is A-scope records at points a, b, c and d in Fig. 1. The gradual decrease of echo intensity at point a is shown in Fig. 2. On the other hand, the decrease of echo intensity at point b is not smooth compared with that at point a. This means that the bedrock topography near point a is comparatively smooth and the ice thickness might have exceeded 1500 m. A strong and broad echo at point b is shown in Fig. 2. The echo of the bedrock at point c is also shown. Broad echo intensity is possibly due to the broad beamwidth of the antenna of this sounder. Namely the echo reflected from the bedrock not only beneath point c but also in the vicinity of point c. The echo intensity at point d is not much decreased between the surface and a depth of about 600 m. This echo intensity curve suggests crevasses or cracks in the vicinity of point d because the echo curve of the crevasses or cracks in the Shirase Glacier, shown in Fig. 4, is similar to that at point d.

After investigation of both the continuous and A-scope records, the bedrock and surface topography along the survey routes is shown in Fig. 5. 169 m/μs (ROBIN *et al.*, 1969) is adopted as a value of the radio wave velocity in ice for calculating ice thickness, and 300 m/μs for calculating elevation of the surface as that in air. The elevation of the surface is calibrated by using the previous result of the oversnow traverse survey carried out by JARE-10 and -14 (SHIMIZU *et al.*, 1972; NARUSE and YOKOYAMA, 1975). The error of the elevation of the surface and the bedrock is estimated to be ± 70 m.

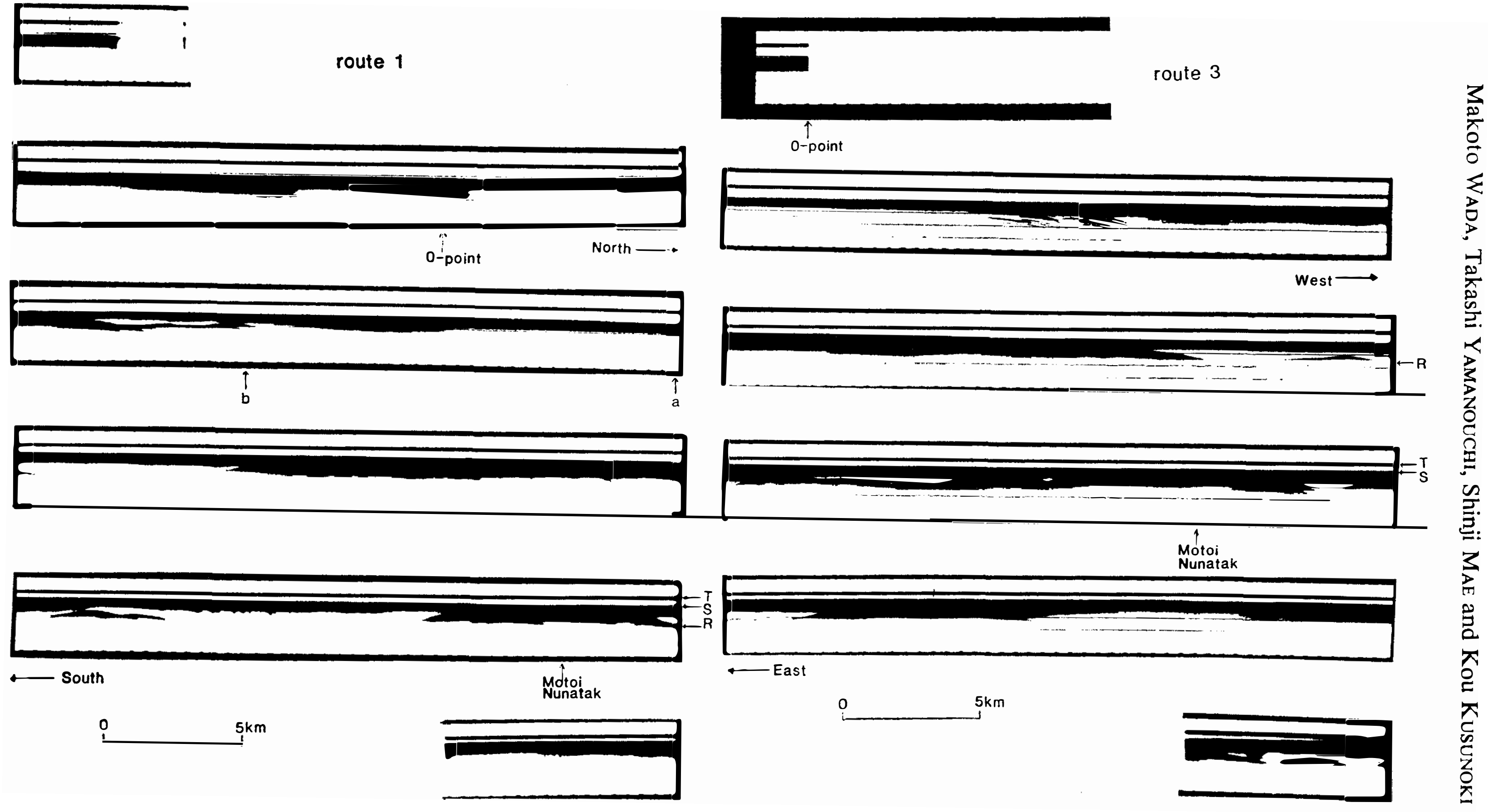

Fig. 2. Continuous records along flight routes 1 and 3 in Fig. 1. T, S and R indicate the position of transmitted wave, reflected wave from the ice surface and reflected wave from the bedrock, respectively.

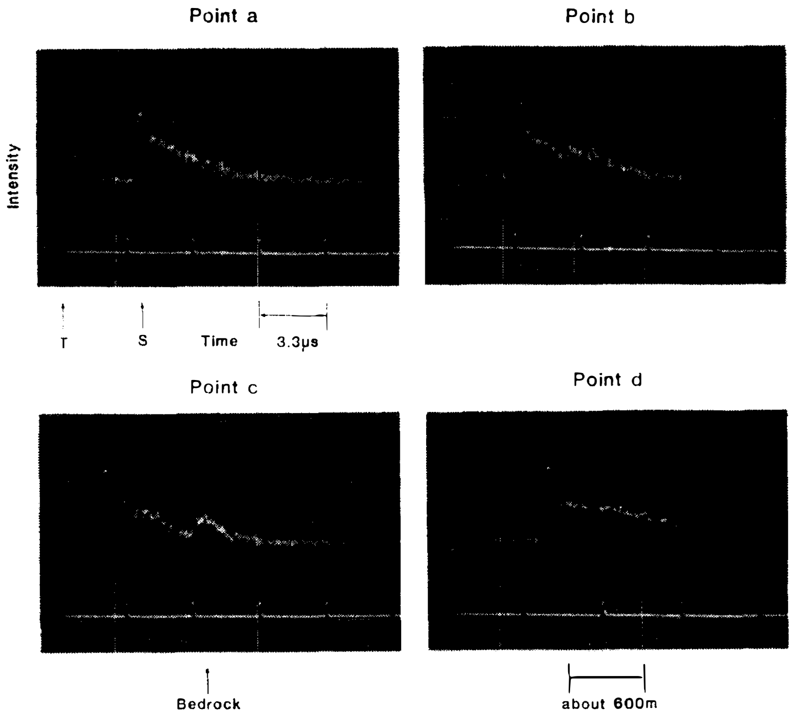

Fig. 3. A-scope records at points a, b, c and d in Fig. 1.

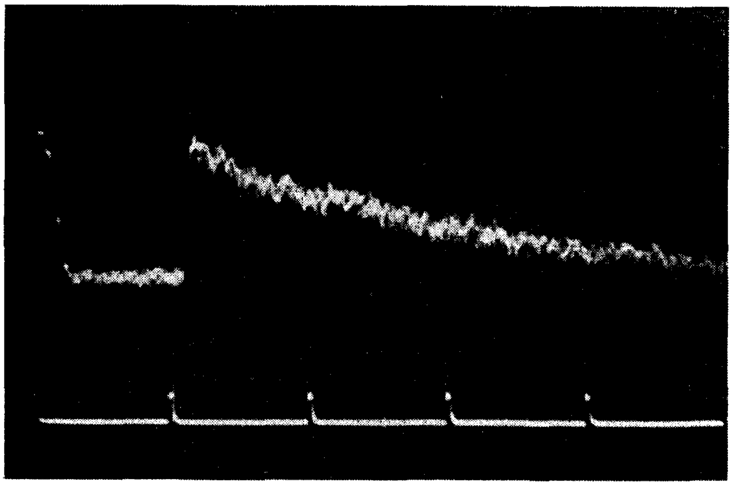

Fig. 4. A-scope record at a point upglacier of the Shirase Glacier.

The bedrock and surface topography obtained along the flight routes 1–5 is shown in Fig. 5. Solid circles show the elevation of the bedrock obtained in the previous survey (SHIMIZU *et al.*, 1972; NARUSE and YOKOYAMA, 1975). At point B1 the elevation of the bedrock obtained by the present survey is approximately equal to that obtained by JARE-10. At point B22, the record of JARE-10 shows multiple echoes,

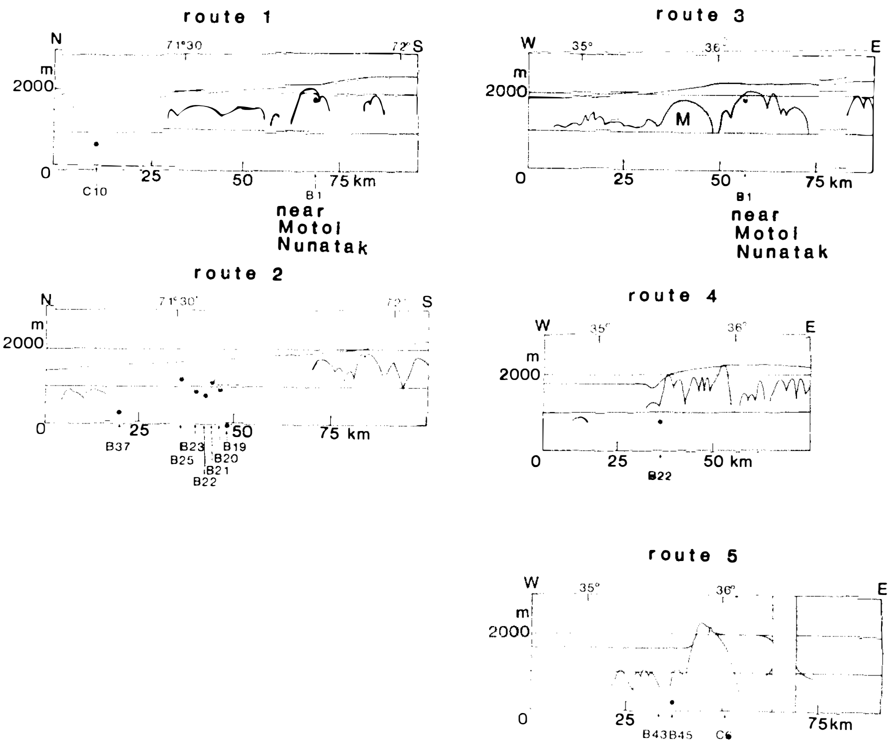

Fig. 5. The bedrock and surface topography along survey routes 1–5 in Fig. 1. C6, B22, etc. show the previous station number.

then the elevation of the multiple echoes, which is denoted by the open circle, is shown in a figure of route 4 in Fig. 5. The present result indicated that the elevation of the bedrock might be the value obtained from a shallower echo. However, the deeper echo does not represent the reflection of radio echo wave from the bedrock at point B22, because it is too deep compared with the present result. At point B45 in a figure of route 5, the shallower echo obtained by JARE-10 is the same as the present result. But at C6 the elevation obtained by JARE-14 and the present survey is entirely different and the reason of the difference is not clear at present.

3.2. Bedrock topography and ice flow in the bare ice area

In the bare ice area near Motoi Nunatak, especially upglacier from Motoi Nunatak, JARE-10 and -14 measured the elevation of the surface, the ice thickness and the flow velocity. JARE-15 and -16 carried out the collection of meteorites in the area (Meteorite Ice Field) (YANAI, 1978; MATSUMOTO, 1978). Therefore, compared with the other areas near the Yamato Mountains precise and good data on the bedrock and surface topography and the ice flow have been obtained in this area. On the basis of these data including the results of the present survey the relation between the Meteorite Ice Field and the subsurface mountains may be considered.

In the present survey the surface and bedrock elevations along routes 1 and 3

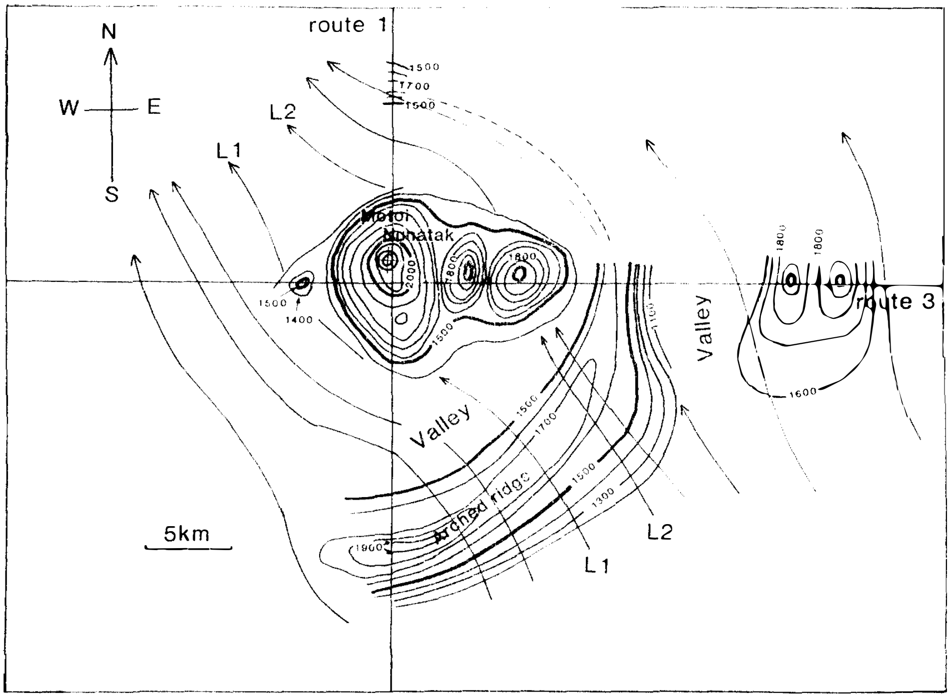

Fig. 6. The contour map of bedrock elevation near Motoi Nunatak. A large number of meteorites were found in a hatched area. Thick lines show surface flow lines.

were obtained. JARE-14 measured the surface and bedrock elevations along A and B routes, shown in Fig. 1, and the velocity of ice flow along A route (NARUSE and YOKOYAMA, 1975). Based on the present and previous data the contour map of bedrock elevation was compiled as shown in Fig. 6. The flow lines are represented in Fig. 6, based on the data of surface elevation and flow velocity. The area where a great many meteorites were found is shown by a hatched part of Fig. 6 (YANAI, 1980). From Fig. 6 it can be seen that if the flow direction does not vary with depth the meteorites found in the hatched part are considered to have been transported by the motion of ice mass between flow lines L1 and L2 in Fig. 6.

As shown in figures of routes 1 and 3 in Fig. 5, there are subsurface mountains near Motoi Nunatak. The ice flow between L1 and L2 shown in Fig. 6 was prevented by the subsurface mountains and Motoi Nunatak in the hatched part and abundant meteorites were exposed in the bare ice area because of the upwelling motion of ice.

Another meteorite rich part in the bare ice area near the southwestern foot of the Yamato Mountains is shown in Fig. 1. Though the detailed bedrock topography of the area was not described due to the lack of previous echo sounding data, there is a subsurface mountains M, shown in a figure of route 3 in Fig. 5, which could have prevented the upwelling motion.

In the Allan Hills region of McMurdo Sound, West Antarctica, a great many meteorites were found and their distribution was not homogenious (NISHIO and ANNEXSTAD, 1980). The same mechanism described above may be applied to the problem of meteorite concentration in the bare ice area around the Yamato Mountains.

The successful performance of this radio echo sounding is due to the kind help rendered by Messrs. M. YAMAGUCHI, T. MIZUSAWA, T. YASHIRO and H. OHMORI, members of JARE-21 led by Prof. S. KAWAGUCHI.

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(Received June 29, 1981; Revised manuscript received September 21, 1981)