SOME INFORMATION ON TOPOGRAPHIC FEATURES AND THE CHARACTERISTICS OF THE ICE SHEET AROUND THE YAMATO MOUNTAINS

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Abstract: Some information and suggestions for future field and theoretical works for meteorite search and glaciology in the Yamato Mountains region, Antarctica are presented based on the preliminary mapping of surface features of the ice sheet by interpretation of aerial photographs and compilation of previous works. A considerably large extent of bare ice areas may be concerned with both regional and local topographies of the ice sheet. Several minor features are distinguished, mapped and described in connection with the movement of ice. The slope of marginal part of the ice sheet at its maximum stage is inferred from glacial topographies of the Yamato Mountains and coastal ice-free areas and from the continental shelf. The results are not conclusive but to be tested by future works. This, in its turn, may be useful as a kind of framework for future field works.

1. Introduction

The fascinating finding of the Yamato meteorites was first experienced during the survey in December 1974 when 663 pieces of meteorites were found in the area of bare ice around the Yamato Mountains (YANAI, 1976). The finding was succeeded by the search in the following seasons, which is expected to be continued for future investigations.

The findings are invaluable especially for the cosmo-sciences because of not only the abundance of meteorites but also the special condition of their occurrence and preservation. Moreover, the characteristics of the ice sheet comprising movement, accumulation and ablation are naturally concerned much with the distribution of meteorites. Some discussions have been made on the cause and mechanism of meteorites concentration based on the mode of occurrence (YOSHIDA *et al.*, 1971; YANAI, 1976), glaciological data about the movement and ablation of the ice sheet (SHIRAISHI *et al.*, 1976), as well as on the theoretical consideration (NAGATA, 1978). However, the necessity of systematic searches for meteorites and detailed glacio-geomorphological studies has been recognized by all these authors.

The materials which the present authors can add to the above-mentioned discussions are still scanty at this stage so that an elaborate field study has not been started yet. Nevertheless, we would like to present some information on the characteristics of the ice sheet for future investigations, on the basis of the previous field surveys and air-photo interpretation.

2. Extent of the Bare Ice Region

A bare ice region indicates the ablation area formed locally on the ice sheet. The formation is caused by the topographic effect of the mountains and subglacial obstacles. As was pointed out before, annual ablation of ice by about 5 cm is compensated with upward flow of ice near the Yamato Mountains (SHIRAISHI *et al.,* 1976), suggesting the formation mechanism of the bare ice area. In such a manner, inland mountains are commonly accompanied with bare ice areas around them.

In the region near the Yamato Mountains, however, the ratio of bare ice areas to ice-free rocky areas seems to be much larger than that in other inland ice-free mountains. Exact comparison with other mountainous regions has not yet been done. But bare ice areas occupy about 3,250 km^2 of the region with the extent of about 125 km$\times$70 km where the ice-free rocky areas of about

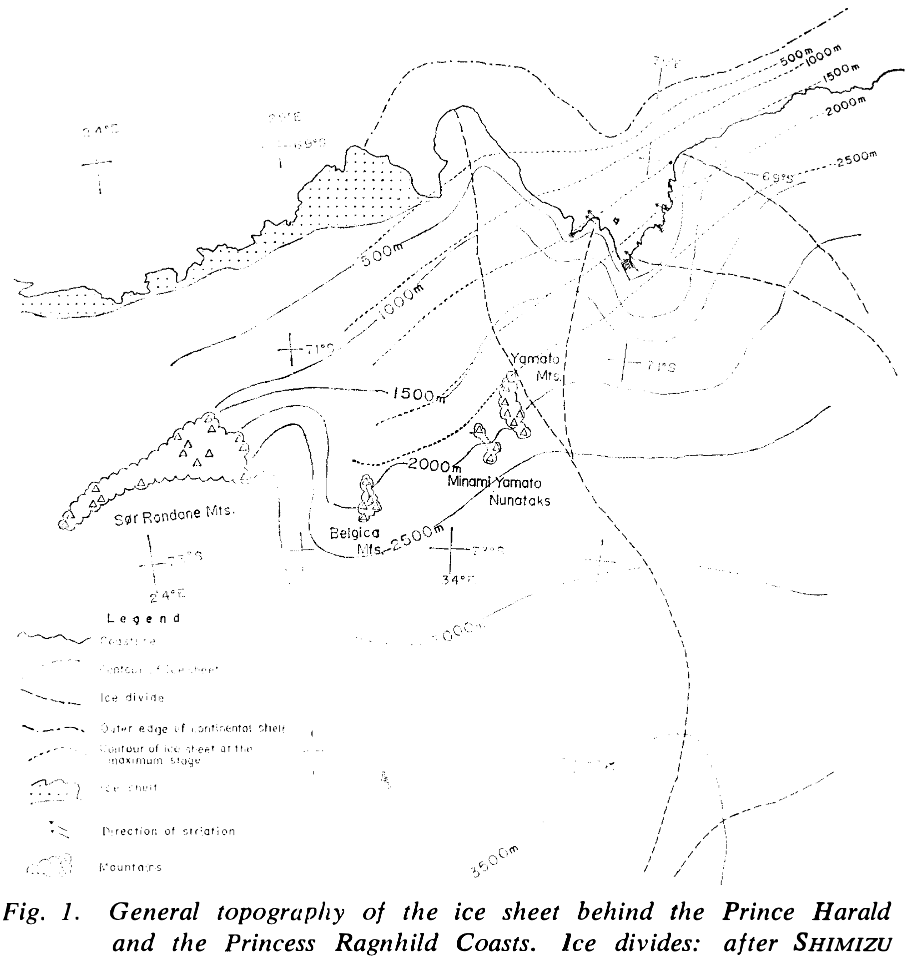

Fig. 1. General topography of the ice sheet behind the Prince Harald and the Princess Ragnhild Coasts. Ice divides: after SHIMIZU ***et al.,*** *1978.* ***Contour lines: after*** SHIMIZU ***et al.,*** *1978;* YOKOYAMA, *1976; 1:25,000 Map of Belgica Mountains by Militair Geografisch Instituut, Brussel 1963; 1:5,000,000 Map of Antarctica by American Geographical Society, 1970.*

50 km^2 are included. The bare ice areas extend further south, amounting to probably over 4,000 km^2. Further investigations will be needed for a reasonable explanation of this fact, and in such a case the following suggestions may be useful.

(i) The step-like topography developed on the ice sheet around the Yamato Mountains may have played an important role in producing the ablation area. Steps are probably due to subglacial obstructions existing relatively close to the surface of the ice sheet. Rather steep slopes (at a gradient of 12/1000 to 27/1000 according to an example measured by the 14th Japanese Antarctic Research Expedition (JARE-14)) produced by such obstructions are efficient to preserve the bare ice area. A gentler slope on an outlet glacier between the D group and the C group is covered with fresh snow.

(ii) An ice divide separating a drainage basin including the Yamato Mountains from the Shirase and the Prince Harald drainage basins runs closely to the Yamato Mountains (SHIMIZU *et al.*, 1978) (Fig. 1). This may mean that snow and ice feeding the ice sheet around the Yamato Mountains are considerably small in amount compared with those in other regions. In the vicinity of the Belgica Mountains 200 km west-southwest of the Yamato Mountains the ice sheet apparently shows no remarkable waning or retardation, judging from the air-photos taken by the JARE-16 in 1975. The air-photos seem to show that the level of the ice sheet has been raised to some extent at the foot of nunataks. Around the Yamato Mountains, on the other hand, the ice sheet is markedly stagnant in its level as is indicated by widely distributed degrading moraines. The difference in ice conditions between the Belgica and the Yamato Mountains may be attributed in part to the different distances from the ice divides.

(iii) Measurements of snow accumulation have been continued since 1968 along the traverse routes to inland. The results (SHIMIZU, 1975) indicate that the snow accumulation around Station S120 has been considerably smaller than at the other stations. Distance from the coast and/or the major ice sheet topography may be responsible for such peculiarity, though the cause is still ambiguous. On this assumption, it is possible to attribute the formation of large bare ice areas near the Yamato Mountains in part to this major topographic effect, because the situation of the Yamato Mountains is somewhat similar to that of S120.

3. Mapping of the Minor Surface Features of the Bare Ice Region

Aerial photographs taken by the JARE-10, -11, and -16 do not cover the whole bare ice areas because the main purpose of the aerial photographing was to cover the ice-free areas and nearby ice fields of the Yamato Mountains for surveying. However, for future detailed surveys it must be useful to map some minor surface features of the ice sheet which are closely related to movement, nourishment, and wastage of the ice sheet.

Mapping (Fig. 2) and the following descriptions of ice surface features are based on the photo-interpretation and the descriptions and figures in literature.

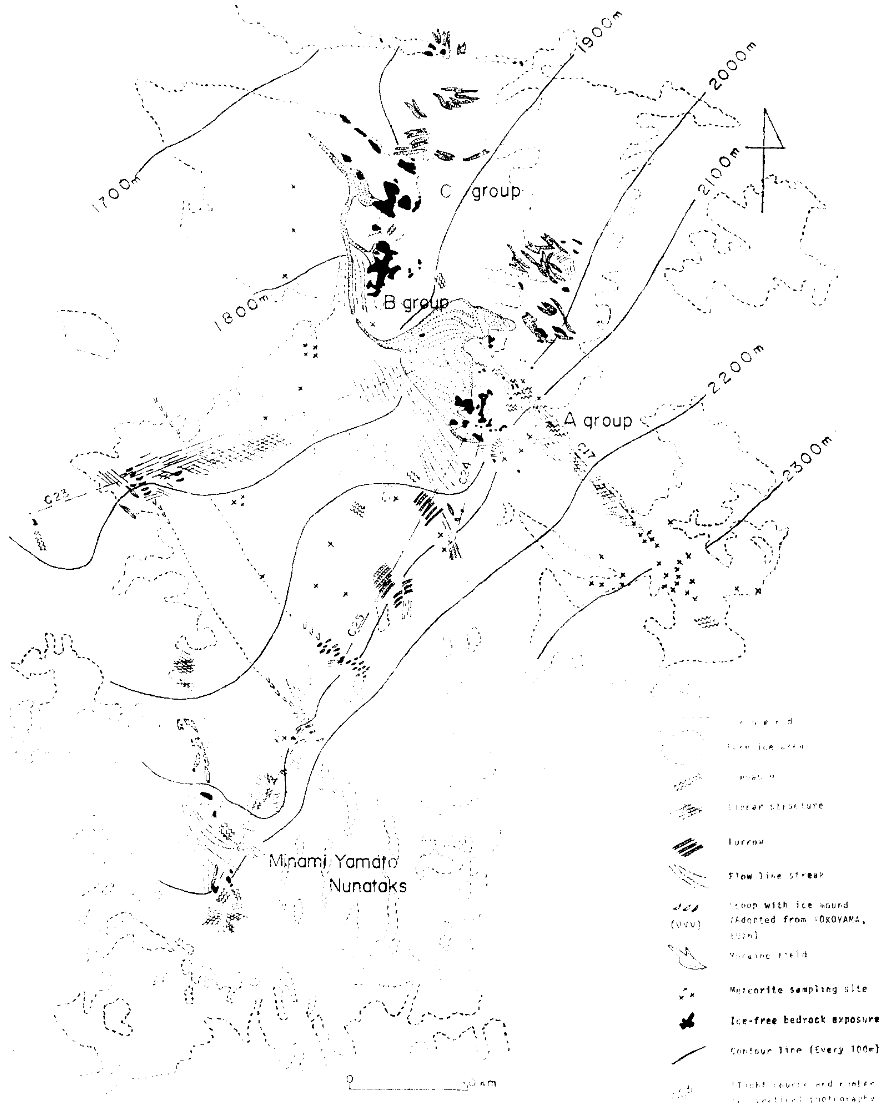

Fig. 2. Surface features of the ice sheet around the southern Yamato Mountains and the Minami-Yamato Nunataks. 1:200,000 Map of Meteorite Ice Field by National Institute of Polar Research is adopted for the distribution of bare ice areas and the ice-free bedrock exposures. Aerial photographs for interpretation are taken mostly by the JARE-16 in 1975.

3.1. Bare ice areas

The bare ice areas have been drawn from the 1:200,000 map of the Meteorite Ice Field which was produced by ERTS images. It is conspicuous that the bare ice areas south of the Yamato Mountains are larger than the areas produced by the mountains themselves. As stated before, the reason is still ambiguous. Retardation of ice flow indicated by steep ice slopes situated between South Yamato Nunataks and the southern end of the A group of the Yamato Mountains and lee-side effect in the rather concave ice surface topography north of the slopes may be possible causes.

Snow stripes or patches in the bare ice areas are located on the lee-sides of small ice rises, domes or slopes. This suggests that the contact between the bottom of snow accumulation and the ice underneath is very discrete.

3.2. *Crevasse and linear structure*

Distinct crevasses are distributed naturally on steep slopes, outlet glaciers, and around nunataks. On the other hand, linear patterns designated as linear structure here can be seen in many places on the aerial photographs. They stretch markedly straight, and often two sets of them intersect each other obliquely. In such a case either of the two is marked generally by deposition of snow. It is possible that they have originated in cracks associated with pressure wave due to ice flowage. Some of them may indicate transverse crevasses. Cracks seemingly related to contraction of ice (Fig. 9 in YOKOYAMA, 1976) and to crevassing (YOSHIDA and FUJIWARA, 1963) were observed before.

3.3. *Furrow*

Shallow furrow-like depressions with a width of about 20 m and a length of 500 to 1,200 m or more develop in the limited areas near the foot of the steep ice slope in a parallel arrangement. Furrows, simply designated here, stretch perpendicular to the deduced direction of ice flow. The origin is still unknown. It is probable, however, that transverse crevasses on the steep ice slope have been transformed into furrows.

3.4. *Flow line streak*

This is a dark-colored streak pattern identified on the aerial photographs. It seems to indicate the flow line of ice, so that the term flow line streak is applied. However, the associated topography is not conspicuous. Flow line streaks are very remarkable near the west side of the largest moraine field in the A group. YOKOYAMA (1976) reported the presence of several clay bands running longitudinally to the moraine fields near Kabuto Nunatak. At least some of flow line streaks are probably a kind of clay bands.

3.5. *Scoop with ice mound*

Distinctive features on the ice surface are elongated depressions associated with ice mounds. They were seen far from the tops of peaks in the Yamato Mountains in 1960. Based on this observation and the obscure aerial oblique photographs taken by the Belgian party, one of the present authors described them as scoops (YOSHIDA and FUJIWARA, 1963). YOKOYAMA represented them as ice hills based on his ground survey (1976). As is described below, the term scoop with ice mound is introduced here from the interpretation of the aerial photographs.

Along the Cessna flight course (C25, meaning course 25) from the A group to Minami-Yamato Nunataks two groups of scoops are observed in the aerial photographs. The distance between two groups is about 6 km. The southwestern one is marked by larger scoops in a single row. The length of a scoop ranges from 200 m to 350 m, and the distance from one scoop to another amounts to 300 m to 550 m. The northeastern group is marked by smaller scoops flocking in a rather wider area. The length of a scoop averages 80 m, and the distance between scoops is 60 to 170 m. Only one scoop is observed near the small nunatak south of the A group.

Along the flight course (C23) from the moraine field of the A group to Kabuto Nunatak, two groups of similar scoops are also seen on the aerial photographs. The southwestern one is quite similar to the southwestern one in C25. But the northeastern one consists of only two scoops within the aerial photograph, and differs considerably from that in C25.

YOKOYAMA suggested that ice hills (scoops) originated in the crevassed areas on steep ice slopes and were being transported by ice flow. Therefore, the ice hills in C23 might be the continuation of those in C25. He also noted the direction of the ice hills was coincident with the direction of prevailing wind.

The scoop shape may be an essential feature, and the ice hill or mound, or properly "drift-snow ice", may be a secondary feature, so far as the authors' examination of the aerial photographs goes. However, the observation on the ice hills was made by YOKOYAMA at the locality somewhat downstream from the place shown in the aerial photographs. It would be interesting if the transformation of scoops into ice hills with shallower depressions could be traced along this train of scoops, since YOKOYAMA described "ice hills" as "past gigantic scoops".

3.6. Moraines and meteorites

Most of moraines occur as moraine fields. Larger moraine fields near the A, C, D and F groups form conspicuous "flow line" patterns. They have "pitted" surface in some places, indicating a rather stagnant condition. A part of these larger moraine fields stretches in a row as a kind of lateral moraine, forming a moraine bank. Smaller moraine fields consist of two or three to some tens of moraine banks.

With a few exceptions of rock debris supplied directly from exposed bedrocks, the detritus composing moraine fields seems to have originated in the subglacial moraines contained in the sole of the ice sheet, as inferred from erratics, roundness of blocks, and their mode of occurrence. That is, they have been brought from the bottom of the ice sheet by upwelling.

On the other hand, the distribution of "found" meteorites differs greatly from that of moraines. This is caused naturally by the difference in the mechanism of supply to the ice sheet. This has been suggested correctly by YANAI (1976) in connection with search for meteorites. However, this does not mean that meteorites never occur in the moraine fields, because some of meteorites trapped in the ice sheet as englacial materials can join the moraine fields through upwelling of ice. Subglacial moraines, on the other hand, can emerge from ice only at places where the ice becomes sluggish having been completely obstructed by exposed mountains or by very shallow subglacial rock threshold.

4. Former Ice Sheet

It has been recognized for a long time that the Antarctic ice sheet had expanded some time in the past. The identification of "multi-glaciations" and the chronological studies of fluctuation of the ice sheet have considerably progressed in the McMurdo Sound region (for example, BULL and WEBB, 1973). However, the data are still meager for detailed discussion in other ice-free regions, especially in the inland mountains.

In the Yamato Mountains, one of the authors discussed deglaciation of the ice sheet around the mountains (YOSHIDA and FUJIWARA, 1963), and proposed three stages of the ice sheet fluctuation, namely, the Yamato (maximum), the Fukushima (intermediate), and the Meteorite (present ice level) Glacial Stages, based on the geomorphological study (YOSHIDA, 1977). However no direct evidence was obtained for chronology.

For future study of relationship between meteorites accumulation and ice behavior, the contours of the marginal part of the ice sheet at its maximum stage are reconstructed (Fig. 1). This is based on the glacial landforms of the Yamato Mountains, the glacial striation in the coastal ice-free areas (YOSHIDA, 1973; MORIWAKI, 1976), and the outer edge of the continental shelf; the first gives the minimum elevation of surface of the past ice sheet, the second the direction of the former ice movement, and the third the maximum extent of the former margin of the ice sheet. It is a matter of course that the reconstruction is not much reliable. And the ice sheet farther inland might be influenced very little. Nevertheless, the contour lines suggest that former flow lines and shapes of drainage basins of ice were considerably different from those at present. The Yamato Mountains region might have been subjected to more active flow of ice from southeast before. The present ice divide east of the Yamato Mountains might have been formed comparatively later. The proper reconstruction of the former ice sheet should be a future problem to be solved. Distribution of meteorites on the ice sheet and their fall ages may give valuable information on that problem.

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