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GEOMORPHOLOGICAL AND GLACIOLOGICAL ASPECTS AROUND THE HIGHEST DOME IN QUEEN MAUD LAND, EAST ANTARCTICA

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Abstract: The oversnow traverse party of the Japanese Antarctic Research Expedition in 1985 found the location of the top of the second highest dome in the Antarctic Ice Sheet at 77°22′S, 39°37′E with an elevation of 3807 m, and surveyed the dome. A ridge of the ice divide runs from the dome top in a west-northwest direction, and a narrow subsurface basin lower than 500 m above the sea-level extends in a scale of 100 km long below the dome top in a similar direction to that of the surface ridge. In view of the larger scale of 1000 km order on the subsurface topography, this dome is classified into "the subglacial basin type" in contrast with "the subglacial mountain type" such as Dome A, the highest dome in the Antarctic Ice Sheet. Comparative study between such types is important for discussions on the formation, development and variation of the ice sheet in the geological time scale, as well as their dynamics.

From climatological and glaciological observations around the dome, the directions of prevailing winds and the lapse rates of snow temperature at 10 m depth (annual mean air temperature) are described, and the effect of the surface slope on such surface environments is discussed briefly. Annual mean air temperature at the dome top is estimated to be −58.0°C. By the use of mean annual net accumulation of 3.2 cm in water equivalent which was obtained from the 5 m-pit profile of tritium content near the dome top, age of the dome ice with depth is simply estimated.

1. Introduction

As a part of the Glaciological Research Program in East Queen Maud Land (1982–1987), the inland plateau-like dome which is the second highest dome of the Antarctic Ice Sheet was observed in November and December, 1985 (Fig. 1), by the oversnow traverse party of the 26th Japanese Antarctic Research Expedition (JARE-26). The highest place of this dome was found at 77°22′S, 39°37′E with an elevation of 3807 m by the Doppler satellite positioning system in conjunction with the barometric altimetry

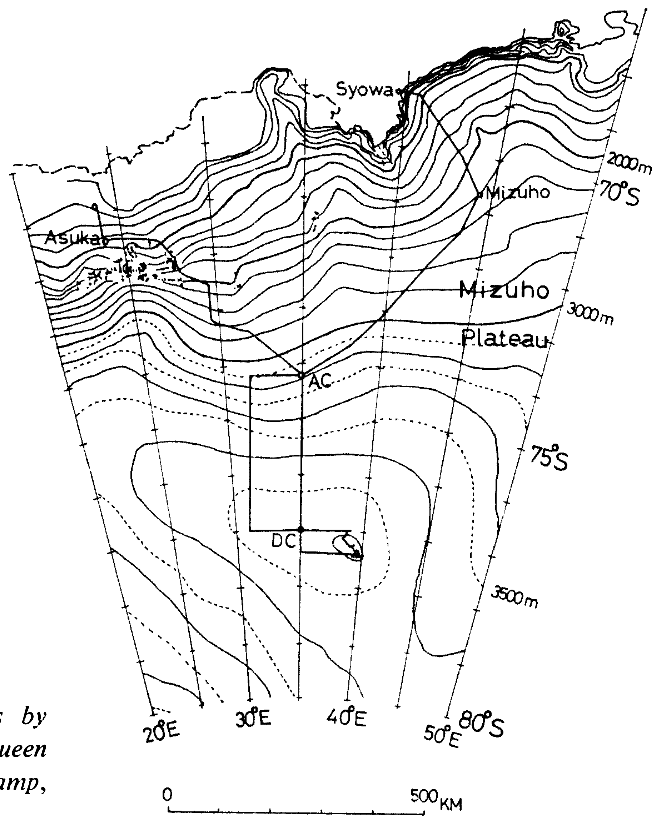

Fig. 1. Routes of oversnow traverses by JARE 26 (1985–86) in East Queen Maud Land. AC: Advance Camp, DC: Dome Camp.

and the theodolite survey of slopes toward the surrounding horizon at many points on the route, as reported by AGETA *et al.* (1987).

This highest place is located about 50 km west-northwest from the 'Fuji Divide' which the traverse party of JARE-9 crossed on the round trip between Syowa Station and the South Pole in 1968–69 (MURAYAMA, 1971; FUJIWARA *et al.*, 1971). This high dome was named 'Valkyrjedomen' in the map compiled by DREWRY (1983) and tentatively called 'Dome Fuji' (Dome F) by JARE-26.

In this report, we describe the observed results on geomorphological, climatological and glaciological features around the highest dome of the inland plateau in East Queen Maud Land.

2. Geomorphological Aspects

2.1. Surface topography

In the elevation map of Antarctica compiled by LEVANON (1982) on the basis of constant-density balloon altimetry, the location of a dome peak was indicated in the area around 76°–78°S and 30°–40°E with the elevation higher than 3700 m. The surface topography around this area was observed by the traverse party of JARE-26 using the means mentioned above in Chapter 1, and an elevation at each position was reported by AGETA *et al.* (1987).

From these observations, it was found that the topography of this area was more similar to the map compiled by DREWRY (1983) from the balloon altimetry (LEVANON,

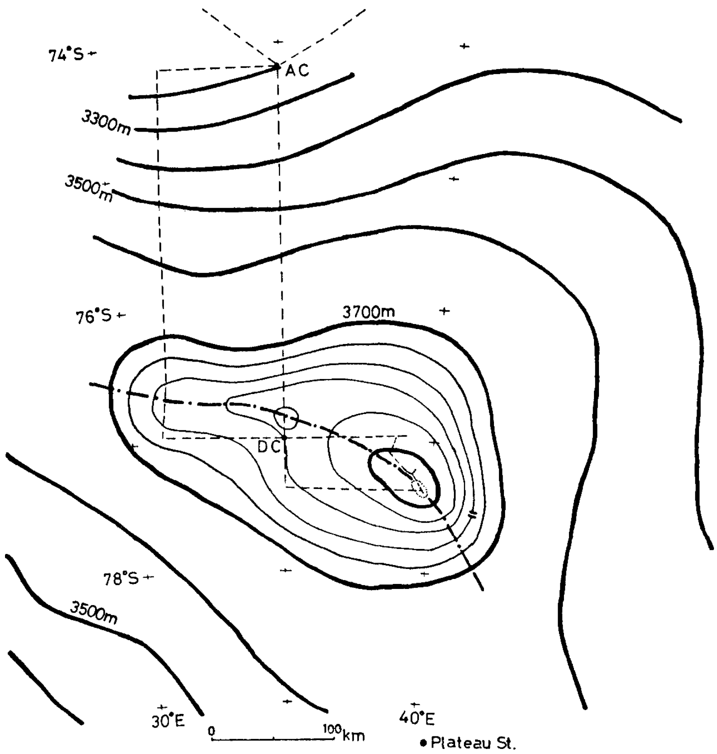

Fig. 2. Surface topographic map around the highest dome in Queen Maud Land. AC: Advance Camp, DC: Dome Camp, =: Fuji Divide, Dashed line: observation route, Dash-dotted line: ice divide, Interval of contour lines — thick line: 100 m: thin line: 20 m, dotted line: 5 m.

1982) and other various kinds of data than the map compiled by LEVANON (1982) from his balloon altimetry. Consequently, we compiled the surface topographic map of this area based on the map by DREWRY (1983) and our field data.

The result is shown in Fig. 2 wherein the contour-lines are slightly modified from Fig. 1 by the use of survey data of directions of the maximum surface slopes along the route. It can be seen in this map that a ridge, namely an ice divide, extends from the highest place (elevation more than 3800 m) in a west-northwest direction.

2.2. *Ice thickness and subsurface topography*

The ice thickness was measured by the use of a radio echo sounder equipped on an oversnow vehicle. The measurements were carried out at the stations for lunch-timestops and overnightstops. These results were reported by AGETA *et al.* (1987), and the map of ice thickness and the subsurface topography (obtained from the surface elevation and the ice thickness) are shown in Figs. 3 and 4, respectively.

It can be seen in Fig. 4 that a long and narrow subsurface basin lower than 500 m above the sea-level extends below the highest surface in the direction between west-northwest and west, slightly to the south of the surface ridge. Ice thickness is more than 3000 m around this basin, as seen in Fig. 3. Figures 3 and 4 show preliminary results; the final maps on the whole research area of the Glaciological Research Program in East Queen Maud Land will be published in the near future.

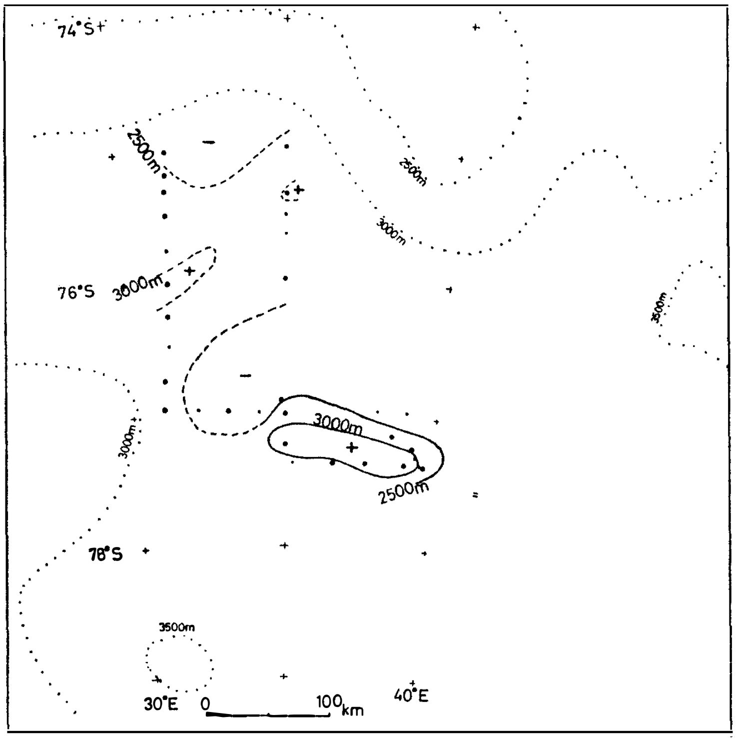

Fig. 3. Ice thickness around the highest dome in Queen Maud Land. Dashed contour: tentative, Dotted contour: after DREWRY *(1983) for comparison, Solid circle: observation point (small circles show the points where the echoes of the ice radar were distinguished but not so obvious).*

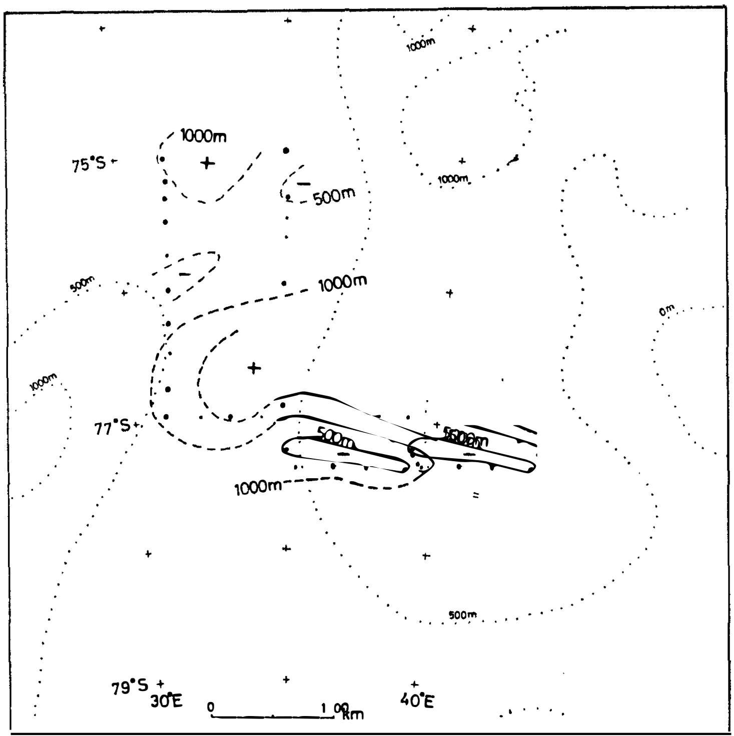

Fig. 4. Subsurface topography around the highest dome in Queen Maud Land. Notes for the contours and solid circles: same as Fig. 3.

2.3. Geomorphological characteristics of the ice sheet domes

The highest dome in the Antarctic Ice Sheet is called Dome Argus (Dome A), which is located in the area around 80°–82°S and 70°–85°E; the elevation is higher than 4000 m, the ice thickness less than 3000 m (DREWRY, 1983). Characteristic geomorphological difference between Dome A and Dome F can be seen in the subsurface topography around the domes, that is, Dome A is formed over the Gamburtsev Subglacial Mountains, of which the highest place has an elevation of about 3000 m above sea-level. On the contrary, there are no such large subglacial mountains beneath Dome F and the surrounding area, but at the periphery of this ice plateau, the mountain chain of Sør Rondane, Belgica and Yamato (Queen Fabiola) retard the ice flow from Dome F to the coast; in other words, it can be said that Dome F is located on the large subglacial basin in a scale of 1000 km in diameter.

Consequently, the ice sheet domes can be classified into two contrasted types according to the subsurface togography in a large scale, namely, 'the subglacial mountain type' and 'the subglacial basin type'. Such classification of the domes is considered to be important for discussions on the formation, development and variation of the ice sheet in the geological time scale, as well as for the comparison of their dynamics.

3. Climatological and Glaciological Aspects

3.1. Topographic effect on surface environments

Surface slopes become gradually smaller toward the center of the ice sheet dome from the surrounding area. In case that the surface slope is small, the lapse rate of snow temperature at 10 m depth (annual mean air temperature) for the elevation becomes large, since the temperature is generally lower at the higher latitude. Table 1 shows surface slopes and the lapse rate of snow temperature at 10 m depth for the elevation in Mizuho Plateau reported by SHIMIZU *et al.* (1978) and in the dome plateau observed by JARE-26 (Fig. 1). Annual mean air temperature at the highest place of the dome can be estimated to be −58.0°C by the extrapolation of values of snow temperature at 10 m depth along the route.

Prevailing wind is also affected by the surface topography, in particular the surface slope is one of main controlling factors of the speed and the direction of the katabatic wind (BALL, 1956). Along the traverse routes, the flow line directions of prevailing wind were observed from the surface relief such as sastrugi and dune, and the results are show in Fig. 5.

It can be seen in Fig. 5 that the flow line direction changes from the down-slope

Table 1. Surface slope and the lapse rate of snow temperature at 10 m depth for the elevation in Mizuho Plateau and the dome plateau.

	Mizuho Plateau		The dome plateau	
Surface slope (10^{-3})	<3100 m<		<3600 m<	
	>2.2	1.7>	>2.0	1.5>
10 m snow temperature (−°C/100 m)	1000 m∼3000 m∼3750 m		3100 m∼3400 m∼3650 m	
	1.3	2.2	1.5	2.2

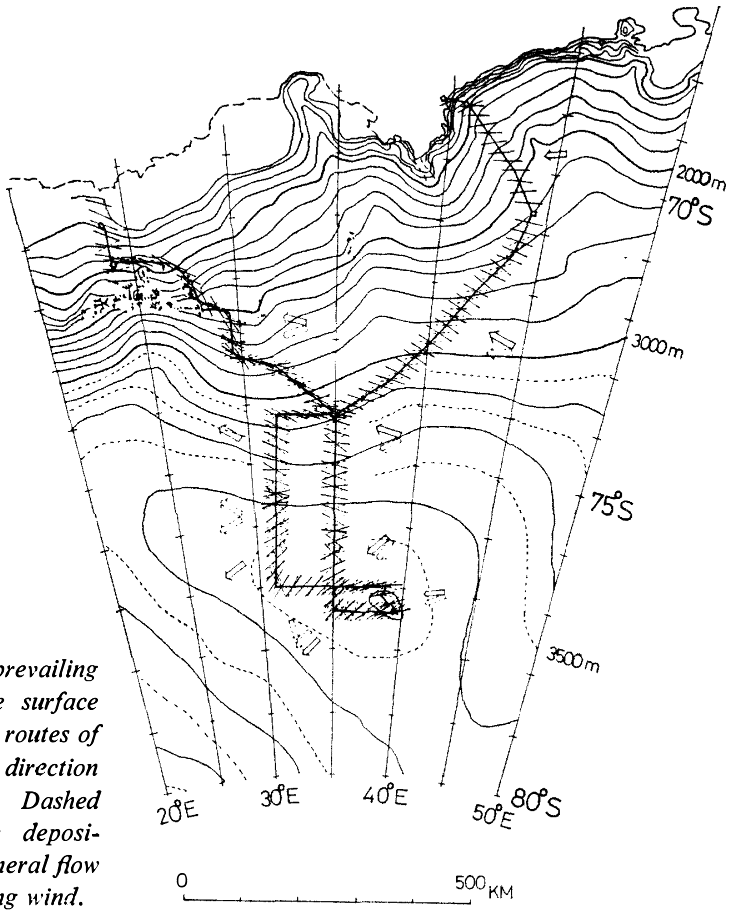

Fig. 5. Flow line directions of prevailing wind observed from the surface relief along the traverse routes of JARE-26. Solid line: direction of the erosional relief. Dashed line: direction of the depositional relief. Arrow: general flow line direction of prevailing wind.

direction to the up-slope one around the elevation of 3400–3600 m. From the area of this elevation to the top of the dome, surface relief became small, and the directions of the relief were not clear and not concentrated except for the south-west slope of the ice divide around the dome camp (DC: 77°00′S, 35°00′E, 3761 m a.s.l.), where the wind flowed down the slope. Generally over the whole observed area, the direction of depositional surface relief shifts counterclockwise from that of erosional relief, though it was not easy to distinguish erosional from depositional relief in the region higher than 3600 m.

The results described above and other observational results such as snow stratigraphy and snow hardness profiles indicate that the effect of the katabatic wind on the surface environments disappears above the elevation around 3500 m in the present study area. Such environmental difference corresponds to geochemical characteristics in this plateau as reported by KAMIYAMA *et al.* (1987).

The elevation limit of katabatic wind is around 3100 m in the case of the Mizuho Plateau (SHIMIZU *et al.*, 1978). This elevation is 400 m lower than that in the present study. As seen in Table 1, surface slopes in the dome plateau are similar to those in the Mizuho Plateau at the lower and the upper areas around the different elevation limits of katabatic wind in both plateaus. Consequently, surface topography, in particular its slope, which affects the katabatic wind, is considered to be an important factor for the climatological and glaciological environments on the ice sheet surface.

3.2. Mean annual net accumulation and preliminary estimation of age of the dome ice with depth

Observations on snow stratigraphy and corings to 10 m depth were carried out at several points in the dome and the surrounding area. At the dome camp (DC), a pit study of 5 m depth and a coring of 40 m depth were made. These glaciological results will be reported in detail in the near future. In this section, we will describe mean annual net accumulation at DC and a time scale of the dome ice which is roughly estimated from the net accumulation rate.

A continuous profile of tritium content was obtained from snow samples of 3.5 cm-depth interval in the 5 m-depth pit at DC by KAMIYAMA *et al.* (1989). At the depth of 174 cm in snow (60 cm in water equivalent) in this profile, they found a remarkble peak of tritium content which corresponds to the winter layer in 1966 according to the results at the South Pole by JOUZEL *et al.* (1979). From this result, mean annual net accumulation in the period from 1966 to 1985 can be calculated as 3.2 cm in water equivalent. This value is reasonable in comparison with the mean annual net accumulation obtained from the profiles of gross β activity in the high plateau in East Antarctica, such as 2.7 cm at Plateau Station (PICCIOTTO *et al.*, 1970) and 3.0 cm at the Pole of Relative Inaccessibility (PICCIOTTO and CAMERON, 1968).

Since the ice flow model at the top of the ice sheet dome is considered to be simple, ages of the dome ice (t: year) at the various depths can be estimated using the following equation (NYE, 1957; LORIUS *et al.*, 1979) which assumes a uniform vertical strain rate and a constant annual net accumulation:

$$t=\frac{H}{\lambda}\ln\frac{H}{H-z},$$

where λ is the annual net accumulation, H the total ice thickness, and z the depth, all expressed in ice equivalent (meter).

The ice thickness and the annual net accumulation of the highest place of the dome are approximately 2800 m and in a range of 3.0–3.5 cm in water equivalent, respectively. Using these values, the age of the dome ice with depth was calculated from the above equation and is shown in Fig. 6. It can be said from this estimation that

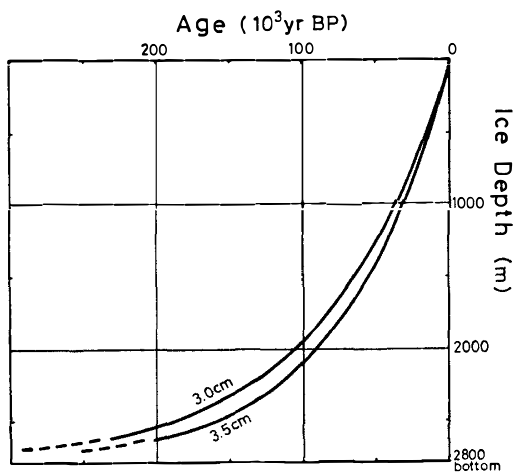

Fig. 6. The age of the dome ice with depth (cm: annual net accumulation in water equivalent).

the dome ice at the depth of 2000 m was deposited around a hundred thousand years ago and that at the approximate depth from 500 m to 2000 m corresponds to the ice formed during the last ice age.

4. Concluding Remarks

Geomorphological, climatological and glaciological characteristics of the highest dome in Queen Maud Land were briefly described in this report. There still remain many interesting research topics in respect to the inland dome. The top of the dome is the simplest place in the ice sheet for the ice dating from the flow model, since the ice movement from the upper stream does not need to be considered. Therefore, deep coring at the dome top is expected to be carried out for the studies which require the time scale, such as studies on climatic and other environmental changes in a global scale. In relation to such studies, it is important to observe and make models on the transportation and deposition of various materials (being contained in the ice core) through the atmosphere to the inland ice sheet, where the katabatic wind is not dominant.

Acknowledgments

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