Memoeirs of the Faculty of Science, Kyoto University, Series of Geol. & Mineral.
Vol. XXXVI, No. 1, pp. 1-18

Glaciological Studies in the Vicinity of Syowa Station, Lützow-Holm Bay, East Antarctica

By

Tadashi Maegoya*

(Received May 6, 1969)

Abstract

There is a marked ablation zone some 15 km wide along the periphery of the Soya Coast, Lützow-Holm Bay, and here the firn limit has a maximum height of about 600 m. A controlled analysis of the snow-firn stratigraphy on the marginal slope of the ice sheet at 700 m elevation was carried out on Nov. 3, 1966. The mean annual net accumulation for the period 1956-1965 was calculated as 7.1 ± 2.2 g/cm^2. The incidence of a cyclic pattern of melt-features and icy layering formed during the Antarctic summer is helpful in distinguishing winter layers from summer layers. Examination of the snow-firn stratigraphy at another observation point, 930 m above sea level, shows few melt-features and an average annual net accumulation of 14.2 ± 6.6 g/cm^2 for the period 1963-1966. Also, a rather low value of maximum mean annual snow deposition in 1966 (several tens of centimeters of snow depth at the end of October) in the Ongul Strait, suggests low precipitation in the Syowa region.

1. Introduction

This report concerns the glaciology of the vicinity of Syowa station, situated on East Ongul Island in Lützow-Holm Bay, latitude 69°00′S, longititude 49°35′E (see Figure 1).

The 5th Japanese Antarctic Research Expedition's Wintering Party in 1961 set up an automatic climatological station, temporarily named L/L, on the marginal slope of the ice sheet of the Soya Coast at an elevation of about 700 m, 30 km south-east from Syowa station. Japanese activity in the Antarctic was interrupted and Syowa station was evacuated in 1962. L/L was left unvisited until 1966 when Syowa station was reopened by the 7th Japanese Antarctic Research Expedition. Measurements of both the distance from a marked point on the wind mast to the snow surface and of the snow depth above the box in which a

* Present address: the College of General Education, Kyoto Industrial University. Member of the 7th Wintering Party, the Japanese Antarctic Research Expedition, 1965-1967.

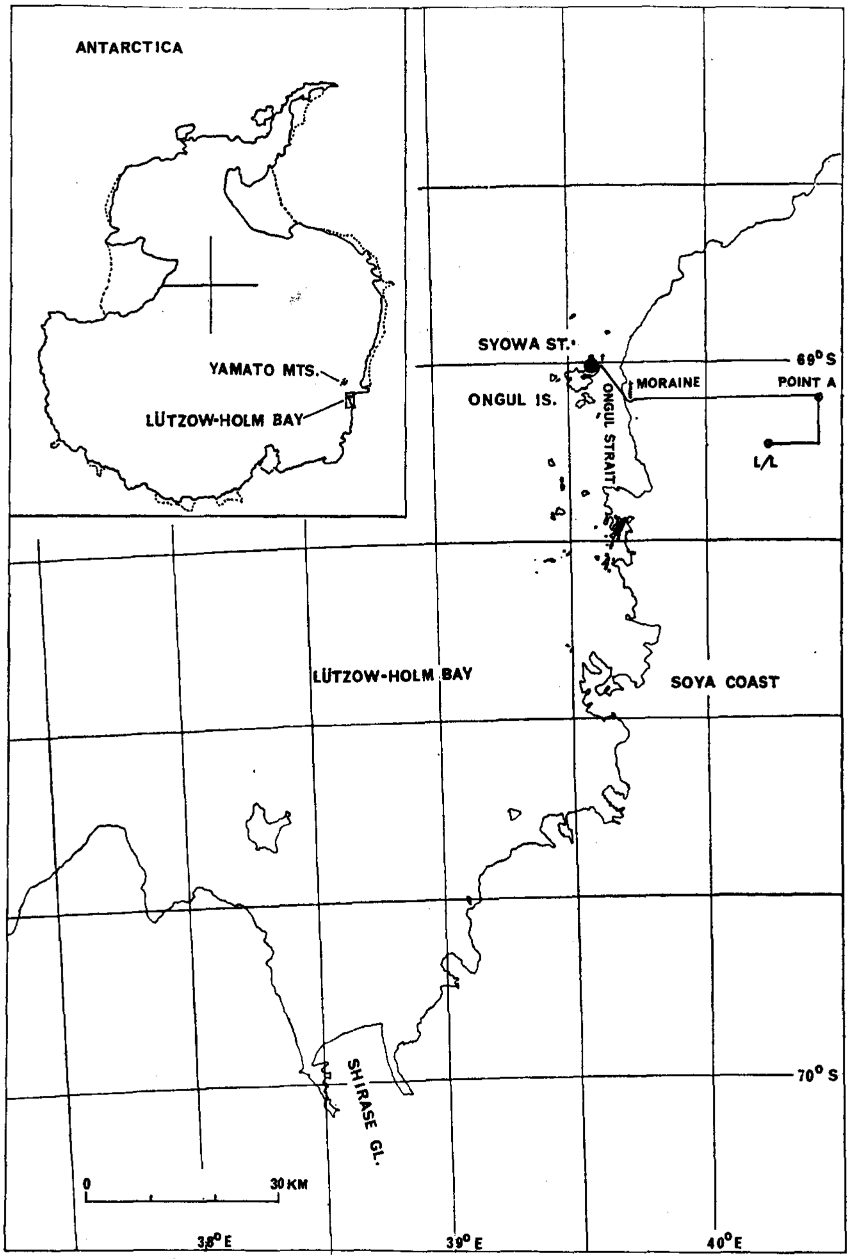

Figure 1. Index map showing Soya coast, Lützow-Holm Bay, Antarctica, and the area of investigation.

set of automatic meteorograph was housed revealed that snow accumulation at L/L from Jan. 15, 1962 to Oct. 31, 1966 was 99 cm (SEINO, 1967). Numerous determinations of annual snow accumulation have been made by observation of the stratigraphy in snow pits, but it has been pointed out that the delineation of annual boundaries may be subjective and inconsistent (SHIMIZU, 1964; KOERNER, 1964; *etc.*). Since 99 cm of snow accumulation at L/L for the period Jan. 15, 1962-Oct. 31, 1966 is a reliable value, it affords a good opportunity for a controlled analysis of snow-firn stratigraphy. Hence, a pit 4 m deep was dug for this purpose.

As a result of this pit study, combined with other field observations by the writer while wintering at Syowa station in 1966-1967, some clarification has been made of the present glaciological condition of the marginal slope of the ice sheet along the Soya Coast.

2. Physical Description

Geological Setting. Exposed rock on the Soya Coast and neighbouring islands comprises various gneisses with pegmatite dykes (TATSUMI and KIKUCHI, 1959; KIZAKI, 1964). Recorded radiometric ages of these rocks range from 350 my to 530 my, but recent Rb-Sr determinations give an isochron age of 458 ± 10 my, and appear to indicate that the last metamorphic activity in the region occured in early Palaeozoic (MAEGOYA *et al.*, 1968).

Numerous small islands lie along the north-eastern coast of Lützow-Holm Bay. Morphologically these islands are rather flat and smooth, showing evidence of extensive glaciation in the past. According to MEGURO *et al.* (1963), near the Ongul Islands an ice sheet formerly existed at least 20 km in advance of the present day ice terminus. Beaches have been raised up to 15-20 m above sea level, possibly by isostatic rebound after the ice retreated. Although no evidence has been obtained of past multiple glaciations, at least several thousand years seem to have passed since the last glaciation here, judging from the weathering condition of the bed rock and from C-14 dating of fossil shells (MEGURO *et al.*, 1963).

Climate. The East Ongul Island on which Syowa station is situated lies on the west side of Ongul Strait some 5 km from the Antarctic Continent (see Figure 1). Hence, Syowa station is somewhat insulated from the low temperatures on the ice sheet. The influence of the katabatic wind which usually develops over the slope of the Antarctic coast is very weak at Syowa station across the Ongul Strait, and is discernible only in the early morning. Mean annual air temperature at Syowa station for the period 1957-1961, excluding 1958, is - 10.9° C. The prevailing wind direction is NE or ENE throughout the year and the mean wind velocity from total course is 6.0 m/sec. The absolute minimum temperature recorded at Syowa is - 42.7°C on Jul. 28, 1961, and the maximum is 8.1°C on Dec. 9, 1967 (JAPAN METEOROLOGICAL AGENCY, 1964).

Sea Ice. In Lützow-Holm Bay a vast stretch of shore ice is typically developed, some 100 km or more wide in winter and some 40-50 km wide in summer. Some of this ice normally persists as polar ice enduring more than one full season. Part of the Ongul Strait became free of ice, however, during the summer of 1966, affording an occasion for systematic observations on the development, growth, and decay of the sea ice around Syowa station. An empirical equation of

$$i^2+50i=9R$$

(where i : Ice thickness (cm), R : Degree-days of frost)

was derived from observations of new ice formed in the Ongul Strait at the beginning of March 1966 (see Figure 2). Since the mean of effective degree-days of frost at Syowa station over the past several years is about 3,800, the maximum thickness of winter ice developed in the Ongul Strait will be around 160 cm. In a future publication it is hoped to discuss the effect of fluctuating air temperature and snow depth upon ice growth, and upon the ultimate possible thickness of polar ice in the region.

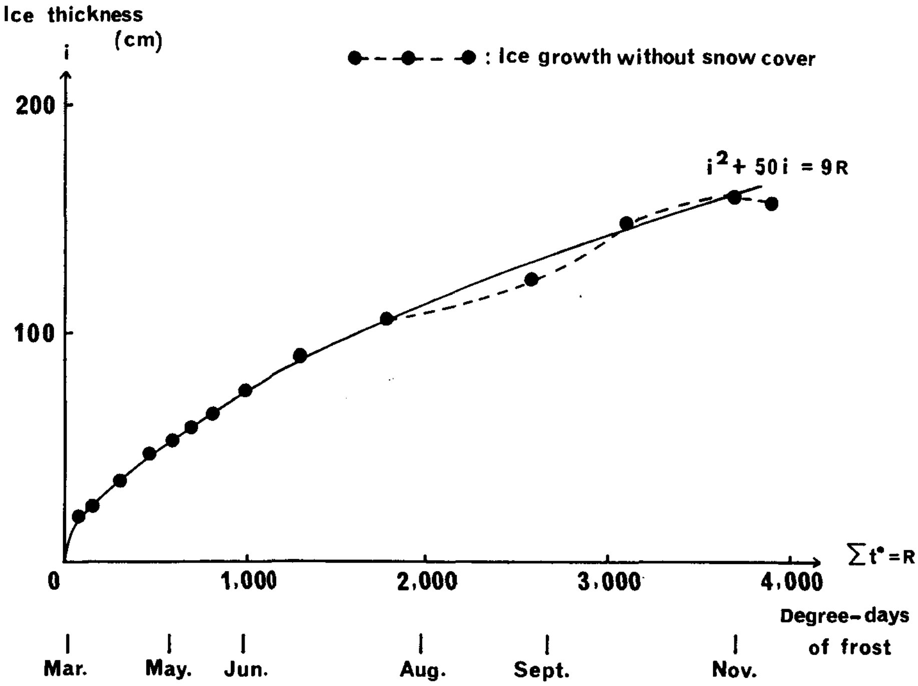

Figure 2. Curve of sea ice growth with the total number of degree-days of frost and with time at Syowa station.

Snow Deposition and Ablation. In common with most of the Antarctic coast, snow deposition in the Syowa region occurs mainly from March until November, and results from cyclonic storms (blizzards) with 10°-15°C increase in air temperature. Snow deposition is irregular throughout the year because of the wind activity, and exact measurements of the snow fall are therefore extremely difficult to obtain here. According to snow stake measurements carried out by SEINO in 1966, the amount of snow deposited on the sea ice in the Ongul Strait attained a maximum mean thickness of 70 cm at the end of October (see Figure 3). This figure was obtained by setting a 1 kilometer long line of 8 stakes approximately E-W in the sea ice, and measuring the accumulation of snow two or three times a month throughout 1966. However, this measurement may not be acceptable *per se* since the site lies in the immediate vicinity of the East Ongul Island. Little snow (less than 50 cm) accumulates on the sea ice 1-3 km from the shore and there is hardly any snow on the ice 0-1 km from the shore. Generally, nearer to the Island, snow accumulation is deeper. More data on snow deposition on sea ice in the Ongul Strait were obtained during the writer's study of the

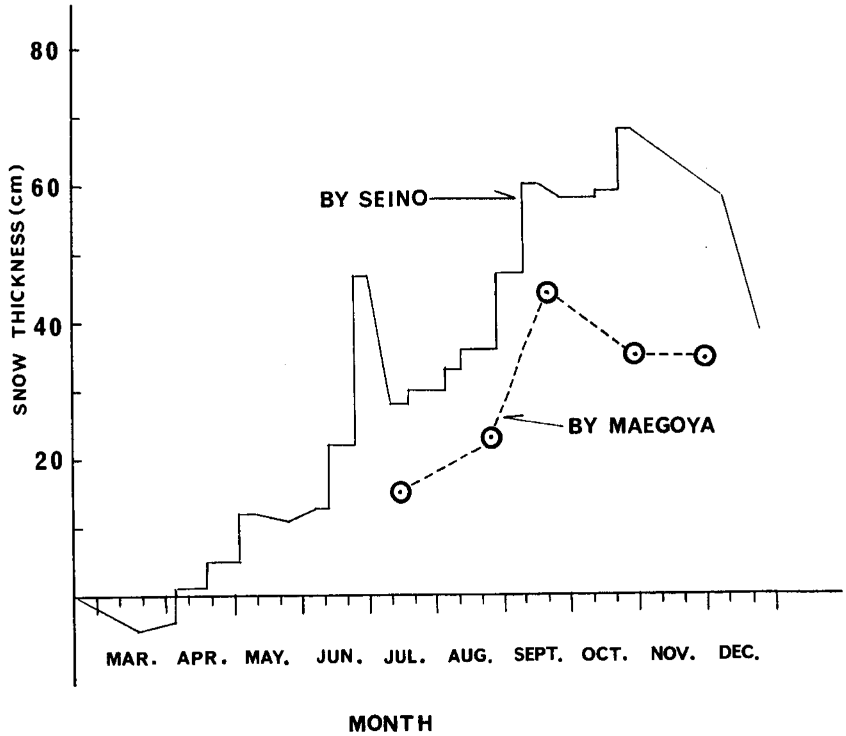

Figure 3. Snow accumulation at stakes in the Ongul Strait, cumulative and mean accumulation during 1966.

sea ice in 1966. A maximum mean thickness of 44 cm at the end of September was measured at 14 snow stakes set in the sea ice across most of the Ongul Strait (see Eigure 3).

The first signs of ablation in the Syowa region appear at the end of October and the depth of accumulated snow gradually decreases till mid-December. Sunny, almost cloudless and windless days often occur during the summer in the Syowa region. Yearly maximum air temperatures range from 8.1°C (1967) to 4.5°C (1961). Thus, ablation from mid-December till early February is so intense, sometimes exceeding 1 cm/day, that practically all the accumulated snow disappears or metamorphoses into ice by the interaction of sunshine with infiltrating sea water before the commencement of new snow deposition at the end of March. Where conditions permit, snow-drifts form during the winter on the islands in Lützow-Holm Bay, and some of these drifts last through the summer. But the volume and area of the remaining snow-drifts vary from year to year according to weather conditions and show no sign of progressive yearly accretion. This suggests that no annual surplus of snow accrues in the vicinity of Syowa station, although snow deposition during the winter reaches several tens of centimeters.

Lower Parts of the Marginal Slope of Ice Sheet. The profile of the ice sheet

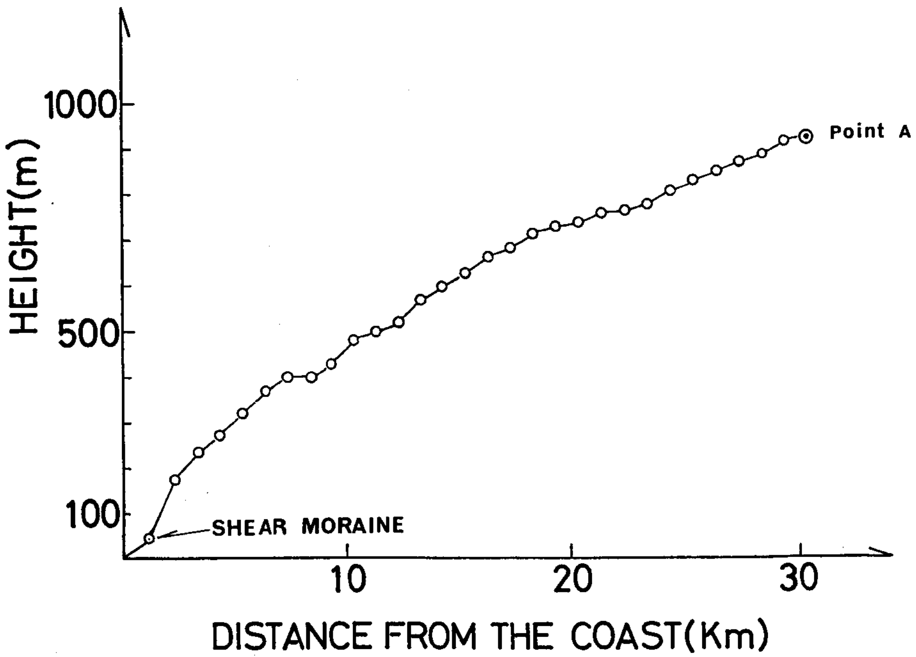

Figure 4. Profile of the ice sheet along the meridian 69°03′S, east of the Ongul Strait.

east of Syowa station across the Ongul Strait is parabolic. The ice surface rises rather abruptly from the coast, attaining a height of 1,000 m only 30-40 km inland. Details of the ice sheet microrelief are shown in Figure 4 and Table 1. The average angle of elevation up to Point A is 1°47′. The steepest gradient is found at a height 50-180 m with an inclination of about 6°. As shown in Figure

Table 1. Ice Sheet Micro-relief

Site	Distance from the Coast (km)	Dominant Wind Direction(deg.)*	Elevation (m)	Angle of Elevation
Landing Point	0.0	40	0	
				) 2°14′
Moraine	1.2	45	47	
				) 6°04′
F00	2.4	40	174	
				) 3°37′
F01	3.4	45	237	
				) 2°01′
F02	4.4	50	273	
				) 2°42′
F03	5.4	52	319	
				) 2°42′
F04	6.4	60(40)	366	
				) 1°54′
F05	7.4	45	399	
				) 0°00′
F06	8.4	50	399	
				) 1°57′
F07	9.4	63	432	
				) 2°45′
F08	10.4	58	480	
				) 1°16′
F09	11,4	70(48)	502	
				) 1°26′
F10	12.4	55	527	
				) 2°42′
F11	13.4	68	574	
				) 1°30′
F12	14.4	60	600	
				) 1°45′
F13	15.4	75	631	
				) 1°52′
F14	16.4	50(70)	665	
				) 1°20′
F15	17.4	60	688	
				) 1°33′
F16	18.4	50(85)	715	
				) 0°46′
F17	19.4	90(55)	729	
				) 0°38′
F18	20.4	40	740	
				) 1°07′
F19	21.4	45	760	
				) 0°14′
F20	22.4	60(85)	764	
				) 1°09′
F21	23.4	45(95)	784	
				) 1°20′
F22	24.2	65(85)	807	
				) 1°44′
F23	25.4	55(85)	837	
				) 0°59′
F24	26.4	55(90)	855	
				) 0°58′
F25	27.4	80(60)	872	
				) 1°20′
F26	28.4	85	895	
				) 1°17′
F27	29.4	80	918	
				) 0°59′
F28 (Point A))	30.4	90(60)	936	

* Prevailing wind direction as determined by the orientation of sustrugi. Figures in parentheses indicate subsidiary wind directions where sustrugi form more than one set.

4, the relief is rather simple in the area 22.5-30 km from the coast where it rises uniformally with an angle of elevation of 1°14′. Terrace-like ledges are found with crevasses on their seaward slopes.

No firn or neve exists on the slope of the ice sheet up to a height of about 600 m, some 10-15 km from the coast. Local variation in the firn line is due to topographic and wind influences. Even in winter the blue ice remains exposed on the slope and 10-30 cm of snow accumulate in parts, forming long narrow bands. A slight ablation of the bare blue ice, of the order of one or two centimeters, due to sublimation and evaporation and perhaps to wind erosion, occurs even in winter, as demonstrated by means of marker flag-poles set up to indicate the original level of the ice surface. In summer many melt water rills and rivulets form below 400-500 m on the slope of the ice sheet and run in torrents. "Hillocky structure" or "radiation hollows", reliable indication of melting phenomena in summer, are commonly observed in the bare blue ice zone (KUZNETSOV, 1961). A typical shear moraine, described by WEERTMAN (1961), develops at a height of 50-100 m, a little above the ice terminus. The ice terminus is grounded forming an ice cliff 20-30 m high, so that only a few landing places are to be found along the Soya Coast, at which points snow-drifts form, producing gentle slopes. These facts lead to the conclusion that there is a distinct zone of ablation in a narrow strip along the Soya Coast. The absolute mass budget in the region, however, is a subject for future research;

i.e. (Precipitation + Snow drift carried from the interior + Replenishment from the interior by ice flow + Condensation) − (Snow drift carried away to the sea + Calving + Sublimation and Evaporation + Melting)

It seems most likely that an equilibrium is maintained, for no remarkable changes of the coastal line and physiological features in the region have been observed over the past ten years.

Sustrugi. The deposited snow on both the sea ice and the land in Lützow-Holm Bay is packed and eroded by intensive winds, forming sustrugi which usually show the prevailing wind direction. These are formed mainly during cyclonic storms (blizzards) and those found on the ice sheet slope are modified by the katabatic wind which constantly blasts the slope. The sustrugi developing around Syowa station are mostly from 10-30 cm high and rarely exceed 50 cm. The direction indicated is predominantly NE-SW. Along the meridian 69°03′ S, small sustrugi 5-15 cm high are common. In some places they are oriented towards several different directions. The direction gradually changes from NE-SW at Syowa station to E-W towards the interior of the ice sheet. At Point A the direction was exactly E-W (see Table 1). Since the area covered in this study is very limited, it is almost impossible to form any conclusions concerning the wind regime along the Soya Coast.

3. Pit Studies at L/L and Point A

Firn Stratigraphy at L/L. At L/L in early November, 1966, the writer studied

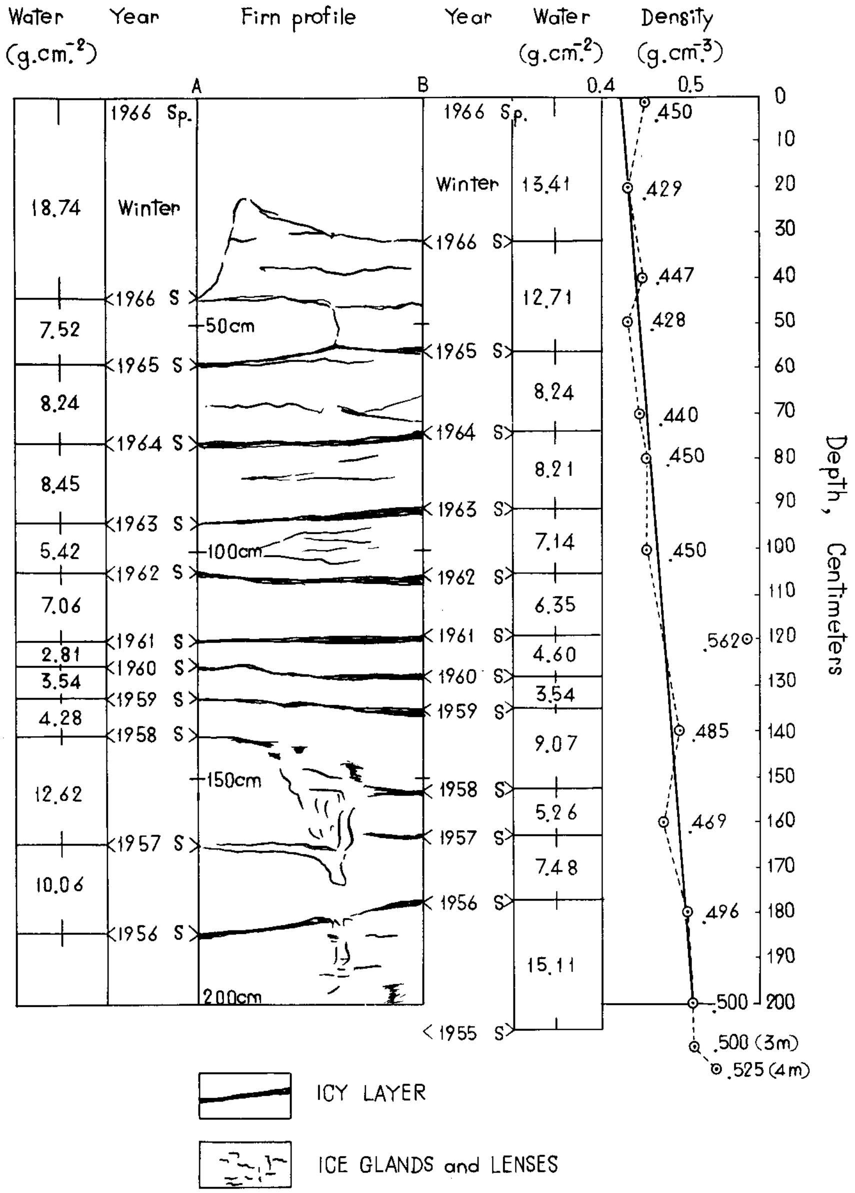

Figure 5. Stratigraphic profile of snow accumulation in the wall of a pit at point L/L. (Horizontal scale from the profile A to the profile B is 1 m)

the firn profile of a wall 1 m wide oriented NW to SE in a pit 1.5 × 2 m in area and 4 m deep, located about 20 m from the automatic climatological station. Horizontal variation in the amount of snow accumulation between the pit and station sites for the period Jan., 1962 to Nov., 1966 was very small, the one showing 99 cm and the other about 105 cm. Characteristic of the firn at L/L was the existence of melt-features, e. g., 1-3 cm icy layers, and small ice lenses and glands (see Figures 5 and 6). There is clearly seen undulation of the horizontal icy layers. The thickness of these layers is seldom constant and they show poor continuity. Because of this irregularity, the mean annual net accumulation at L/L for the period 1956-1965 was calculated, as 7.1 ± 2.2 g/cm², by averaging the values at profiles A and B (see Figure 5 and Table 2). Snow deposited during the 1966 winter period was excluded from the calculation because it had not suffered summer ablation. The lower contact of the icy layers and the firn snow beneath is usually sharp and clear-cut ; the upper contact is more gradational. Horizontal movement and downward channeling of melt water are apparent in the firn. Some downward movement breaking into the firn of the previous budget year is also evident. Most of these melt-features seem to be due to metamorphism of the surface snow and freezing of melt water in the firn during the summer under the combined effect of intense sunshine and relatively high air temperature (a little above freezing point at L/L). The mechanism of formation of these melt-features is not clear, but a "green house" effect may play an important role.

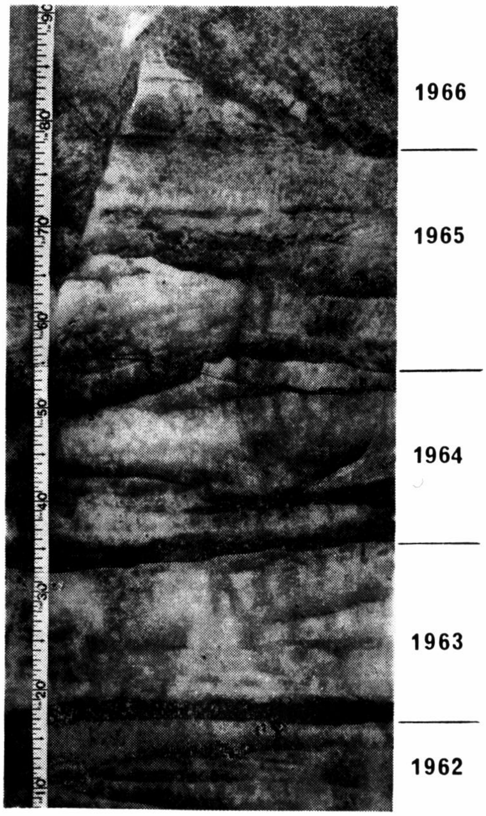

Figure 6. Part of Firn Profile in the wall of a pit at Point L/L, showing the icy layers (dark bands) and the net accumulation for successive budget years.

Grain size of the firn was assessed from hand specimens under a × 10 magnifying glass. Grain size of the freshly deposited snow immediately under the surface consists of plate and columnal cystals varying from 0.1-0.5 mm in diameter, and grain size of the old snow beneath, from 0.5-1.0 mm. The grain size of snow at a depth of 2 m is around 1.5 mm.

Density determinations were made in the top 2 m of the pit by weighing a known volume of rectangular block sample from each layer in the firn. The sampler used was not sturdy enough to penetrate the hard icy layers. Densities were calculated to 3 places of decimals, no greater accuracy being possible with the method and equipment used. The density at the surface of the firn is rather high due to wind packing action and attains a value of 0.450 g/cm³. Just below

Table 2. Yearly Vales of Accumulation at L/L (69°07′ S, 40°14′ E).

Year	Density (g cm⁻³)	Depth A (cm)	Accumulation A (g cm⁻²)	Depth B (cm)	Accumulation B (g cm⁻²)	Mean Accumulation $\left(\frac{A+B}{2}\right)$ (g cm⁻²)
1966	0.426	0.0—44.0	18.74	0.0—31.5	13.41	16.07
1965	0.519	44.0—58.5	7.52	31.5—56.0	12.71	10.11
1964	0.471	58.5—76.0	8.24	56.0—73.5	8.24	8.24
1963	0.483	76.0—93.5	8.45	73.5—90.5	8.21	8.24
1962	0.493	93.5—104.5	5.42	90.5—105.0	7.14	6.28
1961	0.471	104.5—119.5	7.06	105.0—118.5	6.35	6.75
1960	0.512	119.5—125.0	2.81	118.5—127.5	4.60	3.70
1959	0.507	125.0—132.0	3.54	127.5—134.5	3.54	3.54
1958	0.504	132.0—140.5	4.28	134.5—152.5	9.07	6.67
1957	0.526	140.0—164.5	12.62	152.5—162.5	5.26	8.94
1956	0.516	164.5—184.0	10.06	162.5—177.0	7.48	8.77
1955	0.526			177.0—206.0	15.11	

the surface, and to a depth of 44.0 cm at the firn profile A, and to a depth of 31.5 cm at the firn profile B, the new snow deposited during the winter period in 1966 has an average density of 0.426 g/cm³. Below it, to a depth of 2 m, is firn with icy layers and small ice lenses and glands. The firn densities gradually increase from about 0.43 g/cm³ at the top to 0.50 g/cm³ at a depth of 2 m. Despite the irregularity, there exists the gradual density increase rate normally expected with depth (see Figure 5). The average density increase rate excluding the icy layers and ice bodies (ice lenses and glands) is 0.00035 per cm in the upper 2 meters of the firn. Below 3 m, density could not be accurately measured since the faulty sampler was inoperable in hard firn snow. The firn snow at depths of about 4 m is very hard with densities of 0.55 to 0.60 g/cm³, suggesting that the total thickness of the snow and firn cover (firn-ice transition depth) is not deep, perhaps not exceeding 20 m. The densities of the firn in which icy layers and ice bodies are included are extremely high and always more than 0.6 g/cm³, which results in rather high average densities in the layers of each budget year (see Table 2). Also noteworthy with reference to density is the existence of layers of low density consisting of isometric loose grains just beneath some of the icy layers. These layers might correspond the "depth hoar" layers reported in many glaciological works on Antarctica (SHIMIZU, 1964; *etc.*).

Firn temperatures were measured in the wall of a 4 m pit with a thermister to an accuracy of ± 0.05°C. A MITSUBISHI 1 kw electric drill was used at the bottom of the 4 m pit to reach a depth of 10 m. A depth of only 9 m was at-

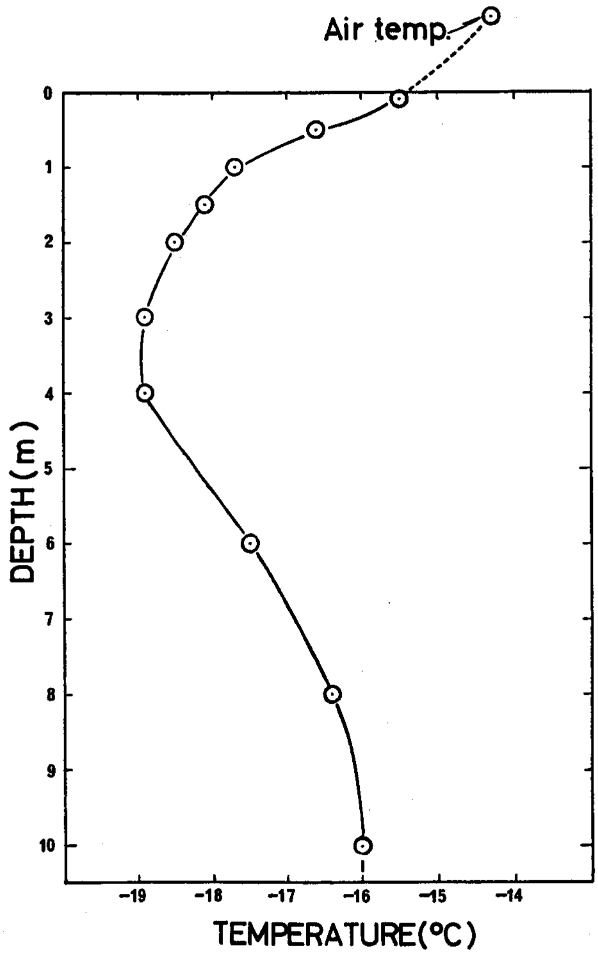

Figure 7. Temperature gradient in the firn at L/L on November 3, 1966.

tained, however, owing to difficulty in extracting the snow from the bore-hole. The final 1 m was melted out with a stake-shaped 1 kw electric heater. Temperature measurements of the firn snow in the pit at the 10, 50, 100, 150, 200, 300, 400, 600, 800, and 1,000 cm levels are given in Figure 7. Temperature in the firn fell very rapidly from - 15.5°C at the top to - 18.9°C at a depth of 3 m, and the lowest temperature was found to exist between 3 m and 4 m. Below this, temperature in the firn increased gradually from - 18.9°C at 4 m to - 16.0°C at 10 m at which depth seasonal variations vanish indicating the approximate mean annual air temperature. The influence of the low winter temperatures was still apparant in the firn at this time of the year. But it is clear from Fig. 7 and Fig. 8 that a marked change in temperature gradient in the upper 3 m of the firn occurs during October.

The firn temperatures at 4 m, 6 m, 8 m, and 10 m in the bore-hole at the bottom of the 4 m pit were measured continuously from 20.55 local time on Nov. 2, 1966 to 07.00 local time on Nov. 3, 1966 using a Hokushin automatic 6 point thermocouple temperature recorder. It was some five hours before stabilization in the reading of the firn temperatures was achieved after filling and covering the hole with snow and ice (see Figure 9). The obtained 10 m firn temperature of - 16.0 ± 0.5°C agrees approximately with the measurements of Oura (1963) conducted at L/L in 1961 (see Figure 8). Changes in the firn temperatures reflecting air temperature fluctuation were hardly noticeable below 6 m. A slight change in the 4 m firn temperature corresponding to that of the air can be deduced from Figure 9, but in this case the values may not show the true 4 m firn temperature because of the conditions under which measurements were made. The 10 m hole was bored at the bottom of the 4 m pit, so that the 4 m temperature was liable to reflect air temperature even though the measuring thermocouple was set under a snow cover. In comparison with a true 4 m temperature of - 18.9°C obtained on Nov. 2, 1966 by a thermister, our stabilized recorded values were approximately 1.5°C higher. This difference may be due to the effect of exposure to the air at the bottom of the pit.

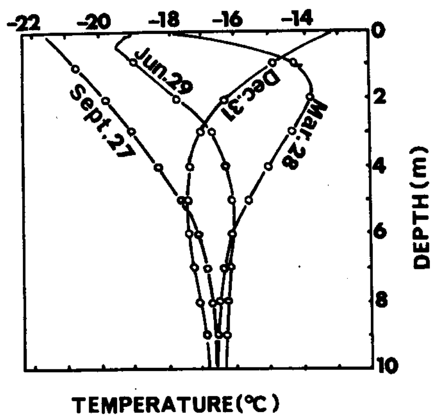

Figure 8. Seasonal temperature chanegs in the upper 10 meters of firn at L/L in 1961. (Aftter Oura, 1963)

Firn Stratigraphy at Point A. Point A is located at 69°03′S, 40°25′E at a height of about 930 m, 30 km inland from the coast. No distinct melt-features were ob-

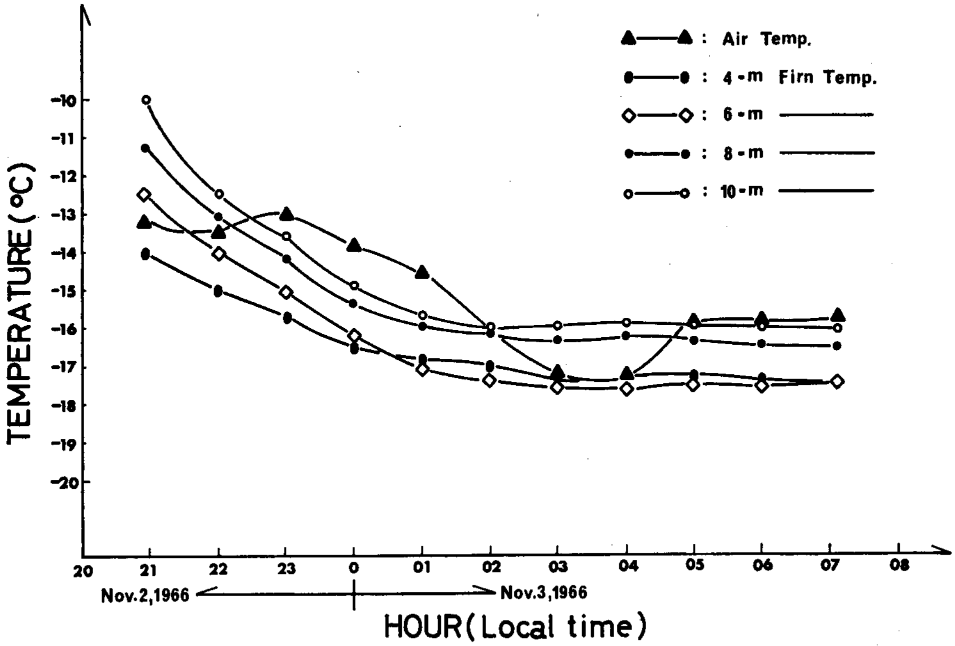

Figure 9. Continuous recordings of the firn temperatures in a bore-hole at the bottom of a 4 m pit at L/L. (Temperatures at the start of recordings are rather high due to the effect of a 1 kw electric heater which was used to melt out the final 1 m of snow in the bore-hole to reach a depth of 10 m)

served in the firn at this height. The 8 m firn temperature was - 17.5 ± 0.5°C. The mean annual net accumulation for the period 1963-1966 was calculated as 14.2 ± 6.6 g/cm² (see Figure 1 and Table 3).

Table 3. Yealy Values of Accumulation at Point A (69°03'S, 40°25'E)

Year	Density (g cm^{-3})	Depth (cm)	Accumulation (g cm^{-2})
1966	0.428	0.0—14.0	17.55
1965	0.421	41.0—65.0	10.10
1964	0.435	65.0—79.0	6.09
1963	0.438	79.0—132.0	23.21

4. Discussion and Summary

To calculate the value of the total annual precipitation at L/L, the amount of snow lost by sublimation and evaporation must be added to the recorded annual net accumulation of 7.1 ± 2.2 g/cm². *Judging from the existence of distinct* melt phenomena in the firn, the amount of snow lost from L/L during the summer period is substantial. Some speculation about this can be made using the observations at Point A. Although the differences in relative position between L/L and Point A are small, i.e., about 200 m in height and several kilometers in distance from the coast, there is a marked distinction between them in that at one there are clear melt-features in the firn and at the other these features are negligible. Thus the amount of snow lost during the summer period at Point A can not have been as much as at L/L. It is likely, therefore, that the annual net accumulation of 14.2 ± 6.6 g/cm² at Point A is close to the value of total annual precipitation there. Rather low precipitation in the narrow region along the Soya Coast is suggested by the following four figures obtained in this study;

1. Snow deposition in the Ongul Strait during the 1966 winter period: Several tens of centimeters in snow depth.
2. Snow deposition at L/L during the 1966 winter period: 16.07 g/cm².
3. Snow deposition at Point A during the 1966 winter period: 17.55 g/cm².
4. Mean annual net accumulation at Point A for the period 1963-1966: 14.2 ± 6.6 g/cm².

The glaciological observations made at Syowa station, L/L, and Point A also show that the annual net accumulation in the Syowa area is much smaller than has been estimated previously (BENTELY *et al.*, 1964). This is probably due to the rather low precipitation. The existence of an ablation zone along the narrow periphery of the ice sheet and the lack of ice shelves in the region may also result from low precipitation and from higher summer temperatures, lasting from December to February.

In 1957-1958 TATSUMI and KIKUCHI, members of the first Japanese Wintering Party at Syowa station, studied this region and reported (1959) that there were several marked differences between the north-eastern and the north-western coasts of Lützow-Holm Bay, i.e., the morphology and topograohy of the ice sheet, wind direction, and amount of precipitation. The writer had an opportunity of observing both the regions from the air in a Soviet plane on Dec. 23, 1966, and could see no evidence contradicting this statement. No ablation zone was noticed on the north-western side. The extensive development of ice shelves from the Riser Rarsen Peninsula westwards to the Weddell Sea and the comparatively high accumulation rates along this region (see Table 4) point to the rather high precipitation normally encountered along the coastal zone in Antarctica. Regions of net ablation in a narrow strip along the Antarctic coast have been reported by MELLOW in the Mawson region (1958), and HOLLIN *et al.* in the Wilkes region (1961). Sections of net ablation extending from approximately 40° to 135°E were assumed to exist by GIOVINETTO (1964). A marked change in amount

Table 4. Amounts of Mean Net Accumulation in the Regions from Riser Rarsen Penisula westward to the Weddle Sea. (After GIOVINETTO, 1964)

Station	Location	Elevation MASL	Period yr	Mean Net Accumulation g cm^{-2} yr^{-1}
Lazarev	70° S 13° E	40	20	22.2
Halley Bay	75° 36′S 26° 41′W	35	15	35.4
Maudheim	71° 03′S 10° 56′W	37	17	36.5
Roi Baudouin	70° 26′S 24° 19′E	40	25	38.4
S. A. N. A. E.	70° 19′S 02° 32′W	52	16	40.6
Norway	70° 30′S 02° 32′W	55	20	49.5

of precipitation occurs along the north-western coast of the Lützow-Holm Bay. The reason for this change has not yet been clarified, but it is certainly related to the tracks of intruding cyclones that bring intensive snow fall. The mountain belt in Queen Maud Land running parallel to the coast is one of the contrasting topographic differences between the Syowa region and the region west of the north-western coast of the Lützow-Holm Bay. These mountain may strongly affect the courses of the cyclones and consequently the amount of precipitation.

The results of the present study may be summarized as follows ;

1. There is no annual surplus of snow at Syowa station (69°00′S, 39°35′E), and there is a marked ablation zone some 15 km wide in a narrow strip along the Soya Coast, Lützow-Holm Bay.
2. The firn line has a maximum elevation of about 600 m, although local variation in height is found to exist due to topographic and wind influences.
3. The mean annual net accumulation at L/L (69°07′S, 40°14′E) for the period 1956-1965 was 7.1 ± 2.2 g/cm².
4. The mean annual net accumulation at Point A (69°03′S, 40°25′E) for the period 1963-1966 was 14.2 ± 6.6 g/cm².
5. The mean annual precipitation at Syowa station and a neighbouring narrow strip on the marginal slope of the ice sheet is estimated at approximately 15-20 g/cm².
6. The mean annual temperature at a height of 700-900 m on the ice sheet ranges from - 16.0 ± 0.5°C to - 17.5 ± 0.5°C.
7. The lowest temperature in the 10 m firn at L/L on Nov. 3, 1966 was observed at a depth between 3 m and 4 m, showing that the influence of the low

winter temperatures is still felt at this time of the year. A marked change occurs during October, however, in the temperature gradient of the upper 3 m of the firn.

8. The rate of newly formed shore ice growth in relation to effective degree-days of frost in the Syowa region is given by an empirical equation of

$$i^2 + 50i = 9R$$

(where i: Ice thickness (cm), R : Degree-days of frost). This shore ice is expected to increase in thickness by about 160 cm during one winter season.

9. The absolute mass budget on the Soya Coast margin may have maintained an equilibrium over the past ten years.

10. There are marked distinctions between the region east of the Shirase Glacier in Lützow-Holm Bay and the region lying to westward thereof. These may have resulted from differences in the amount of precipitation and topography.

5. Acknowledgements

The writer would like to acknowledge his debt to all members of the 7th Japanese Antarctic Research Expedition headed by Mr. M. MURAYAMA. Special thanks are due to Dr. A. MUTO, leader of the 7th Wintering Party, who greatly facilitated the writer's field work.

Acknowledgements are also due to Dr. P. K. SENKO and Professor M. G. RAVICH of the 12th Soviet Antarctic Expedition, who kindly enabled the writer to join their airborne expedition to the Yamato Mountains.

The writer further wishes to express his gratitude to Emeritus Professor S. MATSUSHITA and Professor T. KAMEI of Kyoto University for their continued encouragement and guidance throughout this study.

6. References

BENTLEY, C. R., R. L. CAMERON, C. BULL, K. KOJIMA, and A. J. GOW (1964): Physical Characteristics of the Antarctic Ice Sheet, Antarctic Map Folio Series, Folio 2, *Amer. Geographical Society*, New York.

CAMERON, R. L. (1964): Glaciological Studies at Wilkes Station, Budd Coast, Antarctica, *Antarctic Res. Ser.*, Vol. 2, pp. 1-36 ; *Amer. Geophys. Union.*

GIOVINETTO M. B. (1964): The Drainage Systems of Antarctica: Accumulation, *Antarctic Res.*, *Ser.* 2, Vol. pp. 127-155; *Amer. Geophys. Union.*

HOLLIN, J. T. and R. L. CAMERON (1961): IGY Glaciological Work at Wilkes Station, Antarctica, *J. Glaciology*, 3 (29), pp. 833-843.

JAPAN METEOROLOGICAL AGENCY (1964): Surface Meteorological Data at the Syowa Base, *Antarctic Meteorological Data*, Vol. 2.

KIZAKI, K. (1964): Tectonics and Petrography of the East Ongul Island, Lützow-Holm

Bukt, Antarctica, *JARE* 1956-1962 *Sci. Rep. Ser. C*, No. 2, pp. 1-24; *National Science Museum*, Tokyo.

KOERNER, R. M. (1964): Firn Stratigraphy Studies on the Byrd-Whitmore Mountains Traverse, 1962-1963, *Antarctic Res. Ser.*, Vol. 2, pp. 219-236; *Amer. Geophys. Union.*

KUZNETSOV, M. A. (1964): Sculptured Forms of the Ice Surface in Antarctica and their Origin, *Soviet Antarctic Expedition*, Vol. 2, pp. 189-192; *Elsevier Publishing Co.*, Amsterdam London New York.

LOEWE, F. (1960): Contribution to the Glaciology of the Antarctic, *J. Glaciology*, 3 (28), pp. 773-782.

MAEGOYA, T., S. NOHDA, and I. HAYASE (1968): Rb-Sr Dating of the Gneissic Rocks from the East Coast of Lützow-Holm Bay, Antarctica, *Mem. Coll. Sci. Univ. Kyoto, Ser. of Geology and Mineralogy*, Vol. XXXV, No. 2, pp. 131—138.

MEGURO, H., Y. YOSHIDA, T. UCHIO, K. KIGOSHI, and K. SUGAWARA (1963): Quaternary Marine Sediments and their Geological Date with Reference to the Geomorphology of Kronprins Olav Kyst, *Antarctic Geology*, pp. 73-80; *North-Holland Publishing Co.*, Amsterdam.

MELLOR, M. (1958): Australian Glaciological Contributions in Antarctica——Preliminary Report, *J. Glaciology*, 3 (24), pp. 279-285.

OURA, H. (163): Snow and Ice, Antarctic Circle, *Grand Series of World Geography*, pp. 365-372 (in Japanese); *Seibundo-Shinkosha Publishing Co.*, Tokyo.

SEINO, Z. (1967): Report of the 7th Wintering Party, JARE, 1967-1967, pp. 71-88 (in Japanese); *Ministry of Educ.*, Tokyo.

SHIMIZU, H. (1964): Glaciological Studies in West Antarctica, 1960-1962, *Antarctic Res. Ser.*, Vol. 2, pp. 37-64; *Amer. Geophys. Union.*

TATSUMI, T., and T. KIKUCHI (1959): Report on Geomorphological and Geological Studies of the Wintering Team (1957-1958) of the First Japanese Antarctic Research Expedition, Part 1, 2. *ibid.*, No. 7, pp. 373-388, No. 8, pp. 443-463 (in Japanese with English abstract); *Ministry of Educ.*, Tokyo.

TATSUMI, T., T. KIKUCHI and K. KIZAKI (1963): Geology of the Region around Lützow-Holmbukt and the "Yamato Mountains" (Dronning Fabiolafjella), *Antarctic Geology*, pp. 293-303; *North-Holland Publishing Co.*, Amsterdam.

WEERTMAN, J. (1961): Mechanism for the formation of inner moraines found near the edge of cold ice caps and ice sheets, *J. Glaciology*, 3 (30), pp. 965-978.

YOSHIKAWA, T., and H. TOYA (1957): Report on Geomorphological Results of the Japanese Antarctic Research Expedition, 1956-1957, *Antarctic Record*, 1, pp. 1-13; *Ministry of Educ.*, Tokyo.