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FORMER ICE SHEET BASED ON THE NEWLY OBSERVED GLACIAL LANDFORMS AND ERRATICS IN THE CENTRAL SØR RONDANE MOUNTAINS, EAST ANTARCTICA

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Abstract: Reconstruction of the former ice sheet extent was revised on the basis of newly observed glacial landforms and erratics in the central Sør Rondane Mountains. Roches moutonnées on the summit of southern Lunckeryggen and erratics on the flat summit surface of west Brattnipene are in particular significant to revise the reconstruction of the former ice sheet and its longitudinal profile. Central Sør Rondane Mountains were mostly overridden by the ice sheet, except several small nunataks. Roches moutonnées and ice-smoothed mountain slope in the summit area of southern Lunckeryggen attaining to 1000 m or more above the present outlet glacier surface are evidence of the northward advance of ice fall, *ca.* 10 km, where ice generally at least 400 m thicker than at present.

1. Introduction

The thick erratic deposits and roches moutonnées in the summit area of the Sør Rondane Mountains (Fig. 1) found during the field survey of JARE-28 (28th Japanese Antarctic Research Expedition) allowed us to reconstruct the maximum extent of glaciation in these mountains, East Antarctica, situated *ca.* 200 km from the nearest coast (HIRAKAWA *et al.*, 1988). Major results were as follows: 1) the southern half of the central Sør Rondane Mountains was once covered mostly with the ice sheet from the southern ice plateau, 2) ice fall flowing down from the ice plateau to the outlet glaciers was located *ca.* 10 km further north than at present, 3) ice was about 300-350 m thicker than at present, and 4) the northern half of the Mountains rose relatively widely above the ice sheet and outlet glaciers.

However, the careful observations at several key localities during the JARE-30 of 1988-1989 (MORIWAKI *et al.*, 1989) called for a partial revision of our former reconstruction of the ice sheet surface. The purpose of this note is to describe the newly observed glacial landforms and deposits, and to discuss a significance of them to the reconstruction of the past glaciation over the inland mountains of East Antarctica.

2. Evidence of Glacial Landforms and Erratics

2.1. *Brattnipene*

As shown in Fig. 2, glacial landforms and deposits to be examined in Brattnipene

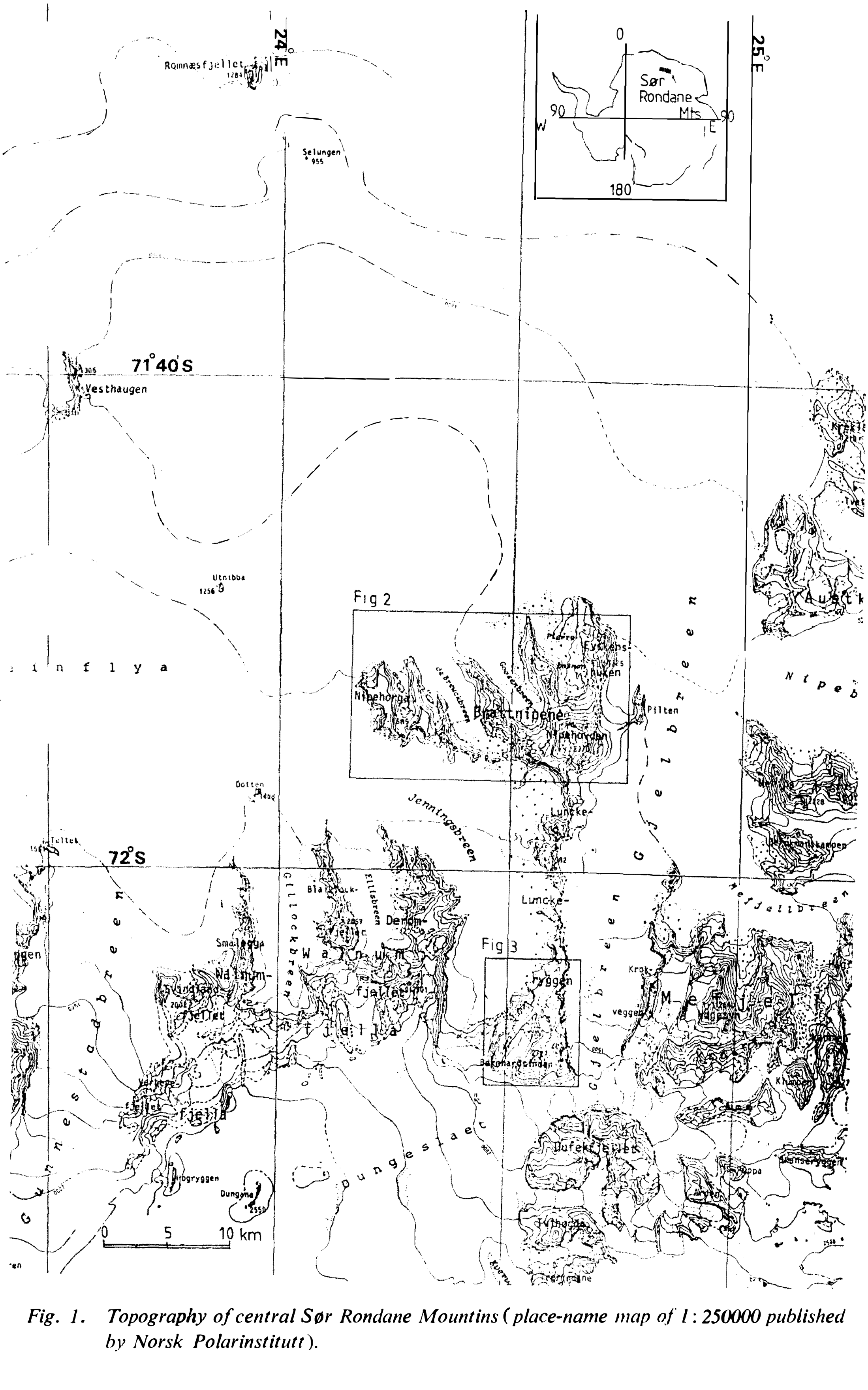

Fig. 1. Topography of central Sør Rondane Mountins (place-name map of 1 : 250000 published by Norsk Polarinstitutt).

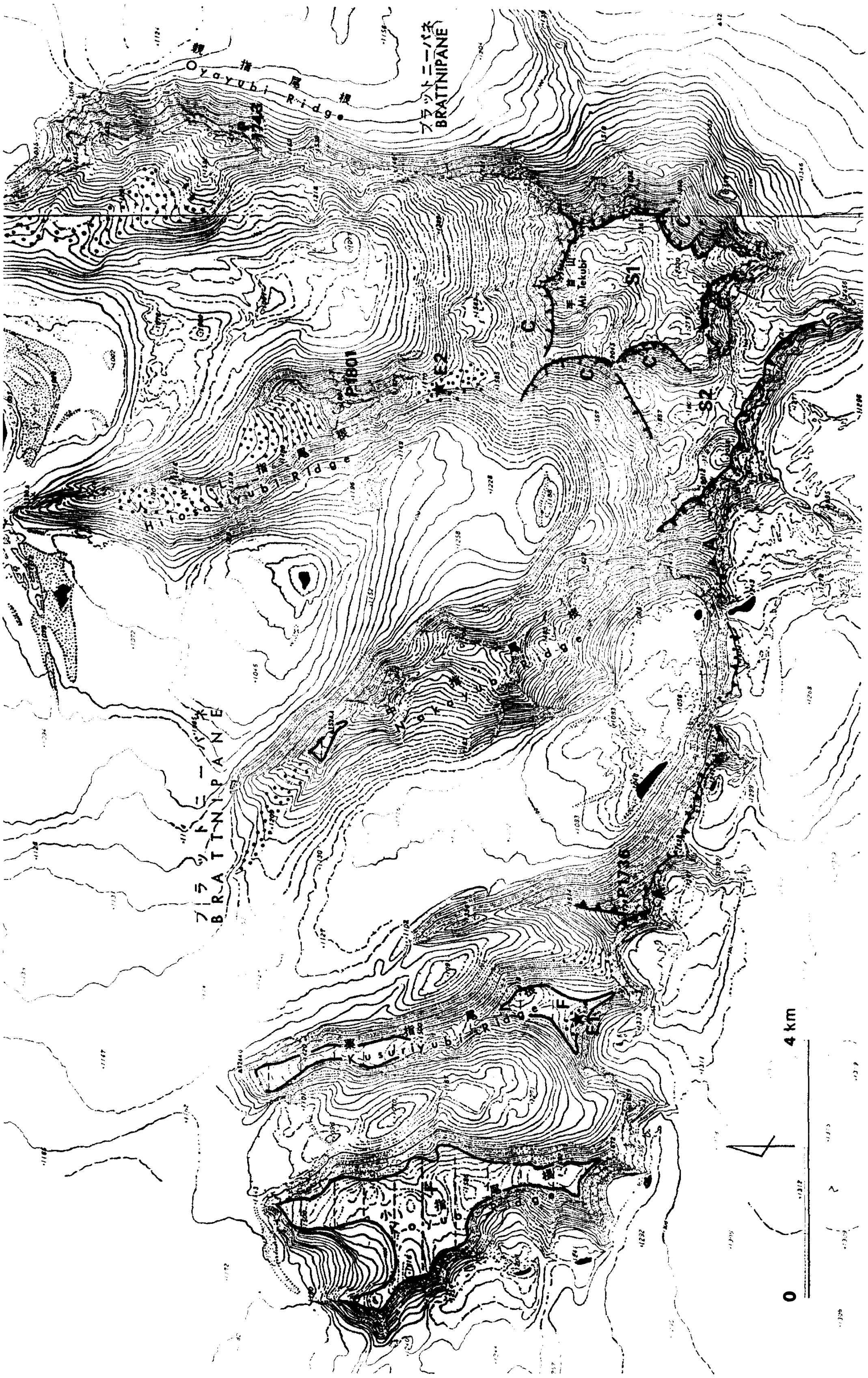

Fig. 2. Glacial landforms and distribution of erratics (dotted) used for the reconstruction of the maximum glacial extent in Brattnipene. Symbols: see text and Fig. 3.

are flat summit surface (F), low-relief summit (S1 and S2), erratic cover at a relatively high elevation (dotted), isolated pyramidal peak, arete and cirques (C).

The highest part of Brattnipene (Mt. Tekubi in the topographical map of 1: 50000 complied by Geographical Survey Institute, or Nipehovden in the place-name map of 1:250000 published by Norsk Polar institutt) is characterized by a relatively low-relief summit (S1 in Fig. 2) and is surrounded by several cirques or cirque-like topography (C in Fig. 2). At the elevation of 1700–2000 m a.s.l., the other low-relief surface having depressions and hillocks (S2 in Fig. 2) is dominant, which is bordered by the steep cliff indicating a glacial trough wall. This low-relief surface roughly corresponds to the cirque floor facing the west.

Erratic blocks of syenite and hornblendite were found at two localities: E1 and E2 in Fig. 2. As the basement rocks of these erratics are exposed only in southern Lunckeryggen (KOJIMA and SHIRAISHI, 1986), they are definite evidence of a former ice cover at these two localities. Erratics at E1 are on the flat summit surface (southernmost part of the Kusuriyubi Ridge; Photo 1 and Fig. 2) at an elevation of *ca.* 1540 m a.s.l. Such remarkable flat summit surface stretches widely in western Brattnipene from *ca.* 1650 m to 1300 m a.s.l. (F in Fig. 2).

Erratics at E2 are found on the glacial col between Mt. Tekubi and Peak 1801 on the Hitosasiyubi Ridge at an elevation of 1470 m a.s.l. (Photo 2). The steep slope facing the north of Peak 1801 (Photos 2 and 3) is covered by morainic deposits up to the height of *ca.* 1550 m a.s.l. This moraine cover spreads over the Hitosasiyubi Ridge downsloping northward (Fig. 2). The north-facing slope of Peak 1743 on the Oyayubi Ridge (Fig. 2) demonstrates a similar landscape and moraine cover. The north-facing steep slope of Mt. Tekubi has a debris cover up to the height of *ca.* 1700 m, which is weathered yellowish brown to red in color (2.5 YR–5 YR 6/4 of Mancel System). This slope corresponds to the former cirque wall.

Peak 1736 of western Brattnipene (P 1736 in Fig. 2) shows a pyramidal form in the view from the north. Slope facing the southwest (Photo 1 shot at E1) and the east are markedly steep. They appear to be glacial trough walls cut by the former outlet glacier. However, the southwest-facing slope has a convex break at an elevation of *ca.* 1700 m a.s.l., as shown in Photo 1 (see arrow). This topographical difference of slopes might indicate that the break of slope corresponds to the upper limit of the former glacial erosion.

2.2. *Southern Lunckeryggen*

Landforms of southern Lunckeryggen are divided into two parts: a plateau-like topography with considerably flat summit in the northern part, and ridges or isolated peaks and glacial troughs in the southern half (Fig. 3). They rise 700–1400 m out of the outlet glaciers. In this area of Lunckeryggen, erosional glacial landforms are dominant, in addition to an end moraine ridge (HIRAKAWA *et al.*, 1988). They are glacial troughs, arete, roches moutonnées and ice-smoothed mountain slope, as shown in Fig. 3.

Three giant roches moutonnées sculpturing granite are recognized over the plateau-like summit surface (R in Fig. 3 and Photo 4). Each roches moutonnées is *ca.* 300–400 m across and 50–60 m hight, and has steepened facets on the north side

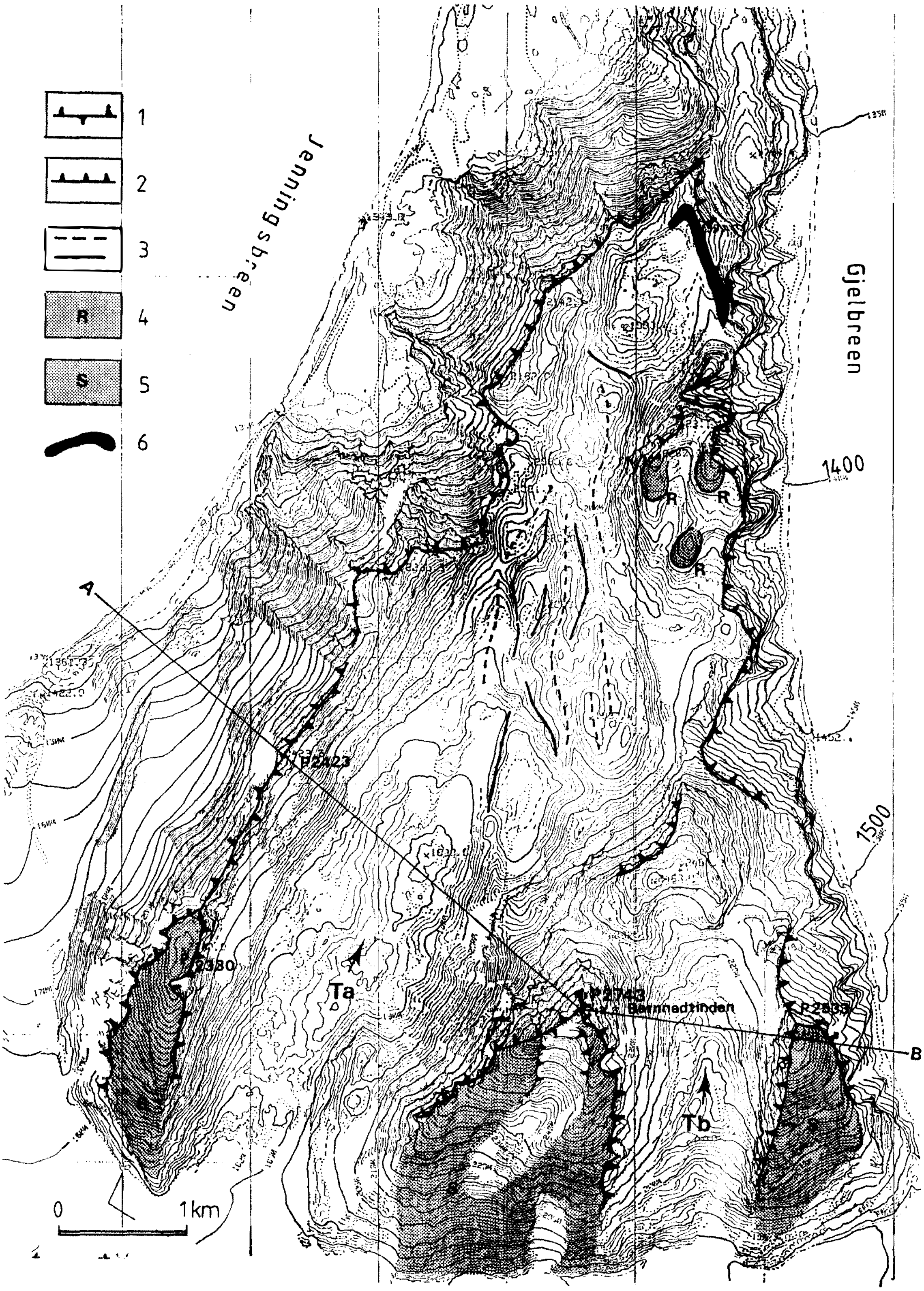

Fig. 3. *Glacial landforms of southern Lunckeryggen. 1: arete, 2: upper edge of glacial trough, 3: low ridges and shallow depressions covered with thin morainic deposits, 4: roches moutonnées, 5: ice-smoothed mountain slope, 6: moraine ridge.*

regarded as the direction of ice movement from the south to the north. A partial erratic cover mainly composed of tonalite and hornblendite also supports the direction of ice movement from the south. Low ridges and shallow depressions on the shallow trough floor in the summit area of Lunckeryggen (Fig. 3 and Photo 7) show a similar ice flow direction. They are mostly erosional landforms with a thin morainic cover.

The southernmost part of Lunckeryggen comprises arete, two glacial troughs (Ta and Tb in Figs. 3 and 4) and the ice-smoothed mountain slopes (see Figs. 3 and 4). They also demonstrate the former ice movement from the south to the north.

Bernnardtinden, the highest peak of Lunckeryggen (2743.6 m) appears to be a part of arete between the glacial troughs of Ta and Tb. However, ice-smoothed slope (S in Fig. 3) spreads clearly up to the height of *ca.* 2650 m a.s.l. from the south (Photo 6). A concave break of slope angle divides the steep arete slope and the gentle ice-smoothed one at only *ca.* 100 m below the mountain top. Peak 2533 also shows an arete-like topography between the trough Tb and the present Gjelbreen, just as Peak 2423 does between the trough Ta and the present Jenningsbreen. However, the ice-smoothed slope spreads over these two peaks (S in Fig. 3 and Photo 5).

Assuming that the concave break of slope angle below the top of Bernnardtinden indicates the former upper limit of glacial erosion, the ice sheet surface was at the height of *ca.* 2650 m a.s.l. Bernnardtinden was a small nunatak during the period of maximum glaciation.

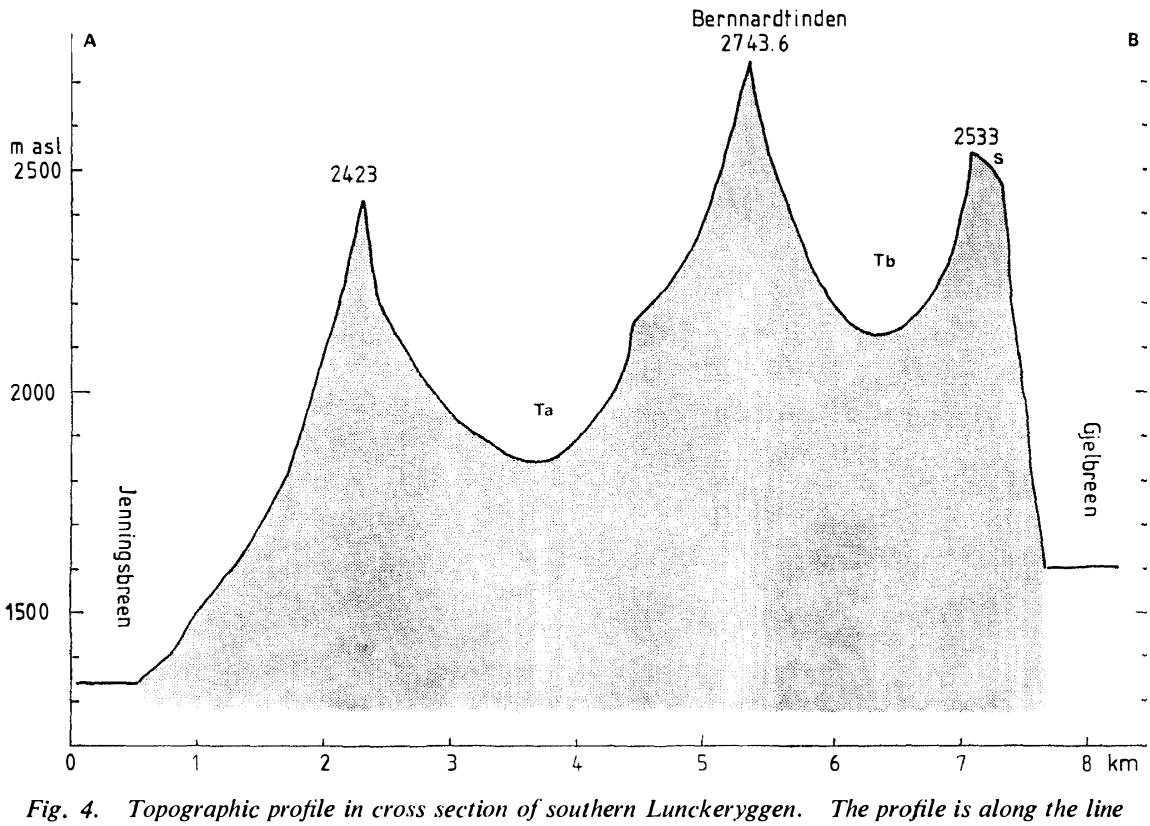

Fig. 4. Topographic profile in cross section of southern Lunckeryggen. The profile is along the line A–B in Fig. 3.

2.3. *Romnaesfjellet*

Romnaesfjellet is located *ca.* 40–45 km north from the northern margin of Brattnipene, and rises *ca.* 500 m above the present ice sheet. We could not find any erratics in the southern part of the summit area including the highest point, although the field survey was insufficient because of the bad weather.

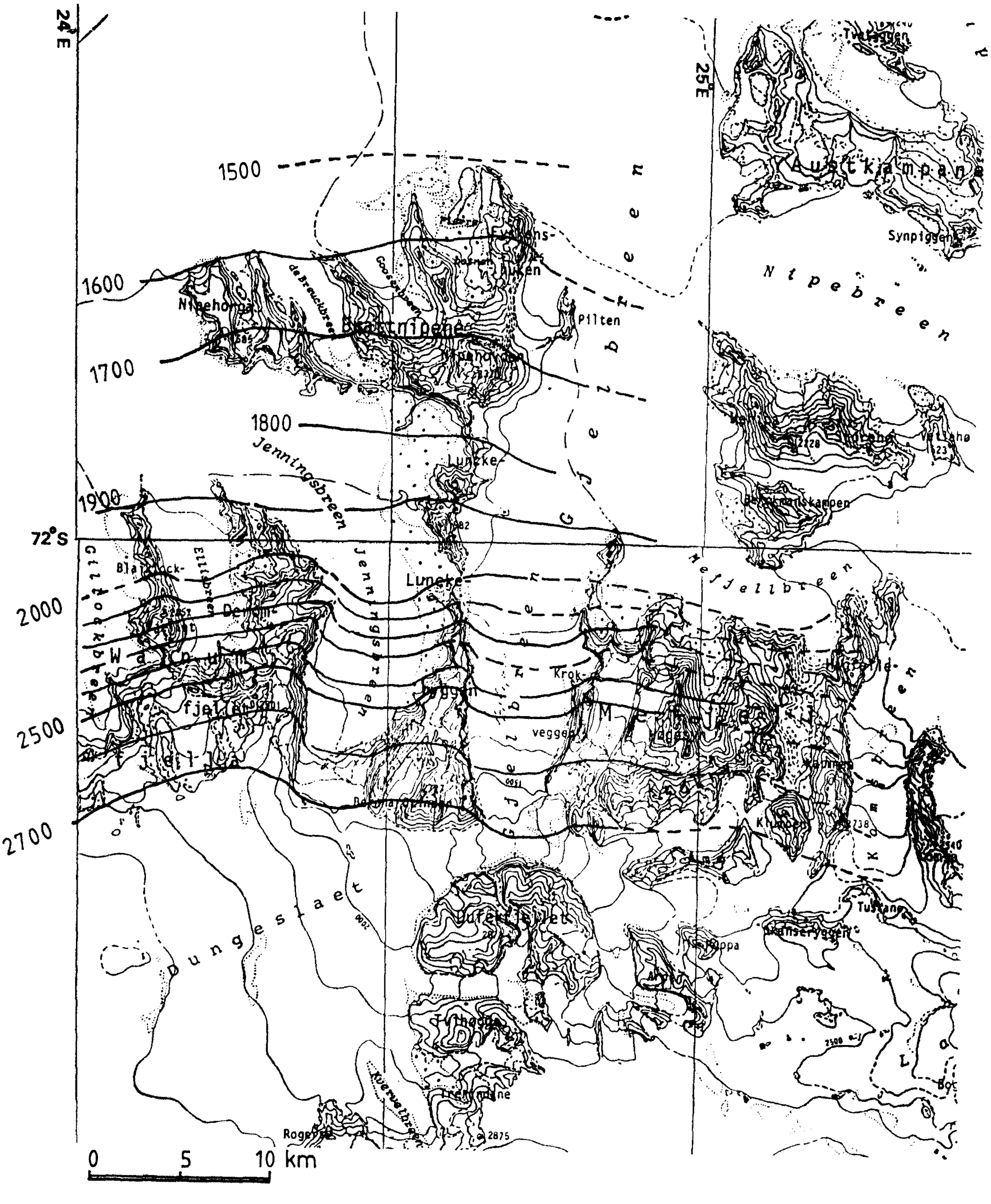

Fig. 5. Reconstruction of ice sheet at the maximum stage of glaciation.

The small nunatak Selungen (955 m a.s.l.; 30–50 m above the present ice sheet surface), 6–7 km SSE from Romnaesfjellet, had been totally scoured under the ice sheet.

3. Reconstruction of Former Ice Sheet: Discussion

Figures 5 and 6 indicate a revised reconstruction of the elevation of ice sheet surface and the longitudinal ice sheet profile at the maximum stage of glaciation.

Glacial landforms in southern Lunckeryggen present definite evidence that the summit area, rising 1000 m or more above the present outlet glacier, was once totally sculptured by areal scouring of ice sheet, except the highest peak Bernnardtinden. The ice sheet surface at that time was in general *ca.* 400 m higher than the present surface of ice sheet and outlet glacier. However, the reconstructed ice sheet surface was higher than the present one of 1000 m or more in southern Lunckeryggen, where

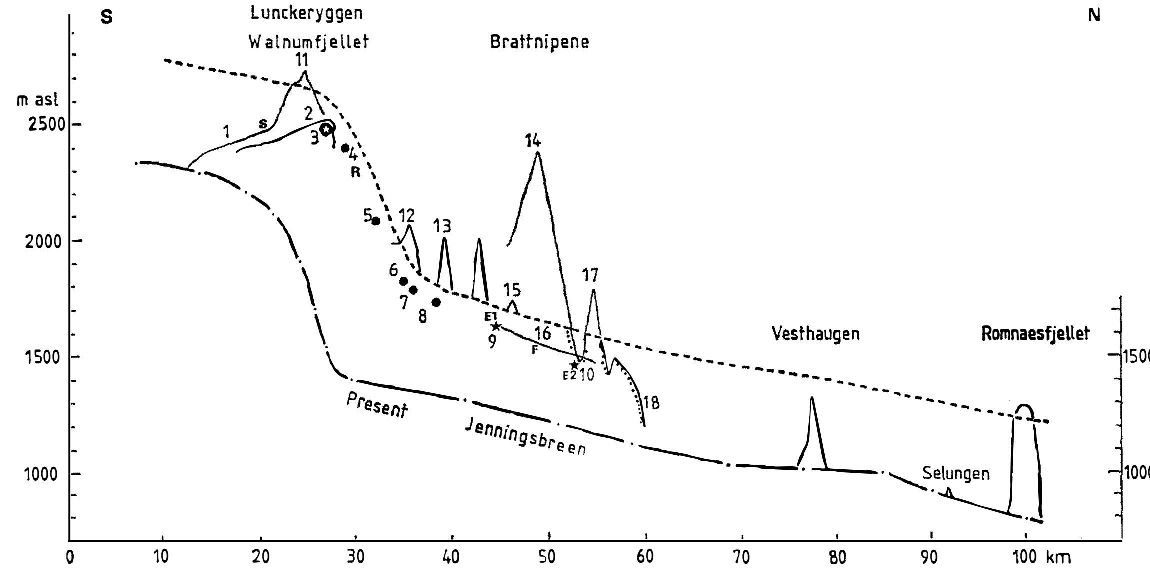

Fig. 6. Longitudinal profile of the ice sheet at the maximum stage of glaciation. Thick dashed line is the revised longitudinal profile along Jenningsbreen, extrapolated to Romnaesfjellet 1: ice-smoothed south-facing slope in southern Lunckeryggen, 2: flat summit surface overridden by ice sheet in southernmost Walnumfjellet, 3: roches moutonnées on the ridge in Walnumfjellet, 4: roches moutonnées in the summit area of southern Lunckeryggen (R), 5: thick erratics with moraine ridge on the summit of southern Lunckeryggen, 6: moraine-covered peak in southern Lunckeryggen, 7: depositional surface of thick moraines on the summit between Gillockbreen and Ellisbreen, 8: erratics on the summit of northern tip of southern Lunckeryggen, 9: erratics on the flat summit surface of the Kusuriyubi Ridge in Brattnipene (E1), 10: erratics on the Hitosasiyubi Ridge in Brattnipene (E2), 11: peak of Bernnardtinden (2743.6 m a.s.l.), 12: Peak 2052 m a.s.l. in Walnumfjellet, 13: pyramidal peak in northern Lunckeryggen, 14: Mt. Tekubi (Nipehovden) in Brattnipene, 15: Peak 1736 m a.s.l, in western Brattnipene, 16: flat summit surface in western Brattnipene, 17: Peak 1801 m a.s.l. on the Hitosasiyubi Ridge in Brattnipene, 18: moraine cover on the Hitosasiyubi Ridge in Brattnipene. Localities 1, 4, 9, 10, 17 and 18 are used for the revision of reconstruction of former ice sheet. Other localities are described in the previous paper (HIRAKAWA et al., 1988).

giant roches moutonnées are found in the summit area. This fact implies that the ice fall dividing the southern ice plateau and the outlet glaciers advanced *ca.* 10 km further north than at present. On the basis of the reconstructed ice sheet surface and the glacial landforms, ice thickness up to *ca.* 200–300 m can be expected on the roches moutonnées, 1000 m on the glacial troughs in southern Lunckeryggen. If an ice thickness of *ca.* 500 m is neccessary for the areal scouring, as postulated by DENTON *et al.* (1983), for the summit area in the Transantarctic Mountains, ice could have been 200–300 m thicker than the present reconstruction, or more.

In certral Brattnipene, the height of former ice sheet surface seems to have been *ca.* 1700 m a.s.l., referring to the landforms of isolated peaks and the elevation of moraine cover or debris cover on slopes. Peak 1736 and Peak 1801 seem to have been small nunataks. The ice sheet surface was *ca.* 1500 m a.s.l. along the northern marginal area of Brattnipene; *ca.* 400 m higher than at present. Therefore, Brattnipene was also mostly covered by the ice sheet except for several nunataks. The highest part of Brattnipene, Mt. Tekubi, might have been sculptured by local cirque glaciers.

Five main ridges in Brattnipene, now dividing glacial troughs, were mostly overridden by the ice sheet, as illustrated by VAN AUTENBOER (1964). However, the problem whether the flat surface was totally originated from the areal scouring of ice sheet remains insufficiently explored.

Extrapolating the longitudinal profile of the reconstructed ice sheet within the mountains further north, Romnaesfjellet seems to have projected *ca.* 100 m in height above the ice sheet, as a small nunatak. Although VAN AUTENBOER (1964) supposed that Romnaesfjellet was subjected to areal scouring of the former ice sheet, we could not find any erratics in the summit area of Romnaesfjellet.

Acknowledgments

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References

DENTON, G. H., KELLOG, D. E. and KELLOG, T. B. (1983): Ice sheet overriding the Transantarctic Mountains. Antarct. J. U. S., **18**, 93–95.

HIRAKAWA, K., MATSUOKA, N., TAKAHASHI, T., SAKIYAMA, T., OSANAI, Y. and TANAKA, K. (1987): Sêru Rondâne Sanchi chigaku chôsatai hôkoku 1987 (JARE-28) (Report on the geological, geomorphological and geodetic field party in the Sør Rondane Mountains, 1987 (JARE-28)). Nankyoku Shiryô (Antarct. Rec.), **31**, 206–229.

HIRAKAWA, K., MATSUOKA, N. and MORIWAKI, K. (1988): Reconstruction of maximum glacial extent in the Sør Rondane Mountains, East Antarctica. Proc. NIPR Symp. Antarct. Geosci., **2**, 146–161.

KOJIMA, S. and SHIRAISHI, K. (1986): Note on the geology of the western part of the Sør Rondane Mountains, East Antarctica. Mem. Natl Inst. Polar Res., Spec. Issue, **43**, 116–131.

MORIWAKI, K., FUNAKI, M., HIRAKAWA, K., TOKIEDA, K., ABE. H., HIGASHI, S. and MIYAWAKI, H. (1989): Sêru Rondâne Sanchi chigaku seibutsu chôsatai hôkoku 1988–89 (JARE-30) (Report on the geomorphological, paleomagnetic, geodetic, zoological and botanical field work in the Sør Rondane Mountains, 1988–89 summer season (JARE-30)). Nankyoku Shiryô (Antarct. Rec.), **33**, 293–319.

VAN AUTENBOER, H. (1964): The geomorphology and glacial geology of the Sør Rondane. Dronning Maud Land, Antarctica. Antarctic Geology, ed. by R.J. ADIE. Amsterdam, North-Holland, 81–103.

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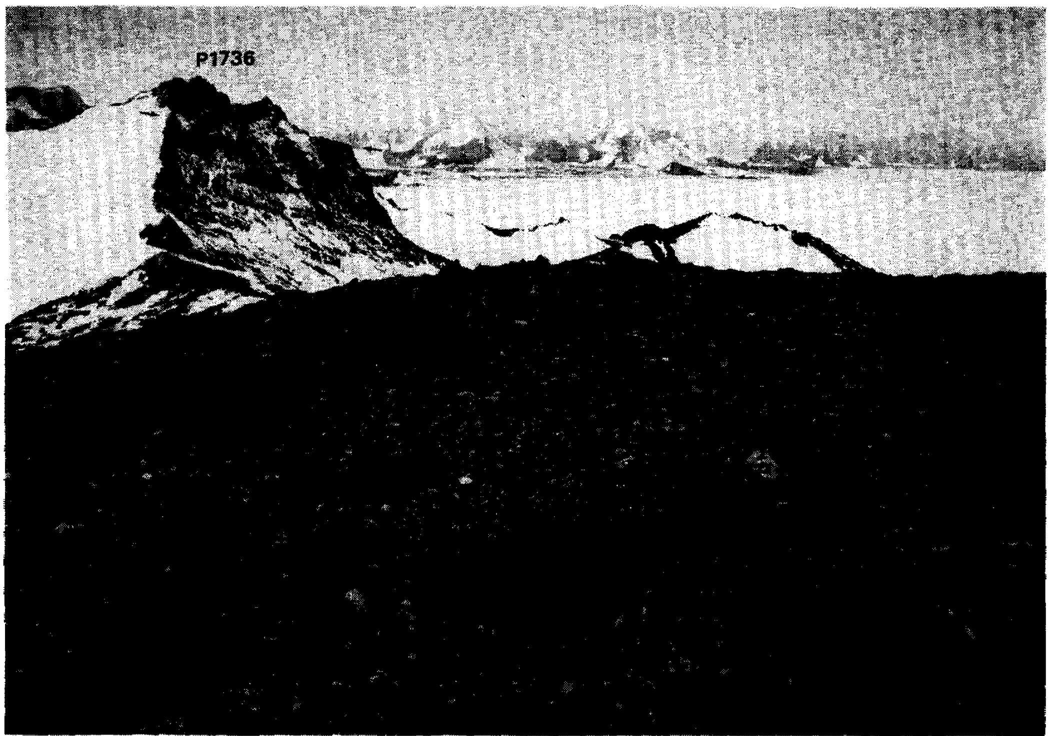


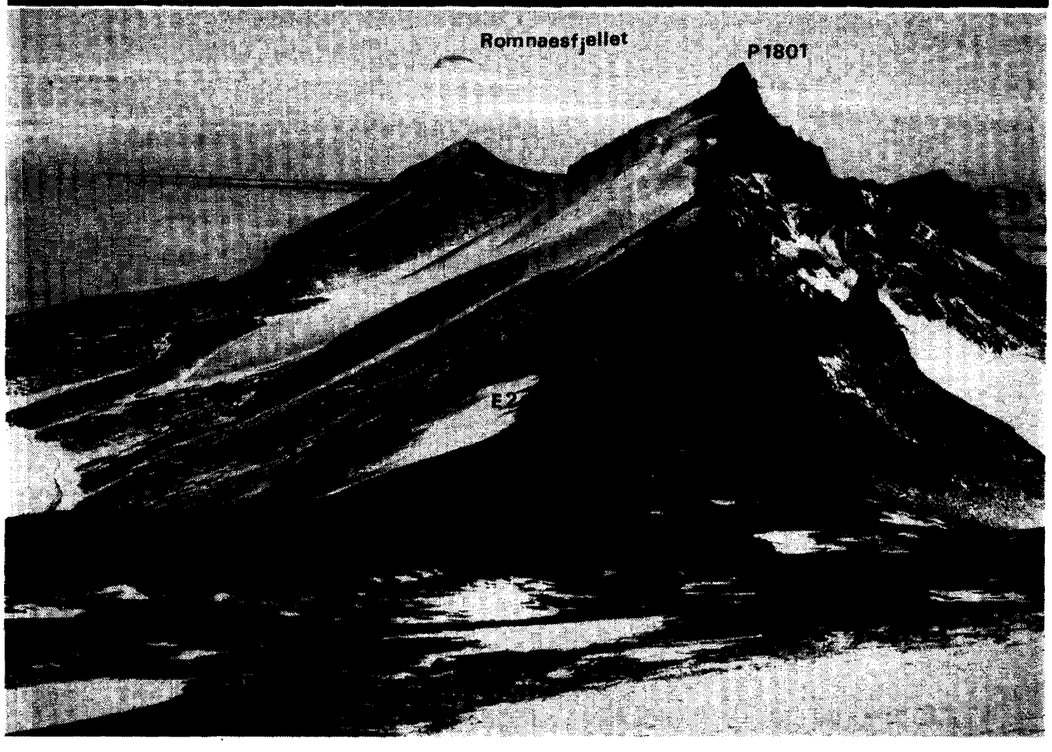
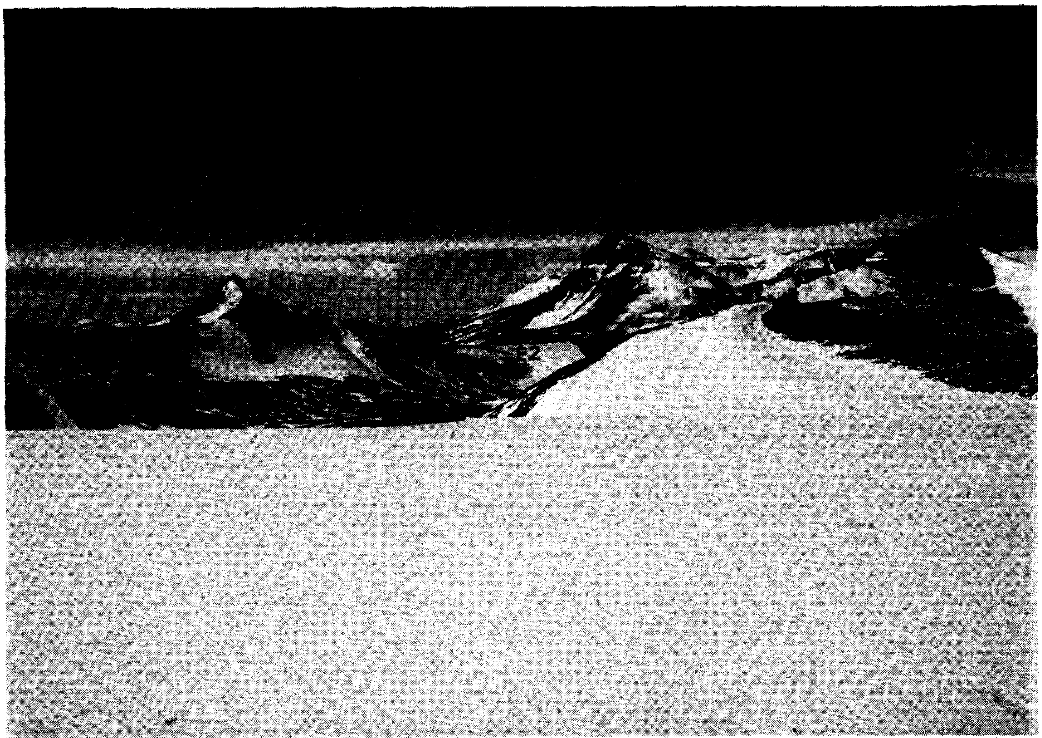


Photo 1. The moraine cover containing erratics of syenite on the flat summit surface, and Peak 1736 in western Brattnipene viewed from locality E1. Arrows indicate a break of slope.

Photo 2. Peak 1801 on the Hitosasiyubi Ridge viewed from the south, which may have been a residual summit during the maximum stage of glaciation. The foreground is a glaciated col (E2) with thin moraine cover cantaining erratics of syenite.



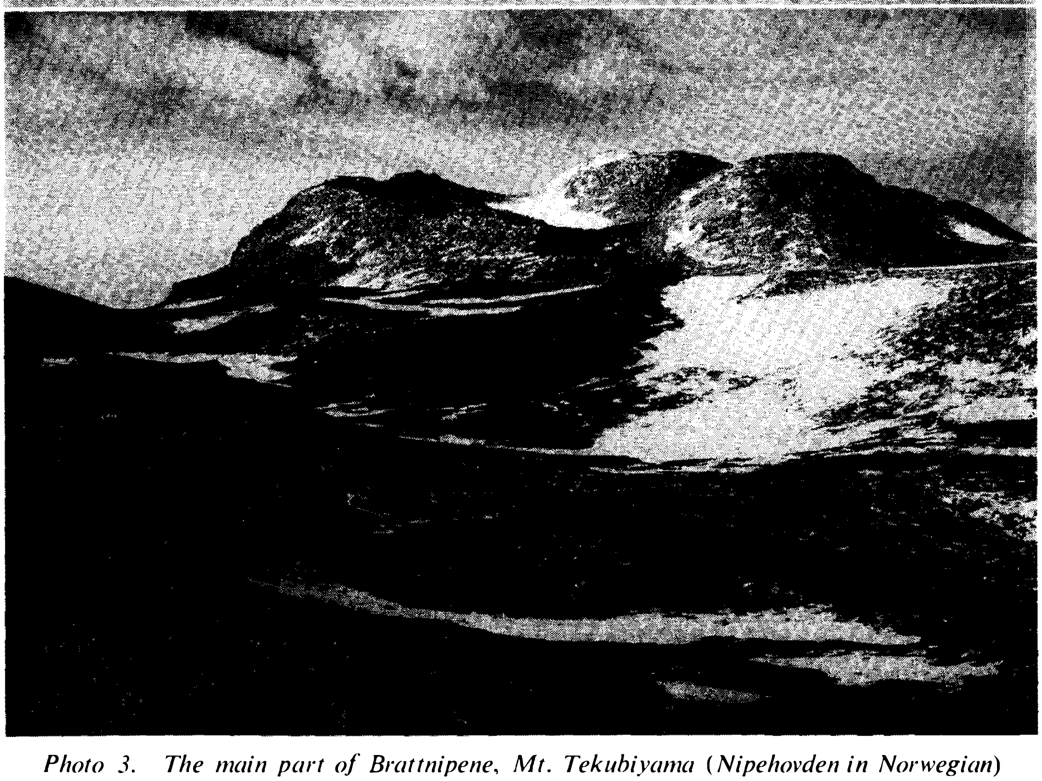


Photo 3. *The main part of Brattnipene, Mt. Tekubiyama (Nipehovden in Norwegian) and Peak 1801 on the Hitosasiyubi Ridge. Erratics of syenite were found at locality E2. Looking from the northwest.*

Photo 4. *Roches moutonnées in the summit area of southern Lunckeryggen viewed from the south.*

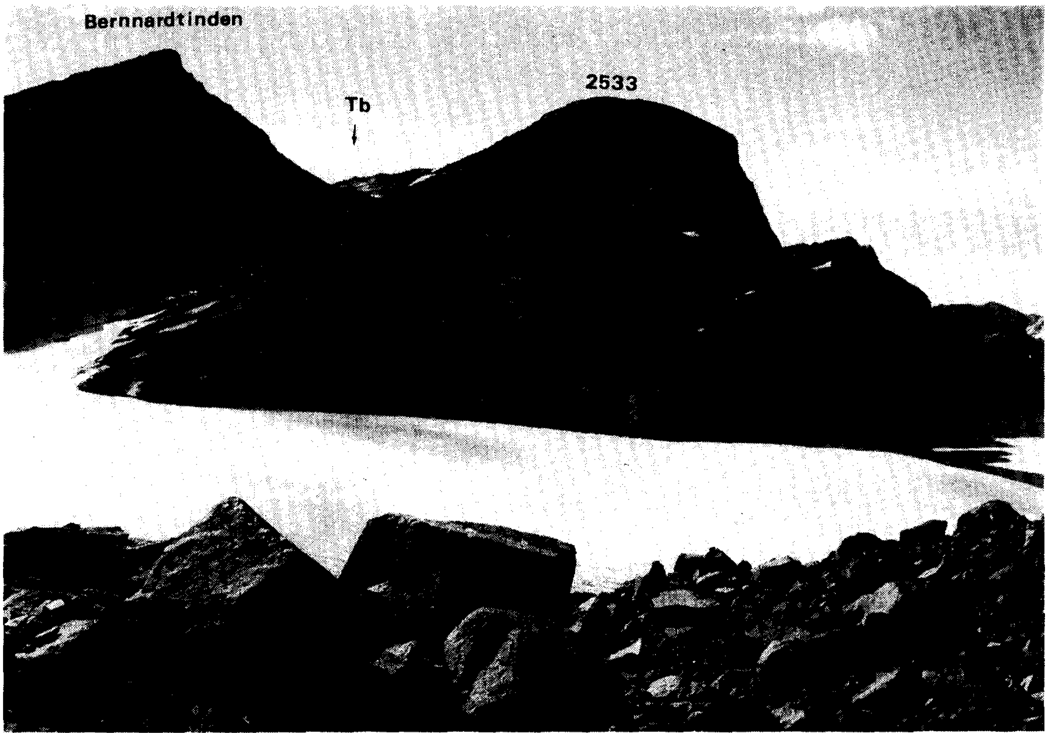


Photo 5. Southernmost area of Lunckeryggen viewed from Dufekfjellet, indicating the marked ice-smoothed mountain slope and glacial trough (Tb). Bernnardtinden and Peak 2533 apear to have been almost totally scoured by ice sheet.

Photo 6. The highest peak of Bernnardtinden and glaciated trough (Ta) in the southernmost area of Lunckeryggen, viewed from the north.

Photo 7. Lunckeryggen and Brattnipene (in the background) from the peak of Bernnardtinden. Note the irregular pattern of low ridges and shallow depressions covered with thin morainic deposits.