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Ice Flow Conditions in the Ice Sheet Draining Part of the Central Queen Maud Land, East Antarctica

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Abstract

The area of central Queen Maud Land described here, lies between longitudes 9° to 14°E and latitudes 70° to 72°S. The present day flow conditions of the area have been described to provide a first hand information about the dynamic state of this segment of the ice sheet, and to lay a basis for future work. The flow direction of the inland polar ice, as observed in the field, and the location of the grounding line is demarcated, based on surface studies. Coordination of four stakes fixed on the margin of the inland ice on experimental basis, has revealed movement of the ice varying from a minimum oi 0.031 m to a maximum of 1.91 m per day, based on the observation of one year. The outline of a part of shelf ice surveyed (January-February, 1986) and compared with the satellite imagery of. 1975, shows very little change in its outline. The present work could form a basis for inducting various techniques to assess the flow movement and mass flux in this part of central Queen Maud Land.

Introduction

Central Queen Maud Land encompassed between longitudes 9°E and 14°I and latitudes 70°S and 72°S reveals the two classical divisions of Antarctic ice, i.e the shelf ice and the inland continental ice. Between the two there has to be a line where the polar ice, moving over the bedrock, starts floating on the sea This 'grounding line' is very important component of the system of the ice sheets and ice streams and throws light on their mass flow and dynamics, but at the same time is least understood because of the highly crevassed nature oi its surface and lack of knowledge about the subglacial topography. Northwards the shelf ice is limited by the 'calving line', wherefrom the ice breaks in the form of icebergs into the sea. This is defined to a good extent by the presem ice shelf boundary. Between the grounding line and the calving line, at least four ice rises are located in the above sector.

About 150 to 200 km inside towards south from the shelf boundary, the Wohlthat mountains act as a barrier to the flow of the ice emanating from the plateau area and impart a local flow system, controlled by the spatial distribution of these barriers and their intervening ice streams.

The Mountain Barrier

The ice emanating from the plateau area from altitudes of 3000 to 4000 m.a.s.I. swerves on the eastern and western extremities of the Wohlthat mountain range which acts as a barrier to its flow for a linear distance of about 200 km. But between these two extremities, the plateau ice branches off and flows between the blocks of the dissected mountain range. At least ten such offshoots are recognised, some of which are occupying what are most likely the structurally controlled lineaments obviously generated prior to major ice inundation. On account of this phenomenon, the ice streams have attained many swerves, attenuated or modified by local offshoots, emerging in different directions, thus giving rise to a localised flow pattern within the environs of the mountain chain (Fig. 1). This local flow pattern is quite distinct from the regional flow of the ice sheet. The dominant flow components therefore, are:

1. Main northeasterly flow of Musketov glacier south of Gruber massif, swerving around the massif to a northwesterly flow. The northeasterly component is joined by the southeasterly flow of ice, from the elevated levels.

2. The northerly or north-northeasterly flow of the major offshoots dissecting the mountain range. These are joined by the west to southwesterly flowing streams from elevated levels on the interior slopes within the mountain range.

3. A divergent flow from the 'mountain glaciers' occupying higher elevations on the mountains, some of which join the main offshoots. Their flow direction is controlled by the aspect of the mountain slope they occupy.

The interference of various flow directions in this manner has had effect on the development of related ogives and on the orientation of moraine trails which are in the incipient stage of development. Three distinct types of such moraine trails named here as 'incipient' moraines, on which the flow pattern has a pronounced effect, were noticed viz. the trails parallel, tangential and at right angles to the flow direction. The incipient moraines that are parallel are exemplified by the Austbanen and Vestbanen moraine trails developing on either side of Petermann range (Fig. 1). Another such example is offered by the moraine trail developing north of Vasskilsata nunatak (Fig. 2). This type of moraine is developing between two parallel flow vectors defined by two sub-streams of ice in the main ice stream. These moraines thus offer the initial trace of a developing medial moraine. The moraines tangential to the flow direction have their convexity at right angles to the.flow and appear to be beyond the zone of influence of this flow. The present disposition of these moraines is attributed to the action of tributary glaciers which are in the process of generating a terminal moraine. The moraine trail at right angles to the flow direction, south of Vasskilsata nunatak (Fig. 2) shows parallelism with the prevailing ogives at that location. The genesis of such moraines is attributed to the ablation of sediment laden ice that underlies it (Faure and Taylor, 1985)

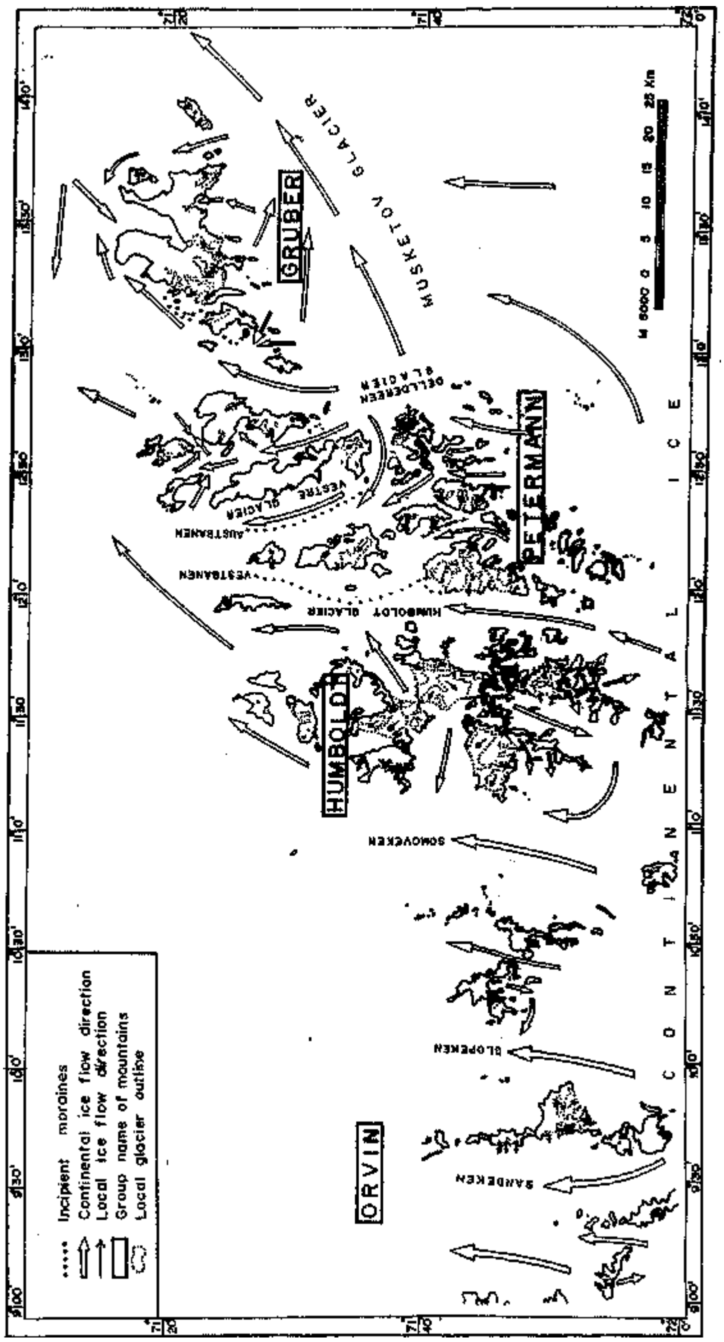

Fig. 1. Ice flow directions around Wohlthat Mountains

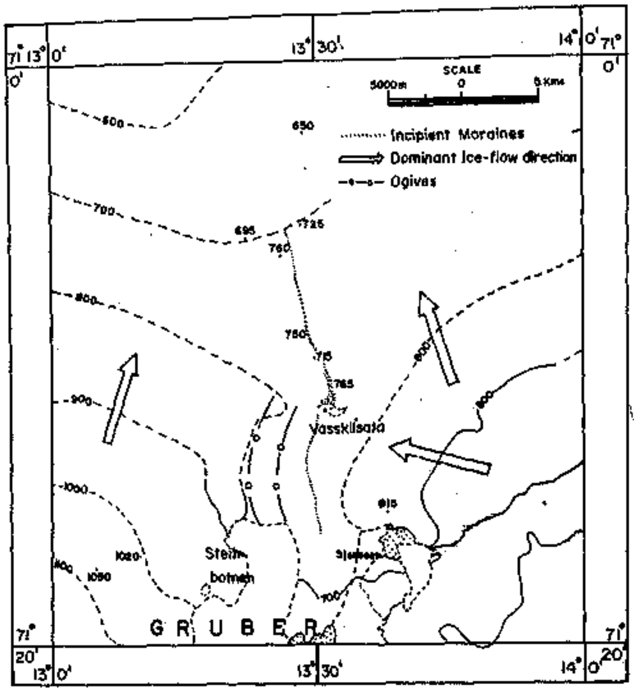

Fig. 2. Incipient moraines and ice-flow direction north of Gruber massif.

The Ice Field

Field observations would reveal that north of the mountain barrier the dominant flow component of the ice sheet has a north-westerly and a northerly component. The northerly component swerve back to the northwest direction in the region east of Schirmacher hills while it continues to dominate in rest of the area. However, ground traverses during the expedition in this area have revealed many local variations as determined by complex orientation of ogives and flow lines. The data collected from the Soviet geophysical and drilling exploration in this area has led to the deduction of a sub-surface trough between' the Wohlthat mountains and the nunataks (Hermichen *et al.,* 1984 and an undulating bedrock north of the nunataks upto Schirmacher hills (Fig. 3). The complexity of the flow pattern observed on the present ice level resting on the 'sub-surface trough' region with highly crevassed sectors may reveal that in addition to other factors, the regional surface relief and bedrock topography may have an important role. The role of nunataks in defining the flow and deformation of ice sheet at this place has also to be properly understood because the deformation of the ice layers involves a component of flow around the nunataks. As observed by Robin and Millar (1982), this process may permanently distort the ice layering downstream and the consequent surface flow pattern. More data is, therefore, necessary to update the bedrock configuration in this sector.

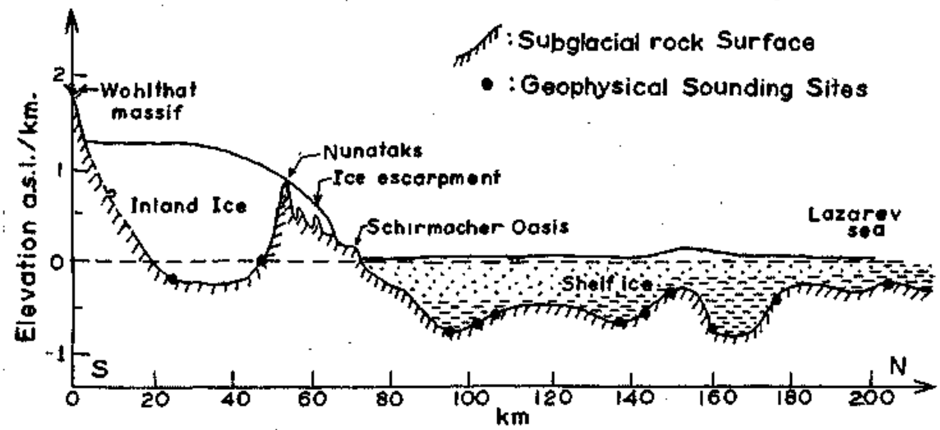

Fig. 3. Subglacial rock Surface near long. 12°E, north of Woblthat range (adopted from Hermichen et al., 1984)

Hermichen *et* al., (op. *cit.)* have stated a movement of 1 m to 5 m/a for ice north of nunataks towards Schirmacher. They also estimte a figure of 10 m/a as the rate of flow of the plateau ice emerging south of Gruber massif. No data on the rate of flow was, however, collected during the present expedition in these areas which is suggested to be taken henceforth on a systematic basis. However, on an experimental basis, some flow directions and velocity were recorded on the polar ice front conspicuously exposed towards the southern periphery of the Schirmacher hills. Four aluminium stakes A, B, C and D were fixed on the polar ice during the austral summer of 1985-86, locating them 200 m to 600 m away from the ice margin towards south (Fig. 4). The stakes (Markers) were monitored during Jan. '86, Nov. '86 and Feb. '87 by electronic distance measuring device (EDM) from a firmly established station on solid rock. The summarised observations are given in Table I.

Table I. Stake Movements

Marker	6.1.86 to 27.1.86			27.1.86 to 5.11.86			27.1.86 to 6.2.87			6.2.87 to 10.2.87		
	a	b	c	a	b	c	a	b	c	a	b	c
A	40.28	1.91	244				11.64	0.031	260			
B	88.75	4.26	207	37.50	0.13	156						
C										16	3.20	90
D										12	2.40	100

a = total movement (m); b = rate/day(m); c = azimuth of movement

From the movement of stakes it is observed that they do not follow the regional flow direction as deduced from the field observations during the present work. The ice movement at this locality reflects, perhaps, a local deviation. The stake A shows a general westerly movement, the rate of movement being as high as 1.91 m/day during summer, whereas average rate of movement for the entire year was 0.031 m/day. The stake B moving in a southwesterly direction showed a movement of 4.26 m/day during summer whereas over a period of nine months it moved at a rate of 0.13 m/day. Stakes C and D fixed about 300 m to 400 m away from stake A in southerly direction showed a summer movement rate of 3.2 m and 2.4 m per day, respectively. However, the direction of movement was easterly. A large network of stakes if fixed up in subsequent expeditions could give a regional flow pattern.

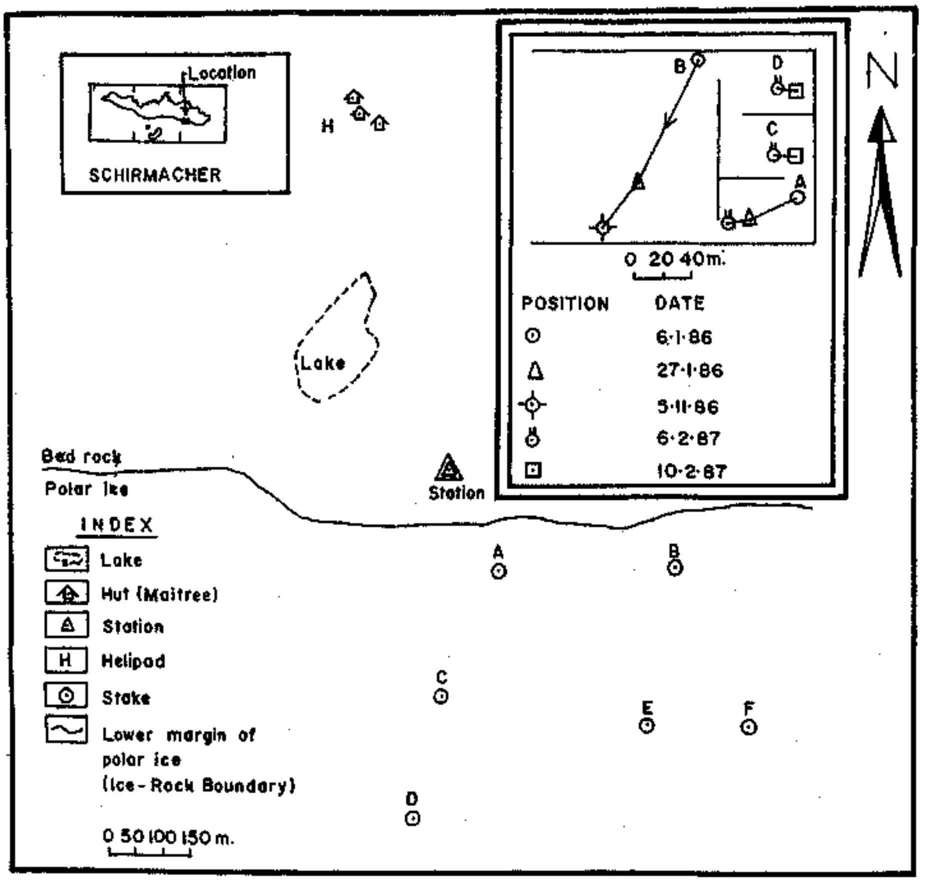

Fig. 4. Position of stakes on polar ice for flow movement studies (Inset on right band shows direction and rate of flow).

The Grounding Line

This component of the flowing ice sheet is least understood of its physical forms. The ice has sometimes an imperceptible gradation into its floating form and sometimes it is highly crevassed to restrict any surfacial examination. But the greatest handicap is lack of knowledge about subglacial topography along this line. Based on field observations, geomorphological set-up and tidal bending, delineation of a part of grounding line was attempted as closely as possible (Fig. 5). It is generally seen that the ice, entering the ice shelves, crosses a

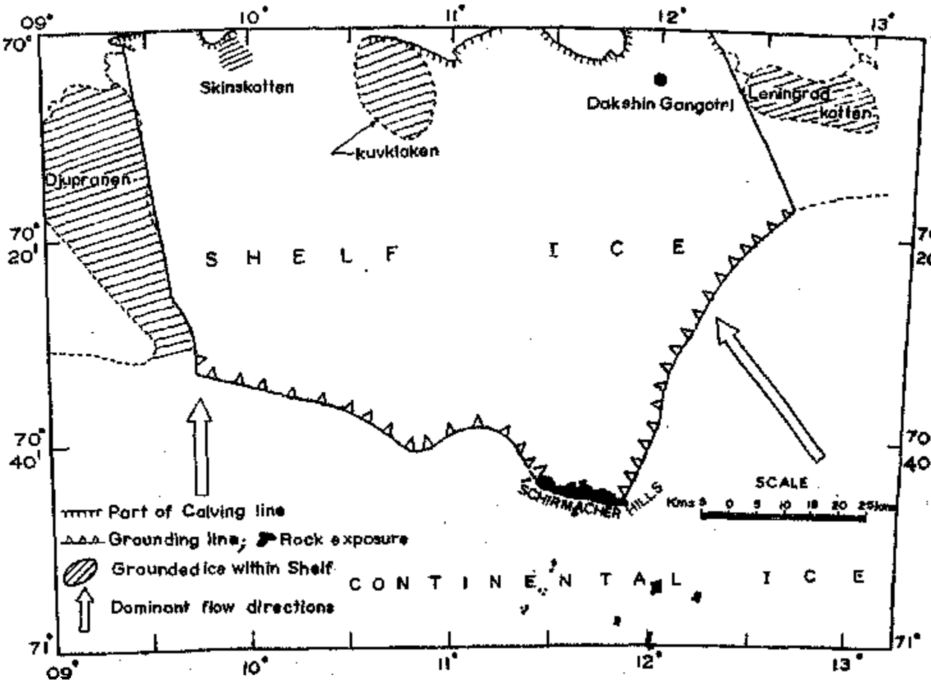

Fig. 5. Grounding line South of Daksbin Gangotri as inferred from field observations.

grounding line perimeter that exceeds the calving line perimeter (Hughes, 1982) wherefrom ice breaks and floats as icebergs. A simplified demarcation of the grounding line and calving line in the present case (Fig. 6) shows that the perimeters of both the lines are more or less same and hence there is no converging flow from the grounding line to the calving line. It is presumed that the shelf ice north of Schirmacher hills in the Dakshin Gangotri area has a partly confined flow between the Djupranen ice tongue and Leningrad Kollen ice rise with a small corridor of shelf ice south of the latter. With these two controls i.e. equal grounding and calving perimeters and partly confined flow there is no spectacular movement on the shelf ice as could be expected if the

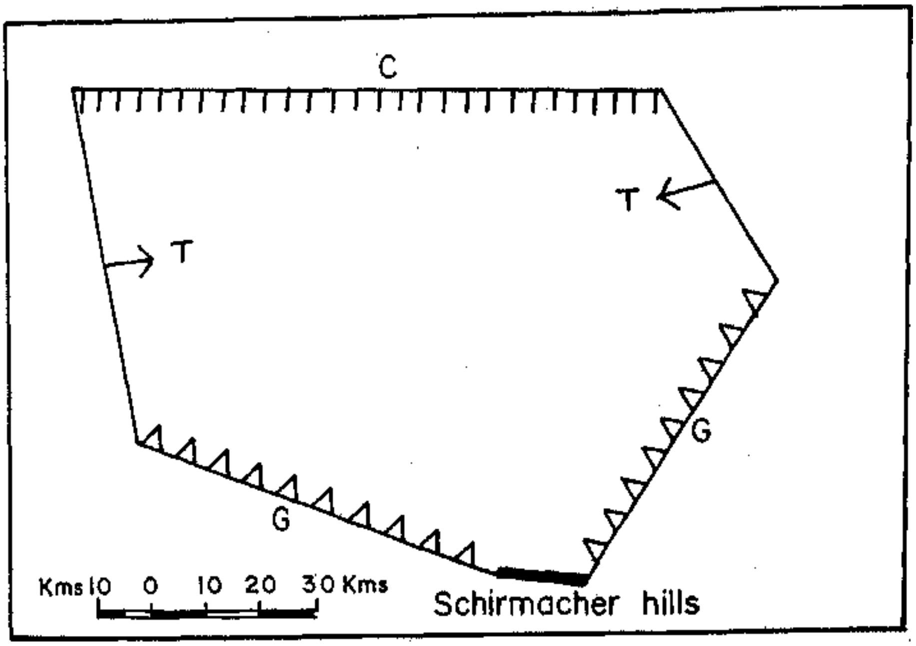

Fig. 6. Simplified diagram showing grounding line perimeter (GJ and Calving line perimeter (C) in the area studied (T: Confining pressure).

grounding line perimeter was more than calving line perimeter and the shelf was confined in an embayement. The central part of the shelf, however, will move relatively faster than at the edges due to confining pressures of the ice rises.

The Shelf Outline

The outline of the shelf around Dakshin Gangotri was surveyed between longitudes 10°E and 13°E during the expedition in Jan.—Feb., 1986. The doppler navigation system fitted in the naval helicopters was used for the survey, which was zeroised at Dakshin Gangotri station in position latitude 70°05'35" arid longitude 12°E. The helicopter was then flown at a steady height of 300 feet and speed of 60 knots following the shape of the shelf as far as possible, while the doppler position readings were recorded every 05 to 10 seconds. The outline of the shelf thus obtained is given in (Fig. 7). For obtaining the shelf height, the helicopter was flown above water before commencing the Tun and the radioaltimeter was used to calibrate pressure altimeter for height. The difference between the radalt and pressure height (which would be the height of ice shelf above water in feet) was recorded along with the position every 10 seconds. The limitation of the accuracy of survey was 3% and the height accuracy would be within 20 feet due to limitation of the scale readability of the radalt used.

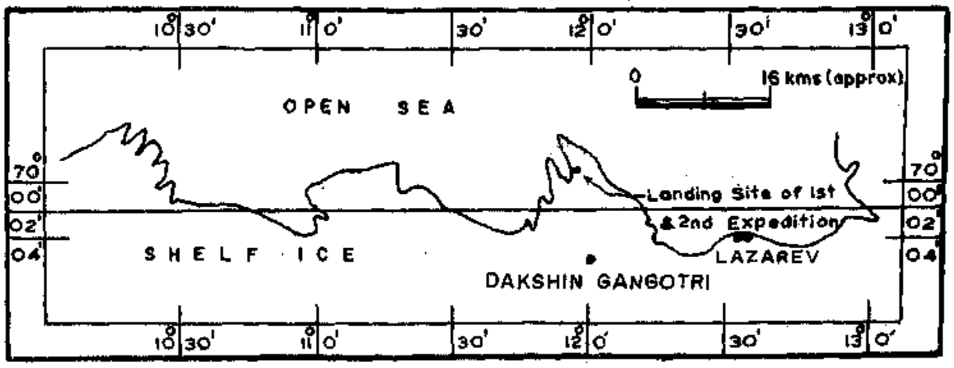

Fig. 7. Outline of the shelf (February, 1986)

The shelf outline which has been marked thus is considered to have near parallelism with the calving line along which the ice degenerates, barring a few sections. The wastage is limited along this line in this sector quantitatively, possibly because no unpinning of the ice shelf is induced on account of a grounding line which does not show retreat as per field evidences.

A comparison of this map (Feb. '86) with the satellite picture (Fig. 8) of the area (Nov. 75) showed very little change as far as configuration of the shelf is concerned. Though the kinks and bulges appear slightly shifted in plan, yet

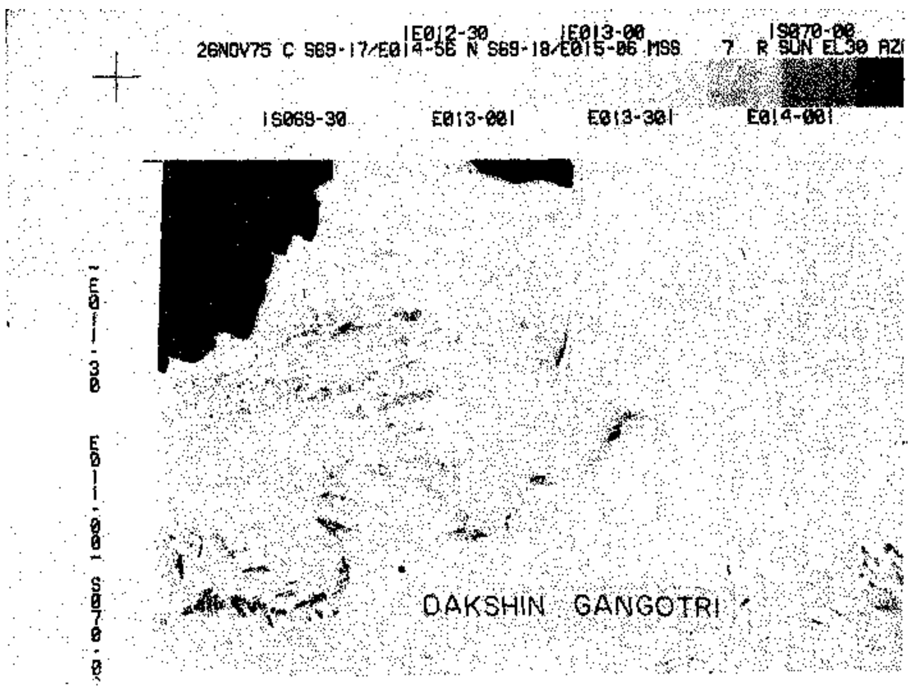

Fig. 8. Shelf outline and Dakshin Gangotri station (Satellite imagery, 1975)

there appears to be refinement in some of these, pointing out to calving and/or melting though on a small scale considering the time period of a decade. However, absence of exact parallelism between the scales of the two maps and the limitations imposed on the accuracy of the survey restrict any further detailed correlation between the above mentioned frontal positions.

Conclusions

The flow patterns of the ice sheet in this part of the central Queen Maud Land is evidently influenced by the mountain barrier and nunataks north of the barrier. More measurements with the help of stake network and more clear outline of the subglacial topography are needed to form a concrete picture of the flow of this area. The stake network within the ice field and around the ice bordering Schirmacher hills, might indicate the flow rates and direction more. accurately.

The grounding line position and its profile are important parameters in assessing the mass flux of ice in this area and the retreat or advance of this line and the calving line may help in understanding the wastage or replenishment of the shelf ice. Attempts have to be made on more precise demarcation of this line by the aid of geophysics in future. Regular analyses of satellite imageries over a period of time also might help in estimating wastage of the ice sheet on its calving line, thereby furnishing an important parameter in understanding the degeneration pattern of this part of shelf.

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