Indian Expedition to Weddell Sea Antarctica, Scientific Report, 1995
Department of Ocean Development, Technical Publication No. 7, pp.1-14

Reconnaissance of the Filchner Ice Shelf and Berkner Island, Weddell Sea, Antarctica

V.K. RAINA, S.MUKERJI, A.S. GILL AND F. DOTIWALA*
Geological Survey of India; Oil & Natural Gas Commission

Introduction

Antarctic continent is surrounded, all around by a permanent ice shelf, at places almost 100 km wide. Besides this circum-continental shelf, there also exist three major ice shelves,

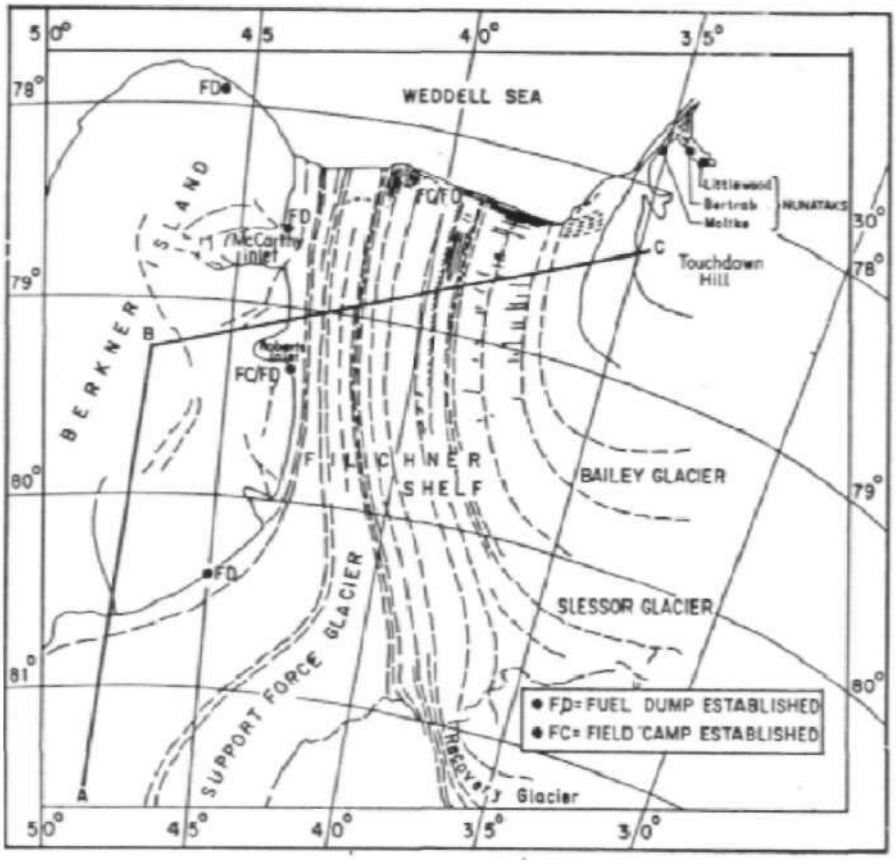
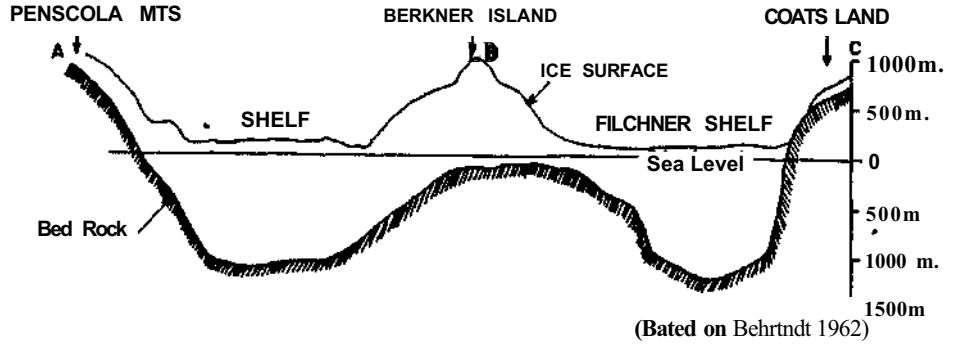


Fig.1. The area along south Weddell Sea reconnoitred by the Expedition.

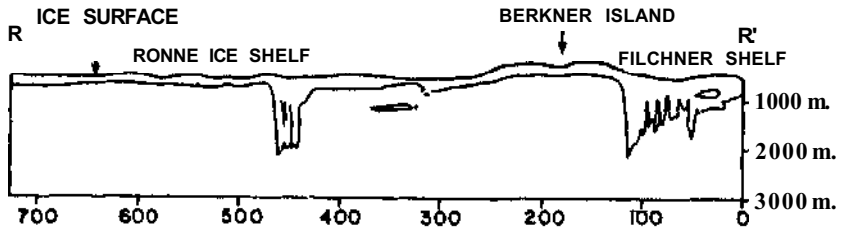
namely: Ross ice shelf; Amery ice shelf and the Filchner-Ronne ice shelf, which cover the embayments (inlets) within the physiographic domain of this continent. The Filchner and Ronne ice shelves exist along the southern and the south-western limits of the Weddell Sea within the longitudes 34° W and 63° W and latitudes 78° S to 82° S and cover an area of about 5,00,000 km including some large ice rises. This shelf, as the name suggests, comprises the Filchner shelf, in the east, and larger of the two, Ronne shelf in the west, separated, along the northern extremity i.e. north of 81° S latitude, by the largest ice rise in Antarctica - the Berkner island. Southward, the two shelves merge into one.

Filchner Shelf is named after Wilhelm Filchner, the Leader of the German Expedition that landed and established a field station on it, for the first time, way back in 1912. This shelf differs from the circum-continental shelf in being more rugged, crevassed and rumpled with large escarpments, and is primarily the extension of the Polar ice. It is formed by the confluence of four main glaciers flowing out of the Polar ice cap; namely, from north to south, the Bailey glacier, the Slessor glacier, the Recovery glacier and the Support Force glacier; besides the numerous relatively small ice streams which flow into it from the Shackleton Ranges in the east and the Berkner Island in the west (Fig.l). Radio echo-soundings and seismic surveys have revealed this shelf to have an ice thickness of 1200 m to 1500 m south of 80° S latitude where, it is reported to be grounded to the bed rock. Northward, the ice cover thins down and along the front, the shelf is reportedly floating in the oceanic waters (Fig. 2 and Fig. 3). Faster flow from the hinter land has often led to caving in front; the largest of which, recorded in recent history, was that of 1986, when the entire



(Bated on Behrtndt 1962)

Fig.2. Profile over the Filchner Shelf from Polar ice cap in the vicinity of Penscola mountains to Berkner to Coats Land.



Fig, 3. Radio echosounding profile over the Ronne ice shelf- Filchner ice shelf (based on Robin, 1971).

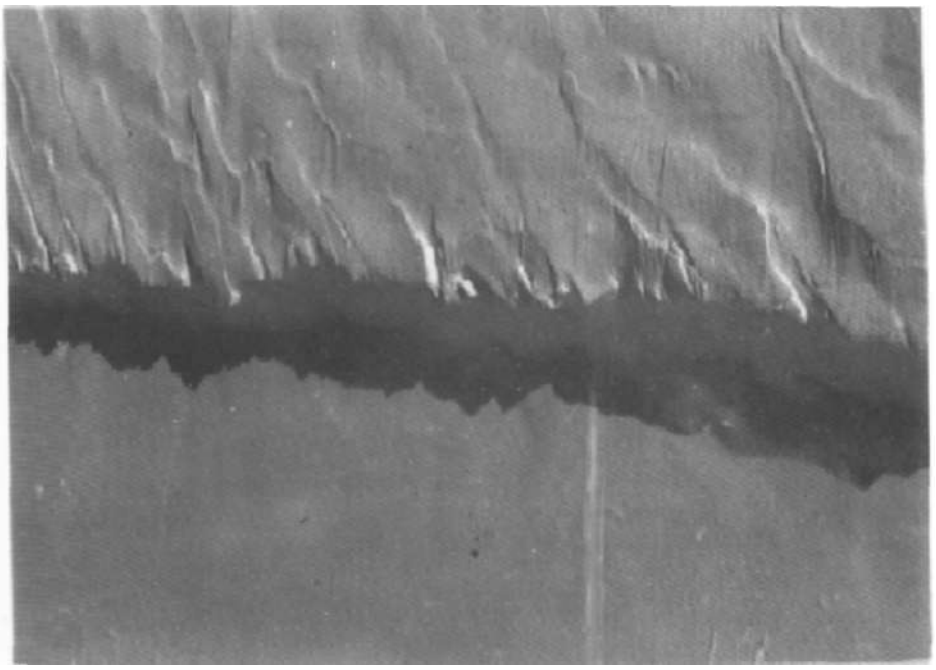


Fig. 4. Front of Filchner ice shelf, Weddell Sea.

front, north of the "Grand Chasm" floated away in the form of series of icebergs — ice islands — some of which covered an area of more than 1200 km^2 .

Present Nature and Positions of the Shelf

The Filchner ice shelf along its front, as observed by our team, is about 30-50m high with large overhangs (Fig. 4) and exhibits almost a similar nature from east to west except near 41°W latitude where, besides the development of a protrusion—horn—the ice surface exhibits a highly corrugated, fractured and crevassed nature (Fig. 5).

Reconnaissance of shelf revealed that, along the central axis, between the front at 78° 10'S and southward for about 12 km, it exhibited an undulating wavy nature where the crests were marked by crevasses while the troughs were free from it. It was in one of these troughs at 78° 15'S: 40°W that the Indian field station (Fig.3, page vii) was established. Further south, upto over next 50 kilometres or so, helicopter recce revealed the shelf to be highly crevassed, later trending almost east-west. Hence onwards, upto 80° 30'S, barring a solitary opening, here and there, the shelf was found to be free of crevasses; most likely these are covered by drift snow, hence not exposed along the surface. Along the western limits, nearer to Berkner island, the shelf, along its front between 78° 10'S & 78° 40'S is highly crevassed and fractured. In fact, about 15 km inland from the shelf a deep and wide chasm (Fig. 6) has developed in this area. Further south, however, a crevasse free area, covered by drift ice, exists along the border with the Berkner island between 79°S and upto 80° 30'S.

Fig. 5. Highly crevassed front (Horn), Filchner Shelf, Weddell Sea.

Fig.6. Chasm along the western limits, Filchner Shelf, Weddell Sea.

Filchner ice shelf is reported to exhibit divergent flow with prominent flow lines — apparent impact of the confluencing glacier streams — clearly seen in the satellite imagery. These flow lines as observed in the field, unlike the continental glaciers but more so in Himalaya, were found to be of morainic material, at least in the area reconnoitred.

Changes in the Front

Filchner ice shelf has undergone a considerable change, along its front, since its discovery in December, 1912 when it was, as reported by Filchner to be 30-40 m thick but had a rather sloping surface along its eastern front. During the IGY i.e. in late fifties, when teams from a number of countries visited the shelf, the position of its front, as depicted in the British Territorial charts, was close to 78°S latitude. The existence of the "Grand chasm", a gigantic rupture, 60 km south of the front was reported, for the first time, during this period only. This chasm in 1957 was about 100 km long from east to west, and about 5 km wide at its maximum, narrowing down to 400 m along its limits (Fuchs & Hillary, 1958). It was reported to be 50 m deep and, towards the bottom, ice blocks floating on Sea could be observed. By 1973, the chasm had increased its length and extended right across the shelf from east to west with a width of about eleven kilometres which in fact had gone upto 19 km by the year end. Observations made by Orheim (1979) and Crabtre and Doake (1980) had indicated a flow movement of the order of 1.2 km to 2 km per year for the frontal portion i.e. north of chasm. With the increase in the chasm width, northern limits of the front had extended upto 77° 30'S by September, 1973 at the horn, locale of the Russian Station - Druzhnaya I and upto 77° 15'S by February, 1986. By September 1986 (Fig. 7) most of the shelf, north of the chasm, had broken off to form icebergs of enormous dimension. The frontal area totalling 7000 km which floated off, in the form of icebergs, is being monitored, regularly with the help of satellite and some of the broken portions have drifted to a distance of 50 km northward from the place of origin.

During the austral summer of 1989-90, the shelf front, as observed between the eastern limit at 37° W and the western limit near the boundary with Berkner island was situated around 78° 10'S with a small projection at around 41° W. It would appear that, with the breaking of the shelf front, north of the chasm, the rest of the shelf has remained practically stable during the last four years or so as the present position of the front coincides, more or less, with the position the shelf had south of the chasm. In fact, some of the features, as observed in the imagery of '86, could be easily identified by our team during the reconnaissance of the shelf between the front and 80°S, along its western margin bordering the Berkner Island. It is possible that the shelf, in the present vicinity of the front and south of it, is anchored to bed rock either all along or at most of the places which restricts its northward movement and consequently the relative stable position.

Along its eastern limit, towards the Luitipold coast, the shelf front was observed to swing north and east around the coastal contour and merge with Polar ice. Eastern extension of the ice shelf, at the foot of the Luitipold coast, *sensu stricto,* not part of the Filchner shelf, is highly crevassed and overridden by equally crevassed and fractured polar ice. Narrow cascading ice falls, along the coastal front have overridden the relatively undisturbed typical flat ice shelf (Fig. 8). Latter, but for a major gap at the head of the Vahsel Bay could

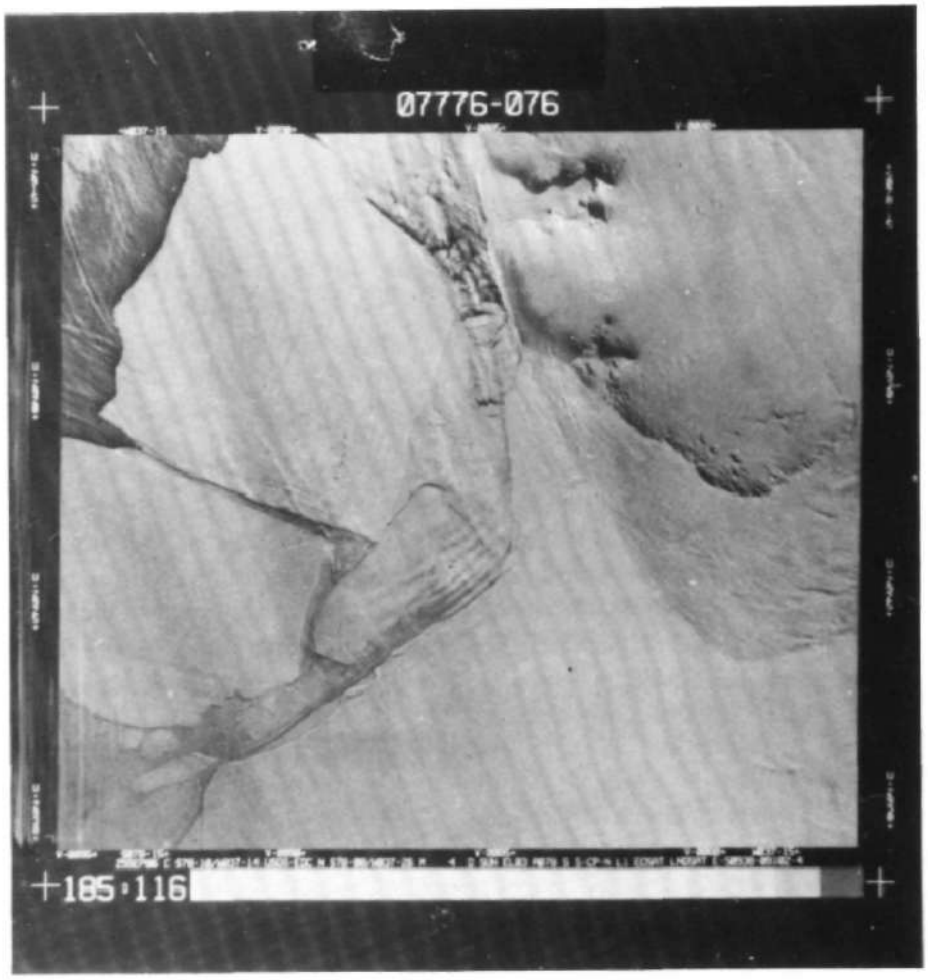


Fig.7. Imagery of part of Weddell Sea area showing huge ice-islands.

otherwise have been the continuity of the Brunt ice shelf. The contact zone between the polar ice and the ice shelf in the vicinity of Moltke Nunatak, wherever exposed from under the cover of the drift ice, was observed to have given rise to a highly crumpled and fractured surface. Frontal position of the shelf, in this area, apparently floating, has already, under the pressure of the fast moving polar ice at the rear, given rise to a rift - precursor to the development of an iceberg (Fig. 9). Eastern end of this rift is wide and open exposing the sea underneath with floating blocks of ice (Fig. 10). Westward extension, after certain distance appeared buried under drift snow; closer examination, however, revealed existence of shelf ice underneath.

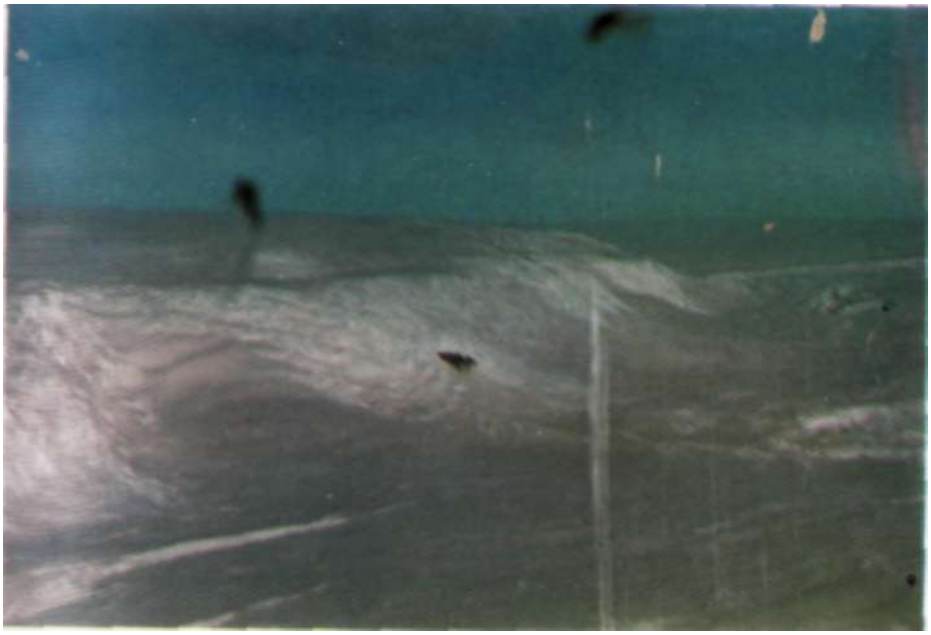


Fig .8. C*ascading ice falls of the polar ice off the Luitipold coast. Weddell Sea. Dark patch in ice is the Eastern Moltke Nunatak, exposing limestone and arkose.*

Fig.9. Rifting in shelf ice. Luitipold coast. Weddell Sea. Precursor to the development of an iceberg.

New Chasms

The Filchner Shelf along its western limits, near the boundary with the Berkner Island, north of McCarthy's inlet, is highly cracked and fissured. A new chasm like feature, about 100 m wide, sinuous in nature (Fig. 11, also see Fig.6), 30 m to 50 m deep, with the bottom all along marked by caves, channels and a chaotic conglomeration of broken ice blocks, could be traced, from near the Berkner edge, eastwards for about 15 km, whence it gradually sloped upward to merge with the shelf. At the latter spot, it shows the nature of a big decline with steep walls (Fig. 12).

Further south, within the glacier stream originating from the McCarthy's inlet, an ice rumple aligned ENE-WSW about 4 km long (Fig. 13) was observed to have developed as a consequence of warping of otherwise east-west trending crevasses. This feature apparently represents a local shallow basement and grounding of ice. In appearance it is comparable to similar feature which marked the eastern extremity of the "Grand Chasm" as can be seen in the photograph entitled "Part of the Great east-west chasm ....", (Fuchs & Hillary, 1958, pp.20-21). Examination of the imagery (Fig. 7) has revealed the existence of this feature, practically at the same spot, thereby further substantiating our observation that there has been hardly any change in the shelf front, along its western limits, over the last two decades. Contrary to the observations and recordings made along the central front by Orheim *(Op. Cit)* and others. A possible explanation for a slow or practically nil movement could be the probable shallow nature of the ocean bottom along the eastern side of the Berkner Island. Apparently ice here is grounded to ocean bottom or to a high rise rocky ledge conversely restricting the ice movements as is also borne out, to a great extent, by the cross profile (Fig. 2 and Fig.3). Examination of the latter also reveals the fact that the cross section of the ' Filchner shelf, though not typical, is in fact a "U" shaped feature— characteristic of a glacier

Fig.10. Eastern open end of the rift in shelf.

Fie.ll. New Chasm in Filchner Shelf, close to Berkner Island, Weddell Sea.

Fig.12. Decline at the Eastern limit of the Chasm, Filchner Shelf, Weddell Sea.

Fig. 13. Ice rumple in the glacier stream originating from McCarthy's inlet, Berkner Island, Weddell Sea.

eroded valley. It would appear to have been carved out of the continental shelf by the active erosion of a glacier stream pouring out of the polar ice cap. At present, it represents a typical Fjord still buried under the ice cover. Erosion to such abysmal*depths could possibly have been helped by a weak zone — existence of a large fault or tectonic sheet zone — aligned to glacier flow or even controlling the glacier flow.

New Horn

The shelf front, at about 78° 10'S: 41°W, shows a protrusion like feature which exhibits a highly crisscrossed rectangular pattern of crevassing (Fig. 5). This characteristic feature is developed in a pyramidal fashion with the apex facing north. This area, with close, well developed seracs and depression, practically impossible to negotiate on foot was, however, a distinct advantage for aerial navigation as it could be identified even at a distance of 50 km when viewed from a height of 2000 m and above (Fig. 14). It, in fact, served as a distinct marker for flying operations. Development of such a highly crevassed and fractured frontal zone within a relatively less disturbed ice, baffles imagination as to how and why it is so. The only explanation coming forth to mind is that, it probably represents a localised grounded portion, along the ice front, which, under the continuous flow pressure from the rear and relatively fast moving ice on either side has developed this fractured nature. Incidentally this zone is also well observed in the imagery of 1986 and may likely give rise to a new horn typical of the Filchner Shelf in the past times. Concentration of pack ice west

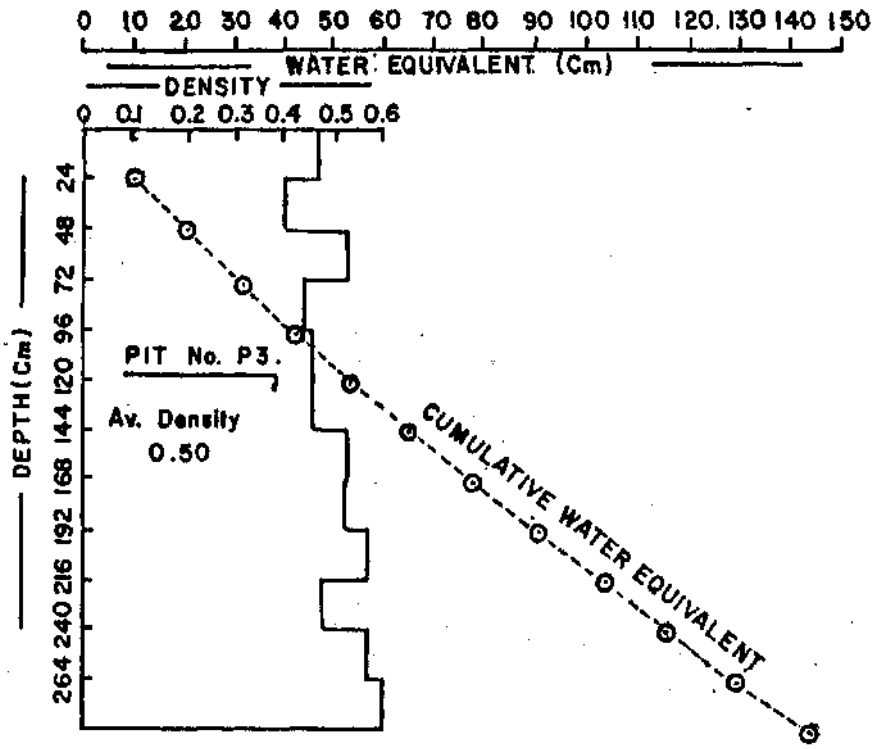
Fig. 14. Highly crevassed Shelf-Horn, Filchner Shelf, Weddell Sea (aerial view).

Fig.15.Pit excavated for shelf ice density profiling, Filchner Shelf, Weddell Sea.

of this horn was so thick that the ice breaker could make no progress for movement westward along the shelf front.

Density Profiling of Shelf Ice

Pits were dug upto depth of 3 m or so at and around the site of field camp (Fig. 15) to assess the nature and accumulation of top layers of the shelf ice. Snow density was observed to vary from 0.40 gm/cm^3 to 0.60 gm/cm^3. Overall nature of the ice is dry, powdered with low cumulative water equivalent. Thin, but denser, bands representing surface hoars are, however, present. But for the association of these thin depth hoar bands, overall density rate would be much lower than recorded (Fig. 16).



Fig, 16. Density profile of Filchner Shelf.

Berkner Island

It is an oval shaped ice rise — largest in Antarctica — covering an area of 56,700 km^2 and separates the Filchner ice shelf from Ronne ice shelf. It extends from 77° 47'S, in north, to 80° 50'S, in south, and is bounded by longitudes 44° W in east and 52° W in west (Fig. 1). It rises to a height of about 1000 m above the sea level along its central axis and apparently is an independent ice cap built on a localised shallow ocean bottom in the continental shelf. Bed-rock topography (Fig. 2) has been found at places to be as shallow as 80 m below sea level (Behrendt, 1970).

Its eastern flank is conspicuously marked by three inlets; northern one is named McCarthy's inlet, the central one is the Robert's inlet and southernmost is unnamed. These inlets are occupied by glacier streams originating in terraced-escarpment type ice falls from the slopes of the ice rise. These glacier streams, near the confluence with the Filchner ice shelf, swing northward in tongue like forms and are distinctly different from the Shelf ice. The glacial stream originating from the McCarthy's inlet, being larger in size, is perceivable even under the cover of thick drift snow and exhibits well developed flow lines. Ice streams flowing out of the Robert's inlet and the unnamed inlet south of it, are relatively less perceivable.

Along the eastern side, between 79° S in north to 80° 30'S in south, surveyed by the present team, from its field camp INDIA II (Fig. 17), this ice rise exhibits two level terraced nature culminating along the central axis into a thin knife edge ridge. The lower of the two terraces, which is larger of the two, slopes gradually eastward and merges with the Filchner ice shelf. Slope angle, which is steep just north and south of the McCarthy's inlet, becomes gradually less steep southward. A well developed depression marks the contact of the slope with the shelf in the northern part i.e. north of McCarthy's inlet. South of the unnamed inlet (80° 30'S : 45° W) the slope gently merges with the shelf and the confluence is buried under a thick cover of loose drift snow.

Surface of the Berkner island is covered by 40-50 cm thick coarse but soft, dry, drift snow exhibiting geometrically patterned arched Sastrugis - with longer arm trending almost eastwest and the shorter NE-SW. The ice surface, as could be revealed by aerial recce and traverses by snow scooters,, was observed to be free of crevasses, which could of course be

Fig.17. Field Camp, lndia-II, at 79° 18' S: 43^{0} W, Berkner Island: Weddell Sea.

due to the thick cover of drift snow. A number of crevasses were, however, seen to have developed close to the flank just south of Robert's inlet.

References

Behrendt, J.C. (1962): Geophysical and glaciological studies in the Filchner ice shelf area of Antarctica. *Jour. Geophy.,* **Vol.** 67 No. 1, pp.221-234.

Behrendt, J.C. (1965): Snow surface elevation of the Filchner ice shelf area, Antarctica. *Jour, of Glac.*, **Vol.** 5, No. 41, pp.735-738.

Crabtree, P.D. and Doake, E.C.S.M (1980): Flow lines on Antarctic Ice Shelves. *Polar Record,* **Vol.20,** No. **124,** pp.31-37.

Fuchs, V. and Hillary, E, (1958): The Crossing of Antarctica. Cassell, London.

Orheim, O. (1979): Flow of Antarctic Ice Shelves between longitudes 29" E and 44° W (abs), *Jour. of Glac,* **Vol.24,** No. 90, pp.484-485.

Robin, G.D.E.Z. (1971): Radio Echo Sounding applied to the investigation of the ice thickness and sub-ice Relief of Antarctica in Adie, R.J. *ed.* Antarctic Geology and Geophysics, pp.675-681.