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SUBGLACIAL MORPHOLOGY IN NORTHERN PALMER LAND, ANTARCTIC PENINSULA

by

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ABSTRACT

Ice-thickness and surface-elevation data gathered from radio echo flights over the Antarctic Peninsula are presented as profiles for five major outlet glaciers in northern Palmer Land and as contour maps for an area of 8 000 km² to the east of George VI Sound. Glacier profiles appear to be closely related to ice discharge especially to convergent and divergent flow. Comparison of subglacial topography with geological evidence of faulting suggests that the area around George VI Sound is a region where structure is an important influence on the pattern of glacial erosion.

INTRODUCTION

Since 1966 the British Antarctic Survey has flown over 80 000 km of radio echo traverses over the Antarctic Peninsula from which information about ice thickness and surface elevation has been obtained. The data discussed here come from flights over northern Palmer Land (Fig. 1), many of which followed the courses of major outlet glaciers. Figures 2 and 3 show longitudinal profiles of five such outlets: Weyerhaeuser Glacier and the Sunfix-Casey glacier system on the eastern side of Palmer Land, and Chapman, Meiklejohn and Millett glaciers on the western side. The profiles run as nearly along flow lines as is possible to achieve when flying over the glaciers; sometimes it is not easy to determine which is the main ice stream, especially when flying at low altitude. Gaps in the profiles occur when attenuation of the signal, caused by a combination of ice thickness and temperature, is so great that a return from bedrock cannot be detected. The flight tracks along the glaciers are also shown in Figures 2 and 3.

Where radio echo coverage is more intensive, contour maps of ice thickness and bottom elevation can be drawn. Figure 4 shows generalized contours of ice thickness in 8 000 km² of northern Palmer Land between Riley Glacier and Gurney Point. The five outlet glaciers are among several which drain the plateau ice sheet westwards into George VI Sound where they coalesce to form George VI Ice Shelf which, in this region, flows northwards between Palmer Land and Alexander Island into Marguerite Bay (Fig. 1). Ice cover is continuous and the glaciers flowing down wide valleys are connected by ice fields; divides are marked by isolated nunataks rather than by continuous ranges. The ice-thickness contours have been drawn with the aid of satellite images. When scanned under low angles of illumination these show an enhanced surface topography and, in thinner ice, bottom irregularities are reflected in surface undulations. The subglacial pattern so revealed enables contours to be extrapolated into areas for which no radio echo data exist.

Much of the area is covered by ice more than 1 000 m thick. The upper parts of Bertram and Meiklejohn glaciers are more than 1 250 m thick and to the east-north-east of Meiklejohn Glacier the ice thickens locally to over 1 500 m. All the outlet glaciers are between 250 and 400 m thick at the ice-shelf boundary and thinning downstream is not uniform.

The form of the bedrock is shown in Figure 5. The elevations are found by subtracting the ice thickness from surface elevation as determined by pressure and radar altimetry. Fixing altitude in this way is subject to errors due to changes in atmospheric pressure through time and from place to place. However, over a fairly local area these changes should not be great and errors in bedrock elevation should not exceed ± 100 m over the entire map.

Considering the great ice thickness it is not surprising that a large proportion of the bedrock is below sea-level. The bottom of Bertram Glacier is below sea-level for its entire length and, in common with Millett, Meiklejohn and Chapman glaciers, contains overdeepened sections. The head of Meiklejohn Glacier appears to be at 70°18'S, 66°45'W (although there is an area overdeepened below sea-level 15 km further inland) and the head of Millett Glacier is similarly extended inland by 25 km.

OUTLET GLACIER PROFILES AND ICE DISCHARGE

The irregular nature of long profiles of glacial troughs is well known (Sugden and John 1976). The gross form is characterized by a steep gradient at the trough head and a gentler, sometimes reversed, slope towards the mouth, which has given rise to the term "overdeepening". On this is superimposed a pattern of basins or rock steps separated by rock bars. Although in the cases cited here absolute values of ice discharge are not known, it appears that the profiles can be explained largely in terms of relative variations in discharge particularly with respect to convergence and divergence of ice. A good example is provided by Weyerhaeuser Glacier (Fig. 2A) which flows north from Wakefield Highland into Mercator Ice Piedmont and ultimately to Larsen Ice Shelf. It does not exhibit a trough head, perhaps because this has been eroded back up the trough until the divide with Airy Glacier was breached. At A the ice

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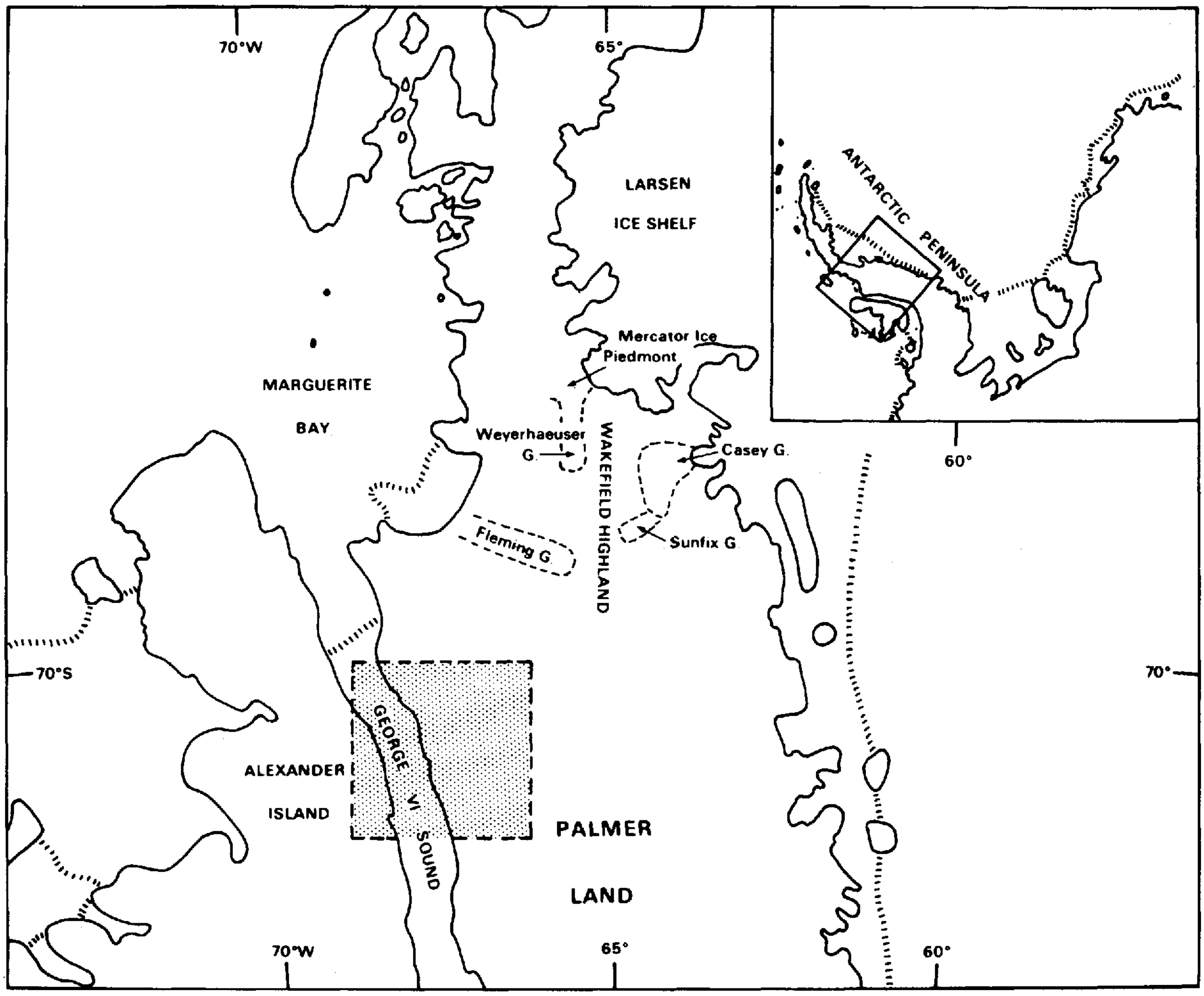

Fig.1. Map of northern Palmer Land, Antarctic Peninsula. Stippling shows the area covered in Figures 4, 5 and 6.

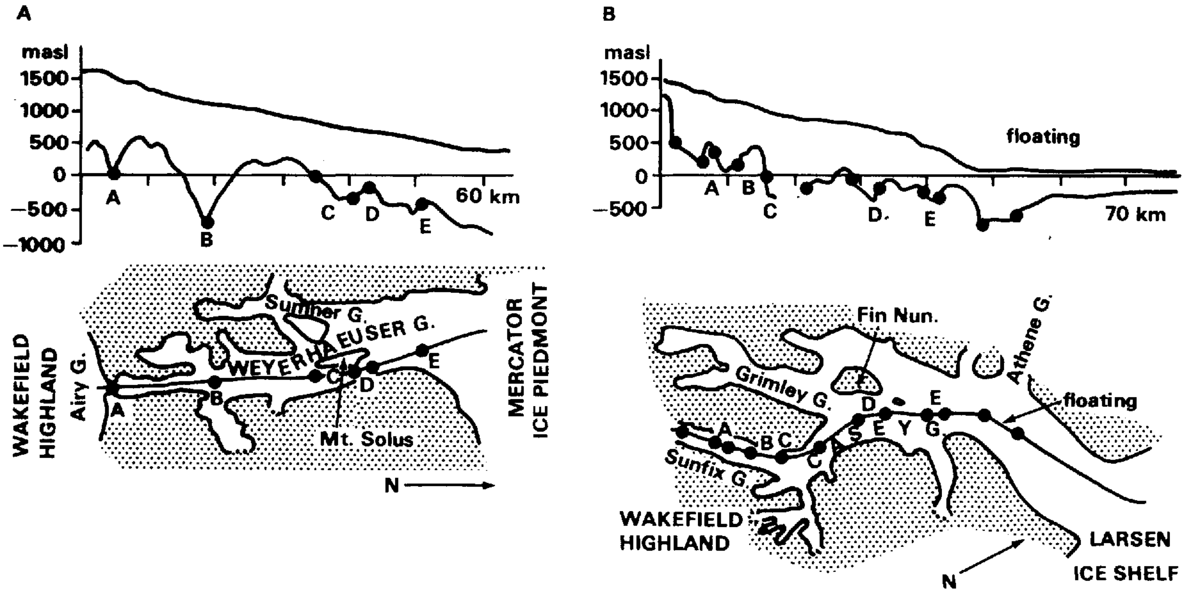

Fig.2. Long profiles of Weyerhaeuser (A) and Sunfix and Casey glaciers (B). Heavy dots relate features on the profiles to their position along the flight tracks. Vertical exaggeration is x 10.

flows through a constriction caused by the incursion of a rock spur on the western bank: marked overdeepening occurs at this point (ice thickness increases from 1 000 to 1 500 m). This may be associated with the high ice velocities needed to discharge ice through the constriction. As the valley widens down-glacier, the ice thins to 700 m before thickening to 1 800 m where a tributary glacier enters from the east. This convergence has resulted in the erosion of the bedrock 700 m below sea-level at B. The flight track follows a flow line between

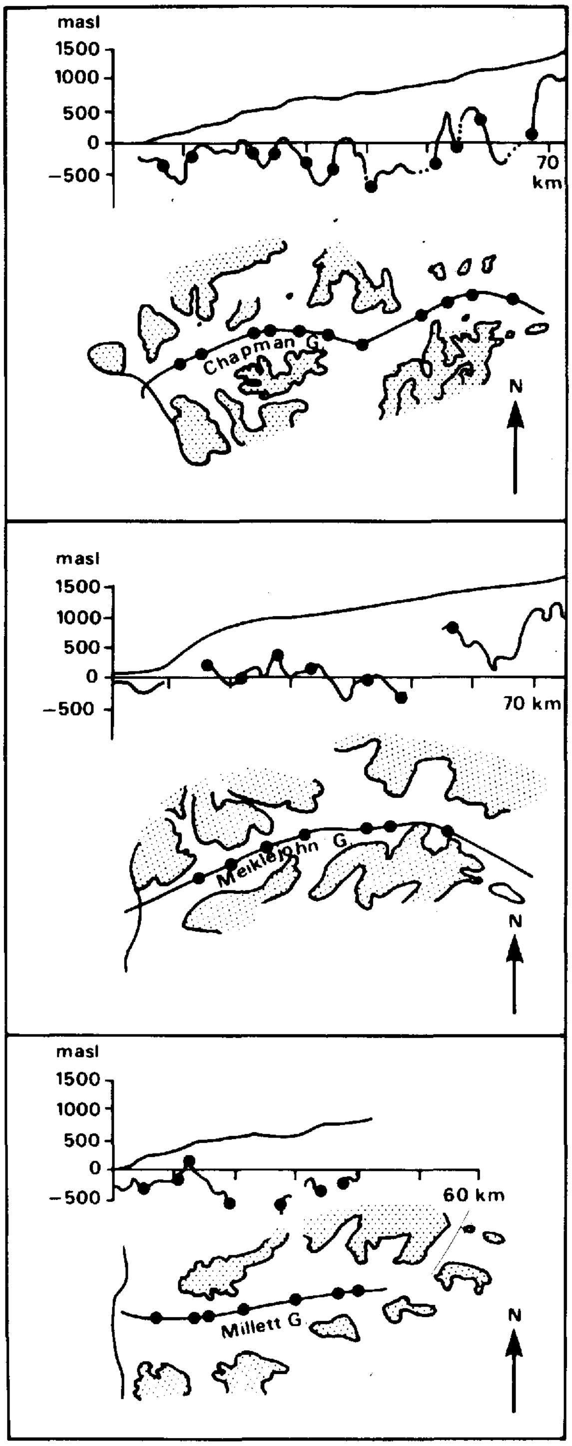

Fig.3 Long profiles of Chapman, Meiklejohn and Millett glaciers. See Figure 2 for details.

Mount Solus and the eastern bank. As the valley narrows, ice thickness increases and a basin occurs at C followed by a bar at D located opposite the down-stream extremity of Mount Solus where ice flow diverges after it has passed through the constriction. The ice gradually thickens down-glacier due to the influx of Sumner Glacier and others from the west. A final bar occurs at E opposite the sudden turn eastwards of the right bank, which again causes divergent flow in the glacier.

Similar effects can be seen in the Sunfix-Casey glacier system (Fig. 2B) which flows north-east from Wakefield Highland to Larsen Ice Shelf. Immediately obvious is the marked trough end: the bedrock drops by 800 m in 1 km (a slope of about 40°). There is a rock bar in the profile at A which may be an extension of a spur on the southern side. The rock bar at B occurs just before entry of Sunfix Glacier into Casey Glacier. Sunfix Glacier is in a hanging valley and the convergence of the glaciers at what is effectively the trough head of Casey Glacier (C) has led to overdeepening. Ice here is at least 1 200 m thick and the bottom radar reflection has been lost. Further basins occur at D, the convergence of Casey and Grimley glaciers, and at E where ice flows in from north of Fin Nunatak; both are about 300 m below sea-level. The grounding line of Casey Glacier is difficult to place but thickening of ice in this region may be due to influx of ice from Athene Glacier.

Similar patterns relating basins and rock bars to convergent and divergent ice flow can be seen in the profiles of Chapman, Meiklejohn and Millett glaciers in Figure 3. Small bars are found at the foot of Chapman and Millett glaciers just before the grounding line where the ice begins to float. The same may be true of Meiklejohn Glacier but the profile is discontinuous.

SUBGLACIAL MORPHOLOGY AND THE EFFECT OF STRUCTURE

Irregularities in the profiles of outlet glaciers have been explained in terms of convergence and divergence of ice. It may be that the differential erosion of varying lithology and structure is as important, but since no direct observation of subglacial geology can be made, this is difficult to demonstrate. However, there is evidence that geological structure may control the pattern of glacial erosion in that part of northern Palmer Land for which contours of ice thickness and bedrock elevation have been drawn. Here, the major feature is the area overdeepened to more than 250 m below sea-level, running north to south across the middle of Meiklejohn and Millett glaciers (A to B in Figure 5). Two other overdeepened areas under Bertram Glacier (C and D) lie along the same line, all between 25 and 30 km from the grounding line.

The straight parallelism of the sides of the northern section of George VI Sound has led to the general belief that it represents all or part of a rift valley. Nichols (1953) observed that it was assumed to be a tectonic valley but could just as well be a controlled erosional valley. Adie (1964) has taken the view that the northern section is a genuine rift valley but that the southern section is the result of glacial erosion. There is no unequivocal evidence of rifting but Edwards (1980) points out the existence of the sub-parallel "LeMay Range fault" on Alexander Island some 20 to 25 km west of the western edge of George VI Sound (Fig. 6). Although evidence of sub-parallel faulting on Palmer Land is slender, Skinner (1973) observed

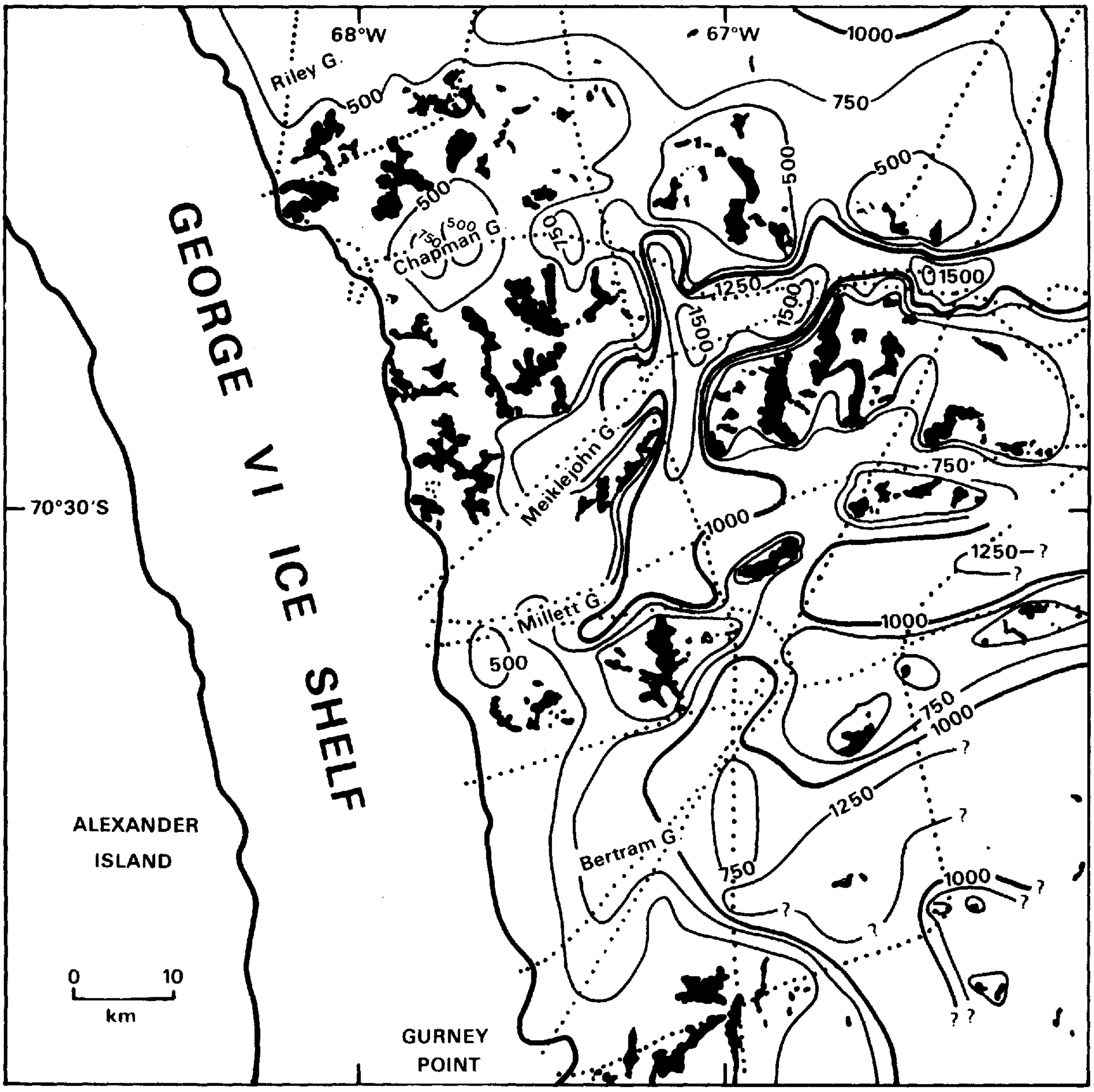

Fig.4. Ice thickness in part of northern Palmer Land. Contour interval is 250 m. Radio echo flights are shown by dotted lines.

that many major faults in the area north of Meiklejohn Glacier follow the same north-south trend and Rowe (1973) noted that block-faulting in the Riley-Bertram glacier area shows parallelism with the local trend of the Antarctic Peninsula (and therefore with George VI Sound). While the "LeMay Range fault" has a downthrow to the east, most of the faults mentioned on Palmer Land have a downthrow to the west. The major overdeepened areas in Figure 5 (A to B,C and D) parallel the coast of George VI Sound. They are uninterrupted by nunataks except those which crop out between Millett and Bertram glaciers and it is significant that a fault through these nunataks has been shown by Rowe (and indicated in Figure 6) to be sub-parallel to the line of the overdeepened zone. Edwards argues that the "LeMay Range fault" may be the western boundary of the rift valley of which George VI Sound forms a part. It is suggested here that the overdeepened areas occur along a fault which may be the eastern boundary, or one of a series of steps comprising the eastern boundary. The extension westwards to the "LeMay Range fault" gives the rift valley a minimum width of 40 km (Edwards 1980); the suggested extension eastwards to the line A-B-C-D increases the width to 70 km. Such a fault zone would be preferentially eroded by ice draining Palmer Land and Alexander Island. Soundings taken at the northern ice front of George VI Ice Shelf have revealed a W-shaped cross-section to the sound. The maximum depths of the eastern and western parts are 900 and 750 m, respectively (Lennon, unpublished). It is suggested that there are two troughs extending southwards beneath the ice shelf which are glacially eroded features. Ice discharge from Palmer Land would always have been greater than that from Alexander Island because of the larger catchment area. This may explain the deeper of the troughs being on the Palmer Land side of the sound. The ice would have to be only 1 000 m thick to ground in this deepest part and the surface would be less than 100 m

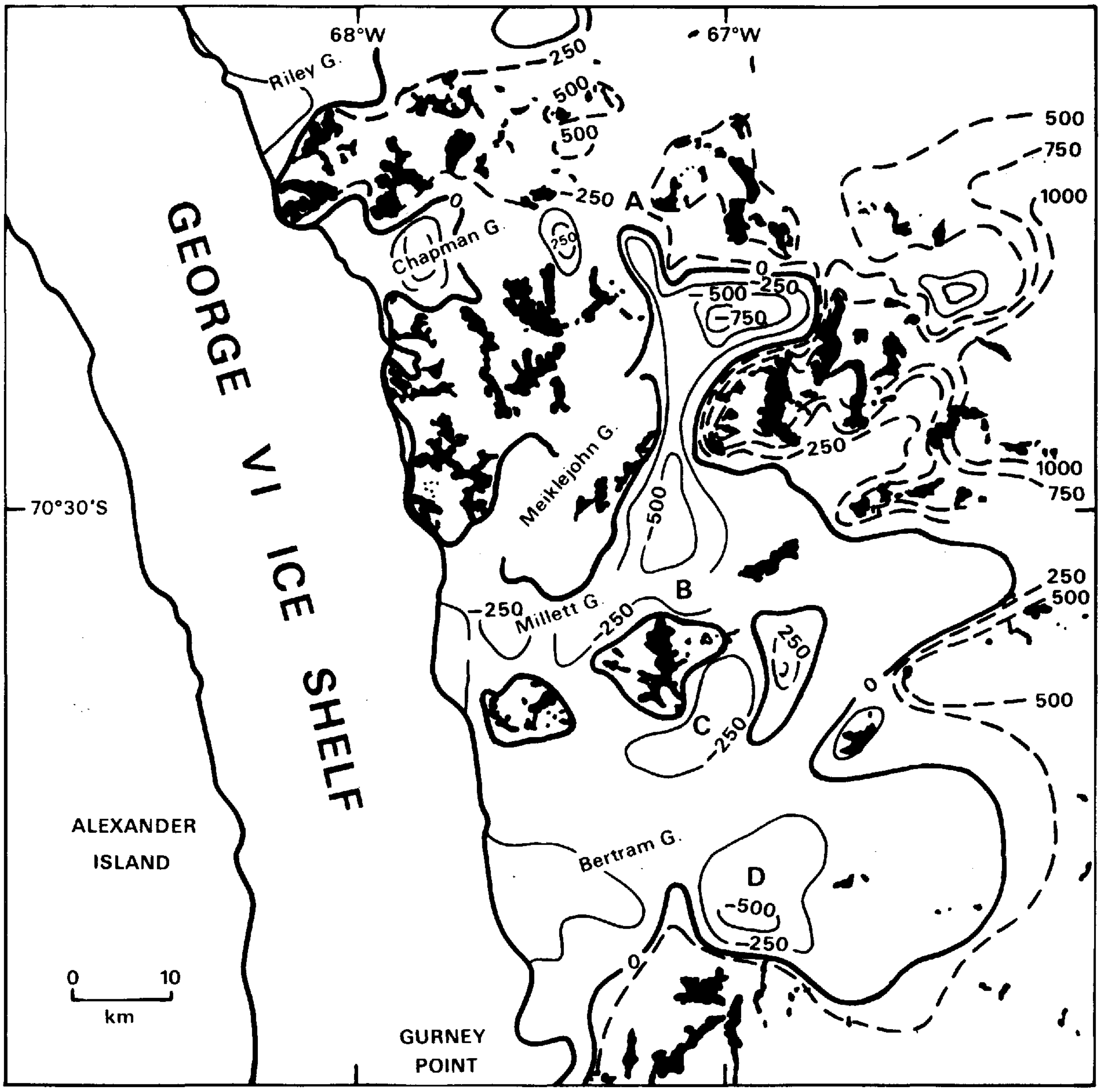

Fig.5. Bedrock elevation in the same area as Figure 4. The heavy line is the sea-level contour. Solid lines represent heights below sea-level, dashed lines above sea-level. Contour interval is 250 m. Contours are not shown close to nunataks.

above its present level. Smith (unpublished) cites truncated spurs along the east coast of George VI Sound as indicating a former ice surface up to 300 m higher than at present. Finally, the five major outlet glaciers draining westwards into George VI Sound parallel known major faults transverse to the main north-south trend (Fig. 6). Smith suggests that the valleys down which the glaciers flow are pre-glacial in origin and initiated along other transverse faults. In such a strongly block-faulted region the pattern of glacial erosion has been considerably modified.

CONCLUSIONS

Variations in ice discharge may account for the irregular valley profiles of the five outlet glaciers discussed. Basins are related to sections where flow is convergent due to narrowing of the valley sides or the confluence of tributary glaciers, whereas bars occur under sections of diverging flow associated with a widening valley or entry into an ice shelf. Geological structure appears to have directed the pattern of glacial erosion in the area around northern George VI Sound and areas of very thick ice may indicate the location of a preferentially eroded fault zone. This may be the eastern boundary of the rift valley of which George VI Sound forms a part and is 25 to 30 km to the east of the eastern side of the sound.

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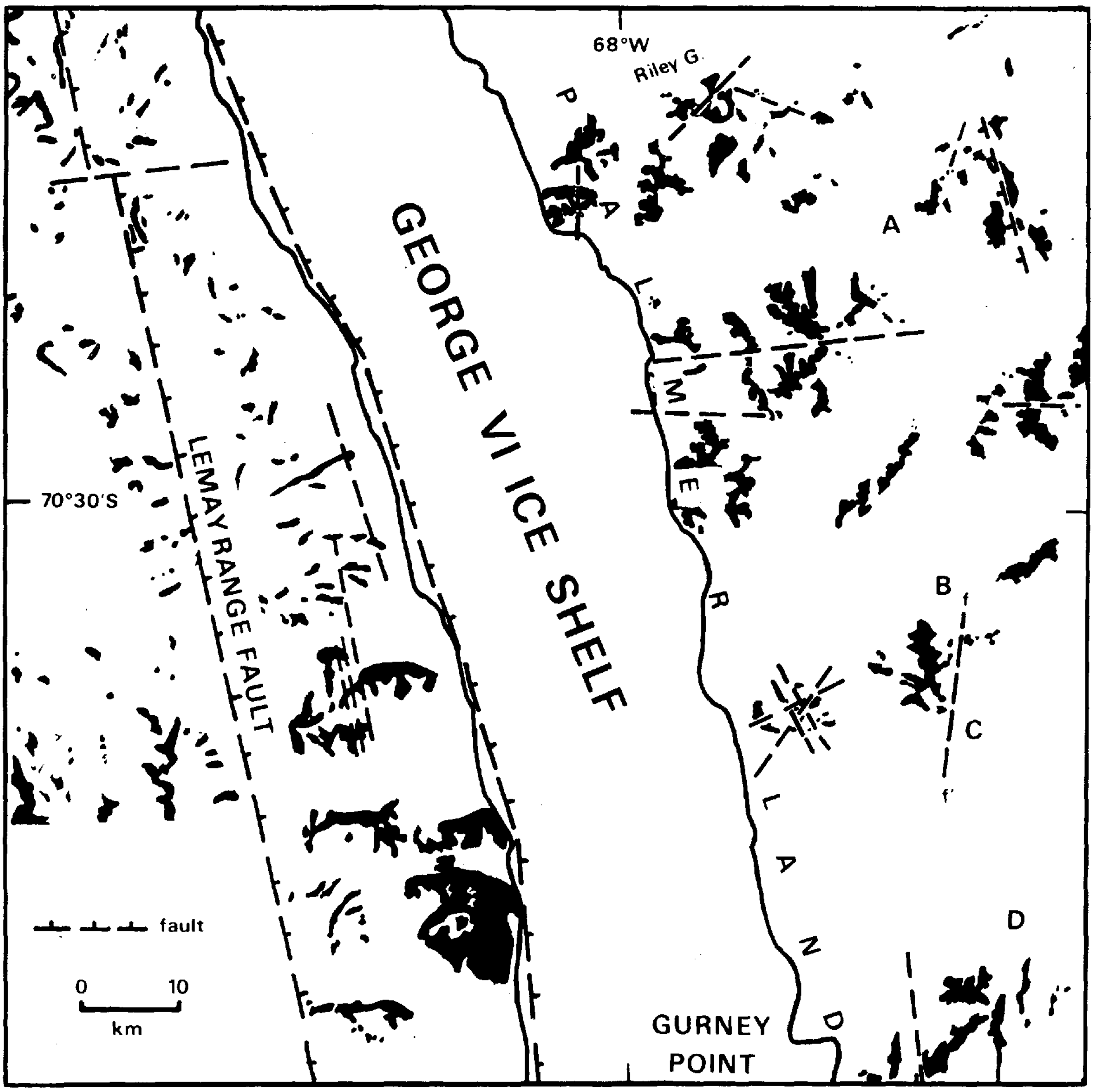

Fig.6. Inferred faults around George VI Sound between Riley Glacier and Gurney Point. Ticks are on the downthrow side. For further explanation see text.

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