THE PHYSIOGRAPHY OF PART OF NORTHERN PALMER LAND

By T. G. Davies

Abstract. The physiography and glaciation of part of northern Palmer Land are described. The presence of at least one truncated spur in the Eternity Range indicates an appreciable fall in the ice level since the period of maximum glaciation. There are possible planed surfaces at six levels and their origins are discussed in relation to recent literature. Included with the minor glacial features are "rill" structures not hitherto described.

Palmer Land is that part of the Antarctic Peninsula south of a line between Cape Jeremy and Kenyon Peninsula, and this coincides with the area where the peninsula widens abruptly southward from about 70 km. to more than 150 km.

The area discussed here (Fig. 1) lies between lat. 69° 15′ and 70° 00′ S. and long. 63° 00′ and 69° 00′ W.; it was mapped geologically by the author during 1970 and 1971. Natural boundaries to this area are Bingham and Fleming Glaciers to the north, George VI Sound to the west and Eureka Glacier to the south.

It was not until it became practicable to use aircraft for polar travel that the topography of Palmer Land began to be known. Flights over northern Palmer Land were carried out by Wilkins (1929) and Ellsworth (Joerg, 1936), and these reconnaissances were extended by the flights and sledge journeys of the British Graham Land Expedition in 1936 (Fleming, 1938). A sledge party of the United States Antarctic Service Expedition, 1939–41, crossed the plateau from the Wordie Ice Shelf to the Eternity Range (Black, 1945) and further valuable information was obtained from the trimetrogon air photographic cover taken during the Ronne Antarctic Research Expedition, 1947–48 (Ronne, 1948). Since that time numerous members of the Falkland Islands Dependencies and British Antarctic Surveys have crossed northern Palmer Land and completed various geological and topographical surveys.

Physiography

Behind the coastline around Cape Jeremy is the massif of Mount Edgell, Mount Guernsey and their satellite ridges and nunataks, and eastward the plateau gradually increases in altitude through the Relay Hills, Kinnear Mountains, Mayer Hills and Crescent Scarp bordering Fleming Glacier, to the Eternity Range which forms the backbone of the peninsula. Beyond, the land descends to the Larsen Ice Shelf in 75 km.

Main physiographical features

Mount Edgell area

Mount Edgell (1,676 m.) is steep-sided with a rounded summit and it dominates the landscape in north-west Palmer Land; the surrounding mountains and nunataks, although sharp-crested and impressive in relief, rarely exceed 850 m. in height. Above 1,100 m., Mount Edgell is approximately 5 km. wide, triangular in shape, closing northward to its summit at the northern apex of the triangle. The northern part of the mountain is indented by a large cirque 3 km. wide with its headwall rising from sea-level to 1,100 m. (Fig. 2); the upper 500 m. are largely rock but they are partly cloaked by ice falls from the plateau top.

The western side of the cirque comprises a sharp serrated ridge from which two short spurs protrude westward forming two minor cirques. The northern one is low in altitude, the upper walls are largely of rock, and the headwall corresponds to a marked indentation in the main ridge so it is likely that in the future the main cirque, being at a lower level, will capture the glacier in the other one. The southern minor cirque is at a much higher level on the ridge, contains a large volume of ice and snow and has virtually no rock walls; its upper edge merges into the summit icefield at a line of ice falls. Both of the cirque glaciers flow westward in their sections and exhibit transverse north–south crevassing but lower down they turn northward where they join the steep narrow glacier which disgorges into the sea east of Brindle Cliffs. This glacier, 7 km. long and 2 km. wide, drains the western side of Mount Edgell, whereas beyond its western edge the ground slopes gently towards Cape

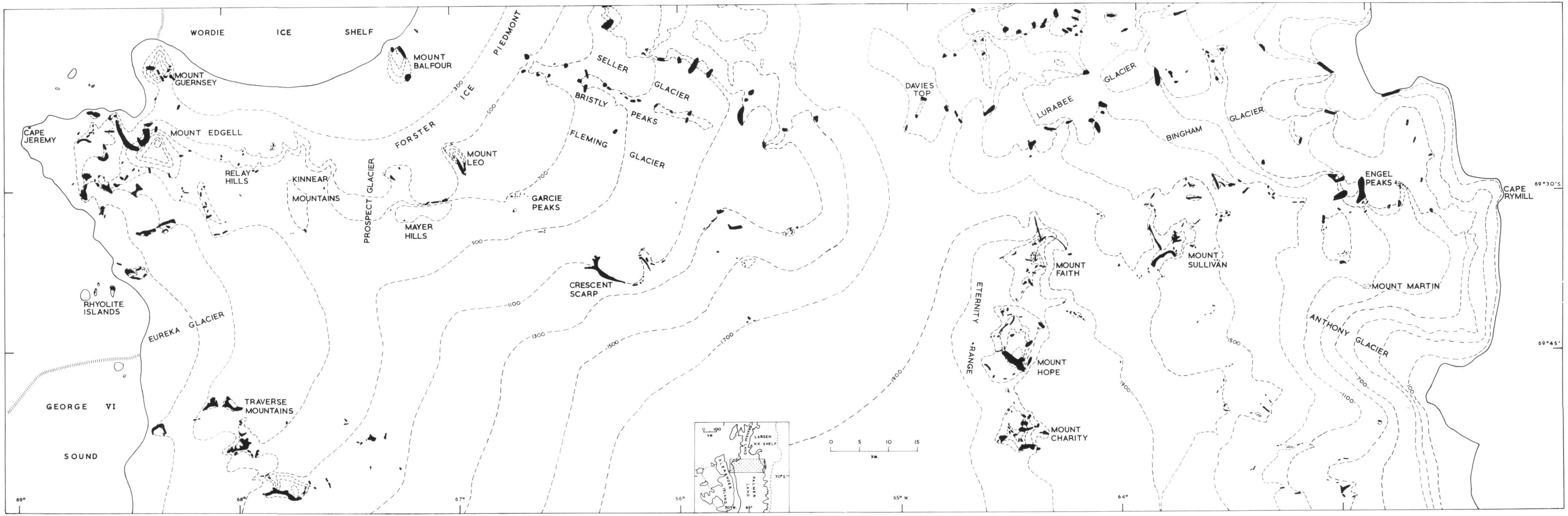

Fig. 1 Topographical sketch map of northern Palmer Land.

[face page 99

Fig. 2. The rounded summit and large cirque of Mount Edgell viewed from the north. (U.S. Navy photograph.)

Jeremy. Crevassing is transverse except for chaotic ice falls where the ice from the cirques joins the main flow and where the glacier reaches the sea.

A scarp about 200 m. high, marking the south-western and southern margins of Mount Edgell, is 12 km. long and trends from the major northern cirque to the south-eastern rock spur of the mountain. It is mainly an ice scarp with isolated rock outcrops and ten steep spurs, vestiges of the inter-trough divides, one of which links Mount Edgell via a snow col with a prominent south-south-west trending ridge comprising three spectacular spire-like peaks. This scarp feature continues for 4 km. along the eastern side of the mountain past the south-eastern spur, a low rock and ice ridge terminating in a pyramidal peak; northward the scarp gives way to a highly crevassed slope of moderate steepness which continues north-westward to the edge of the main cirque.

Mount Guernsey is the second highest mountain in this area with a flattish snow summit surrounded by steep scarp faces of rock or ice; it is similar to but smaller than Mount Edgell. Three cirques define its rhombic shape; two of them face east and the other one north-west. All three cirques have steep rock walls and only relatively small steep cirque glaciers. Ice from the plateau-like top flows down the inter-cirque divides, forming ice bulges and falls. The south-western side of the mountain is largely a steep snow scarp. A small ice piedmont, less than 1 km. wide in the south-west but increasing to 2–3 km. farther north, surrounds the mountain and passes eastward into the Wordie Ice Shelf, but in the west and north it merges with sea ice or fast ice. Mount Guernsey is separated from Mount Edgell by a 6 km. wide col at an altitude of 250 m.

The triangular ice piedmont, 75 $km.^2$ in area, situated to the west of Mount Edgell is bordered by coastline to the north and west. Severe crevassing is encountered towards the coastline which has ice cliffs for most of its length. The only rock outcrops seen were at Cape Jeremy.

Numerous nunataks and ridges occupy the area south-west and south of Mount Edgell and they trend either north-north-west or west-south-west. Nunataks near the coastline have much higher relief on their western sides and heavily crevassed glaciers flow westward to George VI Sound where they form a series of ice tongues (Fig. 3).

Fig. 3. Glacier tongues formed where heavily crevassed glaciers flow westward off Palmer Land into George VI Sound. (U.S. Navy photograph.)

Relay Hills to the head of Fleming Glacier

East of Mount Edgell are several ranges of hills and mountains. These are mostly snow-covered with smooth outlines of gentle slope where they have been over-ridden by plateau ice from the south, but scarp faces and cirques have been formed on their northern sides.

The Relay Hills are separated from Mount Edgell by a 5 km. wide snowfield which slopes northward and becomes a heavily crevassed glacier with increasing gradient towards the Wordie Ice Shelf. They are of low relief, reaching a height of 930 m., and are W-shaped in outline with two broad northward-facing cirques.

Separated from the Relay Hills by a narrow col is the larger massif of the Kinnear Mountains, characterized by a 900 m. plateau-like top from which four ridges splay out northward dividing three deep cirques. Rock exposure occurs only as very small outcrops in the cirque walls.

To the east, Prospect Glacier is the main northward drainage channel for this part of the plateau. Beyond it are the Mayer Hills which have rounded summits and north-facing cirques, and they are largely inaccessible due to heavy crevassing. A tributary to Prospect

Glacier separates these hills from Mount Leo (1,270 m.) with its sharp rock and snow peak and long gently sloping north ridge. To the north-east, Fleming Glacier merges into the Forster Ice Piedmont, and it is crevassed where it is pinched between the mountain and Bristly Peaks on its north side.

Garcie Peaks (960 m.), a low massif comprising a number of peaks, lie between Mount Leo and Crescent Scarp, a prominent and aptly named feature on the south side of Fleming Glacier. The concave scarp, 250 m. high, faces north and attains its maximum height of 1,480 m. at the western end. It is formed of rock for much of its length but plateau ice forms a total capping and cascades down the face in a number of places.

Eternity Range to the Larsen Ice Shelf

Towards the head of Fleming Glacier there are several rocky buttresses and snow hills, up to 1·8 km. long, but farther east there is a 35 km. belt of featureless plateau rising gradually to the three mountains comprising the Eternity Range, which forms a barrier 45 km. long by 13 km. wide. The highest in this north–south range is Mount Hope (3,226 m.) with Mount Charity next at 2,921 m. and Mount Faith approximately 100 m. lower than the latter. Whereas Mount Hope has only one major peak, Mount Charity has three within 100 m. in altitude of each other. All three mountains are massive and rather squat in appearance, rising from the plateau at about 2,000 m. with long digital ridges separating wide gently sloping cirques. The eastern faces of the range have a much greater relief than western ones.

Mount Hope is the best developed mountain with its single pyramid peak and three main radiating ridges (Fig. 4). Its southern ridge has been truncated (Fig. 4) at a height of approximately 500–700 m. above the plateau level, indicating a substantial lowering of the ice level since the period of maximum glaciation. Koerner (1964) has suggested that at least 300 m. of ice have been removed from Graham Land, and Nichols (1960) has given evidence for a reduction in ice level of up to 3,000 ft. [915 m.] in Marguerite Bay.

The south-western and south-eastern sides of Mount Hope are open amphitheatres with steep rock and ice walls but the northern sector is a vast snowfield extending almost to the summit. On both Mounts Faith and Charity, the main rock exposures are on their southern

Fig. 4. Mount Hope viewed from the south, showing its truncated southern ridge.

sides. A few low nunataks which are satellites of the main range can be seen as remnants of former ridges of the mountain massif.

East of the Eternity Range the plateau slopes relatively steeply to the Larsen Ice Shelf over a distance of 75 km. The relief is variable and is characterized by vast expanses of snow with small isolated nunataks and a few low mountains. At the base of the range is a level section, 1,800–2,000 m. in altitude, which varies in width between 2·5 km. in the north to 17 km. east of Mount Charity. East of long. 63° 45′ W. the plateau is deeply dissected by Bingham and Anthony Glaciers except for a broad gently sloping spur between them. Both Bingham and Anthony Glaciers have cut back the plateau escarpment to form inlets and they are severely crevassed with belts of pressure extending out into the Larsen Ice Shelf. Anthony Glacier, which is 25 km. long and 10 km. wide, emerges from the plateau surface to the east of Mount Sullivan; it has an overall slope of 1 : 20. To the south, where it enters the ice shelf, it is bordered by a 10 km. long scarp but generally the edges of the glacier merge into the surrounding snow slopes.

20 km. east of Mount Faith is Mount Sullivan, an elongate north-east trending mountain 8 km. long and 3 km. wide, which rises from the plateau at 1,600 m. to 2,255 m. Like the mountains of the Eternity Range, Mount Sullivan has a massive appearance with long ridges; one such ridge, 9 km. long, trends north-north-west from the backbone of the mountain and, although it slopes steeply off the mountain, for most of its length it is only about 1,700 m. high. Rock outcrops are largely confined to its crest and take the form of long ribbon exposures or isolated patches. The ridges on the south-eastern side of the mountain are shorter and steeper but again rock exposures are found mainly on the crests. Relatively gently sloping snowfields showing little crevassing occupy the areas between the ridges.

East of Mount Sullivan, the ground slopes in towards Anthony Glacier in a series of steps marked by small nunataks, their eastern sides being much lower than their western ones. Rock outcrops form small strips or patches, often covered with felsenmeer, near the crests of nunataks. Wind scour exposes rock, sometimes leaving a blue-ice surface on the western side and depositing a tail of snow to leeward east.

East and north-east of Mount Sullivan the spur between Anthony and Bingham Glaciers is 15 km. across and is dotted with nunataks; Engel Peaks (1,457 m.) and Mount Martin (1,340 m.) are the most prominent. The former overlooks a tributary of Bingham Glacier and the latter overlooks Anthony Glacier so that both have steep rocky scarp slopes on these sides; the slope around Engel Peaks descends from 1,300 to 700 m. in a steep scarp, and Mount Martin descends from 1,300 to 1,000 m. East of these peaks, the slope becomes increasingly convex towards the ice shelf but it is broken by the nunataks of Rhino Rocks which have a rock scarp to the east. Between the nunataks forming this scarp there are belts of crevasses. With increasing distance to the east, the nunataks are lower and more rock is exposed. The boundary between the plateau and the ice shelf is difficult to define but it is generally marked by severe crevassing and a break in slope.

Planed surfaces

Possible planed surfaces occur at various levels in northern Palmer Land:

i. The accordant summits of Mount Faith, Mount Hope and Mount Charity, and peaks in the Eland Mountains.
ii. The erosion level at 2,200–2,600 m. on Mount Charity.
iii. East of the Eternity Range between 1,800 and 2,000 m.
iv. South of Mount Charity at 2,100 m.
v. Relicts in the west on the summits of Mount Edgell and Mount Guernsey, 1,250–1,650 m. (Fig. 5).
vi. Between sea-level and about 250 m. to the east and south-east of Cape Jeremy.

The summits of the mountains of the Eternity Range show approximate accordance of altitudes between 2,850 and 3,226 m., and these are comparable to those of the peaks in the Eland Mountains farther south. Such accordant summit levels may be the remnants, but at a slightly lower level, of a peneplaned surface that has been dissected and destroyed by erosion. However, the Eternity Range and many of the peaks in the Eland Mountains are

Fig. 5. Planed surfaces on Mount Edgell and Mount Guernsey. (Photograph by J. Yates.)

mainly composed of granitic rocks, and Daly (1905) considered that erosion of such resistant rocks may also give rise to accordant summit levels.

At an altitude of 2,200–2,600 m. on Mount Charity, adamellite is overlain by a gently dipping succession of conglomerates containing adamellite and volcanic clasts, and reddish brown and green-coloured arkoses which are succeeded by andesitic tuffs and lavas. These volcanic and sedimentary rocks can be compared with the Lower Cretaceous rocks of Alexander Island where syndepositional volcanicity has resulted in the intercalation of andesitic material in the sedimentary rocks (Horne, 1968) and has laid down vitric shard deposits (Horne and Thomson, 1972). This erosion level has not been observed elsewhere but faulted, fossiliferous sedimentary rocks occurring at Crabeater Point, 150 km. to the north of Mount Charity have been given a probable Cretaceous age by Thomson (1967).

It is possible that the planations at 1,800–2,000, 2,100 and 1,250–1,650 m. represent the remnants of a surface considered to be an uplifted peneplain (Nichols, 1960; King, 1964; Linton, 1964) formed in the late Tertiary and having a residual relief of 1,000–1,500 ft. [305–457 m.] (Linton, 1964). This was dissected by rejuvenated rivers and subsequently by glaciation.

The peneplain has been affected by faulting in many places. The largest tectonic feature is George VI Sound which separates Palmer Land from Alexander Island. Many authors have considered it to be a rift valley (Adie, 1964, p. 151; King, 1964, p. 63) but Horne (1967, p. 21) has suggested that the western side was formed by thrusting. Faulting similar to that described by King (1964) in Alexander Island probably controlled the position of many of the glaciers in northern Palmer Land and is responsible for the differing altitudes of many of the planation surfaces.

Recent radio-echo sounding traverses over Palmer Land (Smith, 1972) have revealed that the ice is much thicker than Linton supposed, up to 1,630 m., and the plateau surface does not seem to reflect the sub-ice topography, suggesting that either the pre-glacial surface was not as smooth or low as Linton anticipated or that subsequent erosion has been much more effective than he thought.

The time of formation of the peneplain is also now in doubt. From evidence of Tertiary volcanism, ice-scoured erosion surfaces and till deposits in Marie Byrd Land, it is thought that an ice sheet has existed in Antarctica since the Miocene (Rutford and others, 1968) and even possibly since the Eocene (LeMasurier, 1971). In Graham Land, fossil penguins have been found in strata of a Lower Miocene age; in addition, the marine Mollusca show evidence of a colder marine environment and the flora is of cold-temperate type (Adie, 1964, p. 155). These discoveries are endorsed by Australian palaeotemperature measurements (Dorman, 1966) for the Tertiary which indicate a fairly large drop in temperature from Oligocene to Middle Miocene.

It is uncertain whether the ice piedmont to the west of Mount Edgell rests on a rock platform. There is a small rock outcrop at Cape Jeremy but no other rock exposure was seen underlying the ice piedmont. Moraine was absent. Similar ice piedmonts are common in the Antarctic Peninsula and Holtedahl (1929), Fleming (1940), Koerner (1964) and Dewar (1967) have discussed their mode of formation.

Glaciation

Major glacial features

All of the major glaciers are outlet glaciers draining various parts of the Palmer Land plateau, either to the east or the west. The largest is Fleming Glacier, 50 km. long and 20 km. wide which, like its neighbours farther north, drains the narrow Wakefield Highlands and nourishes the Forster Ice Piedmont in its lower reaches. Compared with other glaciers in the area, it has a very gentle gradient of 1 : 55. To the north it is bordered by Bristly Peaks, a continuous ridge of rock and snow, but to the south by several buttresses and hills, e.g. Garcie Peaks and Crescent Scarp; these are separated by gentle snow slopes in the west but by ice falls farther east. This side of the glacier is backed by the wide featureless plateau that characterizes Palmer Land south of lat. 69° 30′ S., from which there is a marked movement of ice into Fleming Glacier. Features like Crescent Scarp show little relief on their southern sides where plateau ice is thrust against the rock, whereas their steep north-facing rock buttresses are capped with ice which periodically collapses down their faces.

The glaciers that stem from the much wider part of the plateau south of the Wakefield Highlands are shorter and steeper than Fleming Glacier; Anthony Glacier, east of the Eternity Range, is only half as long and has a much steeper gradient of 1 : 22. These glaciers are also more severely crevassed by transverse crevasses which are convex up-stream, except where the glaciers merge with or enter the Forster Ice Piedmont. Prominent ice tongues have developed where such glaciers enter the Larsen Ice Shelf or George VI Sound. A number of median ice ridges are produced where ice passing between Mount Leo and the Mayer Hills merges with Prospect Glacier (Fig. 6), but no moraine was observed.

Where the mass of ice draining from the Wakefield Highlands via Airy, Rotz and Fleming Glaciers meets ice from the plateau to the south, flowing largely via the south side of Mount Leo and Prospect Glacier, the westward flow is constricted between Triune Peaks and Mount Balfour and between the latter and the Kinnear Mountains. This gives rise to a continuous series of crevasses covering virtually the whole of the western part of the Forster Ice Piedmont and extending out into a large section of the Wordie Ice Shelf.

Away from the main glaciers, changes in slope at the edge of the plateau are marked by belts of transverse crevasses accentuated where the ice is constricted between nunataks.

Cirques are common throughout this area and they are largest, with long divides, on north-facing slopes; this is well marked on Mounts Faith and Hope. It is probable that some of the long divides, e.g. the 9 km. long northward-trending ridge on Mount Sullivan, have a pre-glacial origin. The Relay Hills, Kinnear Mountains, Mayer Hills and other buttresses on the south side of Fleming Glacier are protected on their southern sides from cirque formation by their carapace of plateau ice.

As cirque sculpture proceeds, there is a steady elimination of minor divides (Linton, 1963), as on Mount Hope, where three main ridges radiate from the pyramidal summit and separate

Fig. 6. Median ice ridges formed where the glacier flowing northward between Mount Leo (left of photograph) and the Mayer Hills merges with Prospect Glacier. (U.S. Navy photograph.)

three wide cirques. A continuation of the process of divide reduction and shortening will ultimately produce a steep-sided horn. The large cirque on the north side of Mount Edgell has been formed by the coalescence of three smaller ones and vestiges of the inter-trough divides are still visible. A major cause of the rapid reduction of such divides is probably the presence of two sets of joints formed parallel to the cirque walls by spontaneous dilatation due to a release of pressure in the rock as erosion takes place (Battey, 1960). Joints such as these, together with tectonic joints, provide excellent media for freeze-thaw action and the constant cascade of debris down the south face of Mount Hope in summer is evidence of the efficiency of this process of erosion.

There seems to be no lithological control of the orientation of cirques. Most have been cut in volcanic rocks or gneisses in the west and in the Eternity Range in granitic rocks. Cirques cut across faults and contacts between igneous and volcanic rocks without being affected. This observation agrees with those made by Battey (1960) and Marsh and Stubbs (1969).

Minor glacial features

Minor glacial features vary considerably to the east and west of the Eternity Range. The area around Mount Edgell is studded with many sharp rocky nunataks and ridges which are partly surrounded by wind scoops varying in depth from 1 or 2 m. to as much as 30 m. These, as well as the large multiple cornices of soft snow that often decorate their edges, are mainly caused by wind eddying around the nunatak. The base of the wind scoop is flat, usually of blue melt ice and often contains a shallow lake in summer. Its surface is littered with debris loosened by freeze-thaw processes from the nunatak, and some of this has sunk into the ice to produce cryoconite holes. Bergschrund crevasses are sometimes present but there is always a gap between rock and ice caused by melting due to radiation from the rock face. Small circular mounds exhibiting radial crevasses, similar to those described by Van Autenboer (1962) and Brook (1972) are present at the bottoms of some wind scoops. They are thought to be formed by expansion due to water freezing at depth.

Apart from Mount Sullivan, nunataks east of the Eternity Range take the form of low snowy bumps in the landscape with small patches or strips of rock at their crests. At lower altitudes, below 1,250 m., more rock is exposed and east-facing rock scarps are prominent in parts. Rock exposure has been severely affected by frost shattering which produces felsenmeere (Fig. 7). The scouring effect of wind is very marked on the windward western side of these nunataks and tails of snow are deposited in their lee. Strong katabatic winds generated in the Eternity Range blow either east or west except where nunataks produce local effects.

Fig. 7. Felsenmeer which is common on nunataks to the east of the Eternity Range.

Sastrugi form intermittently over the whole area but in most parts they are short-lived and are soon buried by heavy frequent falls of snow. The only sastrugi found to exist for long periods were close to the base of the Eternity Range on its western side.

Blue icefields occur at altitudes below 1,250 m. to the east of the Eternity Range on the leeward (eastern) sides of the larger nunataks, e.g. at the base of Engel Peaks. It is thought that they represent older glacial ice appearing as a result of strong sublimation (Van Autenboer, 1964).

Examples of cavernous weathering (Fig. 8) are restricted to a small area on the north-east ridge of Mount Faith. They comprise round holes about 12 cm. in diameter and 12 cm. deep, cut into coarse granite whose surface dips to the south and they contain a small quantity of fine gravel. All of the conditions thought to be necessary for their formation are present in this area, i.e. a combination of strong insolation, excessive dryness with resultant chemical weathering and concentration of free salts, the physical action of freeze-thaw, and strong wind action which is also responsible for the removal of weathered material (Van Autenboer, 1964). A combination of frost action and chemical weathering is probably also responsible for the exfoliation boulders of granitic rocks found to the east of the Eternity Range (Fig. 9).

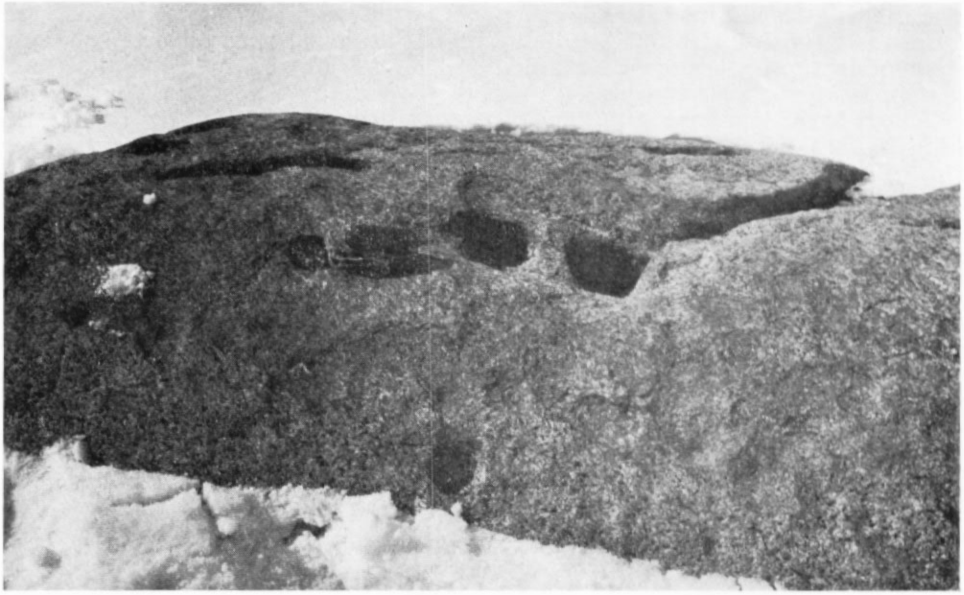

Fig. 8. Cavernous weathering on the north-eastern ridge of Mount Faith.

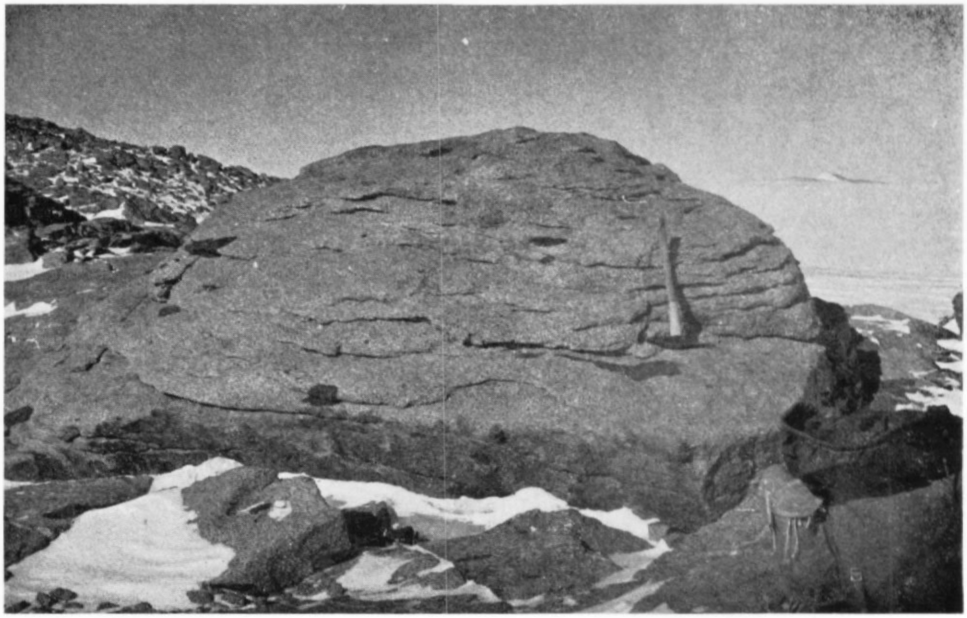

Fig. 9. Exfoliation boulder of granitic rock to the east of the Eternity Range.

Here, the sub-horizontal exfoliation layers bear no relationship to the vertical joints in the rock.

Very interesting "rill" features (Fig. 10) were observed north of the Relay Hills. They occur in an elongated amphitheatre which opens eastward; its northern side is formed by a nunatak with several rock buttresses and a curving snow spur forms the head and south side of the amphitheatre. A bergschrund traverses the northern slope under the lowest buttress and opens into a large depression at the head of the amphitheatre; it does not extend to the southern arm. The "rills" have a marked dendritic pattern and they converge and "flow" as one stream at the base of the hollow. Upwards they branch repeatedly and become progressively shallower before petering out just below the bergschrund. From a distance, these features seem to have smooth though gently curving courses but on closer examination they are seen to be very sinuous. They are less than 30 cm. in depth and are found on a relatively hard snow cover; blue ice was not seen near the surface in the amphitheatre nor in the bergschrund.

Fig. 10. "Rill" features on a north-facing snow slope to the north of the Relay Hills.

There is no record of occurrences of similar features in other parts of the Antarctic Peninsula or Alexander Island and, so far, no completely satisfactory explanation for their origin has been found. The "rills" exhibit few of the characteristics of wind ridges and their marked dendritic pattern suggests an origin due to water action. It is possible that these features reflect the shape of melt-water channels found in blue ice some distance beneath the present snow cover.

Seligman (1962) quoted examples of channels formed in rain crust caused by the freezing of wetted snow but these tend to be narrow and deep with steep sides compared with those found in the Relay Hills. A hard crust is often formed in this area due to melting of the surface during the day (down to a depth of 30 cm.) and freezing at night but no heavy falls of rain have been reported so far south in the Antarctic Peninsula.

Nichols (1953) described sun ridges and trenches ("*nieves penitentes*") from Marguerite Bay but these tend to have a wedge-shaped cross-section which dips southward at an angle approximately equal to the altitude of the sun at noon and they are closely associated with bare rock.

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REFERENCES

Adie, R. J. 1964. Geological history. (*In* Priestley, R. E., Adie, R. J. *and* G. de Q. Robin, *ed. Antarctic research*. London, Butterworth and Co. (Publishers) Ltd., 118–62.)

Battey, M. H. 1960. Geological factors in the development of Veslgjuv-botn and Vesl-Skautbotn. (*In* Lewis, W. V., *ed. Investigations on Norwegian cirque glaciers*. London, Royal Geographical Society, 5–10. (R.G.S. Research Series, No. 4.))

Black, R. B. 1945. Geographical operations from East Base, United States Antarctic Service Expedition, 1939–41. *Proc. Am. phil. Soc.*, **89**, No. 1, 4–12.

Brook, D. 1972. Physiography and glacial geomorphology of the Theron Mountains. *British Antarctic Survey Bulletin*, No. 27, 25–37.

Daly, R. A. 1905. The accordance of summit levels among Alpine mountains. *J. Geol.*, **13**, No. 2, 105–25.

Dewar, G. J. 1967. Some aspects of the topography and glacierization of Adelaide Island. *British Antarctic Survey Bulletin*, No. 11, 37–47.

Dorman, F. H. 1966. Australian Tertiary paleotemperatures. *J. Geol.*, **74**, No. 1, 49–61.

Fleming, W. L. S. 1938. Geology and glaciology. (*In* Fleming, W. L. S., Stephenson, A., Roberts, B. B. *and* G. C. L. Bertram. Notes on the scientific work of the British Graham Land Expedition, 1934–37. *Geogrl J.*, **91**, No. 6, 508–12.)

———. 1940. Relic glacial forms on the western seaboard of Graham Land. *Geogrl J.*, **96**, No. 2, 93–100.

Holtedahl, O. 1929. On the geology and physiography of some Antarctic and sub-Antarctic islands. *Scient. Results Norw. Antarct. Exped.*, No. 3, 172 pp.

Horne, R. R. 1967. Structural geology of part of south-eastern Alexander Island. *British Antarctic Survey Bulletin*, No. 11, 1–22.

———. 1968. Petrology and provenance of the Cretaceous sediments of south-eastern Alexander Island. *British Antarctic Survey Bulletin*, No. 17, 73–82.

———. *and* M. R. A. Thomson. 1972. Airborne and detrital volcanic material in the Lower Cretaceous sediments of south-eastern Alexander Island. *British Antarctic Survey Bulletin*, No. 29, 103–11.

Joerg, W. L. G. 1936. The topographical results of Ellsworth's trans-Antarctic flight of 1935. *Geogrl Rev.*, **26**, No. 3, 454–62.

King, L. 1964. Pre-glacial geomorphology of Alexander Island. (*In* Adie, R. J., *ed. Antarctic geology*. Amsterdam, North-Holland Publishing Company, 53–64.)

Koerner, R. M. 1964. Glaciological observations in Trinity Peninsula and the islands in Prince Gustav Channel, Graham Land, 1958–60. *British Antarctic Survey Scientific Reports*, No. 42, 45 pp.

LeMasurier, W. E. 1971. Volcanic record of Cenozoic glacial history of Marie Byrd Land. (*In* Adie, R. J., *ed. Antarctic geology and geophysics*. Oslo, Universitetsforlaget, 251–59.)

Linton, D. L. 1963. The forms of glacial erosion. *Trans. Inst. Br. Geogr.*, **33**, 1–28.

———. 1964. Landscape evolution. (*In* Priestley, R. E., Adie, R. J. *and* G. de Q. Robin, *ed. Antarctic research*. London, Butterworth and Co. (Publishers) Ltd., 85–99.)

MARSH, A. F., *and* G. M. STUBBS. 1969. Physiography of the Flask Glacier–Joerg Peninsula area, Graham Land. *British Antarctic Survey Bulletin*, No. 19, 57–73.

NICHOLS, R. L. 1953. *Geomorphology of Marguerite Bay, Palmer Peninsula, Antarctica.* Washington, D.C., Department of the Navy, Office of Naval Research. [Ronne Antarctic Research Expedition, Technical Report No. 12.]

————. 1960. Geomorphology of Marguerite Bay area, Palmer Peninsula, Antarctica. *Bull. geol. Soc. Am.*, **71**, No. 10, 1421–50.

RONNE, F. 1948. Ronne Antarctic Research Expedition, 1946–48. *Geogrl Rev.*, **38**, No. 3, 355–91.

RUTFORD, R. H., CRADDOCK, C. *and* T. W. BASTIEN. 1968. Late Tertiary glaciation and sea-level changes in Antarctica. (*In* TANNER, W. F., *ed.* Tertiary sea-level fluctuations. *Palaeogeogr., Palaeoclim., Palaeoecol.*, **5**, No. 1, 15–39.)

SELIGMAN, G. 1962. *Snow structure and ski fields.* 2nd edition. Brussels, Jos. Adam.

SMITH, B. M. E. 1972. Airborne radio echo sounding of glaciers in the Antarctic Peninsula. *British Antarctic Survey Scientific Reports*, No. 72, 11 pp.

THOMSON, M. R. A. 1967. A probable Cretaceous invertebrate fauna from Crabeater Point, Bowman Coast, Graham Land. *British Antarctic Survey Bulletin*, No. 14, 1–14.

VAN AUTENBOER, T. 1962. Ice mounds and melt phenomena in the Sør-Rondane, Antarctica. *J. Glaciol.*, **4**, No. 33, 349–54.

————. 1964. The geomorphology and glacial geology of the Sør-Rondane, Dronning Maud Land. (*In* ADIE, R. J., *ed. Antarctic geology*. Amsterdam, North-Holland Publishing Company, 81–103.)

WILKINS, H. 1929. The Wilkins-Hearst Antarctic Expedition, 1928–29. *Geogrl Rev.*, **19**, No. 3, 353–76.