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RAISED BEACH DEPOSITS AND THE DISTRIBUTION OF STRUCTURAL LINEAMENTS ON MACQUARIE ISLAND

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(with two text-figures and seven plates)

ABSTRACT

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The distribution of previously-unmapped raised beaches on Macquarie Island makes it difficult to accept earlier interpretations of landform evolution. These raised beaches occur up to 270 m ASL, and in places previously thought to have been glaciated. The elevation of the beaches and the distribution and shape of many of the island's plateau lakes and structural lineaments would appear to be consistent with a history in which rapid uplift associated with block-faulting and other tectonic factors played a much more important role in landform evolution than has been recognised in the past.

INTRODUCTION

Some interest from time to time has attached to the geomorphic history of Macquarie Island but since the long period of field work there (late 1911-late 1913, see Mawson 1942: 277-298) by Blake (Mawson 1943) the number of people-hours spent researching this aspect of the island's evolution has been both spatially and chronologically scattered and rather sparse, being mainly limited to a few days during re-supply of the ANARE station established on the northern end of the island in 1948. Since then, results of comparatively extensive and detailed biological, geological and related work (e.g. see Betts 1980, 1981a, 1981b, 1981c, 1981d) together with some results from work in oceanography and marine geology (e.g. Hayes 1972, Kennett *et al.* 1974, specifically pages 121-3) form a background against which ideas about the landform evolution of Macquarie Island can be reassessed. In particular it is worth awaiting the opportunity to test conflicting theories about the nature and extent of Quaternary glaciation (e.g. Mawson 1943, Colhoun & Goede, 1974, Peterson 1975, Orlov 1977, and Loffler & Sullivan 1980). Remote and isolated, amid a large expanse of the Southern Ocean, Macquarie Island is a lonely representative of the few terrestrial environments which are so important to many Southern Ocean species, the origin and dispersal of which will have been influenced by Quaternary events. The history of these events must be assembled from evidence on the islands and on the sea floor.

The bathymetry of the ocean south of the Tasman Sea (e.g. Cullen 1969, Hayes & Talwani 1972, fig.1), suggests that Macquarie Island is situated on the emergent crestal sector of a ridge (The Macquarie Ridge) which has been formed by the interaction of the Pacific and Indian tectonic plates. The northernmost part of the ridge is coterminous with New Zealand from whence it runs south to join the Indian-Pacific mid-ocean ridge system on a part of the Antarctic Ridge (e.g. see Varne *et al.* 1969, fig. 1) which continues through the Balleny Islands to the Ross Sea.

The island is formed of brecciated and pillowed basalts together with dolerites, gabbros and serpentinized peridotites (Varne & Rubenach 1972). This ophiolitic association has been recognised as relatively pristine mid-Tertiary oceanic lithosphere created at the Antarctic mid-oceanic ridge (Griffin & Varne 1980, Griffin 1982). These have been uplifted during activity along the seismically-active Macquarie Ridge to form a plateau some 35 km long by five km wide standing 300-400 m above sea level.

Geological fault-zones are common, the island consisting of a number of fault-bounded blocks, probably on all scales (Varne & Rubenach 1972, p.251). Earthquakes are shallow and first-motion analyses imply that the ridge is associated with normal, thrust and strike-slip faulting (Hayes & Talwani 1972).

Such a geological setting suggests that overall uplift, and the distribution of lineaments (mainly fault-lines) will be very important influences upon landform evolution. Such a notion has guided our recent field work on Macquarie Island (R.L. Nov. 1976 to Nov. 1977, Nov. 1979 to Nov. 1980; J.A.P. Nov. 1980, Nov. 1982) which, instead of concentrating upon searching for evidence of glaciation, has involved extending observations made by earlier workers of features that can be related to structural and tectonic control of geomorphology. Thus, this paper is predominantly about the distribution of raised beaches and of lineaments.

RAISED BEACHES

Previous Discoveries

Mawson (1943) noted that "As viewed from the sea, the skyline of the land is generally uniform as to be strongly suggestive of former planation, probably marine planation prior to [... what he envisaged as ...] the period of glaciation." (plate 1)

He also noted a coastal raised beach predominantly along the northern part of the west coast of the island from the isthmus southwards to Bauer Bay with intermittent narrow strips on the east coast. Evidence for this beach is backed up by the occurrence of several sea caves and arches five to ten m above sea level (Aurora and Eagle caves, plate 2) and a surprising amount of mostly overgrown flotsam and evidence of shipwrecks up to 300 m from the waters edge. An abundance of sea stacks can also be seen between Handspike Point and Soucek Bay on the western coastal plain with many others scattered along other sections of the coast.

Plate 1 The plateau surface in the region of Scoble and Island Lakes. It is in this northern part of the plateau that the majority of the beaches discovered so far are preserved. Several terraces can be seen on the plateau edge in the left centre foreground. The 260-270 m and the 180-210 m beaches occur on the plateau.

Mawson also noted that there exists at Bauer Bay, deposits capped by a layer of boulders which he stated probably belong to the time of the raised beach. The boulder beds are approximately 15 m above sea level and the sand below contains King penguin and diving petrel bones.

Orlov (1977) in the company of one of the authors (R.L.) discovered beach pebbles overlain by 3-4 m of peat on Wireless Hill in 1976 (Beach 1, fig. 1 N). The remnants of this beach stand 100 m above present sea level. Orlov also remarked on numerous terraces at various heights between 28 and 240 m ASL which he thought were of marine origin. The presence of the higher terraces calls into question some previous accounts of the distribution of glacial landforms in that beach pebbles would probably be redistributed and terraces smoothed out if overridden by ice.

Although the raised beach pebbles on the terraces described here indicate a marine origin for them, it is other (periglacial) terrace types that have been mapped to date (e.g. Taylor 1955, Loffler *et al.* 1983). Clearly the distribution of the beach pebbles and their terraces should also be mapped.

Distribution of Raised Beaches and Related Terraces

Between the present sea level and the hills of the island plateau, several clearly-defined beach terraces have been located. These terraces have been mapped (fig. 1) and many of them are thought to have been of marine origin. The most clearly-defined of these levels are found 260-270 m, 180-210 m, 150 m, 90-100m, and 10-15 m above sea level. On all these terraces beach deposits varying from coarse sand or cobbles to large rounded boulders have been found. The remainder include terraces with exposed bedrock that may carry shingle, as do present-day wave-cut platforms, but which on the older raised terraces is buried by debris from the back-slope. These features are not mapped as comprehensively as those with rounded beach pebbles.

The results of the mapping are presented in the folding maps (figs 1 and 2) and described below. Terraces at heights between about 270 m and 1-3 m are mapped. Because of the extensive block-faulting referred to above, the conveniently-clustered terrace height-ranges should not be taken as indicating contemporaneity between separated terraces. The ranges, nevertheless form convenient categories within which the occurrences are described and discussed below. Some locations are reported with reference to spot heights marked on the National Mapping Division map (1:50 000) Macquarie Island (first edition, Nov. 1971).

Plate 2 - The west coast of Macquarie Island showing many of the abandoned sea stacks which occur on the 8-9 m beach below the plateau surface. Aurora Caves looking north.

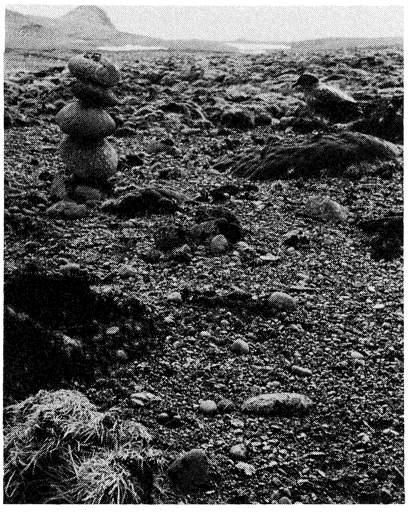
Plate 3 - Beach cobbles at about 260 m ASL, NNE of Scoble Lake.

1. 260-270 m Beaches

Scoble Lake Beach

During 1980 an area of well-rounded boulders (plate 3) of considerable size (30-40 cm) was found on the well-worn path 200 m NNE of Scoble Lake on the northern section of the plateau (Beach 2, fig. 1 N). On tracing this raised beach which intersected the path at a NNW/SSE line, areas of boulders were found extending for 1000 m across the face of the hill on the slopes of North Mountain at a height of 260-270 m ASL. The boulders were unbedded with other beach deposits varying from coarse sand to small pebbles. A shallow excavation revealed the depth of the deposits to be in excess of 0.25 m and there appeared to be two definite horizons, one 10 m above the other. Heights were measured by aneroid altimeter and were therefore not particularly accurate but checks with trig. points suggest an accuracy of ±20 m. These beach deposits are not obvious topographically but occupy a gently-sloping hillside with only one area of clearly-defined notching forming a low cliff-line along the face of North Mountain. At the northwestern extremity, the slope is much more gentle and the deposits are widely scattered over the hillside with no clearly-defined margin.

A search of the northern slope of North Mountain revealed the remnants of the beach on the other side of what must have been a small island consisting of North Mountain, Mt Elder and Mt Blair when Macquarie Island first rose above sea level as a result of tectonic uplift (Beach 3, fig. 1 N).

To the south, other mountains would have probably been exposed, but no definite beaches have yet been found at a level as high as those on North Mountain.

A search of the northern third of the island, north of the Sandy Bay/Bauer Bay line revealed a large number of terraces particularly where the slopes became quite gentle, or on flats such as ridge tops. On some of these, beach deposits were found. It became clear early in the investigations that only on these gently-sloping areas would clear evidence of beaches be found. On the rocky and steep hillsides, platforms and beach deposits still in place would be masked by talus.

2. 180-210 m Beaches

Island Lake, Scoble Lake Terraces

Several flat-topped terraces, 190 m ASL and facing NW can be seen between Scoble and Island Lakes. Scattered round boulders 0.2 to 0.3 m in length (see plate 3) and clearly beach-worn (Beach 4, fig. 1 N) form the surface. The terraces are flat-topped, unvegetated (except by clumps of moss) and 50-100 m wide. They form two distinct lobes. This area however is somewhat confusing since a few of the boulders have, on their lower surfaces, striae which may be glacial on origin. It is suggested that such boulders may have originated at a higher level (perhaps on the 260-270 m beach) on the south side of Boot Hill and have been carried down to their present site by a small glacier. These terraces may therefore mark the limit of glaciation in the Scoble Lake/Island Lake Basin. A diligent search of the valley above the terraces up to Boot Hill failed to reveal any sign of the occasional pebble which would have inevitably been dropped *en route*. Nor are there any beach pebbles below the terraces to indicate that they were deposited during a retreat of the glacier from lower altitude. This area warrants further investigation.

Stony Creek and Flat Creek Beaches

On the northern side of Stony Creek valley, at a height of 180 m ASL, a beach extends for 100 m along the hillside in an area which has been eroded of its peat cover (Beach 5, fig. 1 N). The exposure is approximately 20 m in width. Many of the larger boulders, which range up to 0.35 m in diameter, have moved down slope. The vertical thickness of the deposit is therefore difficult to estimate; it is probably two to three metres.

In contrast, on the southern side of Flat Creek at 190 m ASL, where slopes are much gentler, a similar deposit rests, comparatively unmoved, with regolith above and below fashioned into solifluction terraces (Beach 6, fig. 1 N).

Tulloch Lake

Several beach pebbles were found at 170 m near the SW corner of Tulloch Lake and similar terraces to those on the south side of Flat Creek were found on the ridge between Flat and Stony Creek near spot height 178. Exposed rock outcrops suggest the survival of an old wave-cut platform. No pebbles were found.

Other localities

At roughly the same height above sea level as those described above, several other localities support the case for a beach at 180-210 m ASL in this area.

Island Lake.- On the walking track about one km SSW of Island Lake beach pebbles up to 0.15 m in diameter were found.

Douglas Bay.- On the plateau edge above Douglas Bay 150 m south of spot height 243, beach pebbles up to 0.1-0.2 m in diameter were found.

Prion Lake.- Several beach pebbles were found at 180 m at the NE end of the lake near the walking track.

Skua Lake.- On the plateau edge between Sellick and Soucek Bays about one km north of Skua Lake, and also in the valley of the river draining the lake between Mt Eitel and Mt Ifould and running into Skua Lake, numerous beach pebbles can be found on the cliff edge (Beach 8, fig. 1 N).

Major Lake.- On the northwestern (windward) shore of Major Lake, between the edge of the lake and the plateau cliffs, a bank of fine beach shingle, with boulders up to 0.4 m in diameter, has been found (Beach 9, fig. 1 N). Major Lake faces west, directly into the prevailing winds. That shingle is found on the windward but not on the lee shores of this and other lakes illustrates the difference in rates of shingle formation on lake and sea shores on Macquarie Island. Pebbles subject to lake shore processes on Macquarie Island are not yet modified beyond sub-angularity. In each case examined to date the presence of well-rounded cobbles on lake shores can be attributed to a raised (marine) beach deposit there or nearby.

In addition, a number of terraces can be seen at various parts of the island at approximately the same heights as the above-mentioned beaches. At 180 m elevation on the slopes above Gadget Gully (Heartbreak Hill) a well-defined terrace can be traced north towards Perseverance Bluff. Several clearly-defined terraces can also be seen on the walking track between Island Lake and Bauer Bay, particularly near a small un-named lake one km south of spot height 219. Others can be seen in the Finch Creek, Green Gorge and Pyramid Peak areas.

On either side of Jessie Niccol Creek, Waterfall Bay, an extensive area of terraces between 180-200 m ASL has been mapped but no definite evidence to indicate marine origin was found during one brief search.

3. 150 m Beach

The 200 m contour defined the lower edge of the plateau over the majority of Macquarie Island. Only in a few areas, mainly the major river valleys, does gently-sloping or flat-lying ground occur below this height.

Between the plateau edge and the coastal plain the coastal cliffs are steep, and eroding so rapidly that raised-beached deposits would be redistributed and/or buried. Thus scope for preservation of readily-identifiable *in situ* beach deposits here is limited.

A beach, however, has been found consisting of sand with cobbles up to 0.1 m in diameter on the summit of the windswept ridge between Stony Creek and Flat Creek at a height of 150 m ASL; one of the few areas of gently-sloping ground below 200 m. The beach material covers a large area on the summit of the ridge (Beach 7, fig. 1 N). It is essentially flat-lying and well-exposed between small banks of moss and grass. An excavation down to 0.2 m revealed mainly rounded shingle between 50 and 200 mm in length with some angular fragments of frost-shattered rock. Below this beach lies a series of peat-covered terraces extending northwards down to Gentoo Flat. These terraces occur at approximately ten m intervals between 100 and 140 m above sea level. Two others can be seen at 50 and 80 m respectively.

Further evidence of a 150 m beach occurs in the form of well-developed terraces at Sawyer Creek, Jessie Niccol Creek, Lusitania Creek and in Caroline Cove Creek below Mt Haswell.

4. 100 m Beach

The 100 m level forms a distinct shelf-like platform on both sides of the deeply-incised bed of Stony Creek near Bauer Bay. Rock is exposed immediately below the lip of the southern bank terrace, capped in parts by a thin layer of peat. This area may therefore have been a wave-cut platform.

The plateau edge on the side of Wireless Hill has been eroded to expose the raised beach (plate 4) mentioned previously (Orlov 1977). This beach is overlain by 3-4 m of peat which has been found to contain marine littoral diatoms and pollen from seashore plants (Selkirk *et al.* 1983). A near-basal sample of this peat (about four m below the surface of the peat) indicates a minimum age of about 5500 years for the beach (see Selkirk *et al.* 1983, table 1 and fig. 6). Samples taken at 394 m contained phytoliths, diatoms, chysomonad cysts and abundant grass pollen all of which indicate a sequence of deposition in a seashore environment (Selkirk *et al.* 1983).

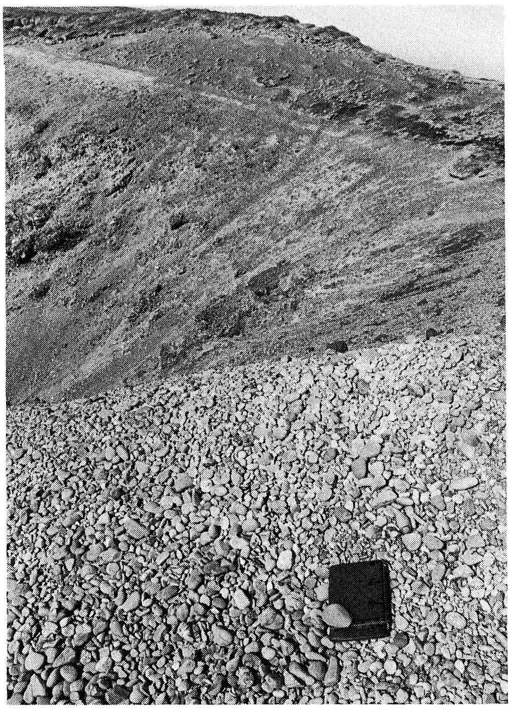

Plate 4 - Beach pebbles at 100 m elevation on the western edge of the plateau-top of Wireless Hill. Photograph: J.J. Scott.

Several pebbles were also found on a terrace approximately 400 m north of Green Gorge at a height of 110 m ASL and may have resulted from the same sea level. Several other terraces have been mapped 1.5 km NW of Green Gorge and also in Sawyers Creek 5 km SW of Green Gorge.

5. 8-9.1 m Beach

The evidence for the existence of a 9 m beach has been discussed by Colhoun & Goede (1973). This terrace is exposed in three areas, Bauer Bay, Green Gorge and Finch Creek (Sandy Bay) and consists of several metres of interbedded deposits containing fossil King penguin bones capped by sand and cobble beach-deposits. The penguin bones have been dated to a maximum of 6100 ±120 years B.P. (Gak - 643) and the peats above the cobbles to an age of approximately 2000 years B.P.

Terraces of similar height to these beaches are widespread through the island (plate 2).

6. 1-3 m Beaches

The isthmus surface is covered by a layer of shingle surmounted by several abandoned sea stacks. Excavations have revealed rock platform at approximately 3 m ASL in the area of the ANARE station. Two distinct wave-cut platforms can be seen on Garden Bay rock on the north side of Garden Bay. One is exposed below a rock face only about a metre above present normal high tide. The other is approximately 2 m ASL and is exposed to seaward of the lower beach and on the eastern top of the rock point. Both of these wave-cut platforms can also be sighted at various parts of the coast – notably the east coast, the lower platform (1 km approx.) can be seen on the rocks at the north side of Sandy Bay (where it is often covered by heavy swells) and also in Secluded Beach and Goat Bay.

The higher platform is well developed at the northern end of Secluded Bay and also at Green Gorge approximately 300 m north of the hut.

Raised Beaches and Landscape Evolution

Raised beaches represent net changes in sea level and may, in the form of isostatic marine limits, be important indicators of local ice margin fluctuations. Particularly-well-dated flights of raised beaches or terraces have been used to construct eustatic sea level curves once allowance has been made for tectonic effects (e.g. Chappell 1983). Alternatively, if the terrace sequence is but sparsely dated such information as exists may be used to infer uplift rates after correction factors from the eustatic curves have been applied. Thus in southern Fiordland, New Zealand, an average uplift rate of 4.3 mm/yr for the last 240 000 years has been inferred (Bishop 1983) and further north, in southern Westland a rate of 5 mm/yr for the last 9700 years is reported (Cooper & Bishop 1979). Macquarie Island is on the same plate boundary as these localities. Selkirk *et al.* have inferred a maximum possible uplift rate that would average 14 mm/yr for the Wireless Hill area for the last 5500 years. During the last two thousand years or so lower rates appear to have prevailed south of the isthmus, as indicated by the dating of basal peats on marine terraces on both sides of the island close to sea level (e.g. 1.5-4.5 m/1000 years - see Colhoun & Goede 1973). However late Quaternary uplift rates need not have been constant, nor evenly distributed. The rocks of Macquarie Island are part of the mid-Tertiary oceanic lithosphere (Griffin & Varne 1980) and their uplift to elevations higher than that of any other part of the Macquarie Ridge suggests that uplift rates for the island must be amongst the highest for the ridge as a whole. Clearly, as for other parts of this same plate-boundary collision zone, raised terraces such as those described above bespeak rates of tectonic activity commensurate with a high degree of endogenic control of landscape evolution. It is argued in the next section that this control is evident in the landscape.

STRUCTURAL GEOMORPHOLOGY

Seismic activity on Macquarie Island is frequent though generally minor. Historically, earthquakes have been documented since the first recorded visitors arrived at Macquarie Island in 1810 (see Cumpston 1968, pp.5, 37). Bellinghausen recorded earthquakes when lying at anchor offshore (*op. cit.*, p.44). Cumpston (1968) recorded earthquake reports by several sealing expeditions. Mawson (1943, pp.64-65) listed ten earthquakes of varying intensity (some quite severe) during the A.A.E. party's sojourn during 1911-1913, and several very severe tremors were felt by a sealing gang from the vessel *Betsy* between October 1915 and May 1916.

In recent times a strong earthquake (Richter scale 6.7 - Ledingham 1978) in 1977 and a similar one in 1980 (Ledingham 1981) caused widespread rockfalls and mud slides around the island. The epicentres of both were shallow and 20-40 km to the west of the island. Many aftershocks were even closer - some 200-300 being recorded in a few days after the 1980 shock.

Such activity prompted closer examination of the few good-quality air photographs available of the plateau, and it became evident that the structural geology, and in particular the distribution of faults, may have played a much greater role in the formation of geomorphological features of Macquarie Island plateau than previously thought. Prominent lineaments were mapped (figs 2 N and 2 S) and can be seen to coincide with many of the main topographic trends. The patterns evident from these maps prompt an alternative interpretation of many of the features formerly attributed to glaciation. For instance, many of the lakes and straight valleys mapped as glacial troughs are fault-controlled in such a way as to preclude glaciation as a necessary agent in their formation (e.g. see plate 5).

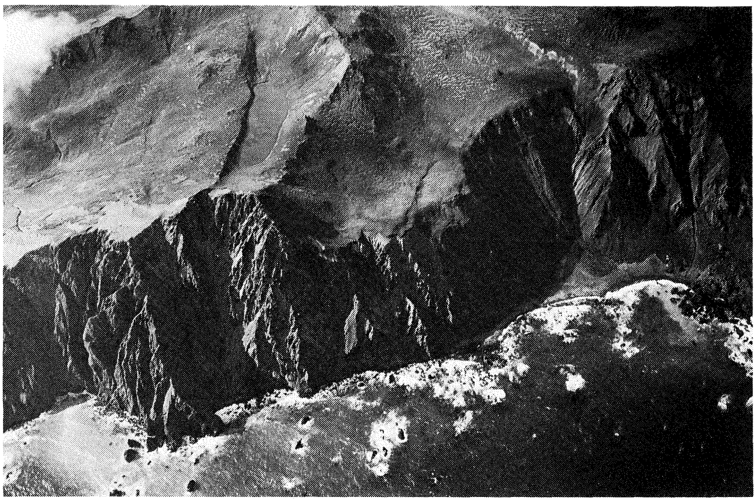

Plate 5 - A typical faulted lake basin on the south coast of Macquarie Island near Hurd Point. Several other faults can be seen in the area.

Scoble Lake

The 260-270 m marine terrace lies at its closest point, some 200 m from Scoble Lake and some 20-30 m above it, extending through into the col between North Mountain and Boot Hill above the lake. Many of the smaller surrounding lakes are on the lower terraces, between 220-256 m, which also may be of marine origin. Scoble Lake, however, is bounded on its southern side by a rock wall which forms part of a lineament running west into Half Moon Bay and to the east into Nuggets Creek forming the col between Boot Hill and North Mountain.

Soundings taken in the lake revealed that it is much deeper on the rock wall side (5 m) which presumably forms a natural dam. This type of lake is quite common on the island. For example, a lake immediately south of Mt Ainsworth (near Hurd Pt, plate 5) is bounded on one side by a clearly-defined lineament; one of a number in this area (plate 5 and fig. 2 S) A minimum age for the oldest deposits beneath the floor of this lake is 8700 ± 220 B.P. (Wk-349) (Salas 1983).

South of a line between Sandy Bay and Bauer Bay the island consists of fault-bounded blocks of volcanic rocks (mainly pillow lavas). Several major, and a large number of minor faults have formed depressions in which many of the island's lakes lie. The fault lines are evident on air photographs and have been mapped as lineaments.

Square Lake

The distribution of lineaments in this area suggests that Square Lake is fault-dammed on its western side. The wall is now breached by a small stream and the basin so formed, is filled almost completely by silt. Before breaching the fault wall, the lake has obviously overflowed to the northeast into Finch Creek. A small corrie glacier may have existed on the southern face of the hill (210 m) immediately to the north. The lineament can be seen on the western flank of this hill extending south across the headwaters of

Flat Creek where what are probably fault lines (at least three) mark sunken road-like depressions at right angles to the line of the valley.

Tulloch Lake

Further east, two parallel lineaments trending NE towards Finch Creek, outline the depression in which Tulloch Lake now lies.

Prion Lake

Prion Lake, Macquarie's deepest lake, also lies in a depression bounded by lineaments that strike in the same direction as the Tulloch Lake faults (NE). On the NW bank, which is very steep, the main lineament is paralleled by two others. All three can be traced NW to Mt Tulloch. The lineament forming the SE bank can be traced SW along the flank of Mt Eitel eventually forming the back wall of the valley which drains SW into Skua Lake.

Nearing the walking track to the NE of the lake, several beach pebbles were found. These pebbles were up to 60 mm in diameter and are unlikely to have been deposited by skuas or ANARE personnel. A beach, therefore, may have existed in this area; perhaps *in situ* or on the flanks of Mt Eitel whence the pebbles were transported by mass wasting (probably periglacial) to their present site.

Barker Lake - 1 km east of Mt Ifould

This lake is also bounded by lineaments on both sides with a series of terrace-like steps formed by parallel fault-lines on the flanks of Mt Ifould and Mt Eitel.

An upthrusted fault-block, described by Colhoun & Goede (1974, p.12) as a low-level kame terrace, follows the line of Red River. The continuation of this same lineament, to the southwest past Mt Ifould, was mapped by the same authors as a melt-water channel. Close inspection reveals that this lineament can be traced over the col to the south into the next valley. For this to be a melt-water channel it would, because it rises over a col, have to be subglacial and therefore beneath a relatively thick glacier which would probably have left a more obvious legacy than is evident.

Brothers Fault-line

Brothers Fault-line has been used as a convenient name for one of the most impressive and clearly defined lineaments on the island, apart from those that actually determine the general outline of the coast and plateau edge (plates 6 and 7).

From Nuggets Point to Sandy Bay, the Brothers Fault-line probably defines the edge of the coastal rock platform. South of Sandy Bay it strikes inland between Brothers Point and Mt Tulloch causing the formation of a coastal ridge as far south as Green Gorge. It continues south from Green Gorge along the western flank of Sawyer valley, again forming a flat-topped coastal plateau at a height of about 200-250 m. After crossing Jessie Niccol Creek, it can be traced in the coastal cliffs south of Waterfall Bay. The same fault, or another parallel to it, forms the rock-bar at the mouth of Lusitania Creek and continues southwest of Mt Aurora, Mt Jeffryes and across the head of Whiskey Creek finally terminating in the sea at Hurd Point. An ESE dip is suggested by the displacement of its line to the east where it is close to sea level.

The northern section of this lineament, Brothers Point and Green Gorge stands out very clearly on air photographs (plate 6). The upward displacement of the eastern side is clearly visible on the coastal cliffs south of Brothers Point where a rampart-like ridge runs parallel to the plateau edge, but some 50 m below it for approximately 300 m. Scree-covered slopes have developed from fault-breccias shed from the uplifted (eastern) side of the fault and may be traced as far south as Red River. These unusual screes also occur between Green Gorge and Pyramid Peak. The structural control of topography in the area is reflected in the drainage pattern: eastward draining streams have been dammed by upthrust rock thresholds. The lakes thus formed have been silted and their outflows have subsequently breached the threshold to flow eastward into the sea (plate 6).

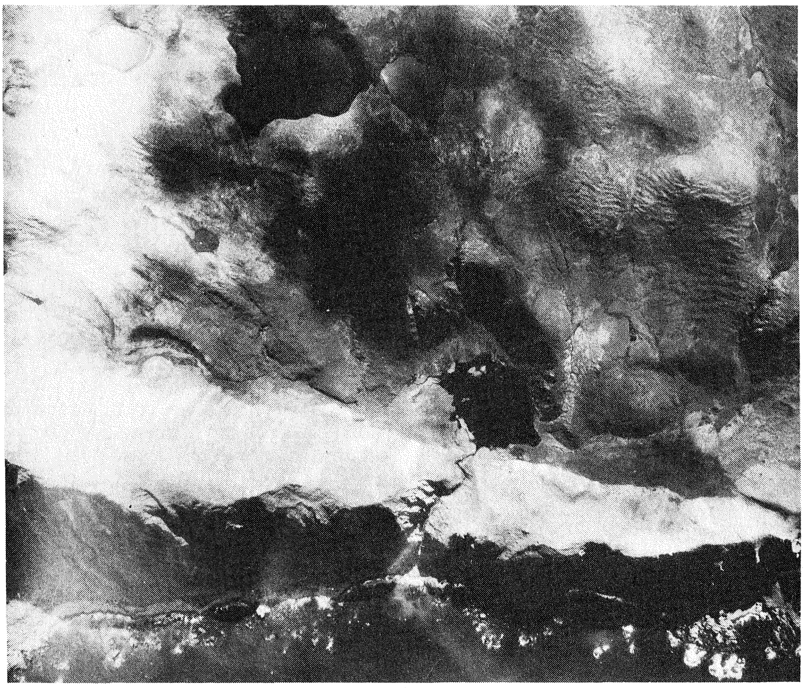

Plate 6 - The prominent lineament of the Brothers Fault-line showing breccia screes (lighter shading) and the small fault-dammed lake which has breached the upthrusted coastal ridge (lower). Vertical air photograph, Macquarie Natmap run 6, CAS8470 No.66, 6/2/76 (ANARE negative number 31999).

Among other lakes dammed by such faulting, some, including those drained by Red River and Lusitania Creek, have been drained because of incision but a small remnant of the Green Gorge Lake remains.

Doubts about a glacial origin for Major Lake have been published (Peterson 1975). This is further confirmed by the existence of raised beach pebbles on the 50-100 m wide lip of the plateau edge between the lake and the sea. The distribution of lineaments in this area suggests that faulting accounts for lake-forming drainage disorganisation. Some of the lineaments are more persistent than others. For instance, the lineament forming the depression in which the small triangular lake at the NE corner of Major Lake lies, extends south through the col between Mt Gwyn and Mt Martin and the line of it can be traced down into Lusitania Creek.

The pattern of lineaments around the lake south of Mt Blake further support tectonic origin as the most likely explanation for most lakes in this area.

Steep cliffs on the Mt Blake side of Flynn Lake and on the Mt Waite side of Lake Gratitude suggest that these lakes too, were dammed as the result of block or step-faulting.

LANDSCAPE EVOLUTION

The presence of raised beaches and of structural lineaments is to be expected in tectonically-active locations such as the boundary zone between tectonic plates. The distribution pattern of the lineaments indicates the nature of structural control upon the landscape, and casts doubt upon some landscape interpretations invoking extensive glaciation.

Plate 7 - Brothers Fault-line clearly showing the upthrust eastern coastal wedge (right) and a small lake basin partially filled with sediment and bog. This was interpreted earlier as a melt-water channel.

Such interpretations are based on the identification of glacial landforms, mainly on the basis of morphology and, at least to date, without any detailed stratigraphic or petrographic evidence. Maps published previously, depict generalised patterns of glacier flow as indicated on fig. 2. It is evident that glacial landforms have been mapped in areas where we have identified raised beaches. Many of the "deepened" glacial lakes and glacial melt-water channels previously mapped are as easily explained by recourse to evidence of widespread faulting resulting from the tectonic instability of the island.

Glacial histories of other tectonically-active areas with summits at or near the Pleistocene snowline may have been modulated or inhibited by this tectonic factor (e.g. see Verstappen 1959). We suggest, in short, that the elevation of Macquarie Island above sea level has been a late Quaternary event. Juxtaposition of the various geomorphic interpretations represented in figs 1 and 2 reveals distributions, that, if true, would require some far from simple rationalisations. There are also some incompatible distributions. For instance the raised beaches east and northeast of Scoble Lake (e.g. plate 3) occur in an area which is mapped as glaciated by both Colhoun & Goede (1974) and Loffler & Sullivan (1980). It is unlikely that unconsolidated deposits of beach cobbles on the terraces would have survived glaciation without redistribution and/or burial.

The implications of this juxtaposition of interpretations include the following:

1. Perhaps the glacial landforms mapped by previous workers are examples of "convergence of form". In other words they possess similarities to some undoubtedly glacial landforms in other and more thoroughly documented parts of the world, but on Macquarie Island have been formed without glaciers. Landform descriptions reminiscent of those published by advocates of a glacial origin for the geomorphology of Macquarie Island occur in papers on the physiography of the "Australian Alps". The glacial interpreta-

tions attached to many of these descriptions have been refuted (e.g. see Galloway 1963, Peterson 1971).

2. Perhaps the uplift of most or all of Macquarie Island to elevations close to glacial-stage snow lines post-dates the last glacial stage.
3. The interpretations here advanced, and also those challenged, would be tested if the age and environmental history of the lakes could be studied in more detail than hitherto.
4. The debate about the evolution of landforms on Macquarie Island would be greatly advanced if all interested workers had access to a set of good quality aerial photographs, side-looking radar and other remotely-sensed images covering the whole island.

SUMMARY AND FUTURE WORK

The elevation of the beaches and the distribution and shape of many of the island's plateau lakes and structural lineaments would appear to be consistent with a history in which rapid uplift associated with block-faulting and other tectonic factors played a much more important role in landform evolution than was previously recognised.

The debate about the age of the terrestrial environments would be much advanced if dateable materials could be unearthed from the raised terraces. Diachronous lake formation as implied by the structural as opposed to the glacial origin could be tested by collecting lake-bottom cores and comparing dated lacustrine stratigraphies. Detailed appraisal of the raised shorelines would include study of the possible influence of glaciation and of their preservation and/or modification in the face of periglacial activity (Griffin 1980, Loffler *et al*. 1983, Peterson *et al*. 1983). Study of the age and altitudinal distribution of raised beaches may give an indication of rates and nature (possibly differential?) of uplift. Thus there is the opportunity for integrating the study of geomorphology and tectonics for the mutual benefit of advancing debate in both of these aspects of geology.

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