Landscape and Man

A RECONNAISSANCE OF THE GEOMORPHOLOGY OF CENTRAL WESTERN TASMANIA

by Maxwell R. Banks, Eric A. Colhoun and Neil K. Chick,
University of Tasmania,

ABSTRACT

Central western Tasmania, the area between the Pieman and the Gordon rivers, lies within the superhumid precipitation province and has a temperate marine climate. The main agent now affecting the topography is running water. Drainage of the area is commonly trellised, controlled by the lithological variation of folded rocks. During the Pleistocene, glaciers affected the higher parts of the area and tongues of ice pushed more than once down the Pieman, Henty and King River valleys. A feature of the area is the Henty Surface, probably a fluvial erosional surface of post-Miocene age. Raised beaches are found below 22 m. Although wind does not now play a major part in sculpturing the land surface, it earlier produced a spectacular series of parabolic dunes along the coast north of Strahan.

INTRODUCTION

The most important geomorphological characteristics of this region depend primarily on the lithology and structure of the region and on past and present climatically influenced processes operating on the rocks. It is the purpose of this paper to describe the geomorphology in both its typical and its distinctive aspects, to relate these to the geology and climate, and from the geomorphology to deduce some aspects of the history.

Most of the area is covered by 1:100,000 topographic sheets with 40 m contour intervals published by the Lands Department, Hobart. The sheets are Conical Rocks (Sheet 7814), Pieman (Sheet 7914), Franklin (Sheet 8013) and Sophia (Sheet 8014). A map in the same series (Cape Sorell, Sheet 7913) is to be published shortly. For summary reference the positions of rivers and coastal features are shown on figure 3. Transport lines, towns and mountains are shown on figure 2.

GEOLOGY, CLIMATE AND WEATHERING

Geology

As the geology is the subject of a separate contribution (Corbett *et al*. 1977) a detailed treatment will not be given here. It is sufficient to note that the area is bordered on the east and northwest by Precambrian quartzites and schists, overlain around Dundas and along the Sticht Range by Cambrian siltstones, wackes and volcanic rocks which also crop out west of Zeehan, from the Pieman near Renison Bell to the Professor Range, southeast of Strahan and along the West Coast Range. Ordovician conglomerates and quartz sandstones occur along the West Coast Range, along the western faces of mountains from the Cracroft Hills almost to the Lyell Highway on the eastern side of the King Synclinorium, on the Professor Range and at Mt. Zeehan. Ordovician to Early Devonian limestones, sandstones and siltstones underlie the King River and tributary valleys, the valleys of the Nora, Baxter, Spence, Looker and Andrew rivers, the valley of Duck Creek near Granville Harbour, the Zeehan Basin and much of the drainage of the Little Henty, and a large area south and west of Queenstown. Permian rocks, associated with Jurassic dolerite occupy the heights of the Eldon Range, Mt. Sedgwick and Mt. Dundas and occur on the lowlands near the Pieman River north of Mt. Heemskirk, northwest of Zeehan and near the mouth of the Badger and Henty rivers.

Continental sediments may be found in isolated outcrops behind the coastal dunes from north of the Henty River to Swan Basin and Strahan and along the northern and
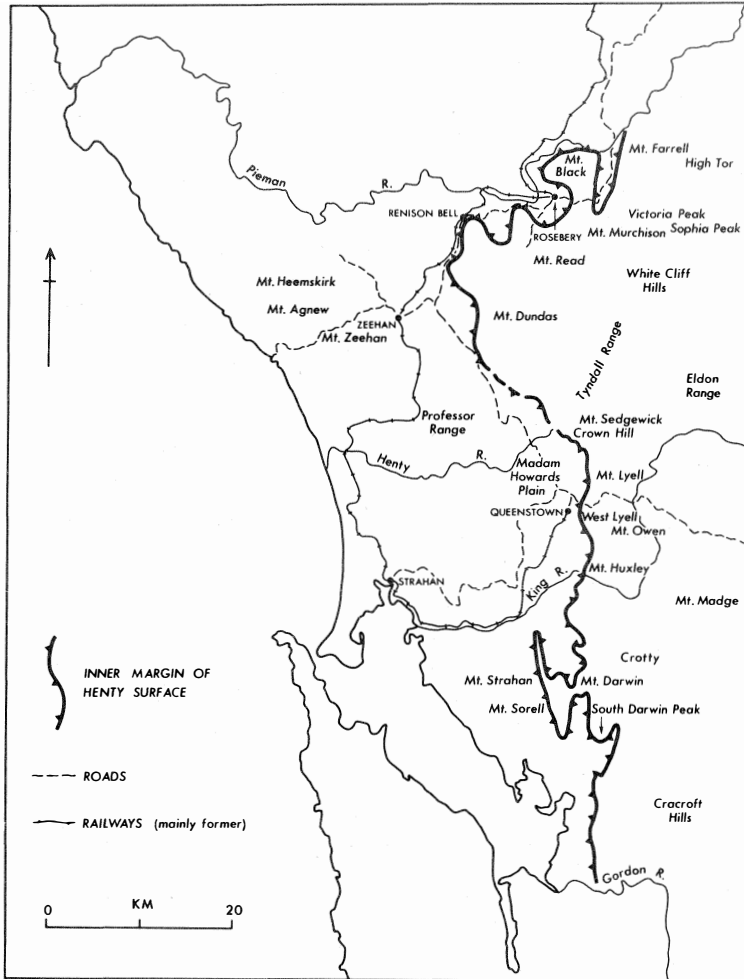
Geomorphology

FIG. 2 - Map of the area showing transport lines, towns and mountains.

Maxwell R. Banks, Eric A. Colhoun and Neil K. Chick

eastern shores of Macquarie Harbour.

Quaternary glacigenic sediments occur sporadically especially in the higher country. Quaternary aeolian sediments form a coastal belt from the mouth of the Little Henty River to the mouth of Macquarie Harbour and there are small areas of alluvium in some of the river valleys.

Climate

Rainfall varies from less than 1600 mm on the coast to a little over 3200 mm on parts of the West Coast Range (Tasmanian Year Book 1975), Queenstown having an average rainfall of 2466 mm. The precipitation gradient is thus quite steep. Rainfall occurs throughout the year with a maximum in late winter. The mean annual evaporation rate varies from less than 750 mm inland to somewhat more than 1000 mm along the coast north of Trial Harbour. The area falls within the superhumid province. The rainfall is very reliable (Langford 1965). Along the West Coast Range the variation is less than 10 per cent of the average rainfall and reaches a maximum of 16 per cent on and adjacent to the Heemskirk Range.

Temperature varies greatly, with summer temperatures up to almost 41°C and winter frosts down to about - 10°C. The greatest annual range ($\sim$ 30°C) probably occurs near Renison Bell and near Eldon Peak. The mean of January maxima lies between 18° and 20°C, the mean of July minima between 2° and 5°C. The variation between maxima and minima tends to rise inland towards the high country. Frosts occur between mid-April and mid-December in inland areas and between early June and late October on the coast (Langford 1965). Frosts may occur at any time above 1200 m.

Winds at Cape Sorell exceed moderate gale force about one day in five. At Strahan gales are rare. At Cape Sorell winds are mainly from south or southwest in summer but at Strahan winds are mainly from the north in summer and from the west in winter (Langford 1965, p. 11).

However, the present climate in no way provides an adequate key to understanding the processes which have shaped most of the present landscape. Late Quaternary climates similar to the present have existed in Tasmania only during the Holocene and the Last Interglacial. During the Last Glacial Stage temperatures for the most part were about 5°C lower (Galloway 1965, Davies 1967, Derbyshire 1973) and at the maximum may have been as much as 8°C lower than at present (Bowden 1974, Colhoun 1975). The temperature reduction was probably accompanied by a reduction of precipitation (Colhoun, 1975) and an increase in the pressure gradient and hence in wind strength. The intensity, magnitude and frequency of present fluvial, frost and aeolian processes were all accentuated and glacial processes, now absent, operated on parts of the West Coast Range during the later part (25000-12000 BP) of the Last Glacial Stage.

Weathering Processes and Soils

The rate and results of weathering depend on many factors: amount of available moisture, temperature, vegetation type, soil fauna, slope, rock type and state. The relative importance of such factors, now and at different times during the development of the present landscape has not yet been evaluated, but some comments on the influence of rock type and climate can be made.

The Soil Map (Atlas of Tasmania, fig. 6) shows most of the area to be covered by different types of yellow podzolic soils with the exception of a small area of basalt near Granville Harbour, which has developed a krasnozem. Nicolls and Dimmock (1965) described the general characters of the soils and noted groundwater podzols in the dune area north of Strahan, skeletal soils near the coast further north on granites and quartz-rich rocks. Many of the quartzite and quartz schist ridges east of the

West Coast Range are also covered with skeletal soils. Moor podzol peats occur on the lower slopes, high valley plains and high moors in such areas.

SOILS IN RELATION TO PARENT ROCK

Influence of Parent Rock

Quartzite and quartz schists (mainly of Precambrian age), strongly cemented siliceous conglomerate and quartz veins decompose to a thin sandy mantle but shatter readily under frost action to produce a mantle of angular and, with schistose parent material, tabular fragments. Where soils occur on such parent materials they are skeletal, commonly only a few tens of millimetres thick. Sandstones of Ordovician Siluro-Devonian, Permian and Tertiary age decompose to form thicker regolith mantles of more uniform grain size. Yellow podzolic soils are predominant on these rocks (Nicolls and Dimmock 1965). The composition and amount of cement in the sandstones affects the depth to which the weathered mantle develops. Ordovician quartz sandstones form bare outcrops or have a thin cover as at several places near Zeehan whereas Siluro-Devonian or Permian sandstones with a less siliceous or a calcareous cement develop a deeper mantle. Ordovician sandstones near Zeehan have a thicker mantle than similar rocks of the same age along the West Coast Range, probably the result of predominantly chemical weathering in the lowland over a long period and of predominantly glacial scouring and frost shattering in the higher country. Skeletal quartz-rich soils and podzols have developed on the granitoid rocks of the Heemskirk Range.

The more aluminous rocks have decomposed to greater depth than siliceous rocks as is normal under humid conditions. Thus chlorite, mica or garnetiferous schists, slates, greywackes or lithic wackes of different grain sizes, siltstones or argillites, silts and volcanic or pyroclastic rocks tend to have produced deeper, more clay-rich soils. As a consequence, these aluminous rocks crop out less commonly than the siliceous rocks of the region. Where highly fractured surfaces of these rocks were exposed to frost action during the Last Glacial Stage mantles of frost-produced debris have also been formed.

Limestones which are widespread in the lower country crop out but rarely because of solution by strongly acid groundwaters. The Ordovician limestones, which normally contain silty, dolomitic, bituminous and other types of carbonaceous beds, weather to thick dark grey or black clay-rich soils, sometimes referred to as "black pugs" (Hills 1914, p. 55). These are well exposed, for example, near Linda. In a few areas, e.g. south of Darwin (Hills 1914, pp. 20-21) and along the Gordon River, limestone crops out as high hills or cliffs.

Influence of Climate

Dolerite occurs from almost sea-level near the mouth of the Little Henty to the summits of Mt. Dundas, Mt. Sedgwick and the Eldon Range. In the low country it produces thick clay-rich yellow podzolic soils and has little topographic expression, dolerite dykes in the northeast Dundas area having none at all (Conder, 1918). The dolerite of the highlands has little or no soil developed on it in most places. The deep krasnozem soils developed on basalt near Granville Harbour are probably relics of an earlier period of warm seasonally moist climate. Although deep chemical weathering is widely known in the area it is of a distinctly lesser degree than in tropical parts of Australia. The poor development of gossans (oxidised zones) on top of sulphide ore bodies when compared with development in more northerly parts of Australia (Twelvetrees and Ward 1910) seems likely to be a result of slow reaction rates controlled by low temperatures through much of the Quaternary.

The effects of frost action are most obvious in the higher altitude zones. The dolerites of the Eldon Range are surrounded by a fringe of scree and thick screes occur locally in the Linda Valley. Solifluction deposits occur in many places, e.g. at Henty Bridge, on the Henty Surface west and southwest of the Professor Range, and partially filling gullies between Queenstown and Strahan. Glacial action has left

R. Banks, Eric A. Colhoun and Neil K. Chick.

bare rock faces in many parts of the higher country but only on Frenchmans Cap is there any present approach to glacial conditions in the form of snowpatch erosion (Davies 1967).

Mass Movement

Downslope movement has occurred on many steep slopes which have a basal veneer of material rich in angular quartz fragments (Spry 1957). Landslides have seldom been reported but can be observed on steep slopes on schists and some other rock types. Their best expression is probably in areas of Tertiary siltstones and sandstones bordering Macquarie Harbour (Bradley 1954).

HYDROLOGY

River Systems

Almost the whole area is characteristic of the fold structure province (Davies 1967) with ridge and valley landscape, steep slopes, a high drainage density and a trellis drainage pattern.

The major rivers, Pieman and Gordon, flow generally west and cut across the structure (fig. 3). Other main streams such as the Little Henty, Henty and King also flow west across the structure for much of their lower courses, but their upper structurally controlled courses flow south. Yet other streams, e.g. Comstock, Linda, South Eldon, Nelson and others flow east or west mostly under local structural control. Davies (1965) drew attention to some general lines of drainage in the area, lines such as the Pieman - Murchison, Henty - Comstock - South Eldon, King - Governor - Franklin and Gordon - Jane lines. These and other lines in western Tasmania form a pattern of major drainage, radiating from the Central Highlands. Gregory (1903, p. 179) postulated an early version of the King River rising in the Central Highlands near the Eldon Range following the line of the South Eldon and Comstock Creek. Davies (1965, p. 24) followed this suggestion and further suggested that the wind-gaps at Comstock Creek and Gormanston represent earlier courses of the King River with a possible corollary of progressive capture by south flowing streams of west flowing streams. Bradley (1954) following in principle a comment by Hills (1914, p. 24), suggested that the King River was structurally controlled at a level 150 m above its present level by limestone in a faulted saddle between two contra-plunging synclines and became entrenched in underlying harder rocks by uplift. A somewhat similar explanation may apply to the wind-gap at the head of the Comstock Valley. Continuation of this process leading to capture of the Baxter by the Andrew (Bradley 1954) would then leave the King Gorge as a wind-gap. However, these suggestions are based on preliminary interpretations of gross morphology and need detailed morphological and stratigraphic testing.

Although the general course of the Murchison and Pieman rivers cuts across the structure, both rivers and their tributaries show minor structural control by faults, joints and schistosity. Drainage of the granite of the Heemskirk Ranges has an overall radial pattern with joint control producing a secondary trellised pattern. In the Precambrian and Cambrian rocks of its headwater region the Little Henty River system has no clear structural control but where this system is cutting Ordovician to Lower Devonian rocks of the Zeehan Basin the drainage is markedly controlled by rock type. The limestone and silty units tend to form the stream valleys, the sandstones the linear or curvilinear interfluves. The Little Henty has developed a wide swampy basin at 130 to 160 m above sea-level above a knickpoint in Mt. Zeehan Conglomerate near the junction with Amber Creek at about 125 m above sea-level (Blissett 1962, p. 12). Below this point the Little Henty is incised and its course is controlled generally by faults. The Badger River in its
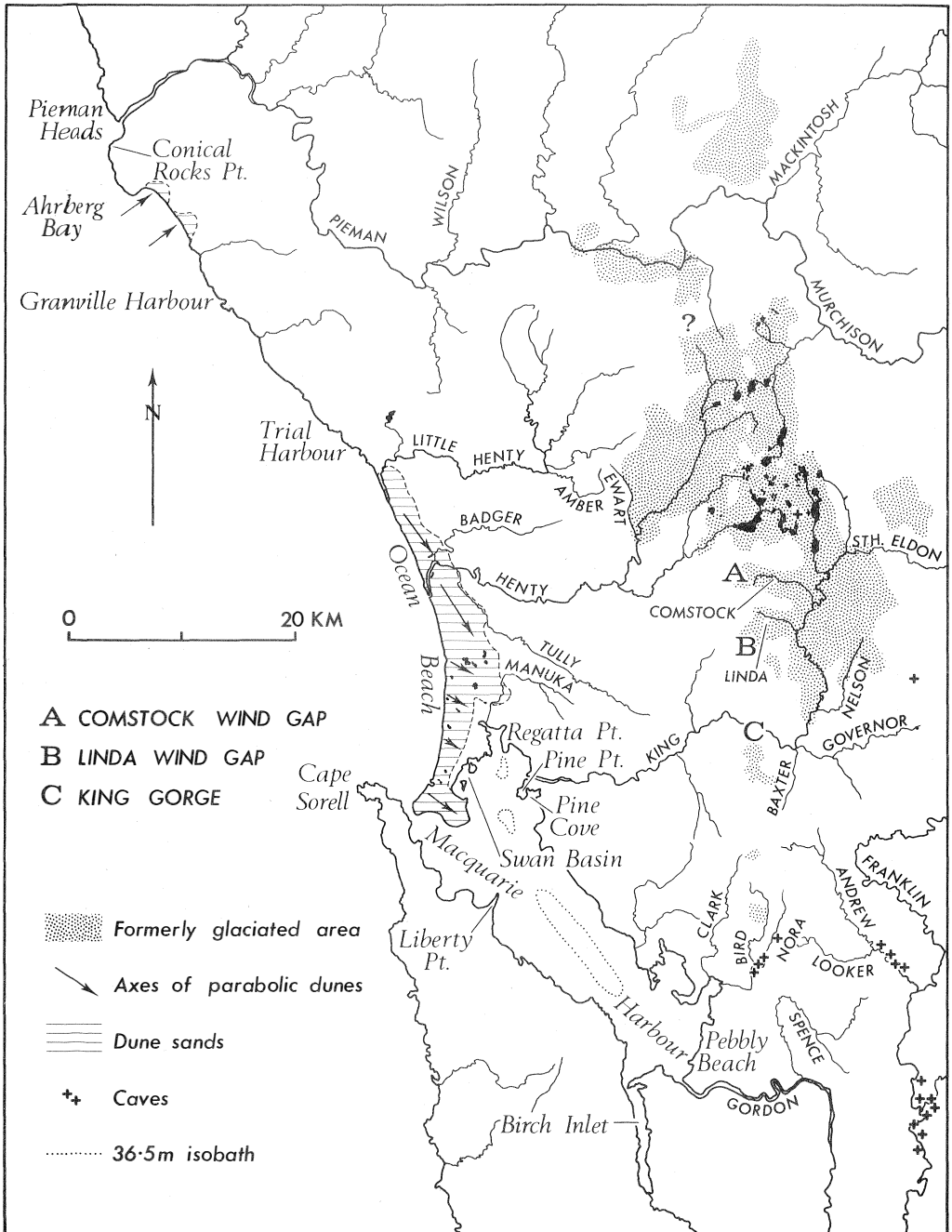
Geomorphology

Fig. 3 - A map showing the distribution of the effects of present and Pleistocene
geomorphological processes. Limits of Pleistocene glaciation mainly after
Glacial Map (Derbyshire *et al*. 1965).

upper course is strongly lithologically controlled but after crossing a fault from Ordovician limestone onto Permian siltstones and sandstones it cuts across the strike without much change of gradient to a knickpoint about 80 m above sea-level, below which it falls precipitously to about 15 m.

The Henty River rises south of Mt. Read and follows a generally straight course to the SSW, parallel to major structural trends. The valley which in places has concave slopes widens out near Henty Bridge before narrowing markedly just below the junction of Ewart Creek at about 75 m above sea-level. Below this point the course is tortuous, steep and lacks major structural control. The main tributaries, including the Tully River, flow in from the ESE along trends of folds in the Bell Shale (Baillie and Williams 1975, p. 2). These tributaries have numerous but short minor branch streams.

The King River flows south along the east side of the West Coast Range and has predominantly latitudinal tributaries such as Comstock Creek, the South Eldon River, Linda Creek, Nelson River and Governor River. The Baxter River joins the Governor River after flowing north and just before its junction with the King. From the junction with the Governor and Baxter the King flows generally west across the strike of the West Coast Range. The south-eastern part of the area is drained by the Gordon and its tributary the Franklin River. The Franklin flows partly along the strike, partly across the strike in the Precambrian rocks and in its lower reaches along the strike of the Gordon limestone. One of the main tributaries of the Franklin, the Andrew River also flows for much of its course along a belt of Gordon Limestone. Many of the tributaries of the Andrew are controlled by lithological variation within the Siluro-Devonian rocks.

The drainage of the area south of the watershed between the King and the Andrew Rivers is complex and in many places strongly structurally controlled. The main drainage systems are the Andrew, Spence and Nora rivers and their tributaries. Drainage of the Tertiary continental beds bordering Macquarie Harbour is dendritic (Bradley 1954, commentary on Mt. Sorell Sheet).

Only the very shortest streams flowing directly to the seas have developed smoothly concave longitudinal profiles. The Pieman is over-deepened in its lower course, having cut to 40 m below sea-level at Hells Gates (Twidale 1957, p. 9). The lower Pieman has Last Interglacial and Penultimate glacial age deposits in its course at the Stringer Creek confluence. The main valley is older.

Lakes

There are numerous lakes and tarns on the plateau at the northern end of the West Coast Range at about 760 m above sea-level. Other high level lakes occur on the eastern side of the West Coast Range from Mt. Murchison south to Mt. Jukes and on the eastern side of Mt. Farrell. A few small lakes occur on the south side of the Eldon Range, north and east of Eldon Bluff and Castle Mountain, and many lakes occur in the Frenchmans Cap National Park.

The biggest lake is Lake Margaret which is about three kilometres long and like all of the high level lakes is of glacial origin. Many of them occupy over-deepened glacially scoured rock basins and a few are dammed by glacial moraine.

Low level lakes occur just inland from the coast at Big Pebbly Beach at the eastern end of Macquarie Harbour and especially behind and between dunes inland from Ocean Beach. Cumberland lake is artificial.

Underground Drainage.

     Despite the abundance of limestone, there is little record of caves or under-
ground drainage systems in the area. Loftus Hills (1914 p. 54) noted limestone caves
on the Kelly Basin line about 7.25 km from the basin. Other caves in the area are
noted by Mr. A. Goede in an unpublished catalogue "Caves of Tasmania". Caves are
known in Ordovician limestone near Lake Spicer, near Bubs Hill by the Lyell Highway,
several places on the Franklin River and near Marble Cliffs on the Gordon River.
Caves occur in limestone of unknown age (possibly Silurian or Early Devonian) on the
Nelson River. The Precambrian dolomites to the east contain some caves near Mt.
Ronald Cross and on the Jane River.

     It may well be that karst features are more widespread than stated here but are
not evident because of the thick vegetation in many areas likely to have caves.

                              HIGH LEVEL SURFACES

     The recognition of remnants of ancient land surfaces in western Tasmania goes
back at least to 1903 when Gregory noted (p. 12) a surface that extended from Hampshire
Hills to Farrell and the West Coast Range which he called the Henty Surface.

     In 1941 Edwards recognised an exhumed sub-Permian surface below the Permian rocks
on Mt. Sedgwick at about 960 m above sea level. This surface has also been recognised
on Mt. Dundas at about 880 m above sea-level (Bradley 1954, p. 19) and on the slopes of
Mt. Read at about 960 m above sea-level (Banks and Ahmad 1962). This surface falls
from Mt. Read and Mt. Sedgwick gradually to the east as shown by Scott (1960, p. 6)
and Banks (1962, p. 195) who showed that, contrary to earlier statements (e.g. Edwards
1941, Bradley 1954, Scott 1960) it was not a peneplain.

     Davies (1959) analysed the Tasmanian landforms in terms of former erosion surfaces
and provided (fig. 5, p. 201) several sets of superimposed profiles covering the south-
eastern part of the area. He recognised five surfaces and some monadnocks which proj-
ect above the highest surface. On the eastern border of the area Frenchmans Cap rises
as a monadnock above other surfaces such as the Higher Plateau Surface (1200 m - 1350 m
approximately) represented by the Frenchmans Cap Plateau, the top of Eldon Bluff and
the Eldon Range. Below this surface is the Lower Plateau Surface (915 m - 1065 m)
represented in the area by the summits of the Tyndall Range, the Sticht Range, Mt. Read,
Mt. Black, Granite Tor, Sophia Peak, Victoria Peak, Mt. Mary, Flat Bluff, Wards Bluff
and many of the peaks or summit plateaus of the southern part of the West Coast Range
(Davies 1959, p. 201). It is worth noting that Mt. Murchison (1275 m) and the plateau
near the peak lie above this at 1160 m - 1200 m and may be related to the Higher
Plateau Surface. The next surface down, the St. Clair at 730 m - 825 m, is widely
represented. Davies (1959, p. 201) noted it on East Jukes Peak, Mt. Madge, the
Collingwood Range and the shoulders of Mt. Alma. Bradley (1954, p. 196) noted a sur-
face at this level on Mt. Farrell (712 m). Scott (1960, p. 6) noted it on the Heem-
skirk Range (747 m +), Mt. Zeehan (707), the plateau east of the Tyndall Range (approx-
imately 800 m), north Owen Peak (approximately 800 m), Mt. Strahan (855 m), and other
peaks to the south and east. Several summits east of Mt. Murchison fall within or
close to this range, e.g. High Tor, Mt. Selina, Whitecliff Hills and Canning Peak
(860 m).

     The Higher Coastal Surface (365-460 m) appears to be represented by the highest
accordant hill tops (fig. 2) called by Bradley (1954, p. 195) the "Howards Peneplain".
This is the apparently flat surface seen from the ridge east of the former West Lyell
Open Cut and is probably the surface named "Henty Peneplain" by Gregory. Gregory
(1903, p. 12) noted that the view westward from the summit of the Haulage at West Lyell

Maxwell R. Banks, Eric A. Colhoun and Neil K. Chick

"shows the features of the peneplain of the Henty and Queen Rivers exceptionally well". His comments made it clear that this surface was revealed by accordant ridge tops and some plains such as Madam Howards Plain. He gave the height of the landward edge along the western side of the West Coast Range as 1300 ft (400 m). Subsequently many authors have commented on this surface and attributed various values to the altitude of the landward edge of this surface: Twelvetrees and Ward (1910); 230 m east of Zeehan, 215 m at North Dundas; Bradley (1954) 300 m along the West Coast Range (he called it the Howards Peneplain); Scott (1960b) as 425 m and 335 m on the western slopes of Mt. Sorell and 365 m near Queenstown. These differences are at least partly due to lack of adequate contour maps which have become available only recently, partly to distance of observation point from the coast and perhaps to the existence of two surfaces at not very different heights.

In an attempt to determine the extent of this surface a series of cross profiles were prepared at intervals of 5 km and more closely spaced (1 per 2 km) west of the West Coast Range. Two of these profiles are reproduced here (fig. 4). The attempt was undoubtedly too crude for objective judgement, being based on maps with contour intervals of 40 m over most of the area and 15 m west of the West Coast Range. Study of individual profiles and inspection of the contour maps suggest that the height of the landward edge does vary depending upon position relative to the coast and to the Pieman River. Near Rosebery the surface appears to be at about 220 m above sea level. East of Zeehan the landward edge also lies at about 240 m above sea level. Along the West Coast Range on the western slopes of Mt. Huxley the level appears to be at about 320 m above sea level but on the western slopes of Mt. Strahan at about 440 m above sea level and south of South Darwin Peak it seems to lie at about 400 m above sea level. One recalls Gregory's comments (1903, pp. 178-9) on the level rising to the north from Madam Howards Plain, being bounded on the north by Crown Hill and the Professor Range and on the south by the hills north of the King River. An attempt has been made to delimit the landward edge but it needs field work before much confidence can be placed in it.
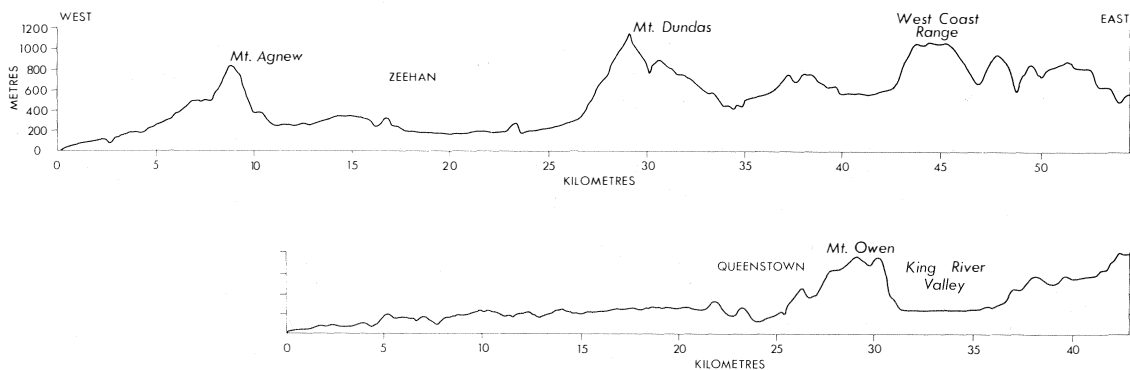

Fig. 4 - East-west profiles across the area passing through (a) Zeehan and Mt. Dundas and (b) Queenstown.

Davies (1959, p. 201) recognised as extensions of the Higher Coastal Surface the hill summits around the King River and valley flats such as the Collingwood Plains (360 m approximately). Scott (1960, p. 5) also noted evidence for this surface in the upper Andrew, Spence and Nora watersheds as hilltop accordances. Slopes (in a due westerly direction) calculated for the Henty Surface in the map area vary from about 1 in 75 to about 1 in 600.

Geomorphology

Gregory (1903) regarded the Henty Surface as a peneplain and wrote of its form-
ation by an earlier, west-flowing version of the King River south of Queenstown.
Gravels occur on the surface in places, e.g. on the Old Strahan Road nine miles (14 km)
from Strahan (Montgomery 1894), south of the Pieman (Blissett 1962, p. 9;
Waterhouse 1914, p. 7; 1916, p. 11), and north and south of the Pieman.
(Twidale 1957, pp. 10-12). The surface has been assigned a marine origin by Gregory
(1903) and many later authors. No marine fossils have been found on it. No marine
cliffing, rock stacks nor other signs of marine erosion or deposition are known. The
pattern of its height variations within the area, particularly its relatively low level
along the Pieman River valley support a fluvial rather than a marine origin. Twidale
called attention to the inadvisability of referring to it as a peneplain and suggested
that terms such as partial peneplain or strath were more appropriate (1957, p. 11).
The surface cannot yet be properly dated. In this area it is clearly older than the
Late Pleistocene glaciation as pointed out by Gregory (1903). Near Granville Harbour
this surface includes basalt overlying Late Oligocene or Early Miocene limestone
(Quilty 1972). Elsewhere a surface correlated with this surface cuts basalts resting
disconformably on Middle Miocene limestone. If the correlation is correct, the surface
must be of post-Middle Miocene age.

The Lower Coastal Surface (90 m - 275 m) is widely represented west of the
West Coast Range and can be recognised on the profiles (fig. 4) as an accordance
of hill summits and plains from about 265 m at the landward edge to about 100 m
at the seaward edge. Madam Howards Plain forms part of this surface at 120 m
above sea-level as also does the floor of the Queen River valley and the old flood
plain of the King River as pointed out by Bradley (1954, p. 195). It is doubtful that
this surface can be referred to as the Henty Surface in the sense of Gregory (1903)
as was done by Bradley (1954, p. 195) and Davies (1959).

Within the Lower Coastal Surface (90 m - 275 m) there are in central western
Tasmania several recognisable levels. Twidale (1957) noted a level close to 120 m
near the mouth of the Pieman, and Banks and Ahmad (1959) noted the presence of a
surface from 105 m to 120 m above sea-level near Firewood Siding.

Scott (1960b, p. 10) noted levels at 9 m, 17 m, 40 m, 64 to 70 m, 116 m, 122 m,
245 m, 300 m, 400 m, and 425 m above sea level at different places. The significance
of these levels has not been established. The well marked terraces at Strahan were
noted by David (1923, 1926) who recorded a terrace about 75 m above sea level at its
maximum height, and others between this level and a raised beach at 4.5 m above sea
level. He interpreted these as depositional terraces made of material laid down during
the Pleistocene by "extra-moraine streams", and classed them as "outwash apron" gravels
or "schotter". They may however, be cut surfaces in the Tertiary Macquarie Harbour
Beds. Davies (1960) regarded some at least of these terraces (at about 50 m and at
36 m) as marine. The area, which has profound significance for establishing the
sequence and magnitude of Late Quaternary glacial and interglacial events is being re-
investigated by the authors.

GLACIATION

Although there is no present glacial activity in the area, glaciation was present
during the Pleistocene. The extent of this as known in 1965 is shown in fig. 3, based
on the Glacial Map of Tasmania (Derbyshire *et al*. 1965). The distribution shown can
be regarded as approximate as it is possible that ice was more extensive especially
near Strahan. The map also does not differentiate landforms or deposits produced at
different stages.

Maxwell R. Banks, Eric A. Colhoun and Neil K. Chick

Lewis (1945) maintained that there were three periods of glaciation, the Malanna, Yolande and Margaret stages, all with type areas in the region. Banks and Ahmad (1959) showed that the Malanna Glaciation was based on an incorrect interpretation of the geology at Firewood Siding near Malanna. Jennings and Banks (1958) regarded the Yolande and Margaret glaciations as two stages of the same glaciation, so they could not be regarded as separate glacial stages. Thus a three fold division of glaciation in western Tasmania was rejected and a tendency towards explanation of the glaciation in terms of a single stage predominated (Derbyshire *et al* 1965).

Recent work by Colhoun has shown that, as suspected for other areas in 1965, a single glaciation view was too conservative and the known glacial deposits of this region belong to two glacial stages.

Evidence for pre-Wisconsin age glaciation

On the south bank of the Henty River 150 m east of Henty Bridge thick deposits of strongly weathered till grade vertically, laterally and in a down-valley direction into weathered outwash gravels. Many of the volcanic fragments up to 250 mm across in the till are completely weathered. On the south bank of the Henty, 50 m west of the bridge, the outwash gravels overlie 0.1 - 0.15 m of iron-stained sandy silt, weathered to clay. The silt rests on 1 - 1.5 m of gelifluction deposits consisting of weathered angular fragments of volcanic rocks up to 20 mm in diameter set in a weathered clay matrix. Two hundred metres south of Henty Bridge a section west of the road shows the weathered till and outwash gravels overlain by unweathered gelifluction deposits derived from volcanic rocks. These deposits interdigitate with organic alluvial silts that contain abundant pollen of alpine and subalpine shrubs, herbs and grasses. Two organic horizons from these silts have been ^{14}C dated to 25,660 ± 1200 BP (GaK - 5596) and 23,640 ± 1030 BP (GaK - 5597) and wood, probably transported, from the base of the section has been assayed at > 34,600 BP (GaK - 5595) (Plate 1). These deposits are sealed beneath more than 2.8 m of unweathered sandy-silt till derived on the evidence of its rock fragments from the Tyndall Range. On the north bank of the river west of Henty Bridge similar organic silts are seen to have been strongly deformed by ice pushing.

The deposits at Henty Bridge, therefore, show that ice from the Tyndall Range flowed down the Henty Valley at least as far as Henty Bridge both prior to and during the maximum stage of the Last Glaciation. The very strong weathering of the older glacigenic and associated alluvial and gelifluction deposits and the largely unweathered character of the overlying younger till, organic alluvial silts and gelifluction deposits, suggest that the buried deposits are of pre-Wisconsin age.

A deep section made during exploration work for the Pieman Damsite revealed thick deposits of quartzite outwash gravels resting on a strath terrace cut into schists on the southern slope of the valley. The outwash gravels contain thin beds of strongly iron cemented sands and are overlain by 4.5 m of organic silts which contain a temperate rain forest flora dominated by *Nothofagus cunninghamii* and *Eucryphia lucida*. Wood from the surface of these organic deposits has been dated (the same piece) to >39,000 BP. (SUA-310) and >54,000 BP. (GrN-7555). The organic silts are overlain by 16-17 m of inorganic alluvial silts and 1-2 m of slope deposits (plate 2).

The 4.5 m of organic rich silts at Pieman damsite contain not only pollen evidence for the presence of a mature *Nothofagus cunninghamii* - *Eucryphia lucida* temperate rain forest flora but also abundant macroscopic leaf remains of these species. Although the larger wood fragments may have been transported and deposited in the accumulating back-swamp deposits at the site they would still have come from the valley of the Pieman prior to 54,000 BP. The abundant whole leaves show that much of the deposit accumulated *in situ*. The contrast in floral composition of these alluvial deposits with the
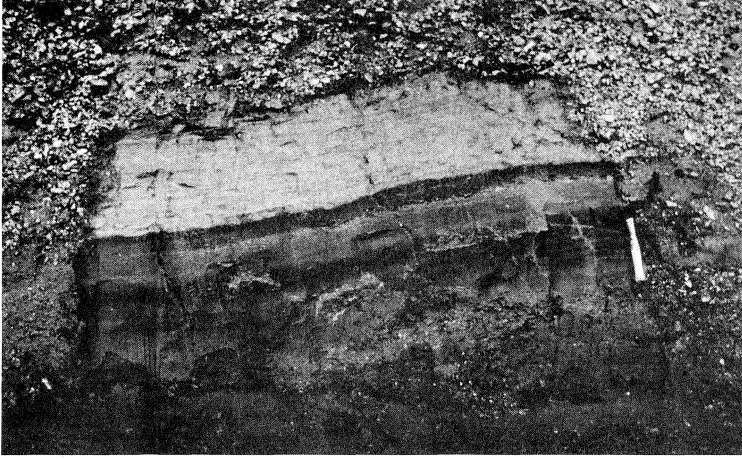
PLATE 1. Laminated organic silts and clays at Henty Bridge. The youngest date comes from the uppermost strongly organic horizon and the oldest date from water level at the base of the section.

PLATE 2. Backswamp deposits at Pieman Damsite overlain by alluvial silts and slope deposits.

glacial age alluvial deposits at Henty Bridge, which demonstrates the presence of an alpine-subalpine shrubland, and an alpine herbfield - grassland association between slightly >25,660 BP. and slightly >23,640 BP., with the climatic treeline depressed to near sea level, strongly supports the interpretation that the Pieman organic silts are of Last Interglacial age.

A large stream of ice, probably coming down the Mackintosh Valley from the extensive ice-cap of the Central Plateau and Highlands, flowed around Mt. Black near Rosebery, sent a distributary north towards Bulgobac and one south almost to Williamsford, while the main tongue of ice went down the Pieman Valley almost to the junction with the Wilson River. Its age is uncertain and there may well be evidence of more than one glaciation. The area needs re-examination.

West of the King River Bridge at the entry to the Linda Valley roadside sections reveal a sequence of thick stratified scree deposits overlying soliflucted till deposits. A palaeosol at least 1 m thick and strongly enriched with iron and manganese separates the soliflucted till from the screes which occur as two members that are separated by an undulating bed of fine sand and silt up to 0.5 to 1 m thick. The mobilisation and redeposition of the iron and manganese in the palaeosol indicates the presence of a former stable vegetated land surface prior to the formation of the screes. At the eastern end of the road sections, unweathered morainic deposits marginally overlie the scree deposits. These deposits are associated with striated (Carey 1955) and ice smoothed rock surfaces, and with marginal meltwater channels that have been cut across the spur to the north. The presence of the soliflucted lower till, the palaeosol, the great thickness of scree, and the marginally overlying unweathered glacial deposits suggests that the limit of Wisconsin age ice may occur at the entry to the Linda Valley. If this interpretation is proved correct it may become necessary to assign the Gormanston Moraine a pre-Wisconsin age as was originally done by Lewis.

The significance of the radiocarbon date of 26480 ± 800 BP on wood from Gormanston from which a Wisconsin age for the glaciation was deduced (Gill 1956) now requires reassessment, but this must be coupled with new field mapping of the landforms and deposits.

The strong concentrations of oxidised iron, often in the form of pan layers, and the advanced chemical decomposition of volcanic and coarse grained igneous rocks, often to considerable depths, seems to be ubiquitous in the till, moraine and outwash deposits that have been assigned here to the older glaciation, and contrast markedly with the general absence of these characteristics in deposits associated with the Last Glaciation of the area. Very strong chemical weathering of the landscape is evident also in areas of volcanic and igneous rocks where deep podzolised soil profiles of 1 - 2 m, with local weathering of rock to 10 m depth, are widespread outside the limits of the Last Glaciation but do not occur within them, where thin podzols, peaty podzols, peats, lithosols and ice-eroded rock surfaces predominate. Both the spatial distribution and stratigraphic relationships of these contrasting characteristics suggest that the last major phase of strong chemical weathering of rock and glacial drifts occurred mainly during the Last Interglacial.

Evidence for Glaciation of Wisconsin Age

The main areas of accumulation of ice of Last Glaciation age were the deep cirque basins south of Mount Murchison and east of the Tyndall Range (Bowden 1974). From the Mount Murchison area the ice flowed eastwards and northwards, passing east of Mount Read, towards Williamsford. Further south, ice from the Lake Julia area and Rolleston Valley flowed westwards through gaps in the Tyndall Range and passed westwards and southwards across a flat area towards the Henty and Yolande valleys. The ice that accumulated east of the Tyndall Range flowed eastwards and southeastwards across the Lake Dora plateau towards the Eldon valley. Further south the ice flowed through Lake Spicer and Beatrice into the King River Valley. The ice that originated in the cirque north of Mount Geikie flowed southwestwards via the Lake Margaret Valley to the

Hamilton Moraine. On the west Coast Ranges to the south, small cirque glaciers existed on the eastern sides of Mount Owen and Mount Jukes.

This extensive area of ice accumulation is characterised by numerous deeply eroded cirque basins, roches moutonnées, ice scoured lake basins, and extensive glacially smoothed and striated bare rock surfaces. Surface deposits of till are generally thin and patchy in distribution but in areas of thicker moraine, as at Lake Rolleston, fluted ridges occur. Numerous erratic boulders of Owen Conglomerate are distributed throughout the glaciated area (e.g. Loftus Hills Memorial) and at the northern end of Lake Rolleston some of the boulders form distinct block and tail landforms. The upper marginal and outer limits attained by the ice, and the retreat stages, are variously characterised by large complex and undissected areas of moraine, single and multiple moraine ridges, and narrow block moraines. Terraces and plains of outwash gravel occur locally outside the limits of some of the distinctive moraine stages (Bowden 1974).

East of the Tyndall Range the ice was sufficiently thick to form an extensive icecap which at its maximum extended southwards to Lake Spicer, eastwards across the Lake Dora plateau, and connected northwards via the Rolleston Valley and the upper part of Anthony Creek with the ice masses that formed south of Mt. Murchison.

The ice limits have not been traced in the area of the North Eldon and South Eldon valleys. To the south, Ahmad, Bartlett and Green (1959) have suggested that the limits occur east of the Nelson River along the Lyell Highway and continue southwards to the Crotty Plains in the King River Valley. However, as discussed previously for the Linda Valley there is the possibility that ice limits of more than one glacial stage are represented in these valleys.

West of the Tyndall Range the ice formed an extensive piedmont ice sheet that occupied a flat bench and extended as short glacier tongues along the Yolande and Henty valleys. However, this icecap was not thick enough at maximum glaciation to submerge the higher summits which projected as nunatak areas. Where the unglaciated summit areas form plateaus and gently sloping surfaces, as on parts of the Tyndall Range, strong frost processes have shattered and dislodged the exposed jointed Owen Conglomerate to form large block fields. On Mount Read, the summit of which lay above and beyond the northwestern limit of glaciation, the finely bedded volcanic rocks have been frost shattered to produce not only an angular regolith of mountain top detritus but also small jagged pinnacles of 0.5 to 2 m height. West of the Tyndall Range this ice attained its maximum areal limits just south and west of Lake Margaret Village in the Yolande Valley, and just west of Henty Bridge. North of Henty Bridge glacial till and gravels extend along the Murchison Highway for several kilometres. Although these deposits belong mainly to the Last Glaciation they may also partly belong to the earlier glaciation, as the ice limits of both glaciations seem to have been close together in this area. Large unweathered morainic deposits southeast of Williamsford possibly mark the northwestern limits of Last Glaciation ice.

The presently known field evidence supports the interpretation that the glacigenic deposits of the Yolande Valley are of Wisconsin age (Davies 1967, 1974; Derbyshire 1972) and that they do not belong to an earlier glacial stage as suggested by Lewis (1934, 1939). The deposits at Henty Bridge demonstrate that Wisconsin age ice reached its maximum limit after 23,640 ± 1080 BP. (GaK-5597) and indicate that the unweathered glacigenic and associated deposits are separated from the older weathered glacigenic and associated deposits which certainly predate 34,600 BP. (GaK-5595). If the older till and outwash deposits exposed at Henty Bridge correlate with the weathered outwash gravels at Pieman Damsite as seems likely, then this glaciation must predate the Last Interglacial.

Three moraine ridges descend the southern spur of Mount Geikie and merge in the 100 m high Hamilton End Moraine (Plate 3) which bounds Basin Lake, swings north of Lake Margaret Village and banks against the northern spur of Mount Sedgwick. This moraine,

Maxwell R. Banks, Eric A. Colhoun and Neil K. Chick

PLATE 3. The Hamilton
End Moraine and
Basin Lake.

PLATE 4. The raised beach
at Strahan Airport

which marks the limit of Lewis's Margaret Glaciation, truncates several lesser morainic ridges on the southwestern slopes of Mount Geikie, which were formed as laterals along the decaying ice margin of the piedmont ice sheet that flowed southwestwards across the flat bench west of the Tyndall Range towards the Yolande Valley (Bowden 1974). If the Hamilton Moraine represents a major glacial climatic stage as suggested by Lewis, then it is to be expected that similar very large end-moraines would occur in many of the valleys throughout this region. Although there are very large moraines north of Lake Rolleston and at the exit of the Tyndall valley (which appear to be readvance moraines) which probably correlate with the Hamilton Moraine, the peculiar geographic positioning of the exit of the Lake Margaret valley with respect to the southern ice source east of the Tyndall Range seems to have been the most important factor which localised the position of this striking Hamilton Moraine readvance stage.

When the ice that originated east of the Tyndall Range was at its maximum extent the ice that flowed through the northern gap in the range and passed across the flat bench west of the range was confluent with that which flowed through the Lake Margaret Valley, and the combined ice limit was south and west of Lake Margaret Village in the Yolande valley. During glacial retreat the Rolleston-Tyndall ice, with its greater mass, longer course, lower basal slope and surface gradient withdrew further from the western outlet of the Lake Margaret Valley than the ice which accumulated north of Mount Geikie which, although it had a small mass, had also a short course, a steep basal slope and a steep surface gradient. If a significant short term climatic deterioration occurred during general deglaciation then the ice from the southern source areas would have readvanced and flowed through the Lake Margaret Valley to the Hamilton Moraine while the glaciers from the northern source areas would have still remained within the valleys east and north of the mountains. If the climatic deterioration and glacial readvance was relatively short lived the northern ice would not have had time to attain its former maximum limits before renewed retreat commenced.

The field evidence does not indicate that the Hamilton Moraine represents a distinct long term climatic stage of glaciation as suggested by Lewis (1934) but it seems to represent a significant shorter term deterioration of climate during which the glaciers readvanced. The Hamilton Moraine, therefore, appears to represent a distinct readvance stage the magnitude of which is emphasised by the proximity to the ice source of a gap that leads westward through the Tyndall Range which has a steep bedrock profile descent at its exit below the Lake Margaret Dam.

A core taken from a small lake completely enclosed by moraine deposits between the Hamilton Moraine limit and Lake Margaret contained 2.95 m of organic lake mud overlying 0.31 m of silt that rested directly on moraine. A ^{14}C assay of 11,420 ± 770 BP. (GaK-6297) was obtained from the basal organic mud between 2.90 and 2.95 m. If the sedimentation of the silts occurred at the same rate as the organic mud then the age of glacial retreat from the Hamilton Moraine would be approximately 12,730 BP. However, in the open alpine late glacial environment sedimentation rates were probably higher than in the later forested environment which could reduce this estimate slightly. Analysis of pollen from this core shows that by 11,420 BP, the grass, herb and alpine shrub vegetation communities that developed after the ice retreat were replaced by temperate rain forest and heath-shrub associations.

A small mountain glacier occupied a rock basin on the eastern side of Mt. Farrell. Small mountain and valley glaciers occupied the heights around Frenchmans Cap (Peterson 1966) and occurred along the northeastern, eastern and southern sides of the Eldon Range.

Post-glacial peat from a small rock depression near Lake Nancy in the Frenchmans Cap area has been assayed at 8,270 ± 220 years BP by radiocarbon dating (Peterson 1966, p. 127).

Maxwell R. Banks, Eric A. Colhoun and Neil K. Chick

COASTAL PROCESSES AND LANDFORMS

Coastline and Beaches

There are four elements of coastline. The coasts north of Trial Harbour and south of Cape Sorell are dominated by hardrock structures and exposed to very heavy wave attack. The almost landlocked coastline of Macquarie Harbour is subject to waves of local generation. The 32 km length of Ocean Beach is also exposed to southern ocean swell.

The sea floor off the coast slopes at about 1 in 220 to a depth of 90 m then shows a decrease to 1 in 300 to 180 m, the average slope from shore to 180 m (100 fathoms) being about 1 in 275 (Aus. Naval Chart 422). The submarine contours trend SSE-NNW. Some detailed naval charts (Aus. Naval Chart 353, 1967) suggest that slopes from the coast to 30 to 50 m depths increase from south (1:213, 1:145) to north (1:78, 1:64) between Cape Sorell and Pieman Heads. This trend is not evident at greater depths for which information is more limited. This may indicate thicker and more extensive sediments off the mouth of Macquarie Harbour than further north probably due to deltaic deposition by the combined King and Gordon rivers during glacial stage low sea level periods. The offshore topography refracts the waves, especially the long period southwesterly swells which predominate. The refraction is responsible for the sediment transport observed in this segment of coast.

North of Trial Harbour the coastline is remarkably straight, and cuts northwest across the geological grain of the country. This has been considered as a fault-controlled coastline which is parallel or sub-parallel to mapped faults further south (Corbett and Brown 1976). The coast consists of rocky, mainly granitic, stretches as near Conical Rocks Point and from Granville Harbour to Trial Harbour, separated by 12.5 km of sandy zetaform beach (Davies 1972, p. 137) north of Granville Harbour. The sharply curved end of this beach is to the north, and the direction of long-shore drift is towards the south. In detail the rugged rocky coastline is markedly joint controlled. Local patches of wind-blown sand mantle the cliffs north of Ahrberg Bay, at Tasman River and between Granite Creek and Trial Harbour.

South of Cape Sorell the rocky coastline is strongly controlled by structures in the Precambrian and Cambrian rocks and features cliffs, stacks, offshore reefs and islets that separate small, swash-aligned pocket beaches.

Most of the shoreline around Macquarie Harbour is cliffed, the cliffs being cut both in Tertiary continental sediments on the northern and eastern sides of the Harbour and in Precambrian and Palaeozoic rocks on the southern side. Sandy beaches interrupt these cliffs near the mouths of rivers entering the Harbour, e.g. King, Clark, Bird and Gordon Rivers. Connellys Point, Brisbanes Bay, Charcoal Burners, Big Pebbly and Wright Bay beaches are all aligned normal to the direction of maximum fetch of locally generated wind waves across Macquarie Harbour. The northern side of the Harbour is more indented than the southern. The southern shoreline from Birches Inlet to Pilots Bay is generally straight, trending northwesterly and cutting across the structures in the Precambrian and Palaeozoic rocks. It seems likely that this, like the coast north of Trial Harbour, is fault controlled. Scott (1960a, p. 8) deduced a northwesterly trending major fault in Macquarie Harbour. Depths within the Harbour reach a maximum of 51 m just south of Regatta Point and there is another depth approaching this (49 m) southwest of Pine Cove (British Admiralty Chart 1629). This chart also reveals a basin below 36.6 m with a northwesterly elongation from SSW of Phillips Island to east of Liberty Point and slightly nearer to the northeastern than the southwestern shore of the Harbour (fig. 3).

Ocean Beach is an uninterrupted sandy beach in the form of an uneven curve 32 km long from Trial Harbour to the mouth of Macquarie Harbour. From Trial Harbour to the

mouth of the Henty River the beach is almost straight, and the mouths of the Little
Henty and Henty Rivers are deflected to the south 2.7 km and 4.2 km respectively,
consistent with beach drifting from the north. Small soaks drain the sand dune country
east of the beach between Henty River and the mouth of Macquarie Harbour. The southern
end of Ocean Beach is more sharply curved and continues as a hook into Macquarie
Harbour, the recurved end of the hook terminating at Neck Island. Much of the east-
erly extension of the hook, however, is due to aeolian rather than marine sand trans-
port.

Beach sand granulometry, mostly by Davies (*pers. comm.*) shows the essentially
compartmentalised nature of sediment movement on this part of the west coast (see
fig. 5). The beach sands north of Trial Harbour and south of Cape Sorell are coarser,
more negatively skewed and less well-sorted than those of Ocean Beach south of the
Henty River. They show more variation between beaches than within any one beach.
Fig. 5 shows the extraordinary uniformity of the sands of Ocean Beach proper. The
pocket beaches have far higher quartz/feldspar ratios (6.7 to 7.6, c.f. 0.8 for Ocean
Beach) indicating the more local and probable Holocene derivation of sand on the small
pocket beaches in comparison with the wider provenance and probably older origin (in
the sense of reworking of old terrigenous, marine and probably glacial and glacifluvial
sediments) of Ocean Beach. These tentative conclusions are supported by the smaller
proportion of heavy minerals of the more unstable species and the higher degree of
roundness of the sands of Ocean Beach. The carbonate content of the pocket beaches
(3 - 38 per cent) is far higher than that of Ocean Beach (0.6 - 2.5 per cent) due to
the more extensive shellfish-supporting, hardrock substrates off the shores north and
south of Ocean Beach. Fig. 5 also shows the increase in sorting and decrease in grain-
size with distance south of the granite at Trial Harbour which is consistent with the
direction of drift inferred from the deflection of the mouths of the Little Henty and
Henty rivers.

The northern 25 km of Ocean Beach has a cut profile (Davies 1957) at all seasons
and is receding. Embryo foredunes are absent except on the southern 7 km of the beach.
Elsewhere it is backed by cliffs cut in Holocene beach ridge/dune sand and dune-
slack peat deposits. The orientation of these ridges is at a slight angle to the pres-
ent coast. This, together with the beach drift deflected mouths of the Little Henty
and Henty rivers and the stranding of the Holocene cliff-mantling sand sheets north of
Trial Harbour by the complete erosion of beach sand once at their foot indicates that
coastal recession has been of the order of at least 150 m at the northern end of the
beach. The sand eroded is now found in three principal deposits: the massive threshold
sand bar at the mouth of Macquarie Harbour, the body of the recurved spit inside the
Harbour, and in the transgressive dunes immediately east of the beach.

Wind Action
Wind action has not played a major part in moulding the landscape except in a
belt just inland from Ocean Beach and Ahrberg Bay. There are also local cliff-
mantling sand sheets elsewhere.

Behind the beach bordering Ahrberg Bay there are foredunes with minor blowouts
of southwesterly derivation. The sandy coast is too broken by rocky reefs to allow
major transport of sand along the beach. Between the mouth of the Little Henty
and that of the Henty there are minor unvegetated blowouts and sandsheets advancing
from the south but they are advancing onto a large, complex, vegetated but eroded
parabolic dune oriented north of northwest.

There exists a very striking contrast in the relative degree of soil development
between the unvegetated, active dunes behind the beach and the fully vegetated dunes
further inland which rise to an altitude of 145 m and have an amplitude of relief of
90 m north of Strahan (fig. 6). Within the vegetated series there are a number of
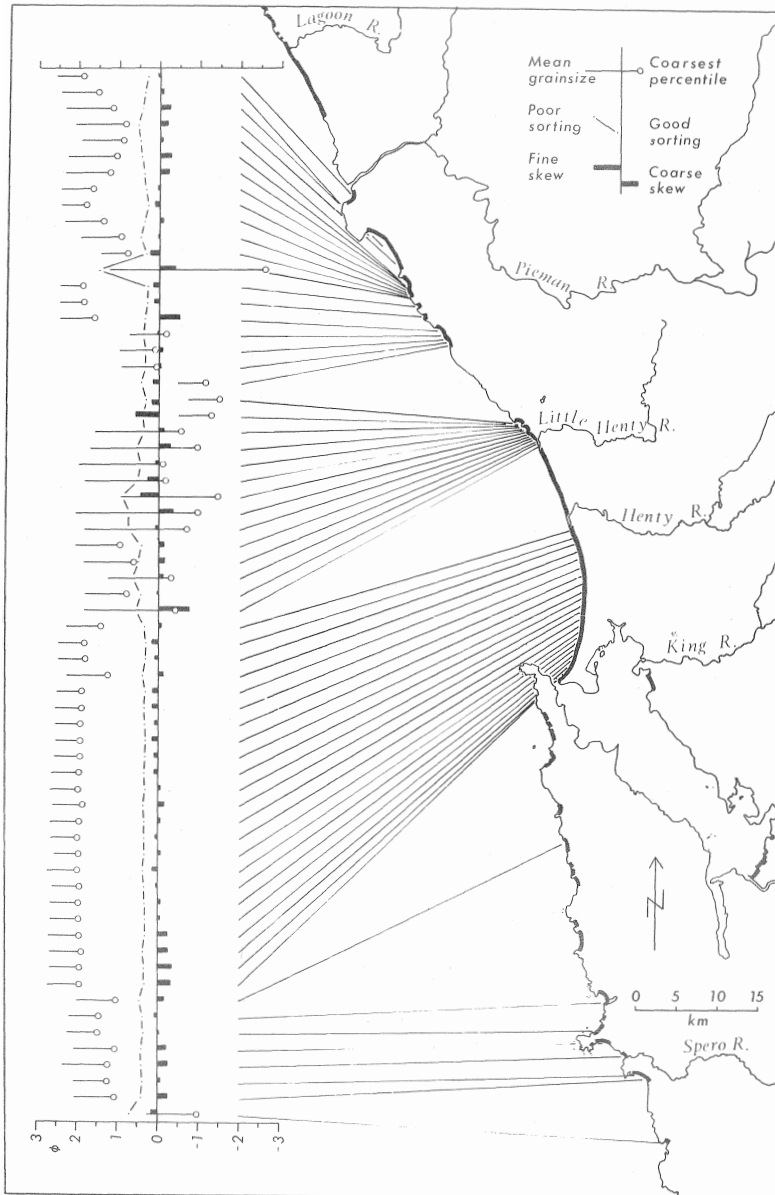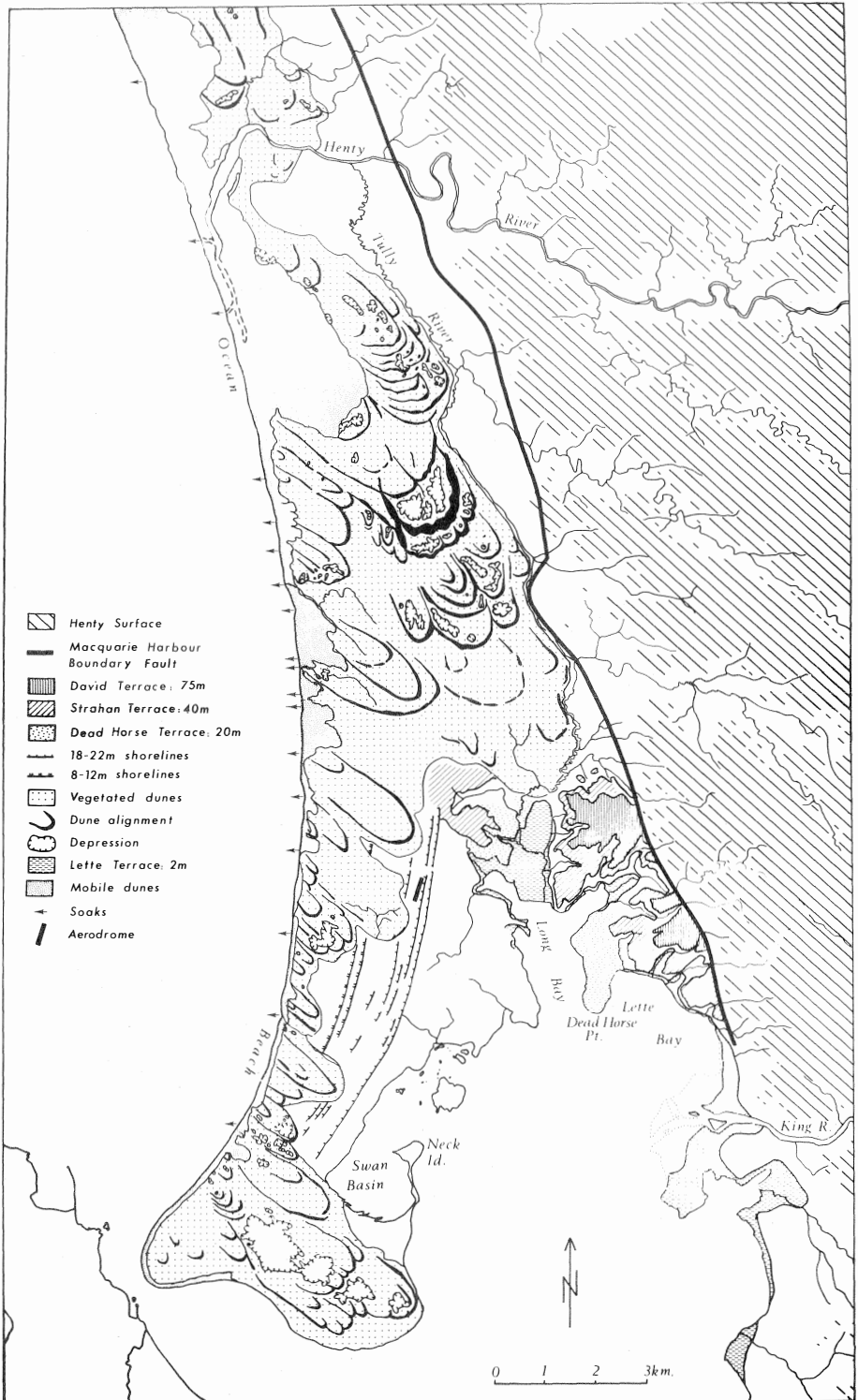
Maxwell R. Banks, Eric A. Colhoun and Neil K. Chick

FIG. 5. - Granulometry of beach sands along central West Coast.

FIG. 6. -
Map of aeolian
features, shore
lines and ter-
races near
Strahan.

Legend:
- Henty Surface
- Macquarie Harbour Boundary Fault
- David Terrace: 75m
- Strahan Terrace: 40m
- Dead Horse Terrace: 20m
- 18-22m shorelines
- 8-12m shorelines
- Vegetated dunes
- Dune alignment
- Depression
- Lette Terrace: 2m
- Mobile dunes
- Soaks
- Aerodrome

Henty River

Tully River

Ocean

Beach

Long Bay

Dead Horse Pt.

Lette Bay

King R.

Swan Basin

Neck Id.

0 1 2 3km.

major dunes each with complex minor blowout features and minor longitudinal sand ridges. The dune train which commences near the mouth of the Henty River is oriented from 312 to 328° (the lines drawn mid-way between the horns of successive parabolas). This dune train is more dissected to the southeast than further northwest, and this, together with the progressive increase in depth of leaching indicated by a thickening of the A_2 horizon and greater intensity of colour and induration of the $B_{h(ir)}$ horizon of the podsols suggests a progressive increase in age from northwest to southeast. Indeed, so thick is the A_2 horizon of the soils of some of the dunes within 5 km of Strahan that it must be depositional rather than pedogenic in origin. This must have required surface conditions very different from those of the present, namely a complete absence of the heavy scrub and timber vegetation now covering them, and a source of sand very different from the beach and frontal dune sand feeding the younger dunes which have advanced from the west at a rate of 17 m per annum since 1953 over the old Zeehan-Strahan railbed where it had been cut through the older dune series. The bulk of the older series was constructed of deflated pre-podsolized sand. The existence of dune lakes within the older series implies a lowering of the water table during its formation. All these conditions seem to demand a Pleistocene age for the older dunes.

Such an age for the older dune series is consistent with the Last Cold Stage formation of terrestrial dunes in northern Tasmania (Colhoun 1975), northeastern Tasmania (Bowden *pers. comm.*), King Island (Jennings 1959, 1961), Flinders Island (Kershaw and Sutherland 1972), various inland sites (Nicolls 1958, 1960, Sigleo 1975), near Moulting Lagoon and on North Bruny Island. The source of sand near Strahan may have been the formerly braided bed of the Henty River where it left its lower winding gorge charged with glacifluvially derived sand, the terrestrial and marine sands exposed by the lowering of sea level in glacial times, the raised beach sands to be discussed below, or all three.

West and south of the dune train are a large number of vegetated and a few unvegetated and active dunes inland from the beach. All show the action of winds from west of northwest. Many of these modern blowouts, both vegetated and active, are complex and interfere with one another. However, none except those near the mouth of the Henty River shows a distinct train of parabolic dunes. These are related to the unstable conditions at the mouth of the Henty River which changes position frequently due to seasonal variations in discharge and conditions of beach cut and fill. This area has also long been subject to stock grazing and firing.

It is not yet completely clear from the wind records kept in the area why the dunes, both vegetated and active, show the variety of orientations they do. What must be considered are not only the frequency but also the magnitude and duration of winds. Sand transporting capacity increases to the third power of the increase in speed above a threshold velocity which itself depends upon grain size, surface roughness, temperature and moisture content. Sand will blow in the direction which is the resultant of all vectors (or onshore vectors only in the case of secondary beach dunes). Obviously, the wider the expanse of exposed sand the greater the probability and magnitude of transport.

It is possible that only winds from the northwest blew over a sufficient expanse of sand to allow transport of large enough quantities of sand to produce the major dune trains located near the Little Henty and Henty Rivers and at the wide and rapidly prograding distal end of the Ocean Beach spit. However, Cape Sorell wind records demonstrate one of the widest ranges of direction of strong winds of any Tasmanian coastal station. There is a marked difference between the resultant of morning winds (from 292°) and afternoon winds (from 260°), between summer winds (November to April, from 260°) and winter winds (May to October, from 280°). None of these directions

agrees with the major secondary coastal dune trends (from 299° to 310°) nor with that of the older dune series (from 312° to 328°). They do generally agree with the direction of advance of the modern transgressive dunes as interpreted from repeated aerial photography over the same time period as the records cover.

Clearly the length of the wind data record is inadequate to reveal the overall long-term northwesterly to north of northwesterly resultant in an area of such a changeable wind regime. The wide range of orientations of the smaller transgressive dunes must be seen as being temporally dependent.

Changes of Sea Level
The features at Strahan regarded by Davies (1960) as raised strandlines at 50 m and 36 m are under investigation. Other features at 18 - 22 m and 8 - 12 m noted by Davies (*pers. comm.*) and shown on fig. 6 near Strahan Airport have been confirmed as being raised beaches (Chick 1976). The drainage ditches at the airport reveal up to 8 cycles of alternating sand and imbricated pebble deposition dipping seawards at 2 - 5° and the sand wedges thickening landward like modern beach berms. (Plate 4).
The degree of induration far exceeds that of the Holocene or Last Glacial stage dunes and is comparable with that of the Last Interglacial beach and dune deposits at Ulverstone (Chick 1971) though far more humic. The sand size is comparable with that of the modern beach, which lacks pebbles. The origin of the pebbles is to be found in the Tertiary terrestrial and probable Pleistocene glacigenic deposits of the Strahan area. The surface beds of pebbles (below the 0.5 m of Holocene peat) have cryoturbation structures in the top 1 m indicating impeded drainage and deep winter freezing of the soil during the Last Glacial Stage when this area would have been at or above the tree line.

Much of the Interglacial raised beach is obscured by the transgressive dunes described above, but at Trial Harbour and again south of the Little Henty River it is observable in windows through the mantling of alluvial fan deposits, Holocene peat and wind blown sand. Sections in the well cemented granule and pebble raised beach deposits near Montagu Creek show structures consistent with transgression followed by regression. There is an abrupt transition upwards to a cemented angular grit derived from Oonah Quartzite overlain by a partially indurated sandy silt which may be a fossil soil. The top surface of this is cut by sludge gullies or rills filled with sharp angular pebbles and covered by wind blown sand and peat. The terrestrial sequence postdating the marine beds may indicate two periods of surface instability.

SUMMARY AND GEOMORPHIC HISTORY

During the Cainozoic the Higher Plateau, Lower Plateau and St. Clair Surfaces may have been produced and then uplifted and eroded. It may well be that due to the initial rifting major river systems such as the Pieman, King and Gordon were initiated and flowed west from central Tasmania into the Macquarie Harbour rift valley. Distant marine conditions are indicated by the presence of microplankton of Palaeocene age in sediments near Strahan (Corbett and Brown 1976, p. 14). The sea is not known to have reached that part of the Macquarie Harbour Graben above present sea level until the Pleistocene. Polyzoal limestone, probably of Late Oligocene or Early Miocene age (Quilty 1972, p. 40) at Granville Harbour marks the nearest known point of marine transgression to Macquarie Harbour during the Tertiary.

Late in the Tertiary or early in the Pleistocene an extensive surface of sub-aerial erosion, the Henty Surface was developed. Subsequent to rejuvenation of the river systems other partial surfaces developed along the coast and around Macquarie Harbour. The West Coast Ranges were glaciated twice during the Late Quaternary. During the earlier glaciation outlet glaciers pushed down the Pieman, Henty and King River valleys but the maximum extent of this glaciation has not yet been determined.

Maxwell R. Banks, Eric A. Colhoun and Neil K. Chick

An interglacial forest flora developed following glacier retreat and sea level rose to at least + 22 m. Climatic deterioration during the Last Glacial Stage saw the development of less extensive recap and outlet glaciers on the West Coast Range, the lowering of the tree line and frost action to near sea level, with strong aeolian activity along the coast following the retreat of the sea. A distinct readvance of ice to the Hamilton Moraine is recorded during the final general deglaciation which was probably complete by about 10,000 BP. The sea around Tasmania reached its present level about 6000 years BP (Chick 1976). Since then the present coast has remained unchanged except for adjustments to the outline and surface form of Ocean Beach due to transport of sand by waves and wind.

REFERENCES

Ahmad, N., Bartlett, H.B., and Green, D.H., 1959: The glaciation of the King Valley, western Tasmania. *Pap. Proc. R. Soc. Tasm.,* 93 11-16.

Baillie, P.W. and Williams, P.R., 1975: Sedimentary and structural features of the Bell Shale correlate (Early Devonian), Strahan Quadrangle, western Tasmania. *Pap. Proc. R. Soc. Tasm.,* 109, 1 - 15.

Banks, M.R. and Ahmad, N., 1959: Notes on the Cainozoic history of Western Tasmania - "Malanna" Glaciation. *Pap. Proc. R. Soc. Tasm.,* 93, 117-127.

_____, 1962: The Permian System in western Tasmania. *Pap. Proc. R. Soc. Tasm.,* 96, 1-18.

Blissett, H.A., 1962: Geological atlas one mile geological series. Sheet K/55-5-50. Zeehan. *Explan. Rep. geol. surv. Tasm.*

Boeuf, M.G. and Doust, H., 1975: Structure and development of the southern margin of Australia. *A.P.E.A.J.,* 15 (1), 33-43.

Bowden, A.R., 1974: *The Glacial Geomorphology of the Tyndall Mountains, Western Tasmania.* B.Sc. Honours Thesis, Department of Geography, University of Tasmania.

Bradley, J. 1954: The Geology of the West Coast Range of Tasmania. *Pap. Proc. R. Soc. Tasm.,* 88, 193-243.

Carey, S.W., 1955: A new record of glacial grooving near Queenstown, Tasmania. *Aust. J. Sci.,* 17 (5), 176.

Chick, N.K., 1971: Fossil Shorelines of the Ulverstone District, Tasmania. *Pap. Proc. R. Soc. Tasm.,* 105, 29-40.

_____, 1976: Tasmania (in) 1974-1976 Research on Quaternary Shorelines in Australian and New Zealand - a summary report on the ANZAAS Quaternary Shorelines Committee. *Aust. Quat. Newsletter,* 8, 24-26.

Colhoun, E.A. 1975: A Quaternary Climatic Curve for Tasmania. (Paper presented to the Royal Meteorological Society Australasian Conference on Climate and Climatic Change, Monash University).

Conder, H. 1918: The tinfield of North Dundas. *Bull. geol. Surv. Tasm.,* 26.

Corbett, K.D. and Brown A.V. 1976: Geological atlas 1:250,000 series. Sheet SK-55/5 Queenstown. *Explan. Rep. geol. Surv. Tasm.*

Corbett, K.D., Green, G.R. and Williams, P.R. 1977: The Geology of Central western Tasmania, *This volume,* pp. 7-28.

David, T.W.E., 1923: Geological evidence of the antiquity of man in the Commonwealth *Pap. Proc. R. Soc. Tasm.*, (1922), 109-150.

_____, 1926: Pleistocene glaciation near Strahan, Tasmania. *Rep. Aust. Ass. Adv. Sci.*, 17 (1924), 91-103.

Davies, J.L., 1957: The importance of cut and fill in the development of sand beach ridges. *Aust. J. Sci.* 20, 105-11.

_____, 1959: High level erosion surfaces and landscape development in Tasmamia. *Aust. Geogr.*, 7 (5), 193-203.

_____, 1960: Quaternary strandlines in Tasmania. In summary of the Report of the ANZAAS Sections C and P Committees. *Aust. J. Sci.*, 23, 75.

_____, 1961: Tasmanian beach ridge systems in relation to sea level change. *Pap. Proc. R. Soc. Tasm.*, 95, 35-40.

_____, 1965: Landforms. *In* Davies, J.L. (Ed): ATLAS OF TASMANIA, Lands and Surveys Dept., Hobart, 19-25.

_____, 1967: Tasmanian landforms and Quaternary climates. *In* Jennings, J.N. and Mabbutt, J.A. (Eds): LANDFORM STUDIES FROM AUSTRALIA AND NEW GUINEA. A.N.U. Press, Canberra, 1-25.

_____, 1972: GEOGRAPHICAL VARIATION IN COASTAL DEVELOPMENT. Oliver and Boyd, Edinburgh.

Deighton, I., Falvey, D.A. and Taylor, D.J., 1976: Depositional environments and geotectonic framework, southern Australian continental margin. *A.P.E.A.J.*, 16 (1), 25-36.

Derbyshire, E., 1972: Pleistocene Glaciation of Tasmania: Review and Speculations. *Aust. Geogr. Stud.*, 10, 79-94.

_____, 1973: Periglacial Phenomena in Tasmania. *Buil. Peryglac.*, 22, 131-148.

_____, Banks, M.R., Davies, J.L. and Jennings, J.N. 1965: Glacial Map of Tasmania. *R. Soc. Tasm. Spec. Publ.*, 2, 11 pp.

Edwards, A.B., 1941: On a remnant of a stripped peneplain of Palaeozoic age at Mt. Sedgwick in western Tasmania. *Pap. Proc. R. Soc. Tasm.*, (1940), 19-22.

Galloway, R.W., 1965: Late Quaternary Climates in Australia. *J. Geol*, 73, 603-18.

Gill, E.D., 1956: Radiocarbon dating for glacial varves in Tasmania. *Aust. J. Sci.*, 19, 80.

_____, 1962: Geology of Tasmania. Cainozoic. *J. Geol. Soc. Aust.*, 9, 233-253.

Goede, A., 1974: Caves of Tasmania. *Univ. Tasm.* (unpubl).

Gregory, J.W., 1903: Some features in the geography of north-western Tasmania. *Proc. R. Soc. Vict.*, 16, 177-183.

Hills, C.L., 1914: The Jukes - Darwin mining field. *Bull. geol. Surv. Tasm.*, 16.

Jennings, J.N., 1959: The Coastal Geomorphology of King Island, Bass Strait in relation to changes in the relative level of land and sea. *Rec. Q. Vict. Mus. Launceston,* N.S. 11, 1-39.

_____, 1961: Sea level changes in King Island, Bass Strait. *Zeits. fur Geomorph.* Supp. 3, 80-84.

_____, and Banks, M.R., 1958: The Pleistocene glacial history of Tasmania. *J. Glaciol.,* 3, 298-303.

Kershaw, R.C. and Sutherland, F.L., 1972: Quaternary Geomorphology of Flinders Island. *Rec. Q. Vict. Mus. Launceston,* 43, 1:28.

Langford, J., 1965: Weather and Climate. *In* Davies, J.L. (ed): ATLAS OF TASMANIA, Lands and Surveys Dept., Hobart, 2-11.

Lewis, A.N., 1934: A correlation of the Tasmanian Pleistocene glacial epochs and deposits. *Pap. Proc. R. Soc. Tasm.,* (1933), 75-86.

_____, 1939: Notes on Pleistocene glaciation Mount Field to Strahan. *Pap. Proc. R. Soc., Tasm.,*(1938), 161-73.

_____, 1945: Pleistocene glaciation in Tasmania. *Pap. Proc. R. Soc. Tasm.,* (1944), 41-56.

Montgomery, A., 1894: Notes on the Queen River and Mount Lyell Mining District. *Parl. Pap. Tasm.,* 9th July.

Nicolls, K.D., 1958: Aeolian deposits in River valleys in Tasmania. *Aust. J. Sci.,* 21, 50-1.

_____, 1960: Erosion surfaces, river terraces and river capture in the Launceston Tertiary Basin. *Pap. Proc. R. Soc. Tasm.,* 94, 1-12.

_____, and Dimmock, G.M., 1965: Soils, *In* Davies, J.L. (Ed): ATLAS OF TASMANIA, Lands and Surveys Dept., Hobart, 26-29.

Paterson, S.J., 1965: Pleistocene drift in the Mersey and Forth valleys - probability of two glacial stages. *Pap. Proc. R. Soc. Tasm.,* 99, 115-124.

Peterson, J.A., 1966: Glaciation of the Frenchmans Cap National Park. *Pap. Proc. R. Soc. Tasm.,* 100, 117-129.

Quilty, P.G., 1972: The biostratigraphy of the Tasmanian marine Tertiary. *Pap. Proc. R. Soc. Tasm.,* 106, 25-44.

Scott, B., 1960 a: Comments on the Cainozoic history of western Tasmania. *Rec. Q. Vict. Mus. Launceston,* N.S. 12, 1-10.

_____, 1960 b: Erosion surfaces in western Tasmania. *Rec. Q. Vict. Mus. Launceston* N.S. 13, 1-11.

Sigleo, W.R., 1975: *Late Quaternary Environment and Man in Southeastern Tasmania.* Ph. D. Thesis, Department of Geography, University of Tasmania.

Spry, A.H., 1957: Precambrian rocks of Tasmania. Part II, Mt. Mary area. *Pap Proc. R. Soc. Tasm.,* 91, 95-108.

54

Geomorphology

Tasmanian Yearbook No. 9: 1975: *Aust. Bur. Stats.*

Twelvetrees, W.H. and Ward, L.K., 1910: The ore-bodies of the Zeehan field. *Bull. geol. Surv. Tasm.,* 8.

Twidale, C.R., 1957: A reconnaissance of the Corinna - Pieman Heads area - geomorphology. *Pap. Proc. R. Soc. Tasm.,* 91, 9-16.

Waterhouse, L.L., 1914: The Stanley River tinfield. *Bull. geol. Surv. Tasm.,* 15.

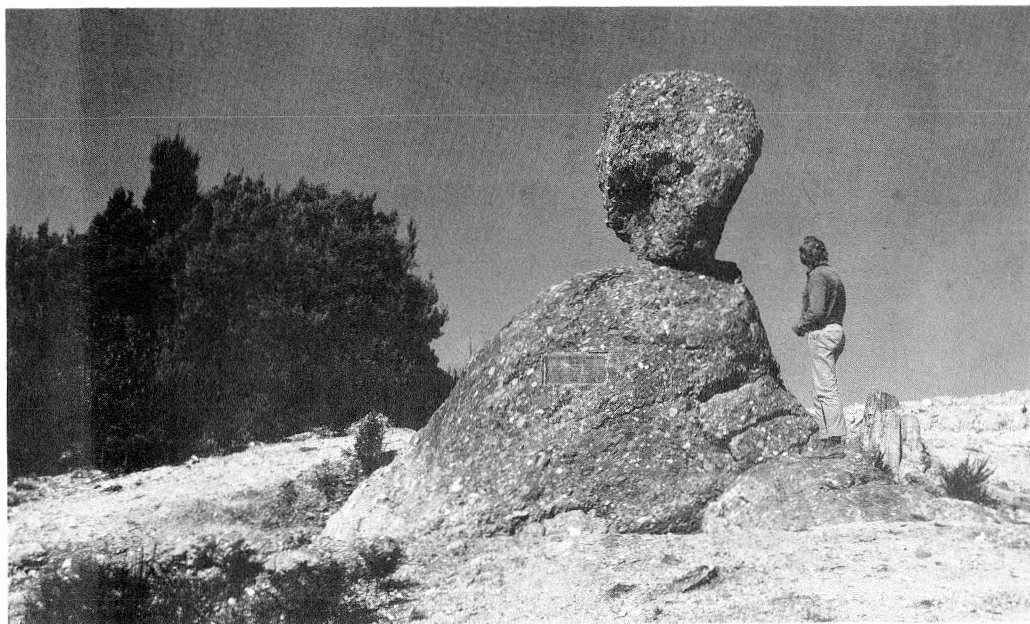_____, 1916: The South Heemskirk tinfield. *Bull. geol. Surv. Tasm.,* 21.

PLATE 5. - The Loftus Hills Memorial is situated 11 km north of Queenstown beside Murchison Highway. An inscribed plaque commemorates Dr. C. Loftus Hills M.B.E. (1884-1967) whose geological research work over many years helped to establish some of the recent major mineral developments in western Tasmania. The natural rock memorial is a glacial erratic of Owen Conglomerate which has been transported from the Tyndall Mountains to its present position which marks the limit attained by ice during the Last Glaciation.