THE GEOLOGICAL SETTING

The Eastern Highlands of Victoria consist of an uplifted and deeply dissected mass of Palaeozoic rocks and igneous intrusions. Southwards, the Palaeozoic formations pass beneath a deep sedimentary basin which contains Cretaceous, Tertiary, and Quaternary deposits, folded and faulted along mainly east-west alignments. Within this basin the South Gippsland Highlands are an uplifted and faulted anticlinorium, unroofed by denudation to expose the Cretaceous rocks; on their northern side lies the Latrobe Valley syncline, and on their northern side the Corner Inlet depression, with the high granitic upland of Wilson's Promontory farther south. The structural run on eastward across the continental shelf, the Rosedale monocline persisting as a prominent boundary between the gently-folded marginal zone to the north and the deeper complex of the Gippsland Basin tot he south (Hocking 1976).

The country north of the Gippsland Lakes consists of marine sandstones, clays and limestones or Tertiary age, which have been uplifted and titled gently seawards by earth movements associated with the raising of the Eastern Highlands late in Tertiary times. The sequence of geological formations encountered in borings has been described by Hocking (1976) as the Seaspray Group, comprising a basal Lakes Entrance Formation (Oligocene), resting on a planed – off Palaeozic basement; an overlying and more extensive Gippsland Limestone Formation (Lower to Middle Miocene) which includes the Bairnsdale Limestone and Lindenow Sandstone, both exposed in the bluffs that border the Mitchell Valley above Bairnsdale; Then the Tambo River Formation (upper Miocene), consisting the Mitchell and Tambo valleys, the river cliffs at Swan Reach providing the type-section; and finally the Jemmys Point formation (Lower Pliocene) at the top of the Group, with sandstone outcrops at Red Bluff and Eagle Point, as well as the type-section at Jemmys Point. Each of these Formations extends beneath the Gippsland Lakes, a southward dip being indicated by the upper boundary of the Tambo River Formation, 10 metres above present sea level in the Mitchell and Tambo valleys, descending to 32 metres below present sea level beneath the Mitchell River silt jetties, and over 100 metres beneath Paynesville and Metung. The Tertiary rocks of the Gippsland Lakes region are the outcome of a marine transgression, which reached its maximum extent with the deposition of the Gippsland Limestone, which overlaps the basal Lakes Entrance Formation. The succeeding Tambo River and Jemmys Point Formations mark the ensuring regression (Hocking 1976), the uppermost beds of the Jemmys Point Formation, termed the Lake Reeve Sand member, occupying a zone beneath the Quaternary coastal barriers; in a sense ancestral to them, commemorating the establishment of predominantly quartzose sedimentation on a sector of the Australian continent where calcareous deposition had prevailed in Miocene times.

The coastal plateau cuts across the tilted strata north of the Gippsland Lakes, and is strewn with superficial gravels derived from denudation of the highlands to the north and composed of well-rounded pebbles and cobbles of granite, quartzite, sandstone and metamorphic rock, all of which can be matched in hinterland outcrops. The gravels are well exposed in the upper part bluff (Plate 4), where they overlie Upper Tertiary (Kalimna stage) sandstones. Their distribution is patchy across the coastal plateau, and it appears that they were originally laid down by rivers much larger and stronger than those which now drain into the lakes. Probably they formed during colder climatic phases of the Pleistocene, when periglacial weathering disintegrated rocky outcrops in the Highlands, and torrential rivers, nourished by rapidly-melting snow, swept the coarse debris down on to what is now the coastal plateau. The gravels have been locally reworked, and incorporated into younger river terrace deposits, and into the alluvial deposits underlying valley floors.

Old dune formations, typically or parabolic form, with a stabilising cover of woodland and heath vegetation are also found on the coastal plateau north of Lake Wellington and Lake Victoria (Figure 1). Their origin is uncertain, but they may have been derived from earlier barrier deposits associated with higher Pleistocene shorelines, rearranged and driven eastwards by wind action, possibly during subsequent arid phases. The incised valleys are bordered by dissected terraces, the pattern of which indicates successive episodes of valley-floor plantation related to earlier and higher base levels of fluvial denudation, interrupted by

stream incision and valley-floor dissection in phases when base level (i.e. sea level) was lowered.

East of the Tambo valley, and extending to the crest of the bluffs between Metung and Jemmys Point, remnants of the highest terrace stand 60 – 75 metres above sea level. Other terraces bordering the incised valleys stand 25 – 30, 12 – 18, and 6 – 9 metres above the present valley floors and, as will be seen, the coastal plains include depositional features that formed during the late Pleistocene phase with the sea up to 3 metres above its present level. These terraces possibly correspond with higher eustatic sea level stands during interglacial phases of the Pleistocene period: the 6 – 9 metre level, widely reported on the Australian coast, has been correlated with an interglacial still stand (Gill 1961; Jennings 1961), and its presence north of Lake King indicates the relative stability of this part of the coast since lat Pleistocene times.

The country west of the Gippsland Lakes differs in several respects. The Tertiary formations have been more strongly folded and faulted along the synclinal trough beneath the Latrobe Valley (Figure 10), and there is evidence that tectonic deformation continued, possibly into Recent (Holocene) times, producing fault scarps and warped and faulted river terraces (Boutakoff 1955). The eastward swing of the Mitchell valley as it leaves the Eastern Highlands at Glenaladale may reflect gentle updoming of the coastal plateau to the south, disrupting a former southward flow, and father west the superficial gravels have been displaced by late Pleistocene or Holocene earth movements. East of Sale the 6 – 9 metre terrace between the Latrobe and Avon valleys (marking the late Pleistocene delta built by these rivers) fails to maintain its level relative to the present valley floors and has evidently been tilted eastwards to pass beneath the swamps that border the western shore of Lake Wellington. It is crossed by 'prior streams' that flowed eastward across a Pleistocene Avon-Latrobe delta: locally, these have been re-shaped into dune topography.

South of the Latrobe valley at Longford there are terraces at about 15 and about 8 metres above sea level, traceable eastwards through Duston, and along the northern slope of the Deadmans Hill ridge. This slope if a topographic feature that follows the Rosedale monocline, an east-west flexure with northward dips of up to 35º in tertiary formations draped across a major fault displacement in the underlying Cretaceous rocks (Figure 10). It forms a structural boundary to the Latrobe Valley syncline to the north, the crest of Deadmans Hill ridge coinciding with the axis of the Baragwanath anticline to the south.

Many details remain to be worked out, but it appears that there have been successive marine transgressions into the Latrobe Valley syncline during Tertiary times. To the west the Tertiary deposits are predominantly terrestrial, with brown coals indicative of former swamp forests west of Traralgon; to the east, they are predominantly marine in the Lakes entrance district; and in the centre they are estuarine. Estuarine lagoons ancestral to Lake Wellington evidently existed in the Sale district when the Jemmys Point marine sands (Kalimna stage) were laid down farther east (Boutakoff 1957).

In Quaternary times, coastal evolution has been influenced by subsidence along the Latrobe Valley syncline, the axis of which passes beneath Lake Wellington and out to sea, and by elevation along the Rosedale monocline to the south. The Gippsland Lakes therefore border a coast that has been relatively stable to the north-east, but unstable to the south-west, Lake Wellington lying athwart the Latrobe Valley syncline as it crosses the present coastline. Boutakoff (1955) traced warped Pleistocene marine cliffs south-west from Lake Wellington into the Woodside district, and there is evidence of continued subsidence around Corner Inlet, on the northern side of Wilson's Promontory, an area which has relatively high frequency earthquakes. Although the Ninety Mile Beach presents a smooth depositional outline, the coast of Gippsland, south-west from the Gippsland Lakes, has been essentially a 'shoreline of transverse deformation' (Cotton 1951).

The shaping of the coastal embayment in which the Gippsland Lakes are now enclosed therefore began in Tertiary times. It continued through Pleistocene times, influenced by tectonic deformation along the Latrobe Valley syncline and by successive marine transgressions and regressions when eustatic movements of sea level accompanied the

waxing and waning of the earth's glaciers and ice sheets (Fairbridge 1961). Five phases of high Pleistocene sea level have been recognised in this study (Bird 1965), and Ward and Jessup (1965) listed a sequence that included the equivalents of these five, and four earlier phases ranging up to 128 metres above present sea level. The embayment is backed by the marginal bluff (a former sea cliff), and underlain by a shelf of consolidated Pliocene (and possibly early Pleistocene) rocks, encountered in borings beneath a cover of Quaternary barrier, swamp and alluvial deposits in the coastal region. This interpretation is based on records of borings in search of oil inspected at the Mines Department in Melbourne. At the Lakes Entrance pilot station, beside the artificial entrance, a boring passed into consolidated formations at a depth of 16 metres below sea level, an at Letts Beach the Dulungalong bore encountered solid rocks at a depth of 18 metres. On sperm Whale Head, the underlying shelf was reached at 15 metres and on Rigby Island, part of the inner barrier at Lakes Entrance, at 8 metres. It is inferred that the underlying shelf slopes seaward from the base of the marginal bluff to a depth of about 20 metres beneath the Ninety Mile Beach, emerging to form the sea floor beyond the 10 fathom contour (Figure 3). The cutting of this shelf, and the cliffing and recession of the marginal bluff behind it at the edge of the coastal plateau are attributed to marine denudation during successive marine transgressions in Pleistocene times.

At the same time, valley development continued in the coastal region. The present valleys are incised into the coastal plateau, but their alluvial floors are aggradational, concealing deeper channels which extend well below present sea level. Each time sea level fell, the rivers became incised into their former valley floors, and new valleys developed, extending across the emerged sea floor to a lower sea level. During marine transgressions which succeeded low sea level phases, the incised valleys were submerged to form inlets, so that the coastal embayment had branched extensions into the river valleys. Deposition, mainly of fluvial sediment, has partly filled these inlets and built up aggradational cycles of incision, submergence, and reclamation because each phase of incision has obliterated much of the morphological and stratigraphical legacy of preceding stages. The present morphology of the coastal region has taken shape since late Pleistocene times, the coastal embayment attaining essentially its present form during the penultimate marine transgression; in chapter IV it will be shown that the earliest parts of the existing barriers were deposited in late Pleistocene times, when the sea stood at, or slightly (up to 3 metres) above, its present level. There was dissection during the Last Glacial phase, when sea level fell by at least 130 metres, and renewed submergence, with addition of younger barriers, during the Holocene marine transgression (20, 0 00 to 6, 000 years ago) and the succeeding still stand, with the sea at or about its present level, during the past 6, 000 years (Fairbridge 1961; Shepard 1961). The question of a higher Holocene sea level remains controversial, but in the Gippsland Lakes region there are depositional features, including low plains and stranded beach ridges, which seem to indicate a phase when sea level stood 1 to 2 metres higher than it does now. Evidence for such a phase can be seen in the form of a 'raised beach' along the north shore of Lake Victoria behind Mason Bay and Duck Bay, at Bluff Head and Butlers Point, and on Tambo Bluff. Ward and Jessup (1965) claimed five stages of higher Holocene sea level, but they did not provide detailed evidence to justify so close a sequence or such precise determinations, and until such evidence is forthcoming their conclusions cannot be accepted.

Where it faces seaward across the Gippsland Lakes and the coastal barriers the marginal bluff is clearly a former sea cliff that has been degraded by subaerial denudation since the development of coastal barriers excluded marine attack. From Metung to Jemmys Point and on to Red Bluff (where it breaks the outline of the Ninety Mile Beach as a rocky sea cliff) the bluff is high and bold (Plates 5 and 6), truncating the 60 – 75 metre terrace. It is cut mainly in sandstones of the Jemmys Point Formation. A point of interest is the absence of shore platforms at its base, close to present sea level. The shore platforms that formed as the cliffs receded evidently stand below present sea level, indicating that cliffing took place when the sea stood relatively lower or the land relatively higher than it does now. At Red bluff, where the marginal bluff becomes an active sea cliff, marine erosion has cut a sandstone platform between high and low tide marks.

West of Paynesville the marginal bluff is more subdued in profile, partly because it intersects lower terraces, partly because the sandstones give way to less resistant siltstone and clay formations, and partly because it has been protected from marine attack for a longer periods,

since it lies behind the prior barrier. The Pleistocene gravels strewn across the coastal plateau cap sections of the bluff, and shingle derived from them is abundant in beaches and spits on the northern shores of Lake Wellington, Lake Victoria, and Lake King. Along the sides of the incised valleys the marginal bluff becomes a valley-side feature overlooking the alluvial plains, levees, and backswamps formed by valley-floor aggradation. A beach consisting of sand and shingle, formed at the height of the Holocene marine transgression, extends along the base of these valley-side bluffs, marking the shoreline of the submerged area that has since been reclaimed by sedimentation. Mechanical analyses of these deposits show clearly their affinities with the beaches that border the northern shore of Lake Victoria at the present time, the sand fraction being coarser than in the sands of the Ninety Mile Beach (Figure 11, A and C). Along the valley sides the bluff becomes subdivided into smaller bluffs separating river terraces, and passes beneath the aggraded valley floors to merge with the underlying valley.

The marginal bluff is almost always a relict feature, a slope bearing a soil and vegetation cover, but locally it is freshly cliffed, either by lake waves (as at Tambo Bluff on the shore of Lake King) or by river scour (as at Eagle Point Bluff in the lower Mitchell valley). Allowing for these modifications it provides a convenient boundary between the older terrain of coastal plateau, shaped mainly by denudation, and the younger terrain of the coastal plain, shaped mainly by deposition.

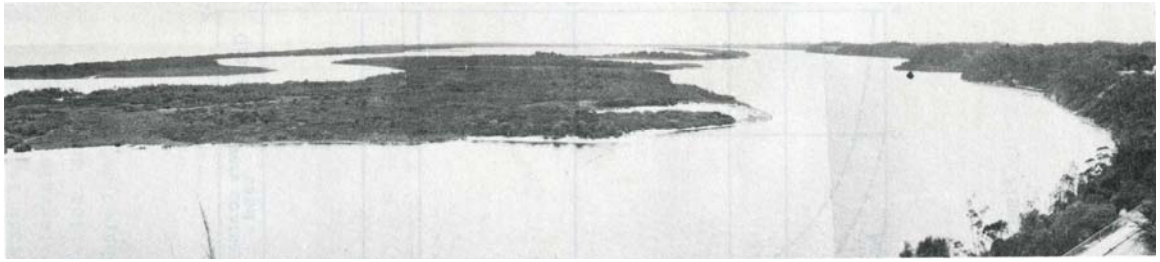

Plate 5 – Marginal bluff and barriers west from Jemmys Point (J McArthur)

Plate 6 – Marginal bluff and outer barrier east from Lakes Entrance (ECF Bird)

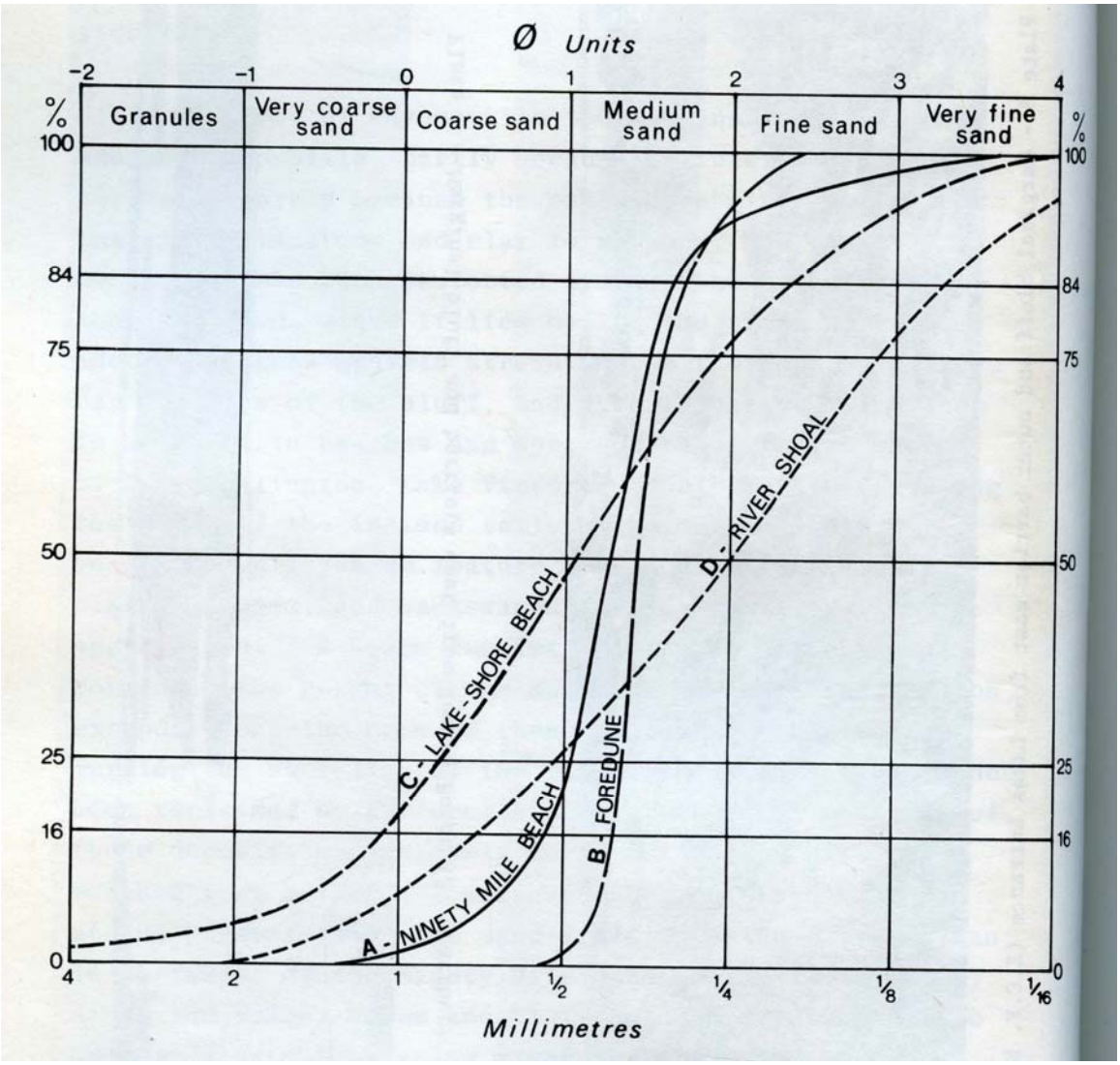

Figure 11 – Representative grain size analysis

Plate 7 – New foredunes west of Lakes Entrance (ECF Bird)

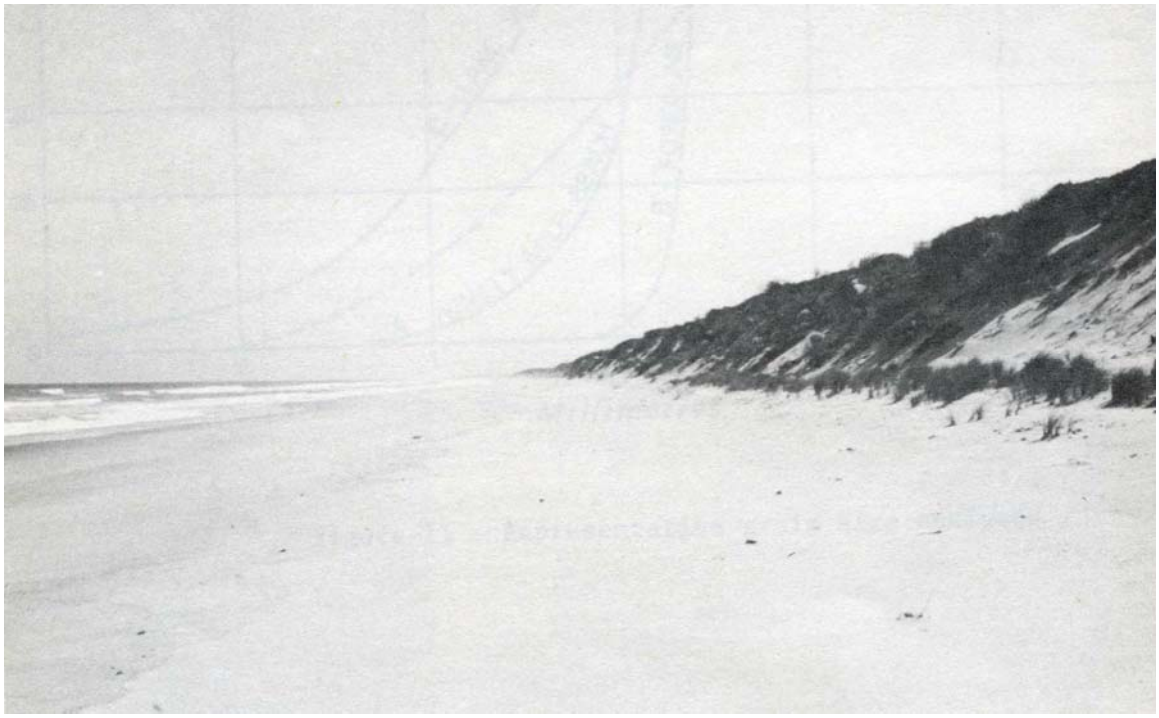

Plate 8 – Eroding dune cliff, Ninety Mile Beach (ECF Bird)