The victorian naturalist

Vol. 92, No. 7 July, 1975

Published by the

FIELD NATURALISTS CLUB OF VICTORIA

in which is incorporated the Microscopical Society of Victoria

Registered in Australia for transmission by post as a periodical. Category "B"

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The Shaping of the Nepean Peninsula Victoria, Australia

by

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The Nepean Peninsula (Fig. 1) consists largely of hummocky dune terrain, some of the dunes being active and mobile while others are stable beneath a cover of scrub, woodland, or grassland. The crests of the dunes are generally between 50 and 100 feet above sea level, but some rise higher, with summits locally exceeding 200 feet in the Sorrento district. There are no surface streams or lakes, for the dune sands are highly permeable and rainwater quickly percolates into the ground.

Beneath the superficial dunes are sandstones formed by the consolidation and cementation of older dune formations; they are well exposed in the rugged cliffs and broad shore platforms that border the ocean coast of the Peninsula (Plates 1 and 2). Inland, Tootgarook Swamp is a corridor of lowland, now largely drained and reclaimed as pastureland, bordered by bold dune topography on its western side and more subdued hummocky country to the east, on the lower slopes of the Arthur's Seat range. Arthur's Seat is an area of ancient crystalline and volcanic rocks, and the country south and east, descending to the rocky coast between Cape Schanck and Flinders, is developed on thick basaltic lavas, weathered at the surface to the dark brown clays which sustain rich green pastures and orchards.

The story is a complicated one, and it will be necessary first to mention some basic geological concepts (Keble, 1950). Geological time is divided into a succession of periods from the Cambrian, which began about 600 million years ago, through to the Holocene (or Recent), which covers the past 10,000 years. The ancient rocks which outcrop in Arthur's Seat were formed during Devonian times, about 400 million years ago, whereas the basalts of Cape Schanck date from a phase of volcanic activity in Eocene times, between 40 and 50 million years ago. The dune sandstones of the Nepean Peninsula are of Pleistocene age, deposited within the past million years or so: they include fossil remains of kangaroo species now extinct (Gregory, 1901). The superficial dunes are generally of Holocene age, and some of the processes of erosion and deposition which have shaped them are still active, notably along the ocean coastline.

Within the past million years there have been many changes in the natural environment of south-eastern Australia. Sea level has risen and fallen relative to the land in response to variations in the Earth's climate: during the colder phases of the Pleistocene epoch, when more of the Earth's water was locked up in polar and mountain glaciers, ocean levels were lowered, and during relatively mild episodes they rose again. Although there was little if any glaciation in Victoria, the Pleistocene epoch

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here included phases of both warmer and cooler climate than that now experienced; at times it was wetter, and at times drier than at present; there were phases when the winds were stronger and more consistently westerly than they are now, and phases when the wind regime was weaker and more varied in direction. In attempting to reconstruct the geological history of an area such as the Nepean Peninsula it is necessary to be aware of these past variations in sea level and climate.

The prelude to the formation of the Nepean Peninsula was a period of intermittent warping and fracturing of the Earth's crust in this part of Victoria spanning several million years. Mornington Peninsula to the east and the Bellarine Peninsula to the west were uplifted as a result of these movements, and the intervening area of crustal depression became the Port Phillip basin; a structural feature called a sunkland. Selwyn Fault runs through the eastern side of the Nepean Peninsula (Fig. 1), which thus lies

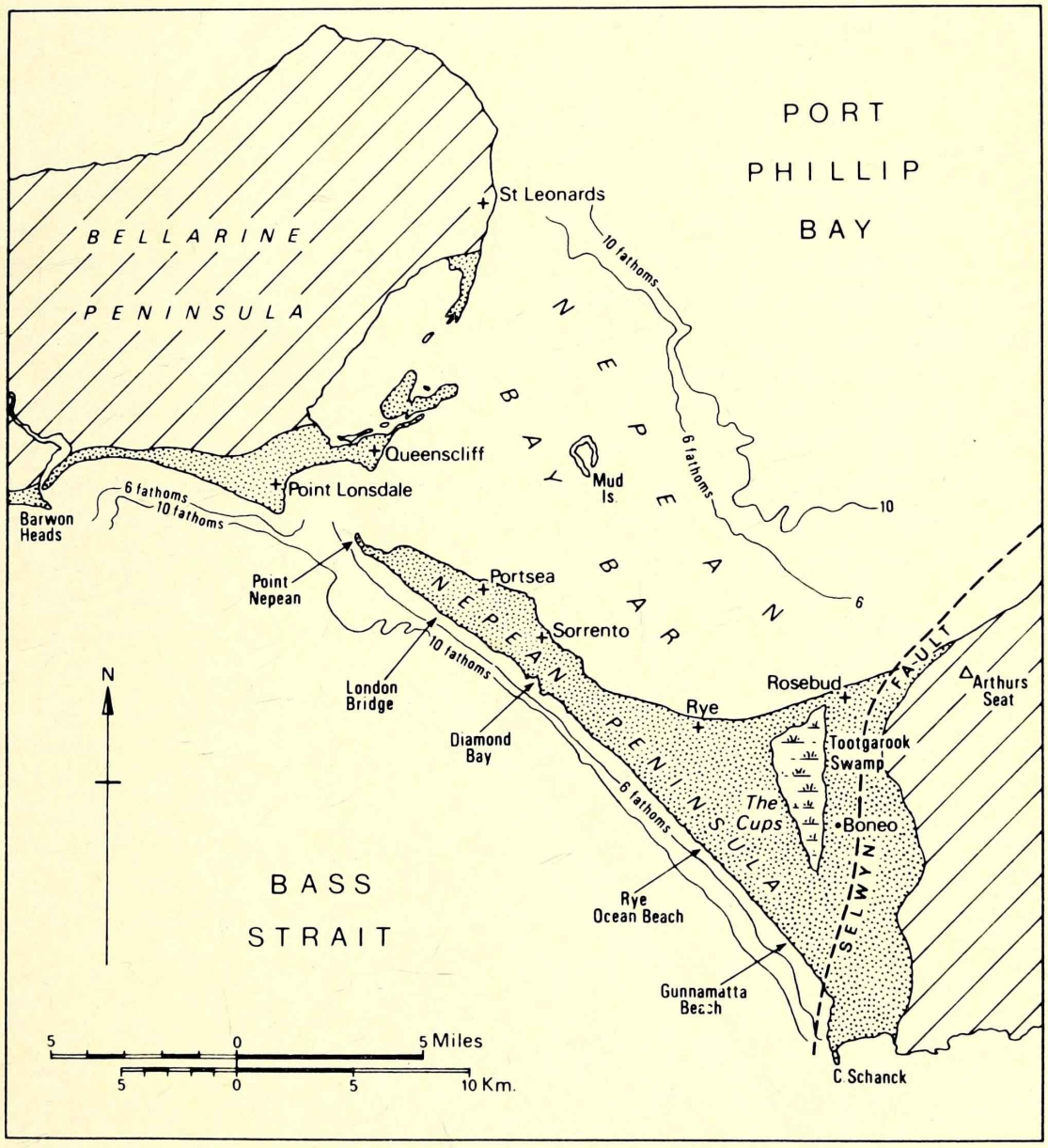


Figure 1
Nepean Peninsula.

Plate 1

Air view of Koreen Point, showing cliffs, dunes, beaches and shore platforms.

within the area of downwarping. During the past million years these crustal movements have continued, and indeed there are still earthquakes in the Port Phillip region, some of which have been traced to movements along faults. The Mornington earthquake of 1932 was due to a displacement along Selwyn Fault, the alignment of which passes from Frankston to McCrae and thence southward through the Nepean Peninsula to emerge on the ocean shore just west of Cape Schanck.

During Pleistocene times the sunkland created by these crustal movements became a marine embayment on the site of Port Phillip Bay at stages of relatively high sea level, and drained out as a coastal lowland when sea level fell. As the sea withdrew, the ancestral Yarra River extended its course, and was joined by

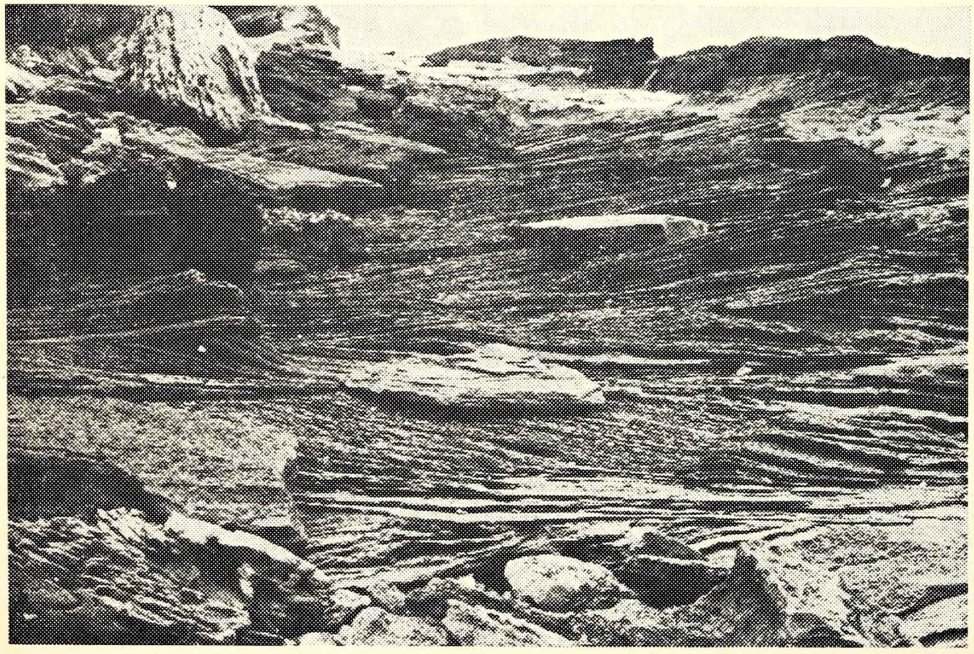


Plate 2

Dune bedding on the shore near Pearse's Beach.

tributaries from the bordering uplands, and probably from King Island and northern Tasmania as well, before it entered the lowered ocean somewhere south of Cape Otway, on the west coast of an isthmus of land that extended across what is now Bass Strait. When sea level rose again the Bassian isthmus was submerged, isolating Tasmania from mainland Australia, and the Port Phillip embayment was revived. Its configuration differed at each stage, depending on the level attained by the rising sea, and on intervening changes due to continuing crustal deformation and the modification of the land surface by erosion and deposition processes. Rivers gradually carved out valleys and built up flood-plains and deltas; rainwash smoothed hill slopes; waves trimmed back the land margin to form cliffs in some sectors, and built up beaches in others; tidal currents scoured the floor of the Port Phillip embayment when sea level was high, and winds winnowed sand from its drying surface to build dune formations when sea level was low.

The most remarkable effect of all this geomorphological activity was the progressive development of a broad embankment built up by deposition across the mouth of the Port Phillip embayment. Part of this embankment now stands above sea level, in the form of the Nepean Peninsula and the similar dune and sandstone terrain around Point Lonsdale and Queenscliff, west of the present entrance to Port Phillip Bay. The intervening sector is the shallowly submerged Nepean Bay Bar, the limits of which are indicated by the 6 and 10 fathom contours in Fig. 1. Its inner margin is a slope, facing north-eastwards, and extending from St. Leonards across to Rosebud, and its outer flank is the sloping ocean floor off the gently-curved coastline between Barwon Heads and Cape Schanck. With the sea at its present level, the Nepean Bay Bar is traversed by deeper channels maintained by tidal scour, but at stages of low sea level it must have emerged as a coastal ridge, through which the Yarra maintained an outlet, probably in the form of a narrow, steep-sided river gorge. The pattern of sea floor contours off the present entrance to Port Phillip Bay suggests a possible route for such a gorge, leading out on to a gently undulating coastal plain at low sea level stages.

The Nepean Peninsula is thus part of a larger formation, all of which has been deposited by wind or sea, and much of our knowledge of its internal structure comes from the record of rocks encountered in the deep borehole put down near Sorrento in 1910. This borehole went through more than 400 feet of Pleistocene dune sandstones similar to those exposed in the ocean cliffs of the Nepean Peninsula, but with intervening layers of marine sediment, including shelly sands and clays of the kind which are now accumulating on the floor of Port Phillip Bay. The dune sandstones must have developed above sea level, and the layers of marine sediment were deposited when pre-existing dunes had been submerged by the sea. Below 400 feet the borehole entered older rock formations on the downwarped floor of the former Port Phillip embayment.

Alternations of dune sandstone and marine sediment in the Pleistocene rocks of the Sorrento bore can be explained as the result of the oscillations of sea level mentioned previously, with the complication that this area, between the Bellarine Fault and Selwyn Fault, has also been subject to intermittent crustal subsidence as the Pleistocene rocks accumulated. Twenty thousands years ago the sea

was at a low level, probably at least 300 feet lower than it is now, and at this stage the Yarra must have flowed through the broad embankment by way of a gorge that now lies submerged between the Port Phillip Heads. The subsequent rise of the sea to its present level, attained about 6000 years ago (with perhaps a short interval when it stood 5 to 10 feet higher than at present), submerged the Port Phillip basin to produce its modern outlines, and led to the establishment of tidal channels athwart the Nepean Bay Bar. The dunes and dune sandstones of the Nepean Peninsula persist as a land area above the level so far attained by the sea in Holocene times. Ocean waves are now trimming back the southern margins of the Nepean Peninsula, carving the Pleistocene dune sandstones into a coastal topography of rugged cliffs and broad shore platforms, and in several sectors onshore winds are moving dunes inland from beaches and eroding cliff-top areas.

A vast quantity of sand has been deposited to form the Nepean Bay Bar and the bordering Nepean and Point Lonsdale Peninsulas. It is a mixture of calcareous (lime-bearing) sand, derived originally from the shelly organisms that live in coastal waters south of Australia, and quartz sand washed into the sea by rivers and eroded from coastal rock outcrops by wave scour; other minerals are present only in minor proportions. Calcareous sand is usually dominant, ranging from about 50% to more than 95% calcium carbonate in samples taken from the dunes and dune sandstones of the Nepean Peninsula.

During episodes of falling sea level, beaches built by wave action are left stranded as beach ridges on the emerging land. Sand from these may be eroded and piled up as dunes by wind action, but the extent to which this happens depends on how quickly and how effectively the stranded sand deposits are colonised and stabilised by vegetation. This in turn depends on climatic factors, especially humidity and wind strength. Under wet conditions a luxuriant vegetation is likely to develop quickly and impede wind erosion, but if the climate is relatively dry, vegetation colonisation may be sufficiently slow and incomplete for wind action to generate dune formations. As the phases of falling sea level coincided with cooling episodes of the Pleistocene epoch, it is probable that the climate of Victoria became wetter and windier, like that of the area south of Tasmania today. There were certainly dunes at one time on the Bassian Isthmus (detailed soundings of Bass Strait have located drowned dune formations near Flinders Island), but it is not clear how far dune formations initiated at low sea level stages contributed to the depositional structure built across the southern part of the Port Phillip embayment.

When sea level rises, waves erode and re-distribute sandy deposits that were stranded during the preceding emergence. If the sea rises rapidly, some of the beaches and dunes may be quickly submerged, and persist as features on the sea floor. If the sea rises more gradually, wave attack trims back the margins of sandy deposits, removing vegetation and thus enabling onshore winds to excavate blowouts in the exposed sand. These can then develop and grow into parabolic dunes of the kind now seen near Point Hicks in East Gippsland, or into broader transgressive dunes, as behind Discovery Bay in western Victoria and in the Cape Howe district. This dune mobilisation, in advance of a rising sea, is the most likely explanation of the embankment built across the southern part of the

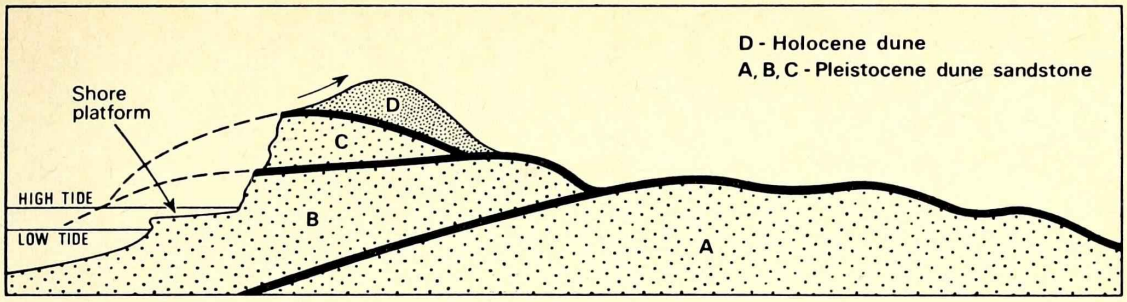


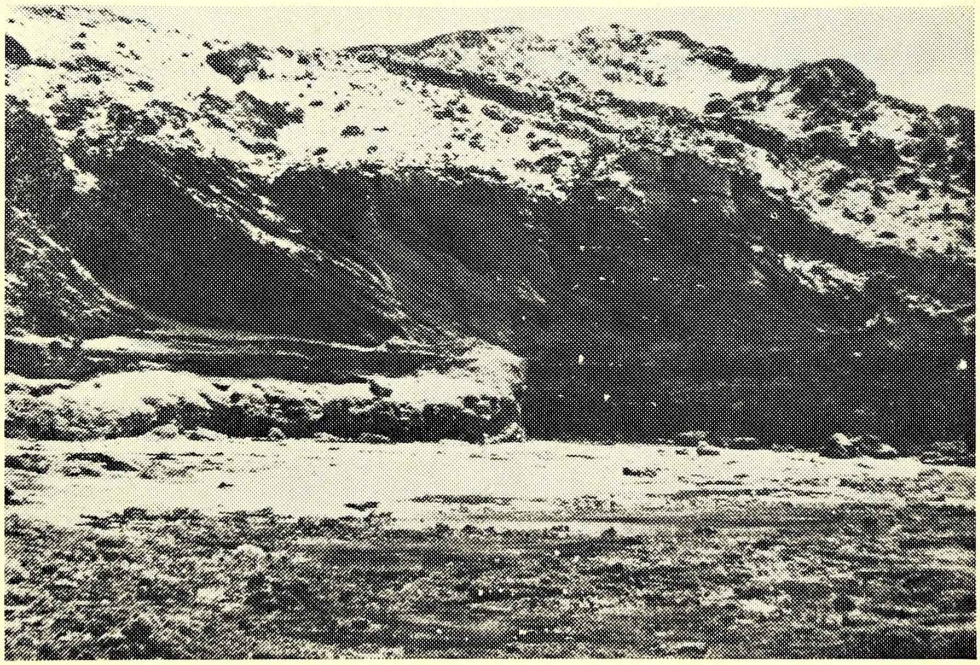
Figure 2

Port Phillip embayment. As the sea advanced, successive dunes were piled one upon another, in the manner shown in Fig. 2.

This is the structure revealed in the rock outcrops along the cliffs of the ocean shore of the Nepean Peninsula (Plate 3). There are sections of dune sandstone, sometimes with steeply-inclined thin seams of biscuit rock, formed on the slopes of an active, advancing dune. Each dune sandstone formation is capped by an undulating layer of brown or white calcareous sandstone, with relics of ancient brown or red soils formed during intervening phases of topographic stability. Branching tubular structures associated with these layers are found where calcareous sandstone has hardened around the roots, or more rarely the stems and branches, of plants that grew in these ancient soils; they commemorate the vegetation cover that once stabilised the underlying dune.

The dune sands are highly permeable, and rain water falling on the surface percolates downward through them. Rain water is weakly acid, due to the presence of dissolved atmospheric carbon dioxide, and as it seeps through the dunes it dissolves out part

Plate 3



Dune structures in cliff, Jubilee Point.

of the calcium carbonate from the calcareous sand. The stalactites and curtains of dripstone in Angel Cave, near Cape Schanck, are evidence that rainwater percolating through calcareous sand becomes saturated with calcium carbonate, which is precipitated as the water drips from the roof of the cave. Within a dune, precipitation takes place a few feet below the surface, and accumulation of precipitated carbonate binds the sand grains together as a firm calcareous sandstone. In some layers the originally calcareous sand has been so enriched by carbonate precipitation as to form a sandy limestone — the rock layers that were quarried for the local lime-burning industry in the nineteenth century. The tubular structures have developed where carbonate precipitation from saturated water has cemented the dune sands in the vicinity of plant roots.

The ancient soils are sandy, but also contain varying proportions of brown clay, thought to have arrived as surface accessions of wind-blown dust, accumulating in the soil. In some sections the palaeosols are several feet thick, and must represent a phase of topographic stability lasting for perhaps thousands of years. The rock sequence in the ocean cliffs, however, is indicative of recurrent instability. Over each ancient soil is another mass of dune sand, representing the arrival of a younger dune which advanced to bury the vegetation, the soil, and the calcareous sandstone layers of the previous dune landscape. The younger dune, in turn, became stabilised, and developed a soil and vegetation cover; and then yet another dune spilled across it. The cliff sections at Diamond Bay show several such superimposed dune formations, and the process is still going on at the top of the cliffs, where dunes are locally spilling inland over the vegetation that stabilised the preceding dune topography. Blowouts in the younger, unconsolidated dunes here expose dark-coloured buried soils, and organic matter extracted from the lowest of these gave a radiocarbon age of about 5350 years, indicating that the unconsolidated dune capping is of Holocene age, in contrast with the underlying dune sandstones which date from the Pleistocene (Bird 1972).

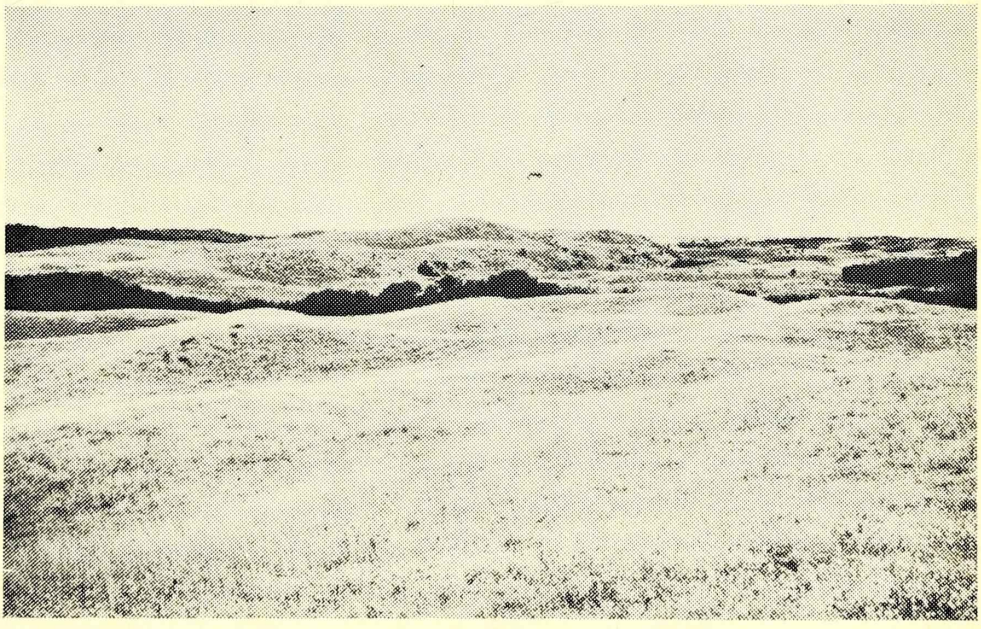
Traced laterally in the cliffs, the soil layers vary in thickness, and rise and fall as they mark out the contours of the ancient dunes. They also branch and re-unite in a manner which shows that parts of the ancient dune landscape remained stable while other parts developed blowouts, from which dunes spilled down-wind. At other stages there was widespread burial of the dune landscape by the arrival of a new and massive advancing dune, probably developed in front of a rising sea, or during a phase of more arid climate. The record is one of great complexity, and many of the details have still to be worked out.

In the landscape of the Nepean Peninsula it is possible to distinguish the extent of some of these phases of dune deposition. An early phase is represented by the dunes of quartzose sand, bearing heathy woodland, on the slopes of Arthur's Seat south of McCrae. The subdued hummocky terrain east of the road from Rosebud to Boneo consists of calcareous dune sandstones overlain by a brown clayey soil; they pass beneath Tootgarook Swamp (from which the higher parts locally protrude as isolated hillocks) and are probably equivalent to the dune rocks exposed in the ocean cliffs, as well as at White Cliffs, The Sisters, and west of Sorrento on the shores of Port Phillip Bay. They are overlain by younger dune sands and soft sandstones extending inland to the

western edge of Tootgarook Swamp; their limits are clearly marked by the slope that runs south-south-east from Tootgarook, converging on the highway that ascends from Boneo to the Cape Schanck road. The pattern is well displayed in the view from the crest of the Cape Schanck ridge: the younger, steeper dunes (including the area of intricate hillocks and hollows known as The Cups—Plate 4) west of Tootgarook Swamp represent the last major transgression by dunes on to the Nepean Peninsula; the older, more subdued topography east of the Boneo road dates from a much earlier phase of calcareous dune deposition, and the intervening wedge of Tootgarook Swamp was a low-lying area submerged by the sea during the last few thousand years, then cut off by the Holocene beach ridges built along the Bay shore between Rye and Rosebud to form a shallow lagoon which became choked with swamp vegetation. There is no evidence to support Keble's (1950) suggestion that this was once a 'tideway' leading to an old outlet from Port Phillip Bay near Gunnamatta Beach: it was simply a depression between the older and the younger dune topography of the Nepean Peninsula.

The extent of active, mobile dunes on the Nepean Peninsula at the present time is due, at least in part, to the impact of man's activities. Under the present relatively mild and humid climate, one would expect the dune topography here to have become stable beneath a natural vegetation mantle, the only blowouts and spilling dunes being those immediately atop eroding ocean cliffs. It is possible that the natural vegetation was weakened by the effects of fires set by the Aborigines, whose ancient kitchen-middens are found at various points along the shore, for example on the cliffs near Jubilee Point, west of Diamond Bay. These middens originated as feasting sites, where shellfish collected from adjacent shores were cooked and eaten. They persist as layers or mounds of broken shell waste, mixed with charcoal from the

Plate 4



Stable dune landscape near Boneo.

fire. It is likely that man-made bushfires resulted from these activities, and that dune instability ensued.

The impact of modern man has been more severe. Much of the natural vegetation (evidently she-oak woodland with a seaward fringe of tea-tree scrub, similar to that on the Yanakie Isthmus, near Wilson's Promontory, at the present time) was cleared, burned, and modified by grazing; introduced animals included sheep, cattle, horses and rabbits. After 1839, limeburners cut areas of woodland to provide the fuel for the kilns in which they burned the locally-quarried limestone. In the eighteen-fifties there were sheep and cattle on the pastoral holdings of Tootgarook, Boneo and Cape Schanck, and much of the extensive dune erosion near Gunnamatta Beach probably dates from this phase. By the turn of the century, holidaymakers were visiting Sorrento and Portsea, and the trampling of dune vegetation increased. Latterly, motor vehicles, including trail bikes and dune buggies, have damaged dune vegetation and accentuated erosion, especially near Gunnamatta. On the cliffed sector between London Bridge and Rye Ocean Beach the damage done by people trampling vegetation and scrambling over the dunes is considerable; it is much more extensive than on the similar coastal fringe within the Commonwealth reserve at Point Nepean, where access by the public has been more limited: dense scrub vegetation extends to the cliff-top near Point Nepean, and there can be little doubt that the sector south-east from London Bridge was formerly in a similar stable condition. Restoration of this topography is a major challenge to conservationists.

Features of shorelines bordering the Nepean Peninsula have been shaped largely during the 6000 years since the sea reached its present level. On the ocean shore, the dune sandstones have been cut back by storm wave attack to produce steep, rugged cliffs. The more resistant rocks, notably the hardened calcareous sandstone layers, persist as ledges and promontories, while the less consolidated dune sands have been excavated as coves and embayments, often containing sandy beaches. South-east from Rye Ocean Beach the rocky sectors become intermittent, and there are long stretches of sandy beach backed by dunes that are partly stabilised by grasses and scrub, and partly active and mobile. Sandstone cliffs reappear south-east of Gunnamatta, and extend to the cove where Selwyn Fault emerges, with high cliffs of black layered basaltic lava on its eastern side, flanking Cape Schanck.

Subjected to wave attack, dune sandstones disintegrate to sand, and pebbles and boulders are derived from the more resistant layers. Storm waves use these rock fragments as ammunition in pounding and scouring the cliff base, and occasionally rocks collapse on undermined sectors. In addition, there are stacks and pinnacles of intricately weathered dune rock, which owe their form to corrosion by rain water and sea spray, and to the scraping, drilling and plucking effects of the various marine organisms, notably barnacles and mussels, which live on their pitted and honeycombed surfaces. Storm wave erosion can be spectacular, but these quieter forms of continuous physical, chemical and biological erosion on the foreshore are just as effective in sculpturing landforms.

The shore platforms which front the cliffed ocean coast between Rye Ocean Beach and Point Nepean are unusual in being almost horizontal (Plate 5): they stand at a level which is exposed at low tide and submerged at high tide. Shore platforms on

Plate 5

Cliff and shore platform, Jubilee Point.

stormy coasts usually slope seaward between high and low tide mark, but here the weathering processes, notably corrosion, are effective only down to about mid-tide level, and immediately below this level the sandstones have been rendered more resistant by internal precipitation of calcium carbonates. The outcome is the development of an almost flat platform, which is being undermined and dissected by storm waves at its scalloped outer edge. It is noteworthy that beaches are best developed, and cliff recession most rapid, on sectors where the shore platform is narrow, or absent altogether. In these sectors storm waves reach the back of the shore, instead of dissipating their energy in breaking across the platform.

Wave action is less vigorous on the Port Phillip Bay shore. Active cliffing is limited, and instead of shore platforms, there are irregular rocky outcrops, and extensive sandy shoals offshore, partly exposed at low tide. At one point near The Sisters the cliffs expose relics of a beach deposit about five feet above present high tide level. This commemorates a phase, possibly in Holocene times, when the waters of Port Phillip Bay stood higher than they do now. Between Sorrento and Rosebud the Bay Shore is low and sandy, backed by successively-formed beach ridges carrying scrub and Banksia woodland. The development of this sandy barrier cut off Tootgarook Swamp from the open waters of Port Phillip Bay.

The shaping of the Nepean Peninsula has been a long and complicated process. Changes still continue, especially on the stormy ocean coast and in sectors where the dunes are mobile, but the main outlines of the topography have not altered greatly in the seventeen decades since the first settlers arrived at Sullivan's Bay.

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