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THE

SANDRINGHAM ENVIRONMENT

SERIES

No. 8

STRUCTURE AND SURFACE

THE GEOLOGY AND GEOMORPHOLOGY OF THE SANDRINGHAM DISTRICT

by ERIC BIRD

1990

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TABLE 1 **Geological Time Scale**

Era	Period	Epoch	Age
			0
	QUATERNARY	HOLOCENE	10,000 years
		PLEISTOCENE	2 million years
		PLIOCENE	7 million years
		MIOCENE	26 million years
		OLIGOCENE	38 million years
		EOCENE	54 million years
		PALAEOCENE	65 million years
	CRETACEOUS		136 million years
MESOZOIC	JURASSIC		195 million years
	TRIASSIC		225 million years
	PERMIAN		280 million years
	CARBONIFEROUS		345 million years
PALAEOZOIC	DEVONIAN		395 million years
	SILURIAN		440 million years
	ORDOVICIAN		500 million years
	CAMBRIAN		570 million years
PRE-CAMBRIAN			

The Geological Column is divided into four eras, which are in turn subdivided into periods and epochs on the basis of the fossil content of the rock formations.

TABLE 2 Geological Formations in the Sandringham District.

Epoch	Formation
HOLOCENE	Surface soils and swamps Beach sands
PLEISTOCENE	Dune sand ridges
PLIOCENE	Red Bluff Sand
MIOCENE	Black Rock Sandstone Fyansford formation
SILURIAN	Sandstones and mudstones

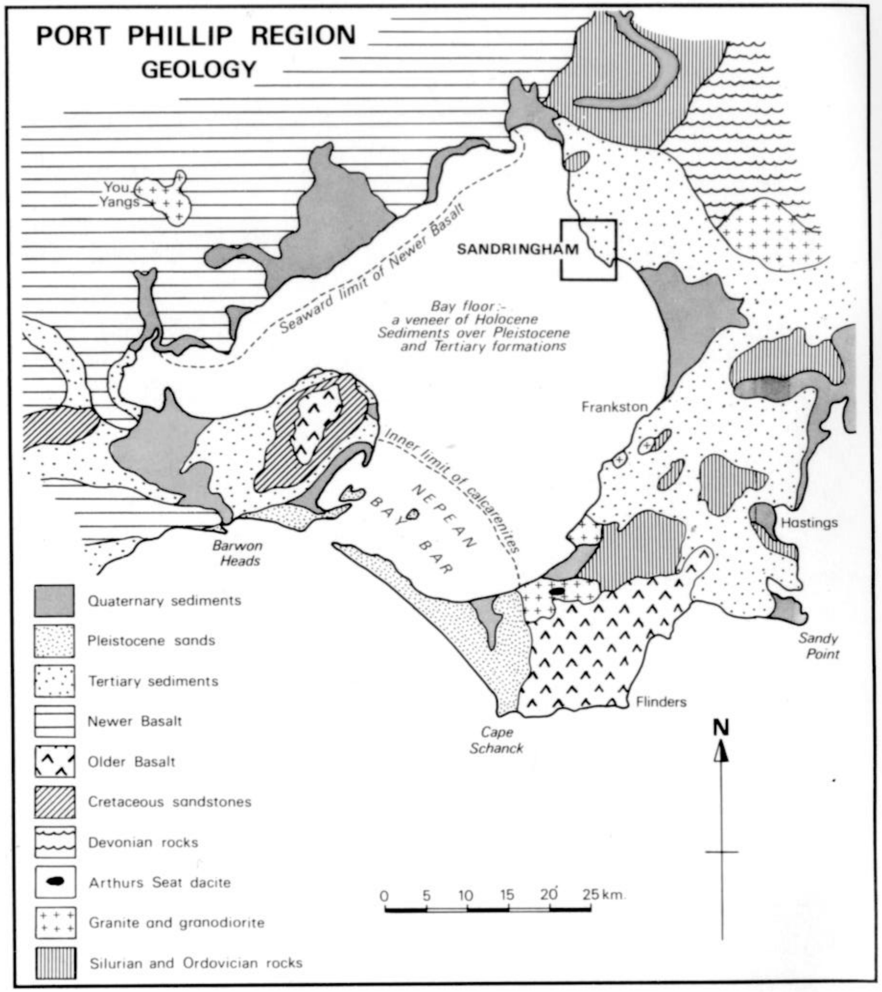

Fig. 1 – Geological map of the country bordering Port Phillip Bay. The box indicates the Sandringham district.

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THE GEOLOGY AND GEOMORPHOLOGY OF THE SANDRINGHAM DISTRICT

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INTRODUCTION

Geology is the study of the rock formations that make up the Earth's crust, whereas Geomorphology deals with the shaping of the present land surface - the evolution of landforms.

The rock formations in the Earth's crust have accumulated through geological time, and may be classified in terms of their age, as shown in Table 1. They are of two main kinds: **sedimentary rocks** laid down on earlier land surfaces or on the sea floor, and **igneous rocks** produced by the cooling of molten material from the Earth's interior. The sedimentary formations often contain fossils, which indicate their geological age. The igneous formations either cooled slowly within the Earth's crust to form crystalline rocks such as granite, or were extruded on to the surface by volcanic activity to form lavas such as basalt.

Earth surface history has been long and complicated. Rock formations have been upheaved to form mountain ranges, which have been gradually worn down by weathering and by the effects of rivers, snow and ice, and marine processes. Ancient structures, with folded and faulted rock formations, have been truncated in this way, and then buried beneath younger sedimentary formations. The outcome is that the land surface consists of a mosaic of outcrops of rocks of different kinds and contrasting ages, as portrayed on geological maps. Fig. 1 shows the pattern of geological outcrops around Port Phillip Bay, where several of the stages listed in Table 1 are represented.

The geological evolution of the Earth's crust has been reconstructed from evidence found in surface outcrops, and from the patterns of rock formations exposed in surface outcrops, and from the patterns of rock formations exposed in coastal and inland cliffs and quarries around the world. Further information has been obtained from borings which penetrate the successive rock formations. At any one location, only part of the geological story is represented. In the Sandringham district, for example, the rocks exposed at the surface are relatively young, of Miocene to Holocene age, although it is known that these overlie a basement of Lower Palaeozoic rocks (Silurian and older) at depths of 40 to 80 metres below present sea level (Fig. 2 and Table 2). Thus there is a gap representing over 350 million years of geological time, during which mountains were formed and worn away, and any intervening formations laid down on the eroded surface of the Silurian rocks were also removed, before the late Tertiary sedimentary rocks were deposited.

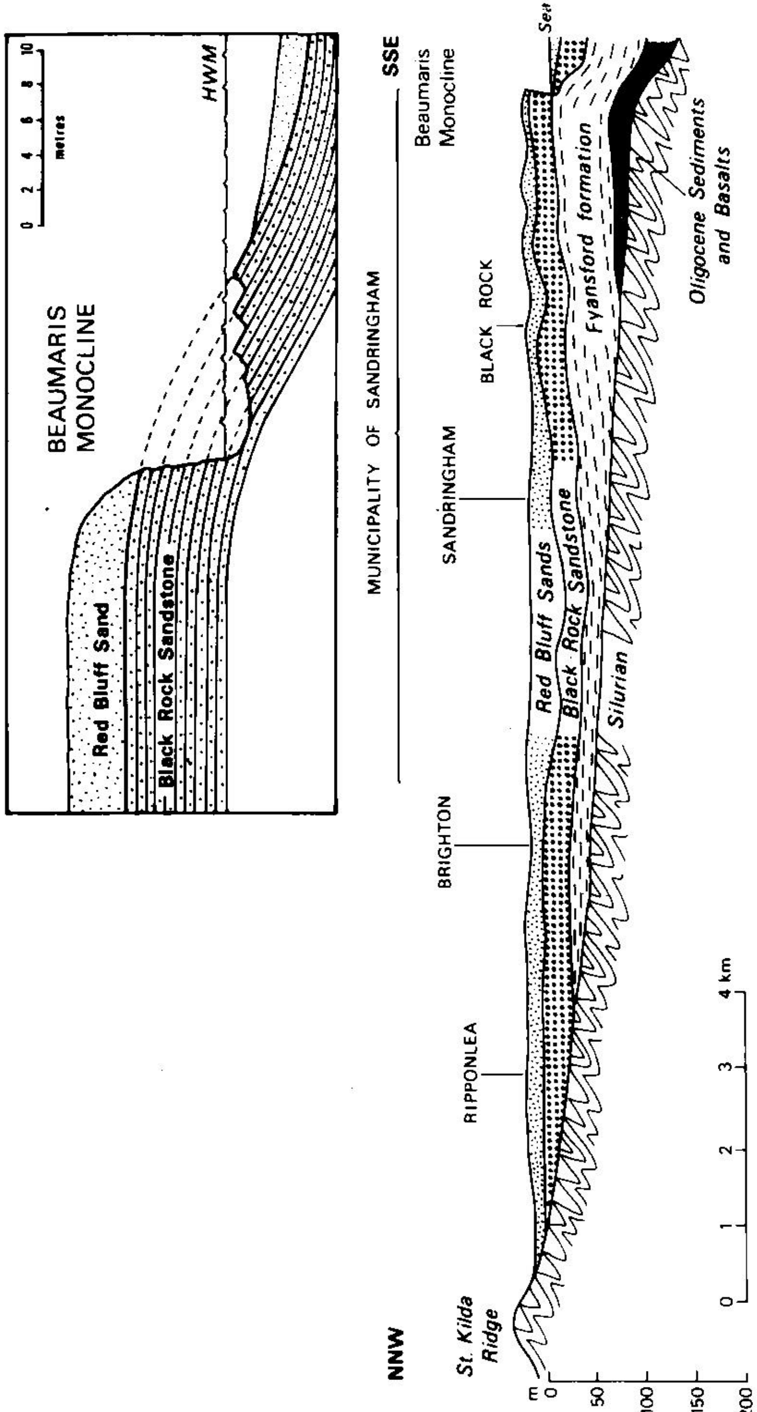

Fig. 2 – Geological section from St. Kilda to Beaumaris, showing the structure and formations which underlie the Municipality of Sandringham. *(Inset the Beaumaris monocline)*

The geology and geomorphology of the Sandringham district is best considered in terms of the evolution of Port Phillip Bay. This account is based largely on information published in the **Geology of Victoria**, and the Geological Survey of Victoria's Bulletin on the **Geology of the Melbourne District** (see "Further Reading" and "Geological Maps", page 12).

GEOLOGICAL EVOLUTION OF PORT PHILLIP BAY

Port Phillip Bay is a marine embayment with an area of 1950 sq. km, a coastline 260 km long, and a narrow entrance from Bass Strait, 3.2 km wide at high tide. The northern part is a relatively deep saucer - shaped basin (maximum depth of 24 metres), but the southern part is shallow, with extensive sandy shoals exposed at low tide between deeper channels that converge towards the entrance.

The Bay occupies part of a fault-bounded structural depression, known as a "sunkland" between Rowsley Fault, to the west, and Selwyn Fault, to the east (Fig. 3). Within this area, the Earth's crust has subsided intermittently to form a broad lowland, the north-western part of which has been covered by volcanic lava to form the basalt plain between Geelong and Melbourne, while the south-eastern part, submerged by the sea, forms Port Phillip Bay. The southern part is constricted on the western side by the uplifted Bellarine Peninsula, and on the eastern side by the Nepean Peninsula, an area of accumulated dunes, partly consolidated into dune sandstones. The eastern side is made up of the Mornington Peninsula, an uplifted area of geological complexity, and Carrum Swamp, which occupies a broad depression between Frankston and Mordialloc. In the north-east there is a slightly uplifted sandy plateau between Beaumaris and Brighton, declining northward to the Yarra valley. The boundary between this plateau and the Carrum Swamp depression is a structure known as the Beaumaris Monocline, a flexure between higher and lower horizontal strata (see inset, Fig. 2) that is followed by the line of cliffs between Table Rock Point and Mentone.

The earliest stages in the evolution of this part of the Australian continent must be inferred largely from what is known of the evolution of the world's continents, rather than from local evidence. The Earth is thought to have existed as a planet for about 4700 million years, but little is know of its early geological history, when the crust first cooled, and rain and rivers began to erode continental land areas and carry sediment down into the bordering seas, to be deposited as layers of sedimentary rock. Formations dating from this era are termed Pre-Cambrian (more than 570 million years ago) undoubtedly exist at depth, but they do not outcrop in the Port Phillip region. They formed part of an ancient single continent of Pangaea, surrounded by a vast ocean in which primitive forms of life were developing. Late in the Pre-Cambrian Pangaea began to split up, one part becoming Gondwana, a continent that included much of what is now Antarctica, India, Africa and South America, as well as Australia.

The Palaeozoic and Mesozoic eras

Early in Palaeozoic times the area that was to become Victoria lay far to the north of its present position on the Earth's surface, in one of several wide marine basins bordering the ancient continent of Gondwana. This was a massive desert continent, because the land plants and animals had not yet evolved, and all living organisms were confined to the sea. The bordering marine basins were subsiding areas, in which sandy and muddy sediment was accumulating, together with fossils such as graptolites (simple sketetal animals) and primitive shelly organisms. These sedimentary formations were then uplifted and strongly folded, to build mountain ranges on the fringes of Gondwana. Thus four hundred million years ago the site of Sandringham lay deep within these mountains. It is their planed-off basement, cut across Silurian rocks, that now declines from the St. Kilda ridge to pass beneath Tertiary sediments in the south-eastern suburbs of Melbourne (Fig. 2).

These Silurian rocks, yellow and grey sandstones and mudstones, tightly folded into anticlines (up-folded or arched strata) and synclines (down-folded strata) that trend NNE-SSW, and can be seen in quarries and cuttings in the Melbourne district. They used to outcrop in coastal cliffs at St. Kilda, but these are now concealed behind the Esplanade. Inland they can be seen in the railway cutting south of Windsor Station, where the folded Silurian rocks are overlain by horizontal Tertiary sandstone and clay layers. The Silurian basement declines southward, to be about 40 metres below sea level in the Brighton area, 60 metres under Hampton, and 75 to 80 metres beneath Beaumaris.

Farther south, Ordovician and Silurian rocks in the planed-off mountains form the hilly country of the Mornington Peninsula, where in Devonian times masses of molten (igneous) rock had been intruded into the foundations of the mountains, cooling slowly to form crystalline granite and granodiorite. These igneous rocks have been exposed by later denudation (removal of the overlying formations) to form the uplands of Mount Eliza and Mount Martha.

From the beginning of the Carboniferous (345 million year ago) through the Permian to the end of Triassic times (195 million years ago) the Port Phillip region was an eroding mountain range near the margins of Gondwana: no sedimentary formations of these ages are found in the present landscape. Erosion by rain and wind gradually reduced these mountains to almost flat plains, but in Triassic times earth movements began to disrupt the land surface, forming subsiding basins which became lakes and swamps in what are now the Otway, Port Phillip and South Gippsland regions.

About 180 million years ago, in Jurassic times, the ancient continent of Gondwana began to break up. Australia, New Zealand and Antarctica formed a combined land mass that drifted away from Africa, Eurasia, and the Americas. The Port Phillip region became a subsiding lowland near the edge of this drifting continent.

In the succeeding Cretaceous period, about 150 million years ago, the sea began to invade this lowland, and rivers from the adjacent uplands delivered sand and silt, deposited as marine sediment. Sandstones and shales deposited in similar areas to the east and west were later uplifted to form the South Gippsland Highlands and the Otway Ranges. The Port Phillip region became a swampy deltaic plain, on which the siltstones and coal deposits now seen at Sunnyside (north of Mornington) were laid down. Plant fossils indicate that vegetation had become established on the bordering land.

About 100 million years ago, Australia became for the first time a distinct continent, from which Antarctica and New Zealand had diverged, creating an intervening Southern Ocean and Tasman Sea respectively.

The Tertiary period

Early in Tertiary times, about 50 million years ago, south-eastern Australia began to take on essentially its present outlines. Areas bordering the northern part of the Port Phillip region were uplifted and dissected, and swift-flowing rivers draining them carried gravel and sand down to be deposited on a lowland surface of planed-off Silurian rocks. The older Tertiary sediments (Eocene and Oligocene) can be seen in cliff sections between Frankston and Mount Martha, together with some interbedded Older Basalts, indicating that volcanoes were again active.

Port Phillip Bay became a marine embayment in Oligocene times, when the sea began to rise at the beginning of a world-wide marine transgression which culminated in the Miocene. About 20 million years ago, Port Phillip and Westernport Bays existed on the northern side of a large embayment underlain by the Bass Basin (Fig 4). At this stage the bordering highlands had been reduced to low hilly country, from which gently-flowing rivers were delivering mostly silt and clay, with some fine sand, into these bays. The Miocene sea was warm, with a rich shelly fauna which was mixed with inwashed silts to form marls (calcareous clays) of the kind that outcrop on the foreshore near Keefers Pier, Beaumaris (Plate 1). Here the Fyansford formation (also known as the Newport formation) contains fossils, including various kinds of shells, sponge spicules, and foraminifera, which are exposed at low spring tides. This formation has long been of interest to fossil-hunters (palaeontologists). It is the oldest formation seen at the surface in the Sandringham district.

Black Rock Sandstone

About 12 million years ago, late in Miocene times, there was a regression of the sea, accompanied by uplift of the hinterland. This steepened the channels of the rivers, so that they again carried coarser sediment down to the sea. As the sea retreated, these coarser sediments were deposited in shallow water to form the Black Rock Sandstone, which is well exposed in cliffs and shore platforms from Sandringham to Beaumaris and Mentone. It consists mainly of quartz sand, which is sometimes calcareous (rich in lime), but generally strongly ferruginous (rich in iron compounds). It contains fossils of marine and estuarine shells, as well as plants, including fossil wood, ferruginised remains of which can be seen in the shore platforms at Beaumaris. It was evidently part of a large delta built by an ancestor of the Yarra River, spreading out into a shallowing sea.

Sands deposited in such marine or estuarine environments often include grains of the greenish mineral glauconite. Weathering results in the oxidation of this iron-bearing mineral to iron oxides which are yellow, orange, red or brown in colour. These form a coating of the quartz sand grains which coalesces and binds them together as a firmer sandstone. In general, the darker the iron oxides, the harder the sandstone. Close examination of the sandstones exposed at Red Bluff, for example, shows that the dark brown rock (Black Rock Sandstone) at the base is more resistant than the red, brown, orange, yellow and grey sandstones at higher levels (Plate 2). The pattern is exaggerated by the blackened algae coating the rocks just above high tide level.

At Red Bluff and Black Rock only the top 3 metres of the Black Rock Sandstone is visible, but the formation is just over 15 metres thick in the Beaumaris cliffs, between Table Rock Point and Mentone Corner. The base of the Black Rock Sandstone is marked by a 7.5 centimetre layer of phosphatic and calcareous nodules, which overlie the fossiliferous Fyansford formation mentioned previously. Above the nodule layer, the Black Rock Sandstone is stratified (laid down in layers), the lower part consisting of 6.7 metres of calcareous sandstone and sandy marl, with a rich fossil fauna, including various kinds of shells, together with sea urchins, crabs, foraminifera, and remains of whales, sharks, rays, dolphins, birds and marsupials. This represents an Upper Miocene palaeontological stage know as the Cheltenhamian.

The upper part of the Black Rock Sandstone consists of 8.5 metres of brown ferruginous rock with prominent vertical joints, etched out as crevices in cliffs and shore platforms. There are layers of coarse quartz grit and pebbles which run out across the shore platform at Black Rock Point. Fossil wood (including tree trunks, branches and twigs, often with bark texture resembling **Banksia**) is preserved in ironstone, as are some mollusc shells. Pollen of **Nothofagus** (Antarctic beech) trees has been found in the Black Rock Sandstone at Red Bluff.

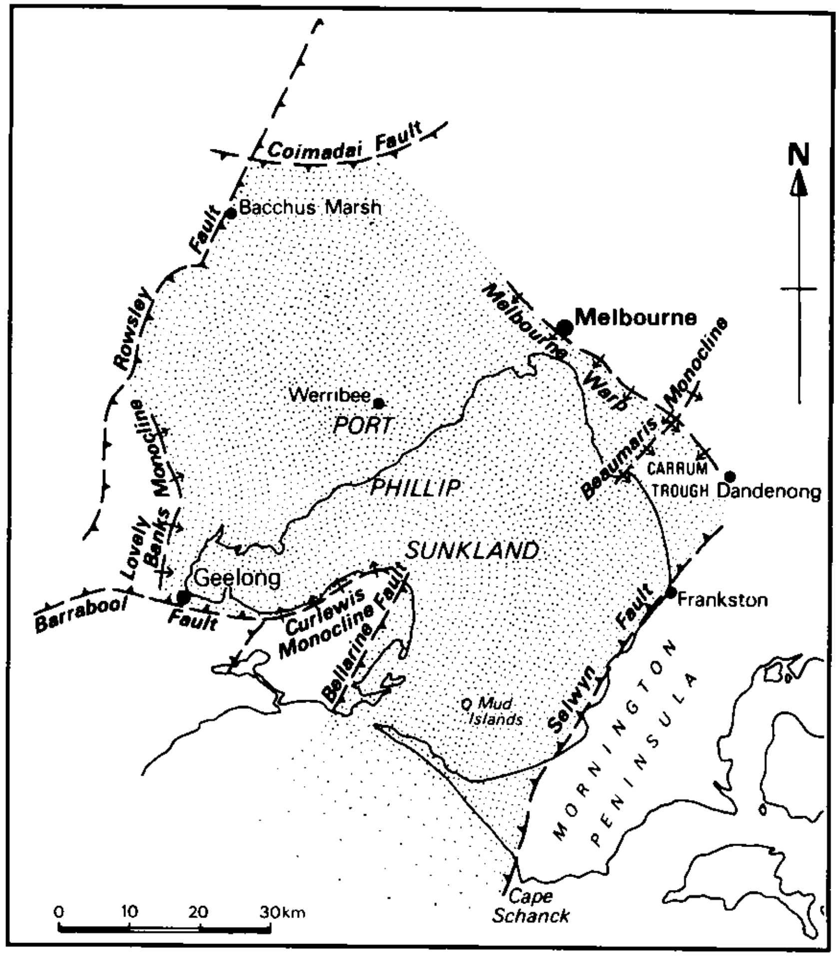

Fig. 3 – The Port Phillip Sunkland, showing the bordering fault lines. This has been a region of intermittent subsidence since Triassic times.

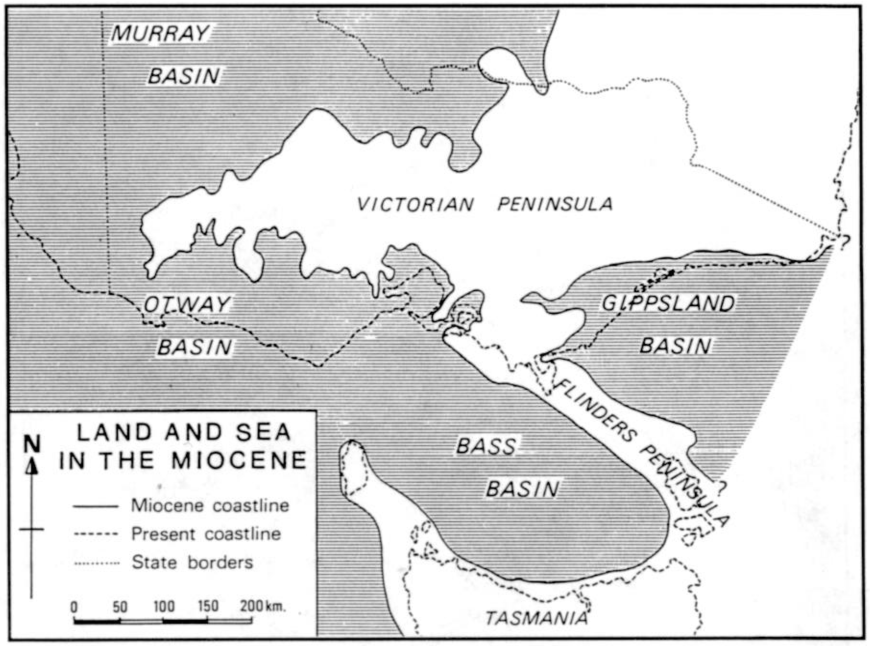

Fig. 4 - By Miocene times the Port Phillip and Westernport basins existed as embayments, with an intervening ridge in the Mornington Peninsula, on the northern shore of the Bass Basin *(sea area shaded)*.

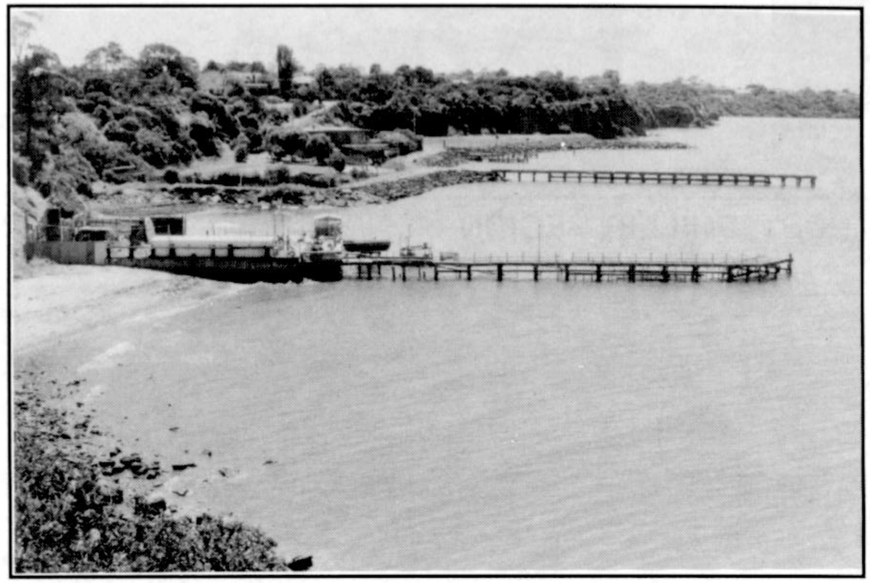

Plate 1 – Keefer's Pier, Beaumaris. A rich assemblage of marine fossils of Miocene age can be found in the rock outcrops at the base of the cliffs, and on the sea floor.

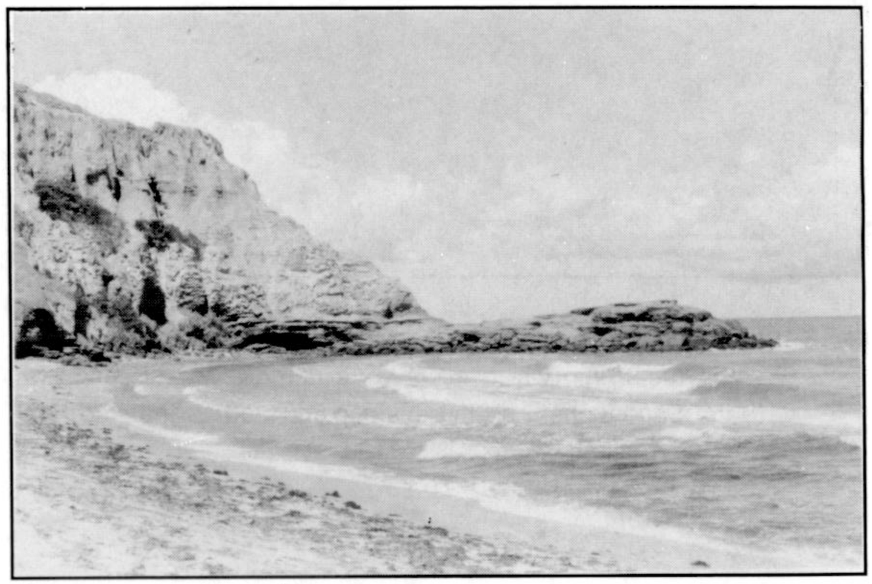

Plate 2 – The cliff at Red Bluff, cut in Red Bluff Sand underlain by Black Rock Sandstone, which protrudes as a basal ledge.

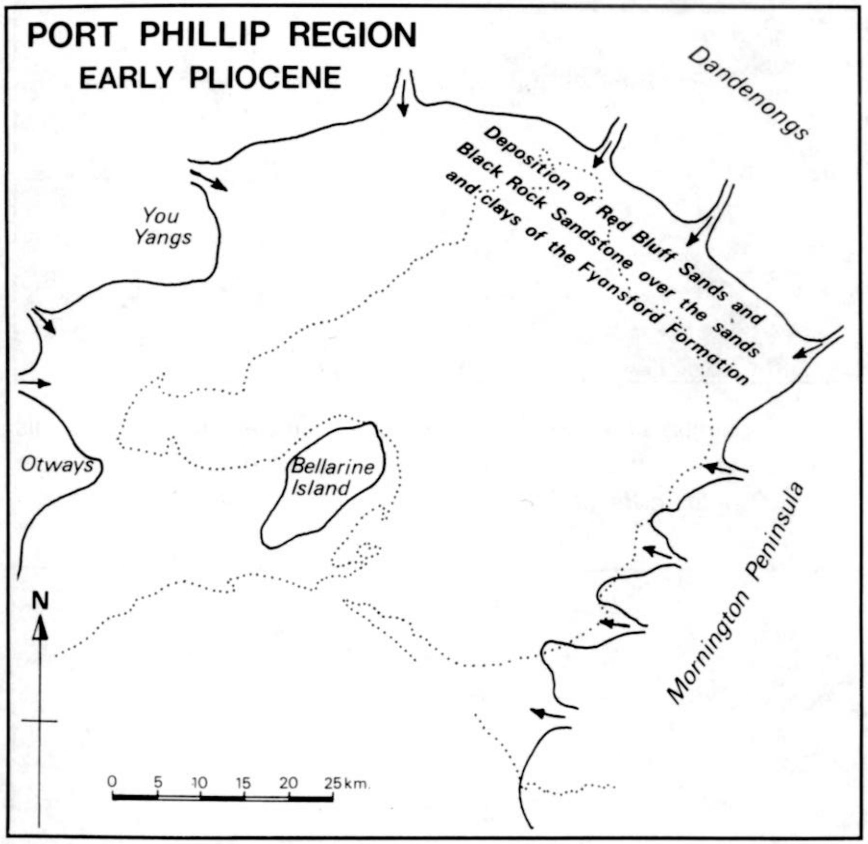

Fig. 5 – In early Pliocene times the Port Phillip region was a marine embayment, into which rivers were carrying sandy sediment. In the Sandringham district this accumulated as the Red Bluff Sand formation.

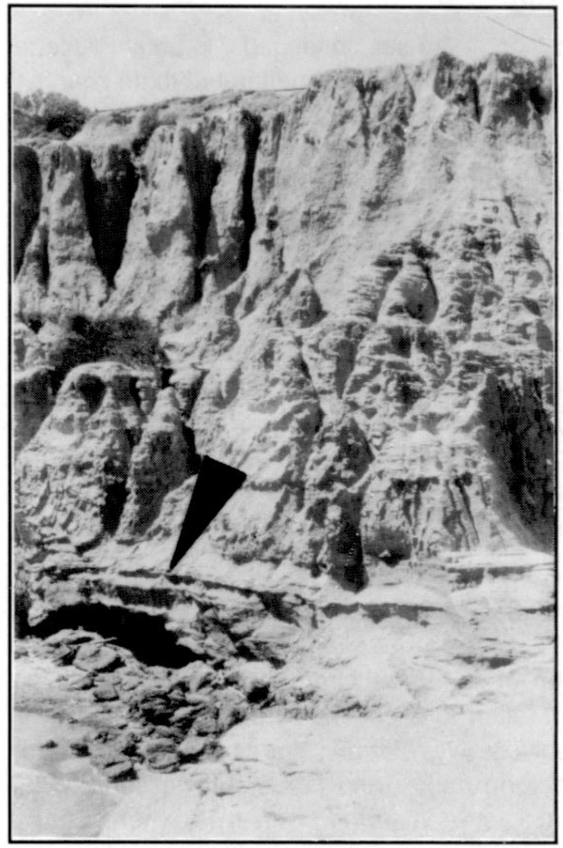

Plate 3 – The gullied cliff at Red Bluff. The dark horizon *(arrowed)* marks the base of the Red Bluff Sand, underlain by the Black Rock Sandstone.

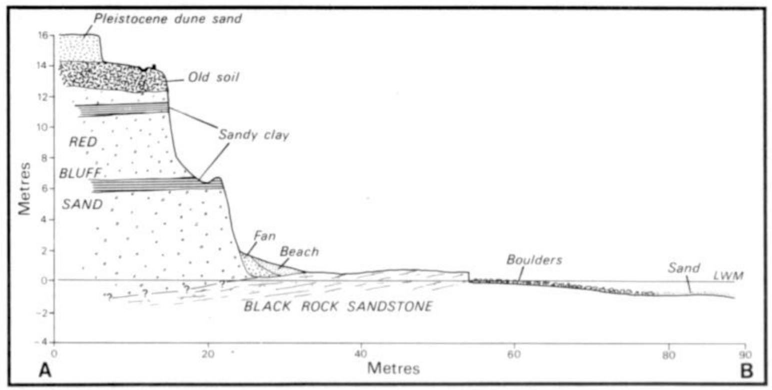

Fig. 6 – At Black Rock Point the cliff section exposes Red Bluff Sand, underlain by Black Rock Sandstone which forms the shore platform, and capped by Pleistocene dune sand.

Red Bluff Sand

The regression of the sea continued into early Pliocene times (Fig. 5), when further uplift of the hinterland generated more coarse fluvial sediment (i.e. carried down by rivers), deposited in the northern parts of Port Phillip Bay. These sands and gravels accumulated in shallow water, or as terrestrial deposits on the slowly subsiding deltaic plains, to form the Red Bluff Sand, which overlies the Black Rock Sandstone, and is well exposed in the cliffs in the type-section at Red Bluff (Plate 3), and also at Black Rock Point (Plate 4 and Fig. 6). The Red Bluff Sand formation consists of 24 metres of clayey sand and gravel with clay lenses, and a bed of carbonaceous silty sand up to 30 centimetres thick near the base. It is poorly stratified, sometimes current-bedded (as in the cliffs south of Quiet Corner) and iron-stained, but with less iron oxide than the Black Rock Sandstone. It contains few fossils apart from some plant remains and a few sponges.

The Late Pliocene epoch

Towards the end of Pliocene times these sedimentary deposits were uplifted, gently folded, and subjected to intensive weathering in a warm and wet climate. As has been mentioned, the colour of the sands is related to the oxidation of associated iron compounds. The yellow sandstones owe their colouration to a coating of iron oxides, which in some places has been dissolved away, leaving the sands grey or white, and in others precipitated to form darker and harder brown sand rocks. This kind of weathering is still active in northern Australia, where it has produced deep laterite soils, reddish-brown at the surface and pale grey underneath, as seen in the cliffs of the Darwin district. Similar lateritic profiles may be seen at Red Bluff and Black Rock Point.

The dark brown sandstones harden after erosion exposes them to the atmosphere, producing shore platforms and ledges along the coast from Picnic Point to Table Rock Point (Plate 5), and resistant cliff faces along the shore of Beaumaris Bay.

Although the Red Bluff Sand and Black Rock Sandstone have been treated as two separate formations, there are places where it is difficult to separate them, and some geologists have combined them as the Brighton Group, a single formation laid down in Mio-Pliocene times and later differentiated by weathering.

During Pliocene times sea level again fell, exposing the top of the Red Bluff Sand, which had minor undulations (amplitudes up to 4.5 metres) caused by folding along parallel axes that trend NNW-SSE (Fig. 7). The edges of the exposed land have since been trimmed back to form the cliffs and bluffs that border the plateau country south-east of Melbourne.

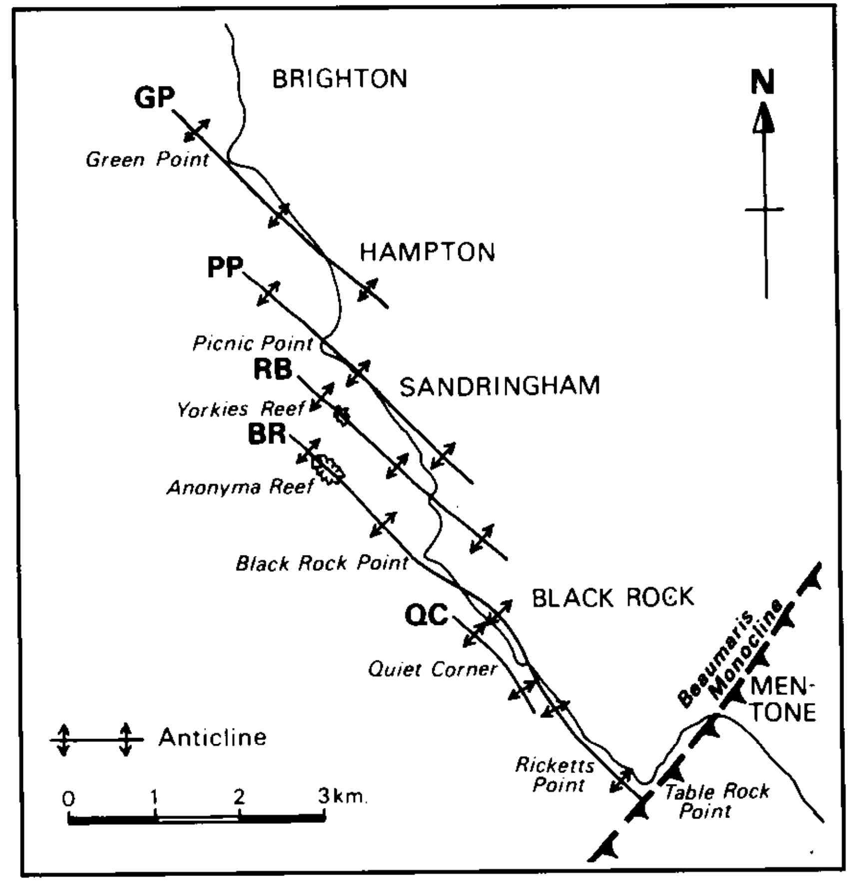

Fig. 7 – Anticlinal folding on the Sandringham coastline.

GP – Green Point anticline
PP – Picnic Point anticline
RB – Red Bluff anticline
BR – Black Rock anticline
QC – Quiet Corner anticline

Promontories occur where each anticline crosses the coastline, and bays in the intervening synclines.

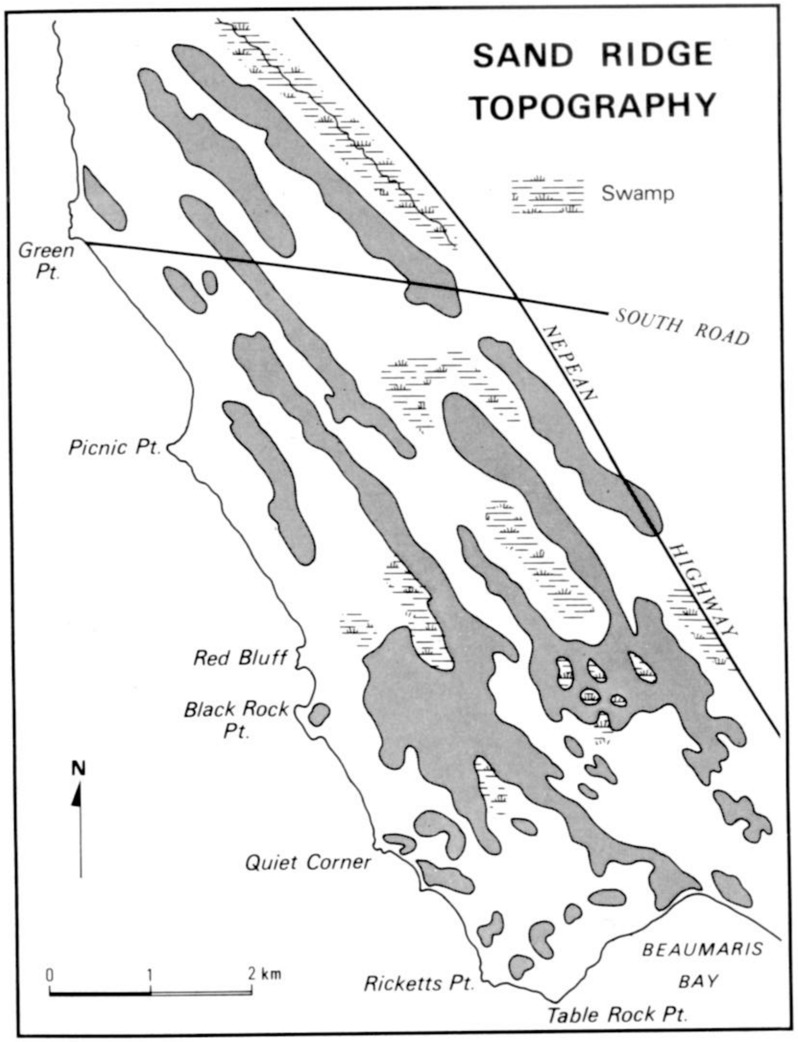

Fig. 8 – Sand ridge topography in the Sandringham district. The ridges were built by north-westerly winds during Pleistocene times, and the intervening swales and hollows contained streams and swamps.

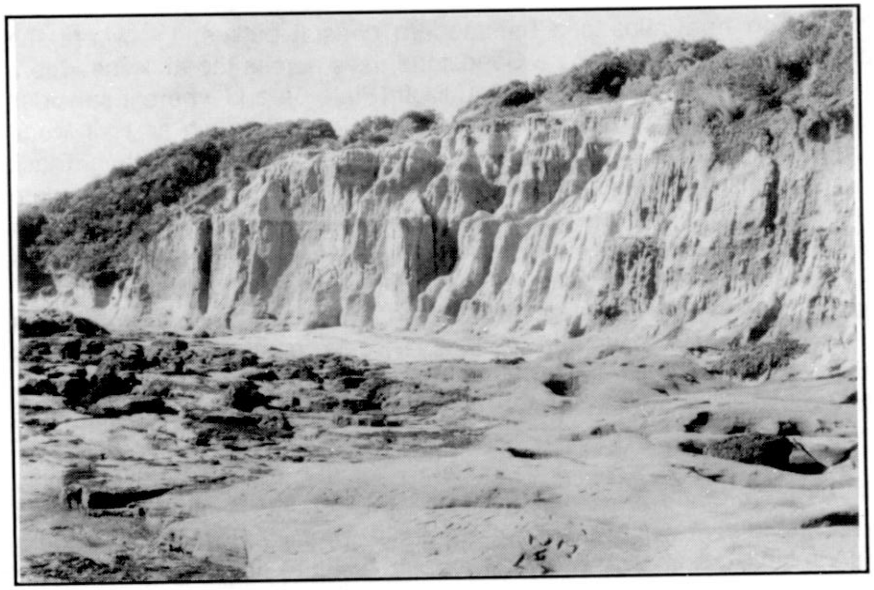

Plate 4 – The rilled cliffs in pale, soft sandy clays (Red Bluff Sand) at Black Rock Point are fronted by shore platforms cut in harder ferruginous Black Rock Sandstone. (cf. Fig. 6).

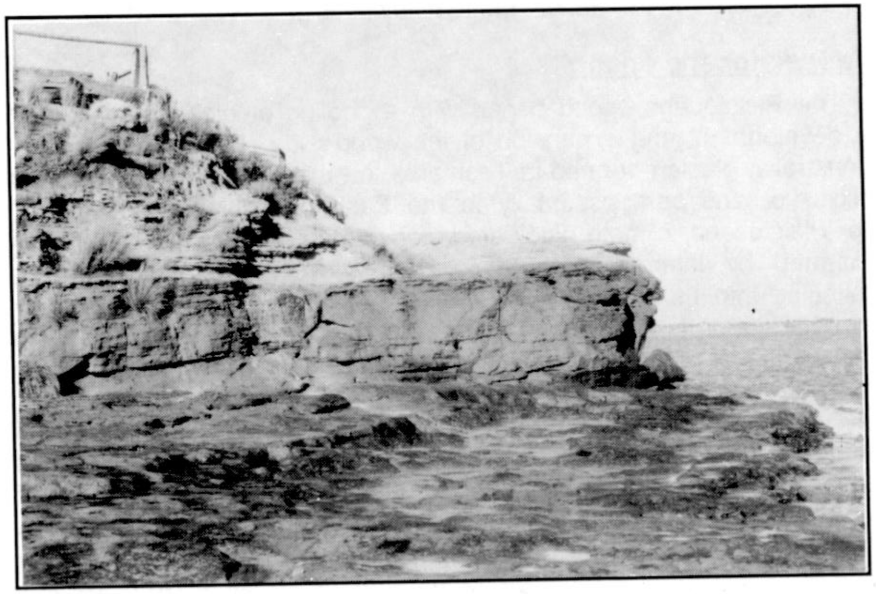

Plate 5 – The headland at Table Rock shows almost horizontal Red Bluff Sand overlying the more resistant, darker Black Rock Sandstone. The coastline changes direction at this point to run north-eastward along the Beaumaris Monocline (cf. Plate 8).

The folding has influenced the modern coastal outline, for where the harder underlying Black Rock Sandstone rises across the anticlines there are coastal promontories, as at Red Bluff (Plate 6), and where it subsides into the intervening synclines there are embayments such as Half Moon Bay (Plate 7), cut out in the softer Red Bluff Sand. Outlying reefs of Black Rock Sandstone at Anonyma Reef and Yorkies Reef mark the seaward continuations of anticlinal axes.

Between Table Rock Point and Mentone the dip of the rock steepens south-eastwards across the Beaumaris monocline, which terminates the coastal plateau. The south-eastward dip of the rock strata can be seen in cliff sections and elongated nearshore reefs east of the Beaumaris Motor Yacht Club (Plate 8). The top of the Fyansford formation descends about 35 metres from north-west to south-east across the Beaumaris Monocline.

About 5 million years ago, in Late Pliocene times, volcanic activity revived to produce the extensive lava flows of the Western District of Victoria. These Newer Basalts poured out from vents (such as Mount Cotteril) and fissures, and flowed around residual uplands such as the You Yangs to form the wide Werribee Plains between Melbourne and Geelong. They extended into the western fringes of Port Phillip Bay, where they formed the Williamstown peninsula, and into the Yarra valley, but they stopped short of the south-eastern suburbs of Melbourne, and do not occur in the Sandringham district.

The Pleistocene epoch

The Pleistocene epoch began with a cooling of global climate and the development and expansion of the world's ice sheets and glaciers. In Australia, glaciers formed in Tasmania, on the Australian Alps around Kosciusko, and perhaps locally in the Eastern Highlands of Victoria. The Pleistocene climate fluctuated considerably, with glacial phases separated by interglacials and followed by the 'postglacial' phase, continuing into the Holocene. In glacial phases the Port Phillip region often had a prolonged snow cover and frequent frosts, especially in winter. Rainfall diminished in the interglacial phases, when the climate was milder, at times warmer than it is now. Under these drier conditions the vegetation cover became sparse, allowing the prevailing north-westerly winds to winnow unconsolidated surface sands into dune ridges on the sandstone plateau south-east of Melbourne. These ridges are essentially similar to those found in desert regions of interior Australia: they are not like the dunes that are built up behind beaches along the coastline. They can be traced through the suburban landscape of the Sandringham district (Fig. 8), where they are separated by low corridors (swales), some of which were swampy. In places the dune ridges have been truncated by the retreating cliffed coastline, as at Red Bluff and Black Rock Point.

Early in the Pleistocene, the land surface of the Port Phillip region was disrupted by revived movements on faults originally established back in Palaeozoic times. One of these is Selwyn Fault (Fig. 3) which runs along the western fringe of the Mornington Peninsula, then through to the Bass Strait coast beside Cape Schanck. Uplift along the eastern side of this fault raised the Mornington Peninsula. Minor earth movements have continued into Holocene times, and there are still occasional earthquakes, particularly along Selwyn Fault, where on September 3, 1934 a tremor centred near Mornington attained 5.5 on the Richter Scale, causing damage to many buildings. Slight tremors are occasionally felt in the Sandringham district.

During Pleistocene and Holocene times there were fluctuations in global sea level associated with the waxing and waning of polar and mountain glaciers and ice sheets. Sea level fell during cold (glacial) phases, and rose to relatively high levels during the milder interglacials. As a result, Port Phillip Bay existed as a marine embayment only intermittently, when sea level was relatively high, and its configuration varied with successive rises and falls of sea level. In the Last Interglacial phase the sea rose above its present level, for at various points around the Bay there are emerged coastal features, including the wide platform just above high tide level at Ricketts Point, backed by bluffs that were cliffs cut when the sea stood higher than it does now. At one stage the sea penetrated up the Yarra valley as far as South Yarra, for there are marine fossils in the silts overlying Pleistocene basalts at Olympic Park.

In Late Pleistocene times, about 75,000 years ago, the sea began to fall again, withdrawing from the cliffs and beaches that had formed the coastline of Port Phillip Bay. Abandoned, the cliffs weathered into bluffs. Eventually the sea drained out of Port Phillip Bay altogether, the emerged sea floor becoming a coastal plain. This was the Last Glacial phase of the Pleistocene, when the sea fell at one stage as much as 140 metres below its present level. Port Phillip Bay, together with much of Bass Strait and the Australian continental shelf had become a land area, with soils and a vegetation cover. Aborigines were able to walk out across the floor of Port Phillip Bay and over plains that are now beneath Bass Strait to reach Tasmania.

During this low sea level phase, the Yarra, Maribyrnong, Werribee, and other rivers and creeks draining into Port Phillip Bay extended their courses across the emerged sea floor (Fig. 9). They flowed into a large river that meandered through a gorge cut into the dune sandstones of the southern part of the Bay - the deep channel beneath The Rip is a legacy of this phase - and out across the coastal plain (the emerged continental shelf) to flow into the sea, probably somewhere between Cape Otway and King Island.

About 18,000 years ago the last major cold phase of the Pleistocene Ice Age came to an end. As the Earth's climate grew warmer there was extensive melting of mountain glaciers and polar ice sheets, releasing water to the ocean basins, so that sea level rose. The Holocene period is taken as the last 10,000 years, when the climate became milder and drier than it had been in the Late Pleistocene; indeed similar to that of the present time.

GEOMORPHOLOGY

It was during Holocene times that the land surface of the Sandringham district finally attained its present outlines. The rising sea re-created Port Phillip Bay in roughly its present configuration about 6,000 years ago, when it became fringed by cliffs, shore platforms, and beaches, backed by a generally forested landscape. The sea penetrated into the mouths of river valleys, forming estuarine inlets which have since been at least partly infilled with alluvial sediment. The lower Yarra valley, submerged by the sea level rise, became an estuary into which the Yarra began to deposit silt and clay to form the modern Yarra delta below Princes Bridge.

There was a brief mid-Holocene phase, about 4,000 years ago, when the climate was slightly warmer, and sea level rose 1 or 2 metres higher than it is now. Along the Sandringham coast rocky shore platforms developed as cliffs were cut back into the Red Bluff Sand and Black Rock Sandstone formations. Then sea level fell slightly, exposing these rocky shore platforms. At Picnic Point an emerged platform 2.6 metres above mean low spring tide level (i.e. about 2 metres above mean high spring tide level) carried a sandy "raised" beach with shelly material dating from this phase, but it has been concealed by the building of the car park and ramp to the beach. As sea level fell, cliff erosion slackened, so that much of the Sandringham coastline became vegetated bluffs. A century ago, cliffs persisted only on a few sectors in Hampton Bay, at Red Bluff and Black Rock Point, at Quiet Corner, and between Table Rock Point and Mentone.

Sand eroded from these cliffs and shore platforms has been deposited to form beaches in the embayments along the Sandringham coast. These are dominated by quartz sand, with some gravel from disintegration of the dark brown ferruginous Black Rock Sandstone, and shelly material washed in from the sea floor. Small proportions of broken glass, plastic, brick and concrete fragments can also be found on these beaches.

The shape of the beaches has been determined by the patterns of waves approaching the coastline. Where the sea floor is gently shelving, waves have produced straight or gently-curved beach outlines, as on the Hampton coast, between Picnic Point and Red Bluff, in Half Moon Bay, and along the Black Rock shore north and south of Quiet Corner. Where the waves arrive over shoals or shore platforms, the wave crests are bent (refracted) so that they shape cuspate beaches, such as those at Ricketts Point.

Plate 6 – The protruding ledge of Black Rock Sandstone at the base of Red Bluff marks one of several anticlines (up-folded rock strata) that cross the coastline (cf. Fig. 7).

Plate 7 – Half Moon Bay has been cut out by the sea in soft Red Bluff Sand in the syncline between two anticlines: the Black Rock anticline forming the farther headland, and the Red Bluff anticline in the foreground, both of which bring the harder Black Rock Sandstone above sea level (cf. Fig. 7).

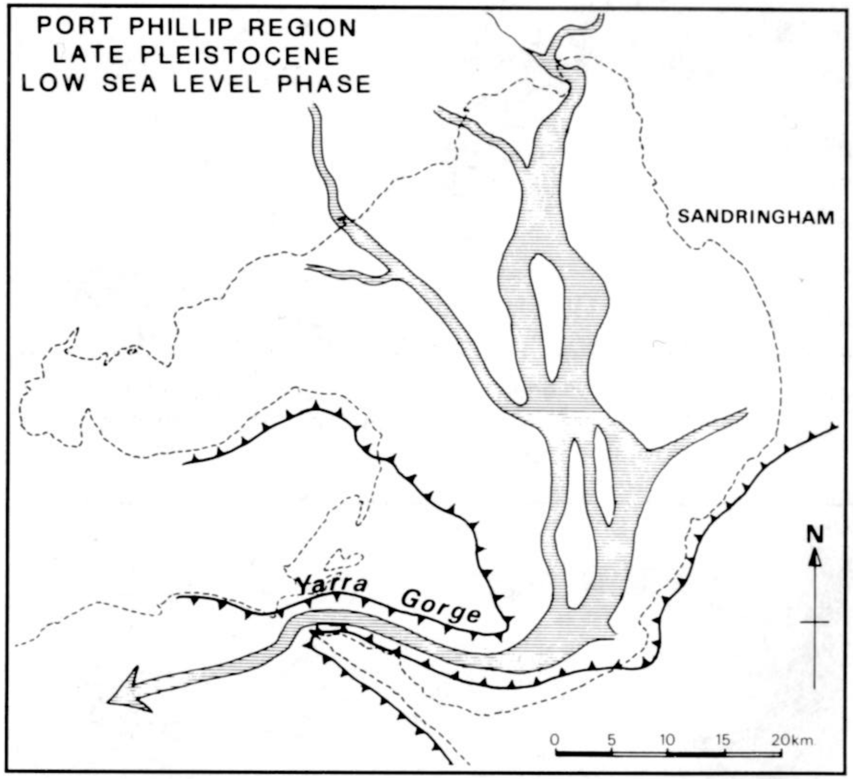

Fig. 9 – 18,000 years ago the Port Phillip region was a land area, across which the Yarra and its tributaries flowed southward, then westward to a coastline about 140 metres below present sea level.

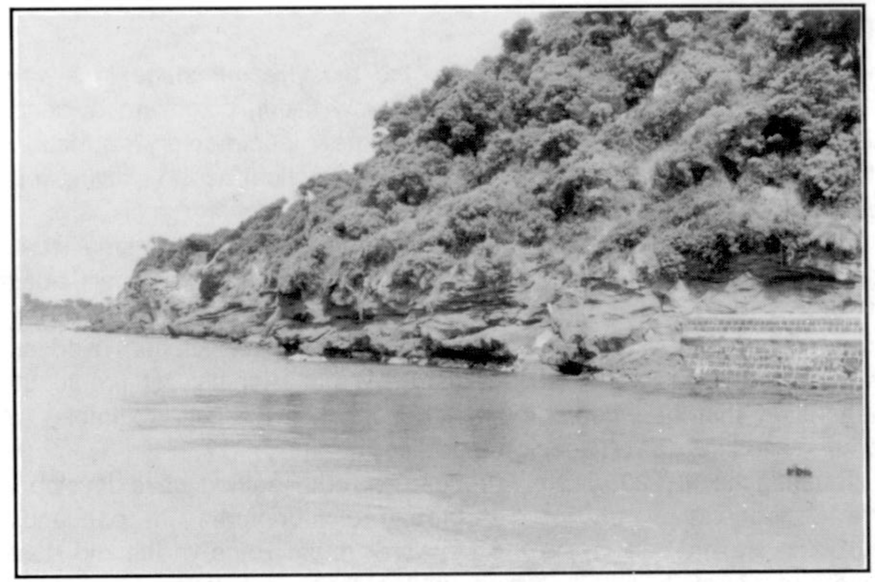

Plate 8 – The cliffs south-west from Mentone Corner run close to the axis of the Beaumaris Monocline (cf. Figs. 2 and 3).
The seaward dip of Black Rock Sandstone can be seen in the cliff outcrops.

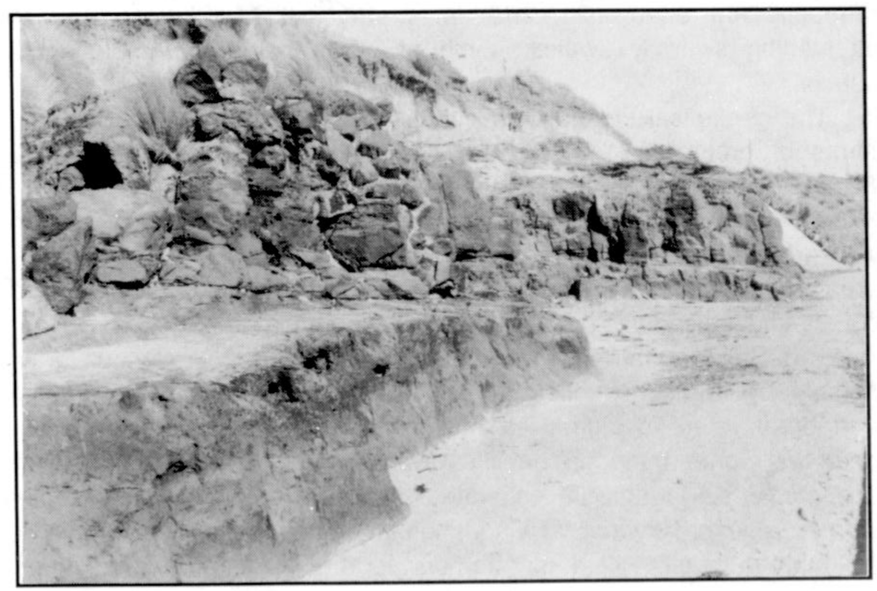

Plate 9 – Outcrop of Black Rock Sandstone on the Undercliff Walk just south of Black Rock. Sandstone was quarried from here in the eighteen-fifties for use in the building of nearby Black Rock House.

THE HUMAN ERA

The present landforms are thus the most recent stage in a very long geological evolution, and changes now taking place are evidence that this evolution is continuing, with new sedimentary formations developing on parts of the coast and on the Bay floor as the existing rock outcrops are consumed by coastal erosion.

The impact of human activities on landforms started on a small scale during the long period of aboriginal occupance, which began about 40,000 years ago in Late Pleistocene times. Aborigines probably initiated dune erosion in the vicinity of their coastal kitchen middens, where they cooked and ate shellfish, and occasionally set fire to the vegetation that had been holding the dunes in places. Examples of kitchen middens can be seen on Black Rock Point.

During the past 200 years, European and other settlers have developed the Sandringham area as a suburban environment with parklands, including Beach Park along the seaward fringe. Parts of the old dune landscape survive, little modified, in the local golf courses. Outcrops of Black Rock Sandstone in cliffs north of Quiet Corner were quarried in the 1850's to provide building stone for the construction of Black Rock House (Plate 9). As the suburbs developed, gardeners became aware of soil variations related to the sand ridge topography, where the soils are often acid, and apt to dry out in summer, and the intervening swampy swales, some of which have impermeable clay subsoil.

The geological structure which has been described is important in terms of groundwater resources. The planed-off basement of folded Silurian sandstones and mudstones is impermeable, but the overlying flat or gently undulating Tertiary formations contain lenses of sand with ground water which has been tapped by numerous borings in the area from Sandringham to Beaumaris. During recent droughts the golf courses have used this groundwater to maintain the greens.

The Sandringham coastline has been changed in various ways, notably by the construction of sea walls, boulder ramparts, groynes and breakwaters designed to halt coastal erosion or establish boat harbours. Some of the former cliffs have been stablised behind sea walls, and converted to artificial vegetated bluffs, as at Hampton and Quiet Corner. The breakwater at Sandringham has trapped drifting sand to build up a beach within the harbour to the north of Picnic Point, a process which greatly depleted the beach at Hampton. In the last decade, beaches south of Quiet Corner and at Dalgetty Road have been artificially nourished, using sand dredged from the sea floor.

People travelling to and from intensively used beaches made numerous trackways down bluffs, some of which became erosion gullies on the coastline between Hampton and Beaumaris. Many of these have recently been infilled and stabilised by Sandringham Council.

After the many million years of geological evolution, the landforms of the Sandringham district have been more and more influenced by human activities. For further details see a previous booklet **(Geology and Landfoms of Beach Park)** in the Sandringham Environment Series.

APPENDIX

The Origins of our Plants

by Don Neale

Australia was probably an equatorial country 400 million years ago, when land plants first began to establish themselves on land adjacent to estuaries and salt marshes. The first land plants reproduced by single-celled spores after the manner of their marine ancestors, as did the ferns and mosses which evolved from them to occupy zones where fresh water was plentiful. Some 200 million years ago, reproduction by seeds, each containing embryo and food store, developed in plants ancestral to cycads, ginkas and conifers, of which fossils can be found in rocks elsewhere in Victoria. Such plants were widespread when Australia was part of the Gondwana super-continent 100 million years ago, and supported the dominant dinosaur population.

It is likely that flowering plants first evolved on the more tropical areas of Gondwana, perhaps in the rift area between Africa and South America. Flowering plants adapted to warmer conditions (Acacias, Casuarinas, Myrtles) would then have reached the Australian area via the adjoining African and Indian sections, along with the insects associated with them, while cooler climate plants such as beech would have traversed the Antarctic section. The tropical connection was disrupted by the withdrawal to the north of Africa and India, but the climate of the residual land mass containing South America, Antarctica and Australia remained mild enough to support rain forests of such species as myrtle beech, along with the more ancient cycads and hoop pine. The dinosaurs had been replaced by a largely marsupial fauna when Australia began its lonely northward journey some 60 million years ago.

Increasing periods of aridity favoured the development of a drought and fire-adapted flora, typified by our Banksias and heathland plants, and forced the retreat of fire-sensitive rainforest into moister areas.

About 20 million years ago there was a rapid diversification of Wattles and of the Eucalypts which had evolved from rainforest myrtles, so that the dry Australian bushlands began to assume their modern character. A worldwide spread of grasslands favoured the rapid increase of grazing animals descended from shrub-grazing (browsing) ancestors.

The Australian land mass began to impact on that containing the south-east Asian islands, enabling the interchange of some species. New arrivals included violets and buttercups which spread rapidly through cooler and moister areas. Man appeared on the world scene within the last four million years, and probably reached Australia within the past 50,000. Aboriginal "fire stick farming" would have significantly influenced the vegetation before the time of European settlement. The changes subsequent to this last event have included a disastrous compaction and erosion of fragile top-soils and a disruption of drainage systems and water tables to a perilous degree.

OTHER BOOKLETS IN THE SANDRINGHAM ENVIRONMENT SERIES

1. *Common Birds* by Pauline Reilly
2. *Geology and Landforms of Beach Park* by Eric Bird
3. *List of Local Native Plants* by Dr. J.H. Willis
4. *Signature Plants* by Philip Bachelor
5. *Weather and Climate* by Frank Woodcock
6. *Marine Life of the Coastal Fringe* by Bob Whiteway
7. *The Bushlands of Sandringham* by Daintry Fletcher

In the Sandringham area bushlands have been reduced to scattered remnants of heathland on sand dunes, a few patches of woodland on the somewhat better soils derived from Tertiary sandstones and clays or in the sites of wetlands long since drained and a thin line of coastal plants clinging precariously to our eroding cliffs. The concentration of natural vegetation in such areas enriches the lives of our community, and contributes to the understanding of the ecosystems upon which our very survival will depend.

FURTHER READING

Geology and Geomorphology

Bell, G and others 1967 **Geology of the Melbourne District, Victoria.** Geological Survey of Victoria, Bulletin No. 59

Bird, E.C.F. 1987 **Geology and Landforms of Beach Park: An Excursion Guide.** The Sandringham, Environment Series, No. 2 (4th edition).

Bird, E.C.F. 1988 Geological and Geomorphological Evolution of Port Phillip Bay, in **Making the Most of the Bay.** Ministry for Planning and Environment: 10-31.

Douglas, J.G. and Ferguson, J.A. 1976 **Geology of Victoria.** Geological Survey of Australia, Special Publication No. 5.

Leonard, J.G. (undated) **Preliminary assessment of the groundwater resources of the Port Phillip region.** Geological Survey of Victoria, Report No. 66.

Thompson, B.R. and Harris, L.F. 1972 **A survey of the groundwater resources in the southeastern suburbs of Melbourne.** Geological Survey of Victoria Report No. 1972/7.

Plant Evolution

White, M.E. 1986 **The greening of Gondwana.** Reed.

GEOLOGICAL MAPS

Geological Survey of Victoria, 1: 63,360 series, **Melbourne** and **Ringwood** sheets. Obtainable from 140 Bourke Street, Melbourne 3000.