Part 1

PHYSICAL ENVIRONMENT

Palaeontology of Victoria

Introduction

Palaeontology is the study of past life. It is the science that deals with fossils, which are the remains of animals and plants naturally embedded in the rocks. It seeks to reconstruct the forms of life of past ages and their environments, with a view to understanding life on this planet. Palaeontology also has many economic applications.

This article describes the succession of life through time as shown by fossils found in Victorian rocks. The subject is not developed as in a textbook, but by description of a series of representative occurrences of fossils in Victoria. It begins with the recent past and proceeds back to those distant geological periods whose forms of life are not so well understood.

Palaeontology describes the succession of life through hundreds of millions of years. How time is measured in geology will now be explained.

Time in Palaeontology

A distinction is made between relative dating (by which one stratum or fossil is said to be older than another) and dating by years. The first dating was relative dating. Lyell stated the Law of Superposition, namely, that one sedimentary layer deposited over another must be younger than it, and that when pieces of one formation are included in another, that including pieces of the first formation must be the younger. It was further noted that beds could be recognized by their fossil content and so traced across country for long distances. Moreover, the older the beds the smaller the percentage of living species. The oldest fossiliferous beds were noted to possess no vertebrates; trilobites became extinct before the age of dinosaurs; and after the dinosaurs came mammals, with man the last to appear. Thus a succession of life was increasingly recognized whereby formations in different continents could be placed in their correct geological eras. The development of the principle of evolution greatly assisted relative dating. In evolutionary successions, the more primitive forms were recognized as the older, and the more advanced forms the younger.

But what did this mean in actual years? Rates of deposition per annum of marine sediment were measured, and then an estimate made of the total thickness of marine sediments in the earth's crust. Allowance had to be made for obvious gaps. Even by this rough measure it was clear that the earth was millions of years old and not a few thousands as popularly held then. Another attempt at "absolute" dating was made by measuring the amount of salt in rivers entering the sea, and estimating the total tonnage of salt in the sea. This method made the unjustified assumption that the sea was fresh to begin with, and airborne cyclic salt was overlooked. Some estimates of the earth's age were too great and some too small, but the efforts were very commendable in view of the limited methods available. Lord Kelvin tried to solve the question by measuring the heat loss from the earth, and concluded the age to be only 20 to 40 million years. The method was a bright idea, but unfortunately the presence of radioactivity was not then known, with the result that the age suggested was far too small.

Acting on a suggestion from Rutherford, Boltwood in 1907 first showed that uranium could be used as a timepiece for the earth. The uranium-lead method is good for the oldest rocks but is inaccurate for rocks younger than 50 mill. years. Dates to over 2,000 mill. years for rocks of the earth's crust have been obtained, and it is estimated that the earth is 4,000 to 5,000 mill. years old. Plentiful fossils occur from 600 mill. years ago to the present, but there are many signs of life earlier still. Probably it is the absence of hard parts that makes the tracing of early life so difficult.

Many other methods of isotope dating have now been discovered of which potassium/argon is the most important for ages involving millions of years. For age determinations involving only 40,000 years or less, radiocarbon has proved to be the most useful. Dates within 3 per cent. years are possible, so this method is very accurate. Another advantage is that the fossil itself is dated and not some associated material which in some circumstances may have a different date.

In Fig. 1 the geological eras and periods are plotted against time as calculated from isotope determinations. The main groups of fossils as known from Victoria (with indication of their world occurrence) at the present time are plotted against the time line.

Reconstructing the Past

How the remains of the past are studied, and their environment reconstructed, may be illustrated simply from a bone discovered during an excavation in the West Melbourne Swamp on the shore of Hobson's Bay. This bone (Plate 1, Fig. 3) was recognized as the characteristic heavy frontal bone of the head of a snapper, and by comparison with the size of the same bone in present day fish of known weight, it was estimated that the fish weighed about 20 lb. This fossil came from dark grey clayey silt, and these fine sediments indicate quiet waters. Numerous molluscs accompanied the snapper bone, and were of species still living in the contiguous waters of Port Phillip, with one exception. Thousands of well-grown shells of *Anadara trapezia,* sometimes called the Sydney Cockle, crowded the sediments, but at the present time this species is almost extinct in Port Phillip. In Sydney Harbour great numbers of these molluscs can still be found inhabiting the mudflats between tidemarks, but the few shells still living in Port Phillip are at low tide or below. The winter temperatures are too low for this species in Port Phillip and it is at the limit of its present range. However, at the time the grey silts with the snapper bone were laid down, this species thrived, and so it is inferred that the climate was a little warmer. Also, at that time, the Western District shallow lakes dried

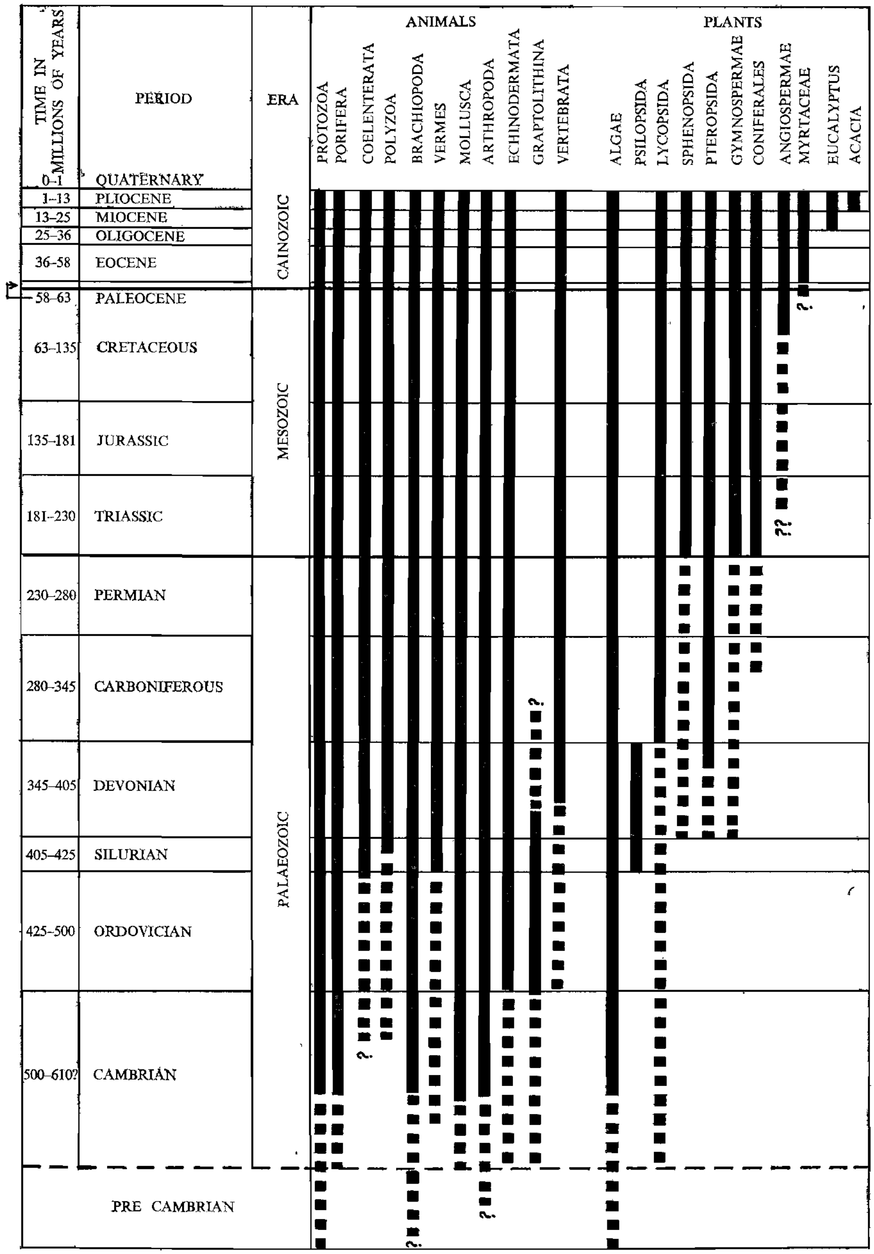


FIGURE 1.—Geological Chart.

up in summer, and the sediments from the lake floors were blown up into dunes. There is evidence all round the world for slightly warmer climate in that period. Although the sediments with the snapper bone were laid down below low water, they now occur a little above high water mark, so the sea then was higher relative to the land. The formation of grey mud with its numerous fossils is called the Coode Island Silt and it extends across the Yarra delta and for some miles up the Yarra and Maribyrnong River valleys. It is thought that the warmer climate melted more ice from polar ice caps and so produced the higher sea level.

A radiocarbon dating for a piece of fossil red gum bored by marine borers, and found in this formation, was of the order of 5,000 years ago. Thus the snapper, molluscs, and other forms of life lived in a slightly warmer and enlarged Port Phillip 5 millenia ago, when the Egyptian civilization had developed and man was in the early stages of establishing city life. Barnacles, sharks' teeth, bones of the dolphin *Delphinus delphis*, echinoderms (sea eggs), foraminifera (single celled animals with calcareous cells), and diatoms (single celled plants with silica skeletons), have also been collected from the Coode Island Silt, and help us to reconstruct the life of the time in that environment.

Buried River Channels and Their Fossils

The Coode Island Silt forms a layer across the Yarra delta, covering the low ground in West Melbourne, South Melbourne, Port Melbourne, and Albert Park, but also infills deep channels in which the local rivers ran when the level of the sea was much lower during the Pleistocene Period (Ice Age—previous to 10,000 years ago). At that time both Hobson's Bay and Port Phillip were dry. The building of the great ice caps in polar areas took so much water from the oceans that their level was reduced between 300 and 600 feet below present level. The colder temperatures also reduced the volume of oceanic waters by contraction. At Melbourne, the channel of the former Yarra River lies 58 feet below sea level at Punt-road, 63 feet at Swan-street, 70 feet at Russell-street, and 83 feet at Spencer-street. At Port Melbourne, the bottom of the old channel is over 100 feet below sea level. This is why bridge and pier foundations have to be so deep.

At Williamstown the length of Breakwater Pier was formerly limited by the presence of such a channel because the soft sediments infilling it were useless as foundations. When it was purposed to use this pier for oil tankers, accommodation had to be increased, so the silt was excavated along the line of pier extension to 60 feet below sea level. The trough so formed was filled with sand from the floor of Hobson's Bay off Middle Brighton, and the extension of the pier constructed on this new foundation. The upper part of the Coode Island Silt was crowded with fossil *Anadara trapezia,* but this species disappeared at depth in the sediments and cooler water diatoms are found. There was thus some biological evidence of the change of temperature going on progressively with the deposition of the sediments.

Under the south abutment of the Spencer-street bridge at 63 feet below present sea level, a red gum stump (probably *Eucalyptus camaldulensis*) about 4 feet in diameter was found in position of growth during the excavation of the bridge foundations. Nearby was a layer of peat which consisted largely of a bog moss now found on the high plains above 4,000 feet (*Sphagnum cristatum*). Pollen of beech trees was also found in the sediments at this level. Similarly, bore core material from the foundations of the King-street bridge yielded remains of the plant *Azolla filiculoides,* and pollen of *Nothofagus cunninghamii* (beech), *Banksia, Acacia, Casuarina* and *Eucalyptus*; also spores of *Cyathea australis* (rough tree fern), *Dicksonia antarctica* (soft tree fern), *Todea barbara* (king fern), and *Microsorium diversifolium* (kangaroo fern). Pollens of some herbaceous plants were also found. These indicate that the climate in Melbourne was then colder and wetter than at present. At the same time as these fossils were being embedded, the Maribyrnong River was flooding up to some 10 feet higher than the maximum flood level of the present time, because floodplain sediments are found to that height.

Radiocarbon Dating of Fossils

It is possible to say that the growing of the red gum in the old river channel below Spencer-street bridge at about 63 feet below present sea level and the high flooding of the Maribyrnong River were contemporary processes by reason of precise dating by the radioactive carbon method. Bombardment of the earth's atmosphere by particles from outer space changes some nitrogen (^{14}N) atoms into radioactive carbon (^{14}C), which then oxidizes to carbon dioxide. This is breathed in by plants, absorbed in waters, and ingested by animals so that it comes to be more or less evenly spread through all living things (the biosphere) at a concentration of 10^{-12} (one radiocarbon atom in every mill. mill. carbon atoms). When an animal or plant dies, it ceases taking in ^{14}C atoms, but those already present continue breaking down to nitrogen (^{14}N) again by loss of an electron. Thus the proportion of radiocarbon atoms to other carbon atoms is gradually reduced with time. As the rate of breakdown of radioactive carbon is known, measurement of the proportion of radioactive carbon in a fossil makes it possible to calculate its age. The method is good for dating up to 40,000 years. Radiocarbon analysis shows that both the Spencer-street fossil red gum and charcoal from the high floodplain sediments of the Maribyrnong River are about 8,500 years old. Red gum wood from 64 feet below sea level at the new National Gallery and Culture Centre site in South Melbourne, gave a date of about 9,340 years. One value of radiocarbon dating is that fossils from many different parts of the world can be directly compared with respect to age. Thus the Scripps Institute of Oceanography took shells from 73 to 75 feet in a bore in the Gulf of Mexico near Rockport, Texas, and obtained a date of about 9,300 years. In other words, the shells were living at about the same time as the red gum at South Melbourne.

Radiocarbon dates for charcoal layers in the Doutta Galla Silt that forms the Keilor Terrace of the Maribyrnong River range from 18,000 years to 8,500 years ago, suggesting that the Terrace was built over the period of something like 20,000 years to 6,000 years ago. The famous Keilor Cranium that belonged to a middle-aged Australian aborigine could be as old as 15,000 years.

When the available evidence is assembled, the climatic changes indicated are for a drier and warmer period about 4,000 to 6,000 years ago, and for a cooler and wetter period before that extending beyond the range of radiocarbon dating. The fossil evidence is gradually being collected to show the effect of these changes on the flora and fauna.

Diprotodon - Extinct Marsupial

Under the Coode Island Silt of the Yarra delta a similar formation is found, the Fishermen's Bend Silt, which therefore is older. Like the younger formation above, it has plentiful *Anadara trapezia* shells, and so must belong to a slightly warmer time and not a glacial period. The silt is yellow because the sediments were oxidized when exposed to the atmosphere during the last low sea level. Thus, there was a higher sea level to deposit the Fishermen's Bend Silt, then a lower sea level to allow it to be oxidized and the deep channels (discussed earlier) to be cut. and finally the sea rose again to deposit the Coode Island Silt. The Fishermen's Bend Silt is believed to belong to the Last Interglacial of the order of 100,000 years ago.

The marine molluscs in the formation are of the same species as those which live today in Port Phillip. At a depth of 35 feet in Arden-street, North Melbourne, part of the huge jaw of the extinct marsupial *Diprotodon optatum*? was found. Marine shells were found 200 feet from the bone. *D. optatum* is the largest marsupial that ever lived, and its remains are known from all States of mainland Australia and from King Island in Bass Strait, but not from mainland Tasmania. It was a large four-footed herbivore 5 to 6 feet high and about 10 feet long. The weight of this animal may have been of the order of a ton. The whole family to which *Diprotodon* belonged (Nototheriidae) has become extinct. A radiocarbon date of 6,700 years has been obtained for a *Diprotodon* tooth from Orrorroo in South Australia, and so the time of extinction may be very recent from a geological point of view. In Victoria, *Diprotodon* has been recorded from the Melbourne, Lara, Geelong, Camperdown, Beeac, Colac, Lancefield, Talbot, and Omeo districts. Its presence on King Island, Bass Strait, suggests that it migrated there from Victoria when the sea level was low and Bass Strait was dry land.

The fossils in the Coode Island Silt were all of living species, but in passing back to the older Fishermen's Bend Silt, we find an extinct animal, and so begin to gain perspective in looking at the life of the past.

Marsupials Recently Become Extinct

The town of Camperdown is in the lakes district of Western Victoria and was first settled in 1839 by the brothers Manifold who built a house on the banks of the freshwater Lake Purrumbete, which occupies a volcanic crater. Just north of Camperdown is Lake Colongulac, a brackish water lake formerly called Lake Timboon, and on the south-east shore of this lake the first settler, William Adeney, settled in 1843. He found numerous fossil bones on the shore of the lake and asked the aborigines what they were. They replied " bunyip ". In those days Lake Bullenmerri was full of water and in times of heavy rainfall overflowed into Lake Gnotuk. The channel through which the water flowed, about a chain wide, was explained by the aborigines as due to a bunyip dragging itself from one lake to the other. The " bunyip " bones on the shore of Lake Colongulac were collected by Adeney and sent to Dr. Henry Hobson in Melbourne. In January, 1846, Dr. Hobson wrote to Professor Sir Richard Owen at the Royal College of Surgeons in London, and sent him the bones as he was a noted comparative anatomist. Dr. Hobson himself visited Lake Colongulac to see where the bones occurred. Professor Owen described many of these bones in his classic work " On the Fossil Mammals of Australia ". After doubts for nearly 100 years about the origin of these fossil bones it was discovered in 1950 that they came from an unusual reddish gravel consisting of minute pebbles of lithified red silt and grey silt. This was excavated for making a tennis court by the occupiers of Adeney's original property and it revealed the origin of the fossil bones. The bones are infilled with grey silt, so are apparently derived from such a bed, but they have not travelled far because they have practically no signs of wear. In the gravel were thousands of shells of the small brackish water gasteropod *Coxiella*. A large quantity of these was painstakingly extracted, and a radiocarbon analysis made. This gave a date of approximately 13,700 years. As the bones were derived, they would be older than this, but probably not much older.

Lake Colongulac has an area of 3,500 acres, but is not very deep, and between 1927 and 1941 (fifteen years) it dried up in ten summers. It went dry again in 1945, but since then has not been dry. In 1962, the level began to fall and beach deposits were swept away so that the red and grey gravel was exposed in various places. This was eroded by the lake waves and many more fossils excavated. Similar fossils have been found on the shores of Lake Weeranganuk and Lake Kariah nearby. Fossils of apparently more recent date have been found at Lakes Keilambete, Gnotuk, Bullenmerri, and Purrumbete.

Probably the most interesting fossil described by Professor Owen was one he called a Marsupial Lion, viz., *Thylacoleo carnifex* (Plate 1, Fig. 1). All Adeney sent him was the brain box and a huge premolar tooth that reminded him of a lion. Many writers since have questioned whether it was a carnivore at all, and the problem is not yet settled. Thirty years after he had collected the type specimen of *Thylacoleo carnifex* sent to Professor Owen, William Adeney collected and sent to Professor McCoy in Melbourne the nasal part of an animal of this same species. Professor McCoy described it in his " Prodromus of the Palaeontology of Victoria " decade 3, published 1876. In 1961, a cast of Owen's specimen was obtained from the British Museum and it was discovered that McCoy's specimen was part of the same individual, as the two bones fitted together perfectly.

From the bone bed at Lake Colongulac various writers have recorded also *Diprotodon optatum*, four extinct kangaroos (*Procoptodon goliah, Macropus titan, M. magister,* and *M. pan*), an extinct species of Tasmanian " Tiger ", *Thylacinus rostralis*, the living kangaroo *Macropus canguru*, a wombat, *Vombatus pliocenus*, and the dingo, *Canis familiaris dingo*. The last three were probably not in place and not as old as the other fossils. It is noteworthy how many of these species of animals have become extinct in the past 14,000 years. The whole family represented by *Diprotodon* (Nototheriidae) and the family Thylacoleontidae (which has only one genus *Thylacoleo*) have become extinct. In Australia there has been a marked recent impoverishment in the vertebrate fauna. Varied and interesting though Australia's remarkable marsupial fauna is at the present time, it was much richer in the late Pleistocene. Since then twenty genera and numerous species of marsupials have become extinct. Radiocarbon dating indicates that many of the extinct marsupial genera (many of them giant forms) lasted till the mid-Holocene. The faunal impoverishment is a recent thing and appears to be still going on, accelerated by European man. *Thylacinus* (Tasmanian "Tiger") was widely spread in Australia in the Late Pleistocene, but was extinct on the mainland when Europeans arrived. It was common in Tasmania until the turn of the century, but now it is debatable whether it still exists. *Sarcophilus* (Tasmanian Devil) was present in Victoria until only a few thousand years ago (as shown by bones in coastal aboriginal middens between Warrnambool and Port Fairy). *Eudromicia lepida*, a phalanger now limited to Tasmania, occurs in recent owl deposits in the Buchan district of Victoria. Recent cave deposits show that the broad-toothed native rat, *Mastacomys fuscus*, was recently widespread in Victoria, but is now limited to certain mountain areas. There are many species that were known in recent times in Victoria from midden and cave deposits, or collected last century, that cannot now be found, e.g., the Pademelon *Thylogale billardieri*, the brown hare-wallaby *Lagorchestes leporides*, the bettongs *Bettongia lesueur* and *B. penicillata*, the rabbit bandicoot *Macrotis lagotis*, and the white-footed rabbit-rat *Conilurus albipes*. It was thought for some 50 years that Leadbeater's Possum *Gymnobelideus leadbeateri*, had become extinct, but recently it was discovered to be still surviving in an area near Marysville. By 1963 it was found at seven localities in an area of 100 square miles.

A giant bird (*Genyornis*) has been described from the Quaternary deposits of Lake Callabonna in Central Australia, and the footprints of a bird of similar size were found in the Pleistocene aeolianite that forms the cliffs at Warrnambool in western Victoria.

The reasons for the faunal impoverishment are not understood. A similar process has been noted in other parts of the world. The effects of climatic changes have been noted, but undoubtedly the increased numbers, mobility, and power to destroy of that Ice Age species called *Homo sapiens* is another factor in the process.

Tertiary Marine Fossils

From the beginning of the Pleistocene to about 70 mill. years ago is called the Tertiary Era. Tertiary fossils are found in many places in Victoria. During that Era the sea invaded the valley of the River Murray and formed a large gulf there; it also covered most of the plains of south-west Victoria, the Port Phillip and Melbourne area, and the Gippsland Plains. Of world fame are the richly fossiliferous marine beds that outcrop in the valleys of Grange Burn and Muddy Creek 4 miles west of Hamilton. Basalt flows cover the district, but the local streams have cut through that rock to the marine beds beneath.

On a basement of hard Palaeozoic quartz porphyry lie three formations, all very rich in fossils. There are over 400 species of molluscs alone present in these strata. The lowest is the Bochara Limestone which contains very large numbers of foraminifera (see Plate 2, Fig. 1), including the large warm water *Lepidocyclina*. The rock consists almost entirely of the skeletons of marine organisms, large and small, whole and broken. There are large numbers of polyzoa, and many echinoderms such as *Brochopleurus*. Molluscs are not as numerous as in the overlying formations, but the scallop *Chlamys* is frequently found. Marine sponges have been described from this bed. Sharks' teeth may be collected from the Bochara Limestone, including the giant *Carcharodon megalodon* (Plate 2, Fig. 5) which was as big as a whale. A well known photograph shows a man sitting on a chair inside the fossil jaws of this enormous shark. The Bochara Limestone has very little terrigenous material, and was formed as the sea transgressed the quartz porphyry from which very little sediment would be derived. A similar facies (environment) may be seen at Batesford where a limestone of the same age has been formed by the sea transgressing the Palaeozoic diabase at Dog Rocks.

The overlying formation at Hamilton is by contrast a muddy one, but containing gargantuan numbers of calcareous fossils, especially molluscs. This is called the Muddy Creek Marl and the best known locality is Clifton Bank. In that formation are found giant cowries (*Gigantocypraea*) many times the size of the largest living cowries. Thus in 1961 there was donated to the National Museum of Victoria by a local resident a *Gigantocypraea,* 9 inches long, 6 inches wide, and 5 inches high. Large numbers of very varied univalves and bivalves occur, many having features associated with tropical forms. Corals, polyzoa (sea mats), and foraminifera are plentiful. Whales and sharks are represented by bones and teeth. There is thus evidence of warm waters that supported a rich fauna of invertebrates and vertebrates. Many of the genera represented are still living, though commonly they survive in more northern latitudes.

Above the Muddy Creek Marl is the Grange Burn Coquina, a shell bed of Lower Pliocene age with a fauna that has much more in common with the marine fauna we know today. In between the Muddy Creek Marl and the Grange Burn Coquina is a layer of phosphatic nodules which represent a not inconsiderable break in time when there was apparently very little sedimentation. Nodules are formed from deposition on shells, polyzoan skeletons, sharks' teeth, crab claws, and other such remains from the ocean floor, of lime phosphate. Three specimens analysed yielded an average of 64 per cent. calcium carbonate, 16·2 per cent. phosphate, 2·2 per cent. fluorine, and 10·3 per cent. silica. The nodule bed has produced large numbers of phosphatized sharks' teeth, whale bone, some whale teeth and ear bones (cetolites), some of the bony crushing palates of the porcupine fish (*Diodon*), the characteristic mandibular and palatine teeth of the extinct elephant fish *Edaphodon sweeti,* and some other fish remains. Other nodules are formed simply by deposition of calcium phosphate in fossiliferous marlstone. The nodules are brown in colour and characteristically are highly polished. Some of the large nodules have been bored by marine borers. In places the surface under the nodules has been bored, and the fossil boring molluscs are still in their fossil burrows.

Above the nodule bed is the Grange Burn Coquina, which consists of a mass of marine shells belonging to shallow water and shoreline ecologies. There are countless numbers of long narrow oysters (*Ostrea manubriata*), sand snails (*Polinices*), and other kinds of molluscs, along with polyzoa, barnacles, foraminifera, and other marine organisms. Evidence of shoreline conditions is provided by limpets (which probably grew attached to the quartz porphyry reefs and rock stacks), mussels

(*Mytilus*), and shallow water foraminifera. Over 150 species of molluscs alone have been noted in this stratum, and something like 10 per cent. of them are still living. The most remarkable fossil from this formation is one side of the jaw (ramus) of a sthenurin kangaroo. This leads to consideration of the terrestrial fauna of Victoria during the Tertiary Era.

Tertiary Terrestrial Fauna

At the time of writing, the oldest known marsupial in Australia is a possum (*Wynyardia bassiana*) that was found in a marine Oligocene stratum at Wynyard in north-western Tasmania. The oldest marsupial fossils found in Victoria come from the uppermost Miocene marine beds at Beaumaris, Victoria. For the past 100 years, large numbers of bones have been collected on the beach or dug out of the cliffs at Beaumaris, although various public works are now making this a difficult procedure. Most of these bones have naturally been of marine animals such as whales, sharks, and stingrays, but there have been a few of marsupials washed in from the contiguous land surface. The preservation of these bones, and their fluorine content, show that they are of the same age as the bones known to be in place in the Miocene bed. They include a large notothere-like (four-legged marsupial) animal and some kangaroos of large size.

On Grange Burn, 4 miles west of Hamilton, where that creek flows off the basalt, there may be seen a fossil land surface of Upper Pliocene age. On the Lower Pliocene marine rocks a soil has been developed, and in place in the soil are stumps of Celery Top Pine (*Phyllocladus*), which is now extinct in Victoria though still living in the temperate rain forest of western Tasmania. In this soil the teeth of various animals living at the time have been found, perhaps brought together by predators. Belonging to this same terrain are pond deposits rich in pollens, spores, diatoms, sponges, and also some leaves. The flora is partly the coniferous forms that characterize the Tertiary beds and partly the eucalypt-wattle association that characterizes the Quaternary Era. All these deposits have been sealed off by basalt flows and so preserved.

On Muddy Creek to the south, there is a series of beds rich in volcanic ash lying between the Lower Pliocene marine sediments and the basalt. Thus volcanoes were active in that area. Analysis of the soil at Grange Burn shows that there is a trace of volcanic ash in that as well.

Thus may be gained some perspective in the history of life in Victoria. Going back in time to the Pleistocene we find that species of animals like those still living are found as well as forms that have become extinct. In the Tertiary, animals related to the living forms are found which are now extinct. In the Pleistocene, there was a flora like the present but varying in distribution patterns, while in the Tertiary we can trace the changes back to types of forest dominated by conifers or in hilly country by beeches.

In the goldmining days many marsupial bones were found in deep leads (old river deposits below basalt flows) and in alluvial deposits of considerable age, but the dating of these finds still presents big problems. Many of these finds will no doubt prove to be of Tertiary age.

The only Tertiary bird fossil discovered in Victoria is a feather in lateritic ironstone from Redruth in western Victoria, and this is considered to be doubtful by some people. From Carapook, north-west of Casterton, comes a fossil tortoise, also in ironstone and so also of poor preservation ; its age is doubted by some.

Two Tertiary crocodilians are known from Victoria. In the Clunes district part of the tibia of a crocodilian was found at 295 feet in the main shaft of the Spring Hill Central Lead Company's goldmine. More recently part of the lower jaw of a crocodilian was found in a marine bed of Oligocene age between Torquay and Point Addis.

Flora of the Brown Coal

Of Lower Tertiary age are the brown coals of Victoria, which are of world note for their thickness and extent. In and near the Latrobe River valley in Gippsland, the brown coal beds have been extensively drilled and some 200 square miles of deposits proved. The beds average 50 feet in thickness, and one bed is 543 feet thick. Near Morwell there are three seams with a total thickness of more than 1,000 feet, and a bore intersected 780 feet of coal in a total depth of 1,100 feet. In the top of the Yallourn seam as many as sixteen horizons are seen in which tree-stumps in the position of growth are associated with fallen logs of coniferous trees up to 50 feet long and with a profusion of leaves and stems. From the palaeontologist's point of view, the brown coals are just immense masses of fossils. They comprise organic material collected in a sinking basin over a long period of time. No bones have as yet been discovered in the brown coals, probably because they were dissolved by the humic acids present in such environments.

In the Port Phillip area there is a seam of brown coal up to 140 feet thick that has been traced for 10 miles. The Altona brown coal mine worked this deposit where at 350 feet a seam 74 to 85 feet thick was mined. Of recent years the brown coal in the Bacchus Marsh district has been extensively worked. There are numerous other deposits that have not been considered as economic propositions, and so not worked. All the foregoing coals are considered to be Oligocene in age. Still older are the brown coals at Wensleydale, Anglesea, and other places in the Otways. These are of Eocene and sometimes Paleocene age.

With this background of their occurrence, the flora the brown coal preserves can now be considered. Study of wood structure has proved the presence of kauri (*Agathis*), podocarps (*Podocarpoxylon* and *Phyllocladoxylon*), *Casuarina* and *Banksia*. In spite of careful search, only one probable *Eucalyptus* fossil and no *Acacia* (wattle) has been found. It is reported by the botanists who made this study that from the material examined it appears that the forests which formed the brown coal were almost purely coniferous, and hardwoods, although occasionally present, may be regarded as accidental. The deposits consist largely of tree-trunks which fell where they grew ; some fell while still on the stump, and the roots are therefore upright, while others rotted at water level, leaving the stumps still in their original position. Owing to the very small percentage of sediment in the coal, the conclusion must be drawn that the trees grew in a swamp which was sinking slowly, so slowly that, during the lifetime of the trees, water did not encroach seriously upon the trunks, and the trees could therefore grow to an age and size equivalent to those on dry land. In the case of trees which fell from the stump, it may be concluded that there were periods of equilibrium in the sinking and that the trees decayed at the water-air level.

The presence of kauri (*Agathis*) has been proved not only by the fossil wood, but also by leaves, male and female cones, and pollen (Plate 3, Figs. 5, 6, 9). The fossil resin common at certain horizons at Yallourn, is no doubt in part derived from kauri trees. Techniques have been developed for the detailed study of fossil leaves that are suitably preserved. Sections show their general structure ; upper and lower cuticular surfaces can be removed and the fine detail of cells, stomata, and hairs elucidated (Plate 3, Figs 5–7). These structures make it possible to recognize a species with certainty. Belonging to the same family as *Agathis* is *Araucaria*, which is also recognized by leaves, cones, and pollen. Podocarpaceous forms recognized in the flora of the brown coals by wood, pollen, and sometimes by leaves as well, include *Phyllocladus*. *Trisaccites* and *Microcachrydites* are conifer pollen form genera of podocarp type. The pollen of the latter is similar to that of the diminutive pine, *Microcachrys tetragona,* now living only in the highlands of Western Tasmania. Silicified wood of this genus from Lower Cretaceous rocks (Merino Group) in Western Victoria shows that it was once a large tree.

Proteaceous plants of *Banksia* type have also been recognized at Yallourn by leaves, cones, and pollen. Other proteaceous pollen types are *Beaupreaidites* (like the genus *Beauprea* of New Caledonia) and *Proteacidites*. Other dicotyledons are *Casuarinidites*, *Anacolosidites* (similar to the genus *Anacolosa* of New Guinea), *Cupanieidites*, *Tricolpites* (one of the earliest Australian gymnosperm pollen types), and *Triorites*.

In the brown coal at Yallourn, pollen is so plentiful at some horizons that it forms pollen coal. One type of pollen that occurs in great quantity is that of the Southern Beech *Nothofagus*, of which numerous species have been described (Plate 3, Figs. 2–4). Although the pollen is so plentiful, no beech wood has been found in the brown coal at Yallourn. Beeches prefer well-drained slopes in areas of high rainfall, so they would not be expected in the swamp environment of the Latrobe Valley brown coals. The abundant pollen with absence of wood suggests that they clothed the slopes of surrounding hills, whence their pollen was wafted to the swamps to be included in the brown coal formations. *Nothofagus* still continues in the forests of Victoria but only as a minor element. During the Tertiary Era it was a major component of the forests. However, the majority of the Tertiary forms are to be compared with those surviving in New Guinea and New Caledonia and not with those surviving in southern Australia.

As the eucalypts (of the family Myrtaceae) form so important a part of modern Australian forests it is interesting to look at their history. Before the Pliocene it is very difficult to discover any trace of them. Only two specimens of wood believed to be pre-Pliocene have so far been identified as *Eucalyptus*. This much is clear, that this genus did not dominate the Tertiary forests as it does the modern forests. Myrtaceous pollen is widespread, two species of *Myrtaceidites* characterizing the lower Tertiary and *M. eucalyptoides* the Pliocene and Quaternary. It should, however, be pointed out that still relatively little is known about the flora and fauna of these past ages in Australia. To date more has been done in Victoria than elsewhere in Australia in elucidating the Cainozoic floras, and this much may be said—that the Tertiary was characterized by conifers and beeches, then in the Pliocene there was a change over so that in the Quaternary the forests were characterized by *Eucalyptus* and *Acacia*. So far the presence of *Acacia* has not been demonstrated in beds older than Pliocene.

Ferns are widespread in the Tertiary of Victoria, including the tree fern *Cyathea*. Interesting fungi have also been recorded.

Tertiary Climate

The presence of forests, the accumulation of vast quantities of carbonaceous material, the nature of sediments deposited, and the types of soil developed all provide evidence of generally wetter climates in Victoria during the Tertiary than obtain today. The widespread occurrence of genera such as *Araucaria* and *Agathis* in the Tertiary forests, the presence of crocodilians, the tropical to sub-tropical nature of the marine fauna in the contiguous seas, and again the nature of the soils developed, show that temperatures were higher. The proportion of light (^{16}O) and heavy (^{18}O) oxygen in a fossil shell (for example) can be used to determine temperatures of the past. This method has been applied in Victoria. Temperatures a little higher than the present are indicated for early Tertiary times, with increasing temperatures to the Miocene, when they began to fall away again till the Quaternary when the glacial and interglacial periods resulted in rapid oscillation of temperatures. We live in a time that is atypical of geological history for both the temperature and humidity changes, and the changes of sea-level are far more rapid than characterized the past. The genus *Homo* (modern man) developed in these unusual conditions; *Homo sapiens* is, from the scientific point of view, an Ice Age animal.

Age of Dinosaurs

The Mesozoic Era (see Fig. 1) was more than twice as long as the Cainozoic Era, and in reconstructing that time in Victoria one sees a flora and fauna as different from the present as though it belonged to another planet. The orientation of the country was also so different as to be unrecognizable. There was no Bass Strait, Tasmania having no distinctive existence, and wide lowlands with lakes and swamps reached far out into what is now the sea. Only at the very end of the Era did the sea begin to encroach on the land, and earth movements brought about a land mass something like the Victoria of today.

The Mesozoic Era is the age of dinosaurs, and some parts of Australia are quite rich in their remains, yet Victoria has but one claw to show that these strange reptiles also lived here (Plate 4, Fig. 5). A solitary ungual phalange of a carnivorous dinosaur was found in the rocks in the vicinity of Cape Paterson in Gippsland many years ago. More recently a reptilian humerus was discovered in the rocks forming the cliffs east of Cape Paterson, and this may have belonged to a Saurischian dinosaur, perhaps a small theropod. From the same beds (now considered to be of Lower Cretaceous age and formerly called Jurassic) came the splenial tooth of a lungfish, *Ceratodus avus* (Plate 4, Figs. 2–3). It is of interest to notice this long history (Devonian to present) of lungfish in Australia. Freshwater mussels have been found in a number of places.

In 1962 extensive collections of fossils were made from a richly fossiliferous band in these Lower Cretaceous rocks exposed in a new road cutting near Koonwarra in South Gippsland. There were large numbers of Leptolepid fish (Plate 4, Fig. 1), larvae of insects, branchiopods, other arthropods not yet described, a king crab, *Mesolimulus* (not found in Australia before), and numerous plants.

Felspathic sandstone (arkose) with shales and some conglomerate, a couple of miles thick (the thickness is difficult to measure because of faulting), constitute the group of Lower Cretaceous rocks outcropping in South Gippsland and the Otways. Inclusions in places of large masses of rock and pebbles out of character with the containing sediment suggest slumping. On the Cape Paterson coast, a shore platform revealed a fossil soil with stumps of fossilized trees. This group of strata contains black coal which has been mined at Wonthaggi, Jumbunna, and Korumburra. The breakdown of the arkoses has led to some unusual means of preservation of fossil woods. Some are preserved in the zeolite laumontite, occasionally with masses of radial crystals. Other woods have been preserved in silica. Some have been ferruginized. Others again have been turned to coal. Tree trunks up to 40 feet long have been exposed by marine erosion along the coast. The ecology of these beds is that of lakes, swamps, and contiguous lowland. The vegetation was mostly conifers and ferns. The former include *Araucarites* (known from cones, wood, and doubtfully from shoots), *Brachyphyllum*, *Bellarinea* (a podocarp named after the Bellarine Peninsula where these fossils are found), and *Elatocladus*. The bryophyte *Marchantites* is known by two species. The tracheophytes *Lycopodites*, *Equisetites*, and *Neocalamites* have been described. There is a rich flora of ferns and fern-like plants including *Osmundites, Cladophlebis* (Plate 3, Fig. 8), *Microphyllopteris, Coniopteris, Adiantites*, also *Phyllopteroides, Taeniopteris, Rhizomopteris*, *Sphenopteris*, *Thinnfeldia*, *Dicroidium*, *Neuropteridium*, and *Czekanowskia*. Fern and fern-like fronds are the most characteristic fossils encountered when these rocks are searched for fossils. The spores of these ferns were distributed by the winds so that the species are very widespread. *Ginkgoites* (related to the living *Ginkgo* or maiden hair tree) belongs to a small but interesting group of gymnosperms that has survived from the Permian to the present. This group would probably be extinct if *Ginkgo* had not been cultivated for centuries in Chinese gardens. This Cretaceous world was dominated by embryophytes, but with the angiosperms (that dominated the Cainozoic) just beginning to appear. The flora and fauna of the black coal rocks, chiefly found in Gippsland and the Otways, is of Lower Cretaceous age, but in the Western District of Victoria, and near Lake Wellington in Gippsland, deep bores for underground water and oil have penetrated Upper Cretaceous marine rocks concealed beneath the Tertiary marine rocks found outcropping at the surface.

The Period before Cretaceous is Jurassic, and it is not yet clear whether this period is represented by fossils in Victoria.

The Mesozoic Era began with the Triassic Period. Rocks of this age are well represented in Tasmania, but only limited outcrops not certainly attributed to that period are found in Victoria, e.g., at Bacchus Marsh.

Bacchus Marsh Glacial Beds

The Werribee Gorge near Bacchus Marsh is one of the best known geological localities in Victoria. The earth movements that created the Great Dividing Range raised the Brisbane Ranges–Ballan area. The scarp that marks off this higher country from the Port Phillip Sunkland runs from Bacchus Marsh round the east side of the Brisbane Ranges towards Geelong. It is called the Rowsley Scarp, and was caused by the Rowsley Fault. The Werribee River, originating on the high block, has cut down deeply into the bedrock, thus exposing the extensive series of strata that make the gorge scenically attractive and geologically interesting.

Tillite, a boulder clay deposited by glaciers, is a prominent member of the stratal sequence. Beneath the rocks of this group (?Permian), glacial pavements, i.e., areas of hard rocks that have been planed and grooved by glaciers have been discovered. The glaciers responsible for these features appear to have come from the south-west—roughly the area that is now Western Tasmania. At that time there was no Bass Strait but continuous land from N.W. Tasmania to Victoria. However, a great part of the area occupied now by Tasmania was then covered by the sea, as marine Permian rocks show. Most of the black coals of Australia occur in Permian non-marine strata.

Some 250 million years separate the Permian glaciation from the Pleistocene one, and a similar span of time separates the Permian glaciation from that at the dawn of the Cambrian.

Fossils are not often found in tillite, but they are not unusual in the outwash sediments and glacial lake deposits. Plants are found in beds of this type in Victoria, and some spores and pollens have been recovered from what may be a fossil soil. The plants give some indication both of the ecology of the area and the age of the rocks. Obviously the plants could only have grown when the terrain was free of ice, and so the fossil plants are taken to indicate periods of climatic amelioration.

Along the Korkuperrimul Creek near Bacchus Marsh there are beds showing frequent alternations of glacial and fluvioglacial conditions due apparently to the waxing and waning of the ice sheets ; some of the disturbed beds in the series may owe this character to the pressure exerted by returning ice sheets. Sandstones 30 ft. thick at Bald Hill near Bacchus Marsh contain fossil wood and the leaves of the characteristic plant *Gangamopteris,* and are interbedded with deposits of glacial origin. Bald Hill is one of the limited number of places on the globe where *Gangamopteris* leaves are directly related to glacial deposits. Where *Gangamopteris* should be put in the classification of plants is not yet clear, but it is probably nearest the gymnosperms. *Gangamopteris,* after reaching the zenith of its development, appears to have been gradually replaced by an equally famous fossil plant—*Glossopteris*. The plant *Rhacopteris* characterizes the Upper Carboniferous glacial strata of New South Wales, where there is evidence that the glacial conditions first developed in the late Namurian or early Westphalian. That *Rhacopteris* has not so far been found in Victoria favours the view that the deposits concerned do not belong to the earliest section of the Permo-Carboniferous glacial sequence. On the other hand, the plentiful occurrence of *Gangamopteris,* but apparent absence of *Glossopteris,* suggests that the latest section of the sequence is not present. The precise age of the *Gangamopteris* beds at Bacchus Marsh cannot be proved, but the most informed approximation is that the beds are Lower Permian with perhaps some Upper Carboniferous as well. More precise dating may come through the discovery of beds with adequate arrays of fossil pollens and spores.

Other formations of Permian age are found in various parts of Victoria—remnants of what must have been a very widespread group of rocks. Some of the pebbles in the tillite are quite dissimilar from any known local types, and so must have been transported a considerable distance by the glaciers.

Grampians Fossils and Mansfield Fish

Just as it is difficult to say where the boundary should be put in Victoria between the Upper Carboniferous and the Lower Permian, so is it also difficult to separate the Upper Devonian and Lower Carboniferous. Time is a continuum, and the floras and faunas suffered no interruption at period boundaries ; these divisions are a matter of convenience.

The Grampians mountains present a vast series of deltaic and marine sediments many thousands of feet thick and remarkable for their lack of fossils. One thin formation has yielded fish teeth and spines, ostracods, and brachiopods (*Lingula borungensis*). A few fragmentary plant remains (sphenopsids) have also been discovered. It is unusual, especially in Victoria, to find so vast a thickness of strata with so few fossils. From such fossils as are present, and from consideration of the types and thickness of sediments in relation to those elsewhere that contain fossils, it is inferred that both Lower Carboniferous and Upper Devonian time are represented in the Grampians strata.

In eastern Victoria there is a wide belt of country between the Macallister and Mitchell Rivers where fossiliferous rocks of this same age are known. These strata outcrop extensively also in the rugged country of the headwaters of the King, Broken, Delatite, and Howqua Rivers. Iguana Creek, a tributary of the Mitchell River, is a well-known locality for fossils in this region ; a fine grained bed has yielded numerous well preserved plants, including *Archaeopteris howitti, Sphenopteris iguanensis,* and *Cordaites australis*. Sandstones on the Avon River and in the Mansfield district have yielded stems of *Lepidodendron,* a plant readily recognized by its diamond shaped markings that represent leaf scars ; this is the most widespread and characteristic plant of this time in Australia. Fossil fish (referred to the Upper Devonian) have also been found in this series of strata, including *Bothriolepis gippslandiensis* and *Striacanthus sicaeformis.* In the Blue Hills near Taggerty the fossil fish *Bothriolepis gippslandiensis, Dipterus* sp., *Phyllolepis* sp., and *Remigolepis* sp. are found.

The Mansfield district has long been famous for its fossil fish. Although mostly fragmentary, there are some slabs showing fairly complete fish that the neophyte collector would recognize. Beds with *Bothriolepis* and *Phyllolepis* are overlain by beds with *Gyracanthides murrayi, Acanthodes australis, Eupleurogmus cresswelli, Ctenodus breviceps, Strepsodus decipiens, Elonichthys sweeti,* and *E. gibbus.* This fauna is referred to the Lower Carboniferous.

With the evidence of these fossils and the sediments containing them, it is possible to attempt a reconstruction of the Victorian area at this time. The plants are land plants, and the fish are freshwater ones. So different were the plants that grew then, that they would appear a strange world to us. When we look at the little herbaceous lycopodiums growing to-day, it is hard to picture that they are the relatives of the plants like *Lepidodendron,* that formed the great " forests " of Carboniferous times, and contributed much of the carbonaceous matter that formed the black coals of the world of that age. *Lepidodendron,* of the Lycopodophyta, was probably the most outstanding element in the world's vegetation of the time. It was ubiquitous, abundant (at times forming pure stands), and capable of growing of the order of 100 feet high. With it was associated *Cordaites,* a similarly widespread and likewise imposing element of the strange vegetation of the Permo-Carboniferous. It could grow to at least 100 feet high and had spreading branches with strap-like leaves. The Cordaitales was one of the two great divisions of the Coniferophyta. Plants like *Lepidodendron* and *Cordaites* formed the top story of the forests of Carboniferous times in Victoria. The lower stories included abundant ferns such as *Archaeopteris* and *Sphenopteris.*

The vegetation, the abundant water-laid sediments, and the fossil fish indicate pluvial conditions. The heavy sediments such as conglomerates and sandstones indicate that there was high country and strong rivers capable of moving torrent gravels and heavy sands. Thus we may visualize mountains and hills resulting from uplifting earth movements, and strong streams running through thick fern, lycopodophyte and coniferophyte forests to the broad lakes where the freshwater fish lived.

The fish are as strange as the vegetation. There is *Bothriolepis,* found in many parts of the world, and consisting of a box of hard plates from which a mobile tail projected. These armoured antiarchs were present in considerable numbers and were one of the most successful vertebrates of the time. There were acanthodians that looked like small, spiny sharks, and *Dipterus,* one of the earliest of the lung fishes. We have already noted a lungfish (*Ceratodus*) in the Lower Cretaceous of Victoria, indicated by teeth found near Cape Paterson. Lungfish were once widespread in the world, but only relics of the group survive as living fossils in Australia (*Epiceratodus*), Africa, and South America. *Phyllolepsis* was a flattened Arthrodire fish with ornamental plates, and it was also a common element in the freshwater lakes of the time.

Upper Silurian and Lower Devonian Land Plants

Victoria is world famous for its well preserved Upper Silurian and Lower Devonian land plants. Although they are found in marine strata, it is clear that they are land plants because they possess a stele for carrying water from the ground to their tissues. Such structures are not needed and do not occur in the plants that live immersed in water. The cell structure of the stele has been demonstrated, and also the nature of the spores by which they reproduced. Modern palaeobotanical methods make it possible to obtain a surprisingly large amount of information from what at first looks like unpromising material. All the plants of the time were primitive in organization and small in size. There were not tall plants as in the Carboniferous forests. From such information as has been gleaned so far, it is likely that none grew to more than 2 feet high.

The most characteristic element of this early flora is *Baragwanathia longifolia* (Plate 5) which consists of branched stems closely clothed with long narrow leaves spirally arranged. This primitive plant is believed to be a lycopod, the early ancestor of our modern lycopodiums. Another plant, *Yarravia*, consists of a smooth stalk with cylindrical fructifications consisting of five or six sporangia. Yet another fossil plant of this flora is *Hedeia*, which like *Yarravia* is believed to be a psilophyte. It has fertile branches with large oval sporangia borne terminally. A further member of the flora is *Zosterophyllum* which possesses erect smooth leafless stems which may bear a fructification of six closely packed sporangia. This genus is known in Europe as well as in Australia. All these plants, and others not so well understood that are found in the same beds, are grouped together as the *Baragwanathia* Flora. In those times there were no forests, but just these spore-bearing herbaceous plants. There were no flowers and so, of course, no bees or other insects that are associated with flowers. Earth's mantle of vegetation was completely different from that we know.

The beds from which the *Baragwanathia* Flora is mainly collected surprise us with their richness of fossil plants. An enormous quantity of plants must have been washed into the areas of the sea where these beds were laid down to provide such plentiful fossils. As the plants were not very big, a considerable area must have been stripped to provide this large volume of plant material. Perhaps the *Baragwanathia* Flora occupied swamps and lowland near the coast that were severely eroded upon uplift of the land. The great thickness of geosynclinal strata that include the fossils presupposes an unstable and rising land mass not very far away. The fossil plants are dated by means of the marine fossils (graptolites, brachiopods) occurring with them.

Fossils and the Tasman Geosyncline

In Palaeozoic (see Fig. 1) time there was a broad seaway down the eastern side of Australia covering a great and complex tectonic depression in which sediments, miles thick, gradually accumulated. This vast trough in which these cubic miles of sediments slowly gathered is a feature of world note ; it is called the Tasman Geosyncline.

During the Silurian Period, and for part of the Devonian, the ocean covered most of Victoria. Great thicknesses of strata were deposited, and countless millions of invertebrate fossils have been preserved in

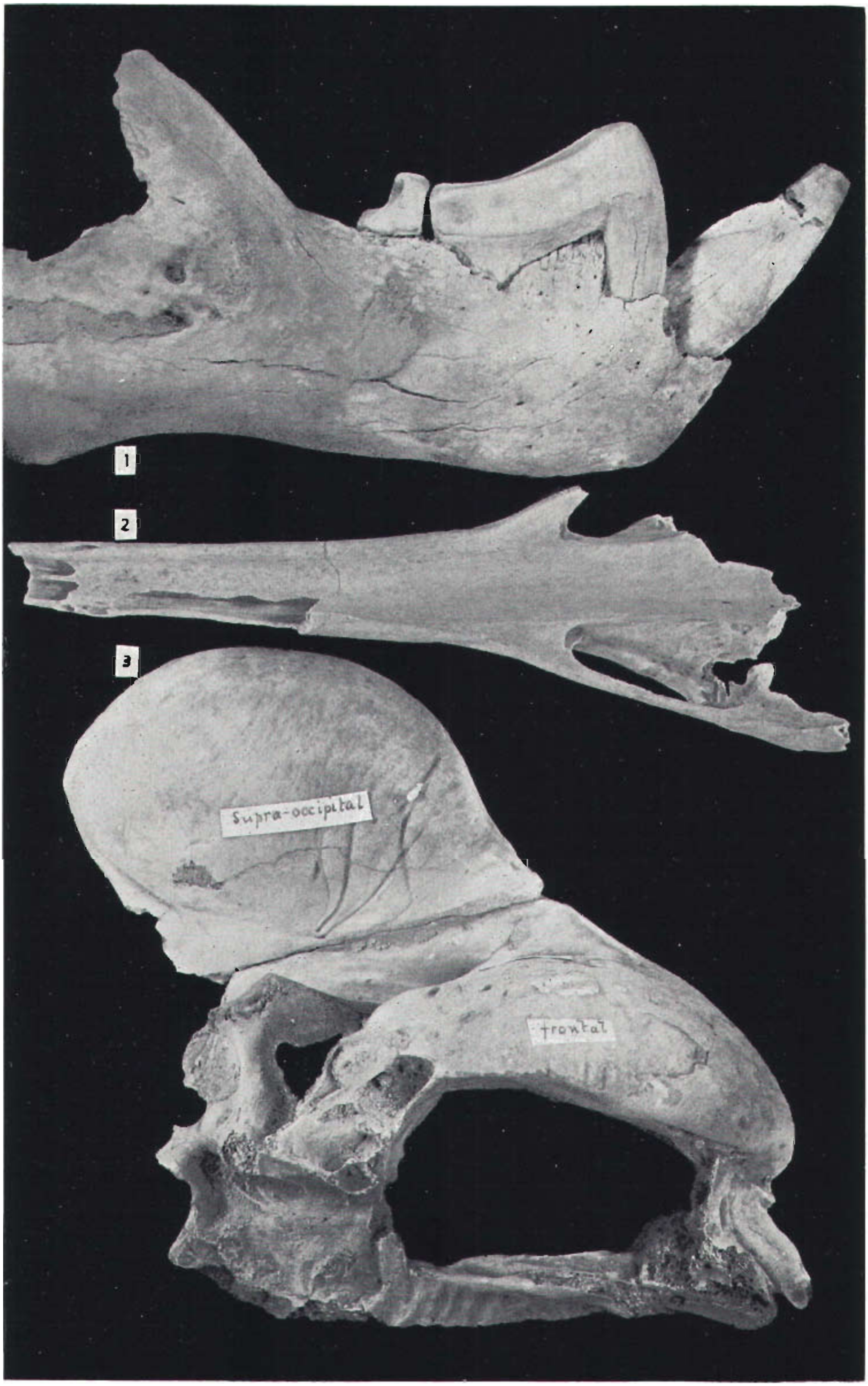


PLATE I

Quaternary Vertebrates

For explanation of plates, see pages 23–24.

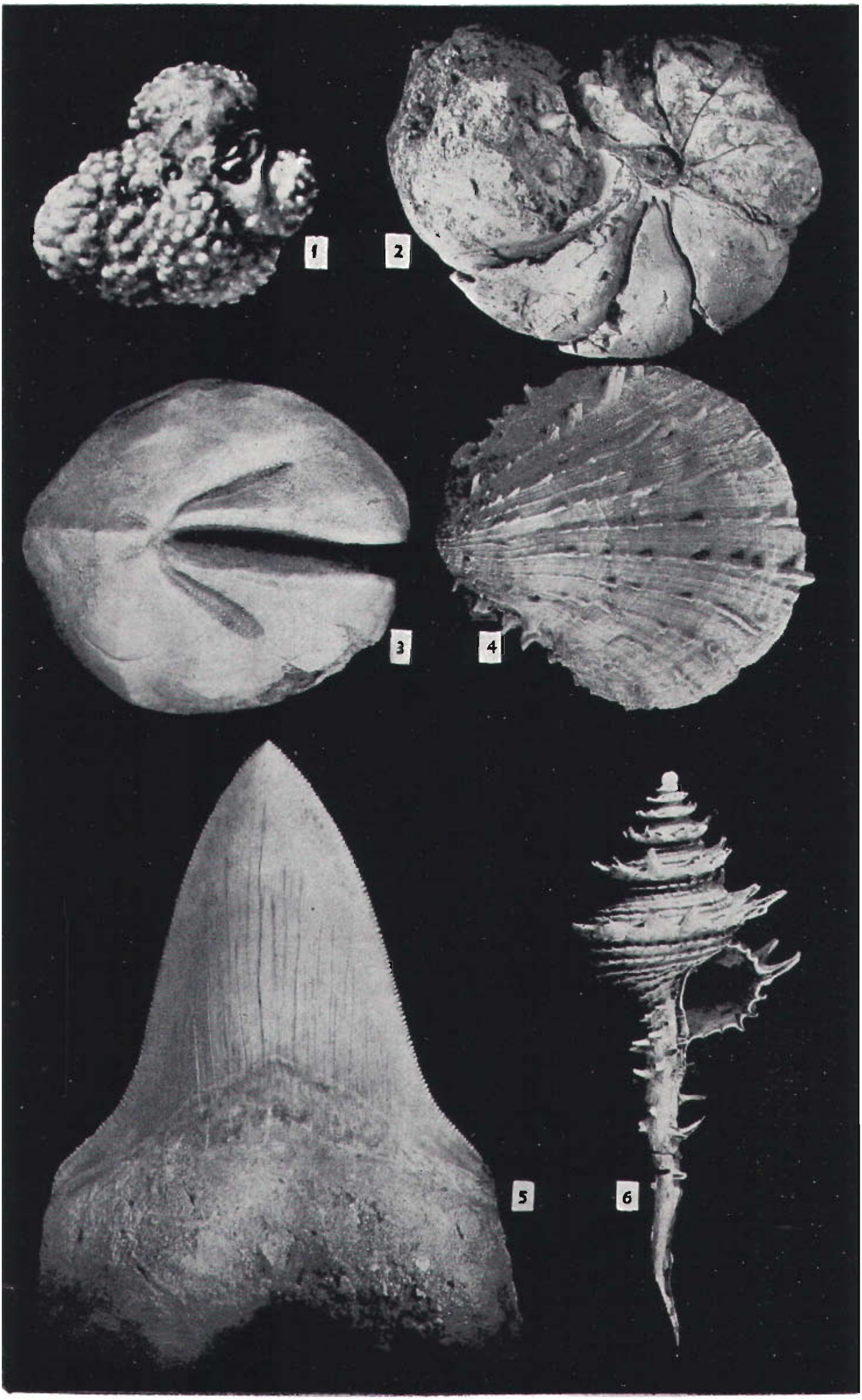


PLATE 2

Tertiary Marine Fossils

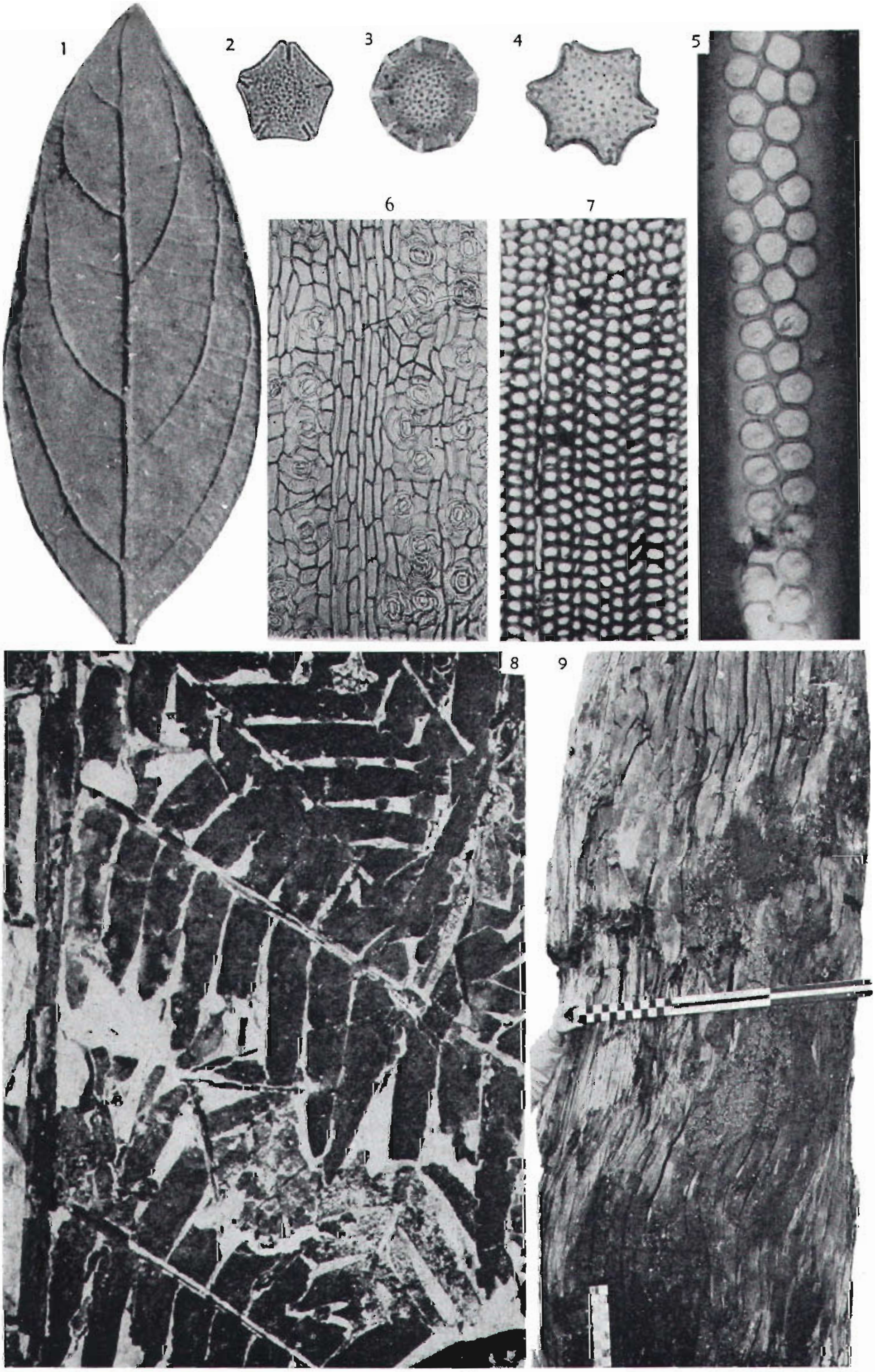


PLATE 3

Tertiary and Mesozoic Plants

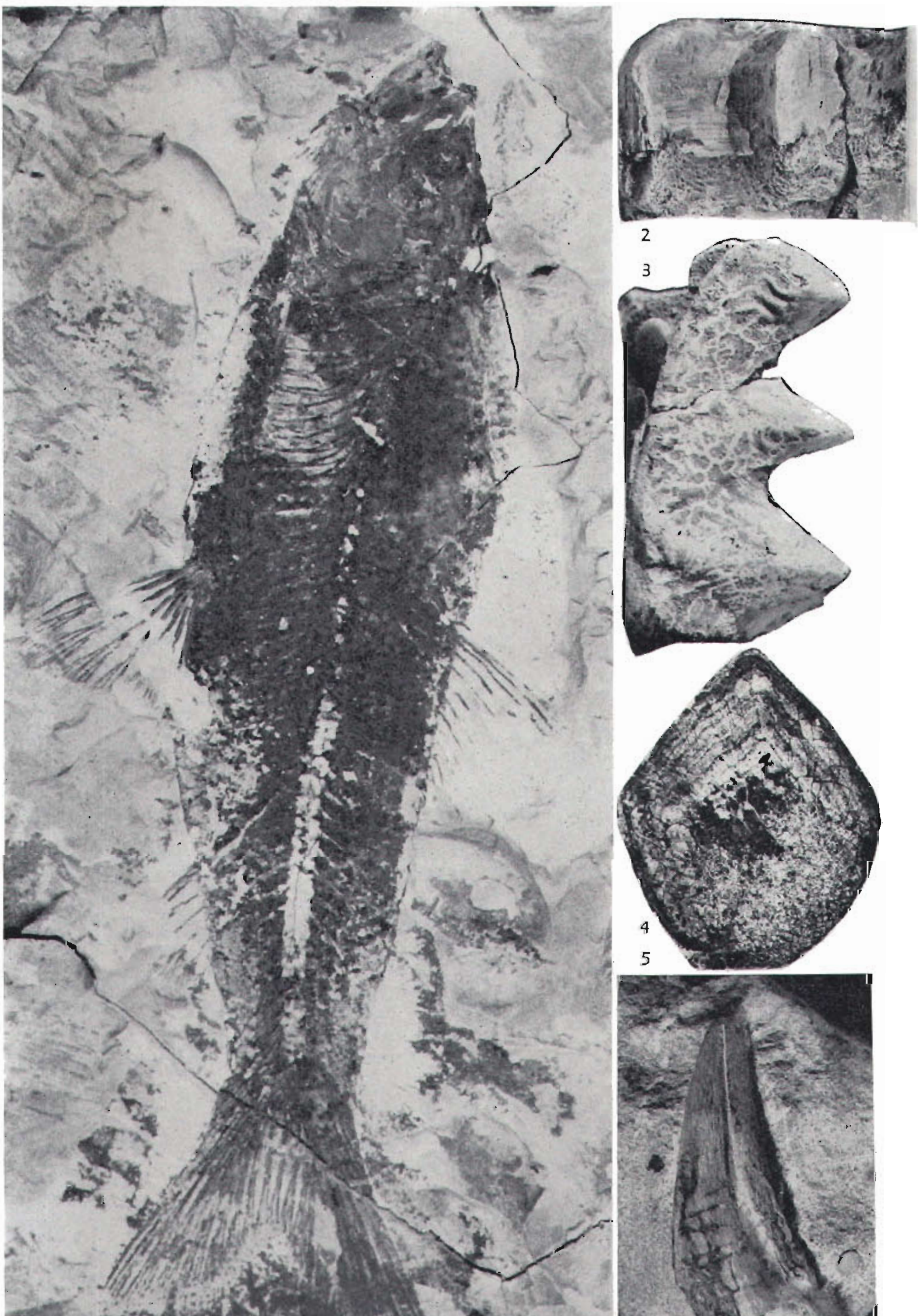


PLATE 4

Mesozoic Vertebrates

PLATE 5

Siluro-Devonian Plants and Graptolites

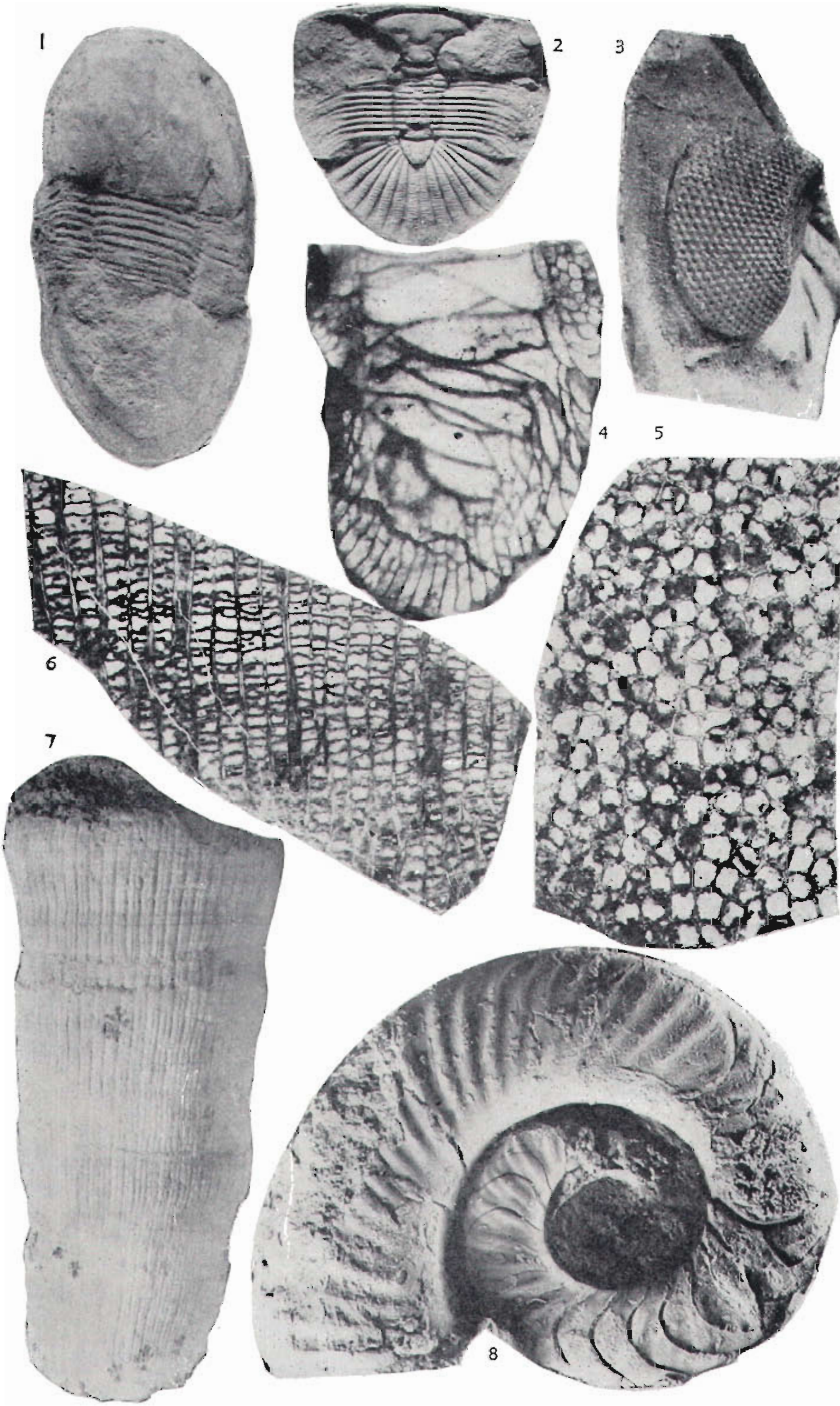


PLATE 6

Silurian and Devonian Marine Invertebrates

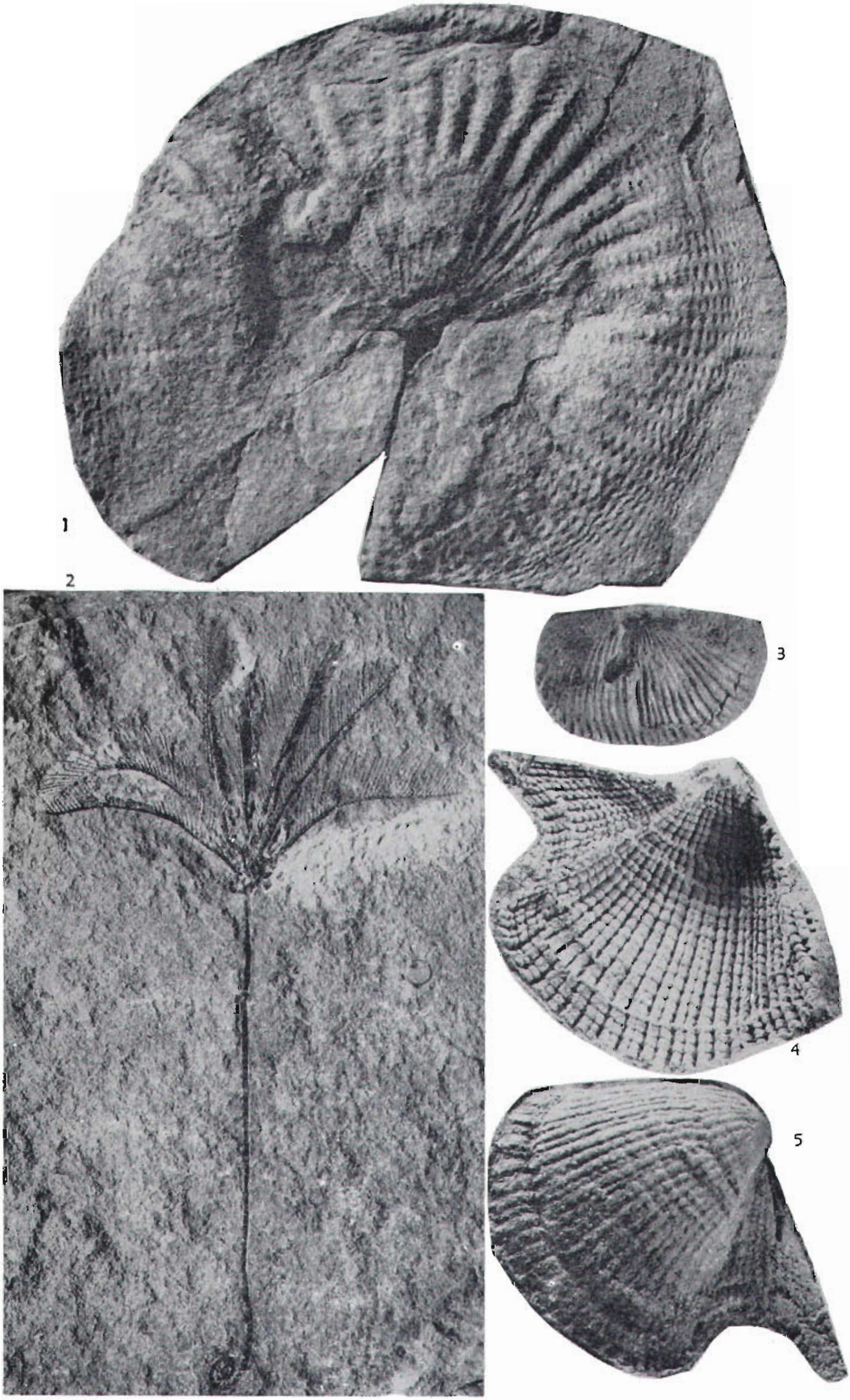


PLATE 7

Palaeozoic Marine Animals

PLATE 8

Ordovician Graptolite

these strata. Splendid successions of these marine rocks and their fossils can be seen in the Melbourne to Lilydale area, in the Heathcote District, and also in many other parts of Victoria, including Eildon, Woori Yallock, Woods Point, Walhalla, and Tabberabbera. The faunas comprise marine algae, protozoa, sponges, corals, stromatoporoids, graptolites, echinoderms (star fish, crinoids, blastoids, carpoids), polyzoa, brachiopods, molluscs, ostracods, trilobites, merostomes, and in the Middle Devonian, some fish (Plates 6–7).

Coral reefs were present in a number of places, and the detritus (sediment) from these constitute some of the useful limestone deposits of the State. Nearest to Melbourne is the Lower Devonian limestone at Lilydale. A review of its fossil content will provide a picture of one of the marine ecologies of that time. Underneath the Lilydale limestone are sandstones and siltstones with marine fossils to be expected in the sandy and muddy facies of the sea, but also in places with land plants such as *Yarravia*, *Zosterophyllum*, and *Hedeia*, but no *Baragwanathia*. Above the limestone is a siliceous conglomerate with marine brachiopods. The limestone itself is rich in the remains of corals and stromatoporoids (a related group of animals), but these are present only as fragments, no ancient reef being preserved there. The strata exposed, therefore, consist of the debris derived from the reef that has been spread out on the surrounding sea floor, so may be said to represent a coral-stromatoporoid biostrome. The bioherm or reef, if still preserved, must be at depth in the rock beneath the surface, but it may have been eroded away.

The limestone is of good quality because it consists almost entirely of fragments of the calcium carbonate skeletons of marine organisms. Crinoid (sea lily) remains are very common.

As on the present day Great Barrier Reef, gasteropods are common. These include the high-spired *Cyclonema* and *Gyrodoma*, the flat-coiled *Euomphalus*, the Chinese-hat shaped *Scalaetrochus*, and the trumpet-like *Tremanotus*. There are some eighteen genera in all, and many species. The lamellibranchs are few in numbers and kinds; only some five genera are represented. Brachiopods, trilobites, and polyzoa are infrequently found, but (strange to say) no fish. Experts in fossil fish have examined the Lilydale limestone many times but not found any fish although they are common overseas in much earlier strata.

From the foregoing evidence, one may visualize warm clear waters such as occur off the Queensland coast at the present time, with a reef consisting of massive and branching corals along with masses of stromatoporoids and algae (*Girvanella*). Debris of all sizes from the reef formed a white spread over the surrounding sea floor. Thus masses of dead coral and other reef organisms along with the shells (especially of gasteropods) collected and consolidated ultimately to form the limestone strata seen at Lilydale.

Ordovician Graptolites

The Ordovician sedimentary rocks of Victoria are of great stratigraphical thickness, and generally of fine grain size, having been laid down in the sinking trough of the Tasman Geosyncline. These rocks were widely intruded by gold-bearing ores, and for this reason were of great economic importance, having much to do with the establishment of the State. The gold was often associated with the close folds of the bedrock, and so the effort was made to understand the structures of the Ordovician strata. Besides being of biological interest and use, fossils are of great economic value as tags for following strata associated with valuable minerals. The graptolites were the fossils used in Victoria (as elsewhere) for unravelling the complex structures of the Ordovician rocks (Plate 8).

Graptolite means writing on stone, and the graptolites as they commonly occur look very much as if marks had been drawn on the slabs of rock. When originally discovered, graptolites were confused with plant remains, and although the famous naturalist Linnaeus named them *graptolithus*, he thought they were inorganic. The whole group has been extinct since Palaeozoic times, and so there are no living forms with which they can be directly compared. However, Wahlenburg in 1812 recognized the true animal nature of graptolites.

Most graptolites have serrated edges which are actually series of cups (thecae) each of which originally carried an animal. *Monograptus* had one series, while some forms had a series on each side of the branch or stipe, and *Phyllograptus* was quadriserial. The whole colony (rhabdosome) was supported at one point by a thread, the nema. The first cup at the end of the nema is the sicula. Graptolites appear to be related to hydroids, since they possess a chitinous tubular skeleton. Also they have similarities to the pterobranchs. Graptolites are not far removed from the vertebrates (Chordata) in certain essentials of organization, and so are generally classified with the Protochordata, but their precise relationships have yet to be proved. The preservation of considerable detail of the graptolite skeleton is due to their possession of a chitinous exoskeleton. Some forms were sessile, but a great number were floating (planktonic) or perhaps attached to floating seaweed as marine organisms are found today associated with the masses of seaweed in the Sargasso Sea. Their very light weight would suit such an ecology. If graptolites were attached to floating seaweed, the nema would be the organ of attachment, and indeed it is difficult otherwise to find a use for it. The nema was certainly not strong enough, if stuck in the mud of the sea floor, to support the colony erect, as was once suggested. The most convincing explanation is that the rhabdosome hung pendant by the nema from floating seaweed.

The presumed planktonic nature of graptolites would explain their very wide distribution round the world, and the fact that they are found in so many different kinds of rock. If they floated at the surface, then sank later to the sea floor, it would not be surprising to find them, as we do, in the muds of deep water facies, in the sandstones of near shore facies, and in the limestones originating from a lime mud facies. The planktonic habitat would also account for the fact that graptolites may occur on the face of only a single stratum in a considerable thickness of rock. Thus when *Monograptus* was found in a piece of ornamental stone from a quarry at Warrandyte, it took a day's intensive work to discover the stratum in the quarry whence they came, although the quarry was a small one.

Because the same species of graptolite may be found in Australia, North America, and Europe, these fossils are among the best for intercontinental correlation. Victoria possesses one of the best series of Ordovician and Silurian graptolites in the world, if not the best. In the great trough of the Tasman Geosyncline, sedimentation was virtually continuous and comparatively rapid, so that an unbroken and full series of graptolite forms is preserved in the great thickness of strata deposited.

With the help of graptolites, palaeontologists have divided the series of Ordovician graptolites into nine stages in Victoria, viz., Lancefieldian (oldest), Bendigonian, Chewtonian, Castlemainian, Yapeenian, Darriwillian, Gisbornian, Eastonian, and Bolindian. These stages can be further subdivided into zones according to the species present, e.g., the Darriwillian can be divided into four zones. It is a study of both great biological interest and stratigraphic usefulness to follow the waxing and waning of the main faunas. Thus the Anisograptid Fauna is found in the Lancefieldian, the Dichograptid Fauna in the Bendigonian to Gisbornian, the Isograptid Fauna from the Castlemainian to the Darriwillian, the Diplograptid Fauna from the Darriwillian to the Keilorian (Lower Silurian), and the Leptograptid Fauna from the Gisbornian to Bolindian.

The rate of evolution of the graptolites can be judged from the fact that the Lower Ordovician (in the sense of Arenigian) can be divided into thirteen zones, but probably covers not more than 10 to 12 million years, which would be about a million years (the length of the Quaternary) for each zone. This is rapid evolution, and even if the period of time were twice the above estimate, the rate of evolution is still fairly fast. The quickness of change in the forms and their widespread occurrence in the world makes the graptolites among the most useful of fossils for the stratigrapher.

Besides graptolites, the Ordovician rocks of Victoria have yielded arthropods (Trilobita, Phyllocarida), echinoderms, corals, polyzoa, cephalopods, brachiopods, hydroids, sponges, and worms.

Cambrian Trilobites

Just as graptolites in the Ordovician Period were a biologically dominant and stratigraphically useful group of animals, so the trilobites were in the Cambrian. Both groups were entirely extinct by the end of the Palaeozoic Era. In tracing fossils back in time it may be noted first that certain species became extinct, and then certain genera, followed by families. Now in the Cambrian we find whole Classes of animals that have been extinct for some 250 mill. years. These facts reflect the continuously changing pattern of life on the earth.

Trilobites are marine arthropods (literally, jointed-limb animals) so called because they possessed in varying degree two longitudinal furrows that divided their carapaces into three parts, a central axial lobe with a pleural lobe on each side. These animals were also divided into three by formation of head (cephalon), thorax, and tail (pygidium). The body was generally flattened, as in a slater, with eyes on the dorsal surface of the cephalon. The exoskeleton or carapace was of calcium phosphate. The thorax consists of numerous free segments that enabled some trilobites to roll up like slaters, no doubt as a protection for the softer ventral surface. The cephalon does not at first appear to be segmented, but upon analysis it can be shown to be formed by the fusion of six segments. Segments of variable number are fused to form the pygidium.

The mouth was on the underside of the head. There were paired limbs under each segment of the thorax and pygidium consisting largely of walking (or swimming) legs and gills, while those under the cephalon were specialized for feeding. Like the lobster, and other animals with an exoskeleton, the trilobites had to shed their shells when they outgrew them. To facilitate this, there were sutures that divided the dorsal side of the cephalon into three. The carapace split along these lines, and the creature crawled out. The new skin underneath then hardened into a carapace. That each animal had a number of carapaces in its lifetime helps to explain the greater number of trilobite remains found in some Cambrian beds.

The many and varied changes on the basic trilobite pattern that resulted from adaptation to many environments are of great interest to the biologist and of considerable value to the stratigrapher. Trilobites explored many ecologies. There were blind, mud-digging forms, others that scoured the sea-floor, some that swam, and yet others that lived with the plankton, being of very light weight and fitted with long spines to help support them, and eyes on stalks to improve vision.

Cambrian strata are well developed in the Mount William–Heathcote–Colbinabbin belt, whence trilobites were described as far back as 1896. The " *Dinesus* Band " includes *Dinesus ida*, *Kootenia fergusoni*, *Centropleura neglecta*, *Peronopsis* sp. and " *Amphoton* " sp., while another trilobite horizon known as the " *Amphoton* Band " includes *Nepea narinosa*, *Peronopsis* cf. *normata*, *Dinesus* sp., *Solenoparia* sp., *Dorypyge* sp., " *Amphoton* " sp., and *Fuchouia* sp. Some of the black shales near Monegeeta contain a rich fauna of some seventeen species of " hydroids " including *Archaeolafoea longicornis* and *Mastigograptus tenuiramosus*. The brachiopod *Acrotreta antipodum* is also present.

The Barkly River–Jamieson River and the Mount Wellington–Howqua River belts constitute the main outcrops of Cambrian strata in eastern Victoria. The best known formation is the Dolodrook Limestone which contains more than a dozen species of trilobites including *Ptychagnostus australiensis*, *Pseudagnostus vastulus*, *Crepicephalus etheridgei*, *Thielaspis thielei*, and *T. minima*. Brachiopods, gasteropods, and marine algae complete the fauna as at present known. The trilobite faunas from Victoria so far mentioned are all of Middle Cambrian age, but at Waratah Bay near Wilson's Promontory the Digger Island Limestone carries a Tremadocian trilobite fauna. Some include this stage in the Upper Cambrian and some put it in the Lower Ordovician.

Pre-Cambrian Fossils

There are no rocks proved to be of greater age than Cambrian in Victoria, although such rocks are common in Australia. However, to complete the story it should be stated that of recent years many evidences of life going back far beyond the 500–600 mill. years of the beginning of the Cambrian have been found. Such information as exists indicates that the fauna of that time was without hard parts and this accounts for the apparent sudden burst of fossils at the beginning of the Cambrian, for it was then that hard skeletons for marine animals became common.

Explanation of Plates*

Unless otherwise stated, the figures are the same size or nearly so. The photographs were mostly taken by the Department of Photography, Royal Melbourne Institute of Technology (Mr. Frank Guy), but Plate 3, Figures 2–7, was taken by Dr. Suzanne Duigan; Plate 3, Figure 1, by Mr. E. Faisst; Plate 3, Figure 9, by the State Electricity Commission; while Plate 6, Figures 4–6, 8, and Plate 7, Figures 4–5, were taken by Dr. J. A. Talent. In the following descriptions V. = Victoria.

PLATE 1.—QUATERNARY VERTEBRATES

Fig. 1. Large marsupial called "The Marsupial Lion", but perhaps was a sloth-like animal. Premolar tooth of *Thylacoleo carnifex* Owen, extinct. From cave just south of East Buchan State School, Gippsland, V. Quaternary.

Fig. 2. Part of head of large echidna with long curved snout, now confined to New Guinea. *Zaglossus* sp. from limestone cave in Section 22, Parish of Kaladbro, near Strathdownie, western Victoria. Palatal view. Pleistocene.

Fig. 3. Skull of snapper, *Chrysophrys auratus,* found during excavation of Cole's Dock at 14 feet from the surface, Port of Melbourne, V. Holocene.

PLATE 2.—TERTIARY MARINE FOSSILS

Fig. 1. A foraminifer, *Victoriella plecte* (Chapman), type specimen, from between 24 and 25 feet in the 1912 Bird Rock bore at Torquay, V. Diameter 2·25 mm. Oligocene.

Fig. 2. A cephalopod, *Nautilus felix* Chapman, from Happy Valley, S.A. Type specimen.

Fig. 3. An echinoid, *Schizaster sphenoides* Hall, type specimen from cliffs at the mouth of the Sherbrooke River, east of Port Campbell, V. Upper Miocene.

Fig. 4. A lamellibranch, *Spondylus pseudoradulus* McCoy, from marl bed at Drier's, bank of Mitchell River, Gippsland, V. Miocene.

Fig. 5. Giant shark the size of a modern whale, *Carcharodon megalodon,* from the Middle Tertiary of Newmerella, V.

Fig. 6. A gasteropod, *Columbarium acanthostephes* Tate, from the bluish-grey Balcombian siltstone at Fossil Beach, Balcombe Bay, V. Length 6 cm. Middle Miocene.

PLATE 3.—TERTIARY AND MESOZOIC PLANTS

Fig. 1. Typical angiosperm Tertiary leaf, formerly called "Cinnamomum". This specimen is from the Eocene plant beds at Narracan, V.

Fig. 2. Fossil pollen grain from a species of Southern Beech, *Nothofagus emarcida,* from the brown coal mine at Yallourn, V. x 525. Probably Oligocene.

Fig. 3. Pollen grain of another species of Southern Beech, *Nothofagus hetera,* from a bed of brown coal under a marine bed at Balcombe Bay, V. x 525. Probably Oligocene.

Fig. 4. Pollen grain from a third species of fossil Southern Beech, *Nothofagus falcata,* from the brown coal under a marine bed, brown coal mine, Altona, V. x 525. Probably Oligocene.

Fig. 5. Section through fossil kauri wood, *Agathis resinifera,* showing pits on the radial wall of the tracheid; from Yallourn brown coal mine, Gippsland, V. x 600. Probably Oligocene.

Fig. 6. Cuticle of lower epidermis, showing cells and stomata, from fossil kauri leaf, Yallourn. *Agathis yallournensis.* x 100. Probably Oligocene.

Fig. 7. Transverse section of fossil wood from Yallourn. *Podocarpoxylon australe,* x 100. Probably Oligocene.

Fig. 8. A Mesozoic plant, *Cladophlebis australis,* from siltstone in shore platform on the coast east of Cape Paterson, V. The fossil is a fern, and its age is Lower Cretaceous.

Fig. 9. Log of kauri, *Agathis,* taken from the brown coal mine at Yallourn, V. The scale across the middle of the log is 3 feet long. Probably Oligocene.

* Facing page 18.

Plate 4.—Mesozoic Vertebrates

Fig. 1. Leptolepid fish from Lower Cretaceous siltstone in road cutting at Koonwarra, near Leongatha, South Gippsland, V. 11 cm. long.

Fig. 2. Lungfish tooth seen from above. *Ceratodus avus* Woodward, from rocks exposed in coastal cliff, ¼ mile west of Eagle's Nest, i.e., about 3 miles east of Cape Paterson. Greatest length 25 mm. Lower Cretaceous.

Fig. 3. Same lungfish tooth seen from the side.

Fig. 4. Lungfish scale from depth of 268 feet in bore 2, Parish of Kirrak, South Gippsland, V. Greatest diameter 5·8 cm. Lower Cretaceous.

Fig. 5. Claw (ungual phalange) of a carnivorous dinosaur from Lower Cretaceous arkose (felspathic sandstone) in the coastal cliffs east of Cape Paterson. Same locality and age as Fig. 2.

Plate 5.—Siluro-Devonian Plants and Graptolites

A Middle Palaeozoic plant, *Baragwanathia longifolia.* On the right of the *Baragwanathia* is a piece of a smooth-stemmed plant. On the left are specimens of the graptolite *Monograptus.* The rock is a marine siltstone, and came from the 19-mile quarry on the Yarra Track between Warburton and Woods Point. These rocks have long been thought to be Upper Silurian in age, but evidence is accumulating to suggest they are actually Lower Devonian.

Plate 6.—Silurian and Devonian Marine Invertebrates

Fig. 1. A blind trilobite, *Thomastus jutsoni* (Chapman), from the quarry on the east side of Bulleen-road, ½ mile south of Manningham-road, Templestowe, V. Type specimen. Silurian.

Fig. 2. A trilobite, *Scutellum greenii* (Chapman), complete except for the free cheeks and preglabellar field, from Ruddock's Quarry, north-west of Lilydale, V. Type specimen. Lower Devonian.

Fig. 3. Eye of phacopid trilobite to show the numerous cells. Lilydale district. Lower Devonian.

Fig. 4. Longitudinal section through a rugose coral, *Breviphyllum simplex* Talent, from the Tabberabbera Formation, Kilgower Member, Tabberabbera, V. x 5. Lower Devonian.

Figs. 5–6. A tabulate coral, *Favosites moonbiensis* (Etheridge). Transverse and longitudinal sections x 5. Tabberabbera Formation, Kilgower Member. Lower Devonian.

Fig. 7. Coral, *Mictophyllum cresswelli* (Chapman), from the Lilydale Limestone at Cave Hill quarry, Lilydale. 6·5 cm. long. Lower Devonian.

Fig. 8. Goniatite cephalopod. *Teicherticeras desideratus* (Teichert). x 1·5. Taravale Formation, Buchan. Middle Devonian.

Plate 7.—Palaeozoic Marine Animals

Fig. 1. Silurian Jellyfish, *Paropsonema mirabile* (Chapman), upper surface, from marine siltstone of a brick pit at Brunswick, V. Type specimen.

Fig. 2. Silurian crinoid, *Helicocrinus plumosus* Chapman, from the siltstone of a brick pit at Brunswick, V. Type specimen.

Fig. 3. Brachiopod, *Chonetes robusta* Chapman, showing both valves. From quarry, north of Lilydale, V. Breadth about 2·2 cm. Type specimen.

Figs. 4–5. Lamellibranch, *Actinopteria resplendens* Talent. External and internal moulds of a juvenile specimen, x 8. Kilgower Member of Tabberabbera Formation, Sandy's Creek, Tabberabbera. Lower Devonian.

Plate 8.—Ordovician Graptolite

Loganograptus logani australis (McCoy) from Geological Survey locality Ba 78, Barker-street, Castlemaine. Type specimen. Graphic scale at base of photo.

Geographical Features

Introduction

Australia is situated in middle and lower-middle latitudes, with about two-fifths of its area lying between the Tropic of Capricorn and the Equator. It is, therefore, one of the warm continents and, since most of its area lies within the zone of the dry, sub-tropical anti-cyclones (" the horse latitudes "), it is for the most part a dry continent. Much of the continent has only small variation in temperature from season to season and receives low rainfall with marked concentration into either summer (in the north) or winter (in the south).

Victoria is, in these respects, not typically Australian. It has a cool to cold winter, and although there are hot periods in each summer, they are interspersed with pleasantly warm or even cool periods. Rainfalls are rather low in the northern parts of the State, and particularly in the north-west, but the greater part is well watered with no marked seasonal concentration. Most of Australia is plateau or plain country with little relief; Victoria has a larger proportion of high country in its total area than any other State except Tasmania and its highest mountains reach over 6,000 feet above sea level. Not surprisingly, it could be called the " most English " part of the mainland, although a closer climatic and agricultural analogy is probably south-western and south-central France. Victoria is in fact transitional between the sub-tropical situation of New South Wales and the temperate situation of Tasmania, between the high rainfall character of the south-eastern Australian coastlands and the arid interior. One finds, then, year-round, open-air dairying and livestock-and-grass farming in Gippsland and the Western District, and dry-farming of grains and irrigated horticulture of citrus fruits and vineyards in the north. Its climatic conditions made no difficulties for the establishment of secondary industry and, once its power resource problem had been solved, Victoria reaped the advantages in interstate trade offered by its central position on coastal shipping routes.

Victoria has 2·96 per cent. of the area of Australia (mainland Australia and Tasmania, but not including external territories) and had 27·99 per cent. of the Australian population at 30th June, 1963. In relating population to area, Victoria is the most densely populated of the States with an average density at 30th June, 1963, of 34·77 persons per square mile and is exceeded only by the Australian Capital Territory (78·22 per square mile).

The Victorian population is growing rapidly; comparing the enumerated population of the Census of 30th June, 1954, with the estimate of 30th June, 1963, the population of Victoria increased by

24·60 per cent., being exceeded by South Australia (26·58 per cent.), the Australian Capital Territory (142·30 per cent.), and the Northern Territory.

The distribution of population over the State, however, is very uneven. At 30th June, 1963, it is estimated that 65·55 per cent. of the total population of the State was living in the Melbourne Metropolitan Area, a larger concentration of population in the metropolis than was to be found in any other State of the Commonwealth. On the other hand, there are considerable areas of Victoria which are uninhabited or have only a very sparse and seasonal population; these areas are mainly in the Eastern Highlands and in the western and north-western parts of the State along the South Australian border, as in the Mallee, where sandy soils and low, unreliable rainfalls inhibit agriculture. The non-metropolitan population is fairly evenly divided between the rural population (15 per cent. of the State's total in 1961) and the urban centres other than Melbourne (20 per cent. of the total in 1961). Both percentages refer to the Census of 1961.

In the rural areas, population is densest in the irrigation areas, in the dairying areas of Gippsland and the Western District, and in the livestock-and-crop farming areas between Ballarat and Bendigo. Lower densities are found in the wheat-farming areas of the Wimmera, and still lower densities in the wheat areas of the Mallee and in the stock-raising areas generally.

Among the non-metropolitan cities four large centres stand out: these are Geelong (estimated population at 30th June, 1963, 96,510), Ballarat (56,550), and Bendigo (41,610), each of which has a variety of manufacturing industries as well as being marketing and transport centres, and the Latrobe Valley group of towns which together contain about 52,000 people and are mainly concerned with power generation and distribution. The next group, in order of population size, has between 12,000 and 16,000 people each and contains, in addition to the normal urban retail and service functions, fairly large-scale industries processing local products: Warrnambool (dairy products, textiles and clothing), Shepparton (fruit canneries), Wangaratta (a rather special case of decentralized industries), and Mildura (fruit and vegetable packing). Next, there are a number of regional urban centres of between 7,000 and 10,000 people in which retail and service functions predominate; for instance, Hamilton, Colac, Horsham, Benalla, Ararat, Sale, Wodonga, Bairnsdale, Maryborough, and Castlemaine. Smaller towns serve more restricted areas and more local requirements.

Although European settlement in Victoria is little over one and a quarter centuries old, there have already developed distinctive regional characteristics in the various parts of the State, and most of these are recognized in popular speech by regional names. The Mallee is the north-western plain of ancient sand ridges, once waterless and covered with the distinctive dwarf eucalypt from which the name is derived, but now with extensive wheat fields and sheep paddocks and with water for stock and domestic purposes supplied through winding channels from storages outside the region. The Wimmera, with red-brown soils and tall eucalypts, with a denser pattern of farms and market towns, has the highest yielding wheat fields in Australia and a considerable sheep and cattle population as well. The Western District, with lush pastures on its well-watered volcanic plains, has both a long tradition of the growing of fine wools on sheep stations dating back to the early days of the pastoral expansion and a much more recent development of intensive dairying. The north-east has irrigated citrus and stonefruit orchards, market gardens, and pastures on the plains of the middle Murray and its tributaries, which give way to cattle stations upstream where the valleys run back into the rugged slopes of the Australian Alps. Gippsland spells dairying and fodder-crop growing, timber extraction in the tall forests of the hills, off-shore and coastal fishing, and the industrial enterprises based on the power derived from the Morwell–Yallourn brown coal deposits in the Latrobe Valley. The Port Phillip Bay region holds Melbourne, the financial and administrative hub of the State and a fast growing port, metropolitan market, and industrial centre, while on the eastern shore commuters' and holiday homes stretch through the Mornington Peninsula to the ocean shores. On the west, secondary industry is extending through Williamstown and Altona to Geelong.

Area and Boundaries

Victoria is situated at the south-eastern extremity of the Australian continent, of which it occupies about a thirty-fourth part, and contains about 87,884 square miles, or 56,245,760 acres.

Victoria is bounded on the north and north-east by New South Wales, from which it is separated by the River Murray, and by a straight line running in a south-easterly direction from a place near the head-waters of that stream, called The Springs, on Forest Hill, to Cape Howe. The total length of this boundary, following the windings of the River Murray from the South Australian border along the Victorian bank to the Indi River, thence by the Indi or River Murray to Forest Hill and thence by the straight line from Forest Hill to Cape Howe, is 1,175 miles. The length of the River Murray forming part of the boundary is approximately 1,200 miles, and of the straight line from Forest Hill to Cape Howe, 110 miles. On the west it is bounded by South Australia, on the south and south-east its shores are washed by the Southern Ocean, Bass Strait, and the Pacific Ocean. It lies approximately between the 34th and 39th parallels of south latitude and the 141st and 150th meridians of east longitude. Its greatest length from east to west is about 493 miles, its greatest breadth about 290 miles, and its extent of coastline 980 miles, including the length around Port Phillip Bay 164 miles, Western Port 90 miles, and Corner Inlet 50 miles. Great Britain, inclusive of the Isle of Man and the Channel Islands, contains 88,119 square miles, and is therefore slightly larger than Victoria.

The most southerly point of Wilson's Promontory, in latitude 39 deg. 8 min. S., longitude 146 deg. 22½ min. E., is the southernmost point of Victoria and likewise of the Australian continent; the northernmost point is where the western boundary of the State meets the Murray, latitude 34 deg. 2 min. S., longitude 140 deg. 58 min. E.; the point furthest east is Cape Howe, situated in latitude 37 deg. 31 min. S., longitude 149 deg. 59 min. E. The westerly boundary lies upon the meridian 140 deg. 58 min. E., and extends from latitude 34 deg. 2 min. S. to latitude 38 deg. 4 min. S.—a distance of 280 miles.

The following table shows the area of Victoria in relation to that of Australia :—

AREA OF AUSTRALIAN STATES

State or Territory	Area	Per Cent. of Total Area
	sq. miles	
Western Australia	975,920	32·85
Queensland	667,000	22·45
Northern Territory	523,620	17·62
South Australia	380,070	12·79
New South Wales	309,433	10·42
Victoria	**87,884**	**2·96**
Tasmania	26,215	0·88
Australian Capital Territory	939	0·03
Total Australia	2,971,081	100·00

Mountain Regions

The mountainous regions of Victoria comprise the Central Highlands and a belt known as the Southern Uplands lying to the south and separated from the Central Highlands by plains.

The Central Highlands form the backbone of Victoria, tapering from a broad and high mountainous belt in the east until they disappear near the South Australian border. In the eastern sector patches of Older Volcanic rocks occur and peaks rise more than 6,000 feet, while in the western sector the volcanic rocks belong mainly to the Newer Volcanic Series and the peaks reach 3,000 feet.

The Highlands descend to plains on their southern and northern flanks. On the south are the Western District Plains and the Gippsland Plains, and beyond these again rises a group of uplifted blocks constituting the Southern Uplands. The Otway Ranges and the hills of South Gippsland are composed of fresh-water Mesozoic sediments and Tertiary sands and clays with Older Volcanic rocks in South Gippsland, and the Mornington Peninsula is an upraised fault block of complex geology, including granites.

By 1875 the mountainous areas of the State were embraced by a geodetic survey which had been started in 1856. This was the first major survey, although isolated surveys had been carried out as early as 1844. Further surveys were carried out by the Australian Survey Corps during the Second World War, and by the Department of Lands and Survey, in the post-war years. Most recent values for some of the highest mountains in Victoria are Mount Bogong, 6,516 feet; Mount Feathertop, 6,307 feet; Mount Nelse, 6,181 feet; Mount Fainter, 6,157 feet; Mount Loch, 6,152 feet; Mount Hotham, 6,101 feet; Mount Niggerhead, 6,048 feet; Mount McKay, 6,045 feet; Mount Cobboras, 6,030 feet; Mount Cope, 6,026 feet; Mount Spion Kopje, 6,025 feet; and Mount Buller, 5,919 feet.

FURTHER REFERENCE

Year Book 1962 (*43–67*).

Coastline

The Victorian ocean coastline stretches some 682 statute miles from the South Australian border to the New South Wales border. Small stations of whalers and sealers were operating along the coast, mainly at Westernport, Portland, and Wilson's Promontory long before the advent of Henty and Batman.

The coastline is now well served with lighthouses*, though in the early days it proved hazardous to navigation and no fewer than six ships were wrecked at Port Fairy before 1850. Port Phillip Bay is a safe harbour for shipping and the cities of Geelong and Williamstown afford excellent facilities.

The main features of the coastline are as follows :—

Nelson to Cape Bridgewater	Sandy beach backed by dunes.
Cape Bridgewater to west end of Portland Bay	Cliffs of basalt tuff dune limestone and Miocene limestone.
Portland Bay to Port Fairy	Sandy beach backed by dunes with low cliffs of basalt and dune limestone near Port Fairy.

* See Victorian Year Book 1964 (*816–821*).

Port Fairy to Warrnambool	Beach dunes and dune limestone.
Warrnambool to Childers Cove	Cliffs of dune limestone.
Childers Cove to Point Ronald	Bold cliffs of Tertiary limestone.
Point Ronald to Cape Volney	Cliffs of lower Tertiary sandstone and dune limestone.
Cape Volney to Castle Cove	Bold cliffs of Mesozoic sandstone.
Castle Cove to Point Flinders	Bold cliffs of dune limestone.
Point Flinders to north of Lorne (Eastern View)	Cliffs of Mesozoic sandstone.
Eastern View to Torquay	Cliffs of Tertiary sandstone and limestone interspersed with bays and sandy beaches.
Torquay to Cape Schanck	Sandy beach backed by dunes with intermittent low cliffs of dune limestone.
Cape Schanck to Nobbies	Bold cliffs of basalt.
South coast of Phillip Island	Sandy beaches backed by dunes with granite at Pyramid Rock and Cape Woolamai.
Cape Woolamai to Anderson's Inlet	Cliffs of Mesozoic sandstone.
Anderson's Inlet to Cape Liptrap	Sandy beach backed by dunes with low cliffs of dune limestone at south end.
Cape Liptrap Promontory	Cliffs of lower Palaeozoic sediments and diabase.
Waratah Bay as far east as Tongue Point	Sandy beach backed by dunes.
Tongue Point to Mount Hunter	Granite headlands interspersed with bays with sandy beaches backed by dunes.
Mount Hunter to Conran	Sandy beach backed by dunes with lagoons behind dunes.
Cape Conran (granite) to Cape Howe	Granite headlands with beaches between them and some local cliffs of metamorphosed lower Palaeozoic sediments at Cape Everard, Little Ram Head, and near Mallacoota.

The area of Port Phillip Bay is 762 square miles and the coastline of the bay stretches for some 164 statute miles.

Rivers

Length

The characteristics of rivers which relate to land are fixed, whereas those relating to water are variable. The land or geographic features include :—

(1) The length, and

(2) the catchment.

The following table shows the main river basins of Victoria and flows of the main streams :—

VICTORIA—SCHEDULE OF FLOWS OF MAIN STREAMS

Basin No. *	Stream	Site of Gauging Station	Catchment Area (Square Miles)	Year Gauged from	Annual Flows in 1,000 Ac. Ft.			
					Mean	No. of Years	Max.	Min.
1	Murray ..	Jingellic	2,520	1890	1,974	71	4,978	549
2	Mitta	Tallandoon ..	1,840	1886	1,138	75	3,460	203
3	Kiewa	Kiewa	450	1886	527	75	1,684	146
4	Ovens	Wangaratta ..	2,100	1887	1,229	74	3,991	141
5	Broken ..	Goorambat ..	740	1887	208	74	886	15·3
6	Goulburn ..	Murchison ..	4,140	1882	2,385	79	6,139	516
7	Campaspe ..	Elmore	1,240	1886	194	75	667	0·6
8	Loddon ..	Laanecoorie ..	1,613	1891	207	70	659	8·9
9	Avoca ..	Coonooer ..	1,000	1890	62	71	321	3·8
11	Wimmera ..	Horsham ..	1,570	1889	106	72	479	0
12	Glenelg ..	Balmoral ..	606	1889 (a)	117	60	439	2·5
14	Hopkins ..	Wickliffe ..	460	1921 (b)	27	29	102	1·3
15	Carlisle ..	Carlisle	30	1930 (c)	37	26	89	14·8
17	Barwon ..	Winchelsea ..	369	1922 (d)	116	28	412	25
18	Moorarbool ..	Batesford ..	434	1908 (e)	57	16	147	2·5
19	Werribee ..	Melton	446	1917 (f)	64	43	190	5·3
20	Maribyrnong ..	Keilor	264	1908 (g)	92	30	265	3
21	Yarra	Warrandyte ..	899	1892	726	41	1,215	334
22	Bunyip ..	Bunyip	268	1908 (h)	124	47	247	55·7
24	Latrobe ..	Rosedale ..	1,604	1901 (i)	788	42	2,633	361
25	Thomson ..	Cowwarr ..	421	1891	335	68	1,050	142
25	Macalister ..	Glenmaggie ..	730	1919	478	42	1,277	181
26	Mitchell ..	Glenaladale ..	1,530	1938	814	23	1,779	368
27	Tambo ..	Bruthen	1,030	1906 (j)	179	29	575	50
28	Snowy ..	Jarrahmond ..	5,100	1907	1,682	42	3,254	766

Note	Years Excluded in Estimating Mean	Note	Years Excluded in Estimating Mean
(a)	1933–34 to 1938–39	(f)	1952–53
(b)	1933–34 „ 1943–44	(g)	1933–34 to 1955–56
(c)	1943–44 „ 1946–47	(h)	1951–52
(d)	1933–34 „ 1943–44	(i)	1919–20 „ 1936–37
(e)	1921–22 „ 1945–46	(j)	1924–25 „ 1937–38

* 10 Mallee Basin, no rivers.
23 South Gippsland Basin } Short term records only. These are not suitable for inclusion in
29 East Gippsland Basin } the table.

A table showing the lengths of streams and rivers will be found on pages 31 to 35 of the 1963 Victorian Year Book.

Catchments

Another useful characteristic of streams is their " catchment " which may be defined as the area from which there is run-off to the stream. Catchments may be regarded as the hydrologically effective part of a " basin ". Thus, the whole of any area may be subdivided into basins, but part of some basins may be regarded as non-effective, being either too flat or the rainfall too small to contribute to normal stream flows. There is little or no contribution in the north-west of the State where the annual rainfall is less than 18 ins. to 20 ins. Above this amount, roughly half the rainfall appears as stream flow.

Figure 2 shows the 29 basins into which Victoria has been divided by the State Rivers and Water Supply Commission for hydrologic purposes.

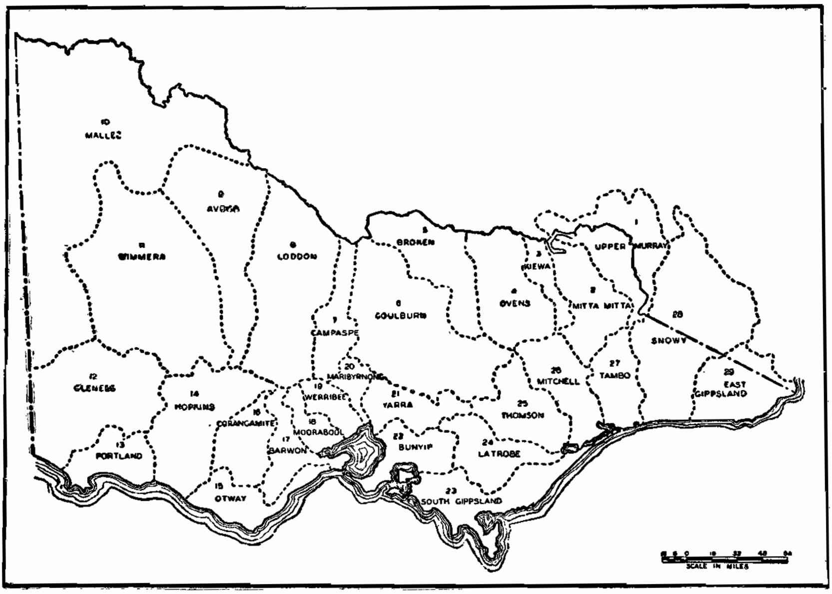


FIGURE 2.—Victoria's water resources showing key plan to river basins.

Total Flow

The current estimate of mean annual flow is 17 million acre ft. per annum, about half of which flows into the Murray; the other half flowing southward to the Victorian coast. The geographic distribution of flow is heavily weighted towards the eastern half where the total flow is about 14 million acre ft. (with about 8 million acre ft. in the north-east and 6 million acre ft. in the south-east) and hence leaving 3 million acre ft. in the western half.

Location of Streams

The location of about 2,500 streams in Victoria may be obtained by referring to the " Alphabetical Index of Victorian Streams " compiled by the State Rivers and Water Supply Commission in 1960. Owing to the replication of names for some streams there are over 2,900 names; these have been obtained by examining Department of Lands and Survey, and Commonwealth Military Forces maps, so as to include names which have appeared on them. There are, in addition, many unnamed streams, those with locally known names, and those named on other maps or plans. No attempt was made in the Index to suggest a preferred name, as it was considered that further legislation is necessary before any such action can be made effective.

STREAM RESERVES, FLOWS, FLOODS, AND DROUGHTS

Year Book 1964 (*18–19*).

Lakes

Introduction

Apart from recreational aspects, lakes have a utilitarian value; and this article is mainly concerned with the questions of lake utilization. The scientific study of lakes is called limnology.

Lakes may be classified into two major groups—those without natural outlets which are called "closed" lakes such as Lake Corangamite, and those such as Lake Hindmarsh with a natural overflow-channel (Outlet Creek) which by analogy may be termed "open" lakes. For closed lakes to form, annual evaporation must exceed the rainfall, otherwise they would overflow. This applies to most of Victoria where the potential evaporation ranges from about 30 inches to 60 inches, whereas the average rainfall over the State is only about 25 inches.

There are few mountain lakes in Victoria, although Lake Tali Karng, created by a landslide in rather inaccessible country near Mt. Wellington in Gippsland, is known to enthusiastic hikers. Another lake formed by a landslide in 1952, on the East Barwon River in the Otway Ranges, had a short life, for in the following year it washed out and released 4,000 acre ft. of water, thus causing damage downstream.

Early Discoveries

Lake Corangamite, the largest inland lake in Victoria situated in the volcanic area of the south western district was known by the aborigines as Kronimite, meaning bitter, no doubt because of the salty or brackish nature of the water. On early surveys of this area the lake became known as Korangamite and later the "C" was substituted for the "K". The first pastoralists to take up land on the shores of the lake were the Manifold brothers who took advantage of the rich pasture in the volcanic area before 1843.

The shores of Lake Colac once constituted the hunting grounds of a tribe of natives who through constant warring with neighbours were reduced in numbers to forty by 1837. At that time the lake had become almost dry according to Captain Foster Fyans, Crown Lands Commissioner, but by 1852 it had mysteriously filled again and its waters overflowed their banks. The native name for this lake was "Kolak" meaning "sand", possibly because of the high bank of sand along the shores where the Botanic Gardens are now laid out. The first pastoralist to settle on the shores of Lake Colac was Hugh Murray in 1839.

Messrs. T. L. and S. L. Learmonth, with four others, settled in the Ballarat district in 1837. One member of the party by the name of Yuille occupied the site of Ballarat East and West. On his run was a swamp known as "Yuille's Swamp" and the district by the native name of "Wendaaree", meaning "be off" or "off you go". Later "Yuille's Swamp" was filled and became Lake Wendouree.

Lake Victoria was discovered by an exploring party led by Angus McMillan in December, 1839, and named after Queen Victoria who was on the eve of her marriage at that time. A day or so after, the party reached a fresh water lake which McMillan took to be part of

Lake Victoria. It was subsequently called Lake Wellington. Later in 1840, Strzelecki followed in the tracks of McMillan to the head of Lake Victoria and re-named it Lake King after Captain Phillip Parker King. The latter name has been retained and the former given to the stretch of water between Lake Wellington and Lake King.

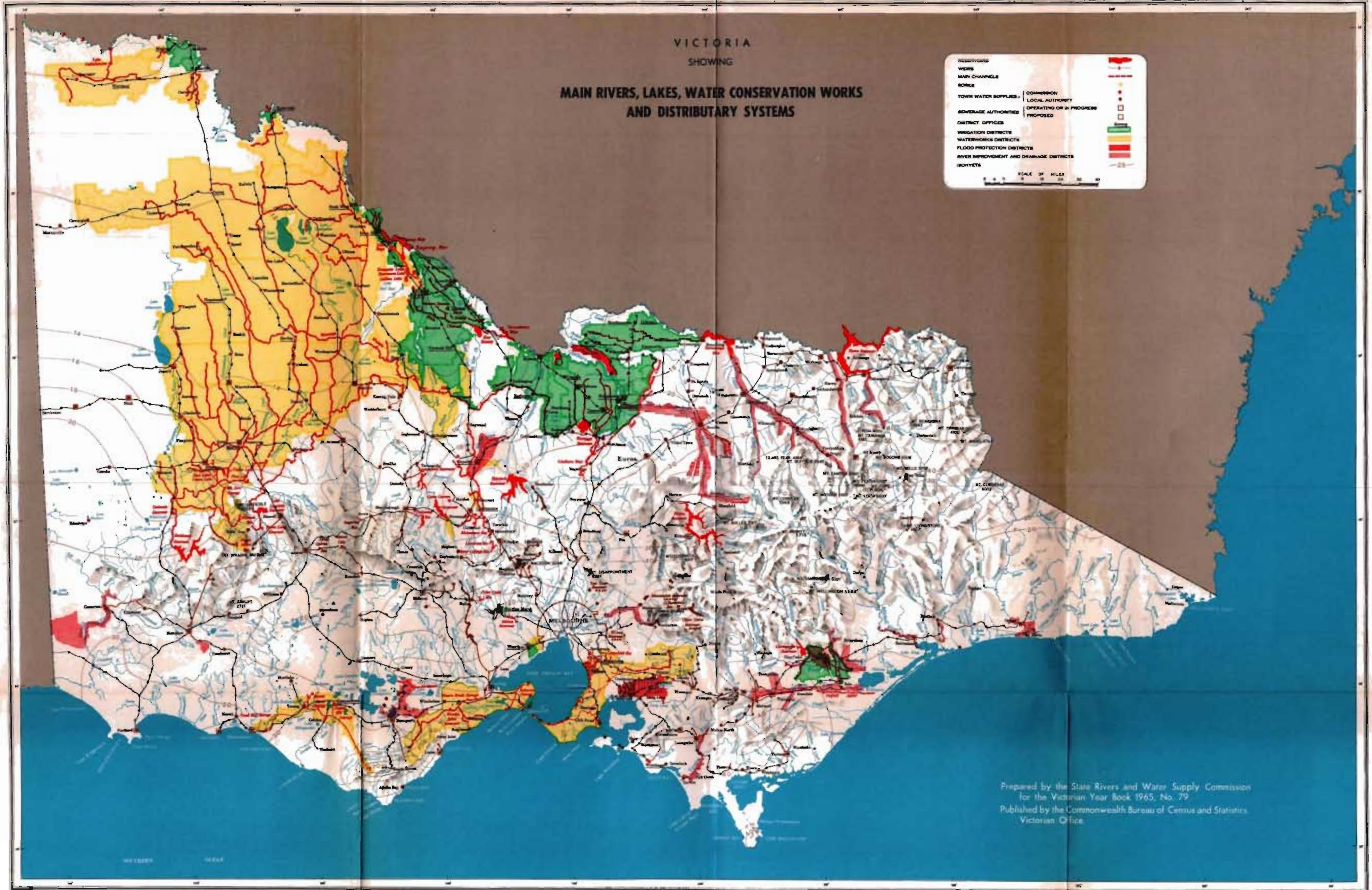
Physiography

Certain physiographic conditions are necessary for lakes to form. These occur mainly in the flat western part of the State where most of Victoria's lakes are situated (see map). The number of closed lakes tends to increase with increasing aridity, measured by the excess of evaporation over rainfall ; hence, if aridity is too high, the lakes tend to dry up, forming " dry lakes " or " playas " which rarely carry water. Closed lakes which do not become dry fluctuate in capacity much more than open lakes, reflecting the net cumulative effect of run-off into the lake and the evaporation from its surface. In Victoria there is little permanent run-off in areas where the average rainfall is less than about 18 inches, the amount which applies to about one-third of the State. However, many rivers in the north-west rise in higher rainfall areas and carry their flows into other areas with rainfalls down to about 12 inches. Physiographic conditions in the north-west have resulted in the formation of lakes such as Lakes Tyrell, Hindmarsh, Albacutya, and others at or near the termini of these rivers. Lake Tyrrell, in a rainfall area of only about 12 inches, is normally dry throughout the summer and consequently can be used for salt harvesting. Lakes in the 18 inch rainfall belt, such as Lake Cooper, dry up less frequently. This lake has been dry for about 10 years in the last century and overflows about one year in six.

The level of the water in an open lake is much more stable than that in a closed lake, for as the lake rises the outflow tends to increase, thus " governing " the upper lake level. If these lakes do not dry up, the flow from streams emanating from them or passing through them is partly regulated and hence is less variable than in other streams under similar climatic conditions. As most lakes occur in the western part of Victoria (whereas the major streams are in the eastern part), Victoria does not possess such large lake-regulated streams which are of considerable value for the economic development of water resources. However, there are some small streams of this type in the Western District ; Darlot's Creek is partly regulated by Lake Condah, and Fiery Creek by Lake Bolac. Outflow from this latter lake usually ceases during the summer.

Salinity

In recent years there has been considerable research into the desalinization of water. If an economic process could be developed, salinity would not be the factor which frequently limits the use of lake water. For example, as the Barwon River is used for irrigation during the summer, the extent of artificial diversion of the excess waters of Lake Corangamite into the Barwon River at this time is largely governed by the resulting salinity. However, even the use of


VICTORIA
SHOWING
MAIN RIVERS, LAKES, WATER CONSERVATION WORKS
AND DISTRIBUTARY SYSTEMS
WEIRS
MAIN CHANNELS
TOWN WATER SUPPLIES
COMMISSION
LOCAL AUTHORITY
SEWERAGE AUTHORITIES
OPERATING OR IN PROGRESS
PROPOSED
DISTRICT OFFICES
IRRIGATION DISTRICTS
WATERWORKS DISTRICTS
FLOOD PROTECTION DISTRICTS
RIVER IMPROVEMENT AND DRAINAGE DISTRICTS
ISOHYETS
SCALE OF MILES
MELBOURNE
Prepared by the State Rivers and Water Supply Commission
for the Victorian Year Book 1965, No. 79
Published by the Commonwealth Bureau of Census and Statistics,
Victorian Office

freshwater lakes for water supply purposes is not extensive in Victoria as pumping is often necessary for development and this is usually uneconomic in comparison with gravity schemes.

The average salinity of closed lakes covers a wide range, primarily caused by differences in geological conditions in the catchments from which the lakes derive their water supply. If reference is made to average conditions, then lakes may be termed " fresh ", " brackish ", or " salt ", but as the content and hence the salinity of closed lakes is exceedingly variable, such terms are only relative.

Lake Corangamite

For practical purposes, Victoria's largest lake—Lake Corangamite—can be regarded as a closed lake although during the wet period in the late 1950's it rose 11 ft. to come within 4 ft. of overflowing, carrying at this stage about four times its normal volume. Although it has not overflowed during the recorded history of Australia, there is considerable geological evidence to suggest that it once covered a very much larger area than at present. With more normal inflows and under the influence of increased evaporation caused by the larger surface area, the lake is returning to its normal level, this return being accelerated by a diversion scheme.

The total salt content of Lake Corangamite is of the order of 16 mill. tons, giving, under average water level conditions, a salinity somewhat higher than seawater. As this total volume of salt changes but slowly with time, the salinity when the lake was at its maximum volume was only about a quarter of its average value. Likewise, when the lake falls well below its mean level, the salinity rises proportionately.

As water vapour derived from the evaporation of the lake is less saline than water entering it, there would appear to be a secular tendency for the average salinity of a lake to increase. This suggests that salinity could be used as an indicator of the age of the lake. However, most closed lakes contain less than 5 per cent. dissolved matter, unless they are geologically youthful ; hence it is apparent that salt accumulation must be offset by salt wastage. If lakes become dry, salt which crystallizes on the surface may be blown away. In some cases in Victoria it is actually harvested for manufacturing and other purposes.

Gippsland Lakes

The Gippsland Lakes are a group of coastal lagoons in eastern Victoria, separated from the sea by broad sandy barriers bearing dune topography, and bordered on the ocean shore by the Ninety Mile Beach. They include Lake Wellington (54 square miles), Lake Victoria (43 square miles), Lake King (36 square miles), and a number of smaller lagoons associated with extensive swamps on a low-lying coastal plain. They are shallow, much of Lake Wellington being less than 10 ft. deep, while Lake Victoria and Lake King barely exceed 30 ft.; the deepest points are in McLennan's Strait (36 ft.) which links Lake Wellington to Lake Victoria, and off Metung, where

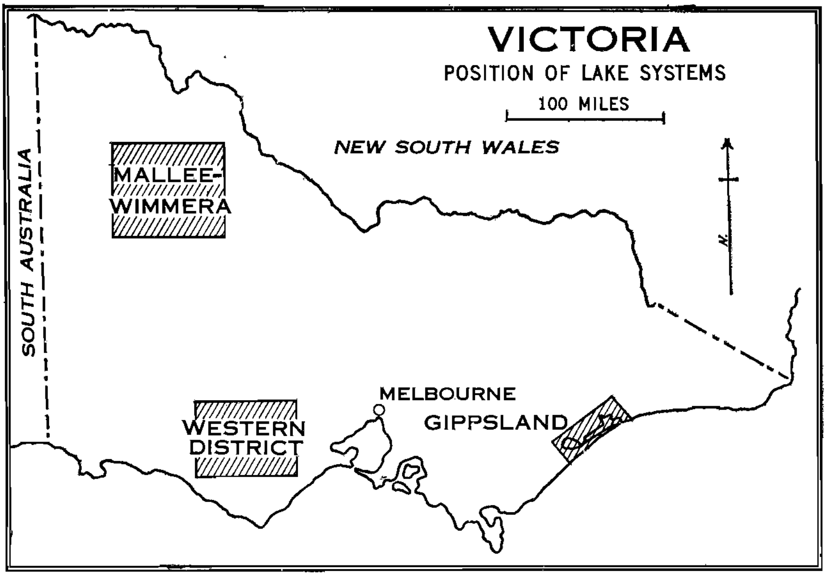


FIGURE 3 (*a*).

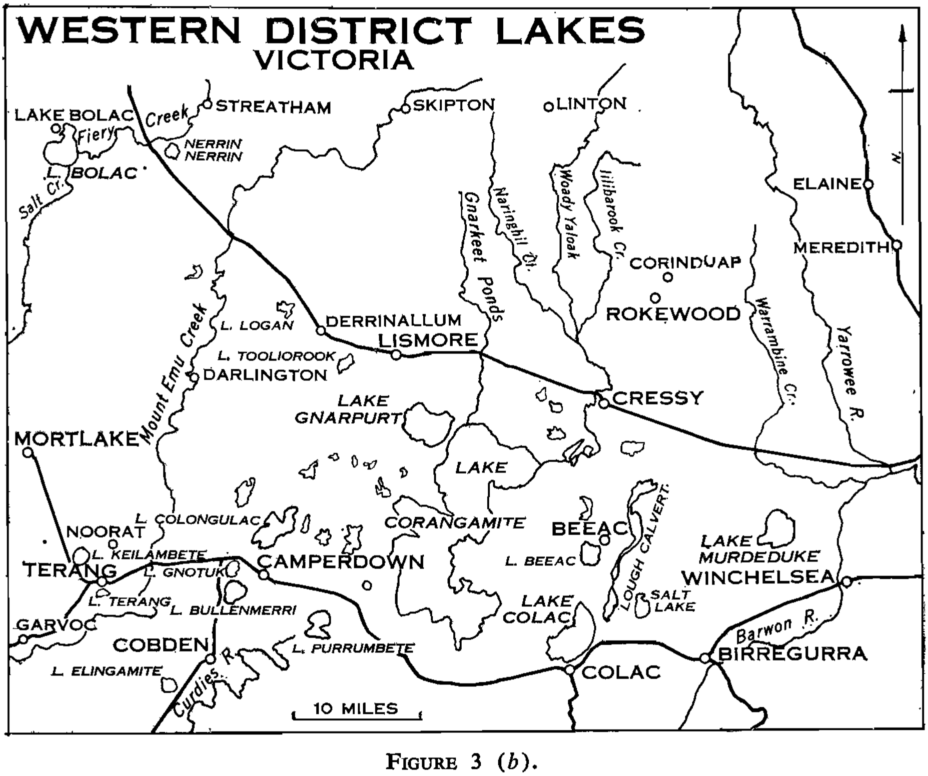


FIGURE 3 (*b*).

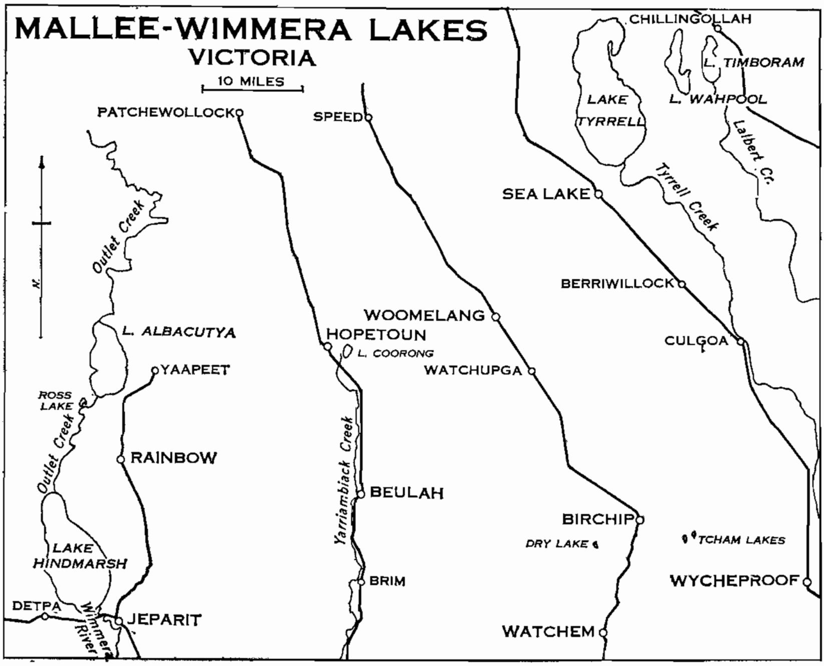


FIGURE 3 (*c*).

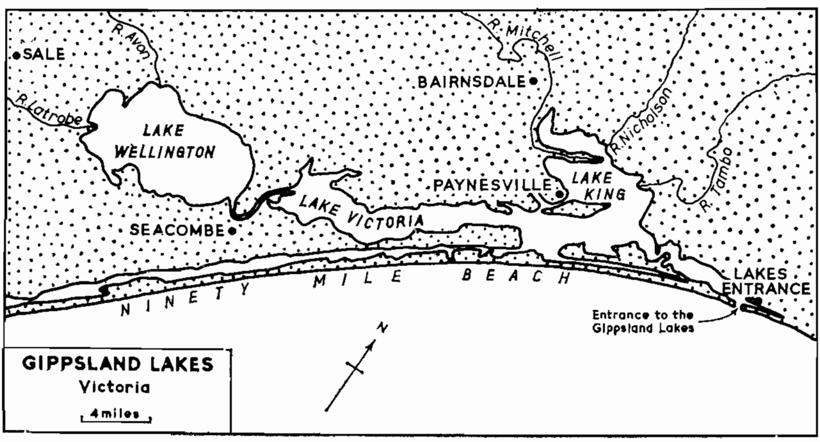


FIGURE 3 (*d*).

a depression 54 ft. deep has been formed by current scour. Rivers flowing into the Gippsland Lakes include the Latrobe and Avon (into Lake Wellington), the Mitchell, Nicholson, and Tambo (into Lake King), and a number of smaller creeks.

The explorer Angus McMillan arrived on the northern shores of the Gippsland Lakes in December, 1839, during one of his journeys across eastern Victoria. Soon afterwards, the first settlers came, mostly by sea from Melbourne, sailing into the Lakes by way of a gap through the coastal dune barrier near Red Bluff, at the eastern end. As this natural entrance was variable in width and depth and sometimes sealed off completely by sand deposition, it was decided that a permanent artificial entrance should be cut through the barrier a few miles to the west. This entrance, opened in 1889, is maintained by tidal scour, but a shallow sand bar offshore limits the size of vessels that can use it, and makes the approach from the sea difficult in rough weather. Nevertheless, the adjacent township of Lakes Entrance has developed as a fishing port and holiday resort, and towns have grown up at Metung and Paynesville on the shore of Lake King. The dune barriers on the seaward side of the Lakes are covered by dense scrub, and include Sperm Whale Head, which has been declared a National Park and Wildlife Reserve.

Mean annual rainfall in the Gippsland Lakes region is 23 to 28 ins., distributed evenly through the year, but annual evaporation is comparatively high (35 to 40 ins.), and during the summer months droughts occur from time to time. Before the artificial entrance was opened, the Lakes were relatively fresh, with reed swamp bordering their shores, but they are now brackish with a seasonal salinity regime ; in winter they may be freshened by river floods, but during the summer months they become more saline as sea water invades them, replacing the fresh water lost by evaporation. As a rule, salinity diminishes from the entrance (30–35 per cent. salt) towards the mouths of rivers where fresh water flows in, and during calm weather a vertical stratification of fresh water over salt water sometimes develops. Reed swamp still borders much of the southern and western shores of Lake Wellington, farthest from the artificial entrance, but around Lake Victoria and Lake King it has been killed by increasing water salinity, and the shores which it formerly protected are suffering erosion.

The deltas built into Lake Wellington by the Latrobe and Avon are still growing, sediment being deposited in reed swamp around the river mouths, but the deltas built into Lake King by the Mitchell and Tambo have lost their former reed fringe, and are being destroyed by wave erosion. The Mitchell had built a remarkable elongated delta, consisting of silt jetties protruding more than four miles into the Lake, but this is now withering and breaking up into islands.

Waves and currents are generated by winds blowing over the surface of the Lakes, particularly by the prevailing westerly winds, which generate strong waves on Lake Wellington and Lake Victoria, driving large quantities of water eastwards through McLennan's Strait. Under these conditions the water level is lowered in Lake Wellington and built up in Lake King, but normal level is restored after the wind dies down, sometimes with a series of oscillations of water level (seiches). Currents are also produced by river floods, and by tides entering and leaving the artificial entrance, where maximum tide range is about 3 ft. Tide range diminishes westwards into the Lakes, and is only a few inches at Metung, seven miles from the entrance.

The shores of the Gippsland Lakes are in part low-lying and swampy, in part bordered by dunes, with sandy shores, and in part backed by steep bluffs. On the northern shores of Lake King and Lake Wellington, low-lying land has been reclaimed for pasture, and some of this, adjacent to the lake shores, is now being eroded by waves. The Lakes have been of value for commercial fishing and private angling, and surveys have been carried out to determine the best means of conserving the fishery, which is thought to have become less productive in recent years. The lakes also attract many tourists.

In terms of the geological time scale; coastal lagoons of this type are ephemeral, rarely persisting for more than a few thousand years. As deposition of sediment proceeds and bordering swamps encroach, the Gippsland Lakes will gradually be converted into a coastal plain, across which the rivers will meander, uniting to pass out to sea somewhere in the Lakes Entrance district.

Conclusion

A number of Victorian lakes and swamps have been converted to reservoirs, their natural capacity usually being increased at the time. Waranga Reservoir is an example of this, as are Fyans Lake, Batyo Catyo, and Lake Whitton in the Wimmera. An example of lake utilization in an irrigation system is on the riverine Murray Plains near Kerang in north-west Victoria. The use of the Kerang lakes to form part of the Torrumbarry Irrigation System was comparatively inexpensive initially, but to reduce the high evaporation from such shallow storages, proposals to exclude some of the lakes from the System are being investigated.

List of Lakes

The following is a list of natural lakes in Victoria with their approximate location and areas, as well as their characteristics. Natural lakes which are now utilized as artificial storages are indicated by an asterisk.

VICTORIA—NATURAL LAKES

Name of Lake	Salinity	County and Location	Approx. Acreage
L. Agnes ..	..	Weeah, 23 miles S.E. of Linga	500
L. Albacutya ..	F	Weeah, 10 miles N. of Lake Hindmarsh ..	14,430
Albert Park L. ..	F	Bourke, at South Melbourne	105
Andersons Inlet ..	T	Buln Buln, at Inverloch	5,000
L. Awonga ..	..	Lowan, 7 miles N.E. of Edenhope ..	120
L. Bael Bael ..	F	Tatchera, 9 miles W. of Kerang	1,075
L. Baker.. ..	F	Tatchera, 7 miles S.E. of Swan Hill ..	700
L. Barracoota ..	F	Croajingolong, 6 miles W. of Cape Howe..	600
L. Beeac ..	S	Grenville, 10 miles N. of Colac	1,500
Belfast Lough ..	T	Villiers, at Port Fairy	250
Beniagh Swamp ..	..	Follett, 13 miles N.W. of Dergholm ..	250

VICTORIA—NATURAL LAKES—*continued*

Name of Lake	Salinity	County and Location	Approx. Acreage
Big Swamp ..	..	Ripon, 6 miles N.W. of Willaura ..	3,000
L. Birdebush ..	B	Hampden, 8 miles N. of Camperdown ..	64
L. Bitterang ..	F	Karkarooc, 35 miles S.E. of Mildura ..	180
*L. Boga	F	Tatchera, 8 miles S.E. of Swan Hill ..	2,240
Boikerbert Swamp	..	Lowan, 1 mile W. of Apsley	150
L. Bolac ..	F	Ripon, 8 miles E. of Wickliffe	3,500
L. Bong Bong ..	F	Normanby, 10 miles S.E. of Nelson ..	250
L. Bookaar ..	B	Hampden, 6 miles N. of Camperdown ..	1,075
Booroopki Swamp	F	Lowan, 20 miles N. of Edenhope ..	1,030
L. Boort ..	F	Gladstone, at Boort	1,120
L. Bow	..	Lowan, 11 miles S. of Mt. Arapiles ..	500
Brady Swamp ..	..	Ripon, 17 miles N.W. of Wickliffe ..	600
L. Brambruk ..	F	Karkarooc, 20 miles N.W. of Hopetoun ..	120
Bridgewater Lakes	F	Normanby, 11 miles W. of Portland ..	500
L. Bringalbart ..	F	Lowan, 10 miles N.E. of Apsley ..	250
L. Bullen Merri ..	B	Hampden, 2 miles S.W. of Camperdown	1,330
L. Buloke ..	F	Borung, 4 miles N. of Donald	400
L. Bunga ..	F	Tambo, 3 miles E. of Lakes Entrance ..	300
L. Bunga ..	B	Tanjil, 2 miles S. of Metung	1,000
L. Buninjon ..	F	Ripon, 15 miles S.W. of Ararat ..	430
L. Burn ..	S	Grenville, 8 miles N.E. of Colac ..	130
L. Burrumbeet ..	F	Ripon, 10 miles W. of Ballarat	5,200
*Lough Calvert ..	S	Grenville, 12 miles N. of Colac (now drained)	5,200
L. Campbell ..	..	Lowan, 8 miles N.W. of Harrow ..	150
L. Cantala ..	F	Karkarooc, 37 miles S.E. of Mildura ..	250
L. Carchap ..	F	Lowan, 9 miles S. of Mt. Arapiles ..	220
L. Carpolac ..	..	Lowan, 13 miles N. of Edenhope ..	100
L. Cartcarrong ..	F	Villiers, 10 miles N. of Warrnambool ..	80
L. Catani ..	F	Delatite, in Mt. Buffalo National Park ..	45
Centre L. ..	F	Lowan, 12 miles N.E. of Harrow ..	660
L. Charlegrark ..	..	Lowan, at Booroopki	100
Charam Swamp ..	..	Lowan, 14 miles N.E. of Edenhope ..	150
*L. Charm ..	F	Tatchera, 10 miles N.W. of Kerang ..	1,230
Clear L. ..	F	Lowan, 12 miles S. of Mt. Arapiles ..	300
L. Cogumbul ..	..	Lowan, 8 miles N.E. of Edenhope ..	100
L. Colac ..	F	Polwarth, at Colac	6,650
L. Coleman ..	B	Buln Buln, 14 miles S.E. of Sale ..	2,500
L. Colongulac ..	B	Hampden, 3 miles N. of Camperdown ..	3,500
L. Condah ..	..	Normanby, 23 miles N.E. of Portland ..	700
L. Connewarre ..	T	Grant, 7 miles S.E. of Geelong	3,880
L. Cooper ..	F	Rodney, 10 miles E. of Elmore	2,400
Cooper L. ..	..	Lowan, 20 miles N.E. of Edenhope ..	150
L. Coorong ..	F	Karkarooc, at Hopetoun	2,000
L. Cope Cope ..	F	Kara Kara, 16 miles S. of Donald ..	400
L. Coragulac ..	B	Grenville, 7 miles N.W. of Colac ..	90
L. Coradgill ..	..	Hampden, 7 miles N.E. of Camperdown ..	160
L. Corangamite ..	S	Grenville, 10 miles N.W. of Colac ..	57,700
L. Corringle ..	F	Tambo, 5 miles S. of Orbost	400
L. Craven ..	T	Polwarth, 5 miles N.W. of Cape Otway ..	200
L. Cullen ..	F	Tatchera, 10 miles N.W. of Kerang ..	1,520
L. Cullulleraine ..	F	Millewa, 8 miles N. of Werrimul ..	100
L. Cundare ..	S	Grenville, 8 miles S. of Cressy	350
Curdies Inlet ..	T	Heytesbury, at Peterborough	650
L. Curlip ..	F	Croajingolong, 6 miles S.E. of Orbost ..	400
L. Daylesford ..	F	Talbot, at Daylesford	30
Deep L.	S	Hampden, 10 miles W. of Lismore ..	250
L. Denison ..	..	Buln Buln, 28 miles N.E. of Yarram ..	350
Dock Inlet ..	T	Croajingolong, 5 miles E. of Cape Conran	60
*Dock L. ..	F	Borung, 6 miles S.E. of Horsham ..	535

VICTORIA—NATURAL LAKES—*continued*

Name of Lake	Salinity	County and Location	Approx. Acreage
L. Doling Doling	F	Dundas, 3 miles N.E. of Hamilton ..	50
L. Dollanoke ..	F	Lowan, 9 miles N. of Harrow	100
Dowdle Swamp ..	F	Moira, 6 miles S. of Yarrawonga ..	700
Duck L. ..	F	Tatchera, 7 miles N.W. of Kerang ..	870
L. Elingamite ..	F	Heytesbury, 3 miles S.W. of Cobden ..	800
L. Elizabeth ..	F	Tatchera, 5 miles W. of Kerang	200
L. Eyang ..	S	Hampden, 9 miles E. of Chatsworth ..	180
L. Furnell ..	F	Croajingolong, 11 miles N.W. of Cape Everard	800
*L. Fyans ..	F	Borung, 9 miles S.W. of Stawell ..	1,300
L. Garnook ..	F	Tatchera, 10 miles S.E. of Swan Hill ..	500
*Loch Garry ..	F	Moira, 10 miles N.W. of Shepparton ..	1,700
L. Gellie ..	..	Hampden, 9 miles S. of Streatham ..	130
L. Ghentgen ..	S	Ripon, 5 miles E. of Wickliffe	40
L. Gherang ..	F	Grant, 4 miles E. of Winchelsea ..	250
L. Gilmour ..	F	Tatchera, 8 miles E. of Quambatook ..	106
L. Gnarpurt ..	S	Hampden, at N.W. extremity of L. Corangamite	5,500
L. Gnotuk ..	S	Hampden, 2 miles W. of Camperdown ..	600
L. Goldsmith ..	F	Ripon, 7 miles S. of Beaufort	2,130
*Green L. ..	F	Borung, 7 miles S.E. of Horsham ..	450
Green Hill L. ..	F	Ripon, 2 miles E. of Ararat	300
L. Guthridge ..	F	Tanjil, at Sale	70
L. Hattah ..	F	Karkarooc, 40 miles S. of Mildura ..	150
Heywood L. ..	..	Tatchera, 41 miles N.W. of Swan Hill ..	160
L. Hindmarsh ..	F	Lowan, 3 miles N.E. of Jeparit	30,000
L. Iraak ..	..	Karkarooc, 11 miles S.E. of Red Cliffs ..	200
Jack Smith L. ..	S	Buln Buln, 19 miles N.E. of Yarram ..	300
L. Jarracteer ..	..	Lowan, 8 miles N. of Harrow	100
L. Jingeel ..	F	Lowan, 1 mile E. of L. Jarracteer ..	90
Johnson Swamp ..	F	Gunbower, 8 miles W. of Cohuna ..	160
L. Jollicum ..	F	Hampden, 4 miles S.W. of Streatham ..	130
Jubilee L. ..	F	Talbot, 1 mile S. of Daylesford	10
L. Kakydra ..	B	Tanjil, 8 miles E. of Sale	450
L. Kanagulk ..	..	Lowan, 10 miles N. of Balmoral.. ..	870
*Kangaroo L. ..	F	Tatchera, 11 miles N.W. of Kerang ..	2,180
L. Kariah ..	B	Hampden, 5 miles N.E. of Camperdown ..	350
L. Karnak ..	B	Lowan, 19 miles N.E. of Edenhope ..	300
L. Keilambete ..	B	Hampden, 15 miles W. of Camperdown ..	770
L. Kemi Kemi ..	F	Lowan, 2 miles S. of Edenhope	130
L. Kennedy ..	B	Villiers, 8 miles N.W. of Penshurst ..	690
L. King ..	T	Tanjil, 6 miles E. of Bairnsdale	22,500
L. Konardin ..	F	Karkarooc, 36 miles S. of Mildura ..	300
L. Koreetnung ..	S	Hampden, 6 miles N.E. of Camperdown ..	560
*L. Koynock ..	..	Lowan, 20 miles N.E. of Edenhope ..	200
Kow Swamp ..	F	Gunbower, 10 miles S. of Cohuna ..	6,730
L. Lalbert ..	F	Tatchera, 31 miles W. of Kerang ..	1,250
L. Lawloit ..	..	Lowan, 12 miles S.W. of Nhill	100
L. Leaghur ..	F	Tatchera, 18 miles S.W. of Kerang ..	130
L. Learmonth ..	F	Ripon, 11 miles N.W. of Ballarat ..	1,200
L. Linlithgow ..	B	Villiers, 8 miles N.W. of Penshurst ..	2,450
Little L. ..	F	Tatchera, 10 miles S.W. of Kerang ..	80
L. Lockie ..	F	Karkarooc, 39 miles S. of Mildura ..	350
L. Logan ..	..	Hampden, 10 miles W. of Lismore ..	600
Long L.	F	Tatchera, 1 mile W. of Lake Boga ..	500
*L. Lonsdale ..	F	Borung, 6 miles W. of Stawell	3,260
L. Lookout ..	..	Tatchera, 14 miles W. of Kerang ..	160
L. Lorne ..	..	Grant, at Drysdale	30
L. Lyndger ..	F	Gladstone, 1 mile N.E. of Boort.. ..	450

VICTORIA—NATURAL LAKES—*continued*

Name of Lake	Salinity	County and Location	Approx. Acreage
L. McLaren ..	S	Hampden and Ripon, 2 miles S. of Streatham	450
L. Martin ..	S	Grenville, 4 miles S.W. of Cressy ..	900
Mallacoota Inlet ..	T	Croajingolong, 12 miles W. of Cape Howe	1,700
L. Mannaor ..	F	Tatchera, 11 miles S.E. of Swan Hill ..	40
L. Marma ..	F	Borung, at Murtoa	50
L. Marmal ..	F	Gladstone, 12 miles N.E. of Charlton ..	250
The Marsh ..	F	Tatchera, 10 miles N.W. of Kerang ..	1,700
L. Meering ..	F	Tatchera, 11 miles S.W. of Kerang ..	500
L. Melanydra ..	B	Tanjil, 6 miles E. of Sale	150
*Middle L. ..	F	Tatchera, 4 miles N. of Kerang	430
Miga L.	F	Lowan, 16 miles N. of Harrow	230
Mitre L. ..	S	Lowan, 3 miles N. of Mt. Arapiles ..	1,280
L. Modewarre ..	S	Grant, 6 miles E. of Winchelsea ..	1,025
L. Moinmuick ..	..	Lowan, 9 miles N.E. of Edenhope ..	90
L. Moinalwar ..	..	Lowan, 10 miles N.E. of Edenhope ..	50
Moira Lakes ..	F	Moira, 4 miles N. of Barmah	600
Mokoan Swamp ..	..	Moira, 13 miles S.W. of Wangaratta ..	3,600
L. Moodemere ..	F	Bogong, 3 miles W. of Rutherglen ..	850
Morea L. ..	F	Lowan, 13 miles N. of Edenhope ..	180
L. Mournpall ..	F	Karkarooc, 37 miles S. of Mildura ..	600
L. Mullancoree ..	B	Lowan, 7 miles N. of Harrow	200
L. Mundi ..	F	Follett, 22 miles W. of Casterton ..	1,280
L. Murdeduke ..	S	Grenville, 6 miles N.W. of Winchelsea ..	2,800
L. Murphy ..	F	Tatchera, 6 miles S. of Kerang	560
L. Natimuk ..	F	Lowan, 7 miles N.E. of Mt. Arapiles ..	920
Nerrin Nerrin Swamp	..	Hampden, 4 miles S.W. of Streatham ..	800
North L. ..	S	Lowan, 13 miles N.E. of Harrow ..	500
L. Omeo ..	F	Benambra, 10 miles N.E. of Omeo ..	1,970
L. Ondit ..	S	Grenville, 5 miles N. of Colac	250
L. Oundell ..	F	Hampden, 5 miles S.W. of Streatham ..	180
L. Paracalmir ..	S	Ripon, 6 miles E. of Wickliffe	160
Pelican L. ..	F	Tatchera, 2 miles W. of Kerang	95
L. Pertobe ..	T	Villiers, in City of Warrnambool.. ..	50
Picnic Lakes ..	S	Hampden, 4 miles N. of Chatsworth ..	150
*Pine Lake ..	F	Borung, 9 miles S.E. of Horsham ..	1,814
Pine Hut L. ..	F	Lowan, 16 miles S.W. of Mt. Arapiles ..	200
Pink Lakes ..	S	Weeah, 8 miles N. of Linga	1,000
L. Powell ..	F	Karkarooc, 10 miles S.E. of Robinvale ..	320
L. Punpundal ..	S	Hampden, 14 miles N.E. of Camperdown	60
L. Purdiguluc ..	F	Grenville, 7 miles N.W. of Colac ..	180
L. Purrumbete ..	F	Heytesbury, 5 miles S.E. of Camperdown	1,450
*Racecourse L. ..	F	Tatchera, 10 miles N.W. of Kerang ..	464
Red Morass ..	..	Tanjil, 17 miles E. of Stratford	500
*Reedy L. ..	F	Tatchera, 3 miles N. of Kerang	480
Reedy L. ..	..	Grant, 5 miles E. of Geelong	1,200
Reedy L.	F	Rodney, 4 miles N. of Nagambie ..	700
L. Reeve ..	T	Buln Buln, 28 miles E. of Rosedale ..	9,000
L. Repose ..	F	Villiers, 7 miles S.E. of Dunkeld.. ..	280
L. Rosine ..	S	Grenville, 3 miles W. of Cressy	380
Ross L.	..	Weeah, 7 miles N.W. of Rainbow ..	50
Round L. ..	F	Tatchera, 10 miles S.W. of Kerang ..	35
Round L. ..	F	Tatchera, 9 miles S.E. of Swan Hill ..	50
Round L. ..	B	Hampden, 7 miles N.E. of Camperdown ..	160
St. Mary's L. ..	F	Lowan, 4 miles W. of Mt. Arapiles ..	230
Salt L.	S	Grenville, 9 miles N.E. of Colac ..	870
Salt L.	S	Hampden, 12 miles S. of Streatham ..	200
Salt L.	S	Hampden, 5 miles N.E. of Camperdown ..	300
Salt L.	S	Lowan, 5 miles N.W. of Dimboola ..	160
Salt L.	S	Ripon, 9 miles S. of Beaufort	180

VICTORIA—NATURAL LAKES—*continued*

Name of Lake	Salinity	County and Location	Approx. Acreage
Salt L.	S	Tatchera, 9 miles W. of Kerang	100
Sand Hills L. ..	S	Tatchera, 13 miles W. of Kerang ..	220
Sea L.	F	Karkarooc, at Sea Lake..	30
Shallow Inlet ..	T	Buln Buln, 10 miles S. of Foster ..	2,000
Small L. ..	..	Kara Kara, 7 miles W. of Charlton ..	200
Great Spectacle L.	F	Tatchera, 10 miles S.W. of Kerang ..	130
Little Spectacle L.	F	Tatchera, 10 miles S.W. of Kerang ..	45
St. Georges L. ..	F	Talbot, 1 mile S.E. of Creswick ..	25
L. Struan ..	..	Hampden, 5 miles S.E. of Lismore ..	90
L. Surprise ..	F	Normanby, 5 miles S.W. of Macarthur ..	50
Swan L. ..	F	Mornington, W. end of Phillip Island ..	60
Swan L. ..	..	Normanby, at Mt. Richmond	50
Sydenham Inlet ..	T	Croajingolong, 13 miles E. of Cape Conran	2,300
Tamboon Inlet ..	T	Croajingolong, 8 miles W. of Cape Everard	1,150
L. Tali Karng ..	F	Tanjil, 10 miles N.E. of Licola	25
L. Tatutong ..	S	Hampden, 14 miles N.E. of Camperdown..	50
*L. Taylor ..	F	Borung, 11 miles S.E. of Horsham ..	2,718
Tcham Lakes ..	F	Tatchera, 5 miles E. of Birchip	260
Tea Tree L. ..	..	Lowan, 5 miles N. of Harrow ..	100
L. Terang ..	F	Hampden, at Terang	300
L. Terangpom ..	S	Hampden, 11 miles N.E. of Camperdown	500
*Third L. ..	F	Tatchera, 6 miles N.W. of Kerang ..	570
L. Timboran ..	S	Tatchera, 14 miles N.E. of Sea Lake ..	2,000
Tobacco L. ..	F	Tatchera, 10 miles S.W. of Kerang ..	25
L. Tooliorook ..	B	Hampden, 4 miles S.E. of Lismore ..	850
Tower Hill L. ..	F	Villiers, 1 mile S. of Koroit	850
L. Turangmoroke..	S	Ripon, 9 miles E. of Wickliffe	250
L. Tutchewop ..	F	Tatchera, 16 miles N.W. of Kerang ..	2,080
L. Tyers ..	T	Tambo, 6 miles E. of Lakes Entrance ..	3,950
L. Tyrrell ..	S	Karkarooc, 4 miles N. of Sea Lake ..	42,600
Un-named ..	..	Lowan, 5 miles N. of Edenhope ..	120
Un-named ..	S	Lowan, 14 miles S. of Mt. Arapiles ..	300
Un-named ..	..	Lowan, 16 miles S. of Mt. Arapiles ..	200
Un-named ..	..	Lowan, 4 miles S. of Mt. Arapiles ..	300
Un-named ..	..	Lowan, 6 miles S.E. of Mt. Arapiles ..	250
Un-named ..	S	Lowan, 7 miles S. of Mt. Arapiles ..	180
Un-named ..	..	Lowan, 9 miles N.E. of Mt. Arapiles ..	420
Un-named ..	..	Lowan, 11 miles N. of Harrow	250
Un-named ..	..	Ripon, 6 miles N.W. of Willaura ..	2,000
Un-named ..	S	Grenville, 5 miles S. of Cressy	50
Un-named ..	S	Grenville, 12 miles N. of Colac	100
Un-named ..	S	Grenville, 9 miles N. of Colac	100
Un-named ..	..	Grenville, 1 mile N. of Ondit	100
Un-named ..	S	Grenville, 3 miles N.E. of Ondit ..	100
Un-named ..	S	Hampden, 6 miles W. of Mortlake ..	160
Un-named ..	S	Lowan, 9 miles S. of Dimboola ..	180
L. Victoria ..	T	Tanjil, 12 miles S. of Bairnsdale ..	28,500
Victoria Lagoon ..	..	Tanjil, 20 miles E. of Stratford	500
Victoria Lagoon ..	..	Dundas, 12 miles N.E. of Cavendish ..	120
L. Wallawalla ..	F	Millewa, 18 miles S.E. of N.W. corner of Victoria	600
L. Wahpool ..	S	Karkarooc, 13 miles N.E. of Sea Lake ..	5,000
L. Wallace ..	F	Lowan, at Edenhope	450
L. Wandella ..	F	Tatchera, 2 miles W. of Kerang	200
L. Wangoom ..	F	Villiers, 6 miles N.E. of Warrnambool ..	200
L. Wau Wauka ..	F	Croajingolong, 3 miles W. of Cape Howe	600
L. Weeranganuck	S	Hampden, 7 miles N.E. of Camperdown ..	1,280
L. Weering ..	S	Grenville, 4 miles S.E. of Cressy.. ..	920
L. Wellington ..	F	Tanjil, 8 miles E. of Sale	34,500

VICTORIA—NATURAL LAKES—*continued*

Name of Lake	Salinity	County and Location	Approx. Acreage
L. Wendouree ..	F	Grenville, at Ballarat	500
L. Werowrap ..	F	Grenville, 8 miles N.W. of Colac ..	50
White L. ..	S	Lowan, 10 miles N.E. of Harrow ..	1,400
White L. ..	S	Lowan, 15 miles N. of Harrow	90
Wingan Inlet ..	T	Croajingolong, 13 miles E. of Cape Conran	200
Winter L. ..	..	Lowan, 10 miles N.W. of Edenhope ..	350
L. Wirraan ..	S	Hampden, 9 miles N. of Camperdown	60
L. Wongan ..	S	Ripon, 6 miles N.E. of Streatham ..	500
L. Wooronook ..	F	Kara Kara, 8 miles W. of Charlton ..	250
Wurdiboluc Reservoir	F	Grant, 4 miles S.E. of Winchelsea ..	1,025
Yallakur L. ..	F	Lowan, 8 miles N.E. of Edenhope ..	870
L. Yambuk ..	T	Villiers, 11 miles W. of Port Fairy ..	200
L. Yampitcha ..	..	Lowan, 3 miles N. of Edenhope ..	150
L. Yando ..	F	Tatchera, 7 miles N.E. of Boort ..	200
L. Yuangmania ..	S	Ripon, 10 miles E. of Wickliffe	75
L. Yelwell ..	F	Karkarooc, 37 miles S. of Mildura ..	200
L. Yerang ..	F	Karkarooc, 38 miles S. of Mildura ..	160

* Natural Lakes which are now utilized as artificial storages.

Legend :—F = Fresh, B = Brackish, S = Salt, and T = Tidal.

[Source : Surveyor-General

The following list shows the artificial storages or lakes utilized as storages in Victoria :—

VICTORIA—ARTIFICIAL STORAGES OR LAKES UTILIZED AS STORAGES

Name of Storage	Location	Capacity	Surface Area
		ac.ft.	acres
Almurta Reservoir ..	12 miles N.E. of San Remo	1,200	140
Barkers Creek Reservoir ..	3 miles N. of Harcourt ..	2,180	143
Batyo Catyo L.	10 miles S. of Donald ..	3,900	550
Beaconsfield Reservoir ..	3 miles E. of Berwick ..	711	40
Beale Reservoir	9 miles E. of Ballarat ..	360	63
Bellarine Basin	3 miles N. of Ocean Grove ..	375	66
L. Bellfield	3 miles S. of Halls Gap ..	63,675	1,186
Bittern Reservoir ..	6 miles E. of Mt. Martha ..	556	64
L. Boga	8 miles S.E. of Swan Hill ..	29,700	2,240
Bostock Reservoir ..	2 miles W. of Ballan ..	5,500	250
Cairn Curran Reservoir ..	5 miles W. of Maldon ..	120,600	4,740
Clover Pondage ..	15 miles S.E. of Bright ..	240	10
L. Charm	10 miles N.W. of Kerang ..	17,810	1,230
Crusoe Reservoir ..	5 miles S.W. of Bendigo ..	1,241	87
L. Cullen	10 miles N.W. of Kerang ..	12,389	1,520
L. Cullulleraine	8 miles N. of Werrimul ..	2,000	100
Devilbend Reservoir ..	4 miles E. of Mt. Martha ..	11,839	600
Dock L.	6 miles S.E. of Horsham ..	4,800	535
L. Eildon	At Eildon	2,750,000	34,200
Evansford Reservoir ..	8 miles E. of Lexton ..	1,200	50
Expedition Pass Reservoir	3 miles E. of Castlemaine ..	240	19
L. Eppalock	14 miles S.E. of Bendigo ..	250,000	7,900

VICTORIA—ARTIFICIAL STORAGES OR LAKES UTILIZED AS STORAGES—*continued*

Name of Storage	Location	Capacity	Surface Area
		ac.ft.	acres
Frankston Reservoir ..	2 miles S. of Frankston ..	560	40
L. Fyans	9 miles S.W. of Stawell ..	17,100	1,300
L. Gilmour	8 miles E. of Quambatook ..	1,320	106
L. Glenmaggie	4 miles N. of Heyfield ..	154,310	4,350
Gong Gong Reservoir ..	3 miles E. of Ballarat ..	1,520	72
Green L.	7 miles S.E. of Horsham ..	6,600	450
Goulburn Weir	At Nagambie	20,700	4,467
Hepburn Lagoon ..	6 miles N.E. of Creswick ..	2,460	280
Hazelwood Power Station Cooling Water Storage	At Hazelwood	25,000	1,250
L. Hume	6 miles E. of Albury ..	2,500,000	56,000
Junction Pondage ..	16 miles S.E. of Bright ..	1,200	40
Kangaroo L.	11 miles N.W. of Kerang ..	26,670	2,180
L. Kerferd	At Beechworth	800	60
Kirks Reservoir ..	3 miles E. of Ballarat ..	340	17
Konong Wootong Reservoir	7 miles N. of Coleraine ..	1,500	150
Korweinguboora Reservoir	10 miles S. of Daylesford	1,700	500
Kow Swamp Reservoir ..	10 miles S. of Cohuna ..	40,900	6,730
Laanecoorie Reservoir ..	10 miles E. of Dunolly ..	6,300	1,180
Lance Creek Reservoir ..	8 miles N.E. of Wonthaggi ..	1,540	116
Lauriston Reservoir ..	4 miles W. of Kyneton ..	16,600	522
L. Lonsdale	6 miles W. of Stawell ..	53,300	3,260
L. Lookout	14 miles W. of Kerang ..	1,300	160
Lysterfield Reservoir ..	4 miles N.E. of Dandenong ..	3,400	207
McCay Reservoir ..	3 miles E. of Chewton ..	1,100	48
Malmsbury Reservoir ..	5 miles N.W. of Kyneton ..	14,400	760
Maroondah Reservoir ..	1 miles E. of Healesville ..	25,000	570
Melton Reservoir ..	4 miles S. of Melton ..	15,500	628
Middle L.	4 miles N. of Kerang ..	2,180	430
Moondarra Reservoir ..	7 miles N.E. of Yallourn ..	25,000	570
Moorarbool Reservoir ..	12 miles N.E. of Ballarat ..	5,430	392
Moora Moora Reservoir ..	8 miles S.W. of Halls Gap ..	5,100	1,200
Mount Ewan Reservoir ..	7 miles S.W. of Camperdown	458	33
L. Mulwala	At Yarrawonga	95,100	11,200
Newlyn Reservoir ..	6 miles E. of Creswick ..	2,700	180
O'Shannassy Reservoir ..	7 miles N.E. of Warburton ..	3,440	74
Pincott Reservoir ..	4 miles E. of Ballarat ..	180	25
Pine L.	9 miles S.E. of Horsham ..	52,000	1,814
Pykes Creek Reservoir ..	4 miles E. of Ballan ..	19,400	500
Racecourse L.	10 miles N.W. of Kerang ..	4,100	464
Reedy L.	3 miles N. of Kerang ..	3,250	480
Rocklands Reservoir ..	8 miles E. of Balmoral ..	272,000	16,200
Rocky Valley Reservoir ..	20 miles S.E. of Bright ..	23,000	650
Ryans Creek Reservoir ..	18 miles S.E. of Benalla ..	522	40
Sand Hills L.	13 miles W. of Kerang ..	2,200	220
Spring Gully Reservoir ..	2 miles S. of Bendigo ..	2,000	107
Silvan Reservoir ..	2 miles E. of Mt. Dandenong	32,520	822
Talbot Reservoir ..	6 miles S.W. of Talbot ..	674	50
Tank Hill Reservoir ..	12 miles N.E. of Warrnambool	580	31
L. Taylor	11 miles S.E. of Horsham ..	30,000	2,718
Third L.	6 miles N.W. of Kerang ..	3,000	570
Toolondo Reservoir ..	15 miles N.E. of Balmoral ..	86,000	3,124
Toorourrong Reservoir ..	3 miles N. of Whittlesea ..	230	60
Tullaroop Reservoir ..	7 miles W. of Maryborough	60,000	1,785
Torrumbarry Weir ..	20 miles N.W. of Echuca ..	28,900	..
L. Tutchewop	16 miles N.W. of Kerang ..	..	2,080
Upper Coliban Reservoir	4 miles S.W. of Kyneton ..	25,700	830

VICTORIA—ARTIFICIAL STORAGES OR LAKES UTILIZED AS STORAGES—*continued*

Name of Storage	Location	Capacity	Surface Area
		ac.ft.	acres
Upper Stony Creek Reservoirs (Nos. 1, 2, and 3)	7 miles E. of Meredith ..	7,300	500
Upper Yarra Reservoir ..	12 miles N.E. of Warburton..	160,000	1,830
Waranga Reservoir ..	2 miles E. of Rushworth ..	333,400	14,450
Wartook Reservoir ..	16 miles W. of Stawell ..	23,800	2,550
White Swan Reservoir ..	4 miles N.E. of Ballarat ..	12,000	310
L. Whitton	2 miles S. of Warracknabeal	1,300	80
West Barwon Reservoir ..	15 miles S.E. of Colac ..	18,000	450
Wilson Reservoir ..	9 miles N.E. of Ballarat ..	880	90
Yan Yean Reservoir ..	3 miles S. of Whittlesea ..	27,000	1,360
Yallourn Power Station Cooling Water Storage	At Yallourn	6,500	850
Wurdiboluc Reservoir ..	4 miles S.E. of Winchelsea ..	15,400	1,025

[Source : State Rivers and Water Supply Commission

Survey and Mapping

The surveying and mapping of the State is the responsibility of the Department of Crown Lands and Survey. General small scale mapping, however, is carried out by the Royal Australian Survey Corps, Department of the Army, as part of the defence programme. Complete information on survey and mapping is obtainable from the Central Plan Office which operates under the *Survey Co-ordination Act* 1958. Aerial photography with its attendant photogrammetry is a most important and valuable aid, both in preparing maps and in providing information where adequate maps do not exist. Aerial photography is carried out by commercial aerial survey companies.

The programme for 1963–64 required re-photographing of approximately 20,000 square miles of the State. Apart from general photographic cover, many areas such as cities, towns, and other highly developed localities are photographed specially at frequent intervals. Individual photographs or mosaics prepared from them in photo-map form are available to the public subject to security regulations.

In addition to photographic cover, maps are prepared where the greatest demand exists. This work is divided into two main categories, cadastral and topographic mapping. Cadastral mapping includes plans showing original information concerning the alienation of Crown Lands and base maps at a scale of 400 feet to 1 inch showing all title boundaries, contours, and certain photographic features. These maps are required mainly for town planning and reticulation purposes. Topographic mapping includes large scale detailed maps for engineering projects, and small maps showing topography and all cultural features. A standard series at a scale of 2 inches to 1 mile is being produced by the State and smaller scale maps are being produced by the Royal Australian Survey Corps. This work is being co-ordinated by the National Mapping Council of Australia.

The State standard series topographic maps have been modernized by employing the latest drawing methods and modern type. More than 90 of these have been printed and published. Considerable progress has also been made in the Base Map programme which still remains one of the main tasks undertaken for State development. In co-operation with the Melbourne and Metropolitan Board of Works, 113 plans at a scale of 400 feet to 1 inch have been printed and published. These cover a wide area of the outer suburbs of the City of Melbourne. A similar series linking up with the Frankston area extends through the Shires of Mornington, Flinders, and Hastings, covering almost all of the Mornington Peninsula. In this series 81 sheets have been published. In the Latrobe Valley project 132 sheets at the scale of 400 feet to 1 inch have been completed, and among the other areas deriving considerable benefit from this type and scale of mapping are the City of Ballaarat, Melton, Phillip Island, Lakes Entrance, and Echuca.

The compilation of a new map of the State at a scale of 1 : 500,000 (i.e., approximately 8 miles to 1 inch) has been commenced. This map drawn to transverse mercator projection will show all main features and will supersede the present 8 miles to 1 inch scale map which has been in existence for well over 50 years.

State Aerial Survey

Year Book 1961 (*35–36*).

Natural Resources Conservation League

The League, which commenced its activities in 1944 as the " Save the Forests Campaign ", seeks to arouse public interest in forestry, to enlist public assistance in preventing and in fighting bush fires, and to ensure that the water, timber, soil, and wildlife resources of the State are fully conserved. Because of the co-operation given to the Campaign by government departments and municipal bodies, a permanent organization known as the Natural Resources Conservation League was formed in 1951.

At present the League's membership consists of two Commonwealth and 22 State Government or semi-government bodies, 32 land use and other organizations, 12 regional committees, and 187 municipalities. The League also welcomes farmer members and individuals who have a genuine interest in conserving Victoria's natural resources.

The League is assisted financially by donations from private citizens and firms, as well as by a substantial annual grant from the State Government. This enables some 400,000 trees to be grown at the League's Springvale nursery. The trees are distributed annually for planting on farms and for street and roadside planting, and are supplied free for community plantations and at naturalization ceremonies. The League also conducts talks given by experts to groups of people employed in some aspect of conservation of natural resources.

Physical Geography

Physical Divisions

This article should be read in conjunction with the articles on geographical features, area, and climate.

The chief physical divisions of Victoria are shown on the map (Fig. 4). Each of these divisions has certain physical features which distinguish it from the others, as a result of the influence of elevation, geological structure, climate, and soils, as is recognized in popular terms such as Mallee, Wimmera, Western District and so on. The following is a table of these divisions :—

1. *Murray Basin Plains :*
    - (*a*) The Mallee
    - (*b*) The Murray Valley
    - (*c*) The Wimmera
    - (*d*) The Northern District Plains

2. *Central Highlands :*
    - A. The Eastern Highlands, within which—
        - (*a*) the Sandstone Belt and
        - (*b*) the Caves Country may be distinguished from the remainder
    - B. The Western Highlands :
        - (*a*) The Midlands
        - (*b*) The Grampians
        - (*c*) The Dundas Highlands

3. *Western District Plains :*
    - (*a*) The Volcanic Plains
    - (*b*) The Coastal Plains

4. *Gippsland Plains :*
    - (*a*) The East Gippsland Plains
    - (*b*) The West Gippsland Plains

5. *Southern Uplands :*
    - (*a*) The Otway Ranges
    - (*b*) The Barabool Hills
    - (*c*) The Mornington Peninsula
    - (*d*) The South Gippsland Highlands
    - (*e*) Wilson's Promontory

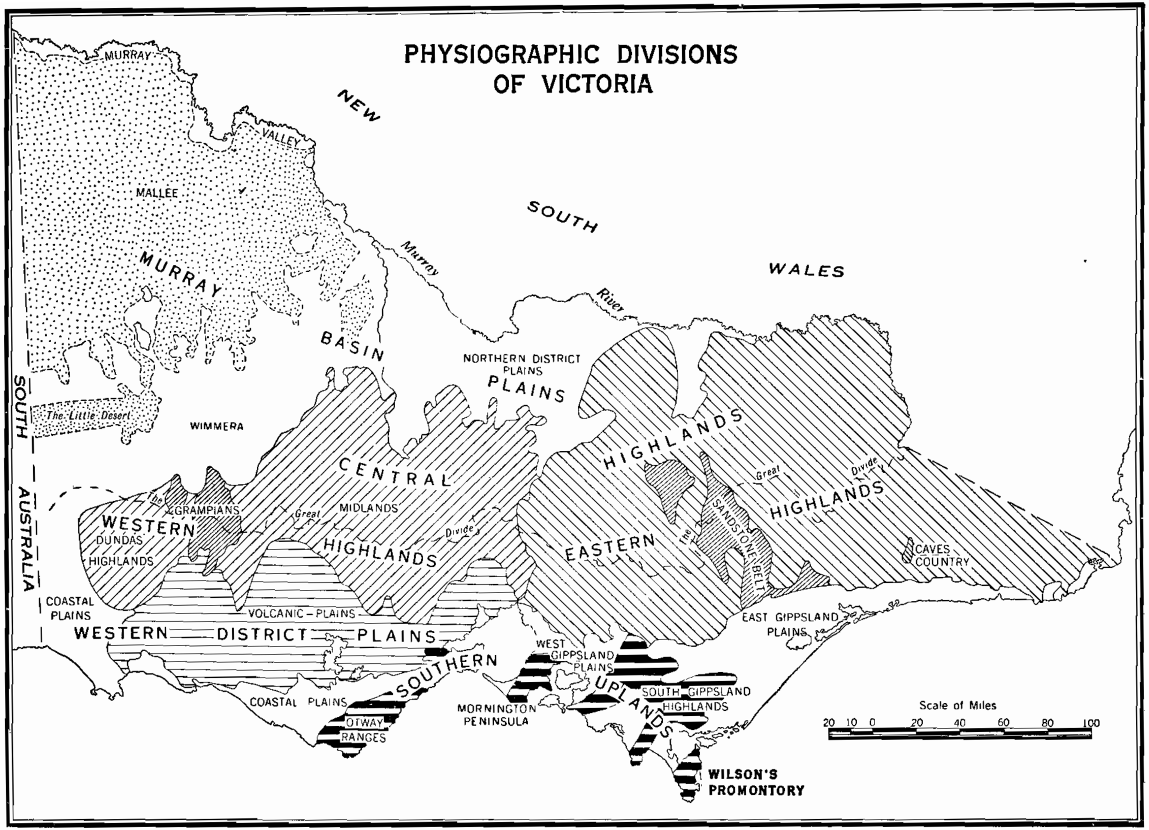

PHYSIOGRAPHIC DIVISIONS
OF VICTORIA
NEW
SOUTH
WALES
MURRAY
VALLEY
MALLEE
MURRAY
BASIN
Murray
River
NORTHERN DISTRICT
PLAINS
PLAINS
WIMMERA
The Little Desert
SOUTH
AUSTRALIA
CENTRAL
HIGHLANDS
The GRAMPIANS
WESTERN
DUNDAS
HIGHLANDS
Great
MIDLANDS
Divide
HIGHLANDS
EASTERN
Great
Divide
HIGHLANDS
The
SANDSTONE BELT
CAVES
COUNTRY
COASTAL
PLAINS
VOLCANIC – PLAINS
WESTERN
DISTRICT
PLAINS
EAST GIPPSLAND
PLAINS
WEST
GIPPSLAND
PLAINS
SOUTHERN
UPLANDS
SOUTH GIPPSLAND
HIGHLANDS
COASTAL PLAINS
OTWAY
RANGES
MORNINGTON
PENINSULA
WILSON'S
PROMONTORY
Scale of Miles
20 10 0 20 40 60 80 100

FIGURE 4.

Murray Basin Plains

These plains include the Mallee, the Wimmera, the Northern District Plains and the Murray Valley itself. The most noticeable distinguishing features of the Mallee are the soils, vegetation, and topography. It is not a perfect plain, but exhibits broad low ridges and depressions which appear to be due to folding and faulting of the rocks. Sand ridges trending due east and west are an indication of a former more arid climate, but they are now fixed by vegetation. When cleared, the sand distributes itself irregularly without forming new ridges. There is evidence of a succession of former wet and dry periods in the Mallee, but at the present time all the streams that enter it lose so much water by evaporation and percolation that they fail to reach the Murray and terminate in shallow lakes, many of which are salt. The Murray Valley itself is cut into the higher Mallee land and is subject to periodical flooding by the river.

The Northern District Plains are formed from the combined flood plains of rivers flowing to the Murray, with an average gradient of between 3 and 5 feet to the mile, the surface being almost perfectly flat except where small residual hills of granite rise above the alluvium as at Pyramid Hill.

The Wimmera lies between the Western Highlands and the Mallee and is also composed mainly of river plains except to the north of the Glenelg where old abandoned river channels contain a succession of small lakes. Most of the lakes of the Murray Basin Plains have crescentic loam ridges (lunettes) on their eastern shores.

Central Highlands

The Central Highlands form the backbone of Victoria, tapering from a broad and high mountainous belt in the east until they disappear beyond the Dundas Highlands near the South Australian border. They were formed by up-warping and faulting. The Eastern Highlands differ from the Western in their greater average elevation, with peaks such as Bogong, Feathertop, and Hotham rising above 6,000 feet, while the Western Highlands are generally lower, the peaks reaching above 3,000 feet, and the valleys being broader. Also, in the Eastern Highlands patches of Older Volcanic rocks occur, whereas in the Western the volcanic rocks belong mainly to the Newer Volcanic Series. Several well known volcanic mountains are still preserved, Mounts Buninyong and Warrenheip near Ballarat being examples.

Because of the great variety of geological formations in the Central Highlands and the effects of elevation and deep dissection by streams, the features of the country are very varied and there are many striking mountains and gorges. The severe winter climate, with heavy snow on the higher land, is also a special feature of the Eastern Highlands. Included in the area are several high plains such as those near Bogong and the Snowy Plains. Caves are well known in the limestone around Buchan.

In the Western Highlands the Grampians, with their striking serrate ridges of sandstone, may be compared with the belt of sandstones stretching from Mansfield to Briagolong in the east.

The Dundas Highlands are a dome which has been dissected by the Glenelg and its tributaries, the rocks being capped by ancient laterite soils which form tablelands with scarps at their edges.

Western District Plains

Many of the surface features of the Western District Plains are a result of volcanic activity, very large areas being covered with basalt flows of the Newer Volcanic Series above which prominent mountains rise, many of them with a central crater lake. Some of the youngest flows preserve original surface irregularities practically unmodified by erosion, thus forming the regions known as " Stony Rises ".

The coastal plains of the Western District are for the most part sandy, the soils being derived from Tertiary and Pleistocene sedimentary deposits, which in places attain a thickness of some 5,000 feet, and yield considerable quantities of artesian water.

Gippsland Plains

Continuing the east-west belt of plains on the eastern side of the drowned area represented by Port Phillip Bay and Western Port Bay are the Gippsland Plains. These are underlain by marine and non-marine Tertiary and Pleistocene sedimentary deposits, including the thick seams of brown coal of the Latrobe Valley. A notable feature is the Ninety Mile Beach and the lakes and swamps that lie on its landward side. This beach is an off-shore bar on which aeolian sand ridges have accumulated.

Southern Uplands

Lying to the south of the plains above mentioned is a group of uplifted blocks for which faulting is mainly responsible, these constituting the Southern Uplands. The Otway Ranges and the South Gippsland Highlands are composed of fresh-water Mesozoic and Tertiary sediments with Older Volcanic basalts in South Gippsland, and the Mornington Peninsula is an upraised fault block of complex geology, including granites. The Sorrento Peninsula is entirely composed of Pleistocene calcareous dune ridges which have been responsible for practically blocking the entrance to Port Phillip Bay.

LAND SURFACE OF VICTORIA

Year Book 1964 (*24–25*).

GEOLOGY OF VICTORIA

Year Book 1961 (*42–56*).

E. S. Hills *The Physiography of Victoria* : Whitcombe and Tombs, Melbourne, Fourth Edition, 1959.

Resources Surveys—Preliminary Reports : Published by the Central Planning Authority, Premier's Department, Melbourne.

Climate

Climate of Victoria

General

The State of Victoria experiences a wide range of climatic conditions ranging from the hot summer of the Mallee to the winter blizzards of the snow-covered Alps, and from the relatively dry wheat belt to the wet eastern elevated areas where many of Victoria's permanent streams spring.

Temperatures

February is the hottest month of the year with January only slightly cooler. Average maximum temperatures are under 75° F. along the coast and over elevated areas forming the Central Divide and North-East Highlands. Apart from these latter areas, there is a steady increase towards the north, until, in the extreme north an average of 90° F. is reached. Values decrease steadily with height, being under 70° F. in alpine areas above 3,000 feet and as low as 60° F. in the very highest localities.

Temperatures fall rapidly during the autumn months and then more slowly with the onset of winter. Average maximum temperatures are lowest in July; the distribution during this month again shows lowest values over elevated areas, but a significant feature is that apart from this orographically induced area, there is practically no variation across the State. Day temperatures along the coast average about 55° F. in July; much the same value is recorded over the wheat belt, and only a few degrees higher in the far north-west under conditions of few clouds and relatively high winter sunshine. The Alps experience blizzard conditions every year with minimum temperatures 10° F. to 20° F. less than at lowland stations.

Conditions of extreme summer heat may be experienced throughout the State except over the alpine area. Most inland places have recorded maxima over 110° F. with an all time extreme for the State of 123.5° F. at Mildura on 6th January, 1906. Usually such days are the culmination of a period during which temperatures gradually rise, and relief comes sharply in the form of a cool change with rapid temperature drops of 30° F. at times. However, such relief does not always arrive so soon and periods of two or three days or even longer have been experienced when the maximum temperature exceeds 100° F. On rare occasions extreme heat may continue for as long as a week with little relief.

Night temperatures, as gauged by the average minimum temperature, are, like the maximum, highest in February. Values are below 50° F. over the elevated areas, but otherwise the range is chiefly

55° F. to 60° F. The highest night temperatures are recorded in the far north and along the coast. In mid-winter, average July minima exceed 40° F. along the coast and at two or three places in the far north. The coldest point of the State is the north-east alpine section, where temperatures frequently fall below freezing point. Although three or four stations have been set up at different times in this area, none has a very long or satisfactory record. The lowest temperature on record so far is 9° F. at Hotham Heights (station height 5,776 feet) at an exposed location near a mountain. However, a minimum of minus 8° F. has been recorded at Charlotte Pass (station height 6,035 feet)—a high valley near Mount Kosciusko in N.S.W.—and it is reasonable to expect that similar locations in Victoria would experience sub-zero temperatures (i.e., below 0° F.), although none has been recorded due to lack of observing stations.

Frosts

With the exception of the exposed coast, all parts of Victoria may experience frost, but frequencies are highest and occurrences usually more severe in elevated areas and valleys conducive to the pooling of cold air. All inland stations have recorded extreme screen temperatures less than 30° F., whilst at a large number of stations extremes stand at 25° F. or less. Thus frost may be expected each year over practically the whole of the State, but the bulk of the occurrence is restricted to the winter season. Spring frosts may constitute a serious hazard to agriculture, and in some years a late frost may result in serious crop damage. Periods of frost lasting for more than three or four consecutive days are unusual.

Rainfall

Rainfall exhibits a wide variation across the State and although not markedly seasonal, most parts receive a slight maximum in the winter or spring months. The relatively dry summer season is a period of evaporation, which greatly reduces the effectiveness of the rainfall. Average annual totals range between 10 inches in the driest parts of the Mallee to over 60 inches in parts of the North-Eastern Highlands. An annual total exceeding 140 inches has been reported from Falls Creek in the north-east; however, with the sparse population and inaccessibility of the highland localities, it is not practicable to obtain a representative set of observations from this area. Most areas south of the Divide receive an annual rainfall above 25 inches, with over 40 inches in the Central Highlands, Otway Ranges, and South Gippsland. The wheat belt receives chiefly between 12 and 20 inches. With the exception of Gippsland, 60 to 65 per cent. of the rain falls during the period May to October. This proportion decreases towards the east, until over Gippsland the distribution is fairly uniform with a warm season maximum in the far east. All parts of the State have on rare occasions been subjected to intense falls, and monthly totals exceeding three times the average have been recorded. Monthly totals exceeding 10 inches have been recorded on rare occasions at most places on and south of the Divide; the chief exception being over the lowlands extending from Melbourne to the Central Western District. Occurrences are more frequent, but still unusual, over the north-east and East Gippsland and isolated parts such as the Otways. This event has, with few exceptions, never been recorded over the north-west of the State. The highest monthly total ever recorded in the State was a fall of 35·09 inches at Tanybryn in the Otway district in June, 1952.

Floods

Floods have occurred in all districts, but they are more frequent in the wetter parts of the State such as the north-east and Gippsland. However, although a rarer event over the North-West Lowlands, they may result from less intense rainfall and continue longer owing to the poor drainage in this section of the State. In many instances the frequency of flooding is increased by valley contours and damage is often greater because of the higher density of adjacent property and crops.

Snow

Snow in Victoria is confined usually to the Great Dividing Range and the alpine massif, which at intervals during the winter and early spring months may be covered to a considerable extent, especially over the more elevated eastern section. Falls elsewhere are usually light and infrequent. Snow has been recorded in all districts except the Mallee, Wimmera, and Northern Country. The heaviest falls in Victoria are confined to sparsely populated areas and hence general community disorganization is kept to a minimum. Snow has been recorded in all months on the higher Alps, but the main falls occur during the winter. The average duration of the snow season in the alpine area is from three to five months.

Winds

The predominant wind stream over Victoria is of a general westerly origin, although it may arrive over the State from the north-west or south-west. There are wide variations from this general description, however, and many northerlies and southerlies are experienced. The latter is the prevailing direction from November to February with a moderate percentage of northerlies often associated with high temperatures. Easterly winds are least frequent over Victoria, but

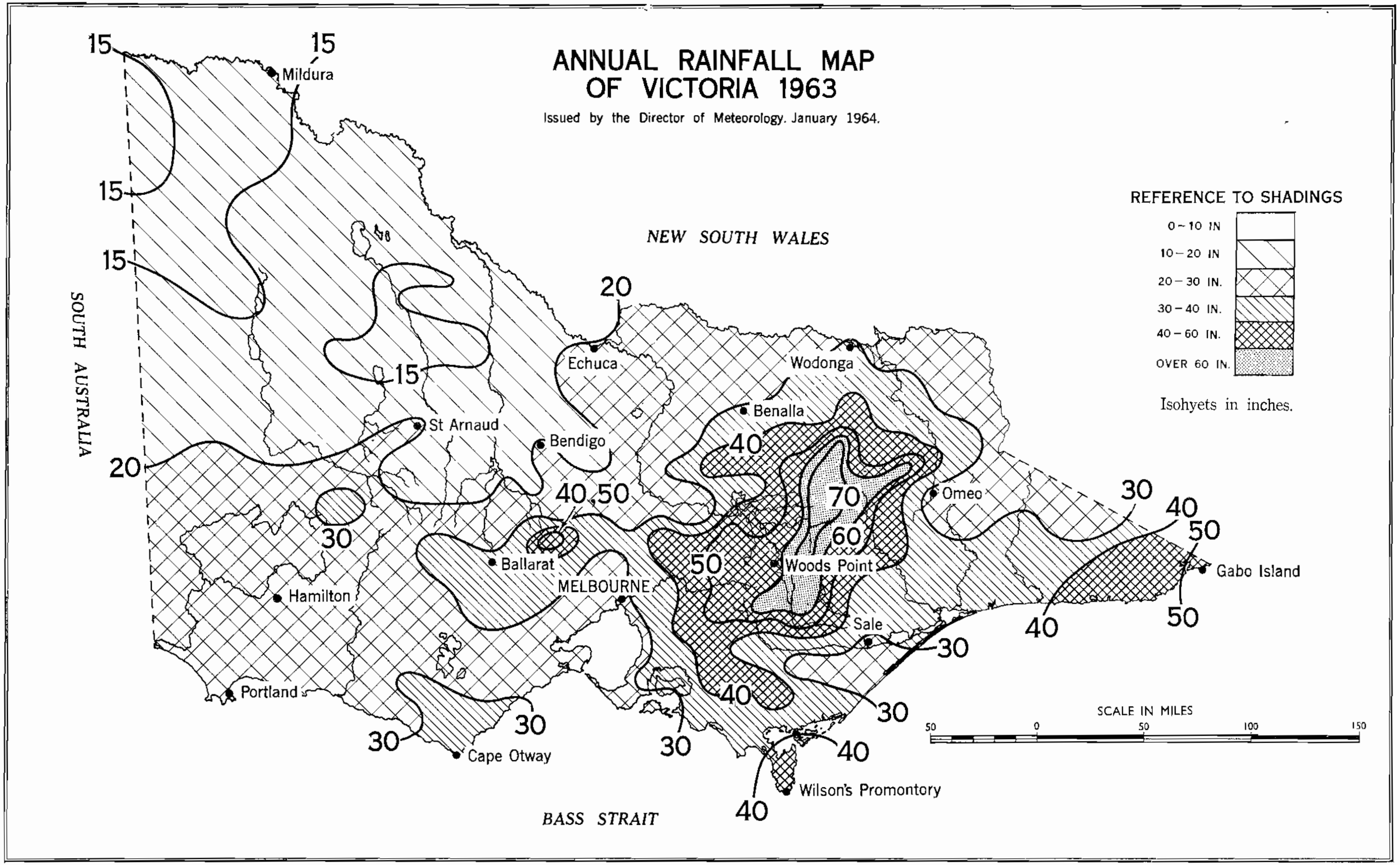
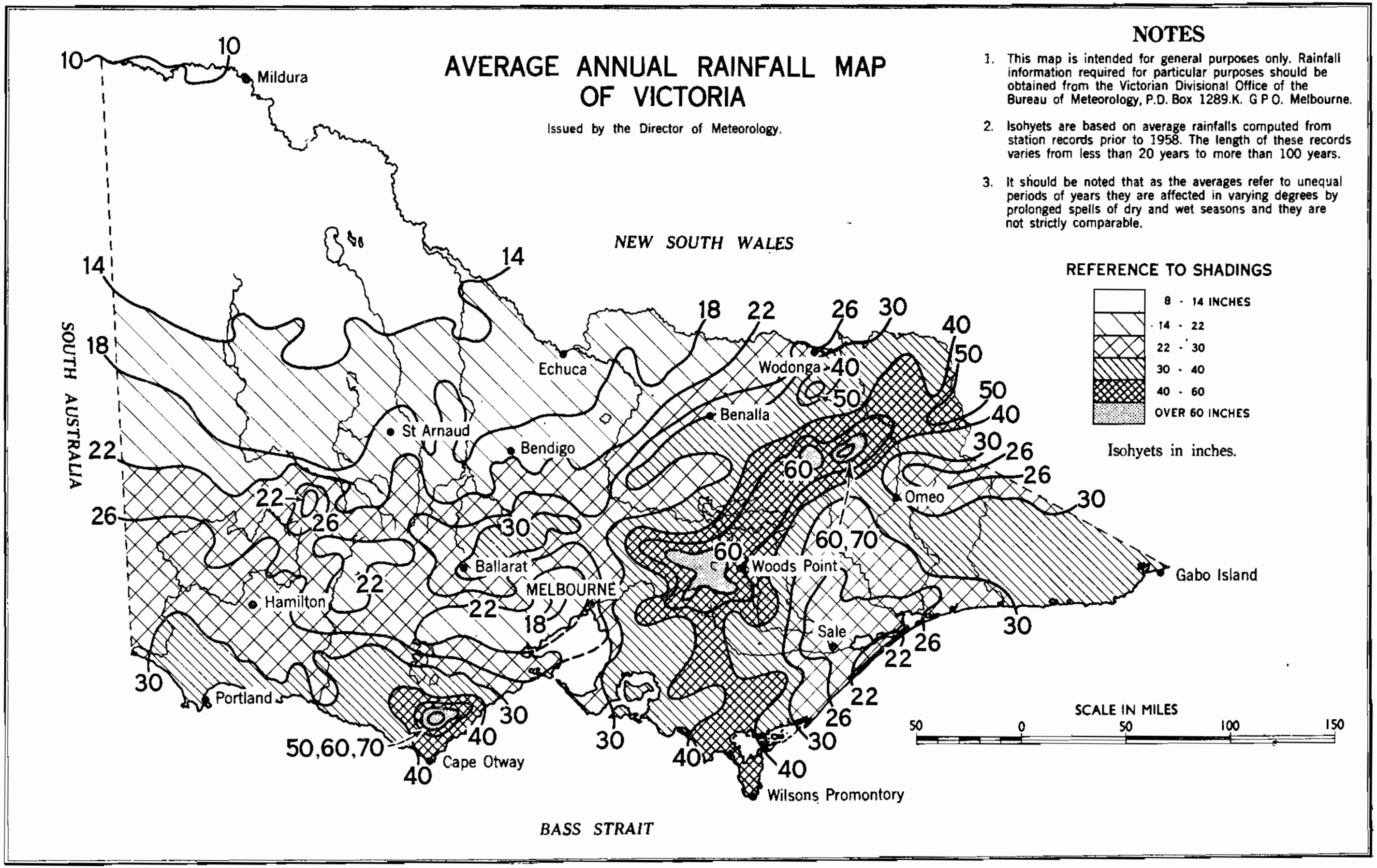

ANNUAL RAINFALL MAP
OF VICTORIA 1963
Issued by the Director of Meteorology. January 1964.
REFERENCE TO SHADINGS
0 – 10 IN
10 – 20 IN
20 – 30 IN.
30 – 40 IN.
40 – 60 IN.
OVER 60 IN.
Isohyets in inches.
NEW SOUTH WALES
SOUTH AUSTRALIA
BASS STRAIT
Mildura
Echuca
Wodonga
Benalla
St Arnaud
Bendigo
Omeo
Ballarat
MELBOURNE
Woods Point
Gabo Island
Hamilton
Sale
Portland
Cape Otway
Wilson's Promontory
SCALE IN MILES
50 0 50 100 150
15
20
30
40
50
60
70

FIGURE 5.



AVERAGE ANNUAL RAINFALL MAP OF VICTORIA
Issued by the Director of Meteorology.
NOTES
1. This map is intended for general purposes only. Rainfall information required for particular purposes should be obtained from the Victorian Divisional Office of the Bureau of Meteorology, P.O. Box 1289.K. G P O. Melbourne.
2. Isohyets are based on average rainfalls computed from station records prior to 1958. The length of these records varies from less than 20 years to more than 100 years.
3. It should be noted that as the averages refer to unequal periods of years they are affected in varying degrees by prolonged spells of dry and wet seasons and they are not strictly comparable.
REFERENCE TO SHADINGS
8 - 14 INCHES
14 - 22
22 - 30
30 - 40
40 - 60
OVER 60 INCHES
Isohyets in inches.
SCALE IN MILES
50
0
50
100
150
NEW SOUTH WALES
SOUTH AUSTRALIA
BASS STRAIT
Mildura
Echuca
Wodonga
Benalla
St Arnaud
Bendigo
Omeo
Ballarat
MELBOURNE
Woods Point
Hamilton
Sale
Gabo Island
Portland
Cape Otway
Wilsons Promontory
50,60,70
60,70

FIGURE 6.

under special conditions can be associated with some of the worst weather experienced over the State. Wind varies from day to night, from season to season, and from place to place. Examples of the diurnal variation are the sea breeze, which brings relief on many hot days along the coastline, and the valley or katabatic breeze, which brings cold air down valleys during the night. The latter is well developed in many hilly areas of Victoria, being the result of differential cooling after sunset. It springs up during the night, often suddenly, and continues after sunrise until the land surfaces are sufficiently heated again. The sensitive equipment required to measure extreme wind gusts has been installed at only about five or six places in the State and to date the highest value recorded is just slightly over 90 m.p.h. There is no doubt, however, that stronger gusts have been experienced over the State, although not in the vicinity of a recording anemometer. A number of tornadic squalls have been experienced and from the severe local damage engineers have estimated wind strengths over 100 m.p.h. It is considered that any place in Victoria could feasibly experience at some time a local gust of 100 m.p.h. or more.

Droughts

Since records have been taken, there have been numerous dry spells in various parts of Victoria, most of them of little consequence but many widespread enough and long enough to be classified as droughts. The worst drought since white settlement in Australia occurred in the period 1897 to 1902. Since 1945 there have been no serious droughts in Victoria, nor serious dry spells with a duration greater than twelve months. The severity of major drought or dry spells is much lower in Gippsland and the Western District than in Northern Victoria. An approximate idea may be formed of the liability of these areas to drought or dry spells from the following table which shows the figures for total duration of unbroken dry periods :—

Northern Victoria : 412 months in 98 years of records.
Western Victoria : 222 months in 94 years of records.
Gippsland : 291 months in 77 years of records.

Of the above totals, 88 per cent. are due to droughts of a duration of twelve months or more in the North, 77 per cent. in the West, and 69 per cent. in Gippsland.

The figures are taken from the publication " Droughts in Australia ", Bulletin Number 43 of the Commonwealth Bureau of Meteorology, published in 1957. Readers are referred to this publication for a definitive treatment of the subject of droughts in Victoria.

Thunderstorms

Thunderstorms occur far less frequently in Victoria and Tasmania than in the other two eastern States. They occur mainly in the summer months when there is adequate convective heat to provide energy. On an average, more than 20 per year occur on the North-Eastern Highlands and in parts of the Northern Country, but particularly in the north-east. Melbourne has an average of less than three in November, and in each of the summer months. Isolated severe wind squalls and tornadoes sometimes occur in conjunction with thunderstorm conditions, but these destructive phenomena are comparatively rare. Hailstorms affect small areas in the summer months ; and showers of small hail are not uncommon during cold outbreaks in the winter and spring.

Humidity

By and large, humidity in the lower atmosphere is much less over Victoria than in other eastern States. This is because the extreme south-east of the continent is mostly beyond the reach of tropical and sub-tropical air masses. For several periods in the summer, however, air from the Tasman Sea has a trajectory over Bass Strait and other parts of the State, and it is then that the moisture content rises to show wet bulb temperatures above 60° F. The incidence of high humidity is important to the vine and fruit industry, tobacco growers, and wheat farmers.

Evaporation

Measurements of evaporation in Victoria are made with the standard form of evaporation tank at about 27 stations, about half of which are owned by the Commonwealth Bureau of Meteorology. Results from these stations show that evaporation exceeds the average annual rainfall in inland areas, especially in the north and north-west, by about 40 inches. In all the highland areas and the Western District the discrepancy is much less marked, and in the Central District and the lowlands of East Gippsland annual evaporation exceeds annual rainfall by 8 to 15 inches. Evaporation is greatest in the summer months in all districts. In the three winter months, rainfall exceeds evaporation in many parts of Victoria, but not in the north and north-west.

As a consequence of the awakening of various authorities to the vital importance of evaporation in agricultural and hydrological studies, the Australian network of recording stations has almost doubled during the past twenty years.

Rainfall Reliability

It is not possible to give a complete description of rainfall at a place or in a district by using a single measurement. The common practice of quoting the annual average rainfall alone is quite inadequate in that it does not convey any idea of the extent of the variability likely to be encountered. Examination of rainfall figures over a period of years for any particular place indicates a wide variation from the average ; in fact it is rare for any station to record the average rainfall in any particular year. Thus for a more complete picture of annual rainfall the variability or deviation from the average should be considered in conjunction with the average.

Rainfall variability assumes major importance in some agricultural areas. Even though the average rainfall may suggest a reasonable margin of safety for the growing of certain crops, this figure may be based on a few years of heavy rainfall combined with a larger number of years having rainfall below minimum requirements. Variability of rainfall is also important for water storage design, as a large number of relatively dry years would not be completely compensated by a few exceptionally wet years when surplus water could not be stored.

Although variability would give some indication of expected departures from normal over a number of years, variability cannot be presented as simply as average rainfall.

Several expressions may be used to measure variability, each of which may have a different magnitude. The simplest form of variability is the range, i.e., the difference between the highest and lowest annual amounts recorded in a series of years. Annual rainfall in Victoria is assumed to have a " normal " distribution. These distributions can be described fully by the means and the standard deviation. To compare one distribution with the other, the coefficient of variation $\left(\frac{\text{standard deviation}}{\text{the average}}\right)$ has been used. The coefficient of variation has been calculated for the fifteen climatic regions of Victoria (see Fig. 7) for the 30 years 1913 to 1942 and the results are tabulated below in order of rainfall reliability :—

VICTORIA—RAINFALL VARIATION

District	Average Rainfall	Standard Deviation	Coefficient of Variation
	points*	points*	
1. West Coast	2960	347	0·117
2. West Gippsland	3468	519	0·150
3. Volcanic Plains	2390	388	0·162
4. East Gippsland	2940	485	0·165
5. East Central	3530	589	0·167
6. Wimmera South	1911	355	0·186
7. West Central	2350	446	0·190
8. Wimmera North	1583	321	0·203
9. North Central	2666	615	0·231
10. Mallee South	1326	334	0·252
11. Upper North-east	4299	1113	0·259
12. Lower North-east	2985	825	0·276
13. Upper North	1964	546	0·278
14. Lower North	1658	468	0·282
15. Mallee North	1155	344	0·298

*100 points=One inch.

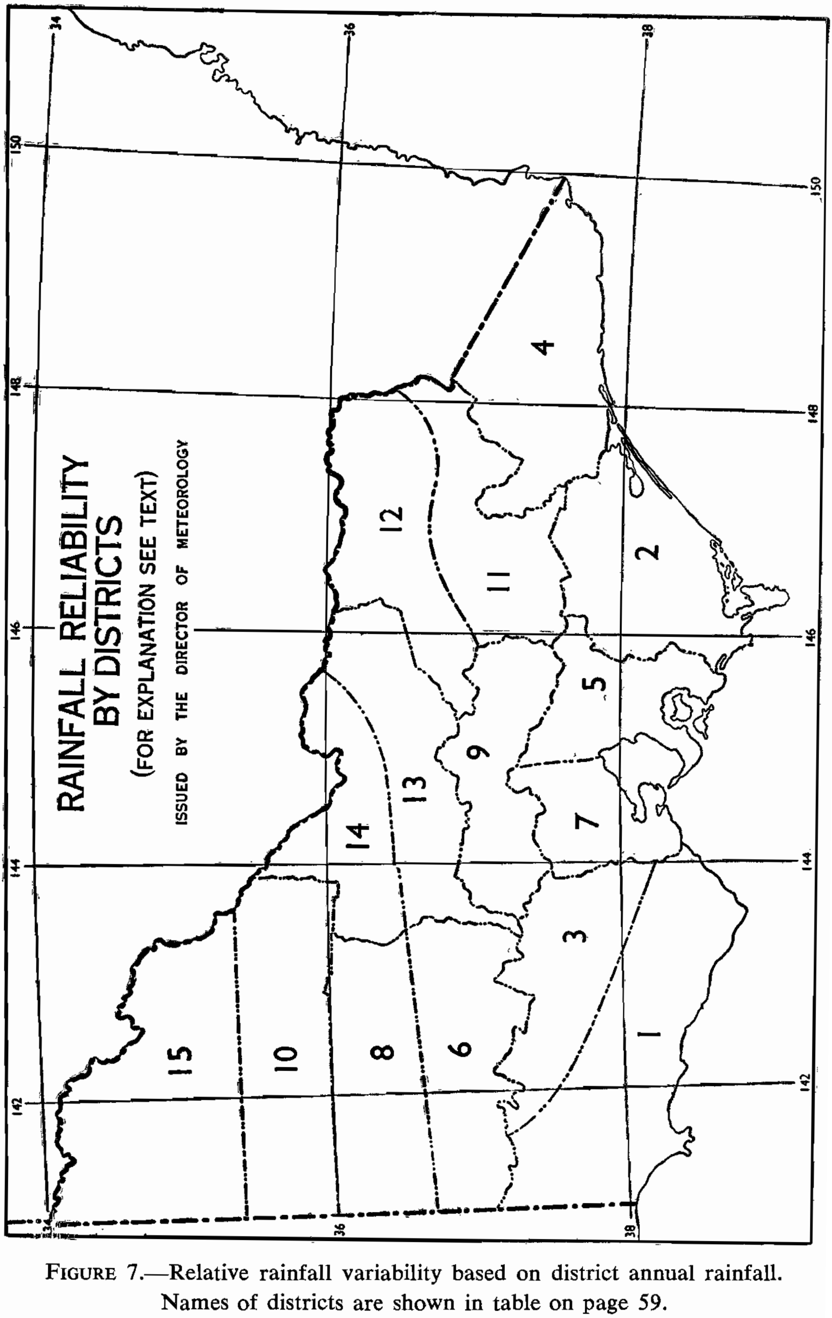


FIGURE 7.—Relative rainfall variability based on district annual rainfall. Names of districts are shown in table on page 59.

The higher the value of the coefficient of variation of the rainfall of a district, the greater the departure from the average and hence the more unreliable the rainfall.

Most of the elevated areas of eastern and southern Victoria normally receive over 40 inches and over 60 inches in some wetter sections. Interspersed between these wet mountainous areas are sheltered valleys which are deprived to some extent of their rainfall by neighbouring highlands. Along practically the whole south coastline of Victoria the average number of wet days (0·01 inches or more in 24 hours) is over 150, with an average rainfall below 30 inches. The average number of wet days a year is reduced to 100 at a distance of approximately 100 miles inland from the coast.

The variability of annual rainfall is closely associated with the incidence of drought. Droughts are rare over areas of low rainfall variability and more common in areas where this index is high.

AGRICULTURAL METEOROLOGY

Year Book 1964 (*33–34*).

Climate of Melbourne

Temperatures

The proximity of Port Phillip Bay bears a direct influence on the local climate of the Metropolis. The hottest months in Melbourne are normally January and February when the average is just over 78° F. Inland, Watsonia has an average of 81° F., whilst along the Bay, Black Rock, subject to any sea breeze, has an average of 77° F. This difference does not persist throughout the year, however, and in July average maxima at most stations are within 1° F. of one another at approximately 55° F. The hottest day on record in Melbourne was 13th January, 1939, when the temperature reached 114·1° F. which is the second highest temperature ever recorded in an Australian Capital City. In Melbourne, the average number of days per year with maxima over 100° F. is about four, but there have been years with up to twelve and also a few years with no occurrences. The average annual number of days over 90° F. is just on nineteen.

Nights are coldest at places a considerable distance from the sea such as at Watsonia, which has a good open exposure and where average minima are a few degrees lower than those observed in the City, where buildings may maintain the air at a slightly higher temperature. The lowest temperature ever recorded in the City was 27° F. on 21st July, 1869, and likewise, the highest minimum ever recorded was 87·0° F. on 1st February, 1902.

In Melbourne, the average overnight temperature remains above 70° F. on only about two nights a year and this frequency is the same for nights on which the air temperature falls below 32° F. Minima below 30° F. have been experienced during the months May to August, whilst even as late as October, extremes have been down to 32° F. During the summer, minima have never been below 40° F.

Wide variations in the frequencies of occurrences of low air temperatures are noted across the Metropolitan Area. For example, there are approximately ten annual occurrences of 36° F. or under around the bayside, but frequencies increase to over twenty in outer suburbs and probably to over 30 a year in the more frost susceptible areas. The average frost free period is about 200 days in the outer northern and eastern suburbs, gradually increasing to over 250 days towards the City, and approaches 300 days along parts of the bayside.

Rainfall

The range of rainfall from month to month in the City is quite small, the annual average being 25·91 inches over 143 days. From January to August, monthly averages are within a few points of two inches ; then a rise occurs to a maximum of 2·71 inches in October. Rainfall is relatively steady during the winter months when the extreme range is from half an inch to five inches, but variability increases towards the warmer months. In the latter period totals range between practically zero and over seven and a half inches. The number of wet days, defined as days on which a point or more of rain falls, exhibits marked seasonal variation ranging between a minimum of eight in January and a maximum of fifteen each in July and August. This is in spite of approximately the same total rainfall during each month and indicates the higher intensity of the summer rains. The relatively high number of wet days in winter gives a superficial impression of a wet winter in Melbourne which is not borne out by an examination of total rainfall.

The highest number of wet days ever recorded in any one month is 27 in August. On the other hand, there has been only one rainless month in the history of the Melbourne records—April, 1923. On occasions, each month from January to May has recorded three wet days or less. The longest wet spell ever recorded was sixteen days and the longest dry spell 40 days. Over four inches of rain have been recorded in 24 hours on several occasions, but these have been restricted to the warmer months, September to March. No fall above 2 inches in 24 hours has ever been recorded in the cooler months. Fogs occur on four or five mornings each month in May, June, and July, and average 21 days for the year. The highest number ever recorded in a month was twenty in June 1937.

Cloud and Sunshine

Cloudiness varies between a minimum in the summer months and a maximum in the winter, but the range like the rainfall is not great compared with many other parts of Australia. The number of clear days or nearly clear days averages two to three each month from May to August, but increases to a maximum of six to seven in January and February. The total number for the year averages 98. The high winter cloudiness and shorter days have a depressing effect on sunshine in winter and average daily totals of three to four hours during this period are the lowest of all capital cities. There is a steady rise towards the warmer months as the days become longer and cloudiness decreases. An average of nearly eight hours a day is received in January; however, the decreasing length of the day is again apparent in February, since the sunshine is then less in spite of a fractional decrease in cloudiness. The total possible monthly sunshine hours at Melbourne range between 465 hours in December and 289 in June under cloudless conditions. The average monthly hours, expressed as a percentage of the possible, range between 55 per cent. for January and February to 34 per cent. in June.

Wind

Wind exhibits a wide degree of variation, both diurnally, such as results from a sea breeze, etc., and as a result of the incidence of storms. The speed is usually lowest during the night and early hours of the morning just prior to sunrise, but increases during the day especially when strong surface heating induces turbulence into the wind streams, and usually reaches a maximum during the afternoon. The greatest mean wind speed at Melbourne for a 24 hour period was 22.8 m.p.h., whilst means exceeding 20 m.p.h. are on record for each winter month. These are mean values: the wind is never steady. Continual oscillations take place ranging from lulls, during which the speed may drop to or near zero, to strong surges which may contain an extreme gust, lasting for a period of a few seconds only, up to or even over 60 m.p.h. At Melbourne, gusts exceeding 60 m.p.h. have been registered during every month with a few near or over 70 m.p.h., and an extreme of 74 m.p.h. on February 18, 1951. At both Essendon and Aspendale wind gusts over 90 m.p.h. have been measured.

There have been occurrences of thunderstorms in all months ; the frequency is greatest during November to February. The greatest number of thunderstorms occurring in a year was 25. This figure was recorded for both 1928 and 1932.

Hail and Snow

Hailstorms have occurred in every month of the year; the most probable time of occurrence is from August to November. The highest number of hailstorms in a year was seventeen in 1923, and the greatest number in a month occurred in November of that year when seven hailstorms were reported. Snow has occasionally fallen in the city and suburbs; the heaviest snow storm on record occurred on 31st August, 1849. Streets and housetops were covered with several inches of snow, reported to be 1 foot deep at places. When thawing set in, floods in Elizabeth and Swanston streets stopped traffic causing accidents, some of which were fatal. One report of the event indicates that the terrified state of the aborigines suggested they had never seen snow before.

Victorian Weather Summary During 1963

Summer

The year began with a wet January, rainfall being up to five times the normal. The Australia Day holiday brought Melbourne the heaviest 24 hour rainfall it has ever experienced—4¼ inches fell by 9 a.m. on the 29th January. The monthly total of 692 points was also a record. Daytime temperatures were generally below normal, and there were comparatively few centuries. This cool and moist weather limited the fire risk, and there were only scattered grass and scrub fires, although the pattern changed in February, which was a drier month.

Autumn

About half of Victoria received more than normal autumn rain, the exceptions being the Wimmera, North-East, East Central, and Western Districts. Mean temperatures for the season were close to normal, although in the northern Mallee the maxima were lower than average, and those for the lower northern country were consistently warmer.

Winter

Mid-July brought record low minimum temperatures to many places in the Central District. Melbourne had its coldest morning for 34 years, with lowest readings ever recorded at Geelong (26° F.) and at Powelltown (23° F.) on the 4th July. Average temperatures for the season were a little below the long term figure, but rainfall was everywhere either close to or well above the normal.

Spring

The Spring, however, was dry, particularly in the Western District and the Northern Mallee, where rain was approximately 36 per cent. below that expected. This dry trend continued into December and much of the country was drying rapidly as the year came to a close.

Meteorological Records

The above particulars about climate have been furnished by the Commonwealth Bureau of Meteorology, and some figures are given in the following tables. In the first is shown the rainfall for each district for each of the years 1954 to 1963, together with the average rainfall covering a period of 30 years :—

VICTORIA—RAINFALL IN DISTRICTS
(Inches)

Year	Districts							
	Mallee	Wimmera	Northern	North Central	North Eastern	Western	Central	Gippsland
1954	13·41	17·68	21·22	29·88	35·58	25·92	30·93	34·02
1955	17·68	22·44	26·00	35·99	49·05	32·40	34·12	33·86
1956	20·85	24·31	31·45	41·17	55·59	34·02	34·29	44·25
1957	9·67	14·87	13·55	23·01	27·32	26·82	24·85	31·98
1958	15·45	17·65	21·40	31·57	37·78	29·05	28·99	35·42
1959	9·97	15·16	16·56	26·09	27·69	24·46	26·53	33·63
1960	18·08	24·75	22·70	38·45	40·16	36·01	34·98	37·26
1961	13·44	15·07	14·90	25·27	27·60	24·03	22·90	33·04
1962	11·29	17·69	18·85	27·77	33·78	25·99	26·07	31·41
1963	16·15	18·55	20·66	30·46	35·49	25·87	28·36	35·61
Averages* ..	12·49	17·52	18·09	28·16	34·81	27·59	28·89	33·47

* Averages for a standard 30 years' period 1911–1940.

The heaviest rainfall in the State occurs in the Eastern Highlands (from the Yarra watershed to the Upper Murray), in the Cape Otway Forest in the Western District, and in the South Gippsland, Latrobe and Thomson Basin sections of the Gippsland District. The lightest rainfall is in the Mallee District, the northern portion of which receives on the average from 10 to 12 inches only per year.

The following table shows the average monthly rainfall and mean temperatures recorded in various Victorian country centres and is followed by a graph of the district monthly rainfall for 1963 :—

VICTORIA—WEATHER CONDITIONS IN SELECTED VICTORIAN TOWNS: AVERAGE VALUES

(Points : 100 = 1 inch).

Locality		Legend No.*	January	February	March	April	May	June	July	August	Sept.	October	Nov.	Dec.
MALLEE	Mildura	1	73	90	70	55	101	105	91	101	96	100	84	71
		2	89·8	90·0	84·4	74·5	66·9	60·4	59·5	63·9	69·9	76·5	83·2	88·2
		3	61·0	61·7	57·2	50·5	45·6	41·3	40·5	42·5	46·1	50·9	55·4	59·6
	Ouyen	1	63	113	66	80	121	131	117	122	133	116	78	103
		2	89·4	86·0	82·1	73·1	65·7	59·4	58·7	62·8	68·9	74·1	79·9	86·7
		3	58·7	58·4	54·1	47·8	44·5	40·7	39·8	40·6	43·3	47·2	52·6	56·0
WIMMERA	Horsham	1	75	121	74	123	178	198	189	190	198	148	126	137
		2	85·1	86·3	80·2	70·7	63·0	56·6	56·0	59·0	64·1	70·2	77·2	82·7
		3	55·2	55·9	51·9	47·0	42·9	40·2	38·8	39·9	41·9	45·1	49·6	53·2
	Nhill	1	64	106	64	99	154	175	172	178	175	129	113	118
		2	84·3	85·0	79·6	70·5	63·3	57·0	56·5	59·4	64·4	70·4	76·9	82·2
		3	55·2	56·3	52·8	47·6	43·9	40·4	38·6	40·1	42·5	45·7	49·7	53·8
WESTERN	Ballarat	1	126	179	183	213	243	267	268	292	284	241	208	234
		2	75·7	76·9	71·6	63·0	56·3	50·4	49·8	52·5	57·1	62·4	67·4	72·5
		3	50·5	52·9	50·1	45·8	42·6	39·5	38·4	39·4	41·2	43·6	46·0	49·3
	Hamilton	1	110	145	143	214	264	265	277	306	300	248	199	194
		2	77·3	78·7	74·2	66·3	60·1	55·1	54·1	56·2	59·9	64·8	69·1	74·0
		3	50·7	52·4	49·9	46·3	43·2	40·2	39·3	40·4	42·3	44·0	46·3	49·2
	Warrnambool	1	107	147	151	199	276	280	298	286	261	221	193	160
		2	69·9	70·9	69·1	64·6	60·5	56·3	55·6	56·9	59·4	62·6	64·8	67·9
		3	54·7	56·0	54·2	51·0	47·8	44·8	43·6	44·4	46·2	48·1	50·2	53·0
NORTHERN	Bendigo	1	114	150	127	149	197	226	221	211	204	170	125	133
		2	83·0	83·9	78·1	68·8	61·3	54·8	54·2	57·0	62·5	68·9	75·2	80·5
		3	56·5	58·3	54·0	48·2	43·7	40·7	39·4	40·2	43·0	46·7	50·9	54·9
	Echuca	1	84	130	104	137	154	181	172	165	158	166	105	117
		2	86·2	86·8	80·7	71·1	63·6	56·7	56·0	59·0	64·7	71·7	78·5	84·1
		3	58·9	60·1	55·9	49·3	44·5	41·3	40·2	41·2	44·3	48·6	52·7	56·9

NORTH CENTRAL ..	Alexandra ..	1	149	170	194	222	242	289	276	304	268	273	198	199
		2	84·6	85·3	78·8	69·1	61·3	53·9	53·6	57·3	62·6	69·2	75·7	81·9
		3	52·5	53·7	49·1	43·8	39·7	37·5	36·8	37·8	40·3	43·3	46·7	50·7
	Kyneton ..	1	129	170	176	215	270	331	328	324	287	249	183	228
		2	81·2	81·5	74·7	65·0	57·5	51·0	50·1	53·1	59·1	65·2	72·3	77·5
		3	49·8	50·5	47·2	42·3	38·5	36·2	34·8	35·3	37·9	40·4	44·1	47·6
CENTRAL ..	Geelong ..	1	104	157	176	165	175	198	185	180	209	196	202	185
		2	76·2	77·3	73·9	67·6	62·1	57·2	56·5	59·0	62·8	67·3	70·3	73·8
		3	55·4	56·9	54·7	50·7	46·6	43·1	42·0	42·9	45·0	47·5	50·4	53·7
	Mornington	1	184	143	205	249	255	297	266	264	278	265	223	207
		2	76·5	77·1	73·9	66·8	61·5	56·3	54·9	56·7	60·6	64·4	69·0	73·6
		3	55·2	55·9	54·4	50·5	47·8	44·5	42·9	43·8	45·9	48·4	51·1	53·4
NORTH EASTERN ..	Omeo ..	1	227	211	231	184	187	219	208	214	243	250	204	241
		2	77·8	78·7	73·0	65·2	57·9	51·4	50·5	54·0	59·7	65·4	71·2	75·9
		3	48·3	48·9	45·8	40·2	35·8	33·0	31·9	33·2	37·3	39·7	43·2	47·1
	Wangaratta ..	1	151	175	161	199	209	312	261	268	224	244	163	190
		2	86·7	87·5	80·9	71·3	63·5	56·4	55·2	58·3	63·8	70·2	78·2	84·1
		3	58·5	59·3	54·0	46·9	41·9	39·3	38·1	39·7	42·8	46·7	51·4	56·3
WEST GIPPSLAND ..	Wilson's Promontory	1	188	212	250	328	385	468	411	417	365	328	268	237
		2	66·7	68·2	66·4	62·3	58·6	55·1	53·9	55·1	57·3	60·3	62·2	65·1
		3	56·9	58·7	57·4	54·7	52·1	49·0	47·7	47·7	48·8	50·3	52·2	55·1
	Yallourn ..	1	267	272	266	362	226	327	280	338	289	330	308	271
		2	77·7	77·4	74·3	65·8	60·7	55·3	54·9	57·3	62·0	66·3	70·2	75·3
		3	53·7	54·7	49·1	48·2	43·9	40·5	38·8	40·5	42·5	45·7	49·1	52·3
EAST GIPPSLAND ..	Bairnsdale ..	1	248	209	264	202	159	216	206	173	208	268	219	263
		2	75·3	76·1	73·0	67·5	62·5	57·5	57·0	59·5	63·2	67·5	70·6	74·0
		3	53·5	54·5	51·7	46·9	42·5	38·8	38·1	39·6	42·7	46·1	49·0	52·4
	Orbost ..	1	280	223	325	263	243	273	301	228	245	284	237	313
		2	76·5	75·6	73·1	67·5	62·5	57·9	58·0	60·0	64·0	66·4	70·2	74·3
		3	54·3	54·5	52·5	48·2	44·2	40·3	38·5	39·7	42·1	45·9	49·7	52·0

NOTE: Average for a standard 30 years' period 1911–40.

* Legend :—1. Average Monthly Rainfall in Points. 2. Average Daily Maximum Temperature (°F.). 3. Average Daily Minimum Temperature (°F.).

VICTORIA—DISTRICT MONTHLY RAINFALL: AVERAGE AND 1963

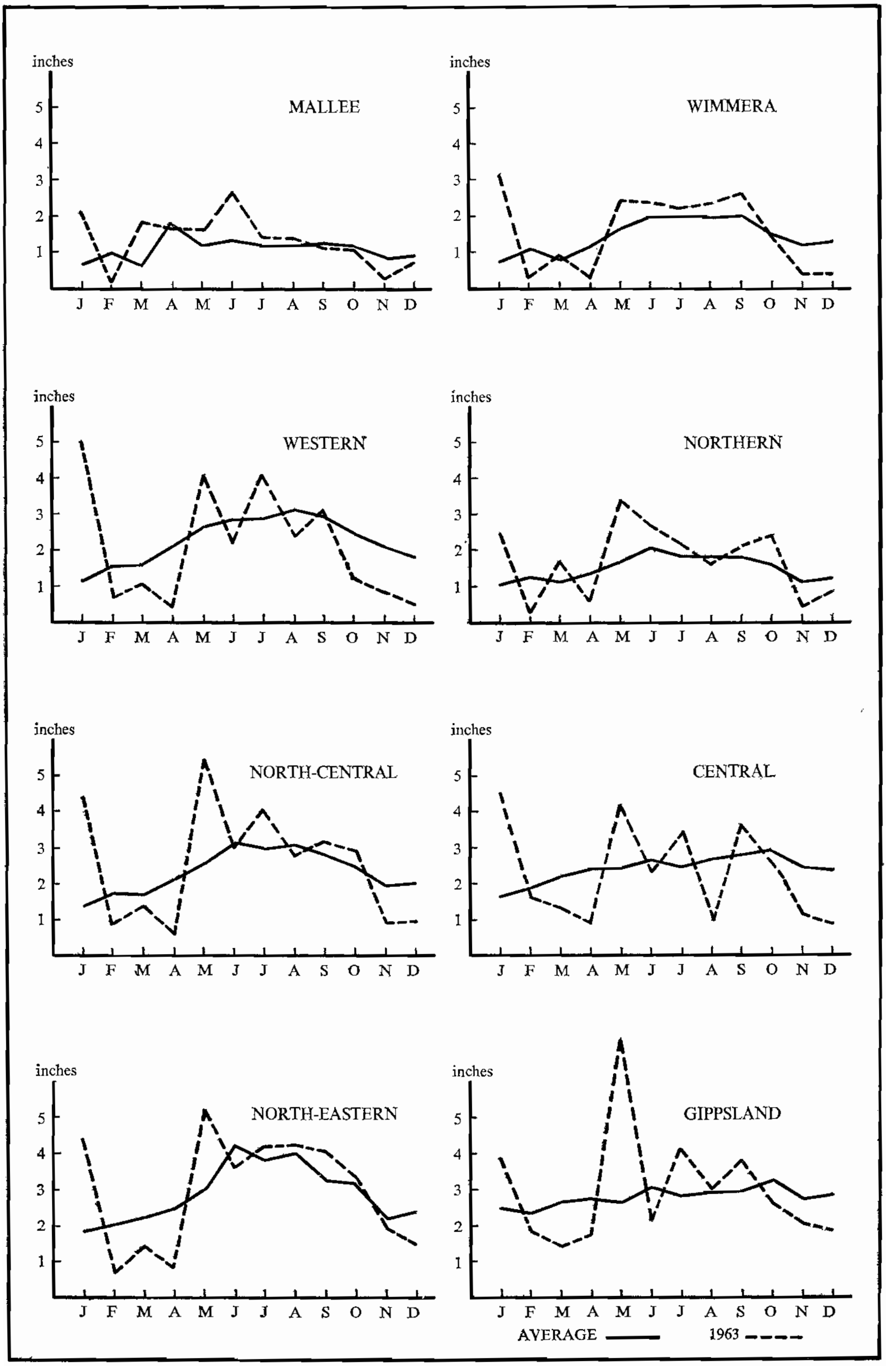


FIGURE 8.

The means of the climatic elements for the seasons in Melbourne deduced from all available official records are given in the following table :—

MELBOURNE—MEANS OF CLIMATIC ELEMENTS

Meteorological Elements	Spring	Summer	Autumn	Winter
Mean Pressure of Air (Inches)	29·971	29·920	30·075	30·076
Monthly Range of Pressure of Air (Inches)	0·889	0·763	0·816	0·973
Mean Temperature of Air in Shade (° F.) ..	57·7	66·7	59·4	50·1
Mean Daily Range of Temperature of Air in Shade (° F.)	18·7	21·1	17·4	14·0
Mean Relative Humidity (Saturation = 100)	64	59	69	74
Mean Rainfall in Inches	7·36	6·10	6·58	5·86
Mean Number of Days of Rain	40	25	34	44
Mean Amount of Spontaneous Evaporation in Inches	10·23	17·33	8·09	3·79
Mean Daily Amount of Cloudiness (Scale 0 to 8)*	4·8	4·2	4·7	5·1
Mean Number of Days of Fog	1	1	6	12

* Scale : 0 = clear, 8 = overcast.

In the following table are shown the yearly means of the climatic elements in Melbourne for each year 1959 to 1963. The extremes between which the yearly mean values of such elements have oscillated in the latter periods are also included.

MELBOURNE—YEARLY MEANS AND EXTREMES OF CLIMATIC ELEMENTS

Meteorological Elements	1959	1960	1961	1962	1963
Atmospheric Pressure (Inches)—					
Mean	30·080	29·996	30·050	30·010	30·012
Highest	30·669	30·570	30·620	30·594	30·597
Lowest	29·233	29·157	29·367	29·366	29·315
Range	1·436	1·413	1·253	1·228	1·282
Temperature of Air in Shade (°F.)—					
Mean	59·5	58·8	61·1	60·1	59·5
Mean Daily Maximum ..	68·8	67·6	70·4	68·6	68·0
Mean Daily Minimum ..	50·7	50·0	51·9	50·7	51·0
Absolute Maximum	109·0	105·0	107·0	104·0	99·0
Absolute Minimum	29·5	31·3	33·4	31·8	29·3
Mean Daily Range	18·4	17·5	18·5	17·8	17·5
Absolute Annual Range ..	79·5	73·7	73·6	72·2	69·7
Terrestrial Radiation Mean Minima (°F.)	47·5	45·9	48·2	47·3	48·5
Rainfall (Inches)	25·84	33·50	22·05	23·06	29·04
Number of Wet Days	131	162	129	140	149
Year's Amount of Free Evaporation (Inches)	38·43	41·44	42·17	43·21	37·79
Percentage of Humidity (Saturation = 100)	65	65	63	61	67
Cloudiness (Scale 0 to 8)* ..	4·6	4·9	4·4	4·5	4·7
Number of Days of Fog ..	24	21	18	9	20

* Scale : 0 = clear, 8 = overcast.

An estimate of the areas of the State subject to different degrees of average annual rainfall, and the actual distribution of rainfall in Victoria as shown by area for 1962 and 1963 are shown in the following table :—

VICTORIA—DISTRIBUTION OF AVERAGE AND ANNUAL RAINFALL

Rainfall (Inches)	Area ('000 Square Miles)		
	Average	1962	1963
Under 10	Nil	8·2	Nil
10–15	19·7	10·2	7·8
15–20	13·4	14·8	21·6
20–25	15·7	33·0	17·9
25–30	15·8	15·0	14·9
30–40	14·2	4·0	14·2
Over 40	9·1	2·6	11·5