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PHYSICAL ENVIRONMENT

Minerals in Victoria

History

General

Victoria owes its rapid settlement and increase in population to the rich gold discoveries in the early 1850s. The discovery of gold, which attracted migrants in large numbers and led to their permanent settlement, quickly reached its peak in 1856, with a production of 3 mill. oz. From the period 1851 to 1857, the population of Victoria rose from 77,345 to 408,998, and continued to increase until more than one million had settled by 1891. Between the years 1851 and 1967, Victoria produced over 78 mill. oz gross of gold or 40 per cent of the total for Australia, and the greater part of this production came from the Bendigo and Ballarat fields.

The effects of gold discovery were far reaching. One major consequence of the gold rushes was that Melbourne became an important financial centre—a position it retains to the present day. Exploitation of these deposits required improved transportation facilities and led to the rapid development of railways to serve the mining communities. At the same time, improved access to large areas of good land, aided by rapidly increasing population, allowed a considerable expansion of farming and pastoral industries.

Although for a long time gold production dominated the mining industry, more recently mining activities have been characterised by marked progress in open-pit mining, particularly of construction materials and brown coal. At the present time, the bulk of mineral production is accounted for by fuels and non-metallic minerals, production of brown coal having increased threefold between 1950 and 1967.

The spectacular discoveries in the metalliferous mining field have, however, had an effect of promoting exploration for base metals throughout the State, and large scale geophysical, geochemical and airborne surveys are being undertaken by companies, both large and small. Introduction of legislation, in 1964, giving mineral exploration rights over areas of up to 1,000 sq miles per licence, has given security of tenure to those who are prepared to undertake costly mineral exploration. The granting of exploration licences gives the licensee, at his election, prior rights to mining leases for mining a number of minerals within the area.

Gold

Before the official record of gold discovery by Louis Michel at Andersons Creek, Warrandyte, and by James Esmond at Clunes, both in July 1851, gold had been found in many places; the first, in Gippsland, was found in 1839 by Strzelecki and this information was published in London. For various reasons, gold prospecting and mining were discouraged by the authorities, but the Californian and Bathurst finds, of 1849 and February 1851, respectively, brought about a revision of policy, and a reward of £200 ($400) was soon offered for the discovery of gold within 200 miles of Melbourne.

On 1 July 1851, Victoria became a Colony in its own right; on 5 July, recognition was given to gold mining and finds of gold, previously made at Clunes and Warrandyte, were officially recorded.

It was not until 1854, however, that gold rewards were paid, when the Government Gold-Rewards Committee (set up to inquire into gold discoveries) awarded £1,000 ($2,000) to Esmond for the Clunes discovery, £1,000 ($2,000) to Michel for that at Warrandyte, while Dr Bruhn was awarded £500 ($1,000) for discoveries at Mt Franklin, and William Campbell, £500 ($1,000) for other discoveries at Clunes.

The gold rush began in July and August 1851 and was to alter completely the economy of the State from one based solely on agriculture to one based on mining. The rush which started at Clunes spread rapidly, and gold fever ran high through the population. Finds were made in and around the city of Melbourne. The Flagstaff Gardens were "salted" with brass filings, which caused a minor flurry. Gold was reported at Newtown, near Geelong, at Heidelberg, Bacchus Marsh, Kangaroo Ground, and Buninyong, and on 24 August, Ballarat saw a rush that, by late September, swelled the population to 6,000 miners, some of whom were reputed to have made £100 ($200) a day. This pattern was followed at Spring Hill, Creswick, Daylesford, Mt Alexander, and Forest Creek, which was to develop into the Castlemaine Gold Field. In mid-October, two ladies were reported to be digging on Bendigo Creek, initiating work which was to develop the richest goldfield in the State.

By the end of 1851 there was a thriving economy, based on gold. By this time, gold had also been found on Smythes Creek, Broken River, the Upper Delatite, Mitta Mitta, Mitchell and Tambo Rivers, and at Omeo and Bendock. The year 1852 was marked by both discovery and development, particularly at Bendigo where 475,000 oz were produced. Some idea of the population increase can be gained from the fact that, in October of this year, some 6,000 men left Bendigo for Wedderburn.

In these early years, the mining of gold was confined to the accessible gravels in the gullies and creeks. Gold was readily recovered from material by washing in dishes or cradles. As the treatment of larger amounts of gold bearing material developed, the simpler methods gave way to more elaborate washing methods with larger and longer sluice-boxes, fitted with cross-bars or riffles. As water washed the gravel and clay along the sluice, the riffles served to retain the heavy gold.

It was not long before miners came to realise that the bottom of many of the gold-bearing gravel deposits did not represent the true bed of the old stream, and that alluvial gold could be expected to occur in lower horizons, down to the valley floor. The deposits of buried streams, or water-courses, came to be known as

" deep leads ", a local term which has persisted to the present day. Such buried placer deposits were to provide large quantities of gold, but many of the workings proved to be very dangerous, because the water saturated strata were unstable and the underground workings were subject to sudden flooding, by both mobile sand and water.

Bendigo developed rapidly in 1852, as did Ballarat in 1853. During the first rush at Ballarat the rich gravels of Golden Point were mined. Later, deposits were found at Prince Regent Gully, White Flat, Sailors Gully, Scotchmans, and New Chum. Early in 1853, miners from New South Wales arrived at Beechworth to take advantage of the discoveries that had hitherto received little attention. In May, the McIvor (Heathcote) field was discovered and gold was also found at Steiglitz, Mt Tarrengower (Maldon), and Stawell.

In 1854, attention was directed to the sources from which alluvial gold came, that is, the quartz reefs within older rocks. The first stamp battery, a mechanical form of the ancient mortar and pestle, was set up to crush gold-bearing reef quartz taken from the Specimen Hill reefs, at Bendigo. The erection of similar stamps, throughout the other fields, followed very quickly, and quartz-crushing soon became a dominant feature of the goldfields. Reef mining, necessitating hard rock underground methods, called for a different type of miner, while the heavy machinery necessitated the establishment of heavy industries. This caused demand for specialised labour. By the end of 1854, the population of Ballarat had reached between 30,000 and 40,000 persons. During this year also, grievances among the miners, regarding an unjust licensing system and the manner in which licensing fees were collected, led to meetings of protest and ultimately riot, in which the Eureka Hotel was burned. Finally on 29 November, open armed revolt flared and was only suppressed by 3 December after many were killed and injured. Although the revolt collapsed, it was instrumental in bringing about great changes in the goldfields administration.

The Stawell, Ararat, and Great Western fields were discovered in 1857, as were Bealiba, Wehla, Craigie, and Moliagul. Mt Hope in the Mallee was the scene of tragedy in the hot summer of 1857–58 when lack of water resulted in the loss of life of both men and animals. During 1858, the " Welcome " gold nugget, weighing 2195 oz, was found on ground in Yarrowee Creek at Ballarat. At this time, placer deposits were becoming exhausted and the total production of 686,230 oz for 1857 fell to 467,223 oz in 1859.

Demand for capital for extensive underground development of both buried placer and quartz-reef mines resulted in a Parliamentary Act, which provided for the formation of limited liability companies.

Further afield, gold was found at Gaffneys Creek and Enochs Point on the Big River and gold was mined actively in these areas for over a hundred years. One mine, the A 1 Consolidated, was taken over by a new company in 1969.

By 1860, Bendigo and Ballarat were settled cities. Quartz mining had become the norm. Gold mining in the swarm of dykes running through the Walhalla–Woods Point Belt opened up an area containing the richest mine of the State. Over their lives, the Long-Tunnel and Long-Tunnel-Extended Mines, on Cohen's Reef at Walhalla, produced 1,285,300 oz of gold, from 1,206,600 tons of ore. During 1860 also, the gold-antimony veins of Costerfield were discovered and became major producers of gold and stibnite (antimony sulphide). During the first decade, Victoria exported more than 23 mill. oz gross of gold, representing 34 per cent of the world's gold output for this period.

In 1862, the New Zealand gold rush, which had attracted many Victorians in 1861, ended and these men returned to steady employment at Ballarat, where development difficulties, associated with shaft sinking and de-watering of mines, had been overcome.

Although a number of finds opened up new fields between 1863 and 1906, these lacked the fervour and excitement of earlier days. The introduction of a Crown Leasing System, in 1866, gave security of tenure to companies which were obliged to raise increasingly greater amounts of development capital. A secure leasing system increased speculation and interest in mining with the result that a large number of shafts were sunk on many reefs which proved to be very rich. In 1870, however, a financial collapse resulted in share losses which were estimated to be over £2 m ($4 m) in Ballarat alone. The population fell from 50,835 in 1869 to 44,650 in 1871.

The Garden Gully line of reefs at Bendigo was developed in 1873, followed by the Virginia and New Moon lines in 1900, and the Deborah in 1930. Exploitation of large volumes of low grade alluvial materials was made possible, at the turn of the century, by methods of hydraulic sluicing and dredging. Apart from the obvious advantages of large scale operations, the tailings from dredging operations were passed back into the pond on which the dredge floated and the areas later re-soiled. This method of gold winning was very productive, particularly in the Ovens Valley in north-east Victoria, where more than forty dredges, one of which was the largest in the Southern Hemisphere, were in operation.

After a peak production of about 3 mill. oz in 1856, gold production progressively fell to just over 500,000 oz in 1891. A slight revival occurred until 1902 but production again fell until it was negligible in the late 1920s. During the depression years of the early 1930s, the Government encouraged mining and prospecting, with the result that production increased until 1940, when the Second World War diverted men and materials to strategic industries. After the war, gold mining revived for a small production of gold, but by late 1968, the Wattle Gully Mine at Chewton was the only listed gold mining company in operation. During this post-war period, a pegged gold price was one factor contributing to the operations of a number of mines becoming uneconomic.

Victorian gold production for each decade is listed below :

VICTORIA—GOLD PRODUCTION
(Gross Oz)

1851–1860	23,334,263
1861–1870	16,276,566
1871–1880	10,156,297
1881–1890	7,103,438
1891–1900	7,476,038
1901–1910	7,643,275
1911–1920	3,297,628
1921–1930	652,178
1931–1940	1,171,082
1941–1950	911,734
1951–1960	558,831
1961–1967	181,947
Total	78,763,277

Other Resources

Although other metallic minerals have been mined including (in order of value) tin, antimony, copper, molybdenite and wolframite, gold accounted for $674m in a total of $680m. Production of these metallic minerals, being mainly from small ore bodies, has generally depended on current metal price fluctuations.

The future of metalliferous mining in Victoria now depends upon renewed interest in the scarcer, higher priced metals, and the extent to which modern surface and sub-surface exploration methods are successful. In contrast to the gradual decline in production of metallics, non-metallic production has increased steadily. Brown coal operations in the Latrobe Valley rank amongst the world's major workings, and although coal had been mined from Yallourn North since 1889, major development was the direct result of strikes on the New South Wales coal fields shortly after the First World War. Since 1924, more than 350 mill. tons of coal have been mined from Yallourn and Morwell and total reserves are currently estimated at 20,000 mill. tons to 40,000 mill. tons, of which 10,000 mill. tons are economically recoverable. Lesser production is from Anglesea, where 115 mill. tons have been proven, while smaller quantities are mined at Bacchus Marsh.

Matching the increase in brown coal production is that of construction materials. The main products are road and concrete aggregates, sand for concrete, lime for Portland cement, clay for paper-filler, porcelain, brick and pipe, and gypsum for plaster and agricultural purposes.

Although construction materials form a most important part of the State's resources, these are not described in this article. Neither are the highly significant discoveries of oil and natural gas in Bass Strait which have been noted in detail in the 1968 and 1969 *Victorian Year Books*. Another omission, related to minerals, is that of salt. The section following describes the geological setting of the deposits under two headings. The first group, magmatic minerals, are those derived from hot, molten, deep-seated rocks (magmas), intrusive into the outer crust of the Earth, while the second group includes the sedimentary and residual deposits.

Sedimentary rocks are those derived from the erosion of pre-existing rocks, transported by rivers and deposited beneath the rivers themselves, in lakes, or in the sea. Residual deposits are those derived in place from the alteration of rock by external agencies such as the weather.

The third section of the article treats each mineral and describes its uses, properties, and occurrences.

Magmatic Mineral Deposits: Their Geological and Tectonic Setting

The Australian continent is divided into two major geological regions : the areas of relatively stable, old rocks of the central and western parts, and those of the east in which instability has been greater during Palaeozoic times. Geological activity, in the form of intense crustal movements, although somewhat reduced, has persisted to the present time. Within each of these regions, provinces may be recognised.

Victoria lies at the southern end of the unstable belt of the predominantly older group of Palaeozoic rocks of eastern Australia. Rocks of pre-Palaeozoic age are not exposed and the geological history of this belt has been one of crustal instability and intrusion of granitic rocks up to the Triassic period. Rocks of the oldest Palaeozoic period, the Cambrian, crop out as infaulted wedges along some of the narrow meridional belts of high angle thrust faulting, which are shown on geological maps of Victoria. These belts form boundaries of the structural units which control the distribution of Palaeozoic rocks of differing age.

In the mineral map of Victoria, the provinces shown are separated by fault belts, the most westerly running through Mt Stavely and Mt Drummond (Western), the second through Heathcote and Mt William (Central Victoria) and the third through Dookie, Mansfield, and Licola, bending from a south-easterly direction to south-west and extending on through Waratah Bay near Wilsons Promontory. The western and eastern-most provinces can be further subdivided. In the western, structural faults run south from Kerang, through Wedderburn, separating unfossiliferous sediments of possible Cambro-Ordovician age on the west from fossiliferous Lower Ordovician strata to the east. The eastern province is subdivided into an " Eastern Goldfields " and a Cobar sub-province, the latter being characterised by Lower Palaeozoic granitics, which extend from Cobar in Central New South Wales, south-east through the Beechworth-Yackandandah area on to Bullumwaal. If mineral occurrences and associations are considered, these structural units show certain regional differences, each province and sub-province exhibiting characteristic mineralisation.

These are shown on the accompanying mineral map and are as follows :

(1) *Western*

(*a*) Western Victorian Goldfield Province of gold-pyrite-pyrrhotite association of deep-seated, shear stresses (Stawell).

(*b*) West-Central Victorian Goldfield Province of gold-quartz association of fold and fissure structures (Bendigo–Ballarat).

(2) *Central*

Central Victorian Goldfield Province of gold-quartz-pyrite and antimony mineralisation of the fissure zones (Costerfield–Walhalla–Woods Point).

(3) *Eastern*

(*a*) Eastern Victorian Goldfield Province of gold-quartz fissure veins (Bright–Harrietville–Dargo).

(*b*) Cobar Province, within the Eastern Highlands, of lead-zinc-copper-gold mineralisation (Deddick-Buchan-Cassilis).

Western Victorian Goldfield Province

This province is bounded on the east by a faulted belt through Wedderburn running south to the west of Ballarat. No fossils have been found in the folded shales and sandstones and a considerable thickness of sedimentary rocks as far west as the Glenelg River may be of Cambrian to lowermost Ordovician age. The calc-silicate rocks, interbedded with greenstones, slates, and sandstones and intruded by basic rocks outcropping north of Casterton, and at depth at Stawell, are not matched by similar rocks in Central Victoria.

The gold occurrences of Stawell associated with quartzitic, talcose, and chloritic schists and greenstones, intruded by felspar-porphyry dykes, show a great similarity to the older rock occurrences, west of Victoria, whereas later Palaeozoic gold mineralisation in West Central and Central Victoria tends to be an association of gold and quartz. Total production of gold from Stawell was nearly 1,284,000 oz. Some gold associated with galena and sphalerite was mined in the St Arnaud area from branching fissure veins. Most gold from the Wedderburn, Landsborough and Avoca areas was alluvial.

West Central Victorian Goldfield Province

This belt, which lies between the meridia through Wedderburn on the west and Heathcote on the east, is essentially an area of strongly folded and faulted marine Ordovician sandstones, shales, and slates. Detailed structure and age can often only be elucidated by use of zone fossils which, in places, are abundant. Age ranges from Lower to Upper Ordovician.

Intruded into these folded sediments are granodiorite and granite batholiths but no direct genetic link between mineralisation and igneous intrusion can be established. All that can be deduced is that minerals and quartz veins were introduced during the initial stages of tectonic activity and pre-date the final stage of intrusion.

All non-placer gold of this region has been mined from quartz veins, intruding rocks of Lower Ordovician age. Mineralisation tapers off in passing up the sequence until no gold is to be found in Middle Ordovician rocks. The association is one of free gold and quartz.

Commencing with the lowermost Ordovician, the Lancefieldian Stage, mineralisation is characterised by precipitation in favourable horizons. For example, gold enrichments are asssociated with thin graphite or pyrite laminae, called "indicators" by miners because of the persistence of occurrence, the ease with which they can be traced, and their apparent association with gold. Rich deposits of this type were mined at Wedderburn, Inglewood, Tarnagulla, Moliagul, Dunolly, Maryborough, Ballarat, Creswick, and Elaine.

From the next oldest stage, the Bendigonian Stage, gold was mined from saddle veins conformable with the fold structures of the sediments and associated fissure lodes, as at Bendigo.

From the Chewtonian and Castlemainian Stages, gold was mined from rich, spurry, quartz formations where west-dipping veins extend upward, intersecting east-dipping beds. Veins are generally developed along thin slate beds, the gold is coarse, and only a minor development of sulphides is apparent.

Central Victorian Goldfield Province

This province occurs as a down-faulted block of younger rocks of Silurian to Lower Devonian age, outcropping between the Heathcote–Mt William belt and the Dookie–Mansfield–Licola belt. Inthrusted blocks of Cambrian, Ordovician, and Silurian rocks along the eastern margin represent a complex fault system and inthrusted Cambrian and Ordovician rocks of the Dolodrook River area suggest that complex structures extend to the eastern edge of the Upper Palaeozoic (Carboniferous) sandstones and mudstones of the Tolmie Highlands–Mt Cobbler–Mt Kent belt.

Silurian and Lower Devonian sediments consist of marine sandstones, siltstones, shales, slates, grits, and conglomerates containing shell-graptolite and plant-graptolite fossil assemblages. These sediments form the bedrock of the Melbourne area but folding of the rocks is generally less intense than that of the Ordovician sediments. Eastwards, the intensity of folding increases until the belt of complex thrust faulting is reached.

Intruding these rocks are many dykes and their associated gold-sulphide-quartz veins. Very rich deposits of gold have been worked from veins intersecting dykes of Middle Devonian age. The latter form an arcuate swarm of sub-parallel dykes extending from Eildon, through Jamieson and Woods Point, to Walhalla. The Long Tunnel Mine, at Walhalla, yielded a recorded 815,570 oz of gold, being the largest single producer in Victoria, although the whole reef (Cohen's Reef) which was worked to a vertical depth of 3,375 ft, yielded a total of 1,285,300 oz of gold.

Widely dispersed throughout this province is stibnite (antimony sulphide) with one occurrence of cinnabar (mercury sulphide) situated on the Jamieson River. Gold-antimony deposits have been worked at Costerfield, Whroo, Coimadai, Steeles Creek, Hoddles Creek, and Ringwood, while metals of the platinum and nickel groups have been found in small quantities in altered basic intrusives at Walhalla, Matlock, and Dolodrook River. Copper also occurs at Walhalla.

Eastern Victorian Goldfield Province

This province occurs as a subdivision of the Eastern Highlands and lies between the belt of Upper Palaeozoic sandstone of the Mt Kent–Tolmie Highlands and the metamorphic rocks of the Eastern Highlands. Mineralisation is represented by gold-quartz fissure veins of the Bright, Harrietville, and Dargo areas. Fissure veins, spurry formations, and occasional saddle veins occur in slates and sandstones of Ordovician age, mostly at shallow depth. The Oriental Mine at Wandiligong, south of Bright, produced 60,000 oz of gold.

Cobar Province within the Eastern Highlands

This province is represented in far eastern Victoria by its southern termination. It is a fault-bounded block of Palaeozoic rocks with Upper Ordovician, Upper Silurian, and Upper Devonian granites and acid porphyry lavas. Copper, lead, and zinc mineralisation is widespread. Gold-copper mineralisation occurs at Bethanga ; gold-arsenopyrite-pyrrhotite at Cassilis ; gold–arsenopyrite–chalcopyrite–galena at Glen Wills and Towonga ; tin at Eldorado, Walwa, and Cudgewa in the Eastern Highlands ; and lead-zinc-silver mineralisation extends from Buchan to Mt Deddick.

The Palaeozoic sediments of Eastern Victoria consist of sandstones, shales, and slates, the age, where fossil evidence has been found, being Upper Ordovician. A large area of these rocks has been regionally metamorphosed forming a wide belt of phyllites, knotted schists, and gneisses, with which are associated foliated granites. Many boundaries between different rock types are faulted but some schist-shale boundaries may be gradational. The acid porphyries, or Snowy River Volcanics, consist of a great thickness of Lower to Middle Devonian rhyolitic and rhyodacitic lavas, pyroclastics and associated non-marine conglomerates outcropping from Limestone Creek in the north to Nowa Nowa on the Gippsland Lakes. Silver, lead, copper, wolfram, bismuth, and arsenic minerals appear to be widely dispersed. Iron-manganese occurrences are dominant along a fractured zone, within or below the Snowy River Volcanics extending from Nowa Nowa, northward to Buchan. Fluorite and barite are also scattered and may be associated with lead-zinc and copper mineralisation.

Sedimentary and Residual Mineral Deposits

Unlike the magmatic deposits, which are introduced into the crust as solutions or vapours from below, and localised by contemporaneous, tectonic events and rock structures, sedimentary and residual mineral deposits are formed or concentrated from pre-existing surface materials, or organic remains, and prevented from erosion and dispersion by barriers formed by subsequent tectonic, or other geological, events.

For example, coal is deposited in basins from luxuriant plant growth at times of warmth and high humidity. Such basins are later protected from erosion by down-warping or graben formation.

Limestones are formed from coral, shellfish, or polyzoa detritus ; sedimentary clays are formed during times of rapid weathering of pre-existing rocks under climatic and topographic conditions which favour the formation of kaolinite ; while residual clays and bauxite are formed in regions of low topography during prolonged periods of high temperature and humidity. Formation of gypsum deposits requires an arid or semi-arid climate and a continuing supply of water, rich in dissolved salts. Alluvial tin and gold deposits simply result from the erosion of mineral bearing rocks, and their concentration in drainage channels of stream beds is dependent upon the high specific gravity of the mineral or metal.

Metals and Compounds : Their Nature, Uses, and Mode of Occurrence

Aluminium

Aluminium is a soft, silvery, ductile metal with a specific gravity of 2·7 and a melting point of 660° C. Weight for weight, it is the most efficient conductor of heat and electricity, and is of the greatest importance to the aircraft industry. It is used extensively and because of its low density, high electrical and thermal conductivity, resistance to corrosion, non-toxicity, malleability, reflectivity, non-magnetic and non-sparking properties, and high strength-to-weight ratio, has come into direct competition with many metals, wood, plastics, and glass.

Most of the alumina (aluminium oxide) produced is used for the manufacture of the metal, the remainder being used as abrasives, refractories, and for chemicals in water and sewage treatment, dyeing, tanning leather, sizing paper, oil absorbents, catalysts, etc.

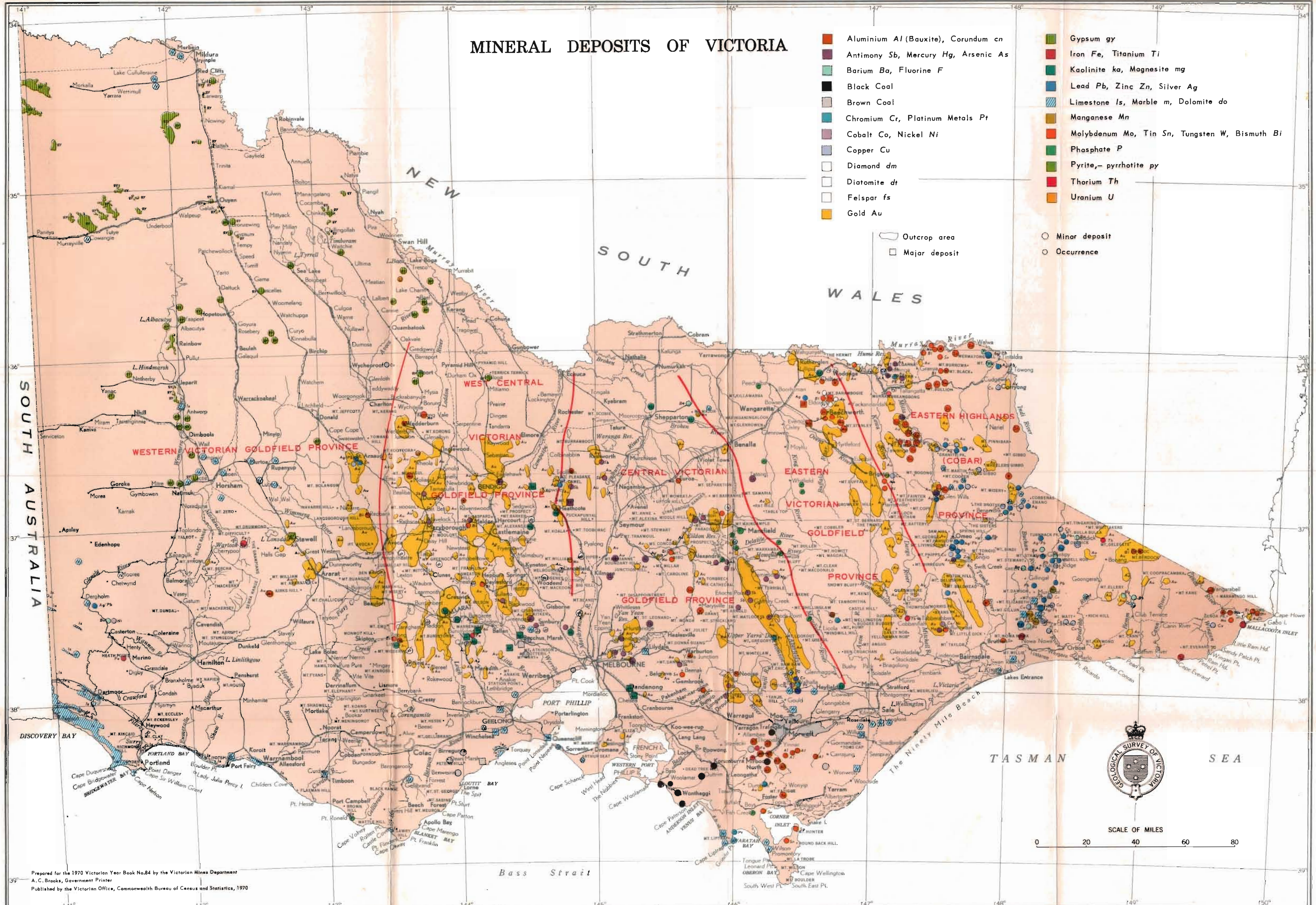
Although aluminium is a major constituent of many rocks, particularly clays and shales, the only commercial source is bauxite, formed by the weathering of rocks under humid, tropical conditions, coupled with maximum fluctuation of the water table. Bauxite, a mixture of aluminium oxides and hydroxides, may be white, greyish, ochre-yellow, pinkish, or brown and concretionary, oolitic, earthy or clay-like in form. Oolitic forms of bauxite are relatively easy to identify but clay-like forms are identifiable only by chemical methods of analysis or those employing measurement of heat absorption or exolution during thermal decomposition.

Bauxite occurs in small but commercial quantities in the Mirboo North–Boolarra areas of south Gippsland. Some forty occurrences exist, but only eight or so are of workable size. At present, one deposit at Boolarra is mined. The bauxite is largely overlain by clay, sand, and gravel with intercalated brown coal. Formation of bauxite may have taken place after block faulting of the area, since the location and shape of deposits appear to be controlled by fault structures which have displaced gravels against Eocene basalt, and tuffs.

Alumina content of the bauxites is generally greater than 50 per cent while silica and iron are generally less than 10 per cent.

Antimony

Antimony is a brittle, soft, tin-white metal of specific gravity 6·68, melting point 630·5° C. Antimony alloyed with lead is used in battery plates, chemical pumps, tank linings, and power cable sheaths. In anti-friction bearings, antimony forms hard crystals of tin-antimony dispersed throughout a soft alloy or lead. Antimony increases hardness, minimises shrinkage, permits sharp definition, and lowers the melting point of printer's type metal.


MINERAL DEPOSITS OF VICTORIA
Aluminium Al (Bauxite), Corundum cn
Antimony Sb, Mercury Hg, Arsenic As
Barium Ba, Fluorine F
Black Coal
Brown Coal
Chromium Cr, Platinum Metals Pt
Cobalt Co, Nickel Ni
Copper Cu
Diamond dm
Diatomite dt
Felspar fs
Gold Au
Gypsum gy
Iron Fe, Titanium Ti
Kaolinite ka, Magnesite mg
Lead Pb, Zinc Zn, Silver Ag
Limestone ls, Marble m, Dolomite do
Manganese Mn
Molybdenum Mo, Tin Sn, Tungsten W, Bismuth Bi
Phosphate P
Pyrite,- pyrrhotite py
Thorium Th
Uranium U
Outcrop area
Major deposit
Minor deposit
Occurrence
NEW SOUTH WALES
SOUTH AUSTRALIA
TASMAN SEA
Bass Strait
WESTERN VICTORIAN GOLDFIELD PROVINCE
WEST CENTRAL VICTORIAN GOLDFIELD PROVINCE
CENTRAL VICTORIAN GOLDFIELD PROVINCE
EASTERN VICTORIAN GOLDFIELD PROVINCE
EASTERN HIGHLANDS (COBAR) PROVINCE
MELBOURNE
PORT PHILLIP
GEELONG
BENDIGO
DISCOVERY BAY
GEOLOGICAL SURVEY OF VICTORIA
SCALE OF MILES
0 20 40 60 80
Prepared for the 1970 Victorian Year Book No.84 by the Victorian Mines Department
A. C. Brooks, Government Printer
Published by the Victorian Office, Commonwealth Bureau of Census and Statistics, 1970

Antimony oxide is used in metal and ceramic enamels and white pigment in paints. Antimony sulphide produces infra-red reflecting paints and these are used extensively for camouflage. Antimony pentasulphide is used in the rubber industry as a vulcaniser while oxide compounds are used in the textile industry to prevent fibre damage by ultra-violet radiation. Antimony salts are used for flame-proofing fabrics, and for manufacture of tracer bullets.

Antimony occurs rarely as a native metal and the chief ore is the sulphide, stibnite (antimony sulphide). Stibnite is a soft, brittle blue-grey to steel-grey mineral with metallic lustre, highly splendent on cleavage or freshly fractured surfaces. Specific gravity is 4·52 to 4·62 and scratch hardness, 2. Crystals are prismatic with vertical striae and may occur as parallel or radiating groups of acicular, fibrous, columnar, or granular crystals. Near the surface, stibnite may be altered to the complex oxide, cervantite, which varies in colour from cream to yellow.

Victoria has been the principal source of antimony mineral in Australia, most of the output coming from operations at Costerfield. Production was more than 23,000 tons of antimony between 1862 and 1951. Auriferous stibnite deposits occur within a belt 10 miles long, but nearly all the production came from the Costerfield and Bombay Mines. Stoping in the Costerfield Mine was extended to a depth of 1,000 ft. Deposits occur in dense, uniform, broadly folded mudstones of Silurian age and consist of short, steeply dipping branching veins averaging 6 inches in width. The Costerfield Reef extended to a depth of 585 ft, was almost 2,000 ft long, and consisted of quartz, stibnite, and gold, the concentrate carrying 2 to 3 oz of gold to the ton. From 1862 to 1883, 21,460 tons of ore were produced, together with 14,700 oz of gold. Between 1905 and 1925, 25,362 tons of stibnite concentrates, averaging 49·8 per cent antimony, were produced, containing 2·36 oz gold per ton. Auriferous stibnite was also found at the Alison Mine, a mile south of Costerfield, and at Redcastle, seven miles to the north. Stibnite was mined at Coimadai, north of Bacchus Marsh, intermittently between 1887 and 1915 for 400 tons of picked ore and between 1942 and 1944 for 4,300 tons of low grade ore and 10 tons picked ore. Lodes consist of quartz-stibnite shear veins in sandstone and slate intruded by felspar porphyry. Small amounts have also been mined at Tallandoon, Kevington, Bailieston, Clonbinane, Ringwood, Whroo, Steeles Creek, and Hoddles Creek. Other occurrences are at Alexandra, Heathcote, Reedy Creek, and Yea. Stibnite is associated with gold at Ballarat, Blackwood, Dunolly, Gaffneys Creek, Maryborough, Steiglitz, Tatong, and Woods Point. Bournonite, a lead-copper sulph-antimonide, occurs in gold reefs at Gaffneys Creek, Steiglitz, and Woods Point.

Barium

Barite or barytes, because of its high specific gravity of 4·3 to 4·6, is commonly called heavy spar. It is white, inclining to yellow, grey, bluish, pink, or brown. It has a vitreous to resinous lustre with a scratch hardness of 2·5 to 3·5.

The most important use of barite (naturally occurring barium sulphate) is as a weighing agent in deep bore drilling muds. Barite, because of its weight, serves the purpose of increasing the specific gravity of the mud, so helping to prevent caving of the sides of the well, and to confine high gas and oil pressures to their formations, thus preventing blowouts. Barite is also used in the glass industry to flux furnace froth, which prevents transfer of radiant heat from furnace gases to the hearth, and also to decolour and increase the brilliance of glass ; it is also used as a filler or extender in paint, inks, oilcloth, linoleum, rubber, etc. Barium chemicals are used as white pigments for X-ray diagnoses, in ceramic glazes, and green signal flares. The metal is used in small quantities as a copper de-oxidiser and because of its high electron-emission rate when subjected to an electrical potential is used in electron-emission alloys for electronic tubes and in spark plugs. Barium titanate is extremely important in the manufacture of miniature electronic and communication equipment.

A number of barite occurrences are associated with the Snowy River Volcanics, in eastern Gippsland, and with those situated at Butchers Ridge, near Gelantipy, South Buchan, Gelantipy East, Canni Creek, and Mt Tara. Only the first has been mined to any extent. The Butchers Ridge deposit occurs as a vein 500 ft long with an average width of 4 ft and the quantity mined appears to be much greater than a recorded 69 tons. Other occurrences are at Dookie, Walwa, Errinundra, Deddick River, Accommodation Creek, the Upper Gellibrand River near Barramunga, and north of Casterton.

China Clay

China clay consists essentially of kaolinite, a hydrous aluminium silicate. Because kaolinite is altered to a mixture of mullite (aluminium oxide) and christobalite (high temperature silica) at temperatures above 950° C, and does not soften until temperatures of the order of 1,785° C are reached, it is used in the ceramic industry for the manufacture of chemical ware, refractories, porcelain, electrical and thermal insulators, and pottery. The high-reflectivity, whiteness, and absorbent properties of high-grade, raw china clay, ensure its extensive use in the paper industry as a filler and surfacer.

Pure kaolinite is white, has a specific gravity of 2·60 to 2·63 and may vary in lustre from pearly to earthy. A small amount of impurities, chiefly iron, may impart a colour, varying from off-white to pinkish. Use of this material is restricted to rubber or linoleum fillers or white-ware. In contrast, brick and pipe-clays are essentially kaolinite-quartz mixtures, with more iron-oxide imparting red to brown coloration on burning, while associated complex clay minerals, such as halloysite and montmorillonite, tend to increase plasticity and lower fusion point. Brick and pipe plants occur throughout Melbourne and other parts of the State and form a major industry.

High grade Tertiary transported kaolinitic clays occur at Axedale, 13 miles east of Bendigo, and at Heyfield north-east of Traralgon. Those at Axedale are of uniform texture, 99 per cent being finer than 200 mesh and 32 per cent finer than a half micron. Here the clay seams vary in thickness from 5 to 64 ft and much of the area is overlain by a soil cover of only 12 in. Deposits are lenticular, grading into sands and gravels. At Darley, north of Bacchus Marsh, similar clays are mined underground for the manufacture of fire-brick. At Heyfield, a succession of crossbedded gravels, sands, and clays of lacustrine origin occupies high land to the north of the Thomson River alluvial flats. Clays of varying quality occur as a number of lenticular horizons within the sedimentary sequence. Adits have been driven on the better clay seams, which are fine-grained, quartz-kaolinite clays, having 45 per cent of the material finer than a half micron.

Thick deposits of Lower Tertiary semi-refractory, transported clays occur in the Upper Parwan Valley, west of Rowsley. The down faulted sequence covers some 30 sq miles. The lower parts of the sequence are exposed in the western end of the valley while upper parts are exposed farther east near Rowsley.

The white refractory clays are used in the manufacture of fire-brick, and may be pulverised and sized for use as filler. Although the grain size of this material is relatively large, milling can produce a product in which about 20 per cent is finer than one micron.

At Gordon, Mt Egerton, and Ballarat a number of quartz-free dyke rocks have been altered to white kaolinite down to depths of many hundreds of feet below the surface. First-grade kaolinite from Mt Egerton has a reflectivity as high as 94 per cent of that of magnesium oxide, and is therefore used for china ware or as first-grade paper-filler. At Hallam, Bulla, Lal Lal, and Pittong, the felspars and micas of granitic rocks have been altered to kaolinite. The kaolin is washed from the coarser, stable quartz grains, concentrated into a slurry or filtered and dried for use as paper-filler.

Chromium

Chromium is a hard, brittle, light blue-grey metal with specific gravity of 6·92 and melting point of 1,930° C. It is resistant to tarnish. Chromium is best known as decorative plating and is indispensable in a broad range of industrial applications. The metal is the chief alloying constituent of stainless steel, its compounds are important as chemical materials, and the raw mineral, chromite, is used as a major furnace refractory.

Chromium metal is used to refine grain size of alloy steels ; it increases hardening qualities, inhibits graphitisation at elevated temperatures, and increases toughness. Nickel-base chromium alloys are resistant to heat and corrosion and are used in jet engines, gas-turbine blades, furnace equipment, etc. Chromium combined with iron, nickel, cobalt, molybdenum, tungsten, or columbium finds use in space and atomic energy applications. Cobalt-base chromium alloys are also used in applications calling for hardness, corrosion resistance, oxidation resistance, and strength at elevated temperatures. They are used as metal cutting tools, hard-facing materials and permanent magnets. Chromium chemicals are used in the manufacture of pigments, in leather tanning, textile processing, and electroplating.

Chromite, ferrous chromate, or iron-chrome spinel, varies in colour from brown-black to honey-yellow, depending on iron content. Most is brown-black. Specific gravity is 4·1 to 4·9, brittle, scratch hardness is 5·5, and the powder is typically milk chocolate brown.

The only chromite to be worked in Victoria has been found in serpentinite on the Dolodrook River, but occurrences are also found in altered Cambrian diabases on the Howqua River, at Tatong, south of Benalla, at Dookie, Mt Staveley, in the Black Range near Horsham, and near Limestone Creek, north-eastern Victoria. Material on the Dolodrook consists of small blocks in serpentinite, broken by subsequent shearing, while a fair amount of blocky material, some lumps 4 ft in length, have been found in soil overlying the chromite bearing serpentinite. Chromite in this area is of high quality, analysing from 45 per cent to 51 per cent Cr_2O_3, the chrome-iron ratio being greater than 3 : 1. Chromite has also been found with quartz at Corryong and Heathcote and in gravels at Beechworth, Benalla, and Cann River.

Black Coal

Coal is a stratified carbonaceous rock formed by accumulation of vegetable matter and subsequent alteration to a compact solid fuel by decay, heat, and pressure.

Victoria has enormous reserves of Tertiary brown coal, but only a few small deposits of black coal. The latter occur in thick sequences of Lower Cretaceous sandstone and shale, and are known in three areas, South Gippsland, the Otway–Bellarine area south-west of Geelong, and the Casterton–Merino area near Hamilton. Seams in the latter two areas are thin, mostly less than 1 ft, and all of the State's production has come from the South Gippsland area. Here seams are narrow and lenticular and because of block faulting, production from the Wonthaggi, Korumburra, and Woolamai districts has shown a steady decline over recent years. These characteristics serve to limit scope for modern mechanised mining, and production at Wonthaggi ceased at the end of 1968.

Brown Coal

Brown coal is an intermediate stage between vegetable matter and bituminous coal of the type found in the Lower Cretaceous strata of South Gippsland.

Extensive Eocene-Oligocene coal measures in the Latrobe Valley contain some of the thickest brown coal seams in the world. Total thickness of seams, separated and subdivided by sandy clay beds, reaches a maximum of 1,000 ft. Thick seams also occur on the southern flanks of the Gippsland Hills, under the Werribee Plains between Melbourne and Bacchus Marsh, and on the eastern and northern flanks of the Otway ranges. Reserves of brown coal in the Latrobe Valley are very large and an almost unexploited field lies between Welshpool and Gelliondale in South Gippsland.

The reserves in the Latrobe Valley have been determined by boring over an area of approximately 235 sq miles, and production, which began in 1889, amounted to 339,359,581 tons by the end of 1967. Broad folding in the Yallourn, Morwell, and Rosedale areas has brought thick brown coal seams close to the surface. Mineable seams are the Yallourn (maximum thickness 320 ft), Morwell No. 1_0 (150 ft), Morwell No. 1, a and b (543 ft), and Latrobe seam (480 ft maximum). Four open cuts operate in the area, these being the Yallourn North, Yallourn North Extension, Yallourn, and Morwell. Overburden average of the Yallourn and Morwell seams is 44 ft and 54 ft, respectively. The brown coals of the Latrobe Valley range in moisture content from 50 to 70 per cent, calorific value varying from 2,500 B.Th.U. to 5,000 B.Th.U. per lb. Estimates of economically recoverable coal are in the region of 10,000 mill. tons.

Other deposits of Tertiary brown coal occur at Anglesea, where reserves have been proven to be about 115 mill. tons. Here, brown coal is used for firing the power house which provides power for the aluminium smelter at Point Henry, Geelong. Calorific value of this coal averages about 6,000 B.Th.U. per lb. Other deposits occur at Bacchus Marsh, where the seam is about 100 ft thick. At Lal Lal, brown coal has been preserved by subsidence of a small graben associated with the Parwan Valley. At Wensleydale, the coal seam is 110 ft thick, and relatively high-grade coal occurs at Dean's Marsh.

Copper

Copper was the first metal used by man. It is copper-red, highly ductile and malleable, and is an excellent conductor of heat and electricity. It melts at 1,084° C. Its value from antiquity was related to its ease of working, its attractiveness, durability, corrosion resistance, and its availability. As a raw metal or alloy it was used for tools and weapons, but its ability to form numerous alloys has led to many applications.

The electric conductivity of copper was fundamental to the spectacular growth of the electric industry and more than half the copper metal produced is used for power transmission, electronics, and electrical equipment. Generation and utilisation of electric energy require extremely large quantities of copper for windings of motors, generators, transformers, heat exchangers, etc. The non-corrosive property of copper and its alloys accounts for its use in plumbing and building.

Copper may occur naturally as native copper, but its most important source is in copper sulphide ores where it may be associated with other base or precious metals. The most important primary copper mineral is chalcopyrite, but ore bodies may contain other copper sulphides. Chalcopyrite (copper iron sulphide), the common copper sulphide, is bright, brittle, metallic, brass-yellow in colour and may be tarnished or iridescent. Specific gravity is 4·1 to 4·3 with a scratch hardness of 3·5 to 4·0. The powder is characteristically greenish-black. Bornite (copper iron sulphide) is brown to black, fresh fracture surfaces speedily tarnishing to a beautiful iridescence, which gives the mineral the name " Peacock Copper Ore ". Azurite (bright azure to berlin blue) and malachite (brilliant green) are basic copper carbonates and occur close to the surface in the upper, oxidised zones of copper deposits.

Although copper minerals have been reported from numerous localities in Victoria, few deposits have been worked and total production is estimated to be 3,580 tons of copper, most of which came from the Coopers Creek Copper Mine, 3 miles south-west of Walhalla. The outcrop of the ore body is 120 ft long and 25 ft wide. Copper mineralisation occurs along a fault zone, parallel to the western margin of a hornblende diorite dyke, and also occurs disseminated within the dyke itself. The fault zone mineralisation varies from a 4 to 10 ft width and is reported to have contained 16 per cent copper. Gold, silver, platinum, palladium, and nickel sulphide were also reported.

Eighty tons of copper were produced from fissure lodes at Bethanga, while fissure lodes from the Black Snake Copper Mine, on Accommodation Creek, 43 miles north of Orbost, produced 19,164 tons of ore up to 1965, and 28 tons of concentrate in 1966. Drought conditions have prevented production since that date. Azurite, malachite, and cuprite formed a lode 15 ft wide at Mt Camel, north of Heathcote. Native copper has been reported from alluvial deposits at Ballarat, Beechworth, Castlemaine, Creswick, and Majorca, while copper sulphides occur in small quantities on most goldfields.

Diatomite

Microscopic water organisms, called diatoms, secreted silica from the prehistoric seas or lakes in which they lived. More than 12,000 different, intricate, often symmetrical, skeletal patterns have been identified. On their death, their remains settled to the lake bottoms to form sedimentary deposits. The porous structure of the individual skeletons and their massed arrangement impart the unusual properties which make the material an ideal filter medium or filler for thermal or acoustical insulation. The primary industrial application of diatomite, however, is as an industrial filtration medium for liquids, ranging from water supplies to alcoholic beverages. It is also used as a porous extender for matt finish interior paint, as a fertiliser dust, and as a source of silica in ceramic glazes.

Diatomite, when dry, has the appearance of chalk but is much lighter and is chemically inert. The majority of diatomite occurrences in Victoria are of freshwater origin occurring in lakes associated with volcanic lava flows. The main deposits are those at Lillicur, Newham, Moranding, Redesdale, and Linton (Happy Valley). Production is probably considerably greater than a recorded 36,595 tons to 1967. In these deposits, diatomite occurs as layers between or beneath flows of basalt. Diatomite may be up to 8 ft thick and contains small clay lenses. Other occurrences are found at Allestrie, Ararat, Broadford, Cardigan, Daylesford, Glengower, Lake Corringle, Lancefield, Lismore, Portland, and Tallarook.

Fluorite

Fluorite, calcium fluoride, is used mainly in the steel, glass, and enamel industries, as hydrofluoric acid, for the manufacture of aerosols, refrigerants, and plastics, and artificial cryolite (sodium aluminium fluoride) flux in the electro-metallurgy of aluminium. In many parts of the world, sodium silicofluoride is used for fluoridation of town water supplies.

Fluorite is a vitreous, white, yellow, greenish, bluish, purple, or brown mineral of specific gravity 3 to 3·25. Scratch hardness is 4. Crystals form cubes or octahedra which fluoresce blue under excitation, by short-wave ultraviolet radiation.

Fluorite production in Victoria, to 1964, was 4,155 tons, and all of this came from Pine Mountain, east of Walwa. The deposit occupies a steeply dipping fissure lode, extending for the greater part of its length along the contact of Upper Ordovician schist with porphyritic granite. The lode is from 3 to 4 ft wide and more than 400 ft long and contains between 60 and 70 per cent fluorite.

Associated minerals are quartz, galena, and some sphalerite. Five miles north-west of Pine Mountain there is a second deposit of fluorite but little work has been done on this. Other occurrences are at Beechworth, Bright, Omeo, and Tintaldra.

Gold

Gold is a golden-yellow metal of specific gravity 19·33 when pure, but in nature, is almost always alloyed with varying amounts of silver and traces of copper and iron. The metal when pure, is the most ductile and malleable of all metals. Melting point is 1,063° C.

Most of the world's production is purchased by governments and central banks to provide stability for paper currencies and to settle international trade balances.

Gold may be alloyed for jewellery or used pure as gold leaf or in ceramic ware. Because of its stability in the metallic form it may be used in electric contacts or as coatings on aircraft engine shrouds or earth satellites.

The primary gold occurrences in Victoria are in the Lower Ordovician or Lower Devonian slates and sandstones which were strongly folded and intruded by granite and granodiorite in the upper Devonian period and are fully explained on pages 6 to 9.

The alluvial gold deposits of Victoria are largely related to events from the Eocene to the Pliocene periods when the eastern seaboard had a low relief, giving rise to considerable accumulation of gold bearing gravels in back-filled valleys. Some of these placer gravels were eroded away, while others were buried beneath lava flows to become buried placer deposits. About half the gold production of the State has been from alluvial sources, and at Ballarat probably more than three quarters of some 20 mill. oz came from such sources.

More spectacular aspects of placer deposits were the large nuggets that were discovered. The two largest were the " Welcome Stranger ", weighing 2,284 oz, and the " Welcome ", weighing 2,195 oz. Of 322 nuggets found weighing over 100 oz, twelve of these were over 1,000 oz in weight.

Gypsum

Gypsum was used for making works of art by the ancient Chinese, Assyrians, and Greeks. The first verified use was as plaster mortar in the pyramid of Cheops about 3000 B.C., and the Romans were familiar with the fact that the vapourisation of chemically combined water in plaster, when used in buildings, consumed heat in a fire, and tended to retard combustion.

Plaster of paris is made by calcining gypsum, and the building and construction industries consume the major proportion. Other important uses are as a vital constituent of Portland cement. Three to seven per cent by weight is added to cement clinker before grinding, and this acts as a retarder to setting. Ground gypsum is added to soils deficient in sulphur and also serves as a soil conditioner. Plaster is also used in the construction of moulds in the heavy and ceramics industries and is used as a binding agent in crayons and chalks, and for medical purposes.

The mineral gypsum is hydrated calcium sulphate. Specific gravity is 2·3 with scratch hardness of 2. Gypsum can be dehydrated or calcined to form plaster of paris which, with the addition of water, will rehydrate to form a compact, strong gypsum mass of small interlocking grains. This property is used in the production of moulded ornaments, and plaster or metal moulds. After setting, dried moulds have the ability to absorb water, which allows their use in what is known as slip-casting of ceramic products. If a slip or slurry of china clay is poured into a dried plaster mould, the mould will absorb water from the outer margins of the slurry, resulting in stability. The remaining slurry can be poured from the centre of the moulded ware, leaving the outer clay shape intact, when it can be removed, dried and fired.

Natural gypsum crystals are transparent, white, greyish, red, or brown. The mineral is widely distributed in the north-west of the State, where it may occur as wind-blown dunes rising above the level of the plains, as lacustrine accumulations in topographic basins, as shallow buried deposits, and as deposits forming at the present time in shallow lakes. Gypsum deposits result from deposition from solution, under arid or semi-arid conditions. All occurrences are within the hot Mallee and Wimmera regions in which annual rainfall is less than 20 inches.

Gypsum has been mined from Nowingie West, Cowangie, Swan Hill, Ouyen, Mildura, and Rainbow. Minor occurrences are mined at widely scattered places for use as a soil conditioner. At Nowingie West, up to 3 ft of gypsum underlies 1 or 2 ft of soil. At Cowangie, gypsum covers an area of 45 sq miles of low hills and flats to an average depth of 9 ft. Analyses of the deposits vary from 70 per cent to 99 per cent gypsum. It also occurs as far south as Dimboola and as far east as Lake Boga. To the end of 1964, Victorian production was approximately 1·5 mill. tons, about 12 per cent of the Australian total.

Lead—Zinc—Silver

Lead was one of the earliest metals utilised by man because of the ease of refining and fabrication. Lead is still used for corrosion-resistant sheets and piping, but principal uses are for storage batteries, tetraethyl lead in gasoline, cable coverings, solder, roof flashing, type, and bearing metals.

Zinc has been used as a component of brass for 2,000 years, but it was not until the middle of the eighteenth century that the metal was produced commercially. Major uses of the metal in addition to alloying with copper for brass, is as a protective coating on iron and steel wire and steel sheet (galvanised iron), and as zinc-base pressure-cast products and zinc-oxide.

Although silver has been used for many centuries for coinage and the arts, its principal use is in the manufacture of photographic materials. Considerable quantities are also used in electroplated silverware, silver solders, and brazing alloys. Silver is also used in astringent and antiseptic pharmaceuticals, dental amalgam fillings, electric contacts, mirror surfaces, and silver-zinc and silver-cadmium batteries, as well as for scientific instruments, which require high power-output for minimum size and weight.

Boring alluvial gravels for gold and tin, Wodonga.

[*North Broken Hill Ltd*

Minerals in Victoria

Morwell brown coal open-cut from the air.
[State Electricity Commission of Victoria

Limestone quarry at Batesford, near Geelong.

[G. Bell

Argentiferous Galena (lead and silver sulphides) from Mt Deddick. [*National Museum*

Malachite (hydrated copper carbonate) from Mt Camel, near Heathcote.
[*Institute of Applied Science*

Micaceous hematite (ferric oxide), Nowa Nowa.
[*Mines Department*

Tarnished chalcopyrite (iron copper sulphide), Bethanga.
[*National Museum*

Turquoise (copper aluminium phosphate) vein in slate, Edi.

[*National Museum*

Stibnite (antimony sulphide), Steeles Creek, near Yarra Glen.

[*Mines Department*

Metallic gold in quartz, A1 Mine, Gaffneys Creek.

[*Mines Department*

Anglesea brown coal open-cut with powerhouse in the background. [G. Bell

Salt pans, Corio Bay, near Geelong. [G. Bell

Gypsum crystals (calcium sulphate), Pink Lakes, Linga. [*National Museum*

Aragonite (calcium carbonate) and ferrocalcite (iron calcium carbonate) from cavity in basalt (bluestone), Collingwood.
[*National Museum*

Large Citrine (quartz) crystal, Eldorado.
[*National Museum*

Molybdenite (molybdenum sulphide) in quartz, Everton.

[*Mines Department*

Cassiterite crystals (tin oxide) in quartz, Walwa.

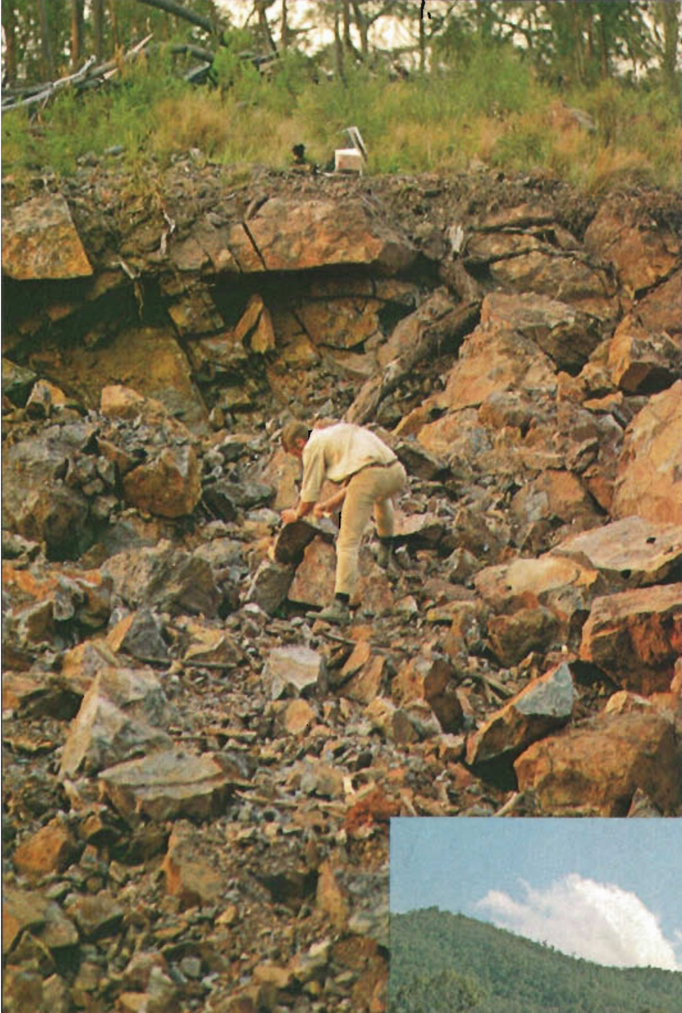
[*Mines Department*

Metallic bismuth nugget, Wombat Creek, Glen Wills.

[*Mines Department*

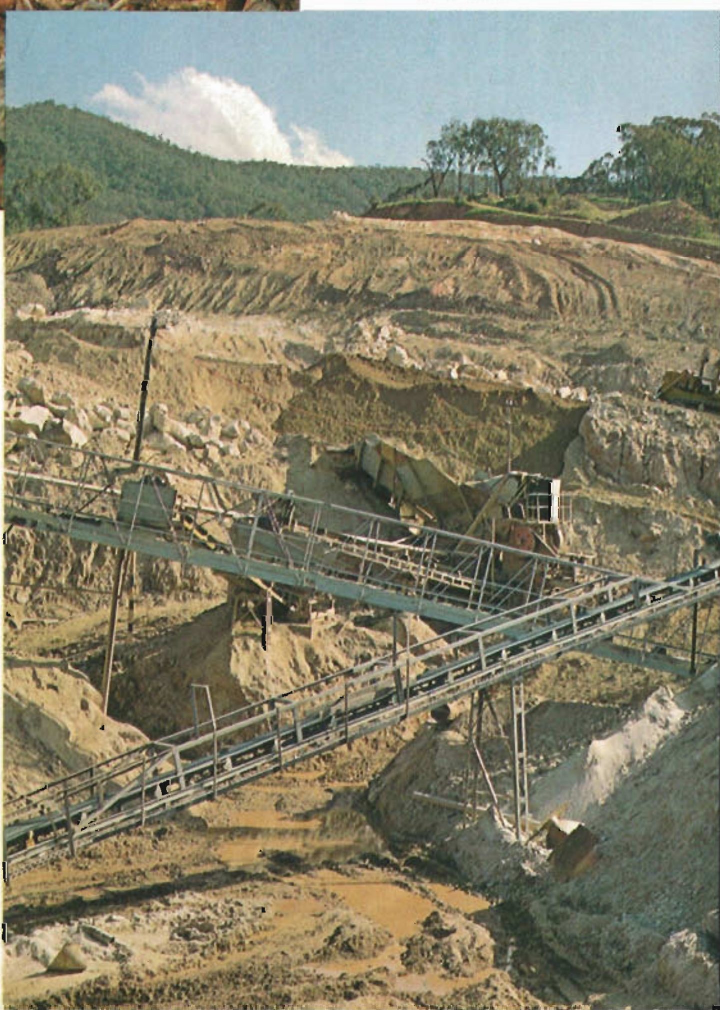
Wolframite (iron manganese tungstate), Mt Murphy.

[*Mines Department*



Iron ore (hematite) deposit, north of Nowa Nowa.

[*G. Bell*



Open-cut tin mining operations, near Walwa.

[*G. Bell*

Lead and zinc minerals are fairly widely dispersed in Victoria, but deposits are small and only 800 tons of lead ore were produced late in the nineteenth century. No zinc production has been recorded, although sphalerite, zinc sulphide, is the major constituent of some of the veins associated with shears in the granites of the Snowy River belt. Small but rich deposits of lead have been mined in east Gippsland, notably at Buchan, where small lenses and threads of galena, lead sulphide, with minor pyrite and gold, occur in limestone. They also occur at Mt Deddick where numerous parallel lenses of galena and sphalerite occur with quartz veins in crushed granite, and at Gelantipy where galena occurs with quartz in a vein. Other occurrences are at Pine Mountain, where most mining has been for the gangue fluorite, at Murrindal, Campbells Knob, north of Buchan, Wombat Creek, near Glen Wills, Omeo, Cassilis, Bethanga, and Redcastle. It is associated with gold at St Arnaud, Percydale, and the Pyrenees.

Silver generally occurs with lead sulphides in these areas, and silver assays of near surface material were often high. A number of assays of ore, taken from small veins on Livingstone Creek, just south of Omeo, gave silver contents as high as 420, 313, and 278 oz to the ton.

Galena, lead sulphide, is lead-grey in colour, the metallic mineral exhibiting perfect cubic cleavage. Scratch hardness is 2·5 to 2·75, and specific gravity is 7·4 to 7·6. Sphalerite, zinc sulphide, may contain iron, and the colour varies from honey yellow to black, with increasing amounts of iron. Its lustre may be adamantine to resinous, with a specific gravity of 3·9 to 4·1, and a scratch hardness 3·5 to 4·0. Silver is found alloyed naturally with gold, but also occurs as sulphides or in solid solution in galena.

Limestone

Although for centuries limestone and its derivative, lime, were used primarily for mortar, plaster, and disinfectant, it now constitutes a basic industrial chemical for use in the neutralisation of industrial wastes, in high temperature and dehydration processes, as a causticising agent in the sulphate process of paper-making, in water purification, and in the manufacture of petrochemicals and insecticides. It is used in the iron and steel industry, for ore fluxing in basic oxygen converters and electric furnaces. Lime is used for the removal of silica from bauxite ores in the production of alumina. Smaller quantities are used in the production of soaps, greases, glue, and gelatine, in the leather industry for removing hair, and in the production of calcium carbide, which on wetting produces acetylene gas.

In construction it is used in masonry mortars, plasters, sand-lime brick, cement, and soil stabilisation for road and aircraft runway beds.

Limestone is the main ore of the metal, calcium, which, although not produced here, is used as a reducant for the refractory metals such as chromium, titanium, zirconium, hafnium, and uranium.

Impure clay-bearing limestones have a major use in the manufacture of Portland cement and in 1967, more than 90 per cent of limestone production was used for this purpose.

Limestone is a sedimentary rock of chemical or organic origin composed largely of the mineral calcite. Younger limestones may consist of recognisable sea shell fragments or polyzoa, while older limestones are often metamorphosed to form recrystallised, hard, compact, impervious marble. Travertine is calcium carbonate, formed in semi-arid climates, at or near the surface, by evaporation of ascending lime-rich water. Chalk is a porous, incoherent rock composed of minute shells, set in a matrix of finely divided calcite. Cocquina is a poorly consolidated debris of larger shells or shell fragments, while marl is a calcareous clay.

Limestones of Cambrian age occur as lenses along the southern margin of the serpentinite belt of the Wellington–Dolodrook River. The Silurian–Devonian limestones, some of which are very pure, are confined to eastern Victoria with principal deposits at Buchan, Bindi, Toongabbie, Walhalla, Lilydale, Limestone Creek, Mansfield, Tyers River, Waratah Bay, Wombat Creek, and Dookie. Tertiary polyzoal limestones occur along the whole of the southern part of Victoria. Although extensive, these outcrop at the surface only as small areas at Bairnsdale, Nowa Nowa, Orbost, Sale, Woodside, Merrimans Creek, Longford, Darriman, Geelong, Batesford, Waurn Ponds, Fyansford, Maude, Curlewis, Tara, Mt Duneed, Kawarren, Timboon, Port Campbell, Moyne near Port Fairy, Curdies River, Warrnambool, Portland, Hamilton, Casterton and elsewhere on the Glenelg River, etc. Pleistocene dune limestones and Recent aeolian calcareous sands occur along much of the coast line. These are mined at Anakie, near Wilsons Promontory, at Warrnambool, and Port Fairy. Huge deposits occur along the coast from Port Fairy to Nelson.

Principal centres of limestone production are Geelong, Lilydale, and Merrimans Creek. Lower Devonian limestone is quarried at Cave Hill, near Lilydale, 25 miles east of Melbourne, for production of quicklime. The deposit consists of bedded limestone forming a steeply dipping lens at least 4,000 ft long and more than 800 ft wide. Quality varies from 70 per cent to better than 96 per cent calcium carbonate. Magnesium oxide content likewise is variable and patches may analyse as high as 17 per cent.

At Buchan, large reserves of limestone of Middle Devonian age occur. The Lower or Buchan Caves sequence consists of 800 ft of dolomite, dolomitic limestone, and almost pure limestone with practically no intercalation of non-carbonate rocks. The higher, Murrindal limestone, although containing intercalations of mudstone, is also of considerable thickness. Mineable reserves are probably more than 200 mill. tons for the Buchan Caves formation and 70 mill. tons for the Murrindal formation. Representative analyses show more than 20 per cent magnesia in the dolomites. At Tyers River and Coopers Creek, thin, steeply dipping, lenticular bodies of Lower Devonian limestones have been quarried, and calcium carbonate content ranges up to 93 per cent.

In the Rosedale–Sale area a number of Miocene limestone deposits outcrop on the flanks of the Baragwanath Anticline, these being notably at Longford, Merrimans Creek, and Darriman. Deposits generally consist of alternating beds of polyzoal limestone and sandy marls.

A thickness of the order of 60 to 80 ft of better than 78 per cent calcium carbonate material occurs at Merrimans Creek, where limestone is quarried for the manufacture of Portland cement. Dips generally range from 2° to 7° and limestone occurs at shallow depth for 12 miles along the strike west of Longford and for at least 3 miles on the south limb near Merrimans Creek. Calcium carbonate content ranges from 40 to 93 per cent.

In the Geelong area, more than 1 mill. tons per annum of Oligocene-Miocene polyzoal limestones are quarried at Fyansford and at Waurn Ponds, for the manufacture of Portland cement. Limestone deposits are extensive in south-western Victoria. Considerable quantities have been quarried on Curdies River near Timboon about 30 miles east of Warrnambool and an attempt at Portland cement manufacture was made at Aringa, 5 miles west of Port Fairy. Limestone has also been mined at Moyne, 10 miles north-east of Port Fairy, and investigation in the Portland–Nelson area reveals dune limestones and enriched dune material to be extensive, some of the material analysing up to 97 per cent calcium carbonate.

Magnesium

Both dolomite and magnesite are sources of magnesium. Dolomite is used in the steel industry as a flux, for repair of open hearth furnaces in the glass industry, as a fertiliser, and in metal polishes. Magnesia may be produced from magnesite (naturally occurring magnesium carbonate), or extracted from sea-water, and is used for basic refractories. Magnesia is also used in refractory cements, uranium processing, fertilisers, electric insulators, pigments, paint, glass, and ceramics.

Magnesium hydroxide is used in sugar refining and in pharmaceuticals. Magnesium chloride is used mainly for production of magnesium metal, which is used in light-weight alloys in the aircraft industry, for machinery, and for tools. Higher proportions of the metal are being used in cast alloys in consumer goods and motor vehicles. No magnesium metal is produced in Australia and the bulk of both dolomite and magnesite is used in the steel industry.

Magnesite, magnesium carbonate, is a brittle, vitreous, silky or earthy, white, yellowish or brownish mineral, generally opaque, and with specific gravity of 3·0 to 3·12. Scratch hardness is from 3·5 to 4·5.

Dolomite, calcium magnesium carbonate, is a brittle, vitreous to pearly mineral, white, pinkish, greenish, brown or grey in colour. Specific gravity is 2·8 to 2·9 and scratch hardness 3·5 to 4·0. It generally occurs as stratified deposits associated with limestones or shale and is a common constituent of mineral deposits. Only small quantities of magnesite and dolomite have been produced in Victoria. Total output of magnesite amounts to approximately 4,430 tons, but dolomite production is small. Most magnesite output has come from deposits near Heathcote and consists of veins and nodules in decomposed diabase. The material assays 46·5 per cent magnesia. At Redesdale, lenticular deposits occur in a belt of slates and sandstones about a quarter mile wide. Reserves are small and total production in 1951–52 was only 214 tons.

Tertiary dolomitic limestone containing between 6·7 to 16·2 per cent magnesia has been mined on a small scale at Coimadai, but large reserves of high quality Middle Devonian dolomite occur at the base of the Buchan Caves limestone. A representative analysis shows 20·85 per cent magnesia, 30·2 per cent lime, 0·72 per cent silica, and 1·87 per cent alumina and iron. The overlying limestone and the Murrindal limestone contain small areas, rich in magnesia, which do not appear to be mineable propositions.

Manganese and Iron

Manganese is a purplish-grey metal, of specific gravity 7·42, and melting point 1,245° C. It is generally produced as an alloy with iron, called ferro-manganese. Manganese in small amounts may be alloyed with steel to counteract the deleterious effects of sulphur, by the formation of harmless globules of a manganese-sulphide phase. Manganese as an oxide is used as a constituent of dry electric cells (batteries). Chemically it is used in the manufacture of potassium permanganate, manganese sulphate, manganous chloride, and manganous oxide. Manganese generally occurs as oxides, which are characteristically brown or black, with a powder colour of blue-black to brown. It frequently occurs with more or less limonite, hydrated iron oxide. Pyrolusite manganese dioxide is a soft iron-black, submetallic material of specific gravity 4·73 to 4·86.

Iron may occur as the hydrated iron oxide, limonite, but larger bodies of iron ore generally consist of hematite and magnetite. The only iron ore produced in Victoria for iron production was 5,400 tons from Lal Lal in the 1880s. Limonite, however, was produced until recently from South Buchan for use in gas scrubbers. The largest iron ore deposit occurs north of Nowa Nowa but has not been exploited. This deposit, containing 5·5 mill. tons, is concealed, apart from a few broken outcrops of hematite, along its western shear-margin. Bodies of a similar nature, some manganese rich, outcrop sporadically over a distance of ten miles along shear zones at the southern termination of the Snowy River Volcanic Belt. The ore at Nowa Nowa consists of massive and micaceous hematite at the surface, passing in depth to magnetite, with micaceous hematite, pyrite, and chalcopyrite. Iron content ranges from 45 to 68 per cent (average 50) with copper up to 0·59 per cent over 70 ft in one bore.

Farther north, higher manganese contents are encountered in iron ore deposits, from the " Iron Mask " assaying up to 13 per cent manganese. Limonite is associated with Middle Devonian limestone at South Buchan. The deepest bore sunk on the largest deposit shows pyrite at the bottom and this may represent the primary iron mineral. This deposit is one half mile long and 600 ft wide. Lateritic deposits at several localities around Casterton have been quarried for road metal and railway track ballast. Smaller, thin, ferruginous cappings occur throughout the State but are of minor importance. There manganese deposits have been worked for a total of 422 tons. Of this, 417 tons came from Heathcote.

Molybdenum

Not until the 1920s did molybdenum achieve importance. Since then it has been used widely as an important constituent of alloy steels and alloy cast irons. These account for most of its use.

Molybdate chrome-orange is a pigment used in paints, printing inks and plastics; molybdenum catalysts are used in desulphurising petroleum and in the hydrogenation of coal. Molybdenum disulphide, added to lubricating oils and greases, is widely used in applications requiring superior performance.

The principal ore of molybdenum is molybdenite, molybdenum sulphide. It is blue-grey of brilliant metallic lustre and its typical form is soft, sectile, flexible laminae having a greasy feeling. Scratch hardness is 1·0 to 1·5 with specific gravity of 4·7 to 4·8.

A major deposit of molybdenite was mined from the pipe-like ore body in porphyritic granodiorite at Everton near Beechworth. Almost all recorded production of 320 tons was from this source. The deposits, which are 2½ miles north-east of Everton, consist of several intrusions of porphyritic granodiorite intruding regionally metamorphosed slate and sandstone. Two molybdenite ore bodies occur in one of these intrusions, one close to the margin, and the other some distance from it. The form is one of steeply dipping annular mineralised zones, each surrounding a barren core of quartz-biotite porphyry, intrusive into the granodiorite. Gangue consists of quartz of the veins and granodiorite into which the veins have been intruded. Ore shoots encompass both veins and granodiorite, the granodiorite yielding the best ore. Molybdenite has also been produced from Mt Douglas near Korong Vale where it occurs in thin, widely separated veins in granite, and as a by-product from the Thologolong wolfram mines. Other deposits occur at Simmons Gap near Bright, Wangrabelle, and at Mt Moliagul.

Phosphate Ores

The major use of phosphate rock is for agricultural purposes but although ground phosphate rock may be applied to the soil in the untreated state, most is acid treated to form superphosphate and triple superphosphate. Phosphorus and phosphoric acid are used to make inorganic and organic chemicals, which are used as water softeners, cleansers, soaps, detergents, and insecticides. Elemental phosphorus is used in the manufacture of phosphor alloys and for military purposes. Phosphate rock does not have a definite chemical composition and the minerals concerned are of the apatite group, a fluor-chlor calcium phosphate. It occurs as nodular phosphate, residual phosphatic limestone, vein phosphates, consolidated and unconsolidated phosphatic sediments.

Calcium and aluminium phosphates (wavellite and turquoise), have been recorded from several places in Victoria, but all production, which to 1926 totalled 16,014 tons, came from Phosphate Hill, near Mansfield. At this locality, dark grey to green, medium to coarse textured phosphorite is associated with cherts and fossiliferous shales of Lower Ordovician Age, which have been folded, crumpled and faulted. The phosphorite is characterised by filaments of wavellite, turquoise, and quartz. Chemically, the ratio of alumina to lime varies considerably. Phosphorus pentoxide content varies from 1 to 23 per cent. Bulk sampling revealed an overall phosphoria content of 15 per cent, alumina content of 10 per cent, and lime content of 17 per cent.

Low grade phosphatic beds reappear farther south, on the Howqua River, and up to 11 per cent phosphoria was recorded from Cambrian tuffaceous beds on the Licola-Jamieson Road where it crosses Fullarton Spur. South of Wangaratta, at Edi and Whitfield, turquoise is associated with Upper Ordovician black shales. At Waratah Bay, small inliers of Lower Ordovician material on Hoddle Range showed low phosphoria analyses. In the Otway Basin, there are a number of minor phosphate occurrences in some of the Upper Cretaceous formations of the Wangerrip group.

Tin

Tin has been used by man for making bronze for 5,000 years. Cassiterite, tin oxide, is the only commercial mineral of tin, and although cassiterite may be dispersed throughout potash-rich granites, it is normally mined from tin-rich greisens or pegmatites (differentiates from potash granites), or from placer (alluvial) deposits, where weathering, water, and stream action have combined to concentrate the heavy mineral.

Low fusibility, malleability, corrosion resistance, fatigue resistance (ability to re-crystallise after working at atmospheric temperatures), and ability to alloy with other metals, accounts for the many uses for which tin is preferred. Tin is used in alloys such as solder (lead-tin), bronze (copper-tin), and brass (copper-zinc-tin). Phosphor-bronzes which have high strength, resistance to corrosion, and superior bearing characteristics contain 8 per cent tin and 0·2 per cent phosphorus. The largest use of tin is as a protective coating for copper and steel, the latter mainly in the form of tinplated steel (tin-plate) for cans. Copper wire used for power transmission is coated with tin to prevent corrosion and to facilitate soldering. Gun metal contains 10 per cent tin and 2 per cent zinc, and is used for gas-free, pressure-tight, corrosion resistant castings.

Cassiterite, tin oxide, contains 78·6 per cent tin, and when crystalline, is a brittle, resplendent, black, brown, red, grey, or honey-coloured mineral. It is most commonly black or deep red-brown. Scratch hardness is 6 to 7, specific gravity is 6·8 to 7·1. In spite of its similarity with other black, detrital minerals, particularly ilmenite, it can readily be identified after grains have been treated, with dilute hydrochloric acid, in a drilled hole in a zinc block. The hydrogen produced reduces the cassiterite to tin, which coats the surface of grains, and this becomes bright grey on rubbing. Primary tin oxide or cassiterite is generally deposited in roof zones of granitic intrusives or in veins around their periphery during the closing stages of crystallisation. These intrusives normally have a high potassium to calcium-magnesium ratio and hence tin tends to be confined to pegmatites, aplites, and greisens. Wolframite is a common associate in Victoria. Mineralisation is genetically related to acid granites intruded along structural highs during the late orogenic stages in the history of the Tasman Geosyncline.

Next to gold, tin is in terms of total production, the next most valuable mineral produced in Victoria. However, most of the Victorian output of 19,000 tons of tin concentrates, containing 73 per cent tin, to the end of 1961, was the by-product of gold-dredging of placer deposits in the Beechworth-Eldorado district, centred approximately 40 miles south-west of Albury. At Toora, 96 miles south-east of Melbourne, 363 tons of concentrates were produced from a Tertiary placer preserved in a down-faulted graben. Small tonnages of tin concentrates have been recovered from alluvial deposits at Chiltern and Rutherglen, south-west of Albury, while low-grade primary, cassiterite-bearing aplites and pegmatites are mined at Walwa. Tin occurs in dykes, lenses, and pipes of pegmatite in the Mitta Mitta area and in greisens, which intersect schists at Mt Wills, Eskdale, Tallandoon, and Wombat Creek.

At Cudgewa, quartz veins, transecting schist-granite contacts, carry, in addition to tin, wolframite and tourmaline. Stanniferous deposits are also associated with the granites of the Gembrook, Marysville, Tarago River, and Wilsons Promontory areas.

Tungsten

Tungsten, because it has the highest melting point of all the metals, has become important in nuclear applications where resistance to extremely high temperatures is required. When alloyed with steels it imparts a toughness and resistance to high temperatures which enables its use in die and tool steels. Tungsten carbide is used for cutting edges and other applications where extreme hardness is required. Pure tungsten forms the filaments of light bulbs, electronic tubes and X-ray tube components, and is used in electric contacts. Tungsten derivatives, the phosphors, are used in luminescent pigments, X-ray screens, television picture-tubes, and fluorescent light tubes.

Wolframite, iron-manganese tungstate, and scheelite, calcium tungstate, are the two common tungsten minerals. Scheelite is rare in Victoria. Wolframite is a brittle, brown-black mineral of submetallic lustre. The powdered material is characteristically dark red-brown. Scratch hardness is 5·0 to 5·5 and specific gravity 7·0 to 7·5. All the wolframite occurrences are small deposits associated with quartz veins and reefs near the margin of granite bodies, or in pegmatites associated with tin. Mineralisation is associated with the middle Palaeozoic granites of Eastern Australia.

Most of Victoria's wolfram concentrates came from Mt Murphy, 36 miles north-east of Benambra, where wolframite is found in quartz veins up to 4 ft thick, in slate and metamorphosed sandstone, near the margin of a granitic intrusive. Two wolfram-quartz reefs in granite have been worked at the Womobi mine at Thologolong, east of Albury. Wolframite is the dominant mineral, but sulphides of iron, copper, molybdenum, and bismuth are associated. Ore treated averaged 1·0 per cent wolframite. Shoots probably extend well beyond the areas stoped below the prospecting adit. Other areas where wolfram has been mined include Wilks Creek, Marysville, Ensay, Fainting Range, Koetong, and Wedderburn.

Uranium

A few radioactive occurrences have been reported from Victoria, all being deposits derived from granites, mineral within granite, or within dykes transecting granite.

At Mt Kooyoora, near Inglewood, torbernite has been identified from a superficial ironstone overlying granite. Torbernite has also been identified from the mullock dumps of the Meerschaum and Gentle Annie Mines at Glen Wills. Other radioactive occurrences have been investigated in the Lake Boga granite and in dykes in or near the Dargo granite on Bulgoback Creek. The metamorphics around the Moliagul-Wedderburn areas are reported to show some anomalous radioactivity.

Glossary of Terms

aeolian	..	Deposits, such as sand, transported by wind.
alluvial	..	Deposits resulting from deposition by rivers or streams.
anticline	..	A fold in rocks, arched upwards.
aplite	..	A dyke rock of sugary texture composed of light coloured granitic minerals.
basic (rock)	..	A dark coloured rock consisting of ferro-magnesian silicates, metallic oxides and less calcium-rich alumino-silicates (felspars).
batholith	..	A large solidified mass of magma intruded into the Earth's crust.
Cainozoic	..	See Time Scale, Geological.
Cambrian	..	See Time Scale, Geological.
Carboniferous		See Time Scale, Geological.
chert	..	Ultra-fine-grained, crystalline varieties of silica. Grey chert nodules in limestone are referred to as "flint".
China-clay	..	A clay consisting predominantly of kaolinite, a hydrous aluminium silicate.
concretionary	..	Consisting of nodules or particles of like composition and generally harder than the enclosing rock.
Cobar	..	Gold-copper mining town of central New South Wales.
conglomerate	..	A cemented sedimentary rock of rounded rock or mineral fragments varying in size from gravel to pebbles or boulders.
coral	..	Tiny, bottom dwelling, sedentary, marine animal secreting an external skeleton of calcium carbonate.
Cretaceous	..	See Time Scale, Geological.
deep leads	..	Victorian mining term for buried placer or buried alluvial deposit.
Devonian	..	See Time Scale, Geological.
diorite	..	A coarse grained, light coloured, intrusive, igneous rock composed of white felspar and a dark mineral.
dyke	..	A wall-like intrusive rock, occurring along a fissure in the Earth's crust.
Eocene	..	See Time Scale, Geological.
fault	..	A fracture or fracture zone in the Earth's crust, along which there has been relative displacement of the two sides.
felspar	..	A group of abundant rock-forming minerals. Alumino-silicates of potassium, sodium, and calcium.
fissure-vein	..	A crack or fault in the Earth's crust filled with mineral matter different from the wall rock.
fire-brick	..	See refractory.
fluorescence	..	Emission of visible light by a substance exposed to ultra-violet radiation.
flux ..	..	Substance that reduces the melting point of a mixture to which it has been added.
fossil	..	Remains or traces of animals or plants which have been preserved by natural causes in the Earth's crust.
fusion	..	Melting or softening by the application of heat.
geochemistry	..	Study of the abundance and distribution of elements in the Earth, particularly the Earth's crust, soil, and surface waters.
geophysics	..	That branch of physics dealing with the Earth, with respect to its structure, physical properties, and composition.
geosyncline	..	A large trough in the Earth's crust, that subsided throughout a long period of time, in which a thick succession of stratified sediments has accumulated. Subsequent lateral compression and folding of the sediments form mountain chains.
gneiss	..	A coarse grained banded rock in which minerals have recrystallised in alternating bands.

graben ..	A block of the Earth's crust bounded by faults and downthrown with respect to the surrounding rocks.
granite ..	A coarse grained, pale, white, grey, pink or green rock, intrusive into the Earth's crust consisting of quartz, potash-rich felspars, and mica.
granodiorite ..	Similar to granite except that felspars are soda rich. White and grey varieties only occur.
graphitisation ..	The crystallisation of graphite in cast irons and some steels. Uncontrolled graphite formation results in reduction of strength of these alloys.
greenstone ..	A common term applied to altered basic igneous rocks, which owe their colour to chlorite, serpentine or epidote.
greisen ..	A vein in granite, often altered by hot solutions, composed largely of quartz and mica. Accessory minerals include topaz, tourmaline, cassiterite, wolframite, etc.
hardenability ..	A measure of depth to which steel can be usefully hardened.
infra-red ..	Electro-magnetic radiation of long wave-length, just beyond the red end of the visible spectrum.
lacustrine ..	Pertaining to or formed by lakes.
laterite, lateritic	Residual surface soils or layers, developed under tropical or subtropical conditions. They are leached of silica and contain abundant iron, aluminium, and occasionally manganese hydroxides.
Lower Tertiary	See Time Scale, Geological.
lustre ..	The character of light reflected by minerals, e.g., metallic; vitreous (glassy), pearly, earthy, resinous, etc.
magma, magmatic	Hot, mobile rock material generated within the Earth and capable of intrusion into the crust or extrusion from volcanoes.
marine ..	Of the sea.
mesh ..	An opening in a screen. Mesh sizes are given as number of openings per linear inch.
Mesozoic ..	See Time Scale, Geological.
metamorphism	Process by which consolidated rocks are altered in composition or texture. Pressure, heat, or introduction of new substances are the principal causes.
mica ..	A group of rock-forming minerals, semi-transparent, characterised by perfect fissility in one plane. Essentially alumino-silicates of potassium.
micron ..	A unit of measurement, equivalent to one millionth of a metre and denoted by the Greek letter μ.
mineral ..	A homogeneous, naturally occurring, inorganic substance, having a characteristic molecular composition, structure and characteristic crystalline form.
Miocene ..	See Time Scale, Geological.
nugget ..	A waterworn piece of native gold of some size.
Oligocene ..	See Time Scale, Geological.
oolitic ..	Consisting of spherical particles from 0·25 to 2·00 millimetres in diameter, having a concentric or radial growth structure.
Ordovician ..	See Time Scale, Geological.
orogeny, orogenic	The process of forming mountains in the Earth's crust by folding or thrust faulting.

Palaeozoic	..	See Time Scale, Geological.
pegmatite	..	Granitic rocks of very coarse grain, representing the water rich, late stages of crystallisation of magma.
phyllite	..	A metamorphic rock intermediate in grade between a slate and a schist. Numerous, oriented mica crystals impart a silky sheen to the cleavage surfaces.
placer	..	A stream, coastal, or glacier deposit containing particles of gold or other valuable mineral.
plasticity	..	The property of a material that enables it, without the application of much work, to undergo permanent deformation without volume change, elastic rebound, or rupture.
Pliocene	..	See Time Scale, Geological.
polyzoa	..	Also called Bryozoa, a colony of tiny, marine animals which build calcareous structures.
porphyry	..	Rocks containing conspicuous crystals in a fine-grained groundmass, e.g., quartz porphyry or felspar porphyry.
pyroclastic	..	Detrital volcanic material that has been ejected from a volcano.
radioactive	..	The property shown by some elements of spontaneously changing into others by the emission of atomic particles from their nuclei.
reef ..	..	See vein.
refractory	..	Property of a material to withstand the action of heat, heat-shock, or chemical attack.
residual	..	Remaining in place after all but the least soluble constituents have been removed.
rhyodacite	..	Volcanic equivalent of granodiorite. Generally a light to dark grey, finely crystalline rock containing free quartz.
rhyolite	..	Volcanic equivalent of granite. A grey to brown, very fine-grained rock which may show pronounced flow-banding.
saddle-vein	..	A vein bedded in an anticline, to form the general shape of a saddle.
sandstone	..	A cemented or compacted sediment composed predominantly of quartz grains.
schist	..	A finely banded metamorphic rock, with subparallel orientation of micaceous minerals.
scratch hardness		An empirical measure of hardness. Mohs scale ranges from 1 (talc) to 10 (diamond), with calcite designated as 4, and quartz as 7.
serpentinite	..	A rock composed of the serpentine group of minerals, which are derived from alteration of rocks rich in iron-magnesium silicates.
shale	..	A laminated, consolidated sediment in which the constituent particles are predominantly of clay size.
Silurian	..	See Time Scale, Geological.
slate	..	A fine-grained metamorphic rock possessing a well developed fissility (slaty cleavage).
sluicing	..	The washing of gold or mineral bearing soil or clay through long boxes or races provided with riffles or other mineral retaining devices (sluices).
specific gravity		Ratio of the weight of material to the weight of an equal volume of water, e.g., quartz, SG = 2·6, i.e., 2·6 times heavier than water.
spurry veins	..	Subordinate veins which break off at an angle from a main bedded or fissure vein.
stope	..	An underground excavation from which ore has been extracted.

syncline .. A fold in rocks, arched downwards.

tailings .. Those parts of milled and treated ore that are regarded as too poor or uneconomic to be treated further.

tectonic .. Relating to major deformations of the Earth's crust, such as folding or faulting.

Time Scale, Geological

Era		Period	Age	Characteristics
CAINOZOIC	Quaternary	Holocene (Recent)	years	
			12,000	
		Pleistocene		Man appears
			1·5 millon	
	Tertiary	Pliocene Miocene		
			25 million	
		Oligocene Eocene Paleocene		
			67 million	Mammals appear
MESOZOIC		Cretaceous		Flowering plants appear
			137 million	
		Jurassic		Reptiles
			195 million	
		Triassic		
			235 million	
PALAEOZOIC		Permian		Amphibians
			285 million	
		Carboniferous		Ferns, mosses, luxuriant plant growth
			350 million	
		Devonian		Fishes
			405 million	
		Silurian		
			440 million	Marine invertebrate life
		Ordovician		
			500 million	
		Cambrian		
			570 million	
PROTEROZOIC		Pre-Cambrian		Primitive marine life
				"Dawn of Life"
ARCHEAN			4,500 million	Cooling of the planet

Triassic .. See Time Scale, Geological.

tuff .. .. A compacted rock composed of fine-grained volcanic fragments.

ultra-violet .. Electro-magnetic radiation of short wavelength just beyond the violet end of the visible spectrum.

vein .. .. An occurrence of ore disseminated through less valuable material and having a regular development in length, depth, but particularly width. See also fissure-vein and saddle-vein.

volcanic .. Pertaining to a volcano.

Geographical Features

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 covers about 87,884 sq miles or 56,245,760 acres.

It is bounded on the north and north-east by New South Wales, from which it is separated by the Murray River and a boundary about 110 miles long running north-westerly from Cape Howe to the nearest source of the Murray River, being a point known as The Springs, on Forest Hill. All the waters of the Murray River are in New South Wales, the State boundary being the left bank of the stream. The total length of the New South Wales boundary is about 1,175 miles.

On the west the State is bounded by South Australia and on the south by the Indian Ocean and Bass Strait. 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, Westernport 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 Wilsons 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	32·88
Queensland	667,000	22·47
Northern Territory	520,280	17·53
South Australia	380,070	12·81
New South Wales	309,433	10·43
Victoria	**87,884**	**2·96**
Tasmania	26,383	0·89
Australian Capital Territory	939	0·03
Total Australia	2,967,909	100·00

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 (Figure 1). 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 recognised 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*) Wilsons Promontory

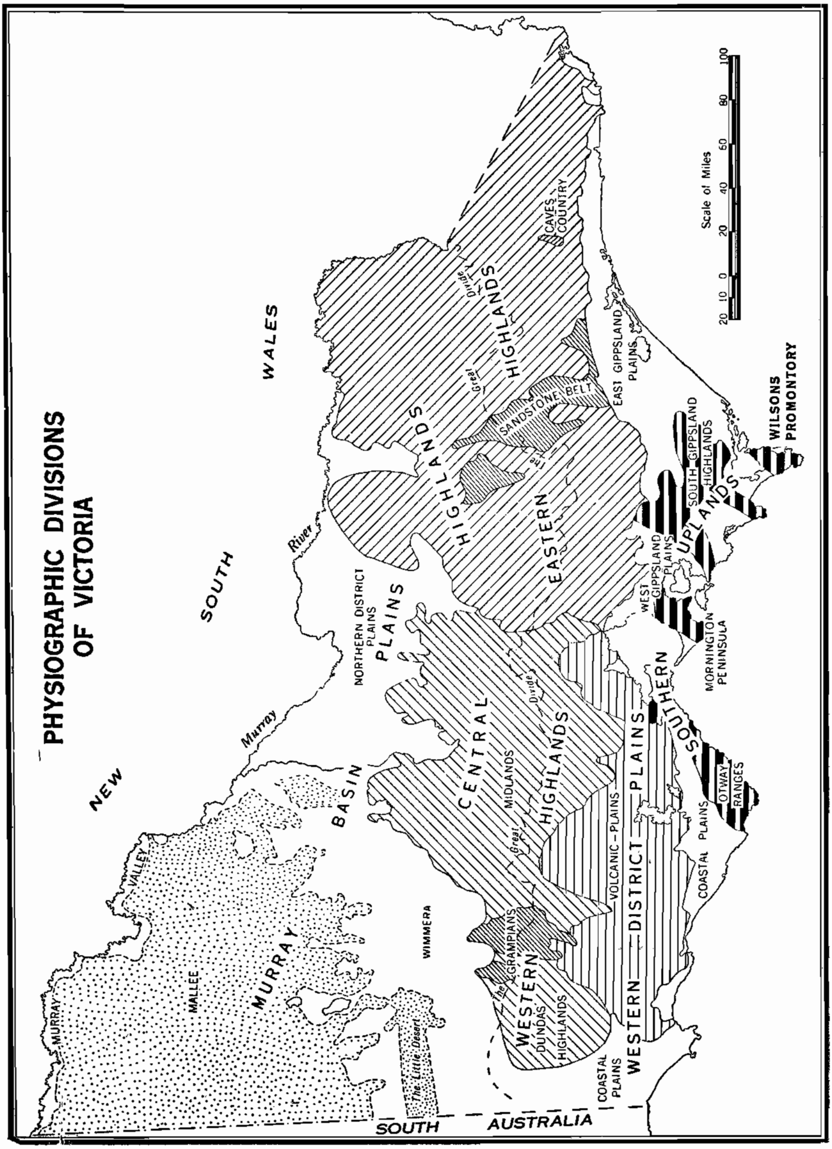


FIGURE 1.

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 periodic 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 ft 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 ft, while the Western Highlands are generally lower, the peaks reaching above 3,000 ft, 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 ft, 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 Westernport 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 offshore 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.

Further References

Victorian Year Book 1961—Geology of Victoria.

Victorian Year Book 1964—Land Surface of Victoria.

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.

Physical Environment and Land Use

The Central Highland Zone (see Figure 1) is the dominant physiographic region of Victoria. The greatest importance of these Highlands is their influence on the drainage pattern of the State. They act as a drainage division and catchment areas between the long north and north-west flowing rivers which are part of the Murray System and the shorter south flowing rivers.

The Highlands are divided into two parts by the 1,200 ft Kilmore Gap, a natural gateway for transport routes leading north from Melbourne.

Eastern Highlands

To the east, the Eastern Highlands form a broad, rugged region of deeply dissected high plateaux with elevations of up to 6,000 ft. They form a barrier to east-moving air masses, giving rise to heavy orographic rainfall of over 50 inches p.a. in the higher parts. This is the wettest part of the State, and is the coldest region in winter with substantial snowfalls at higher elevations, a factor responsible for the development of skiing resorts at locations such as Mt Buffalo, Mt Buller, Mt Hotham, and Falls Creek. Because of the elevation, this is also the coolest part of the State in summer. The rugged topography and dense forest cover of the Eastern Highlands makes them rather inaccessible and of little agricultural potential, so that they are the only large area of Victoria that is very sparsely settled and almost devoid of transport routes. However, the foothill zone adjoining the East Gippsland Plains is an important forestry area, while the lower slopes and valleys are used for grazing, particularly of cattle. High alpine grassland areas in the north-east, such as the Bogong High Plains, are used for summer grazing, this area being one of the rare cases of a transhumance farming economy in Australia. The high run-off and steep stream gradients have made the Eastern Highlands important for water storage and hydro-electricity generation at Kiewa, Eildon, and Rubicon.

Western Highlands

West of the Kilmore Gap, the Western Highlands are much lower than those to the east. These Highlands culminate in the west in a series of block mountains, of which the Grampians and the Dundas Highlands form the final western outlines of the Highland Zone. Stream gradients are more gentle than in the Eastern Highlands, so that hydro-electricity potential is low. However, the Rocklands Dam and the Eppalock and Cairn Curran Reservoirs are important storages for water supply to farms of the northern plains of Victoria.

The Western Highlands, because of their lower elevation, have a lower rainfall than the Eastern Highlands, and they do not act as a barrier to settlement and transport. The reasonably reliable rainfall of 20 inches to 30 inches p.a., cool winters, warm summers, rolling topography, open dry sclerophyll forest and grasslands, and moderately fertile, although thin, volcanic soils offer an environment suitable for sheep grazing for wool and fat lambs, fodder cropping, dairying, and potato growing. Early settlement of the area was stimulated by the gold discoveries of the 1850s and 1860s in the Ballarat and Bendigo districts, and these two cities have developed as important regional centres. Castlemaine, Maryborough, and Clunes are additional service centres.

Murray Basin Plains

North of the Central Highland Zone are the flat Murray Basin Plains (see Figure 1). The western section is comprised of the Mallee–Wimmera Plain, characterised by areas of east-west running sand ridges, grey-brown and solonised Mallee soils, and some areas of sandy wastelands. Rainfall is around 20 inches p.a. in the southern Wimmera, but it decreases to under 10 inches p.a. in the north-western Mallee, which is the driest area of the State. As well as being low, rainfall is erratic and unreliable in the Mallee–Wimmera, but the warm winters and hot summers ensure a year round growing season where water is available. Early farms were too small, and over-cropping led to widespread crop failures and soil erosion. Since the 1930s farming here has become more stable as a result of the provision of adequate and assured water supplies from the Mallee–Wimmera Stock and

Domestic Water Supply System (See pages 801–804), larger farms of over 1,000 acres, crop rotations, the development of a crop-livestock farming pattern, the use of superphosphate and growing of legumes to maintain soil fertility, and soil conservation practices. The winter rainfall maximum and dry summer harvesting period, the good rail and road network and bulk handling facilities, and scientific farming techniques have enabled the Wimmera to become a region of high-yielding wheat and mixed farms. The drier areas of the Mallee are characterised more by larger sheep properties.

Of great significance in the Mallee are the irrigation areas of the Mildura–Merbein–Red Cliffs and Swan Hill districts, with close settlement farming growing vines and fruits. Mildura, Ouyen, Swan Hill, Horsham, Warracknabeal, and St Arnaud are the main regional centres of the Mallee–Wimmera Plains.

The Northern District Plains form the narrower eastern section of the Murray Basin Plains. Here rainfall increases from 15 inches p.a. in the western part to over 30 inches p.a. in the eastern part of the plain adjoining the Eastern Highlands. Rainfall is more reliable than in the Mallee–Wimmera District. However, there is generally a summer water deficiency which restricts pasture growth, so that the Northern District Plains are characterised by extensive grazing and mixed wheat-sheep farms. Recently there has been increasing emphasis on " ley " farming (i.e., rotation of crops and pastures) in order to increase carrying capacities and productivity. The higher, eastern section of the Northern District Plains with more reliable rainfall is one of the best sheep and cattle grazing areas in the State.

There is a marked contrast in the Northern District Plains between the " dry " farming areas and those closely settled irrigation areas of the Murray and its tributaries, especially in the Kerang, Echuca–Rochester, Kyabram–Shepparton, and Cobram–Yarrawonga areas using water from the Loddon, Campaspe, Goulburn, and Murray Rivers, respectively. Fruits, vegetables, hops, and tobacco growing with local specialisations, and dairying based on improved pastures are the main activities in the irrigated districts. Shepparton has become an important centre for canned and frozen fruits and vegetables. These areas are also important as suppliers for the metropolitan fresh fruit and vegetable market.

In the Northern District Plains Shepparton, Wangaratta, and Benalla are large and expanding regional centres with manufacturing industries, while Echuca, Rochester, Kyabram, and Wodonga are smaller service centres with a small range of urban functions.

Coastal Region

South of the Central Highland Zone, coastal Victoria is readily divided into three regions.

The first of these is Port Phillip Bay and environs, bounded by the You Yang Range and Keilor Plain in the west, the Central Highlands in the north, the Dandenong Range and West Gippsland Plain in the east, and the Mornington Peninsula in the south-east. Melbourne, Geelong, and the developing Westernport provide port facilities in this region. This region is dominated by the urban areas of Melbourne, which is the hub of the State's transport system, and

Geelong. The urban areas are surrounded by intensively farmed rural landscapes in which market gardening is important in addition to cattle and sheep fattening, dairying, and fodder cropping. The bayside beach resorts and the seaside resorts of the Mornington Peninsula are the centre of an important tourist industry.

The second region of coastal Victoria is the extensive volcanic plain stretching westwards from the Port Phillip region. This is possibly the best agricultural region in Victoria. The rolling surface is characterised by volcanic plains and cones, lakes, and stony rises, with rich but shallow volcanic soils. Rainfall is above 20 inches p.a. in all areas, with a slight winter-spring maximum, and temperatures are warm in summer and mild in winter so that year round pasture growth and cropping are possible. Western District farms produce cattle, sheep for wool and fat lambs, fodder crops, and potatoes. This is also an important dairying district. Rural population densities, along with those of the West Gippsland dairying country, are second highest in the State after the northern irrigation districts. Colac, Warrnambool, Portland, Hamilton, and Camperdown are the main regional centres. Portland has recently developed modern port facilities.

South of the Western District Plains lie the Otway Ranges, a sparsely populated region of rugged scenery and very high rainfall. The coastline between Anglesea and Apollo Bay has a number of popular tourist resorts.

The third region of coastal Victoria is Gippsland. Immediately east of the Bay are the West Gippsland Plains, which are sandy in their western section where large areas of swamp have been drained for market gardening. The South Gippsland Highlands, a sparsely populated area of little agricultural potential, is bounded by the West Gippsland Plain and to the east by a fault trough stretching from Warragul to the Latrobe Valley. (Included in East Gippsland Plains in Figure 1.) The fault trough with its rolling hills, 30 inch rainfall, and year round pasture, is among the best dairying country in the Australian mainland, supplying the metropolitan whole milk market. The Latrobe Valley towns have experienced rapid post-war development as a result of the brown coal mining operations in the Yallourn-Morwell area.

East of the Latrobe Valley, rainfall decreases to below 30 inches p.a. between Traralgon and the Gippsland Lakes. Here the coastline is characterised by sand dunes and lagoons, backed by the riverine plains of the Latrobe, Macalister, Avon, and Mitchell Rivers. The relatively low rainfall necessitates irrigation for cropping. Irrigated farming in the Sale–Maffra, Bairnsdale, and (further east) Orbost districts is based on maize, bean, potato, and fodder growing. Elsewhere the main land use is cattle and sheep grazing.

The plains narrow east of Lakes Entrance when the coastline becomes one of alternating river valleys and hilly headlands where the Eastern Highlands protrude south to the sea. Forestry is the main activity here, with some grazing and fodder cropping in the valleys and foothills. Tourism is important in the area around Lakes Entrance, which is also a fishing port. Gippsland is linked with Melbourne by the Princes Highway and by rail as far east as Orbost.

Variety, then, is the keynote of Victoria's farming system and physiography. Generally, shortage of water is the main environmental problem for agriculture, especially north of the Highlands. Coastal Victoria has a more reliable rainfall. The Highlands are the only region where temperature extremes limit rural activity, and these are less intensively farmed than other parts.

Generally, Victoria's farmers practise progressive and productive agriculture. The State's 73,000 rural holdings produced $810.1m in 1967–68 which was 24·2 per cent of Australia's gross value of production. The importance of Victoria's farmers is seen when it is realised that they produce a substantial amount of Australia's farm output, e.g., 10 per cent wheat ; 17 per cent oats ; 7 per cent barley ; 73 per cent dried vine fruit ; 39 per cent mutton and lamb ; 19 per cent wool ; 25 per cent beef ; 23 per cent pigs ; and 56 per cent butter.

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 ft, while in the western sector the volcanic rocks belong mainly to the Newer Volcanic Series and the peaks reach 3,000 ft.

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 Mt Bogong, 6,516 ft ; Mt Feathertop, 6,307 ft ; Mt Nelse, 6,181 ft ; Mt Fainter, 6,157 ft ; Mt Loch, 6,152 ft ; Mt Hotham, 6,108 ft ; Mt Niggerhead, 6,048 ft ; Mt McKay, 6,045 ft ; Mt Cobberas, 6,030 ft ; Mt Cope, 6,026 ft ; Mt Spion Kopje, 6,025 ft ; and Mt Buller, 5,919 ft.

Further Reference, 1962

Marine Algae of the Victorian Coast

Environment

The Victorian coastline stretches for a distance of 980 miles and in the east abuts Bass Strait and in the west the Indian Ocean. The nature of the coastline is extremely variable, ranging from rocky cliffs to sandy beaches and muddy swamps. Along much of the coastline the characteristic pattern is of sandy bays alternating with rocky headlands. Rocky coasts show both a richer and more variable flora when compared to muddy, and more particularly, to sandy areas.

On the Pleistocene dune limestone, at Port Phillip Bay Heads and westward, low tide shore platforms are well developed ; intertidal shore platforms are found in the Port Campbell area of Western Victoria ; while on some parts of the coast there are no shore platforms at all, for example, at Wilsons Promontory where the granite cliffs plunge steeply into relatively deep water.

This section describes the plants growing in the strip of coast which lies between the upper limit of wave action and the depth to which sufficient light penetrates for plant growth. This is the *littoral* zone in its broadest sense. Its extent depends upon a number of factors, such as the slope of the shoreline, the range of tidal variation, the degree of exposure or shelter, and the turbidity of the water. In Victoria, when wave action and suspended matter are at a minimum, the depth of the illuminated zone is 30 to 40 ft. Tidal range varies from approximately 3 ft in the west of the State to 9 ft at Wilsons Promontory. Waves and wave action are difficult to measure, but waves have been recorded surging over 100 ft up cliffs in the Portland area.

The plants of this littoral zone draw no nutrients from the substrate, and the surrounding seawater provides all the nutrients essential to life. Salinity of seawater is regarded by convention as measurable in terms of the chloride ion concentration and this in large part is provided by sodium chloride (common salt). The salinity of the open ocean is relatively constant, about 3·5 per cent sodium chloride, but at river mouths fresh water inflow will cause the water to become brackish ; in marsh regions, excessive evaporation may increase the salinity, and conversely rain water will lower it.

Sea temperature is much less variable than air temperature ; Victorian coastal waters show an annual variation of only about 10° C. Considerable temperature variation can occur in rock pools exposed at low tide and temperatures of over 30° C are reached in rock pools during summer months.

Although the ocean itself represents a stable environment, the intertidal region is far from this. It is exposed for portion of the day to extremes of physical factors such as air temperatures, desiccation due to wind, and to dynamic factors, such as wave action and sand abrasion.

The sea and the intertidal fringe are inhabited by both plants and animals. These may be attached (*benthic*) or free living (*pelagic*) organisms. This article describes mainly the *benthic* plants of the littoral zone in its widest sense.

Algae

General

The plants consist primarily of algae, commonly called seaweeds. These are a mixed population of different plants all sharing the characteristics of lower or primitive plants; they do not show the complexities found in the higher land plants. The plant body or *thallus* of the algae is not differentiated into root, stem, and leaves; they do not have a vascular tissue transporting water, mineral salts, or manufactured food material; they do not form flowers, true fruits, or seeds. They are essentially water plants and have plant bodies and reproduction adapted for the aquatic environment.

The seaweeds are attached to a *substrate,* usually a rocky surface, or anchored in mud or sand. If attached to other plants they are called *epiphytic,* if growing on animals, *epizoic.* Some live in *symbiosis* with animals such as sponges, others with fungi. The latter group includes those algae which are partners in the *lichen* thallus. Lichens are well represented in the littoral zone in Victoria, and form conspicuous yellow, black or grey bands in the upper littoral and spray zones.

The thalli of algae vary in size from microscopic forms to large brown kelps up to 60 ft long. The simplest form of thallus is a single cell, which can be solitary or aggregated into a *colony. Filaments* consist of cells arranged end to end; and may be simple or branched, solitary or massed and intertwined, giving rise to a large number of different thallus forms. More advanced forms are membranous sheets, hollow tubes, or bladders; others are bushy tufts of cylindrical or flattened branches. Some algae have thick leathery or coriaceous flat thalli; these may be attached by a small *holdfast* or attaching disc which supports the free-floating blade; others have no localised holdfast and are attached by *rhizoids* on the entire surface of the blade forming a carpet-like layer on the substrate. The large brown kelps show the greatest differentiation in their morphology. They are attached by a holdfast composed of different branches or *haptera.* From these arises a *stipe* which supports and elevates the *fronds,* the extended photosynthetic areas of the plant body. These have the same function as the leaves of land plants. In smaller, less differentiated algae, the entire thallus acts as a photosynthetic area. It is as essential for the algae as for the land plants to have a maximum amount of their plant bodies exposed to sunlight, because they use solar energy for the conversion of carbon dioxide to carbohydrates. The site of the conversion is the *chloroplastids,* small diversely shaped *organelles* in the cytoplasm of the plant cell, which contain the green pigment *chlorophyll.*

All the land plants are green, but for centuries it has been observed that seaweeds have green, red, brown, and blue-green representatives. Their diverse colours are due to the presence of accessory pigments, yellow, red, and blue, which mask the ever present chlorophyll. There is not only a relationship between the colour of the algae and the assortment of pigments but also a co-ordination of their *photosynthetic products,* storage products, plastid structure, chemical constituents of the cell wall, and their mode of sexual reproduction. These characteristics are so fundamental that they are used to classify the algae into several large phyla. The main representatives of the benthic algae are placed in four phyla: the green algae *Chlorophyta* (Gk *chloros,* green; Gk *phyton,* plant), the brown algae *Phaeophyta* (Gk *phaeos,* dark), the red algae *Rhodophyta* (Gk *rhodos,* rosy-red), and the blue-green algae *Cyanophyta* (Gk *cyanos,* blue). Although members of these phyla differ in fundamental characteristics they display similar, and even identical plant forms. The types of morphology, ranging from unicells to large differentiated plants, are found in all pyhla, and this is evidence for parallel evolution within the different phyla ; each distinct thallus form is adapted to a particular *microhabitat* of the overall environment.

The higher plants which live on the land have roots and a vascular system for the absorption and transport of water and mineral salts from the soil. In the algae, suspended in an aqueous environment, all essentials for plant growth, including oxygen, carbon dioxide, and mineral salts are taken directly into the cells of the plant thallus.

Chlorophyta

The Victorian coastline displays a wide range of green marine algae, particularly in sheltered bays and rock pools. Some of these are perennial, others are seasonal. The majority are found in the intertidal belt, and rarely in the lower regions. They are grass-green in colour as their pigment complex, with a predominance of chlorophyll, is similar to that of land plants. The chloroplastids frequently contain a *pyrenoid,* a colourless but highly staining organelle of unknown function. They utilise the same wave lengths of the light spectrum as do land plants and grow best when not too deeply submerged. The food reserve is starch ; the cell wall is generally of cellulose. All marine chlorophyta reproduce sexually. The gametes are motile unicells, produced and released in large quantities ; they swim with the aid of two *flagella.* The gametes fuse in pairs to produce a *zygote,* which gives rise to a new alga.

Ulva lactuca, the sea lettuce, is a cosmopolitan alga occurring widely from high tide to low tide mark on rock platforms, in rock pools, and growing between sand and mud. The size of the thin membranous sheet varies from 2 to 3 inches on open rock platforms to very large sheets 5 to 6 ft diameter in most favourable areas. Ulva may be present under submerged conditions in all seasons of the year, but on open rock platforms it develops during the winter months and covers large areas during spring and early summer. It is killed by desiccation in the summer when low tide coincides with a hot windy day, and is then left bleached until washed away by the tide. It is heavily grazed by sea-snails so that leafy fronds are perforated or eaten to the basal holdfast. Closely related to Ulva is *Enteromorpha.* Species of Enteromorpha form thin walled hollow tubes attached by scarcely differentiated holdfasts. Enteromorpha is often found intermixed with Ulva but generally frequents more sandy coasts. It is used and sold commercially as " baitweed " for vegetarian fish. The mermaid's necklace, *Chaetomorpha darwinii,* is an unbranched filament up to 1 ft long composed of small pea-size cells attached by a single cell. It grows as an epiphyte and is found on exposed rocky coasts. The genus *Caulerpa* is represented by almost twenty species and has strong affinities with tropical and sub-tropical regions. The thallus consists of a rhizome, attached by rhizoids to the rocky substrate, which sends up green photosynthetic fronds of diverse shapes and sizes. It is a siphonous alga ; the entire elaborate thallus being a tube with continuous cytoplasm, many chloroplastids, and nuclei. There are no separate cells because there are no cross walls. Another siphonous alga with tropical affinities is *Codium.* It appears in three different growth forms, round balls (e.g., *Codium pomoides,* the sea apple), upright pencil to finger thick dichotomising thalli (e.g., *Codium fragile,* the branching seavelvet), and cushiony or felt-like flat growths. In Asiatic and Pacific countries, Codium is dried and used as a noodle-like food.

Phaeophyta

The abundance of the brown algae makes them a conspicuous feature on the Victorian rocky coast, and they are often washed up on sandy beaches as drift. They are brown to black in colour, because in the chloroplastids the chlorophyll is masked by a yellow-red pigment called *fucoxanthin.* Their food reserve is a sugar alcohol, *mannitol.* Their cell walls contain *algin,* the raw material for the production of *alginates.* This is extracted commercially in Tasmania from the giant brown kelp *Macrocystis. Macrocystis angustifolia* occurs in Victorian waters below the intertidal belt. It is anchored by an enormous holdfast from which arise several stipes up to 60 ft long. These bear the fronds which float on the water surface buoyed by gas-filled bladders. The giant bull kelp, *Durvillea potatorum,* is attached by sucker-like holdfasts and its large leather-like blades mark the lower region of the intertidal zone. The *Cystophora* and *Sargassum* groups characteristically form conspicuous bands in the lower intertidal region. Neptune's necklace, *Hormosira banksii,* is perhaps Victoria's commonest alga, and forms a dense cover on rocks in the mid-intertidal zone.

Rhodophyta

The red colouration of the Rhodophyta comes largely from the accessory pigments *phycoerythrin* (red) and *phycocyanin* (blue). The cell wall is chiefly composed of pectic substances. *Porphyra,* the red laver, is a red membranous sheet similar in appearance to *Ulva.* It is gathered in Wales and commercially farmed in Japan for human consumption. In Victoria it is found only during winter months. *Corallina* has a stiff coral-like thallus impregnated with calcium carbonate. It is found during all seasons of the year and is often associated with *Hormosira banksii.* Also associated with *Hormosira* is the turf-forming *Gelidium pusillum.* Larger species of *Gelidium* are found in Victoria, and such forms are commercially harvested in New Zealand for the production of *agar agar,* used for medical research.

Cyanophyta

The most ubiquitous though inconspicuous group of the algae are the blue-greens. They commonly form slippery growths on rocks in the upper intertidal region, and crusts on salt marshes. Plants are only visible when amassed to form a colony.

Zonation

In every littoral environment a large number of environmental factors are present and active along a gradient. The adaptation of the different plants to varying conditions such as light, temperature, and exposure along these gradients results in a more or less distinct *zonation* of the plants. Zonation is abrupt on steep surfaces as at Wilsons Promontory, but if the rocks are gradually sloping and much dissected, then the pattern of the zonation is broken and less easily recognised.

The characteristic zone forming plants along the Victorian coast are shown in the following table :

Zone	Characteristic Plants
Spray	Lichens ; *Lichina, Caloplaca*
Upper- Intertidal	*Porphyra, Splachnidium, Rivularia*
Mid- Intertidal	*Hormosira banksii, Corallina* mat.
Lower- Intertidal	*Cystophora* species
	Durvillea potatorum (rarely exposed at low tide)
Sub-littoral (never exposed)	*Macrocystis angustifolia*

Hydrography of Coast, 1966 ; Coastal Physiography, 1967 ; Plant Ecology of Coast, 1968 ; Marine Animal Ecology, 1969

Rivers

Stream Flows

Water is a limited resource and a major factor in the development of the State. Hence a knowledge of its water resources is essential to their optimum use. Tabular data giving the mean, maximum, and minimum flows at selected gauging stations are published periodically by the State Rivers and Water Supply Commission in their *River Gaugings*. The data in the table below have been extracted from the latest published volume containing records of 175 gauging stations to 1965.

An average value such as the mean annual flow is a useful relative single measure of magnitude, but variability is equally important. Another crude measure of such variability is given by the tabulated values of the maximum and minimum annual flows ; however, the difference between these extremes, termed the " range ", will increase with increasing length of record.

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

VICTORIA—SCHEDULE OF MAIN STREAM FLOWS

Div.	Basin	Stream	Site of Gauging Station	Catchment Area (Square Miles)	Year Gauged From	Annual Flows in '000 Acre Ft			
						Mean	No. of Years	Max.	Min.
IV—Murray–Darling Division	1	Murray ..	Jingellic ..	2,520	1890	1,933	76	4,978	549
		Mitta ..	Tallandoon ..	1,840	1935	1,063	30	2,613	316
		Mitta ..	Tallangatta ..	2,000	1886	1,147	49	3,460	203
	2	Kiewa ..	Kiewa ..	450	1886	518	80	1,684	144
	3	Ovens ..	Wangaratta ..	2,250	1941	1,308	25	3,367	271
	4	Broken ..	Goorambat ..	740	1887	205	79	887	15·5
	5	Goulburn ..	Murchison ..	4,140	1882	1,795	84	6,139	516
	6	Campaspe ..	Elmore ..	1,240	1886	192	78	667	0·6
	7	Loddon ..	Laanecoorie ..	1,610	1891	205	75	660	8·9
	8	Avoca ..	Coonooer ..	1,000	1890	63	76	321	3·8
	15	Wimmera ..	Horsham ..	1,570	1889	104	77	479	0
II—South East Coast Division	22	Snowy ..	Jarrahmond ..	5,000	1907	1,682	42	3,254	766
	23	Tambo ..	Bruthen ..	1,030	1906 (*a*)	179	29	575	50
	24	Mitchell ..	Glenaladale ..	1,530	1938	764	28	1,779	325
	25	Thomson ..	Cowwarr ..	420	1901	325	50	553	142
	25	Macalister ..	Glenmaggie ..	730	1919	477	47	1,277	181
	26	Latrobe ..	Rosedale ..	1,600	1901 (*b*)	777	51	2,634	362
	28	Bunyip ..	Bunyip ..	268	1908 (*c*)	124	47	246	56
	29	Yarra ..	Warrandyte ..	899	1892	685	48	1,215	265
	30	Maribyrnong ..	Keilor ..	500	1908 (*d*)	91	35	266	3
	31	Werribee ..	Melton ..	446	1917 (*e*)	68	49	259	5·3
	32	Moorabool ..	Batesford ..	430	1908 (*f*)	58	16	149	2·5
	33	Barwon ..	Winchelsea ..	370	1922 (*g*)	115	33	412	25
	35	Carlisle ..	Carlisle ..	30	1930 (*h*)	32	31	71	14·5
	36	Hopkins ..	Wickliffe ..	540	1921 (*i*)	28	34	103	1·4
	38	Glenelg ..	Balmoral ..	606	1889 (*j*)	117	60	439	2·5

[Source : *River Gaugings to* 1965, State Rivers and Water Supply Commission]

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

Catchment and Lengths

Other characteristics relating to streams are the size of the catchment and the lengths of the rivers. Areas of gauged catchments are given in *River Gaugings,* and the lengths of 230 rivers are tabulated on pages 31 to 35 of the 1963 *Victorian Year Book.*

Catchments may be regarded as the hydrologically effective part of a " basin ", or the area from which there is " run-off " to the stream. Thus, the whole of any area may be subdivided into basins, but parts 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 inches to 20 inches. Above this amount, roughly half the rainfall appears as stream flow.

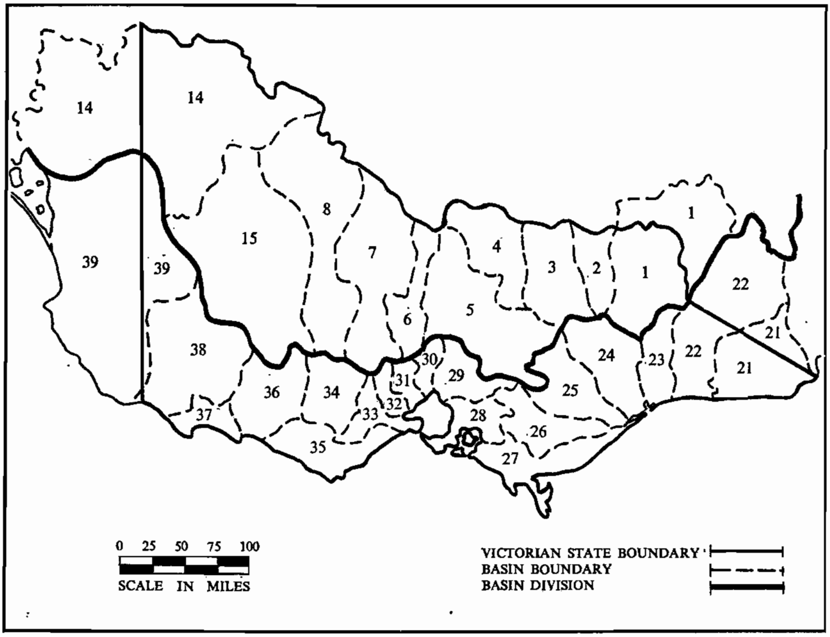


FIGURE 2.—Relevant Basins of the two Divisions (South East Coast Division and Murray–Darling Division) which include Victoria and some adjacent areas. The Basins are numbered as shown on Map 3 (Sheet 2) in *Review of Australia's Water Resources*, published by Department of National Development, 1965.

SOUTH EAST COAST DIVISION

21. East Gippsland
22. Snowy River
23. Tambo River
24. Mitchell River
25. Thomson River
26. Latrobe River
27. South Gippsland
28. Bunyip River
29. Yarra River
30. Maribyrnong River
31. Werribee River
32. Moorabool River
33. Barwon River
34. Lake Corangamite
35. Otway
36. Hopkins River
37. Portland
38. Glenelg River
39. Millicent Coast

MURRAY–DARLING DIVISION

1. Upper Murray River
2. Kiewa River
3. Ovens River
4. Broken River
5. Goulburn River
6. Campaspe River
7. Loddon River
8. Avoca River
14. Mallee
15. Wimmera–Avon River

Total Flow

The current estimate of mean annual flow is 17 mill. acre ft each year, 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 mill. acre ft (with about 8 mill. acre ft in the north-east and 6 mill. acre ft in the south-east) and hence leaving 3 mill. 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 Crown 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 ; this is a function of the committee appointed under the *Survey Co-ordination Place Names Act* 1965.

Stream Reserves

In 1881, under the then current Land Act, an Order in Council created permanent reserves along the banks of streams where they passed through Crown land. These are scheduled in the *Township and Parish Guide* reprinted by the Lands Department in 1955. This schedule indicates the location and width of reservations for 280 streams which (except for the Murray) are 1, 1½, or 2 chains wide on *each* bank of the stream. The areas thus reserved were not fully delineated until subsequently surveyed prior to alienation.

Further Reference, 1963 ; Droughts, 1964

Floods

General

The natural history of unregulated rivers is largely the history of their floods and droughts. Rainfall intensity increases with decrease in latitude and consequently Victoria is less subject to floods than the northern States. The practical importance of floods is, however, largely related to the damage they do in occupied areas.

Flood damage usually occurs because of the occupation of flood plains and once occupied, there is a demand for protection which is commonly provided by levees. Such levees have been constructed along the major streams including the Murray, Snowy, and Goulburn, and also in urban areas occupying the flood plain of the Dandenong Creek. The objection to levees is that by restricting the flood plain, the flood level for a given discharge is increased, and if overtopping does occur, damage is more serious. Other flood mitigation measures used in Victoria, such as straightening the stream to increase the gradient and flow rate, have also been used on such streams as the Bunyip and the Yarra. Provision to prevent excessive scour may be necessary in some cases.

Lake Level Changes

Another form of flood damage that has occurred in the Western District is due to the increase in level of closed lakes flooding marginal land. This has been caused by a series of wet years since 1950 upsetting the normal balance between evaporation and inflow. In the decade since 1950, the winter rainfalls in the region of Lake Corangamite were 15 per cent above average, and the lake level rose 11 ft above its normal level of 380 ft to 391 ft to inundate about 20 square miles of adjacent land.

To reduce the inflow to this lake and hence the area flooded, a 28 mile channel, completed in 1959, diverts water to the Barwon River from the Cundare Pool. This pool, which was formed by building a low barrage across a shallow area at the head of the lake, acts as a temporary storage for the relatively fresh waters of the Woady Yaloak River which normally enter the lake.

The rate of diversion is governed by the level of the Cundare Pool and by the relative salinities of water in the pool and in the Barwon River. If the 60,000 acre ft diverted in 1960 had entered Lake Corangamite, the lake level would have been 9 inches above the maximum observed level. The level would have been almost as high again in late 1964—another very wet year—but for the diversion in the preceding five years of about 180,000 acre ft. These wet years have maintained the relatively high lake level.

Legislation has been passed to permit the Government to pay compensation on a special scale to landowners who may elect to surrender land up to R.L. 388, around Lake Corangamite, plus any higher land rendered inaccessible to the landowner by the initial surrender. The legislation also makes similar provision for the neighbouring Lakes Gnarpurt and Murdeduke.

Other Floods

Owing to the tendency for major floods to overflow the banks and, in flat country, to pass down other channels which may not rejoin the main stream, it is often difficult to determine even the relative magnitude of major floods. The difficulty is magnified by the necessity for maintaining records of the level of the gauge in relation to a permanent datum, if a true comparison is to be made.

The year 1870 is regarded as the wettest that Victoria has experienced for over a century. As there were only thirteen rainfall stations whose records are available, the estimated average of 38 inches over the State is crude, but is 3 inches more than the next highest figure of 35 inches for 1956. River gauges in 1870 were practically restricted to the Murray, and consequently flood estimates on other streams are crude and can only be inferred from dubious evidence. Furthermore, subsequent to the 1870 floods, levees were constructed along the Goulburn and other streams and consequently heights of subsequent floods were augmented by the restrictions imposed.

In the north-east, floods occurred in the years 1906, 1916, 1917, and 1956. Although records of flood flows at gauging stations on the main streams have been published, such estimates are open to correction in the light of more recent evidence. Owing in part to under-estimation of earlier floods, the protection at the S.E.C. works at Yallourn was inadequate and the 1934 flood overflowed the banks of the Latrobe into the open cut at Yallourn. This flood was caused by a storm which is, on the basis of rainfall over large areas, the most severe that has been recorded within Victoria. An earlier storm of December 1893, which occurred over East Gippsland was heavier, but this also covered part of New South Wales.

Lakes

Lakes may be classified into two major groups : those without natural outlets which are called " closed " lakes and those with a natural overflow-channel which may be termed " open " lakes. For closed lakes to form, annual evaporation must exceed the rainfall : this is the case over most of Victoria.

Closed lakes occur mainly in the flat western part of the State. They fluctuate in capacity much more than open lakes and frequently become dry if the aridity is too high. Lake Tyrrell in the north-west is usually dry throughout the summer and can consequently be used for salt harvesting.

The level of water in an open lake is more stable because as the lake rises the outflow increases, thus " governing " the upper lake level and thus partially regulating streams emanating from it. This regulation enhances the economic value of the water resources of open lakes but Victoria does not possess any such large lake-regulated streams. However, there are small streams of this type in the Western District, such as Darlots Creek partly regulated by Lake Condah and Fiery Creek by Lake Bolac.

Salinity is often a factor which limits the use of lake water ; even the use of freshwater lakes is not extensive in Victoria due to the cost of pumping. The average salinity of closed lakes covers a wide range depending upon the geological conditions of the catchments and the water level.

Lake Corangamite is Victoria's largest lake. It can be regarded as a closed lake although during the wet period in the late 1950s it rose to within 4 ft of overflowing. The total salt content is about 16 mill. tons, giving the lake a salinity somewhat higher than seawater under average water level conditions.

The Gippsland Lakes are a group of shallow 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. A gap through the coastal dune barrier near Red Bluff, which was opened in 1899, provides an artificial entrance to the lakes from the sea. However, sea water entering this gap has increased the salinity of some lakes, which in turn has killed some of the bordering reed swamp and led to erosion. The Gippsland Lakes have been of value for commercial fishing and private angling and also attract many tourists. Coastal lagoons of this type rarely persist for more than a few thousand years and as deposition of sediment proceeds and bordering swamps encroach, the Lakes will gradually be transformed into a coastal plain.

A number of Victorian lakes and swamps have been converted to reservoirs. Waranga Reservoir is an example of this, as are Fyans Lake, Batyo Catyo, and Lake Whitton in the Wimmera. A good example of lake utilisation is the Torrumbarry irrigation system on the riverine Murray Plains near Kerang in north-west Victoria.

Further Reference, 1965; Natural Resourses Consevation League, 1965; Survey and Mapping, 1969

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.

Circulation Patterns Affecting Victoria

The predominating pattern which affects Victoria is an irregular succession of depressions and anticyclones. Although these systems generally move from west to east, this is not always the case. Systems can develop or degenerate *in situ.* Their speed of movement can vary considerably. They can remain quasi-stationary for even a week or more at a time.

The mean tracks of the depressions and anticyclones show a marked annual variation across the Australian region. In winter, due to the cold continent, anticyclones are centred over inland Australia, and a series of depressions over southern waters provide a persistent zonal flow across southern parts of the continent. However, on occasions when an anticyclone develops a ridge to southern waters and a depression intensifies east of Tasmania, a " cold outbreak " occurs. This brings cold and relatively dry air from southern waters rapidly across Victoria, giving windy, showery weather with some hail and snow. On other occasions, when an anticyclone moves slowly over Victoria, a prolonged spell of fine weather with frost and fog results.

During the spring, the average track of depressions and anticyclones shifts further south until in summer the average position for anticyclones is south of the continent. At this time of the year the troposphere is warmer, and therefore can hold more moisture. For this reason, rainfall during the summer months tends to be heavier. However, lifting agents in the form of cold fronts are weaker and are not as frequent as the succession of fronts that pass in winter and spring, and so rain days are less frequent in summer.

Heat wave conditions, which usually last between two and three days, and occasionally longer, are not infrequent in summer, when a large anticyclone remains quasi-stationary over the Tasman Sea. Dry air from the hot interior of the continent is brought over south-eastern Australia, and hot gusty northerly winds strengthen with the approach of a southerly change. These changes vary in intensity and while some are dry, others may produce rain and thunderstorms.

During the autumn, the mean track of the anticyclones moves northwards and extremes of temperature become less frequent as the season progresses.

One of the greatest State-wide rain producing systems is a weak surface depression whose centre moves inland across the State and which extends upwards in the atmosphere to 20,000 ft and more. When warm moist air from the Indian Ocean has been advected across the continent in the higher levels of the atmosphere, the presence of such a system can give very heavy rainfall. Not infrequently the " upper low " may be present without any indication at the surface. On occasions, these inland depressions are not closed systems, but are " troughs in the easterlies ", and when moisture is present, these can also produce general rain. These are more common in the summer months, when moist, humid air from the Tasman Sea is brought over southern Victoria.

The heaviest rainfall in East Gippsland is produced by intense depressions to the east of Bass Strait. These may have come from the west and intensified in this area, or alternatively may have developed to the east of New South Wales or further north, and moved southwards along the coast.

The distribution of the average annual rainfall in Victoria is shown in the map on page 53.

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 for the driest parts of the Mallee to over 60 inches for 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 on 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 rarely 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 rarely 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 1962.

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 1967 and 1968 are shown in the following table :

VICTORIA—DISTRIBUTION OF AVERAGE AND ANNUAL RAINFALL

Rainfall (In)	Area ('000 Sq Miles)		
	Average	1967	1968
Under 10	Nil	32·1	1·5
10–15	19·7	21·7	8·8
15–20	13·4	13·7	16·6
20–25	15·7	8·3	17·1
25–30	15·8	7·0	15·9
30–40	14·2	4·7	14·8
Over 40	9·1	0·4	13·2

District Rainfall

Mallee and Northern Country

These districts receive very little rain from western cold fronts, and rain is usually brought by depressions moving inland, " upper lows ", and thunderstorms. The amount received is highly variable from year to year. The average rainfall is fairly even through the year, except near the northern edge of the ranges where more rain falls in winter than in summer.

Wimmera

Rainfall in this district is more reliable than further to the north, as cold fronts bring showers, particularly in winter. The average rainfall shows a slight maximum in the winter months. This district includes part of the Grampians, which receive much higher rainfall than the plains.

Western and Central Districts

Rain may fall in these districts in a variety of situations and they have the most reliable rainfall in the State. Most rain comes with the westerly winds and cold fronts which predominate in winter and the average rainfall shows a winter maximum which is most marked along the west coast. The heaviest rain falls on the Otways, the Dandenongs, and the Upper Yarra Valley, while the plain to the west and south-west of Melbourne has relatively low rainfall due to the " rain shadow " of the Otway Ranges.

C.362/69.—3

North-Central

Most of this district consists of elevated country surrounding the Dividing Range and rainfall is heaviest on the higher parts, particularly towards the east. There is a well marked winter maximum in the yearly rainfall distribution.

North-Eastern

The greater part of this district consists of ranges, some mountains being 6,000 ft in elevation, and rainfall on this higher country is generally heavy. The higher peaks lie under snow cover for most of the winter. A marked rain shadow area is evident near Omeo, which receives only half as much rain as the highlands to the north-west or north-east.

West Gippsland

The western part of this district has a very similar rainfall régime to the Western and Central Districts. The heaviest rain falls on the ranges of the Divide and the south Gippsland hills. Towards the east, however, a "rain shadow" is evident in the Sale–Maffra area. This eastern section receives some of its rain from east coast depressions.

East Gippsland

Depressions off the east coast bring most rain to this district, and such rainfall can be very heavy. The average rainfall shows a summer maximum. Fronts moving in a westerly stream bring very little rain, and with north-westerly winds in winter, the coastal section has the mildest weather in the State. Rain shadows are evident along the valleys of the Mitchell, Tambo, and Snowy Rivers while the heaviest rain falls on the surrounding highlands.

A description of the State's agricultural districts will be found on pages 281 to 286.

VICTORIA—RAINFALL IN DISTRICTS
(In)

Year	Districts							
	Mallee	Wimmera	Northern	North-Central	North-Eastern	Western	Central	Gippsland
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
1964	16·14	25·02	20·93	34·40	40·27	38·69	35·40	37·99
1965	11·76	15·25	15·36	25·83	25·80	24·67	25·09	26·28
1966	12·48	16·47	20·28	31·97	41·26	29·35	32·08	38·97
1967	5·10	8·71	9·46	16·06	17·62	16·43	17·09	23·33
1968	13·68	19·68	20·93	34·66	39·51	33·54	28·84	34·04
Averages*	12·93	18·09	18·50	27·83	34·57	28·48	29·33	33·70

* Averages for 53 years 1913 to 1965.

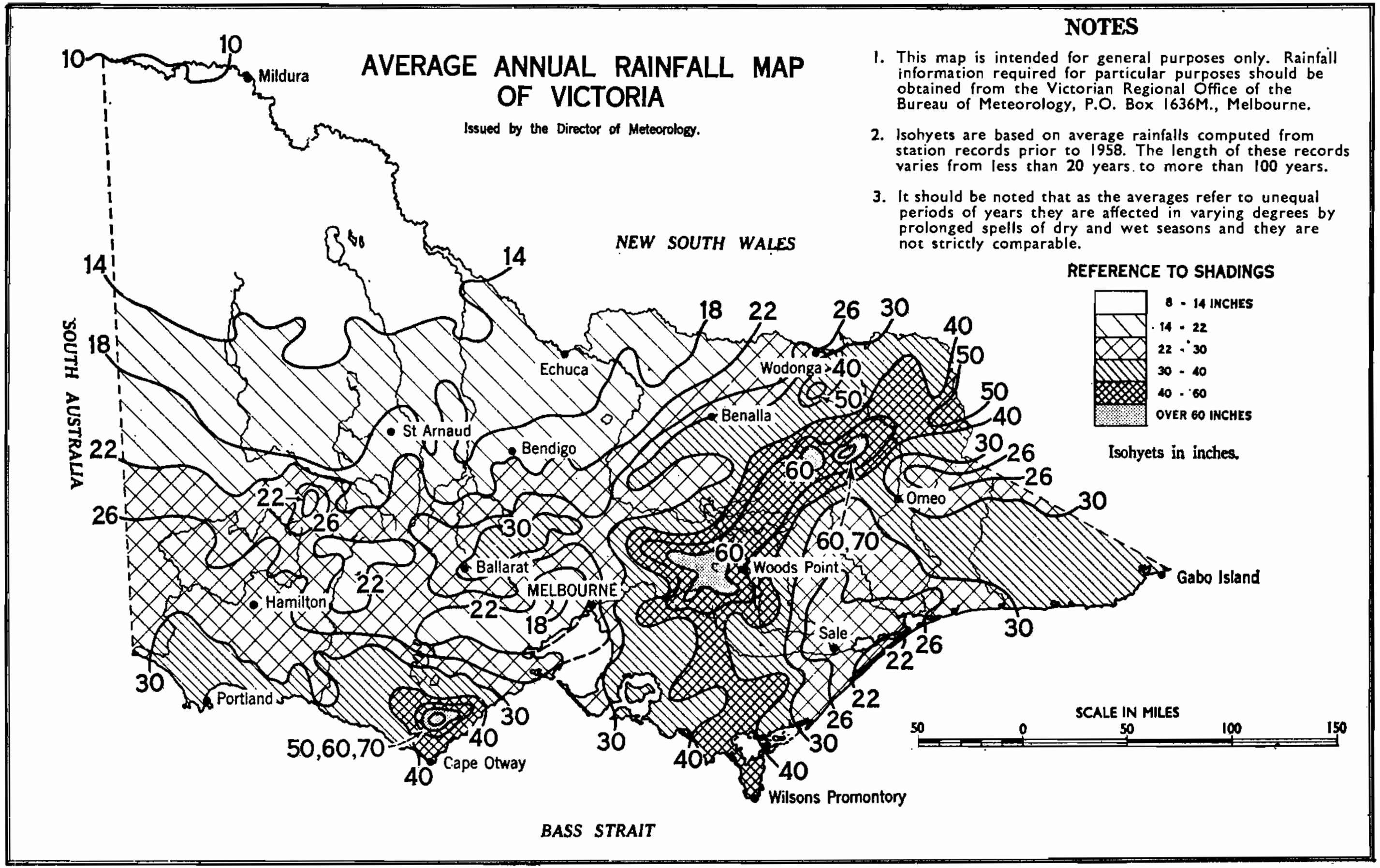

AVERAGE ANNUAL RAINFALL MAP
OF VICTORIA
Issued by the Director of Meteorology.
NOTES
1. This map is intended for general purposes only. Rainfall information required for particular purposes should be obtained from the Victorian Regional Office of the Bureau of Meteorology, P.O. Box 1636M., Melbourne.
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
10
14
18
22
26
30
40
50
60
60,70
50,60,70

FIGURE 3.

VICTORIA—DISTRICT MONTHLY RAINFALL: AVERAGE AND 1968

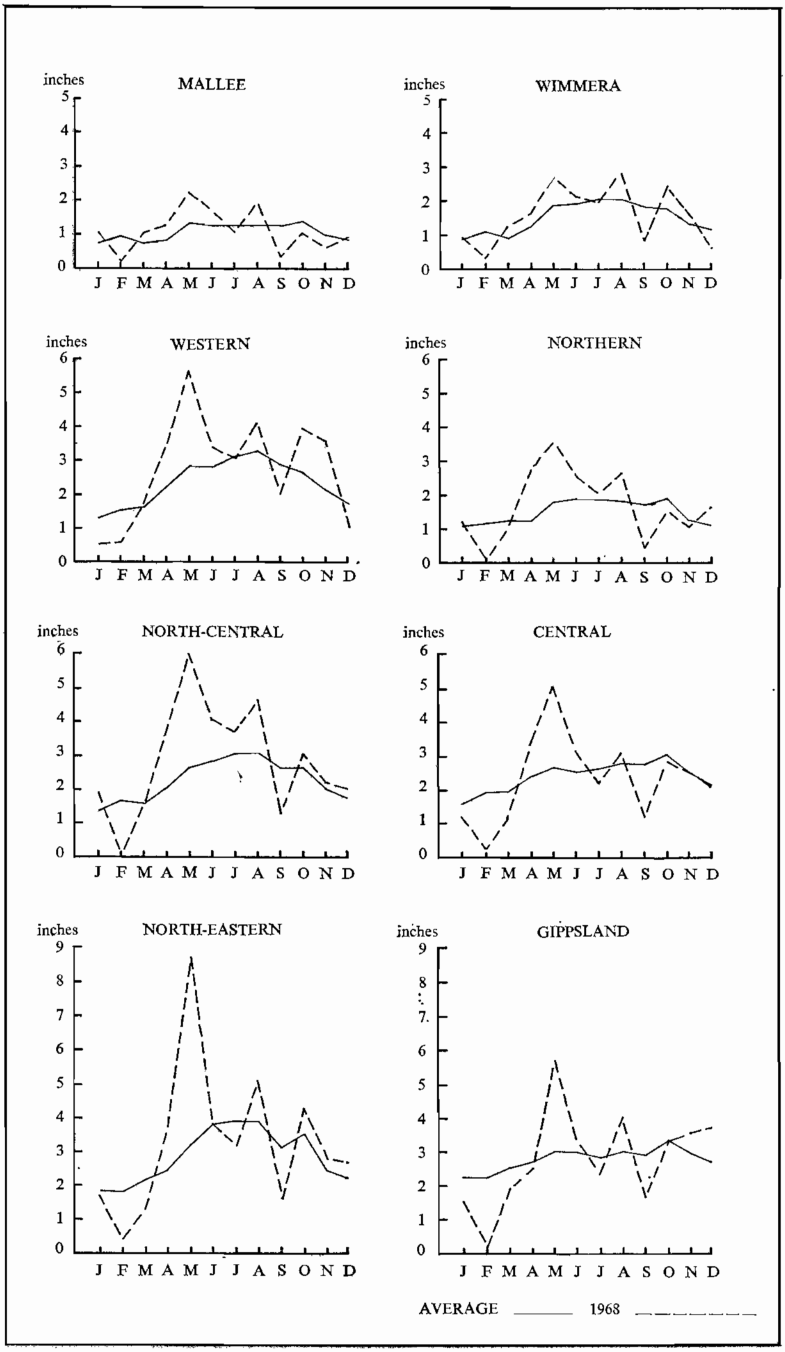


FIGURE 4.

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 measure 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 average and the standard deviation. To compare one distribution with the other, the coefficient of variation $\left(\frac{\text{standard deviation}}{\text{the average}} \times 100\right)$ has been used. The coefficient of variation has been calculated for the fifteen climatic regions of Victoria (see Figure 5) for the 53 years 1913 to 1965 and the results are tabulated below in order of rainfall reliability :

VICTORIA—ANNUAL RAINFALL VARIATION

District	Average Annual Rainfall*	Standard Deviation	Coefficient of Variation
	in	in	per cent
1. Western Plains	24·90	3·34	13·4
2. West Coast	30·34	4·64	15·3
3. West Gippsland	36·06	5·67	15·7
4. East Central	35·27	5·74	16·3
5. East Gippsland	30·20	5·25	17·4
6. West Central	23·89	4·41	18·5
7. Wimmera South	19·53	3·78	19·4
8. Wimmera North	16·30	3·37	20·7
9. North Central	27·83	6·07	21·8
10. Upper North-East	43·77	10·05	23·0
11. Mallee South	13·66	3·44	25·2
12. Lower North-East	30·27	7·68	25·4
13. Upper North	20·01	5·19	25·9
14. Lower North	16·86	4·65	27·6
15. Mallee North	11·86	3·36	28·3

*Average for 53 years 1913 to 1965.

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.

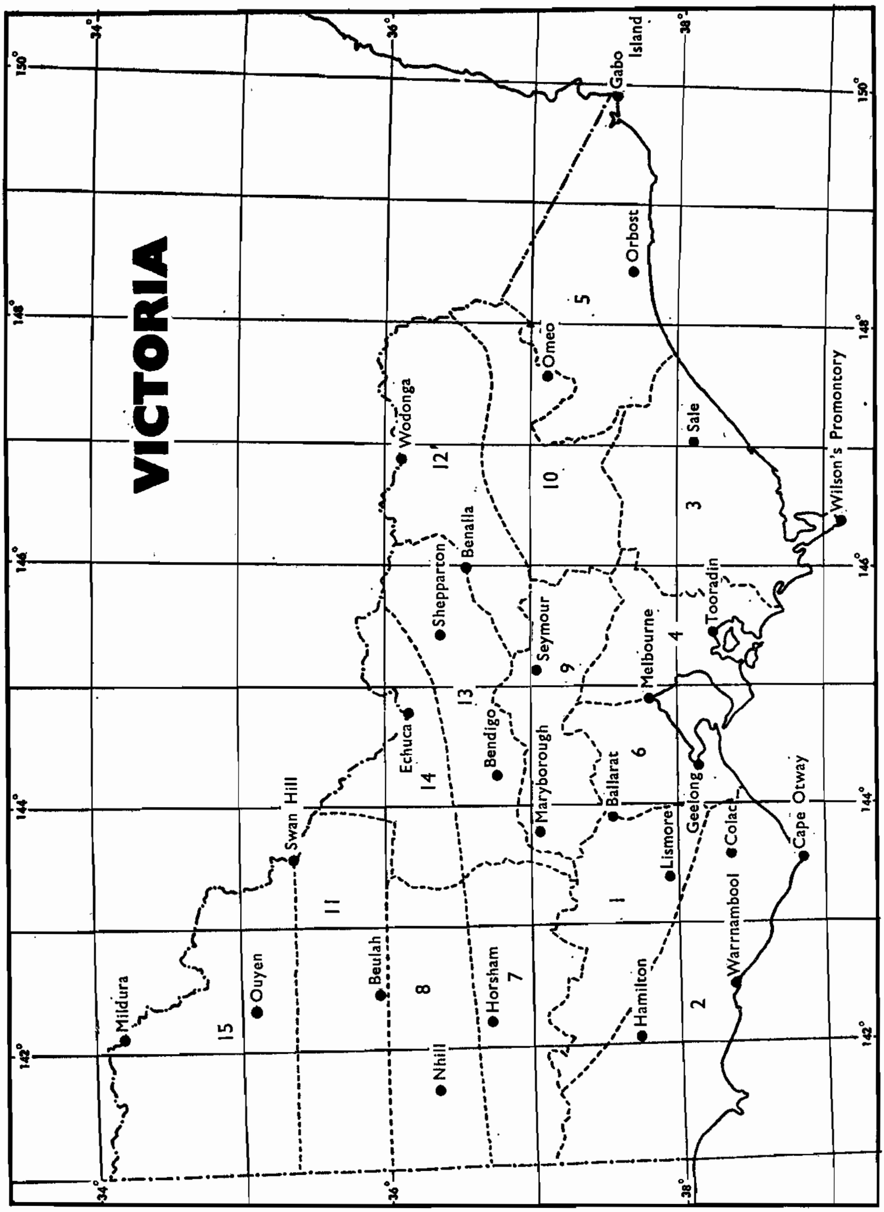


FIGURE 5.—Relative rainfall variability based on district annual rainfall. Names of districts are shown in table on previous page.

Most of the elevated areas of eastern and southern Victoria normally receive over 40 inches and in some wetter sections over 60 inches. 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.

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 and long enough to be classified as droughts. The severity of major drought or dry spells is much lower in Gippsland and the Western District than in northern Victoria.

The earliest references to drought in Victoria appear to date from 1865, when a major drought occurred in Northern Victoria, and predominantly dry conditions prevailed in the Central District. Another dry spell of lesser intensity occurred in 1868.

The most severe and widespread drought recorded since white settlement in Australia occurred in the period 1897 to 1902. Victoria was most affected in the south in 1897–98 and particularly in the north in 1902.

The next major drought commenced about June 1913 and continued until April 1915 in the north and west and August 1916 in Gippsland. The worst period was from May to October 1914.

The period from 1937 to 1945 was marked by three major droughts. The first commenced in February 1937 and continued with a break in the succeeding spring and summer until January 1939, the effects being felt much more severely in northern districts than elsewhere. Good rains in 1939 were followed by another dry period from December 1939 to December 1940. The third drought of the period extended from 1943 to 1945 in which the worst period was from June to October 1944. The drought from 1967 to 1968 is described on pages 53 and 67 of the *Victorian Year Book* 1969 and other effects noted on pages 309 to 312 of this book.

Droughts of shorter duration and lower intensity occurred in 1888, in 1907–08 in Gippsland, and in the 1920s, particularly 1925, 1927, and 1929.

Readers are referred to the publication *Droughts in Australia* Bulletin No. 43 of the Commonwealth Bureau of Meteorology, published in 1957, for a definitive treatment of the subject of droughts in Victoria.

1967–68 Droughts, 1969

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

VICTORIA—MEANS OF CLIMATIC ELEMENTS: SELECTED VICTORIAN TOWNS

	Locality	Legend No.*	January	February	March	April	May	June	July	August	Sept.	October	Nov.	Dec.	Annual
MALLEE	Mildura ..	1	71	79	71	63	103	119	90	102	91	107	79	74	1,049
		2	89·6	88·0	83·4	73·9	65·7	61·9	59·0	62·6	68·2	74·9	81·4	85·3	74·5
		3	61·7	60·9	56·9	49·9	45·2	41·4	39·9	41·8	45·0	49·9	54·0	58·3	50·4
	Ouyen	1	77	94	81	81	128	127	122	128	125	146	100	98	1,307
		2	90·1	87·2	83·1	73·1	65·2	60·1	58·6	62·1	68·4	74·1	80·4	86·1	74·0
		3	58·8	58·3	54·4	48·1	44·5	41·1	39·7	41·1	43·7	47·8	52·1	55·8	48·8
WIMMERA	Horsham	1	85	104	99	131	186	207	175	188	179	170	129	115	1,768
		2	85·5	85·6	79·8	70·4	62·7	56·9	55·8	58·9	64·1	69·7	77·0	82·2	70·7
		3	55·9	56·1	52·4	47·2	43·3	40·3	38·9	40·3	42·3	45·4	49·8	53·5	47·1
	Nhill	1	82	93	88	119	163	196	174	184	172	158	113	108	1,650
		2	85·2	84·5	79·5	70·4	63·0	57·5	56·5	59·2	64·3	70·0	76·9	82·3	70·8
		3	55·0	55·3	51·6	46·7	43·0	39·9	38·1	39·4	41·7	44·9	48·8	53·0	46·5
WESTERN	Ballarat	1	142	193	182	215	269	262	274	293	294	273	218	210	2,825
		2	76·8	76·4	71·4	63·0	56·0	51·0	49·8	52·4	57·2	61·9	67·2	72·6	63·0
		3	51·0	52·4	49·8	45·5	42·5	39·6	38·2	39·1	41·0	43·5	45·8	49·0	44·8
	Hamilton	1	132	126	168	216	269	297	285	300	289	261	196	178	2,717
		2	78·0	77·8	73·2	65·5	59·2	54·7	53·4	55·6	59·6	63·6	69·0	73·9	65·3
		3	52·3	53·3	50·8	47·2	44·3	41·4	40·0	41·0	42·8	44·8	47·1	50·0	46·3
	Warrnambool ..	1	127	137	184	226	294	296	318	306	272	245	198	166	2,769
		2	71·3	71·4	69·5	65·0	60·5	56·7	55·6	57·0	59·8	62·8	65·8	68·8	63·7
		3	54·8	55·5	53·7	50·5	47·4	44·4	43·1	44·0	45·8	47·9	50·0	52·7	49·2
NORTHERN	Bendigo	1	128	133	144	155	210	246	216	215	207	205	147	126	2,132
		2	85·1	84·4	78·8	69·7	61·1	55·2	53·8	56·9	62·2	68·6	75·6	81·3	69·4
		3	57·2	57·7	54·1	48·4	43·6	40·7	38·7	39·9	42·8	46·5	50·6	54·4	47·9
	Echuca	1	100	109	129	132	162	181	161	164	154	173	121	110	1,696
		2	87·5	86·8	81·0	71·6	63·3	57·4	55·9	59·2	64·9	71·7	78·9	84·4	71·9
		3	59·5	59·4	55·5	49·1	44·1	41·0	39·4	41·0	43·8	48·1	52·5	56·8	49·2

North-Central	Alexandra	1	162	146	200	202	250	293	278	290	258	282	224	187	2,772
		2	84·7	84·6	78·7	68·7	60·7	53·7	53·1	56·9	62·8	68·5	74·8	81·3	69·0
		3	52·1	53·0	48·8	43·3	39·6	37·2	36·5	37·3	40·0	42·9	46·5	50·0	43·9
	Kyneton	1	152	159	187	215	290	359	317	322	288	276	206	190	2,961
		2	81·1	80·3	74·6	65·0	57·1	51·2	49·9	52·9	58·9	64·6	71·4	77·0	65·3
		3	49·6	50·3	47·2	42·1	38·4	36·1	34·8	35·5	37·9	40·6	44·0	47·5	42·0
Central	Geelong	1	122	148	163	174	197	198	178	183	204	206	188	155	2,116
		2	77·0	76·7	73·8	67·5	61·8	57·3	56·4	58·7	62·5	66·7	70·5	73·9	66·9
		3	55·6	56·6	54·4	50·4	46·5	43·3	41·6	42·5	44·6	47·2	50·2	53·4	48·9
	Mornington	1	174	158	190	242	271	286	275	270	280	281	232	203	2,862
		2	76·6	76·4	73·5	66·3	60·8	56·0	54·6	56·5	60·6	64·3	68·4	73·2	65·6
		3	55·6	56·3	54·8	51·0	48·2	44·9	43·2	44·1	46·3	49·0	51·2	53·7	49·9
North-Eastern	Omeo	1	205	215	214	182	208	230	207	213	245	282	235	239	2,675
		2	79·3	78·5	73·6	65·6	57·5	51·3	50·2	53·9	59·6	65·3	71·4	76·3	65·2
		3	48·8	49·1	46·1	40·7	35·9	33·8	31·9	33·2	36·9	40·2	43·7	47·0	40·6
	Wangaratta	1	144	153	188	187	221	296	252	250	229	245	181	166	2,512
		2	87·7	87·0	81·0	71·6	63·3	56·5	54·8	58·1	63·8	69·9	77·8	84·0	71·3
		3	58·9	58·6	53·8	46·9	41·8	39·1	38·0	39·4	42·6	46·7	51·5	56·1	47·8
West Gippsland	Wilsons Promontory	1	199	190	280	336	423	487	446	446	380	373	284	247	4,091
		2	68·2	68·7	66·8	63·0	58·7	55·3	53·9	55·0	57·5	60·3	62·9	65·9	61·4
		3	56·6	58·1	56·9	54·4	51·3	48·3	46·6	46·7	47·7	49·4	51·7	54·4	51·8
	Yallourn	1	194	272	198	241	419	360	344	399	364	380	344	266	3,781
		2	76·9	74·6	72·3	65·2	58·0	54·6	52·9	55·2	59·8	63·5	67·3	71·8	64·3
		3	54·5	55·3	53·7	49·0	45·6	43·0	40·6	41·6	44·1	47·0	49·0	52·2	48·0
East Gippsland	Bairnsdale	1	256	221	248	243	207	244	190	186	222	284	237	251	2,789
		2	76·3	76·2	73·4	68·4	62·6	57·8	56·9	59·4	63·4	67·2	70·8	74·2	67·2
		3	53·9	54·6	52·1	47·2	42·7	39·6	38·3	39·6	42·7	46·0	49·1	52·2	46·5
	Orbost	1	279	236	272	285	275	329	268	229	274	311	254	296	3,308
		2	77·1	76·5	74·4	68·7	63·3	58·9	57·9	59·9	63·8	64·6	70·1	74·4	67·5
		3	54·6	55·3	52·9	48·3	43·9	41·0	39·1	40·0	42·5	46·4	49·6	52·6	47·2

* Legend : 1. Average Monthly Rainfall in Points : 100 Points = 1 inch. (For all years of record to 1963)
2. Average Daily Maximum Temperature (°F.) (For all years of record to 1966)
3. Average Daily Minimum Temperature (°F.) (For all years of record to 1966)

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. (See also pages 46–7.)

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 disorganisation 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.

Temperatures

February is the hottest month of the year while January is only slightly cooler. Average maximum temperatures are under 75° F. along the coast and over elevated areas forming the Central Divide and North-Eastern 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 ft 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 6 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 ft) at an exposed location near a mountain. However, a minimum of minus 8° F. has been recorded at Charlotte Pass (station height 6,035 ft)—a high valley near Mt Kosciusko in New South Wales—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., while 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.

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 65° F. The incidence of high humidity is important to the vine and fruit industry, tobacco growers, and wheat farmers.

Evaporation

Since 1967, the Class A Pan has been the standard evaporimeter used by the Bureau of Meteorology. This type is being progressively installed at evaporation recording stations in Victoria; there were fifteen at the end of 1968.

Measurements of evaporation have been made with the Australian tank at about thirty stations, about half of which are owned by the 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.

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 occur. 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 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 mph. 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 mph. It is considered that any place in Victoria could feasibly experience at some time a local gust of 100 mph or more.

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 surface heating to provide energy for convection. On an average, more than twenty 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 per month from November to February. 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.

Meteorological Observations

The basis of meteorological service and research is the regular and accurate observation of the atmosphere by a wide variety of methods.

The most easily measured element, as well as the most variable in space and time, is rainfall. There are over 7,000 voluntary rainfall observers in Australia who make daily observations of the amount of rain. Almost 1,000 of these observers are situated in Victoria. About 700 part-time observers in Australia make more frequent observations of pressure, temperature, humidity, wind, cloud, and atmospheric phenomena. These part-time observers come from a wide cross-section of the community—for example, a power station at Geelong, a monastery at Ballarat, a prison at Bendigo. Some of these observers telegraph their observations to the Bureau for forecasting purposes and public information. A figure code is used, which is the same the world over, and enables an entire description of weather at a certain place to be relayed in the space of one or two lines. All observers send a monthy return to the Bureau, where the data is placed on punch cards and magnetic tape. The data can then be analysed by computer for a great variety of purposes.

Weather observations from other countries such as New Zealand, Indonesia, Malayasia, the Philippines, and the Pacific islands are also regularly received by cable, radio-teletype, or radio broadcasts. Observations are also received from ships at sea and from aircraft. With the development of Melbourne as a World Meteorological Centre, observations will eventually be received from most countries in the world.

Upper wind observations are made at sixty Bureau field offices four times daily. In Victoria, there are offices at Essendon, Laverton, Mildura, and East Sale. Wind speed and direction are found by tracking a hydrogen filled balloon.

Observations of pressure, temperature, and humidity of the upper air are made once or twice daily at about thirty of the Bureau's field offices. This is done by the use of radiosondes which are small packages containing instruments linked to a small radio transmitter. The package is borne aloft by a large hydrogen-filled balloon and the signals from the transmitter are received at the ground station. Eventually the balloon bursts and the package then descends, supported by a small parachute. In Victoria, a radiosonde is released from Laverton at 9 am each day.

Other observations which supplement the more conventional network are sferics and radar weather. A network of radio-direction finding stations can detect lightning flashes or atmospherics (sferics) anywhere over the continent or surrounding oceans. The Bureau's radar stations can trace rain up to 150 miles from the station. In Victoria, radar is installed at Laverton and Melbourne.

Pictures from satellites, received at the Bureau's read-out station at Melbourne, cover an area from New Zealand to Perth and from Cape York Peninsula almost to the Antarctic. Other read-out stations have been established at Perth and Darwin. These pictures have already contributed to the knowledge of weather by identification of storm systems in ocean waters adjacent to the continent. Further developments will include measurement of temperature and water vapour by satellite and the tracking of balloons floating at a constant high level.

The knowledge of the atmosphere is far from complete and some of the associated theoretical problems have defied solution until the present time. Nevertheless, improvements in forecasting, warning, and other services will only result from persistent scientific research. This research must be based on reliable observations, not only in Australia, but in the remoter parts of the world only now being reached by satellite and balloon sounding techniques. For this reason, the World Meteorological Organisation has inaugurated a global atmospheric research programme as well as the more operational world weather watch.

Agricultural Meteorology, 1964; Maritime Meteorology, 1966; Aeronautical Meteorology, 1967; Meteorology in Fire Prevention, 1968; Meteorological Services for Commerce and Industry, 1969

Climate of Melbourne

Temperature

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., while 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 13 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 approximately nineteen.

Nights are coldest at places a considerable distance from the sea and away from 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 21 July 1869, and likewise, the highest minimum ever recorded was 87° F. on 1 February 1902.

In Melbourne, the 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 of 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 thirty 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 25·84 inches over 143 days. From January to August, monthly averages are within a few points of 2 inches ; then a rise occurs to a maximum of 2·67 inches in October. Rainfall is relatively steady during the winter months when the extreme range is from half an inch to 7 inches, but variability increases towards the warmer months. In the latter period totals range between practically zero and over 8 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 average rainfall varies considerably over the Melbourne metropolitan area. The western suburbs are relatively dry and Deer Park has an average annual rainfall of 19·01 inches. Rainfall increases towards the east, and at Mitcham averages 35·95 inches a year. The rainfall is greater still on the Dandenong Ranges and at Sassafras the annual average is 53·83 inches.

The highest number of wet days ever recorded in any one month in the City is twenty-seven 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 forty days. Over 3 inches of rain have been recorded in 24 hours on several occasions, but these have been restricted to the warmer months, September to March. Only once has a fall above 2 inches during 24 hours been recorded in the cooler months.

Fogs

Fogs occur on four or five mornings each month in May, June, and July, and average twenty-one 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 forty-seven. 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 over 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 mph, while means exceeding 20 mph 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 mph. At Melbourne, gusts exceeding 60 mph have been registered during every month with a few near or over 70 mph, and an extreme of 74 mph on 18 February 1951. At Essendon a wind gust over 90 mph has 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 twenty-five. 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 31 August 1849. Streets and housetops were covered with several inches of snow, reported to be 1 ft 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 Aboriginals suggested they had never seen snow before.

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

MELBOURNE—MEANS OF CLIMATIC ELEMENTS

Meteorological Elements	Spring	Summer	Autumn	Winter
Mean Atmospheric Pressure (millibar) ..	1015·1	1013·1	1018·3	1018·3
Mean Temperature of Air in Shade (° F.) ..	57·8	66·7	59·5	50·1
Mean Daily Range of Temperature of Air in Shade (° F.)	18·7	21·1	17·4	14·0
Mean Relative Humidity at 9 a.m. (Saturation=100)	63	60	72	80
Mean Rainfall (inches)	7·31	6·03	6·60	5·88
Mean Number of Days of Rain	40	25	34	44
Mean Amount of Evaporation (inches) ..	10·28	17·34	8·13	3·79
Mean Daily Amount of Cloudiness (Scale 0 to 8)*	4·9	4·2	4·8	5·2
Mean Daily Hours of Sunshine	5·9	7·7	5·2	3·9
Mean Number of Days of Fog	1·5	0·6	6·5	11·7

* Scale 0 = clear, 8 = overcast.

In the following table are shown the yearly means of the climatic elements in Melbourne for each year 1964 to 1968. The extreme values of temperature in each year are also included.

MELBOURNE—YEARLY MEANS AND EXTREMES OF CLIMATIC ELEMENTS

Meteorological Elements	1964	1965	1966	1967	1968
Mean Atmospheric Pressure (millibar)	1014·2	1017·3	1017·2	1018·1	1014·5
Temperature of Air in Shade (° F.)—					
Mean	58·6	59·3	59·3	59·5	60·2
Mean Daily Maximum ..	66·5	67·8	67·5	68·1	68·2
Mean Daily Minimum ..	50·7	50·9	51·1	50·9	52·1
Absolute Maximum	103·3	106·9	102·8	105·2	110·6
Absolute Minimum	36·0	32·4	32·9	34·2	35·2
Mean Terrestrial Minimum Temperature (° F.)	47·7	47·9	48·4	48·6	53·5
Number of Days Maximum 100° F. and over	4	7	5	5	8
Number of Days Minimum 36° F. and under	1	10	7	4	3
Rainfall (inches)	27·80	23·24	26·81	13·06	20·96
Number of Wet Days	166	122	157	106	141
Total Amount of Evaporation (inches)*	35·54	44·87	47·08	55·15	59·56
Mean Relative Humidity (Saturation = 100)	66	62	63	63	58
Mean Daily Amount of Cloudiness (Scale 0 to 8)†	5·1	4·4	4·8	4·4	4·8
Mean Daily Hours of Sunshine‡ ..	5·4	6·2	6·0	6·5	6·4
Mean Daily Wind Speed (mph) ..	8·4	7·2	6·9	5·9	6·2
Number of Days of Wind Gusts 39 mph and over	97	62	47	46	79
Number of Days of Fog ..	12	21	6	24	3
Number of Days of Thunder ..	12	9	6	3	12

* Since 1967 evaporation has been measured by Class A Pan.
† Scale 0 = clear, 8 = overcast.
‡ For 1968 sunshine has been measured at Laverton.

Victorian Weather Summary 1968

Summer

The rainfall in January was above average in the north, but in the south it was only between one half and one quarter of the normal. Temperatures were above average and a heat wave at the end of the month gave Melbourne a maximum temperature of 110·6 F., the highest since 13 January 1939.

In February, the first major bushfire of 1968 occurred and 40,000 acres were burnt in the Myrtleford area. Outbreak of fires was frequent during February as dry warm conditions prevailed. For many stations, mainly in Gippsland, it was the driest February on record. Temperatures above the century were recorded on five days in Melbourne, the greatest number of days ever recorded for this month, and the mean temperature for the month was the second highest on record.

Autumn

Although some useful rains fell in all districts, drought conditions continued in March. The fire danger remained high ; however, only one major outbreak occurred when 1,000 acres burnt near Sassafras. April rainfall was above average in all districts except East Gippsland. Most of the rain fell in the second half of the month with the passage of successive cold fronts and their accompanying depressions. Light snow, the first for the year, fell on the higher ranges on 22 and 23 April.

This trend continued in May when many stations experienced their wettest May on record. Melbourne had twenty-three rain days, equalling the highest number of rain days recorded for that month. In contrast to the preceding months, May temperatures were below average and strong winds were a feature of the latter half of the month. A severe thunderstorm with hail on 24 May caused much damage to buildings in the metropolitan area.

Winter

June was wet, except in the far east. Much of the rain was due to thunderstorms in the first week of the month. Temperatures were below average and scattered fogs occurred on most days of the month ; on 18 June at Swan Hill, fog persisted most of the day and the maximum temperature was only 49° F. Fairly widespread frosts were recorded in the middle of the month with snow falls on the highlands in the last two weeks. Minor flooding occurred early in the month in eastern Victoria.

Almost average rainfall fell in July, but temperatures remained below normal. For the first time in 20 years, the temperature in Melbourne did not reach 60° F. during the month. August was a cool, wet month and on 20 August, Melbourne had its lowest August maximum (48° F.) since 1951.

Spring

Strong winds approaching gale force occurred in September, which was a cool, dry month. In many places it was the driest September on record, contrasting with August. This was the first September since 1913 when the temperature in Melbourne did not exceed 71° F.

Rainfall in October was below average in a broad band orientated north-west to south-west across the State. However, in the upper north-east and along the south-west coast, it was the wettest October for ten and twenty years, respectively, resulting in minor to moderate flooding. This rainfall distribution pattern continued in November. Temperatures were again below average for the eighth successive month in all districts except the Mallee and East Gippsland, which did experience some warm days during October.

Summer

Apart from two brief warm periods early in the month, December was a wet, cool month for most areas. Widespread rain, thunderstorms, frosts, and strong to gale force winds were a feature of the last week of the year in the eastern half of the State. On Christmas Day, snow fell on the higher ranges of the north-east, while Boxing Day was the coldest (only 62° F.) in Melbourne since 1922 and minor flooding occurred in East Gippsland on 26 and 27 December.