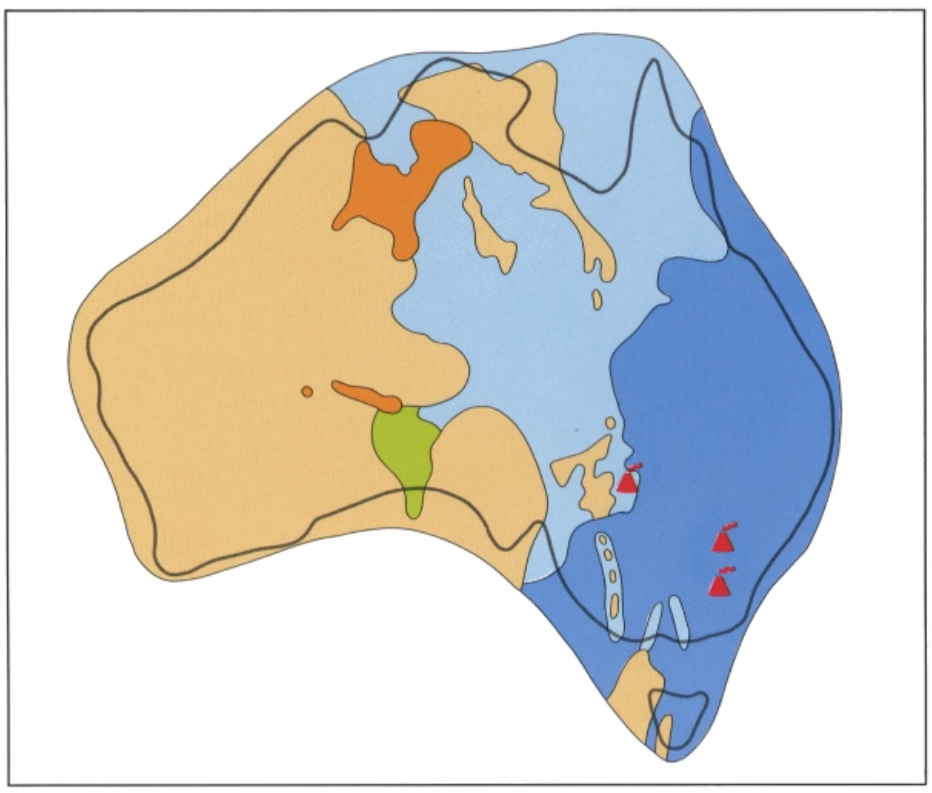
Palaeozoic
570 to 235 million years ago

Cambrian — 570 to 500 million years ago

The foundations of eastern Australia were laid down. Life became abundant in the oceans and creatures with external skeletons or shells began to proliferate.



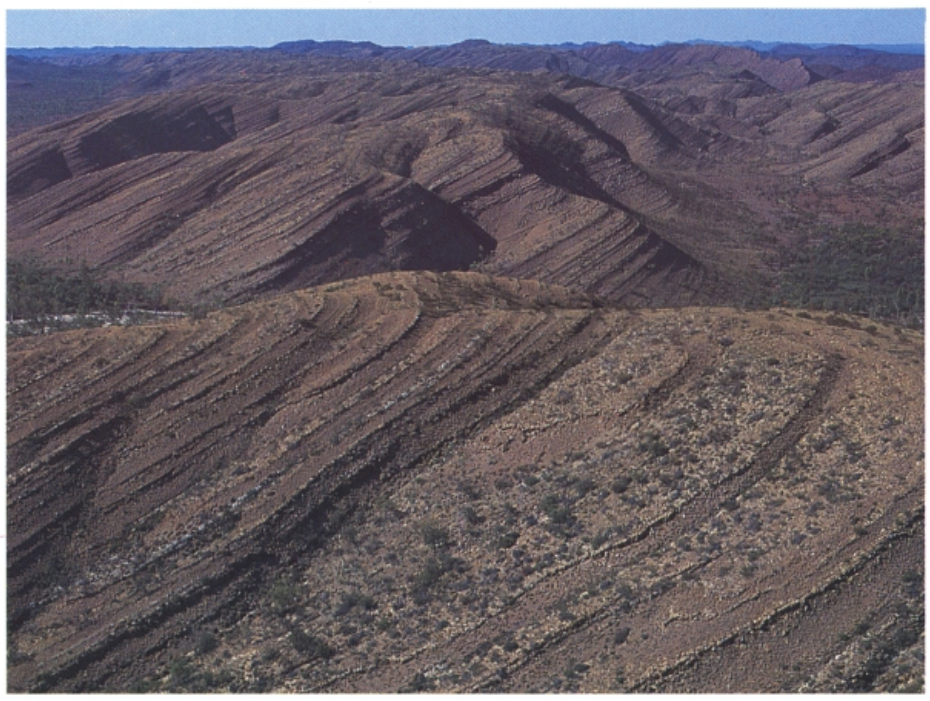
During the Cambrian the crustal blocks formed earlier were either dry land or under shallow seas. The land relief was generally low though mountain regions existed in what is now central and north-western Australia.

A significant early event was the outpouring of large volumes of basaltic lava which covered extensive areas in the north and also further south. In the shallower seas sedimentation consisted mostly of lime (derived from the increasingly abundant calcium-secreting marine organisms) with some sand and silt.

The 'construction' of eastern Australia began in the Cambrian. Early in the period the Kanmantoo Fold Belt (S.A.)—then a marine trough—was rapidly filled with a thick sequence of sand and silt. Further east, notably in the Lachlan Fold Belt, longitudinal troughs and submerged volcanoes formed in the deeper ocean and the troughs quickly filled with sand, silt, mud and volcanic material. At the end of the Cambrian the Kanmantoo Fold Belt and what is now western Tasmania were uplifted, folded, metamorphosed and intruded by granite to cement a further section to the slowly growing Australian landmass.

During the Cambrian the Australian crustal platform was located just north of the equator and for most of the period experienced a warm to hot climate, causing the widespread occurrence of evaporitic sediments and limestone deposits.

Life forms during the Cambrian continued to evolve and diversify and, importantly, creatures with external skeletons or shells began to proliferate. Trilobites (large, segmented marine arthropods) and lamp shells were abundant and are now commonly found fossils. By the end of the Cambrian bivalve shells and squid-like creatures (cephalopods) were also abundant.



Alternating beds of limestone and shale, eastern Macdonnell Ranges (N.T.)
This mid to late Cambrian sequence was deposited in an extensive shallow sea during a period of fluctuating sea levels.

The complete fossilised external skeleton of a trilobite found near Mount Isa (Qld). During the Cambrian all life was still confined to the sea, where trilobites were common and widespread.

Key to
Palaeogeographic sketch maps on pages 16-23
showing the distribution of land and sea since the Cambrian

- Deep marine
- Shallow marine
- River, lake, aeolian
- River, lake with coal swamp
- Land undergoing erosion
- Flood basalt
- Glacial
- Fluvioglacial
- Central-type volcano

SCALE 1:40 000 000

SOURCE: Adapted by W.D. Palfreyman from maps in 'Phanerozoic Palaeogeography' in *BMR Earth Science Atlas of Australia.*

During the 235 million years of the Palaeozoic Era—the time of early life—life evolved from a comparatively few, small soft-bodied marine life forms to a diverse range of plants and animals inhabiting both land and sea. The invasion of the land by plants led to the formation of Australia's very large resources of black coal. Continental rocks that now form Australia built up to their fullest extent and drifted—still as part of the Gondwana super continent—from the equator to near the South Pole before venturing northward at the end of the era.

Ordovician

500 to 435 million years ago

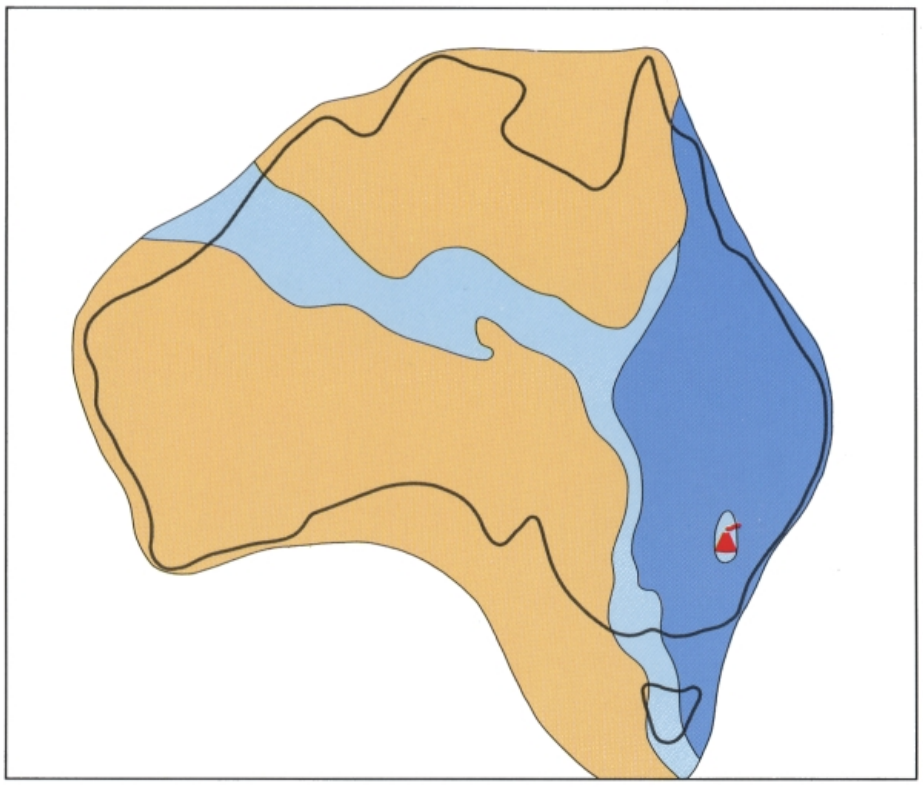
Despite sedimentation and volcanicity during the Cambrian most of what is now eastern Australia was still deeply submerged at the start of the Ordovician. However, these processes persisted in this area, gradually causing the sea to become shallower and isolated volcanic islands to emerge.

The remainder of the newly enlarged Australian crustal platform was mostly dry land during the Ordovician. Early in the period down-warping began in the Canning, Daly River and Bonaparte Basins, leading to shallow marine transgression and sedimentation of lime, sand and silt. The down-warping in the Canning Basin later extended eastward to cut across the new continent and cause shallow marine sedimentation in the Wiso, Amadeus and Georgina Basins in present-day central Australia.

As these shallow troughs filled with sediment the water in them slowly retreated. By the middle of the Ordovician the smaller northern Daly River and Bonaparte Basins had dried out. Except for the deeper Amadeus Basin the larger trough to the south had also largely dried out by the end of the period.

During Ordovician times the Australian crustal platform had slipped south to lie directly across the equator. A generally warm climate prevailed, apparent from the occurrence of evaporitic sediments and limestones.

Life-form evolution during the Ordovician again led to an increasing divergence and complexity of existing species and the development of new ones. The abundant trilobites and shellfish of the Cambrian evolved further and proliferated. They were joined by new species such as graptolites (small planktonic organisms), sea-urchins (echinoderms) and the first corals and sea lilies (crinoids). Possibly the most significant event was the evolution of the first primitive fish.



Eastern Australia continued to form. The first vertebrates—primitive fish—evolved and some of the earliest fossils have been found in the Amadeus Basin of central Australia.

Silurian

435 to 410 million years ago

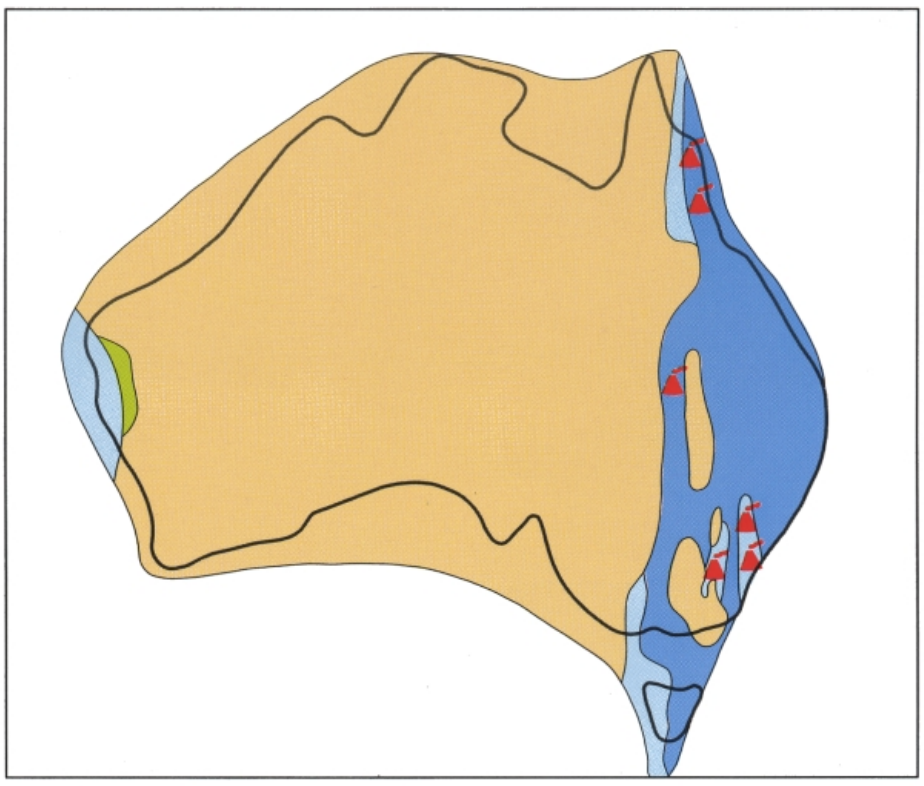
Throughout the Silurian the now well established Australian crustal platform remained predominantly above sea level. Uplift and folding, associated with granitic intrusion which had begun in the central area in the Ordovician, continued into the early Silurian and ended the marine transgression then still persisting in the Amadeus Basin.

Similar uplift occurred in the south-east, extending the mainland coast eastwards and forming offshore islands in what is now termed the Lachlan Fold Belt. Elsewhere in this fold belt sedimentation of sand, silt and mud continued in the troughs that had remained submerged since the Ordovician. Volcanicity also continued, extruding lava over the seabed and in places forming volcanic island arcs.

In the west sand and silt were laid down by rivers on the underlying older rocks in the Perth and Carnarvon Basins whereas further north, in the Canning Basin, shallow marine and evaporitic sediments accumulated.

The Australian crustal platform remained in the equatorial zone throughout the Silurian. A warm climate prevailed, leading to desert conditions and evaporitic deposition. Marine life including shellfish, corals, graptolites, trilobites, crinoids, cephalopods and various types of fish continued to proliferate and further evolve. However, the most significant evolutionary event in the Silurian was the invasion of the land (though only the wetter parts) by spore-bearing plants similar to present-day club mosses.

The granitic intrusion associated with the south-eastern uplift introduced the rich central Victorian gold deposits and, probably, the gold, silver-lead and copper deposits in central and south-eastern New South Wales.

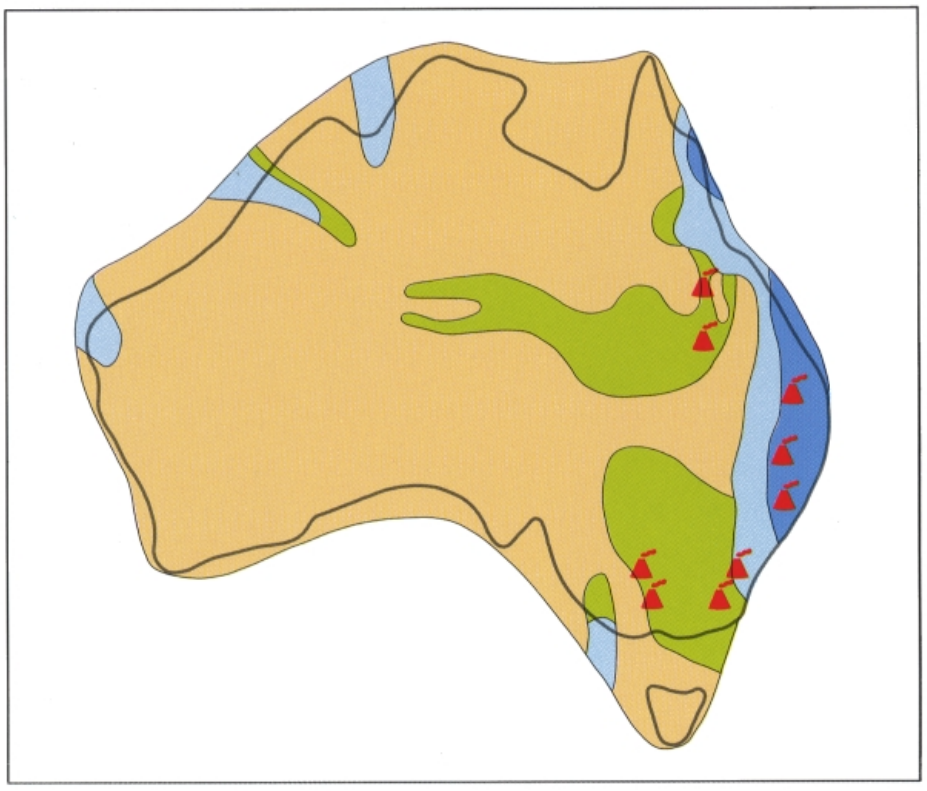


Life, in the form of primitive moss-like plants, first appeared on land. In the shallow Silurian seas then covering eastern Australia great coral reefs were formed. These eventually became limestone formations such as those now found at Chillagoe (north Qld), and Jenolan and Bungonia (N.S.W.) where the limestone has dissolved to form extensive networks of caves. Melbourne is built on Silurian marine deposits and fossils are frequently found during construction work.

'London Bridge', a natural arch in Silurian limestone near Queanbeyan (N.S.W.)
This arch has developed in recent times in limestone which originated as a small reef in the late Silurian.

Devonian

410 to 345 million years ago



All but a small portion of what is now eastern Australia was raised above sea level for the first time. Land plants further developed with the evolution of tree-like club mosses. By the end of the Devonian the first thin seams of coal were already being laid down in club moss swamps. Air-breathing fish ventured ashore, giving rise to the first amphibians.

During the Devonian the now well-established western and central parts of the Australian crustal platform remained stable and mostly above sea level. However, crustal down-warping in the Carnarvon, Canning and Bonaparte Basins began in the first half of the Devonian and led to shallow marine incursions. In the Canning Basin silt and mud were first deposited, followed by shallow evaporitic deposits and coral reef formation as the sea shallowed. In the Carnarvon Basin deltaic sand and shallow water limestone accumulated. Only one small area of Devonian rocks, composed of sandstone with plant fossils overlain by thick limestone, is exposed in the Bonaparte Basin.

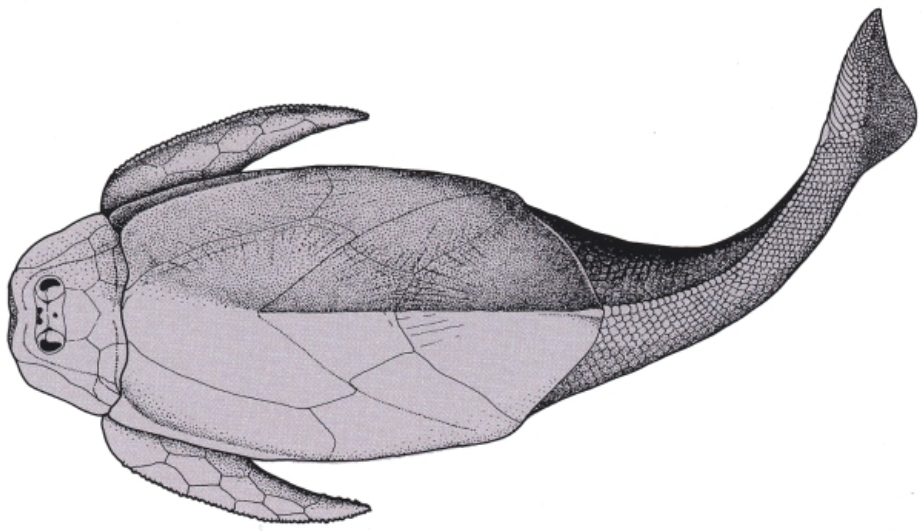
The only other area of extensive water sedimentation on the established crustal platform occurred in the Wiso, Georgina and Amadeus Basins, where an extensive river and lake system deposited sand and silt.

The major centre of tectonic activity and crustal development remained in the east and south-west. In the mid Devonian, around 360 m.y. ago, a period of folding and uplift, accompanied by widespread volcanic activity, occurred in the south-east and raised all but a small portion of what is now eastern Australia above sea level. In the Devonian seas off this newly formed shore both shallow and deep water marine sediments were laid down together with rhyolite and andesite lavas from undersea volcanoes. Typical sediments were sand and grit, and iron-rich silts from which shale (particularly a red variety forming what are now termed 'red beds') was formed.

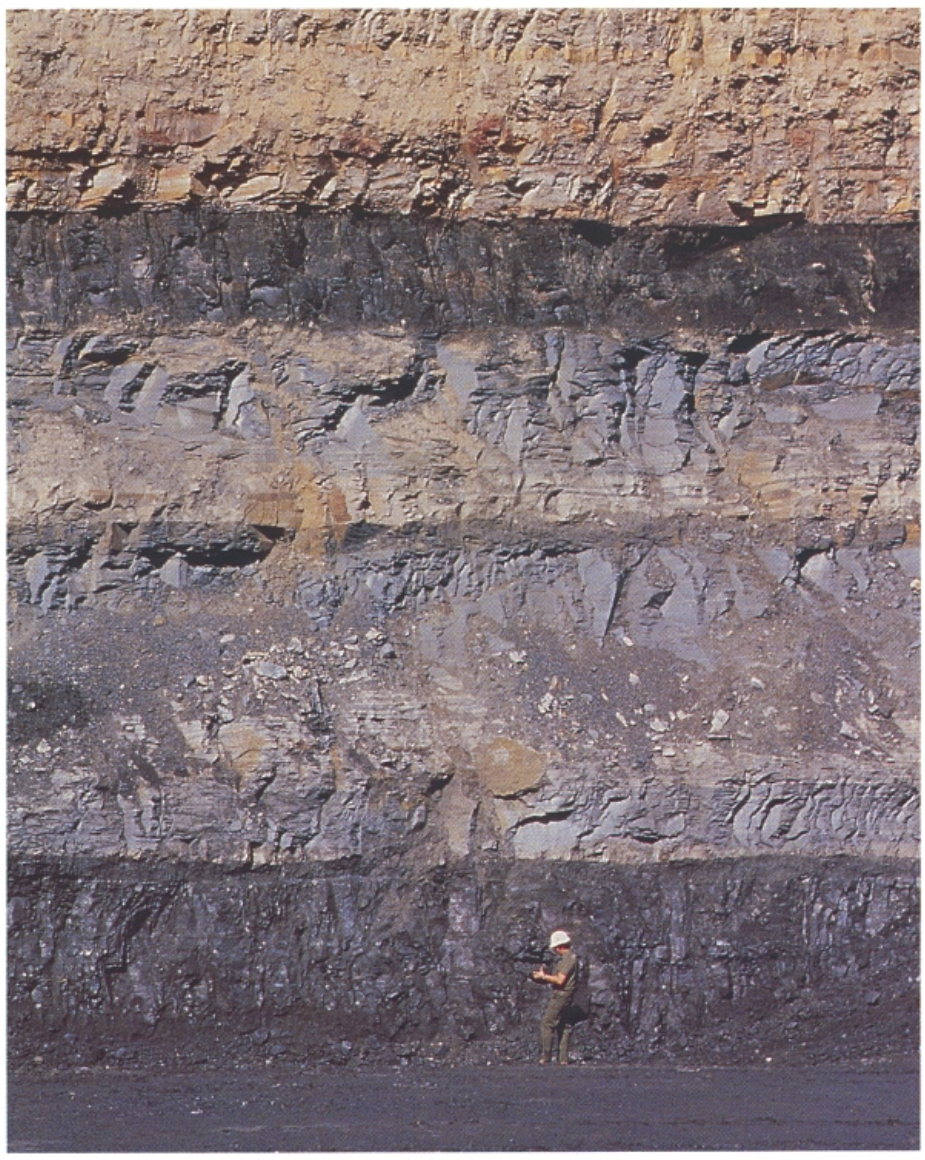
In Devonian times the Australian crustal platform—still attached to the Indian and Antarctic platforms—lay astride the equator. The climate was generally warm, leading to widespread evaporitic deposits and coralline limestone formed in warm seas. The abundant and diverse marine life of the Silurian seas increased and further diversified in the Devonian. Reef-forming corals were particularly plentiful and many new fish evolved. Brachiopods and ammonoids also proliferated but trilobites and graptolites began to decline. Land plants further developed with the evolution of giant club mosses but these were still confined to damp areas. By the end of the Devonian the first thin seams of coal were being laid down in club moss swamps.

The Cobar gold and copper deposits in central New South Wales were probably formed during the tectonic activity in the mid Devonian. The chromite and nickel deposits of north Queensland are also Devonian in origin. Limestones and sandstones of this period are extracted for cement and building material. Devonian sediments also form reservoir rock for natural gas in western Queensland.

The distinctive Elder Sandstone of the Bungle Bungle Range, eastern Kimberleys (W.A.)
This residual landscape has resulted from the erosion of friable and heavily jointed late Devonian sandstone.



A 30 cm-long armoured fish reconstructed from fossil specimens found near Canowindra (N.S.W.). This fish was common in freshwater lakes and streams of eastern Australia during the late Devonian.



Greta Coal Measures, Drayton opencut coal mine near Muswellbrook (N.S.W.)
Formed in swamps on a floodplain in the Permian, these black coal seams are interbedded with shale and siltstone and capped with sandstone.

Carboniferous

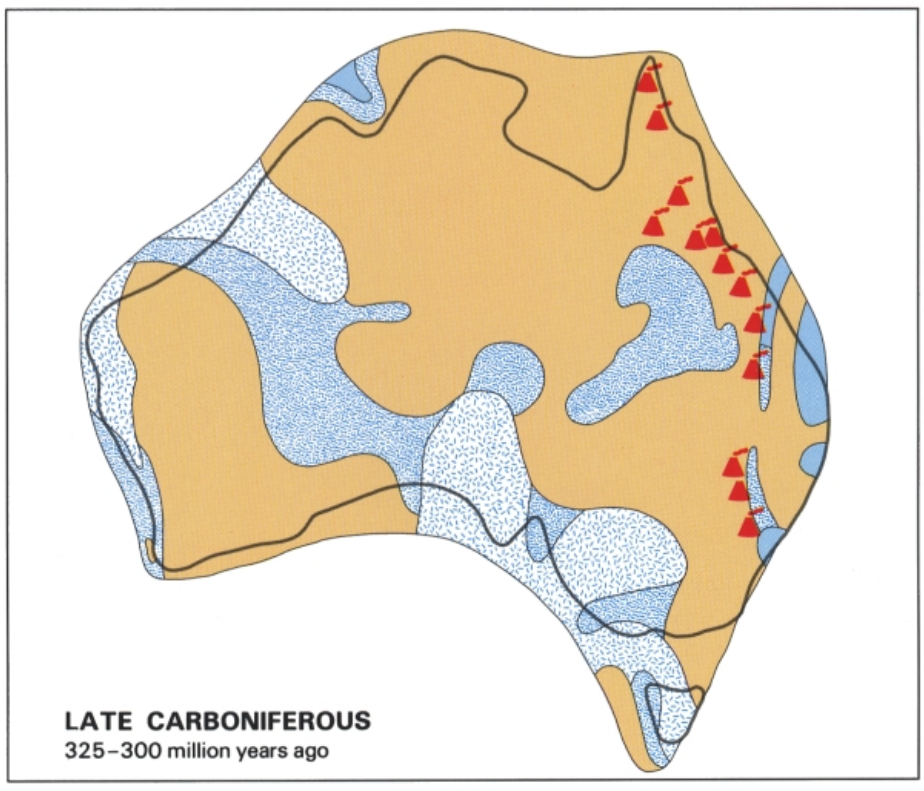
345 to 300 million years ago

Early Carboniferous geological activity in eastern Australia was centred around northern New South Wales and southern Queensland. As before, sedimentation continued in surrounding troughs with much of the material originating from an active volcanic island arc in this area. Further east sedimentation in deeper water continued.

In central Australia river systems, formed during the Devonian, continued to deposit sand in the interior. In western and north-western Australia shallow marine sedimentation continued, with lime, silts and evaporitic sediments being deposited in the Carnarvon and Canning Basins. Some alluvial sands were also deposited in the Carnarvon Basin. Further north in the Bonaparte Basin silts and muds were laid down in deeper water.

During the late Carboniferous, commencing around 325 m.y. ago, the climate cooled markedly for the first time since the late Proterozoic as Australia drifted towards the South Pole. By the end of the period much of the continent was covered by ice. Evidence for this glaciation is found in Carboniferous rocks from western, southern and south-eastern Australia where, in places, glacial pavements are still preserved together with extensive glacial till and fluvioglacial deposits. Shallow marine or river deposits occur away from the ice-covered area—in the Canning Basin of the north-west and in eastern Australia, where sands and silts containing boulders dropped from melting icebergs (dropstones) accumulated.

During the early part of the Carboniferous warm water faunas such as corals flourished in the Australian region. Club mosses thrived on land and were joined by seed-bearing ferns and horsetails. Later, as temperatures declined, many plants and animals became extinct but were replaced by others more adapted to the colder conditions.



LATE CARBONIFEROUS
325–300 million years ago

In the Northern Hemisphere tropical conditions gave rise to luxuriant swamps which harboured the first winged insects and where reptiles first evolved. The Australian portion of Gondwana, however, was drifting towards the South Pole and experiencing increasingly colder conditions. In most of the Northern Hemisphere this period is known as the 'Age of Coal'—hence *Carboniferous*—but in Australia the major coal deposits were laid down later.

Permian

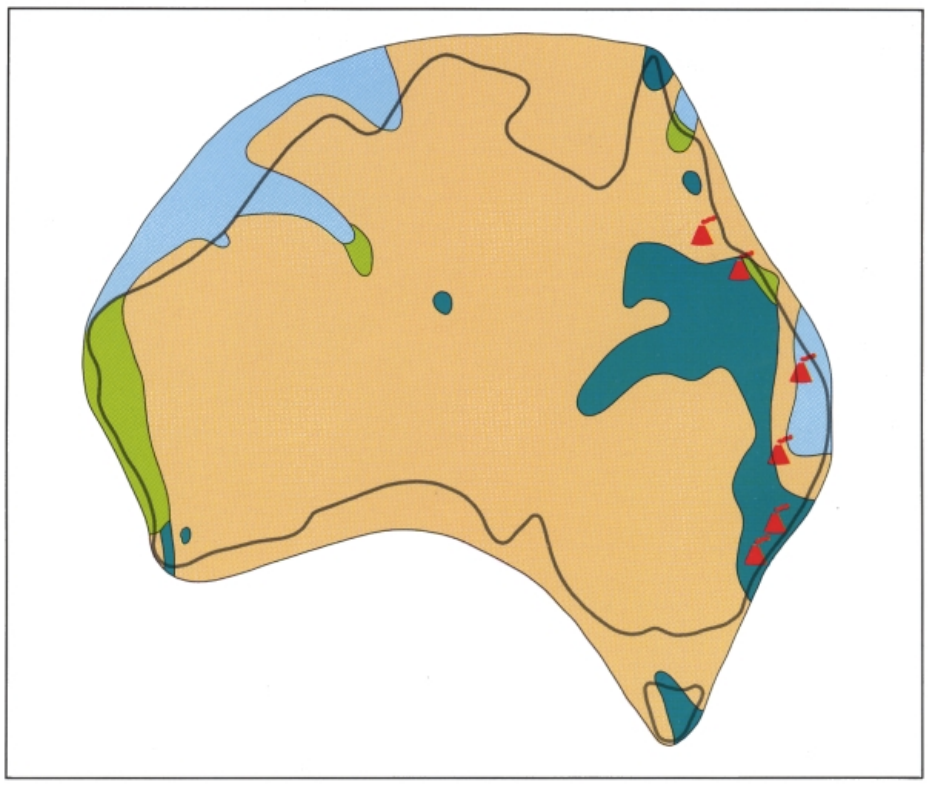
300 to 235 million years ago

The glacial conditions of the late Carboniferous persisted during the early Permian but had abated by the start of the late Permian, around 260 m.y. ago. The ice caps and glaciers had melted though cool climates persisted over much of the continent throughout the remainder of the Permian.

Following the deposits left by glaciers, marine sedimentation of sands, silts and limes took place in the Perth, Carnarvon, Canning, Bonaparte, Arckaringa, Tasmania, Sydney and Bowen Basins. These marine sediments contain dropstones in places, indicating the presence of icebergs. Towards the end of the early Permian the sea retreated and, with a general warming of the climate, coaly swamps formed in these basins and in the Officer, Cooper, Pedirka and Galilee Basins of central and north-eastern Australia. Such swamps are the origins of Australia's rich coal deposits, particularly in the Bowen, Sydney and Collie Basins.

Throughout the early Permian uplift continued in eastern Australia, notably in the New England Fold Belt in northern New South Wales. By the late Permian, and extending into the Triassic, much of eastern and north-eastern Australia was further uplifted, folded and, in places, metamorphosed and intruded by granite.

As much of southern Australia was covered by ice during the early Permian the flora (glossopterids) and fauna were predominantly cold-adapted species. Then, as the climate improved in the late Permian the water temperature increased and marine organisms became more diverse. However, the close of the period saw the mass extinction of several ancient faunal groups though the cause is not known.



Swamp forests dominated by glossopterid trees flourished as Australia drifted away from the South Pole into a more temperate zone. These forests led to the formation of Australia's major black coal deposits, mostly in what are now the Bowen and Sydney Basins. One coal seam alone at Blair Athol (Qld) is more than 30 m thick. Insects, fish and large amphibians were plentiful but reptiles had still not appeared in Australia.

(far left)
Fossil glossopterid leaves from near Newcastle (N.S.W.)

(left)
Iron-stained fern and glossopterid leaves from coal measures near Dunedoo (N.S.W.)

Leaf fossils of the now extinct glossopterids are common in Permian sediments from all of the continents which once made up Gondwana. Cool temperate forests dominated by Glossopteris trees flourished at this time, and in eastern Australia led to the formation of vast coal deposits.