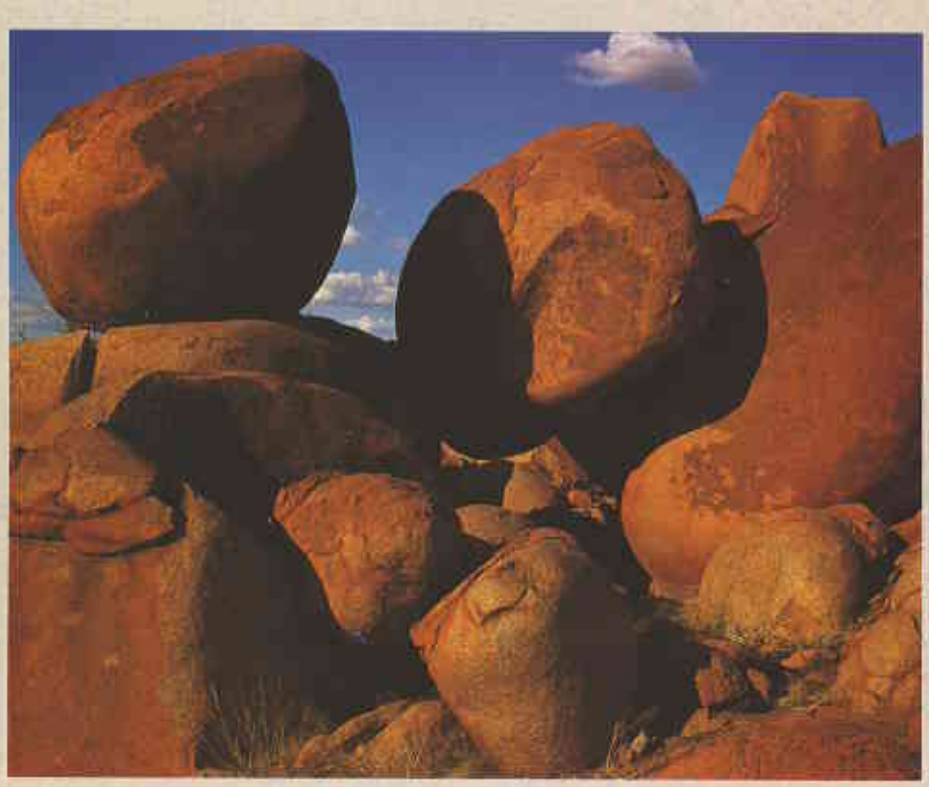


Rocks Of Ages

The gold prospectors who pushed their barrows through the mulga scrub a century ago had long walks between outcrops. The rocks that make up the old, weathered landmass of Western Australia are hidden from view over wide areas by their own debris and by sand, saltpans and vegetation. Geologist Geoffrey Shaw describes the processes that formed the State's rocks and land surface over billions of years.

WESTERN AUSTRALIA is made up of a complex arrangement of rock formations. This geological structure results from the interplay of many geological processes that have operated for billions of years and still operate today.

Throughout the State powerful forces have gradually warped, folded and fractured the crust's upper levels. Some fractures, called faults, may stretch several kilometres. In earthquakes, rocks adjoining them may move metres vertically or laterally. The Darling Fault, for example, may be traced for nearly 1000 km; near Perth it shows vertical movement of up to 10 km.

Erosion caused by rain, rivers, waves, wind and glaciers has worn away the land. Within the crust other processes such as the transformation and melting of rocks by heat and pressure have taken place. These processes are part of cycles of change that have been moulding and remoulding the outer "skin" of our planet. The cycles are thought to be powered by currents deep in the earth that cause continents to glide slowly about. Continental drift occurs when segments of crust are slowly forced down to great depths where they become heated and compressed. Metamorphism and intrusion of bodies of molten rock take place and belts of volcanoes and earthquake zones are formed. Great thicknesses of sedimentary rocks are deposited and over millions of years become folded and thrust up as mountains. When they are eventually worn down by erosion, their debris forms new generations of strata (layered rock).

Western Australia was once part of the supercontinent of Gondwana, which included Antarctica, Africa and India. Australia began to break away about 200 million years ago.

WHEN THE WORLD WAS YOUNG

The State's geological history begins in the Precambrian - the time that extended from the earth's formation until the Cambrian period some 600 million years ago. It consists of two eras - an older or Archaean, followed about 2.5 billion years ago by the Proterozoic. Precambrian rocks form about two-thirds of WA and contain most of the State's mineral resources. In the early Precambrian only the simplest life forms evolved and even the younger Precambrian rocks contain few traces of living things.

A Geological Survey team in the Goldfields in the early 1920s.
Photo - Courtesy of WA Geological Survey ▲

THE YILGARN CRATON

The rocks of the inland Murchison are among the oldest in Australia. Zircon crystals from rocky ridges such as Mount Narryer and Jack Hills are around 4.5 billion years old - the oldest minerals so far found in any part of the world. The Murchison rocks are part of the Yilgarn Craton, a vast, stable part of the earth's crust, dating from the Precambrian. It is built almost entirely of Archaean granites and gneisses and has been dry land for hundreds of millions of years. Much of it has been worn down, but, in Archaean times, mountains and volcanoes formed, and other enormous forces transformed and buckled rocks. These ancient rocks can be seen in the Darling Range; for example, at Mundaring Weir and Serpentine Dam. Many belts of volcanic and sedimentary rocks, known to goldminers as "greenstones", run through the Craton. They have yielded large quantities of gold, as at Kalgoorlie, Southern Cross and Cue.

THE PILBARA AND KIMBERLEY

The Pilbara Craton in the State's North-West is another vast, stable block of Archaean rocks. There, greenstone belts border huge granite intrusions. Striking views of these major structures are given by Landsat satellite images.

About 1.8 billion years ago the Yilgarn and Pilbara cratons slowly "drifted" and collided, rucking up massive thicknesses of late Precambrian sediments. Worn-down remnants of these great folded structures can now be seen in the Ashburton, Gascoyne and Hamersley regions (such as the Opthalmia Range).

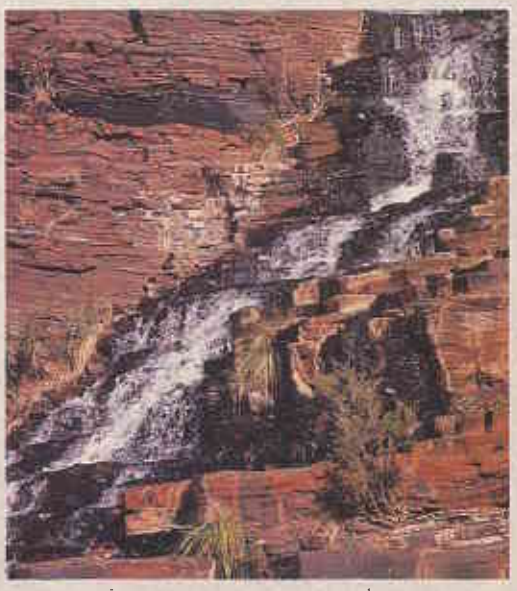
In Marble Bar Gorge in the Pilbara, ancient volcanic lavas show the striking "pillow" form caused when lava cascades into the ocean (this can be seen happening today in Hawaii). The Pilbara's ancient sedimentary rocks contain many fossilised stromatolites - primitive colonial bacteria (cyanobacteria). Near the old mining centre of North Pole, some have been dated at 3.2 billion years - so far the earliest evidence of life on earth.

The Kimberley region in the far north has large expanses of Precambrian rocks, including the massive sandstones that form the Kimberley Plateau. Much is written about the Pleistocene Ice Age from which the world has recently emerged; but the Kimberley is one of the few places in the world with traces of glaciations that occurred in the late Precambrian. There, areas of hard bedrock show scouring and polishing caused by moving ice; extensive deposits of sand, clay and boulders represent fine debris and rocks dropped from floating ice sheets.

Coastal cliffs provide clear exposures of limestone rocks at Pt D'Entrecasteaux.
Photo - Kerry Cook

A HAMERSLEY PUZZLE

In the southern Pilbara, Archaean rocks vanish beneath later Precambrian rocks, including those from which the Hamersley Range has been carved. In the walls of the beautiful gorges of Hamersley Range National Park are layers of "banded iron formation". The formation consists of alternating thin layers (bands) of dark iron-rich rock and lighter silica-rich rock. Each dark band contains many "microbands" a few millimetres thick; geologists have been able to trace individual bands and microbands for tens, even hundreds of kilometres. It is thought that the sediments accumulated in an extensive, calm arm of the sea about 2.5 billion years ago. The surrounding land was low and arid and sluggish streams brought in only small amounts of fine-grained debris. As the seasons changed, there was alternating precipitation of iron-rich and silica-rich deposits which compacted to form the banded ironstone - the original source of the massive iron-ore deposits of the Pilbara.



Thin layers that make up the banded iron formation of Hamersley Range National Park have been traced for kilometres. Photo - Elizabeth Paton ▲

THE PAST 600 MILLION YEARS

Phanerozoic time, which follows the Precambrian, spans about 600 million years and embraces three eras - the Palaeozoic, Mesozoic, and Cenozoic.

While Precambrian rocks show few traces of the many simple forms of life that must have existed then, many of the world's sedimentary rocks dating from the Phanerozoic are rich in fossils. The earliest contain only primitive marine creatures such as sponges and brachiopods, but later many more advanced invertebrate animals and land plants evolved. By about 350 million years ago fish, the earliest vertebrate animals, were abundant; they were followed by the amphibia, reptiles, birds and mammals.

THE LOCAL SCENE

Many fossil remains are preserved in rocks of Phanerozoic age in Western Australia. As well as many more familiar kinds of molluscs, echinoderms and crustacea, there are interesting extinct groups including graptolites, trilobites and ammonites. Silurian sandstones of the Murchison Gorge in the Kalbarri National Park reveal tracks made 400 million years ago by now-extinct eurypterids - fearsome predatory arthropods that grew to several metres in length. Early reptiles are represented by scattered bones of giant marine plesiosaurs and ichthyosaurs. Footprints of a huge carnivorous dinosaur are seen on Cretaceous sandstone beds near Broome and the bones of many extinct marsupial mammals have been found in late Cenozoic deposits in caves.

By the late Precambrian, WA had become a fairly stable part of the earth's crust. It was part of the vast supercontinent, Gondwana, which also included South America, Africa, India and Antarctica. The fairly quiet conditions continued throughout the Phanerozoic and no major mountain building occurred. Instead, the ancient Precambrian land surfaces were gradually lowered by weathering and erosion. These processes continue today.

Crustal movements that did occur were mainly large-scale warping of parts of the old land surface and sinking of crustal blocks, caused by stretching of the crust in the Mesozoic era as Gondwana

began to break up. The movements created broad depressions called "sedimentary basins" that were filled as they deepened. Ten such Phanerozoic basins lie beneath about 40 per cent of WA's land surface. Some have been intensively studied, as they contain the State's valuable resources of underground water, oil, gas and coal.

Sedimentary deposits several kilometres thick piled onto the floors of the deeper basins as they sank. Although most of these strata are hidden from view, they have been pierced and sampled by exploratory drillholes, sunk thousands of metres. Seismic and gravity surveys have also probed their depths.

MAJOR BASINS

The Perth Basin is a narrow trough about 1000 km long and up to 12 km deep, bounded to the east by the Darling Fault. Sunken Precambrian rocks form its floor and lowlands such as the Swan Coastal Plain occupy parts of its surface. The deep Carnarvon Basin contains most of the State's known oil and gas reserves, tapped at Barrow Island and the Rankin gas platform. The Canning Basin occupies a vast area north-east of the Pilbara, including parts of the southern Kimberley, and extends hundreds of kilometres offshore.

An early Cambrian trilobite (extinct marine arthropod) preserved in sedimentary rocks of the Ord River Region in the Kimberley.
Photo - Courtesy of the WA Museum ▲

Geological processes constantly change our land; waves tear at the Zuytdorp cliffs, south of Shark Bay.
Photo - Michael Morcombe ◀

ROCKS OF MANY KINDS

Rocks can be divided into three major groups - igneous, sedimentary and metamorphic.

IGNEOUS

Basalt columns west of Black Point.
Photo - Jiri Lochman

Igneous rocks are formed from molten magma which rises from deep within the earth's crust. It may break through and pour out as volcanic rocks such as basalt or andesite, or cool slowly beneath the surface, forming bodies of intrusive igneous rocks such as granite, diorite or gabbro. Large bodies of granite and similar rocks are called batholiths, which may be exposed by erosion millions of years after they were formed.

SEDIMENTARY

Sedimentary rocks are formed by the accumulation of sediments such as sand, silt and mud on the sea-floor or in depressions on land. These sediments compact to form layers (strata) of sandstone, siltstone, shale, and other rock types. Limestone is sedimentary rock formed by accumulation of the skeletal remains of creatures such as molluscs and corals. Coal is a rock formed from plant remains.

Sandstones of the Bungle Bungle Ranges.
Photo - Jiri Lochman

METAMORPHIC

Metamorphic rocks, such as schist and gneiss, form when pre-existing rocks are subjected to great heat and pressure in the crust. Heat may come from the intrusion of igneous rock, or from deep burial; pressure is caused partly by major earth movements. During metamorphism, the mineral composition and appearance of rocks may be transformed. A soft shale may, for example, become a coarsely crystalline gneiss.

Coarsely crystalline gniess near Walpole.
Photo - John Myers

The small Collie and Wilga Basins contain the State's main coal reserves and coalmines. Their Permian coal seams, up to 13 metres thick, are the remains of swamp deposits and forests that existed about 275 million years ago. Fossil leaves and plant spores have been found in the coal-bearing strata, including those of *Glossopteris*, an extinct plant also found in other far-flung remnants of Gondwana. The basins also contain deposits formed during the great Permian glaciation of Gondwana, about 200 to 300 million years ago.

A coal seam exposed at Collie. Ancient swamp deposits and forests have been compressed by the weight of sediments accumulated above them.
Photo - Geoffrey Shaw ▲

The deposits provide many clues to the ages of the basins and to the marine and terrestrial conditions under which they were formed. For example, coarse sandstones and old delta beds are evidence of shallow-water deposition; thick, fine-grained mudstones indicate deeper water.

The evidence suggests that the major events that took place in WA during the Phanerozoic were direct responses to the prodigious forces associated with the gradual break-up of Gondwana. "Greater India" tore away first, from the western margin, beginning in the Jurassic period. In the south, Antarctica began to break free in the Cretaceous. There were widening rift valleys where the submerged continental shelf and slope now lie. These filled to form the present offshore basins and also extend onshore.

THE AGE OF ROCKS

When discussing the age of rock formations, geologists use two approaches. Today they can speak of the 'absolute age', which is the age in years, based on the rate of decay of radioactive elements found in rocks. More often, however, geologists use terms of 'comparative age', referring rocks to the internationally-used Geological Time-Scale. Fossils, the remains of animals and plants preserved in rocks, have been of critical importance in developing the Time-Scale. The earth's history is divided into major units called eras, the later of which are further divided into periods. WA has rocks from all eras and periods.

	ERAS	PERIODS	APPROX. AGE
PHANEROZOIC	CENOZOIC	Pleistocene Pliocene Miocene Oligocene Eocene Paleocene	65 million
	MESOZOIC	Cretaceous Jurassic Triassic	225 million
	PALAEOZOIC	Permian Carboniferous Devonian Silurian Ordovician Cambrian	600 million
PRECAMBRIAN	PROTEROZOIC		2500 million
	ARCHAEAN		4000+ million

Erosion has exposed pillars of harder limestone at the Pinnacles in Nambung National Park.
Photo - Marie Lochman

LANDSCAPES OF NOTE

Many of the State's interesting scenic features were shaped from rocks formed during the Phanerozoic. Ancient tropical Devonian barrier reefs wind across the countryside for hundreds of kilometres, forming the Napier and Oscar Ranges of the southern Kimberley. These 350 million-year-old reefs are built largely of colonial creatures such as stromatoporoids. Softer rocks that once surrounded the reef have been eroded away and it now stands boldly above the plains. Their structure can be seen in the walls of the gorges of Windjana National Park and Geikie Gorge National Park. The massive main reef, the rocks of the steeply inclined margin that faced the

ocean, and strata that accumulated in lagoons behind the reef are clearly visible. At a nearby cattle station ancient skeletons of Devonian armoured fish are preserved in sediments that surround the reefs.

The ranges of the Purnululu (Bungle Bungle) National Park of the east Kimberley consist of flat-lying, hard and weak layers of Devonian sandstone, broken by many vertical joint fractures. Erosion has eaten along the joints and selectively eroded the soft rock layers, creating a landscape that resembles gigantic piles of pancakes. On the beach at Bunbury steam bubbles and cooling cracks can still be seen in large areas of black basalt lava flows. They were poured out during the crustal rupturing that accompanied the breakup of Gondwana in the Cretaceous.

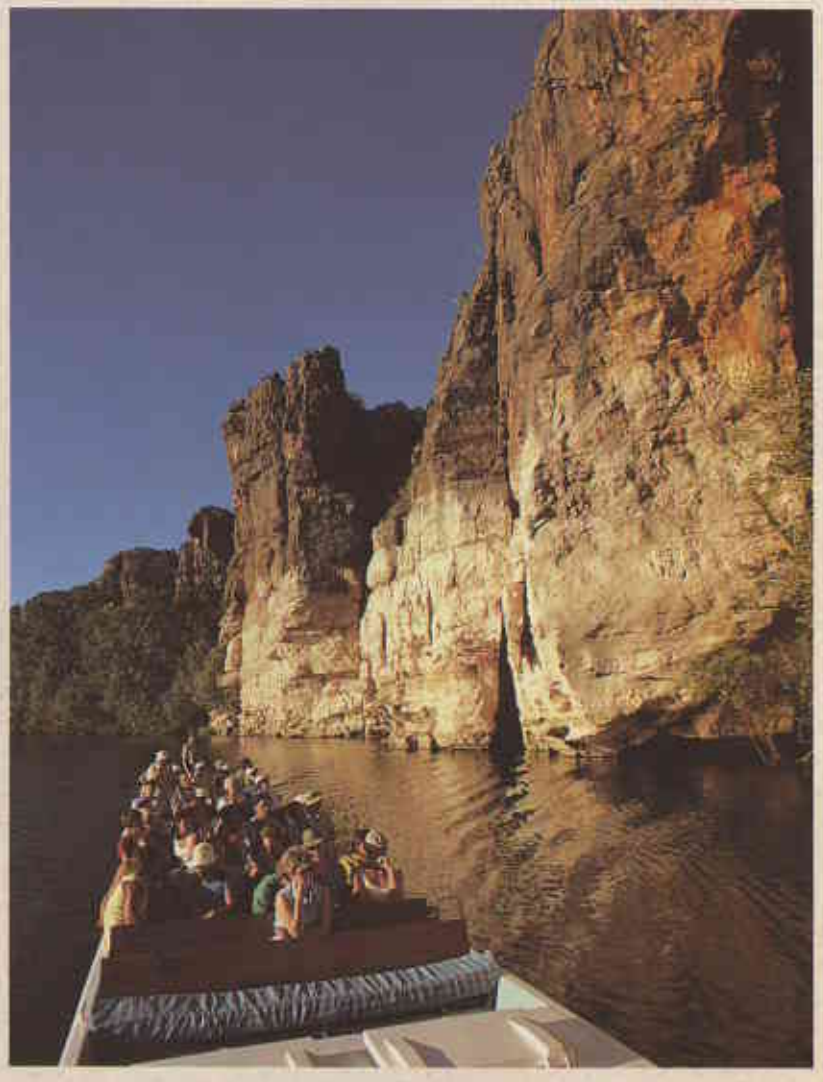
Basalt lava flows are the source of "blue-metal" used to make roads.
Photo - Geoffrey Shaw ▲

TOWARDS THE PRESENT

During the later part of the Phanerozoic there were major climatic changes. In the early Tertiary, Western Australia had a moist temperate to tropical climate under which the surface rocks were converted to a reddish crust known as laterite. In the Miocene and Pliocene the climate became more arid.

Our State has taken on its familiar form mainly over the past few millions of years. There were major glaciations in both hemispheres during the Pleistocene, but ice only lightly chiselled Australia's mountains.

Coastlines of all continents were, however, greatly affected by rises and falls of sea-level that accompanied the waxing and waning of vast ice sheets. At times of low sea-level, WA's continental shelf became dry land and ancestors of the Aboriginal people may have migrated to Australia along it. About 5000 years ago sea level was at its highest and coastal lowlands were submerged, as they may be again if polar ice caps melt.



Layers of fossils and the limestone construction of a Devonian tropical reef have been exposed at Geikie Gorge.
Photo - Jiri Lochman ▲

Many landscape features result from these climatic changes, including the extensive areas of desert sand ridges formed in an arid interglacial episode and the chains of saltpans that occupy valleys of vanished rivers.

WA's structure and landscape will continue to change: the powerful earthquakes that have struck the Wheatbelt in recent years are a reminder that the forces shaping our State are still at work. ◘

GEOLOGICAL SURVEY MAP

The Geological Survey of Western Australia (a branch of the Mines Department) has the main responsibility for State-wide mapping of geological formations and assessment of mineral resources. In 1988 the Survey marked 100 years' existence by issuing a special Centennial edition of the Geological Map of Western Australia (Scale 1:2,500,000). It shows the major groups of rocks (ages ranging to 3700 million years) that can be encountered throughout the State.

It is available from the Mines Department, 1st floor, Mineral House, 100 Plain St, Perth 6000. Also through agents in Kalgoorlie, Esperance Geraldton and Canberra.

LANDSCOPE

VOLUME 5 NO 2 SUMMER EDITION 1989/1990

Dolphins, whales and seals frequently strand along the WA coast. Find out who helps them and what they do on p. 10.

Powerful forces have formed the rocks and land surface of WA over billions of years. See p. 48.

Why are the thousands of feral camels that roam inland Australia the scourge of the desert? Turn to p. 22.

Explore the fascinating subterranean worlds deep beneath the earth on p. 28.

Inlets and rivers, towering karri and tingle forests, rugged coastline and remote wilderness areas - Walpole-Nornalup National Park has it all. See p. 15.

C O V E R

Australian sea-lion (Neophoca cinerea). *Photo - Nick Gales*

F E A T U R E S

R E G U L A R S

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