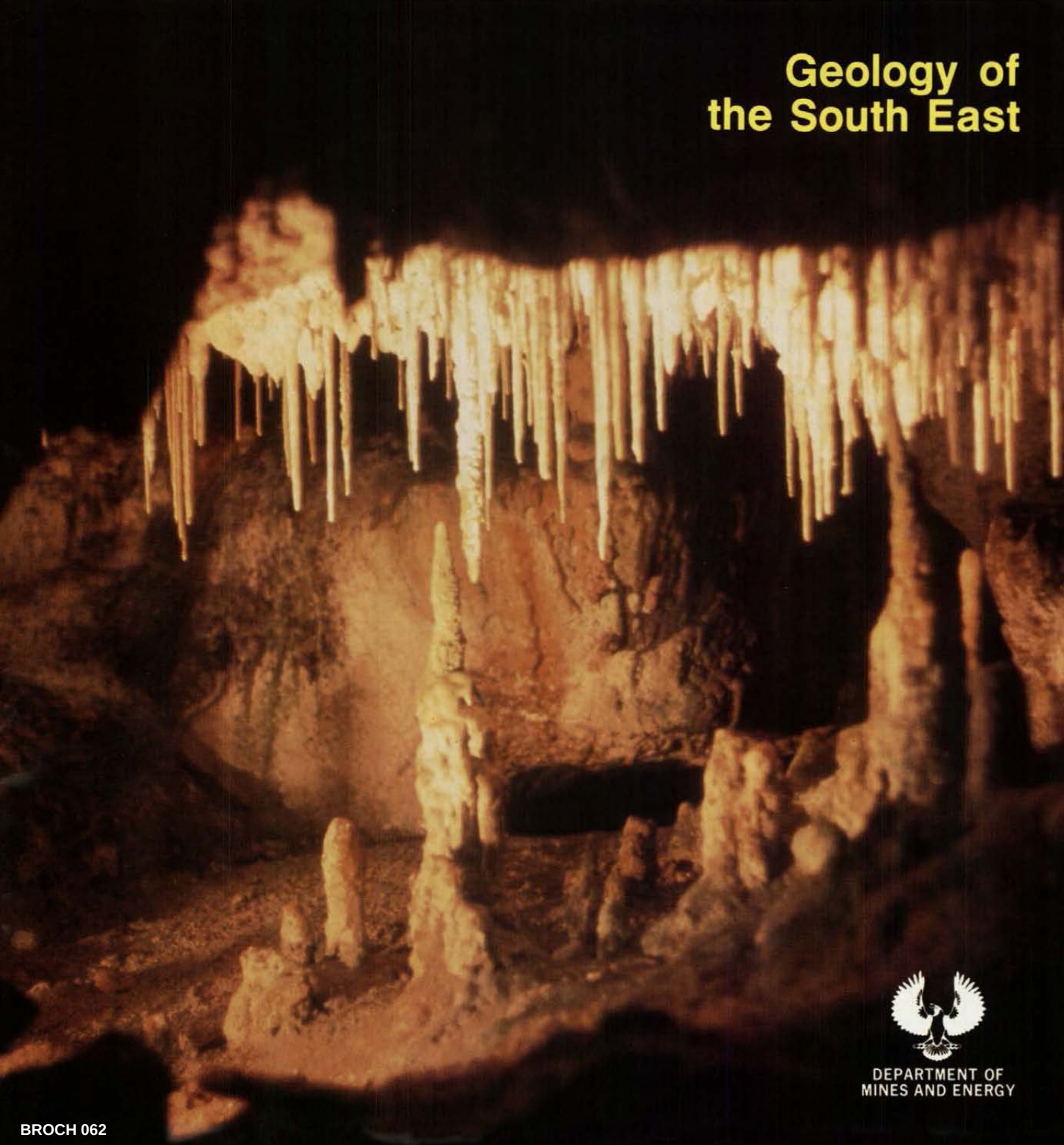
# Geology of the South East



DEPARTMENT OF MINES AND ENERGY

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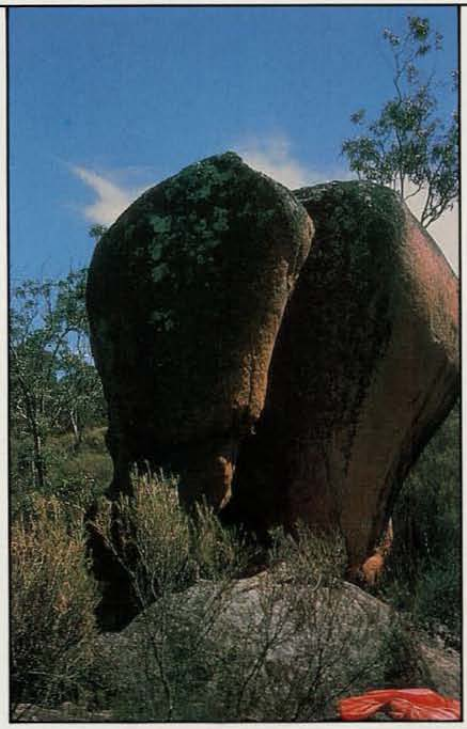
# An ancient archipelago

The South East was covered by a shallow sea for nearly half of the Tertiary Period. Within the sea was an archipelago, or group of islands, consisting of ancient granitic rocks. These formed part of the original crust of the Gondwana supercontinent and are about 450 million years old. The region between Kingston and Keith is underlain by a shallow ridge of these crustal rocks which still protrude above the modern land surface as isolated rocky hills.

The granite has been weathered into groups of large boulders known as 'tors'. These have been weathered and sculptured into varied shapes characteristic of granitic rocks in many parts of the world. The flat plains separating the tors are underlain in places by marine rocks and sediments indicating that at times the Tertiary sea covered much of the area.

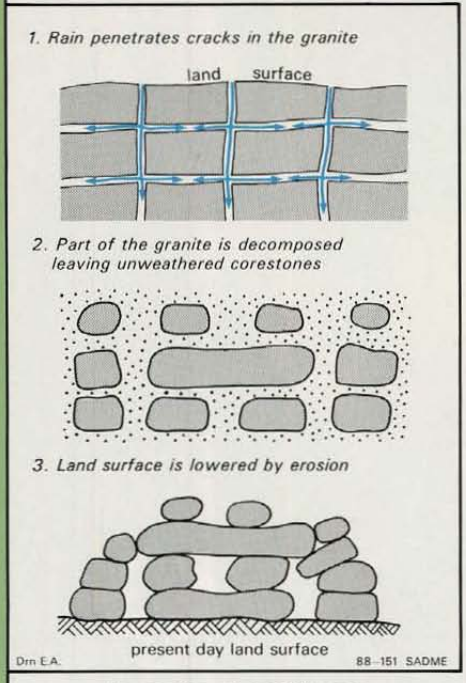


Mount Monster and Christmas Rocks are signposted along the Keith-Naracoorte road and may be visited by the public. At Jip Jip Conservation Park, granite boulders show a variety of curious shapes and interpretive signs describe how the tors have been formed. Low tors also occur on the beach at 'The Granites' near Taratap, north of Kingston; these elongate humped boulders are known as 'whalebacks'.

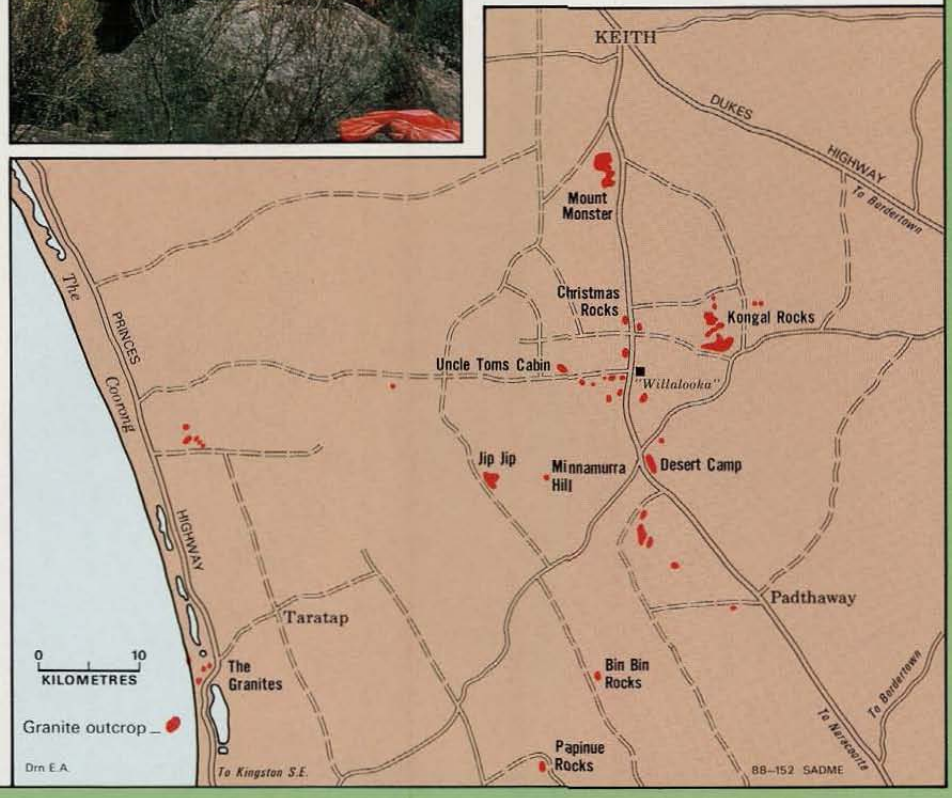
Other tors in this region are located on private land and permission should be obtained from the landowner before visiting them.

Left: *Granite tors at Jip Jip Conservation Park (D. Corbett)*

Below: *Major granite outcrops in the South East*



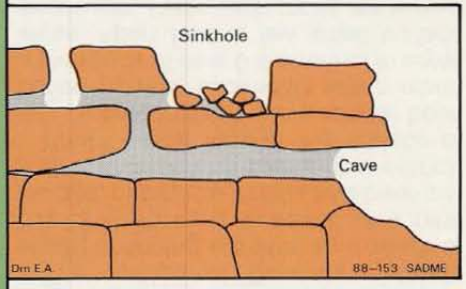

*Formation of granite tors*



# Caves and sinkholes

The caves and sinkholes so typical of the South East have been formed in the limestone that underlies much of the area. Limestone is permeable and absorbs rainfall, while cracks in the rock mass allow the water to circulate underground. Because of this, surface water disappears rapidly underground and surface streams are few.

As rainwater passes down through the atmosphere, it absorbs carbon dioxide and becomes mildly acidic. Limestone is readily dissolved by this weak acid and caves and sinkholes are formed as the water circulates underground. Inside the caves, dissolved limestone is redeposited to form decorative shapes such as stalactites and stalagmites.




*Formation of caves and sinkholes*

## Caves

In the South East there are several cave areas open to the public around which regular tours are run. The cave at Tantanoola contains a highly decorative display of stalactites, stalagmites and drip curtains. It occurs within an ancient stranded sea cliff and may have been formed partly by wave action.

At Naracoorte several caves are open to the public. These are famous for the great accumulations of fossil animal bones which have been found in them since the 1860s. The largest deposit was discovered in Victoria Fossil Cave where the remains of many thousands of animals ranging from frogs, reptiles

*Tantanoola Cave (The Subterranean Foundation)*

and rodents, to extinct giant marsupials lie buried in sediments filling the cave. This is one of the most important fossil sites in the world and an interpretive display showing how the fossils are excavated, cleaned and classified has been set up in the Conservation Park headquarters. Victoria Cave fossils are also on display in a reconstruction of the cave floor in the Lady Nelson Park, Mount Gambier.

It appears that for millennia these caves have acted as pitfall traps for the unwary, as dens for carnivores, and as roosts for owls and bats. Some of the remains have been dated as up to 150 000 years old.

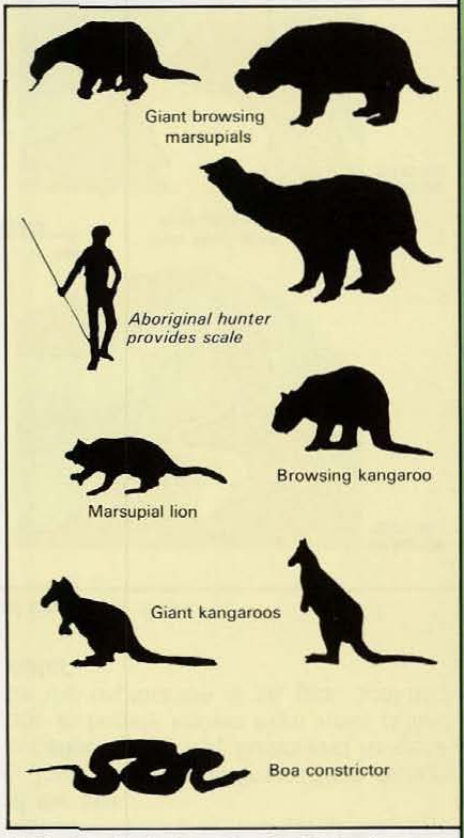
Almost half of the species of animals represented in the cave faunas are no longer found in the South East and many are extinct. Studies of fossil pollen show that during the last 40 000 years local vegetation changed from eucalypt forest and scrub to open woodland; this could account for the disappearance of the larger browsing animals.

## Sinkholes

These occur scattered all over the lower South East but are most easily seen at Mount Gambier where they occur above the water table. One in the centre of the city has been landscaped as the Cave Garden and another may be visited at Umpherston Cave on the eastern outskirts of the city.

South of Mount Gambier, sinkholes occurring below the water table may be visited at Little Blue Lake, Ewens Ponds, and Piccaninnie Pond.

Sinkholes can be dangerous and care should be taken when visiting them.




*Extinct animals from the South East. (Royal Society of S.A.)*

# Geological Map of the South East

*Note: The sites described in this brochure have been classified as Geological Monuments by the Geological Society of Australia.*

*Please do not damage them by unnecessary collection of rock specimens.*

Keith
DUKES HIGHWAY
BORDERTOWN
THE BLACK RANGE
The Coorong
WEST WOOLUMBOOL RANGE
Padthaway
NARACOORTE RANGE
Frances
KINGSTON S.E.
LACEPEDE BAY
PRINCES HIGHWAY
WEST REEDY CREEK RANGE
EAST AVENUE RANGE
Avenue
Lucindale
STEWART RANGE
NARACOORTE
KANAWINKA NARACOORTE LINEAMENT RANGE
Cape Jaffa
GUICHEN BAY
Robe
Conmurra
Bool Lagoon
PENOLA
Furner
Beachport
WOAKWINE RANGE
RIVOLI BAY
Mount Burr
Mt Muirhead
Mt McIntire
Kalangadoo
Cape Buffon
Southend
MILLICENT
CANUNDA CONS. PK
RANGE
Lake Bonney
Tantanoola
GAMBIER LINEAMENT
MOUNT GAMBIER
BURLEIGH RANGE
Mt Schank
Carpenters Rocks
Cape Northumberland
Port MacDonnell

**CAINOZOIC ERA**

QUATERNARY
- Recent sand dunes
- Volcanic centres *
- Volcanic rocks
- Stranded shoreline deposits
- Lagoonal muds and shell beds

TERTIARY
- Limestone, sand and clay

**MESOZOIC ERA**

No outcrop: sediments encountered in boreholes only

**PALAEOZOIC ERA**

ORDOVICIAN
- Granitic rocks

Fault zone (lineament)

Major sealed roads

0 10 20 30 40 50
KILOMETRES

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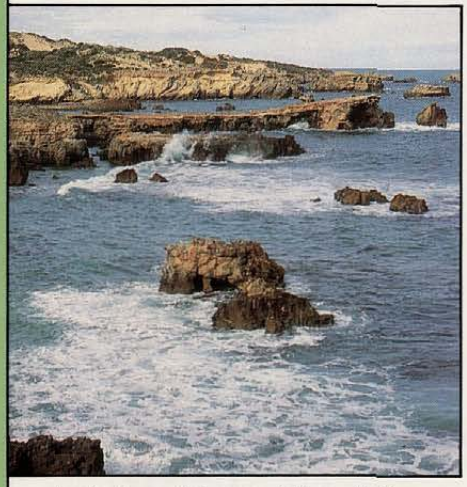
88–154 SADME

# Stranded shorelines

The broad flat plain of the South East is broken by a series of low ridges hundreds of kilometres long, running roughly parallel to the present coast. These represent stranded shorelines and provide a unique record of Quaternary sea level changes. Between Naracoorte and the coast, thirteen different ridge systems have been recognised, formed during the last 700 000 years by fluctuating sea levels.

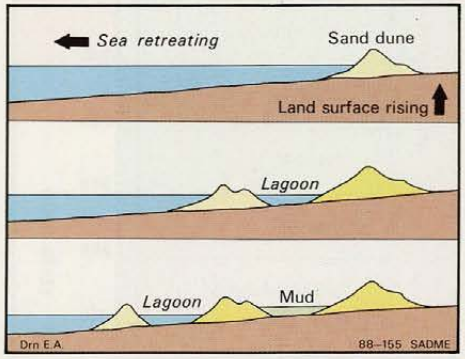
The ridges consist of sand with many marine shell fragments. In places the sand has been hardened to rock by percolating groundwater. Cuttings for roads and drains show that the sand layers are inclined in many directions—a feature called crossbedding, characteristic of windblown sand dunes. This feature can be seen in the main road cutting at Naracoorte and along Woakwine drain cutting, signposted along the Beachport-Robe road.

Behind many of the dune ridges is a low lying area of silt and mud deposited in a former lagoon of sea water trapped on the lee side of the ridge. This process continues along the modern coastline where the lagoons of the Coorong occur behind the modern beach dunes



*Ancient sand dunes at Cape Buffon*

Eroded remnants of cemented sand dunes, found as cliffs and headlands, give the modern shore a rugged picturesque character, for example at Cape Northumberland, Carpenters Rocks, and along the Canunda Conservation Park south of Cape Buffon.




*Formation of stranded shorelines*

The geological map shows how the sea is progressively destroying the Woakwine Range dune system. At Beachport, it has broken through the dune barrier, eroding the soft lagoonal sediments behind to form Rivoli Bay. North of Robe the dune system has been completely removed, while between Robe and Beachport a string of lagoons remains protected behind the as yet unbreached dune.

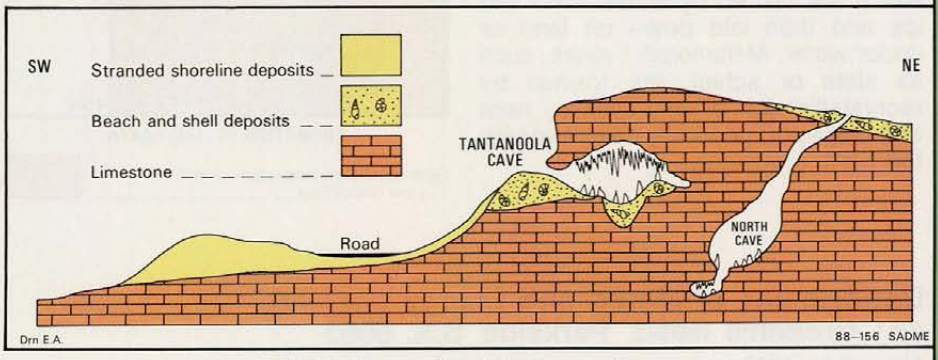
## The Ice Age

Formation of these stranded shorelines was caused partly by climatic changes associated with the Ice Age.

About 10 million years ago the global climate began to cool. Large ice masses formed in the Northern Hemisphere and the Antarctic ice cap began to expand. There is no evidence that ice extended to the South East but the region was affected by the many cycles of changing climates and sea levels that characterised the Quaternary Period. As the ice masses expanded, water was removed from the ocean, climates became colder and drier and sea levels fell. As the areas of ice contracted, climates became warmer and wetter and sea levels rose. At the same time uplift of the land surface, caused by geological forces, assisted the sea's retreat.

## Tantanoola Cave

This occurs within a stranded sea cliff. At one time the area was totally submerged, as fossil shells have been found at the top of the cliffs over 70 metres above present sea level. Younger shell deposits occur at the base of the cliff together with stranded sand dunes, and fossil seal remains have been found in the cave.




*Stranded sea cliff at Tantanoola Cave*

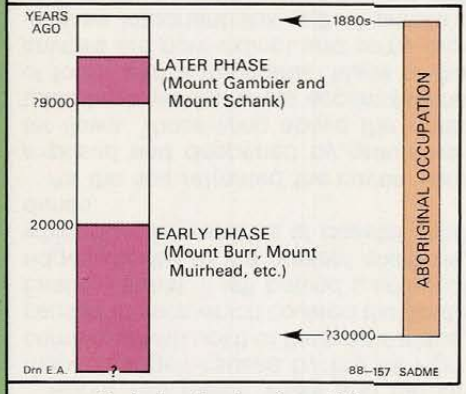
# Volcanoes

Volcanic activity is caused by movements of the gigantic plates which make up the Earth's crust. Cracks in the crust caused by this movement allow hot gas and molten rock to well up from the Earth's interior.

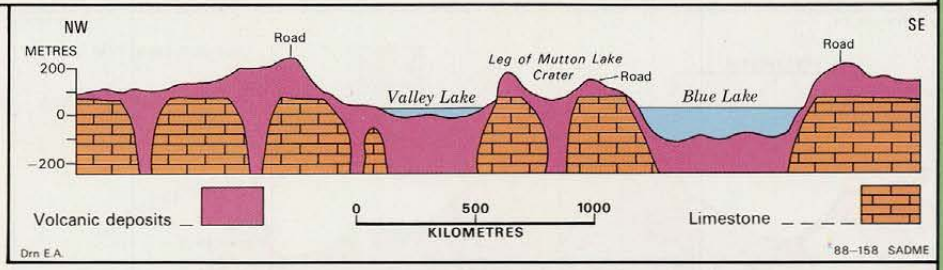
Australia is the only continent not to have active volcanoes but there is plenty of evidence of past volcanic activity. The volcanoes of the South East are geologically quite young and their craters are well preserved.

Local aboriginal legends tell of the giant Craitbul and his family who wandered around the South East looking for a place to settle. They camped and made ovens at Mount Muirhead and Mount Schank but were frightened away from both sites by the moaning voice of a bird spirit. Moving to Mount Gambier they again made an oven but one day water came up from below and put out their fire. They made others and these are now the craters of Mount Gambier.

It is not possible to date this legend but geologists believe that volcanic activity took place in two phases, the last of which occurred between 5 000 and 10 000 years ago—a period during which Aborigines are known to have inhabited the area. This later phase of activity produced the craters of Mount Gambier and Mount Schank.




*Periods of volcanic activity*




*Section across the Mount Gambier volcanic complex*

## Mount Gambier

The craters at Mount Gambier have been blasted through the rocks and sediments which underly the region. Layers of volcanic ash, cinders, and lava were deposited on the land surface over a radius of about 8 kilometres. Lumps of lava known as 'bombs' were blown out and have been found resting within the ash layers. Some of the ash deposits show small rainwater channels: rain often accompanies volcanic eruptions owing to the large amounts of water vapour released from the vents.

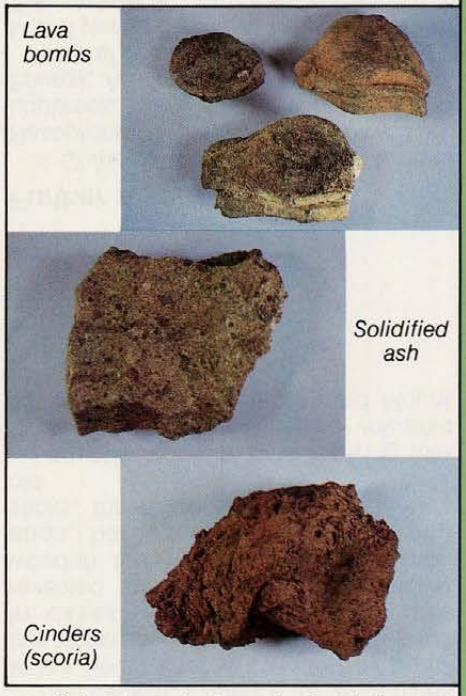
An interesting feature of the Mount Gambier complex are blowholes where steam has discharged through cracks in the limestone. The best known is the Devils Punchbowl in the Crater Lakes, although other blowholes are scattered through the city.

## Mount Schank

This volcano rises abruptly from the plain south of Mount Gambier and may be climbed by a trail which passes around the crater rim. Mount Schank differs from the craters at Mount Gambier in that its floor is dry, being approximately at the same level as the surrounding plain. On the south side of the main crater is a smaller and earlier cone partially buried by ash ejected from the main crater. Both cones consist of bedded ash, consolidated to form rock, visible on the inside walls of the main crater.

## Future activity

Although no volcanic eruption has occurred within recorded memory, several earthquakes have been experienced, including two of South Australia's largest at Kingston (1897) and Robe (1948). Carbon dioxide, presumably of volcanic origin, is produced commercially southeast of Mount Gambier. It is impossible to say whether this volcanic province is extinct or merely dormant.




*Volcanic rocks from the South East*

# Geological Evolution of the South East

## PALAEOZOIC ERA

The geological history of the South East began at a time when the continents were arranged differently on the Earth's surface. Australia and Antarctica were joined and formed part of a supercontinent called Gondwana. This existed for hundreds of millions of years and drifted slowly around the globe moved by subterranean geological forces.

The surface of Gondwana experienced changing climates as a result of this drift. There is evidence of a past ice-age, of tropical forests and swamps, and of animals and plants now extinct.

Rocks which formed the surface of this supercontinent have since been buried by later sediments which reach a thickness of over 6 kilometres in some areas. Apart from a few small surface exposures, these early rocks are known only from boreholes.

## MESOZOIC ERA

### Gondwana breakup

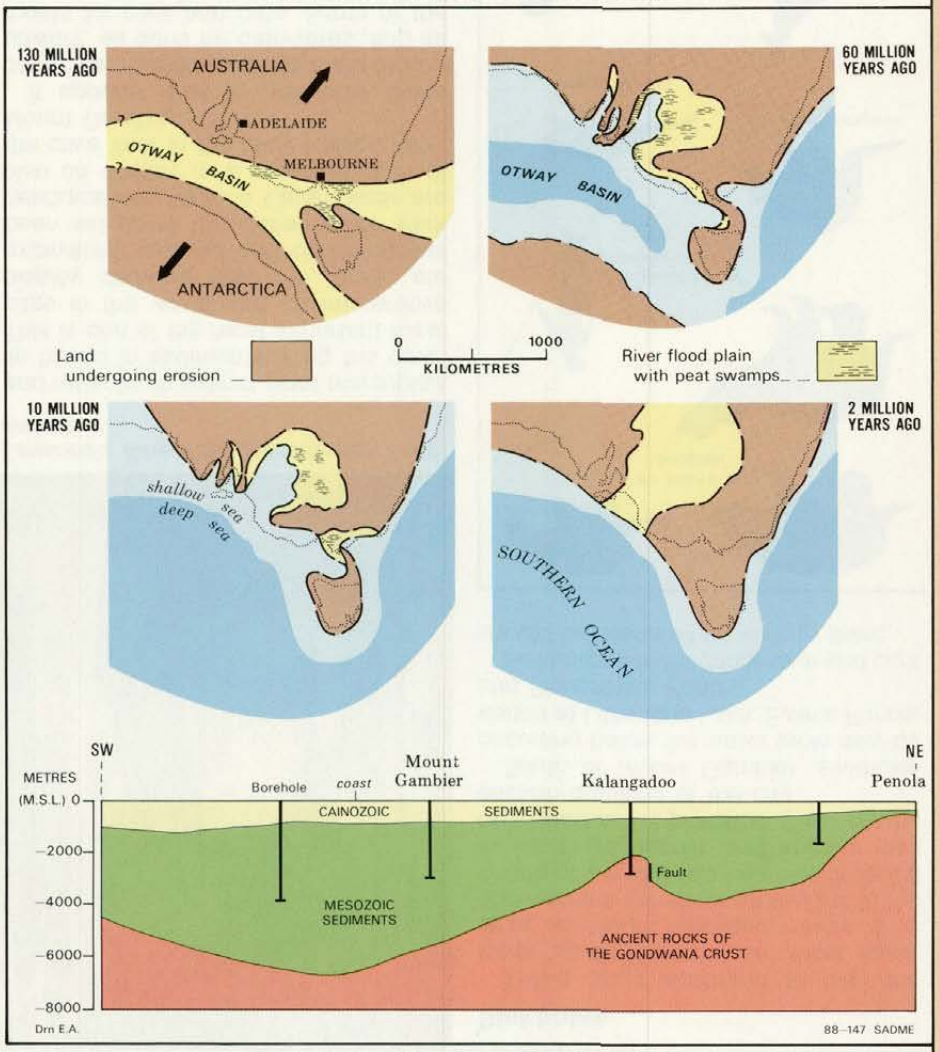
About 150 million years ago the Gondwana supercontinent became unstable. Large rifts developed in its crust and molten lava was extruded onto the surface. Gondwana broke up into a series of crustal plates which slowly dispersed to form what is now Australia, Antarctica, South America, Africa and India. Fault movements which raised and lowered parts of the land combined with world wide climatic changes, caused the sea to advance and retreat over parts of the new continent of Australia.

### The Otway Basin

One of these crustal rifts occurred between Australia and Antarctica and led to the eventual separation of the two continents. At first sand and silt was deposited in swamps and alluvial floodplains occupying a narrow land trough. As the continents moved apart the trough widened and deepened. Sea flooded in on several occasions and marine sediments containing the remains of fish, molluscs, and microscopic organisms were deposited; coal was also formed in swamps at the edge of the sea.

This elongate sediment-filled trough is called the Otway Basin and its geology is largely known from wells drilled for the exploration of oil, gas, coal and water.

*Geological evolution of the Otway Basin*

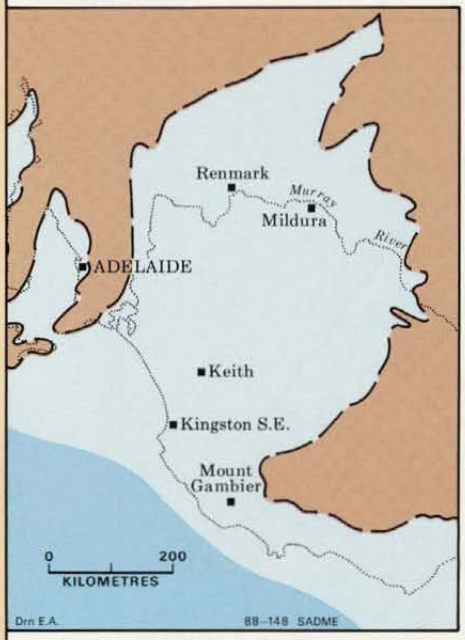



*Geological section across the Otway Basin*

## CAINOZOIC ERA

### The Southern Ocean

The final separation of Australia from Antarctica took place about 50 million years ago. This process, which still continues, resulted in the formation of the Southern Ocean and the development of circum-Antarctic ocean currents. The ocean has had a major effect on the climate of the region and on the development of its flora and fauna. Its development is also recorded by the sediments laid down in the Otway Basin during the Tertiary Period. Firstly terrestrial and then marine sediments were deposited as the seaway became established. About 40 million years ago the sea penetrated far inland, into what is now the Riverland, covering the South East for the next 25 million years. Between Kingston and Keith was a group of small islands, probably surrounded by coral reefs. These islands were all that remained of the ancient crystalline rocks which form the floor of the Otway Basin.



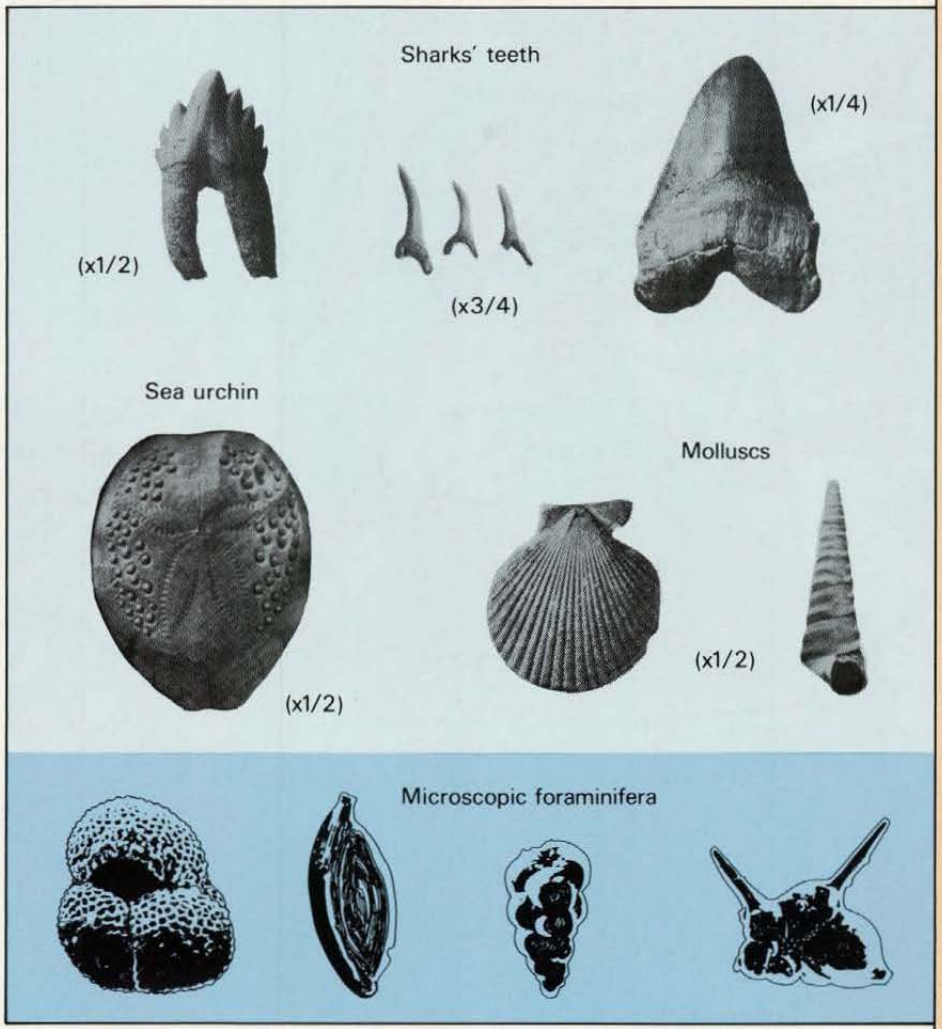

*Maximum extent of the Tertiary sea*

### Life in the Tertiary sea

The sea which advanced and retreated over this part of South Australia during much of the Tertiary Period teemed with life. Its waters provided a home for sea urchins, molluscs and microscopic foraminifera, while the sea floor was covered in lace corals. Whales and sting rays swam in the ocean, together with several varieties of shark, one of which may have been up to 20 metres long.

The hard parts of these creatures, many of which closely resemble modern life forms, were preserved as fossils in the sand and limestone reefs deposited on the sea bottom.

About 15 million years ago the sea retreated and the limy sand dried out to form the thick fossil bearing Gambier Limestone deposits that underlie much of the South East. This limestone, now used extensively for building stone, was exposed to weathering which created a surface dominated by sinkholes and caves.




*Marine fossils from the Tertiary sea*

## Retreat of the sea

About two million years ago the climatic changes caused by the Ice Age, combined with uplift of the land surface, caused the sea which covered the South East to retreat. It left behind a series of ridges parallel to the present coastline, which are the remains of coastal sand dunes.

As the sea retreated the caves were exposed and deepened by groundwater flows. Those lying above the water table have yielded great accumulations of fossil animal fragments. Many of the animals are now extinct and some provide an important link with Australia's early marsupial fauna which has evolved in isolation from the other continental fragments which once formed the Gondwana supercontinent.

By this time widespread rainforests had been replaced by the open vegetation dominated by Eucalyptus which is such a distinctive feature of the modern Australian landscape.

## Volcanic activity

Volcanic activity is caused by movement of the gigantic plates which make up the Earth's crust. Cracks in the crust caused by this movement allow hot gas and molten rock to well up from the Earth's interior.

The geological forces which caused the separation of Australia and Antarctica gave rise to irregular volcanic activity. The most recent phase occurred in Victoria and extended into the South East where nearly twenty eruptive centres have been discovered. An earlier group is centred on Mount Burr, northwest of Mount Gambier, where some of the volcanic structures have been shaped by the action of onshore winds and coastal erosion by the sea; there is also evidence of a submarine lava flow near Beachport. The most recent activity, which formed the craters of Mount Gambier and Mount Schank, occurred between 10 000 and 5000 years ago.

## Aboriginal occupation

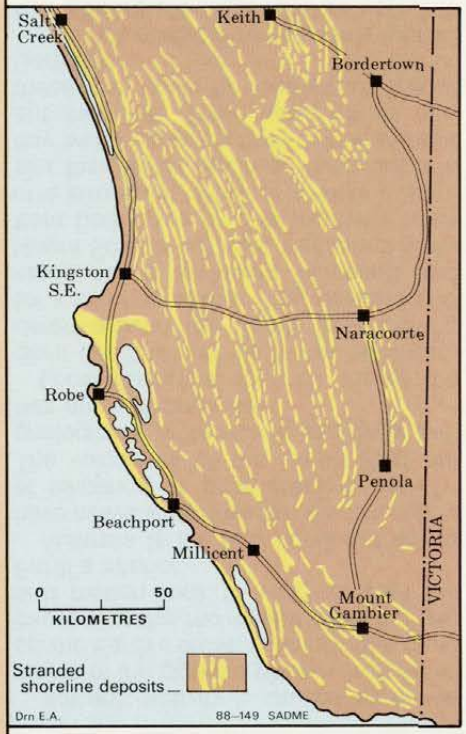
The earliest evidence of Aborigines in the South East is provided by primitive stone hand axes and scrapers found in caves. Peat swamps have also revealed some of the world's oldest wooden tools which include boomerangs, barbed spears and throwing sticks; these are around 10 000 years old.

Legends record events implying that local Aborigines witnessed volcanic activity at Mount Gambier and Mount Schank.

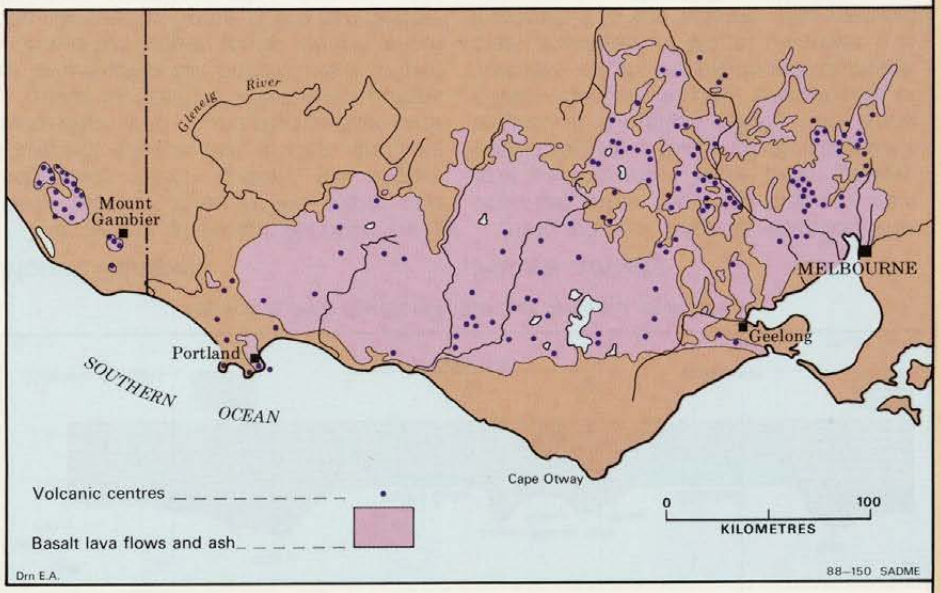
## Further reading

*A Guide to the Geology and Mineral Resources of South Australia* by N.H. Ludbrook. S.A. Department of Mines and Energy, Adelaide.

*Natural History of the South East* by M.J. Tyler and others. Royal Society of S.A., Adelaide.




*Stranded beaches marking stages in the retreat of the sea*




*Volcanic activity in southeastern Australia*

# Geology and the Earth's History

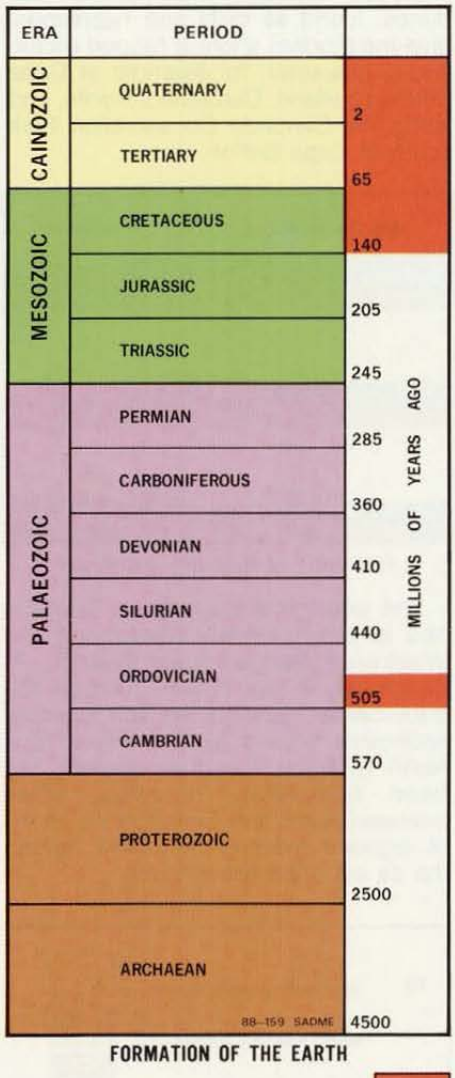
Geology is the study of planet Earth and the materials of which it is made. Geologists also study the processes which act on these materials and the history of the planet and its life forms.

Early geologists, working in the 19th century, relied almost entirely on information obtained from rocks exposed at or near the surface. Since then, many indirect methods such as deep drilling, geophysics, and satellite imagery have been developed. All of these techniques can be used to provide us with a picture of the history of our planet and of the time scale involved.

We know that the Earth formed around 4500 million years ago at about the same time as the solar system. Earth is believed to have condensed from a cloud of gas and dust, and to have passed through a molten stage from which the first rocks crystallised. Since then, a variety of natural processes have moulded and changed these early rocks to form the surface of the Earth as we know it today.

Rocks are divided into three classes according to their origins. *Igneous rocks,* such as basalt, have crystallised from molten material either on the surface or below ground. *Sedimentary rocks,* such as sandstone, have been formed from the weathering of existing rock into small grains which are carried by water, wind and ice and then laid down on land or under water. *Metamorphic rocks,* such as slate or schist, are formed by recrystallisation of any rock by heat and pressure, generally deep beneath the Earth's surface.

GEOLOGICAL TIME SCALE




FORMATION OF THE EARTH

Geological time scale represented in the South East

The first rocks studied by geologists were mainly sedimentary in origin and their relationships were used to set up a geological time scale. By comparing their position with respect to each other and the fossils within them, the rocks were ranked in order of increasing age. This process has been refined so that nowadays most rocks can be assigned to the time scale, which has a universal application.

Until recently it was not possible to date rocks accurately and the geological time scale was based on relative ages and indirect estimates only. However, during the last fifty years, radioactive elements have been used as geological clocks. These elements emit radiation at constant rates to form more stable elements and the extent to which this has occurred gives a measure of the ages of rocks containing them. It is now possible to date certain rocks fairly accurately and express geological time in years.

The geological time scale forms the basis of this brochure, and the history of the rocks, together with the fossils found in them, is presented in order of the geological periods shown on the table.

**Department of Mines and Energy**
**191 Greenhill Road, Parkside S.A. 5063**
November, 1989

STATE PRINT SA B3020

Front cover: *Alexandra Cave, Naracoorte (Dept of Premier and Cabinet)*

Back cover: *Mount Schank volcanic crater*

*Rocks and sediments which underlie the South East have a history dating back over 150 million years. At this time Australia and Antarctica were joined, forming part of the supercontinent of Gondwana. This ancient continent later broke apart and the piece that became Australia drifted very slowly northwards. As it did so, what was originally a rift in the crust began to widen and the Southern Ocean was formed.*

*A thickness of over 6 kilometres of sediment was deposited gradually in the rift. As the rift widened, the sea flooded parts of the land depositing marine limestone packed with fossils.*

*Later the sea withdrew, leaving behind a series of ridges which are the stranded remains of coastal sand dunes, and limestone caves were formed.*

*Volcanoes blasted their way through the crust to form craters and cones around Millicent and Mount Gambier. Some of this activity took place during the period of known Aboriginal occupation and is mentioned in their legends.*