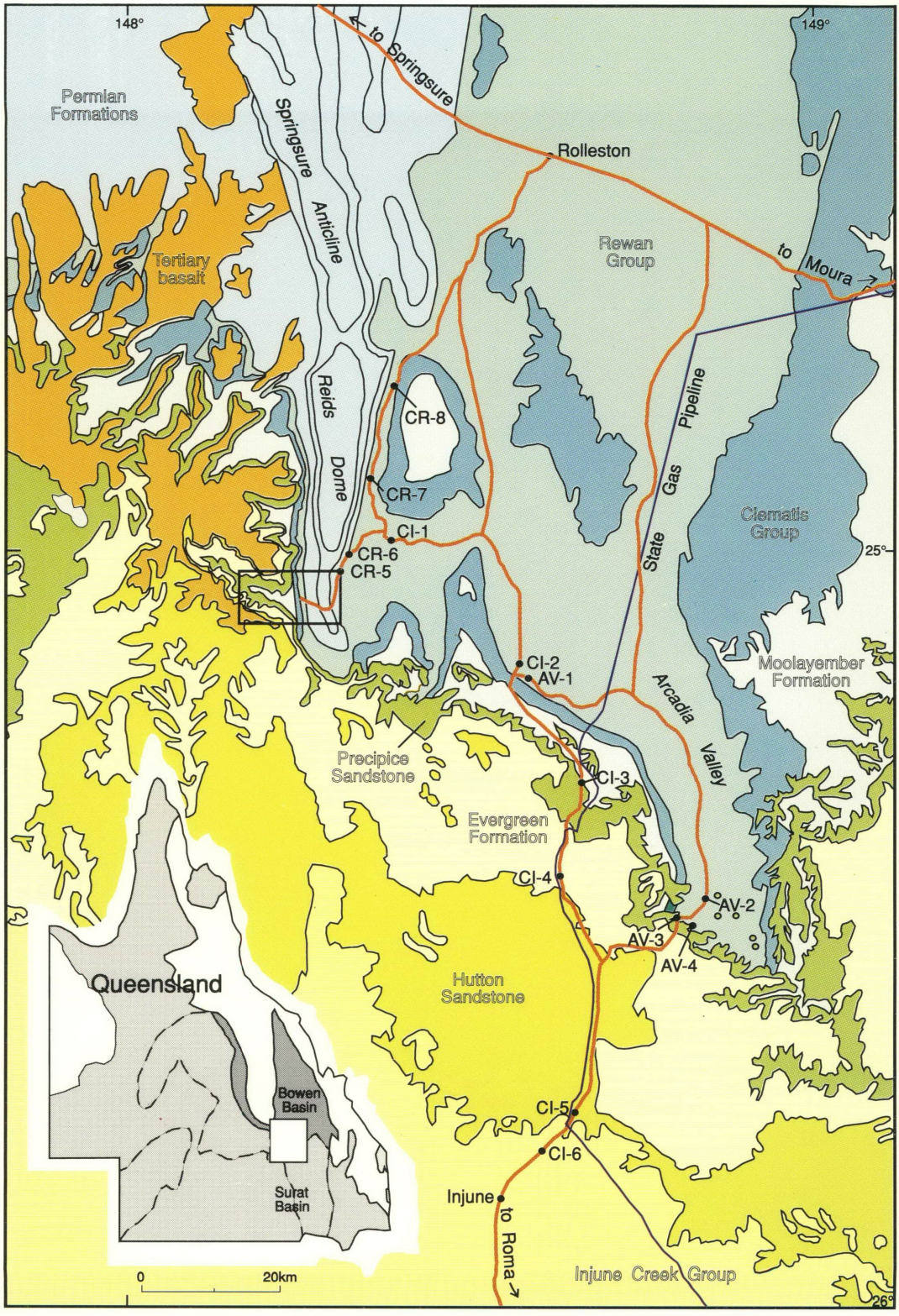
The Ancient Rocks of Carnarvon Gorge

Jim Beeston & Allan Gray

DEPARTMENT OF MINERALS AND ENERGY
QUEENSLAND

1993


148°
149°
25°
26°
to Springsure
Permian Formations
Springsure Anticline
Rolleston
Rewan Group
to Moura
Tertiary basalt
Reids Dome
CR-8
CR-7
CI-1
CR-6
CR-5
State Gas Pipeline
Clematis Group
CI-2
AV-1
Moolayember Formation
Arcadia Valley
Precipice Sandstone
CI-3
Evergreen Formation
CI-4
AV-2
AV-3
AV-4
Hutton Sandstone
Queensland
Bowen Basin
Surat Basin
CI-5
CI-6
Injune
to Roma
Injune Creek Group
0
20km

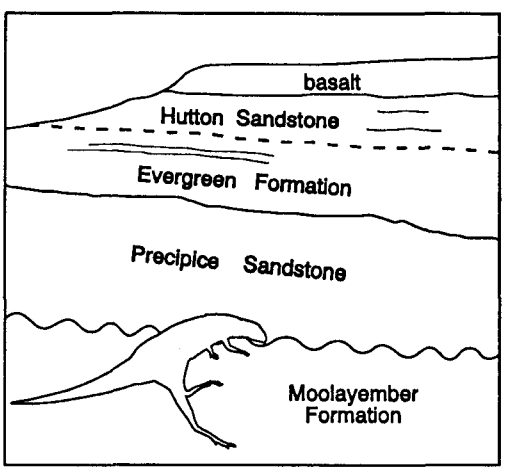
The Ancient Rocks of Carnarvon Gorge

Jim Beeston & Allan Gray

Department of Minerals and Energy, Queensland

CONTENTS

Cover Photo: The panoramic view across Carnarvon Gorge from Boolimba Bluff shows the white sandstone cliffs of Precipice Sandstone, overlain by the Evergreen Formation containing the Boxvale Sandstone Member outcropping as a narrow line of white cliffs, and the partially outcropping Hutton Sandstone on the middle to upper slopes. Flat-bedded basaltic lava flows of the Buckland Volcanics form the capping.



Rear Cover Photo: Outcrop of moderately dipping Clematis Group sandstones at the swimming hole in Carnarvon Creek.

Inside Front Cover (MAP 1): Geological map showing the Permian rocks of the Bowen Basin exposed in the Denison Trough (blue, top left); the overlying Triassic rocks of the Bowen Basin on the Comet Ridge / western Taroom Trough (blue-green, top right), and the Jurassic rocks of the northern Surat Basin (green, lower). The Carnarvon Gorge area is left of centre (see MAP 2 in centrefold).

Also published in this series:

'Rocks and Landscapes of the Chillagoe District'.

'Rocks and Landscapes of the Cairns District'.

'Rocks and Landscapes of the Townsville District'.

Published in a companion series by the Geological Society of Australia, Queensland Division:

'Rocks and Landscapes of the Gold Coast Hinterland'.

'Rocks and Landscapes of the Sunshine Coast'.

'Rocks and Landscapes of Brisbane and Ipswich'.

How to reference this booklet:

BEESTON, J.W. & GRAY, A.R.G., 1993: *The ancient rocks of Carnarvon Gorge*. Department of Minerals and Energy, Queensland. Brisbane.

Acknowledgements: The authors are indebted to the Ranger (Joe Adair) and staff of the National Parks Headquarters, Carnarvon Gorge, for their assistance. The Manager, Oasis Lodge (John Knox), and staff are thanked for their assistance and courtesy during our stay. Contributions to this booklet were made by other staff of the Department of Minerals and Energy, in page order:- Dr Alan Robertson (Tertiary volcanics), Dr Susan Parfrey (Photos of fossil animals in Appendix A) and Mr John Draper (Appendix C). Mr John Rigby (Queensland University of Technology) supplied most of the photos of fossil plants (Appendix A), and Dr Tony Thulborn (University of Queensland, St Lucia) provided the information on the dinosaur footprints (Appendix B).

The booklet was produced within the Corporate Services, Geological Survey and Energy Divisions, and funded by the Geological Survey Division

Issued under the authority of the Minister for Minerals and Energy

National Library of Australia card number and ISBN 0 7242 5229 0

Cartography by LJ Genn and TS Moore
Compiled on Xerox Ventura Desktop Publisher by JW Beeston

Copies of this booklet can be obtained from:

Department of Minerals and Energy
Queensland Minerals & Energy Centre
61 Mary Street
BRISBANE QLD 4811
(07) 237 1433

GPO Box 194
BRISBANE QUEENSLAND 4001

Department of Environment & Heritage
160 Ann Street
BRISBANE QLD 4000
(07) 227 8185

PO Box 155, North Quay
BRISBANE QUEENSLAND 4001

Also, The Oasis Lodge, Carnarvon Gorge
and other local outlets

Issued June, 1993.

THIS BOOKLET

Carnarvon Gorge is a major tourist attraction situated in the Carnarvon National Park. It features spectacular cliff and rock formations which form the framework for the region, and is also noted for its diverse flora, fauna, and cultural history. Visitors cannot help but be amazed at the grandeur of the cliffs, and wonder how such rock formations came about. But the formation of the cliffs is only a relatively recent event. The geological history of the area precedes their formation by hundreds of millions of years.

This booklet is a brief, relatively simple guide to this geological history, and to the contribution each phase has made to the present landscape. Also described are interesting geological features on the recognised walks in the Gorge, typical examples of the different rocks, both in the Park and in adjacent areas including the Arcadia Valley, with a guide to their location, and the economic geology of the area. Geological terms, which may be unfamiliar to some, are included in a glossary near the back of the booklet.

Twenty thousand years ago, ancestors of the Bidjara Tribe inhabited the Carnarvon Gorge. Although availability of food and water, and protection from the elements, would have played an important part in their presence, they undoubtedly also appreciated the beauty of their environment. Their contribution to the area is highlighted in the treasure trove of cave paintings to be found in the Gorge. In more recent times, pioneers and pastoralists became the main human occupants of the area. But this was not to last. The magnetism of the Gorge for bushwalkers, naturalists and tourists eventually dominated.

Apart from being a tourist destination, the Carnarvon Gorge is an educational arena for students, explorationists, and others, (including, of course, yourself!), wishing to gain a greater understanding of the complexities of the earth's history. Vast areas of Queensland contain rocks equivalent, in many ways, to those that can be seen at the surface in the Carnarvon Gorge-Arcadia Valley region, but which are buried beneath younger sediments and rocks, and can only be studied by expensive drilling and seismic surveys. The outcrops in this area provide an opportunity to study the variations in the sequence in detail, and gain a better understanding of similar sequences elsewhere that contain the State's vital resources of water, petroleum and coal. So as well of being of interest to 'non-geologists', this booklet is a valuable guide for all explorationists and students of geology visiting Carnarvon Gorge and nearby areas.

(If possible, the Miles Museum should be visited in conjunction with a visit to the Gorge and the reading of this booklet, to view the montage and detailed cross-section through the Bowen and Surat Basins on display there at the Great Artesian Basin Centre building).

THE AUTHORS

James W Beeston MSc PhD

Jim graduated from the University of Queensland, St. Lucia, in 1972, received an MSc in 1981, and a PhD in 1988. He has been employed in the DME since 1968, and worked mainly in the fields of coal geology, petroleum geology, and palaeontology. In 1978, he founded the Coal Geology Group of the Geological Society of Australia Inc., a society catering for the scientific pursuits of several hundred geologists involved in coal exploration, and is presently the Editor of the groups' journal 'Australian Coal Geology'.

Allan R G Gray BSc

Allan graduated from the University of Queensland, St Lucia, in 1961 with a major in geology. He has been employed with the DME since graduation, and has over 30 years experience in various aspects of petroleum geology including the subsurface correlation of wells, the relationship of the subsurface to outcrop, stratigraphic drilling, and the basic framework of Queensland's sedimentary basins. He was the project geologist for the first stratigraphic drilling ever undertaken by the Department in the Injune - Carnarvon Gorge area in the 1960's. He is the senior author of a major analysis of petroleum in Queensland, the recently published 'Petroleum Resources of Queensland' Review, and the project leader and senior author of the geological cross-section of the Great Artesian Basin, on display at the Miles Museum.

HISTORY AND NATURE OF THE ROCKS

The Carnarvon Gorge - Arcadia Valley area lies on the outcrop boundary between two major sedimentary basins - the Bowen and the Surat (see MAP 1, inside front cover). Geographically, these two basins represent a significant portion of Queensland, as well as being prime contributors to Queensland's wealth. The older Bowen Basin yields much of the State's coal as well as some gas and oil, and the younger Surat Basin, as part of the Great Artesian Basin, most of the State's groundwater, much of the oil and gas, and some coal. The basins combined contain sedimentary rocks deposited in alternating marine and freshwater conditions which prevailed some 280 to 100 million years ago.

Settling and stabilisation of these massive accumulations of rocks caused a major impact on the landscapes of central Queensland, and few as spectacular as those around the Carnarvon Gorge.

To explain the various rocks and how they formed, the different episodes of geological history as we understand them are described in sequence. A diagram on page 15 shows this history against the geological time scale, and the geological map (inside front cover) shows where the main rock groups now occur in the region.

It should be appreciated that the further back in time we consider, the less complete is our knowledge of the events, as the older rocks are obscured by later rock sequences. An understanding of the vast span of geological time is not easy to grasp, and the concept is also difficult to represent. Geologists have divided time into several 'Periods' with formal names, such as Permian, Triassic, and Jurassic. The ages of the different rocks in the region are mentioned in terms of these periods and on page 15, are listed in millions of years on the Geological Time Scale.

1. THE BASEMENT MYSTERY

The oldest rocks in the Carnarvon Gorge area occur at considerable depth, and are known from drilling and geophysical (gravity, magnetic) surveys. Some are related to outcrops west of the Gorge.

Early Palaeozoic gabbro forms in the core of the Maranoa Anticline, a subsurface ridge which extends from west of Carnarvon Gorge to the south-southwest, under the Great Artesian Basin. This isolated outcrop occurs 60km WSW of Carnarvon Gorge, and represents some of the most deeply eroded rocks of the earth's crust (which solidified at great depth, and at high temperature - see page 15).

Closer to Carnarvon Gorge, sedimentary rocks of Devonian age have been encountered in drillholes. These consist of shale, siliceous siltstone, quartzose sandstone and phyllite, and contain plant fossils. Devonian continental rocks are known from the Drummond Basin which outcrops north-west of Carnarvon Gorge (from west of Springsure to just south of Charters Towers), and from the Adavale Basin (beneath the Galilee Basin to the west).

Near Roma, the Devonian rocks in the subsurface are intruded by granites, thought to be of Carboniferous age.

2. MAJOR EARTH MOVEMENTS - A MARGIN IN TURMOIL

Around 300 million years ago, near the end of the Carboniferous Period, the coastline of Queensland was much further west, stretching in a line from Townsville out to the Carnarvon Gorge - Arcadia Valley region, and further southwards to Goondiwindi. To the east, near where the present coastline occurs, an active volcanic arc was issuing lavas and tuffs into the surrounding ocean. Queensland was also much closer to the South Pole (see sketch below).

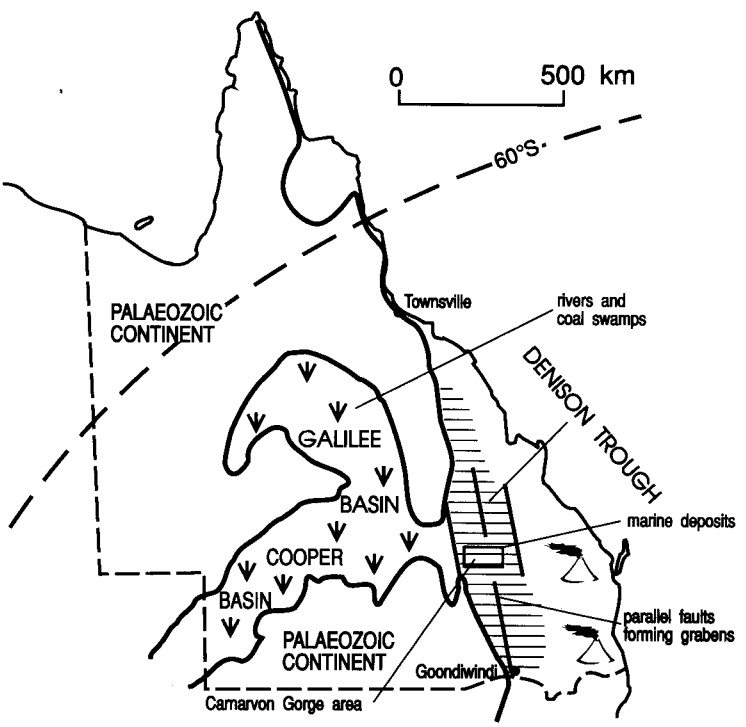
Major 'pull-apart' forces were in action along the coastline during this time, subsequently breaking up the crust and causing large sections to subside. Many parallel grabens (valleys bounded by faults) were formed, into which sediments accumulated. These grabens ran approximately NNW-SSE, paralleling the coastline at that time.

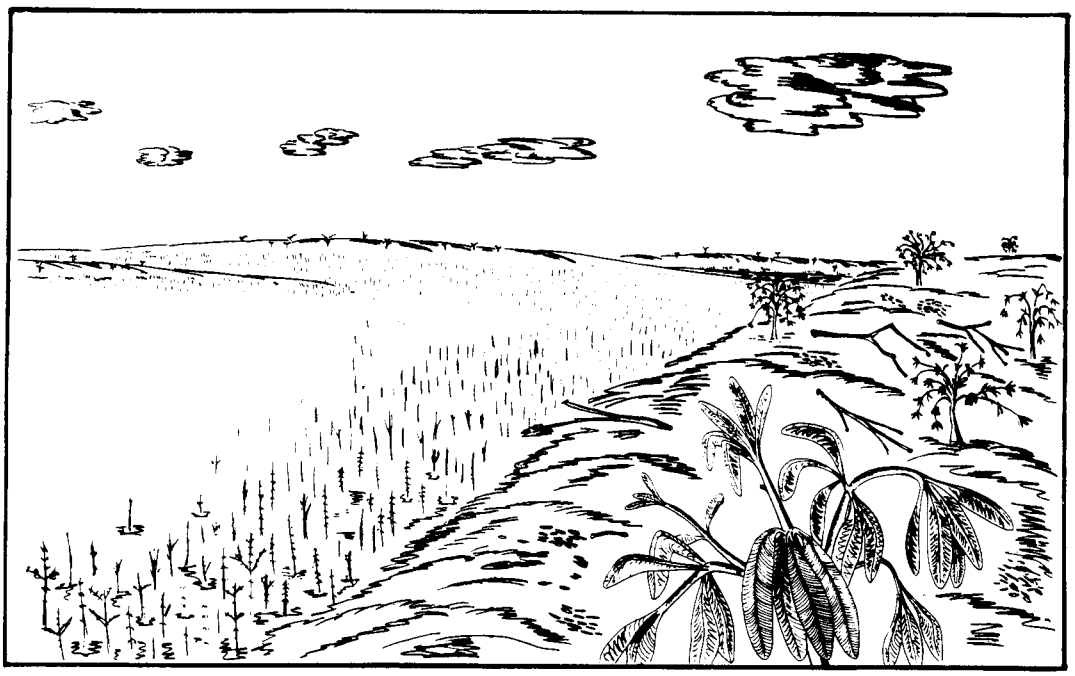
This represented the initial stage of development of the Bowen Basin, known as the Denison Trough in the Carnarvon Gorge - Arcadia Valley area.

3. EARLY PERMIAN COAL MEASURES DEPOSITED

During the Early Permian Period, 275-265 million years ago, much of the eastern part of Queensland was below the sea, and large tracts of the western part of the mainland (Cooper Basin and Galilee Basin) were covered by extensive peat swamps (see below).

Reconstruction of the coastline of Queensland during the Permian





At different times during the Permian Period, from 290 to less than 250 million years ago, large tracts of Queensland were covered by river systems associated with extensive peat swamps.

During the Early Permian, coal measures, now known as the Reids Dome beds, were deposited in the Denison Trough grabens. Lakes, swamps, and meandering streams abounded in the region, and alluvial fans were formed from sediments washed down from the western hills. To the east, deltas fanned into the sea.

Glossopteris (see Appendix A) growth was sporadic on river levee banks and in abandoned channels, and these largely deciduous trees and shrubs dropped plant matter into associated flood-bound swamps. Articulates (see *Leptocalamites*, Appendix A) flourished in the wetter parts of the swamp, along with lycopods and ferns, and algal buildup occurred in the many ponds and lakes associated with the rivers. All this deposited plant matter eventually became buried in peat deposits, to later form coal.

Due to the close proximity to the south pole, the rivers froze in winter, the plants were shrubby, and substantial swamps were not established. Many of the peats were formed from transported plant material, and with few exceptions, the resultant coal seams are generally thin or contain much interbedded mudstone. Seasonal thaw caused many areas to become inundated with water, thereby destroying potential sites of plant growth, which could otherwise have formed long-standing peat swamps. Eventually, sediments to several kilometres in thickness accumulated in the grabens.

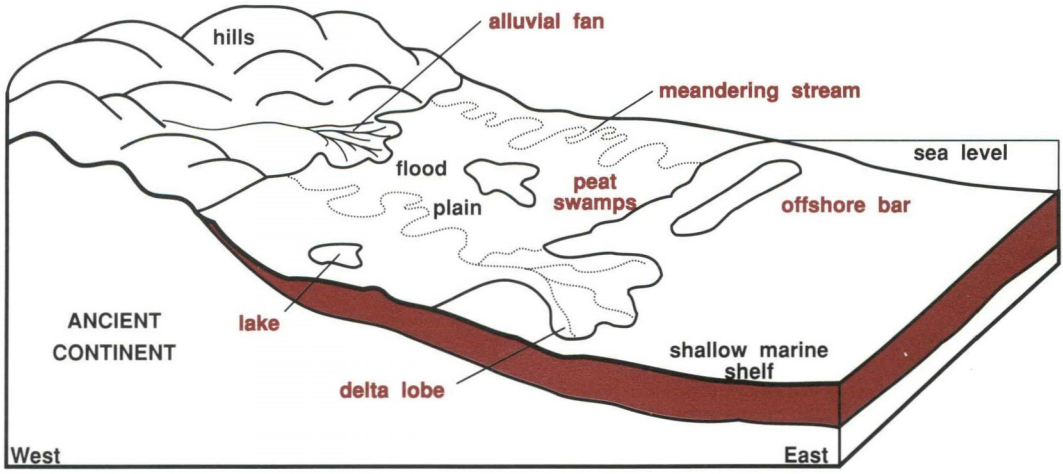
Only the uppermost part of the Reids Dome beds appears at the surface - to the north near Springsure. The formation is known mainly from drilling.

4. SAGGING AND MARINE DEPOSITION

Following deposition of the Reids Dome beds, between 265 and 255 million years ago, sagging of the coastal region caused the sea to inundate the land, and off-shore marine sediments with widespread deltas dominated deposition in the Denison Trough. Cold water marine life was abundant and varied, and included corals and shells (See Appendix A, Plate 2), as well as sea mats, sea lilies, and forams.

Evidence for the continuing cold climate also includes river pebbles found in the marine mudstones. Such pebbles were caught up in ice when the rivers froze during winter, and during the summer thaw, large floating lumps of ice (ice-rafts) made their way down the river to the sea, where the ice melted, and the pebbles dropped to the muddy seabed.

Formations deposited during this time include the offshore marine Cattle Creek Formation and the overlying fluvial/deltaic Aldebaran Sandstone. These formations crop out in Reids Dome, 20 to 30km north of Carnarvon Gorge, and in the Staircase Range on the road to Springsure. The Aldebaran Sandstone, Cattle Creek Formation and Reids Dome beds occur at depth in the Carnarvon Gorge area, where they have been intersected in drillholes.



Erosion of uplifted rocks in the hinterland causes sediment to be washed down streams and deposited. Sediments deposited near the foothills form poorly sorted, angular grained, alluvial fan deposits. Sediment which is carried across the flood plain is sorted, with the mud size particles deposited in the swamps, and the coarser sands in the river channels or offshore, as deltas and sandbars. Some fine material is carried out beyond the coastline to be deposited on the marine shelf.

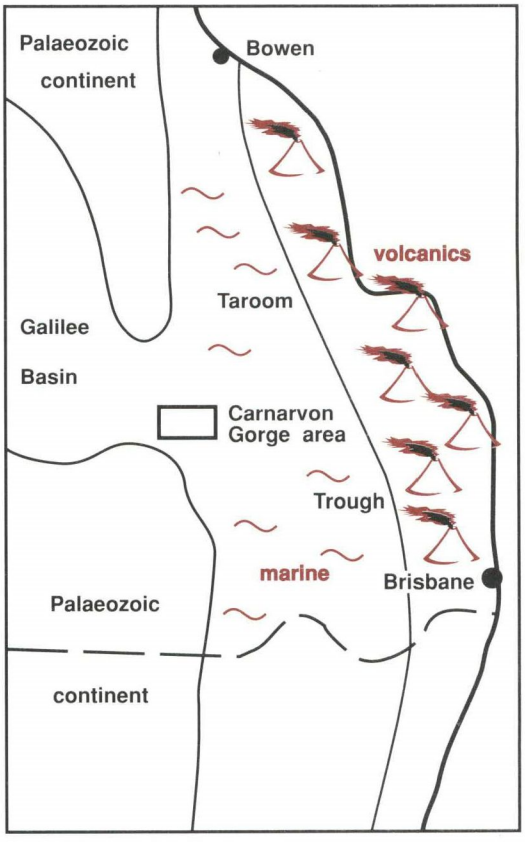
5. FURTHER MAJOR SAGGING - THE TAROOM TROUGH

After deposition of the Aldebaran Sandstone there was a period of non-deposition in the Denison Trough. This coincided with the adjustment of the western margin of the developing Bowen Basin to the major downwarping in the Taroom Trough, between the continental margin and the newly formed chain of volcanic islands to the east (see sketch).

Deposition then returned to the area and eventually extended beyond the limits of the Denison Trough. During this time (255-250 million years ago - mostly in the Late Permian) sedimentation was dominated by alternating delta and offshore marine deposition forming the Freitag Formation, Ingelara Formation, Catherine Sandstone, and Peawaddy Formation. As sedimentation continued and the volcanic arc to the east became more pronounced, the Bowen Basin was cut off from the ocean, and a brackish inland sea developed. The Black Alley Shale was then deposited.

Only the Peawaddy Formation and the Black Alley Shale are exposed near Carnarvon Gorge. The Freitag Formation, Ingelara Formation and Catherine Sandstone occur at depth, but are exposed further to the north on private property, in the vicinity of Reids Dome.

Continual downwarping in the Taroom Trough to the east of the Denison Trough caused widespread deposition to occur in the Late Permian. This deposition extended from the newly activated volcanic arc in the east, westwards across the Denison Trough, and into the Galilee Basin.



Peawaddy Formation and Black Alley Shale - the rocks

Sedimentary rocks mostly of marine origin, consisting of siltstones, shales, mudstones, and sandstones with minor tuff. Dips range from a few degrees up to 15°. Marine fossils, mainly shells and corals commonly occur in limestone concretions in the mudstones and siltstones, or are found distributed randomly throughout the sequence. Numerous crinoid fragments (segments of calcified sea-lilies) have been identified in cored sections.

- **Peawaddy Formation:** Thinly bedded and laminated dark grey, micaceous, carbonaceous siltstone, sandstone and shale with crinoid and shell fragments in the lowermost two-thirds and light green-grey fine to coarse-grained sandstone with scattered shells in the uppermost one-third. The upper sandstones are strongly burrowed in the Carnarvon Gorge area. In Reids Dome, the top of the Peawaddy is defined by a bed, up to 1m thick, composed largely of fossil shells (Mantuan Productus bed). This bed is not present in the Carnarvon Gorge area. The Peawaddy Formation is up to 140m thick.
- **Black Alley Shale:** Thinly bedded and laminated dark grey to black carbonaceous, micaceous shale, siltstone and mudstone, in part gypsiferous, and interbedded light green-grey silty bentonite and very fine-grained sandstone. Sandstone occurs mainly in the upper part. The formation is generally about 160m thick.

6. CONTINENTAL BASIN FILLING

From the Late Permian to the Middle Triassic (250 - 230 million years ago), the sea was entirely absent from the area, and sedimentation occurred in freshwater continental environments. Initially, peat-forming conditions in extensive swamps associated with thick leaf banks and lake accumulations produced the coal-bearing Bandanna Formation. These widespread coal measures represented the cessation of Permian deposition in the region.

Following this period the climate probably became considerably drier, and the Rewan Group, dominantly of red-beds, was deposited. This group consists of two formations, the lowermost - the Sagittarius Sandstone, and the uppermost - the Arcadia Formation. Then, during the Middle Triassic, around 240 to 230 million years ago, warm/humid conditions prevailed in the Bowen Basin during deposition of the Clematis Group and the overlying Moolayember Formation.

The deposition of the Clematis Group represents a marked change in sediment source and depositional environments from that of the Rewan Group. The Clematis Group consists of two formations, the lowermost - the Glenidal Formation, and the uppermost - the Expedition Sandstone. The Group is an extensive blanket sandstone unit which was deposited by streams flowing from the north and northwest during a time of increased stream gradients.

Renewed subsidence occurred during deposition of the Moolayember Formation in lake and stream environments, with coal swamp environments prevailing during deposition of the upper part. Sediment transport was again mainly from north to south.

Bandanna Formation to Moolayember Formation - the rocks

Sedimentary rocks almost entirely of freshwater origin, consisting of sandstones, siltstones, shales, mudstones with fewer conglomerates, coals, limestones, tuffs and oil shale. Dips range from a few degrees to about 45° near major structures. Plant fossils are numerous, except in the red beds of the Rewan Group.

- **Bandanna Formation**: Thinly bedded and laminated grey to black siltstone, shale, sandstone, coal, tuff and oil shale and interbedded light green-grey, fine to medium grained sandstone. Micaceous partings with carbonised plant fragments and leaf fossils occur throughout, and white cherty leaf beds are a marker unit in the lower part. Coal seams in the area range from a few centimetres up to at least 2.5m thick. Oil shale and fossilised tree trunks are known east of Carnarvon Gorge. The Bandanna Formation is up to 130m thick.
- **Rewan Group**: Thinly to massively bedded red-brown and mottled red-brown and green silty mudstone and interbedded light green siltstone and green/khaki, fine to medium-grained micaceous sandstone with mudstone fragments (Arcadia Formation). The sandstone is generally medium to coarse-grained and pebbly near the bottom of the formation (Sagittarius Sandstone). Fossilised lung fish and amphibian and reptilian bones have been recovered from several localities. Plant fossils are absent in the red beds in the Carnarvon Gorge - Arcadia Valley area but are present in the Taroom Trough further east, where green-grey and dark grey to black sandstones and shales are interbedded. The Rewan Group is up to 560m thick.
- **Clematis Group**: Medium to thickly bedded, cross-bedded, light grey to white, fine to coarse-grained sandstone and conglomerate in the upper part (Expedition Sandstone) and light green-grey medium-grained sandstone and laminated to thinly bedded green-grey to dark grey shale, mudstone, siltstone and very fine-grained sandstone, mainly in the lower part (Glenidal Formation). Plant fragments and carbonaceous, micaceous partings commonly occur. Some shales and mudstones in the lower part are red-brown and mottled green and red-brown. The Clematis Group forms red and white coloured cliffs throughout the area. It is up to 240m thick.
- **Moolayember Formation**: Thinly bedded and laminated grey to black siltstone, mudstone, shale, sandstone, coal and limestone and interbedded light green-grey fine to medium-grained sandstone. Plant fossils and micaceous, carbonaceous partings commonly occur. The Formation weathers characteristically to colours of olive, khaki and mottled red-brown, purple and white. The topmost part where it is unconformably overlain by the Precipice Sandstone of the Surat Basin is mainly an erosional surface. It is commonly represented by a one to two centimetre thick band of red ironstone. The Moolayember Formation is up to 500m thick.

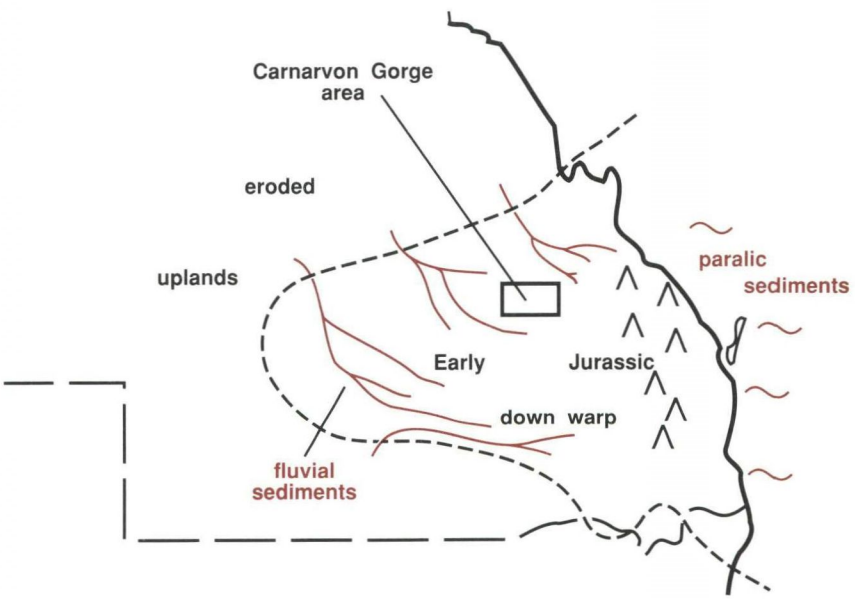
Following cessation of deposition, the Bowen Basin was uplifted during the Late Triassic into a major mountain chain, and large faults, anticlines (for example, Springsure Anticline and Reids Dome), and synclines formed. Erosion then followed.

7. THE GREAT INLAND SEA

Over 200 million years ago, in the Early Jurassic, a major downwarping (sagging) began in south-eastern Queensland over part of the older Bowen Basin, and sediments were deposited from extensive inland river systems, to form the Surat Basin. This sagging and sediment accumulation eventually extended across two thirds of the State, to form the Great Australian Basin. As downwarping continued, and in correspondence with world-wide sea-level changes, the basins were periodically inundated to form vast inland seas.

The first unit deposited in the Surat Basin during this time, the Precipice Sandstone, is presently a major cliff-former in the Carnarvon Gorge. It was deposited as cross-bedded, river sands, as part of a major drainage system discharging to the east (see sketch).

Over 200 million years ago, the south-eastern part of Queensland was again inundated by major fluvial systems and marginal marine conditions.



Overlying the Precipice Sandstone is the Evergreen Formation, which was deposited in streams, lakes, and deltas. This formation is considered to be indicative of a deepening of the Surat Basin, and the forerunner of later incursions of the sea into Queensland.

Overlying the Evergreen Formation is the Hutton Sandstone, which represents predominantly meandering stream deposition following a relative drop in sea level. This was then followed by widespread coal swamp, lake and meandering stream deposition, represented by the Eurombah Formation and Walloon Coal Measures of the Injune Creek Group.

Precipice Sandstone to Walloon Coal Measures - the rocks

Sedimentary rocks of almost entirely freshwater origin, consisting of sandstones, siltstones, mudstones, shales with minor interbedded conglomerate, oolitic ironstone and coal. Dips are usually less than 2°, in contrast with dips of up to 45° in the Bowen Basin rocks. Many of the sandstones in this interval act as intake beds and reservoirs for groundwater supplies obtained in deeper parts of the Surat Basin to the south. The distribution of the various reservoir units in the Surat Basin can be studied in detail in a geological cross-section of the eastern part of the Great Artesian Basin, displayed at the Artesian Basin Centre, Miles Museum, Miles.

- **Precipice Sandstone**: Medium to thickly bedded, cross-bedded, white, fine to coarse-grained, friable sandstone and minor interbedded grey sandy shale and siltstone. Micaceous, carbonaceous partings commonly are associated with the shales and siltstones. The Precipice Sandstone forms prominent white and light brown-coloured cliffs throughout the area. The most obvious are those forming the walls of Carnarvon Gorge, the Carnarvon Range and the southern margins of the Arcadia Valley. The Precipice Sandstone also caps most of the mesas in the valley floor. It is about 60m thick.
- **Evergreen Formation**: Laminated and thinly bedded light grey to dark grey siltstone, shale, mudstone and sandstone with minor oolitic ironstone, coal, and interbedded, green-grey, fine to medium grained sandstone. Abundant plant fossils occur. A unit of sandstone (Boxvale Sandstone Member) up to 30m thick is developed in the upper two-thirds of the Formation. This is overlain by an interval dominantly of poorly outcropping dense black mudstone with interbedded oolitic ironstone which contains a few estuarine and freshwater shell fossils (Westgrove Ironstone Member). The Evergreen Formation overall is about 120m thick.
- **Hutton Sandstone**: Light grey to white, fine to medium-grained sandstone with minor pebble bands, shale fragments and interbedded and laminated grey siltstone, shale, mudstone and minor coal. Carbonaceous, micaceous partings are commonly developed. The Hutton Sandstone mostly outcrops poorly but where present, the rocks generally weather to a characteristic yellow-brown colour. It is consistently about 200m thick.
- **Eurombah Formation**: Light grey to green-grey, fine to coarse-grained, clayey, cross-bedded sandstone in part pebbly, and interbedded grey carbonaceous siltstone, mudstone and some conglomerate. The Eurombah Formation outcrops poorly but if present, the sandstone generally weathers to a pale grey or speckled white and red-brown colour.
- **Walloon Coal Measures**: Interbedded and thinly bedded to laminated light to dark grey carbonaceous mudstone, siltstone, fine to medium grained sandstone, coal, and minor limestone, ironstone, and bentonite (clay). Plant fragments are abundant. The formation outcrops very poorly. Commercial coal deposits occur in some areas.

Younger deposits including the Cretaceous great inland sea sequence, which crop out to the south and west, probably once extended across the Carnarvon Gorge area, but subsequent uplift and erosion have removed them from this area.

8. TERTIARY VOLCANICS

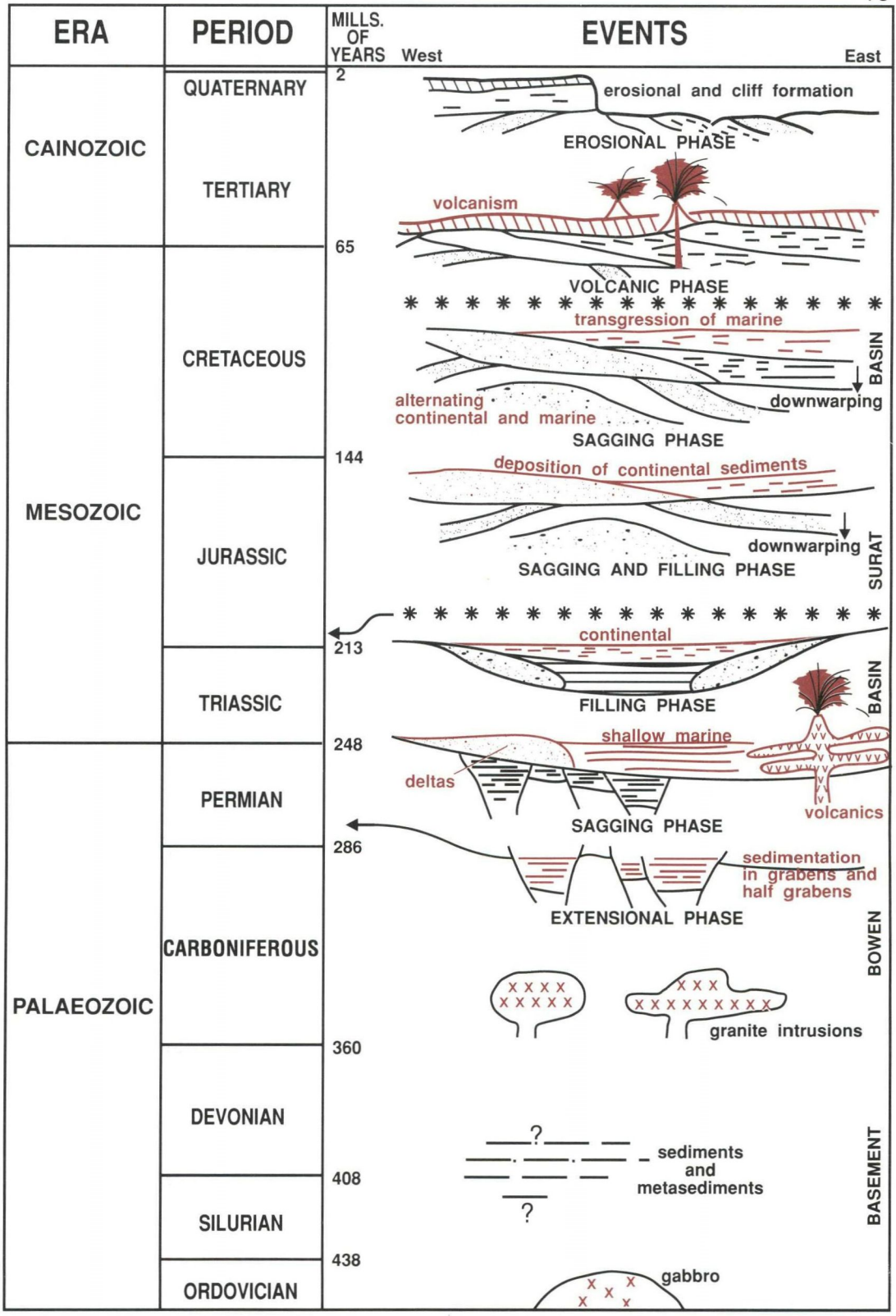
In the Carnarvon National Park, approximately 300m of basalt volcanic lavas rest on the Jurassic sandstones. Some sedimentary rocks are interbedded with the lava flows. These volcanics form a part of the Buckland Volcanic Province. They were extruded during the Tertiary Period, the first flow about 27 million years ago (based on radiometric dating). Several flows containing different types of basalts have been recognised. Some basalt flowed down streams running east from the Buckland Tableland and Great Dividing Range, and tongues of basalt are still preserved in valleys in the Permian rocks across the Springsure Anticline.

Basaltic dykes, cross-cutting the sandstones and mudstones, occur in a number of places in the Gorge near creek level. These dykes, which represent feeders to the main volcanic province, can be seen near the Moss Garden, in Kamooloo Creek, and at the junction of Boowinda Creek and Carnarvon Creek adjacent to Cathedral Cave (see photograph below). Some of the dykes contain cobbles and pebbles of upper mantle and lower crustal rock fragments brought to the surface during extrusion.

Waterborn boulders and cobbles of the various basalt types can be found in Boowinda Creek and Carnarvon Creek.

Basalt - the rock.

- Black, tough, fine-grained volcanic rock with some flows containing inclusions of olivine or calcite. Vesicles (cavities formed by the entrapment of gas bubbles) occur in most flows. Sedimentary rocks interbedded with the basalt include mudstone, sandstone and conglomerate.

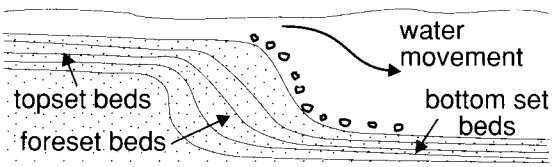


Geological Time Scale with sequence of geological events in the Bowen and Surat Basins including the Carnarvon Gorge - Arcadia Valley area.(*** = time of uplift, erosion and non-deposition).

THE ORIGIN OF CROSS-BEDS IN SANDSTONE

Cross-bedding is a very obvious feature of the Precipice Sandstone (particularly near the base) and Clematis Group in the Carnarvon Gorge. This cross-bedding, the lack of marine fossils, and the large thickness of sandstone with only minor interbedded shale, suggest deposition occurred in extensive sandy, braided stream systems. For the Precipice Sandstone, some have likened the depositional environment to the present 'Channel-Country' of central Australia.

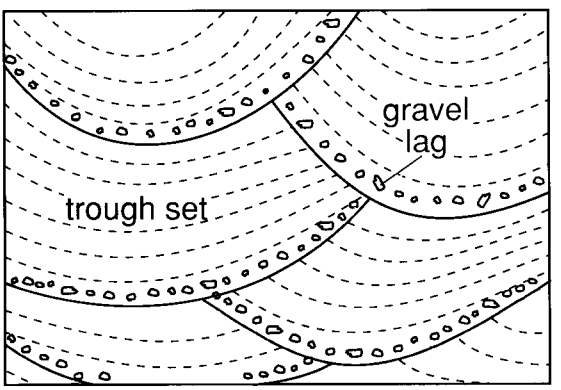
A cross-bedded sequence showing successive layers of sand built up during periods of deposition.



The study of modern braided streams shows that the sedimentary process is complex. Different types of cross-bedding form in different parts of the fluvial system and change occurs with each new period of flood and deposition. Simply, two main types of cross-bedding, trough and tabular (planar), are recognised.

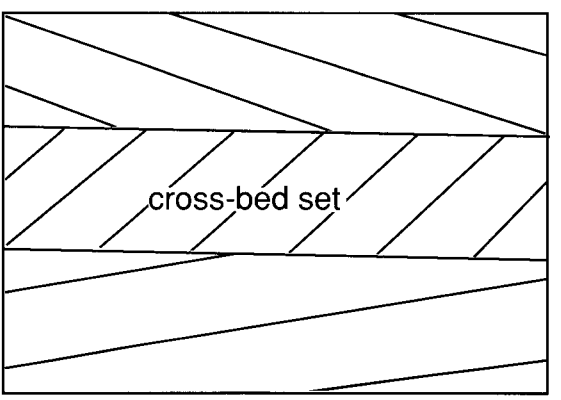
TROUGH CROSS-BEDDING.

This type can be formed by migrating (slowly shifting) underwater sand dunes or 'megaripples' with wavey crests, found in deeper, more strongly flowing parts of stream channels. Bedding planes are concave upwards and erosive contacts exist between different troughs. Gravel lags commonly occur at the bottom of troughs. Each trough represents a separate phase of deposition.



TABULAR CROSS-BEDDING.

This type of bedding can be formed by migrating sand waves, with straight or slightly curved crests, found in shallower, weaker flowing parts of the fluvial system. The individual cross sets can be very extensive and the boundaries between sets commonly are sub-parallel. Bedding planes are straight towards the bottom of each set, and non-erosive contacts can exist between different sets.

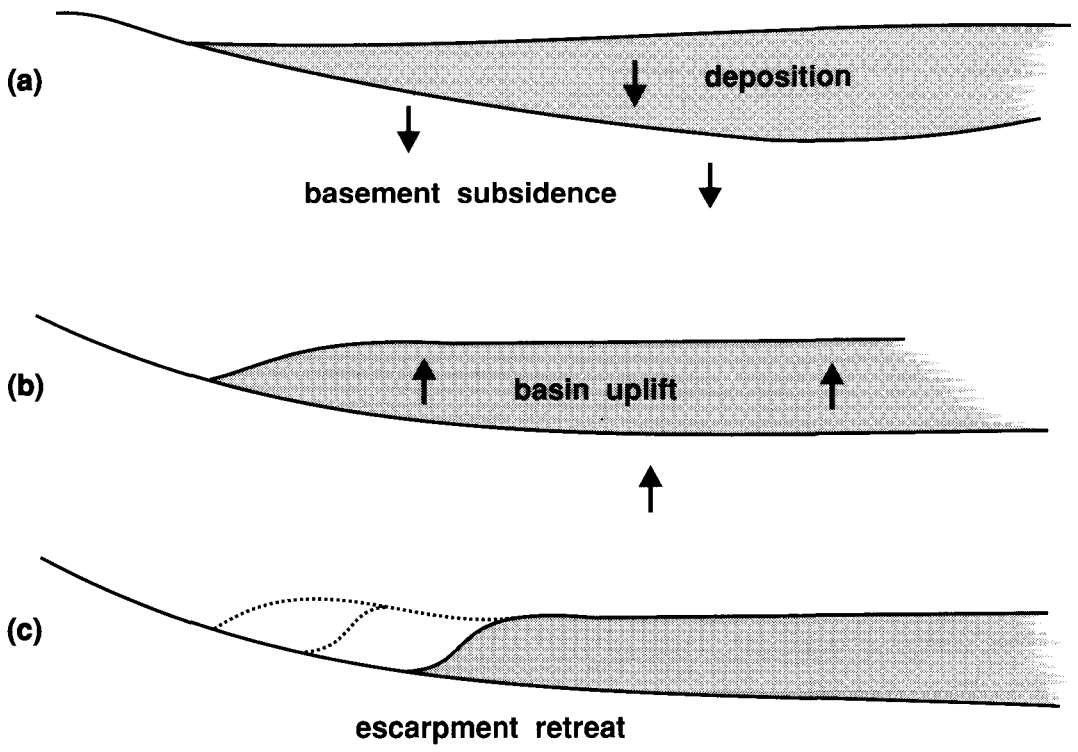


FORMING THE PRESENT LANDSCAPE

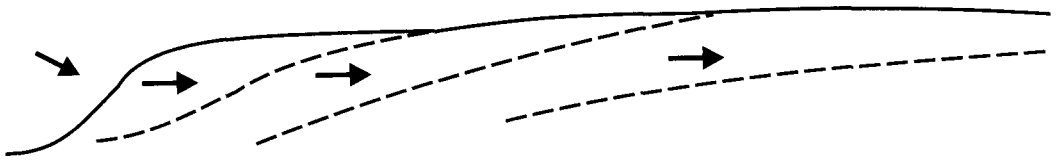
Carnarvon Gorge forms part of the Carnarvon Range, which stretches in a northwesterly - southeasterly direction along the northwestern margin of the Surat Basin. The Range forms a major escarpment produced by uplift of the Basin margin, and subsequent erosion.

The escarpment has been accentuated in the Carnarvon Gorge area by at least two additional controls. Firstly, major outpourings of basalt during the Tertiary have formed resistant cap rocks on the Surat Basin sequence, preventing erosion, and secondly, the Carnarvon Gorge has formed in an area of major jointing (fracturing) in the rocks.

Following completion of deposition in the Surat Basin (a), deep tectonic forces produced upwards movement (b) as a response to the rapid burial of the Basin (somewhat akin to a person jumping on an inner-spring mattress - a recoil, but at a much slower rate). This caused the margin of the Basin to be uplifted into a mountain range. Subsequent erosion, mainly through stream action, has cut into Carnarvon Range, causing escarpment retreat (c).

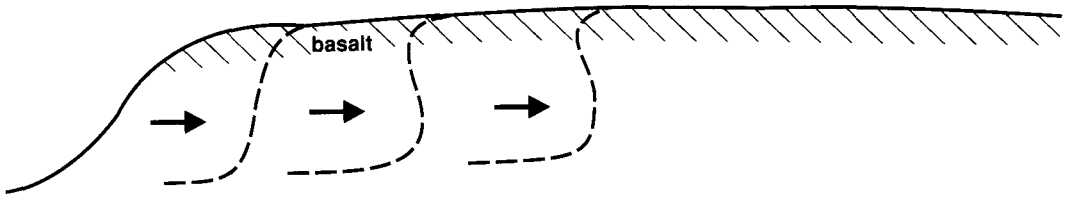


Where the uplifted Basin is exposed in this way to the erosive forces of wind and water, erosion occurs in both vertical and horizontal directions, forming relatively flat terrain (d).



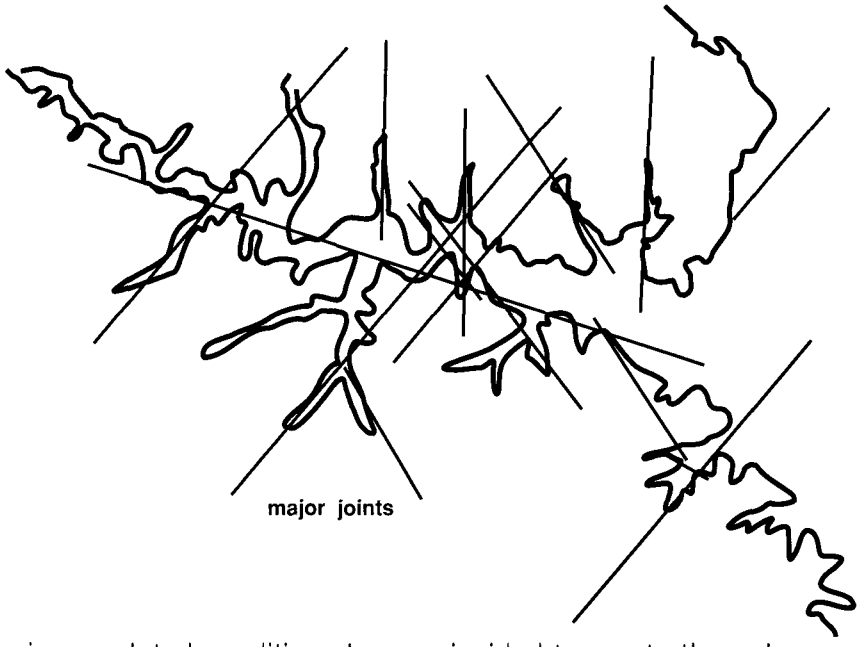
(d) Progressive erosion of uplifted strata with no basalt capping

In the vicinity of Carnarvon Gorge, the basalts form a resistant cap to the underlying sedimentary rocks. Consequently, erosion has been chiefly in the horizontal direction, causing the formation of steep cliffs and gorges (e).



(e) Progressive erosion of uplifted strata with basalt capping

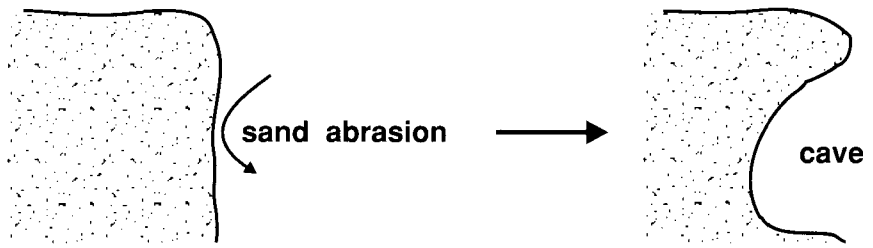
As this process took place, any areas of weakness in the rocks became the sites of major erosion. Carnarvon Gorge formed in an area of the Surat Basin which is strongly jointed. These major joints run north-west / south-east, with weaker sets running north-south and north-east / south-west. Many of the features in the Gorge can be seen to be oriented in relation to these major joints (see sketch).



These major unrelated conditions have coincided to create the unique geological feature that is the Carnarvon Gorge.

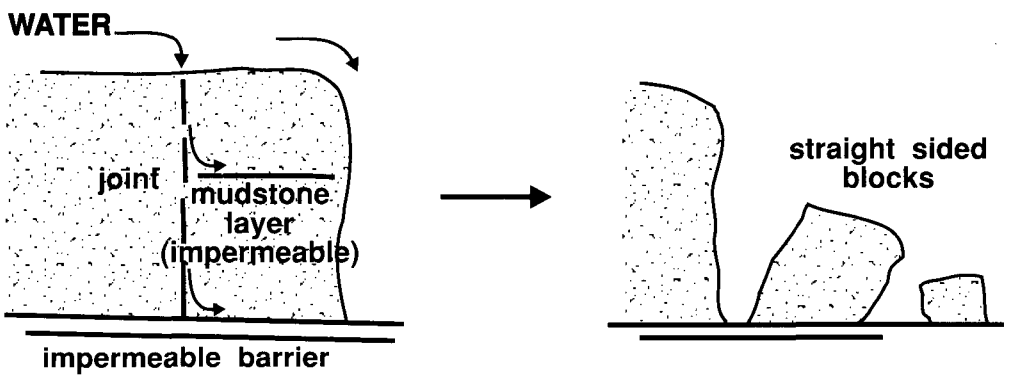
FEATURES OF SANDSTONE EROSION

WIND



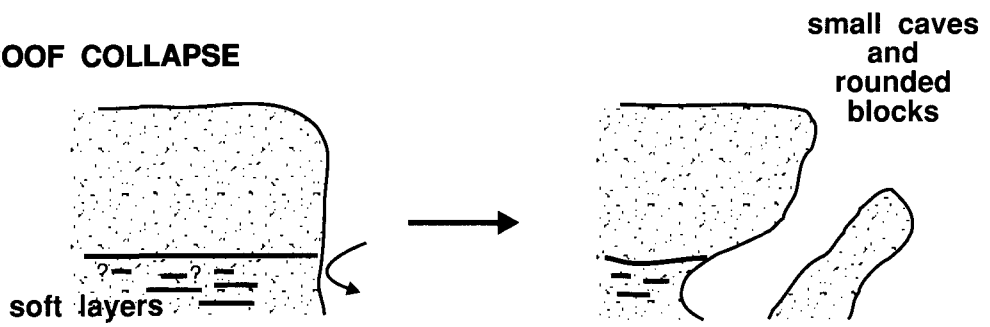
Wind erosion is caused by fine particles of sand being blown against a cliff face. Because the coarser particles are closer to ground level, the major erosion is in the lower areas. Caves tend to have smooth, rounded walls, and sand mounds are common on the floor.

WATER



Water erosion tends to be concentrated along weaknesses (e.g. down vertical joints) and along planes between permeable and impermeable strata. The surfaces tend to be straight sided and etched, with the formation of large blocks common. The sand produced is generally transported further downstream.

ROOF COLLAPSE



Water and /or wind erosion cause severe erosion to occur along levels of softer strata, resulting in overhanging roofs which will eventually fail and collapse. Undercuts tend to be low and localised, and roof collapse blocks tend to be rounded to irregular.

ECONOMIC GEOLOGY

Petroleum

Because of the apparent abundance of potential reservoirs (medium to coarse-grained, porous sandstones), source rocks (dark grey shales) and traps (large anticlines) known from outcrop, the Carnarvon Gorge - Arcadia Valley area has long been considered prospective for petroleum. Exploratory drilling, first undertaken in the mid 1930's and then during the 1950's, met with some early success. Gas (mainly carbon dioxide) flowed from a well drilled in the Arcadia Valley, between 1936 and 1939, and gas blew out from a shallow Permian sandstone reservoir in the first well drilled in Reids Dome in 1954. The first significant gas reserves were discovered in the region in the late 1960's.

The area has the potential to be a substantial gas producer with the South Denison Fields (near Injune) and the North Denison Fields (near Rolleston) currently supplying gas to the State Gas Pipeline from Wallumbilla to Gladstone which crosses the area (see MAP 1 inside front cover, and picture below). Gas markets at Gladstone and Rockhampton are expected to be supplied into the 21st Century.

In the Denison Trough, gas and minor condensate (presently 50 barrels/day), are produced mainly from the Permian Aldebaran Sandstone and Peawaddy Formation. Other production is from the Freitag Formation and the Triassic Rewan Group, and gas reserves are held for the Reids Dome beds, Cattle Creek Formation, and Catherine Sandstone.

Further south in the Roma-Surat area, some Permian sequences, the Triassic Rewan Group, Clematis Group (Showgrounds Sandstone), Moolayember (Wandoan) Formation, and the Jurassic Precipice Sandstone and Boxvale Sandstone Member are also petroleum producers at depth.

Oil Shale

In the Carnarvon Gorge area, the occurrence of oil shale in the Permian Bandanna Formation south east of "Early Storms" homestead (refer Locality CR4 - Carnarvon Gorge to Rolleston Excursion) has been known since 1926. The oil shale occurs in a sandstone/mudstone sequence between coal seams near the head of the gully, and can be traced along strike in a north-south direction for about 680m. The bed ranges in thickness from 0.71m in the south to 0.66m in the north and appears to be lenticular and limited in distribution.

Assuming a down-dip extent of 200m and a conversion factor of 1 tonne/m^3 of shale, a reserve of about 100,000 tonnes of oil shale has been estimated. Two samples analysed in the early 1970's, from near bottom and the middle of the bed, gave oil yields of 45 and 274 litres/tonne respectively.

Oil shale and kerosene shale have also been reported from the Jurassic Walloon Coal Measures of the Surat Basin in the Injune area. The highest yield of crude oil was 225 litres/ton.

State Gas Pipeline under construction in 1990

Coal

In the Bowen Basin sequence in the Carnarvon Gorge area, coal seams are well developed in the Permian Reids Dome beds and Bandanna Formation but none have been mined. In the Reids Dome beds, coal seams up to several metres thick have been intersected in petroleum exploratory wells and in one deep Departmental stratigraphic bore north east of Injune. At present these seams are too deep for economic mining.

The coal in the Bandanna Formation may be of commercial value. Seams are commonly 30 to 60cm thick, but in the "Early Storms" area (refer Locality CR4), the presence of several seams up to 1.2m thick below and above the oil shale was confirmed by a Departmental coal bore at the head of Oil Shale Gully.

Thin coal seams also occur in the Cattle Creek Formation and Aldebaran Sandstone of the Bowen Basin. In the Surat Basin, at the Maranoa Colliery 3km south of Injune, 542,000 tons of coal were mined from the Jurassic Walloon Coal Measures, between 1933 and 1963. The workings followed one seam which had a maximum thickness of 1.4m.

Bentonite

In the Carnarvon Gorge area, bentonitic clay has been found in exposures of the Permian Black Alley Shale at several localities including Locality CR1 (refer the Carnarvon Gorge - Rolleston Excursion).

Bentonitic clay is best exposed in a small tributary of Carnarvon Creek, about 400m downstream from "Early Storms" homestead. The clay, in beds generally between 0.3m and 0.6m thick, is yellow-green and light grey, greasy, and is commonly associated with tuff (mostly white) and black shale. It is characterised by polygonal shrinkage cracks caused by alternate swelling and shrinkage after rainfall. This produces a skin on the outcrop and obscures the bedding. Investigation of the deposit at "Early Storms" has shown that the bentonite is suitable for use in drilling muds.

Groundwater

The sandstones of the Surat Basin sequence which dominate the upper cliffs and mesas of the Carnarvon Gorge - Arcadia Valley area represent intake beds for the vast reserves of underground water in the Great Artesian Basin further to the south. A cross-section through the Great Artesian Basin displayed at the Miles Museum shows the relationship of the various intake beds to other formations, and lists water supply and quality for some of the aquifers.

The water-bearing ability of the Precipice Sandstone is demonstrated by the numerous springs in evidence throughout the Gorge (e.g. in the Moss Garden). Carnarvon Creek and some other water-courses in the area (e.g. the Dawson River and Hutton Creek north of Injune) are spring-fed in some parts.

Recharge to the Great Artesian Basin occurs from rainfall and stream flow across the exposed aquifers, which in the Carnarvon Gorge - Arcadia Valley area, include porous and permeable intervals of the Precipice Sandstone, Boxvale Sandstone Member of the Evergreen Formation, and the Hutton Sandstone. Discharge takes place in the form of springs, artesian flows, and pumped extraction. At Injune, the town bore taps water from the Hutton and Boxvale Sandstones, with the best supply and quality coming from the latter.

North of the Gorge, supplies of underground water are obtained from the Aldebaran Sandstone and Clematis Group of the Bowen Basin, and from Tertiary basalt. At Rolleston, the town bore produces from Tertiary basalt and the Aldebaran Sandstone, and at Springsure, the town supply is from Tertiary basalt and associated sandstones.

The Arcadia Valley, because of its location below the Surat Basin (which is part of the Great Artesian Basin), and the virtual lack of any aquifers in the Bowen Basin sequence present there, appears to be devoid of useful supplies of underground water. Property owners rely on dams and earth tanks for water.

ROAD METAL AND AGGREGATE

Tertiary basalt which is commonly used for road metal or aggregate is widespread over the Rolleston-Springsure area and caps the sandstone cliffs adjacent to Carnarvon Gorge. Near the Gorge, basalt has been quarried for road metal near "Early Storms" (refer Locality CR3 - Carnarvon Gorge to Rolleston Excursion) and "Rewan" (refer to start of Carnarvon Gorge to Injune Excursion).

FURTHER READING

BEESTON, J.W. & DRAPER, J.J., 1991: Organic matter deposition in the Bandanna Formation, Bowen Basin. *Queensland Geology* **2**, 35-51.

DRAPER, J.J., 1988: Origin of pebbles in mudstones in the Denison Trough. *Proceedings of the Symposium on the Permian Geology of Queensland.* Geological Society of Queensland (Queensland Division), Brisbane.

DRAPER, J.J. & BEESTON, J.W., 1985: Depositional aspects of the Reids Dome beds, Denison Trough, Queensland. *Queensland Government Mining Journal* **86**, 200-210.

EXON, N.F., 1976: Geology of the Surat Basin in Queensland. *Bureau of Mineral Resources Bulletin* **166**.

FIELDING, C.R., 1989: Hummocky cross-stratification from the Boxvale Sandstone Member in the northern Surat Basin, Queensland. *Australian Journal of Earth Sciences* **36**, 469-471.

GRAY, A.R.G., 1972: Stratigraphic drilling in the Surat and Bowen Basins, 1967-1970. *Geological Survey of Queensland Report* **71**.

GRAY, A.R.G., 1980: Stratigraphic relationships of Permian strata in the southern Denison Trough. *Queensland Government Mining Journal* **81**, 110 - 130.

HILL, D. & WOODS, J.T., 1964: *Permian Index Fossils of Queensland.* Queensland Palaeontographical Society, Brisbane.

HILL, D., PLAYFORD, G. & WOODS, J.T., 1965: *Triassic Fossils of Queensland.* Queensland Palaeontographical Society, Brisbane.

HILL, D., PLAYFORD, G. & WOODS, J.T., 1966: *Jurassic Fossils of Queensland.* Queensland Palaeontographical Society, Brisbane.

MOLLAN, R.G., DICKINS, J.M., EXON, N.F. & KIRKEGAARD, A.G., 1969: Geology of the Springsure 1:250 000 Sheet area, Queensland. *Bureau of Mineral Resources Report* **123**.

PARFREY, S.M., 1988: Biostratigraphy of the Barfield Formation, southeastern Bowen Basin, with a review of the faune from the Ingelara and lower Peawaddy Formations, southwestern Bowen Basin. *Queensland Department of Mines Report* **1**.

PLAYFORD, G., RIGBY, J.F., & ARCHBALD, D.C., 1982: A Middle Triassic flora from the Moolayember Formation, Bowen Basin Queensland. *Geological Survey of Queensland Publication* **380**.

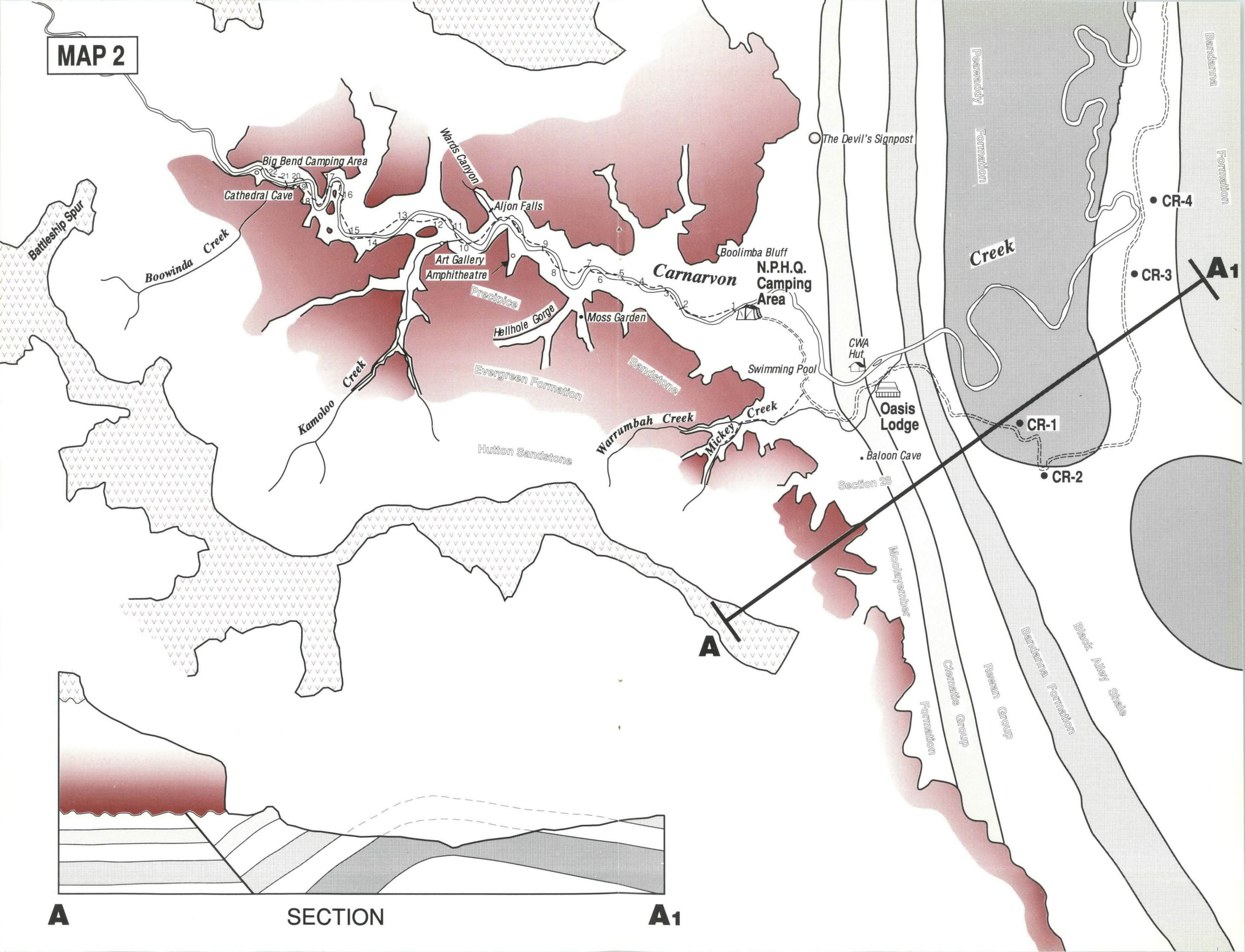
RIGBY, J.F., 1978: Jurassic plant fossils from the Walloon Coal Measures at Rosewood Consolidates Colliery. *Queensland Government Mining Journal* **79**, 526 - 529.

RIGBY, J.F., 1978: Permian glossopterid and other cycadopsid fructifications from Queensland. *Geological Survey of Queensland Publications* **367, 1-21.**

THULBORN, R.A., 1971: Origins and evolution of Ornithischian dinosaurs. *Nature* **234**(5324), 75-78.

THULBORN, R.A., (in print): Ornithopod dinosaur tracks from the Lower Jurassic of Queensland. Alcheringa (in print).

WHITE, M., 1986: *The Greening of Gondwana.* Reed, Sydney.


MAP 2
Big Bend Camping Area
Cathedral Cave
Wards Canyon
Aljon Falls
Battleship Spur
Boowinda Creek
Art Gallery
Amphitheatre
Precipice
Hellhole Gorge
Moss Garden
Carnarvon
N.P.H.Q.
Camping
Area
Boolimba Bluff
The Devil's Signpost
Peawaddy Formation
Bandanna Formation
Creek
CR-4
CR-3
CR-1
CR-2
A1
CWA
Hut
Swimming Pool
Oasis
Lodge
Baloon Cave
Section 28
Kamoloo Creek
Evergreen Formation
Sandstone
Warrumbah Creek
Mickey Creek
Hutton Sandstone
Moolayember Formation
Clematis Group
Rewan Group
Bandanna Formation
Black Alley Shale
A
A
SECTION
A1

WHERE TO SEE THE ROCKS

The self-guiding geological excursions below are outlined for the Carnarvon Gorge area locally, and for the roads leading into / away from the Gorge, including a detour through the Arcadia Valley. The excursions in the Gorge include the designated tourist walks, as well as two other for the more adventurous (pages 22,23). Outside the Gorge most of the localities are located next to, or only a short distance from, the main roads through the district.

NOTES:

1. Hammering rocks or collecting samples in a National Park is prohibited.

2. **Preserve and protect our geological heritage.** Inspect the outcrops and sample outside the park only where necessary. Several of the outcrops are uncommon and will be damaged if not protected.

3. Many of the rock exposures are situated in road-cuttings which can be dangerous because of traffic or rock falls. Ensure that you park safely and keep off the carriageway as much as possible.

4. Some outcrops may be on private land. Remember the rights of the property owners.

TOURIST EXCURSIONS IN THE GORGE

CATHEDRAL CAVE

The main walk up the Gorge takes you to Cathedral Cave. This walk is just over 20km return from the National Park headquarters, and can be done comfortably in a day. The more adventurous can camp at the Big Bend camping area overnight, and tackle walks further upstream or up the cliffs to Battleship Spur on the following day.

The main walk gives an opportunity to examine the towering cliffs of Precipice Sandstone. In many instances you can see the major joints that have controlled the formation of the Gorge as flat-sided cliffs. They are in three main directions - north-west / south-east, north-east / south-west, and north / south.

The Precipice Sandstone consists mainly of fine to coarse-grained, porous sandstone, and, as such, erodes very quickly. In the cliffs a myriad of truncated cross-bed sets (angular bedding) can be observed, and the finer-grained, thinner-banded siltstone / sandstone layers can be seen to have eroded more deeply (see photograph, opposite). These mainly represent ancient channel-fill and overbank deposits (refer Appendix C, inside back cover).

The present creek bed is covered with gravel and boulders, and the underlying Moolayember Formation cannot be seen. This Formation first comes into view in the bank of Carnarvon Creek at the entrance to the side gorge containing the Moss Garden, and is obvious by its dominantly greenish colour (see photograph opposite).

Further upstream, the Moolayember Formation is apparent on the eastern side of crossing No. 12 and in the southern bank of the creek upstream from crossing No. 15, where it forms a relatively flat-lying, dominantly sandstone outcrop about 4m thick. Between crossing Nos. 17 and 18, the Moolayember Formation forms a terrace for the tourist path, where it consists of red, grey and mauve mudstones, siltstones and some sandstones. Individual beds can be

traced across the creek to the opposite bank. Further outcrops occur on the northern bank between crossing Nos. 18 and 19.

Upstream from here the creek has not cut deep enough to penetrate to the Moolayember Formation, and the bottom of the creek is in the Precipice Sandstone.

At Big Bend there are excellent examples of truncated cross-bed sets in the Precipice Sandstone, with their pebble-lag bases clearly visible. Also obvious in the outcrop are the remains of fossil logs in the sandstones, generally preserved in the wall as remnant moulds where the logs have been weathered out. Multicoloured stylolites can also be seen at this locality.

Cathedral Cave is a large wind-eroded cave in the Precipice Sandstone where aboriginal paintings can be seen on the smooth walls.

THE ART GALLERY

The only formation visible on the side track to the Art Gallery is the cliff-forming Precipice Sandstone. The Gallery is located in a chiefly wind-eroded cave, and several major joints can be seen. The cave is slowly being further undercut by wind erosion.

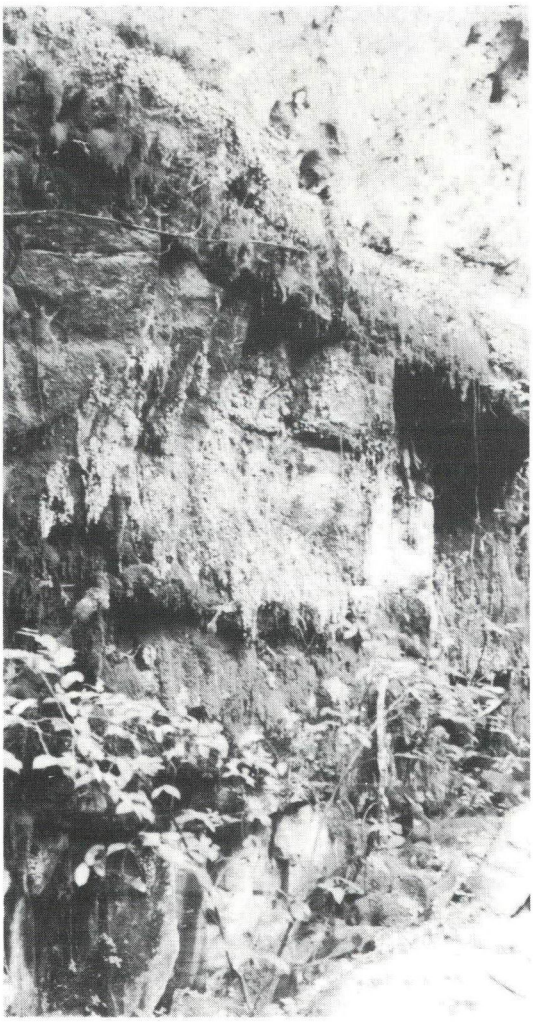
Cross-bedding sets with gravel lags and wood lags can be seen in the walls. Some of these features show evidence of 'wind polishing', caused by fine silt being blown across the walls (see photograph below). Remnant moulds where fossil wood has been weathered out are also present.

ALJON FALLS (WARDS CANYON)

At the start of the side track it is possible to see the Precipice Sandstone on the opposite side of the Gorge, where truncated cross-bed sets in different directions, alternating fine and coarse sandstone bands, and many major joints are preserved in the cliffs.

Excellent outcrops of Precipice Sandstone can be observed on the walk to Aljon Falls up Wards Canyon. Fine-grained, flat-bedded sandstone forms the bench of the lower falls, and good examples of gravel lags can be seen on the overlying western wall.

At the upper falls, cross-bed sets are distinct in the eastern wall above the *Angiopteris evecta* (King fern) stands.



MOSS GARDEN

On the south bank of Carnarvon Creek near the entrance to the walk to the Moss Garden, grey, khaki and red siltstone/mudstones, and green sandstones of the Moolayember Formation, dipping east-south-east at about 5 to 10°, outcrop in a section 9m thick. This is different to the regional dip, and presumably represents a local anticline.

This dip is mirrored at the Moss Garden, where the unconformity between the underlying very resistant Moolayember Formation and the overlying Precipice Sandstone forms the bench of the waterfall. The unconformity, which represents a period of non-deposition of about 20 to 30 million years, can be easily traced along the wall above the moss-covered boulders, where it marks the major seepage of water from the overlying permeable sandstone. The impermeable Moolayember Formation has created a barrier for further downward movement of water, which emerges from the Precipice Sandstone to create the moist conditions required for the growth of the ferns and mosses (see photograph).

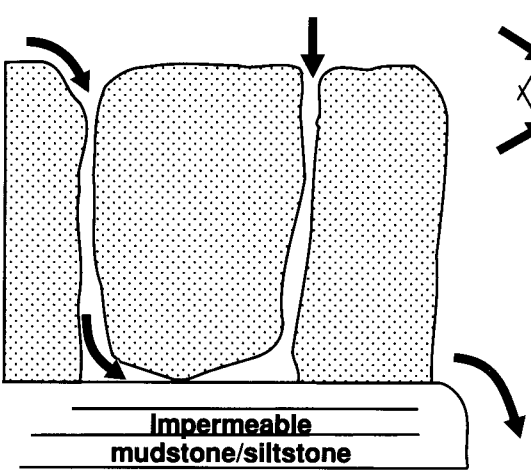
The main gully follows a conspicuous joint in the rocks.

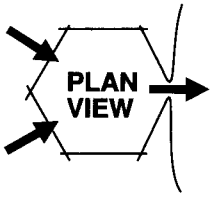
THE AMPHITHEATRE

On the approach to the Amphitheatre, the boundary between the underlying Moolayember Formation and the overlying Precipice Sandstone is clearly visible on the western wall. The Moolayember Formation appears as flat-lying cream, pink, mauve, and red mudstones and siltstones beneath the coarse-grained, white, cross-bedded sandstones of the Precipice Sandstone.

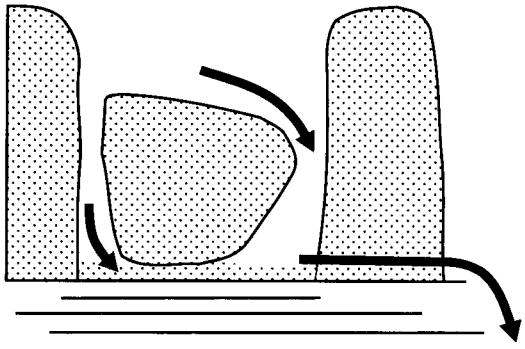
The unconformity can be followed around the wall to where it crosses the entrance to the Amphitheatre about 3m above the upper metal platform. Here a section of the Moolayember Formation can be seen to consist of 3 to 4m of red and mauve mudstones / siltstones, and layers of grey mudstones with numerous rootcasts, overlying about 6m of interbedded sandstones, siltstones, and mudstones. The Formation here shows a slight dip to the west.

FORMATION OF THE AMPHITHEATRE

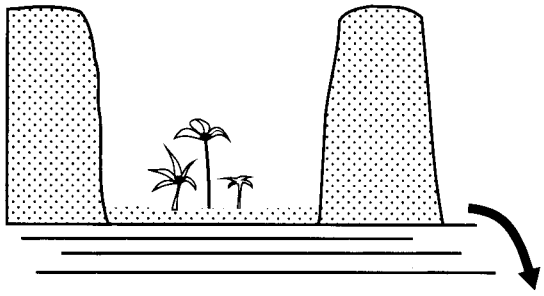




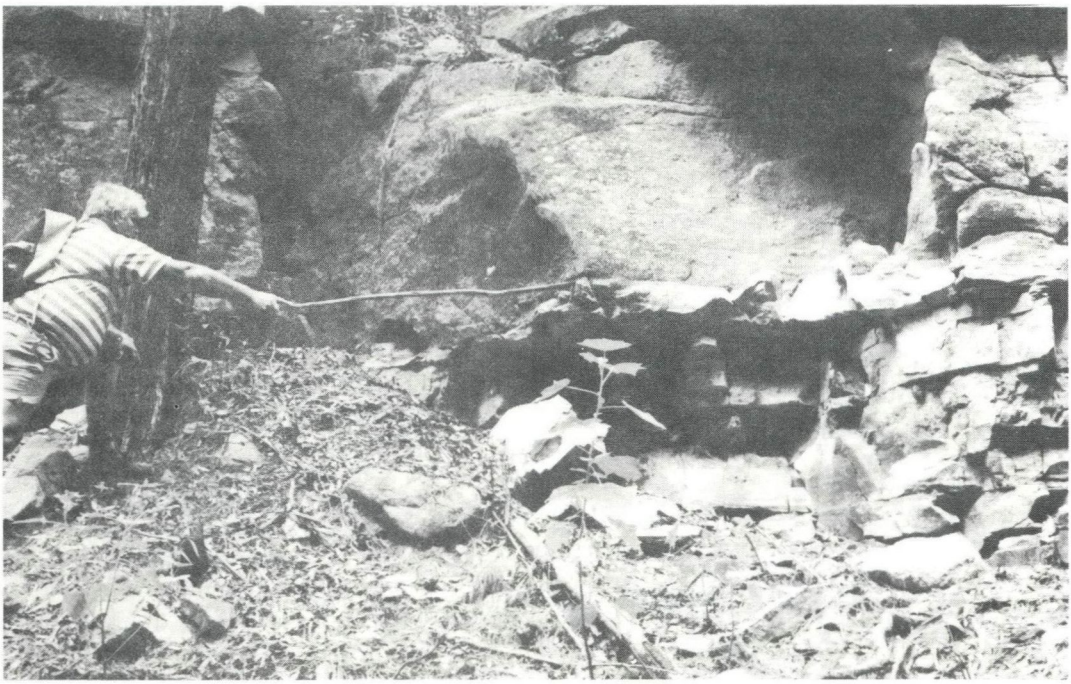
Initially, water erosion had the greatest impact on the softer sandstone layers along lines of weakness, particularly the major vertical joints and along the boundary between the sandstone and the harder, impermeable mudstone/siltstone.



As this erosion progressed, the joints widened and the cavity formed by these three intersecting joints became the focus of water movement. The eroded sand was transported through the joint cavity leading out to the main escarpment.



This concentration of erosion, particularly acting along the base of the sandstone block formed inside the cavity, quickly eroded it to sand, producing the hollowed out structure evident today.



Inside the Amphitheatre there are excellent examples of multiple-truncated cross-bed sets in the Precipice Sandstone.

The walls are commonly straight-sided to curved, indicating the overall controlling effect that the joint patterns had on the formation of this feature. The amphitheatre was probably formed as a result of water erosion (and possibly some wind erosion) along three sets of joints, and the unconformity between the more resistant Moolayember Formation and the less resistant Precipice Sandstone (see previous page).

BOOLIMBA BLUFF

The walk to Boolimba Bluff takes you progressively higher up the Precipice Sandstone sequence. From the lookout, the relationship between the westerly-dipping Bowen Basin strata and the overlying near-horizontal strata of the Surat Basin can be seen.

The westerly-dipping Clematis Group forms a prominent sandstone ridge at the entrance to the Park. Above the major cliff line of the Precipice Sandstone, two lines of discontinuous, white sandstone cliffs can be seen. The lowermost of these is the Boxvale Sandstone Member of the Evergreen Formation, and the uppermost is the Hutton Sandstone. Overlying all of these are several layers of horizontally-bedded black basalt flows (see photograph on the front cover).

MICKEY CREEK

Both Mickey Creek Gorge (see photograph above) and Warrumbah Creek Gorge provide good opportunities to observe the unconformity between the Moolayember Formation and the Precipice Sandstone.

The Moolayember Formation here consists of hard, cream to buff, pink and red silicified and fractured mudstone/siltstone with ripple marks, and is overlain by friable white medium to coarse-grained, cross-bedded Precipice Sandstone. Warrumbah Creek Gorge provides the more continuous outcrop of the unconformity.

Here, as in the Moss Garden, the unconformity is the catalyst for continual water seepage causing the mosses and ferns to flourish along its outcrop.

NATURE WALK/SWIMMING POOL

The track which follows the creek from the Park Headquarters to the swimming hole ends up at the Oasis Lodge.

This track crosses three major formations of the Bowen Basin sequence. The first large ridge east of the Headquarters is Moolayember Formation, and consists of deeply weathered brown to khaki siltstones, mudstones, and sandstones. Isolated outcrops show moderate dips to the west.

The second large ridge consists of the Clematis Group. Sloping sandstone cliffs, 150m high, abut the swimming hole, and the western slope coincides with the dip slope of the unit (see photograph above).

The track then winds towards the Oasis Lodge, across the boundary between the Clematis Group and the underlying Rewan Group which is hidden beneath the soil.

BALOON CAVE

The walk to the Baloon Cave follows the western side of the Clematis Group ridge, and the dip surface can be readily seen. Some unusual weathering patterns transecting the bedding - possibly related to jointing, can be seen on this surface. Near the Batswing Coral Tree sign the Clematis Group dips at about 40-45' to the west - south - west.

Baloon Cave is formed from the undermining of a coarse-grained channel sandstone (see Appendix C) in the Clematis Group, above and below which finely-bedded sandstones/siltstones have been exposed by wind erosion and roof collapse. The lower layers of mudstone are iron oxide-rich, and are presumably the source of the red pigment used for the aboriginal art.

OTHER EXCURSIONS NEAR THE MOUTH OF THE GORGE

Section 28

This excursion relates to Section 28 as described in the Bureau of Mineral Resources, Geology and Geophysics, Canberra Report No. 123 (Geology of the Springsure 1:250 000 Sheet Area, Queensland). It is located south of Baloon Cave, on the southern side of the prominent ridge in which Baloon Cave is situated.

To view the section in younging stratigraphic order (from oldest to youngest rocks), it is necessary to travel across country from the Oasis Lodge in a southerly direction, keeping the Clematis Group ridge to your right. About 1.2km south of the Lodge you will encounter a boulder-strewn creek running almost east-west.

Negotiating this creek bed upstream (to the west) will bring you to below the Clematis Group ridge, which dips steeply to the west. The first outcrops met are khaki and brown cross-bedded sandstones of the uppermost Rewan Group in the southern bank. Further upstream, white, fine to coarse-grained and pebbly, cross-bedded sandstones and some siltstones of the Clematis Group outcrop. In the upper part of the Clematis Group (Expedition Sandstone), iron-rich mudstones and siltstones correlative with those exposed beneath the Baloon Cave show the regional dip on the northern side of the bank (see photograph).

Further upstream, near the western edge of the Clematis Group ridge is the lowermost part of the overlying Moolayember Formation. The contact between the two units is obscured by rubble but can be traced to within a few metres. The Moolayember Formation outcrops in both banks of the creek, and consists chiefly of mottled grey, white and black mudstones and siltstones, and green-brown sandstone with some red ironstone bands. Fossilised plant remains are common.

A round trip is made by travelling northward across-country from the creek, and keeping the Clematis Group ridge to the right. You will finally encounter Baloon Cave, and the track leading back to the Lodge.

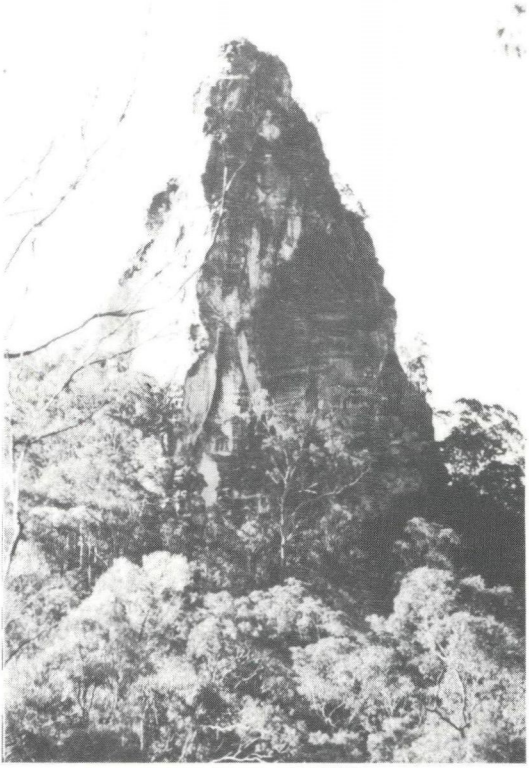
DEVIL'S SIGNPOST

Access to the Devil's Signpost is made by travelling from the Park headquarters through the camping ground, in an easterly direction for about 1km until the track crosses Carnarvon Creek (Crossing 1). Immediately to the left after crossing, a steep track follows the incline northwards along a ridge of Moolayember Formation.

NOTE: This is a strenuous walk.

The Devil's Signpost (see photograph) is reached by continuing along the ridge for about 2.5km, some sections of which are fairly slow going because of the steepness. Good examples of westerly dipping Moolayember Formation (westerly dipping) are exposed just south of the Devil's Signpost.

A walk around the base of the pinnacle at the end of the track gives an excellent view of the unconformity between the underlying Moolayember Formation and the overlying Precipice Sandstone, which forms the main pinnacle (see photograph below).



Particularly good examples of coarse gravel bands at the base of the Precipice Sandstone are evident, and the undulating nature of the unconformity surface directly below can also be appreciated.

The Signpost also affords near-uninterrupted views of the Arcadia Valley and the Comet River plain to the east, Reids Dome to the north, and the entrance to Carnarvon Gorge to the south.

EXCURSIONS OUTSIDE CARNARVON GORGE

Good outcrops of Bowen Basin and Surat Basin rocks can be seen on the roads leading away from Carnarvon Gorge.

IN ORDER TO FIND THE LOCALITIES DESCRIBED IN THE FOLLOWING EXCURSIONS IT IS NECESSARY TO KEEP A RECORD OF THE DISTANCES TO BE TRAVELLED. EITHER SET YOUR TRIP-METER AT ZERO, OR RECORD THE VALUE ON YOUR KILOMETRAGE INDICATOR AND FOLLOW THE INSTRUCTIONS BELOW. ALL DISTANCES HAVE BEEN MEASURED FROM THE FRONT ENTRANCE TO THE OASIS LODGE.

CARNARVON GORGE TO ROLLESTON EXCURSION

Depart the Oasis Lodge. For the first few kilometres the road traverses progressively older formations of the Bowen Basin exposed near the southern end of the Springsure Anticline. Units outcropping include, from youngest to oldest, the Rewan Group, the Bandanna Formation, the Black Alley Shale, and the Peawaddy Formation.

LOCALITY CR-1 (Map 2)(2.4km)

2.4km from the Lodge the road dips into a small creek-crossing on a sharp bend.

Park off the road to avoid accidents.

On the upstream (western) side of the road, a contact between the Peawaddy Formation (grey sandstone in the creek bed) and overlying Black Alley Shale (black silty mudstones), can be seen. About 50m further upstream a thick continuous outcrop of the mostly marine lower section of the Black Alley Shale occurs in the bank.

It consists of thinly-bedded grey to black mudstones interbanded with numerous thin white tuff layers and bentonitic clay. Some white blades of crystalline gypsum can be seen in the fractures as a result of leaching during weathering.

In the creek bank on the downstream (eastern) side of the road, a sandstone section of the underlying marine Peawaddy Formation can be seen. A characteristic feature of the outcrop here is the prominent dark brown iron-stained vertical burrows made by marine organisms, millions of years ago, which stand out in relief in the white sandstones.

LOCALITY CR-2 (Map 2)(3.3km)

A further 0.9km along the road, another creek crossing is encountered. This is located near the signpost for the entrance to Carnarvon National Park.

Be careful to park well off the road and watch your step around the edge of the gully, which is starting to undermine the road.

As at locality CR-1, about 50m on the upstream side of the road, the Black Alley Shale is exposed in a few low outcrops in the creek bank. One zone, with noticeable brown iron-staining, contains numerous marine fossils, such as bivalves, brachiopods (see Appendix A), crinoids and bryozoans.

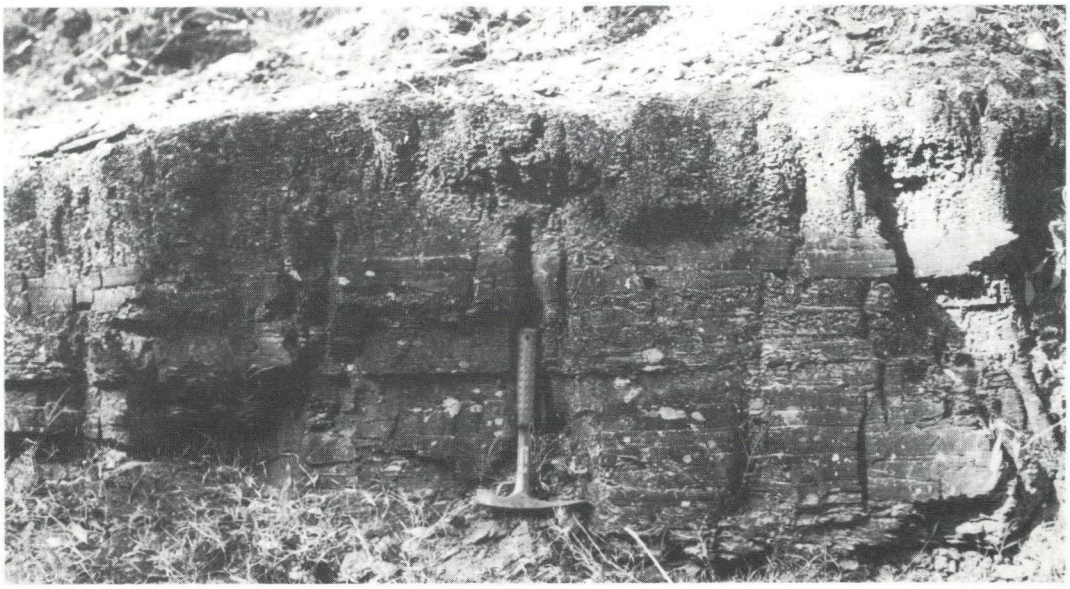
The contact between the Black Alley Shale and the Peawaddy Formation approximates the creek crossing on the road.

The downstream side of the road consists of a deeply incised crevice in which the Peawaddy Formation is exposed. Like the previous locality, the sandstone is characterised by iron-stained, vertical burrows made by marine organisms.

These outcrops of Peawaddy Formation are the oldest rocks in the area within easy access. When the road turns north, you will travel up the eastern limb of the Springsure Anticline, and traverse younger formations.

LOCALITY CR-3 (Map 2)(7.7km)

4.4km from the previous locality, a small hill of Tertiary basalt can be seen on the right-hand side of the road. This basalt has been quarried for road metal.



LOCALITY CR-4 (Map 2)(8.3km)

0.6km further along the road is the stop for 'Oil Shale Gully'.

In a gully to the east of the road, rocks of the Bandanna Formation outcrop, with sandstones and mudstones, commonly containing plant fossils and silicified wood, along with several seams of coal and torbanite (oil shale) (see photograph above). The oil shale, first recognised in 1926, has been investigated several times as an energy source, notably during the Second World War.

The Formation dips to the east, and a walk up the gully will take you progressively higher in the sequence.

NOTE: 'OIL SHALE GULLY' IS ON "EARLY STORMS" PROPERTY. THE OWNERS HAVE GIVEN MR GEORGE BRASHAN PERMISSION TO CONDUCT GUIDED TOURS OF SOME OF THE OUTCROPS IN THE VICINITY. MR BRASHAN CAN BE LOCATED AT HIS CAMP WEST OF THE ROAD, WHERE HE ALSO RENTS CAMP SITES, SELLS FIREWOOD, AND CONDUCTS PONY RIDES.

LOCALITY CR-5 (Map 1)(9.9km)

On a ridge 1.6km north of 'Oil Shale Gully' the road passes the turnoff to "Early Storms" homestead.

This ridge, which represents outcrop of the lower Bandanna Formation, is rich in silicified wood and plant remains, including *Glossopteris*, *Leptocalamites* and *Plumsteadia* (see Appendix A), *Araucarioxylon* and *Vertebraria*.

PLEASE INSPECT THE ROCKS AND THEN LEAVE THEM AT THE OUTCROP SO THAT OTHERS WHO COME AFTER MAY ALSO INSPECT AND LEARN.

LOCALITY CR-6 (Map 1)(12.6km)

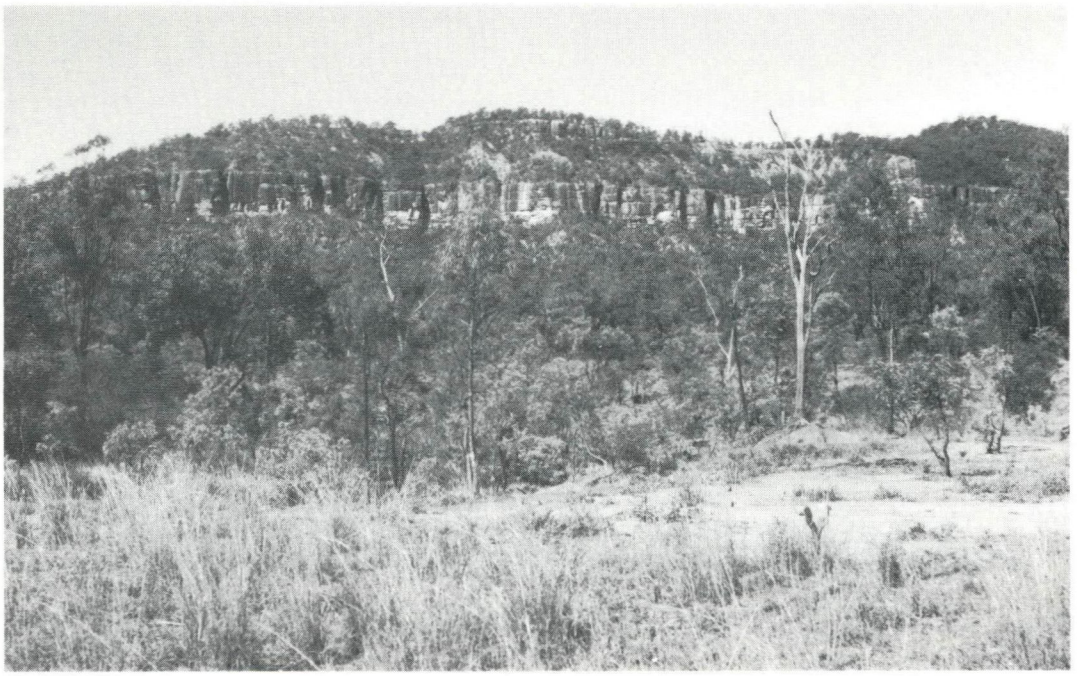
A further 2.7km north of "Early Storms" turnoff the road crosses Carnarvon Creek.

Downstream (to the east) are dipping beds of the lower Bandanna Formation, which consist of brown siltstones and mudstones with plant fragments, interbedded with cross-bedded sandstones. These were deposited as distributary channel-fill sands with bay and prodelta silts and muds. The outcrop is overlain by several metres of Quaternary billy gravels and soil.

Proceed 9.8km to the north (to 22.4km) and take the Rolleston turnoff (Rolleston 69km).

(THOSE JOURNEYING TO INJUNE CAN NOW TURN TO THE CARNARVON-INJUNE EXCURSION - next page)

For the next 50km, as you travel north towards Rolleston, the red-stained sandstone cliffs of the Triassic Clematis



Group are obvious to the right (east). To the west, timbered dip slopes of Permian sandstones which outline Reids Dome can be seen at times during the first half of the trip.

LOCALITY CR-7 (30.4km)

In some areas, such as a locality 8km north of the Injune turnoff, red, mauve, and pale green mudstones and sandy siltstones of the Rewan Group (Arcadia Formation) can be seen in low road cuttings. The Rewan Group is the oldest Triassic unit in the Denison Trough. At this locality, the overlying Clematis Group and Moolayember Formation can be seen in a cliff section in the distance to the northeast. The Clematis Group is represented by the red sandstone cliffs, and the overlying Moolayember Formation by the khaki and light grey shales and sandstones forming the upper slopes and the capping (see photograph above).

LOCALITY CR-8 (47.4km)

About 25km north of the turnoff the road runs near the base of some cliffs, and a brief walk up the slope can be made to inspect the rocks. These sandstones are considered to represent typical Glenidal Formation, the lower unit of the Clematis Group.

The Carnarvon Highway (met 70.3km north of the Lodge) runs north to Rolleston (19km). On the way, other cliffs of Clematis Group rocks can be seen in the distance to the east. Arrive Rolleston (89.3km).

CARNARVON GORGE TO INJUNE EXCURSION

This excursion starts as the CARNARVON GORGE TO ROLLESTON EXCURSION, but deviates at the Rolleston and Injune turnoffs, 22.4km from Lodge.

Take the Injune turnoff (Injune 131km). About 0.5km along the road a small hill of Tertiary basalt with a road metal quarry occurs north of the road. To the south-west, a panorama of the Precipice Sandstone escarpment flanking the Gorge can be seen.

LOCALITY CI-1. (Map 1)(24.6km)

2.2km east of the turnoff the road crosses Carnarvon Creek. On the southern bank an easterly dipping thick section of the red and green mudstones and sandstones of the upper Rewan Group (Arcadia Formation) occurs. The outcrop is partly overlain by billy gravel. 15.9km further east, at Wyseby, the road reaches the Carnarvon Highway (Injune 116km).

LOCALITY CI-2. (Map 1)(60km)

About 19.5km south of the Wyseby turnoff, red and grey mudstones of the Rewan Group (Arcadia Formation) are exposed in a road cutting on the Carnarvon Highway.

(3.4KM TO THE SOUTH OF THIS CUTTING, THE CARNARVON HIGHWAY MEETS THE NORTHERN TURNOFF TO THE ARCADIA VALLEY. THE ARCADIA VALLEY ALTERNATIVE EXCURSION OF ABOUT 80KM (next page) - REJOINS THE PRESENT EXCURSION 13.8KM SOUTH OF LOCALITY CI-4.)

Just south of the Arcadia Valley turnoff, a down-faulted block of Clematis Group sandstone is exposed in a new cutting on the eastern side of the road. The fault block is enclosed by red mudstones of the Arcadia Formation.

For a further 1.5km, the road winds through south-westerly dipping sandstone escarpments of the Clematis Group. The overlying Moolayember Formation can first be seen in the last road cutting in the range, about 2.5km south of the turnoff. It is dominantly of sandstone. Numerous road cuttings of khaki and olive mudstones and sandstones occur in the Moolayember Formation for the next 18km.

LOCALITY CI-3 (90.8km).

A thick unweathered section of cross-bedded sandstones and grey siltstones of the Precipice Sandstone is exposed in a recent cutting as the road makes a steep ascent onto the tableland, about 27km south of the Arcadia Valley turnoff. The Precipice Sandstone can also be examined in a cliff section and in cuttings on the old highway by taking the turnoff to Wallaroo to the left (east) near the base of the incline and travelling 4.2km up the incline to rejoin the new highway at the top.

Further south, the upper Precipice Sandstone outcrops in the bed of the Dawson River at the next two crossings, and shales and sandstones of the overlying Evergreen Formation are exposed in road cuttings and gullies near the road, south of the first of the crossings. Some Evergreen Formation rocks can also be seen in the bank of the Dawson River at the last (third) crossing, about 15km south of the top of the range. The Boxvale Sandstone Member, a predominantly sandstone unit in the upper part of the Evergreen Formation, occurs as timbered mesas in the area. This unit is composed mostly of white, massive to cross-bedded and flaggy, resistant sandstones.

LOCALITY CI-4 (108km).

An excellent exposure of the Boxvale Sandstone Member occurs in the road cutting through the mesa 1.8km south of the Dawson River last (third) crossing. It consists mainly of fine to medium-grained, thinly to medium bedded, sandstones. Here, trace fossils and low-angle cross-bedding have been recognised in the Boxvale Sandstone, as well as a variety of wave ripples, hummocky stratification and parting lineation. It is presently being debated if this unit is the result of continental or marine sedimentation.

Further south for about 10km, the highway again crosses the Boxvale Sandstone Member (in gullies), and the overlying upper Evergreen Formation (represented by weathered outcrop of black soil with ironstone boulders), and lowermost Hutton Sandstone on the crests of rises (represented by weathered outcrop of sandy soil and white sand).

13.8km south of Locality CI-4 (121.8km) the road meets the southern turnoff to the Arcadia Valley (ARCADIA VALLEY EXCURSION). 4.9km south of the turnoff, the road cutting at Baffle Creek exposes a section of the Hutton Sandstone.

LOCALITY CI-5 (145.5).

A further 18.8km to the south (23.7km from the Arcadia Valley southern turnoff), about 1km past Hutton Creek, the road passes through a large cutting of Hutton Sandstone. Here the formation contains thinly to thickly bedded, yellow-brown, cross-bedded, ripple-marked sandstones featuring channel deposition. Some shale interlayers and clasts are present.

LOCALITY CI-6 (152km).

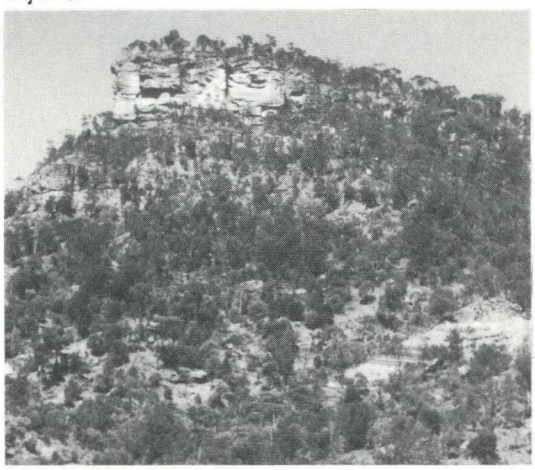
6.5km further to the south, the road cuttings are in the Eurombah Formation, the basal

unit of the overlying Injune Creek Group. The Formation consists mainly of cross-bedded sandstones. The road to Injune (6.9km) then passes over several cuttings of the overlying Walloon Coal Measures which is poorly outcropping. Arrive Injune(158.9km).

At the Maranoa Colliery about 4km south of Injune, this unit was mined for coal for the Roma-Injune railway until 1963. Spoil heaps from the mine, of light grey to grey carbonaceous sandstone, siltstone, shale and coal with plant fossils, can be seen on the eastern side of the highway.

ARCADIA VALLEY EXCURSION

22.9km south of the Carnarvon Gorge turnoff at Wyseby, the northern turnoff to the Arcadia Valley joins the Carnarvon Highway. This detour, of about 80km, follows sandstone cliffs of the Clematis Group along the western side of the Arcadia Valley, before the road climbs the range and rejoins the Carnarvon Highway 37.1km north of Injune.



LOCALITY AV-1.

2.6km east of the turnoff, the cliff-forming Expedition Sandstone (white to yellow-brown sandstone) and Glenidal Formation (grey-brown and red sandstone with mudstone interlayers) of the Clematis Group, overlying the Arcadia Formation of the upper Rewan Group can be seen in the hillside (see above). The Arcadia Formation is obvious in a slip-slope of red and light green banded mudstones and sandstones in the lower part of the hill.

LOCALITY AV-2.

A further 50.6km along the road some spectacular outcrops of Precipice Sandstone, unconformably overlying the Rewan Group, occur as mesas and as cone-shaped hills on the valley floor east of the road.

LOCALITY AV-3.

62.4km from the northern turnoff to the Arcadia Valley, the road climbs up the escarpment into Lonesome National Park. Halfway up the climb, green-grey sandstones and chocolate mudstones of the Arcadia Formation (Rewan Group) are exposed in the cuttings (see photograph opposite).

Further up the hill the boundary (obscured) between the Rewan Group of the Bowen Basin and the unconformably overlying brown, iron-stained, cross-bedded Precipice Sandstone of the Surat Basin is crossed. The road then continues for another 0.5km to the turnoff to the Lonesome National Park lookout.

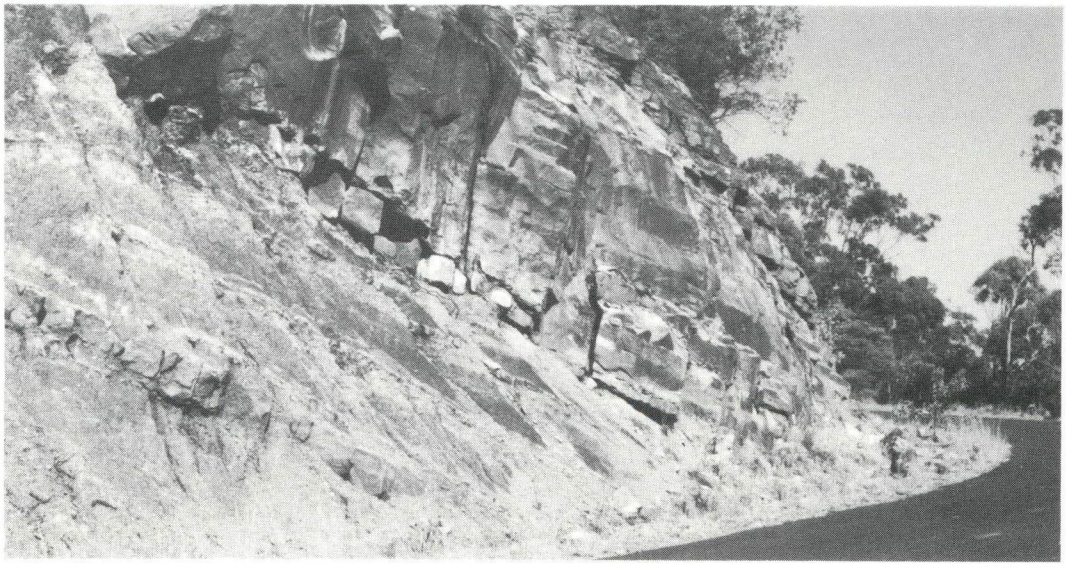
LOCALITY AV-4.

The 600m long track to the lookout follows along the upper part of the Precipice Sandstone. The lookout provides, a panoramic view of the Arcadia Valley, and the Precipice Sandstone outcrops as cliffs nearby, and overlies the Rewan Group in the floor of the valley. The cliffs that can be seen in the distance to the east are mainly outcrops of the Clematis Group, or Precipice Sandstone overlying Clematis Group.

In earlier geological time, the area of the Valley formed part of the extensive Arcadia Anticline which was subsequently eroded.

This anticline probably formed in the Late Triassic, at the same time as the Springsure Anticline and Reids Dome near the Gorge, but has only been eroded down to Early Triassic rocks (Rewan Group) and not to underlying Permian rocks, as is the case further west.

15.7km south-west of the lookout turnoff, the road meets the Carnarvon Highway from Rolleston to Injune (see CARNARVON GORGE - INJUNE EXCURSION - page 36).



FOR THOSE WISHING TO CARRY OUT THE EXCURSIONS IN THE REVERSE DIRECTION, THE FOLLOWING DISTANCES ARE SUPPLIED.

ROLLESTON TO CARNARVON GORGE

(For details, refer to CARNARVON GORGE TO ROLLESTON).

Depart Rolleston. (START)

Turnoff to Carnarvon Gorge - 19km (19km).

Locality CR-8 - 22.9km (41.9km).

Locality CR-7 - 17km (58.9km).

Turnoff to Carnarvon Gorge (near Rewan homestead) - 8km (66.9km).

Locality CR-6 - 9.8km (76.7km).

Locality CR-5 - 2.7km (79.4km).

Locality CR-4 - 1.6km (81km).

Locality CR-3 - 0.6km (81.6km).

Locality CR-2 - 4.4km (86.km).

Locality CR-1 - 0.9km (86.9km).

Arrive Oasis Lodge - 2.3km (89.3km).

The kilometres in brackets are distances from Rolleston and Injune

INJUNE TO CARNARVON GORGE

(For details, refer to CARNARVON GORGE TO INJUNE).

Depart Injune (START).

Locality CI-6 - 6.9km (6.9km).

Locality CI-5 - 6.5km (13.4km).

Southern turnoff to the Arcadia Valley - 23.7km (37.1km).

Locality CI-4 - 13.8km (50.9km).

Locality CI-3 - 17.2km (68.1km).

Northern turnoff to the Arcadia Valley - 27.4km (95.5km).

Locality CI-2 - 3.4km (98.9km).

Turnoff to Carnarvon Gorge (at Wyseby) - 19.1km (118.4km).

Locality CI-1 - 15.9km (134.3km).

Turnoff to Carnarvon Gorge (near Rewan homestead) - 2.2km (136.5km).

For remainder of localities (CR-6 to CR-1) go to the adjacent 'ROLLESTON TO CARNARVON GORGE'- Refer page 35 for Locality CR-6 - 9.8km (146.3km).

Arrive Oasis Lodge (158.9km).

GLOSSARY

(The definitions used below have been derived mainly from the 'Glossary of Geology' by the American Geological Institute, Washington D.C., USA).

Alluvial fan — A mass of sediment deposited by a river where there is a significant decrease in gradient (e.g. from a mountain to a plain).

Anticline — A fold or fold system in the form of an arch.

Aquifer — Part of a rock formation that can yield significant quantities of water to bores, wells and springs.

Artesian basin — A sedimentary basin containing aquifer(s) where the water level in a bore tapping the aquifer stands above the top of the water body it taps.

Basalt — A fine-grained, sometimes glassy, black volcanic rock generally found in the form of lava flows.

Bentonite — A clay mineral, commonly associated with the weathering of volcanic rocks

Billy — A hard crust made of silica (SiO_2) formed on the top of some weathered sediments.

Bivalve — A shell having two equal, or sub-equal, usually moveable valves that open and shut (e.g. a clam, oyster, mussel).

Brachiopod — A marine shell, generally now extinct, having two unequal valves.

Braided stream — A stream system in which numerous channels separate and remerge to form a mesh-like pattern.

Bryozoan — An aquatic, colonial (growing together) organism, commonly fan-shaped or stick-like (e.g. a sea-mat).

Calcite — White to pale grey common rock-forming mineral consisting of calcium carbonate ($CaCO_3$). Main constituent of limestone.

Carbonaceous — Describes a sedimentary rock containing organic matter.

Channel-fill — A sedimentary deposit in a stream channel.

Cherty — Containing chert, a hard, very compact sedimentary rock consisting mainly of silica (SiO_2).

Clast — A grain or a fragment produced by the disintegration of a larger rock mass.

Coal measures — A sedimentary rock sequence containing coal seams.

Concretion — A hard, compact, normally subspherical mass or aggregate of mineral matter formed by orderly and localised precipitation from aqueous solution, commonly about a nucleus which could be a shell or leaf.

Condensate — The liquid hydrocarbon that emanates from a gas well or from the gas-cap of an oil well.

Conglomerate — A sedimentary rock composed of rounded (to subangular) fragments larger than 2 mm in diameter (commonly granules and pebbles), set in a matrix of sand, silt, or clay.

Continental — A sedimentary deposit laid down on land or in bodies of water not directly connected with the ocean.

Crevasse splay — A sedimentary deposit laid down on the flood plain of a river following breaching of the levee bank.

Crinoid — A marine animal, fixed or free-living, consisting of a stem (in fixed forms only) and a calyx or cup bearing five arms, the whole structure being made up of separate calcareous plates (e.g. a sea lily).

Cross-bedding — Sedimentary structures usually found in sandstones, showing series of inclined bedding planes having some relationship to the direction of current flow and the rate of supply of the sediment. Cross-bedding is produced by swift, locally changing currents of water, generally in rivers and streams (see page 16).

Cross-bed set — An individual set of cross-beds, the inclined bedding is generally truncated (eroded) at the top, but approaches the bottom contact in a broad curve in trough cross-bedding).

Cross-section — A drawing or sketch in a vertical plane showing the relationship and correlation of various geological units in the subsurface.

Crust — The outermost layer or shell of the earth (to a depth of about 20 to 30km).

Current ripple — A sedimetary structure formed by currents of water (or air) moving more or less constantly in one direction over a sandy surface such as a stream bar, tidal flat, or beach.

Delta — The sediments deposited at or near the mouth of a river.

Dip — The angle that a structural surface, e.g. a bedding plane, makes with the horizontal.

Dome — An anticlinal structure, either circular or elliptical in outline, in which the strata dip away (down) in all directions.

Dyke — A sheet-like body of igneous rock which cuts across the bedding planes of a sedimentary rock.

Fault — A crack or failure in a rock along which opposing faces have moved.

Flaggy — Describes a rock that splits into layers from 1cm to 5cm thick (e.g. a flagstone).

Fluvial — Produced by the action of a stream or river.

Foram(inifer) — A single-celled organism characterised by a test (shell) composed of cemented particles or secreted calcite (rarely of silica), and commonly found in marine to brackish waters.

Friable — A rock that crumbles naturally or is easily reduced to a powder.

Gabbro — A medium to coarsely grained igneous rock consisting of basic plagioclase (a suite of basic aluminium silicate minerals) and clinopyroxene (a suite of basic chain silicates).

Gastropod — An organism characterised by a distinct head with eyes and tentacles, and in most, by a single shell closed at the apex, which may be spiralled (e.g. a snail).

Glossopterid — Any member of the fossil plant family Glossopteridae.

Graben — An elogated downthrown crustal block bounded by faults on its long sides (e.g. a rift valley).

Gypsum A widely distributed, very soft, white to colourless mineral consisting of hydrous calcium sulphate ($CaSO_4.2H_2O$), commonly found in evaporite deposits (formed from the evaporation of saline water) or in limestones, shales and clays.

Hummocky stratification Uneven bedding of small elevation, generally of equidimensional shape, and not ridge-like.

Impermeable The condition of a rock where it is incapable of transmitting fluids under pressure.

Intermittent swamp A flood plain adjacent to a river system receiving periodic inundation of water interspersed with periods of dry conditions.

Ironstone A sedimentary rock containing a substantial proportion of an iron oxide, carbonate, or silicate.

Joint A surface of actual (or potential) parting in a rock, without displacement (differential movement). The surface is usually plane or gently curved, and commonly occurs parallel to other joints to form part of a joint set.

Kerosene shale refer oil shale.

Lag Coarse sediments that remain after currents have washed away the finer material, particularly in local depressions in a stream or river.

Lake delta fill Coarse sediment accumulations on the margins of a lake.

Levee A raised river bank formed by natural deposition, which allows the water level in the river to rise above the surrounding land or flood plain.

Limestone A sedimentary rock consisting essentially of carbonates, the two most important being calcite ($CaCO_3$) and dolomite ($Ca/MgCO_3$).

Mantle The portion of the earth's interior below the crust and above the core, that is from a depth of about 35 km to 3480 km.

Marker horizon A relatively thin layer of rock which, because of some peculiarity of its type, structure, or fossil content, is easily recognised.

Mesa A steep sided, flat topped hill.

Micaceous Describes a sedimentary rock containing mica, a siver-white or dark green to black mineral which occurs as flakes or scales.

Mudstone A sedimentary rock composed of clay-sized particles.

Oil shale A fine-grained black or dark grey sedimentary rock which yields liquid or gaseous hydrocarbons when heated.

Olivine Olive to grey-green coloured mineral, $(Mg, Fe)_2SiO_4$.

Oolitic Describes a sedimentary rock containing ooliths (spherical concretions with a diameter of 0.25 to 2mm) Ooliths are commonly composed of calcite or iron oxide and indicate shallow water, wave-agitated conditions.

Outcrop That part of a geological formation or structure that appears at the surface of the earth.

Overbank deposit Fine-grained sediment (silt or clay) deposited by floodwaters on a flood plain beyond the limits of the stream channel.

Oxbow lake A crescent-shaped body of standing water which is the abandoned (cut-off) channel of a previous meander (bend).

Paralic	Describes deposits laid down on the landward side of the coast, or in shallow water subject to invasion by sea water.
Parting	A plane or surface along which a sedimentary rock is readily separated or is naturally divided into layers.
Parting lineation	A sedimentary feature on bedding planes consisting of weakly defined parallel ridges and grooves a few millimetres wide, caused by flowing water.
Peat	An accumulation of rotting organic material in a swamp.
Permanent swamp	A flood plain adjacent to a river system which is always flooded.
Permeable	Describes a rock that is capable of transmitting fluids under pressure.
Point bar	Low arcuate ridges of sand and gravel developed on the inside of a growing meander (bend) as the river channel migrates towards the outer bank.
Porous	Describes a rock which can contain fluids in the cavities between the grains making up the rock.
Prodelta	The part of a delta front that is beyond the effective depth of wave erosion.
Radiometric dating	A method of obtaining the age of a rock by measuring the presence of a short-life radioactive element, e.g. carbon-14, or a long-life radioactive element plus its decay product, e.g. potassium-40/argon-40.
Reservoir	In petroleum geology, any rock with adequate porosity or joint and fracture systems to contain liquid or gaseous hydrocarbons (commonly sandstone or limestone).
Ripple lamination	A small-scale internal sedimentary structure formed in fine-grained sand or silt by currents or waves, as opposed to a ripple mark formed on the surface.
Root cast	A slender, tubular, near-vertical, and commonly downward-branching sedimentary structure formed by the filling of a tubular opening left by a root.
Sandstone	A sedimentary rock composed of abundant rounded to subangular fragments ranging in size from 0.0625 to 2 mm diameter, set in a matrix of silt or clay and cemented mainly by silica, iron oxide, or calcium carbonate.
Scour and fill	A sedimentary structure consisting of a small erosional channel that is subsequently filled.
Sedimentary	Pertaining to or containing sediment–fragmental material that originates from the weathering and erosion of rocks and is transported and deposited by air, water, or ice.
Seismic survey	The gathering of seismic data which uses the generation, reflection, refraction, detection and analysis of elastic waves in the Earth to map subsurface geological structures.
Sequence	A succession of rocks arranged in chronological order to show their relative position and age with respect to geological history as a whole.
Shale	A sedimentary rock composed of clay-sized (<0.0039 mm diameter) particles with well-developed parting along the bedding planes, as opposed to mudstone which has none.

Siltstone A sedimentary rock composed of particles ranging in size from 0.0039 to 0.0625 mm diameter.

Sorting Dynamic process by which sedimentary particles with a similarity of size, shape or specific gravity are naturally selected and separated from associated but dissimilar particles by agents of transportation, especially running water.

Source rock A sedimentary rock with organic material, which under pressure and heat, and after time, was transformed to liquid or gaseous petroleum.

Strata Sedimentary rocks which display layering or bedding.

Stratigraphy The study of stratified rocks (sedimentary and volcanic), especially their sequence in time, the character of the rocks, and their correlation with different localities.

Strike The direction (compass bearing) that a bedding plane takes when it intersects the horizontal.

Stylolite An irregular, interlocking, suture - like surface of contact that can be developed in limestones and more rarely in sandstones, and generally independant of the bedding planes. Presumably they have developed from some kind of pressure-controlled solution in fully consolidated rock.

Tectonics The study of the major structural features of the earth's crust, or the broad structure of a region.

Trace fossil A fossilised track, trail, burrow, tube, boring, or tunnel resulting from animal activities in soft sediment at the time of its deposition.

Trap A structure in which oil and/or gas may collect.

Truncated Describes bedding or a sedimentary sequence that has been cut off by erosion.

Tuff A compact deposit of volcanic ash and dust that may contain up to 50% of sand and/or clay.

Unconformity A substantial break or gap in the geological record where an older rock unit is overlain by another (the younger) that is not next in stratigraphic succession. It results from some change that caused deposition to cease for a considerable time and normally implies subsequent uplift and erosion with loss of some of the older rock unit before deposition of the younger unit.

Uplift A structurally high area in the crust, produced by positive movements that raised or upthrusted the rocks.

Volcanic arc A curved chain of volcanic islands adjacent to the continent, generally with a deep oceanic trench on the outwards facing convex side and a deep basin on the landward side (e.g. Japan, Aleutian Islands). Recent theory suggests that this feature is the result of an oceanic plate (large rigid part of Earth's crust) sliding underneath a continental plate, during expansion of the Earth.

Wave ripple A sedimentary structure consisting of a symmetric ripple mark with a narrow straight crest between rounded troughs, formed by the to and fro motion of waves.

Weathering The process by which rocks are broken down and decomposed by wind, rain, temperature changes, plants, and bacteria.

APPENDIX A: FOSSILS IN THE GORGE AND ITS VICINITY

Fossilised remains of ancient land plants and marine animals occur in Permian rocks in the vicinity of the Gorge, and in Triassic and Jurassic rocks the Gorge itself (mainly plants in the Moolayember Formation and wood and plants in the Precipice Sandstone). The following pages show some of the fossils known from the area.

It must be stressed that hammering of rocks in the search for fossils, or collecting samples within Carnarvon Gorge National Park is strictly prohibited.

LEGEND FOR APPENDIX A

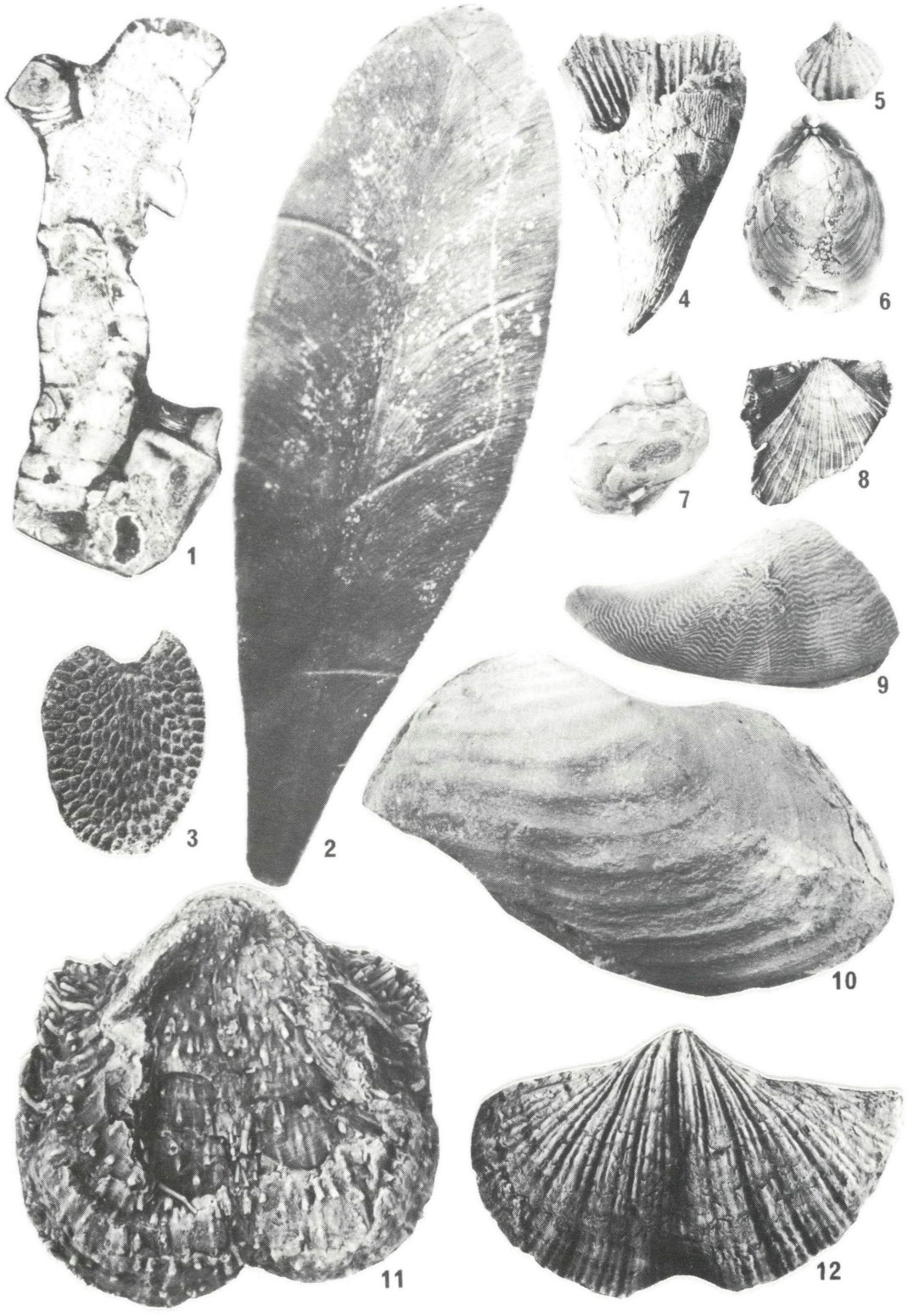
Plate 1.

1. *Leptocalamites rigbyi* (horse-tail stem) Permian.
2. *Glossopteris* sp. (glossopterid) Permian.
3. *Plumsteadia semnes* (glossopterid fruit) Permian.
4. *Euryphyllum* sp. (coral) Permian.
5. *Plekonella acuta* (brachiopod) Permian.
6. *Gilledia* sp. (gastropod) Permian.
7. *Platyteichum coniforme* (gastropod) Permian.
8. *Etheripecten* sp. (bivalve) Permian.
9. *Glyptoleda reidi* (bivalve) Permian.
10. *Myonia carinata* (bivalve) Permian.
11. *Taeniothaerus acanthoporus* (brachiopod) Permian.
12. *Trigonotreta* sp. (brachiopod) Permian.

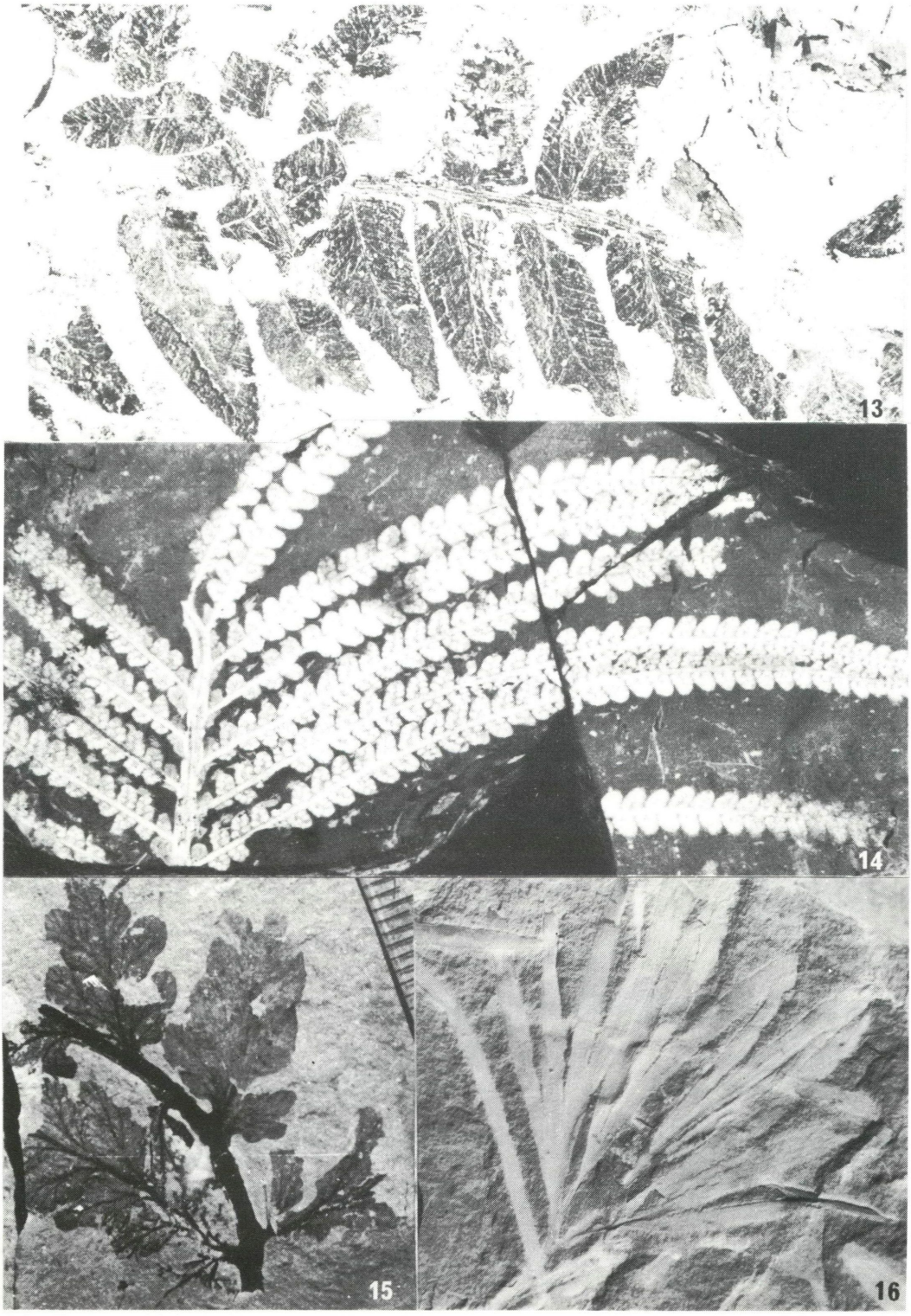
Plate 2.

13. *Cladophlebis mendozaensis* (seed fern frond) Jurassic.
14. *Eboracia herbstii* (fern frond) Jurassic.
15. *Archangelskya eurae* (fern frond) Triassic.
16. *Ginkgoites bidens* (ginkgophyte frond) Triassic.

APPENDIX A, Plate 1: Permian plants and animals.



APPENDIX A, Plate 2: Triassic and Jurassic plants.



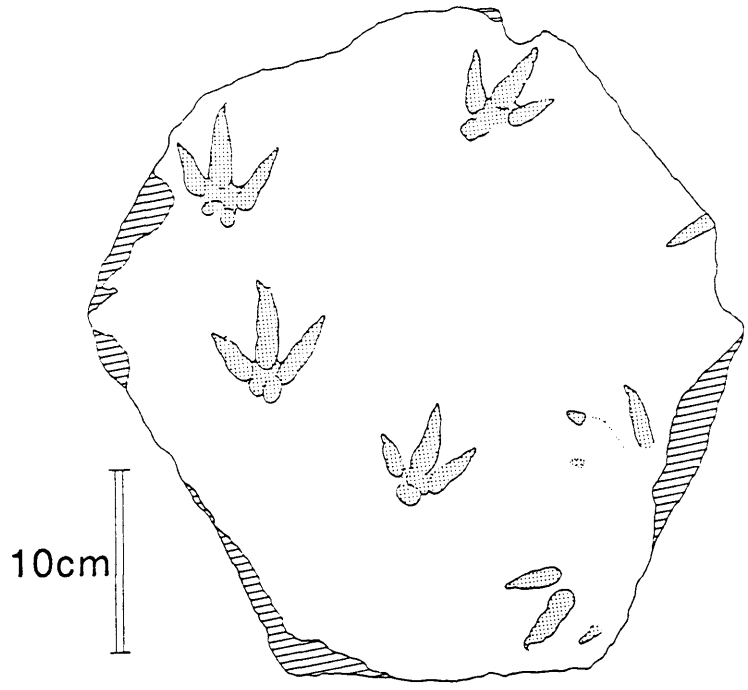
APPENDIX B: FOOTPRINTS IN THE GORGE

"*Fabrosaurus*"

leaves

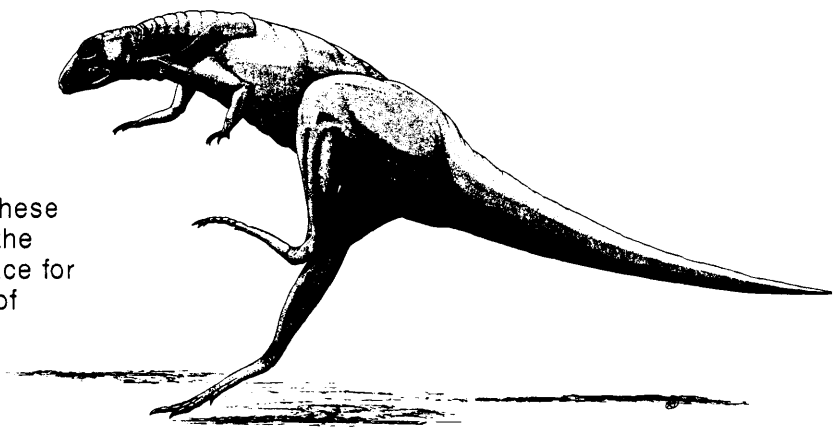
its

mark

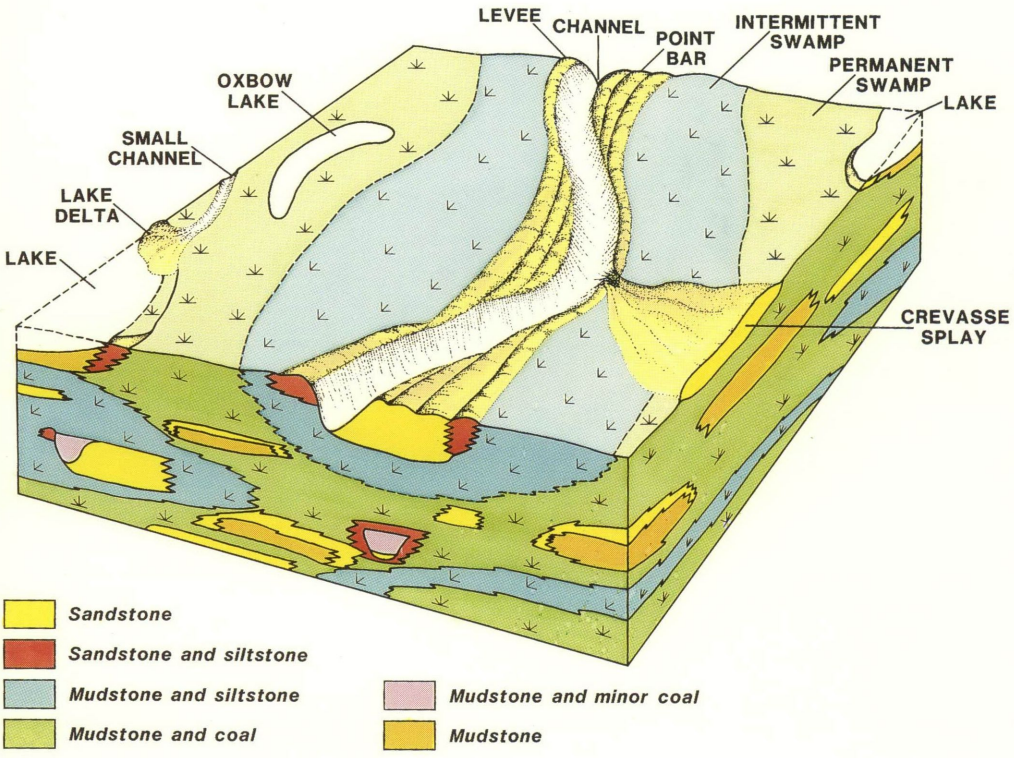


Footprints of a small dinosaur have been discovered in Carnarvon Gorge, in rocks of the Precipice Sandstone (Early Jurassic). The prints, which show similarities to the ichnospecies *Anomoepus gracillimus*, may have been left by dinosaurs resembling the plant-eating *Fabrosaurus* (*Lesothosaurus*) known from Africa (see sketch below).

The footprints suggest at least four dinosaurs, all about 30cm high at the hip and less than 1.3m in total body length. These footprints are the earliest evidence for the existence of ornithischian dinosaurs in Australia.



APPENDIX C: FLUVIAL ENVIRONMENTS



Environment: Rock type

Point bar (Channel): sandstone, pebbles and mudstone clasts at base; sharp basal contacts; logs, plant fragments

Oxbow lake (Abandoned channel): mudstone, coal, sandstone at base; laminations, roots, plant fossils

Levee: sandstone and siltstone; ripples, laminations, rooting; plant fragments, coal

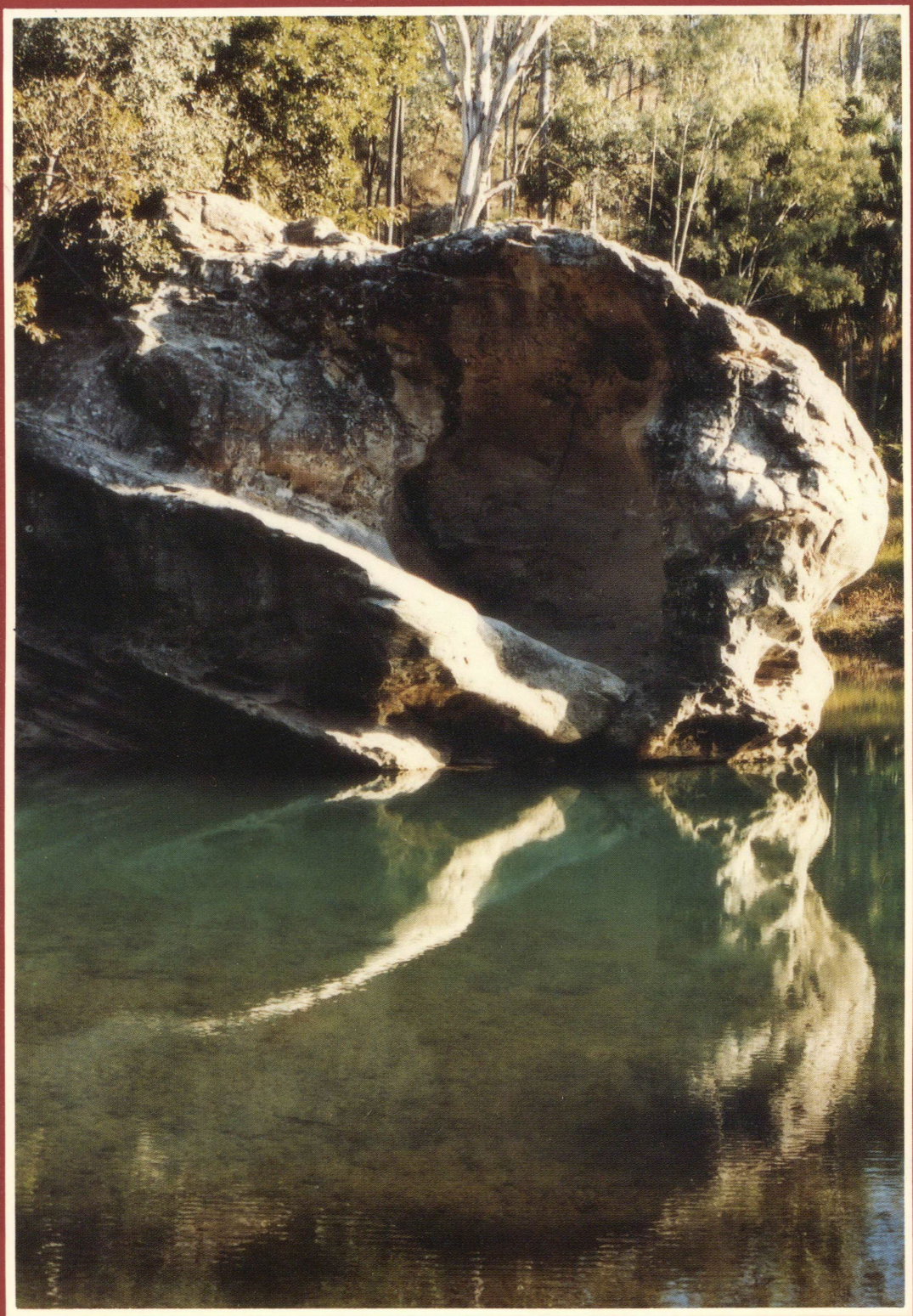
Crevasse splay: sandstone; ripples, scour and fill; plant remains

Intermittent swamp: mudstone, siltstone; small scale structures; plant fossils

Permanent swamp: coal, carbonaceous mudstone; laminations, burrows; plant fossils

Lake: mudstone; laminations, burrows; rare plant fossils

Lake delta fill: siltstone, sandstone; variable bedding, soft sediment deformation; plant fragments



ISBN 0 7242 5229 0