

## Geology and landforms of the Pilbara

The Pilbara is geologically one of the oldest regions in Australia. Most of the rocks in the Pilbara were formed between 2500 and 3600 million years ago during the Archean period, when the Earth's crust was still very young. This represents one of the world's best preserved fragments of ancient continental crust—one of the Earth's earliest continents. **by Iain Copp**

The oldest part of the Pilbara Craton is made of greenstones, a mixture of volcanic and sedimentary rocks, intruded by granite magma to form 'granite-greenstone terrain'. The greenstones continued to be deposited, and were intruded by more granite throughout the following 800 million years. During this time, huge stresses within this newly formed crust caused many rocks to be severely sheared, folded and faulted. Large volumes of hot fluid were generated deep within the craton as a result, and many rocks and faults became mineralised with gold, copper, nickel, zinc, tin and tantalum.

### Granite-greenstone country

Today, the landscape of much of the northern Pilbara is still dominated by distinct granite and greenstone landforms. Granite-greenstone country tends to form a mixture of low undulating hills, monadnocks (large isolated hills that stand above a

generally flat plain), sandy plains, and rugged hills and ridges with narrow valleys that may be very steep-sided.

Granite, the dominant rock type of the two in the northern part of the Pilbara, forms several vast ovoid intrusions, up to 120 kilometres in diameter. Granite is mostly a coarse-grained rock consisting of quartz, feldspar and mica, and commonly weathers to a smooth surface.

Greenstones are a mixture of volcanic and sedimentary rocks, which in the Pilbara include rhyolite, basalt, komatiite, banded iron formation (BIF), shale, siltstone, conglomerate and chert. The greenstones lie between the large granite intrusions, as linear or curved belts, tens of kilometres long. In cross-section, these belts are commonly v-shaped folds, or synclines, and have very steeply dipping beds.

There is an excellent exposure of greenstones at Maree Pool, where the North West Coastal Highway crosses the Maitland River. At the southern

end of the pool is a highly flattened and stretched rock type called mylonite. It formed when a major fault, called the Sholl Shear Zone, sheared and ground the granite and greenstones deep within the Earth's crust under extreme pressure. This is one of the major faults within the Pilbara, extending for at least 250 to 350 kilometres in a roughly north-east to south-west direction. Geologists believe that, at one stage, movement along this fault zone caused the rocks on the northern side to be displaced 150 to 200 kilometres to the left, relative to those on the southern side.

### Marble Bar

About three kilometres west of Marble Bar is a spectacular outcrop of Marble Bar Chert, after which the town was named. It is an unusually large and impressive water-polished rock bar across the Coongan River, surrounded by rugged hills and ridges. Marble Bar Chert is a sedimentary rock composed of microscopic silica grains. It is part of the Marble Bar greenstone belt, a 12-kilometre-thick succession of volcanic and sedimentary rocks that formed during the Archean, about 3490 to 3350 million years ago.

Evidence of volcanic activity can be seen on the southern side of the bar, just south of the parking lot and on the eastern side of the river. Here, basalt overlying the chert contains beautifully preserved 'pillow structures'. These formed when lava was extruded in deep water then quickly cooled to form 'pods' of basalt.

During the time that the granite-greenstones seen throughout the Pilbara were forming, the Earth's surface was a hostile place, with little oxygen in the atmosphere, and only simple microbial life that formed stromatolites. Some of these are up to

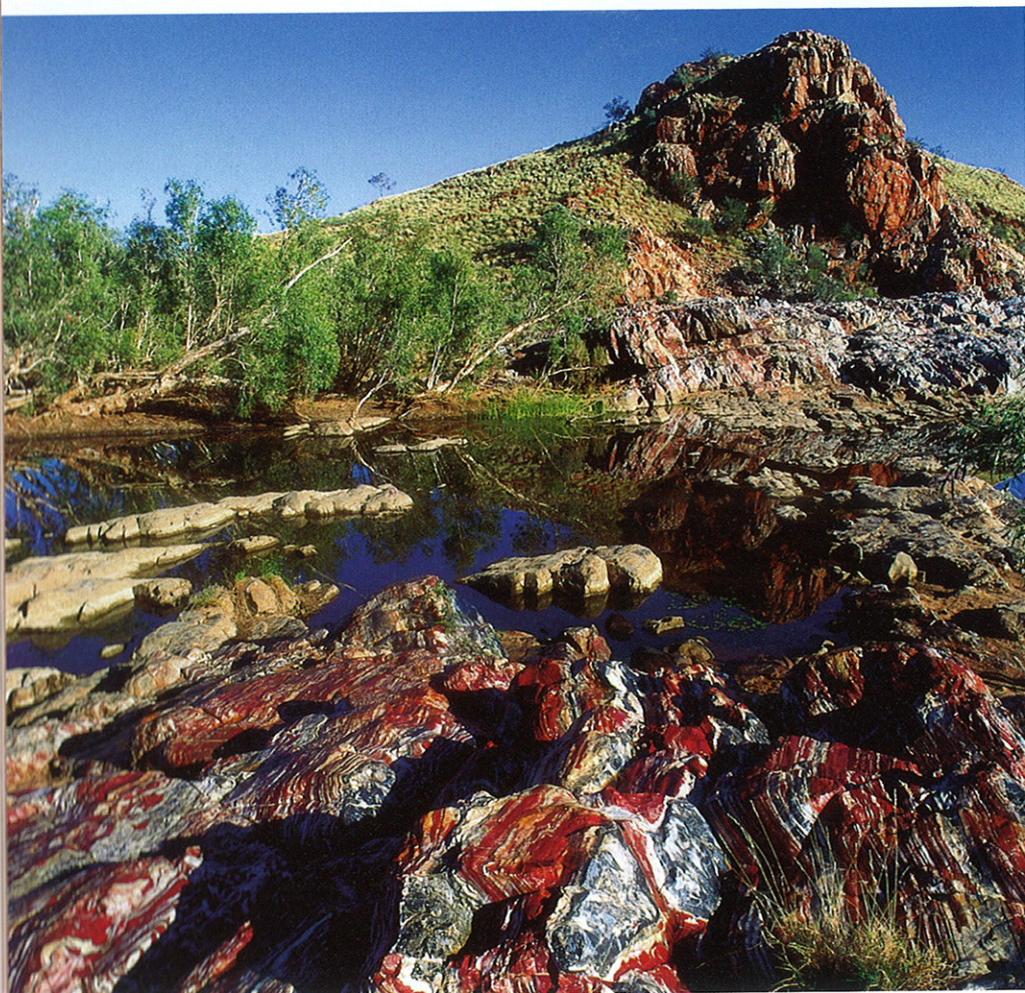
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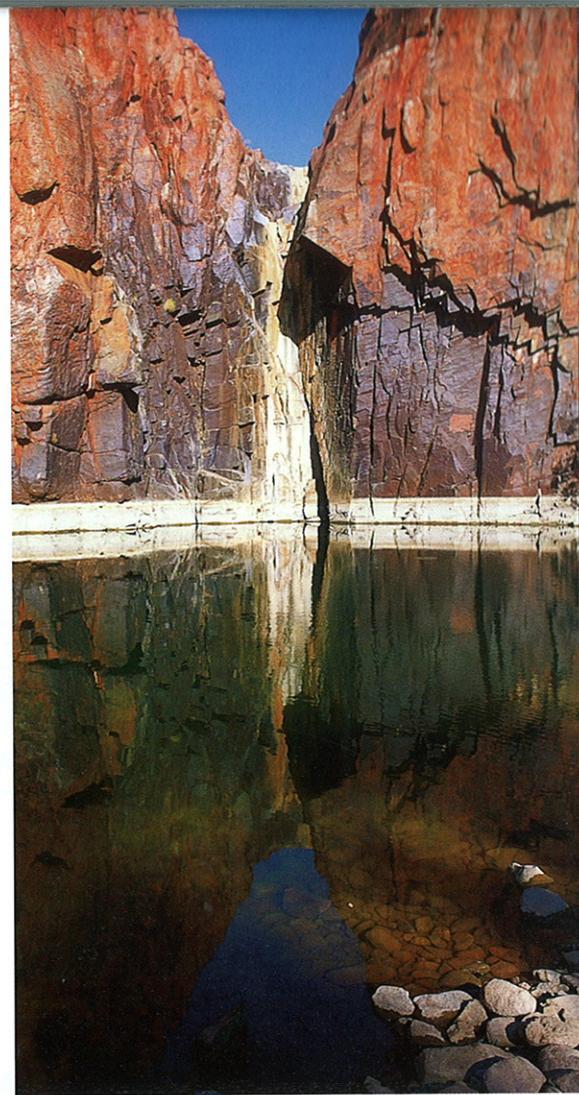
**Main** Handrail Gorge.

*Photo – Michael Pelusey*

**Left** Jasper outcrop at Marble Bar in the Pilbara.

*Photo – Dennis Sarson/Lochman  
Transparencies*





3490 million years old—the world's oldest fossils and the first visible evidence of life on Earth. The world's oldest evidence of meteorite impacts also occurred in the Pilbara during this time (3460 to 2490 million years ago).

### **Uplift and erosion**

By around 2800 million years ago, the formation of granite-greenstone terrain had ended, and a major period of uplift and erosion took place throughout the Pilbara. The Pilbara Craton at this time was part of a larger continent that began to break apart along what is today its southern margin. As the crust stretched and became thinner, an extensive rift was formed that ran in a west-north-westerly direction. Consequently, around 2770 million years ago, a huge volume of molten rock from the underlying mantle was extruded along this zone, forming a 'sea of basalt lava' that buried the older granite-greenstone terrain. These lava flows are preserved as part of a thick succession of volcanic and sedimentary rocks, known as the Fortescue Group. This was the beginning of the deposition of

the vast Hamersley Basin, the youngest part of the Pilbara Craton.

As the main period of crustal extension came to an end by about 2690 million years ago, the Hamersley Basin then began to fill with sediments deposited on a shelf or platform that opened to an ocean. During this time, extensive deposits of banded iron formation were laid down, such as those in the Hamersley Range.

### **Continents collide**

Between about 2200 and 1800 million years ago (during the Proterozoic), the ocean that lay to the south of the Pilbara Craton was closed during a series of collisions with other ancient continents that included the Yilgarn Craton. This caused the rocks of the Hamersley Basin to be deformed into large folds, as they were squeezed between two continents. Together, the landmasses formed the vast new West Australian Craton. Extensive mountain building took place along this collision zone, leading to another major period of erosion and the formation of a sedimentary basin called the Ashburton Basin.

**Above left** Fortescue Falls, Karijini National Park.

*Photo – David Bettini*

**Above** Python Pool at Millstream-Chichester National Park.

*Photo – Alex Bond*

Soon after, at around 1760 million years ago, the West Australian Craton collided with another continent to the north-east, called the North Australian Craton. This continental collision brought together most of what is now the western and central parts of the Australian continental landmass. Further collisions brought together a much bigger assemblage of cratons that formed the supercontinent of Rodinia by 1000 million years ago.

Following the collisions, the crust then sagged over the junction between the cratons, allowing an immense basin to develop that filled with sediments deposited by shallow seas, rivers and glaciers. In the eastern part of the Pilbara, where the Little Sandy Desert

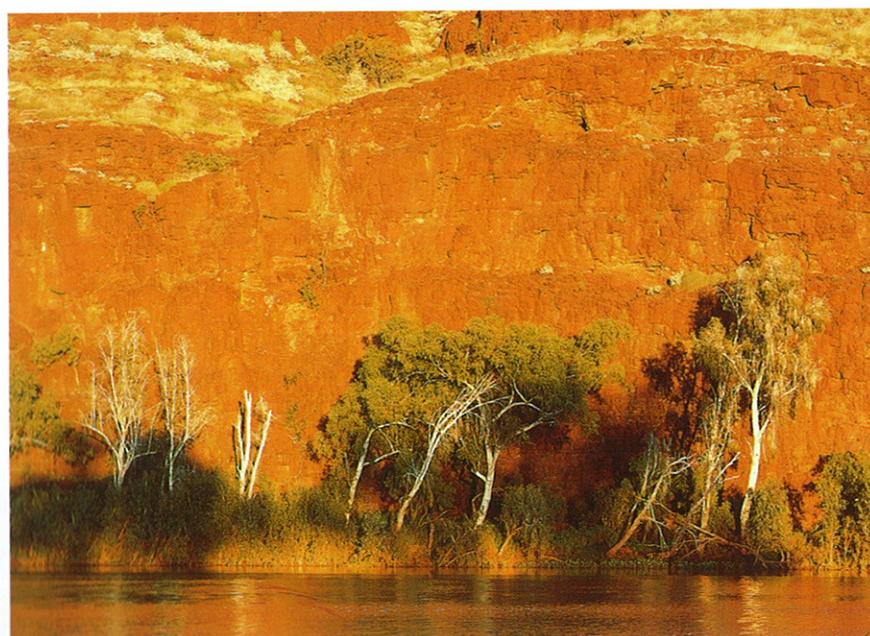


is today, this part of the basin is called the Officer Basin. By about 750 million years ago, towards the end of the Proterozoic, Rodinia began to break apart and, although the Australian continent remained mostly intact, old 'joins' between cratons were reactivated. Consequently, about 550 million years ago, substantial faulting and folding took place in the Rudall River area.

North-east of the Pilbara, where the Great Sandy Desert is today, a huge basin called the Canning Basin began to form around 490 million years ago. As it slowly filled with marine and continental sediments, it partly covered older rocks at the edge of the Pilbara Craton and in the Rudall River area. Glaciers formed some of these deposits around 295 million years ago, during the Permian. Australia was then part of the Gondwanan supercontinent and lay close to the South Pole. The glaciers deeply scoured the landscape, carving huge glacial valleys that are recognisable today in the north-eastern part of the Pilbara.

### Glaciers

One of the largest such valleys in the Pilbara is the Wallal Embayment. This wedge-shaped area, nearly 150 kilometres long, extends in a south-easterly direction from east of Shay Gap, where it is about 50 kilometres wide, and ends just south of Carwine Pool, roughly paralleling today's Oakover River valley. The ancestral Oakover River may have in fact originated when the Permian glaciers began to melt.



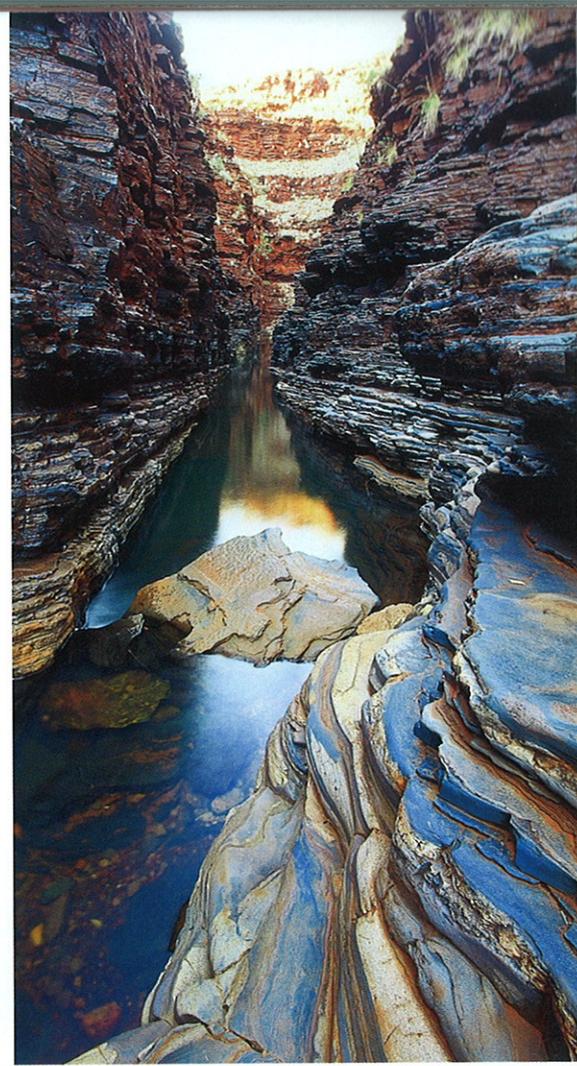
**Top left** Aerial view of Lake Disappointment in the Little Sandy Desert.

*Photo – Jiri Lochman*

**Centre left** Rooney Valley, in Rudall River National Park, was carved by glaciers.

**Left** Carwine Gorge.

*Photos – Marie Lochman*



**Above** Rock formations in Hancock Gorge.  
*Photo – Dennis Sarson/Lochman  
 Transparencies*

**Above right** Hancock Gorge, Karijini  
 National Park.  
*Photo – Jiri Lochman*

The great weight and force of moving ice ground up rocks from the valley floor and walls, redepositing them as beds of sediments, or tillite, when the ice melted. For instance, beds of scattered pebbles, cobbles and boulders up to two metres across can be seen along the four-wheel-drive track into Carawine Pool, and also at Shay Gap and Rudall River. Some of the rock surfaces near Carawine Pool are highly polished with sets of parallel grooves, called striations. These resulted from scouring by rocks embedded in the moving glaciers.

### Rocky rift

Around 170 million years ago, a large rift developed within the crust off the northern side of the Pilbara, at the site of the present day North West Shelf. This marked the beginning of the break-up of Australia from

Gondwana and, as the continental crust pulled apart, a sedimentary basin called the Northern Carnarvon Basin developed along this rift. Slowly, it filled with an enormous thickness of sediment, some of which was transported by rivers from the eroding rocks of the nearby Pilbara Craton.

During the last 90 million years, thick deposits of limestone have accumulated over the North West Shelf, some of which is now exposed as islands and coastal ranges.

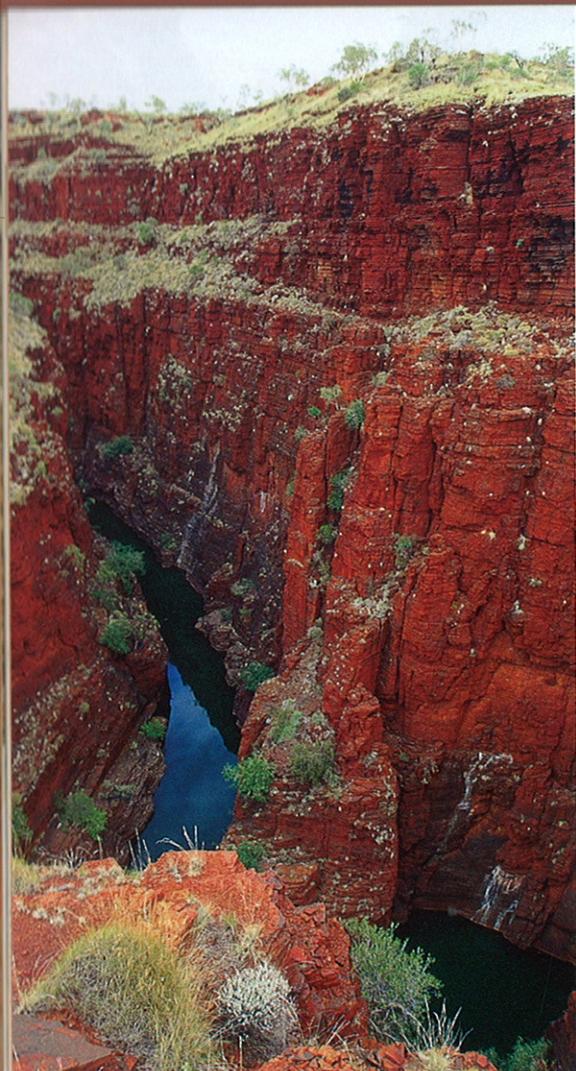
### Evolution of the Pilbara landscape

Today, the Pilbara region has a spectacular landscape of plateaus, gorges, ranges, razor-backed hills and ridges, narrow steep-sided valleys, low hills, plains, dunefields, coastal flatlands and islands. The diverse landscape is very old, and much of it probably began to form at least 295 million years ago when Australia was part of Gondwana. Glaciers carved broad deep valleys into the landscape, particularly on the north-eastern side of the Pilbara. After the glaciers retreated, the surface continued to be eroded as rivers cut down through the landscape.

Around the late Jurassic (about 170 million years ago), as Australia began to break apart from Gondwana, the Pilbara was probably gently uplifted. This caused an extensive interior drainage system—the ancestral Ashburton River—to develop. By the late Cretaceous (around 100 million years ago), warm and humid climatic conditions prevailed over the Pilbara region, and the underlying rocks consequently underwent deep weathering.

### Karijini gorges

There are many gorges in the Hamersley Range, but the most spectacular are in Karijini National Park. Here, the plateau that forms the range has been deeply dissected to reveal magnificent vertical exposures of the 2500-million-year-old banded iron formation (BIF). Although these rocks are ancient, most of the landscape has formed in the last tens of millions of years. It is uncertain when and how this erosion took place, but it was probably during the Late Cretaceous and Early Cainozoic, when the Pilbara was gently tilted towards the north-west. This caused rivers in the range to

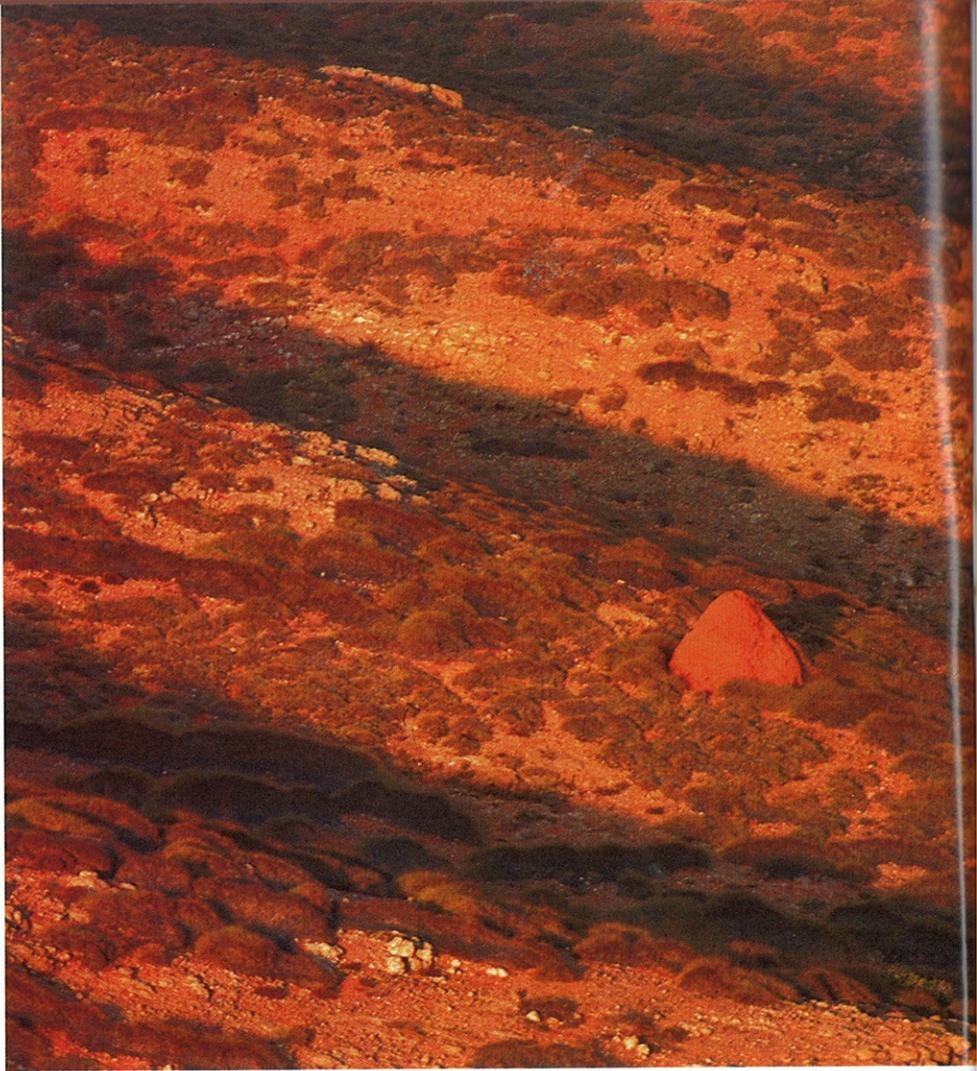


**Above** View of Red Gorge from Oxers Lookout.

Photo – Jiri Lochman

**Above right** Undulating inland landscape with scattered termite mounds.

Photo – Marie Lochman



downcut through the rocks, rapidly eroding the softer shale and dolomite beneath the BIF, giving rise to spectacular gorges and waterfalls. Lines of weakness within these rocks, such as faults and joints, would have aided this erosion. This process was enhanced by the onset of an arid climate in WA, depleting the vegetation able to cover and protect the valley sides.

Material that was eroded at the higher levels was transported to the sides and floors of valleys, to form thick, iron-rich deposits. As erosion continued, these deposits were themselves dissected, and are now preserved as mesas and tablelands, like those at Deepdale near Pannawonica. By around 40 million years ago, as Australia began to drift northwards

after separating from Antarctica, the Pilbara probably began to dry out, leading to lakes forming in old river valleys, such as those of the Fortescue and the Oakover.

During the last two million years, successive ice ages made the climate throughout Western Australia extremely arid. Between 25,000 and 13,000 years ago during the last ice age, aridity was at a peak, probably causing the last significant activity of the dunefields in the Great Sandy Desert and Little Sandy Desert. As the polar ice caps contracted for the last time, about 18,000 years ago, and the climate became warmer and more humid, sea level began to rise and coastal areas were flooded, leaving behind higher areas as islands, like the Dampier Archipelago and Barrow Island.

### Huge field laboratory

With such ancient rocks, the Pilbara is now internationally known as the best 'field laboratory' for studying the early history of the Earth. Research is carried out by scientists from Japan, France, the USA (including NASA), the United Kingdom and Australia.

This field laboratory is equally available to the public. So why not take a copy of the Bush Book *Geology and Landforms of the Pilbara* on your next holiday to the region and discover some of this history for yourselves, whether you are visiting some of the vast vistas of Karijini National Park and its famous gorges or the chert of Marble Bar.

Iain Copp is an interpreter in the Department of Conservation and Land Management's Interpretation and Visitor Information Unit. A geologist, Iain also wrote the Bush Book *Geology and Landforms of the South-West*. He can be contacted on (08) 9334 0553 or by email (iainc@calm.wa.gov.au).

This article is based on the full-colour, pocket-sized Bush Book *Geology and Landforms of the Pilbara*, also by Iain Copp, which can be purchased from CALM or from most bookshops for \$6.50. The author acknowledges the assistance of Kath Grey, Ian Williams, Arthur Hickman, Ian Tyler, Alan Thorne, Roger Hocking and Leon Bagas in writing the Bush Book.