

A wandering continent

While measurements made today can give a very accurate estimate of crustal movement over the last 100 m.y. (the period over which most of the present oceanic crust has formed) and a fairly accurate estimate over the last 500 m.y., estimates of the global position and configuration of landmasses earlier than this are largely conjectural. Neverthe-

less, it can be estimated with reasonable confidence that around 500 m.y. ago Australia was part of a super continent (today called 'Gondwana') also composed of Africa, India, Antarctica and South America. Australia was a northward extension of this super continent, lying largely in the Northern Hemisphere and experiencing tropical conditions.

Earthquakes in Australia

Earthquakes occur when rocks move suddenly, usually to relieve pressure built up along fault lines and subductive zones. The vast proportion of earthquakes occur at tectonic plate boundaries though fortunately most of Australia is distant from this type of intense geological activity. However, 16 earthquakes of magnitude 6 or more on the Richter scale have been recorded in the last 100 years and, on average, 3.6 quakes exceeding magnitude 5 have occurred each year since 1960. The causes of such severe seismic activity on the otherwise very stable Australian crustal plate are not yet known.

The table below lists the eight most severe earthquakes that have caused property damage this century. Others of equal severity have occurred but in areas more distant from human settlement.

Damaging Australian earthquakes since 1900 and their relation to the Richter scale

Richter scale	Earthquake	Date	Intensity	Characteristic effects near epicentre
3			Unfelt	Detected only by instruments
			Slight	Similar to vibrations from heavy trucks
4	4.3 Lithgow (N.S.W.)	13.2.85	Moderate	Trees sway; loose objects fall; slight damage
5	5.3 Warrnambool (Vic.)	14.7.03	Strong - very strong	Walls crack; some buildings collapse
	5.4 Adelaide (S.A.)	1.3.54		
	5.5 Robertson (N.S.W.)	21.5.61		
	5.5 Picton (N.S.W.)	9.3.73		
6	6.2 Cadoux (W.A.)	2.6.79	Destructive	Most buildings collapse; ground badly cracked
	6.8 Tennant Creek (N.T.)	22.1.88		
	6.8 Meckering (W.A.)	14.10.68		
7			Disastrous	Nearly all buildings collapse; landslides
8			Catastrophic	Total destruction

(Right) The most recent destructive earthquake, at Tennant Creek (N.T.) in January 1988, damaged buildings and services in the town and the nearby Alice Springs-Darwin gas pipeline. Total losses amounted to at least \$0.5 million.

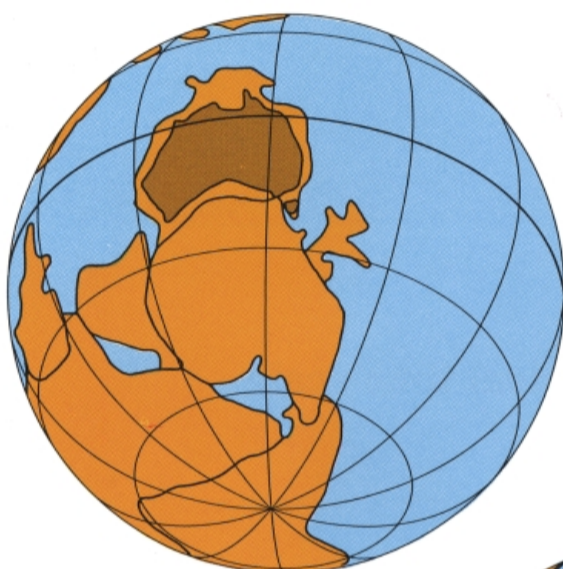
(Far right) Spectacular faulting of the ground surface was caused by the severe quake at Meckering (W.A.) in 1968, when the town was virtually destroyed. The total cost of this earthquake, including damage which occurred in Perth, 120 km away, exceeded \$2 million.



480 million years ago



400 m.y. ago

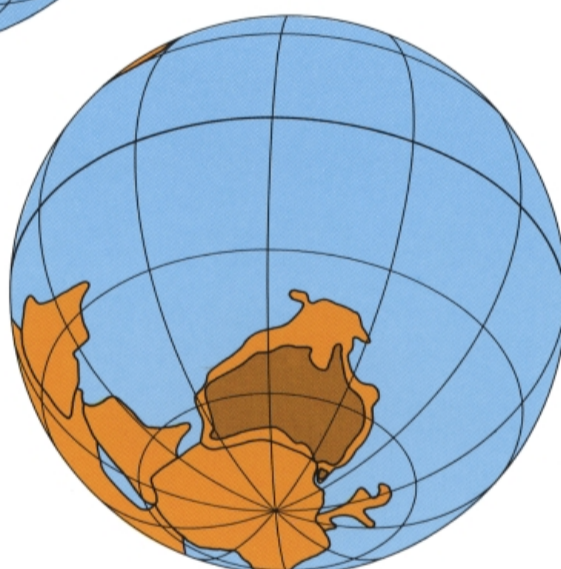


Once good navigational charts of continental coastlines became available it was noticed that there was a close correspondence in the outline of many continents, particularly the east coast of South America and the west coast of Africa. This observation led to the theory that some of today's continents, including Australia, were once joined together as a super continent before gradually drifting apart over geological time.

While this theory was initially treated with scepticism the evidence for it is now overwhelming. Indeed, it is now possible to determine the movement of continents by very accurate measurement of intercontinental distances by laser ranging to the moon and orbiting satellites. These movements, averaging about 5-10 cm per year, are all that are needed to account for the extensive 'drift' of continents over the great length of geological time.

In addition to the close correlation of continental coastlines there is further evidence to support this theory. While flora and fauna of the southern continents are now largely dissimilar, related fossil plant types have been uncovered in many countries separated by vast oceans. This suggests that migration of species was easier in the past and that oceans did not separate the present continents.

280 m.y. ago



Over the next 200 m.y. Australia, still part of Gondwana, drifted steadily south to very near the South Pole and experienced glacial

conditions in Carboniferous and Permian times. Australia then drifted generally northward but still as part of Gondwana.

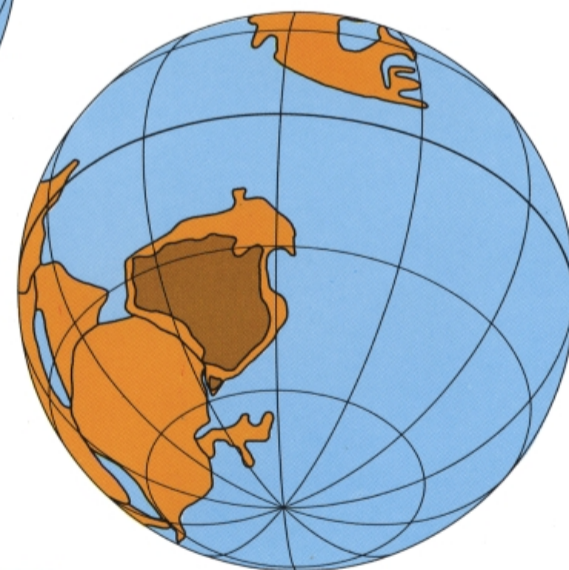
Plate tectonics

The theory of continental drift is formalised in the study of *plate tectonics*, so called because the solid surface of the earth is now known to consist of about a dozen major 'plates' of rock, each moving separately.

These plates of solid rock consist of a thin veneer of crustal rock and a somewhat thicker layer (about 100-150 km) of denser sub-crustal rock (the *lithosphere*) resting on a much thicker layer of 'soft' rock (the *asthenosphere*). The asthenosphere consists of 'rock' in a plastic state due to the combination of great pressure and temperature and which, when occasionally squeezed to the surface as volcanic lava, changes to a liquid state with the reduction in pressure.

Within the soft layer there are narrow zones of convective activity sending up plumes of even 'softer' rock towards the surface. Where they reach the surface, magma is extruded as lava flows which solidify to form new crustal rock. Because this newly formed rock is denser than rocks forming the landmasses, it lies at a lower level and therefore forms the ocean floors. A near-continuous network of ridges—the *spreading margins*

200 m.y. ago



The super continent began breaking apart about 160 m.y. ago, though Australia and Antarctica remained attached to one another for about another 100 m.y.

shown on the accompanying map 'Major World Tectonic Plates'—occurs along this zone of volcanic activity, which lies mostly in the centre of the oceans.

Ocean floor crustal rock is continually solidifying and pushing previously formed rock away from both sides of the mid-ocean ridges. Platforms of crustal rock forming the continental landmasses such as Australia 'float' on the oceanic crustal and lithospheric rocks because they are less dense and are carried along on this moving carpet of denser rock. This process continues until the lithosphere and its floating platform of continental crust meet another crustal plate. Here one plate rides over the top of the other, driving its leading edge back down into the asthenosphere in what is termed a *subductive margin*. At the conjunction of continental plates major mountain building may take place, for example the Himalayas where the Eurasian Plate is overriding the Indo-Australian Plate. Where oceanic plates collide massive trenches may form at the subductive margins and some, such as the Mariana Trench east of the Philippines, are up to 10 km deep. Island arcs are often formed through associated volcanic activity.

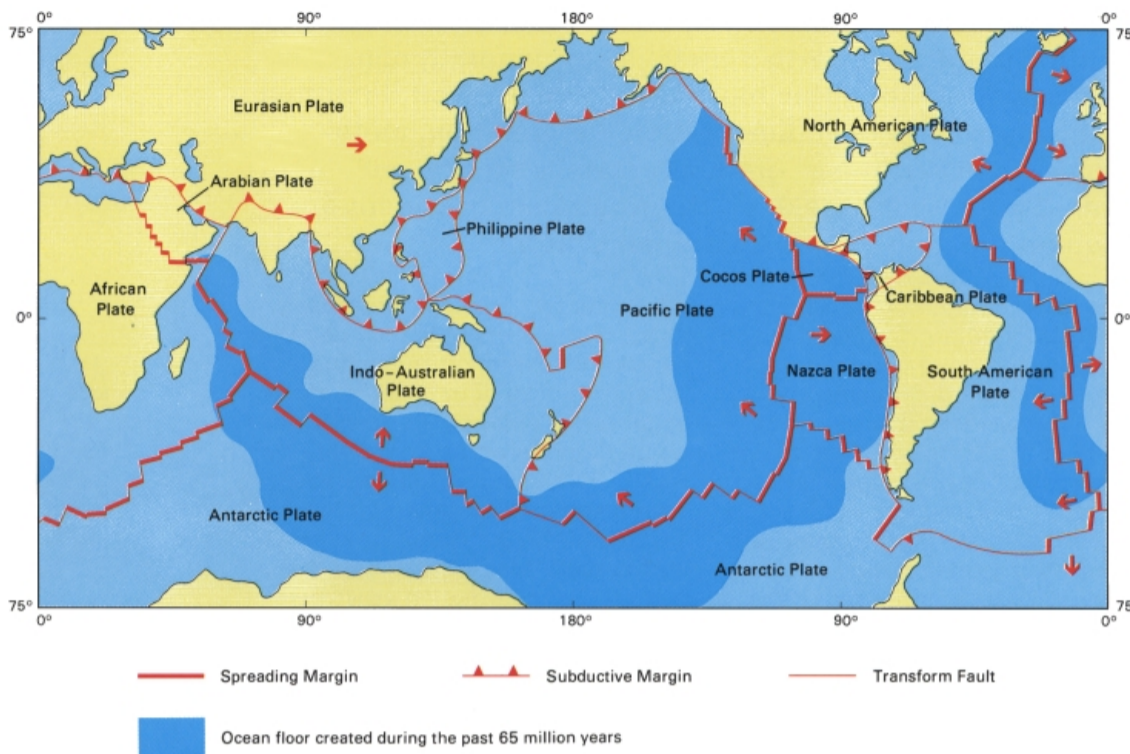
Alternatively the two plates may merely rub against each other along an extensive *transform fault*. Such faults are, nevertheless, regions of potentially hazardous earthquake activity as more sudden plate movements can quickly result in massive urban destruction and loss of life. Perhaps the most famous is the San Andreas fault in California, U.S.A. Over a long period the relative displacement of plates along transform faults may amount to hundreds or even thousands of kilometres.

The Indo-Australian Plate is currently experiencing both subductive and transform fault activity at its edges. The Australian continent, however, is considered to be relatively stable and at low risk from major earthquakes because the

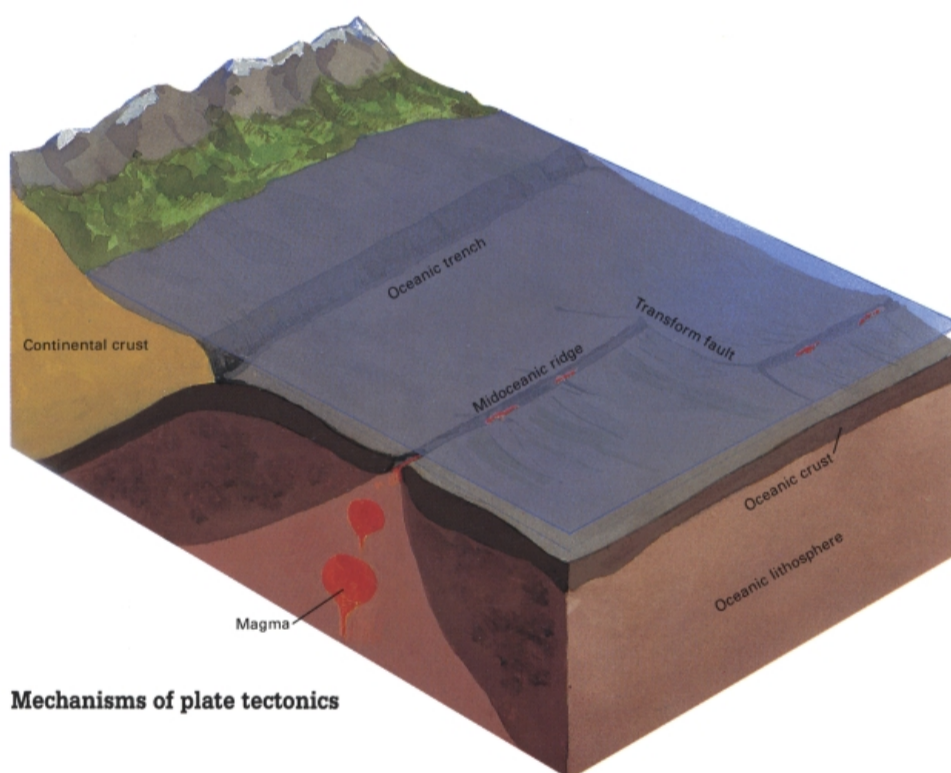
landmass is generally distant from the plate margins. To the north-west it is being driven underneath the much larger Eurasian Plate. Here a deep oceanic trough has formed where Indo-Australian rock is being forced downward by the Eurasian Plate. But immediately to the north a line of islands (the Indonesian Archipelago) has formed as a result of intense volcanic activity associated with this subduction. Here crustal rock and much seawater have been returned to the asthenosphere from where, under intense heat and pressure, they have been forced back to the surface by violent volcanic eruptions.

On the other hand, further east, where the Indo-Australian Plate is rubbing against less massive plates, transform faulting and crustal deformation (the strong folding of crustal rocks) is occurring. This has resulted in vigorous mountain building activity and some, though less violent, volcanic activity has given rise to the highlands of New Guinea and the New Zealand landmass.

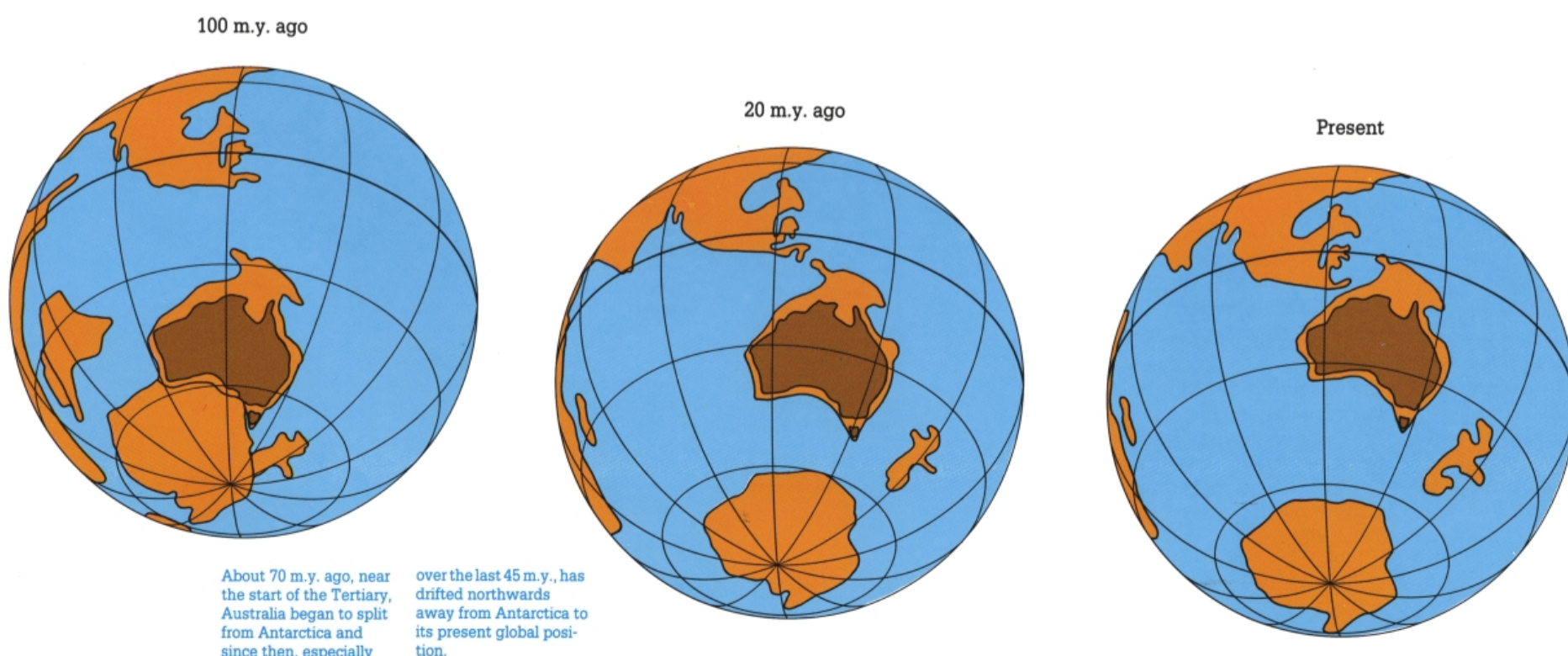
The present global position of Australia is the result of many millions of years of floating on a moving carpet of denser rock. Its previous global positions can be estimated from the study of fossilised magnetic fields in rocks that contain easily magnetised minerals (most commonly iron). As igneous rocks solidify, their mineral components susceptible to magnetisation take on the local direction of the earth's magnetic field. Thus their latitude and orientation relative to the poles at the time of their formation can be measured. Also, because the earth's magnetic polarity reverses several times each million years (that is, magnetic 'north' becomes magnetic 'south' and vice versa), the chronology of the formation of oceanic crustal rock, which is highly magnetic, can be measured and interpreted in a way similar to the study of tree growth through annual growth rings.



Major world tectonic plates
Adapted from Flint and Skinner (1974), Long (1974), and Plummer and McGeary (1985).



Mechanisms of plate tectonics



About 70 m.y. ago, near the start of the Tertiary, Australia began to split from Antarctica and since then, especially over the last 45 m.y., has drifted northwards away from Antarctica to its present global position.