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Geology of granite

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Abstract

The genesis of granite is intimately related to the dynamic structure of the Earth. Granite is the main component of continents; it is one of the oldest known rocks; and the geological history of granite provides the main evidence about the growth and evolution of continents through time. Granite formed in a number of different situations. Some granite was generated in zones of rifted continental or oceanic crust, but most granite was generated in zones of collision between continents and oceanic crust, and where continents were amalgamated. Granite formed by two different processes: by fractional crystallization of basaltic magma; and by melting older continental crust. Between these end members, there is a spectrum of hybrid processes, including mixing of basaltic and granitic magmas, and contamination of basaltic magma by partial melts of different kinds of continental crust. Although superficially simple and similar, most granites reflect a complicated history of multistage, hybrid processes. This complexity has led to a diversity of interpretations, and the origin of granite has been one of the most hotly debated topics in geology.

The following review outlines the nature and diversity of granite; where, how, and when granite was generated; how it was intruded through the crust; the structures that it formed; and the history of debates over its origin.

What is Granite?

Granite is one of the most abundant, and most widely known, rocks on Earth. The continents are dominated by granite; it forms the most ancient cores of long eroded continents, as well as lofty peaks of the youngest mountain ranges.

Granite is an igneous rock comprising crystals of quartz, feldspar, mica and/or hornblende or pyroxene. The crystals are generally large (a few mm); they can be seen directly on outcrops, and give granite its rough texture on weathered surfaces. If most crystals are of similar size, a granite is described as even grained. If a granite contains very large crystals of feldspar (0.5 – 3.0 cm long), set in an even grained matrix, it is described as **porphyritic**, and the very large crystals are called **phenocrysts** (Fig 1). The crystals in granite are large because granite crystallized slowly from molten rock (**magma**), over 2 km below the Earth's surface. Where the same magma escaped upwards, and was erupted through fissures or volcanoes, it crystallized rapidly, forming small crystals or glass, and produced volcanic rocks.

The colour of most granites ranges from pink to cream, white and grey, and generally reflects the colour of the dominant feldspars. Many granites contain straight, parallel-sided, cream or pink veins of **pegmatite** (Fig 1). This is generally a very coarse grained variety of granite that crystallized from residual granitic magma in cracks that formed during, or soon after, the solidification of the host granite.

Quartz and feldspar are the dominant minerals in granite, and together make up 90% of the rock. Quartz itself generally ranges from 20-45% and feldspar up to 60% of the granite. The proportions of these minerals, and the kinds of feldspars, are used to divide granites into a number of types. Feldspars are alumino-silicates

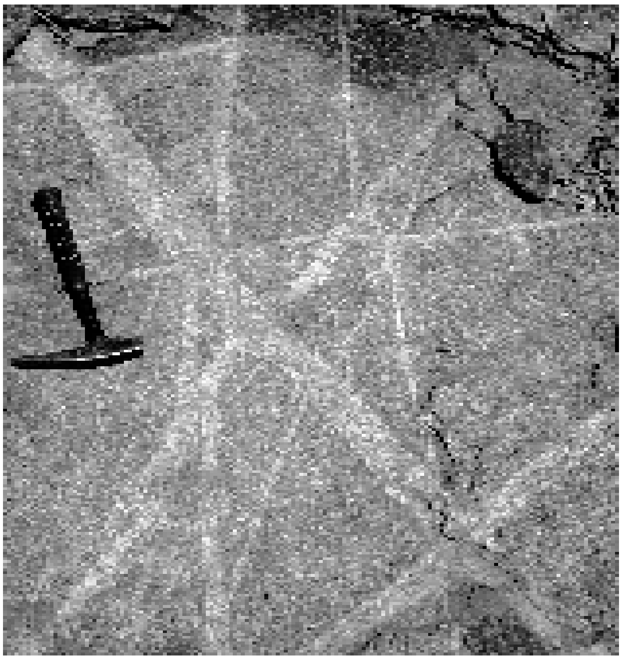

Figure 1. Typical outcrop of (porphyritic) granite in Western Australia. The rock comprises large, short tabular (white) feldspar crystals (phenocrysts) in an even grained matrix of smaller crystals of biotite (black), quartz (white), and feldspar (white). The granite is crossed by a number of white pegmatite veins, comprising quartz and feldspar crystals that grew in fissures as the fissures opened. The granite is about 2700 million years old, and is located about 120 km northwest of Meekatharra.

Granite Outcrops Symposium, 1996

that contain a range of calcium, potassium and sodium. They are divided into two groups on the basis of these three elements: potassium or alkali feldspar, and plagioclase that itself ranges from calcium-rich to sodium-rich end members.

Granite *sensu stricto* is rich in potassium feldspar (up to 65% of feldspars) relative to plagioclase, and has a high content of quartz (20-60%). With increasing plagioclase/potassium feldspar ratio, and increasing calcium/sodium ratio in plagioclase, granite grades into rocks called granodiorite (plagioclase 65-90% of feldspars) and tonalite (plagioclase 90-100% of feldspars). With decreasing quartz content (quartz less than 20%), granite grades into (potassium feldspar - rich) syenite, monzonite, and (plagioclase-rich) quartz monzonite. For simplicity in this review, all these rocks of the granite family are referred to broadly as granite. They are all generally massive, coarse grained rocks, and form similar kinds of outcrops.

Granite Generation in a Dynamic Earth

The crust of the Earth is divided into two types, continental and oceanic. The continents are generally 30-40 km thick and mainly consist of granite, whereas the crust beneath the oceans is generally 5-10 km thick, and mainly consists of basalt. Granite largely consists of silica (65-75%) and has a lower density (average 2.7) than more iron- and magnesium-rich basalt (average density 3.0) with only 50% silica. Therefore the continents are more bouyant, more elevated, and thicker than oceanic crust.

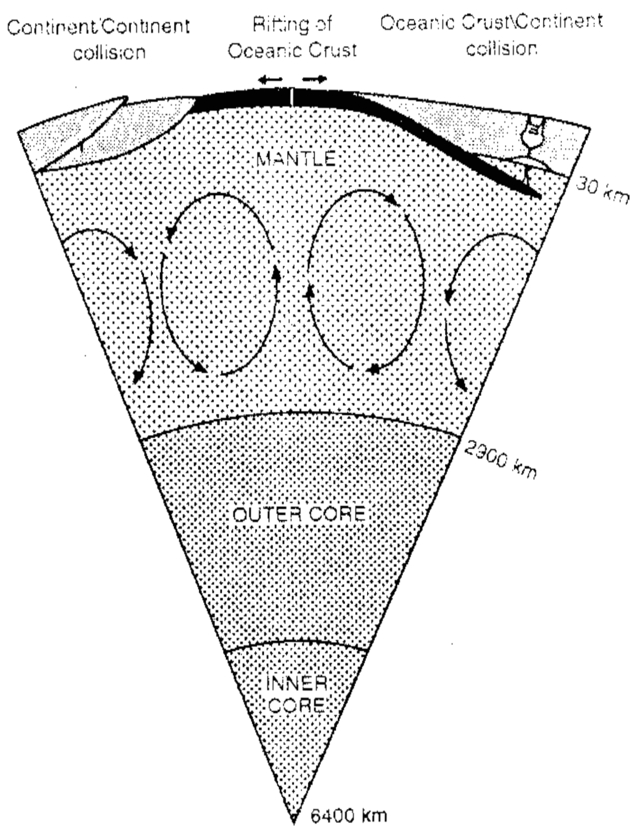

Figure 2. Section showing the main structure of the Earth.

The main structure of the Earth is shown in Figure 2. Both the oceanic and continental crusts of the Earth are relatively thin, and their thickness is exaggerated in this illustration. They float on a region of ductile, semi-molten rock called the **Mantle**, and below that lies a ductile Outer Core and a more rigid Inner Core of iron and nickel. Heat generated by radioactive decay leads to **convection** within the Mantle.

Rift zones

Where convection currents rise and move apart, the thin crust is split, and basaltic magma is erupted through the resulting fissures. Where this occurs beneath the oceans along mid-ocean ridges, more oceanic crust is generated. Most of this remains submerged, except locally where the submarine mountain chains rise above sea level, or where the oceanic crust is abnormally thick, such as in Iceland (Fig 3).

In some cases, the magma collects in pools deep in the crust and starts to crystallize. The first crystals to form, dense iron and magnesium - rich minerals (olivine, pyroxene, and spinel), may sink in the magma and accumulate at the bottom of these magma chambers. Thus the composition of the residual magma gradually becomes relatively richer in silica and alumina. This process is called **fractional crystallization** and leads to the generation of a variety of igneous rocks.

Only a small amount of granite is generated in this situation where oceanic crust is pulled apart, but where continents are pulled apart some of the older continental crust may be partly melted and rise as granitic magma. A good example of this can be seen on the east coast of Greenland which was rifted from northwest Europe about 53 million years ago as the Atlantic Ocean started to form. Basaltic magma was erupted through steep fissures called **dykes** in the splitting continental crust (Fig 4). The magma was erupted as lava flows over the subsiding edges of the rifting continent and formed extensive piles of basalt several kilometres thick. These basalt flows are well preserved in East Greenland and in northwest Britain, including the famous localities of the Giant's Causeway in Ireland, and Fingal's Cave on Staffa in Scotland.

Some basaltic magma that remained in pools within the crust crystallized slowly as gabbro (Fig 6), the coarse grained equivalent of basalt. Many of these gabbros are compositionally layered and show fractional crystallization. In some places fractional crystallization of basaltic magma, and partial melting of the continental crust, generated granitic magma (Fig 5).

Collision zones

Most granite was not formed in rift situations, but where Mantle convection currents converged. There the crust was pushed together and thickened, and the deeper parts melted. The two main situations are shown on Figure 2;

1. continent/oceanic crust collision in which granite was generated in a number of stages, and intruded passively into extending crust, and

Figure 3. Basalt lava (grey) forming extensive flows and small volcanic cones that were erupted between 1725 and 1729 AD at Krafla in northeastern Iceland. Iceland is located on the mid-Atlantic ridge that marks rifting between North America and Europe. The small valley extending between the volcanic cone in the left foreground and the cone on the far right, lies along the axis of the main rift, and formed during an episode of rifting at about 1725 AD. The darker, new lava, in the vicinity of the fumaroles in the centre and left centre of the photograph, was erupted in December 1975 at the start of a new phase of rifting and volcanic activity that continues to the present. View to the north in July 1977.

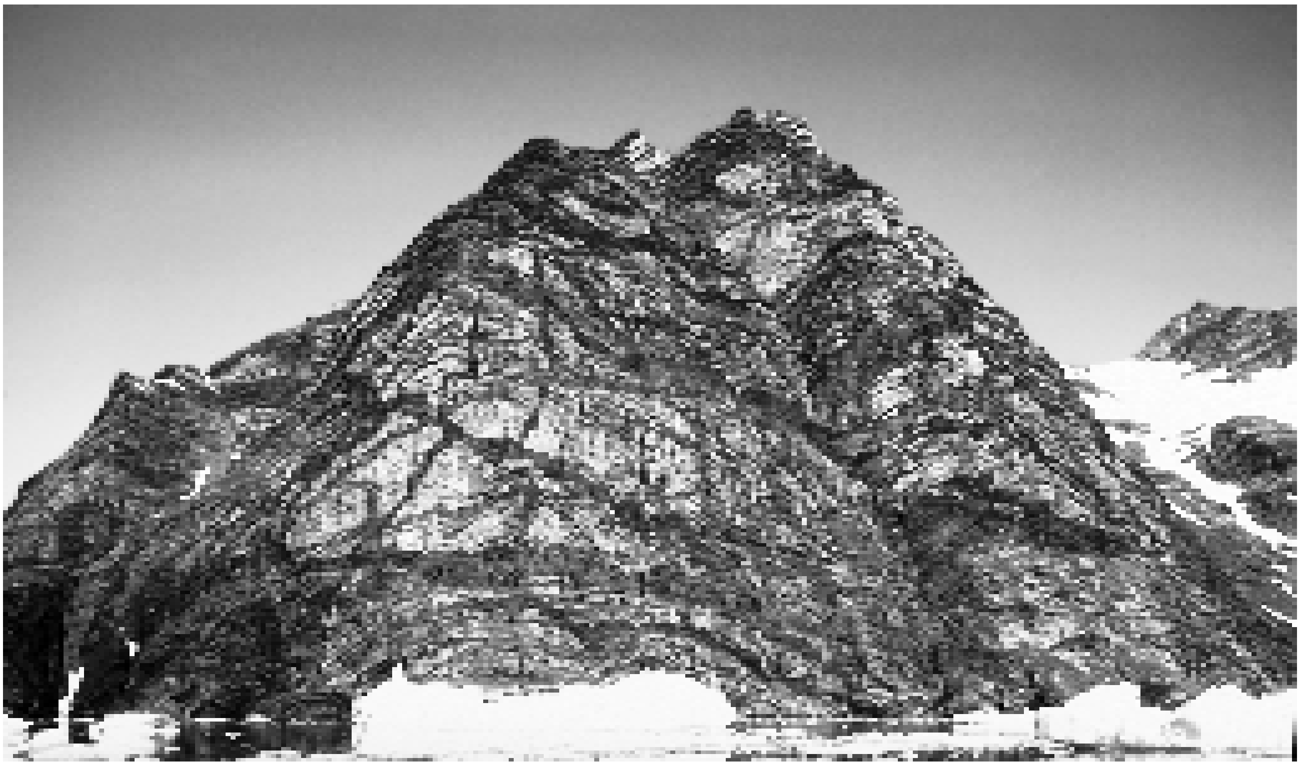

Figure 4. Black dykes of basalt intruded into fissures in much older (*ca* 2800 Ma) granitic gneiss, during initial rifting between North America and Europe. Headland between Tasîlaq and Østre Tasîssaq, west of Kap Gustav Holm, East Greenland. The mountain is 1000 m high.

Figure 5. Granite generated during continental rifting between North America and Europe. The mountain exposes the upper, dome-shaped portion of a circular granite body (white), intruded into black diorite 35 million years ago. Thin sheets of granite occur in the diorite parallel to the roof of the main granite. Auluiartik island, Kialineq, East Greenland. The mountains are 500 m high.

Figure 6. Igneous layers rich in plagioclase feldspar (pale) or pyroxene (dark) in uniform gabbro, formed during the crystallization of basaltic magma. The magma was intruded into an opening cavity at the base of a thick pile of basalt lava flows (forming the upper parts of the mountains), during initial rifting between North America and Europe about 53 million years ago. Skaergaard Intrusion, East Greenland.

2. continent/continent collision in which granite was generated directly by melting of continental crust, and was intruded as sheets that were deformed during and after crystallization.

Continent/Oceanic Crust Collision

The main features of continent/oceanic crust collision are shown in Figure 7. Oceanic crust is pushed down into the Mantle below the continental crust, forming a structure called a **subduction zone**. At depth, within this zone, the oceanic crust melts, and also introduces saline fluids which induce melting in the overlying Mantle. The melts are basaltic in composition. They collect, rise, and spread out in the lower crust where they may crystallize as gabbro, or form granitic magma by fractional crystallization and contamination with melting continental crust. The granitic magmas collect and rise to form large bodies that may fractionate further, forming a whole spectrum of different granitic magmas that, with increasing contents of silica and alkalis, may crystallize as tonalite, granodiorite and granite.

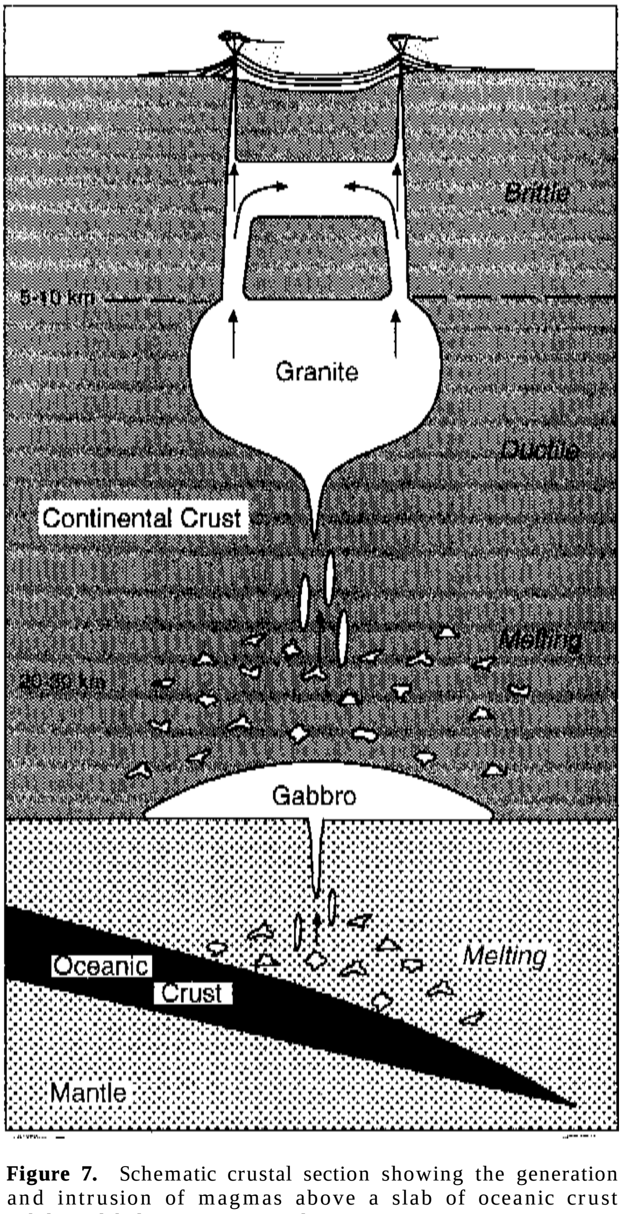

Figure 7. Schematic crustal section showing the generation and intrusion of magmas above a slab of oceanic crust subducted below a continental margin.

Granite intrusion processes

In the lower, ductile, part of the continental crust, granitic magma may rise as diapirs that push aside the adjacent rocks (Fig 8). In higher, semi-ductile, parts of the crust, where the magma can no longer rise diapirically, it may spread out to form bodies with flat floors and dome-shaped roofs called **laccoliths** (Fig 8). In the upper, brittle, part of the crust, granitic magma is intruded along fractures (Figs 8 and 9). In some cases the fracturing leads to the collapse of large blocks of crust, with dimensions of several kilometres, that founder into underlying pools of magma. The magma rises up the vertical fractures and fills the space being created by the sinking block. This is the main process by which large volumes of granitic magma are intruded to high levels in the crust, and is called **cauldron subsidence** (Figs 8

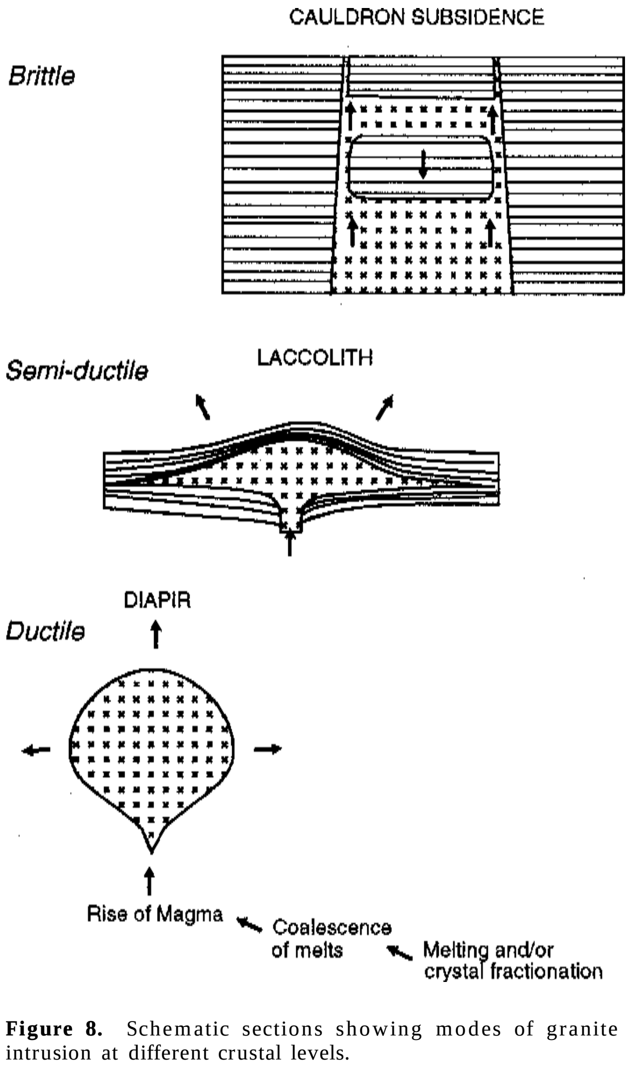

Figure 8. Schematic sections showing modes of granite intrusion at different crustal levels.

and 9). The process of fracturing of the older rocks around granite intrusions is called **stoping**, and leads to the incorporation of angular fragments of wall and roof rocks into granitic magma chambers (Fig 10). These rock fragments are trapped in the granite as it solidified and are known as **xenoliths** or inclusions.

Inclusions can also arise by a completely different process. In many instances, dykes of basaltic magma were intruded from deeper magma chambers up through and into granite plutons and crystallizing bodies of granitic magma. Where the granite was already solidified, the basaltic dykes crystallized in the straight fractures into which they were intruded. But where the granite was still a mixture of liquid and crystals, the dykes, after intrusion as linear bodies along shock induced fractures, broke up into linear trains of globular fragments called **pillows** within the still unconsolidated granite (Fig 11).

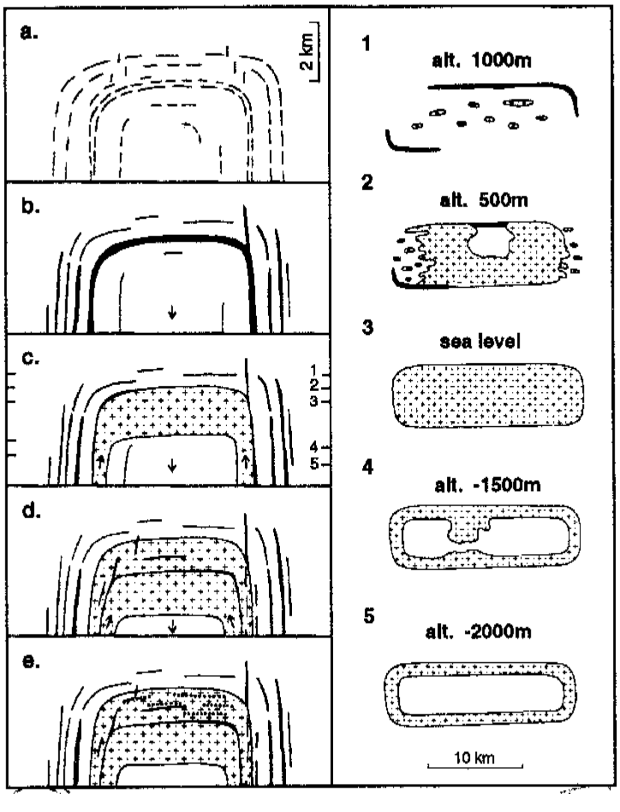

Figure 9. Left: Vertical sections showing progressive stages **a - e** in the intrusion of granite by cauldron subsidence in the Coastal Batholith of Peru. **a**: fractures define the framework of cauldron subsidence; **b**: turbulent mixtures of gas and magma (black) move up the fractures; **c**: the central block of older rocks (white) subsides and granitic magma (crosses) is intruded into the opening space; **d**: the granite body is displaced downwards by a second episode of cauldron subsidence; **e**: flat-lying sheets of pegmatite (dots) are intruded into the roof region of the second granite body during further slight subsidence. **Right**: Horizontal sections of the granite plutons at the five levels marked on section c.

Figure 10. Angular fragments of older rocks (stippled) incorporated by stoping into granite (white) 66 million years ago. Puscao granite, Coastal Batholith of Peru, 25 km ESE of Huarmey.

Granite structures and cordilleran batholiths

Magmas generated along subduction zones rise to form narrow, linear belts, generally 50 - 100 km wide and thousands of kilometres long. These belts occur within, and parallel to, the margins of continents. The Andes (Fig 12) provides one of the simplest examples. Here, in a head-on collision, the South American continent is being pushed over Pacific oceanic crust. This situation has existed for over 100 million years, and Figure 12 shows the extent of granite and associated volcanic rocks generated during this time by the processes shown on Figure 7.

The granites and volcanic rocks form a major part of the Andes, and in Peru their structure can be clearly seen in mountainous desert with vertical relief of 5 km (Fig 13). The granite bodies have steep walls and flat roofs. The cross section, Figure 14, shows some of the complexity of repeated granite intrusion by cauldron subsidence into the same 50 km wide belt, over a period of 35 million years, between 100 and 65 million years ago. A complex of related granite bodies such as this is called a **batholith**, and batholiths that formed above subduction zones are known as **cordilleran batholiths**.

Associated volcanic debris

Here in the Andes, the granites rose into volcanic rocks derived from the same magmas. In some places they are associated with calderas, large circular depressions, up to 25 km in diameter, in which the older volcanic rocks sank into underlying bodies of magma. At the same time, large volumes of volcanic rocks were explosively erupted from circular fissures around the caldera rims. High clouds of ash, steam and gas, dropped rock and crystal fragments over vast areas, forming deposits that later solidified to form a volcanic rock called tuff. In some cases the ash columns collapsed, or the eruptions did not become airborne, and the erupted mixtures of hot gas, magma, crystals and rock fragments travelled as turbulent flows for huge distances (often over 50 km), very fast on thin cushions of gas, and left deposits of fused fragmentary volcanic rocks called ignimbrite. These deposits are widely preserved in southern Peru and northern Chile (Fig 15) where, because of extreme aridity, there has been less incision by erosion than in central and northern Peru, and southern Chile.

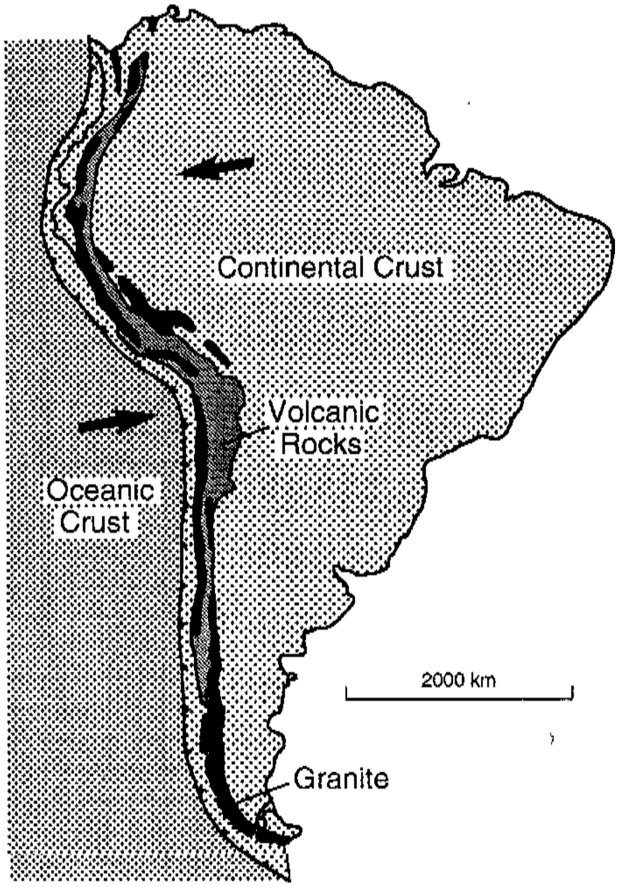

Figure 12. Map showing major outcrops of granite and volcanic rocks of the Andes, formed along the continental margin of South America where Pacific oceanic crust is subducted below continental crust. Arrows indicate the main direction of movement of the two slabs of crust.

Figure 11. Black pillow fragments of a basalt dyke intruded into a granite before the granite had solidified. Note the cauliform margins of the pillows indicating that both basalt and granite were ductile when the basalt dyke was fragmented. Lilleø, Kialineq, East Greenland.

Continent/Continent Collision

Granite was also generated from melting of continental crust where continents collided and thickened as one was pushed over the other (Fig 2). This situation is still active in the Himalayas and beneath the Tibetan Plateau where the Indian continent has already been pushed for 2000 km under the edge of the Eurasian continent during the past 50 million years.

Many continental margins involved in continent/continent collisions were preceded by episodes of continent/ocean collision in which granite was generated above subduction zones, as in the Andes. In the Himalayas, the 2500 km long Transhimalayan Batholith and part of the Karakoram Batholith (Fig 16) formed as Andean-type cordilleran batholiths above subduction zones, before the collision of India and Eurasia. In many cases, thin strips of older continental crust, ocean ridges, oceanic plateau, and basaltic island arcs such as those now forming in Java and Japan where oceanic crust is subducted below another slab of oceanic crust, were swept against a continental margin and trapped and deformed during later continent/continent collision. Therefore the structure and geological history of most continent/continent collision zones is much more complicated than those of continent/ocean collision.

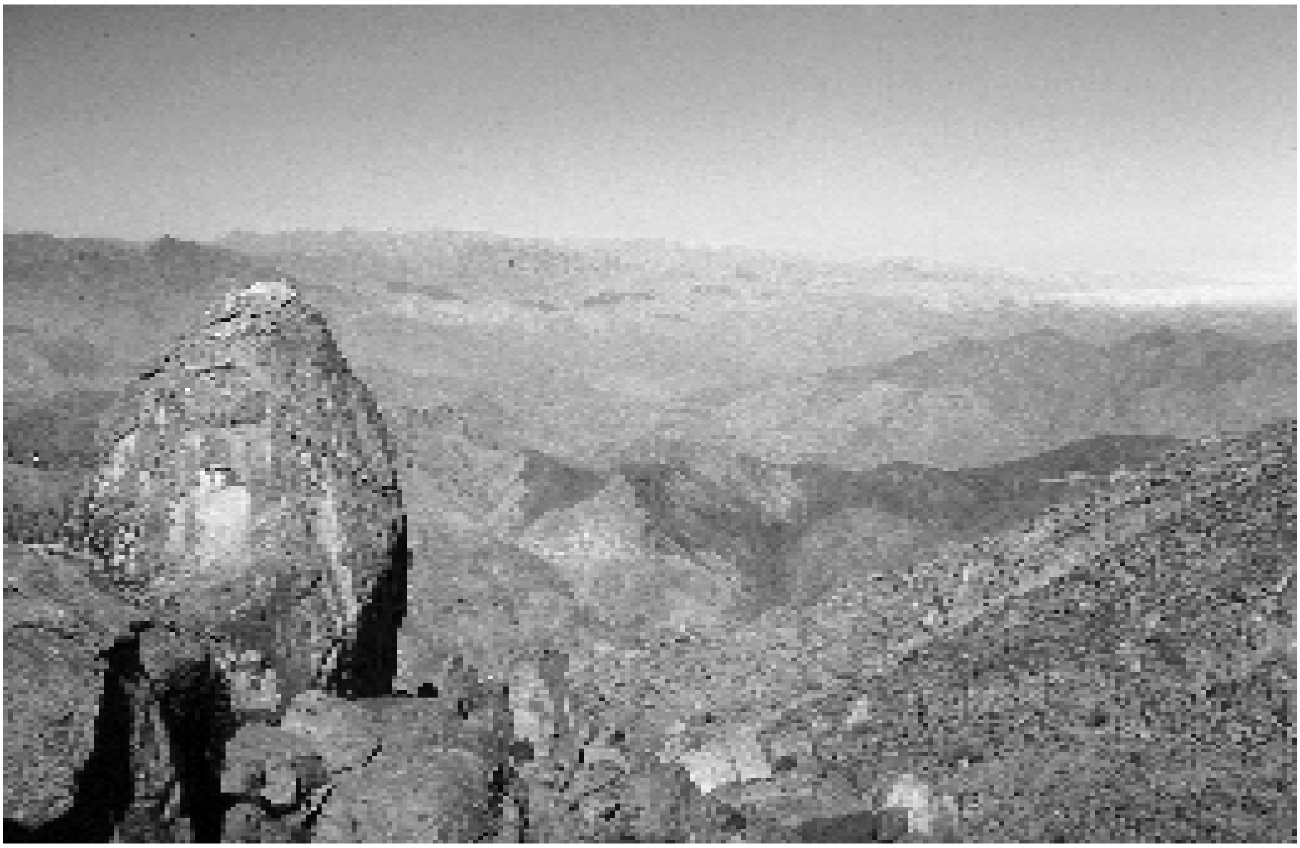

Figure 13. Extensive granite outcrops forming a belt 50 km wide and 2000 km long in the Andes in Peru. View southeast along the Coastal Batholith from an altitude of *ca* 2100 m, west of Chasquitambo. The batholith was mainly intruded between 100 and 65 million years ago into coeval volcanic rocks. The volcanic rocks (black), forming the flat roof of the batholith, can be seen in the distant (left) mountain peaks, and on a chain of peaks in the distant centre within a ring dyke of granite, 1 km thick and 25 km in diameter, emplaced by cauldron subsidence. Similar volcanic rocks occur beneath the fog (distant right), where they form the western vertical margin of the batholith adjacent to the Pacific Ocean. The black rocks in the middle foreground are large fragments of gabbro that crystallized from basaltic magma before the intrusion of the granite.

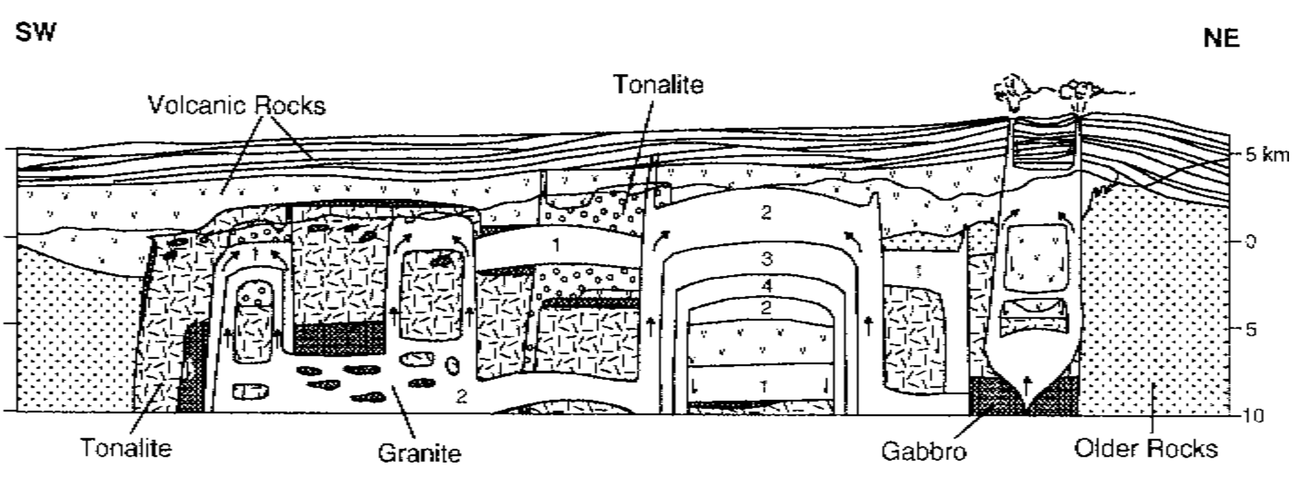

Figure 14. Vertical section across a typical cordilleran batholith showing the structure formed by repeated episodes of igneous intrusion of gabbro, tonalite and granite by cauldron subsidence into related volcanic rocks. Section across the Coastal Batholith of Peru, located due west of the word continental crust on Figure 12. Note that horizontal and vertical scales are equal.

Figure 15. Valley (foreground) incised into extensive sheets of ignimbrite, erupted from granitic magma in northern Chile. The ignimbrites were erupted from fissures parallel to the western summits of the Andes (left) and flowed down towards the Pacific Ocean (off to the right), between 10 and 5 million years ago. Volcanic cones (distant left) formed from eruptions of basalt and andesite during the past 1 million years. View south from an altitude of 4300 m between Tatio and Lasana.

Figure 16. Granite (distant snow-covered 7000 - 8000 m peaks) of the Karakorum Batholith that initially formed at c. 90 Ma during subduction of oceanic crust beneath the margin of Asia before the collision with India about 50 million years ago. View to the north from an altitude of *ca* 2500 m, east of Hunza, Pakistan. The Hunza valley (foreground) was incised during recent, ongoing uplift of the Himalayan range.

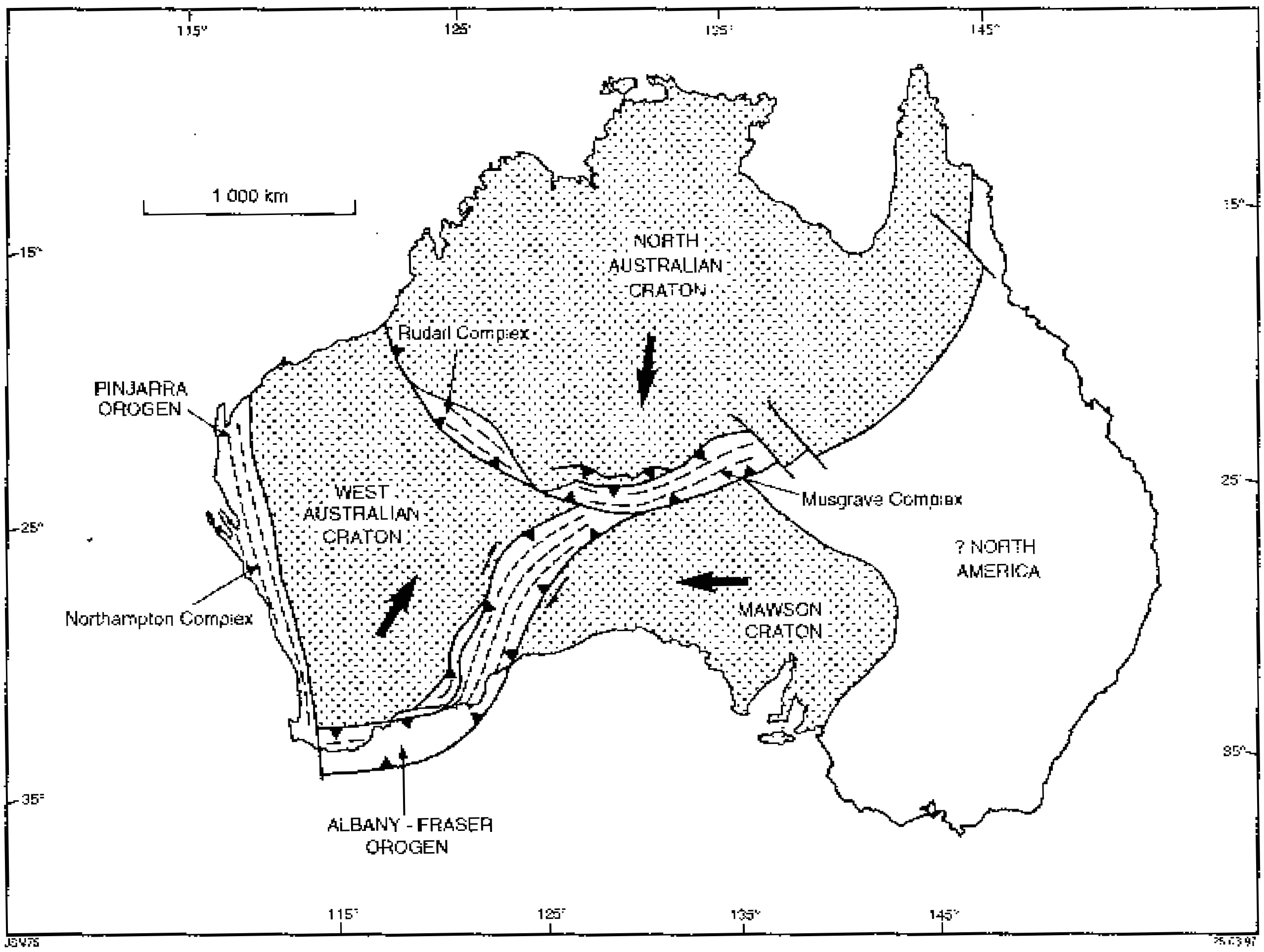

Figure 17. Map showing the assembly of three independent rafts of continental crust (cratons) 1300 million years ago, and the location of the Albany-Fraser Orogen, Arrows indicate the main directions of movement of the three continental rafts.

Albany-Fraser Orogen

Some of the products of continent/continent collision can be seen in the old, deeply eroded remnants of former mountain belts in Western Australia, such as the Albany-Fraser Orogen. About 1300 million years ago, three rafts of continental crust were joined to form a major part of what is now the Australian continent (Fig 17). The south coast of Western Australia exposes the roots of a mountain belt that formed at this time when a West Australian **craton** or continent, was joined to a combined South Australian - East Antarctic continent called the Mawson Craton. This kind of collision zone is called an **orogen,** and this particular zone is known as the Albany-Fraser Orogen.

Granite was extensively generated during two distinct episodes of this continental collision, and forms the main rock outcrops of the region. The older granite, called Recherche granite, was intruded intermittently during the collision 1300 million years ago (Fig 18). At that time the margin of the Mawson continent was being deformed and thickened as slabs of continental crust were stacked over each other. Some of the granite was intensely deformed and recrystallized, deep in the crust. Pegmatite veins and inclusions were all streaked out into parallel layers and the granite was converted into a metamorphic rock called **gneiss** (Fig 19). There is widespread evidence that a smaller amount of granite also locally formed *in situ* by melting of older (1700 - 1600 Ma) granite of the Mawson continent, immediately after the initial episode of deformation and crustal thickening at 1300 Ma (Fig 20). This kind of metamorphic rock, comprising a mixture of older rocks with younger veins of granite, and diffuse patches of melting, is known as **migmatite**.

The younger granite, intruded about 1180 million years ago, is called Esperance granite (Fig 21), and is prominent to the east and northeast of Esperance, along the south coast from William Bay through Albany to Mount Manypeaks, and forms the Porongorups. This granite, like the Recherche granite, may be largely derived by melting of older continental crust at depth, during another episode of oblique compression in which

Figure 18. 1300 Ma Recherche Granite with angular stoped and veined fragments of previously deformed, darker, 1700 - 1600 Ma granite containing remnants of basaltic dykes. Albany-Fraser Orogen: coast south of Lake Gore, west of Esperance.

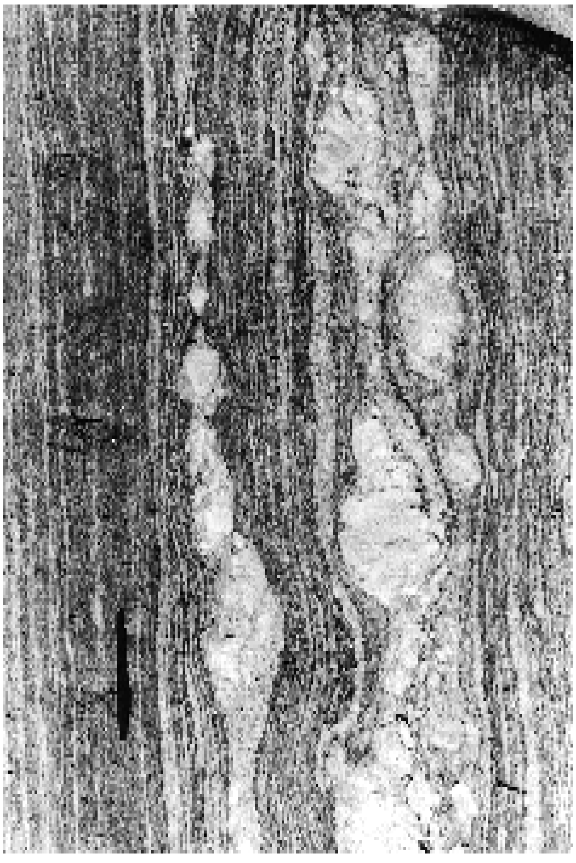

Figure 19. Banded granitic gneiss formed by intense deformation of granite and pegmatite veins (Recherche Granite) 1300 million years ago in the Albany-Fraser Orogen. Butty Head, west of Esperance.

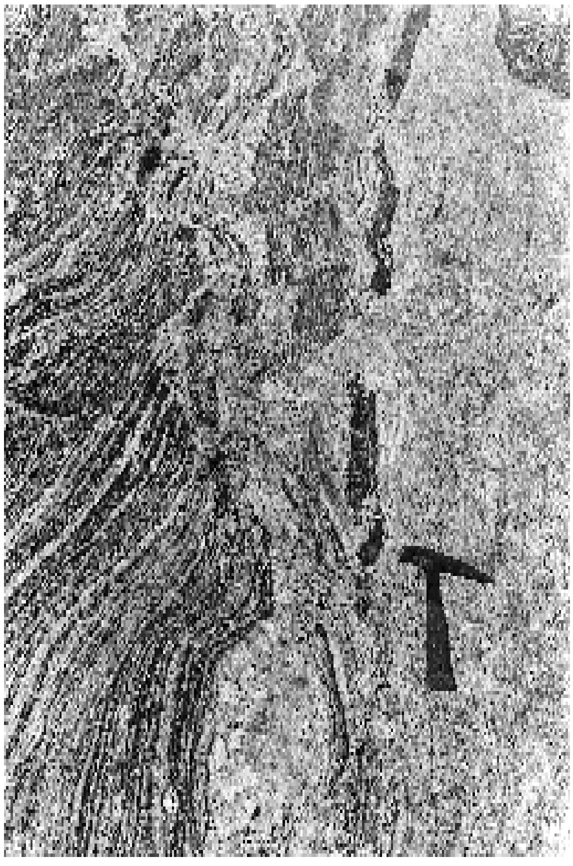

Figure 20. Irregular, diffuse veins of (pale) granite (beneath the hammer) formed 1300 million years ago by melting of older banded granitic gneiss (1650 Ma) in the Albany-Fraser Orogen. South of Lake Gidong, west of Esperance.

Figure 21. Outcrops of porphyritic Esperance granite in the Albany-Fraser Orogen, east of Esperance. This granite contains fragments of older Recherche granite, into which it was intruded 1180 million years ago. View to the southeast, at Thistle Cove, east of Cape Le Grand.

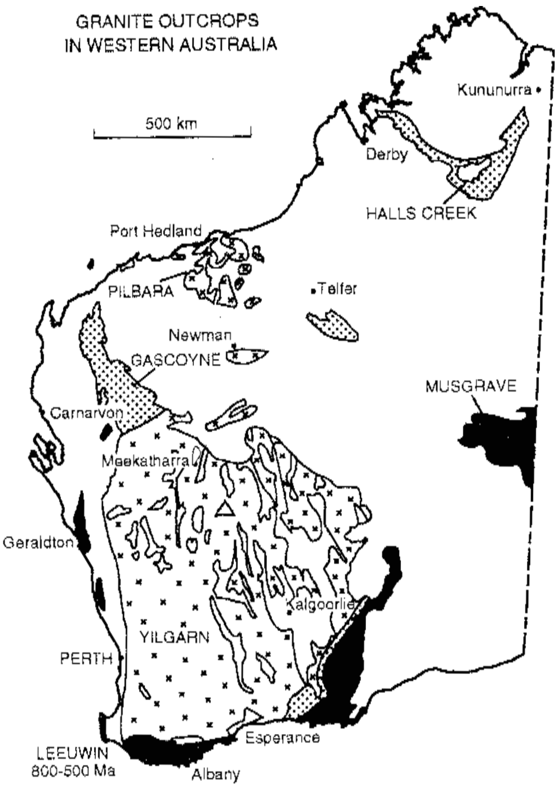

Figure 22. Map showing the main granite outcrops in Western Australia, with the ages of granites given in million years (Ma). Note that the granite in the vicinity of Cape Leeuwin is much younger than all the other granites shown.

the West Australian continent continued to slide northeastward relative to the more westerly-moving Mawson continent.

Older orogens in Western Australia

There are several remnants of even older orogens in Western Australia that mark former episodes of continental collision and granite generation. The most prominent orogens with extensive granite outcrops occur in the Kimberley region (Halls Creek and King Leopold orogens), and in the Gascoyne region (Capricorn Orogen) (Fig 22). The Capricorn Orogen marks the joining of the formerly independent Pilbara and Yilgarn continents about 2000 million years ago. Granite was generated in a cordilleran-type batholith before the collision (Fig 23), and again during and after the collision by melting of thickened continental crust.

These older Pilbara and Yilgarn continents also largely consist of granite, although in the Pilbara much of this is buried by volcanic rocks and the Hamersley banded iron formations. The most extensive granite outcrops form part of the Yilgarn Craton or continent. Most of these granites were generated by melting of older continental crust between 2700 and 2600 million years ago (Fig 1), when this continent was assembled from a number of smaller rafts of continental crust. Deformed remnants of older continental crust are exposed in the Narryer gneiss complex that forms the northwest part of the Yilgarn Craton, northwest of Meekatharra. These gneisses are largely derived from granite, including some of the oldest known rocks on Earth that formed 3600 million years ago (Fig 24).

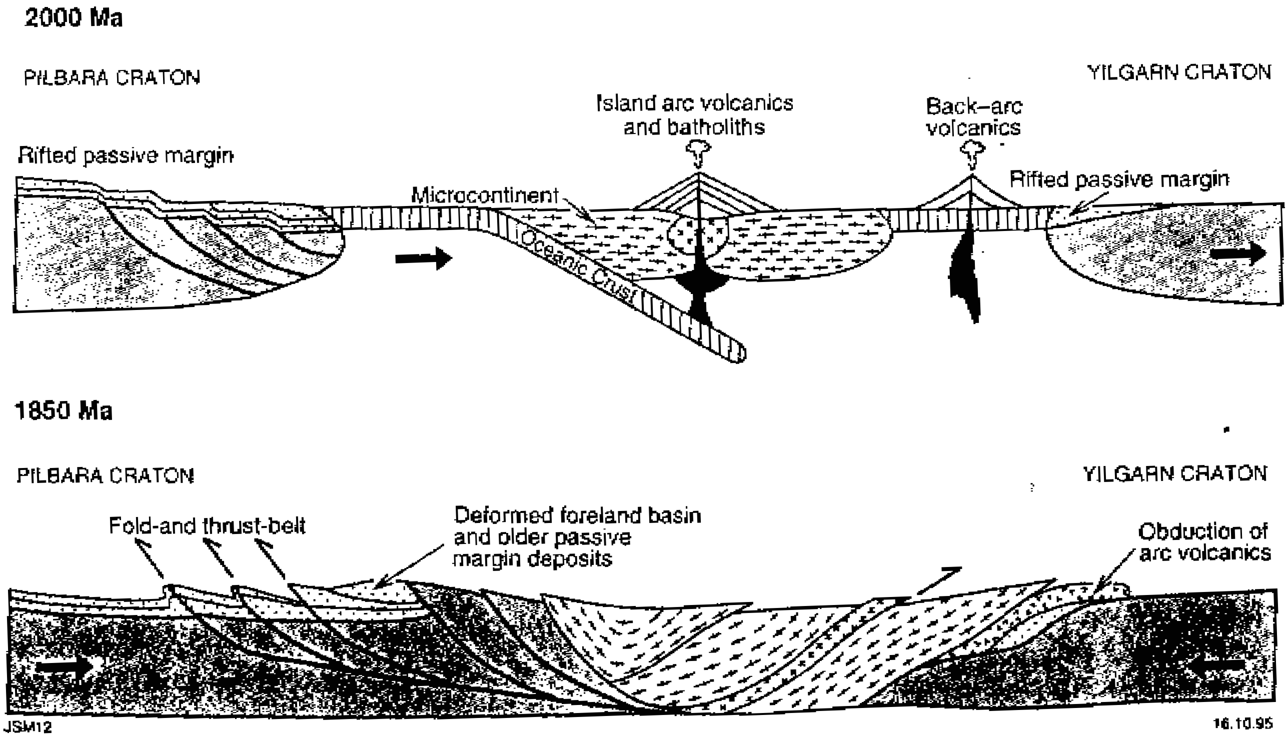

Figure 23. Schematic, vertical cross-sections showing the generation (at 2000 Ma) and deformation (at 1850 Ma) of granite (diagonal crosses) in a cordilleran batholith involved in continental collision between the Pilbara and Yilgarn cratons.

Figure 24. Granite (below the hammer) intruded between 2700 and 2600 Ma into banded gneiss (top right), derived from much older, 3600 Ma, granite by deformation and recrystallization. Narryer gneiss complex, 170 km northwest of Meekatharra.

Granite in Historical Perspective

During the late 18th century, when geology was in its infancy, it was widely believed that granite was the oldest of rocks and was a precipitate from a world-wide ocean of molten rock. Supporters of this idea, advocated most strongly by Abraham Werner from the Mining Academy of Freiburg in Saxony, were known as **Neptunists**. This concept was first challenged in 1795 by James Hutton of Edinburgh who described veins of granite cutting across sedimentary rocks in Scotland, in his book "Theory of the Earth". He saw that the sedimentary rocks were baked by the granite and concluded that the granite must have been intruded as a hot liquid from subterranean regions of molten rock. His supporters were known as **Plutonists**, but were a small minority until joined by the influential Charles Lyell in the 1830s.

During the 1830s, just as Hutton's concept of the igneous origin of granite was becoming widely accepted, granite was found in many places to be closely associated with rocks that had been transformed under conditions of high temperature and pressure, deep in the Earth, into rocks that Charles Lyell called metamorphic. Various kinds of igneous and sedimentary rocks appeared to have been converted into granite by a process known as **granitisation**. This theory of granite formation became predominant during the latter part of the 19th century, and remained so until the early 1960s. Its supporters were generally known as **transformists**. This theory was widely supported in France by Michel-Levy, Lacroix, Termier and others; in Scandinavia by Keilhau and Sederholm; in Switzerland by Wegmann; and in Britain by Read. Meanwhile, during the first half of the 20th century, a minority led by the experimental and geochemical work of Bowen and Nockolds demonstrated the importance of fractional crystallization in producing a diversity of igneous rocks from basalt to granite.

The last 30 years has seen a general decline in the popularity of granitisation, and more popular support for an igneous origin of granite. The advent of plate tectonic theory during the late 1960s provided a framework in which a diversity of different interpretations of different kinds of granite could be reconciled.

Some granites formed by melting, or partial melting, of older heterogeneous continental crust, ranging from gabbro and granite to sedimentary rocks. Some granites formed by fractional crystallization from basaltic magmas. Many granites were derived by a combination of both processes: by fractional crystallization of basaltic magma, contaminated by heterogeneous continental crust; and by mixing of basaltic and granitic magmas.

The bulk composition and texture of many granites are superficially similar, but this often masks a complicated history of multistage, hybrid processes. Detailed geochemistry, especially of trace elements and isotopes, and detailed geochronology, especially analysis of individual zircons, are becoming increasingly important in deciphering the source rocks, the conditions of melt generation, and the evolution of granitic magmas.

Debates on the origin of granite continue. Although abundant and superficially simple, the interpretation of granite still offers exciting challenges for future generations of geologists.

References

Much of what is said here about granite can be found in current geological textbooks. In addition, a recent book by Pitcher (1993) on granite, provides a detailed account of current knowledge of granite and its historical perspective. Another overview of granite geology is given by Atherton (1993). The proceedings of a 1995 conference on granite (Brown *et al.* 1996) present a spectrum of recent work on the geology of granite. Other recent key references to Western Australian granites mentioned above are included in this selected bibliography.

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