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The late Archaean and early Proterozoic: what happened next? (extended abstract)

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One of the most interesting processes of the Archaean and early Proterozoic is the development of continental crust, from the generation of greenstone belts to the gradual amalgamation, rifting and regrouping of continental fragments. The geological history of Western Australia is an excellent illustration of this process. This abstract gives a brief and simplified overview of the main events.

Western Australia consists of two Archaean blocks, the Pilbara and Yilgarn Cratons, which have completely different histories (Figure 1). The Pilbara Craton is discussed in detail by White et al., Nijman and Zegers et al. in this issue and consists of half a dozen oval to round granitoid batholiths surrounded by greenstone belts and small sedimentary basins. This apparently simple structure was built up during three main cycles of greenstone formation and sedimentation, each associated with intrusion of granitoid rocks within the batholiths (Figure 2). The relatively simple-looking round and oval shape of the batholiths is therefore misleading, since each batholith is composed of several intrusions of different age; their present shape is largely due to the development of shear zones between the surrounding rocks and the batholiths. Although younger sequences occur dominantly in the west of the Pilbara, and older ones in the east, there are no indications that the Pilbara is made up of terranes of different age. Cratonisation of the Pilbara took place around 2.77 Ga, followed by deposition of a platform sequence of the Mt. Bruce supergroup (Fortescue and Hamersley Basins) between 2.77 and 2.4 Ga (Figures 1, 2).

The Yilgarn Craton has a completely different history. This craton has a structural 'grain' of elongate greenstone belts and granitoid batholiths trending NNW-SSE. Granitoid rocks occupy up to 70% of the present erosion surface. Contrary to the Pilbara, the Yilgarn Craton consists of up to a dozen crustal fragments with apparently different histories, that can be interpreted as terranes (Figure 1).

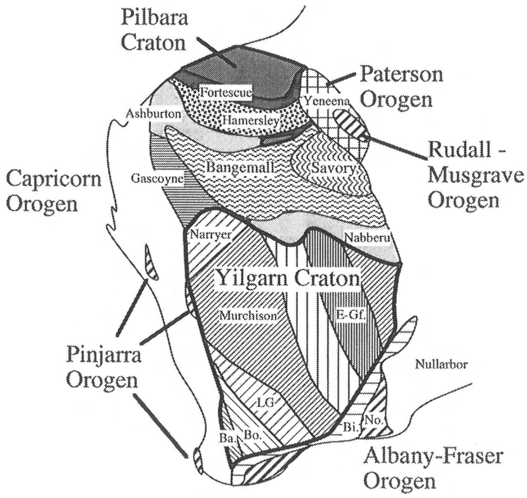

Figure 1. Schematic map of Western Australia showing the main tectonic units and basins, as discussed in the text and shown in Figure 2. E-Gf. – eastern Goldfield terrane, LG – Lake Grace terrane, Bo. – Boddington terrane, Ba. – Balingup terrane, Bi. – Biranup Complex, No. – Nornalup Complex. Area shown measures ~ 1600 km from north to south.

Although most crustal fragments contain younger material than the Pilbara, the Narryer Terrane in the north (Figures 1, 2) contains some of the oldest rocks of Western Australia and the oldest zircon crystals in the world. The different nature of the crustal fragments is well illustrated in the south-western fragments (Murchison, Lake Grace and Boddington; Figure 1) which each contain a granulite-facies metamorphic assemblage of different age (2.8, 2.64 and 3.18 Ga, respectively) in outcrops that are relatively close together (Figure 2). This fact, the completely different nature of metamorphic and tectonic history, and the presence of listric eastward dipping detachments

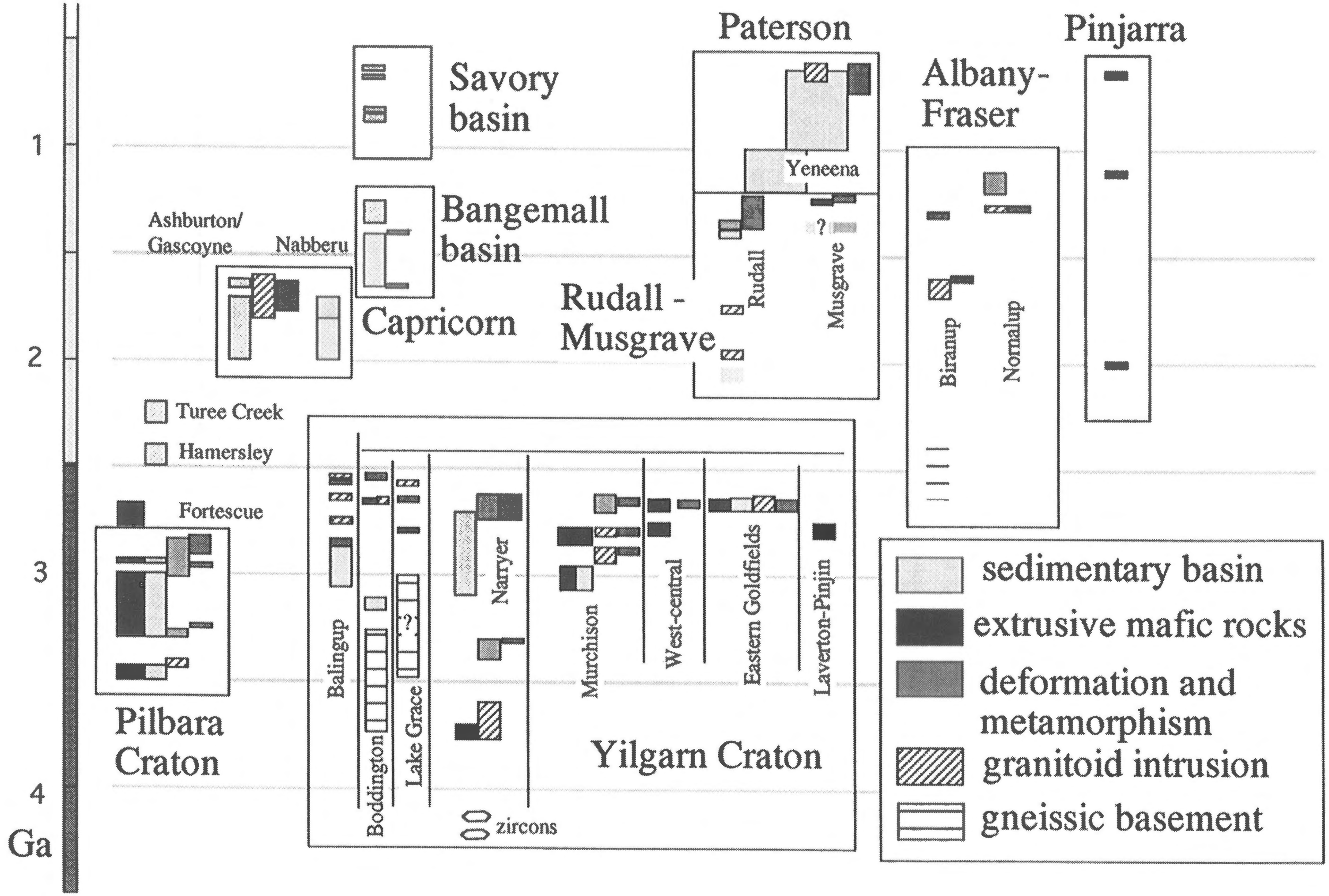

Figure 2. Schematic diagram of the main Precambrian events in Western Australia.

between these crustal fragments are good proof for an origin of these blocks as terranes that formed in different areas and amalgamated to form the Yilgarn Craton. The eastern and northern terranes amalgamated during a major tectonic event between 2.7 and 2.6 Ga while the south-western ones described above docked later (Figure 2).

Throughout the Yilgarn Craton, the 2.7–2.6 Ga tectonic event had several effects. In the east, early outpouring of mafic extrusive rocks (forming the greenstones) was followed by thrusting and possibly regional extensional movement, and by intrusion of granitoid plutons. The mafic rocks were apparently deposited on existing continental crustal material, possibly of andesitic composition. The composition of the granites changes gradually with age, and this change can be attributed to melting of progressively younger crustal material and decreasing depth. The complete picture seems to be one of massive melting in the upper mantle and extrusion and possibly underplating of mafic magmas, followed by a gradually rising metamorphic front associated with deep crustal melting. A major event of E-W shortening created the presently prominent N-S trending 'grain' of the Yilgarn by penetrative ductile deformation throughout the eastern craton, which had assembled by that time. Figure 2 shows that the western terranes (Lake Grace and Boddington) docked later than the eastern ones, and this docking on the western side of the developing craton may be associated with the structural grain of the Yilgarn. Most of the Yilgarn, with exception of the small Balingup Terrane in the utmost south-west (Figures 1, 2), was cratonised by 2.41 Ga, as shown by the presence of undeformed E-W trending dolerite dykes of this age. The Balingup Terrane docked possibly even later than this dyke intrusion event. All together, the large-scale contemporaneous generation of mafic and granitic material in the Yilgarn Craton could correspond to the presence of one or a series of mantle plumes during amalgamation of the Yilgarn Craton.

Interestingly, the 2.7–2.6 Ga event is partly contemporaneous with massive outflow of mafic lavas (Fortescue) on the Pilbara, which was cratonised by that time. There is, however, no other indication to suggest that the Pilbara and Yilgarn Cratons were already close together at this time.

Amalgamation of the Yilgarn and Pilbara Cratons to a larger crustal block took place between 2.0 and 1.6 Ga during development of the Capricorn Orogen. It is important to realise that the crustal fragments that collided along this orogen were probably larger than today, part of them having been rifted off in the late Proterozoic. Also, these larger blocks may themselves have been fragments of larger Proto-Pilbara and Yilgarn blocks. In any case, the events that took place in the presently exposed part of the Capricorn Orogen appear to have been less exotic than those in the Pilbara and Yilgarn. The central Gascoyne metamorphic complex is flanked on its northern and southern sides by foreland basins (Ashburton, Nabberu) which are internally deformed by thrusting onto the Pilbara and Yilgarn forelands. Slabs of the Pilbara and Yilgarn craton edges are interleaved in these thrust belts. The southern foreland basin contains arc-related material and rocks reminiscent of ophiolites. This fact, and the asymmetry of the thrust belts suggest that the orogen formed by collision after subduction of ocean crust towards the south. There are even indications that collision started in the east and migrated gradually westward. Molasse-type sediments occur in the northern foreland basin.

The sequence Pilbara-Yilgarn-Capricorn shows an evolution in tectonic style which is striking. In the Archaean cratons, there are periodic massive outpouring of mafic magmas and associated granite intrusion over large areas, but no ophiolites, linear thrust belts or foreland basins. This applies to the Pilbara and Yilgarn Cratons, but the Yilgarn Craton is special since it seems to consist of a large number of amalgamated terranes. In this sense, the Yilgarn is more 'modern' than the Pilbara. Finally, the Capricorn Orogen has most of the characteristics of modern orogens.

Further evolution of Western Australia is a repeated sequence of rifting and amalgamation of new continental fragments. Around 1.3–1.0 Ga, the Pinjarra, Rudall-Musgrave and Albany-Fraser Orogens have formed along the western, southern and eastern rims of a truncated crustal fragment containing the Australian parts of the Pilbara, the Yilgarn and part of the Capricorn Orogen. Originally this fragment was probably more extensive, but the fate of the fragments that rifted off the present core of Western Australia before the 1300-Ma event is unknown. However, strong similarities of the Pilbara and its cover with the Kaapvaal Craton, and of the Yilgarn with the Zimbabwe Craton could mean that these cratons are some of the missing fragments.

Presently, the only crustal fragment that is still attached to the Western Australian core is the crust underlying the Nullarbor plane southeast of the Albany-Fraser Orogen. The Rudall-Musgrave Orogen was reactivated as the Paterson Orogen when central Australia was juxtaposed against Western Australia between 0.75 and 0.6 Ga; it is uncertain in how far this was an intercratonic event. Quite possibly, another continental fragment was Western Australia's neighbour in the east between the 1.3 and 0.75-Ga events. Finally, the Pinjarra Orogen was reactivated in the period 0.75–0.55 Ga and the crustal fragment on its western side rifted off during the break-up of Gondwanaland and was deformed beyond recognition in the collision of India and Asia.

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