

# Evidence of thick Archaean crust in the East Pilbara

by

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New mapping and geochronological evidence gathered during the recent joint GSWA–AGSO National Geoscience Mapping Accord project in the Pilbara Craton show that the greenstone succession of the East Pilbara Granite–Greenstone Terrane (EPGGT in Fig. 1) is an upward-younging succession, 12–15 km thick, and that there was no tectonic thickening through thrusting. This, and additional evidence from numerical models, suggests that the crust may have been at least 55 km thick and that its formation may not have involved plate tectonics.

The Marble Bar greenstone belt is located along the western flank of the Mount Edgar Granitoid Complex (Fig. 1). A recent model has suggested that the greenstones represent a tectonically inverted, downward-younging succession with thrusts along bedding-parallel shear zones (van Haaften and White, 1998). This model is inconsistent with several newly obtained U–Pb zircon dates that indicate that the 12–15 km-thick succession was deposited, right way up, over 25 m.y. or more (Fig. 2: Thorpe et al., 1992; McNaughton et al., 1993; Nelson, 1999, in prep.). In addition, field mapping of synvolcanic, listric normal growth faults across unit boundaries, and of chert feeder-dike swarms that link together large parts of the stratigraphy, indicates that the bedding-parallel shears identified in the previous model accommodated only minor displacement.

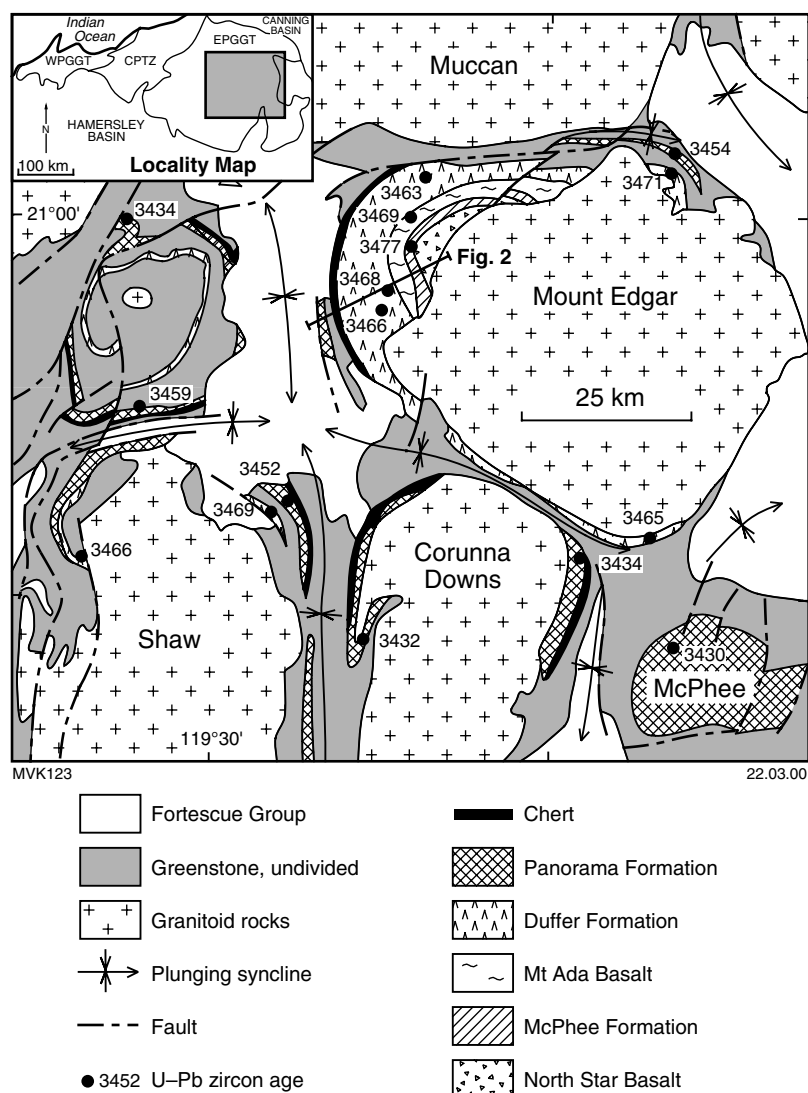
The example of the Marble Bar belt is applicable throughout much of the rest of the East Pilbara Granite–Greenstone Terrane, where numerous dates from felsic volcanic units show an extensive blanket of volcanic rocks around the granitoid complexes, spanning an age range from 3471 to 3430 Ma. In these other areas, estimates of the stratigraphic thicknesses are also up to 15 km. These are minimum estimates because they do not allow for tectonic flattening.

The mechanism of generating the dome-and-basin pattern through punctuated partial convective crustal overturn over 800 m.y. has been described previously (Hickman, 1984; Collins et al., 1998). An estimate of the total crustal thickness can be made by scaling the numerical model of diapirs by Mareschal and West (1980) to the actual dimensions of the dome-and-basin pattern. This yields a minimum original crustal thickness of 44 km

and indicates that at least 10 km of crust have been eroded away. However, the local occurrence of maximum metamorphic pressures of approximately 6.5 kbars, combined with the fact that Pilbara granitoid complexes are wider than those of the scaled model at 10 km depth, suggests that the crust has been eroded to some 20 km depth and that it may therefore have been at least 55 km thick.

A viable model for the formation of Archaean crust that is 55 km thick or more must account for a) the observed thickness of the volcano-sedimentary successions, b) the lack of thrusts that could structurally thicken the succession, c) the dome-and-basin structural pattern, and d) the distribution of metamorphic assemblages and metamorphic gradients. Although much of the modern oceanic crust is 5–8 km thick, oceanic plateaus formed over mantle hotspots or wetspots may reach 35–42 km (e.g. Iceland and Ontong-Java). At the base of these pieces of crust, and even more so where crust may have been approximately 55 km thick or more, hydrous basalt will melt to form typical tonalite–trondhjemite–granodiorite (TTG) magmas — all that is required is depths great enough for melting to be within the stability field of garnet and/or hornblende in order to generate the high La/Yb ratios typical of Archaean TTG. Whereas Archaean TTG magmatism has been almost exclusively interpreted as having occurred within subduction zones, recent work suggests Archaean TTGs are crustal melts that may not be related to subduction (Smithies, in prep.). A crustal origin for Pilbara TTG and associated felsic volcanism is supported by the fact that these magmas were emplaced over a roughly circular area 220 km in diameter (vs modern arcs which are linear and 50–100 km wide) and that the duration of magmatism was 60 m.y. (compared with modern arc segments that last only approximately 10 m.y.). This suggests that subduction may not have been the main mechanism for TTG magma genesis; rather the Pilbara TTG may have formed through melting of hydrated basalt and/or intraplated gabbros during prolonged plume magmatism.

Emplacement of the TTG as sheeted sill complexes into the lower greenstones stabilized the crust, made it buoyant, and shielded the upper greenstones from the higher heat flow emanating from the primitive, hotter



**Figure 1.** U–Pb zircon data on felsic volcanic rocks in the East Pilbara Granite–Greenstone Terrane. References cited in text. Sub-divisions of the North Pilbara Terrain of the Pilbara Craton: WPGGT — West Pilbara Granite–Greenstone Terrane; CPTZ — Central Pilbara Tectonic Zone; EPGGT — East Pilbara Granite–Greenstone Terrane. Location of stratigraphic column in Figure 2 is shown

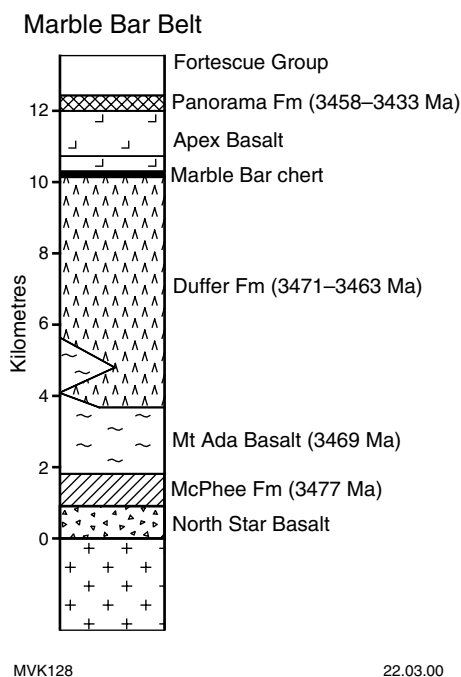
mantle. Subsequent tectonothermal events — be they extension, plume magmatism, or compression — served to amplify original topographic irregularities in the sill complex at c. 3300 Ma, 3240 Ma, 2950 Ma, 2850 Ma, and 2760 Ma.

The bedding-parallel shears noted by van Haaften and White (1998) are interpreted to have formed during tilting of the greenstones from the horizontal to the vertical within narrow inter-diapir synclines as a result of deformation associated with granitoid diapirism. The low overall metamorphic grade of the greenstones may also be explained by diapirism, as may the local occurrences of higher grade assemblages (Collins and Van Kranendonk, 1999). Contact metamorphism of greenstones occurred along the margins of progressively more steeply inclined

granitoid domes at discrete intervals throughout the protracted history of the region. These domes acted as conduits for the escape of heat from the mantle and lower crust to the surface through conduction, and in this light, the domes may be viewed as very long-lived crustal-scale boils.

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**Figure 2. Stratigraphic column of the Marble Bar Belt, showing age range and thickness of the volcanic succession**

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