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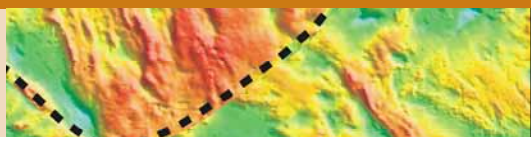
Broken Hill and Mount Isa: linked but not rotated

Gravity datasets point to a link between the Mount Isa and Broken Hill mineral provinces



Paul Henson, Natalie Kositcin and David Huston

The Broken Hill Block and the Eastern Succession of the Mount Isa Inlier are two of the most highly mineralised provinces in Australia. They are also among the most highly mineralised Proterozoic provinces in the world.

Similarities between these provinces

Since the early ideas of Bill Laing, a consultant and academic (Laing and Beardsmore 1986; Laing 1996), for a 'Diamantina Orogen' connecting the Eastern Succession of the Mount Isa Inlier with the Broken Hill Block, similarities in the geological histories of these provinces have led many researchers (such as Betts et al 2002; Giles et al 2004; Betts and Giles 2006) to infer that they were contiguous through much of the Proterozoic. These similarities, which are detailed in Kositcin (2010) and illustrated in Figure 1, include:

1) Emplacement of voluminous ~1850 Ma (or million years) granites in north-south belts along the eastern margin of the Gawler Craton (Donington Suite) and the central part of the Mount Isa Province (Kalkadoon Supersuite).
2) Similar chemistry of around 1790 to 1780 Ma mafic and felsic volcanic rocks in the eastern Gawler and Mount Isa provinces.
3) Synchronous deposition of the Willyama Supergroup (Curnamona Province) and Eastern and Western Successions (Mt Isa Province) between around 1710 to 1600 Ma, including bimodal magmatism in both terranes at around 1710 to 1670 Ma.
4) Low-pressure upper amphibolite to granulite facies metamorphism at around 1600 to 1580 Ma during the Olarian Orogeny (Curnamona Province) and D_2 phase of Isan Orogeny (Mount Isa Province).
5) The coincidence of 1600 to 1580 Ma bimodal magmatism in the Gawler Province with high-temperature, low-pressure metamorphism at mid-crustal levels in the eastern Mount Isa Province.
6) Similar timing of the Kararan Orogeny (Gawler Province) to the D_3 and D_4 phases of the Isan Orogeny (Mount Isa Province) between 1580 and 1540 Ma.

Although there is a general consensus that these provinces were contiguous through much of the later Paleoproterozoic, the relative position and orientation of these provinces when they were contiguous is contentious.

The Broken Hill Block contains the world's largest single sediment-hosted zinc-lead-silver deposit (Broken Hill) plus a number of small iron-oxide-copper-gold (IOCG) deposits (for example, Portia, Kalkaroo). The Eastern Succession contains major IOCG deposits (such as Ernest Henry, Mount Dore, and Mount Elliott) as well as a number of significant sediment-hosted zinc-lead-silver deposits (for example, Cannington, Pegmont). The zinc-lead-silver deposits in both provinces formed at ~1690 to 1680 Ma, whereas the iron-oxide copper-gold deposits formed between ~1520 and 1500 Ma (King and Thomson 1953; Page and Laing 1992; Gibson and Nutman 2004; Huston 2009; Duncan et al 2011).

To account for similarities presented above, Betts et al (2002) and Giles et al (2002, 2004) proposed that the Kimban Orogeny (and the Strangways Orogeny in the Arunta Province) was a consequence of collision between the Gawler Craton (as part of the Mawson Continent) and the North Australian Craton

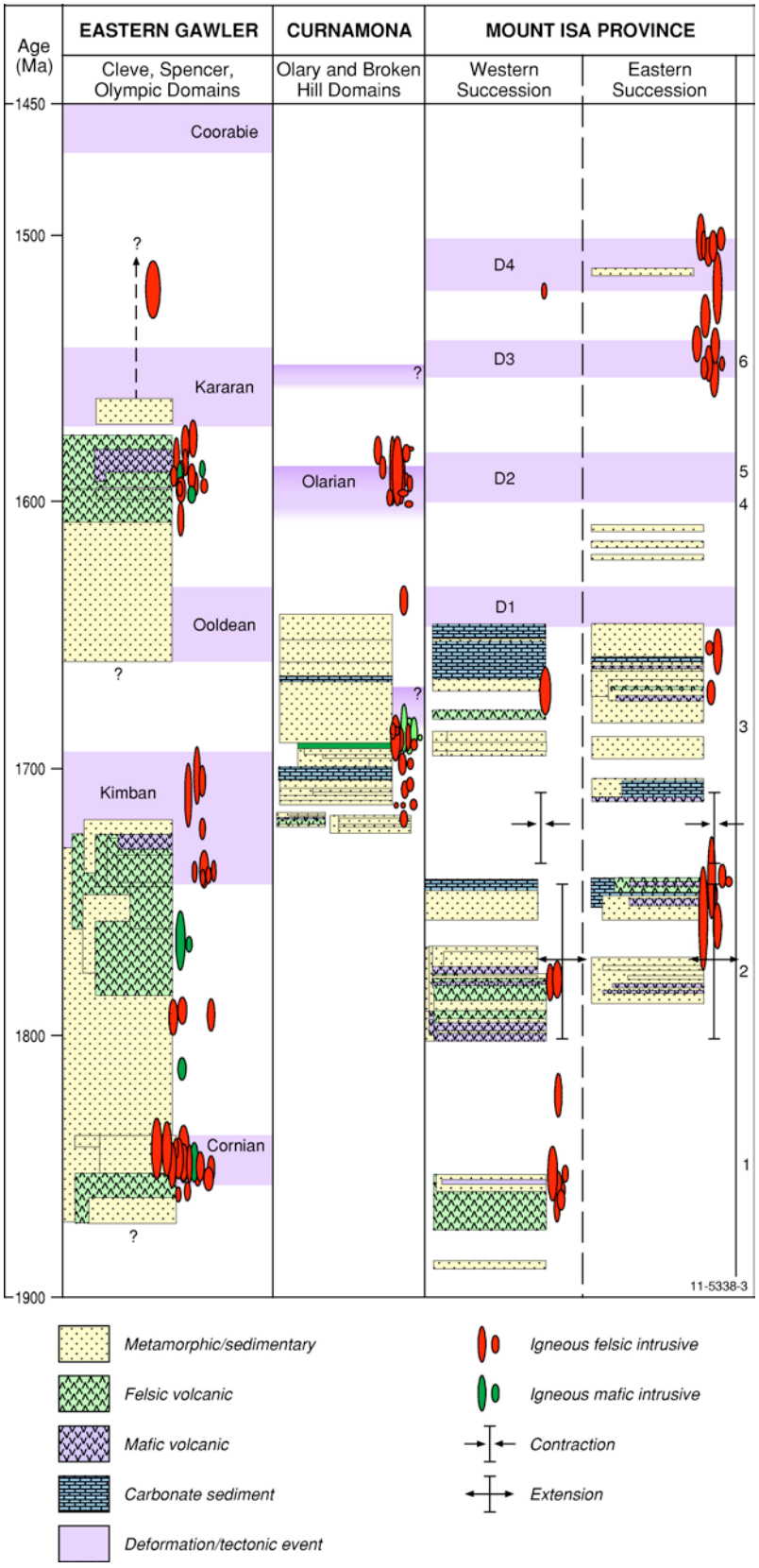


Figure 1. Simplified time-space-event plot for the Eastern Gawler, Curnamona Province and Mt Isa Province for the period 1900 Ma-1450 Ma, showing the similarities between them (see Kositcin, 2010 for details). The numbers on the right of the figure correlate with the similarities listed in the text.

(including the Arunta and Mount Isa provinces) between around 1740 Ma and 1690 Ma. Betts and Giles (2006) modified this model so that crust east of the Kalinjala Mylonite Zone in the Gawler Province was originally part of the North Australian Craton and the proto-Gawler Province to the west was the colliding terrane during the Kimban-Strangways Orogeny. In these models, the ~1720 Ma Kimban Orogeny is interpreted to connect with the Strangways Orogeny in the Arunta Province to form an approximately east–west trending collisional belt. This interpretation requires the South Australian Craton (including the Gawler and Curnamona provinces) to be rotated 52 degrees counterclockwise relative to its current position. This places the Curnamona Province adjacent to the current southern subsurface extent of the Mount Isa Province and Georgetown Region (Giles et al 2004) thus linking the Eastern Succession and Willyama Supergroup (Broken Hill Block) as part of the same stratigraphic package.

Alternatively, based on studies in the Mount Isa Province Gibson et al (2008) proposed a Basin-and-Range-style model in which crustal evolution was dominated by extension along the eastern margin of Proterozoic Australia. In this interpretation, the north-south relative positions of the North Australian and South Australian cratons did not change significantly through the Paleo- to Mesoproterozoic.

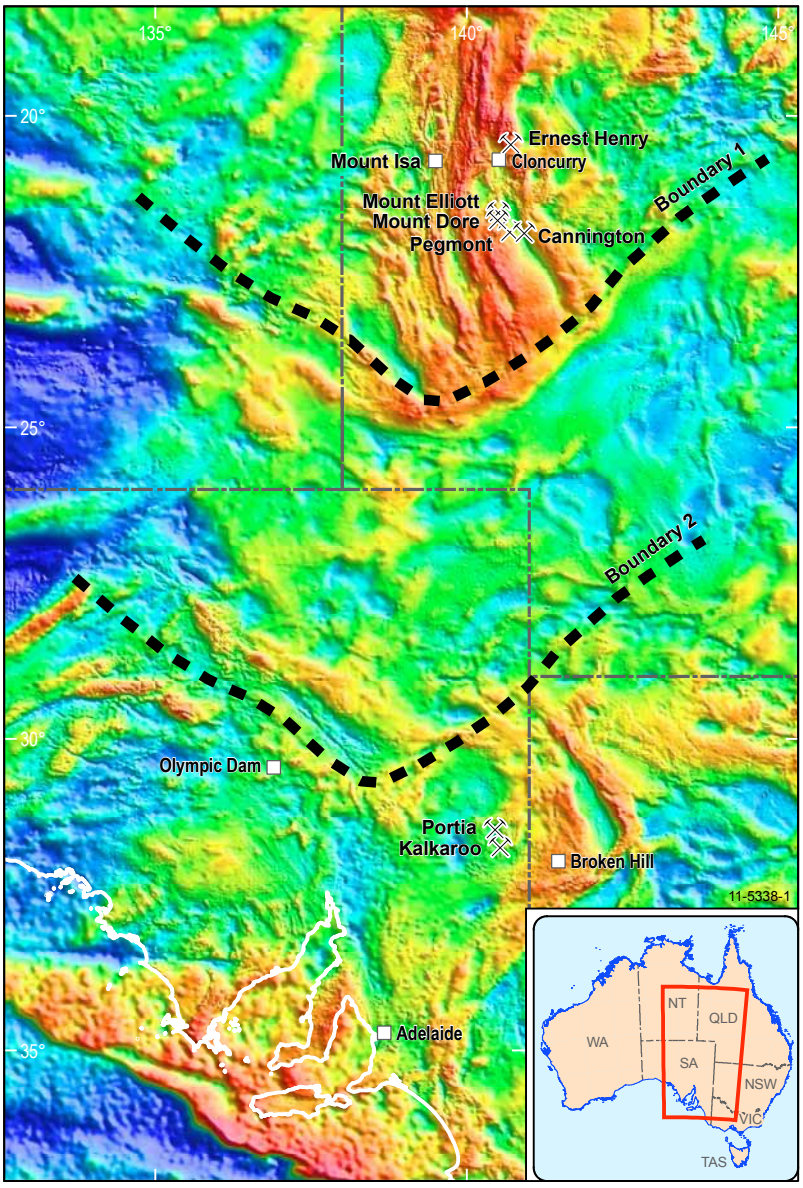


Figure 2a. Bouguer gravity image showing the proposed boundaries (broken black lines) between the Mt Isa province (Boundary 1) and the Broken Hill Block (Boundary 2), and the co-joined Curnamona Province and Gawler Craton. The locations of major towns are shown as white squares and the mine symbol denotes mines.

Linked but not rotated

Hence, there is significant controversy as to the relative position, rotated or not, of the Gawler and Mount Isa provinces. Potential field datasets, including gravity and aeromagnetic datasets, have the potential to resolve this controversy as large-scale geophysical trends should be less susceptible to re-orientation and have fewer complexities of interpretation than geological datasets. However, the age of geophysical trends, in many cases, cannot be established conclusively. Figure 2a illustrates the variations in the Bouger gravity field for the eastern margin of Proterozoic Australia. This dataset and the aeromagnetic dataset are characterised by a major (under cover) boundary along the southern margin of the Mount Isa Province that truncates a broadly north–south geophysical grain.

Although less certain, the geophysical data in the Curnamona Province are also characterised by a north–south grain and a northern boundary (Boundary 2 on figure 2b) sub-parallel to the boundary that defines the southern margin of the Mount Isa Province (Boundary 1). To further assess this north–south trend, Figure 2b juxtaposes the Curnamona Province with the Mount Isa Province using the sub-parallel boundaries discussed above. This fit is remarkable: not only are the trends continuous, but individual linear anomalies in the gravity dataset can be traced across the province boundaries. If the Curnamona Province was rotated 52 degrees counterclockwise relative to the Mount Isa Province, the trends should not be traceable across the now separated province boundaries. This relationship is considered to favour a simple geological link without rotation, which is more consistent with models such as Gibson et al (2008) and the original interpretations of Bill Laing.

The white band in Figure 2b is intended to indicate that the Broken Hill Block and the Mount Isa Eastern Succession were not juxtaposed directly. Rather, they would have been

separated by attenuated crust. The zone between the two boundaries in Figure 2a is characterised by crust that is significantly thinner than crust in either the Broken Hill Block or the Mount Isa Eastern Succession (30 to 35 kilometres, including ~5 kilometres of Paleozoic basins, compared to 40 to 45 kilometres, or more: Collins 1991; Meixner and Holgate 2009). It is possible that the attenuation of the crust was accompanied by granite emplacement (Meixner and Holgate 2009), as indicated by the large gravity lows in Figure 2a.

Implications for mineral potential

This reconstruction has important implications for the mineral potential of Proterozoic Australia, particularly its eastern margin. The Curnamona and Mount Isa Provinces are some of the most highly mineralised provinces in the world, and large parts of these provinces are under cover. The reconstruction discussed above suggests that the southern extension of the Mount Isa Province under cover has high potential for both sediment-hosted zinc-lead-silver and iron oxide copper-gold deposits. This potential will extend into the inferred attenuated crust between the two boundaries. In addition, younger parts of the Curnamona Province, particularly the Paragon and Sundown Groups, may have potential for sediment-hosted zinc-lead-silver deposits akin to the Mount Isa and Hilton-George Fisher deposits.

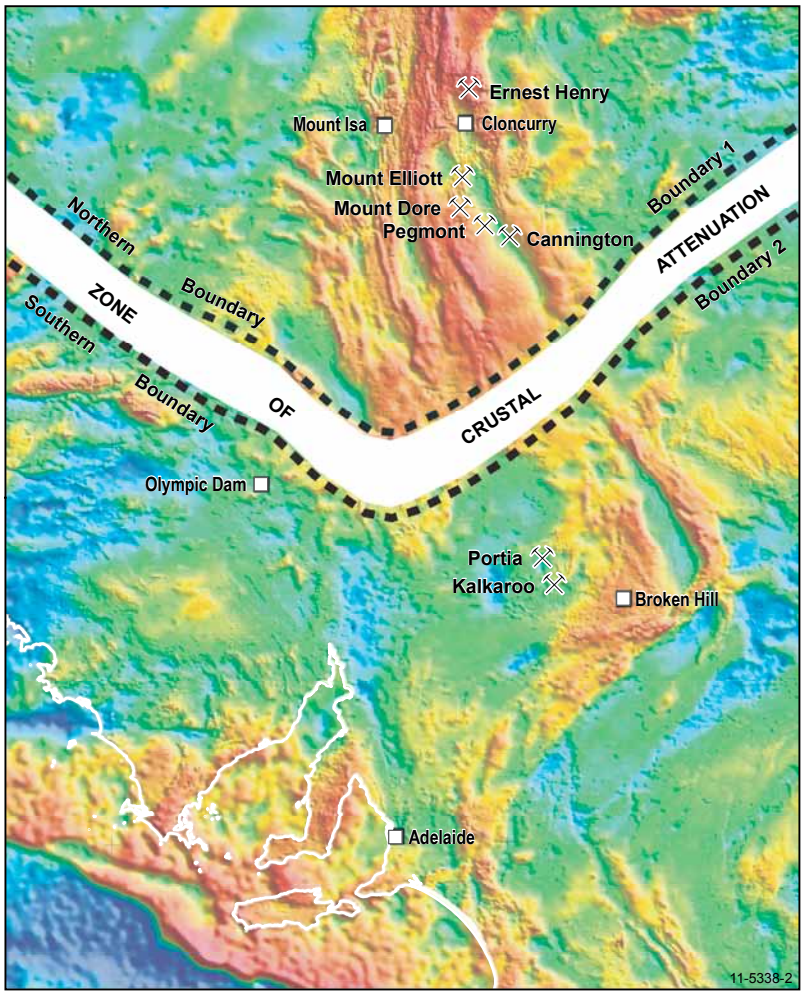


Figure 2b. Reconstruction using the gravity image of the Mt Isa Province and the Broken Hill Block, and the co-joined Curnamona Province and Gawler Craton. Boundary 1 and Boundary 2 have been repositioned (with no rotation) to show a proposed reconstruction of the architecture during the Mesoproterozoic (the white area between Boundary 1 and Boundary 2 represents crust that was attenuated). The locations of major towns are shown as white squares and the mine symbol denotes mines.

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