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Basin architecture and evolution in the Mount Isa mineral province, northern Australia: Constraints from deep seismic reflection profiling and implications for ore genesis

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ABSTRACT

Deep seismic reflection profiling confirms that the Paleo- to Mesoproterozoic Mount Isa mineral province comprises three vertically stacked and partially inverted sedimentary basins preserving a record of intracontinental rifting followed by passive margin formation. Passive margin conditions were established no later than 1655 Ma before being interrupted by plate convergence, crustal shortening and basin-wide inversion at 1640 Ma in both the 1730–1640 Ma Calvert and 1790–1740 Ma Leichhardt superbasins. Crustal extension and thinning resumed after 1640 Ma with formation of the 1635–1575 Ma Isa Superbasin and continued up to ca. 1615 Ma when extensional faulting ceased and a further episode of basin inversion commenced. The 1575 Ma Century Pb–Zn ore-body is hosted by syn-inversion sediments deposited during the initial stages of the Isan Orogeny with basin inversion accommodated on east- or northeast-dipping reactivated intrabasinal extensional faults and footwall shortcut thrusts. These structures extend to considerable depths and served as fluid conduits during basin inversion, tapping thick syn-rift sequences of immature siliciclastic sediments floored by bimodal volcanic sequences from which the bulk of metals and mineralising fluids are thought to have been sourced. Basin inversion and fluid expulsion at this stage were entirely submarine consistent with a syn-sedimentary to early diagenetic origin for Pb–Zn mineralisation at, or close to, the seafloor. Farther east, a change from platform carbonates to deeper water continental slope deposits (Kuridala and Soldiers Cap groups) marks the position of the original shelf break along which the north–south-striking Selwyn-Mount Dore structural corridor developed. This corridor served as a locus for strain partitioning, fluid flow and iron oxide–copper–gold mineralisation during and subsequent to the onset of basin inversion and peak metamorphism in the Isan Orogeny at 1585 Ma. An episode of post-orogenic strike-slip faulting and hydrothermal alteration associated with the subvertical Cloncurry Fault Zone overprints west- to southwest-dipping shear zones that extend beneath the Cannington Pb–Zn deposit and are antithetic to inverted extensional faults farther west in the same sub-basin. Successive episodes of basin inversion and mineralisation were driven by changes in the external stress field and related plate tectonic environment as evidenced by a corresponding match to bends in the polar wander path for northern Australia. An analogous passive margin setting has been described for Pb–Zn mineralisation in the Paleozoic Selwyn Basin of western Canada.

1. Introduction

As host to several world-class mineral deposits, including Mount Isa, McArthur River and Century (Fig. 1), the Paleoproterozoic–earliest Mesoproterozoic (1800–1575 Ma) rift basins of northern Australia constitute one of the most richly endowed and intensely studied mineral provinces in the world (Broadbent et al., 1998; Duncan et al., 2014; Groves and Bierlein, 2007; Huston et al., 2006; Large et al., 2005; Leach et al., 2005, 2010; Oliver et al., 2008; Pollard et al., 1998). Differences of opinion nevertheless persist about many aspects of basin evolution and its relationship to mineralisation, including the extent to which syn-depositional extensional faults were instrumental in localising fluid flow during successive stages of rifting. In the case of stratiform to stratabound Pb–Zn deposits of the SEDEX or Mount Isa-type, such faults are widely regarded as central to the ore-forming

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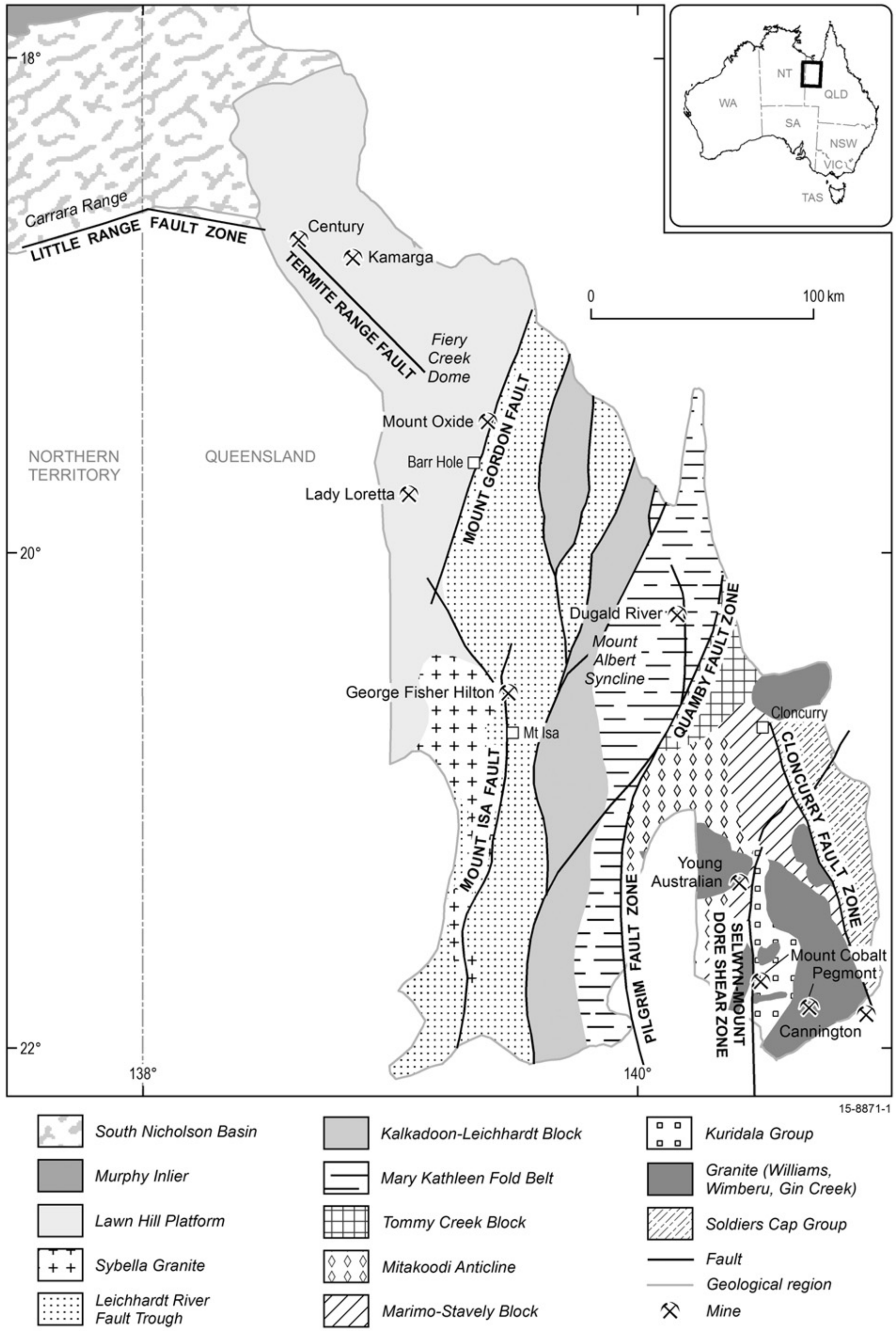

Fig. 1. Simplified geological map for Mount Isa region showing principal tectono-morphological subdivisions and their bounding faults, along with position of main mineral deposits.

process, serving not only as fluid conduits but the principal means whereby connectivity was maintained between the more deeply buried parts of the basin (where the metal-bearing fluids are sourced) and the water–sediment interface where mineralisation is deemed to have actually taken place. Integral to this model of ore genesis is the idea that mineralisation occurred contemporaneously with active rifting and is thus primarily syngenetic or early diagenetic in origin (Betts et al., 2003; Feltrin, 2008; Feltrin et al., 2009; Goodfellow et al., 1993; Huston et al., 2006; Large et al., 2005; Leach et al., 2005). Competing models in which mineralisation occurs later and is decoupled from active rifting have yet to gain the same level of support but typically involve basin inversion or some other form of post-rift deformational process as the principal driver of fluid flow and ore genesis (Broadbent et al., 1998; Hobbs et al., 2000; Zhang et al., 2006). In these models, preservation of the original rift-basin geometry and extensional faults is commonly assumed with the latter acting as the principal conduits along which the mineralising fluids were introduced. However, as with most rift basins, crustal architecture is far from simple and incorporates faults of more than one generation and orientation. At least three phases of extensional faulting and rifting, and as many episodes of post-rift deformation, are currently identified in the Mount Isa region (e.g. Blake, 1987; O'Dea et al., 1997; Betts et al., 2006; Gibson et al., 2012). There is consequently little agreement about the direction and duration of rifting during any one period of basin development let alone which faults or generation of structures were the most important in controlling fluid flow at the time of mineralisation. A better understanding of the geodynamic evolution and kinematic framework of the Mount Isa region is called for.