Tectono-metamorphic evolution of the Cambro-Ordovician Balcooma Metamorphic Group, Greenvale Province, north-eastern Australia

Volume I

(Text)

Thesis submitted by

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Introduction to thesis

This research work is focused on the Balcooma Metamorphic Group in north-eastern Queensland, Australia, which consists of multiply deformed Cambro-Ordovician metasedimentary and felsic metavolcanic rocks. The Balcooma Metamorphic Group crops out as the very northernmost portion of the Thomson Fold Belt in the Greenvale Province. The Balcooma copper, lead and zinc massive sulphide deposit lies within these multiply deformed rocks. The sequential growth of metamorphic index minerals (chlorite, muscovite, biotite, garnet, staurolite, plagioclase, kyanite, andalusite, cordierite and fibrolitic sillimanite) indicates prograde metamorphism well into the amphibolite facies in the region. Five deformation events can observe in the matrix (D_1-D_5, Huston, 1990; Van Der Hor, 1990; Withnall et al., 1991; Ali, 2009 A).

Multiply deformed rocks generally contain schistosity parallel to bedding or compositional layering and locally an oblique crenulation cleavage and/or some crenulations (Bell et al., 2003, 2004; Ham & Bell, 2004; Aerden, 2004). This parallelism of compositional layering and schistosity is predominantly a function of reactivation of the bedding during younger deformation events. Reactivation destroys developing foliations and rotates pre-existing ones into parallelism with S_0 (Bell, 2009). Reliance on matrix foliations alone can lead to incorrect geological interpretations, lack of precision and a degree of uncertainty. Unravelling a much more complete tectono-metamorphic history of multiply deformed rocks requires a very thorough study of the microstructures preserved within porphyroblasts because they preserve earlier-formed foliations from the effects of reactivation due to continuing or younger deformation within the matrix. The measurement of Foliation Intersection Axes preserved within porphyroblasts (FIAs) provides a robust tool that allows the elucidation of a much more extensive history of deformation and metamorphism. Prior to the development of this innovative technique, this history that predates schistosity parallel to compositional layering could not be distinguished (e.g., Bell & Newman, 2006). A FIA forms perpendicular to bulk shortening direction (Cihan 2004). Therefore, the preservation of FIAs in P-T sensitive minerals such as garnet, staurolite, kyanite, andalusite and cordierite can effectively be used to constrain compression and decompression directions during orogenesis. This research work combines all applications of the FIA technique used so far to elucidate the tectono-metamorphic history of the multiply deformed Balcooma Metamorphic Group.

The thesis divided into four sections. Each section has been written in paper format. The papers presented here encompass a range of structural, metamorphic, geochronological and tectonic topics.

Section A

Porphyroblast growth in metapelitic rocks is generally considered to be controlled by the bulk composition and P-T conditions (Spear, 1993). Bell et al. (1986, 2004) and Williams et al. (2001) suggested that once these first 3 conditions have been met, a fourth control exists on whether a porphyroblast starts or stops growing. They argued that growth begins when deformation partitions through an outcrop such that crenulations form at the scale of a porphyroblast and ceases when a differentiated cleavage begins to develop against its margins (Bell & Bruce, 2006, 2007). If this the case, then mineral phases expected to result from one specific reaction for a particular bulk composition on any particular prograde P-T path, could grow several times rather than just once. This section of the thesis documents the role and importance of deformation partitioning during porphyroblast growth apart from appropriate bulk composition and P-T.

Section B

Monazite dating has proved a useful geochronological technique for determining absolute timing of deformation and metamorphism across and along an orogenic belt (Williams &

Jercinovic, 2002; Forbes et al., 2007). Monazite grains can best be used an effective tool for determining absolute timing of tectonic processes when they are overgrown by porphyroblasts and are thus protected from younger deformation within the matrix (Bell & Welch, 2002). A succession of 5 FIA sets preserved in garnet, staurolite, plagioclase, kyanite and andalusite porphyroblasts is described in the Section A. This succession records 5 changes in the direction of bulk shortening across the Balcooma Metamorphic Group. The FIAs hosted by these porphyroblasts are partially defined by monazite inclusions that can be dated on an electron microprobe to provide a minimum age estimate of the time over which they grew. This allows the relative succession of ages determined using core, median, rim relationships in porphyroblasts to be tested against the absolute ages determined by electron microprobe dating. Furthermore it allows the timing of deformation and metamorphic events that affected this portion of the Thomson Fold Belt to be determined and compared with ages determined elsewhere.

Section C

Amphibolite facies metamorphism in the Greenvale Province potentially began in an extensional backarc tectonic environment that was followed by compression in the Early Silurian with exhumation in the Early Devonian (Fergusson et al., 2007). Whether such a path occurred can potentially be resolved by calculating the P-T-t-D path using the appearance and disappearance of pressure and temperature sensitive index minerals (e.g., garnet, staurolite, kyanite, andalusite and cordierite). This section uses porphyroblast growth along the P-T-t-D path, microtextures, FIAs, conventional geothermobarometry, garnet isopleth intersections for X_{Mn}, X_{Fe} and X_{Ca} on P-T pseudosections, and phase equilibria modelling using P-T pseudosections to deduce a tectonic history and P-T-t-D path for this portion of the Greenvale Province.

Section D

The N-S trending Tasman Orogen is generally regarded as forming by a succession of periods of orogenesis that migrated from west to east along the active Pacific-margin of East Gondwanaland after the break-up of Rodinia. It includes the Early Palaeozoic Delamerian, the Early and Middle Palaeozoic Thomson and Lachlan Fold Belts, the Middle and Late Palaeozoic Hodgkinson-Broken River Fold Belt and the Late Palaeozoic to Early Mesozoic New England Fold Belt. The Northern Thomson Fold Belt is an anomalous portion of this orogenic zone because it contains well preserved W-E trending batholiths and foliations. These W-E trends potentially connect with those dominating central Australia but are poorly understood because they are covered by the younger sediments of the Eromanga Basin. This section examines the significance of W-E magnetic and age trends in the Northern Thomson Fold Belt using FIA data from the Balcooma region, Greenvale Province. This region would have lain on the northern side of the Northern Thomson Fold Belt as currently exposed prior to the effects of the younger W-E directed crustal shortening that is typically associated with the Tasman Orogenic Zone. This data suggests a new tectonic interpretation can be proposed that may aid explorers after Balcooma and Charters Towers style mineralization correlatives.

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