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Evolution of the Sybella Batholith: Petrographic, geochemical and structural development of an A-type intrusive complex, Northwest Queensland

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in September 2003

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Elizabeth Hoadley September 2003

ABSTRACT

The Sybella Batholith is an A-type composite granitoid complex that was emplaced as a series of distinct phases. The first phase began with the intrusion of tholeiitic doleritic (Mosses Tank Dolerite, 45-55 wt% SiO_2) and dioritic hybrid magmas (Mafic Hybrid Complex, 58.2 - 65 wt % SiO_2). The second phase involved intrusion of a minor suite of rapakivi hybrid (63-69 wt % SiO_2). Subsequent phases included the volumetrically largest part of the batholith, the high-K, Fe-enriched K-feldspar megacrystic syenogranites (known as 'Main Phase', approximately 70 wt % SiO_2), associated porphyritic and aplitic dykes, and a phase of microgranites (75-77 wt % SiO_2). Intruded during an extensional phase during the development of the Mount Isa Basin, the Sybella Batholith is ideal for the assessment of petrogenetic processes (including magma mixing and mingling) that gave rise to a composite batholith, and also the effect of syn- to post-magmatic deformation during emplacement (~1670 Ma) and subsequent metamorphism and deformation during the Isan Orogeny (1590-1500 Ma).

Mixing and mingling were significant processes in the evolution of the batholith. In the mafic rocks in both the Easter Egg and Guns Knob regions, hybridization was found to have taken place to some extent at a deeper level before the magmas were emplaced as distinct intrusions to form the Mafic Hybrid Complex. Within the Mafic Hybrid Complex there is a lack of mafic rocks that show no contamination with felsic magmas. Minor hybridization also occurred locally at emplacement level. The Main Phase granite, although relatively homogeneous, displays features indicative of hybridization at depth (rapakivi textures) and of interaction with the Mafic Hybrid Complex at emplacement level with true hybrid rocks at the contacts. In the northern Kitty Plains region, fractionation was probably the dominant process in the evolution of the mafic rocks of the Mosses Tank Dolerite (MTD), with hybridization limited to the contacts with intruded sheets of microgranite. Along the eastern margin of the pluton, large areas of MTD were brecciated by the intruding microgranite as rheological contrast between felsic and mafic magmas inhibited voluminous mixing. However, behaviour of the dolerite transitional between solid and liquid was observed along many of the intrusive contacts and within magmatic shear zones (dated at ~1673 Ma) with partially solidified mafic enclaves being mechanically broken-up during high strain forming schlieren and hybrids.

Few methods for determining the intensive parameters (T, P, fO_2, fH_2O) of granitic magmas are applicable to rapakivi A-type magmas, the main difficulty being that the granites consists of disequilibrium mineral assemblages (different generations and order of mafic/silicic minerals etc) and the high Fe-content of minerals. However, calculated temperatures of 850-900°C at approximately 4 kbars for the Main Phase granite are similar to other A-type granites. The absence of source rock restites is also indicative of high magma temperatures. The composition of minerals in the Main Phase granite is indicative of relatively low fO_2 for granites; however it was still higher than the initially low fO_2 in the Mafic Hybrid Complex. Oxidation of the mafic magmas during mixing resulted in abundant magnetite and other mineralogical changes. The occurrence of large biotite flakes ± late amphibole in the mafic units, and the apparent late crystallization of mafic minerals in the granites indicates H_2O undersaturated magmas. The low water fugacities and high-temperature of the melts enabled the magmas to intrude into the upper crust at relatively shallow depths.

The Main Phase of the Sybella Batholith contains 64.32 ppm Nd and 11.40 ppm Sm, and has a εNd of –3.86. A T_2 model source age of 2419 Ma was calculated using the emplacement age of ~1670 Ma. The Nd and Sm contents of the main phase hybrids have a positive correlation with the SiO_2, which is not consistent with fractionation (fractionation of amphibole would partition Nd and Sm from the melt), but rather mixing between the mafic and felsic end member magmas. No mafic end member was analysed; however a mafic enclave from within the Main Phase granite (with similar geochemical properties to the dolerites) had the lowest εNd of –6.15 and a T_2 model source age of 2587 Ma. The older model source age for the mafic rocks indicates that the melt from the mantle source region (dolerite) was probably contaminated with radiogenically older crustal material (Archaen crust). This is also consistent with the intrusion's enriched LREE, K and Rb contents. The microgranite contains 41.46 ppm Nd and 6.96 ppm Sm, has a εNd of –2.24 and a T_2 model source age of 2300 Ma. These values are outside the range determined for the Main Phase granites and are likely to represent a different source. The Mosses Tank Dolerite has a εNd of –2.27 and a T_2 model source age of 2303 Ma suggesting the dolerite was also contaminated with radiogenically older crustal material.

The shallow origin of A-type granites is a result of tectonic extension that is associated with crustal thinning and mantle upwelling possibly in a back-arc setting (Giles *et al.* 2002). Fluid absent partial melting of metaluminous protoliths (metamorphosed igneous rocks in the lower crust) heated by underplated or intraplated mafic magma produced the potassic incompatible and radiogenic element-rich high-temperature character of the Sybella Batholith. However, in the Sybella Batholith, the mafic rocks are iron-enriched resulting from fractionation of minerals at depth rather than direct emplacement from the mantle.

The Sybella Batholith was emplaced into strongly deformed country rocks of mafic and felsic gneisses and amphibolites of the May Downs Gneiss and Eastern Creek Volcanics of the Haslingden Group, Cover Sequence 2. At the time of the emplacement of the Sybella Batholith, the Mount Isa Inlier experienced large magnitude extension (O'Dea *et al.* 1997) and a suite of sedimentary basins developed in areas of extension (i.e Cover Sequence 3). In the Sybella Batholith, three stages of development for the fabric were determined: (1) magmatic flow; (2) submagmatic/high-temperature solid-state flow; (3) moderate-high temperature solid-state flow, marked by plastic deformation with temperature above 600°C. Deformation was heterogeneous with the first and second processes dominant within the northern regions at Kitty Plain and Guns Knob and occurring locally within the Easter Egg region. The second and third processes predominate within the Easter Egg Region. The third process may have related to either deformation during emplacement or overprinting regional metamorphism and deformation during the Isan Orogeny. The later deformation has also obscured earlier primary magmatic features or high-temperature fabrics by recrystallization and reactivation.

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During a PhD, you learn a lot from people,
about people and most of all,
about yourself.

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