The importance of lithogeochemistry to the west Musgrave Province mapping project

by

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The Musgrave Province lies at the intersection of central Australia's Proterozoic structural trends, and chronicles a long and complex history of high-grade metamorphism, deformation, and magmatism. Although the region contains significant nickel–copper sulfide and nickel laterite mineralization, the Musgrave Province has remained very much 'greenfields' in terms of its economic mineral endowment and geological understanding. Early work in the area (e.g. Daniels, 1974; Gray, 1971; White, 1997) established a broad lithological and geochronological framework, and Glikson et al. (1996) provided a more detailed lithological and mineralogical background for the mafic–ultramafic Giles intrusions. However, there is a lack of clear understanding of the geological and tectonic context of the Giles intrusions, and broader insight into the geological evolution of the province in general is also lacking.

Since the the west Musgrave Province mapping project commenced in 2004, geological understanding of this region has increased significantly, and views on its geological evolution have changed markedly. A large part of this advance can be directly attributed to the collection and interpretation of large, high-quality lithogeochemical and geochronological datasets. The usefulness of such datasets depends on the ability to successfully characterize real lithological groups, which in turn depends directly on the quality and amount of data collected. The full value of lithogeochemical datasets as both a mapping tool, and as an aid to deciphering the geological history of a region and its deep crustal architecture, cannot be overstated. Examples of how these datasets have contributed to the west Musgrave Province mapping project are given below.

Lessons from the lithogeochemistry

As for many Proterozoic terranes, distinguishing between various generations of mineralogically similar igneous rocks in the field is greatly hindered by general similarities in primary texture, and by locally intense deformational overprints. In the west Musgrave Province, this is particularly the case for the granites, but is also true of the complex magmatic assemblages formed during the 1085–1040 Ma Giles Event.

Granites

Granites, of all ages, regionally dominate outcrop in the west Musgrave Province, and most are virtually indistinguishable feldspar porphyritic monzogranites and syenogranites. Previous regional mapping projects generally failed to provide any reliable basis for subdivision of these rocks, and the prevailing view was that the overwhelming majority formed during the c. 1200 Ma Musgrave Orogeny. However, using a dataset of >1300 high-quality lithogeochemical analyses, all Musgrave granites can now be assigned to one of four compositionally and geochronologically constrained supersuites (Figs 1 and 2), which includes voluminous felsic magmatism both significantly older and younger than the Musgrave Orogeny. These supersuites are:

- The c. 1400 Ma Papulankutja Supersuite and 1345–1293 Ma Wankanki Supersuite, which are mainly concentrated within the central and southern parts of the west Musgrave Province. Both supersuites are of calc-alkaline affinity, formed through the dehydration melting of c. 1900 Ma juvenile crust, most likely in a continental-arc setting.
- The 1220–1150 Ma Pitjantjatjara Supersuite of ferroan, alkali-calcic granites, concentrated in the central and northeastern parts of the west Musgrave Province. These rocks formed through the melting of a source that homogenized c. 1900 Ma juvenile crust into mantle-derived melts in an intracratonic setting.
- The 1085–1040 Ma Warakurna Supersuite of ferroan, alkali-calcic granites and rhyolites, found throughout all but the far northeast of the west Musgrave Province. These rocks formed during the Giles Event as partial-melts of crust incorporated into mantle-derived melts in an intracontinental rift setting.

These granites can now be directly assigned to specific orogenic events, source regions, and tectonic settings, and their geographic extent can be mapped. Combining this information with detailed petrogenetic constraints imposed by the geochemistry of the individual supersuites and component suites allows us to establish a detailed tectonic history for these rocks. For example, the geochemistry of the Pitjantjatjara Supersuite generally indicates unusually

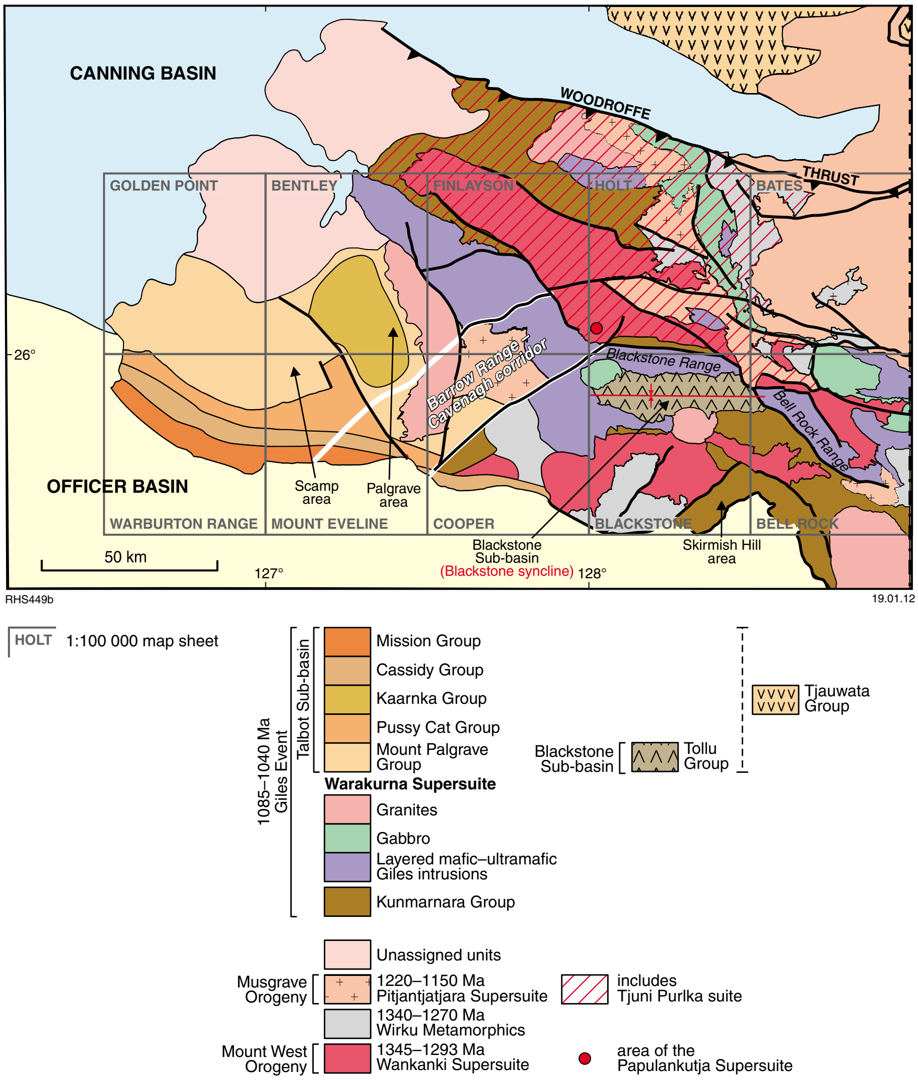

Figure 1. Regional sketch of the west Musgrave Province and Bentley Basin.

high-temperature (>1000°C) magmatism. Within this supersuite, the Tjuni Purlka suite is geochemically unique, and is restricted to a strongly tectonized northwest-trending zone in the central part of the west Musgrave Province, which can then be inferred to be a crustal-scale feature that channelled lower-crustal magmas during the Musgrave Orogeny. A change from ytterbium-depleted to ytterbium-undepleted granite compositions in the early stages of the Musgrave Orogeny reflects both a switch from deep crustal melting to much shallower crustal melting, and a likely change in lower crustal architecture, with this change occurring at slightly different times across major structures. Furthermore, the antithetic distribution of the Wankanki and Pitjantjatjara Supersuites provides information on the changing lower crustal architecture between the c. 1300 Ma Mount West Orogeny and the c. 1200 Ma Musgrave Orogeny, and on the distribution of fertile sources or heat (or both) at depth during the Musgrave Orogeny.

Igneous rocks of the Giles Event

Intrusive and extrusive rocks of the Giles Event (Warakurna Supersuite) outcrop over approximately half of the west Musgrave Province (Fig. 1). These rocks comprise a bimodal suite with mafic and felsic components produced throughout virtually the entire 45 m.y. duration of the event.

The mafic dykes, sills, layered intrusions, and flows form at least ten different units, with the giant, layered Giles intrusions being the most extensive. Each of these mafic units has geochemical attributes that permit unique identification; again, the key here is in collecting enough data to uniquely define these attributes. Of particular interest is the Alcurra Dolerite, a c. 1067 Ma regionally distributed suite that hosts nickel–copper sulfide mineralization at Nebo–Babel, and is associated with copper mineralization elsewhere in the region.

The magmatic conduits for several of these mafic units were major crustal-scale structures active at the time of magmatism (magmatic shear zones).

Likewise, felsic dykes, sills, plutons, and volcanic rocks of the Giles Event form at least 17 different units — each with unique geochemical attributes (Fig. 3). Units in the eastern and northern parts of the region (on BLACKSTONE, BELL ROCK, HOLT, FINLAYSON, and the eastern part of the COOPER map sheet — including units in the Blackstone Sub-basin) are generally older (1078–1068 Ma) and are, as a group, compositionally distinct from units to the south and west (on the MOUNT EVELINE, BENTLEY, WARBURTON RANGE, and GOLDEN POINT map sheets — including units in the Talbot Sub-basin). This implies two regions with distinct mantle and/or crustal source components. The exception to this is the Alcurra Dolerite (which includes fractionated trachydacitic equivalents), which is found in both regions. The boundary between the two regions is the northeast-trending Barrow Range – Cavenagh corridor (Fig. 1). This structural corridor reflects a mantle-tapping, crustal-scale feature, into which the hosts of the Nebo–Babel nickel–copper sulfide mineralization were emplaced.

The volcanic units of the Warakurna Supersuite in the northeastern Talbot Sub-basin provide a particular challenge to mapping, as all felsic units are similar looking, glassy rhyolitic rocks. However, individual units are compositionally distinct (Fig. 3), and this difference has allowed the construction of a robust stratigraphic section significantly different to previous interpretations.

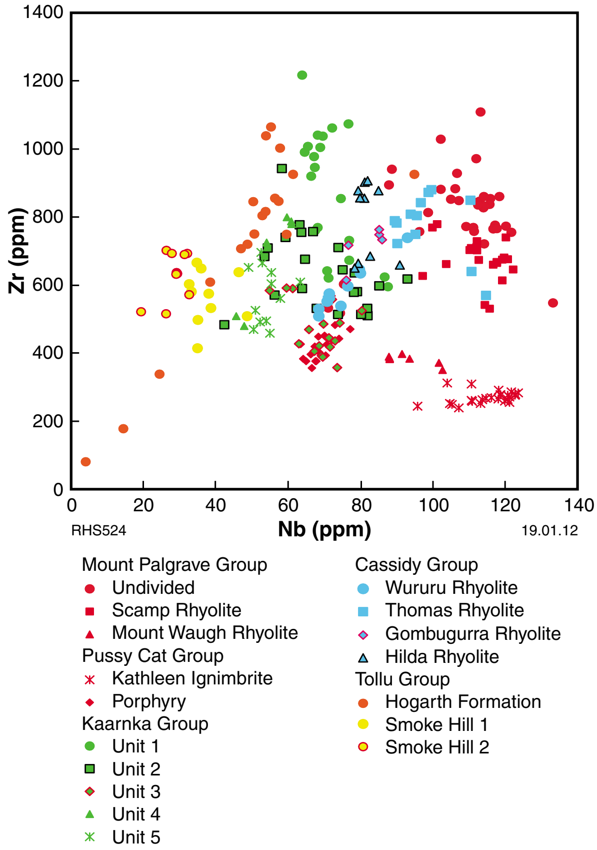

***Figure 3.** Compositional variation diagram for felsic volcanic rocks of the Warakurna Supersuite, plotting zirconium vs niobium.*

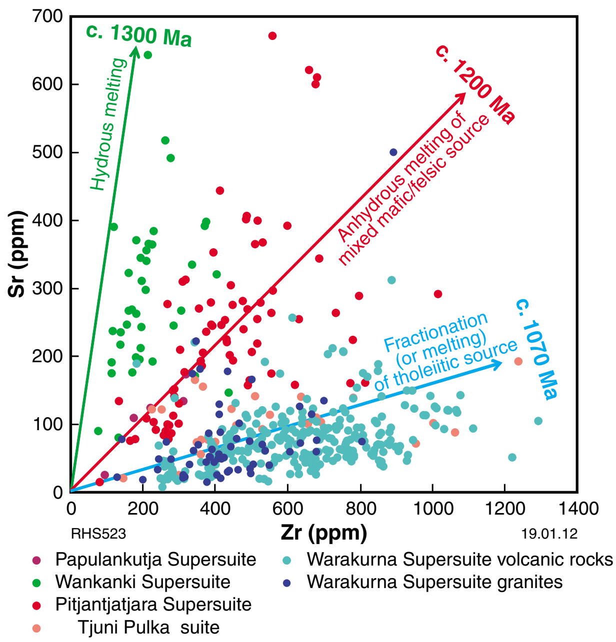

***Figure 2.** Compositional variation diagram for granites of the west Musgrave Province, plotting strontium vs zirconium for the four supersuites, and the felsic volcanic rocks of the Warakurna Supersuite. The arrows give a petrogenetic interpretation of the various trends. Using a combination of this and similar variation diagrams, virtually all granites of the region can be confidently grouped.*

This in turn has altered the interpreted geological history for this unit; for example, the Scamp and Palgrave areas (Fig. 1) have now been combined into a regionally developed basal group (Mount Palgrave Group) of the Talbot Sub-basin, instead of representing two lithologically and chronologically independent calderas. However, the Mount Palgrave Group is overlain by the more geographically restricted Kaarnka Group, which may define a caldera.

References

Daniels, JL 1974, The geology of the Blackstone region, Western Australia: Geological Survey of Western Australia, Bulletin 123, 257p.

Glikson, AY, Stewart, AT, Ballhaus, GL, Clarke, GL, Feeken, EHT, Level, JH, Sheraton, JW and Sun, S-S 1996, Geology of the western Musgrave Block, central Australia, with reference to the mafic–ultramafic Giles Complex: Australian Geological Survey Organisation, Bulletin 239, 206p.

Gray, CM 1971, Strontium isotope studies on granulites: Australian National University, Canberra, Australian Capital Territory, PhD thesis (unpublished), 242p.

White, RW 1997, The pressure–temperature evolution of a granulite facies terrain, western Musgrave Block, central Australia: Macquarie University, Sydney, New South Wales, PhD thesis (unpublished), 256p.