

EVENT CHRONOLOGY AND PROSPECTIVITY OF THE MAFIC MAGMATIC SYSTEMS IN THE ARUNTA PROVINCE

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As part of the National Geoscience Agreement with the Northern Territory Geological Survey (NTGS), Geoscience Australia is evaluating mafic-ultramafic intrusions in the Arunta Province of central Australia. The major aims of this regional study are to constrain the various mafic-ultramafic magmatic systems within the event chronology of the Arunta, and to provide a geoscientific framework for assessing the resource potential of the intrusions. Sixteen bodies were sampled from a 90 000 km² area (Figure 1). SHRIMP U-Pb zircon ages were obtained for thirteen bodies by targeting fractionated mafic rocks with relatively high abundances of Zr (80 to 220 ppm). Our 100% success rate in finding large quantities of zircon in samples targeted by field and chemical criteria opens the way to dating mafic magmatism more routinely elsewhere.

The Arunta Province is a geologist's dream for examining mafic-ultramafic intrusions, for they are generally well exposed, and differential movements along province-wide fault systems have exposed representatives from different crustal depths (Collins 2000). The Arunta intrusions have historically been regarded as having low potential for mineralisation because of their high metamorphic grades and protracted tectonothermal histories. Intermittent phases of company exploration during the last three decades have been restricted to a few intrusions (e.g. Mordor), and university studies (Bonnay *et al* 2000) have generally focussed on structural-metamorphic aspects of granulite bodies (Mount Hay Granulite). This is in contrast to other Proterozoic provinces (Musgrave Block, Halls Creek Orogen, Albany-Fraser Orogen), where more extensive investigations have defined a range of orthomagmatic and hydrothermal PGE, Cr, Ni, Cu, Co, Ti, V, and Au deposits associated with mafic-ultramafic intrusions (Hoatson and Blake 2000). The recent resurgence in exploration in these provinces has generated new interest in the economic potential of the Arunta intrusions.

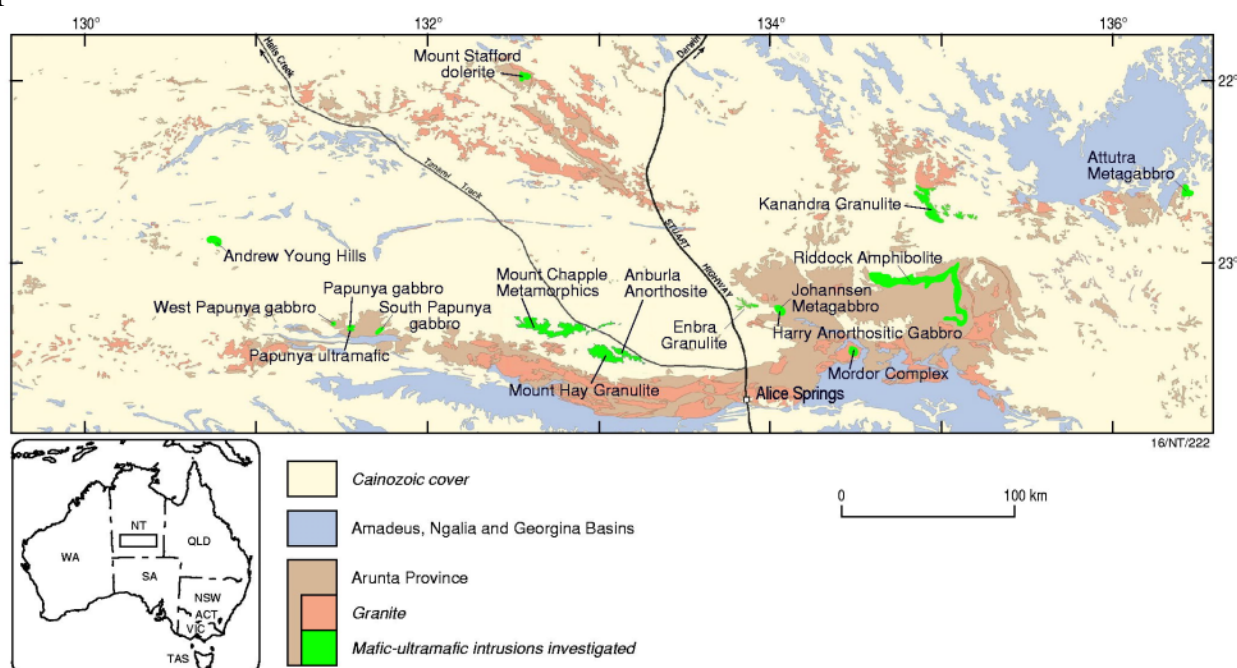


Figure 1. Mafic-ultramafic intrusions investigated in the Arunta Province

Mafic Event Chronology and Preliminary Geochemical Characteristics

The new U-Pb geochronology highlights distinctly episodic emplacement of Proterozoic mafic-ultramafic systems in the Arunta. Ages summarised in [Table 1](#) draw on the following major constraints:

North Arunta intrusions (north of the Redbank Thrust Zone)

1. Valuable crosscutting relations between different intrusions are exposed where the Johannsen Metagabbro is intruded by the Harry Anorthositic Gabbro, which locally interfingers with an un-named tonalite body (Hoatson and Stewart 2001); these are in turn cut by a NNE-trending dolerite dyke. The igneous units record a progression of crystallisation ages at ~1805 Ma, ~1785 Ma, and ~1690 Ma, and zircons within the older bodies record metamorphism synchronous with the younger intrusions; all are consistent with the relative timing evident in outcrop.
2. The Mount Hay and Enbra Hills mafic granulite bodies lack relative timing constraints in the field, but their zircons have complex internal zoning patterns that record 1805-1810 Ma primary ages and subsequent event histories similar to the Johannsen Metagabbro.
3. The ~1780 Ma primary ages of the geographically dispersed Mount Chapple Metamorphics, Attuttra Metagabbro, and tonalite (see point 1) bodies are broadly synchronous with the first metamorphic event recorded in the older mafic granulites (Enbra Granulite, Johannsen Metagabbro, Mount Hay Granulite).
4. Of particular significance is the youngest event in the granulite rocks which records previously unrecognised metamorphism in the central Arunta at ~1690 Ma, together with intrusion of the dolerite dyke (see point 1), indicating an extensional regime at that time. This age correlates within the established Proterozoic event chronologies of the Mt Isa and Broken Hill regions.

South Arunta intrusions (south of the Redbank Thrust Zone)

5. Zircons from the Andrew Young Hills, Papunya gabbro, and Papunya ultramafic bodies in the southern Arunta indicate a single magmatic event at ~1635 Ma and no evidence of zircon inheritance or metamorphic recrystallisation. The South Papunya gabbro has an interpreted primary age at ~1635 Ma and inherited zircons in the range 1670 to 1700 Ma. The distinctive age chronology of all these units is clearly different to the older magmatic systems of the North Arunta, and indicates that the northern boundary of the South Arunta probably passes north of the Andrew Young Hills intrusion.

Mordor Igneous Complex

6. Zircons from a plagioclase pyroxenite plug in the Mordor Igneous Complex have a simple crystallisation age of 1131.8 ± 4.5 Ma, which is consistent with, but more precise than published Rb-Sr and Sm-Nd isochron ages (Nelson *et al* 1989).

Riddock Amphibolite

7. A garnet-bearing para-amphibolite from within the Riddock Amphibolite contains metamorphic zircons formed at 461 ± 6 Ma that preserve zircon cores with a range of Neoproterozoic ages as young as 734 ± 44 Ma. It is interpreted that the sample is a metasediment deposited with orthoamphibolite units at or after 734 ± 44 Ma, and subsequently metamorphosed at 461 ± 6 Ma during the Larapinta Event.

Table 1. Event chronology of Arunta mafic-ultramafic magmatic systems

Magmatic Events (~ Ma)¹	I (1810)	II (1780)	III (1690)	IV (1635)	V (1130)	VI (735-460)
Riddock Amphibolite						734±44 to 461±6
Mordor Igneous Complex					1131.8±4.5	
South Arunta intrusions						
Andrew Young Hills				1632.9±2.8		
South Papunya gabbro				1634.6±4.8		
Papunya gabbro				1636.5±2.4		
Papunya ultramafic				1639.2±2.0		
Mutually cross-cutting intrusions						
Dolerite dyke (cutting Johannsen M. and Tonalite)			1686±8			
Tonalite (cutting Johannsen M.)		1785.6±3.5	1683±20			
North Arunta intrusions						
Mount Chapple Met.		1774.0±1.9	complex history			
Attutra Metagabbro		1786.4±4.2				
Mount Hay Granulite	1805.4±3.4	1777.5±3.1	1693±20			
Johannsen Metagabbro	1805.6±3.2	1783.8±1.9	1697±7			
Enbra Granulite	1812.4±2.4	1786.6±3.9	1685±11			

¹ Events I to VI do not represent a sequential sequence that operated for *all parts* of the Arunta Province. Zircons were dated by SHRIMP II in Canberra using cathodoluminescence imaging to target probe sites within the complex internal zoning patterns that were often found. Ages are quoted at 95% confidence; most have precision better than ±5 Ma. Primary crystallisation ages are in bold type; ‘metamorphic’ ages are in normal type. M. = Metagabbro; Met. = Metamorphics.

Chondrite-normalised multi-element patterns of rocks with melt-like compositions assist in refining the correlations of mafic magmatic systems indicated by the geochronological framework. The ~1810 Ma Mount Hay and Enbra Hills bodies are compositionally the same, but are distinct from the coeval Johannsen Metagabbro, which at comparable degrees of fractionation (8% MgO content), has lower abundances of TiO₂ (0.8%), Zr (42 ppm) and Y (22 ppm). This suggests that magma generation for the Johannsen Metagabbro was by larger degrees of mantle melting, if the low Zr/Sm values (~18) are not related to clinopyroxene accumulation. The estimated parent magma composition of the ~1785 Ma Mount Chapple Metamorphics has chemical affinity with the Attutra Metagabbro, except for higher (La/Sm)_N values (2.5 versus 1.8) and lower Zr/Sm (23 versus 30). Together, they have considerably lower Nb/Th and Nb/Ba values than those of Mount Stafford dolerite and Kanandra Granulite. The South Arunta intrusions have a large range of (La/Sm)_N values (1.8 to 3.5), requiring progressive crustal contamination and crystal accumulation to explain the different ratios of La/Sm, Nb/La, and Zr/Sm. The Andrew Young Hills intrusion is one of the most contaminated mafic bodies investigated in the Arunta.

Economic Potential

Hoatson (2001) has used incompatible-element discrimination diagrams (Figure 2) to show that the Arunta intrusions fall into two major geochemical groups that highlight geographical differences in mineral prospectivity:

(1) A S-rich group (~300 to 1200 ppm S) in the geographical western and central Arunta has some potential for orthomagmatic Ni-Cu-Co sulphide associations. The identification of favourable mineralised environments, such as feeder conduits or depressions within the basal contacts of large prospective contaminated bodies, such as Andrew Young Hills, Mount Chapple, and Mount Hay will be achieved through airborne electromagnetic/gravity and remote-sensing techniques in association with diamond drilling and petrological information.

(2) A relatively S-poor (<300 ppm S), slightly more primitive group in the eastern Arunta has greater potential for orthomagmatic PGE-sulphide associations. Of this group, the Riddock Amphibolite (igneous units) and Attutra Metagabbro appear to have the most favourable low S concentrations for PGE mineralisation. Phlogopite-bearing ultramafic rocks in the Mordor Igneous Complex contain anomalous abundances of Pt and Pd (up to 20 ppb) that also indicate potential for PGE mineralisation.

Both groups have potential for hydrothermal polymetallic deposits of Cu-Au±PGEs±Ag±Pb spatially associated with the intrusions. The absence of thick sequences of primitive ultramafic rocks throughout the Arunta downgrades the potential for PGE-chromite associations. The absence of these economically important rocks is a feature of the Arunta that contrasts with other mineralised Proterozoic provinces (Musgrave Block, East Kimberleys).

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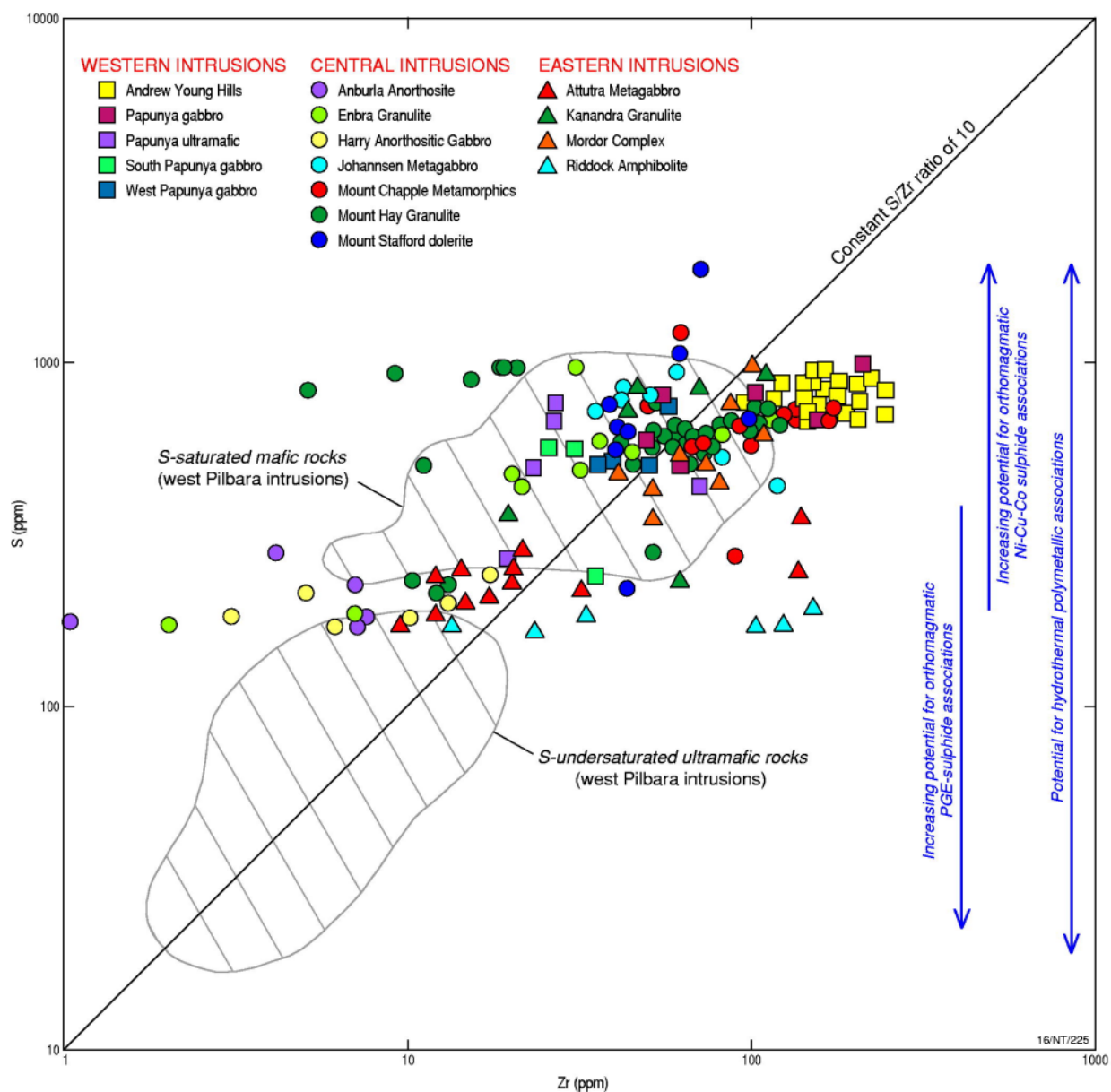


Figure 2. Logarithmic plot of whole-rock S and Zr concentrations for Arunta mafic and ultramafic rocks. Fields for mineralised west Pilbara layered intrusions are also shown.