Summary of Results
Joint NTGS – AGSO Age Determination Program
1999 - 2001

J Smith

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INTRODUCTION

This Record is a source document listing new zircon U-Pb isotopic ages measured for key rocks units in Australia’s Northern Territory. The samples are critical reference points in the conduct of, and interpretations made by, the Regional Geoscience Program of the Northern Territory Geological Survey (NTGS) and the dating was conducted within the Geochronology group of AGSO-Geoscience Australia. The relationships between these ages, their regional significance, and the event chronologies they constrain will be discussed in other NTGS outlets and is not developed here. The source listing of ages is being made available early as a reference document, with brief details of the locations and geological context of each sample and comments on each age interpretation, as a service to all geoscientists and mineral explorers with interests in the geology of the Northern Territory. The analytical data are plotted on Concordia diagrams (see Figures) and are summarised in Appendix Tables A1-A43. These tables are not reproduced here, but are available from NTGS upon request.

NTGS – AGSO Geochronology Partnership

The isotopic dating was generated from a 2-year partnership between NTGS and Geoscience Australia and was based at the SHRIMP (Sensitive High Resolution Ion MicroProbe) laboratory which is a joint facility of Geoscience Australia and The Australian National University (ANU) in Canberra. Geoscience Australia’s provision of laboratory access and infrastructure costs was matched by NTGS funding a 2-year position for Julie Smith to conduct the work.

The geological rationale guiding the dating program was provided by several NTGS geoscientists, including Marc Hendrickx, Andrew Crispe, Leon Vandenberg and Alison Dean (Tanami region); Kelvin Hussey and Ian Scrimgeour (Arunta Province and Tennant Inlier); and Angelique Cutovinos (Victoria-Birrindudu Basin).

All SHRIMP isotope data acquisition was conducted by Julie Smith supported by the Geoscience Australia team including Chris Foudoulis, Tas Armstrong and Steve Ridgeway, under the supervision of Rod Page.

In addition, Nd-Sm isotopic data for 13 samples was provided by Roland Maas of the VIEPS Radiogenic Isotope Laboratory at La Trobe University.

This Record is a compilation by Barry Pietsch (NTGS) from four Geoscience Australia Professional Opinion papers describing the age results obtained (Smith 2000a, b, c; Claoué-Long, Cross and Smith 2001). Interpretation of ages from the SHRIMP data was performed by Julie Smith in the first three papers, and completed by Jonathan Claoué-Long and Andrew Cross (Geoscience Australia) for the fourth.

Geological Considerations

A total of 43 sample localities are described from the following geological regions:

- Tanami Region: 23 rock units
- Arunta Province: 8 rock units
- Tennant Inlier: 8 rock units
- Victoria-Birrindudu Basin: 4 rock units

To assist readers of this listing with a geological context, a brief overview introduces the tectonic units to which the dated samples relate. The individual age contributions are assembled with a uniform protocol of descriptions and age interpretations. However, there is lack of uniformity in the geological contexts and descriptions – a consequence of the disparate reasons for selecting individual samples for dating in various regions. The integration with geological constraints will be developed in other publications by NTGS Regional Programs, for which the dating was obtained. This report is not, therefore, a geochronological study: it is a source documentation on the dating of individual localities that, in many instances, are unrelated. Each of the samples selected for study was directed at solving a geological problem that was recognised in the course of regional geological studies. Inevitably some determinations raise more questions than they answer. This is especially so in attempts to define the timing of major orogenic events in the regions being worked. For example “Barramundi Orogeny” in the Tanami looks significantly younger than the hitherto accepted archetype of 1860-1870 Ma, and for this reason the term Tanami Orogenic Event is used.

Finally it should be noted that the samples discussed in the report are given names of convenience for easy reference. Such names and terms are not intended to be used formally in the lithostratigraphic sense.

Shrimp Analytical Procedures

Care was taken by NTGS geologists to obtain fresh, unweathered samples for isotopic study. However, some key rock units in the Northern Territory are exposed only in limited outcrop, so some important samples, especially from the Tanami Region, are only available in weathered condition.
In cases where a weathered unit is critical to the regional geology the attempt has been made to measure a zircon U-Pb age, accepting that there might be failure due to leaked isotopic compositions. Inevitably this has led to ambiguous discordant age information in some cases – but also the occasional surprising success where zircons in a weathered rock have preserved useful age information.

Zircons were separated from crushed samples by standard techniques including Wilfley table, heavy liquids and Franz magnetic separation. Handpicked grains were mounted in epoxy resin, together with reference zircons SL13 (Uranium abundance standard) and QGNG (Pb/U calibration standard). After polishing to reveal grain interiors, crystals were photographed in high magnification transmitted and reflected light, and cathodoluminescence (CL) images were obtained using an Hitachi S 2250-N SEM at the ANU Electron Microscopy Unit.

U-Pb isotopic analyses were conducted by Dr Julie Smith using both SHRIMP I and SHRIMP II ion microprobes. Analytical and data interpretation procedures followed those described by Claoué-Long et al (1995) and references therein. Briefly, an oxygen ion-beam of diameter between 15-30 µm in diameter was employed to excavate a crater approximately 1–2 µm deep in targeted zircon surfaces. A smaller probe diameter allows accurate placement of the ion beam within narrow overgrowths or small cores but its spatial resolution is gained at the expense of lowered beam strength and reduced counting precision. Ionised particles sputtered from the crater were extracted by a 10 kV potential, passed into the SHRIMP mass spectrometer, and counted with a single electron multiplier by cyclic stepping of the magnet. Each analysis is the average of seven scans through the mass stations.

Calibration of Pb/U ratios follows a power law relationship of Pb+/U+ and UO+/U+ (Claoué-Long et al 1995) and is normalised to an assumed Pb/U ratio of 0.3324 (equivalent to 1850 Ma) for the QGNG standard zircon. Uranium and Thorium abundances are similarly calibrated to the SL13 standard crystal which has a reference abundance of about 236 ppm U (but which is variable by at least ± 20%). Common Pb corrections throughout are calculated by reference to the measured abundance of ^{206}Pb and assuming common Pb of the same age as the zircons modelled by Stacey and Kramers (1975). Ages are calculated using the decay constants recommended by Steiger and Jaeger (1977). All isotopic ratios, ages and uncertainties produced by Julie Smith were been calculated using the in-house PRAWN and LLEAD software of the Canberra SHRIMP laboratory; those completed by Jon Claoué-Long and Andrew Cross used the SQUID and ISOPLOT Excel-based software of Ludwig (2000, 2001). Both sets of software packages implement the calculation procedures described by Claoué-Long et al (1995). Tabulated individual ^{207}Pb/^{206}Pb ratios and ages have 1σ uncertainties which take account of Poisson counting statistics, the dispersion of counts and ratios during the time of analysis, and the uncertainty introduced by correction for common Pb. Any instrumental bias in measured ^{207}Pb/^{206}Pb ages was monitored from concurrent analyses of the standard zircon, and these indicated no correction for mass fractionation. Except where stated otherwise, mean ages for groups of analyses are weighted means with uncertainties quoted at 95% confidence standard error of the mean, denoted as tσ, where t is a t-statistic multiplier appropriate to the number of analyses.

Samarium – Neodymium Analyses

In addition to the zircon determinations, 13 samples were selected for Sm-Nd isotopic work in order to investigate the timing of initial extraction of material from the mantle. This was done by Roland Maas at La Trobe University. The samples and analyses are listed in Table 1.

TANAMI REGION

Geological Overview

The Billabong complex lies to the east of The Granites mine area and consists of banded granitic gneiss with an igneous age of 2514 ± 3 Ma (SHRIMP U-Pb zircon, Page 1995).

The Browns Range Metamorphics outcrop on the southern flank of Browns Range Dome (northwest corner of TANAMI) and define an east-west striking, steeply south dipping shear zone (Vandenberg et al 2001). Granitic orthogneiss (quartz-feldspar-muscovite ± biotite), and muscovite paragneiss and schist are intruded by fine-grained Coomarie suite granitic sills and dykes, aplite and pegmatite (Hendrickx et al 2000, Dean 2001). The Browns Range Metamorphics underwent a high-grade metamorphic event at approximately 1880 Ma. This represents the maximum age for the deposition of the overlying early Proterozoic orogenic sediments and volcanics of the Tanami Region, the stratigraphy of which is presented in Figure 1.

The MacFarlane Peak Group was deposited on a thinned rifted crust. It consists of mafic volcanics, turbiditic sandstone, siltstone, and minor calc-silicate, intruded by mafic sills (now amphibolite). Small economic gold occurrences are hosted in this unit. It outcrops poorly, but has a distinct high magnetic response, which facilitates subsurface interpretation over a wide area.
<table>
<thead>
<tr>
<th>Sample</th>
<th>Sm ppm</th>
<th>Nd ppm</th>
<th>$^{147}$Sm/$^{144}$Nd</th>
<th>$^{143}$Nd/$^{144}$Nd</th>
<th>$\varepsilon^{Nd}$ (now)</th>
<th>$T_{DM}$ in Ga</th>
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All $^{143}$Nd/$^{144}$Nd values relative to a value for the La Jolla Nd standard of 0.511860 external precision for $^{143}$Nd/$^{144}$Nd ±0.000020 (2 sigma pop) external precision for $^{147}$Sm/$^{144}$Nd ± 0.2%.

$T_{DM}$ is the depleted mantle model age, calculated for a depleted mantle model that evolves linearly from $\varepsilon^{Nd}$ (4.55 Ga) = 0 to $\varepsilon^{Nd}$ (0 Ga) = +10 (0.513151), with a $^{147}$Sm/$^{144}$Nd = 0.2136 $\varepsilon^{Nd}$ (now) calculated using a present-day CHUR = 0.512638

Table 1. Sm-Nd Isotope Results

BIRRINDUDU GROUP

--- Unconformity ---

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<tr>
<th>The Granite Suite</th>
<th>Frederick Suite</th>
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<td>Mount Winnecke</td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td></td>
</tr>
<tr>
<td>MOUNT WINNECKE</td>
<td></td>
</tr>
<tr>
<td>GROUP</td>
<td></td>
</tr>
<tr>
<td>Nanny Goat</td>
<td>Coomarie</td>
</tr>
<tr>
<td>Volcanics</td>
<td>Suite</td>
</tr>
<tr>
<td>1816 ± 7Ma</td>
<td>Inningarra</td>
</tr>
<tr>
<td>1821 ± 5Ma</td>
<td>Suite</td>
</tr>
<tr>
<td>Mount Winnecke</td>
<td>Winnecke</td>
</tr>
<tr>
<td>Formation 1824 ± 5Ma</td>
<td>Suite</td>
</tr>
<tr>
<td></td>
<td>Borefield Road</td>
</tr>
<tr>
<td></td>
<td>Suite</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Pargee Sandstone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mount Charles</td>
</tr>
<tr>
<td></td>
<td>Formation</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>TANAMI GROUP</td>
<td></td>
</tr>
<tr>
<td>Killi Killi</td>
<td></td>
</tr>
<tr>
<td>Formation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>MACFARLANES PEAK</td>
<td></td>
</tr>
<tr>
<td>GROUP</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Browns Range</td>
<td></td>
</tr>
<tr>
<td>Metamorphics</td>
<td></td>
</tr>
<tr>
<td>Billabong Complex</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

--- Unconformity ---

Figure 1. Stratigraphy of the Tanami Region

The *Tanami Group* overlies the MacFarlane Peak Group with an inferred disconformity. Sedimentation involved rapid transgression and deep marine sediment-starved deposition, followed by rapid sedimentation of a prograding wedge at the onset of deformation. This is typical passive margin sedimentation. The basal unit of the Tanami Group has a thin (100-400 m) meta-quartzite unit with some vein-quartz conglomerate. It is interpreted as a rapid transgression preceding deep marine deposition of the Dead Bullock Formation.

The *Dead Bullock Formation* consists of siltstone, graphitic shale, iron rich beds (BIF), and silicified nodular chert. Metamorphic grade varies from greenschist to amphibolite facies, with the highest grade in the southeast involving syn-tectonic partial melting of biotite-sillimanite-garnet pelitic gneiss.
This formation is chemically reactive and has demonstrated ability to reduce oxidised fluids and host gold mineralisation (Wygralak and Mernagh 2001). Magnetically responsive mafic sills intrude the Dead Bullock Formation.

The Killi Killi Formation conformably overlies the Dead Bullock Formation. This unit is a thick (2–4 km), monotonous package of interbedded greywacke and siltstone, deposited in a turbiditic marine environment. Mafic and felsic sills intrude the formation. Detritus was derived from a predominantly granitic source, although some felsic volcanics indicate nearby tectonic activity. Metamorphic grade, as with the Dead Bullock Formation, varies from greenschist to amphibolite facies.

Conclusion of Killi Killi sedimentation is marked by the onset of tectonism, with metamorphism and multiple deformation comprising a significant orogenic event, here called the Tanami Orogenic Event (TOE). In the Tanami Region, this event has been previously ascribed to the Barramundi Orogeny (BO), but a significant time break between BO and TOE warrants separation of the TOE from this widespread northern Australian orogeny. The TOE overlaps temporally with the Halls Creek Orogeny (Hendrickx et al 2000).

The Pargee Sandstone unconformably overlies the Killi Killi Formation. It is effected by only some of the deformations attributed to the TOE. It consists of conglomerate and arenite, is restricted to a small area and is considered to be syn-orogenic molasse, occupying a sub-basin formed during the later phases of the TOE.

Crustal extension and volcanism characterise the period immediately after the TOE. The Mount Charles Formation consists of basalt and turbiditic volcanics deposited in a failed rift. This interval is punctuated by felsic volcanism and high-level granite intrusion (Winnecke Group) to the north. Subsequent, widespread granite plutons contact metamorphosed existing lithologies. Granite (Table 2) are mostly I-type and have a similar character to Halls Creek Orogen granites (Table 1, Dean 2001). Structural and alteration features indicate that granites play an important role either ‘priming’ host rocks, acting as structural buttresses, or providing heat. The latest granites intruded about 1790 Ma. The followed peneplanation and deposition of widespread siliciclastic platform sediments of Birrindudu Group. The above stratigraphic description is derived from Vandenberg et al 2001. A summary description of Tanami samples is given in Table 3.

Samples Analysed

**Repulse Aplite**

| AGSO Sample ID: | 98496202 |
| Field Number:   | 98496202 |
| Rock Type:      | aplite dyke |
| Grid Reference: | 575007E 7792859N (WGS84) |

This cream coloured aphanitic to porphyritic dacite dyke cuts folded Tanami Group metasedimentary rocks in the Hurricane opencut, Tanami Gold Mine. The dyke displays well developed chill margins 10-15 cm wide and has a thickness of 3-4 m. Phenocrysts comprise recrystallised embayed quartz, ferromagnesian phases replaced by pyrite, and altered euhedral feldspar set in sericitised felsitic matrix. Centrally within the dyke, phenocrysts display alignment with dyke margins indicating magmatic flow during emplacement.

This sample yielded approximately 350 zircon grains, of which approximately 70% were selected from the non-magnetic fraction for mounting. The zircons are colourless to light brown, rounded anhedral grains, 50–100 µm long by 50 µm wide. Approximately 75% of the grains exhibit concentric zoning in cathodoluminescence, while in the other 25%, no internal structure is observable.

Analyses were made of 38 zircon grains. The analytical data are summarised in Table A1 and plotted on a Concordia diagram in Figure 2. Five analyses are grossly discordant but all others are within 5% of Concordia indicating minimal isotopic leakage. One grain (207.1) has an age of ca 2725 Ma. The remaining 32 compositions group with \( \chi^2 \) of 1.38 indicating a single statistical population. The weighted mean 207Pb/206Pb age of this group is 2528 ± 5 Ma (tσ).

The aplite intrudes Proterozoic stratigraphy and clearly cannot be Archaean in age. It is concluded that no magmatic zircon grains were detected in this sample, despite targeting of a range of zircon zonings, and that all the probed zircons were inherited in the magma.

**Pargee Dyke**

| AGSO Sample ID: | 98496203 |
| Field Number:   | 98496203 |
| Rock Type:      | Igneous intrusive |
| Grid Reference: | 561402E 7767444N (WGS84) |
Table 2. Granitic Suites of the Tanami Region

<table>
<thead>
<tr>
<th>Suite</th>
<th>Rock type</th>
<th>Texture</th>
<th>Magnetic signature</th>
<th>ASI</th>
<th>Oxidation state</th>
<th>Members and Age</th>
</tr>
</thead>
</table>
| The Granites Suite | predominantly biotite monzogranite to granodiorite (= Magnetite) | Porphyritic to equigranular, foliated to massive | Variable low to moderate | metaluminous to weakly peraluminous (fractionation) | reduced and oxidised | Pilatus granite (1795 ± 5 Ma)  
Granites monzogranite (180 ± 5 Ma)  
Twin Bonanza porphyry (1802 ± 8 Ma)  
Bunkers tonalite (1815 ± 4 Ma)  
Watertower tonalite (1821 ± 4 Ma)  
Muriel Range intrusives  
Granwade Ridge intrusives  
Murdoch Cliffs intrusives  
Officer Hill intrusives  
Coomarie Dome Intrusives (1815 ± 4 Ma)  
Browns Range intrusives (variable Na-metasomatism) (1805 ± 7 Ma)  
Frankenia monzogranite (1805 ± 6, 1807 ± 9 Ma)  
Talbot South monzogranite and other intrusives (variable K-metasomatism) (1812 ± 5 Ma)  
MacFarlanes granodiorite (1809 ± 8 Ma)  
Mount Winnecke volcanics (1824 ± 5 Ma)  
Winnecke granodiorite (1825 ± 5 Ma)  
Undefined intrusives  
Nanny Goat volcanics (1816 ± 7 Ma)  
Pipeline granodiorite (1801 ± 4 Ma)  
Mavericks monzogranite  
Apertawonga monzogranite  
Inspiration Peak monzogranite  
MacFarlane Peak monzogranite  
Slatey Creek and Lewis granites (WA)  
Walnut Granodiorite (1801 ± 5 Ma)  
Nova Range monzogranite (1794 ± 8 Ma) |
| Innigarra Suite | predominantly biotite monzogranite to tonalite (= muscovite ± magnetite) | Weakly seriate, coarse to fine grained, porphyritic to equigranular, foliated to massive | Variable high to low | metaluminous to peraluminous (fractionation and alteration) | oxidised |  |
| Coomarie Suite | biotite syeno/monzogranite, biotite granodiorite, biotite-quartz monzodiorite (= hornblende ± magnetite) | Foliated to massive, coarse to medium grained, porphyritic to equigranular | Low | metaluminous to peraluminous (K and Na alteration) | reduced and oxidised |  |
| Winnecke Suite | biotite syeno/monzogranite to granodiorite (= magnetite) | Coarse to medium grained, porphyritic to equigranular | Variable high to low | metaluminous to peralkaline (Na alteration) | reduced and strongly oxidised (weathered) |  |
| Frederick Suite | biotite monzogranite, hornblende-biotite granodiorite to biotite trondhjemite (= magnetite) | Medium to fine grained, weakly porphyritic to equigranular, foliated to massive | Variable high to low | metaluminous | oxidised |  |
| Borefield Road Suite | hornblende-biotite monzogranite to gabbro | Medium to coarse grained, cumulate to subphitic | Moderate to high | metaluminous |  |  |

This is a felsic intrusive drilled by Otter Exploration southwest of Jims Find. It consists of dykes up to 25 m thick. Otter geologists thought this intrusive to be related to the Frankenia Dome granite.

This sample yielded 40 zircon grains. All were mounted for analysis. The zircons are light pink to yellow-brown, anhedral to subhedral, 40-150 µm long. Some exhibit concentric luminescence zoning, whereas others had such weak luminescence that no internal structure was observable.

Analyses were made on all 18 different grains. Analytical data are summarised in Table A2 and plotted on a Concordia in Figure 3. Six analyses are grossly discordant. The concordant compositions record a scatter of individual ages with minor clusters at 206Pb/208Pb ages of 2523 ± 52 Ma (tσ), 1918 ± 26 Ma (tσ), and 1774 ± 44 Ma (t). Clearly the older ages are inherited. However the significance of the sparse youngest concordant ages is not established; they could represent a magmatic age, or inheritance in the magma, or could have been affected by metamorphic events. The data offer no conclusive information about the magmatic age of the dyke.
<table>
<thead>
<tr>
<th>Sample No</th>
<th>Unit</th>
<th>Rock Type</th>
<th>Geological Setting</th>
<th>Age</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>98496202</td>
<td>Repusle Aplite</td>
<td>Aplite dyke</td>
<td>Intrudes Tanami Group</td>
<td>2528 ± 5 Ma</td>
<td>Age of inherited zircons</td>
</tr>
<tr>
<td>98496203</td>
<td>Pargee Dyke</td>
<td>Felsic dyke</td>
<td>Intrudes Tanami Group (Killi Killi Formation)</td>
<td>No reliable ages</td>
<td></td>
</tr>
<tr>
<td>98496204</td>
<td>Jims Find Granite</td>
<td>Granite</td>
<td>Intrudes Tanami Group (Killi Killi Formation)</td>
<td>1807 ± 9 Ma</td>
<td>Contains 2535 ± 5 Ma inherited zircons</td>
</tr>
<tr>
<td>98496205</td>
<td>Crusade Dacite</td>
<td>Dacite</td>
<td></td>
<td>1816 ± 7 Ma</td>
<td></td>
</tr>
<tr>
<td>88495015</td>
<td>Browns Range Dome</td>
<td>Porphyritic granite</td>
<td>Granite from Browns Range Dome</td>
<td>1805 ± 7 Ma</td>
<td></td>
</tr>
<tr>
<td>88495016B</td>
<td>Browns Range Dome</td>
<td>Porphyritic granite</td>
<td>Granite from Browns Range Dome</td>
<td>1780 ± 33 Ma</td>
<td></td>
</tr>
<tr>
<td>88495018A</td>
<td>Browns Range Dome</td>
<td>Porphyritic granite</td>
<td>Granite from Browns Range Dome</td>
<td>1796 ± 7 Ma</td>
<td></td>
</tr>
<tr>
<td>99496206</td>
<td>Pargee Dyke</td>
<td>Rhyolite Sill</td>
<td>Intrudes and folded with Pargee Sandstone</td>
<td>Various inherited zircon ages</td>
<td></td>
</tr>
<tr>
<td>99496207</td>
<td>Pilatus Granite</td>
<td>Porphyritic granite</td>
<td>Intrudes Dead Bullock Formation</td>
<td>1805 ± 5 Ma</td>
<td></td>
</tr>
<tr>
<td>99496208</td>
<td>Twin Bonazer Porphyry</td>
<td>Porphyritic granite</td>
<td>Post dates deformation of Range Sandstone</td>
<td>1802 ± 8 Ma</td>
<td></td>
</tr>
<tr>
<td>99496209</td>
<td>Mac Farlanes Granodiorite</td>
<td>Granodiorite</td>
<td>Foliated granite</td>
<td>1809 ± 8 Ma</td>
<td>Provides minimum depositional age for Mac Farlanes Peak group</td>
</tr>
<tr>
<td>99496210</td>
<td>Bunkers Tonalite</td>
<td>Granodiorite</td>
<td>Foliated, syn-orogenic. Instrudes Dead Bullock Formation</td>
<td>1815 ± 4 Ma</td>
<td></td>
</tr>
<tr>
<td>99496213</td>
<td>Water Tower Tonalite</td>
<td>Granodiorite</td>
<td>Foliated, syn-late orogenic. Instrudes Killi Killi Formation</td>
<td>1821 ± 4 Ma</td>
<td></td>
</tr>
<tr>
<td>99496214</td>
<td>Winnecke Granodiorite</td>
<td>Granodiorite</td>
<td>Sub-volcanic or shallow intrusive</td>
<td>1825 ± 5 Ma</td>
<td></td>
</tr>
<tr>
<td>99496219</td>
<td>Coomarie Granodiorite</td>
<td>Granodiorite</td>
<td>Appears to intrude metamorphosed Mac Farlanes Peak Group and Mt Charles Formation rocks</td>
<td>1815 ± 5 Ma</td>
<td>Age is deemed approximate due to scatter in data</td>
</tr>
<tr>
<td>99496220</td>
<td>Frankeria Monzogranite</td>
<td>Monzogranite</td>
<td>Sample from central Frankenia Dome</td>
<td>1805 ± 6 Ma</td>
<td></td>
</tr>
<tr>
<td>99496221</td>
<td>Maverick Granodiorite</td>
<td>Monzogranite</td>
<td>Large pluton</td>
<td>1801 ± 4 Ma</td>
<td></td>
</tr>
<tr>
<td>99496216</td>
<td>Walnut Granodiorite</td>
<td>Granodiorite</td>
<td></td>
<td>1801 ± 5 Ma</td>
<td></td>
</tr>
<tr>
<td>99496222</td>
<td>Killi Killi Beds</td>
<td>Sandstone</td>
<td>Well-sorted quartzarenite, with minor volcanic and sedimentary clasts</td>
<td>1815 ± 13 Ma</td>
<td>Youngest detrital zircon population</td>
</tr>
<tr>
<td>99496217</td>
<td>Supplejack Volcanics</td>
<td>Felsic Volcanics</td>
<td></td>
<td>1821 ± 5 Ma</td>
<td></td>
</tr>
<tr>
<td>99496218</td>
<td>Nora Range Porphyry</td>
<td>Porphyry</td>
<td>Spatially associated with Nora Range Granite and Killi Killi Formation. May be interbedded volcanic or intrusive in Killi Killi Formation.</td>
<td>1794 ± 8 Ma</td>
<td></td>
</tr>
<tr>
<td>99496223</td>
<td>Inspiration Peak</td>
<td>Monzogranite</td>
<td></td>
<td>1844 ± 8 Ma</td>
<td></td>
</tr>
<tr>
<td>99496224</td>
<td>Talbot South Monzogranite</td>
<td>Monzogranite</td>
<td></td>
<td>1812 ± 5 Ma</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Summary Description of Tanami Region Samples

**Jims Find Granite**

<table>
<thead>
<tr>
<th>AGSO Sample ID:</th>
<th>Field Number:</th>
<th>Rock Type:</th>
<th>Grid Reference:</th>
</tr>
</thead>
<tbody>
<tr>
<td>98496204</td>
<td>98496204</td>
<td>porphyry/granite</td>
<td>565763E 7767770N (AGD84)</td>
</tr>
</tbody>
</table>
This sample was taken from core drilled 33 km south-southeast of Jims Pit. The granite is a non-magnetic body of unknown size. It probably is related to the intrusion of the Frankenlia Granite.

This sample had a total yield of 148 zircon grains, all of which were mounted for analysis. The zircons are cloudy pink to brown; about 40% of the grains are metamict. Most grains are euhedral, 80-200 µm long by 40-100 µm wide. Most exhibit concentric zoning, but the internal structure of some grains reflects the metamict nature observed in transmitted light.

Fifty-four analyses were made on 52 zircon grains. The analytical data are summarised in Table A3 and plotted on a Concordia (Figure 4). Analyses included were 95% to 105% concordant. Twenty-five analyses are grossly discordant along zero-age Pb loss trends, reflecting the altered and metamict nature of the grains. Two concordant populations are distinctive on the Concordia plot (Figure 4). The younger population is interpreted to represent the magmatic age of Jims Find granite and has a weighted mean 207Pb/206Pb age of 1807 ± 9 Ma (tσ) based on 10 analyses and an acceptable χ² (0.83). The older population is interpreted to represent inherited grains and has a weighted mean 207Pb/206Pb age of 2535 ± 5 Ma (tσ) based on 18 analyses (but has a significantly high χ² indicating a dispersion of two or more original ages.

**Crusade Dacite**

<table>
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<th>AGSO Sample ID:</th>
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<tbody>
<tr>
<td>Field Number:</td>
<td>98496205</td>
</tr>
<tr>
<td>Rock Type:</td>
<td>dacite</td>
</tr>
<tr>
<td>Grid Reference:</td>
<td>612744E 7883161N (AGD84)</td>
</tr>
</tbody>
</table>

This dacite sample was taken from the Crusade prospect of Otter Exploration, northern Tanami 1:250 000 mapsheet. It has been mapped as Nanny Goat Volcanics of the Winnecke Group.

This sample yielded in excess of 3000 zircon grains, from which 20% of the non-magnetic fraction were selected for mounting. The zircons are clear, colourless to pale pink, subhedral to euhedral, the majority are close to equant and 100-200 µm long by 50 µm wide. A few contain inclusions. The majority of grains exhibit concentric zoning in CL.

Analyses were made on 26 zircon grains. The analytical data are summarised in Table A4 and plotted on a Concordia in Figure 5. With the exception of two compositions more than 5% discordant, the measured 207Pb/206Pb ages group with χ² of 1.26 indicating a single statistical population. The dacite has a weighted mean 207Pb/206Pb age of 1816 ± 7 Ma (tσ) which is interpreted to be the crystallisation age of the volcanic rock.

**Browns Range Dome Granite**

<table>
<thead>
<tr>
<th>AGSO Sample ID:</th>
<th>88495015</th>
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<tbody>
<tr>
<td>Field Number:</td>
<td>PNC DDH 88-8 57-59 m</td>
</tr>
<tr>
<td>Rock Type:</td>
<td>medium-coarse-grained biotite (± muscovite) K-feldspar porphyritic granite</td>
</tr>
<tr>
<td>Grid Reference:</td>
<td>513000E 7902000N (GDA94)</td>
</tr>
</tbody>
</table>
This sample contains colourless to amber zircon grains, of which approximately 30% have a surficial orange stain. The zircons are euhedral to subhedral, with pyramidal terminations. There are inclusions in some grains, and cracks are common. The zircons are up to 350 µm long, but more commonly 100 - 150 µm long by 50 - 75 µm wide. Concentric zoning is present, indicative of a magmatic origin; cores are present in some grains. Analyses were generally made in unzoned areas.

Single analyses were made on 46 grains of the granitoid (Figure 6; Table A5). Of these, 29 (or more than 60%) are significantly discordant compositions. Three older analyses (120.1, 122.1 and 136.1) have 207Pb/206Pb ages of, respectively, ca 3220 Ma, 2690 Ma, and 2510 Ma, and are interpreted to represent inheritance. The remaining 14 concordant 207Pb/206Pb ages group with an acceptable χ² of 1.43 and yield a weighted mean age of 1805 ± 7 Ma (tσ) which is interpreted as the crystallisation of the Browns Range Dome porphyritic granite.

**Browns Range Dome Granite**

| AGSO Sample ID: | 88495016B |
| Field Number: | PNC DDH 88-13 62.55-63.5 m |
| Rock Type: | altered and weathered porphyritic granite |
| Grid Reference: | 505000E 7899000N (GDA94) |

The selected euhedral to subhedral grains are colourless or faint amber. Some are intact grains, whereas others are fragments. Inclusions are scarce but cracks are common; some grains are almost completely metamict. Most grains are elongate, 200 µm long by 75 µm wide. Concentric zoning in CL is indicative of magmatic origin.

Individual analyses were made on 34 grains of this granitoid (Figure 7; Table A6). Thirty are significantly discordant, leaving only 4 that can be regarded as preserving useful age information. These 4 analyses give a weighted mean 207Pb/206Pb age of 1780 ± 33 Ma (tσ) with an acceptable χ² of 0.19. It is clear that the isotopic system in this sample has been severely disturbed and the age cannot be regarded as well established. However the result is close in age to samples 88495015 and 88495018A.

**Browns Range Dome Granite**

| AGSO Sample ID: | 88495018A |
| Field Number: | PNC DDH 88-15 40.9-41.9 m |
| Rock Type: | porphyritic biotite-muscovite granite (undeformed pink microgranite with small mount of biotite, but otherwise leucocratic) |
| Grid Reference: | 520000E 7902000N (GDA94) |

The zircons are colourless to cloudy amber, with a few metamict grains. They vary from equant to elongate, and are generally subhedral with bipyramidal terminations. The zircons are 100 - 400 µm long by 50 - 200 µm wide. Concentric zoning is visible, as are areas of little or no zoning. Although some high-U rims were observed, none were successfully dated.
Forty-six analyses were made on 45 grains of this porphyritic granite (Figure 8; Table A7). Twenty-six analyses are significantly discordant, leaving 17 (identified in Table A7) for the age calculation. Of these, three (319.1, 323.1 and 326.1) are xenocrysts with individual ages of ca. 3215 Ma, 2030 Ma, and 3300 Ma. The remainder group with an acceptable c^2 of 0.53 and a weighted mean 207Pb/206Pb age of 1796 ± 7 Ma (ts), which is interpreted as the crystallisation age of the granite.

**Pargee Dyke**

| AGSO Sample ID: | 99496206 |
| Field Number:   | TAN99MH551 |
| Rock Type:      | Rhyolitic felsic intrusive |
| Grid Reference: | 523216E 7782520N (GDA94) |

The Pargee Sandstone consists of a thick sequence of interbedded conglomerate, quartz arenite and minor siltstone. It unconformably overlies cleaved Killi Killi siltstone south of the Pingidijara Hills region on the Pargee 1:100 000 sheet, and is unconformably overlain by Gardiner Sandstone, the basal unit of the Birrindudu Group. Deposition of the Pargee Sandstone postdates folding and metamorphism of the Tanami Group and hence it should be younger than 1845-1840 Ma, which is the assumed age of the Barramundi Orogeny in the Tanami Region (Cooper and Ding 1997). Similar rock types are found in the Moola Bulla Formation in the Halls Creek Orogen, with which Pargee Sandstone is tentatively correlated. Based on this correlation, an age of 1835 Ma is inferred (Blake et al 1999).
Figure 8. U-Pb Wetherill concordia plot of all SHRIMP data for the Browns Range Dome granite 88495018A. Shaded analyses are used in the calculation of the weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ age. Error boxes are 1σ for each analysis. Concordia curve labelled in Ma.

Figure 9. U-Pb Wetherill concordia plot of all SHRIMP data for the Pargee dyke 99496206. Error boxes are 1σ for each analysis. Concordia curve labelled in Ma.

Ptilotus Granite

<table>
<thead>
<tr>
<th>AGSO Sample ID</th>
<th>99496207</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Number</td>
<td>TAN99MH705</td>
</tr>
<tr>
<td>Rock Type</td>
<td>Felsic intrusive</td>
</tr>
<tr>
<td>Grid Reference</td>
<td>617735E 7755008N (GDA94)</td>
</tr>
</tbody>
</table>

This is a green-pink coarse-grained slightly porphyritic granodiorite with a moderate foliation. Colouration is due to mild epidote and chlorite alteration. The sample comes from NFM drillcore LRD001, which corresponds to a weakly magnetic pluton identified in the magnetic data. Drill logs indicate the granite intrudes metamorphosed siltstone and meta-dolerite sills attributed to the Dead Bullock Formation. The granite is similar in appearance to the Water Tower tonalite and Bunkers granodiorite and is probably part of the Inningarra Suite. The foliation is probably tectonic in part and probably formed during the later stages of the Barramundi Orogeny. The age of crystallisation should help to constrain the timing of the Barramundi Orogeny in the Tanami area.

The zircon grains are clear, colourless and mostly euhedral with bipyramidal terminations. The length to width ratio is 2:1 and the size ranges from 80-150 µm long.

Twenty-seven analyses were made on 27 grains from the granodiorite (Figure 10; Table A9). All the analyses have Th/U typical of magmatic zircon. Twenty concordant and near concordant analyses give a $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1805 ± 5 Ma (1σ) with an acceptable χ² of 1.3. This age population includes five slightly discordant analyses, but the 15 concordant analyses give an identical age result. The 1805 ± 5 Ma date is interpreted as the crystallisation age of the Ptilotus granite.

Implications of the SHRIMP data:
The 1805 ± 5 Ma age is a magmatic event. The deformation event that affected the Ptilotus granite appears to be too young to correlate with the assumed age of the Barramundi Orogeny in the Tanami Region, which is 1845-1840 Ma (Cooper and Ding 1997). The Th/U ratios of zircons in the pooled age are consistent with a magmatic origin for the zircon, rather than a metamorphic origin associated with the deformation event.

Twin Bonanza Porphyry

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This coarse porphyritic granite comes from the Twin Bonanza prospect 57 km to the west-southwest of Tanami (NFM drill core TBD002). This small body shows localised epidote-chlorite alteration and gold mineralisation along small fractures.
Euhedral feldspar phenocrysts up to 3 cm, are set in a coarse, equigranular groundmass. It is similar to The Granites Granite and other small late intrusions in the Tanami Region and probably is part of The Granites Suite. It post-dates the Barramundi event and the un-named tectonic event that deformed the Pargee Sandstone. The porphyry has previously been dated by single-grain lead fractional evaporation analysis (Cooper and Ding 1997). Three grains gave a crystallisation age of 1787 ± 3 Ma, which is at the younger range for The Granites Suite.

Zircon grains recovered from the non-magnetic fraction consist of clear, colourless to pale brown euhedral to subhedral grains. The length to width ratio is 3:1 to equant for these 250-100 µm long grains.

Thirty-eight analyses were made on 37 grains of porphyry (Figure 11; Table A10). Inheritance, or a component of inheritance, identified by zoning patterns in CL and low Th/U ratio, is indicated in seven analyses. The remaining 31 analyses group with a slightly high χ² of 1.9 and give a ³⁹⁷Pb/²⁰⁶Pb age of 1802 ± 8 Ma (t). The excess dispersion could be analytical, could be due to isotopic disturbance, or could indicated inclusion of one or more inherited zircons in the age population. In the absence of criteria to discriminate these possibilities, the calculated error has been modified to take account of the greater uncertainty, and is interpreted as the best estimate of the time of crystallisation of this porphyry.

Implications of the SHRIMP data:
The 1802 ± 8 Ma for the Twin Bonanza porphyry is interpreted as age of crystallisation. The Twin Bonanza porphyry, which is included in The Granites Suite, is within error of The Granites Granite magmatic age of 1795 ± 6 Ma (sample ID 87495004, Ozychron database, AGSO). The presence of gold mineralisation in this porphyry and its age indicate it may have undergone the same mineralising event as seen at The Granites.

**MacFarlane Granodiorite**

| AGSO Sample ID: | 99496209  |
| Field Number: | TAN99MH707  |
| Rock Type: | Felsic intrusive  |
| Grid Reference: | 545148E 7751884N (GDA94)  |

This sample is a foliated, pink to grey, medium-grained biotite granodiorite obtained from drill core (NFM-MFD001). Magnetic data and surface mapping 47 km to the southwest of Tanami indicate the granodiorite intrudes the MacFarlane Peak Group. The foliation is perpendicular to drill core (drilled 60° to 245°; hence the foliation is oriented approximately 60° to 65°) and consists of strung-out biotite and quartz-feldspar rich domains, which are tectonic in origin. Based on external appearance, the MacFarlane Granodiorite is included in the Inningarra Suite. The intrusion of the granodiorite is inferred to have been synchronous with the waning stages of the Barramundi Orogeny in the Tanami Region. Its age should date this deformation event and provide a minimum depositional age for the MacFarlane Peak Group. The foliation is cut by narrow (0.5 cm) aplite dykelets, the extent of which is not known. They are inferred to be associated with igneous activity at 1814 Ma, the age of the nearby Galifrey granite (1814 ± 2 Ma, Sample ID 96490001 in Ozychron database, AGSO). The rock is somewhat altered and most biotite grains are replaced by chlorite.
Zircon grains recovered from the non-magnetic fraction consist of clear, colourless to pale brown euhedral to subhedral grains. The length to width ratio is generally 2:1, with a few grains up to 4:1, for these 100-250 µm long grains.

A large number of the 28 analyses on 19 grains (Figure 12; Table A11) indicate Archaean inheritance. Six analyses, also representing inheritance, have a mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of $1866 \pm 10$ Ma ($\sigma$). Three analyses in the youngest population of ages are more than 5% discordant, and the remaining 9 give a weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of $1809 \pm 8$ Ma ($\sigma$) with $\chi^2$ of 2.0 indicating some excess dispersion; the calculated error is modified to reflect the excess scatter. This age is interpreted as an estimate of the crystallisation age of the pluton.

**Implications of the SHRIMP data:**

The MacFarlane granodiorite crystallised at $1809 \pm 8$ Ma, which is within error of the age of the nearby Galifrey granite (1814 Ma). It has also $1866$ Ma and $2545-2430$ Ma inherited components. The age of this granodiorite appears to be too young to correlate with the waning stages of the Barramundi Orogeny, but it does indicate a deformation event post-1809 Ma. The minimum depositional age for the MacFarlane Peak Group is 1809 Ma based on field relations with this granodiorite.

**Bunkers Granodiorite**

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This rock is a medium to coarse granodiorite that contains 25% quartz, 35% plagioclase and 20% alkali feldspar. The predominant mafic mineral is biotite with minor hornblende and magnetite. The granodiorite has pervasive foliation defined by alignment of biotite. Feldspars and quartz are not noticeably deformed. This sample is from NFM drill-core (GCD 253), 200 m south of the Bunkers Hill open-cut at The Granites Gold Mine. The drillcore specimen resembles pit exposures, although this is sheared. Mafic minerals are altered to chlorite and feldspars to clay and epidote, whereas the core is relatively fresh. Currently the granodiorite is placed with the Inningarra Suite, based on similarities with other Inningarra Suite granitoids (Water Tower tonalite? and MacFarlane granodiorite). The intrusion predates gold mineralisation and intrusion of The Granites Granite (1795 ± 6 Ma, Sample ID 87495004 in Ozchron database, AGSO, age calculated by R Page). The well developed foliation is assumed to reflect syn-orogenic intrusion during the waning stages of the Barramundi Orogeny. The assumed age of the Barramundi Orogeny in the Tanami Region is 1845-1840 Ma, (Cooper and Ding 1997) and 1858-1845 Ma in Tennant Creek (Compston 1995). An accurate igneous crystallisation age should date this deformation.

Recovered zircons are clear, colourless euhedral with bipyramidal terminations. They are 80-200 µm long with a length/width ratio of 3:1. CL shows oscillatory zoning in most grains and unzoned cores are locally visible.

Twenty-nine analyses were made on 28 grains (Figure 13; Table A12). Three analyses indicate inheritance older than 2240 Ma. Discordant data (<95% concordant) were rejected from age calculations, these analyses had relatively high levels of $^{204}\text{Pb}$. The remaining data form two age populations. The oldest has a $^{207}\text{Pb}/^{206}\text{Pb}$ age of $1863 \pm 6$ Ma ($\sigma$) based on 10 analyses ($\chi^2 = 1.6$). The younger population has a $^{207}\text{Pb}/^{206}\text{Pb}$ age of $1815 \pm 4$ Ma ($\sigma$) based on 12 analyses ($\chi^2 = 1.1$). Grain 113 has a core, which
is visible in both transmitted light and CL, and a rim wide enough to be probed separately. The core corresponds to the 1863 Ma group and the rim corresponds to the 1815 Ma group. Zircons in both of these populations exhibit magmatic growth zoning, making the data difficult to interpret. Th/U ratios in both are typical of magmatic zircon, so the preferred interpretation is that the younger population is the magmatic crystallisation age, rather than a metamorphic event, and that the older population represents inheritance in the magma.

Implications of the SHRIMP data:
The crystallisation age of 1815 ± 4 Ma and field relations imply that gold mineralisation is later than 1815 Ma. It is also consistent with Bunkers granodiorite pre-dating the 1795 Ma The Granites Granite. A deformation event occurred syn- or post-1815 Ma. This is again, younger than the interpreted age of the Barramundi Orogeny in the Tanami region. The 1863 ± 6 Ma is interpreted as the age of an inherited population, similar in age to inherited populations in the MacFarlane granodiorite, Galifrey granite and The Granites Granite.

Water Tower Tonalite

AGSO Sample ID: 99496213
Field Number: TAN99AD114R1
Rock Type: Felsic intrusive
Grid Reference: 648458E 7729654N (GDA94)

This non-magnetic pluton forms isolated subcrops and intrudes the metamorphosed Madigan Beds (Killi Killi Formation) east of The Granites mine. Bulldozed boulders uncovered by pipeline construction along Watertower Road, east of The Granites Gold Mine revealed relatively fresh, medium- to coarse-grained hornblende biotite tonalite to granodiorite with 5-10% alkali feldspar. Assigned to the Inningarra Suite on the basis of field characteristics, the Water Tower Tonalite contains a well-developed foliation defined by the alignment of biotite and hornblende and the elongation of quartz. The fabric is attributed to the waning stages of the Barramundi event. The age of this rock will help to determine intrusive relationships and the timing of deformation. Dating will also test the validity of a conventional zircon age, 1840 ± 11 Ma, obtained by Cooper and Ding (1997).

Zircons recovered are clear, colourless to pale brown, and generally euhedral with bipyramidal terminations. CL reveals oscillatory zoning. Grains have a length to width ratio of 2:1 and are 150-200 µm long.

Single analyses were made on 30 grains from the tonalite (Figure 14; Table A13). One inherited Archaean grain is present (120), and inheritance is observed in other analyses, corresponding to ages between 1965 Ma and 1850 Ma. Data discarded from the calculation include discordant data (<94% concordant) and data influenced by instrumental instabilities. The remaining 16 analyses give a weighted mean 207Pb/206Pb age of 1821 ± 4 Ma (tσ), with acceptable χ² of 1.6. The 1821 ± 4 Ma age is interpreted as the age of crystallisation of Water Tower tonalite.

Implications of SHRIMP data:
The tectonic fabric must be syn- or post-1821 Ma, which is younger than the accepted age of the Barramundi Orogeny. Several intrusive rocks dated in this project indicate a deformation event after the Barramundi Orogeny. The age derived here is not in agreement with the conventional zircon age of Cooper and Ding (1997), being 19 Ma younger. The sample shows evidence of inheritance, which may also have been present in zircons analysed by the conventional method.

Winnecke Granodiorite

AGSO Sample ID: 99496214
Field Number: TAN99AD243
Rock Type: Felsic intrusive
Grid Reference: 632081E 7901351N (GDA94)

This is a dark pink, medium-grained granodiorite with occasional large euhedral to rounded plagioclase phenocrysts rimmed with dark red-stained alkali feldspar (<5%). Plagioclase is equigranular and anhedral in character (35%). Minor interstitial red-stained alkali feldspar is present (15%). Dark grey interstitial quartz forms 35%. Mafic minerals are euhedral to subhedral and comprise (in order of abundance), biotite, hornblende and magnetite. This rock was collected by NTGS helicopter sampling and is a northerly outcrop of the Winnecke Suite. This substantially undeformed and homogenous intrusive body is correlated with the spatially and temporally associated Mount Winnecke Group volcanics. It is possibly a sub-volcanic or shallow intrusion, and therefore may be comagmatic with these volcanics. The Winnecke Granophyre, part of the Winnecke Suite, has an age of 1815 ± 5 Ma (Sample ID 87495004 in Ozchron database, AGSO, age calculated by R Page). A crystallisation age of 1824 ± 5 Ma
has been derived for the Winnecke Group volcanics (Sample ID 87495004 in Ozchron database, AGSO, age calculated by R Page). A crystallisation age on this body will test inferred relationships. The zircons are clear, colourless and contain many inclusions. Morphology is euhedral with bipyramidal terminations. The length to width ratio is 2:1. Grain morphology and zoning observed in cathodoluminescence is consistent with a magmatic origin. Individual analyses were made on 30 grains of this granodiorite (Figure 15; Table A14). Grain 222 has anomalously high U compared with the rest of the population, and is slightly reverse discordant, so it is not included in the age calculation. The remaining 28 analyses give a weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of $1825 \pm 5$ Ma ($\sigma$), with acceptable $\chi^2$ of 1.4, which is interpreted as the crystallisation age of the Winnecke granodiorite.

Implications of SHRIMP data:
The Winnecke granodiorite is coeval with the 1824 Ma Winnecke group volcanics. However, the granodiorite is not within error of the previously dated Winnecke granophyre. This may indicate more than one phase of intrusion within the Winnecke suite.

Coomarie Granodiorite

AGSO Sample ID: 99496219
Field Number: TAN99DDH3R1
Rock Type: Felsic intrusive
Grid Reference: 545070E 7818043N (GDA94)

Drillhole DDH3, from which this sample was obtained, was positioned over the large negative magnetic anomaly known as Coomarie dome. This is interpreted geophysically as a large composite intrusive body. The Coomarie Dome granitoid is only known from limited drillcore, which makes correlation difficult. Drillhole logs show weathered MacFarlane/Mt Charles-type metamorphosed sedimentary rock, meta-basalt, medium-grained biotite granodiorite/monzogranite, then back into metamorphosed sediment. This is either a meta-sedimentary enclave or it represents an irregular pluton margin. The granodiorite is equigranular and homogeneous with no obvious foliation. Green, slightly weathered, euhedral to anhedral plagioclase is present (35%). Pink to white alkali feldspar, rims plagioclase and also is present interstitially (15%). Interstitial quartz forms clear, grey anhedral grains (30%). Fine black biotite, hornblende, opaques, and sulfides represent the remaining minerals (20%). Sedimentary rocks surrounding the granodiorite body contain considerable visible pyrite, chalcopyrite and possible arsenopyrite. Assays indicate high background Au (6-7 ppb). This granodiorite is tentatively placed within the Coomarie Suite, purely on geophysical character and spatial distribution. An age from this drill core will allow tighter control on comagmatic events.

Zircon grains are clear, colourless, and euhedral with bipyramidal terminations. Length to width varies from 2:1 to equant for these 50-200 µm grains.

Twenty-seven analyses were made on 27 grains from the granodiorite (Figure 16; Table A15). Two of the zircons have inherited ages. The remaining data are dominated by 16 concordant to near-concordant analyses with a weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of $1815 \pm 5$ Ma; the $\chi^2$ of this group is high at 2.9. Inclusion of slightly discordant analyses, increasing the data pool to 20 analyses, gives an indistinguishable weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of $1815 \pm 4$ Ma ($\sigma$) with a high $\chi^2$ of 2.4.
The excess dispersion of ages within this group is difficult to assess. There are no obvious correlations of composition with age to justify any discrimination of grains, and no excess scatter was identified in the concurrent analyses of the standard zircon or other unknowns analysed in the same session. If the spread is interpreted as due to inherited components and the data is culled to reach a statistically uniform population, the mean age is reduced to ca 1812 Ma. Although the 1815 Ma age gives an indication of the timing of crystallisation, this should be considered approximate because of the unexplained excess scatter of data.

Implications of SHRIMP data:
The Coomarie Suite is a magmatic event at 1815 Ma, recorded by the Coomarie granodiorite. This age is slightly older than those obtained for the Browns Range Dome (1800 Ma), the Frankenia monzogranite which is interpreted to also be part of the Coomarie Suite (1804 Ma) and the Maverick monzogranite (1801 Ma) of the Mount Frederick Suite. Mineralisation in this sample postdates 1815 Ma.

Frankenia Monzogranite

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This sample was collected by NTGS drilling of inferred intrusive bodies, where there is no outcrop. The drillhole was located centrally to the Frankenia Dome, a large non-magnetic feature, which is interpreted as a composite igneous complex. The sample is of a dark pink to red, medium, equigranular, homogenous biotite monzogranite. Mineralogy comprises pink euhedral to subhedral plagioclase (30%), pink interstitial (some large poikilitic grains) alkali feldspar (30%), grey translucent quartz (30%), fine dark biotite and opaques (10%). The sample is cut by variously oriented thin pegmatite veins and contains miarolitic cavities (which indicates intrusion at shallow crustal level). This sample is placed within the Coomarie Suite because of its spatial association and non-magnetic undeformed character. An age determination would confirm this association.

Euhedral zircon grains recovered from the non-magnetic fraction of the heavy mineral concentrate are colourless, mostly clear with some opaque grains. Some grains have surficial iron staining.

Twenty-eight analyses were made on 27 grains (Figure 17; Table A16). Eighteen analyses have inheritance, of mostly Archaean ages. Ten of these give a concordant mean $^{207}\text{Pb} / ^{206}\text{Pb}$ age of 2521 ± 8 Ma. A second group of 8 concordant analyses give a weighted mean $^{207}\text{Pb} / ^{206}\text{Pb}$ age of 1805 ± 6 Ma ($\sigma$) which is interpreted as the crystallisation age of the pluton.

Implications of SHRIMP data:
The Frankenia monzogranite was emplaced and crystallised at 1805 Ma. Archaean inheritance indicates the presence of Archaean basement, which has also been identified in the Browns Range Dome to the north.
Maverick Monzogranite

AGSO Sample ID: 99496221
Field Number: TAN99DDH2
Rock Type: Felsic intrusive
Grid Reference: 505660E 7786673N (GDA94)

Drillhole DDH2 is situated on intermittent weathered granite outcrop. The granite is expressed as an intensely magnetic oval shaped body on geophysical imagery. This rock is an equigranular, homogenous, undeformed, hornblende-biotite monzogranite to granodiorite. Fine quartz veins in the core are cut by a second generation of fine quartz veins laced with sulfides. Sulfides also occur as disseminated blebs within the granite. Mafic microgranular enclaves and metasedimentary enclaves are noted in outcrop, although only the mafic type was sampled by the drilling. Mineralogy comprises white-green euhedral to subhedral plagioclase (30%), white alkali-feldspar (20%), grey translucent quartz (30%), mafic minerals and opaques (20%) including hornblende, biotite, magnetite, pyrite, pyrrhotite,chalcopyrite, arsenopyrite(?). This monzogranite is one of several near, or straddling, the Western Australian-Northern Territory border. They are grouped as the Mount Frederick Suite.

Zircons are clear, colourless euhedral grains with bipyramidal terminations and few inclusions. They have a length to width ratio of 2:1 and are 80-200 µm long.

Twenty-five analyses were made on 24 grains of zircon (Figure 18; Table A17). Several analyses record inheritance, from 3322 Ma to about 1880 Ma. There is a dominant group of 15 analyses with a weighted mean 207Pb/206Pb age of 1801 ± 4 Ma (tσ) and an acceptable χ² of 1.7. This is interpreted as the crystallisation age of the pluton.

Implications of SHRIMP data:
This member of the Mount Frederick Suite has a magmatic phase at 1801 Ma, and possesses inheritance.

Walnut Granodiorite

AGSO Sample ID: 99496216
Field Number: TAN99AD123
Informal Name: Walnut Granodiorite
Rock Type: granodiorite
Grid Reference: 628848mE-7707509mN (GDA94)

This sample is from fresh outcrop in the Grimwade Range south of the Granites Gold Mine. It is a coarse-grained, slightly porphyritic hornblende-biotite granodiorite. It exhibits alignment of large plagioclase crystals, attributed to flow within the magma, and some alignment of mafics that may indicate syn-tectonic intrusion. Numerous undeformed aplitic and pegmatitic dykes crosscut the outcrop. The granodiorite has a moderate magnetic signature and is placed in the Inningara Suite.

More than 90% of recovered zircons are simple, euhedral, prismatic forms with well developed pyramidal terminations and euhedral oscillatory growth-zoning, consistent with magmatic zircon crystallisation. These were targeted for dating the magmatic age. A subordinate number of grains have rounded anhedral shapes without internal zoning. A few of these were probed and their ages confirm inherited xenocrysts.

The 41 analyses of zircons form a complex array of variably discordant U-Pb isotopic compositions, signifying variable blends of ancient and zero-age Pb loss. There is a distinct correlation with U contents, with higher U being the most discordant (Table A18). On this basis, 19 zircon compositions (about half of the analysed sample) are interpreted to have leaked significant amounts of radiogenic Pb and do not contribute to useful age calculation. The remaining 22 compositions are concordant (with 3 being slightly reversed discordant, probably as an analytical artifact) and all have the same 207Pb/206Pb age within error (Figures 19A, B and C). The mean age is 1801 ± 5 Ma with χ² of 1.3 supporting a homogeneous age population. This result, for concordant compositions, which can be presumed to be unaffected by later leakage, is interpreted to record the crystallisation age of the granodiorite.

Killi Killi Formation

AGSO Sample ID: 99496222
Field Number: TAN99AD355
Informal Name: Killi Killi
Rock Type: Sandstone
Grid Reference: 512095mE – 7778071mN (GDA94)
Figure 18. U-Pb Wetherill concordia plot of all SHRIMP data for the Maverick monzogranite 99496221. Shaded analyses are used in the calculation of the weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ age. Error boxes are $1\sigma$ for each analysis. Concordia curve labelled in Ma.

Figure 19A. U-Pb Wetherill concordia plot of all SHRIMP zircon data for Walnut Granodiorite 99496216. Error boxes are $1\sigma$ for each analysis. Concordia curve labelled in Ma.

Figure 19B. Portion of Figure 19A, showing near-concordant zircon ages.

Figure 19C. Multigrain age histogram of zircons from Walnut Granodiorite 99496216; mean = 1800.8 ± 5.2 [0.29%] 95% confidence; weighted by data-point errors only, 0 of 22 rejected; MSWD = 1.3, probability = 0.17; (error bars are $2\sigma$).
This sample is from outcrop near Wilson airstrip, 10 kms to the northwest of the camp. Well exposed Killi Killi sedimentary rocks consist of purple-weathered, fine sandstone and siltstone. The sandstone is a predominantly well rounded, well sorted quartz arenite containing minor volcanic and sedimentary lithic clasts. A Killi Killi detrital age from this locality will be compared with results obtained elsewhere and will provide a maximum age, and evidence of provenance.

To establish a reliable detrital zircon age spectrum, 70 U-Pb ages were measured for zircons from this sandstone. With this quantity of data, if targeting of zircon grains was random, we can be 95% confident that the largest component of the provenance spectrum that may have been missed completely is less than 5% of the rock.

With the exception of a single discordant grain carrying no useful age information, zircon compositions adhere closely to Concordia in distinct age groupings (Figures 20A, 20B; Table A19). There is a dominant population (49 grains or 70% of the sample) with ages between 1800-1950 Ma. A second cluster of 12 grains (17% of the sample) has ages close to 2500 Ma. There are no other age groupings. Between the two clusters is a single grain near 2000 Ma, four zircons with individual ages between 2100-2200 Ma, a single grain about 2350 Ma, and individual Archaean grains at about 2700 Ma and 2900 Ma.

The youngest concordant zircon ages in the sample are a group of 5 grains whose U-Pb isotopic compositions are identical ($\chi^2 = 0.05$) and agree at a mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1815 ± 13 Ma (Figures 20C, 20D and 20E). This provides a confident maximum age for deposition of the sediment.

**Supplejack Volcanics**

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*Figure 20A. U-Pb Wetherill concordia plot of all SHRIMP zircon data for Killi Killi Formation 99496222. Error boxes are 1$\sigma$ for each analysis. Concordia curve labelled in Ma.*
This sample, obtained from outcrop in the Supplejack EL near Wilsons Creek, has been mapped as Nanny Goat Creek Volcanics, an extensive volcanic deposit comprising several distinct units. Phenocrysts represent 15-20% of the rock and include angular and rounded embayed quartz with evidence of dynamic recrystallisation and sub-grain development. Weathered feldspar phenocrysts are common and have been completely replaced by sericite. The shapes of other altered phenocrysts are suggestive of pyroxene or amphibole. The sample also contains lithic fragments of granophyric and granitic-textured material. The matrix comprises devitrified felsitic-textured feldspar and quartz.

Figure 20B. Age distribution histogram of zircons from Killi Killi Formation 99496222.

Figure 20C. Portion of Figure 20A, showing details of youngest zircon ages.
Figure 20D. Age distribution histogram showing details of youngest zircons from Killi Killi Formation 99496222.

Figure 20E. Multigrain age histogram of youngest zircons from Killi Killi Formation 99496222; mean = $1815 \pm 13$ (0.71%) 95% confidence, weighted by data-point errors only, 0 of 5 rejected. MSWD = 0.051, probability = 0.995 (error bars are 2$\sigma$).
U-Pb isotopic compositions of zircons in this sample are very uniform. All 38 analysed grains plot within error of Concordia, and of each other, indicating minimal disturbance of a simple age population (Figure 21A; Table A20). The mean $^{207}$Pb/$^{206}$Pb age of the group (Figure 21B) is 1821.4 ± 4.5 Ma, with $\chi^2$ of 1.3 supporting the homogeneity of the group. This can be interpreted with confidence as the crystallisation age of the volcanic unit.

**Nora Range Porphyry**

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</tbody>
</table>

This volcanic porphyry is spatially associated with outcropping Nora Range Granite and interbedded Killi Killi fine sandstone and siltstone. The rock is weathered dark purple, feldspathic rhyodacite/trachydacite. Phenocrysts comprise >25% of the rock, and are predominantly alkali feldspar with minor plagioclase, euhedral quartz, and altered mafics, (possibly clinopyroxene), biotite and opaques. Matrix composition is indeterminable. At other localities in this area the rock is less porphyritic and the ratio of quartz to feldspar phenocrysts increases. These volcanics are probably comagmatic with sills and dykes found in the Killi Killi Formation. A chilled margin (10 cm) suggests that the porphyry cuts the granite. An age determination for the volcanics will allow tighter temporal control on magmatic relationships.

Zircon crystals are brown in colour and have a range of short, stubby prismatic shapes. Pyramid terminations lack sharp edges and appear to have been partly resorbed, suggesting dissolution by magma or by metamorphism.

![Figure 21A](image-url). U-Pb Wetherill concordia plot of all SHRIMP zircon data for Supplejack porphyry 99496217. Error boxes are 1σ for each analysis. Concordia curve labelled in Ma.
Zircons have been affected slightly by Pb loss and three grains have lost significant radiogenic Pb. Among concordant compositions there is a dominant group near 1800 Ma, many of which have imprecisely measured compositions owing to the low beam strength employed in the analysis (Figures 22A, 22B; Table A21). In detail, this group has excess dispersion contributed by two grains with ages 1840-1890 Ma, and there is a third obvious xenocryst at about 2600 Ma. The remaining group of 33 zircons agrees at a mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1793.5 ± 8.2 Ma with $\chi^2$ of 1.2, indicating a homogeneous population (Figure 22C). This records the magmatic crystallisation of the porphyry.

The field relations recorded above are ambiguous, with part of the description suggesting a volcanic origin for the unit, and other aspects suggesting that the porphyry is an intrusion. The host Killi Killi Formation has a maximum depositional age of about 1815 Ma reported above, which permits the 1794 ± 8 Ma crystallisation age of the porphyry to fit either interpretation.

**Inspiration Peak Monzogranite**

| AGSO Sample ID: | 99496223 |
| Field Number:   | TAN99DDH28 |
| Rock Type:      | monzogranite |
| Grid Reference: | 601822mE-778379mN(GDA94) |

This intrusion is part of the Frederick Suite and is a small semi-circular pluton with a non-magnetic signature, surrounded by the strongly magnetic thermally metamorphosed Dead Bullock Formation, which defines the pluton dimensions. This granitoid does not outcrop and was sampled by NTGS drilling. It is an undeformed, medium to coarse, biotite monzogranite. Drillcore is cut by numerous randomly oriented quartz veins, aplitic and pegmatitic dykes. In thin section, the monzogranite has a well preserved igneous texture, with crosshatch twinning indicating microcline inversion, sutured quartz margins, subhedral partially sericitised plagioclase and biotite.

Zircons in this rock are uniform in form and are colourless transparent crystals of high optical quality. They have simple euhedral igneous forms with well preserved pyramid terminations and oscillatory growth zoning.

Zircons have uniform compositions. Of 32 analysed grains, one has leaked some radiogenic Pb. The remaining 31 are within error of Concordia and of each other, indicating minimal disturbance of a single age population (Figure 23A; Table A22). The mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of the group is 1844 ± 4 Ma with $\chi^2$ of 1.3, confirming the homogeneity of the group (Figure 23B). This is a confident crystallisation age for the monzogranite.
**Figure 22A.** U-Pb Wetherill concordia plot of all SHRIMP zircon data for Nora Range Porphyry 99496218. Error boxes are 1σ for each analysis. Concordia curve labelled in Ma.

**Figure 22B.** Portion of Figure 22A, showing details of near-concordant zircon ages.
Figure 22C. Multigrain age histogram of zircons from Nora Range Porphyry 99496218; mean = 1793.5 ± 8.2 [0.46%] 95% confidence; weighted by data-point errors only, 0 of 33 rejected; MSWD = 1.2, probability = 0.16 (error bars are 2σ).

Figure 23A. U-Pb Wetherill concordia plot of all SHRIMP zircon data for Inspiration Creek monzogranite 99496223. Error boxes are 1σ for each analysis. Concordia curve labelled in Ma.
Figure 23B. Multigrain age histogram of zircons from Inspiration Creek monzogranite 99496223; mean = 1844 ± 4 [0.22%] 95% confidence; weighted by data-point errors only, 1 of 31 rejected (blue); MSWD = 1.3, probability = 0.12; (error bars are 2\(\sigma\))．

Talbot South Monzogranite

AGSO Sample ID: 99496224
Field Number: TAN99DDH15
Rock Type: monzogranite
Grid Reference: 600480mE-7811307mN (GDA94)

Geophysical imagery of the Talbot South area indicates the existence of several irregularly shaped plutonic bodies cut by numerous faults. NTGS drilling recovered core which is of pink, medium to coarse, equigranular biotite monzogranite that has been pervasively sericitised to depths >100 m. Chloritisation of ferromagnesian phases occurs along fine shears within the granite. A weak magmatic foliation is defined by alignment of biotite.

Zircons are clear, high quality grains with well preserved igneous prismatic shapes and pyramid terminations. Oscillatory internal growth zoning is consistent with single stage magmatic crystal growth. Distinct cores that are present within a few grains infer zircon inheritance in the magma, upon which later magmatic crystallisation seeded.

With two exceptions, zircon compositions in this sample are concordant, indicating minimal isotopic disturbance. One grain is normally discordant, indicating loss of radiogenic Pb, and another exhibits apparent reverse discordance and an anomalous age older than any other measured grain. This probably reflects an analytical artifact, but the analysis is recorded for completeness. The remaining 22 compositions have a wide range of individual age precisions, reflecting the effect of variable U and Pb contents on the counting precision of the analyses. The concordant group has excess dispersion indicated by \(\chi^2\) of 3 and so does not contain a single age population. Excess dispersion is contributed to by high precision analyses of four grains with anomalously high uranium contents, well outside the range of U abundance in the main group of compositions. These 4 grains have individual ages in the range 1820-1840 Ma and may be xenocrysts inherited in the sample. The remaining group of 18 lower-uranium zircons agree at a mean \(^{207}\text{Pb}/^{206}\text{Pb}\) age of 1811.8 ± 4.7 Ma and their \(\chi^2\) of 1.5 is within the threshold of homogeneity at 95% confidence for 18 measurements (Figures 24A, 24B; Table A23). It is interpreted that the 1812 ± 5 Ma group records the crystallisation age of the granite and that the rock contains minor inheritance back to 1820-1840 Ma.
TENNANT INLIER

Geological Overview

A stratigraphic framework for the Tennant Creek and Davenport provinces of the Tennant Inlier is presented in Figure 25. The turbiditic, tuffaceous Warramunga Formation is the lowermost known unit of the Tennant Inlier and is interpreted as synorogenic turbiditic flysch associated with the Barramundi Orogeny.
Syn- to immediately post-tectonic intrusive and extrusive rocks of the Barramundi Igneous Association (BIA) are well represented in the central area of the Tennant Creek province and consist predominantly of dacitic to rhyolitic ignimbrites.

A clear litho- or tectono-stratigraphic break has not yet been identified within the Flynn and Ooradidgee Groups which would correspond with the apparent time break between the ca 1850 (1862-1837) Ma Tennant Creek Supersuite and the ca 1820 (1829-1816) Ma Treasure Suite of Wyborn et al. (1998). Extrusive felsic magmatism may be associated with continuing, localised extension starting late in the Barramundi orogenic cycle and extending into the early stages of the Davenport orogenic cycle, notwithstanding penecontemporaneous compression in the Warramunga basin.

A transition from rift to sag phase of sedimentation in the Davenport geosyncline is coincident with the Ooradidgee Group-Wauchope Subgroup boundary, and the corresponding Flynn-Tomkinson Creek Group boundary in the northern extension of the Davenport geosyncline in the Ashburton province. The Tomkinson Creek Group, and Wauchope and Hanlon Subgroups of the Hatches Creek Group correlate with the Tawallah Group of the McArthur Basin. A tectonic break at this level in the stratigraphy is called the Murchison Event (1810 Ma) and is correlated with the Stafford Tectonic Event (1830 Ma) in the northwestern Arunta, and the Early Strangways Orogeny (1780 Ma) in the northeastern Arunta. This suggests that deformation is diachronous.

The Junalki Formation immediately underlies the Unimbra Sandstone (Wauchope Subgroup, Hatches Creek Group), north of the Murchison Syncline. This formation contains rhyodacite rhyolite crystal-lithic tuff and minor andesite-dacite flows near the top. It changes upward from interbedded tuffaceous volcanic and volcaniclastic rocks at the base to predominantly volcani-lithic sandstone and siltstone. The Junalki Formation was previously interpreted as a correlative of the 1849 Ma Yungkulungu Formation, which similarly varies upward from predominantly volcanic to predominantly sedimentary rocks. However, a lithological similarity between Junalki and undifferentiated Warramunga Group rocks on the northeastern Bonney Well 1:250 000 sheet has been noted. A new date for the latter is 1862 Ma. These volcanic rocks are more deformed than Flynn and Ooradidgee Group volcanic and sedimentary rocks. The Junalki Formation therefore extends south from Tennant Creek to the northern Bonney Well sheet and is considered to be a time equivalent of the Warramunga Formation.

A hiatus was identified by Haines et al. (1991) within the Wauchope Subgroup, at the base of Coulters Sandstone on the Barrow Creek 1:250 000 sheet. There is an erosional unconformity at this level in the stratigraphy throughout the Davenport province (Blake et al. 1987) and a change from fluvial to shallow Marine sedimentation throughout the Inlier. A regional disconformity
is suggested, which is coincident with the onset of the early Strangways Orogeny of the Arunta Province. This hiatus is not contemporaneous with deformation in the Tennant Inlier which, as noted above, was 30-40 my earlier during the Murchison Event. A similar hiatus is postulated within the Yiyintyi Sandstone, of the Tawallah Group in the McArthur Basin, between periods of fluvialite sedimentation and shallow marine sedimentation. The Tennant Inlier samples are summarised in Table 4.

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Unit</th>
<th>Rock Type</th>
<th>Geological Setting</th>
<th>Age</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>99066301</td>
<td>Flynn Group</td>
<td>Felsic volcanic</td>
<td>Oldest known volcanic rock in NE Flynn Group</td>
<td>1853 ± 5 Ma</td>
<td>Crystallisation age</td>
</tr>
<tr>
<td>99066303</td>
<td>Lower Yungkulungu Formation</td>
<td>Dacitic ignimbrite</td>
<td>Lower part of Flynn Group</td>
<td>1849 ± 5 Ma</td>
<td>Crystallisation age</td>
</tr>
<tr>
<td>99066304</td>
<td>Lower Flynn Subgroup</td>
<td>Rhyodacite</td>
<td>Lower part of Flynn Group</td>
<td>1854 ± 4 Ma or 1864 ± 4 Ma</td>
<td>Age dependant on interpretation of data</td>
</tr>
<tr>
<td>99066305</td>
<td>Flynn Subgroup</td>
<td>Dacitic volcanic</td>
<td>Sample from massive flow-banded part of volcanic unit</td>
<td>1852 ± 4 Ma</td>
<td>Crystallisation age</td>
</tr>
<tr>
<td>99116401</td>
<td>Davenport Dacite Lava Granite</td>
<td>Dacitic</td>
<td>Non-outcropping beneath Georgina Basin (Barrow Creek 1:250k)</td>
<td>1862 ± 5 Ma</td>
<td>Crystallisation age</td>
</tr>
<tr>
<td>99116406</td>
<td>Barrow Creek Granite</td>
<td>Dacitic</td>
<td>Non-outcropping beneath Georgina Basin (Barrow Creek 1:250k)</td>
<td>1838 ± 4 Ma</td>
<td>Core sample. Age of crystallisation</td>
</tr>
<tr>
<td>99116407</td>
<td>Barrow Creek Orthongneiss</td>
<td>Granite?</td>
<td>Non-outcropping (Barrow Creek 1:250k)</td>
<td></td>
<td>Core sample. Complex inherited age pattern</td>
</tr>
<tr>
<td>99496302</td>
<td>Babylon Volcaniclastic Sediment</td>
<td>Volcaniclastic rock</td>
<td>Non-outcropping beneath Wiso Basin</td>
<td>1798 ± 5 Ma</td>
<td>Inherited age spectrum. This number interpreted as crystallisation age.</td>
</tr>
</tbody>
</table>

Table 4. Summary Description of Tennant Inlier Samples

Samples Analysed

Flynn Group

AGSO Sample ID: 99066301
Field Number: 99066301
Informal Name: undifferentiated Flynn Group
Rock Type: volcanic
Grid Reference: 452427E 7871168N (GDA94)

Sample 99066301 (drill core), from 57 km northeast of Tennant Creek, is a lithic-bearing biotite-plagioclase-alkali feldspar-quartz crystal phytic rock. It is of dacitic composition and contains a small amphibole-shaped phenocryst replaced by chlorite. With the exception of one other locality, amphibole has not been recognised in other ca 1850 Ma felsic rocks from this region. Alteration assemblages include chlorite, epidote, sericite, calcite, quartz and haematite(?). This volcanic rock forms a massive unit more than 200 m thick. It contains moderately fragmented and fractured, euhedral and embayed phenocrysts of biotite, plagioclase, alkali feldspar and quartz, and in places, angular sedimentary clasts (with light coloured alteration rims).Rare vesicular pumiceous clasts and aligned fiamme are recognised. Angular clasts of coherent porphyritic dacite, presumably from the parent magma, also occur. These features suggest 99066301 is pyroclastic and the thickness points towards it being an ignimbrite. Although there is evidence of squashed and deformed material in the fine groundmass, welding of shards cannot actually be demonstrated in thin section. The original texture is obscured by alteration and devitrification, and in isolation could be misinterpreted as flow banding rather than welding. The precise nature of this unit is unclear only because there is no textural evidence for welding and the actual contact relationships and associations are not seen.
99066301 was sampled for dating to test if it was coeval with or older than the Bernborough Formation volcanics (ignimbrites dated at 1840 Ma and 1845 Ma). Initial NTGS work placed it in the underlying Monument Formation. It was therefore interpreted as the oldest volcanic unit in the northeastern succession of the Flynn Group. The sedimentary units that underlie 99066301 have considerable mineralisation potential. This mineralisation potential is one of the main reasons for dating what is perceived as the pre-1850 Ma lower Flynn Group, and possibly Warramunga-Junalki Formations.

The analysed grains are clear and generally colourless, although some have a reddish (iron oxide) tinge. They are subhedral to euhedral, with a common length to width ratio of 2:1; the grains range from 50-100 µm wide. There are cracks and minor small inclusions. Luminescence images show concentric zoning consistent with magmatic crystallisation.

All 24 analyses of 24 grains (Figure 26; Table A24) are within 5% of concordance and were used in the calculation of a $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1853 ± 5 Ma ($\tau$), with an acceptable $\chi^2$ of 1.05. This is interpreted as a crystallisation age for the eruption of the volcanic rock.

**Implications of the SHRIMP data:**
The Monument Formation (lower Flynn Group) appears to be intruded by the 1848 Ma phase of the Tennant Creek Granite in the north, although intrusive contacts are not seen. The 1853 ± 5 Ma age supports NTGS regional interpretations and coincides with expected ages for the lower Flynn Group. It is within error of ages for dacites from the lower Yungkulungu Formation (99066303) with which it was correlated. It is slightly older than the northern phase of the Tennant Creek Granite indicating that the granite may have intruded Monument Formation.

This age also confirms that the lower Flynn Group has potential for Au-Cu mineralisation. One of the currently favoured models for Tennant Creek Cu-Au mineralisation invokes the 1850 Ma Tennant Creek granites as being a necessary first stage of the thermal process to generate the fluid movement which forms ironstones. Hence ironstones could be generated in any rock that was present before the granites intruded and need not necessarily be constrained to the turbiditic Warramunga Formation. Ironstones do occur in the Flynn Group but they appear to be best expressed in the Warramunga Formation. The Cu-Au mineralisation is a later event (1825 Ma).

**Lower Yungkulungu Formation.**

| AGSO Sample ID:       | 99066303          |
| Field Number:         | 99066303          |
| Informal Name:        | lower part of Yungkulungu Formation |
| Rock Type:            | dacitic volcanic  |
| Grid Reference:       | 448627E 7819968N (GDA94) |

Sample 99066303 (drillcore) is an altered biotite-alkali feldspar-plagioclase-quartz crystal-phryic dacite. It contains abundant embayed and fractured phenocrysts of quartz and feldspars that together comprise 60% of the rock. It also contains 5% biotite phenocrysts (now mostly chloritised). The matrix is a fine quartzo-feldspathic mosaic in which no primary igneous texture is visible. Alteration assemblages include chlorite, sericite, epidote and quartz. There is some crystal fragmentation in this rock. Although fragmented crystals can occur in coherent porphyritic lavas and intrusives, this rock has no obvious relict flow banding or crystal alignment, features that are typical of coherent lavas or intrusives.

This volcanic unit therefore appears to be a lithic-poor, crystal-rich ignimbrite. Ignimbrite and tuffaceous units that outcrop 2 km to the north of this sample locality are correlatives of the dated sample, which is from the lower part of Yungkulungu Formation, 35 km southeast of Tennant Creek. It was dated to constrain the age of volcanism in the lower part of the Flynn Group in the southeastern succession, and to test if it was equivalent in age to the Bernborough Formation and samples 99066301 and 99066305 in this record. The Yungkulungu Formation is known to be older than 1840 Ma, the age of the Channingum Granite which intrudes the Yungkulungu Formation.

The zircons are clear and colourless, with few inclusions or cracks. They are mostly euhedral, with bipyramidal terminations. They have a length to width ratio of 3:1. Most are 50-150 µm wide and have some concentric zoning.

Twenty-three analyses were made on 22 grains from the dacite (Figure 27; Table A25). Analysis 221.1 records inheritance. The remaining 22 agree at a weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1849 ± 5 Ma ($\tau$) with an acceptable $\chi^2$ of 0.8). This is interpreted as the crystallisation age of the volcanic rock.
Implications of the SHRIMP data:
The $1849 \pm 5$ Ma age is within error of ages from the Bernborough Formation volcanics and sample 99066301 (1853 $\pm$ 5 Ma), with which it is correlated. The age of this ignimbrite fixes volcanism in the lower Flynn Group in the southeastern succession to around 1850 Ma. The lower Flynn Group was deposited approximately 10 million years before the emplacement of the Channingum Granite. It is significantly younger than 99116401, which was interpreted as lower Flynn Group.

Lower Flynn Group.

AGSO Sample ID: 99066304
Field Number: 99066304
Informal Name: BIF Hill area, lower part of Flynn Group
Rock Type: rhyodacite
Grid Reference: 392827E 7775468N (GDA94)

Sample 99066304 (drillcore) was collected from a volcanic unit near “BIF hill” (57 km south-southwest of Tennant Creek) in the Bonney Well 1:250 000 sheet. These rocks were thought to be equivalent to volcanics of the Warramunga Group on the basis of close proximity to banded haematite-jasper-quartz rocks.

The nature of this volcanic rock unit is unclear. Most likely it is a quenched porphyritic dacitic lava but it lacks flow banding and crystal alignment.

These volcanics were dated to test whether they were part of the Warramunga Formation or lower Flynn Group. Rocks further to the north were interpreted as resulting from the onset of Flynn Group volcanism (99066305) and were considered atypical of the Warramunga Formation, as mapped in Tennant Creek.

Cu-Au mineralisation is present in the region (Babylon or Rover field) and it is therefore important to understand where these units occur in the stratigraphy.

The zircons are clear and colourless to pale brown. Most are euhedral, with a length to width ratio of 2:1 to 4:1. A few of the 150 grains selected for mounting have cracks and inclusions. Some cores are visible. Some grain terminations are bipyramidal; others are rounded.

Analyses were made on 31 grains from the rhyodacite (Figure 28; Table A26). All of the data are within 5% of concordance. Analysis 310.1 is an inherited xenocryst with age $2137 \pm 6$ Ma ($\sigma$). The remaining 30 analyses give a $207\text{Pb}/206\text{Pb}$ weighted mean age of $1859 \pm 3$ Ma ($\sigma$). However the high $\chi^2$ of 2.4 indicates that more than one population is present in the group. The complexity is not resolvable from morphology. Concentric zoning is visible in most grains and there is no systematic variation of morphology with age. There is no systematic variance of Th/U ratio, or any other compositional constraint with age, to aid in data interpretation. Some grains may record inheritance, or there may be lead loss (or both), giving rise to the excess scatter.
Figure 28. U-Pb Wetherill concordia plot of all SHRIMP data for lower Flynn Subgroup volcanic rock 99066304. Dark shaded analyses are those excluded when assuming inheritance for the calculation of the weighted mean 207Pb/206Pb age (1854 Ma). Light shaded analyses are those excluded when assuming lead loss for the calculation of the weighted mean 207Pb/206Pb age. Error boxes are 1σ for each analysis. Concordia curve labeled in Ma.

Figure 29. U-Pb Wetherill concordia plot of all SHRIMP data for an undifferentiated Flynn Group volcanic rock 99066305. Shaded analyses are used in the calculation of the weighted mean 207Pb/206Pb age. Error boxes are 1σ for each analysis. Concordia curve labelled in Ma.

If assuming inheritance, the older analyses (Table A26) can be culled to give a single population with a 207Pb/206Pb weighted mean age of 1854 ± 4 Ma (χ² = 1.4, n=25). Culling the younger analyses on the assumption of non-zero lead loss gives a 207Pb/206Pb weighted mean age of 1864 ± 4 Ma (σ) with a chi-square of 1.5 (n=22). It is possible that lead loss could be due to intrusion of a large body of granite to the east. However, there is no evidence in any of the other samples from the region for non-zero lead loss, whereas there is evidence of inheritance in the other samples, and in this sample itself (analysis 310.1). Neither of these scenarios is totally satisfactory as each age is derived from statistical parameters alone, rather than from morphological or chemical composition. The age information must be interpreted with caution, although it will indicate the approximate time of eruption.

Implications of the SHRIMP data:
The significance of this age is also dependent on interpretation of the rock as an erupted unit, thereby defining the time of eruption. Both of the 1864 ± 4 Ma and 1854 ± 4 Ma age alternatives are geologically plausible. The older age is within error of the maximum age of Warramunga Formation deposition and the age of 99116401. The younger age is within error of Flynn Group volcanism (99066301, 99066303 and 99066305), and is equivalent to the Epenarra Volcanics (1837 ± 5 Ma from uppermost unit) which broadly correlates with Flynn Group volcanism at 1854-1840 Ma. This volcanic rock most closely resembles dacitic lavas to the north (99066305) and was probably erupted in a subaqueous environment.

Flynn Group.

AGSO Sample ID: 99066305
Field Number: 99066305
Informal Name: Undifferentiated Flynn Group
Rock Type: volcanic
Grid Reference: 391707E 7788704N (GDA94)

Sample 99066305 (drillcore) is from a dacitic volcanic that is interpreted to be the basal unit of a subaqueous cryptodome. It represents the onset of volcanism, and was originally placed in the lower Flynn Group. This volcanic unit does not outcrop in Tennant Creek. It contains graded volcanosedimentary mass flow units that pass upward into autobreccias with intercalated sedimentary and lithic clasts, and finally a thick succession of massive flow-banded porphyritic lava. The top of this volcanic unit is missing. This lava, containing pseudofiamme, could be misinterpreted as representing a welded ignimbrite.

The underlying mass flows are proximal deposits and are very different in appearance to Warramunga Formation turbidites. For this reason it is placed in the lower part of the Flynn Group. Sedimentary units outcropping to the northeast of this locality overlie the volcanic unit. These sedimentary rocks are mapped as undifferentiated Flynn Group and may correlate with the Monument Formation and lower Yungkulungu Formation.
99066305 is an altered flow-banded biotite-plagioclase-alkali feldspar-quartz crystal-phyric dacite. It contains greenish pseudofiamme (altered flow-banded glassy material) and minor autobrecciation. No sedimentary lithic clasts were apparent in the dated sample. Alteration minerals include chlorite, epidote, calcite, sericite, quartz, alkali feldspar and Fe oxides.

The sample was collected from the massive flow-banded part of the volcanic unit. It was selected to date the initiation of volcanism, and to identify possible correlates.

Zircon grains are clear, colourless and euhedral. They are 150-200 µm long, with a length to width ratio of 2:1 to 3:1. Inclusions and cracks are plentiful. Concentric zoning is visible in CL images.

Twenty-two analyses were made on 22 unknown grains (Figure 29; Table A27). Only 2 compositions have significant discordance. Zircons 434.1 and 445.1 are xenocrysts with ages, respectively, of ca 2025 Ma and 2480 Ma. Analyses 433.1 and 438.1 also represent inheritance because the probe sites incorporated some core material and the ages are outliers from the main group of $^{207}$Pb/$^{206}$Pb ages. The weighted mean $^{207}$Pb/$^{206}$Pb age of the main group of 16 concordant zircons is 1852 ± 4 Ma (tσ) with an acceptable $\chi^2$ of 1.6, which is interpreted to be the crystallisation age of this unit.

**Implications of the SHRIMP data:**
The 1852 ± 4 Ma age suggests that this unit is part of the Flynn Group, as was previously postulated (Hussey pers comm 1999). Sample 99066305 correlates with samples 99066301 (1853 ± 5 Ma) and 99066303 (1849 ± 5 Ma).

**Davenport Dacite**

<table>
<thead>
<tr>
<th>AGSO Sample ID:</th>
<th>99116401</th>
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</thead>
<tbody>
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<td>Field Number:</td>
<td>99116401</td>
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<tr>
<td>Informal Name:</td>
<td>un-named</td>
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<tr>
<td>Rock Type:</td>
<td>dacitic volcanic</td>
</tr>
<tr>
<td>Grid Reference:</td>
<td>473231E 7764609N (GDA94)</td>
</tr>
</tbody>
</table>

Surface sample 99116401 is of a coherent flow-banded phorphyritic biotite-quartz-feldspar dacite lava. Phenocrysts are altered and the groundmass is partially recrystallised to fine-grained quartz-muscovite-biotite. Relict flow banding is visible in the groundmass. Outcrops near the sample site also contain quartz-chlorite-alkali feldspar-tourmaline veins. This metamorphism and alteration probably relates to intrusion of the 1848 ± 7 Ma Hill of Leaders Granite.

This unit was previously mapped as a volcanic within the Warramunga Group on the Bonney Well 1:250k sheet, 85 km to the southeast of Tennant Creek. A SHRIMP I age of 1872 ± 9 Ma (Ozchron database, AGSO) has been obtained from weathered outcrop in the same unit several kilometres to the west of this sample locality. This age seemed to be unusually old for the lower Flynn Group; it possibly reflects inheritance and is therefore older than the true age.

Zircon grains are clear and colourless to pale brown. Most are euhedral, with a length to width ratio of 2:1, and have bipyramidal or rounded terminations. Some inclusions are present; cracks are rare.

Analyses were made on 34 grains from the volcanic rock (Figure 30; Table A28). Analysis 401.1 has very high U (1465 ppm) and its reverse discordance may be an analytical artifact; it is excluded from age calculation. Seven analysed grains with rounded terminations have inherited cores ranging in age from 1908 Ma to 2462 Ma; the rims were too thin to analyse. The zoning pattern of grain 421 indicates analysis 421.1 also represents inheritance. The remaining 25 concordant analyses give a weighted mean $^{207}$Pb/$^{206}$Pb age of 1862 ± 5 Ma (tσ). The $\chi^2$ of 1.59 indicates slightly excess dispersion, and the calculated error has been modified to reflect excess scatter. However, there are no obvious correlations of composition with age to justify further discrimination of the data.

**Implications of the SHRIMP data:**
The 1862 ± 5 Ma age for sample 99116401 is 10 million years younger than the earlier SHRIMP I age for the same unit, indicating there may have been an inheritance component in the earlier sample. The 1862 Ma age also suggests that these volcanic units are coeval with volcanics that sourced Warramunga Formation turbidites, for which Compston (1994) obtained maximum depositional ages of 1862 ± 9, 1861 ± 11, 1861 ± 7 and 1859 ± 13 Ma. The source of those turbidites included subaerial pyroclastic units, which have not been recognised in the region, but which must exist. These 1862 Ma volcanic units are significantly older than the volcanic units that were mapped as lower Flynn Group in Tennant Creek.

Originally all dacitic units were assigned to the onset of Flynn Group volcanism, independent of whether they were subaerial or subaqueous, coherent or fragmental. This appears to be incorrect, as sample 99116401 is older than the ages obtained for the previous four samples reported. However, the complexity of the isotopic data indicates that the age for 99116401 must be used with some caution.
Barrow Creek Granite

AGSO/NTGS ID: 99116406
Province: Davenport
Rock Type: Felsic intrusive
Grid Reference: 415628E 7676570N (GDA94)

Sample location: core from 331.5-339.6 m in NTGS DDH BC5, located near GR 53KMR144549 (AGD66) in the vicinity of Spinifex Bore, adjacent to the Stuart Highway in the Barrow Creek 1:250k sheet.

Map unit: no outcrop; undifferentiated granite beneath Georgina Basin.

Relationships: This coarse megacrystic granite shows a pervasive tectonic fabric and is unconformably overlain by the Middle Cambrian Chabalowe Formation. The gneissic fabric is at a low angle to the core axis indicating a subvertical orientation. The following is interpreted from observations of this granite in drill core (15 m interval), the geophysical expression in this vicinity and regional geological considerations.

99116406 is distinctly different in hand specimen from other known “late” granites of the Tennant Inlier and may be older, given its megacrystic appearance (typical of the early Tennant Creek granites) and well developed tectonic fabric. Dating aimed to test whether it relates to the 1850 Ma Tennant Creek granite suite, or the later 1810 Ma suite (Barrow Creek Granitic Complex) or to a late granite suite in the Tennant Inlier which is less than 1720 Ma.

99116406 is located 1 km to the south of the regionally interpreted boundary of the Tennant Inlier. This interpretation of the Davenport province originally portrayed a large body of “late” granite (Pg2) in the southwest Bonney Well 1:250k sheet based on old geophysical data. The extension of these granite bodies into the Barrow Creek 1:250k sheet was not portrayed, but 99116406 would probably have been included in this suite based on current boundaries and old geophysical data.

A distinction between 99116406, which shows a subtle high frequency magnetic character, and the late uniformly non-magnetic granites, is apparent in the new regional aeromagnetic data. These data also suggest 99116406 is not an enclave, but part of a large granitic body in the northern Barrow Creek and southern Bonney Well 1:250k sheets. It is distinct from the late granites, which occur to the north and northwest, and which appear to intrude it.

Sample description: 99116406 is a deformed, coarse grey granodiorite. Rounded white-cream alkali feldspar megacrysts to 5 cm are prominent (30-40%). Plagioclase is present in similar amounts to alkali feldspar but is smaller in size and typically rounded and deformed. Quartz (20%) is deformed and typically occurs as elongate ‘ribbons’. Biotite (5-10%) defines a prominent gneissic fabric wrapping around quartz and feldspar.

Thin section description: 99116406 predominantly consists of quartz, alkali feldspar, plagioclase and biotite with accessory titanite, zircon and apatite. Small euhedral yellow-brown to pale blue tourmaline(?) is present as a trace mineral in intensely foliated parts, suggesting later possibly syntectonic migration of boron-rich fluids. Haematite, sericite, epidote and chlorite are present as trace alteration products. Alkali feldspar is an orthoclase microperthite. Plagioclase is a weakly zoned andesine with more calcic-rich cores, and is altered to sericite, epidote and chlorite. Myrmekitic intergrowths invade alkali feldspar. Feldspars contain mineral inclusions, mostly of biotite. Magnetite is rare, appearing only as inclusions in large alkali feldspars. Quartz typically shows a granoblastic texture. Biotite is straw-coloured to greenish-brown. Deformation appears to have occurred at biotite grade (greenschist facies).
Crystals in this rock have a very wide range of sizes, but are uniform in their short length:breadth ratios, euhedral prismatic forms and internal oscillatory growth zoning consistent with magmatic zonation. There is no evidence of metamorphic overgrowths. A few grains have older cores that are obvious in transmitted light and CL images.

Zircon compositions are concordant or near-concordant, indicating minimal secondary disturbance of isotopes. The data indicate a dominant group of 44 grains recording magmatic crystallisation, and 12 inherited zircons, whose individual ages range mostly between 1850-2000 Ma, but which also include five ages between 2200-2700 Ma (Figure 31A; Table A29). This indicates considerable inheritance in the magma. The dominant group of 44 concordant compositions has a mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1837.9 ± 4.4 Ma with acceptable $\chi^2$ of 1.3, which is interpreted as the magmatic crystallisation age of the pluton (Figure 31B).

![Figure 31A](image-url)

**Figure 31A.** U-Pb Wetherill concordia plot of all SHRIMP zircon data for Barrow Creek granite 99116406. Error boxes are 1σ for each analysis. Concordia curve labelled in Ma.

**Barrow Creek Orthogneiss**

- **AGSO /NTGS ID:** 99116407
- **Province:** Davenport
- **Rock Type:** Felsic intrusive
- **Grid Reference:** 414428E 7654970N (GDA94)

**Sample location:** core from 16-21.6 m in NTGS DDH BC4, located near GR 53KMR156765 (AGD66) in the Barrow Creek 1:250k sheet, adjacent to the road linking Murray Downs to the Stuart Highway, just north of Osborne Range.

**Map unit:** transported sand covers outcrop in this vicinity; outcrop to the south is mapped as undifferentiated orthogneiss.

**Relationships:** Orthogneiss occurs north and northeast of the Osborne Range, where it is intruded by small bodies of late granite. The relationship between the orthogneiss and Strzeleckie Volcanics is uncertain. It is probable that the Strzeleckie Volcanics unconformably overlie this orthogneiss, or less likely, the orthogneiss may have intruded Strzeleckie Volcanics. If the latter, then 99116407 should be younger than 1820 Ma. Alternatively if it is older than 1820 Ma, then it may be part of the 1850 Ma Tennant Creek Suite.

**Rock description:** Fine grey biotite orthogneiss with minor (3%) 0.5- 3.0 cm augens of pink feldspar. Some biotite-rich zones and rare enclaves are present in the 45 m interval of core. Some weak layer differentiation, which is expressed by separate quartzofeldspathic and biotite layers is present, but in general the rock is uniform and homogeneous. The gneissic fabric is mostly at a low angle to the core axis suggesting that it is subvertical. This fabric is cut at a high angle by later veins of chlorite, calcite, alkali feldspar+magnetite-chlorite+quartz, and quartz. These veins, and their narrow alteration zones, were excluded from the sample selected for geochronology.
Figure 31B. Multigrain age histogram of zircons from Barrow Creek granite 99116406; mean = 1837.9 ± 4.4 [0.24%] 95% confidence; weighted by data-point errors only, 0 of 40 rejected; MSWD = 1.3, probability = 0.14; (error bars are 2σ).

Thin section description: 99116407 is a fine muscovite-biotite quartzofeldspathic gneiss of granitic composition. It is composed of alkali feldspar, quartz, plagioclase, biotite, magnetite, titanite and muscovite, along with accessory apatite and zircon. Minor chlorite, sericite and epidote are present as alteration products in plagioclase. Alkali feldspar (microcline) is more abundant than plagioclase (andesine) and is present in similar proportions to quartz. Quartz and feldspar have a granoblastic texture whereas biotite gives the rock a lepidoblastic texture. Biotite is straw-coloured to brown or greenish-brown and is mostly small (<0.2 mm). Orientated biotites indicate secondary growth (recrystallised, metamorphic). Euhedral to subhedral titanite is common and, along with magnetite, is concentrated in clusters in biotite-rich zones. Thus, titanite is also metamorphic.

This sample yielded a mixture of zircon grain types, in which no two grains are exactly alike. Few grains retain original igneous shapes and most are anhedral. Many are broken and some exhibit a pitted external surface as is characteristic of sedimentary abrasion. The zircon sample is therefore more characteristic of sedimentary detritus than a granitic melt and this casts doubt on the attribution of this rock as an orthogneiss. If this is an S-type granitic rock, then there is little or no evidence of new magmatic growth of zircon even overgrowing the inherited grains.

U-Pb isotopic compositions obtained for 85 zircons in this rock record a complex array of concordant measured ages between 1820 Ma and 2900 Ma, indicating a dominance of inherited ages (Figures 32A, 32B; Table A30). The pattern is similar to that of a detrital age spectrum in a sediment. Of these ages, 87% form a dominant and continuous age spectrum in the range 1820-2000 Ma, beyond which is a distinct age gap between 2000-2200 Ma (Figures 32C, 32D). There are 12 scattered individual ages between 2200-2900 Ma. Assessed in detail, the continuous spectrum of 73 ages between 1820-2000 Ma is dominated by three overlapping clusters of ages. There is a numerically dominant group centred near 1870 Ma. A subordinate older cluster is near 1960 Ma, with a few individual ages in the range 1820-2000 Ma. There is also a distinct group of grains close to 1820 Ma. The youngest group is of interest for placing a constraint on the maximum crystallisation age of the rock, but it is difficult to establish this age with confidence because the 1820 Ma and 1870 Ma groups overlap, and can only be separated arbitrarily. The youngest individual crystal is grain 421 with an age of 1782 ± 36 Ma (2σ), but this is imprecise and may or may not be representative. A more reliable youngest age is derived from the youngest statistical cluster of ages. Using a statistical criterion of grouping those ages with acceptable dispersion from the youngest individual grain, a group of 23 zircons can be identified whose 207Pb/206Pb ages agree at a mean value of 1819 ± 6 Ma, with v2 of 1.3, supporting their grouping as a statistically uniform population (Figures 32E). This provides a more robust maximum age of the unit, but it should be noted that the “youngest” group of ages identified this way does include individual grain ages near 1850 Ma, which could possibly belong to the 1870 Ma inherited population.

Babylon Volcaniclastic Sediment

| AGSO/NTGS ID: | 99496302 |
| Region: | Davenport province |
| Rock Type: | volcaniclastic sediment |
| Grid Reference: | 53 331232.95mE 7791462.09mN (AGD66) |
Figure 32A. U-Pb Wetherill concordia plot of all SHRIMP zircon data for Barrow Creek unnamed orthogneiss 99116407. Error boxes are 1σ for each analysis. Concordia curve labelled in Ma.

Figure 32B. Age distribution histogram of zircons from Barrow Creek unnamed orthogneiss 99116407.
Figure 32C. Portion of Figure 32A, showing dominant age groupings.

Figure 32D. Portion of Figure 32B, showing detail of dominant age groupings.
Figure 32E. Multigrain age histogram of zircons from Barrow Creek unnamed orthogneiss 99116407; youngest zircon ages; mean $^{207}\text{Pb}/^{206}\text{Pb}$ age 1819 $\pm$ 6; 95% confidence; 23 analyses; MSWD = 1.3 (error bars are 2$\sigma$).

Sample location: half core from 452-469 m in Explorer 142 DDH4; located in the Babylon area (formerly known as the Rover area) in the southeastern Green Swamp Well 1:250k sheet.

Map unit: no outcrop; undifferentiated beneath 200 m of Wiso Basin strata. Relationships: 99116302 is a distinct immature massflow volcaniclastic unit of 4 m true thickness underlying a banded haematite-jasper-quartz rock (BIF). This volcaniclastic unit shows a weak, pervasive, low-grade tectonic fabric and is unconformably overlain by the Middle Cambrian Montejinni Formation.

Sample description: 99496302 contains angular tabular lithic clasts and quartz crystals set in a pale green-grey matrix. The rock is graded from coarse pebbly volcaniclastic sandstone at the base to fine quartz-volcanolithic wacke at the top. The thin section appears to be from the upper part of the unit.

Thin section description: 99496302 consists of quartz (10-15%), rare alkali feldspar and accessory zircon in a matrix (80%) of chlorite and sericite. Lithic clasts form 5-10% of this thin section. Quartz is 0.1-1.5 mm in diameter (averaging 0.5 mm) and is either euhedral (sometimes embayed) or angular in shape. Quartz is thus texturally immature although rare rounded quartz does exist. Zircon is well zoned and elongate prismatic. Some small rounded zircons are present. Small cubes of pyrite(?) are present.

There are two forms of zircon. The dominant form is euhedral prismatic in shape, and has simple well preserved pyramid terminations and euhedral oscillatory growth zoning. This type is consistent with juvenile magmatic zircon crystallisation and was targeted to provide a constraint on the deposition age of the unit. Combined with this population is a heterogeneous mixture of variably abraded, broken and anhedral shapes with a variety of internal zoning patterns. These grains are consistent with admixture of zircons from adjacent rocks during deposition, or redeposition.

U-Pb isotopic data for the magmatic zircon group are complicated by Pb loss affecting the analysed compositions. Of 22 analyses, six have leaked significant radiogenic Pb and do not contribute usefully to age calculation (Figures 33A, 33B, 33C; Table A31). The remaining 13 compositions are concordant or near-concordant, and form a single dominant age grouping (11 grains) and two younger apparent ages. The main group of 11 grains agree at a mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1798 $\pm$ 5 Ma with a $\chi^2$ of 0.9, supporting a homogeneous grouping of compositions (Figure 33D).
Figure 33A. Wetherill concordia plot of all SHRIMP zircon data for Babylon district volcaniclastic 99496302. Shaded analyses are used in the calculation of the weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ age. Error boxes are 1σ for each analysis. Concordia curve labelled in Ma.

Figure 33B. Portion of Figure 33A, showing youngest zircon ages.
**Figure 33C.** Age distribution histogram of concordant and near-concordant zircons from Babylon district volcaniclastic 99496302.

**Figure 33D.** Multigrain age histogram of youngest zircon age group from Babylon district volcaniclastic 99496302; mean = 1798.3 ± 4.5 [0.25%]; 95% confidence; weighted by data-point errors only, 0 of 11 rejected; MSWD = 0.91, probability = 0.52; (error bars are 2σ).
The two younger apparent ages for grains 105 and 139 are problematic. If included in the main group, they contribute excess dispersion beyond error, indicating that their apparent ages are resolvably younger than the main group. However, grain 5 has very high uranium content, raising the possibility that it may have been susceptible to isotopic disturbance. Both analyses have common Pb contents of 1%, which are significantly higher than the common Pb in other grains and this makes their age calculation more sensitive to bias introduced via the common Pb correction. On these grounds, the two young apparent ages are not regarded as reliable and the 1798 ± 5 Ma age of the main group of magmatic grains is interpreted to record a maximum crystallisation age of the volcaniclastic unit. This crystallisation age may approximate to the eruption age of the unit if the zircons had minimal residence time in the magma chamber before eruption, and if the final deposition or redeposition of the volcanic detritus was close to the time of eruption.

Mixed with this juvenile age component is a significant proportion of inherited zircon ages, dominated by a group near 1870 Ma, with lesser groups in the range 1950-2100 Ma, 2400-2500 Ma, and two individuals at 2600 Ma and 2850 Ma. These ages could represent zircon grains inherited in the felsic magma, or zircons from country rocks admixed during deposition or redeposition of the volcaniclastic detritus.

**ARUNTA PROVINCE**

**Geological Overview**

The Arunta province is a large (200 000 km²) multiply deformed, polymetamorphic Proterozoic terrain. It contrasts markedly with adjacent terrains of similar age, because of the intensity and frequency of deformation, the high grade of much of its metamorphism and the abundance of granite. A regional tectonic and stratigraphic framework has yet to be erected. A summary description of analysed samples is given in Table 5.

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Strato-tectonic Package</th>
<th>Unit</th>
<th>Rock Type</th>
<th>Geological Setting</th>
<th>Age</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>98096001</td>
<td>Strzeleckie Volcanics</td>
<td>Welded rhyolite ignimbrite</td>
<td>Equivalent to Newland Volcanics in lower Wauchope Subgroup in Davenport Province</td>
<td>1819 ± 9 Ma</td>
<td>Crystallisation age</td>
<td></td>
</tr>
<tr>
<td>98096002</td>
<td>Bean Tree Granite</td>
<td>Granite</td>
<td>Cuts foliation seen in Davenport Province. Intrudes Bullion Schist</td>
<td>1803 ± 6 Ma</td>
<td>Crystallisation age</td>
<td></td>
</tr>
<tr>
<td>98096003</td>
<td>Ooralingie Granite</td>
<td>Granite</td>
<td>Intrudes Bullion Schist</td>
<td>1809 ± 5 Ma</td>
<td>Crystallisation age</td>
<td></td>
</tr>
<tr>
<td>98096004</td>
<td>Reynolds Deep Bore Metamorphics</td>
<td>Cordierite-Orthopyroxyene-Biotite gneiss</td>
<td>Granulite metamorphics. Probable sedimentary and volcanic(?) precursor</td>
<td>1805 ± 7 Ma</td>
<td>Protolith population – youngest detrital or volcanic population</td>
<td></td>
</tr>
<tr>
<td>98096005</td>
<td>Narwietooma Granulite</td>
<td>Granulate facies pelitic gneiss</td>
<td>Post Mi high strain event (M3)</td>
<td>1730 ± 7 Ma</td>
<td>Metamorphic zircon growth</td>
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<tr>
<td>99096011</td>
<td>Bullion Schist Psamino-peltic schist</td>
<td>Pervasively retrogressed from amphibolite facies</td>
<td>Indication of metamorphic zircon growth between 1642 Ma and 1747 Ma. Partial resetting at 1820 Ma. Inconclusive data indicates possible 1587 ± 55 Ma retrogression event and 1845 Ma maximum age.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>99096007</td>
<td>Lander Coniston Schist</td>
<td>Foliated quartzfeldspar</td>
<td>Probable shallow – level intrusive into Reynolds Range Group</td>
<td>1780 ± 10 Ma</td>
<td>Crystallisation age of igneous prothl</td>
<td></td>
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<tr>
<td>99096008</td>
<td>Ennugan Mountains Granite</td>
<td>Foliated granite intrudes Lander Rock Beds</td>
<td></td>
<td>1622 ± 7 Ma</td>
<td>Crystallisation age</td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Summary Description of Arunta Province Samples

**Samples Analysed**

**Strzeleckie Volcanics**

AGSO Sample ID: 98096001  
Field Number: KHD 31  
Rock Type: Welded rhyolitic ignimbrite  
Grid Reference: 407925E 7644008N (AGD66)
This welded rhyolitic ignimbrite from the Strzeleckie Volcanics is part of an extensive volcanic sheet in the northern part of the Barrow Creek 1:250k sheet. It is an excellent marker horizon and should provide a reference for regional correlations between the northern Arunta and the main part of the Davenport province. Previous workers suggested that it correlates with the 1820 Ma Newlands Volcanics. Field relationships show it to be cut by latter porphyritic dacite sills, folded about northwest axes and locally metamorphosed to biotite grade (contact metamorphism). The sample site is distant from these contact effects. The Strzeleckie Volcanics overlies another separate volcanic and volcaniclastic package which may in turn overlie, or in part be equivalent to the Bullion Schist.

Approximately 700 zircon grains were recovered from the sample, and 60% of the non-magnetic fraction were selected for mounting. These zircons are colourless to light brown, clear and generally euhedral with simple terminations; many are fragmented and contain inclusions. The zircons are 100-200 µm long, by 50-100 µm wide. They exhibit concentric zoning, indicative of crystallisation from magma.

Twenty analyses were made on 19 different grains. The analytical data are summarised in Table A32 and plotted on the Concordia (Figure 34). All 20 compositions are concordant and agree at a weighted mean 207Pb/206Pb age of 1819 ± 9 Ma (tσ) with an acceptable χ² of 1.27. This is interpreted as the crystallisation age of the volcanic unit.

Bean Tree Granite

| AGSO Sample ID: | 98096002 |
| Field Number:   | KHD 50   |
| Rock Type:      | granite  |
| Grid Reference: | 384279E 7622769N (AGD66) |

The Bean Tree Granite is a two-mica granite that is clearly post tectonic and cuts a northwest striking foliation in the Ooralingie Granite, which is coaxial with the main folding in the north. Field relationships indicate that the Bean Tree Granite and a related pegmatite are associated with Sn-Ta-W mineralisation.

This sample yielded about 1600 zircon grains, of which 20% from non-magnetic and magnetic fractions were mounted. The zircons are colourless to light brown, subhedral to euhedral, 100-200 µm long by 35-80 µm wide. Most exhibit weak concentric zoning indicative of a magmatic origin.

Thirty-three analyses were made on 30 grains. The analytical data are summarised in Table A33 and plotted on a Concordia in Figure 35. Ten analyses have significant discordance (Table A33). The data are dominated by 19 concordant analyses which agree at a weighted mean 207Pb/206Pb age of 1803 ± 6 Ma (tσ) with an acceptable χ² of 1.06. Two slightly younger compositions (221.3 and 229.3) have cathodoluminescence images, which indicate that the original zoning has recrystallised; on this basis they are interpreted as disturbed compositions.
Analyses 232.3 and 232.4 are slightly older than the main group and are interpreted as xenocrysts. The $1803 \pm 6$ Ma (t$\sigma$) age is interpreted to represent the crystallisation age of the pluton.

**Ooralingie Granite**

<table>
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<tr>
<th>AGSO Sample ID</th>
<th>98096003</th>
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</thead>
<tbody>
<tr>
<td>Field Number</td>
<td>KHD 63</td>
</tr>
<tr>
<td>Rock Type</td>
<td>granite</td>
</tr>
<tr>
<td>Grid Reference</td>
<td>384256E 7622832N (AGD66)</td>
</tr>
</tbody>
</table>

The Ooralingie Granite is a foliated, megacrystic biotite-rich granite with abundant enclaves. It is notably distinct from the two-mica Bean Tree Granite and similar in appearance to the 1820 Ma Haverson Granite.

This sample yielded numerous zircon grains. Approximately 30% of the non-magnetic fraction were selected for mounting. The zircons are pink to light brown, clear, subhedral to euhedral, mostly equant grains, 50-200 µm long by 50-150 µm wide. Cathodoluminescence images identify concentric zoning and narrow metamorphic rims.

Individual analyses were made on 34 zircon grains. The analytical data are summarised in Table A34 and plotted on a Concordia in Figure 36. Eight discordant compositions are identified in Table A34, and one young analysis (327.3) is discounted from age calculation because the probe site incorporated both core and rim material in the analysis. The remaining data are dominated by a concordant group of zircons whose compositions agree at a weighted mean age $1809 \pm 5$ Ma (t$\sigma$) with an acceptable $\chi^2$ of 1.54, which is interpreted to be the crystallisation age of the granite. Six other analyses indicate inherited ages between 2600 Ma and 1865 Ma.

![Figure 36](image)

**Deep Bore Metamorphics**

<table>
<thead>
<tr>
<th>AGSO Sample ID</th>
<th>98096004</th>
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</thead>
<tbody>
<tr>
<td>Field Number</td>
<td>ISHU 98.30</td>
</tr>
<tr>
<td>Rock Type</td>
<td>Cordierite-orthopyroxene-biotite gneiss</td>
</tr>
<tr>
<td>Grid Reference</td>
<td>557342E 7557342N (AGD66)</td>
</tr>
</tbody>
</table>

This sample is a cordierite-orthopyroxene-biotite gneiss, which locally contains sillimanite quartz, k-spar, plagioclase, magnetite, minor spinel and zircon. This rock is likely to have had a sedimentary or volcanic precursor. Protolith age (detrital zircon or magmatic zircon populations) and timing of high-grade metamorphic events are sought from this sample.

The estimated yield of zircon grains from this sample is 2400. Approximately 30% of the non-magnetic fraction were selected for mounting. The zircons are brown, subhedral with rounded terminations, 100-200 µm long by 50 µm wide. Most grains exhibit some original zoning in the cores, and have metamorphic rims and embayments into the original grains. Thirty-eight...
analyses were made on 31 grains. The analytical data are summarised in Table A35 and plotted on a Concordia (Figure 37). Three analyses were discarded from the pooled ages because they were less than 95% concordant. Two analyses (408.1 and 425.1) obviously contain inheritance and another analysis (401.1) probably has inheritance as it introduces excess scatter to the pooled age of the protolith. The Deep Bore Metamorphics contain a protolith age population of zircon cores and a metamorphic age population of overgrowths; both have acceptable $\chi^2$ values (1.59 and 0.86, respectively) so are interpreted to represent discrete age populations. The protolith population has a weighted mean $^{207}\text{Pb}^{206}\text{Pb}$ age of 1805 ± 7 Ma (tσ) based on 20 concordant analyses, and the metamorphic population has a weighted mean $^{207}\text{Pb}^{206}\text{Pb}$ age of 1730 ± 7 Ma (tσ) based on 12 concordant analyses.

**Kanandra Granulite**

| AGSO Sample ID: | 98096005 |
| Field Number: | ISHU 98.195 |
| Rock Type: | Semi-pelitic to pelitic gneiss |
| Grid Reference: | 542650E 7486330N (AGD66) |

This sample is a semi-pelitic gneiss that was subjected to initial granulite metamorphism ($M_1$) and a subsequent high strain event, also at granulite conditions ($M_2$).

The sample yielded in the order of 10 000 zircon grains. Approximately 5% of the non-magnetic fraction were selected for mounting. The zircons are colourless to pale yellow-brown, clear, equant, subhedral to anhedral rounded grains, 50-150 μm in diameter. Most exhibit zoning in cores with narrow rims.

Fifty-six analyses were carried out on 53 grains for the Kanandra Granulite. The analytical data are summarised in Table A36 and are plotted on Concordia (Figure 38). There is no clearly defined single age for metamorphism. However, the three youngest analyses (535.1, 535.2 and 544.1) indicate zircon crystallisation between 1642 Ma and 1747 Ma. Other data that track along the Concordia may represent a partial resetting of the U-Pb system at approximately 1820 Ma.

**Bullion Schist**

| AGSO Sample ID: | 99096011 |
| Field Number: | 99096011 |
| Rock Type: | Psammo-pelitic schist |
| Grid Reference: | 412253E 7620737N (GDA94) |

Sample 99096011 is from the Bullion Schist type area, the Home of Bullion mine. Muscovite- and chlorite-rich layers form a schistose fabric in this pervasively retrogressed, chlorite-grade, psammo-pelitic schist. Some larger chlorite blasts define an earlier fabric at a high angle to the predominant foliation. These larger chlorites may originally have been biotite. Quartz is pervasively recrystallised. Prismatic and deformed relict porphyroblasts in this sample that are quartz-mica-rich and preserve inclusion trails, may originally have been andalusite (or possibly cordierite). Large andalusite blasts are common in pelitic layers to the west of the mine and provide further evidence for metamorphic grades higher than chlorite facies.

This pervasively retrogressed (amphibolite-to-greenschist) metasedimentary schist has been affected by two recognised metamorphic events. The protolith was originally a sandy mudstone.

The Bullion Schist is intruded by the 1805 Ma Barrow Creek Granitic Complex, and is also older than the 1819 Ma Strzeleckie Volcanics. It probably correlates with the Ooradidgee and Flynn Groups, rather than the Warramunga Formation. Its date should identify a maximum age for deposition of the protolith, as well as subsequent metamorphic events.

Only eight zircons were recovered from this sample. They are euhedral to subhedral and have rounded terminations. The length to width ratio is 2:1. Most of the grains are clear, pale brown to colourless and contain many cracks. Grains are either mottled or show euhedral zoning in CL.

Sixteen analyses were made on seven zircon grains from the schist (Figure 39; Table A37). The youngest concordant group of five analyses is from two grains (303 and 306), which are unzoned. The weighted mean $^{207}\text{Pb}^{206}\text{Pb}$ age of these five analyses is 1587 ± 55 Ma (tσ), with a $\chi^2$ of 0.9. Other concordant ages are present at 1845 Ma, 2350 Ma and 2533 Ma.
Figure 38. U-Pb Wetherill concordia plot of all SHRIMP data for the Kanandra Granulite 98096005. Error boxes are 1σ for each analysis. Concordia curve labelled in Ma.

Figure 39. U-Pb Wetherill concordia plot of all SHRIMP data for the Bullion Schist 99096011. Shaded analyses are used in the calculation of the weighted mean 207Pb/206Pb age of metamorphism. Error boxes are 1σ for each analysis. Concordia curve labeled in Ma.

The paucity of grains recovered from this schist sample limit the usefulness of any age interpretation.

Coniston Schist

AGSO Sample ID: 99096007
Field Number: 99096007
Rock Type: quartz-feldspar schist
Grid Reference: 249333E 7355256N (GDA94)

Sample 99096007 is a surface sample of the Coniston Schist in Giles Range. It is a foliated quartz-feldspar porphyry which intrudes the unconformity between the Lander Rock beds and overlying Mount Thomas Quartzite at this locality. Two prominent foliations are present in both the Coniston Schist and Mount Thomas Quartzite. The age of the Coniston Schist protolith constrains the depositional age of the Mount Thomas Quartzite (basal Reynolds Range Group).

The Coniston Schist is most likely a correlative of the S-type Warimbi Gneiss in the Reynolds Range. WJ Collins obtained a SHRIMP I U-Pb zircon age of 1785 ± 22 Ma (Hussey pers comm 1999) from the Warimbi Gneiss. There was uncertainty about which igneous event it correlated with. The large error also made it difficult to constrain correlatives of the Mount Thomas Quartzite.

This sample was dated to identify the magmatic age of the igneous protolith of the Coniston Schist. This age would provide a minimum age for the Mount Thomas Quartzite and test a possible correlation with the Warimbi Gneiss.

Zircons were chosen from 1500 non-magnetic grains. The zircons are clear, light amber with no cracks or inclusions. Morphology is euhedral to subhedral; some of the latter have slightly rounded terminations. Length to width ratios vary from 2:1 to 3:1. Grain morphology is consistent with a magmatic origin.

Analyses were made on 32 grains (Figure 40; Table A38). Four zircons have inherited ages between ca 2375 Ma and 1875 Ma. The remaining 28 analyses have a weighted mean 207Pb/206Pb age of 1780 ± 10 Ma (tσ) with an acceptable χ² of 1.3, which is interpreted as the crystallisation age of the Coniston Schist igneous protolith.

Implications of the SHRIMP data:
The 1780 ± 10 Ma age is within error of the 1779 ± 6 Ma Carrington Granitic Suite from further west, on the Mount Doreen 1:250k sheet. A foliated volcanic rock from the Nicker beds on the Mount Doreen sheet has a similar age (1772 ± 5 Ma, Ozchron database, AGSO). It could be intrusive and coeval with the Coniston Schist. The Coniston Schist does not correlate with ca 1805 Ma igneous activity in the Reynolds Range, being slightly younger. It is also younger than 1799 ± 9 Ma volcanic activity in the Patmangala beds on Mount Doreen.
The Mount Thomas Quartzite is older than the Coniston Schist (1780 Ma), and is younger than the 1820 Ma Stafford Granite and 1805 Ma granites in the Reynolds Range. The Coniston Schist protolith is coeval with the 1785 Ma Warimbi Gneiss.

**Ennugan Mountains Granite**

- **AGSO Sample ID:** 99096008
- **Field Number:** 99096008
- **Region:** Arunta province
- **Rock Type:** granite
- **Grid Reference:** 286690E 7553974N (GDA94)

The Ennugan Mountains Granite outcrops in the northern Napperby and southern Mount Peake 1:250,000 sheets, and hosts U-Th-Nb-Sn and possibly REE mineralisation. One whole-rock geochemical analysis and radiometric data indicate that it is amongst the most radiogenic of the high heat production granites in the Arunta.

99096008 is a foliated hornblende-biotite granite which intrudes the Lander Rock beds. It is a coarse porphyritic granite, containing abundant alkali feldspar megacrysts up to 10 cm in length, locally with rapakivi texture. Common enclaves indicate comagmatic mixing and hybridisation of felsic melts. Zircon and apatite are common.

A flow-banded felsic dyke clearly cuts the foliation and should be sampled to confirm if the tectonic fabric in the Ennugan Mountains Granite is related to the 1570-1590 Ma event in the Reynolds Range. Dating of the granite’s magmatic age would allow the identification of comagmatic correlatives (1820 Ma Stafford Granite or late 1570-1600 Ma granites on the Mt Doreen 1:250,000 sheet) and provide the maximum age of the regional tectonic fabric.

Zircon is colourless to pale brown, and euhedral to subhedral. Most grains have a length to width ratio of 3:1, but some range up to 6:1. Grains have bipyramidal or rounded terminations, and generally have concentric zoning in CL images.

Thirty-two analyses were made on 29 of the unknown grains with a range of form (Figure 41; Table A39). Analysis 109.1 is slightly reverse discordant and is not included in the age calculation. The remaining 31 analyses have a weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of $1622 \pm 7$ Ma ($\sigma$) with an acceptable $\chi^2$ of 1.5. This is interpreted as the crystallisation age of the granite.

**Implications of the SHRIMP data:**

The 1622 $\pm$ 7 Ma granite age is similar to the 1635 $\pm$ 9 Ma age for hornblende-biotite granite in the Andrew Young Igneous Complex. Hornblende-biotite granite suggests very high melt temperatures; this could be the result of over thickened crust and mafic underplating and is not common in the northern Arunta province. The Ennugan Mountains Granite is not related to the 1820 Ma Stafford Granite, and it is older than the late granites (1570-1600 Ma) on the Mt Doreen 1:250,000 sheet. It is possible that the fabric in the Ennugan Mountains Granite is related to the 1570-1590 Ma event in Reynolds Range.
VICTORIA-BIRRINDUDU BASIN

Geological Overview

The Proterozoic succession in the Victoria-Birrindudu basins is 6 km thick and consists of relatively undeformed marine siltstone, sandstone and dolostone. The sedimentary rocks were deposited on a broad, stable carbonate-clastic platform. They are underlain by basement of older metamorphic and granitic rocks and are flanked by Phanerozoic volcanic and sedimentary strata.

The component lithostratigraphic groups partly relate to several basin phases of intracratonic sag. Preliminary geochronology indicates that the Limbunya Group may be correlated with the McArthur Group and possibly with the Namerinni Group of the Tennant Inlier, and with the Bungle Bungle Dolomite of the Osmond Basin in Western Australia (Figure 42). The occurrence of aragonite cementstones (coxco needles) similar to those in the Campbell Springs Dolostone have now been recognized in four Proterozoic terrains and may provide a useful correlation tool in other north Australian basins. A summary description of the analysed samples is given in Table 6.

<table>
<thead>
<tr>
<th>Victoria Basin, WA</th>
<th>Victoria-Birrindudu Basins, NT</th>
<th>Tennant Creek Inlier, NT</th>
<th>McArthur Basin, NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Victoria Basin</td>
<td>Ashburton Province</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helicopter Siltstone, Ahern Formation</td>
<td>Auvergne Group</td>
<td>Renner Group</td>
<td>Roper Group</td>
</tr>
<tr>
<td>Lower Wade Creek Formation(?)</td>
<td>Bullita Group</td>
<td>Nathan Group</td>
<td></td>
</tr>
<tr>
<td>Wattie Group</td>
<td>Nathan Group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osmond Basin, WA</td>
<td>Birrindudu Basin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bungle Bungle Dolomite Mt Parker Sandstone</td>
<td>Lumbunya Group</td>
<td>Namerinni Group</td>
<td>McArthur Group</td>
</tr>
<tr>
<td></td>
<td>Campbell Springs Dolostone 1638 ± 9 Ma</td>
<td>Shillinglaw Formation 1639 ± 27 Ma</td>
<td>Barney Ck Formation 1639 ± 3 Ma</td>
</tr>
<tr>
<td></td>
<td>Birrindudu Group</td>
<td>Tomkinson Ck Group</td>
<td>Tawallah Group</td>
</tr>
</tbody>
</table>

Figure 42. Regional stratigraphic correlations between McArthur Basin, Victoria Basin, Tennant Inlier and East Kimberly in WA.

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Unit</th>
<th>Rock Type</th>
<th>Geological Setting</th>
<th>Age</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>98776702</td>
<td>Blue Hole Formation</td>
<td>Tuffite</td>
<td>Sample from tuffite layers in interbedded dolomitic siltstones and mudstones</td>
<td>1636 ± 5 Ma</td>
<td>Magmatic crystallisation age</td>
</tr>
<tr>
<td>98776703</td>
<td>Campbell Springs Dolostone</td>
<td>Tuffite</td>
<td>Interbedded water – lain tuffite and dolostone</td>
<td>1639 ± 7 Ma</td>
<td>Magmatic crystallisation age</td>
</tr>
<tr>
<td>98776701</td>
<td>Fraynes Formation</td>
<td>Tuffite?</td>
<td>Low yield of detrital zircons</td>
<td></td>
<td>No viable age</td>
</tr>
<tr>
<td>98776704</td>
<td>Mount Sanford Formation</td>
<td>Tuffite?</td>
<td>Low yield of detrital zircons</td>
<td></td>
<td>No viable age</td>
</tr>
</tbody>
</table>

Table 6. Summary Description of Victoria-Birrindudu Samples.

Samples Analysed

Bluehole Formation

AGSO Sample ID: 98776702
Field Number: AC98-4318
Rock Type: tuffite, volcaniclastic
Grid Reference: 532983mE 8041552mN (GDA94)

The Bluehole Formation is located near a west-flowing tributary of Moonbool Creek, eight kilometres to the east-northeast of Kirkimbie Homestead on the Napier 100k sheet. It is flanked by a north-trending fault to the west and an antclinal structure to the east. The unit is comprised of tuffite, interbedded and laminated purple dolomitic siltstone and dolomitic mudstone, and is stromatolitic near the upper and lower boundaries. The thickness in drill core is 78 m but this is not a complete section. In outcrop, the unit has a maximum thickness of about 133 m. The Bluehole Formation is conformably overlain by the Campbell
Springs Dolostone and conformably overlies the Farquharson Sandstone. All of these units belong to the Limbunya Group. The Campbell Springs Dolostone comprises silicified stromatolitic dolostone, minor maroon shale and some light pink tuffaceous intervals.

The Bluehole Formation contains upper and middle tuffaceous units up to 16 cm thick. The sample chosen for dating comes from the upper Bluehole Formation, from an outcrop that strikes 360° and dips 40° to the west. Dating of the tuff will fix the age of the Bluehole Formation, which is currently unknown, and provide a top age for the Limbunya Group. The occurrence of tuffaceous horizons in the Bluehole Formation is rare.

Zircon grains in this sample are clear, pale brown, and euhedral. They are 80–150 µm long, with a length to width ratio of 2:1. Euhedral concentric zoning is visible in CL images of most grains. Morphology is consistent with magmatic origin.

Analyses were made on 39 grains (Table A40). A single analysis is slightly discordant and is inferred to have leaked minor radiogenic Pb, but its $^{207}\text{Pb}/^{206}\text{Pb}$ age is indistinguishable from that of the other grains. The remaining 38 analyses are all concordant within error. All 39 compositions agree at a single mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1636 ± 5 Ma with an acceptable $\chi^2$ of 1.19 supporting a homogeneous age population (Figures 43A, B).

The uniform isotopic composition of zircons yields an unambiguous magmatic crystallisation age of zircon in the tuff unit. Linking the magmatic age with the depositional age of the unit requires two further conditions to be satisfied. Firstly, any residence time of zircons within a subvolcanic magma chamber must have been short or coincident with the eruption of the magma; this requirement is supported by the homogeneous form and isotopic compositions of the zircon population. Secondly, any redeposition of the volcanioclastic material should have taken place very soon after eruption.

This unit and a tuff from the overlying basal part of the Campbell Springs Dolostone were dated in the same analytical session (see below). The 1639 ± 7 Ma age calculated for the Campbell Springs Dolostone sample is within error of the age of the Bluehole Formation tuff. It can be inferred from this that deposition took place within the uncertainty of the U-Pb age measurements.
The Campbell Springs Dolostone (within the Limbunya Group) consists of water-laid tuffite, interbedded dololutite, dolarenite, dolorudite and microbial dolostone tuff. The water-laid tuffite is pink-orange, up to 30 cm thick, laterally extensive and has been subjected to potassium metasomatism. The tuffite contains sedimentary structures such as rip-up clasts and lamination. The tuffite horizons in the field give conspicuous high total count gamma logs because of their relatively high potassium content. Sample 98776703 was collected near the base of the Campbell Springs Dolostone at the type section (north of Limestone Yard).

This date (98776703) should fix the age of the basal Campbell Springs Dolostone and enable better correlations with other Proterozoic basins. This may provide baseline data to develop sequence stratigraphy and time progressive sedimentation models for the Limbunya Group.

Zircons separated from this tuffite consist of clear, colourless to pale brown, euhedral grains. The grains vary between equant to 4:1 elongation and have bipyramidal terminations. Many grains are cracked. CL images show concentric zoning consistent with magmatic origin.

Thirty-seven zircons were analysed (Table A41). Of these 20 have leaked significant amounts of Pb and do not contribute to a useful age calculation (Figure 44A). Among the concordant and near-concordant compositions, 14 agree at a mean $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1639 ± 7 Ma with $\chi^2$ of 0.94 supporting a homogeneous age population (Figure 44B and 44C). This mean age is interpreted as the magmatic crystallisation age of the dominant zircon group in the unit. Three grains have distinctly older ages of 1683 Ma, 1704 Ma and 1744 Ma; these are interpreted as xenocrysts in the magma, or they were incorporated in the tuff during deposition.

Although the zircons suffered significant Pb leakage, the age calculated from concordant compositions is confidently established, albeit less precisely than that obtained for the underlying Bluehole Formation, owing to the smaller quantity of useful data. The sample was co-probed with the Bluehole Formation tuff (see above) and the two ages are within measurement error of each other.
**Figure 44A.** U-Pb Wetherill concordia plot of all SHRIMP zircon data for Campbell Springs Dolostone 98776703. Error boxes are 1σ for each analysis. Concordia curve labelled in Ma.

**Figure 44B.** Portion of Figure 44A, showing near-concordant zircon ages.
Figure 44C. Multigrain age histogram of zircons from Campbell Springs Dolostone 98776703; mean = 1639.1 ± 7.1 [0.43%]; 95% confidence; weighted by data-point errors only, 0 of 14 rejected; MSWD = 0.94, probability = 0.50; (error bars are 2σ).

Fraynes Formation

AGSO Sample ID: 99776701
Field Number: 98AC0604
Region: Victoria River Basin
Rock Type: Possible tuffite
Grid Reference: 563000mE, 8070700mN (GDA94)

This sample yielded only 11 zircon grains, all of different broken morphologies, which suggests an entirely detrital origin. Their U-Pb isotopic compositions and ages are scattered and no meaningful age can be interpreted (Figure 45; Table A42).

Figure 45. U-Pb Wetherill concordia plot of all SHRIMP zircon data for Fraynes Formation 98776701, showing no coherent age. Error boxes are 1σ for each analysis. Concordia curve labelled in Ma.
Mount Sanford Formation

AGSO /NTGS ID: 99776704
Region: Victoria River Basin
Rock Type: Possible tuffite
Grid Reference: 563000mE, 8070700mN (GDA94)

This sample yielded only 6 zircon grains, all of different broken morphologies, which suggests an entirely detrital origin. Their U-Pb isotopic compositions and ages are scattered and no meaningful age can be interpreted (Figure 46; Table A43).

![Figure 46. U-Pb Wetherill concordia plot of all SHRIMP zircon data for Mount Sanford Formation 99776704, showing no coherent age. Error boxes are 1σ for each analysis. Concordia curve labelled in Ma.](image)

ACKNOWLEDGEMENTS

Scientific and technical contributions to this record are summarised in the Introduction. The manuscript was edited by Tim Munson and formatted by Stephen Cox. Figures were prepared for reproduction by Ian Burgan, Kirsi Rahikainen and Tim Munson.

REFERENCES


APPENDIX: GEOCHRONOLOGICAL TABLES

Tables A1-A43 summarise all the analytical data referred to in this record. They are not reproduced here, but are available from NTGS on request.