



Australian Government

Geoscience Australia

# New SHRIMP U-Pb zircon ages from north Queensland, 2007–2010

*N.L. Neumann and N. Kositcin*

Record

2011/38

GeoCat #  
72648



# New SHRIMP U-Pb zircon ages from north Queensland, 2007–2010

GEOSCIENCE AUSTRALIA  
RECORD 2011/38

by

N.L. Neumann<sup>1</sup> and N. Kositsin<sup>1</sup>



---

1. Minerals and Natural Hazards Division, Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Australia

**Department of Resources, Energy and Tourism**

Minister for Resources and Energy: The Hon. Martin Ferguson, AM MP

Secretary: Mr Drew Clarke

**Geoscience Australia**

Chief Executive Officer: Dr Chris Pigram



© Commonwealth of Australia (Geoscience Australia) 2011

With the exception of the Commonwealth Coat of Arms and where otherwise noted, all material in this publication is provided under a Creative Commons Attribution 3.0 Australia Licence ([www.creativecommons.org/licenses/by/3.0/au/](http://www.creativecommons.org/licenses/by/3.0/au/))

Geoscience Australia has tried to make the information in this product as accurate as possible. However, it does not guarantee that the information is totally accurate or complete. Therefore, you should not solely rely on this information when making a commercial decision.

**ISSN 1448-2177**

**ISBN 978-1-921954-46-7 (web)**

**ISBN 978-1-921954-45-0 (print)**

**GeoCat # 72648**

**Bibliographic reference:** Neumann, N.L. and Kositsin, N., 2011. New SHRIMP U-Pb zircon ages from north Queensland, 2007–2010. *Geoscience Australia, Record*, **2011/38**, 82 p.

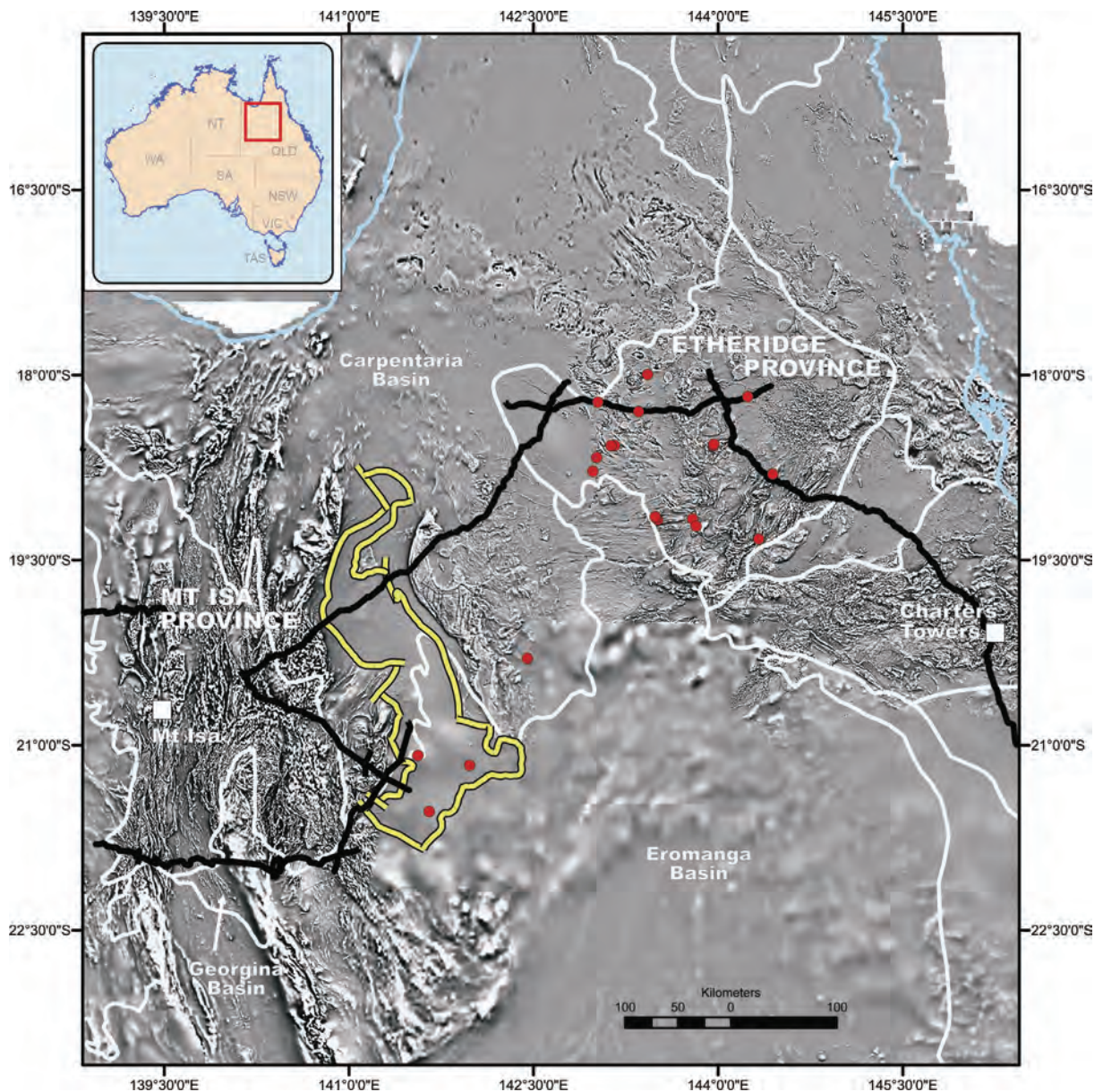
# Contents

|                                                               |           |
|---------------------------------------------------------------|-----------|
| <b>Introduction .....</b>                                     | <b>iv</b> |
| Overview .....                                                | iv        |
| SHRIMP analytical procedures .....                            | viii      |
| <b>Acknowledgements .....</b>                                 | <b>x</b>  |
| <b>Etheridge Province.....</b>                                | <b>1</b>  |
| 1. Bernecker Creek Formation: 2007169002.....                 | 1         |
| 2. Daniel Creek Formation: 2007169003 .....                   | 5         |
| 3. Corbett Formation: 2007169004 .....                        | 10        |
| 4. Townley Formation: 2007169005 .....                        | 14        |
| 5. Heliman Formation: 2007169006.....                         | 18        |
| 6. Langdon River Mudstone: 2007169007 .....                   | 22        |
| 7. Malacura Sandstone: 2007169009.....                        | 25        |
| 8. Unnamed granitic gneiss: 20071690011 .....                 | 29        |
| 9. Einasleigh Metamorphics: 20071690012 .....                 | 33        |
| 10. Einasleigh Metamorphics: 20071690014 .....                | 37        |
| 11. Einasleigh Metamorphics: 20071690015 .....                | 41        |
| 12. Mount Hogan Granite: 2008839046.....                      | 46        |
| 13. Unnamed garnet-biotite monzogranite: 2008839056 .....     | 49        |
| 14. Forest Home Trondhjemite: IWGT552 .....                   | 52        |
| 15. Brandy Hot Granodiorite: IWGT342.....                     | 57        |
| 16. Mywyn Granite: 2007167007-01 .....                        | 60        |
| 17. Gilberton Formation: 2007167002-08.....                   | 63        |
| <b>Millungera Basin .....</b>                                 | <b>66</b> |
| 18. Unnamed sandstone, JHR Glenbede Downs 1: 2010831028 ..... | 66        |
| 19. Unnamed sandstone, JHR Hampden Downs 1: 2010831035 .....  | 69        |
| 20. Unnamed sandstone, JHR Rosevale Downs 1: 2010831041 ..... | 72        |
| 21. Unnamed granite, JHR Gladevale Downs 1: 2010831046 .....  | 76        |
| <b>References .....</b>                                       | <b>80</b> |

# INTRODUCTION

## OVERVIEW

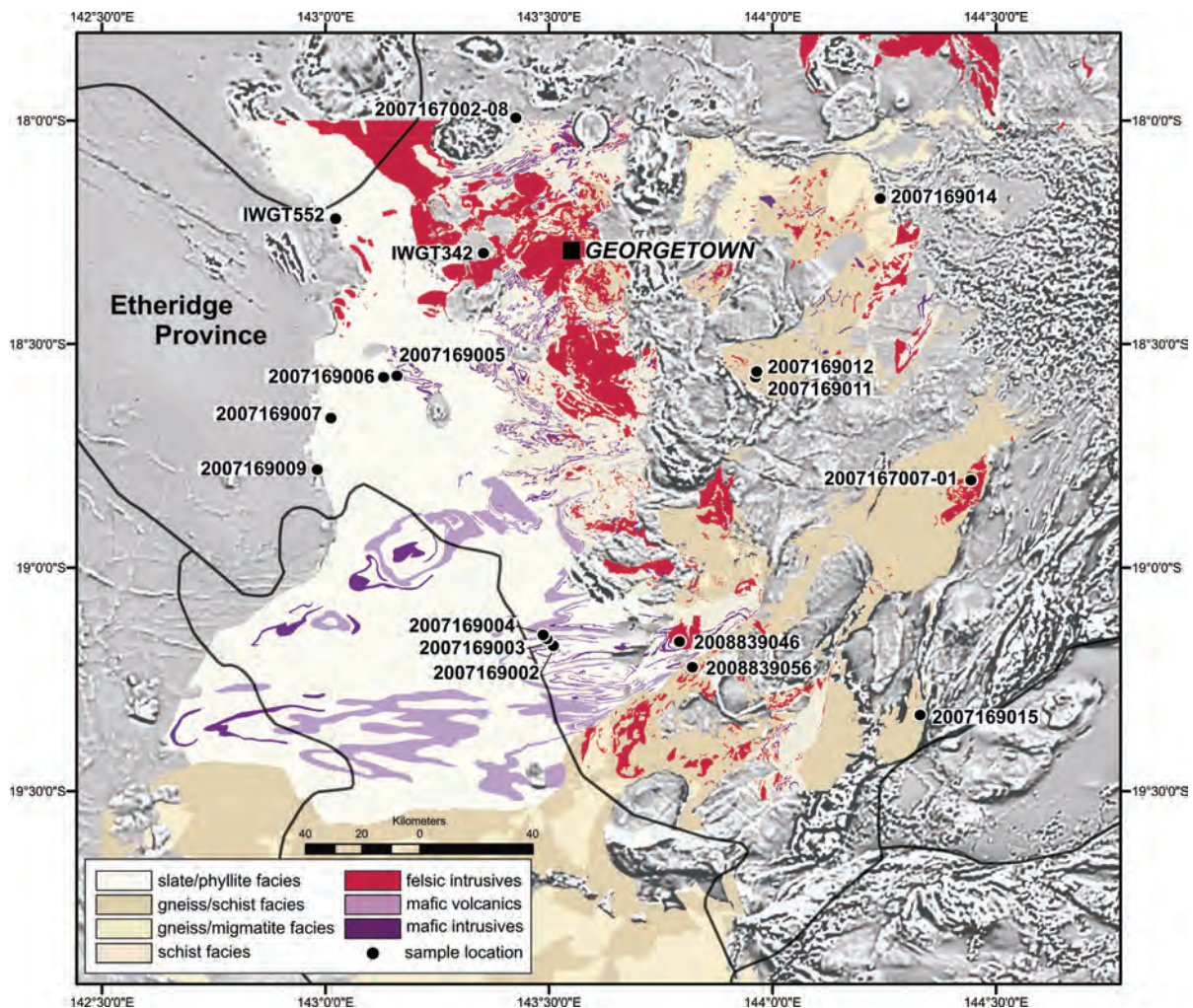
This record presents a compilation of new zircon U-Pb SHRIMP geochronological results for 17 sedimentary and igneous samples from the Etheridge Province, Georgetown Region, north Queensland (Figures i and ii), three samples from the recently identified Millungera Basin (Korsch et al., 2009a, b; 2011) and one sample to the east of the Millungera Basin, located under cover between the Mount Isa and Etheridge Province (Figures i and iv).



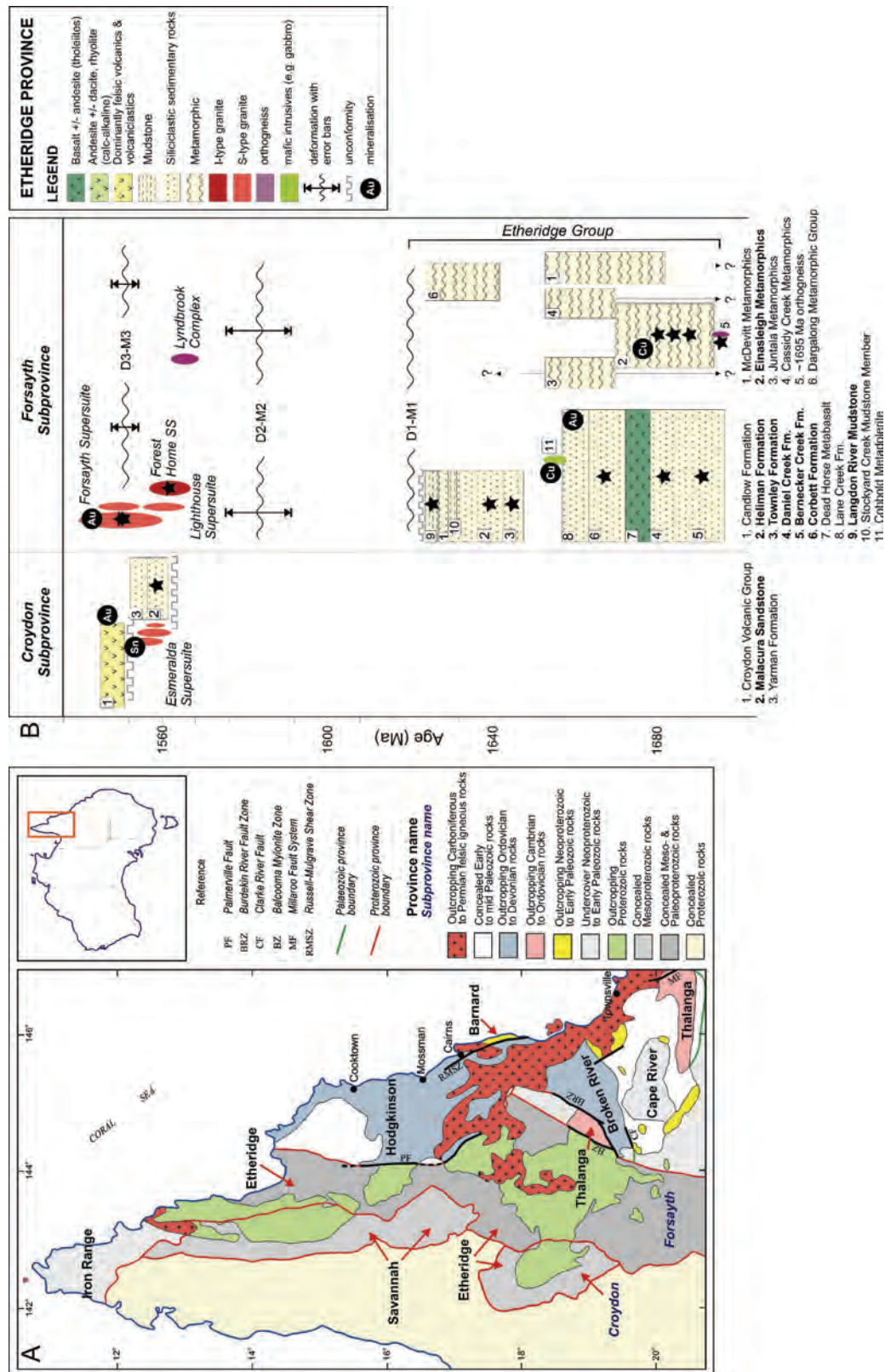
**Figure i.** Location of new SHRIMP geochronology (red circles) samples analysed during this study, on a total magnetic intensity image of the north Queensland region. Also shown are the 2006 and 2007 seismic lines (black lines), province and basin outlines (light grey lines), and the extent of the Millungera Basin (yellow).

Some of the samples were collected in 2007, as part of a project to explore possible correlations between the Mount Isa Province and the Etheridge Province. Other samples were collected in 2008 as part of Geoscience Australia's Onshore Energy Security Program (OESP), in conjunction with a synthesis of north Queensland (Kositcin et al., 2009), and in 2010 in support of the 2006 and 2007 deep seismic reflection surveys in north Queensland (Camuti and Young, 2009; Korsch et al., 2009a, b; 2011). All projects were undertaken in collaboration with the Geological Survey of Queensland through their Smart Mining and Smart Exploration initiatives.

Geological province and subprovince nomenclature used in this report follows Geological Survey of Queensland usage, largely as outlined in Bain and Draper (1997), but with the recent modifications of Withnall et al. (2009b). The succession in the Etheridge Province is assigned to the Etheridge Group, and is at least 6 km thick, and possibly as much as 13 km. A coherent stratigraphic succession can be identified, which is illustrated in a simplified time-space plot in Figure iii. The Proterozoic geology of the Etheridge Province has been described in detail by Withnall (1996) and Withnall et al. (1988, 1997a, b, 2002, 2009a, b). For a detailed synthesis of north Queensland, the reader is referred to Kositcin et al. (2009).

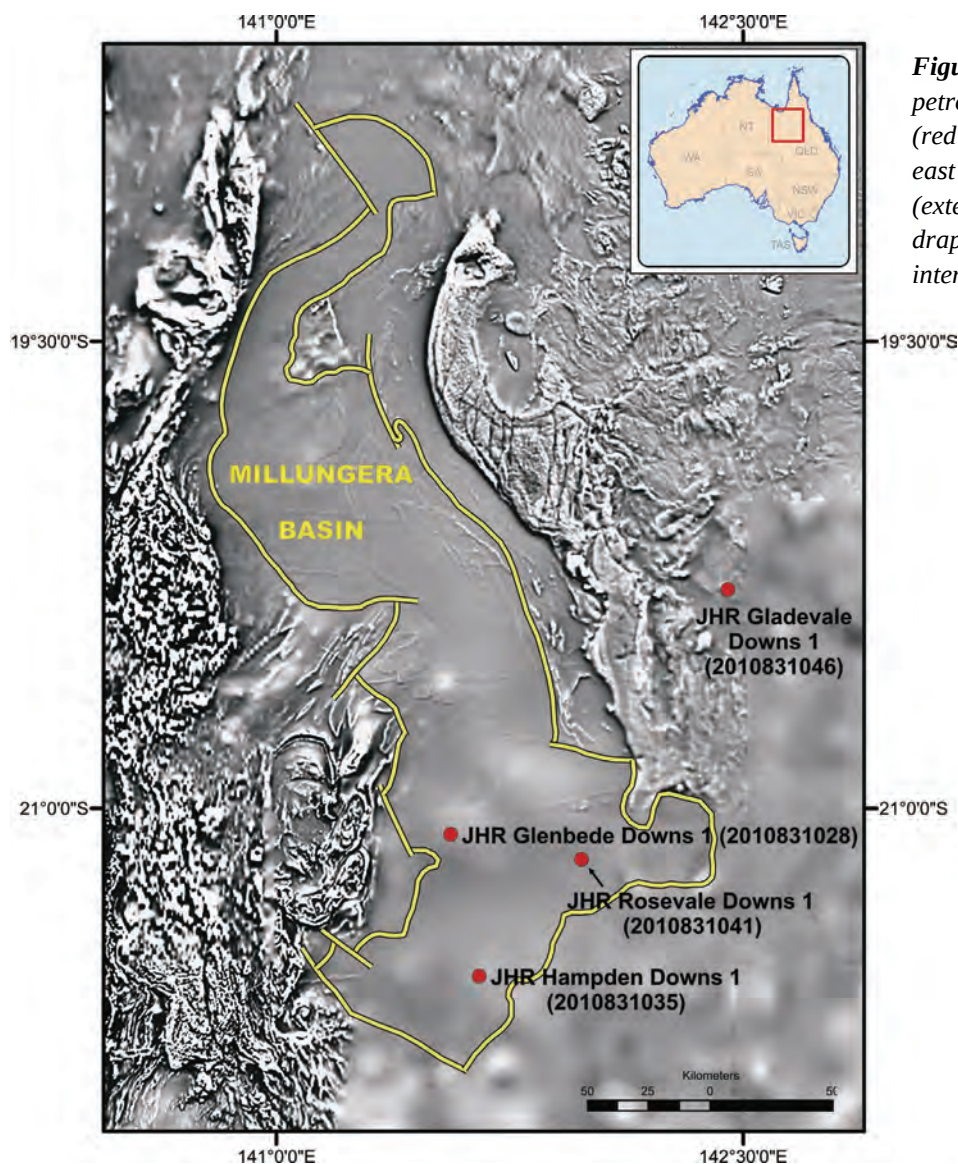


**Figure ii.** Locations of new SHRIMP geochronology samples from the Etheridge Province (black circles, with sample numbers) reported in this study. The background image is a simplified elements geological map of the Etheridge Province (from the Geological Survey of Queensland GIS), draped over a total magnetic intensity image, with province and basin outlines (black).



**Figure iii.** (A) Distribution of geological provinces and subprovinces in north Queensland. Province names and boundaries as defined by Bain and Draper (1997), with modifications from Withnall et al. (2009b) and Kositsin et al. (2009). (B) Simplified time-space plot for the Croydon and Forsayth subprovinces of the Etheridge Province, north Queensland. Units sampled in this study are highlighted in bold font and indicated with stars (modified from Kositsin et al., 2009).

The age of the sedimentary rocks in the Millungera Basin is unknown. The stratigraphic position of the Millungera Basin dates the succession as being younger than the deformed rocks of the Soldiers Cap Group in the Mount Isa Province to the west of the basin (Figure i), and older than the Late Jurassic-Early Cretaceous Carpentaria Basin (see Korsch et al., 2011). SHRIMP U-Pb geochronology on three detrital zircon samples and one igneous sample from cuttings from petroleum exploration wells (Figure iv) was undertaken to provide some constraints on the maximum depositional age of the sedimentary rocks and their likely provenance. For a detailed description of the Millungera Basin, see Korsch et al. (2011).



**Figure iv.** Locations of petroleum drillhole samples (red circles) within, and to the east of, the Millungera Basin (extent outlined in yellow), draped over a total magnetic intensity image.

A separate report for each sample is presented here; these contain sample location information and a sample description, a summary of the data, a preferred geochronological interpretation, and a data table. Locations of samples from the Etheridge Province are shown in Figures ii and iii. Locations of drillhole samples from within, and to the east of, the Millungera Basin are illustrated in Figure iv.

## SHRIMP ANALYTICAL PROCEDURES

All U-Pb isotopic results reported here were collected either on the SHRIMP IIe instrument housed in the SHRIMP laboratory at Geoscience Australia, Canberra, or the SHRIMP II instrument at the Research School of Earth Sciences, Australian National University. The zircon analytical procedures adopted here, and outlined below, follow those published by Compston et al. (1984) and Claoué-Long et al. (1995).

### Mineral separation

Samples were crushed and milled in the mineral separation laboratory at Geoscience Australia, Canberra. Mineral density separation was undertaken using a Wilfley table, with multiple iterations employed in order to reduce the sample to about 1-2% of its post-milling weight. Highly magnetic minerals were removed with a hand magnet, before magnetic separation using a Frantz isodynamic separator. The sample was systematically refined via the progressive removal of successively less paramagnetic fractions, by increasing the tilt of the ramp and the strength of the magnetic field. Subsequent processing was contingent upon the nature of the sample analysed and the desired dating objective.

For igneous and metamorphic samples, the emphasis is on selecting the least metamict and, potentially, the least disturbed isotopic compositions. A final series of runs on the Frantz separator refines zircon qualities by progressive responses to magnetic susceptibility. A selection of grains is then hand picked from the least magnetic fraction for mounting. For sedimentary samples, the emphasis is on avoiding grain selection bias during sample processing. At the first appearance of zircons during initial Frantz magnetic separation, a sample split is taken, from which all zircons are handpicked until sufficient numbers (several hundred) are obtained. This constitutes the random handpick.

### Mount preparation and SHRIMP analysis

The separated zircons are placed in rows on adhesive tape, together with a single grain of a high-uranium, high-lead 'set-up' zircon (currently sourced from the Panton mafic-ultramafic intrusion, Halls Creek Region, Page and Hoatson, 2000), a uranium concentration standard (typically SL13: approximately 238 ppm U, but also CZ3 and M257 may be used with 551 ppm U and 840 ppm U, respectively), a row of Pb/U ratio reference standard (Temora-2; Black et al., 2004) and grains of a Pb-Pb standard (OG1; Stern et al., 2009). The grains are then mounted in epoxy, and once cured the mount surface is polished using a series of diamond pastes until zircons are sectioned approximately in half, exposing their internal structure. They are photographed subsequently in both transmitted light and reflected light and coated with 20 Å of gold for cathodoluminescence imaging using a JEOL JSM-6490LV scanning electron microscope located at Geoscience Australia. After imaging, the gold coat is removed and the mount recleaned before being recoated with about 150 Å of gold for SHRIMP.

Isotopic data were collected using a primary beam consisting of ionised oxygen  $O_2^+$  molecules, purified by means of a Wien filter. After focussing through a Kohler aperture (usually 100-120 µm in diameter), the beam usually formed a spot 20-30 µm in diameter on the mount surface. Before each analysis, the surface of the analysis site was pre-cleaned by rastering of the primary beam for 3-4 minutes, in order to reduce the amount of common Pb on the mount surface. Secondary ions were collected on a single electron multiplier via cycling of the magnet through 5-6 scans through a run table consisting of ten different mass stations (e.g., refer to Carson et al., 2010). All analyses were carried out with a mass resolution of approximately 5000.

Analyses were collected in a sequence consisting of one analysis of a Temora-2 reference zircon and one measurement of an OG1 reference zircon after every third or fourth unknown sample analysis.

For all samples, reflected light, transmitted light and cathodoluminescence (CL) images were used to ensure that analyses were made on discrete zircon growth phases. In all cases, the area selected for analysis was in the clearest portion of each grain, free from cracks, inclusions and metamict regions. For igneous samples, zircons with a range of morphologies and cathodoluminescence responses were analysed to determine a magmatic crystallisation age and to identify any inherited and/or metamorphic ages present. For sedimentary rocks, more than 60 grains were analysed from each sample, where appropriate, in order to ensure a 95% chance of identifying each age component that comprises a significant proportion of the complete age spectrum (Dodson et al., 1988; Vermeesch, 2004), and only grains with surface imperfections were avoided.

### SHRIMP data reduction and presentation

Data processing used the SQUID-1 and SQUID-2 software of Ludwig (2001a, b, 2009) and processed data were plotted via Isoplot 3.7 (April 2008 revision of Ludwig, 2003), with  $^{206}\text{Pb}/^{238}\text{U}$  ratios calibrated using the Temora-2 reference zircon ( $^{238}\text{U}/^{206}\text{Pb}$  age = 416.8 Ma; Black et al., 2004),  $^{207}\text{Pb}/^{206}\text{Pb}$  ratios calibrated using the OG1 reference zircon ( $^{207}\text{Pb}/^{206}\text{Pb}$  age =  $3465.4 \pm 0.6$  Ma; Stern et al., 2009), and U concentrations calibrated using either: the M257 (840 ppm U; Nasdala et al., 2008), SL13 (238 ppm U; Claoué-Long et al., 1995) or CZ3 reference zircon (551 ppm U; Pidgeon et al., 1994).

Assuming that all surface Pb was removed from the mount surface during rastering, analyses of the U-Pb standard were corrected for common Pb using measured  $^{204}\text{Pb}$  and a default isotopic composition calculated using the model of Stacey and Kramers (1975), corresponding to a date of 416.8 Ma. Common-Pb corrections for unknown samples were based on measured  $^{204}\text{Pb}$  and an isotopic composition calculated using the Pb isotopic evolution model of Stacey and Kramers (1975), and a time corresponding to a preliminary  $^{206}\text{Pb}/^{238}\text{U}$  age calculated using the default common-Pb compositions. The result of this calculation is expressed in Tables throughout this report as common  $^{206}\text{Pb}$  as a percentage of total measured  $^{206}\text{Pb}$ . Analyses with relatively high  $^{206}\text{Pb}_c$  (i.e. >0.5%) are excluded from data interpretations.

Discordance is a measure of the internal agreement of the dates derived from the independent  $^{207}\text{Pb}/^{206}\text{Pb}$  and  $^{238}\text{U}/^{206}\text{Pb}$  isotopic systems within a single analysis. In zircons of Mesoproterozoic and older age, discordance values for single analyses (and discordance patterns within a population of analyses) can provide important information about the timing and extent of radiogenic Pb loss, and are usually a valuable indication of geological data quality. Discordance was calculated by the default method used by the SQUID Excel add-in:  $100 * [(^{207}\text{Pb}/^{206}\text{Pb} \text{ age} - ^{206}\text{Pb}/^{238}\text{U} \text{ age}) / ^{206}\text{Pb}/^{238}\text{U} \text{ age}]$ . In most cases, analyses >5 and >10% discordant are excluded from data interpretations for igneous and sedimentary samples, respectively (refer to individual sample results).

Most ages discussed in this report are  $^{204}\text{Pb}$ -corrected  $^{207}\text{Pb}/^{206}\text{Pb}$  ages, and quoted at the 95% confidence level (ca.  $1.96 \sigma$ ) unless otherwise specified. When displaying the data using concordia/cumulative probability plots and/or weighted mean age diagrams, data point error ellipses and error bars are plotted at the  $1\sigma$  uncertainty level, unless otherwise specified. All ages quoted in the data tables are at the  $1\sigma$  level. Unfilled ellipses on Tera-Wasserburg concordia plots represent compositions that are greater than 5% discordant (or 10% for sedimentary samples) and/or have >0.5% common Pb, as described in figure captions.

For all SHRIMP U-Pb zircon isotopic ages reported here, zircons that are over 1000 Ma are reported as  $^{207}\text{Pb}/^{206}\text{Pb}$  ages (as above). For zircons younger than 1000 Ma,  $^{206}\text{Pb}/^{238}\text{U}$  ratios have been used as the  $^{207}\text{Pb}/^{206}\text{Pb}$  ratios become too imprecise. In addition, for zircons younger than 1000 Ma, concordance

cannot be precisely determined because the  $^{207}\text{Pb}/^{206}\text{Pb}$  ratios are too imprecise. Therefore, the degree of concordance is less useful to identify and remove poor analyses.

Instrumental mass fractionation (IMF) was monitored via regular analyses of the  $^{207}\text{Pb}/^{206}\text{Pb}$  reference zircon OG1 (Stern et al., 2009) during each analytical session. Where indicated that IMF corrections have been performed, the reader should be aware that the data presented in the text, concordia and probability density diagrams, and in the data tables, are corrected  $^{207}\text{Pb}/^{206}\text{Pb}$  ages. The final pooled  $^{207}\text{Pb}/^{206}\text{Pb}$  ages determinations are also corrected for Pb-Pb IMF.

In determining the maximum depositional age for sedimentary samples, we have used the youngest age cluster to calculate an age, where this cluster is defined as the group of youngest ages that are separate from the next youngest individual(s), as indicated in the probability density histogram, by grouping the largest number of youngest ages which have a probability of fit value great than 0.05, or as calculated by the mixture modelling method (Sambridge and Compston, 1994).

## Acknowledgements

We would like to acknowledge the support and contributions of colleagues from Geoscience Australia and the Geological Survey of Queensland. In particular, Ian Withnall, David Champion, David Huston, George Gibson and Lex Lambeck are thanked for their collaboration during field work, including sample collection, and for numerous geological discussions that improved our regional geologic understanding, and highlighted important knowledge gaps. Russell Korsch is thanked for providing drill cuttings from the Millungera Basin.

Zircon geochronology is critically dependent on the quality of sample material. At Geoscience Australia we are fortunate to have a highly skilled and dedicated team in the mineral separation laboratory. We thank Chris Foudoulis, Steve Ridgway, Emma Chisholm, David DiBugnara and Benjamin Linehan for the production of high-quality zircon mounts, and associated images, without which this work would not have been possible.

Richard Stern and Patrick Burke were responsible for maintaining the SHRIMP instrument and assisted with instrument tuning and troubleshooting. We also thank Richard Stern and Keith Sircombe for their leadership of the geochronology team at Geoscience Australia, and for advice and technical assistance. Our geochronology colleagues at Geoscience Australia – Simon Bodorkos, Chris Carson, Andrew Cross and Geoff Fraser – are thanked for discussions on various aspects of data collection, processing and interpretation. Andrew Cross and Russell Korsch are thanked for reviewing draft versions of this Record.

## 1. BERNECKER CREEK FORMATION, PERCY RIVER: 2007169002

|                                                |                                                              |
|------------------------------------------------|--------------------------------------------------------------|
| GA Sample ID:                                  | 2007169002                                                   |
| GA Sample Number:                              | 1937151                                                      |
| Other Sample ID:                               |                                                              |
| 1:250,000 Sheet:                               | GILBERTON SE5416                                             |
| Region:                                        | Etheridge Province, Queensland                               |
| Grid Reference (WGS 84):                       | 763956mE 7877996mN Zone 54                                   |
| Collector:                                     | N. Neumann, G. Gibson, I. Withnall, L. Lambeck,<br>D. Huston |
| Collection Date:                               | 23/7/2007                                                    |
| Formal Name:                                   | Bernecker Creek Formation                                    |
| Informal Name:                                 |                                                              |
| Lithology:                                     | Grey, fine-grained sandstone                                 |
| Geochronologist:                               | N.L. Neumann                                                 |
| Mount ID:                                      | GA6038                                                       |
| Instrument:                                    | SHRIMP II Australian National University                     |
| Acquisition Date:                              | 10–14/11/2007                                                |
| U-Pb Standard & reproducibility:               | TEMORA-2; 2.32% (2 $\sigma$ ) [32 of 33]                     |
| <sup>207</sup> Pb/ <sup>206</sup> Pb Standard: | OG1 (3465.4 $\pm$ 0.6 Ma)                                    |
| Measured Value ( $\pm$ 95% confidence):        | 3464.6 $\pm$ 2.7 Ma [16 of 17]                               |
| Interpreted Age:                               | 1844 $\pm$ 11 Ma                                             |
| IMF correction applied?                        | No                                                           |
| Interpreted Age Type:                          | Maximum deposition age                                       |

**Sample Description**

This sample of the Bernecker Creek Formation (Figure iii) was collected from along the Percy River ~2 km north of Ortona Station, in the Ortona Anticline of the Etheridge Province, Queensland. Here, the formation is characterised by packages of turbiditic sandstones which have very thick, massive-graded bases, with reworked upper layers. The sample was collected from the lower part of one of these packages, and is a grey, recrystallised, fine-grained sandstone with grits (Figure 1.1).

**Zircon Description**

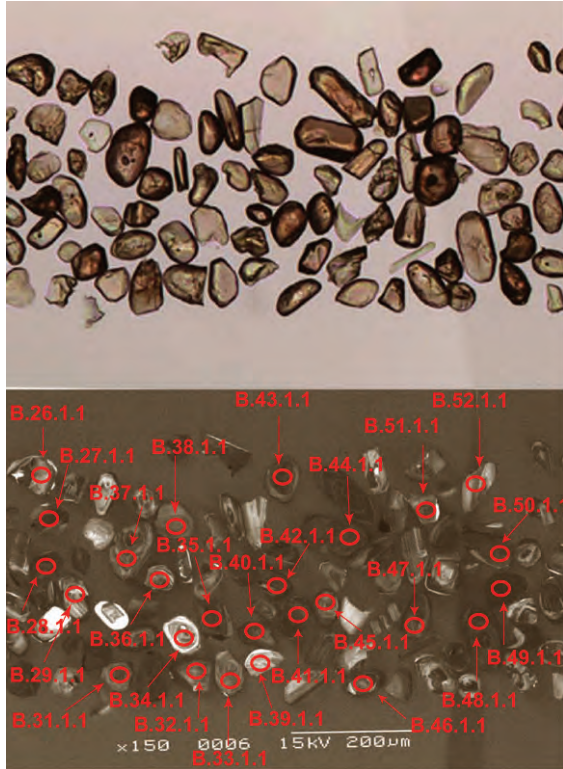
Zircons from this sample range in length from ~50  $\mu$ m to ~90  $\mu$ m, with some larger grains up to ~140  $\mu$ m in length (Figure 1.2). Most grains have a subrounded morphology, with other grains preserving some prismatic edges. Most grains are clear and colourless to brown in colour, with cathodoluminescence images recording oscillatory zoning in some grains, whereas others



**Figure 1.1.** Outcrop photo of Bernecker Creek Formation at the site of sample 2007169002, from the Percy River, Ortona Anticline, Etheridge Province.

record either a dark or bright cathodoluminescence response. As this sample

was analysed to determine a maximum depositional age, analyses were located on the central zones of grains away from any rims which may record later metamorphism.



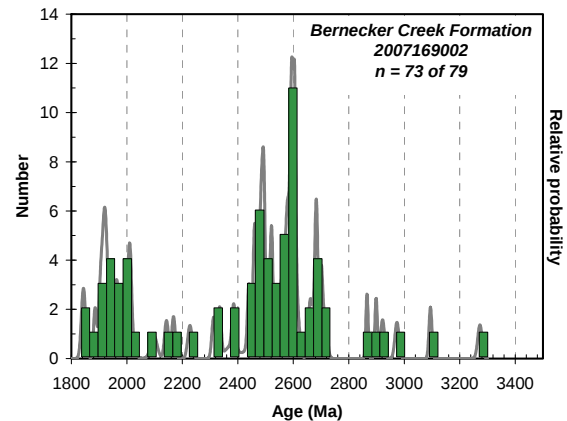
**Figure 1.2.** Representative transmitted light and cathodoluminescence images of zircons from the Bernecker Creek Formation (2007169002), with locations of some SHRIMP analyses.

### U-Pb Isotopic Results

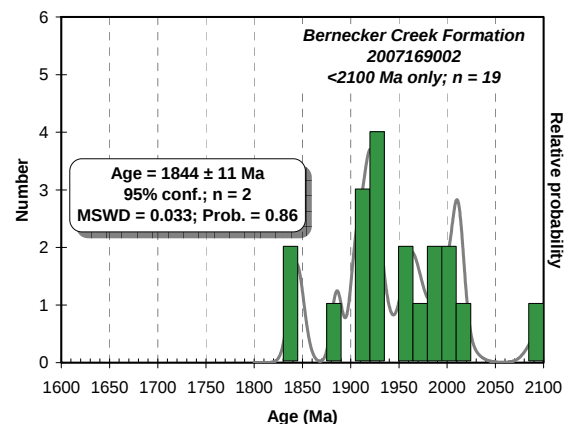
Seventy-nine analyses were undertaken on this sample, the results of which are presented in Table 1.1 and illustrated in Figures 1.3 and 1.4. U concentrations of the analysed zircons range between 931 and 23 ppm, with Th/U ratios between 2.21 and 0.04.

Six analyses >10% discordant were excluded from further consideration, and the remaining 73 analyses range in age from ~3273 Ma to ~1843 Ma (Figure 1.3). There are a range of ages between ~3273 Ma and ~2300 Ma, with approximately 70% of the ages from this sample occurring within this range. There are a smaller number of ages younger than this range, with smaller clusters at ~2000 and 1900 Ma. The

youngest individual ages are  $1843 \pm 14$  Ma and  $1845 \pm 16$  Ma ( $2\sigma$ ), and these 2 ages are statistically separate from the next youngest individual. The combined weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age of the youngest two individuals is  $1844 \pm 11$  Ma (95% confidence; MSWD = 0.033; probability of fit = 0.86; Figure 1.4).



**Figure 1.3.** Probability density diagram of zircon analyses from the Bernecker Creek Formation (2007169002).



**Figure 1.4.** Probability density diagram of zircon analyses from the Bernecker Creek Formation (2007169002) yielding  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of less than 2100 Ma.

### Geochronological Interpretation

The weighted mean age of  $1844 \pm 11$  Ma (95% confidence;  $n = 2$ ) can be used to define a maximum depositional age for this sample of the Bernecker Creek Formation.

**Table 1.1.** SHRIMP U-Pb isotopic data for zircons from sample 2007169002 (1937151), Bernecker Creek Formation, Percy River.

| Grain.area                     | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|--------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| <i>Detrital zircon (n= 73)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| B.22.1.1                       | 0.01                                               | 298        | 72          | 0.25                                   | 1.4934                                 | 1.2         | 0.2643                                  | 0.5         | 3273                                             | 8            | -1          |
| B.26.1.1                       | 0.07                                               | 146        | 63          | 0.45                                   | 1.6613                                 | 1.3         | 0.2362                                  | 0.3         | 3095                                             | 5            | 2           |
| B.75.1.1                       | 0.07                                               | 135        | 45          | 0.35                                   | 1.7158                                 | 1.4         | 0.2190                                  | 0.5         | 2974                                             | 7            | 0           |
| B.8.1.1                        | 0.03                                               | 100        | 63          | 0.65                                   | 1.8105                                 | 1.4         | 0.2121                                  | 0.4         | 2922                                             | 7            | 3           |
| B.50.1.1                       | 0.02                                               | 352        | 83          | 0.24                                   | 1.8405                                 | 1.3         | 0.2091                                  | 0.3         | 2899                                             | 4            | 3           |
| B.11.1.1                       | 0.01                                               | 282        | 179         | 0.66                                   | 1.8584                                 | 1.4         | 0.2049                                  | 0.3         | 2866                                             | 4            | 3           |
| B.68.1.1                       | 0.05                                               | 164        | 130         | 0.82                                   | 1.9528                                 | 1.4         | 0.1870                                  | 0.5         | 2716                                             | 8            | 2           |
| B.3.1.1                        | 0.02                                               | 213        | 71          | 0.35                                   | 1.9495                                 | 1.3         | 0.1854                                  | 0.3         | 2701                                             | 5            | 1           |
| B.86.1.1                       | 0.04                                               | 181        | 244         | 1.39                                   | 1.9389                                 | 1.3         | 0.1851                                  | 0.4         | 2699                                             | 7            | 1           |
| B.47.1.1                       | 0.05                                               | 384        | 212         | 0.57                                   | 2.0548                                 | 1.3         | 0.1835                                  | 0.3         | 2685                                             | 5            | 5           |
| B.27.1.1                       | 0.06                                               | 303        | 289         | 0.99                                   | 2.1149                                 | 1.2         | 0.1834                                  | 0.3         | 2684                                             | 5            | 7           |
| B.64.1.1                       | 0.09                                               | 377        | 265         | 0.73                                   | 2.1350                                 | 1.3         | 0.1830                                  | 0.3         | 2680                                             | 5            | 8           |
| B.82.1.1                       | 0.07                                               | 115        | 49          | 0.44                                   | 1.9300                                 | 1.4         | 0.1817                                  | 0.5         | 2669                                             | 9            | -1          |
| B.46.1.1                       | 0.06                                               | 228        | 67          | 0.30                                   | 2.0107                                 | 1.3         | 0.1807                                  | 0.4         | 2660                                             | 7            | 2           |
| B.37.1.1                       | 0.07                                               | 167        | 116         | 0.72                                   | 2.0485                                 | 1.3         | 0.1761                                  | 0.5         | 2617                                             | 8            | 2           |
| B.15.1.1                       | 0.05                                               | 127        | 184         | 1.50                                   | 2.0373                                 | 1.6         | 0.1749                                  | 0.4         | 2605                                             | 7            | 1           |
| B.79.1.1                       | 0.02                                               | 931        | 37          | 0.04                                   | 2.0947                                 | 1.3         | 0.1749                                  | 0.2         | 2605                                             | 3            | 3           |
| B.57.1.1                       | 0.04                                               | 274        | 155         | 0.58                                   | 1.9872                                 | 1.3         | 0.1748                                  | 0.4         | 2604                                             | 6            | -1          |
| B.4.1.1                        | 0.02                                               | 234        | 165         | 0.73                                   | 2.0239                                 | 1.3         | 0.1746                                  | 0.3         | 2602                                             | 5            | 1           |
| B.54.1.1                       | 0.05                                               | 240        | 73          | 0.31                                   | 2.1066                                 | 1.3         | 0.1745                                  | 0.4         | 2602                                             | 7            | 4           |
| B.44.1.1                       | 0.03                                               | 307        | 101         | 0.34                                   | 2.2604                                 | 1.3         | 0.1741                                  | 0.4         | 2598                                             | 6            | 9           |
| B.5.1.1                        | 0.01                                               | 416        | 174         | 0.43                                   | 2.0723                                 | 1.2         | 0.1738                                  | 0.2         | 2595                                             | 4            | 2           |
| B.70.1.1                       | 0.08                                               | 561        | 489         | 0.90                                   | 2.2220                                 | 1.2         | 0.1738                                  | 0.4         | 2594                                             | 7            | 8           |
| B.71.1.1                       | 0.07                                               | 610        | 228         | 0.39                                   | 2.1374                                 | 1.2         | 0.1735                                  | 0.3         | 2592                                             | 4            | 5           |
| B.55.1.1                       | 0.04                                               | 201        | 95          | 0.49                                   | 2.0946                                 | 1.3         | 0.1728                                  | 0.4         | 2585                                             | 7            | 3           |
| B.51.1.1                       | 0.08                                               | 249        | 128         | 0.53                                   | 2.2759                                 | 1.3         | 0.1727                                  | 0.4         | 2584                                             | 7            | 9           |
| B.61.1.1                       | 0.04                                               | 259        | 61          | 0.24                                   | 2.0928                                 | 1.3         | 0.1722                                  | 0.4         | 2579                                             | 6            | 2           |
| B.83.1.1                       | 0.07                                               | 229        | 131         | 0.59                                   | 2.1764                                 | 1.3         | 0.1715                                  | 0.4         | 2572                                             | 7            | 5           |
| B.38.1.1                       | 0.07                                               | 228        | 61          | 0.27                                   | 2.2627                                 | 1.3         | 0.1715                                  | 0.5         | 2572                                             | 9            | 8           |
| B.58.1.1                       | 0.02                                               | 582        | 123         | 0.22                                   | 2.1505                                 | 1.5         | 0.1704                                  | 0.9         | 2562                                             | 15           | 4           |
| B.10.1.1                       | 0.01                                               | 220        | 163         | 0.77                                   | 2.2349                                 | 1.2         | 0.1699                                  | 0.3         | 2557                                             | 5            | 7           |
| B.85.1.1                       | 0.03                                               | 313        | 176         | 0.58                                   | 2.0891                                 | 1.3         | 0.1684                                  | 0.3         | 2542                                             | 6            | 1           |
| B.78.1.1                       | 0.02                                               | 517        | 281         | 0.56                                   | 2.1356                                 | 1.2         | 0.1665                                  | 0.3         | 2523                                             | 5            | 2           |
| B.48.1.1                       | 0.02                                               | 428        | 170         | 0.41                                   | 2.1350                                 | 1.3         | 0.1664                                  | 0.3         | 2522                                             | 5            | 2           |
| B.76.1.1                       | 0.03                                               | 335        | 106         | 0.33                                   | 2.0911                                 | 1.3         | 0.1657                                  | 0.4         | 2515                                             | 6            | 0           |
| B.43.1.1                       | 0.01                                               | 600        | 75          | 0.13                                   | 2.2747                                 | 1.2         | 0.1639                                  | 0.2         | 2496                                             | 4            | 6           |
| B.42.1.1                       | 0.05                                               | 441        | 281         | 0.66                                   | 2.3846                                 | 1.2         | 0.1637                                  | 0.4         | 2495                                             | 7            | 10          |
| B.9.1.1                        | 0.02                                               | 439        | 242         | 0.57                                   | 2.1823                                 | 1.2         | 0.1634                                  | 0.2         | 2491                                             | 4            | 2           |
| B.40.1.1                       | 0.06                                               | 264        | 133         | 0.52                                   | 2.2879                                 | 1.3         | 0.1630                                  | 0.4         | 2487                                             | 7            | 6           |
| B.56.1.1                       | 0.02                                               | 573        | 299         | 0.54                                   | 2.1469                                 | 1.2         | 0.1628                                  | 0.3         | 2485                                             | 5            | 1           |
| B.62.1.1                       | 0.03                                               | 351        | 209         | 0.62                                   | 2.1230                                 | 1.5         | 0.1624                                  | 0.4         | 2481                                             | 6            | 0           |
| B.2.1.1                        | 0.12                                               | 23         | 15          | 0.69                                   | 2.1234                                 | 1.9         | 0.1614                                  | 1.2         | 2471                                             | 20           | -1          |
| B.66.1.1                       | 0.03                                               | 232        | 129         | 0.57                                   | 2.1362                                 | 1.3         | 0.1609                                  | 0.4         | 2465                                             | 7            | 0           |
| B.7.1.1                        | 0.02                                               | 347        | 303         | 0.90                                   | 2.1450                                 | 1.2         | 0.1604                                  | 0.3         | 2460                                             | 5            | 0           |
| B.39.1.1                       | 0.01                                               | 96         | 57          | 0.61                                   | 2.4454                                 | 1.5         | 0.1602                                  | 0.7         | 2457                                             | 12           | 10          |
| B.67.1.1                       | 0.03                                               | 440        | 138         | 0.32                                   | 2.2383                                 | 1.4         | 0.1600                                  | 1.6         | 2455                                             | 27           | 3           |
| B.59.1.1                       | 0.01                                               | 552        | 56          | 0.10                                   | 2.2548                                 | 1.2         | 0.1585                                  | 0.3         | 2440                                             | 5            | 3           |
| B.13.1.1                       | 0.06                                               | 869        | 263         | 0.31                                   | 2.5434                                 | 1.4         | 0.1535                                  | 0.4         | 2385                                             | 6            | 10          |
| B.74.1.1                       | 0.06                                               | 662        | 84          | 0.13                                   | 2.5323                                 | 1.2         | 0.1525                                  | 1.3         | 2375                                             | 22           | 10          |
| B.6.1.1                        | 0.02                                               | 295        | 302         | 1.06                                   | 2.4496                                 | 1.5         | 0.1490                                  | 0.3         | 2335                                             | 5            | 5           |
| B.12.1.1                       | 0.06                                               | 259        | 138         | 0.55                                   | 2.4755                                 | 1.3         | 0.1471                                  | 0.4         | 2313                                             | 7            | 5           |
| B.20.1.1                       | 0.07                                               | 194        | 117         | 0.62                                   | 2.6602                                 | 1.3         | 0.1400                                  | 0.5         | 2228                                             | 8            | 8           |
| B.18.1.1                       | 0.03                                               | 269        | 130         | 0.50                                   | 2.7397                                 | 1.4         | 0.1353                                  | 0.4         | 2168                                             | 6            | 7           |
| B.1.1.1                        | 0.02                                               | 242        | 111         | 0.48                                   | 2.6016                                 | 1.3         | 0.1334                                  | 0.4         | 2143                                             | 7            | 2           |
| B.73.1.1                       | 0.08                                               | 139        | 83          | 0.62                                   | 2.8159                                 | 1.4         | 0.1300                                  | 0.7         | 2097                                             | 12           | 7           |
| B.84.1.1                       | 0.02                                               | 464        | 201         | 0.45                                   | 2.6931                                 | 1.3         | 0.1238                                  | 0.4         | 2012                                             | 6            | -1          |
| B.23.1.1                       | 0.06                                               | 516        | 266         | 0.53                                   | 2.8166                                 | 1.2         | 0.1237                                  | 0.3         | 2010                                             | 6            | 3           |
| B.80.1.1                       | -0.03                                              | 88         | 75          | 0.89                                   | 2.6856                                 | 1.5         | 0.1235                                  | 0.9         | 2008                                             | 15           | -2          |
| B.35.1.1                       | 0.04                                               | 460        | 166         | 0.37                                   | 2.9986                                 | 1.2         | 0.1226                                  | 0.4         | 1994                                             | 7            | 7           |
| B.65.1.1                       | 0.20                                               | 101        | 85          | 0.87                                   | 2.8199                                 | 1.8         | 0.1226                                  | 1.0         | 1994                                             | 17           | 2           |
| B.14.1.1                       | 0.07                                               | 197        | 110         | 0.58                                   | 2.7576                                 | 1.3         | 0.1211                                  | 0.5         | 1973                                             | 9            | -1          |
| B.24.1.1                       | 0.03                                               | 336        | 108         | 0.33                                   | 2.9755                                 | 1.3         | 0.1203                                  | 0.5         | 1961                                             | 8            | 5           |
| B.63.1.1                       | 0.08                                               | 296        | 134         | 0.47                                   | 2.8155                                 | 1.3         | 0.1202                                  | 0.5         | 1959                                             | 9            | 0           |
| B.81.1.1                       | 0.12                                               | 101        | 204         | 2.10                                   | 2.8265                                 | 1.4         | 0.1183                                  | 0.8         | 1931                                             | 14           | -1          |

SHRIMP geochronology of north Queensland: 2007-2010

| Grain.area                                 | $^{206}\text{Pb}_c$<br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | $\frac{^{232}\text{Th}}{^{238}\text{U}}$ | $\frac{^{238}\text{U}}{^{206}\text{Pb}}$ | $\pm 1\sigma$<br>(%) | $\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$ | $\pm 1\sigma$<br>(%) | $\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$<br>Age (Ma) | $\pm 1\sigma$<br>(Ma) | Disc<br>(%) |
|--------------------------------------------|-----------------------------------------|------------|-------------|------------------------------------------|------------------------------------------|----------------------|-------------------------------------------|----------------------|-------------------------------------------------------|-----------------------|-------------|
| B.77.1.1                                   | 0.19                                    | 341        | 129         | 0.39                                     | 3.0532                                   | 1.3                  | 0.1181                                    | 0.6                  | 1928                                                  | 10                    | 5           |
| B.60.1.1                                   | 0.08                                    | 325        | 54          | 0.17                                     | 3.0795                                   | 1.3                  | 0.1176                                    | 0.5                  | 1920                                                  | 9                     | 6           |
| B.53.1.1                                   | 0.02                                    | 413        | 98          | 0.25                                     | 3.0529                                   | 1.3                  | 0.1176                                    | 0.4                  | 1920                                                  | 7                     | 5           |
| B.52.1.1                                   | 0.07                                    | 278        | 35          | 0.13                                     | 3.0496                                   | 1.3                  | 0.1176                                    | 0.5                  | 1919                                                  | 9                     | 5           |
| B.69.1.1                                   | 0.07                                    | 220        | 161         | 0.76                                     | 3.0484                                   | 1.3                  | 0.1171                                    | 0.7                  | 1912                                                  | 12                    | 4           |
| B.16.1.1                                   | 0.02                                    | 511        | 655         | 1.33                                     | 3.0869                                   | 1.2                  | 0.1166                                    | 0.3                  | 1905                                                  | 6                     | 5           |
| B.49.1.1                                   | 0.02                                    | 766        | 267         | 0.36                                     | 3.0279                                   | 1.2                  | 0.1154                                    | 0.3                  | 1886                                                  | 6                     | 2           |
| B.21.1.1                                   | 0.02                                    | 284        | 203         | 0.74                                     | 3.1102                                   | 1.2                  | 0.1128                                    | 0.5                  | 1845                                                  | 8                     | 3           |
| B.72.1.1                                   | 0.03                                    | 483        | 505         | 1.08                                     | 3.1465                                   | 1.2                  | 0.1127                                    | 0.4                  | 1843                                                  | 7                     | 3           |
| <i>Analyses &gt;10% discordant (n = 6)</i> |                                         |            |             |                                          |                                          |                      |                                           |                      |                                                       |                       |             |
| B.19.1.1                                   | 0.38                                    | 453        | 969         | 2.21                                     | 3.5545                                   | 1.5                  | 0.1192                                    | 0.8                  | 1945                                                  | 14                    | 18          |
| B.25.1.1                                   | 0.04                                    | 482        | 370         | 0.79                                     | 2.4570                                   | 1.2                  | 0.1721                                    | 0.2                  | 2578                                                  | 4                     | 15          |
| B.36.1.1                                   | 0.27                                    | 187        | 199         | 1.10                                     | 2.3824                                   | 1.3                  | 0.1753                                    | 0.5                  | 2609                                                  | 9                     | 13          |
| B.17.1.1                                   | 0.02                                    | 593        | 144         | 0.25                                     | 2.6110                                   | 1.2                  | 0.1526                                    | 0.3                  | 2376                                                  | 5                     | 12          |
| B.45.1.1                                   | 0.08                                    | 268        | 122         | 0.47                                     | 3.0411                                   | 1.3                  | 0.1278                                    | 0.5                  | 2068                                                  | 9                     | 11          |
| B.41.1.1                                   | 0.05                                    | 455        | 253         | 0.57                                     | 1.8743                                   | 1.2                  | 0.2377                                    | 0.3                  | 3105                                                  | 5                     | 11          |

1.  $^{206}\text{Pb}_c$  indicates common  $^{206}\text{Pb}$  as a percentage of the total measured  $^{206}\text{Pb}$ .

## 2. DANIEL CREEK FORMATION, PERCY RIVER: 2007169003

|                                                         |                                                              |
|---------------------------------------------------------|--------------------------------------------------------------|
| <b>GA Sample ID:</b>                                    | 2007169003                                                   |
| <b>GA Sample Number:</b>                                | 1937152                                                      |
| <b>Other Sample ID:</b>                                 |                                                              |
| <b>1:250,000 Sheet:</b>                                 | GILBERTON SE5416                                             |
| <b>Region:</b>                                          | Etheridge Province, Queensland                               |
| <b>Grid Reference (WGS 84):</b>                         | 762483mE 7879684mN Zone 54                                   |
| <b>Collector:</b>                                       | N. Neumann, G. Gibson, I. Withnall, L. Lambeck,<br>D. Huston |
| <b>Collection Date:</b>                                 | 24/7/2007                                                    |
| <b>Formal Name:</b>                                     | Daniel Creek Formation                                       |
| <b>Informal Name:</b>                                   |                                                              |
| <b>Lithology:</b>                                       | Grey, fine-grained sandstone                                 |
| <b>Geochronologist:</b>                                 | N.L. Neumann                                                 |
| <b>Mount ID:</b>                                        | GA6038                                                       |
| <b>Instrument:</b>                                      | SHRIMP II Australian National University                     |
| <b>Acquisition Date:</b>                                | 10–14/11/2007                                                |
| <b>U-Pb Standard &amp; reproducibility:</b>             | TEMORA-2; 2.32% (2 $\sigma$ ) [32 of 33]                     |
| <b><sup>207</sup>Pb/<sup>206</sup>Pb Standard:</b>      | OG1 (3465.4 $\pm$ 0.6 Ma)                                    |
| <b>Measured Value (<math>\pm</math>95% confidence):</b> | 3464.6 $\pm$ 2.7 Ma [16 of 17]                               |
| <b>Geochronologist:</b>                                 | N.L. Neumann                                                 |
| <b>Mount ID:</b>                                        | GA6038                                                       |
| <b>Instrument:</b>                                      | SHRIMP IIe Geoscience Australia                              |
| <b>Acquisition Date:</b>                                | 25–27/3/2008                                                 |
| <b>U-Pb Standard &amp; reproducibility:</b>             | TEMORA-2; 1.68% (2 $\sigma$ ) [26 of 26]                     |
| <b><sup>207</sup>Pb/<sup>206</sup>Pb Standard:</b>      | OG1 (3465.4 $\pm$ 0.6 Ma)                                    |
| <b>Measured Value (<math>\pm</math>95% confidence):</b> | 3466.2 $\pm$ 2.7 Ma [11 of 11]                               |
| <b>Interpreted Age:</b>                                 | 1695 $\pm$ 13 Ma                                             |
| <b>IMF correction applied?</b>                          | No                                                           |
| <b>Interpreted Age Type:</b>                            | Maximum deposition age                                       |

**Sample Description**

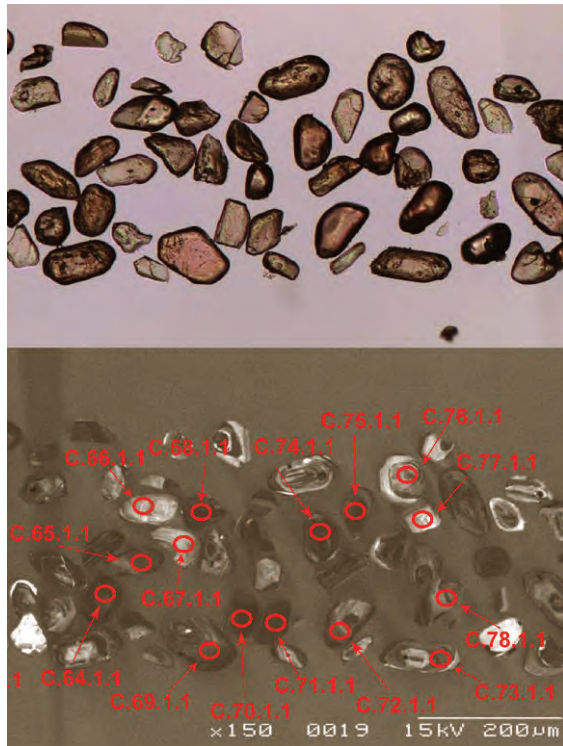
The Daniel Creek Formation (Figure iii) was sampled from along the Percy River ~ 4 km north of Ortona Station, in the Ortona Anticline of the Etheridge Province, Queensland. The sample (2007169003) was collected from the upper part of this formation, ~50 m below the contact with the overlying Dead Horse Metabasalt, and is a grey, fine-grained sandstone from a thick bed interbedded with thinly-bedded siltstones (Figure 2.1).

**Figure 2.1 (right).** Outcrop photo of Daniel Creek Formation at the site of sample 2007169003, Percy River, Ortona Anticline, Etheridge Province.



### Zircon Description

Zircons from this sample range in length from ~50  $\mu\text{m}$  to ~100  $\mu\text{m}$ , with occasional larger grains up to ~130  $\mu\text{m}$  in length (Figure 2.2). Most grains have a subrounded morphology, with other grains preserving some prismatic edges. Most grains are clear and colourless to brown in colour, and some grains are pitted. In cathodoluminescence images, some grains record oscillatory zoning whereas others record either a dark or bright response. As this sample was analysed to determine a maximum depositional age, analyses were located on central zones of grains away from any rims which may record later metamorphism.

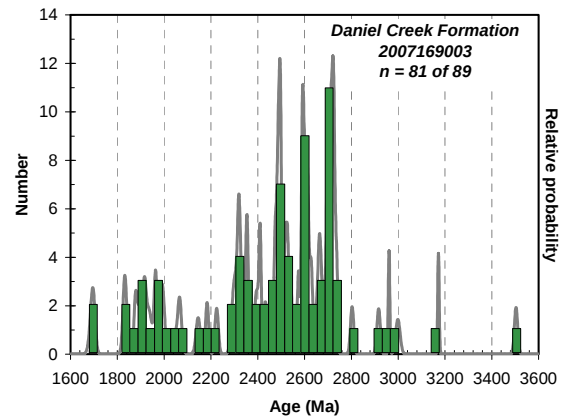


**Figure 2.2.** Representative transmitted light and cathodoluminescence images of zircons from the Daniel Creek Formation (2007169003), with locations of some SHRIMP analyses.

### U-Pb Isotopic Results

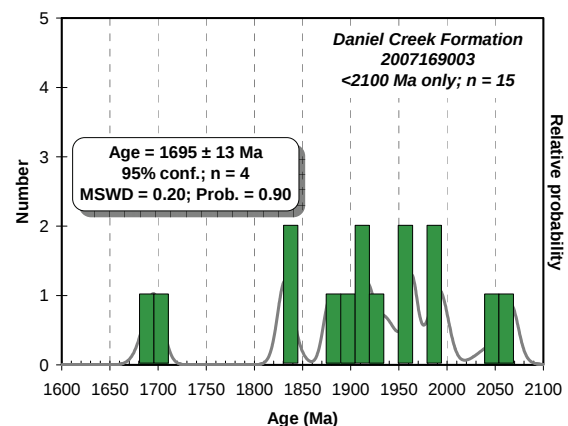
Eighty-seven provenance analyses and two repeat-spot analyses (C.3 and C.4) were undertaken on this sample, the results of which are presented in Table 2.1 and illustrated in Figures 2.3 and 2.4. U concentrations of the analysed zircons range between 1668 and 37 ppm, with Th/U ratios between 1.96 and 0.00.

Three analyses >10% discordant and 3 analyses with common  $^{206}\text{Pb}_c$  contents greater than an arbitrary value of 0.5% were excluded from further consideration. For grains C.3 and C.4, the weighted mean age of both analyses calculated for each grain was used in the provenance spectra. The 81 ages range between ~3503 Ma and ~1686 Ma (Figure 2.3).



**Figure 2.3.** Probability density diagram of zircon analyses from the Daniel Creek Formation (2007169003).

There are a large number of ages between ~3500 Ma and ~2300 Ma, with ~73% of the ages for this sample occurring within this age range. This range includes large clusters at ~2720 Ma, ~2595 Ma and at ~2495 Ma. There are a small number of younger ages that range between ~2200 Ma and ~1800 Ma.



**Figure 2.4.** Probability density diagram of zircon analyses from the Daniel Creek Formation (2007169003) yielding  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of less than 2100 Ma.

The youngest two individual ages are separate from the next youngest ages, and both grains were analysed twice. The resulting weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age for these analyses is  $1695 \pm 13$  Ma (95% confidence;  $n = 4$ ; MSWD = 0.20; probability of fit = 0.90; [Figure 2.4](#)).

#### **Geochronological Interpretation**

The weighted mean age of  $1695 \pm 13$  Ma (95% confidence;  $n = 4$ ) can be used to define a maximum depositional age from this sample from the Daniel Creek Formation.

**Table 2.1.** SHRIMP U-Pb isotopic data for zircons from sample 2007169003 (1937152), Daniel Creek Formation, Percy River.

| Grain.area                                                     | $^{206}\text{Pb}_c$<br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | $^{232}\text{Th}/$<br>$^{238}\text{U}$ | $^{238}\text{U}/$<br>$^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/$<br>$^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/^{206}\text{Pb}$<br>Age (Ma) | $\pm 1\sigma$<br>(Ma) | Disc<br>(%) |
|----------------------------------------------------------------|-----------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|----------------------|-----------------------------------------|----------------------|-----------------------------------------------|-----------------------|-------------|
| <i>Detrital zircon excluding repeat grain analyses (n= 79)</i> |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| C.17.1.1                                                       | 0.05                                    | 88         | 41          | 0.49                                   | 1.3717                                 | 2.1                  | 0.3065                                  | 0.5                  | 3503                                          | 7                     | -1          |
| C.34.1.1                                                       | 0.08                                    | 464        | 266         | 0.59                                   | 1.7425                                 | 1.4                  | 0.2480                                  | 0.2                  | 3172                                          | 3                     | 8           |
| C.28.1.1                                                       | 0.12                                    | 79         | 31          | 0.41                                   | 1.7587                                 | 1.5                  | 0.2225                                  | 0.6                  | 2999                                          | 10                    | 3           |
| C.39.1.1                                                       | 0.03                                    | 531        | 49          | 0.10                                   | 1.8684                                 | 1.2                  | 0.2173                                  | 0.2                  | 2961                                          | 3                     | 7           |
| C.33.1.1                                                       | 0.05                                    | 107        | 63          | 0.61                                   | 1.8124                                 | 1.4                  | 0.2114                                  | 0.5                  | 2917                                          | 7                     | 3           |
| C.58.1.1                                                       | 0.34                                    | 246        | 203         | 0.85                                   | 2.0654                                 | 1.0                  | 0.1972                                  | 0.4                  | 2803                                          | 7                     | 9           |
| C.73.1.1                                                       | 0.01                                    | 382        | 133         | 0.36                                   | 1.9319                                 | 0.9                  | 0.1895                                  | 0.3                  | 2738                                          | 4                     | 2           |
| C.13.1.1                                                       | 0.03                                    | 162        | 173         | 1.10                                   | 1.8672                                 | 1.4                  | 0.1881                                  | 0.5                  | 2726                                          | 8                     | -1          |
| C.29.1.1                                                       | 0.04                                    | 230        | 72          | 0.32                                   | 1.8723                                 | 1.3                  | 0.1881                                  | 0.3                  | 2725                                          | 6                     | -1          |
| C.62.1.1                                                       | 0.06                                    | 244        | 160         | 0.68                                   | 1.9386                                 | 1.0                  | 0.1879                                  | 0.3                  | 2724                                          | 6                     | 2           |
| C.79.1.1                                                       | 0.03                                    | 224        | 73          | 0.34                                   | 1.9403                                 | 1.0                  | 0.1878                                  | 0.4                  | 2723                                          | 6                     | 2           |
| C.15.1.1                                                       | 0.04                                    | 233        | 191         | 0.85                                   | 1.9581                                 | 1.3                  | 0.1872                                  | 0.4                  | 2718                                          | 7                     | 2           |
| C.56.1.1                                                       | 0.03                                    | 110        | 208         | 1.96                                   | 1.9739                                 | 1.1                  | 0.1866                                  | 0.5                  | 2713                                          | 9                     | 3           |
| C.31.1.1                                                       | 0.03                                    | 193        | 64          | 0.34                                   | 1.8866                                 | 1.4                  | 0.1866                                  | 0.4                  | 2712                                          | 6                     | -1          |
| C.52.1.1                                                       | 0.04                                    | 271        | 216         | 0.82                                   | 1.9419                                 | 1.0                  | 0.1865                                  | 0.3                  | 2711                                          | 6                     | 1           |
| C.21.1.1                                                       | 0.19                                    | 244        | 262         | 1.11                                   | 2.1039                                 | 1.3                  | 0.1857                                  | 0.4                  | 2704                                          | 7                     | 7           |
| C.20.1.1                                                       | 0.04                                    | 285        | 179         | 0.65                                   | 2.0080                                 | 1.3                  | 0.1854                                  | 0.3                  | 2702                                          | 6                     | 4           |
| C.10.1.1                                                       | 0.05                                    | 450        | 277         | 0.64                                   | 2.0846                                 | 1.2                  | 0.1850                                  | 0.3                  | 2698                                          | 4                     | 6           |
| C.82.1.1                                                       | 0.06                                    | 347        | 177         | 0.53                                   | 2.0052                                 | 1.0                  | 0.1844                                  | 1.3                  | 2693                                          | 22                    | 3           |
| C.81.1.1                                                       | 0.01                                    | 193        | 159         | 0.85                                   | 1.9233                                 | 1.0                  | 0.1842                                  | 0.5                  | 2691                                          | 9                     | 0           |
| C.80.1.1                                                       | 0.04                                    | 203        | 59          | 0.30                                   | 1.9894                                 | 1.6                  | 0.1821                                  | 0.7                  | 2672                                          | 12                    | 2           |
| C.2.1.1                                                        | 0.09                                    | 253        | 221         | 0.90                                   | 2.0865                                 | 1.3                  | 0.1812                                  | 0.4                  | 2664                                          | 6                     | 5           |
| C.60.1.1                                                       | 0.19                                    | 98         | 59          | 0.62                                   | 1.9988                                 | 1.2                  | 0.1809                                  | 0.6                  | 2661                                          | 10                    | 2           |
| C.5.1.1                                                        | -0.01                                   | 218        | 76          | 0.36                                   | 2.0660                                 | 1.5                  | 0.1787                                  | 0.8                  | 2641                                          | 13                    | 4           |
| C.53.1.1                                                       | 0.02                                    | 430        | 674         | 1.62                                   | 1.9891                                 | 0.9                  | 0.1773                                  | 0.3                  | 2628                                          | 5                     | 0           |
| C.36.1.1                                                       | 0.04                                    | 322        | 167         | 0.54                                   | 2.0233                                 | 1.3                  | 0.1759                                  | 0.3                  | 2614                                          | 5                     | 1           |
| C.8.1.1                                                        | 0.08                                    | 170        | 133         | 0.81                                   | 2.1100                                 | 1.4                  | 0.1758                                  | 0.7                  | 2613                                          | 11                    | 4           |
| C.69.1.1                                                       | 0.04                                    | 269        | 135         | 0.52                                   | 2.0361                                 | 1.0                  | 0.1754                                  | 0.3                  | 2610                                          | 6                     | 1           |
| C.54.1.1                                                       | 0.07                                    | 299        | 200         | 0.69                                   | 2.0448                                 | 1.0                  | 0.1747                                  | 0.4                  | 2604                                          | 6                     | 1           |
| C.66.1.1                                                       | 0.10                                    | 126        | 149         | 1.22                                   | 2.0318                                 | 1.1                  | 0.1745                                  | 0.5                  | 2601                                          | 9                     | 1           |
| C.44.1.1                                                       | 0.05                                    | 210        | 231         | 1.13                                   | 2.0595                                 | 1.6                  | 0.1742                                  | 0.4                  | 2599                                          | 6                     | 2           |
| C.30.1.1                                                       | 0.04                                    | 390        | 219         | 0.58                                   | 1.9966                                 | 1.2                  | 0.1736                                  | 0.3                  | 2593                                          | 5                     | -1          |
| C.48.1.1                                                       | 0.04                                    | 281        | 157         | 0.58                                   | 2.0576                                 | 1.4                  | 0.1735                                  | 0.3                  | 2592                                          | 6                     | 1           |
| C.46.1.1                                                       | 0.07                                    | 470        | 181         | 0.40                                   | 2.1918                                 | 1.2                  | 0.1733                                  | 0.2                  | 2589                                          | 4                     | 6           |
| C.61.1.1                                                       | 0.05                                    | 467        | 323         | 0.71                                   | 2.1703                                 | 1.0                  | 0.1717                                  | 0.3                  | 2574                                          | 5                     | 5           |
| C.40.1.1                                                       | 0.13                                    | 37         | 53          | 1.47                                   | 2.1690                                 | 1.7                  | 0.1699                                  | 1.6                  | 2557                                          | 26                    | 4           |
| C.86.1.1                                                       | 0.01                                    | 508        | 222         | 0.45                                   | 2.0943                                 | 0.9                  | 0.1682                                  | 0.3                  | 2540                                          | 4                     | 1           |
| C.59.1.1                                                       | 0.02                                    | 593        | 92          | 0.16                                   | 2.1606                                 | 1.0                  | 0.1671                                  | 0.2                  | 2529                                          | 4                     | 3           |
| C.1.1.1                                                        | 0.03                                    | 447        | 314         | 0.73                                   | 2.1539                                 | 1.3                  | 0.1664                                  | 0.3                  | 2521                                          | 5                     | 2           |
| C.24.1.1                                                       | 0.04                                    | 305        | 206         | 0.70                                   | 2.1960                                 | 1.3                  | 0.1658                                  | 0.4                  | 2516                                          | 6                     | 4           |
| C.49.1.1                                                       | 0.15                                    | 120        | 99          | 0.85                                   | 2.1668                                 | 1.4                  | 0.1645                                  | 0.6                  | 2503                                          | 10                    | 2           |
| C.35.1.1                                                       | 0.02                                    | 352        | 167         | 0.49                                   | 2.1810                                 | 1.2                  | 0.1642                                  | 0.3                  | 2500                                          | 5                     | 3           |
| C.70.1.1                                                       | 0.03                                    | 625        | 118         | 0.19                                   | 2.2416                                 | 0.9                  | 0.1639                                  | 0.2                  | 2496                                          | 4                     | 5           |
| C.74.1.1                                                       | 0.03                                    | 539        | 415         | 0.80                                   | 2.1858                                 | 0.9                  | 0.1638                                  | 0.3                  | 2496                                          | 4                     | 3           |
| C.84.1.1                                                       | 0.04                                    | 473        | 264         | 0.58                                   | 2.1174                                 | 1.0                  | 0.1633                                  | 0.3                  | 2490                                          | 5                     | 0           |
| C.50.1.1                                                       | 0.02                                    | 546        | 229         | 0.43                                   | 2.1157                                 | 0.9                  | 0.1630                                  | 0.3                  | 2487                                          | 4                     | 0           |
| C.18.1.1                                                       | 0.05                                    | 343        | 251         | 0.76                                   | 2.1207                                 | 1.3                  | 0.1627                                  | 0.4                  | 2484                                          | 6                     | 0           |
| C.45.1.1                                                       | 0.19                                    | 317        | 125         | 0.41                                   | 2.2191                                 | 1.2                  | 0.1622                                  | 0.4                  | 2478                                          | 6                     | 3           |
| C.47.1.1                                                       | 0.03                                    | 333        | 254         | 0.79                                   | 2.1596                                 | 1.2                  | 0.1617                                  | 0.3                  | 2473                                          | 5                     | 1           |
| C.26.1.1                                                       | 0.13                                    | 96         | 40          | 0.43                                   | 2.2583                                 | 1.4                  | 0.1599                                  | 0.7                  | 2455                                          | 11                    | 4           |
| C.83.1.1                                                       | 0.05                                    | 268        | 134         | 0.52                                   | 2.2201                                 | 1.2                  | 0.1578                                  | 0.4                  | 2432                                          | 7                     | 1           |
| C.87.1.1                                                       | 0.01                                    | 674        | 239         | 0.37                                   | 2.2491                                 | 0.9                  | 0.1558                                  | 0.2                  | 2411                                          | 4                     | 2           |
| C.65.1.1                                                       | 0.05                                    | 312        | 161         | 0.53                                   | 2.2194                                 | 1.0                  | 0.1554                                  | 0.4                  | 2407                                          | 6                     | 0           |
| C.43.1.1                                                       | 0.04                                    | 256        | 142         | 0.57                                   | 2.2354                                 | 1.3                  | 0.1542                                  | 0.4                  | 2393                                          | 6                     | 0           |
| C.25.1.1                                                       | 0.04                                    | 1668       | 7           | 0.00                                   | 2.4047                                 | 1.9                  | 0.1513                                  | 1.4                  | 2361                                          | 24                    | 5           |
| C.71.1.1                                                       | 0.02                                    | 582        | 254         | 0.45                                   | 2.3801                                 | 0.9                  | 0.1509                                  | 0.3                  | 2356                                          | 4                     | 4           |
| C.22.1.1                                                       | 0.01                                    | 487        | 254         | 0.54                                   | 2.3152                                 | 1.2                  | 0.1504                                  | 0.3                  | 2351                                          | 5                     | 2           |
| C.6.1.1                                                        | 0.04                                    | 252        | 201         | 0.82                                   | 2.3487                                 | 1.3                  | 0.1484                                  | 0.4                  | 2327                                          | 7                     | 2           |
| C.9.1.1                                                        | 0.11                                    | 84         | 53          | 0.65                                   | 2.5047                                 | 1.5                  | 0.1483                                  | 0.8                  | 2326                                          | 14                    | 7           |
| C.23.1.1                                                       | 0.03                                    | 531        | 195         | 0.38                                   | 2.3128                                 | 1.2                  | 0.1477                                  | 0.3                  | 2319                                          | 5                     | 0           |
| C.55.1.1                                                       | 0.06                                    | 195        | 73          | 0.39                                   | 2.3769                                 | 1.1                  | 0.1473                                  | 0.5                  | 2315                                          | 8                     | 2           |
| C.14.1.1                                                       | 0.31                                    | 151        | 74          | 0.51                                   | 2.3652                                 | 1.4                  | 0.1460                                  | 0.7                  | 2300                                          | 12                    | 1           |
| C.19.1.1                                                       | 0.07                                    | 194        | 143         | 0.76                                   | 2.3437                                 | 1.3                  | 0.1459                                  | 0.5                  | 2298                                          | 9                     | 0           |
| C.16.1.1                                                       | 0.02                                    | 287        | 118         | 0.43                                   | 2.5714                                 | 1.3                  | 0.1398                                  | 0.4                  | 2224                                          | 7                     | 5           |

SHRIMP geochronology of north Queensland: 2007-2010

| Grain.area                                                             | $^{206}\text{Pb}_c$<br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | $^{232}\text{Th}/$<br>$^{238}\text{U}$ | $^{238}\text{U}/$<br>$^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/$<br>$^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/^{206}\text{Pb}$<br>Age (Ma) | $\pm 1\sigma$<br>(Ma) | Disc<br>(%) |
|------------------------------------------------------------------------|-----------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|----------------------|-----------------------------------------|----------------------|-----------------------------------------------|-----------------------|-------------|
| C.63.1.1                                                               | 0.13                                    | 408        | 366         | 0.93                                   | 2.6463                                 | 0.9                  | 0.1365                                  | 0.4                  | 2184                                          | 6                     | 5           |
| C.37.1.1                                                               | 0.05                                    | 181        | 127         | 0.72                                   | 2.6328                                 | 1.4                  | 0.1336                                  | 0.5                  | 2145                                          | 9                     | 3           |
| C.72.1.1                                                               | 0.05                                    | 281        | 72          | 0.27                                   | 2.7619                                 | 1.1                  | 0.1277                                  | 0.4                  | 2066                                          | 8                     | 4           |
| C.77.1.1                                                               | 0.16                                    | 94         | 103         | 1.13                                   | 2.7596                                 | 1.2                  | 0.1266                                  | 1.0                  | 2051                                          | 17                    | 3           |
| C.11.1.1                                                               | 0.04                                    | 278        | 145         | 0.54                                   | 3.0080                                 | 1.3                  | 0.1226                                  | 0.5                  | 1994                                          | 9                     | 7           |
| C.7.1.1                                                                | 0.08                                    | 204        | 156         | 0.79                                   | 2.7803                                 | 1.3                  | 0.1222                                  | 0.6                  | 1988                                          | 10                    | 0           |
| C.32.1.1                                                               | 0.07                                    | 613        | 316         | 0.53                                   | 2.8962                                 | 1.2                  | 0.1205                                  | 0.3                  | 1963                                          | 6                     | 3           |
| C.68.1.1                                                               | 0.24                                    | 131        | 86          | 0.68                                   | 2.8991                                 | 1.1                  | 0.1202                                  | 0.8                  | 1960                                          | 15                    | 3           |
| C.57.1.1                                                               | 0.06                                    | 238        | 239         | 1.04                                   | 2.9102                                 | 1.0                  | 0.1185                                  | 0.5                  | 1934                                          | 10                    | 2           |
| C.38.1.1                                                               | 0.06                                    | 396        | 52          | 0.14                                   | 3.0742                                 | 1.2                  | 0.1174                                  | 0.4                  | 1916                                          | 7                     | 5           |
| C.27.1.1                                                               | 0.18                                    | 132        | 58          | 0.45                                   | 2.9311                                 | 1.4                  | 0.1169                                  | 0.8                  | 1909                                          | 14                    | 1           |
| C.85.1.1                                                               | 0.05                                    | 228        | 86          | 0.39                                   | 2.9877                                 | 1.0                  | 0.1159                                  | 0.6                  | 1894                                          | 10                    | 2           |
| C.51.1.1                                                               | 0.00                                    | 449        | 228         | 0.52                                   | 3.0220                                 | 0.9                  | 0.1149                                  | 0.4                  | 1878                                          | 7                     | 2           |
| C.78.1.1                                                               | 0.03                                    | 232        | 131         | 0.59                                   | 3.2080                                 | 1.0                  | 0.1122                                  | 0.6                  | 1835                                          | 10                    | 5           |
| C.64.1.1                                                               | 0.06                                    | 507        | 140         | 0.28                                   | 3.0892                                 | 1.0                  | 0.1119                                  | 0.4                  | 1831                                          | 7                     | 1           |
| <i>Repeat grain analyses (n = 4)</i>                                   |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| C.3.1.1                                                                | 0.09                                    | 151        | 157         | 1.07                                   | 3.3612                                 | 1.4                  | 0.1034                                  | 0.7                  | 1686                                          | 14                    | 0           |
| C.3.1.2                                                                | 0.26                                    | 158        | 176         | 1.15                                   | 3.4345                                 | 1.6                  | 0.1043                                  | 1.1                  | 1703                                          | 20                    | 3           |
| C.4.1.1                                                                | 0.05                                    | 278        | 153         | 0.57                                   | 3.3937                                 | 1.4                  | 0.1041                                  | 0.6                  | 1698                                          | 10                    | 2           |
| C.4.1.2                                                                | 0.20                                    | 296        | 161         | 0.56                                   | 3.4751                                 | 1.3                  | 0.1039                                  | 0.8                  | 1694                                          | 15                    | 4           |
| <i>Analyses with <math>^{206}\text{Pb}_c &gt; 0.5\%</math> (n = 3)</i> |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| C.67.1.1                                                               | 23.42                                   | 578        | 367         | 0.66                                   | 1.1042                                 | 20.1                 | 0.3004                                  | 49.5                 | 3472                                          | 766                   | -20         |
| C.75.1.1                                                               | 0.59                                    | 455        | 195         | 0.44                                   | 2.0273                                 | 2.6                  | 0.1886                                  | 0.5                  | 2730                                          | 9                     | 5           |
| C.41.1.1                                                               | 0.58                                    | 148        | 269         | 1.88                                   | 2.0386                                 | 1.3                  | 0.1857                                  | 0.8                  | 2704                                          | 13                    | 5           |
| <i>Analyses &gt;10% discordant (n = 3)</i>                             |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| C.42.1.1                                                               | 0.03                                    | 829        | 45          | 0.06                                   | 2.4373                                 | 1.2                  | 0.1730                                  | 0.2                  | 2587                                          | 3                     | 14          |
| C.12.1.1                                                               | 0.28                                    | 55         | 72          | 1.33                                   | 3.4887                                 | 1.8                  | 0.1133                                  | 1.4                  | 1853                                          | 26                    | 12          |
| C.76.1.1                                                               | 0.34                                    | 221        | 203         | 0.95                                   | 2.4748                                 | 1.3                  | 0.1606                                  | 0.7                  | 2462                                          | 12                    | 11          |

1.  $^{206}\text{Pb}_c$  indicates common  $^{206}\text{Pb}$  as a percentage of the total measured  $^{206}\text{Pb}$ .

## 3. CORBETT FORMATION, PERCY RIVER: 2007169004

|                                                |                                                                         |
|------------------------------------------------|-------------------------------------------------------------------------|
| GA Sample ID:                                  | 2007169004                                                              |
| GA Sample Number:                              | 1937153                                                                 |
| Other Sample ID:                               |                                                                         |
| 1:250,000 Sheet:                               | GILBERTON SE5416                                                        |
| Region:                                        | Etheridge Province, Queensland                                          |
| Grid Reference (WGS 84):                       | 761665mE 7880614mN Zone 54                                              |
| Collector:                                     | N. Neumann, G. Gibson, I. Withnall, L. Lambeck,<br>D. Huston            |
| Collection Date:                               | 24/7/2007                                                               |
| Formal Name:                                   | Corbett Formation                                                       |
| Informal Name:                                 |                                                                         |
| Lithology:                                     | Calcareous coarse- to fine-grained sandstone                            |
| Geochronologist:                               | N.L. Neumann                                                            |
| Mount ID:                                      | GA6038                                                                  |
| Instrument:                                    | SHRIMP IIe Geoscience Australia                                         |
| Acquisition Date:                              | 17–19/3/2008                                                            |
| U-Pb Standard & reproducibility:               | TEMORA-2; 2.73% (2 $\sigma$ ) [20 of 20]                                |
| <sup>207</sup> Pb/ <sup>206</sup> Pb Standard: | OG1 (3465.4 $\pm$ 0.6 Ma)                                               |
| Measured Value ( $\pm$ 95% confidence):        | 3465.8 $\pm$ 4.0 Ma [9 of 9]                                            |
| Geochronologist:                               | N.L. Neumann                                                            |
| Mount ID:                                      | GA6038                                                                  |
| Instrument:                                    | SHRIMP IIe Geoscience Australia                                         |
| Acquisition Date:                              | 25–27/3/2008                                                            |
| U-Pb Standard & reproducibility:               | TEMORA-2; 1.68% (2 $\sigma$ ) [26 of 26], 2.42%(2 $\sigma$ ) [12 of 16] |
| <sup>207</sup> Pb/ <sup>206</sup> Pb Standard: | OG1 (3465.4 $\pm$ 0.6 Ma)                                               |
| Measured Value ( $\pm$ 95% confidence):        | 3466.2 $\pm$ 2.7 Ma [11 of 11], 3465.6 $\pm$ 5.9 Ma [3 of 3]            |
| Interpreted Age:                               | 1791 $\pm$ 10 Ma                                                        |
| IMF correction applied?                        | No                                                                      |
| Interpreted Age Type:                          | Maximum deposition age                                                  |

**Sample Description**

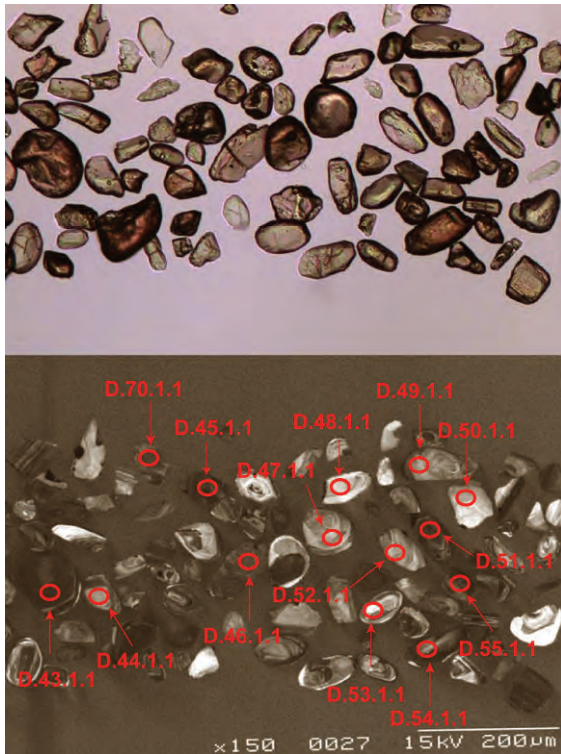
The Corbett Formation (Figure iii) was sampled from the Percy River, north-northwest of Ortona Station, in the Etheridge Province, Queensland. The sample was located a few hundred metres above the Dead Horse Metabasalt (Figure iii), from a package containing occasional thick beds associated with fine-grained, thinly-bedded, laminated siltstones. The sample was collected from one of the thick beds, and is a calcareous fine- to coarse-grained sandstone (Figure 3.1).

**Figure 3.1 (right).** Outcrop photo of Corbett Formation at the site of sample 2007169004, Percy River, Ortona Anticline, Etheridge Province.



### Zircon Description

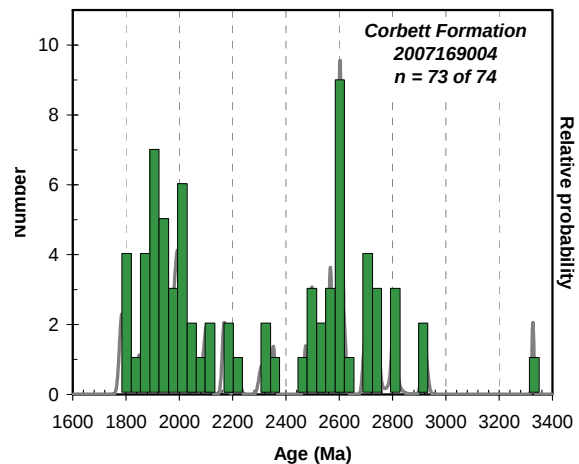
Zircons from this sample range in length from ~50  $\mu\text{m}$  to ~90  $\mu\text{m}$ , with occasional larger grains up to ~120  $\mu\text{m}$  in length (Figure 3.2). Some grains have a subrounded morphology, with other grains preserving some prismatic edges. Most grains are clear and colourless to brown. In cathodoluminescence images, some grains record oscillatory zoning whereas others record either a dark or bright cathodoluminescence response. As this sample was analysed to determine a maximum depositional age, analyses were located on central zones of grains away from any rims which may record later metamorphism.



**Figure 3.2.** Representative transmitted light and cathodoluminescence images of zircons from the Corbett Formation (2007169004), with locations of some SHRIMP analyses.

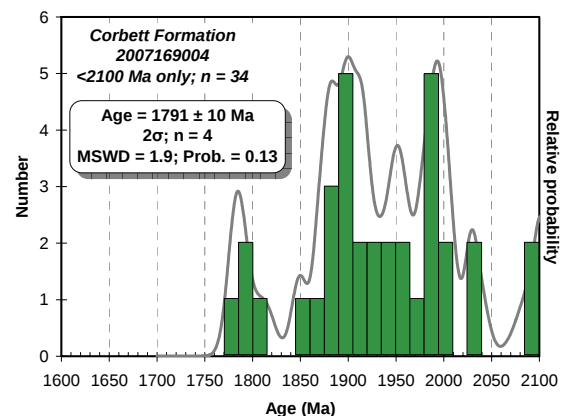
### U-Pb Isotopic Results

Seventy-four analyses were undertaken on this sample, the results of which are presented in Table 3.1 and illustrated in Figures 3.3 and 3.4. U concentrations of the analysed zircons range between 514 and 41 ppm, with Th/U ratios between 1.33 and 0.03. One analysis containing a high common  $^{206}\text{Pb}_c$  content was excluded from further consideration.



**Figure 3.3.** Probability density diagram of zircon analyses from the Corbett Formation (2007169004).

The remaining 73 analyses yield ages between ~3326 Ma and ~1782 Ma (Figure 3.3), and includes a range of ages between ~3326 Ma and ~2400 Ma, with a dominant cluster at ~2600 Ma. There is also a range of ages between ~2300 Ma and ~1850 Ma, with four ages younger than this range. These four individuals are statistically separate from the next youngest age, and their weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age is  $1791 \pm 10$  Ma ( $2\sigma$ ; MSWD = 1.9; probability of fit = 0.13; Figure 3.4).



**Figure 3.4.** Probability density diagram of zircon analyses from the Corbett Formation (2007169004) yielding  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of less than 2100 Ma.

### Geochronological Interpretation

The weighted mean age of  $1791 \pm 10$  Ma ( $2\sigma$ ;  $n = 4$ ) can be used to define a maximum depositional age for this sample of the Corbett Formation.

**Table 3.1.** SHRIMP U-Pb isotopic data for zircons from sample 2007169004 (1937153), Corbett Formation, Percy River.

| Grain.area                      | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|---------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| <i>Detrital zircon (n = 73)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| D.43.1.1                        | 0.03                                               | 306        | 110         | 0.37                                   | 1.4791                                 | 1.3         | 0.2735                                  | 0.2         | 3326                                             | 4            | 0           |
| D.57.1.1                        | 0.09                                               | 86         | 41          | 0.50                                   | 1.8280                                 | 1.4         | 0.2125                                  | 0.5         | 2924                                             | 9            | 4           |
| D.29.1.1                        | 0.02                                               | 102        | 32          | 0.32                                   | 1.8055                                 | 1.1         | 0.2112                                  | 0.5         | 2914                                             | 8            | 3           |
| D.69.1.1                        | 0.06                                               | 84         | 60          | 0.73                                   | 1.8189                                 | 1.5         | 0.1976                                  | 0.6         | 2807                                             | 9            | -1          |
| D.3.1.1                         | 0.08                                               | 169        | 50          | 0.31                                   | 1.9487                                 | 1.5         | 0.1973                                  | 0.4         | 2804                                             | 7            | 5           |
| D.16.1.1                        | 0.03                                               | 362        | 156         | 0.45                                   | 2.0060                                 | 1.4         | 0.1972                                  | 1.4         | 2803                                             | 22           | 7           |
| D.5.1.1                         | 0.05                                               | 128        | 114         | 0.92                                   | 1.9071                                 | 1.5         | 0.1902                                  | 0.4         | 2744                                             | 6            | 1           |
| D.74.1.1                        | 0.13                                               | 53         | 20          | 0.39                                   | 1.8952                                 | 1.6         | 0.1900                                  | 0.8         | 2742                                             | 13           | 0           |
| D.68.1.1                        | 0.00                                               | 118        | 118         | 1.04                                   | 1.8610                                 | 1.4         | 0.1884                                  | 0.6         | 2728                                             | 10           | -2          |
| D.23.1.1                        | 0.05                                               | 308        | 307         | 1.03                                   | 1.9761                                 | 1.0         | 0.1871                                  | 0.3         | 2717                                             | 5            | 3           |
| D.48.1.1                        | 0.10                                               | 81         | 44          | 0.56                                   | 1.8827                                 | 1.5         | 0.1866                                  | 0.6         | 2713                                             | 11           | -1          |
| D.8.1.1                         | 0.02                                               | 190        | 163         | 0.89                                   | 1.9583                                 | 1.5         | 0.1858                                  | 0.3         | 2705                                             | 5            | 2           |
| D.64.1.1                        | 0.00                                               | 161        | 129         | 0.83                                   | 1.9170                                 | 1.3         | 0.1845                                  | 0.4         | 2694                                             | 7            | 0           |
| D.39.1.1                        | 0.01                                               | 514        | 100         | 0.20                                   | 2.0243                                 | 1.3         | 0.1765                                  | 0.4         | 2621                                             | 6            | 1           |
| D.67.1.1                        | 0.04                                               | 147        | 188         | 1.32                                   | 2.0378                                 | 1.4         | 0.1755                                  | 0.5         | 2611                                             | 8            | 1           |
| D.7.1.1                         | -0.01                                              | 268        | 134         | 0.52                                   | 2.0326                                 | 1.4         | 0.1752                                  | 0.3         | 2608                                             | 5            | 1           |
| D.30.1.1                        | 0.05                                               | 407        | 139         | 0.35                                   | 2.1091                                 | 0.9         | 0.1752                                  | 0.3         | 2608                                             | 5            | 4           |
| D.54.1.1                        | 0.07                                               | 124        | 78          | 0.65                                   | 2.0491                                 | 1.4         | 0.1747                                  | 0.5         | 2604                                             | 8            | 2           |
| D.9.1.1                         | 0.02                                               | 161        | 72          | 0.46                                   | 2.0763                                 | 1.5         | 0.1747                                  | 0.4         | 2603                                             | 6            | 3           |
| D.11.1.1                        | 0.03                                               | 309        | 180         | 0.60                                   | 2.0726                                 | 1.4         | 0.1746                                  | 0.3         | 2602                                             | 4            | 2           |
| D.45.1.1                        | 0.01                                               | 318        | 137         | 0.45                                   | 2.0216                                 | 1.3         | 0.1745                                  | 0.3         | 2602                                             | 5            | 0           |
| D.22.1.1                        | 0.02                                               | 501        | 167         | 0.34                                   | 2.0284                                 | 0.9         | 0.1743                                  | 0.2         | 2599                                             | 4            | 1           |
| D.46.1.1                        | 0.03                                               | 216        | 92          | 0.44                                   | 2.0343                                 | 1.3         | 0.1740                                  | 0.4         | 2596                                             | 6            | 1           |
| D.41.1.1                        | 0.05                                               | 191        | 112         | 0.61                                   | 2.0362                                 | 1.4         | 0.1710                                  | 0.4         | 2568                                             | 7            | 0           |
| D.6.1.1                         | 0.00                                               | 305        | 36          | 0.12                                   | 2.1298                                 | 1.4         | 0.1709                                  | 0.3         | 2566                                             | 4            | 3           |
| D.52.1.1                        | 0.16                                               | 86         | 49          | 0.59                                   | 2.0916                                 | 1.4         | 0.1708                                  | 0.6         | 2566                                             | 10           | 2           |
| D.18.1.1                        | 0.21                                               | 55         | 66          | 1.24                                   | 2.1381                                 | 1.3         | 0.1677                                  | 0.7         | 2535                                             | 12           | 2           |
| D.4.1.1                         | 0.06                                               | 167        | 150         | 0.93                                   | 2.1189                                 | 1.5         | 0.1677                                  | 0.5         | 2534                                             | 8            | 2           |
| D.32.1.1                        | 0.17                                               | 81         | 43          | 0.55                                   | 2.0553                                 | 1.5         | 0.1647                                  | 0.7         | 2504                                             | 12           | -2          |
| D.13.1.1                        | 0.01                                               | 356        | 144         | 0.42                                   | 2.2177                                 | 1.4         | 0.1640                                  | 0.3         | 2497                                             | 4            | 4           |
| D.37.1.1                        | 0.05                                               | 132        | 67          | 0.52                                   | 2.1360                                 | 1.4         | 0.1637                                  | 0.5         | 2495                                             | 9            | 1           |
| D.70.1.1                        | 0.05                                               | 320        | 164         | 0.53                                   | 2.1011                                 | 1.3         | 0.1617                                  | 0.3         | 2474                                             | 6            | -1          |
| D.10.1.1                        | 0.03                                               | 250        | 160         | 0.66                                   | 2.3637                                 | 1.4         | 0.1506                                  | 0.3         | 2353                                             | 6            | 3           |
| D.2.1.1                         | 0.03                                               | 188        | 91          | 0.50                                   | 2.3889                                 | 1.6         | 0.1486                                  | 0.5         | 2330                                             | 9            | 3           |
| D.38.1.1                        | 0.12                                               | 129        | 54          | 0.43                                   | 2.3756                                 | 1.4         | 0.1467                                  | 0.6         | 2308                                             | 10           | 2           |
| D.62.1.1                        | 0.05                                               | 185        | 169         | 0.95                                   | 2.5047                                 | 1.3         | 0.1392                                  | 0.5         | 2217                                             | 9            | 2           |
| D.35.1.1                        | 0.05                                               | 190        | 80          | 0.44                                   | 2.4948                                 | 1.6         | 0.1354                                  | 0.5         | 2169                                             | 9            | 0           |
| D.14.1.1                        | -0.02                                              | 236        | 125         | 0.55                                   | 2.4770                                 | 1.6         | 0.1353                                  | 0.4         | 2167                                             | 6            | -1          |
| D.36.1.1                        | 0.03                                               | 316        | 81          | 0.26                                   | 2.5984                                 | 1.3         | 0.1303                                  | 0.4         | 2103                                             | 7            | 0           |
| D.34.1.1                        | 0.08                                               | 118        | 59          | 0.52                                   | 2.6760                                 | 1.4         | 0.1300                                  | 0.7         | 2098                                             | 13           | 2           |
| D.1.1.1                         | 0.04                                               | 90         | 49          | 0.56                                   | 2.6857                                 | 1.6         | 0.1292                                  | 0.8         | 2086                                             | 14           | 2           |
| D.28.1.1                        | 0.08                                               | 238        | 251         | 1.09                                   | 2.7484                                 | 1.0         | 0.1256                                  | 0.5         | 2038                                             | 9            | 2           |
| D.25.1.1                        | 0.05                                               | 402        | 11          | 0.03                                   | 2.7534                                 | 0.9         | 0.1250                                  | 0.4         | 2028                                             | 7            | 2           |
| D.65.1.1                        | 0.15                                               | 265        | 119         | 0.46                                   | 2.8867                                 | 1.3         | 0.1233                                  | 0.5         | 2005                                             | 9            | 4           |
| D.42.1.1                        | 0.05                                               | 270        | 103         | 0.39                                   | 2.7514                                 | 1.3         | 0.1231                                  | 0.5         | 2002                                             | 8            | 0           |
| D.27.1.1                        | 0.04                                               | 351        | 416         | 1.23                                   | 2.8106                                 | 0.9         | 0.1225                                  | 0.4         | 1993                                             | 7            | 2           |
| D.47.1.1                        | 0.07                                               | 121        | 32          | 0.28                                   | 2.7954                                 | 1.4         | 0.1225                                  | 0.8         | 1992                                             | 13           | 1           |
| D.53.1.1                        | 0.30                                               | 72         | 67          | 0.96                                   | 2.7769                                 | 1.5         | 0.1224                                  | 1.1         | 1992                                             | 20           | 0           |
| D.73.1.1                        | 0.06                                               | 301        | 261         | 0.89                                   | 2.7311                                 | 1.3         | 0.1223                                  | 0.5         | 1990                                             | 8            | -1          |
| D.58.1.1                        | 0.08                                               | 314        | 124         | 0.41                                   | 2.8344                                 | 1.3         | 0.1216                                  | 0.4         | 1980                                             | 8            | 2           |
| D.72.1.1                        | 0.08                                               | 213        | 151         | 0.73                                   | 2.7816                                 | 1.5         | 0.1212                                  | 0.6         | 1975                                             | 10           | 0           |
| D.17.1.1                        | 0.04                                               | 346        | 32          | 0.09                                   | 2.9057                                 | 0.9         | 0.1202                                  | 0.4         | 1959                                             | 7            | 3           |
| D.59.1.1                        | 0.03                                               | 357        | 166         | 0.48                                   | 2.8086                                 | 1.3         | 0.1196                                  | 0.4         | 1950                                             | 7            | -1          |
| D.55.1.1                        | 0.08                                               | 232        | 283         | 1.26                                   | 3.1416                                 | 1.3         | 0.1193                                  | 0.6         | 1946                                             | 10           | 8           |
| D.60.1.1                        | 0.13                                               | 77         | 31          | 0.41                                   | 2.9339                                 | 1.5         | 0.1191                                  | 0.9         | 1943                                             | 17           | 3           |
| D.49.1.1                        | 0.11                                               | 126        | 46          | 0.38                                   | 2.9403                                 | 1.7         | 0.1181                                  | 0.7         | 1927                                             | 13           | 2           |
| D.63.1.1                        | 0.14                                               | 145        | 67          | 0.48                                   | 2.9029                                 | 1.4         | 0.1178                                  | 0.7         | 1924                                             | 13           | 1           |
| D.21.1.1                        | 0.05                                               | 460        | 427         | 0.96                                   | 2.9479                                 | 0.9         | 0.1173                                  | 0.4         | 1915                                             | 6            | 2           |
| D.24.1.1                        | 0.13                                               | 141        | 181         | 1.33                                   | 3.1013                                 | 1.0         | 0.1169                                  | 0.6         | 1909                                             | 11           | 6           |
| D.44.1.1                        | 0.20                                               | 82         | 47          | 0.60                                   | 2.9329                                 | 1.5         | 0.1164                                  | 1.0         | 1902                                             | 18           | 1           |
| D.19.1.1                        | 0.05                                               | 269        | 101         | 0.39                                   | 2.9622                                 | 1.0         | 0.1164                                  | 0.5         | 1902                                             | 8            | 1           |
| D.33.1.1                        | 0.11                                               | 353        | 175         | 0.51                                   | 3.1103                                 | 1.3         | 0.1162                                  | 0.5         | 1898                                             | 8            | 5           |
| D.66.1.1                        | 0.05                                               | 109        | 39          | 0.37                                   | 2.8710                                 | 1.4         | 0.1160                                  | 1.0         | 1895                                             | 17           | -2          |
| D.31.1.1                        | 0.07                                               | 264        | 186         | 0.73                                   | 2.9412                                 | 1.0         | 0.1158                                  | 0.5         | 1892                                             | 9            | 0           |

SHRIMP geochronology of north Queensland: 2007-2010

| Grain.area                                                          | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|---------------------------------------------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| D.20.1.1                                                            | 0.04                                               | 429        | 217         | 0.52                                   | 2.9800                                 | 1.1         | 0.1151                                  | 0.4         | 1881                                             | 6            | 1           |
| D.61.1.1                                                            | 0.07                                               | 385        | 172         | 0.46                                   | 3.0091                                 | 1.3         | 0.1150                                  | 0.4         | 1880                                             | 8            | 2           |
| D.50.1.1                                                            | 0.32                                               | 87         | 43          | 0.52                                   | 3.0047                                 | 1.5         | 0.1148                                  | 1.2         | 1877                                             | 21           | 1           |
| D.51.1.1                                                            | 0.06                                               | 453        | 143         | 0.33                                   | 3.0580                                 | 1.3         | 0.1144                                  | 0.4         | 1870                                             | 6            | 2           |
| D.15.1.1                                                            | 0.00                                               | 204        | 85          | 0.43                                   | 3.0745                                 | 1.4         | 0.1130                                  | 0.4         | 1849                                             | 8            | 2           |
| D.56.1.1                                                            | 0.15                                               | 248        | 249         | 1.04                                   | 3.0506                                 | 1.3         | 0.1108                                  | 0.6         | 1812                                             | 10           | -1          |
| D.71.1.1                                                            | 0.07                                               | 249        | 118         | 0.49                                   | 3.0715                                 | 1.3         | 0.1093                                  | 0.6         | 1788                                             | 11           | -2          |
| D.12.1.1                                                            | 0.08                                               | 228        | 106         | 0.48                                   | 3.2019                                 | 1.4         | 0.1092                                  | 0.5         | 1785                                             | 10           | 2           |
| D.40.1.1                                                            | 0.03                                               | 281        | 102         | 0.37                                   | 3.1701                                 | 1.4         | 0.1090                                  | 0.5         | 1782                                             | 9            | 1           |
| <i>Analyses with <sup>206</sup>Pb<sub>c</sub> &gt; 0.5% (n = 1)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| D.26.1.1                                                            | 0.57                                               | 41         | 13          | 0.32                                   | 2.8220                                 | 1.4         | 0.1229                                  | 1.5         | 1998                                             | 27           | 2           |

1. <sup>206</sup>Pb<sub>c</sub> indicates common <sup>206</sup>Pb as a percentage of the total measured <sup>206</sup>Pb.

## 4. TOWNLEY FORMATION, SOUTHWEST OF GREEN HILLS: 2007169005

|                                                |                                                           |
|------------------------------------------------|-----------------------------------------------------------|
| GA Sample ID:                                  | 2007169005                                                |
| GA Sample Number:                              | 1937154                                                   |
| Other Sample ID:                               |                                                           |
| 1:250,000 Sheet:                               | GEORGETOWN SE5412                                         |
| Region:                                        | Etheridge Province, Queensland                            |
| Grid Reference (WGS 84):                       | 727953mE 7945315mN Zone 54                                |
| Collector:                                     | N. Neumann, G. Gibson, I. Withnall, L. Lambeck, D. Huston |
| Collection Date:                               | 25/7/2007                                                 |
| Formal Name:                                   | Townley Formation                                         |
| Informal Name:                                 |                                                           |
| Lithology:                                     | Fine-grained sandstone                                    |
| Geochronologist:                               | N.L. Neumann                                              |
| Mount ID:                                      | GA6038                                                    |
| Instrument:                                    | SHRIMP II Australian National University                  |
| Acquisition Date:                              | 10–14/11/2007                                             |
| U-Pb Standard & reproducibility:               | TEMORA-2; 2.32% (2 $\sigma$ ) [32 of 33]                  |
| <sup>207</sup> Pb/ <sup>206</sup> Pb Standard: | OG1 (3465.4 $\pm$ 0.6 Ma)                                 |
| Measured Value ( $\pm$ 95% confidence):        | 3464.6 $\pm$ 2.7 Ma [16 of 17]                            |
| Interpreted Age:                               | 1650 $\pm$ 6 Ma                                           |
| IMF correction applied?                        | No                                                        |
| Interpreted Age Type:                          | Maximum deposition age                                    |

**Sample Description**

The Townley Formation (Figure iii) was collected southwest of Green Hills, in the Etheridge Province, Queensland. The sample (2007169005) was collected ~400 m below the contact with the overlying Heliman Formation, from a thick bed within a siltstone-sandstone package, and is a fine-grained sandstone (Figure 4.1).

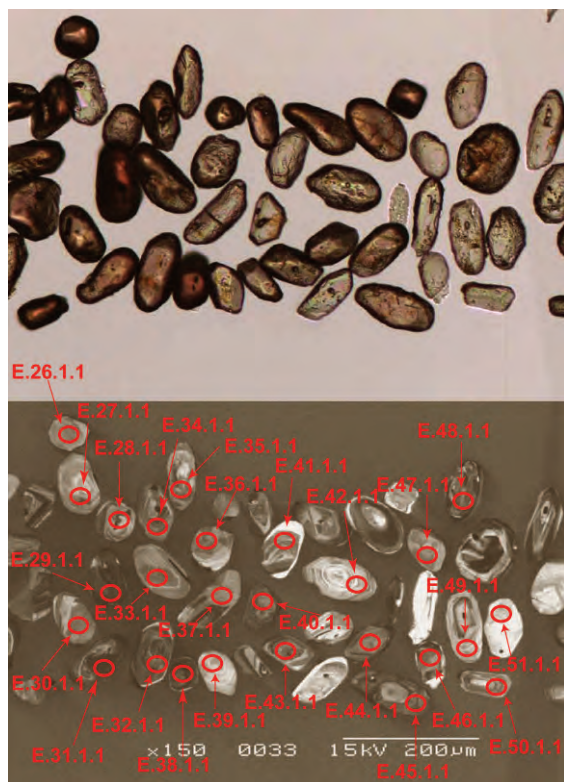
**Zircon Description**

Zircons from this sample range in length from ~80  $\mu$ m to ~140  $\mu$ m, and are generally subrounded to subhedral, with some grains exhibiting pitted surfaces (Figure 4.2). Most grains are colourless to brown in colour, with some inclusions. In cathodoluminescence images, most grains record oscillatory zoning, whereas some record either a dark or bright cathodoluminescence response. As this sample was analysed to determine a maximum depositional age, analyses were located on central



**Figure 4.1.** Outcrop photo of Townley Formation at the site of sample 2007169005, southwest of Green Hills, Etheridge Province.

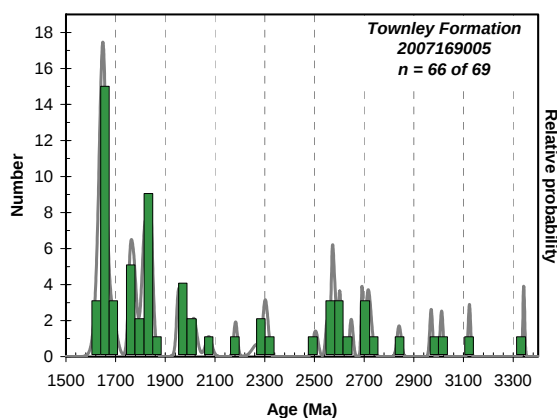
zones of grains away from any rims which may record later metamorphism.



**Figure 4.2.** Representative transmitted light and cathodoluminescence images of zircons from the Townley Formation (2007169005), with locations of some SHRIMP analyses.

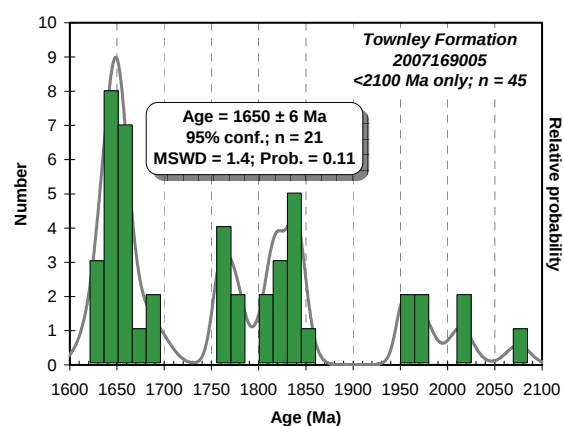
### U-Pb Isotopic Results

Sixty-nine analyses were undertaken on this sample, the results of which are presented in Table 4.1 and illustrated in Figures 4.3 and 4.4. U concentrations of the analysed zircons range between 523 and 55 ppm, with Th/U ratios between 1.55 and 0.17.



**Figure 4.3.** Probability density diagram of zircon analyses from the Townley Formation (2007169005).

Three analyses greater than 10% discordant were excluded from further consideration, and the remaining 66 analyses yield ages between ~3342 Ma and ~1632 Ma (Figure 4.3). The spectra include a small number of ages between ~2700 Ma and ~2500 Ma, and five older individuals between ~3342 Ma and ~2850 Ma. There is a small cluster of ages at ~2300 Ma, between ~2050 Ma and ~1950 Ma, at ~1840 and ~1770 Ma, and a large cluster at ~1650 Ma. The youngest individual age forms part of this youngest cluster and the weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age for the entire group is  $1650 \pm 6$  Ma (95% confidence;  $n = 21$ ; MSWD = 1.4; probability of fit = 0.11; Figure 4.4).



**Figure 4.4.** Probability density diagram of zircon analyses from the Townley Formation (2007169005) yielding  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of less than 2100 Ma.

### Geochronological Interpretation

The weighted mean age of  $1650 \pm 6$  Ma (95% confidence;  $n = 21$ ) can be used to define a maximum depositional age for this sample of the Townley Formation.

**Table 4.1.** SHRIMP U-Pb isotopic data for zircons from sample 2007169005 (1937154), Townley Formation, southwest of Green Hills.

| Grain.area                      | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|---------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| <i>Detrital zircon (n = 66)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| E.2.1.1                         | 0.02                                               | 226        | 152         | 0.70                                   | 1.4738                                 | 1.3         | 0.2763                                  | 0.2         | 3342                                             | 4            | 0           |
| E.23.1.1                        | 0.03                                               | 174        | 260         | 1.55                                   | 1.7301                                 | 1.3         | 0.2405                                  | 0.3         | 3124                                             | 5            | 6           |
| E.48.1.1                        | 0.05                                               | 276        | 130         | 0.49                                   | 1.8738                                 | 1.2         | 0.2243                                  | 0.4         | 3012                                             | 6            | 8           |
| E.47.1.1                        | 0.05                                               | 155        | 79          | 0.53                                   | 1.7972                                 | 1.3         | 0.2185                                  | 0.3         | 2970                                             | 5            | 4           |
| E.46.1.1                        | 0.09                                               | 181        | 53          | 0.30                                   | 1.8983                                 | 1.3         | 0.2018                                  | 0.5         | 2841                                             | 8            | 4           |
| E.24.1.1                        | 0.23                                               | 274        | 108         | 0.41                                   | 2.1098                                 | 1.9         | 0.1877                                  | 0.7         | 2722                                             | 12           | 8           |
| E.63.1.1                        | 0.20                                               | 67         | 50          | 0.78                                   | 2.0785                                 | 1.4         | 0.1870                                  | 0.7         | 2716                                             | 11           | 7           |
| E.4.1.1                         | 0.14                                               | 55         | 20          | 0.37                                   | 2.0217                                 | 1.5         | 0.1868                                  | 0.6         | 2714                                             | 10           | 5           |
| E.18.1.1                        | 0.02                                               | 352        | 84          | 0.25                                   | 2.0537                                 | 1.2         | 0.1842                                  | 0.2         | 2691                                             | 4            | 5           |
| E.13.1.1                        | 0.01                                               | 118        | 33          | 0.28                                   | 2.0660                                 | 1.3         | 0.1795                                  | 0.4         | 2648                                             | 7            | 4           |
| E.28.1.1                        | 0.03                                               | 217        | 228         | 1.08                                   | 2.1055                                 | 1.2         | 0.1746                                  | 0.3         | 2602                                             | 5            | 4           |
| E.21.1.1                        | 0.02                                               | 367        | 148         | 0.42                                   | 2.1675                                 | 1.2         | 0.1739                                  | 1.0         | 2596                                             | 16           | 6           |
| E.70.1.1                        | 0.01                                               | 270        | 168         | 0.64                                   | 2.0386                                 | 1.3         | 0.1726                                  | 0.4         | 2583                                             | 6            | 0           |
| E.45.1.1                        | 0.04                                               | 239        | 116         | 0.50                                   | 2.0158                                 | 1.3         | 0.1715                                  | 0.3         | 2573                                             | 5            | -1          |
| E.30.1.1                        | 0.01                                               | 178        | 98          | 0.57                                   | 2.0662                                 | 1.3         | 0.1715                                  | 0.4         | 2572                                             | 6            | 1           |
| E.38.1.1                        | 0.08                                               | 283        | 140         | 0.51                                   | 2.2970                                 | 1.2         | 0.1694                                  | 0.4         | 2552                                             | 7            | 9           |
| E.53.1.1                        | 0.06                                               | 82         | 73          | 0.91                                   | 2.3593                                 | 1.4         | 0.1647                                  | 0.6         | 2504                                             | 10           | 9           |
| E.44.1.1                        | 0.06                                               | 151        | 80          | 0.55                                   | 2.2987                                 | 1.8         | 0.1469                                  | 0.4         | 2310                                             | 8            | -1          |
| E.36.1.1                        | 0.07                                               | 215        | 106         | 0.51                                   | 2.4990                                 | 1.3         | 0.1459                                  | 0.4         | 2298                                             | 7            | 6           |
| E.37.1.1                        | 0.13                                               | 117        | 55          | 0.49                                   | 2.4951                                 | 1.3         | 0.1436                                  | 1.2         | 2271                                             | 21           | 4           |
| E.11.1.1                        | 0.04                                               | 178        | 133         | 0.77                                   | 2.5566                                 | 1.3         | 0.1365                                  | 0.4         | 2183                                             | 7            | 3           |
| E.60.1.1                        | 0.13                                               | 133        | 61          | 0.47                                   | 2.6699                                 | 1.4         | 0.1283                                  | 0.7         | 2075                                             | 13           | 1           |
| E.14.1.1                        | 0.11                                               | 121        | 104         | 0.89                                   | 2.8656                                 | 1.3         | 0.1240                                  | 0.6         | 2015                                             | 11           | 4           |
| E.9.1.1                         | 0.04                                               | 90         | 76          | 0.87                                   | 2.9204                                 | 1.4         | 0.1238                                  | 0.9         | 2012                                             | 17           | 6           |
| E.15.1.1                        | -0.02                                              | 99         | 45          | 0.47                                   | 2.9724                                 | 1.4         | 0.1213                                  | 0.6         | 1976                                             | 11           | 5           |
| E.41.1.1                        | 0.00                                               | 160        | 102         | 0.66                                   | 3.1348                                 | 1.3         | 0.1207                                  | 0.7         | 1966                                             | 13           | 9           |
| E.32.1.1                        | 0.20                                               | 195        | 88          | 0.46                                   | 2.8011                                 | 1.3         | 0.1204                                  | 0.8         | 1963                                             | 14           | 0           |
| E.8.1.1                         | 0.01                                               | 268        | 383         | 1.48                                   | 2.9371                                 | 1.3         | 0.1197                                  | 0.4         | 1952                                             | 7            | 3           |
| E.57.1.1                        | 0.14                                               | 201        | 238         | 1.22                                   | 3.0354                                 | 1.3         | 0.1128                                  | 0.6         | 1846                                             | 11           | 1           |
| E.20.1.1                        | 0.05                                               | 193        | 34          | 0.18                                   | 3.1130                                 | 1.3         | 0.1127                                  | 0.5         | 1843                                             | 9            | 3           |
| E.31.1.1                        | 0.07                                               | 523        | 84          | 0.17                                   | 3.0564                                 | 1.2         | 0.1125                                  | 0.4         | 1841                                             | 7            | 1           |
| E.56.1.1                        | 0.11                                               | 124        | 55          | 0.46                                   | 3.0639                                 | 1.4         | 0.1120                                  | 0.8         | 1832                                             | 15           | 1           |
| E.12.1.1                        | 0.08                                               | 90         | 23          | 0.27                                   | 3.2217                                 | 1.4         | 0.1119                                  | 0.8         | 1830                                             | 14           | 5           |
| E.58.1.1                        | 0.09                                               | 127        | 67          | 0.54                                   | 2.9866                                 | 1.4         | 0.1119                                  | 0.8         | 1830                                             | 14           | -2          |
| E.52.1.1                        | 0.06                                               | 195        | 156         | 0.83                                   | 3.2754                                 | 1.3         | 0.1118                                  | 0.5         | 1829                                             | 10           | 6           |
| E.1.1.1                         | 0.17                                               | 69         | 53          | 0.80                                   | 3.0816                                 | 1.7         | 0.1115                                  | 1.0         | 1823                                             | 18           | 1           |
| E.22.1.1                        | 0.04                                               | 246        | 92          | 0.39                                   | 3.3909                                 | 1.2         | 0.1111                                  | 0.4         | 1817                                             | 8            | 8           |
| E.66.1.1                        | 0.03                                               | 347        | 143         | 0.43                                   | 3.2581                                 | 1.3         | 0.1109                                  | 0.5         | 1815                                             | 9            | 5           |
| E.54.1.1                        | 0.13                                               | 201        | 93          | 0.48                                   | 3.4888                                 | 1.3         | 0.1102                                  | 0.6         | 1803                                             | 10           | 10          |
| E.7.1.1                         | 0.07                                               | 221        | 55          | 0.26                                   | 3.2027                                 | 1.4         | 0.1087                                  | 0.5         | 1779                                             | 9            | 2           |
| E.26.1.1                        | 0.08                                               | 180        | 62          | 0.36                                   | 3.2559                                 | 1.3         | 0.1084                                  | 0.5         | 1773                                             | 10           | 3           |
| E.3.1.1                         | 0.12                                               | 89         | 26          | 0.30                                   | 3.1844                                 | 1.4         | 0.1082                                  | 0.8         | 1769                                             | 15           | 0           |
| E.55.1.1                        | 0.09                                               | 372        | 119         | 0.33                                   | 3.5457                                 | 1.2         | 0.1081                                  | 0.5         | 1768                                             | 9            | 9           |
| E.10.1.1                        | 0.07                                               | 289        | 94          | 0.34                                   | 3.3721                                 | 1.2         | 0.1076                                  | 0.4         | 1759                                             | 8            | 5           |
| E.59.1.1                        | 0.03                                               | 341        | 97          | 0.29                                   | 3.2180                                 | 1.2         | 0.1075                                  | 0.4         | 1757                                             | 8            | 1           |
| E.39.1.1                        | -0.07                                              | 102        | 72          | 0.73                                   | 3.5578                                 | 1.7         | 0.1039                                  | 0.8         | 1695                                             | 14           | 6           |
| E.68.1.1                        | 0.09                                               | 99         | 73          | 0.76                                   | 3.4873                                 | 1.5         | 0.1032                                  | 1.1         | 1682                                             | 20           | 3           |
| E.61.1.1                        | 0.06                                               | 132        | 118         | 0.93                                   | 3.5462                                 | 1.3         | 0.1028                                  | 0.7         | 1676                                             | 13           | 4           |
| E.50.1.1                        | 0.07                                               | 218        | 149         | 0.71                                   | 3.4775                                 | 1.3         | 0.1020                                  | 0.6         | 1661                                             | 11           | 2           |
| E.69.1.1                        | 0.02                                               | 208        | 219         | 1.09                                   | 3.4734                                 | 1.7         | 0.1019                                  | 0.8         | 1658                                             | 14           | 2           |
| E.6.1.1                         | 0.04                                               | 182        | 118         | 0.67                                   | 3.5344                                 | 1.4         | 0.1017                                  | 0.6         | 1656                                             | 10           | 3           |
| E.16.1.1                        | 0.07                                               | 338        | 221         | 0.67                                   | 3.4480                                 | 1.2         | 0.1017                                  | 0.5         | 1656                                             | 8            | 1           |
| E.17.1.1                        | 0.16                                               | 82         | 57          | 0.72                                   | 3.7816                                 | 1.5         | 0.1016                                  | 1.2         | 1654                                             | 22           | 9           |
| E.27.1.1                        | 0.09                                               | 206        | 144         | 0.72                                   | 3.4457                                 | 1.3         | 0.1016                                  | 0.5         | 1653                                             | 10           | 1           |
| E.5.1.1                         | 0.04                                               | 267        | 319         | 1.23                                   | 3.5883                                 | 1.3         | 0.1015                                  | 0.5         | 1651                                             | 9            | 4           |
| E.33.1.1                        | 0.10                                               | 196        | 147         | 0.78                                   | 3.5449                                 | 1.3         | 0.1013                                  | 0.6         | 1648                                             | 11           | 3           |
| E.71.1.1                        | 0.03                                               | 354        | 266         | 0.78                                   | 3.4138                                 | 1.3         | 0.1013                                  | 0.6         | 1647                                             | 10           | -1          |
| E.43.1.1                        | 0.07                                               | 385        | 310         | 0.83                                   | 3.3863                                 | 1.2         | 0.1012                                  | 0.4         | 1646                                             | 8            | -1          |
| E.65.1.1                        | 0.10                                               | 291        | 268         | 0.95                                   | 3.8206                                 | 1.2         | 0.1011                                  | 0.5         | 1644                                             | 9            | 9           |
| E.40.1.1                        | 0.13                                               | 246        | 73          | 0.31                                   | 3.8335                                 | 1.3         | 0.1008                                  | 0.7         | 1640                                             | 14           | 9           |
| E.51.1.1                        | 0.18                                               | 91         | 102         | 1.16                                   | 3.6856                                 | 1.4         | 0.1007                                  | 1.0         | 1637                                             | 19           | 5           |
| E.42.1.1                        | 0.16                                               | 95         | 77          | 0.84                                   | 3.5190                                 | 1.4         | 0.1007                                  | 0.9         | 1636                                             | 17           | 1           |
| E.67.1.1                        | 0.08                                               | 223        | 168         | 0.78                                   | 3.4651                                 | 1.3         | 0.1006                                  | 0.7         | 1635                                             | 13           | 0           |
| E.19.1.1                        | 0.16                                               | 73         | 91          | 1.28                                   | 3.4072                                 | 1.4         | 0.1006                                  | 0.9         | 1635                                             | 17           | -1          |

SHRIMP geochronology of north Queensland: 2007-2010

| Grain.area                                 | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|--------------------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| E.34.1.1                                   | 0.07                                               | 357        | 393         | 1.14                                   | 3.7137                                 | 1.2         | 0.1005                                  | 0.4         | 1634                                             | 8            | 6           |
| E.49.1.1                                   | 0.22                                               | 112        | 84          | 0.78                                   | 3.5592                                 | 1.4         | 0.1004                                  | 1.1         | 1632                                             | 20           | 2           |
| <i>Analyses &gt;10% discordant (n = 3)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| E.62.1.1                                   | 0.07                                               | 180        | 204         | 1.17                                   | 3.9154                                 | 1.5         | 0.1027                                  | 0.7         | 1674                                             | 13           | 12          |
| E.64.1.1                                   | 0.28                                               | 157        | 125         | 0.83                                   | 3.4895                                 | 1.3         | 0.1129                                  | 0.7         | 1847                                             | 13           | 12          |
| E.35.1.1                                   | 0.06                                               | 195        | 175         | 0.93                                   | 2.5160                                 | 1.5         | 0.1560                                  | 0.5         | 2413                                             | 8            | 11          |

1. <sup>206</sup>Pb<sub>c</sub> indicates common <sup>206</sup>Pb as a percentage of the total measured <sup>206</sup>Pb.

**5. HELIMAN FORMATION, BLACK GIN CREEK: 2007169006**

|                                                         |                                                                  |
|---------------------------------------------------------|------------------------------------------------------------------|
| <b>GA Sample ID:</b>                                    | <b>2007169006</b>                                                |
| <b>GA Sample Number:</b>                                | <b>1937155</b>                                                   |
| <b>Other Sample ID:</b>                                 |                                                                  |
| <b>1:250,000 Sheet:</b>                                 | <b>GEORGETOWN SE5412</b>                                         |
| <b>Region:</b>                                          | <b>Etheridge Province, Queensland</b>                            |
| <b>Grid Reference (WGS 84):</b>                         | <b>724837mE 7944946mN Zone 54</b>                                |
| <b>Collector:</b>                                       | <b>N. Neumann, G. Gibson, I. Withnall, L. Lambeck, D. Huston</b> |
| <b>Collection Date:</b>                                 | <b>26/7/2007</b>                                                 |
| <b>Formal Name:</b>                                     | <b>Heliman Formation</b>                                         |
| <b>Informal Name:</b>                                   |                                                                  |
| <b>Lithology:</b>                                       | <b>Fine-grained sandstone</b>                                    |
| <b>Geochronologist:</b>                                 | <b>N.L. Neumann</b>                                              |
| <b>Mount ID:</b>                                        | <b>GA6046</b>                                                    |
| <b>Instrument:</b>                                      | <b>SHRIMP IIe Geoscience Australia</b>                           |
| <b>Acquisition Date:</b>                                | <b>7–12/5/2008</b>                                               |
| <b>U-Pb Standard &amp; reproducibility:</b>             | <b>TEMORA-2; 2.14% (2<math>\sigma</math>) [35 of 37]</b>         |
| <b><sup>207</sup>Pb/<sup>206</sup>Pb Standard:</b>      | <b>OG1 (3465.4 <math>\pm</math> 0.6 Ma)</b>                      |
| <b>Measured Value (<math>\pm</math>95% confidence):</b> | <b>3467.1 <math>\pm</math> 1.4 Ma [33 of 33]</b>                 |
| <b>Interpreted Age:</b>                                 | <b>1656 <math>\pm</math> 4 Ma</b>                                |
| <b>IMF correction applied?</b>                          | <b>No</b>                                                        |
| <b>Interpreted Age Type:</b>                            | <b>Maximum deposition age</b>                                    |

**Sample Description**

The sample from the Heliman Formation (Figure iii) comes from Black Gin Creek, southwest of Green Hills, in the Etheridge Province, Queensland. A fine-grained sandstone with mud clasts (2007169006) was sampled from a thick bed approximately 50 m from the top of the (mapped) formation (Figure 5.1).

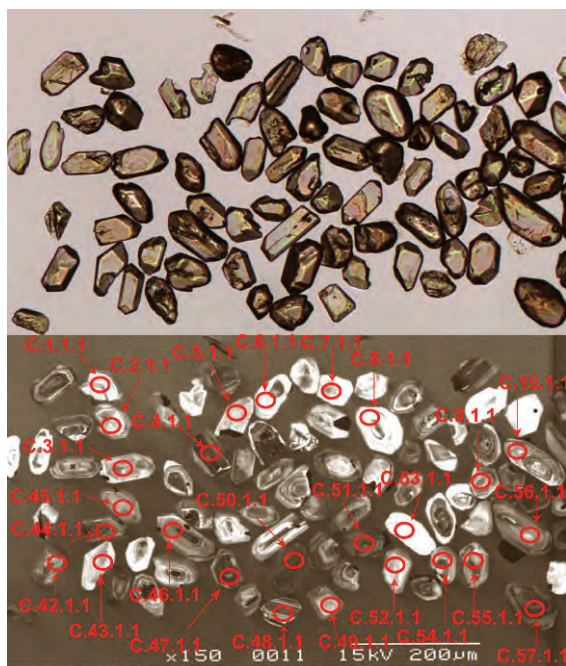
**Zircon Description**

Zircons from this sample range in length from ~50  $\mu$ m to ~110  $\mu$ m, and are relatively uniform in size and morphology. Most grains are anhedral, preserving some prismatic crystal faces, whereas occasional grains are subrounded (Figure 5.2). Most grains are clear and colourless to brown. In cathodoluminescence images, most grains record oscillatory zoning while others record a bright cathodoluminescence response. As this sample was analysed to determine a maximum depositional age, analyses were located on central



**Figure 5.1.** Outcrop photo of Heliman Formation at the site of sample 2007169006, Black Gin Creek, Etheridge Province.

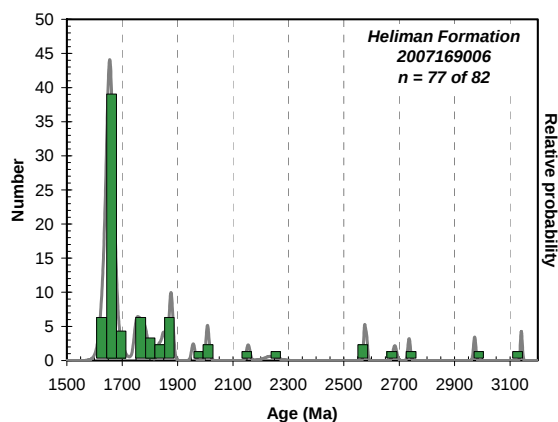
zones of grains away from any rims which may record later metamorphism.



**Figure 5.2.** Representative transmitted light and cathodoluminescence images of zircons from the Heliman Formation, Black Gin Creek (2007169006), with locations of some SHRIMP analyses.

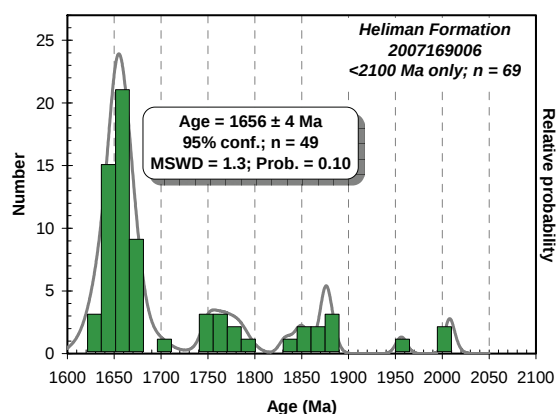
## U-Pb Isotopic Results

Eighty-two analyses were undertaken on this sample, the results of which are presented in Table 5.1 and illustrated in Figures 5.3 and 5.4. U concentrations of the analysed zircons range between 695 and 36 ppm, with Th/U ratios between 2.30 and 0.13. One discordant analysis and 4 analyses with common  $^{206}\text{Pb}_c$  contents greater than an arbitrary value of 0.5% excluded from further consideration.



**Figure 5.3.** Probability density diagram of zircon analyses from the Heliman Formation (2007169006).

The remaining 77 analyses yield ages between ~3141 Ma and ~1622 Ma (Figure 5.3). There is one age at ~3141 Ma, at ~2972 Ma, at ~2736 Ma and at ~2684 Ma and two ages at ~2580 Ma. There are five ages between ~2240 Ma and ~1950 Ma and small clusters at ~1875 Ma and at ~1770 Ma. The spectra is dominated by a large cluster at ~1650 Ma, which also includes the youngest individual age. The weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age for this entire group is  $1656 \pm 4$  Ma (95% confidence;  $n = 49$ ; MSWD = 1.3; probability of fit = 0.10; Figure 5.4).



**Figure 5.4.** Probability density diagram of zircon analyses from the Heliman Formation (2007169006) yielding  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of less than 2100 Ma.

## Geochronological Interpretation

The weighted mean age of  $1656 \pm 4$  Ma (95% confidence;  $n = 49$ ) can be used to define a maximum depositional age for this sample of the Heliman Formation from Black Gin Creek.

**Table 5.1.** SHRIMP U-Pb isotopic data for zircons from sample 2007169006 (1937155), Heliman Formation, Black Gin Creek.

| Grain.area                      | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|---------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| <i>Detrital zircon (n = 77)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| C.60.1.1                        | 0.18                                               | 511        | 320         | 0.65                                   | 1.7747                                 | 1.1         | 0.2432                                  | 0.2         | 3141                                             | 3            | 8           |
| C.38.1.1                        | 0.02                                               | 263        | 144         | 0.56                                   | 1.6447                                 | 1.2         | 0.2189                                  | 0.3         | 2972                                             | 4            | -3          |
| C.48.1.1                        | 0.02                                               | 279        | 308         | 1.14                                   | 1.9114                                 | 1.2         | 0.1893                                  | 0.3         | 2736                                             | 4            | 1           |
| C.10.1.1                        | 0.02                                               | 134        | 82          | 0.63                                   | 1.9511                                 | 1.2         | 0.1834                                  | 0.4         | 2684                                             | 7            | 1           |
| C.4.1.1                         | 0.09                                               | 525        | 491         | 0.97                                   | 2.1854                                 | 1.1         | 0.1725                                  | 0.2         | 2582                                             | 4            | 6           |
| C.58.1.1                        | 0.02                                               | 695        | 84          | 0.13                                   | 2.1959                                 | 1.2         | 0.1717                                  | 0.2         | 2575                                             | 3            | 6           |
| C.53.1.1                        | 0.47                                               | 41         | 92          | 2.30                                   | 2.4783                                 | 1.9         | 0.1408                                  | 1.4         | 2237                                             | 24           | 2           |
| C.69.1.1                        | 0.03                                               | 418        | 163         | 0.40                                   | 2.6399                                 | 1.1         | 0.1343                                  | 0.4         | 2155                                             | 6            | 4           |
| C.13.1.1                        | 0.04                                               | 384        | 138         | 0.37                                   | 2.7402                                 | 1.1         | 0.1237                                  | 0.4         | 2010                                             | 7            | 0           |
| C.17.1.1                        | 0.02                                               | 647        | 258         | 0.41                                   | 2.7889                                 | 1.1         | 0.1235                                  | 0.3         | 2007                                             | 5            | 2           |
| C.51.1.1                        | 0.06                                               | 436        | 360         | 0.85                                   | 2.8863                                 | 1.1         | 0.1200                                  | 0.3         | 1956                                             | 6            | 2           |
| C.57.1.1                        | 0.02                                               | 443        | 126         | 0.29                                   | 3.0833                                 | 1.3         | 0.1151                                  | 0.4         | 1881                                             | 7            | 4           |
| C.66.1.1                        | 0.14                                               | 604        | 358         | 0.61                                   | 2.9406                                 | 1.1         | 0.1149                                  | 0.4         | 1879                                             | 6            | 0           |
| C.20.1.1                        | 0.03                                               | 668        | 278         | 0.43                                   | 3.0433                                 | 1.1         | 0.1148                                  | 0.3         | 1877                                             | 5            | 2           |
| C.50.1.1                        | 0.02                                               | 600        | 439         | 0.76                                   | 3.0790                                 | 1.1         | 0.1146                                  | 0.3         | 1873                                             | 5            | 3           |
| C.27.1.1                        | 0.05                                               | 212        | 104         | 0.51                                   | 3.0011                                 | 1.2         | 0.1143                                  | 0.5         | 1869                                             | 9            | 1           |
| C.19.1.1                        | 0.15                                               | 443        | 140         | 0.33                                   | 3.0393                                 | 1.1         | 0.1132                                  | 0.4         | 1851                                             | 7            | 1           |
| C.74.1.1                        | 0.02                                               | 293        | 135         | 0.48                                   | 3.0207                                 | 1.2         | 0.1130                                  | 0.4         | 1848                                             | 7            | 0           |
| C.41.1.1                        | 0.01                                               | 407        | 118         | 0.30                                   | 2.9545                                 | 1.3         | 0.1120                                  | 0.4         | 1833                                             | 7            | -3          |
| C.61.1.1                        | 0.07                                               | 221        | 79          | 0.37                                   | 3.3123                                 | 1.2         | 0.1093                                  | 0.6         | 1789                                             | 11           | 5           |
| C.25.1.1                        | 0.05                                               | 163        | 52          | 0.33                                   | 3.2834                                 | 1.3         | 0.1089                                  | 0.9         | 1782                                             | 16           | 4           |
| C.75.1.1                        | 0.05                                               | 274        | 62          | 0.23                                   | 3.3364                                 | 1.2         | 0.1089                                  | 0.5         | 1782                                             | 9            | 5           |
| C.15.1.1                        | 0.10                                               | 322        | 96          | 0.31                                   | 3.2119                                 | 1.2         | 0.1081                                  | 0.5         | 1768                                             | 9            | 1           |
| C.36.1.1                        | 0.08                                               | 231        | 85          | 0.38                                   | 3.3211                                 | 1.2         | 0.1081                                  | 0.6         | 1767                                             | 12           | 4           |
| C.11.1.1                        | 0.03                                               | 174        | 46          | 0.27                                   | 3.2614                                 | 1.2         | 0.1076                                  | 0.6         | 1759                                             | 11           | 2           |
| C.59.1.1                        | 0.05                                               | 391        | 119         | 0.32                                   | 3.4640                                 | 1.1         | 0.1073                                  | 0.5         | 1754                                             | 8            | 7           |
| C.39.1.1                        | -0.02                                              | 36         | 47          | 1.35                                   | 3.4690                                 | 1.6         | 0.1070                                  | 1.3         | 1749                                             | 23           | 7           |
| C.44.1.1                        | 0.04                                               | 430        | 157         | 0.38                                   | 3.1848                                 | 1.2         | 0.1070                                  | 0.4         | 1749                                             | 7            | -1          |
| C.26.1.1                        | 0.10                                               | 183        | 41          | 0.23                                   | 3.4052                                 | 1.2         | 0.1042                                  | 0.6         | 1701                                             | 11           | 2           |
| C.12.1.1                        | 0.14                                               | 100        | 74          | 0.76                                   | 3.4818                                 | 1.9         | 0.1029                                  | 1.0         | 1676                                             | 19           | 3           |
| C.18.1.1                        | 0.02                                               | 136        | 101         | 0.77                                   | 3.4462                                 | 1.3         | 0.1028                                  | 0.7         | 1676                                             | 13           | 2           |
| C.72.1.1                        | 0.00                                               | 127        | 48          | 0.39                                   | 3.5808                                 | 1.3         | 0.1028                                  | 0.7         | 1675                                             | 12           | 5           |
| C.81.1.1                        | -0.02                                              | 208        | 340         | 1.69                                   | 3.5263                                 | 1.2         | 0.1027                                  | 0.5         | 1673                                             | 10           | 4           |
| C.55.1.1                        | -0.01                                              | 309        | 201         | 0.67                                   | 3.5636                                 | 1.2         | 0.1025                                  | 0.4         | 1670                                             | 8            | 5           |
| C.71.1.1                        | 0.07                                               | 169        | 157         | 0.96                                   | 3.5658                                 | 1.2         | 0.1025                                  | 0.7         | 1669                                             | 13           | 5           |
| C.7.1.1                         | 0.05                                               | 184        | 178         | 1.00                                   | 3.4779                                 | 1.2         | 0.1024                                  | 0.6         | 1667                                             | 12           | 2           |
| C.68.1.1                        | 0.04                                               | 151        | 151         | 1.03                                   | 3.4634                                 | 1.2         | 0.1023                                  | 0.6         | 1666                                             | 11           | 2           |
| C.3.1.1                         | 0.01                                               | 229        | 143         | 0.65                                   | 3.4804                                 | 1.2         | 0.1023                                  | 0.6         | 1666                                             | 11           | 2           |
| C.80.1.1                        | 0.20                                               | 153        | 137         | 0.92                                   | 3.6867                                 | 1.2         | 0.1021                                  | 0.9         | 1663                                             | 17           | 7           |
| C.30.1.1                        | 0.02                                               | 113        | 173         | 1.58                                   | 3.4053                                 | 1.4         | 0.1021                                  | 0.9         | 1663                                             | 16           | 0           |
| C.52.1.1                        | 0.21                                               | 148        | 118         | 0.82                                   | 3.6569                                 | 1.3         | 0.1021                                  | 0.9         | 1663                                             | 17           | 6           |
| C.62.1.1                        | 0.03                                               | 374        | 397         | 1.10                                   | 3.6849                                 | 1.1         | 0.1021                                  | 0.4         | 1662                                             | 8            | 7           |
| C.8.1.1                         | 0.00                                               | 162        | 204         | 1.30                                   | 3.4750                                 | 1.2         | 0.1020                                  | 0.5         | 1661                                             | 10           | 2           |
| C.82.1.1                        | 0.16                                               | 330        | 362         | 1.13                                   | 3.4654                                 | 1.2         | 0.1019                                  | 0.5         | 1660                                             | 10           | 2           |
| C.54.1.1                        | 0.06                                               | 263        | 300         | 1.18                                   | 3.5694                                 | 1.2         | 0.1019                                  | 0.5         | 1659                                             | 9            | 4           |
| C.49.1.1                        | 0.03                                               | 136        | 123         | 0.94                                   | 3.5102                                 | 1.3         | 0.1019                                  | 0.7         | 1659                                             | 13           | 3           |
| C.56.1.1                        | -0.05                                              | 134        | 119         | 0.92                                   | 3.5898                                 | 1.3         | 0.1019                                  | 0.7         | 1659                                             | 13           | 5           |
| C.9.1.1                         | 0.07                                               | 215        | 155         | 0.74                                   | 3.5068                                 | 1.3         | 0.1019                                  | 0.6         | 1658                                             | 11           | 2           |
| C.33.1.1                        | 0.09                                               | 298        | 205         | 0.71                                   | 3.4428                                 | 1.2         | 0.1019                                  | 0.5         | 1658                                             | 9            | 1           |
| C.45.1.1                        | 0.06                                               | 219        | 229         | 1.08                                   | 3.4358                                 | 1.2         | 0.1018                                  | 0.7         | 1658                                             | 13           | 1           |
| C.21.1.1                        | 0.02                                               | 327        | 359         | 1.13                                   | 3.4986                                 | 1.2         | 0.1018                                  | 0.4         | 1657                                             | 8            | 2           |
| C.76.1.1                        | 0.08                                               | 329        | 261         | 0.82                                   | 3.7796                                 | 1.2         | 0.1018                                  | 0.5         | 1657                                             | 9            | 9           |
| C.32.1.1                        | 0.06                                               | 241        | 267         | 1.14                                   | 3.4005                                 | 1.3         | 0.1017                                  | 0.5         | 1656                                             | 10           | 0           |
| C.63.1.1                        | 0.01                                               | 389        | 462         | 1.23                                   | 3.6195                                 | 1.1         | 0.1017                                  | 0.4         | 1655                                             | 8            | 5           |
| C.22.1.1                        | 0.04                                               | 229        | 232         | 1.05                                   | 3.4434                                 | 1.2         | 0.1017                                  | 0.5         | 1654                                             | 10           | 1           |
| C.1.1.1                         | 0.10                                               | 172        | 144         | 0.86                                   | 3.4713                                 | 1.2         | 0.1016                                  | 0.7         | 1654                                             | 14           | 1           |
| C.67.1.1                        | 0.04                                               | 523        | 373         | 0.74                                   | 3.4089                                 | 1.1         | 0.1015                                  | 0.4         | 1652                                             | 7            | 0           |
| C.70.1.1                        | 0.08                                               | 224        | 325         | 1.50                                   | 3.5518                                 | 1.2         | 0.1015                                  | 0.7         | 1651                                             | 14           | 3           |
| C.14.1.1                        | 0.04                                               | 335        | 431         | 1.33                                   | 3.3950                                 | 1.2         | 0.1014                                  | 0.5         | 1651                                             | 9            | -1          |
| C.64.1.1                        | 0.04                                               | 247        | 230         | 0.96                                   | 3.4888                                 | 1.2         | 0.1014                                  | 0.5         | 1650                                             | 9            | 2           |
| C.79.1.1                        | 0.03                                               | 269        | 316         | 1.22                                   | 3.4481                                 | 1.2         | 0.1014                                  | 0.5         | 1650                                             | 9            | 0           |
| C.42.1.1                        | 0.16                                               | 272        | 177         | 0.67                                   | 3.4055                                 | 1.2         | 0.1013                                  | 0.6         | 1649                                             | 11           | -1          |
| C.31.1.1                        | 0.16                                               | 198        | 133         | 0.69                                   | 3.5414                                 | 1.2         | 0.1013                                  | 0.7         | 1648                                             | 13           | 3           |
| C.2.1.1                         | 0.10                                               | 190        | 201         | 1.09                                   | 3.4711                                 | 1.2         | 0.1013                                  | 0.7         | 1648                                             | 13           | 1           |

SHRIMP geochronology of north Queensland: 2007-2010

| Grain.area                                                         | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|--------------------------------------------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| C.47.1.1                                                           | 0.21                                               | 687        | 538         | 0.81                                   | 3.5960                                 | 1.1         | 0.1013                                  | 0.4         | 1647                                             | 8            | 4           |
| C.5.1.1                                                            | 0.08                                               | 164        | 115         | 0.72                                   | 3.4913                                 | 1.2         | 0.1012                                  | 0.7         | 1647                                             | 13           | 1           |
| C.6.1.1                                                            | 0.16                                               | 141        | 155         | 1.13                                   | 3.5166                                 | 1.2         | 0.1011                                  | 0.8         | 1645                                             | 15           | 2           |
| C.37.1.1                                                           | 0.13                                               | 236        | 356         | 1.56                                   | 3.4029                                 | 1.2         | 0.1010                                  | 0.6         | 1642                                             | 12           | -1          |
| C.28.1.1                                                           | 0.48                                               | 266        | 355         | 1.38                                   | 3.6941                                 | 1.2         | 0.1009                                  | 0.9         | 1641                                             | 17           | 6           |
| C.24.1.1                                                           | 0.11                                               | 131        | 121         | 0.95                                   | 3.4412                                 | 1.3         | 0.1009                                  | 0.8         | 1641                                             | 15           | 0           |
| C.23.1.1                                                           | 0.11                                               | 225        | 232         | 1.06                                   | 3.4936                                 | 1.2         | 0.1009                                  | 0.6         | 1640                                             | 12           | 1           |
| C.29.1.1                                                           | 0.11                                               | 173        | 167         | 1.00                                   | 3.4005                                 | 1.3         | 0.1008                                  | 0.8         | 1640                                             | 15           | -1          |
| C.77.1.1                                                           | 0.20                                               | 142        | 147         | 1.08                                   | 3.6576                                 | 1.3         | 0.1006                                  | 0.9         | 1636                                             | 17           | 5           |
| C.40.1.1                                                           | 0.08                                               | 276        | 275         | 1.03                                   | 3.3535                                 | 1.2         | 0.1006                                  | 0.5         | 1635                                             | 10           | -3          |
| C.43.1.1                                                           | 0.17                                               | 173        | 146         | 0.88                                   | 3.4682                                 | 1.2         | 0.1005                                  | 0.8         | 1633                                             | 14           | 0           |
| C.34.1.1                                                           | 0.13                                               | 192        | 169         | 0.91                                   | 3.4628                                 | 1.2         | 0.1002                                  | 0.8         | 1627                                             | 14           | -1          |
| C.35.1.1                                                           | 0.30                                               | 125        | 157         | 1.29                                   | 3.4666                                 | 1.3         | 0.0999                                  | 1.0         | 1622                                             | 19           | -1          |
| <i>Analyses with <sup>206</sup>Pb<sub>c</sub> &gt;0.5% (n = 4)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| C.65.1.1                                                           | 3.92                                               | 115        | 47          | 0.42                                   | 2.2089                                 | 1.6         | 0.2004                                  | 2.8         | 2830                                             | 46           | 15          |
| C.46.1.1                                                           | 2.83                                               | 373        | 471         | 1.31                                   | 4.4128                                 | 1.2         | 0.1025                                  | 4.0         | 1669                                             | 74           | 21          |
| C.16.1.1                                                           | 1.26                                               | 314        | 311         | 1.03                                   | 3.8962                                 | 1.2         | 0.1019                                  | 4.4         | 1659                                             | 81           | 11          |
| C.73.1.1                                                           | 0.56                                               | 115        | 97          | 0.87                                   | 3.4587                                 | 1.3         | 0.1007                                  | 1.3         | 1638                                             | 25           | 0           |
| <i>Analyses &gt;10% discordant (n = 1)</i>                         |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| C.78.1.1                                                           | 0.12                                               | 247        | 105         | 0.44                                   | 3.6552                                 | 1.2         | 0.1058                                  | 0.6         | 1728                                             | 12           | 10          |

1. <sup>206</sup>Pb<sub>c</sub> indicates common <sup>206</sup>Pb as a percentage of the total measured <sup>206</sup>Pb.

## 6. LANGDON RIVER MUDSTONE, CANDLOW CREEK: 2007169007

|                                                |                                                              |
|------------------------------------------------|--------------------------------------------------------------|
| GA Sample ID:                                  | 2007169007                                                   |
| GA Sample Number:                              | 1937156                                                      |
| Other Sample ID:                               |                                                              |
| 1:250,000 Sheet:                               | GEORGETOWN SE5412                                            |
| Region:                                        | Etheridge Province, Queensland                               |
| Grid Reference (WGS 84):                       | 712237mE 7934931mN Zone 54                                   |
| Collector:                                     | N. Neumann, G. Gibson, I. Withnall, L. Lambeck,<br>D. Huston |
| Collection Date:                               | 27/7/2007                                                    |
| Formal Name:                                   | Langdon River Mudstone                                       |
| Informal Name:                                 |                                                              |
| Lithology:                                     | Fine-grained sandstone-mudstone                              |
| Geochronologist:                               | N.L. Neumann                                                 |
| Mount ID:                                      | GA6046                                                       |
| Instrument:                                    | SHRIMP IIe Geoscience Australia                              |
| Acquisition Date:                              | 7–12/5/2008                                                  |
| U-Pb Standard & reproducibility:               | TEMORA-2; 2.14% (2 $\sigma$ ) [35 of 37]                     |
| <sup>207</sup> Pb/ <sup>206</sup> Pb Standard: | OG1 (3465.4 $\pm$ 0.6 Ma)                                    |
| Measured Value ( $\pm$ 95% confidence):        | 3467.1 $\pm$ 1.4 Ma [33 of 33]                               |
| Interpreted Age:                               | 1629 $\pm$ 12 Ma                                             |
| IMF correction applied?                        | No                                                           |
| Interpreted Age Type:                          | Maximum deposition age                                       |

**Sample Description**

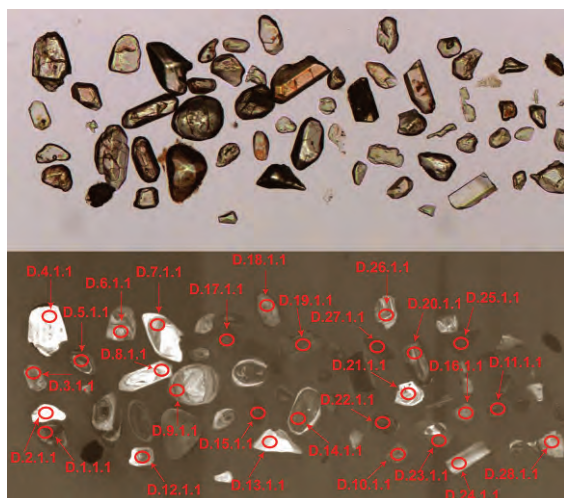
The Langdon River Mudstone (Figure iii) was collected from the Candlow Creek, ~2 km north of West Candlow Dam, in the Etheridge Province, Queensland. The sample (2007169007) comprises dark grey, fine-grained sandstone-mudstone, with planar laminations (Figure 6.1).

**Zircon Description**

Only ~35 zircons were recovered from this sample, and they have a large range of sizes and morphologies (Figure 6.2). They range from glassy euhedral grains through to rounded grains, and are colourless to brown. In cathodoluminescence images, some grains record oscillatory zoning, whereas others record either a dark or bright cathodoluminescence response. Due to the small number of grains recovered from this sample, all grains which were large enough to fit an ion microprobe spot were analysed.



**Figure 6.1.** Outcrop photo of the Langdon River Mudstone at the site of sample 2007169007, Candlow Creek, Etheridge Province.

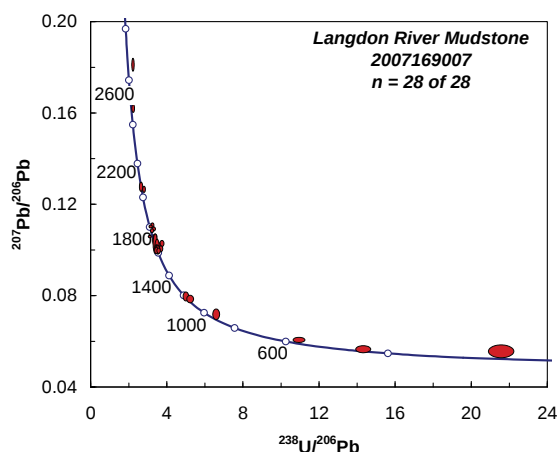


**Figure 6.2.** Representative transmitted light and cathodoluminescence images of zircons from the Langdon River Mudstone (2007169007), with locations of some SHRIMP analyses.

### U-Pb Isotopic Results

Twenty-eight analyses were undertaken on this sample, the results of which are presented in Table 6.1 and illustrated in Figures 6.3 and 6.4. U concentrations of the analysed zircons range between 877 and 65 ppm, with Th/U ratios between 1.60 and 0.01.

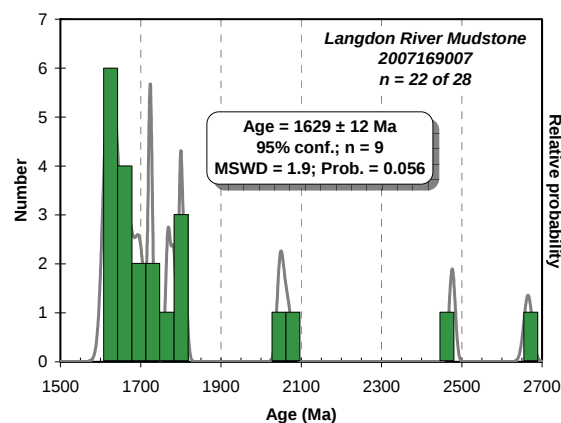
There are six individual ages younger than the main cluster within the population, with  $^{206}\text{Pb}/^{238}\text{U}$  ages of ~1194 Ma, ~1143 Ma, ~920 Ma, ~566 Ma, ~436 Ma and ~292 Ma (Figure 6.3).



**Figure 6.3.** Tera-Wasserburg concordia diagram of zircon analyses from the Langdon River Mudstone (2007169007).

Current age constraints based on field mapping suggest a Proterozoic age for this stratigraphic unit (see the North Head 1:100,000 geological map, sheet 7560 for details). Due to the small number of zircons recovered from the sample, and as these six grains have distinctive ages and do not form a single peak, they have been excluded from further consideration.

The remaining 22 analyses yield ages between ~2665 Ma and ~1612 Ma (Figure 6.3). There is one age at ~2665 Ma and at ~2476 Ma, two ages at ~2055 Ma, and small clusters at ~1800 Ma, ~1720 Ma and ~1630 Ma. The youngest of these clusters includes the youngest individual age, and using the MSWD of the weighted mean age calculation as a statistical guide, provides a  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1629 \pm 12$  Ma for the youngest 9 individuals (95% confidence; MSWD = 1.9; probability of fit = 0.056; Figure 6.4).



**Figure 6.4.** Probability density diagram of zircon analyses from the Langdon River Mudstone (2007169007) yielding  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of less than 2100 Ma.

### Geochronological Interpretation

The weighted mean age of  $1629 \pm 12$  Ma (95% confidence;  $n = 9$ ) can be used to define a maximum depositional age for this sample of the Langdon River Mudstone from Candlow Creek. The significance of the six younger grains is unknown.

**Table 6.1.** SHRIMP U-Pb isotopic data for zircons from sample 2007169007 (1937156), Langdon River Mudstone, Candlow Creek.

| Grain.area                      | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|---------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| <i>Detrital zircons (n= 22)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| D.15.1.1                        | 0.02                                               | 800        | 58          | 0.07                                   | 2.1257                                 | 1.1         | 0.1813                                  | 0.6         | 2665                                             | 10           | 7           |
| D.14.1.1                        | 0.08                                               | 159        | 100         | 0.65                                   | 2.1338                                 | 1.2         | 0.1620                                  | 0.4         | 2476                                             | 7            | 0           |
| D.16.1.1                        | 0.11                                               | 128        | 67          | 0.54                                   | 2.5556                                 | 1.3         | 0.1275                                  | 0.6         | 2064                                             | 11           | -3          |
| D.6.1.1                         | 0.02                                               | 176        | 88          | 0.52                                   | 2.7176                                 | 1.2         | 0.1263                                  | 0.4         | 2048                                             | 8            | 1           |
| D.11.1.1                        | 0.06                                               | 421        | 263         | 0.64                                   | 3.1603                                 | 1.1         | 0.1105                                  | 0.4         | 1808                                             | 7            | 2           |
| D.9.1.1                         | 0.02                                               | 864        | 11          | 0.01                                   | 3.0623                                 | 1.1         | 0.1100                                  | 0.2         | 1799                                             | 4            | -1          |
| D.25.1.1                        | 0.03                                               | 447        | 74          | 0.17                                   | 3.2284                                 | 1.1         | 0.1089                                  | 0.3         | 1782                                             | 6            | 2           |
| D.22.1.1                        | 0.07                                               | 598        | 280         | 0.48                                   | 3.1296                                 | 1.1         | 0.1081                                  | 0.3         | 1768                                             | 6            | -1          |
| D.17.1.1                        | 0.00                                               | 385        | 151         | 0.41                                   | 3.2877                                 | 1.1         | 0.1056                                  | 0.4         | 1725                                             | 7            | 1           |
| D.27.1.1                        | 0.03                                               | 877        | 49          | 0.06                                   | 3.0212                                 | 1.2         | 0.1055                                  | 0.2         | 1724                                             | 4            | -7          |
| D.18.1.1                        | 0.06                                               | 140        | 91          | 0.67                                   | 3.2892                                 | 1.3         | 0.1041                                  | 0.7         | 1699                                             | 13           | -1          |
| D.20.1.1                        | 0.11                                               | 166        | 152         | 0.95                                   | 3.2669                                 | 1.2         | 0.1038                                  | 0.7         | 1693                                             | 13           | -2          |
| D.1.1.1                         | 0.19                                               | 386        | 531         | 1.42                                   | 3.6616                                 | 1.1         | 0.1025                                  | 0.5         | 1670                                             | 9            | 7           |
| D.21.1.1                        | 0.15                                               | 91         | 58          | 0.66                                   | 3.3042                                 | 1.3         | 0.1025                                  | 1.7         | 1669                                             | 32           | -2          |
| D.4.1.1                         | 0.15                                               | 301        | 202         | 0.69                                   | 3.4846                                 | 1.2         | 0.1016                                  | 0.5         | 1653                                             | 10           | 2           |
| D.2.1.1                         | 0.02                                               | 65         | 56          | 0.90                                   | 3.4023                                 | 1.4         | 0.1015                                  | 1.1         | 1652                                             | 21           | -1          |
| D.12.1.1                        | 0.04                                               | 200        | 261         | 1.34                                   | 3.3615                                 | 1.2         | 0.1006                                  | 0.5         | 1635                                             | 10           | -3          |
| D.10.1.1                        | 0.06                                               | 228        | 141         | 0.64                                   | 3.4084                                 | 1.2         | 0.1005                                  | 0.5         | 1633                                             | 10           | -2          |
| D.19.1.1                        | 0.13                                               | 350        | 422         | 1.25                                   | 3.5918                                 | 1.2         | 0.1002                                  | 0.5         | 1627                                             | 10           | 3           |
| D.26.1.1                        | 0.12                                               | 166        | 219         | 1.36                                   | 3.4447                                 | 1.3         | 0.0996                                  | 0.8         | 1617                                             | 14           | -2          |
| D.3.1.1                         | 0.08                                               | 236        | 281         | 1.23                                   | 3.3659                                 | 1.2         | 0.0994                                  | 0.6         | 1613                                             | 11           | -4          |
| D.5.1.1                         | 0.10                                               | 334        | 518         | 1.60                                   | 3.4899                                 | 1.2         | 0.0994                                  | 0.5         | 1612                                             | 9            | -1          |
| Grain.area                      | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>206</sup> Pb/ <sup>238</sup> U<br>Age (Ma)  | ± 1σ<br>(Ma) | Disc<br>(%) |
| <i>Young ages (n = 6)</i>       |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| D.13.1.1                        | 0.06                                               | 163        | 122         | 0.77                                   | 4.9149                                 | 1.2         | 0.0791                                  | 1.0         | 1193.9                                           | 13.3         | -2          |
| D.7.1.1                         | 0.08                                               | 207        | 114         | 0.57                                   | 5.1554                                 | 1.4         | 0.0780                                  | 0.9         | 1142.8                                           | 14.4         | 0           |
| D.28.1.1                        | 0.35                                               | 265        | 58          | 0.22                                   | 6.5212                                 | 1.2         | 0.0713                                  | 1.4         | 919.7                                            | 10.2         | 5           |
| D.23.1.1                        | -0.03                                              | 632        | 131         | 0.21                                   | 10.9011                                | 1.1         | 0.0600                                  | 0.8         | 565.8                                            | 6.2          | 6           |
| D.8.1.1                         | 0.15                                               | 697        | 218         | 0.32                                   | 14.3028                                | 1.1         | 0.0559                                  | 1.1         | 435.7                                            | 4.8          | 3           |
| D.24.1.1                        | -0.16                                              | 246        | 110         | 0.46                                   | 21.5836                                | 1.3         | 0.0549                                  | 2.1         | 292.0                                            | 3.7          | 28          |

1. <sup>206</sup>Pb<sub>c</sub> indicates common <sup>206</sup>Pb as a percentage of the total measured <sup>206</sup>Pb.

## 7. MALACURA SANDSTONE, SOUTHWEST OF RED BULL BORE: 2007169009

|                                                |                                                           |
|------------------------------------------------|-----------------------------------------------------------|
| GA Sample ID:                                  | 2007169009                                                |
| GA Sample Number:                              | 1937158                                                   |
| Other Sample ID:                               |                                                           |
| 1:250,000 Sheet:                               | GEORGETOWN SE5412                                         |
| Region:                                        | Etheridge Province, Queensland                            |
| Grid Reference (WGS 84):                       | 708847mE 7922237mN Zone 54                                |
| Collector:                                     | N. Neumann, G. Gibson, I. Withnall, L. Lambeck, D. Huston |
| Collection Date:                               | 28/7/2007                                                 |
| Formal Name:                                   | Malacura Sandstone                                        |
| Informal Name:                                 |                                                           |
| Lithology:                                     | Poorly sorted, coarse- to fine-grained sandstone          |
| Geochronologist:                               | N.L. Neumann                                              |
| Mount ID:                                      | GA6046                                                    |
| Instrument:                                    | SHRIMP IIe Geoscience Australia                           |
| Acquisition Date:                              | 7–12/5/2008                                               |
| U-Pb Standard & reproducibility:               | TEMORA-2; 2.14% (2 $\sigma$ ) [35 of 37]                  |
| <sup>207</sup> Pb/ <sup>206</sup> Pb Standard: | OG1 (3465.4 $\pm$ 0.6 Ma)                                 |
| Measured Value ( $\pm$ 95% confidence):        | 3467.1 $\pm$ 1.4 Ma [33 of 33]                            |
| Interpreted Age:                               | 1625 $\pm$ 5 Ma                                           |
| IMF correction applied?                        | No                                                        |
| Interpreted Age Type:                          | Maximum deposition age                                    |

**Sample Description**

The Malacura Sandstone (Figure iii), part of the Langlovale Group, was sampled ~3.5 km southwest of Red Bull Bore, in the Etheridge Province, Queensland. The sample (2007169009) was collected ~500 m above the Langdon River Mudstone, from a ~2 m thick bed overlain by a reworked, thinly-bedded siltstone, and is a poorly sorted, gritty, coarse- to fine-grained sandstone (Figure 7.1).

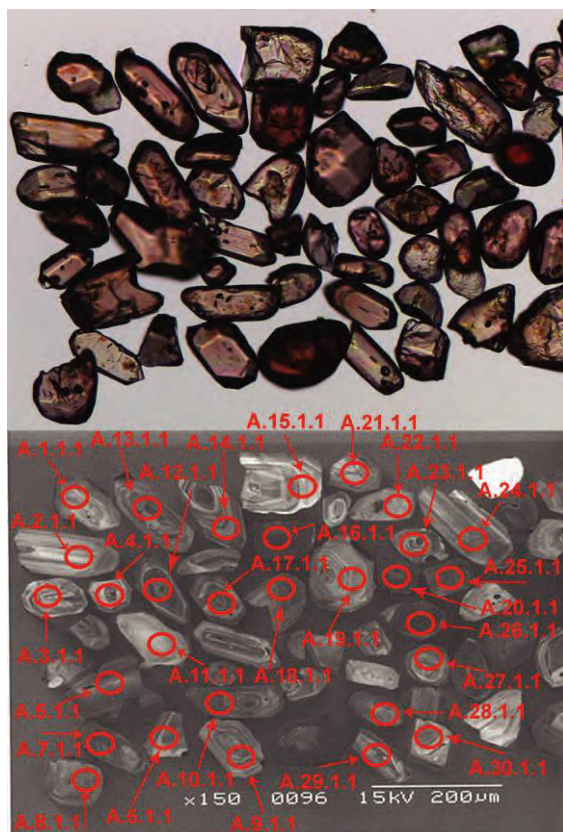
**Zircon Description**

Zircons from this sample range in length from ~75  $\mu$ m to ~150  $\mu$ m, with some larger grains up to ~200  $\mu$ m in length (Figure 7.2). Grains range from subeuhedral morphologies with prismatic crystal faces preserved, to subrounded grains with some pitted surfaces (Figure 7.2). Most grains are brown in colour. In cathodoluminescence images, most grains record oscillatory zoning. As this sample was analysed to determine a maximum depositional age,



**Figure 7.1.** Outcrop photo of the Malacura Sandstone at the site of sample 2007169009, southwest of Red Bull Bore, Etheridge Province.

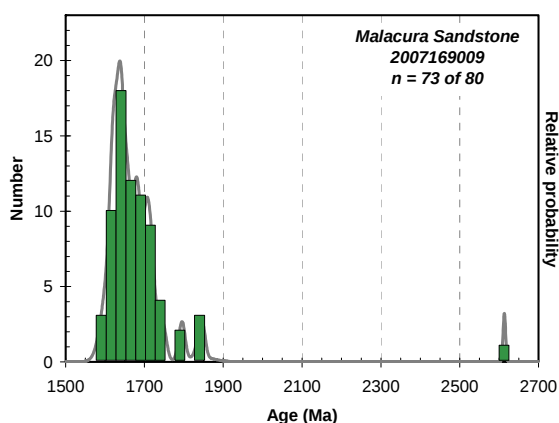
analyses were located on central zones of grains away from any rims which may record later metamorphism.



**Figure 7.2.** Representative transmitted light and cathodoluminescence images of zircons from the Malacura Sandstone (2007169009), with locations of some SHRIMP analyses.

### U-Pb Isotopic Results

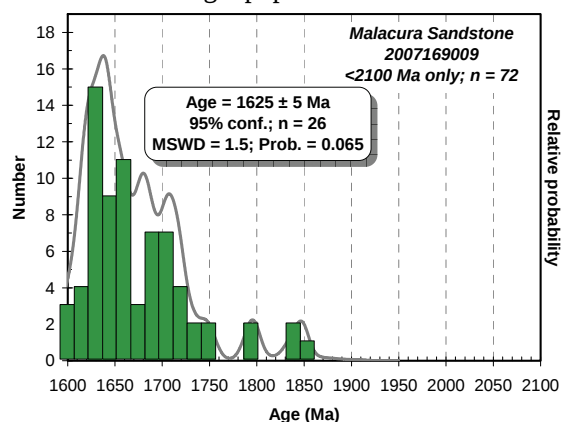
Eighty analyses were undertaken on this sample, the results of which are presented in Table 7.1 and illustrated in Figures 7.3 and 7.4.



**Figure 7.3.** Probability density diagram of zircon analyses from the Malacura Sandstone (2007169009).

U concentrations of the analysed zircons range between 745 and 71 ppm, with Th/U ratios between 1.64 and 0.04. Three discordant analyses and four grains with high common  $^{206}\text{Pb}_c$  content were removed from further consideration.

The remaining 73 analyses yield ages between ~1849 Ma and ~1594 Ma, with one older age at ~2613 (Figure 7.3). There are three ages at ~1850 Ma, and two at ~1800 Ma, and a large number of ages from ~1750 Ma to ~1594 Ma (Figure 7.4). The youngest individual age forms part of this cluster, but the MSWD value of 16 for the weighted mean age of this entire group indicates that it is not a single population.



**Figure 7.4.** Probability density diagram of zircon analyses from the Malacura Sandstone (2007169009) yielding  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of less than 2100 Ma.

Mixture modelling (Sambridge and Compston, 1994) of this cluster ( $n = 67$ ) based on three components provides a youngest modelled age of  $1631 \pm 4$  Ma ( $2\sigma$ ). Alternatively, using the MSWD as a guide for the youngest statically coherent age group provides a weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1625 \pm 5$  Ma (95% confidence) for the youngest 26 analyses in this cluster (MSWD = 1.5; probability of fit = 0.065; Figure 7.4).

### Geochronological Interpretation

Given that the youngest weighted mean age calculated using the MSWD as a guide is within error of the age calculated from mixture modelling, the weighted mean age of  $1625 \pm 5$  Ma (95% confidence;  $n = 26$ ) is the preferred interpretation for a maximum depositional age for this sample of the Malacura Sandstone.

**Table 7.1.** SHRIMP U-Pb isotopic data for zircons from sample 2007169009 (1937158), Malacura Sandstone, southwest of Red Bull Bore.

| Grain.area                      | $^{206}\text{Pb}_c$<br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | $^{232}\text{Th}/$<br>$^{238}\text{U}$ | $^{238}\text{U}/$<br>$^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/$<br>$^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/^{206}\text{Pb}$<br>Age (Ma) | $\pm 1\sigma$<br>(Ma) | Disc<br>(%) |
|---------------------------------|-----------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|----------------------|-----------------------------------------|----------------------|-----------------------------------------------|-----------------------|-------------|
| <i>Detrital zircon (n = 73)</i> |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| A.26.1.1                        | 0.06                                    | 586        | 204         | 0.36                                   | 2.1422                                 | 1.1                  | 0.1758                                  | 0.2                  | 2613                                          | 3                     | 5           |
| A.16.1.1                        | 0.07                                    | 391        | 194         | 0.51                                   | 3.1454                                 | 1.1                  | 0.1130                                  | 0.4                  | 1849                                          | 7                     | 4           |
| A.8.1.1                         | 0.37                                    | 223        | 85          | 0.40                                   | 2.9582                                 | 1.2                  | 0.1127                                  | 1.9                  | 1843                                          | 34                    | -2          |
| A.30.1.1                        | 0.08                                    | 234        | 86          | 0.38                                   | 3.0926                                 | 1.2                  | 0.1124                                  | 0.5                  | 1839                                          | 9                     | 2           |
| A.18.1.1                        | -0.02                                   | 292        | 171         | 0.61                                   | 3.1980                                 | 1.1                  | 0.1099                                  | 0.4                  | 1798                                          | 7                     | 2           |
| A.74.1.1                        | 0.01                                    | 219        | 42          | 0.20                                   | 3.1857                                 | 1.2                  | 0.1095                                  | 0.4                  | 1792                                          | 8                     | 2           |
| A.34.1.1                        | -0.02                                   | 252        | 64          | 0.26                                   | 3.4013                                 | 1.2                  | 0.1070                                  | 0.5                  | 1748                                          | 9                     | 5           |
| A.68.1.1                        | 0.09                                    | 242        | 170         | 0.73                                   | 3.2001                                 | 1.2                  | 0.1068                                  | 0.5                  | 1745                                          | 9                     | 0           |
| A.6.1.1                         | 0.00                                    | 303        | 292         | 1.00                                   | 3.2650                                 | 1.5                  | 0.1059                                  | 0.4                  | 1729                                          | 7                     | 0           |
| A.58.1.1                        | 0.01                                    | 137        | 166         | 1.25                                   | 3.2525                                 | 1.2                  | 0.1057                                  | 0.8                  | 1726                                          | 15                    | 0           |
| A.67.1.1                        | 0.08                                    | 612        | 424         | 0.72                                   | 3.4300                                 | 1.2                  | 0.1053                                  | 0.3                  | 1719                                          | 6                     | 4           |
| A.47.1.1                        | 0.08                                    | 325        | 360         | 1.15                                   | 3.2616                                 | 1.1                  | 0.1051                                  | 0.4                  | 1716                                          | 8                     | 0           |
| A.29.1.1                        | 0.03                                    | 305        | 276         | 0.94                                   | 3.3148                                 | 1.1                  | 0.1049                                  | 0.6                  | 1713                                          | 12                    | 1           |
| A.25.1.1                        | 0.04                                    | 354        | 200         | 0.58                                   | 3.5489                                 | 1.1                  | 0.1049                                  | 0.4                  | 1712                                          | 7                     | 7           |
| A.40.1.1                        | 0.06                                    | 178        | 63          | 0.36                                   | 3.3949                                 | 1.2                  | 0.1047                                  | 0.6                  | 1709                                          | 11                    | 3           |
| A.62.1.1                        | 0.11                                    | 262        | 10          | 0.04                                   | 3.2773                                 | 1.2                  | 0.1046                                  | 0.5                  | 1708                                          | 9                     | -1          |
| A.64.1.1                        | 0.08                                    | 447        | 522         | 1.21                                   | 3.5277                                 | 1.1                  | 0.1045                                  | 0.4                  | 1706                                          | 7                     | 6           |
| A.33.1.1                        | 0.03                                    | 506        | 304         | 0.62                                   | 3.5117                                 | 1.1                  | 0.1044                                  | 0.4                  | 1705                                          | 7                     | 5           |
| A.78.1.1                        | 0.10                                    | 149        | 80          | 0.56                                   | 3.2551                                 | 1.2                  | 0.1044                                  | 0.6                  | 1703                                          | 11                    | -1          |
| A.31.1.1                        | 0.03                                    | 282        | 163         | 0.60                                   | 3.4460                                 | 1.2                  | 0.1040                                  | 0.5                  | 1697                                          | 9                     | 3           |
| A.22.1.1                        | 0.02                                    | 114        | 81          | 0.73                                   | 3.4016                                 | 1.2                  | 0.1039                                  | 0.7                  | 1696                                          | 12                    | 2           |
| A.75.1.1                        | 0.08                                    | 259        | 154         | 0.62                                   | 3.4032                                 | 1.2                  | 0.1036                                  | 0.5                  | 1690                                          | 9                     | 2           |
| A.59.1.1                        | 0.07                                    | 221        | 184         | 0.86                                   | 3.3531                                 | 1.2                  | 0.1034                                  | 0.5                  | 1686                                          | 10                    | 0           |
| A.56.1.1                        | -0.01                                   | 195        | 243         | 1.29                                   | 3.4213                                 | 1.2                  | 0.1034                                  | 0.5                  | 1686                                          | 9                     | 2           |
| A.41.1.1                        | -0.14                                   | 71         | 69          | 1.00                                   | 3.4938                                 | 1.4                  | 0.1033                                  | 1.3                  | 1685                                          | 23                    | 4           |
| A.53.1.1                        | 0.05                                    | 307        | 204         | 0.69                                   | 3.3638                                 | 1.2                  | 0.1032                                  | 0.4                  | 1682                                          | 8                     | 0           |
| A.13.1.1                        | 0.07                                    | 348        | 447         | 1.33                                   | 3.6632                                 | 1.2                  | 0.1031                                  | 0.4                  | 1681                                          | 8                     | 7           |
| A.70.1.1                        | 0.05                                    | 248        | 193         | 0.80                                   | 3.3815                                 | 1.2                  | 0.1031                                  | 0.5                  | 1680                                          | 9                     | 1           |
| A.12.1.1                        | 0.03                                    | 432        | 255         | 0.61                                   | 3.6770                                 | 1.1                  | 0.1030                                  | 0.4                  | 1678                                          | 7                     | 8           |
| A.50.1.1                        | 0.42                                    | 394        | 351         | 0.92                                   | 3.6705                                 | 1.1                  | 0.1029                                  | 0.8                  | 1678                                          | 14                    | 7           |
| A.54.1.1                        | 0.02                                    | 255        | 194         | 0.79                                   | 3.3748                                 | 1.2                  | 0.1028                                  | 0.5                  | 1675                                          | 9                     | 0           |
| A.52.1.1                        | 0.06                                    | 156        | 90          | 0.60                                   | 3.4612                                 | 1.2                  | 0.1022                                  | 0.6                  | 1664                                          | 11                    | 2           |
| A.37.1.1                        | 0.08                                    | 283        | 356         | 1.30                                   | 3.4229                                 | 1.2                  | 0.1021                                  | 0.5                  | 1663                                          | 9                     | 1           |
| A.66.1.1                        | 0.16                                    | 192        | 154         | 0.83                                   | 3.3637                                 | 1.3                  | 0.1020                                  | 0.6                  | 1661                                          | 12                    | -1          |
| A.38.1.1                        | 0.25                                    | 87         | 78          | 0.93                                   | 3.3670                                 | 1.3                  | 0.1018                                  | 1.0                  | 1658                                          | 19                    | -1          |
| A.7.1.1                         | 0.07                                    | 420        | 273         | 0.67                                   | 3.5004                                 | 1.1                  | 0.1018                                  | 0.4                  | 1657                                          | 7                     | 2           |
| A.69.1.1                        | -0.08                                   | 144        | 128         | 0.91                                   | 3.5229                                 | 1.2                  | 0.1017                                  | 0.7                  | 1656                                          | 12                    | 3           |
| A.32.1.1                        | 0.06                                    | 103        | 92          | 0.93                                   | 3.6294                                 | 1.3                  | 0.1017                                  | 0.8                  | 1655                                          | 14                    | 5           |
| A.49.1.1                        | 0.18                                    | 158        | 64          | 0.42                                   | 3.4623                                 | 1.2                  | 0.1016                                  | 0.7                  | 1654                                          | 14                    | 1           |
| A.1.1.1                         | 0.08                                    | 138        | 101         | 0.76                                   | 3.4409                                 | 1.2                  | 0.1016                                  | 0.7                  | 1653                                          | 13                    | 1           |
| A.63.1.1                        | 0.04                                    | 215        | 184         | 0.89                                   | 3.4782                                 | 1.2                  | 0.1015                                  | 0.6                  | 1652                                          | 11                    | 1           |
| A.72.1.1                        | 0.13                                    | 127        | 86          | 0.70                                   | 3.2672                                 | 1.2                  | 0.1015                                  | 0.8                  | 1652                                          | 14                    | -4          |
| A.61.1.1                        | 0.04                                    | 261        | 288         | 1.14                                   | 3.5150                                 | 1.2                  | 0.1013                                  | 0.5                  | 1647                                          | 9                     | 2           |
| A.44.1.1                        | 0.07                                    | 174        | 71          | 0.42                                   | 3.5085                                 | 1.2                  | 0.1012                                  | 0.7                  | 1646                                          | 13                    | 2           |
| A.77.1.1                        | 0.02                                    | 173        | 202         | 1.21                                   | 3.4806                                 | 1.2                  | 0.1011                                  | 0.6                  | 1644                                          | 11                    | 1           |
| A.45.1.1                        | 0.12                                    | 288        | 204         | 0.73                                   | 3.5826                                 | 1.2                  | 0.1010                                  | 0.5                  | 1643                                          | 9                     | 3           |
| A.39.1.1                        | 0.00                                    | 329        | 331         | 1.04                                   | 3.5247                                 | 1.1                  | 0.1010                                  | 0.4                  | 1642                                          | 7                     | 2           |
| A.28.1.1                        | 0.05                                    | 188        | 157         | 0.86                                   | 3.4704                                 | 1.2                  | 0.1009                                  | 0.6                  | 1642                                          | 12                    | 1           |
| A.71.1.1                        | 0.01                                    | 562        | 778         | 1.43                                   | 3.4678                                 | 1.1                  | 0.1009                                  | 0.3                  | 1641                                          | 6                     | 0           |
| A.10.1.1                        | 0.06                                    | 318        | 248         | 0.81                                   | 3.6477                                 | 1.2                  | 0.1007                                  | 0.5                  | 1637                                          | 9                     | 5           |
| A.80.1.1                        | 0.02                                    | 486        | 452         | 0.96                                   | 3.4391                                 | 1.1                  | 0.1006                                  | 0.4                  | 1636                                          | 7                     | -1          |
| A.11.1.1                        | 0.06                                    | 97         | 71          | 0.75                                   | 3.6436                                 | 1.3                  | 0.1005                                  | 0.9                  | 1633                                          | 16                    | 4           |
| A.17.1.1                        | -0.02                                   | 264        | 190         | 0.74                                   | 3.5788                                 | 1.2                  | 0.1003                                  | 0.4                  | 1630                                          | 8                     | 3           |
| A.79.1.1                        | 0.04                                    | 174        | 156         | 0.93                                   | 3.4802                                 | 1.2                  | 0.1002                                  | 0.6                  | 1628                                          | 12                    | 0           |
| A.48.1.1                        | 0.04                                    | 286        | 256         | 0.92                                   | 3.5525                                 | 1.2                  | 0.1002                                  | 0.5                  | 1628                                          | 9                     | 2           |
| A.35.1.1                        | 0.13                                    | 97         | 69          | 0.73                                   | 3.7339                                 | 1.3                  | 0.1002                                  | 1.1                  | 1627                                          | 20                    | 6           |
| A.65.1.1                        | 0.06                                    | 141        | 124         | 0.91                                   | 3.5558                                 | 1.4                  | 0.1001                                  | 0.7                  | 1627                                          | 14                    | 2           |
| A.3.1.1                         | 0.07                                    | 177        | 229         | 1.34                                   | 3.5759                                 | 1.2                  | 0.1001                                  | 0.6                  | 1626                                          | 12                    | 2           |
| A.15.1.1                        | 0.16                                    | 111        | 91          | 0.85                                   | 3.5233                                 | 1.3                  | 0.1001                                  | 0.9                  | 1626                                          | 17                    | 1           |
| A.46.1.1                        | 0.03                                    | 230        | 189         | 0.85                                   | 3.5754                                 | 1.2                  | 0.1001                                  | 0.6                  | 1625                                          | 11                    | 2           |
| A.23.1.1                        | 0.09                                    | 258        | 409         | 1.64                                   | 3.7737                                 | 1.2                  | 0.1000                                  | 0.5                  | 1624                                          | 10                    | 7           |
| A.19.1.1                        | 0.11                                    | 138        | 197         | 1.47                                   | 3.6831                                 | 1.2                  | 0.1000                                  | 0.8                  | 1624                                          | 16                    | 5           |
| A.14.1.1                        | 0.02                                    | 201        | 78          | 0.40                                   | 3.5743                                 | 1.2                  | 0.0999                                  | 0.6                  | 1623                                          | 12                    | 2           |
| A.27.1.1                        | -0.01                                   | 234        | 262         | 1.15                                   | 3.5844                                 | 1.3                  | 0.0999                                  | 0.5                  | 1622                                          | 9                     | 2           |

SHRIMP geochronology of north Queensland: 2007-2010

| Grain.area                                                         | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|--------------------------------------------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| A.57.1.1                                                           | 0.13                                               | 201        | 163         | 0.84                                   | 3.4508                                 | 1.2         | 0.0998                                  | 0.7         | 1621                                             | 12           | -1          |
| A.24.1.1                                                           | -0.01                                              | 345        | 390         | 1.17                                   | 3.7043                                 | 1.3         | 0.0998                                  | 0.4         | 1620                                             | 7            | 5           |
| A.2.1.1                                                            | 0.17                                               | 108        | 90          | 0.86                                   | 3.4676                                 | 1.3         | 0.0997                                  | 0.9         | 1618                                             | 17           | -1          |
| A.76.1.1                                                           | 0.03                                               | 441        | 192         | 0.45                                   | 3.4939                                 | 1.1         | 0.0996                                  | 0.3         | 1617                                             | 6            | 0           |
| A.42.1.1                                                           | 0.16                                               | 136        | 119         | 0.91                                   | 3.6223                                 | 1.2         | 0.0993                                  | 0.9         | 1612                                             | 17           | 3           |
| A.9.1.1                                                            | 0.03                                               | 245        | 256         | 1.08                                   | 3.6632                                 | 1.2         | 0.0990                                  | 0.5         | 1606                                             | 9            | 3           |
| A.55.1.1                                                           | 0.11                                               | 150        | 77          | 0.53                                   | 3.5060                                 | 1.4         | 0.0985                                  | 0.7         | 1595                                             | 14           | -1          |
| A.73.1.1                                                           | 0.16                                               | 228        | 262         | 1.18                                   | 3.5902                                 | 1.3         | 0.0984                                  | 0.7         | 1594                                             | 12           | 1           |
| A.36.1.1                                                           | 0.18                                               | 97         | 144         | 1.54                                   | 3.4950                                 | 1.3         | 0.0984                                  | 1.0         | 1594                                             | 19           | -2          |
| <i>Analyses with <sup>206</sup>Pb<sub>c</sub> &gt;0.5% (n = 4)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| A.43.1.1                                                           | 3.83                                               | 745        | 657         | 0.91                                   | 3.9720                                 | 1.1         | 0.1042                                  | 4.5         | 1701                                             | 83           | 15          |
| A.51.1.1                                                           | 2.04                                               | 386        | 284         | 0.76                                   | 3.8310                                 | 1.1         | 0.1034                                  | 2.5         | 1686                                             | 47           | 11          |
| A.21.1.1                                                           | 2.03                                               | 220        | 108         | 0.51                                   | 4.1079                                 | 1.2         | 0.1033                                  | 2.5         | 1684                                             | 47           | 17          |
| A.4.1.1                                                            | 0.60                                               | 289        | 416         | 1.49                                   | 3.9004                                 | 1.2         | 0.1000                                  | 1.0         | 1624                                             | 18           | 9           |
| <i>Analyses &gt;10% discordant (n = 3)</i>                         |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| A.5.1.1                                                            | 0.26                                               | 236        | 298         | 1.30                                   | 4.3376                                 | 1.2         | 0.1008                                  | 0.7         | 1638                                             | 14           | 18          |
| A.60.1.1                                                           | 0.27                                               | 260        | 282         | 1.12                                   | 4.3847                                 | 1.2         | 0.0984                                  | 0.8         | 1594                                             | 14           | 17          |
| A.20.1.1                                                           | 0.36                                               | 452        | 307         | 0.70                                   | 3.9969                                 | 1.1         | 0.0990                                  | 1.0         | 1605                                             | 19           | 10          |

1. <sup>206</sup>Pb<sub>c</sub> indicates common <sup>206</sup>Pb as a percentage of the total measured <sup>206</sup>Pb.

**8. UNNAMED GRANITIC GNEISS, STOCKMAN CREEK: 2007169011**

|                                                         |                                                                  |
|---------------------------------------------------------|------------------------------------------------------------------|
| <b>GA Sample ID:</b>                                    | <b>2007169011</b>                                                |
| <b>GA Sample Number:</b>                                | <b>1937160</b>                                                   |
| <b>Other Sample ID:</b>                                 |                                                                  |
| <b>1:250,000 Sheet:</b>                                 | <b>GEORGETOWN SE5412</b>                                         |
| <b>Region:</b>                                          | <b>Etheridge Province, Queensland</b>                            |
| <b>Grid Reference (WGS 84):</b>                         | <b>812658mE 7943790mN Zone 54</b>                                |
| <b>Collector:</b>                                       | <b>N. Neumann, G. Gibson, I. Withnall, L. Lambeck, D. Huston</b> |
| <b>Collection Date:</b>                                 | <b>30/7/2007</b>                                                 |
| <b>Formal Name:</b>                                     | <b>Unnamed granitic gneiss</b>                                   |
| <b>Informal Name:</b>                                   |                                                                  |
| <b>Lithology:</b>                                       | <b>Granitic gneiss</b>                                           |
| <b>Geochronologist:</b>                                 | <b>N.L. Neumann</b>                                              |
| <b>Mount ID:</b>                                        | <b>GA6046</b>                                                    |
| <b>Instrument:</b>                                      | <b>SHRIMP IIe Geoscience Australia</b>                           |
| <b>Acquisition Date:</b>                                | <b>7–12/5/2008</b>                                               |
| <b>U-Pb Standard &amp; reproducibility:</b>             | <b>TEMORA-2; 2.14% (2<math>\sigma</math>) [35 of 37]</b>         |
| <b><sup>207</sup>Pb/<sup>206</sup>Pb Standard:</b>      | <b>OG1 (3465.4 <math>\pm</math> 0.6 Ma)</b>                      |
| <b>Measured Value (<math>\pm</math>95% confidence):</b> | <b>3467.1 <math>\pm</math> 1.4 Ma [33 of 33]</b>                 |
| <b>Interpreted Age:</b>                                 | <b>1696 <math>\pm</math> 3 Ma</b>                                |
| <b>IMF correction applied?</b>                          | <b>No</b>                                                        |
| <b>Interpreted Age Type:</b>                            | <b>Magmatic crystallisation age</b>                              |
| <b>Interpreted Age:</b>                                 | <b>1554 <math>\pm</math> 4 Ma</b>                                |
| <b>IMF correction applied?</b>                          | <b>No</b>                                                        |
| <b>Interpreted Age Type:</b>                            | <b>Zircon recrystallisation age</b>                              |

**Sample Description**

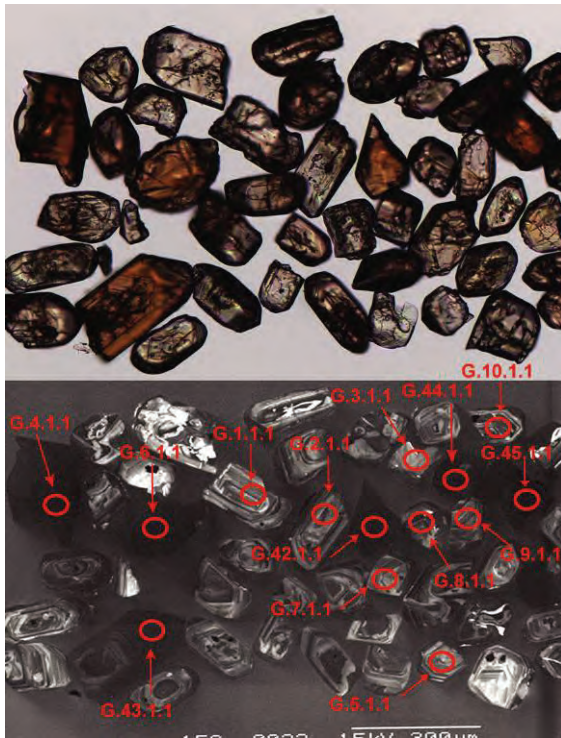
This sample was collected from Stockman Creek, south of the Einasleigh-Forsayth Road, ~15 km southwest of Einasleigh, in the Etheridge Province, Queensland. A previous zircon geochronology study undertaken by Black et al. (1998) included a sample collected from the same creek section. In that study, an igneous crystallisation age of 1675  $\pm$  3 Ma was reported for an amphibolite sample, which also recorded zircon overgrowths at 1553  $\pm$  3 Ma. For the current study, a quartz+feldspar+hornblende granitic gneiss with a strong foliation was sampled from the same creek pavement outcrop (Figure 8.1).



**Figure 8.1.** Outcrop photo of the unnamed granitic gneiss at the site of sample 2007169011, from Stockman Creek, Etheridge Province.

### Zircon Description

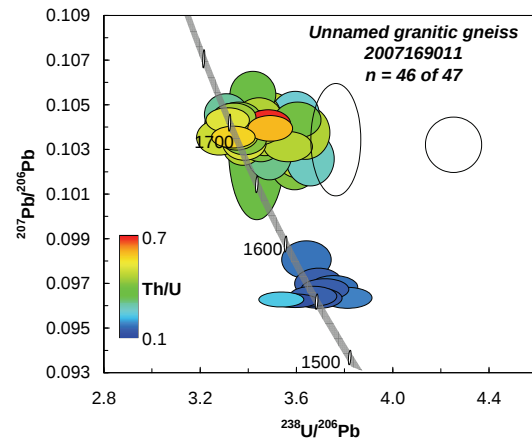
Zircons from this sample range in length from ~110  $\mu\text{m}$  to ~200  $\mu\text{m}$ , and are generally euhedral with prismatic crystal faces preserved on most grains (Figure 8.2). Most grains are either light brown or orange in colour, and some grains contain internal cracks. In cathodoluminescence images, the grains form two groups: the light brown coloured zircons record oscillatory zoning, whereas the orange coloured grains record a homogeneous dark cathodoluminescence response. Zircons from both cathodoluminescence groups were analysed.



**Figure 8.2.** Representative transmitted light and cathodoluminescence images of zircons from the unnamed granitic gneiss (2007169011), with locations of some SHRIMP analyses.

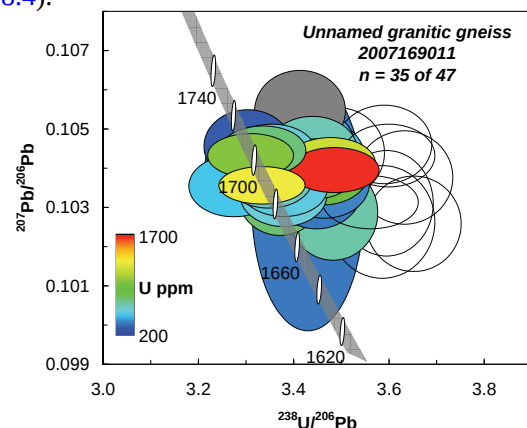
### U-Pb Isotopic Results

Forty-seven analyses were undertaken on this sample, the results of which are presented in Table 8.1 and illustrated in Figures 8.3 to 8.6. U concentrations of the analysed zircons range between 3318 and 252 ppm, with Th/U ratios between 0.70 and 0.12. One analysis (G.25.1.1) collected during a period of analytical instability and two analyses which are  $\geq 10\%$  discordant were excluded from further consideration.



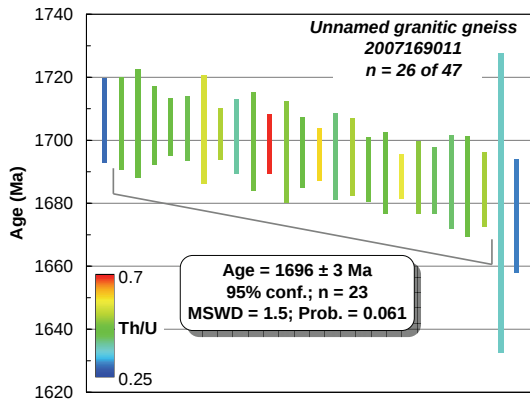
**Figure 8.3.** Tera-Wasserburg concordia diagram showing results of zircon analyses from the unnamed granitic gneiss (2007169011), coloured according to Th/U ratio. Open ellipses represent analyses  $\geq 10\%$  discordant.

The remaining 44 analyses form two distinct groups based on their cathodoluminescence response, Th/U ratios and age (Figure 8.3). The older, higher Th/U ratio group contains 35 analyses, but the MSWD of 2.4 for the entire group indicates that they are not a single statistical group. One analysis (G.32.1.1) records an age of  $1722 \pm 14$  Ma ( $2\sigma$ ), which is older than the main population and is interpreted to represent inheritance (Figure 8.4). Eight analyses greater than or equal to 5% discordant have also been excluded from further consideration (Figure 8.4).



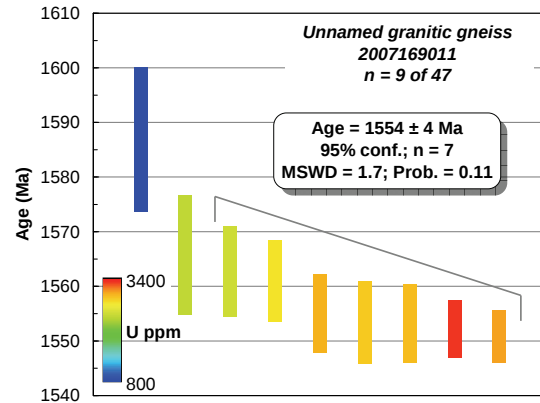
**Figure 8.4.** Tera-Wasserburg concordia diagram showing results of zircon analyses from the older age group of the unnamed granitic gneiss (2007169011), coloured according to U content. Open ellipses represent analyses  $\geq 5\%$  discordant, grey ellipse represents an inherited age.

As the remaining 26 analyses do not form a statistically coherent group, 3 analyses (G.10.1.1, G.33.1.1 and G.3.1.1) with Th/U ratios lower than the remaining analyses (average Th/U = 0.32 compared with average Th/U = 0.49 for the remaining 23 analyses) have been excluded from the age calculation. The remaining 23 analyses form a weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1696 \pm 3$  Ma (95% confidence; MSWD = 1.5; probability of fit = 0.061; Figure 8.5).



**Figure 8.5.** Mean age diagram showing  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of zircon analyses from the older age group of the unnamed granitic gneiss (2007169011).

There are 9 analyses in the younger, lower Th/U ratio group, but the MSWD for the entire group indicates that it is not a single statistically coherent group. Excluding the oldest two individuals provides a weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1554 \pm 4$  Ma (95% confidence; MSWD = 1.7; probability of fit = 0.11; Figure 8.6) for the remaining 7 analyses.



**Figure 8.6.** Mean age diagram showing  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of zircon analyses from the younger age group of the unnamed granitic gneiss (2007169011).

### Geochronological Interpretation

The weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1696 \pm 3$  Ma (95% confidence; n = 23) from the higher Th/U ratio group is interpreted to represent the magmatic crystallisation age of this sample. The sample also records a younger  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1554 \pm 4$  Ma (95% confidence; n = 7) for lower Th/U ratio zircons, which is interpreted to record recrystallisation of zircon within this gneiss.

**Table 8.1.** SHRIMP U-Pb isotopic data for zircons from sample 2007169011 (1937160), Unnamed granitic gneiss, Stockman Creek.

| Grain.area                                                     | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|----------------------------------------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| <i>Inherited age (n = 1)</i>                                   |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| G.32.1.1                                                       | 0.01                                               | 438        | 158         | 0.37                                   | 3.4104                                 | 1.1         | 0.1055                                  | 0.4         | 1722                                             | 7            | 4           |
| <i>Higher Th/U ratio ages (n = 26)</i>                         |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| G.3.1.1                                                        | -0.02                                              | 307        | 87          | 0.29                                   | 3.2992                                 | 1.1         | 0.1045                                  | 0.4         | 1706                                             | 7            | 0           |
| G.36.1.1                                                       | 0.04                                               | 461        | 209         | 0.47                                   | 3.4311                                 | 1.1         | 0.1045                                  | 0.4         | 1705                                             | 7            | 3           |
| G.19.1.1                                                       | 0.07                                               | 252        | 112         | 0.46                                   | 3.3709                                 | 1.3         | 0.1045                                  | 0.5         | 1705                                             | 9            | 2           |
| G.34.1.1                                                       | 0.02                                               | 637        | 284         | 0.46                                   | 3.4363                                 | 1.1         | 0.1044                                  | 0.3         | 1705                                             | 6            | 3           |
| G.11.1.1                                                       | 0.01                                               | 734        | 315         | 0.44                                   | 3.3324                                 | 1.1         | 0.1044                                  | 0.2         | 1704                                             | 5            | 1           |
| G.20.1.1                                                       | 0.01                                               | 546        | 226         | 0.43                                   | 3.3513                                 | 1.1         | 0.1044                                  | 0.3         | 1704                                             | 5            | 1           |
| G.39.1.1                                                       | 0.03                                               | 360        | 194         | 0.56                                   | 3.4176                                 | 1.3         | 0.1044                                  | 0.5         | 1703                                             | 9            | 3           |
| G.8.1.1                                                        | 0.04                                               | 1006       | 506         | 0.52                                   | 3.3052                                 | 1.1         | 0.1043                                  | 0.2         | 1702                                             | 4            | 0           |
| G.23.1.1                                                       | 0.00                                               | 410        | 156         | 0.39                                   | 3.3300                                 | 1.2         | 0.1043                                  | 0.3         | 1701                                             | 6            | 0           |
| G.41.1.1                                                       | 0.04                                               | 498        | 228         | 0.47                                   | 3.4503                                 | 1.2         | 0.1042                                  | 0.4         | 1700                                             | 8            | 3           |
| G.27.1.1                                                       | 0.00                                               | 1190       | 795         | 0.69                                   | 3.4741                                 | 1.1         | 0.1041                                  | 0.3         | 1699                                             | 5            | 4           |
| G.1.1.1                                                        | 0.03                                               | 431        | 206         | 0.49                                   | 3.3015                                 | 1.1         | 0.1040                                  | 0.4         | 1696                                             | 8            | -1          |
| G.13.1.1                                                       | 0.11                                               | 764        | 333         | 0.45                                   | 3.4399                                 | 1.1         | 0.1040                                  | 0.3         | 1696                                             | 6            | 3           |
| G.28.1.1                                                       | 0.02                                               | 1665       | 973         | 0.60                                   | 3.4825                                 | 1.1         | 0.1039                                  | 0.2         | 1695                                             | 4            | 4           |
| G.37.1.1                                                       | 0.02                                               | 589        | 234         | 0.41                                   | 3.4162                                 | 1.1         | 0.1039                                  | 0.4         | 1695                                             | 7            | 2           |
| G.30.1.1                                                       | 0.06                                               | 842        | 418         | 0.51                                   | 3.4595                                 | 1.1         | 0.1039                                  | 0.3         | 1695                                             | 6            | 3           |
| G.24.1.1                                                       | 0.04                                               | 609        | 276         | 0.47                                   | 3.3442                                 | 1.1         | 0.1037                                  | 0.3         | 1691                                             | 5            | 0           |
| G.15.1.1                                                       | 0.04                                               | 395        | 177         | 0.46                                   | 3.4612                                 | 1.1         | 0.1036                                  | 0.4         | 1689                                             | 6            | 3           |
| G.12.1.1                                                       | 0.05                                               | 1296       | 720         | 0.57                                   | 3.3299                                 | 1.1         | 0.1035                                  | 0.2         | 1688                                             | 4            | 0           |
| G.5.1.1                                                        | 0.02                                               | 496        | 238         | 0.50                                   | 3.2701                                 | 1.2         | 0.1035                                  | 0.3         | 1688                                             | 6            | -2          |
| G.16.1.1                                                       | 0.01                                               | 525        | 215         | 0.42                                   | 3.3754                                 | 1.1         | 0.1035                                  | 0.3         | 1687                                             | 5            | 1           |
| G.7.1.1                                                        | 0.07                                               | 377        | 152         | 0.42                                   | 3.4445                                 | 1.1         | 0.1034                                  | 0.4         | 1687                                             | 7            | 3           |
| G.17.1.1                                                       | 0.18                                               | 751        | 338         | 0.47                                   | 3.3679                                 | 1.1         | 0.1033                                  | 0.4         | 1685                                             | 8            | 1           |
| G.2.1.1                                                        | 0.09                                               | 554        | 273         | 0.51                                   | 3.3747                                 | 1.1         | 0.1033                                  | 0.3         | 1684                                             | 6            | 1           |
| G.33.1.1                                                       | 0.04                                               | 376        | 135         | 0.37                                   | 3.4266                                 | 1.4         | 0.1031                                  | 1.3         | 1680                                             | 24           | 2           |
| G.10.1.1                                                       | 0.04                                               | 666        | 197         | 0.31                                   | 3.4794                                 | 1.1         | 0.1028                                  | 0.5         | 1676                                             | 9            | 3           |
| <i>Higher Th/U ratio group analyses ≥5% discordant (n = 8)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| G.40.1.1                                                       | 0.13                                               | 530        | 236         | 0.46                                   | 3.6304                                 | 1.2         | 0.1037                                  | 0.5         | 1692                                             | 9            | 7           |
| G.21.1.1                                                       | 0.03                                               | 408        | 98          | 0.25                                   | 3.5881                                 | 1.1         | 0.1046                                  | 0.4         | 1707                                             | 7            | 7           |
| G.18.1.1                                                       | 0.08                                               | 684        | 264         | 0.40                                   | 3.5966                                 | 1.1         | 0.1043                                  | 0.3         | 1702                                             | 6            | 7           |
| G.38.1.1                                                       | 0.30                                               | 939        | 240         | 0.26                                   | 3.6503                                 | 1.1         | 0.1026                                  | 0.5         | 1671                                             | 9            | 7           |
| G.31.1.1                                                       | 0.34                                               | 717        | 332         | 0.48                                   | 3.5923                                 | 1.1         | 0.1031                                  | 0.5         | 1680                                             | 10           | 6           |
| G.9.1.1                                                        | 0.14                                               | 494        | 200         | 0.42                                   | 3.5839                                 | 1.3         | 0.1026                                  | 0.6         | 1672                                             | 11           | 5           |
| G.14.1.1                                                       | 0.07                                               | 1011       | 454         | 0.46                                   | 3.5588                                 | 1.2         | 0.1031                                  | 0.3         | 1681                                             | 5            | 5           |
| G.29.1.1                                                       | 0.04                                               | 486        | 226         | 0.48                                   | 3.4896                                 | 1.2         | 0.1044                                  | 0.5         | 1703                                             | 8            | 5           |
| <i>Lower Th/U ratio ages (n = 9)</i>                           |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| G.22.1.1                                                       | 0.09                                               | 851        | 138         | 0.17                                   | 3.6341                                 | 1.2         | 0.0980                                  | 0.4         | 1587                                             | 7            | 1           |
| G.43.1.1                                                       | -0.01                                              | 2448       | 350         | 0.15                                   | 3.6851                                 | 1.1         | 0.0969                                  | 0.3         | 1566                                             | 5            | 1           |
| G.47.1.1                                                       | 0.01                                               | 2525       | 402         | 0.16                                   | 3.7489                                 | 1.1         | 0.0968                                  | 0.2         | 1563                                             | 4            | 2           |
| G.44.1.1                                                       | 0.01                                               | 2790       | 392         | 0.15                                   | 3.7113                                 | 1.1         | 0.0967                                  | 0.2         | 1561                                             | 4            | 1           |
| G.46.1.1                                                       | 0.00                                               | 3009       | 433         | 0.15                                   | 3.6624                                 | 1.1         | 0.0964                                  | 0.2         | 1555                                             | 4            | 0           |
| G.45.1.1                                                       | 0.01                                               | 2904       | 494         | 0.18                                   | 3.8056                                 | 1.1         | 0.0963                                  | 0.2         | 1553                                             | 4            | 3           |
| G.42.1.1                                                       | 0.01                                               | 2964       | 400         | 0.14                                   | 3.6837                                 | 1.1         | 0.0963                                  | 0.2         | 1553                                             | 4            | 0           |
| G.6.1.1                                                        | 0.00                                               | 3318       | 714         | 0.22                                   | 3.5297                                 | 1.1         | 0.0962                                  | 0.1         | 1552                                             | 3            | -4          |
| G.4.1.1                                                        | 0.00                                               | 3078       | 360         | 0.12                                   | 3.5878                                 | 1.1         | 0.0961                                  | 0.1         | 1551                                             | 2            | -2          |
| <i>Analyses ≥10% discordant (n = 2)</i>                        |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| G.35.1.1                                                       | 0.19                                               | 605        | 212         | 0.36                                   | 4.2492                                 | 1.1         | 0.1032                                  | 0.5         | 1682                                             | 9            | 19          |
| G.26.1.1                                                       | 0.47                                               | 844        | 395         | 0.48                                   | 3.7578                                 | 1.1         | 0.1034                                  | 1.0         | 1686                                             | 18           | 10          |
| <i>Analysis with a large uncertainty (n = 1)</i>               |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| G.25.1.1                                                       | 0.07                                               | 816        | 551         | 0.70                                   | 3.5815                                 | 4.8         | 0.1068                                  | 1.7         | 1745                                             | 32           | 9           |

1. <sup>206</sup>Pb<sub>c</sub> indicates common <sup>206</sup>Pb as a percentage of the total measured <sup>206</sup>Pb.

## 9. EINASLEIGH METAMORPHICS, STOCKMAN CREEK: 2007169012

|                                                |                                                              |
|------------------------------------------------|--------------------------------------------------------------|
| GA Sample ID:                                  | 2007169012                                                   |
| GA Sample Number:                              | 1937161                                                      |
| Other Sample ID:                               |                                                              |
| 1:250,000 Sheet:                               | GEORGETOWN SE5412                                            |
| Region:                                        | Etheridge Province, Queensland                               |
| Grid Reference (WGS 84):                       | 812923mE 7945004mN Zone 54                                   |
| Collector:                                     | N. Neumann, G. Gibson, I. Withnall, L. Lambeck,<br>D. Huston |
| Collection Date:                               | 30/7/2007                                                    |
| Formal Name:                                   | Einasleigh Metamorphics                                      |
| Informal Name:                                 |                                                              |
| Lithology:                                     | Biotite+quartz psammite                                      |
| Geochronologist:                               | N.L. Neumann                                                 |
| Mount ID:                                      | GA6046                                                       |
| Instrument:                                    | SHRIMP IIe Geoscience Australia                              |
| Acquisition Date:                              | 3-7/7/2008                                                   |
| U-Pb Standard & reproducibility:               | TEMORA-2; 1.90% (2 $\sigma$ ) [30 of 31]                     |
| <sup>207</sup> Pb/ <sup>206</sup> Pb Standard: | OG1 (3465.4 $\pm$ 0.6 Ma)                                    |
| Measured Value ( $\pm$ 95% confidence):        | 3467.2 $\pm$ 2.2 Ma [28 of 29]                               |
| Interpreted Age:                               | 1559 $\pm$ 3 Ma                                              |
| IMF correction applied?                        | No                                                           |
| Interpreted Age Type:                          | Zircon recrystallisation age                                 |

**Sample Description**

This sample was collected from Stockman Creek south of the Einasleigh-Forsayth Road, ~15 km southwest of Einasleigh, in the Etheridge Province, Queensland. The sample was collected from a creek pavement outcrop within the Einasleigh Metamorphics (Figure iii), and is a psammitic biotite+quartz gneiss, which is cross-cut by migmatitic layers up to 1m thick (Figure 9.1). When collecting the sample, the migmatitic selvages were avoided where possible.

**Zircon Description**

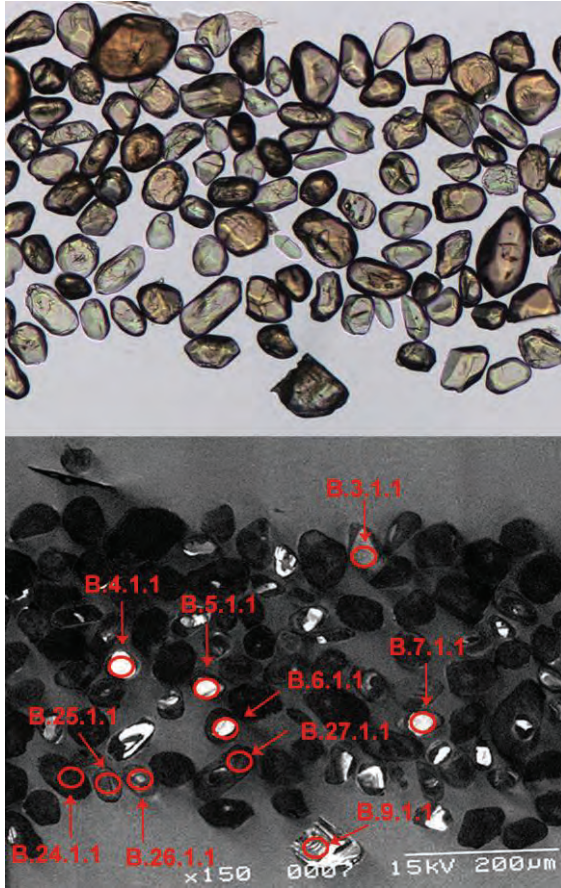
Zircons from this sample range in length from ~40  $\mu$ m to ~80  $\mu$ m, with some larger grains up to ~120  $\mu$ m in length (Figure 9.2). Most grains have euhedral morphologies, with slightly rounded outlines. Most grains are clear, and colourless to light brown in colour. In cathodoluminescence images, many grains record a homogeneous dark cathodoluminescence response. Other grains record either oscillatory zoned or bright



**Figure 9.1.** Outcrop photo of the Einasleigh Metamorphics at the site of sample 2007169012, from Stockman Creek, Etheridge Province.

cathodoluminescence cores, with dark cathodoluminescence rims. Both oscillatory zoned/bright cathodoluminescence cores and grains with a homogeneous dark cathodoluminescence response were analysed.

Where zircons recorded both cores and rims, only the core regions were analysed due to the small size of the zircons.

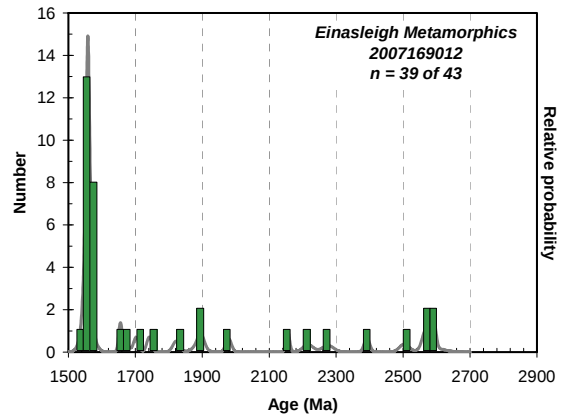


**Figure 9.2.** Representative transmitted light and cathodoluminescence images of zircons from the Einasleigh Metamorphics, Stockman Creek (2007169012), with locations of some SHRIMP analyses.

### U-Pb Isotopic Results

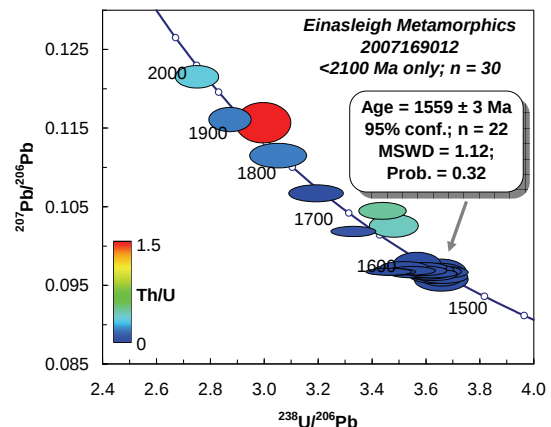
Forty-three zircons were analysed from this sample, the results of which are presented in Table 9.1 and illustrated in Figures 9.3 and 9.4. U concentrations of the analysed zircons range between 3431 and 23 ppm, with Th/U ratios between 1.50 and 0.01. Two analyses containing common  $^{206}\text{Pb}_c$  contents greater than an arbitrary value of 0.5%, and one discordant analysis excluded from further consideration. One other analysis (B.38.1.1) was collected during a period of analytical instability and has also been excluded.

The remaining 39 analyses range in age from ~2594 Ma to ~1539 Ma (Figure 9.3), and the spectra is dominated by an age population at ~1560 Ma. The spectra also includes four ages between ~2594 Ma and ~2556 Ma, and a small number of individuals ranging in age between ~2504 Ma and ~1655 Ma.



**Figure 9.3.** Probability density diagram of zircon analyses from the Einasleigh Metamorphics (2007169012).

The older ages are from oscillatory zoned or bright cathodoluminescence cores, which are surrounded by darker cathodoluminescence rims. The youngest age from this range ( $1655 \pm 10$  Ma;  $2\sigma$ ) corresponds to a zircon which has a Th/U ratio which is lower than most of the other older individuals, and so may have experienced partial isotopic resetting. The next youngest analysis (B.9.1.1) has an age of  $1668 \pm 22$  Ma ( $2\sigma$ ), and a higher Th/U ratio of 0.41.



**Figure 9.4.** Tera-Wasserburg concordia diagram showing results of zircon analyses from the Einasleigh Metamorphics (2007169012) with ages < 2100 Ma, coloured according to Th/U ratio.

The youngest individuals within the spectra form a dominant cluster of ages between ~1576 Ma and ~1539 Ma, and the Th/U ratios of these zircons (0.03 to 0.01) are much lower than the Th/U ratios of the older ~2600 Ma to ~1650 Ma ages (Figure 9.4). These analyses are from dark cathodoluminescence grains. The weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age for the 22 individuals in this lower Th/U ratio group is  $1559 \pm 3$  Ma (95% confidence; MSWD = 1.12; probability of fit = 0.32).

### Geochronological Interpretation

The age of the youngest group of individuals from this sample is  $1559 \pm 3$  Ma (95% confidence;  $n = 22$ ), and as this age is calculated from zircons with low Th/U ratios, it is interpreted to represent the age of zircon recrystallisation within the rock. This sample also has a range of older ages from core regions within some zircons, which may suggest that the precursor rock type was sedimentary in origin. Although it is not possible to interpret a maximum depositional age for this sample due to the small number of ages present, the ~1670 Ma age from the youngest zircon within this group with an Th/U ratio  $>0.1$  may provide a maximum constraint on the age of deposition.

**Table 9.1.** SHRIMP U-Pb isotopic data for zircons from sample 2007169012 (1937161), Einasleigh Metamorphics, Stockman Creek.

| Grain.area                                                             | $^{206}\text{Pb}_c$<br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | $^{232}\text{Th}/$<br>$^{238}\text{U}$ | $^{238}\text{U}/$<br>$^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/$<br>$^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/^{206}\text{Pb}$<br>Age (Ma) | $\pm 1\sigma$<br>(Ma) | Disc<br>(%) |
|------------------------------------------------------------------------|-----------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|----------------------|-----------------------------------------|----------------------|-----------------------------------------------|-----------------------|-------------|
| <i>Detrital zircon (n = 17)</i>                                        |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| B.8.1.1                                                                | 0.06                                    | 381        | 388         | 1.05                                   | 2.0290                                 | 1.1                  | 0.1737                                  | 0.3                  | 2594                                          | 6                     | 0           |
| B.20.1.1                                                               | 0.04                                    | 405        | 464         | 1.18                                   | 2.0495                                 | 1.1                  | 0.1735                                  | 1.8                  | 2592                                          | 30                    | 1           |
| B.19.1.1                                                               | 0.32                                    | 218        | 77          | 0.36                                   | 2.0975                                 | 1.2                  | 0.1715                                  | 0.7                  | 2573                                          | 12                    | 2           |
| B.10.1.1                                                               | 0.01                                    | 377        | 144         | 0.39                                   | 2.1060                                 | 1.1                  | 0.1709                                  | 0.6                  | 2566                                          | 10                    | 2           |
| B.5.1.1                                                                | 0.10                                    | 234        | 147         | 0.65                                   | 2.3740                                 | 1.4                  | 0.1646                                  | 0.9                  | 2504                                          | 14                    | 9           |
| B.6.1.1                                                                | 0.11                                    | 258        | 86          | 0.34                                   | 2.2819                                 | 1.5                  | 0.1541                                  | 0.5                  | 2392                                          | 8                     | 2           |
| B.13.1.1                                                               | 0.21                                    | 536        | 151         | 0.29                                   | 2.6256                                 | 1.3                  | 0.1440                                  | 1.0                  | 2275                                          | 17                    | 9           |
| B.35.1.1                                                               | 0.40                                    | 935        | 89          | 0.10                                   | 2.6740                                 | 1.0                  | 0.1391                                  | 0.9                  | 2216                                          | 15                    | 8           |
| B.26.1.1                                                               | 0.10                                    | 1039       | 188         | 0.19                                   | 2.7894                                 | 1.0                  | 0.1343                                  | 0.3                  | 2155                                          | 6                     | 8           |
| B.16.1.1                                                               | 0.03                                    | 722        | 232         | 0.33                                   | 2.7412                                 | 1.2                  | 0.1215                                  | 0.5                  | 1979                                          | 9                     | -1          |
| B.7.1.1                                                                | 0.09                                    | 323        | 57          | 0.18                                   | 2.8640                                 | 1.1                  | 0.1160                                  | 0.5                  | 1896                                          | 10                    | -2          |
| B.40.1.1                                                               | 0.15                                    | 105        | 153         | 1.50                                   | 2.9875                                 | 1.4                  | 0.1156                                  | 0.9                  | 1890                                          | 16                    | 2           |
| B.28.1.1                                                               | 0.07                                    | 467        | 83          | 0.18                                   | 3.0443                                 | 1.4                  | 0.1114                                  | 0.6                  | 1822                                          | 10                    | 0           |
| B.12.1.1                                                               | 0.05                                    | 1199       | 36          | 0.03                                   | 3.1858                                 | 1.3                  | 0.1066                                  | 0.4                  | 1742                                          | 8                     | -1          |
| B.11.1.1                                                               | 0.14                                    | 738        | 347         | 0.49                                   | 3.4348                                 | 1.1                  | 0.1043                                  | 0.4                  | 1703                                          | 8                     | 3           |
| B.9.1.1                                                                | 0.18                                    | 556        | 223         | 0.41                                   | 3.4768                                 | 1.1                  | 0.1024                                  | 0.6                  | 1668                                          | 11                    | 2           |
| B.18.1.1                                                               | 0.04                                    | 1461       | 105         | 0.07                                   | 3.3253                                 | 1.0                  | 0.1017                                  | 0.3                  | 1655                                          | 5                     | -2          |
| <i>~1559 Ma zircons (n = 22)</i>                                       |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| B.15.1.1                                                               | 0.11                                    | 1697       | 23          | 0.01                                   | 3.5637                                 | 1.0                  | 0.0974                                  | 0.7                  | 1576                                          | 12                    | -1          |
| B.43.1.1                                                               | 0.04                                    | 1296       | 19          | 0.02                                   | 3.5148                                 | 1.0                  | 0.0971                                  | 0.3                  | 1570                                          | 6                     | -3          |
| B.23.1.1                                                               | 0.00                                    | 1647       | 20          | 0.01                                   | 3.5853                                 | 1.0                  | 0.0971                                  | 0.2                  | 1569                                          | 5                     | -1          |
| B.37.1.1                                                               | 0.03                                    | 1138       | 16          | 0.01                                   | 3.5897                                 | 1.0                  | 0.0968                                  | 0.3                  | 1563                                          | 6                     | -1          |
| B.34.1.1                                                               | 0.02                                    | 1025       | 26          | 0.03                                   | 3.6088                                 | 1.0                  | 0.0967                                  | 0.3                  | 1562                                          | 6                     | -1          |
| B.25.1.1                                                               | 0.04                                    | 1285       | 19          | 0.02                                   | 3.4914                                 | 1.1                  | 0.0967                                  | 0.3                  | 1562                                          | 5                     | -4          |
| B.1.1.1                                                                | 0.02                                    | 3431       | 31          | 0.01                                   | 3.5434                                 | 1.0                  | 0.0967                                  | 0.2                  | 1561                                          | 4                     | -3          |
| B.33.1.1                                                               | 0.02                                    | 1564       | 44          | 0.03                                   | 3.5860                                 | 1.0                  | 0.0967                                  | 0.3                  | 1561                                          | 5                     | -2          |
| B.22.1.1                                                               | 0.03                                    | 969        | 25          | 0.03                                   | 3.6034                                 | 1.0                  | 0.0966                                  | 0.3                  | 1559                                          | 6                     | -1          |
| B.39.1.1                                                               | 0.01                                    | 2873       | 36          | 0.01                                   | 3.4569                                 | 1.0                  | 0.0965                                  | 0.2                  | 1558                                          | 4                     | -5          |
| B.42.1.1                                                               | 0.01                                    | 1044       | 28          | 0.03                                   | 3.6362                                 | 1.0                  | 0.0965                                  | 0.3                  | 1558                                          | 6                     | -1          |
| B.41.1.1                                                               | 0.01                                    | 3168       | 31          | 0.01                                   | 3.4723                                 | 1.0                  | 0.0965                                  | 0.2                  | 1558                                          | 3                     | -5          |
| B.32.1.1                                                               | 0.03                                    | 1187       | 26          | 0.02                                   | 3.6607                                 | 1.0                  | 0.0965                                  | 0.3                  | 1557                                          | 6                     | 0           |
| B.29.1.1                                                               | 0.09                                    | 1782       | 19          | 0.01                                   | 3.5419                                 | 1.0                  | 0.0965                                  | 0.3                  | 1557                                          | 6                     | -3          |
| B.21.1.1                                                               | 0.45                                    | 718        | 17          | 0.02                                   | 3.6541                                 | 1.1                  | 0.0964                                  | 0.7                  | 1556                                          | 14                    | 0           |
| B.36.1.1                                                               | 0.28                                    | 986        | 23          | 0.02                                   | 3.6496                                 | 1.0                  | 0.0964                                  | 0.5                  | 1556                                          | 9                     | 0           |
| B.24.1.1                                                               | 0.02                                    | 1887       | 23          | 0.01                                   | 3.6233                                 | 1.0                  | 0.0963                                  | 0.2                  | 1554                                          | 4                     | -1          |
| B.27.1.1                                                               | 0.02                                    | 1219       | 19          | 0.02                                   | 3.6008                                 | 1.0                  | 0.0963                                  | 0.3                  | 1553                                          | 6                     | -2          |
| B.2.1.1                                                                | 0.03                                    | 1370       | 23          | 0.02                                   | 3.6219                                 | 1.0                  | 0.0962                                  | 0.3                  | 1552                                          | 6                     | -1          |
| B.30.1.1                                                               | 0.22                                    | 1041       | 19          | 0.02                                   | 3.6251                                 | 1.0                  | 0.0962                                  | 0.5                  | 1551                                          | 9                     | -1          |
| B.14.1.1                                                               | 0.08                                    | 948        | 22          | 0.02                                   | 3.6606                                 | 1.0                  | 0.0959                                  | 0.4                  | 1546                                          | 7                     | -1          |
| B.3.1.1                                                                | 0.07                                    | 522        | 13          | 0.03                                   | 3.6537                                 | 1.1                  | 0.0956                                  | 0.7                  | 1539                                          | 12                    | -1          |
| <i>Analyses with <math>^{206}\text{Pb}_c &gt; 0.5\%</math> (n = 2)</i> |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| B.4.1.1                                                                | 5.02                                    | 23         | 25          | 1.12                                   | 3.2405                                 | 2.4                  | 0.1086                                  | 8.3                  | 1776                                          | 152                   | 2           |
| B.31.1.1                                                               | 0.62                                    | 806        | 48          | 0.06                                   | 3.4144                                 | 1.0                  | 0.0987                                  | 0.9                  | 1599                                          | 16                    | -4          |
| <i>Analysis &gt;10% discordant (n = 1)</i>                             |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| B.17.1.1                                                               | 0.02                                    | 1454       | 472         | 0.34                                   | 2.8060                                 | 1.0                  | 0.1398                                  | 0.6                  | 2224                                          | 10                    | 12          |
| <i>Analysis with a large uncertainty (n = 1)</i>                       |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| B.38.1.1                                                               | 0.02                                    | 1005       | 13          | 0.01                                   | 2.7193                                 | 1.0                  | 0.1334                                  | 6.5                  | 2143                                          | 113                   | 6           |

1.  $^{206}\text{Pb}_c$  indicates common  $^{206}\text{Pb}$  as a percentage of the total measured  $^{206}\text{Pb}$ .

## 10. EINASLEIGH METAMORPHICS, JUNCTION CREEK: 2007169014

|                                                |                                                              |
|------------------------------------------------|--------------------------------------------------------------|
| GA Sample ID:                                  | 2007169014                                                   |
| GA Sample Number:                              | 1937163                                                      |
| Other Sample ID:                               |                                                              |
| 1:250,000 Sheet:                               | EINASLEIGH SE5509                                            |
| Region:                                        | Etheridge Province, Queensland                               |
| Grid Reference (WGS 84):                       | 208120mE 7988372mN Zone 54                                   |
| Collector:                                     | N. Neumann, G. Gibson, I. Withnall, L. Lambeck,<br>D. Huston |
| Collection Date:                               | 31/7/2007                                                    |
| Formal Name:                                   | Einasleigh Metamorphics                                      |
| Informal Name:                                 |                                                              |
| Lithology:                                     | Sillimanite+garnet granitic gneiss                           |
| Geochronologist:                               | N.L. Neumann                                                 |
| Mount ID:                                      | GA6046                                                       |
| Instrument:                                    | SHRIMP IIe Geoscience Australia                              |
| Acquisition Date:                              | 3-7/7/2008                                                   |
| U-Pb Standard & reproducibility:               | TEMORA-2; 1.90% (2 $\sigma$ ) [30 of 31]                     |
| <sup>207</sup> Pb/ <sup>206</sup> Pb Standard: | OG1 (3465.4 $\pm$ 0.6 Ma)                                    |
| Measured Value ( $\pm$ 95% confidence):        | 3467.2 $\pm$ 2.2 Ma [28 of 29]                               |
| Interpreted Age:                               | 1568 $\pm$ 4 Ma                                              |
| IMF correction applied?                        | No                                                           |
| Interpreted Age Type:                          | Zircon recrystallisation age                                 |

**Sample Description**

This sample was collected from Junction Creek directly north of the Gulf Developmental Road, west of Mount Surprise, in the Etheridge Province, Queensland. The sample is mapped as a subunit of the Einasleigh Metamorphics (Figure iii), and consists of a quartz +feldspar+sillimanite+garnet granitic gneiss (Figure 10.1). The granitic gneiss occurs as pods within a migmatite, which is the dominant rock type at this locality.

**Zircon Description**

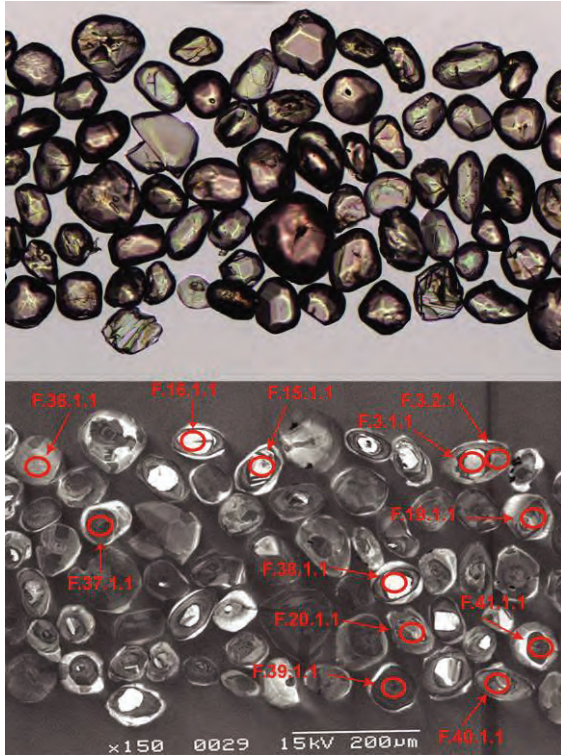
Zircons from this sample range in length from ~50  $\mu$ m to ~130  $\mu$ m (Figure 10.2). Some grains have rounded euhedral morphologies, while others record rounded 'golf-ball'-type morphologies. Grains are clear, and colourless to light brown in colour. Cathodoluminescence images record a number of different responses. Some grains have oscillatory zoned or bright cathodoluminescence core regions which have



**Figure 10.1.** Outcrop photo of a granitic gneiss within the Einasleigh Metamorphics at the site of sample 2007169014, at Junction Creek, Etheridge Province.

irregular shapes, and are rimmed by darker cathodoluminescence rims. Other grains with golf-ball morphologies have a homogeneous dark

zoned cathodoluminescence response, which are sometimes rimmed by bright cathodoluminescence zones. Analyses focussed on the range of cathodoluminescence responses, and on both core and rim regions of single grains, where possible.



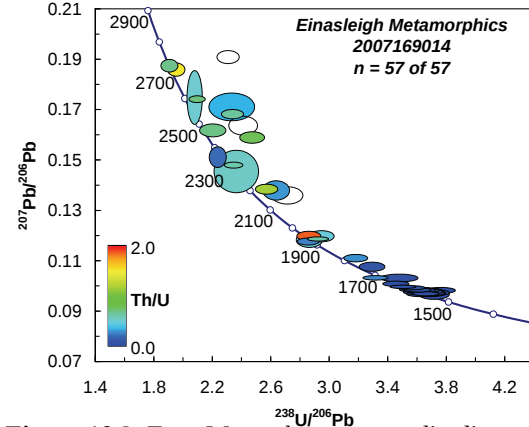
**Figure 10.2.** Representative transmitted light and cathodoluminescence images of zircons from a granitic gneiss within the Einasleigh Metamorphics, Junction Creek (2007169014), with locations of some SHRIMP analyses.

### U-Pb Isotopic Results

Fifty-seven zircons were analysed from this sample, the results of which are presented in Table 10.1 and illustrated in Figures 10.3 and 10.4. U concentrations of the analysed zircons range between 1208 and 64 ppm, with Th/U ratios between 1.87 and 0.01. Two analyses containing common  $^{206}\text{Pb}_c$  contents greater than an arbitrary value of >0.5%, and one analysis >10% discordant were excluded from further consideration.

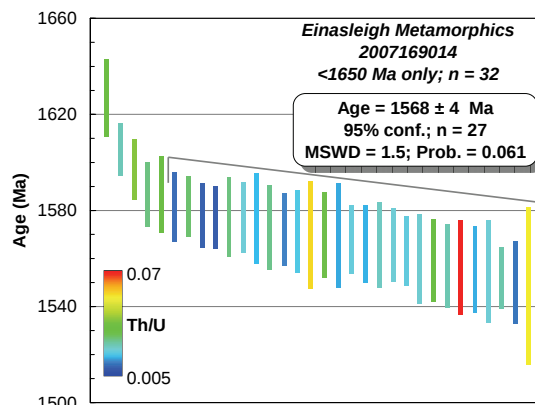
The remaining 54 analyses range in age from ~2719 Ma to ~1548 Ma (Figure 10.3), and include 13 individuals which range in age between ~2719 Ma and ~2196 Ma, five individuals between ~1946 Ma and ~1912 Ma,

individual ages at ~1807 Ma and at ~1749 Ma, and two ages at ~1670 Ma. There is a large cluster of younger ages between ~1627 Ma and the youngest individual at ~1548 Ma, but the MSWD value (= 4.7) of the weighted mean age for this youngest cluster (n = 32) indicates that it is not a statistically coherent group.



**Figure 10.3.** Tera-Wasserburg concordia diagram showing results of zircon analyses from a granitic gneiss within the Einasleigh Metamorphics (2007169014), coloured according to Th/U ratio. Open ellipses represent analyses excluded from age interpretations.

The Th/U ratios for this entire group are low but homogenous, and so cannot be used to distinguish between different groups within the cluster (Figure 10.4). Excluding the oldest 5 individuals provides a weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age for the remaining 27 analyses of  $1568 \pm 4$  Ma (95% confidence; MSWD = 1.5; probability of fit = 0.061; Figure 10.4).



**Figure 10.4.** Mean age diagram showing  $^{207}\text{Pb}/^{206}\text{Pb}$  ages younger than 1700 Ma of zircon analyses from a granitic gneiss within the Einasleigh Metamorphics (2007169014).

### **Geochronological Interpretation**

Due to the low Th/U ratios within zircons recording the youngest ages within the sample, the weighted mean age of  $1568 \pm 4$  Ma (95% confidence;  $n = 27$ ) is interpreted to record the age of metamorphism within this granitic gneiss. Ages older than this group are abundant but dispersed, so it is difficult to interpret a maximum age of deposition or magmatic age of the protolith to this sample.

**Table 10.1.** SHRIMP U-Pb isotopic data for zircons from sample 2007169014 (1937163), a granitic gneiss within the Einasleigh Metamorphics, Junction Creek.

| Grain.area                                                         | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|--------------------------------------------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| <i>Unassigned zircons (n = 27)</i>                                 |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| F.2.1.1                                                            | 0.04                                               | 350        | 230         | 0.68                                   | 1.8935                                 | 1.2         | 0.1874                                  | 0.5         | 2719                                             | 9            | -1          |
| F.18.1.1                                                           | 0.12                                               | 148        | 217         | 1.51                                   | 1.9411                                 | 1.3         | 0.1858                                  | 0.6         | 2706                                             | 10           | 1           |
| F.31.1.1                                                           | 0.01                                               | 774        | 373         | 0.50                                   | 2.0664                                 | 1.0         | 0.1747                                  | 2.5         | 2603                                             | 42           | 2           |
| F.20.1.1                                                           | 0.03                                               | 435        | 296         | 0.70                                   | 2.0839                                 | 1.1         | 0.1740                                  | 0.3         | 2596                                             | 5            | 3           |
| F.46.1.1                                                           | 0.25                                               | 64         | 21          | 0.34                                   | 2.3210                                 | 2.8         | 0.1710                                  | 1.3         | 2567                                             | 22           | 10          |
| F.29.1.1                                                           | 0.21                                               | 550        | 342         | 0.64                                   | 2.3262                                 | 1.4         | 0.1680                                  | 0.5         | 2538                                             | 8            | 9           |
| F.22.1.1                                                           | 0.02                                               | 388        | 258         | 0.69                                   | 2.1912                                 | 1.7         | 0.1614                                  | 0.7         | 2470                                             | 11           | 2           |
| F.49.1.1                                                           | 0.05                                               | 258        | 193         | 0.77                                   | 2.4628                                 | 1.4         | 0.1587                                  | 0.6         | 2442                                             | 10           | 10          |
| F.27.1.1                                                           | 0.02                                               | 868        | 165         | 0.20                                   | 2.2248                                 | 1.1         | 0.1508                                  | 1.1         | 2355                                             | 19           | -2          |
| F.14.1.1                                                           | 0.01                                               | 483        | 283         | 0.60                                   | 2.3352                                 | 1.1         | 0.1476                                  | 0.3         | 2319                                             | 6            | 1           |
| F.54.1.1                                                           | 0.09                                               | 154        | 79          | 0.53                                   | 2.3522                                 | 2.7         | 0.1451                                  | 2.4         | 2289                                             | 41           | 0           |
| F.13.1.1                                                           | 0.03                                               | 205        | 228         | 1.15                                   | 2.5607                                 | 1.2         | 0.1380                                  | 0.6         | 2202                                             | 10           | 4           |
| F.15.1.1                                                           | 0.05                                               | 259        | 73          | 0.29                                   | 2.6269                                 | 1.4         | 0.1375                                  | 1.2         | 2196                                             | 20           | 5           |
| F.21.1.1                                                           | 0.05                                               | 263        | 474         | 1.87                                   | 2.8514                                 | 1.2         | 0.1193                                  | 0.7         | 1946                                             | 12           | 0           |
| F.3.1.1                                                            | 0.03                                               | 350        | 155         | 0.46                                   | 2.9366                                 | 1.2         | 0.1192                                  | 0.8         | 1945                                             | 14           | 3           |
| F.4.1.1                                                            | 0.08                                               | 831        | 489         | 0.61                                   | 2.9154                                 | 1.0         | 0.1181                                  | 0.3         | 1928                                             | 5            | 1           |
| F.38.1.1                                                           | 0.07                                               | 149        | 67          | 0.47                                   | 2.8553                                 | 1.3         | 0.1177                                  | 1.0         | 1921                                             | 19           | -1          |
| F.50.1.1                                                           | 0.02                                               | 583        | 141         | 0.25                                   | 2.8463                                 | 1.1         | 0.1171                                  | 0.5         | 1912                                             | 9            | -2          |
| F.40.1.1                                                           | 0.06                                               | 664        | 178         | 0.28                                   | 3.1737                                 | 1.1         | 0.1104                                  | 0.6         | 1807                                             | 10           | 2           |
| F.19.1.1                                                           | 0.08                                               | 464        | 37          | 0.08                                   | 3.2857                                 | 1.1         | 0.1070                                  | 0.7         | 1749                                             | 13           | 2           |
| F.48.1.1                                                           | 0.06                                               | 790        | 202         | 0.26                                   | 3.3101                                 | 1.1         | 0.1026                                  | 0.4         | 1672                                             | 7            | -2          |
| F.51.1.1                                                           | 0.10                                               | 706        | 45          | 0.07                                   | 3.4725                                 | 1.5         | 0.1025                                  | 0.6         | 1670                                             | 11           | 2           |
| F.33.1.1                                                           | 0.04                                               | 624        | 20          | 0.03                                   | 3.4486                                 | 1.1         | 0.1001                                  | 0.4         | 1627                                             | 8            | -1          |
| F.30.1.1                                                           | 0.03                                               | 1208       | 28          | 0.02                                   | 3.4971                                 | 1.0         | 0.0990                                  | 0.3         | 1606                                             | 6            | -1          |
| F.35.1.1                                                           | 0.02                                               | 967        | 37          | 0.04                                   | 3.5590                                 | 1.0         | 0.0986                                  | 0.3         | 1597                                             | 6            | 0           |
| F.32.1.1                                                           | 0.01                                               | 821        | 22          | 0.03                                   | 3.5902                                 | 1.1         | 0.0980                                  | 0.4         | 1587                                             | 7            | 0           |
| F.21.2.1                                                           | 0.02                                               | 610        | 20          | 0.03                                   | 3.5677                                 | 1.1         | 0.0980                                  | 0.4         | 1587                                             | 8            | 0           |
| <i>~1568 Ma zircons (n = 27)</i>                                   |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| F.39.1.1                                                           | 0.05                                               | 944        | 11          | 0.01                                   | 3.6110                                 | 1.0         | 0.0977                                  | 0.4         | 1581                                             | 7            | 0           |
| F.5.1.1                                                            | 0.02                                               | 945        | 26          | 0.03                                   | 3.6000                                 | 1.0         | 0.0977                                  | 0.3         | 1581                                             | 6            | 0           |
| F.37.1.1                                                           | 0.02                                               | 912        | 9           | 0.01                                   | 3.6296                                 | 1.0         | 0.0976                                  | 0.4         | 1578                                             | 7            | 1           |
| F.25.1.1                                                           | 0.00                                               | 834        | 8           | 0.01                                   | 3.6551                                 | 1.0         | 0.0975                                  | 0.3         | 1577                                             | 7            | 1           |
| F.3.2.1                                                            | 0.07                                               | 568        | 15          | 0.03                                   | 3.6252                                 | 1.1         | 0.0975                                  | 0.4         | 1577                                             | 8            | 0           |
| F.10.1.1                                                           | 0.00                                               | 675        | 13          | 0.02                                   | 3.6722                                 | 1.1         | 0.0975                                  | 0.4         | 1577                                             | 7            | 2           |
| F.45.1.1                                                           | 0.05                                               | 457        | 7           | 0.02                                   | 3.7598                                 | 1.1         | 0.0975                                  | 0.5         | 1576                                             | 9            | 4           |
| F.34.1.1                                                           | 0.07                                               | 594        | 16          | 0.03                                   | 3.6158                                 | 1.1         | 0.0973                                  | 0.5         | 1573                                             | 9            | 0           |
| F.41.1.1                                                           | 0.05                                               | 792        | 10          | 0.01                                   | 3.6108                                 | 1.1         | 0.0973                                  | 0.4         | 1572                                             | 8            | 0           |
| F.12.1.1                                                           | 0.07                                               | 567        | 10          | 0.02                                   | 3.6536                                 | 1.1         | 0.0972                                  | 0.5         | 1571                                             | 9            | 1           |
| F.7.1.1                                                            | -0.02                                              | 292        | 16          | 0.06                                   | 3.6259                                 | 1.1         | 0.0971                                  | 0.6         | 1570                                             | 11           | 0           |
| F.42.1.1                                                           | 0.07                                               | 594        | 18          | 0.03                                   | 3.5979                                 | 1.1         | 0.0971                                  | 0.5         | 1570                                             | 9            | -1          |
| F.24.1.1                                                           | 0.05                                               | 428        | 6           | 0.02                                   | 3.6641                                 | 1.1         | 0.0971                                  | 0.6         | 1569                                             | 11           | 1           |
| F.9.1.1                                                            | 0.02                                               | 754        | 14          | 0.02                                   | 3.6795                                 | 1.1         | 0.0970                                  | 0.4         | 1568                                             | 7            | 1           |
| F.43.1.1                                                           | 0.06                                               | 644        | 10          | 0.02                                   | 3.6294                                 | 1.1         | 0.0969                                  | 0.4         | 1566                                             | 8            | 0           |
| F.44.1.1                                                           | 0.07                                               | 572        | 12          | 0.02                                   | 3.6371                                 | 1.1         | 0.0969                                  | 0.5         | 1566                                             | 9            | 0           |
| F.52.1.1                                                           | -0.01                                              | 644        | 13          | 0.02                                   | 3.6267                                 | 1.1         | 0.0969                                  | 0.4         | 1565                                             | 8            | 0           |
| F.11.1.1                                                           | 0.04                                               | 790        | 15          | 0.02                                   | 3.5943                                 | 1.1         | 0.0968                                  | 0.4         | 1563                                             | 7            | -1          |
| F.28.1.1                                                           | 0.03                                               | 519        | 11          | 0.02                                   | 3.7158                                 | 1.1         | 0.0966                                  | 0.5         | 1560                                             | 9            | 2           |
| F.1.1.1                                                            | 0.06                                               | 537        | 18          | 0.03                                   | 3.6928                                 | 1.1         | 0.0966                                  | 0.5         | 1559                                             | 9            | 1           |
| F.6.1.1                                                            | 0.04                                               | 534        | 13          | 0.02                                   | 3.6360                                 | 1.1         | 0.0965                                  | 0.5         | 1557                                             | 9            | -1          |
| F.36.1.1                                                           | 0.02                                               | 400        | 27          | 0.07                                   | 3.6794                                 | 1.1         | 0.0964                                  | 0.5         | 1556                                             | 10           | 0           |
| F.26.1.1                                                           | 0.13                                               | 648        | 10          | 0.02                                   | 3.6781                                 | 1.1         | 0.0964                                  | 0.5         | 1555                                             | 9            | 0           |
| F.47.1.1                                                           | 0.07                                               | 587        | 12          | 0.02                                   | 3.6929                                 | 1.1         | 0.0964                                  | 0.6         | 1555                                             | 11           | 1           |
| F.1.2.1                                                            | 0.01                                               | 878        | 21          | 0.02                                   | 3.6534                                 | 1.0         | 0.0962                                  | 0.3         | 1552                                             | 6            | -1          |
| F.8.1.1                                                            | 0.10                                               | 681        | 8           | 0.01                                   | 3.6169                                 | 1.1         | 0.0961                                  | 0.5         | 1550                                             | 9            | -2          |
| F.23.1.1                                                           | 0.10                                               | 308        | 16          | 0.05                                   | 3.7126                                 | 1.1         | 0.0960                                  | 0.9         | 1548                                             | 16           | 1           |
| <i>Analyses with <sup>206</sup>Pb<sub>c</sub> &gt;0.5% (n = 2)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| F.17.1.1                                                           | 0.70                                               | 125        | 76          | 0.62                                   | 2.4005                                 | 1.7         | 0.1635                                  | 0.9         | 2492                                             | 16           | 10          |
| F.53.1.1                                                           | 0.52                                               | 151        | 94          | 0.64                                   | 2.7047                                 | 1.6         | 0.1355                                  | 1.0         | 2170                                             | 18           | 7           |
| <i>Analysis &gt;10% discordant (n = 1)</i>                         |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| F.16.1.1                                                           | 0.14                                               | 205        | 171         | 0.86                                   | 2.2969                                 | 1.3         | 0.1908                                  | 0.6         | 2749                                             | 9            | 15          |

1. <sup>206</sup>Pb<sub>c</sub> indicates common <sup>206</sup>Pb as a percentage of the total measured <sup>206</sup>Pb.

# 11. EINASLEIGH METAMORPHICS, SOUTH-SOUTHWEST OF LYNDBURST STATION: 2007169015

|                                                |                                                              |
|------------------------------------------------|--------------------------------------------------------------|
| GA Sample ID:                                  | 2007169015                                                   |
| GA Sample Number:                              | 1937164                                                      |
| Other Sample ID:                               |                                                              |
| 1:250,000 Sheet:                               | CLARKE RIVER SE5513                                          |
| Region:                                        | Etheridge Province, Queensland                               |
| Grid Reference (WGS 84):                       | 219485mE 7860486mN Zone 55                                   |
| Collector:                                     | N. Neumann, G. Gibson, I. Withnall, L. Lambeck,<br>D. Huston |
| Collection Date:                               | 1/8/2007                                                     |
| Formal Name:                                   | Einasleigh Metamorphics                                      |
| Informal Name:                                 |                                                              |
| Lithology:                                     | Hornblende+diopside calc-silicate                            |
| Geochronologist:                               | N.L. Neumann                                                 |
| Mount ID:                                      | GA6046                                                       |
| Instrument:                                    | SHRIMP IIe Geoscience Australia                              |
| Acquisition Date:                              | 3-7/7/2008                                                   |
| U-Pb Standard & reproducibility:               | TEMORA-2; 1.90% (2 $\sigma$ ) [30 of 31]                     |
| <sup>207</sup> Pb/ <sup>206</sup> Pb Standard: | OG1 (3465.4 $\pm$ 0.6 Ma)                                    |
| Measured Value ( $\pm$ 95% confidence):        | 3467.2 $\pm$ 2.2 Ma [28 of 29]                               |
| Interpreted Age:                               | 1568 $\pm$ 4 Ma                                              |
| IMF correction applied?                        | No                                                           |
| Interpreted Age Type:                          | Zircon recrystallisation age                                 |

## Sample Description

This sample was collected from a creek section west of the Kennedy Developmental Road, ~15 km south-southwest of Lyndhurst, in the Etheridge Province, Queensland. A previous zircon geochronological study by Black et al. (2005) analysed a leucocratic quartzo-feldspathic gneiss from the same creek section. In that study, a weighted mean age of 1703  $\pm$  14 Ma was interpreted to record the crystallisation age of the sample, with a younger age of 1563  $\pm$  4 Ma interpreted to represent zircon recrystallisation. In the current study, a hornblende-diopside calc-silicate rock, mapped as a subunit of the Einasleigh Metamorphics (Figure iii), was sampled (Figure 11.1).

## Zircon Description

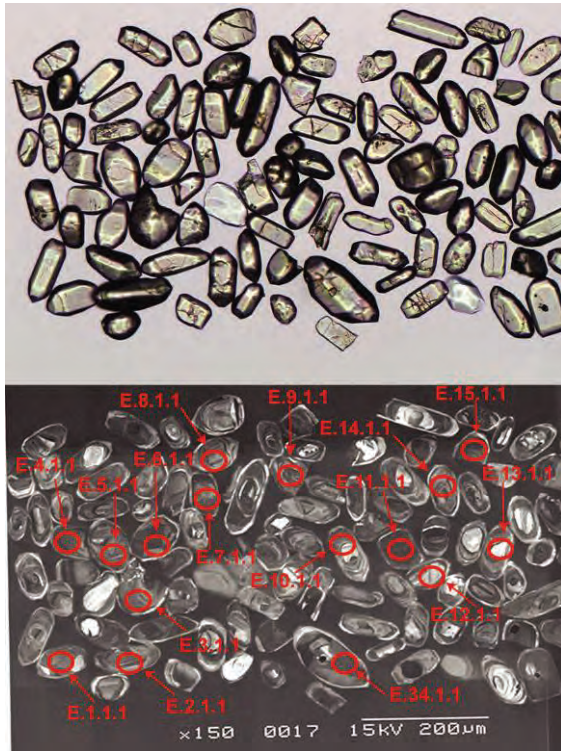
Zircons from this sample range in length from ~60  $\mu$ m to ~100  $\mu$ m, with some large grains up to ~150  $\mu$ m in length (Figure 11.2). Most grains



**Figure 11.1.** Outcrop photo of the Einasleigh Metamorphics at the site of sample 2007169015, south-southwest of Lyndhurst, Etheridge Province.

have rounded euhedral morphologies, and are clear and colourless, with few internal inclusions or cracks.

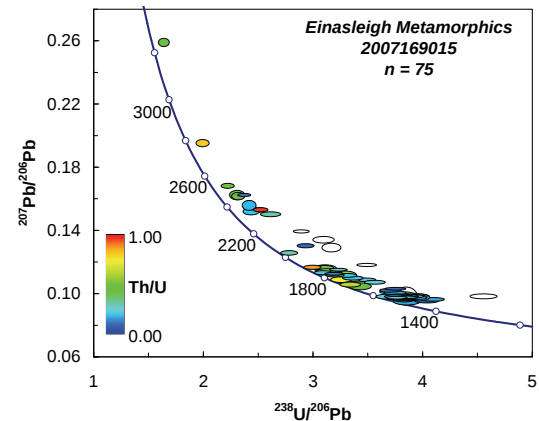
Cathodoluminescence images record a number of different responses. Some grains have oscillatory zoned or bright cathodoluminescence core regions which have irregular shapes, and are rimmed by darker cathodoluminescence rims, while others have thin bright cathodoluminescence rims. Analyses focused on the variety of cathodoluminescence responses, but it was not possible to analyse both the core and rim regions on single grains due to the small size of the zircons.



**Figure 11.2.** Representative transmitted light and cathodoluminescence images of zircons from Einasleigh Metamorphics (2007169015), with locations of some SHRIMP analyses.

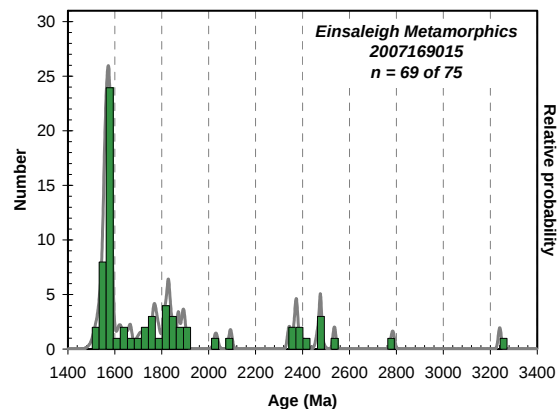
### U-Pb Isotopic Results

Seventy-five zircons were analysed from this sample, the results of which are presented in Table 11.1 and illustrated in Figures 11.3 to 11.5. U concentrations of the analysed zircons range between 1372 and 152 ppm, with Th/U ratios between 0.96 and 0.02. One analysis containing a common  $^{206}\text{Pb}_c$  content greater than an arbitrary value of 0.5%, and five analyses >10% discordant were excluded from further consideration (Figure 11.3).



**Figure 11.3.** Tera-Wasserburg concordia diagram showing results of zircon analyses from the Einasleigh Metamorphics (2007169015), coloured according to Th/U content. Open ellipses represent analyses excluded from age interpretations.

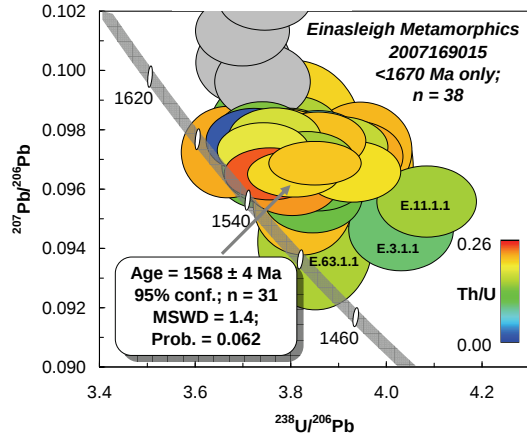
The remaining 69 analyses range in age from ~3240 Ma to ~1512 Ma (Figure 11.4). This spectrum includes individual ages at ~3240 Ma and ~2784 Ma, nine ages between ~2536 Ma and ~2342 Ma, individual ages at ~2093 Ma and ~2031 Ma, and a large number of ages between ~1895 Ma and the youngest individual age at ~1512 Ma (Figure 11.4).



**Figure 11.4.** Probability density diagram of zircon analyses from the Einasleigh Metamorphics (2007169015).

The youngest age forms part of a large cluster of ages between ~1583 Ma and ~1512 Ma, but the MSWD for the weighted mean age of the entire group (MSWD = 2.3;  $n = 34$ ) indicates that it is not a statistically coherent group. Th/U ratios for these analyses range between 0.24 and 0.02 (average = 0.17; Figure 11.5). Using mixture modelling (Sambridge and Compston, 1994) of

this group based on two components gives ages of  $1535 \pm 14$  Ma ( $2\sigma$ ; 14% of the cluster) and  $1569 \pm 4$  Ma ( $2\sigma$ ; 86% of the cluster).



**Figure 11.5.** Tera-Wasserburg concordia diagram showing results of zircon analyses with  $^{207}\text{Pb}/^{206}\text{Pb}$  ages less than 1670 Ma from the Einasleigh Metamorphics (2007169015), coloured according to Th/U ratio. Grey ellipses represent older ages excluded from all age calculations. Three labelled analyses were excluded from weighted mean age calculations.

Alternatively, if the youngest individual (E.63.1.1) which has a large uncertainty, and two of the three next youngest individuals (E.3.1.1 and E.11.1.1), which are greater than 5% discordant, are excluded (Figure 11.5), the remaining 31 individuals provide a weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1568 \pm 4$  Ma (95% confidence; MSWD = 1.4; probability of fit = 0.062; Figure 11.5).

### Geochronological Interpretation

The weighted mean age of  $1568 \pm 4$  Ma (95% confidence;  $n = 31$ ) calculated for the youngest group is within error of the dominant age population identified by mixture modelling. Given the Th/U ratios for most of these zircons is  $<0.20$ , this age is interpreted to represent a recrystallisation age. This is in agreement with the recrystallisation age of  $1563 \pm 4$  Ma of Black et al. (2005) of a sample from this creek section. Given the large range of older ages, it is not possible to determine a maximum depositional age for this sample.

**Table 11.1.** SHRIMP U-Pb isotopic data for zircons from sample 2007169015 (1937164), Einasleigh Metamorphics, south-southwest of Lyndhurst.

| Grain.area                           | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|--------------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| <i>Detrital zircon (n = 35)</i>      |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| E.42.1.1                             | 0.06                                               | 188        | 74          | 0.41                                   | 1.6196                                 | 1.3         | 0.2589                                  | 0.4         | 3240                                             | 7            | 4           |
| E.68.1.1                             | 0.01                                               | 195        | 152         | 0.81                                   | 1.9752                                 | 1.2         | 0.1949                                  | 0.5         | 2784                                             | 8            | 5           |
| E.39.1.1                             | 0.02                                               | 406        | 197         | 0.50                                   | 2.2053                                 | 1.1         | 0.1678                                  | 0.4         | 2536                                             | 6            | 5           |
| E.38.1.1                             | 0.01                                               | 957        | 97          | 0.10                                   | 2.3571                                 | 1.0         | 0.1620                                  | 0.2         | 2476                                             | 4            | 8           |
| E.50.1.1                             | 0.08                                               | 227        | 85          | 0.38                                   | 2.2928                                 | 1.2         | 0.1619                                  | 0.7         | 2475                                             | 12           | 6           |
| E.60.1.1                             | 0.02                                               | 700        | 302         | 0.45                                   | 2.3028                                 | 1.1         | 0.1612                                  | 0.6         | 2469                                             | 10           | 6           |
| E.67.1.1                             | 0.04                                               | 592        | 98          | 0.17                                   | 2.4034                                 | 1.1         | 0.1553                                  | 0.8         | 2405                                             | 14           | 7           |
| E.2.1.1                              | 0.00                                               | 456        | 426         | 0.96                                   | 2.5078                                 | 1.1         | 0.1525                                  | 0.4         | 2374                                             | 6            | 9           |
| E.1.1.1                              | 0.04                                               | 434        | 311         | 0.74                                   | 2.4809                                 | 1.3         | 0.1524                                  | 0.4         | 2373                                             | 7            | 8           |
| E.62.1.1                             | 0.07                                               | 187        | 33          | 0.18                                   | 2.4212                                 | 1.3         | 0.1513                                  | 0.6         | 2361                                             | 10           | 6           |
| E.43.1.1                             | 0.04                                               | 440        | 135         | 0.32                                   | 2.5998                                 | 1.4         | 0.1497                                  | 0.4         | 2342                                             | 7            | 10          |
| E.72.1.1                             | 0.04                                               | 592        | 55          | 0.10                                   | 2.9183                                 | 1.1         | 0.1296                                  | 0.4         | 2093                                             | 7            | 9           |
| E.29.1.1                             | 0.05                                               | 352        | 101         | 0.30                                   | 2.7668                                 | 1.1         | 0.1251                                  | 0.5         | 2031                                             | 9            | 2           |
| E.25.1.1                             | 0.03                                               | 440        | 375         | 0.88                                   | 2.9824                                 | 1.1         | 0.1159                                  | 0.4         | 1895                                             | 8            | 2           |
| E.40.1.1                             | 0.01                                               | 412        | 153         | 0.38                                   | 3.0810                                 | 1.3         | 0.1157                                  | 0.5         | 1891                                             | 9            | 4           |
| E.53.1.1                             | 0.05                                               | 654        | 157         | 0.25                                   | 3.0991                                 | 1.4         | 0.1152                                  | 0.8         | 1882                                             | 15           | 4           |
| E.21.1.1                             | 0.01                                               | 1177       | 277         | 0.24                                   | 3.2193                                 | 1.0         | 0.1144                                  | 0.3         | 1870                                             | 5            | 7           |
| E.66.1.1                             | 0.16                                               | 278        | 181         | 0.67                                   | 3.1070                                 | 1.2         | 0.1131                                  | 0.7         | 1849                                             | 12           | 3           |
| E.69.1.1                             | 0.04                                               | 555        | 106         | 0.20                                   | 3.0817                                 | 1.1         | 0.1125                                  | 0.5         | 1839                                             | 8            | 2           |
| E.45.1.1                             | 0.00                                               | 679        | 75          | 0.11                                   | 3.1790                                 | 1.1         | 0.1119                                  | 0.4         | 1830                                             | 7            | 4           |
| E.48.1.1                             | 0.04                                               | 1170       | 151         | 0.13                                   | 3.1801                                 | 1.0         | 0.1117                                  | 0.3         | 1828                                             | 6            | 4           |
| E.35.1.1                             | 0.03                                               | 567        | 266         | 0.49                                   | 3.1874                                 | 1.1         | 0.1111                                  | 0.5         | 1817                                             | 9            | 3           |
| E.27.1.1                             | 0.17                                               | 152        | 84          | 0.57                                   | 3.2784                                 | 1.3         | 0.1109                                  | 0.9         | 1814                                             | 17           | 5           |
| E.14.1.1                             | 0.02                                               | 548        | 98          | 0.19                                   | 3.3005                                 | 1.1         | 0.1108                                  | 0.4         | 1813                                             | 8            | 6           |
| E.7.1.1                              | 0.01                                               | 460        | 83          | 0.19                                   | 3.3527                                 | 1.2         | 0.1091                                  | 0.5         | 1785                                             | 9            | 6           |
| E.73.1.1                             | 0.06                                               | 263        | 186         | 0.73                                   | 3.2466                                 | 1.2         | 0.1082                                  | 0.7         | 1769                                             | 13           | 2           |
| E.20.1.1                             | 0.03                                               | 616        | 124         | 0.21                                   | 3.4612                                 | 1.2         | 0.1081                                  | 0.4         | 1767                                             | 8            | 7           |
| E.16.1.1                             | 0.03                                               | 805        | 520         | 0.67                                   | 3.3245                                 | 1.2         | 0.1081                                  | 0.5         | 1767                                             | 10           | 4           |
| E.8.1.1                              | 0.04                                               | 584        | 127         | 0.22                                   | 3.5548                                 | 1.1         | 0.1063                                  | 0.5         | 1737                                             | 9            | 8           |
| E.56.1.1                             | 0.06                                               | 330        | 198         | 0.62                                   | 3.3286                                 | 1.2         | 0.1049                                  | 0.6         | 1713                                             | 11           | 1           |
| E.12.1.1                             | 0.07                                               | 205        | 83          | 0.42                                   | 3.4181                                 | 1.2         | 0.1038                                  | 0.9         | 1692                                             | 16           | 2           |
| E.55.1.1                             | 0.03                                               | 934        | 80          | 0.09                                   | 3.7417                                 | 1.1         | 0.1023                                  | 0.4         | 1666                                             | 7            | 8           |
| E.64.1.1                             | 0.04                                               | 785        | 83          | 0.11                                   | 3.6948                                 | 1.1         | 0.1013                                  | 0.5         | 1648                                             | 9            | 6           |
| E.10.1.1                             | 0.10                                               | 436        | 91          | 0.21                                   | 3.6969                                 | 1.1         | 0.1003                                  | 0.6         | 1629                                             | 11           | 5           |
| E.5.1.1                              | 0.05                                               | 510        | 81          | 0.16                                   | 3.7374                                 | 1.1         | 0.0996                                  | 0.5         | 1617                                             | 10           | 5           |
| <i>~1568 Ma age zircons (n = 31)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| E.6.1.1                              | 0.04                                               | 538        | 81          | 0.15                                   | 3.8021                                 | 1.1         | 0.0978                                  | 0.5         | 1583                                             | 10           | 5           |
| E.46.1.1                             | 0.11                                               | 298        | 59          | 0.21                                   | 3.8016                                 | 1.6         | 0.0978                                  | 1.1         | 1582                                             | 20           | 5           |
| E.24.1.1                             | 0.05                                               | 539        | 71          | 0.14                                   | 3.7361                                 | 1.1         | 0.0977                                  | 0.5         | 1581                                             | 10           | 3           |
| E.18.1.1                             | 0.06                                               | 784        | 134         | 0.18                                   | 3.7626                                 | 1.1         | 0.0977                                  | 0.4         | 1581                                             | 8            | 4           |
| E.37.1.1                             | 0.06                                               | 726        | 11          | 0.02                                   | 3.7185                                 | 1.1         | 0.0976                                  | 0.5         | 1579                                             | 9            | 3           |
| E.57.1.1                             | 0.03                                               | 664        | 137         | 0.21                                   | 3.7823                                 | 1.1         | 0.0976                                  | 0.5         | 1579                                             | 8            | 4           |
| E.19.1.1                             | 0.02                                               | 758        | 157         | 0.21                                   | 3.8547                                 | 1.1         | 0.0976                                  | 0.4         | 1579                                             | 8            | 6           |
| E.28.1.1                             | 0.00                                               | 406        | 49          | 0.12                                   | 3.7237                                 | 1.2         | 0.0975                                  | 0.9         | 1577                                             | 17           | 3           |
| E.70.1.1                             | 0.04                                               | 654        | 45          | 0.07                                   | 3.8539                                 | 1.1         | 0.0975                                  | 0.5         | 1577                                             | 9            | 6           |
| E.52.1.1                             | 0.03                                               | 595        | 95          | 0.17                                   | 3.7931                                 | 1.1         | 0.0975                                  | 0.5         | 1577                                             | 10           | 4           |
| E.33.1.1                             | 0.02                                               | 707        | 114         | 0.17                                   | 3.8992                                 | 1.1         | 0.0974                                  | 0.4         | 1575                                             | 8            | 7           |
| E.9.1.1                              | 0.01                                               | 611        | 106         | 0.18                                   | 3.8032                                 | 1.1         | 0.0974                                  | 0.5         | 1574                                             | 9            | 4           |
| E.65.1.1                             | 0.04                                               | 723        | 87          | 0.12                                   | 3.8106                                 | 1.1         | 0.0973                                  | 0.4         | 1573                                             | 8            | 5           |
| E.49.1.1                             | 0.00                                               | 878        | 159         | 0.19                                   | 3.7386                                 | 1.1         | 0.0973                                  | 0.4         | 1573                                             | 7            | 3           |
| E.22.1.1                             | 0.06                                               | 371        | 78          | 0.22                                   | 3.9430                                 | 1.1         | 0.0973                                  | 0.7         | 1573                                             | 13           | 7           |
| E.23.1.1                             | 0.01                                               | 873        | 190         | 0.22                                   | 3.6634                                 | 1.1         | 0.0972                                  | 0.6         | 1572                                             | 12           | 1           |
| E.54.1.1                             | 0.07                                               | 627        | 136         | 0.22                                   | 3.9284                                 | 1.1         | 0.0971                                  | 0.5         | 1569                                             | 10           | 7           |
| E.74.1.1                             | 0.03                                               | 922        | 134         | 0.15                                   | 3.8308                                 | 1.1         | 0.0970                                  | 0.4         | 1567                                             | 7            | 5           |
| E.26.1.1                             | 0.02                                               | 1372       | 281         | 0.21                                   | 3.8479                                 | 1.0         | 0.0969                                  | 0.3         | 1564                                             | 6            | 5           |
| E.59.1.1                             | 0.15                                               | 358        | 48          | 0.14                                   | 3.8022                                 | 1.1         | 0.0968                                  | 0.8         | 1563                                             | 14           | 4           |
| E.34.1.1                             | 0.01                                               | 726        | 150         | 0.21                                   | 3.9493                                 | 1.1         | 0.0968                                  | 0.9         | 1563                                             | 17           | 7           |
| E.58.1.1                             | 0.11                                               | 342        | 50          | 0.15                                   | 3.8757                                 | 1.2         | 0.0968                                  | 0.8         | 1562                                             | 14           | 5           |
| E.44.1.1                             | 0.04                                               | 473        | 61          | 0.13                                   | 3.7551                                 | 1.1         | 0.0967                                  | 0.5         | 1562                                             | 10           | 3           |
| E.30.1.1                             | 0.05                                               | 585        | 124         | 0.22                                   | 3.8256                                 | 1.1         | 0.0967                                  | 0.5         | 1561                                             | 9            | 4           |
| E.4.1.1                              | 0.04                                               | 800        | 156         | 0.20                                   | 3.9263                                 | 1.1         | 0.0966                                  | 0.4         | 1559                                             | 8            | 6           |
| E.31.1.1                             | 0.04                                               | 1023       | 241         | 0.24                                   | 3.7528                                 | 1.0         | 0.0965                                  | 0.4         | 1557                                             | 7            | 2           |
| E.41.1.1                             | 0.01                                               | 1236       | 244         | 0.20                                   | 3.8029                                 | 1.0         | 0.0965                                  | 0.3         | 1557                                             | 6            | 3           |
| E.71.1.1                             | 0.00                                               | 566        | 59          | 0.11                                   | 3.8533                                 | 1.1         | 0.0964                                  | 0.5         | 1555                                             | 9            | 4           |
| E.32.1.1                             | 0.05                                               | 660        | 147         | 0.23                                   | 3.7998                                 | 1.1         | 0.0962                                  | 0.5         | 1552                                             | 9            | 3           |
| E.75.1.1                             | 0.04                                               | 512        | 55          | 0.11                                   | 3.8426                                 | 1.1         | 0.0957                                  | 0.5         | 1542                                             | 10           | 3           |
| E.17.1.1                             | 0.05                                               | 423        | 88          | 0.22                                   | 3.8222                                 | 1.1         | 0.0955                                  | 0.7         | 1538                                             | 14           | 3           |

SHRIMP geochronology of north Queensland: 2007-2010

| Grain.area                                                          | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|---------------------------------------------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| <i>Analyses not included in age calculation (n = 3)</i>             |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| E.11.1.1                                                            | 0.04                                               | 1028       | 149         | 0.15                                   | 4.0829                                 | 1.0         | 0.0956                                  | 0.5         | 1539                                             | 10           | 8           |
| E.3.1.1                                                             | 0.02                                               | 459        | 42          | 0.09                                   | 4.0293                                 | 1.1         | 0.0946                                  | 0.6         | 1520                                             | 11           | 6           |
| E.63.1.1                                                            | 0.15                                               | 246        | 37          | 0.15                                   | 3.8483                                 | 1.3         | 0.0942                                  | 1.0         | 1512                                             | 19           | 2           |
| <i>Analysis with <sup>206</sup>Pb<sub>c</sub> &gt; 0.5% (n = 1)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| E.61.1.1                                                            | 1.37                                               | 553        | 106         | 0.20                                   | 3.8379                                 | 1.1         | 0.0976                                  | 2.4         | 1579                                             | 44           | 5           |
| <i>Analyses &gt;10% discordant (n = 5)</i>                          |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| E.51.1.1                                                            | 0.08                                               | 548        | 50          | 0.09                                   | 4.5496                                 | 1.1         | 0.0974                                  | 0.7         | 1574                                             | 12           | 19          |
| E.13.1.1                                                            | 0.02                                               | 211        | 46          | 0.23                                   | 3.0835                                 | 1.3         | 0.1334                                  | 0.6         | 2143                                             | 11           | 16          |
| E.15.1.1                                                            | 0.02                                               | 816        | 143         | 0.18                                   | 3.4784                                 | 1.1         | 0.1174                                  | 0.4         | 1916                                             | 7            | 15          |
| E.36.1.1                                                            | 0.01                                               | 573        | 97          | 0.17                                   | 3.1549                                 | 1.1         | 0.1284                                  | 0.9         | 2076                                             | 16           | 14          |
| E.47.1.1                                                            | 0.01                                               | 881        | 217         | 0.25                                   | 2.8786                                 | 1.1         | 0.1389                                  | 0.3         | 2213                                             | 5            | 13          |

1. <sup>206</sup>Pb<sub>c</sub> indicates common <sup>206</sup>Pb as a percentage of the total measured <sup>206</sup>Pb.

## 12. MOUNT HOGAN GRANITE: 2008839046

|                                                         |                                                          |
|---------------------------------------------------------|----------------------------------------------------------|
| <b>GA Sample ID:</b>                                    | <b>2008839046</b>                                        |
| <b>GA Sample Number:</b>                                | <b>1977924</b>                                           |
| <b>Other Sample ID:</b>                                 |                                                          |
| <b>1:250,000 Sheet:</b>                                 | <b>GILBERTON SE5416</b>                                  |
| <b>Region:</b>                                          | <b>Etheridge Province, Queensland</b>                    |
| <b>Grid Reference (AGD66):</b>                          | <b>793668mE 7878280mN Zone 54</b>                        |
| <b>Collector:</b>                                       | <b>N. Kositcin, D.C. Champion, D.L. Huston</b>           |
| <b>Collection Date:</b>                                 | <b>4/9/2008</b>                                          |
| <b>Formal Name:</b>                                     | <b>Mount Hogan Granite</b>                               |
| <b>Informal Name:</b>                                   |                                                          |
| <b>Lithology:</b>                                       | <b>biotite monzogranite</b>                              |
| <b>Geochronologist:</b>                                 | <b>N. Kositcin</b>                                       |
| <b>Mount ID:</b>                                        | <b>GA6081</b>                                            |
| <b>Instrument:</b>                                      | <b>SHRIMP IIe Geoscience Australia</b>                   |
| <b>Acquisition Date:</b>                                | <b>17-18/3/2009</b>                                      |
| <b>U-Pb Standard &amp; reproducibility:</b>             | <b>TEMORA-2; 0.00% (1<math>\sigma</math>) [32 of 32]</b> |
| <b><sup>207</sup>Pb/<sup>206</sup>Pb Standard:</b>      | <b>OG1 (3465.4 <math>\pm</math> 0.6 Ma)</b>              |
| <b>Measured Value (<math>\pm</math>95% confidence):</b> | <b>3468.3 <math>\pm</math> 2.0 Ma [18 of 18]</b>         |
| <b>Interpreted Age:</b>                                 | <b>1558 <math>\pm</math> 2 Ma</b>                        |
| <b>IMF correction applied?</b>                          | <b>No</b>                                                |
| <b>Interpreted Age Type:</b>                            | <b>Igneous crystallisation age</b>                       |

**Sample Description**

The Mount Hogan Granite is thought to be part of the Forsayth Supersuite, the largest known accumulation of Proterozoic granite in northern Australia (Withnall et al., 1997a). The Supersuite is Mesoproterozoic (~1550-1555 Ma) based on U-Pb zircon (conventional and SHRIMP) and Rb-Sr methods (Black and McCulloch, 1990; Black and Withnall, 1993). Previous Rb-Sr whole rock age determinations on the Mount Hogan Granite proved inconclusive (Black and Holmes, unpubl.). Black and Withnall (1993) provided a U-Pb zircon age of  $1549 \pm 25$  Ma, which they interpreted as the emplacement age of the granite.

A fresh sample of pink-grey, coarse-grained biotite monzogranite was collected from mostly weathered boulder outcrops located along a small creek exposure. The sample was sparsely K-feldspar porphyritic (up to 3cm, zoned and of random orientation), seriate, with plagioclase, grey-blue quartz (anhedral to 1cm), coarse biotite flakes, and magnetite (magnetic susceptibility values:  $555-873 \times 10^{-3}$  SI units; 6 readings). The outcrop is intruded by a number of micro-aplites, pegmatitic and mafic dykes.

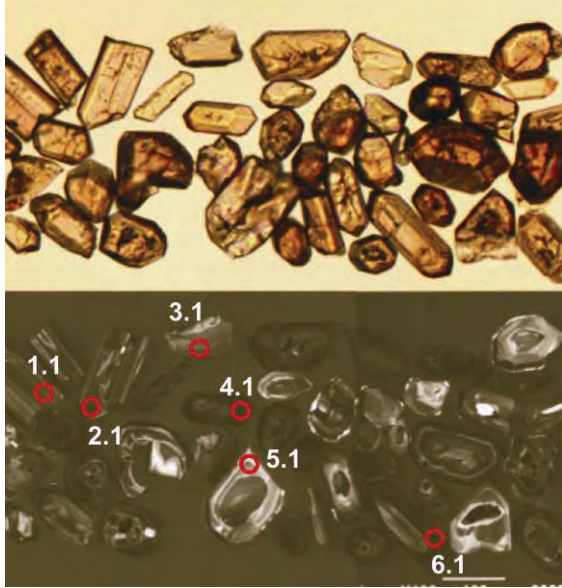
The eastern part of the exposed Etheridge Province contains a number of shear-related mineral deposits hosted by Proterozoic granites, including the Au-U Mount Hogan deposit. This deposit consists of thin (2-600 mm) en echelon quartz veins within sericite-chlorite altered Mount Hogan Granite (Denaro et al., 1997). The Mount Hogan Granite has a very high background  $\gamma$ -ray spectrometric signature, and the uranium in these deposits was probably mobilised from the granite (Withnall et al., 1997a). The sample was collected in order to determine the crystallisation age of the Mount Hogan Granite. It also provides a maximum age for mineralisation.

**Zircon Description**

Zircons extracted from this sample are light brown to dark reddish brown and commonly cracked. They have a restricted range of grain sizes, averaging about 300  $\mu$ m by 120  $\mu$ m, are generally subhedral with fewer more euhedral grains. Aspect ratios are between 1:1 and 1:3 (Figure 12.1).

Most grains display a low to moderate cathodoluminescence response and reveal well defined concentric and planar oscillatory zoning.

Distinct rounded cores are present in a number of grains, and are generally of low cathodoluminescence and weakly zoned. A smaller proportion of cores have a very bright cathodoluminescence response with no obvious features. Where analysed, cores were not chronologically distinctive. A few grains show evidence of regions of recrystallisation, resorption and truncation of primary magmatic features with a mottled appearance in CL images.

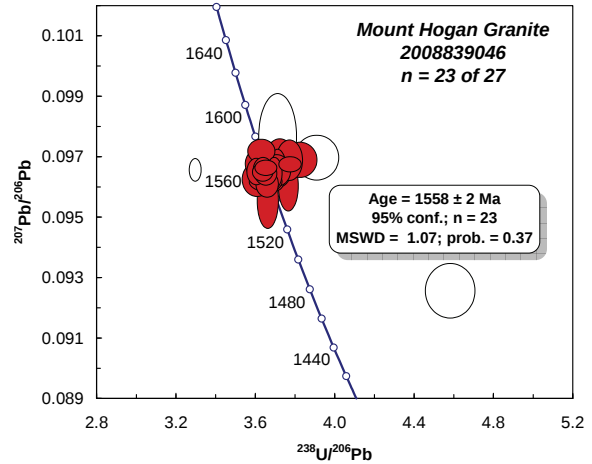


**Figure 12.1.** Representative transmitted light and cathodoluminescence images of zircons from the Mount Hogan Granite (sample 2008839046), with locations of some SHRIMP analyses.

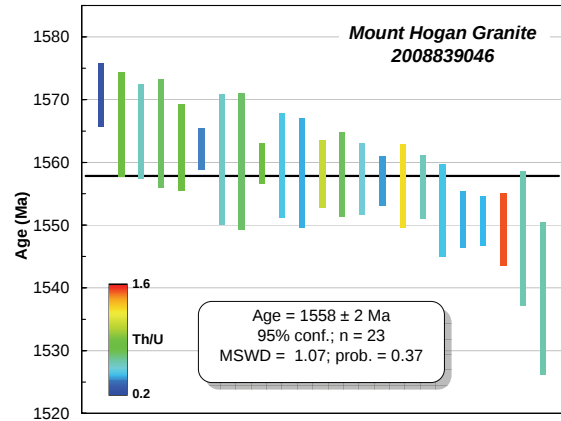
### U-Pb Isotopic Results

Twenty-seven analyses were collected on 27 individual zircon grains from sample 2008839046, the results of which are presented in Table 12.1 and illustrated in Figures 12.2 and 12.3. U concentrations range between 2446 and 174 ppm, with Th/U between 1.52 and 0.26 (Figure 12.3). Common  $^{206}\text{Pb}_c$  contents are low, between zero and 0.6%. Of the 27 analyses collected, 4 were rejected on the basis of excessive discordance (>5%), or excessive  $^{206}\text{Pb}_c$  (14.1.1, >0.5%).

Twenty-three near-concordant analyses form a single population with a weighted mean age of  $1558 \pm 2$  Ma (95% confidence; MSWD = 1.07; probability = 0.37; Figure 12.2).



**Figure 12.2.** Tera-Wasserburg concordia diagram showing results of all zircon analyses for sample 2008839046 (Mount Hogan Granite). Unfilled ellipses are discordant and/or analyses with high  $^{206}\text{Pb}_c$ .



**Figure 12.3.** Mean age diagram showing  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of near-concordant zircons from sample 2008839046 (Mount Hogan Granite), coloured according to Th/U.

### Geochronological Interpretation

The weighted mean age of  $1558 \pm 2$  Ma is interpreted as the igneous crystallisation age of the Mount Hogan Granite.

**Table 12.1.** SHRIMP U-Pb isotopic data for zircons from sample 2008839046 (1977924), Mount Hogan Granite.

| Grain.area                                                   | $^{206}\text{Pb}_c$<br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | $^{232}\text{Th}/$<br>$^{238}\text{U}$ | $^{238}\text{U}/$<br>$^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/$<br>$^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/^{206}\text{Pb}$<br>Age (Ma) | $\pm 1\sigma$<br>(Ma) | Disc<br>(%) |
|--------------------------------------------------------------|-----------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|----------------------|-----------------------------------------|----------------------|-----------------------------------------------|-----------------------|-------------|
| <i>Magmatic analyses (n = 23)</i>                            |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| 924.6.1.1                                                    | 0.39                                    | 2446       | 646         | 0.273                                  | 3.6281                                 | 1.25                 | 0.0972                                  | 0.27                 | 1571                                          | 5                     | 0           |
| 924.10.1.1                                                   | 0.06                                    | 367        | 283         | 0.799                                  | 3.7207                                 | 1.27                 | 0.0969                                  | 0.44                 | 1566                                          | 8                     | 2           |
| 924.9.1.1                                                    | 0.10                                    | 452        | 265         | 0.606                                  | 3.8219                                 | 1.46                 | 0.0969                                  | 0.40                 | 1565                                          | 8                     | 5           |
| 924.11.1.1                                                   | 0.05                                    | 334        | 243         | 0.752                                  | 3.7695                                 | 1.14                 | 0.0969                                  | 0.46                 | 1565                                          | 9                     | 3           |
| 924.18.1.1                                                   | 0.05                                    | 498        | 436         | 0.904                                  | 3.6258                                 | 1.42                 | 0.0967                                  | 0.37                 | 1562                                          | 7                     | -1          |
| 924.4.1.1                                                    | 0.00                                    | 2145       | 815         | 0.393                                  | 3.7715                                 | 0.97                 | 0.0967                                  | 0.18                 | 1562                                          | 3                     | 3           |
| 924.19.1.1                                                   | 0.03                                    | 207        | 119         | 0.595                                  | 3.6831                                 | 0.90                 | 0.0966                                  | 0.56                 | 1560                                          | 10                    | 1           |
| 924.5.1.1                                                    | 0.02                                    | 174        | 126         | 0.746                                  | 3.6632                                 | 0.93                 | 0.0966                                  | 0.58                 | 1560                                          | 11                    | 0           |
| 924.23.1.1                                                   | 0.03                                    | 2150       | 1689        | 0.812                                  | 3.6500                                 | 1.02                 | 0.0966                                  | 0.17                 | 1560                                          | 3                     | 0           |
| 924.3.1.1                                                    | 0.01                                    | 313        | 151         | 0.497                                  | 3.7072                                 | 1.34                 | 0.0966                                  | 0.44                 | 1559                                          | 8                     | 1           |
| 924.24.1.1                                                   | 0.05                                    | 323        | 139         | 0.444                                  | 3.7088                                 | 0.79                 | 0.0965                                  | 0.47                 | 1558                                          | 9                     | 1           |
| 924.2.1.1                                                    | 0.02                                    | 665        | 737         | 1.145                                  | 3.6363                                 | 0.91                 | 0.0965                                  | 0.29                 | 1558                                          | 5                     | -1          |
| 924.12.1.1                                                   | 0.02                                    | 525        | 386         | 0.759                                  | 3.7034                                 | 1.26                 | 0.0965                                  | 0.36                 | 1558                                          | 7                     | 1           |
| 924.7.1.1                                                    | 0.10                                    | 1971       | 1055        | 0.553                                  | 3.6025                                 | 0.87                 | 0.0965                                  | 0.30                 | 1557                                          | 6                     | -2          |
| 924.17.1.1                                                   | 0.02                                    | 1319       | 539         | 0.422                                  | 3.6338                                 | 0.94                 | 0.0965                                  | 0.21                 | 1557                                          | 4                     | -1          |
| 924.27.1.1                                                   | 0.02                                    | 501        | 645         | 1.330                                  | 3.6932                                 | 0.71                 | 0.0964                                  | 0.36                 | 1556                                          | 7                     | 1           |
| 924.13.1.1                                                   | 0.12                                    | 1060       | 626         | 0.610                                  | 3.6511                                 | 0.99                 | 0.0964                                  | 0.27                 | 1556                                          | 5                     | 0           |
| 924.8.1.1                                                    | 0.05                                    | 410        | 194         | 0.490                                  | 3.6062                                 | 1.37                 | 0.0962                                  | 0.39                 | 1552                                          | 7                     | -2          |
| 924.20.1.1                                                   | 0.01                                    | 1075       | 466         | 0.448                                  | 3.6609                                 | 1.29                 | 0.0962                                  | 0.24                 | 1551                                          | 4                     | 0           |
| 924.25.1.1                                                   | 0.02                                    | 1438       | 634         | 0.456                                  | 3.6428                                 | 1.37                 | 0.0961                                  | 0.21                 | 1551                                          | 4                     | -1          |
| 924.1.1.1                                                    | 0.00                                    | 697        | 1058        | 1.569                                  | 3.6564                                 | 1.00                 | 0.0961                                  | 0.30                 | 1549                                          | 6                     | -1          |
| 924.15.1.1                                                   | 0.04                                    | 204        | 126         | 0.635                                  | 3.7631                                 | 0.89                 | 0.0960                                  | 0.57                 | 1548                                          | 11                    | 2           |
| 924.22.1.1                                                   | 0.09                                    | 174        | 108         | 0.643                                  | 3.6597                                 | 0.95                 | 0.0955                                  | 0.65                 | 1538                                          | 12                    | -1          |
| <i>Analyses &gt;5% discordant, or high common Pb (n = 4)</i> |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| 924.14.1.1                                                   | 0.57                                    | 274        | 327         | 1.232                                  | 3.7096                                 | 1.68                 | 0.0977                                  | 0.97                 | 1580                                          | 18                    | 3           |
| 924.26.1.1                                                   | 0.07                                    | 357        | 567         | 1.641                                  | 3.9065                                 | 1.88                 | 0.0969                                  | 0.51                 | 1566                                          | 10                    | 7           |
| 924.16.1.1                                                   | 0.13                                    | 1506       | 291         | 0.200                                  | 3.2956                                 | 0.60                 | 0.0965                                  | 0.26                 | 1558                                          | 5                     | -11         |
| 924.21.1.1                                                   | 0.08                                    | 1643       | 1352        | 0.850                                  | 4.5781                                 | 1.80                 | 0.0925                                  | 0.65                 | 1478                                          | 12                    | 15          |

1.  $^{206}\text{Pb}_c$  indicates common  $^{206}\text{Pb}$  as a percentage of the total measured  $^{206}\text{Pb}$ .

**13. UNNAMED GARNET-BIOTITE MONZOGRAHITE: 2008839056**

|                                                         |                                                          |
|---------------------------------------------------------|----------------------------------------------------------|
| <b>GA Sample ID:</b>                                    | <b>200839056</b>                                         |
| <b>GA Sample Number:</b>                                | <b>1977935</b>                                           |
| <b>Other Sample ID:</b>                                 |                                                          |
| <b>1:250,000 Sheet:</b>                                 | <b>GILBERTON SE5416</b>                                  |
| <b>Region:</b>                                          | <b>Etheridge Province, Queensland</b>                    |
| <b>Grid Reference (AGD66):</b>                          | <b>796478mE 7871852mN Zone 54</b>                        |
| <b>Collector:</b>                                       | <b>N. Kositcin, D.C. Champion, D.L. Huston</b>           |
| <b>Collection Date:</b>                                 | <b>5/9/2008</b>                                          |
| <b>Formal Name:</b>                                     |                                                          |
| <b>Informal Name:</b>                                   | <b>unnamed monzogranite</b>                              |
| <b>Lithology:</b>                                       | <b>garnet-biotite monzogranite</b>                       |
| <b>Geochronologist:</b>                                 | <b>N. Kositcin</b>                                       |
| <b>Mount ID:</b>                                        | <b>GA6082</b>                                            |
| <b>Instrument:</b>                                      | <b>SHRIMP IIe Geoscience Australia</b>                   |
| <b>Acquisition Date:</b>                                | <b>17-18/3/2009</b>                                      |
| <b>U-Pb Standard &amp; reproducibility:</b>             | <b>TEMORA-2; 0.00% (1<math>\sigma</math>) [17 of 17]</b> |
| <b><sup>207</sup>Pb/<sup>206</sup>Pb Standard:</b>      | <b>OG1 (3465.4 <math>\pm</math> 0.6 Ma)</b>              |
| <b>Measured Value (<math>\pm</math>95% confidence):</b> | <b>3468.2 <math>\pm</math> 2.2 Ma [17 of 17]</b>         |
| <b>Interpreted Age:</b>                                 | <b>1559 <math>\pm</math> 2 Ma</b>                        |
| <b>IMF correction applied?</b>                          | <b>No</b>                                                |
| <b>Interpreted Age Type:</b>                            | <b>Igneous crystallisation age</b>                       |

**Sample Description**

A fresh sample of grey, garnet-biotite monzogranite was collected for SHRIMP geochronology. Sparse garnets, up to 6 mm in diameter, occur within an incipiently banded fabric defined by biotite (~8-10%). This is a magnetite series I-type granite, and is highly magnetic (magnetic susceptibility values: 1390-2300 $\times 10^{-3}$  SI units; 11 values). The outcrop is veined by pink monzogranite and pegmatite. This unit is unnamed and has not been classified.

**Zircon Description**

The majority of grains are subhedral to rounded and irregular in appearance, with a large proportion of broken grains. Zircons are commonly 100  $\mu$ m or less, are clear to light yellow and straw colour, with a few larger rounded grains of possible detrital origin. A few grains have obvious core-rim relationships. Aspect ratios are 1:1 and 1:2 (Figure 13.1). Most grains display a moderate cathodoluminescence response and reveal concentric and planar

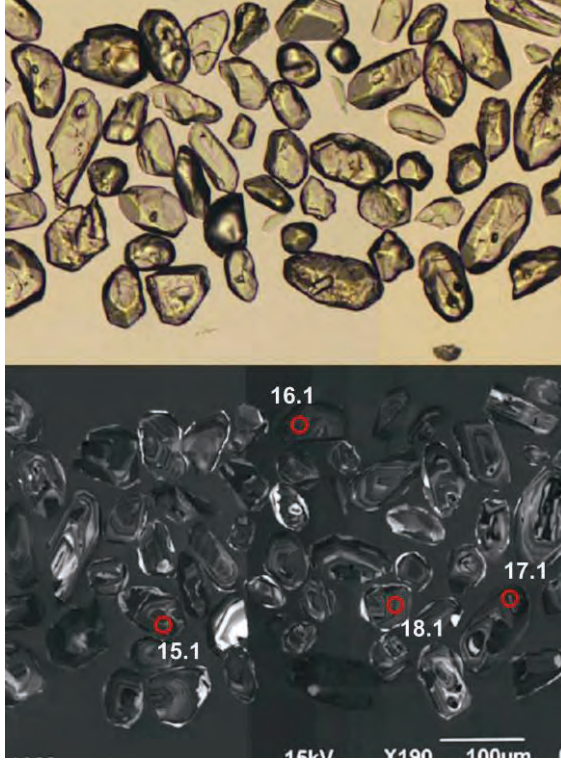
oscillatory zoning. Almost all grains display irregular rims; these tiny <5  $\mu$ m scale rims show a distinctive bright CL, and possibly consist of thorite and/or uraninite. These bright rims infill embayments and irregular grain faces. A large number of grains show evidence of regions of recrystallisation, resorption and truncation of primary magmatic zoning features, exhibiting an internal mottled appearance (Figure 13.1).

**U-Pb Isotopic Results**

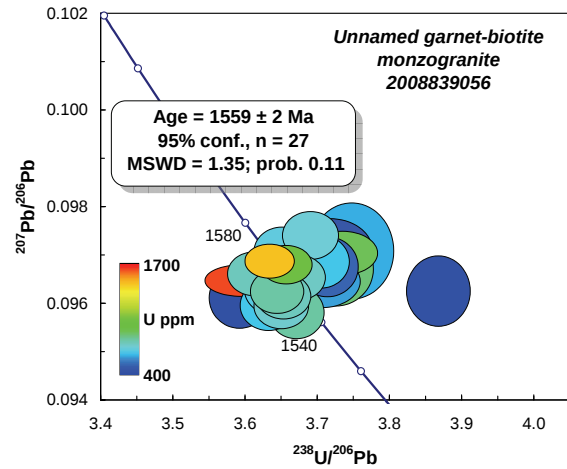
A total of 30 analyses were collected on 30 individual zircon grains, the results of which are presented in Table 13.1 and illustrated in Figures 13.2 and 13.3. One analysis is >5% discordant, and a second one has >0.5% common <sup>206</sup>Pb; both analyses are excluded from interpretation. U concentrations range between 1637 and 437 ppm, with Th/U ratios between 0.86 and 0.01.

The remaining analyses include a single, inherited grain, which gave an age of 1839  $\pm$  5 Ma (1 $\sigma$ ), and 27 analyses which form a coherent

group with a weighted mean age of  $1559 \pm 2$  Ma (95% confidence; MSWD = 1.35; probability = 0.11, Figure 13.3).



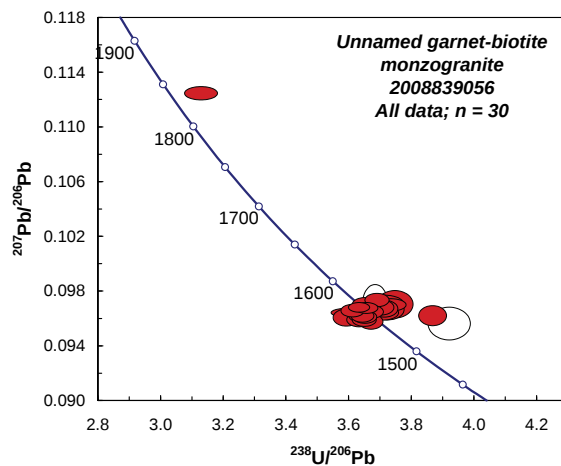
**Figure 13.1.** Representative transmitted light and cathodoluminescence images of zircons from sample 2008839056 (unnamed garnet-biotite monzogranite), with locations of some SHRIMP analyses. Scale bar is 100  $\mu\text{m}$ .



**Figure 13.3.** Tera-Wasserburg concordia diagram showing near-concordant analyses for sample 2008839056 (unnamed garnet-biotite monzogranite), coloured according to U content.

### Geochronological Interpretation

The weighted mean age of  $1559 \pm 2$  Ma is interpreted as the igneous crystallisation age of this sample. Minor older inheritance is present.



**Figure 13.2.** Tera-Wasserburg concordia diagram showing all analyses for sample 2008839056 (unnamed garnet-biotite monzogranite). Unfilled ellipses are those >5% discordant, and/or have high common Pb, and are excluded from interpretation.

**Table 13.1.** SHRIMP U-Pb isotopic data for zircons from sample 2008839056 (1977935), unnamed garnet-biotite monzogranite.

| Grain.area                                                   | $^{206}\text{Pb}_c$<br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | $^{232}\text{Th}/$<br>$^{238}\text{U}$ | $^{238}\text{U}/$<br>$^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/$<br>$^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/^{206}\text{Pb}$<br>Age (Ma) | $\pm 1\sigma$<br>(Ma) | Disc<br>(%) |
|--------------------------------------------------------------|-----------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|----------------------|-----------------------------------------|----------------------|-----------------------------------------------|-----------------------|-------------|
| <i>Inherited grain (n = 1)</i>                               |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| 935.21.1.1                                                   | 0.00                                    | 691        | 87          | 0.13                                   | 3.1297                                 | 1.10                 | 0.1125                                  | 0.29                 | 1839                                          | 5                     | 3           |
| <i>Magmatic analyses (n = 27)</i>                            |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| 935.3.1.1                                                    | 0.00                                    | 714        | 490         | 0.71                                   | 3.6915                                 | 0.69                 | 0.0974                                  | 0.33                 | 1575                                          | 6                     | 2           |
| 935.6.1.1                                                    | 0.02                                    | 472        | 300         | 0.66                                   | 3.7175                                 | 1.05                 | 0.0971                                  | 0.43                 | 1570                                          | 8                     | 2           |
| 935.12.1.1                                                   | 0.02                                    | 612        | 175         | 0.30                                   | 3.7483                                 | 1.02                 | 0.0971                                  | 0.67                 | 1569                                          | 13                    | 3           |
| 935.25.1.1                                                   | -0.01                                   | 684        | 519         | 0.78                                   | 3.6517                                 | 0.70                 | 0.0971                                  | 0.34                 | 1569                                          | 6                     | 1           |
| 935.15.1.1                                                   | 0.01                                    | 903        | 480         | 0.55                                   | 3.7356                                 | 0.86                 | 0.0970                                  | 0.31                 | 1568                                          | 6                     | 3           |
| 935.28.1.1                                                   | 0.03                                    | 1470       | 827         | 0.58                                   | 3.6346                                 | 0.62                 | 0.0969                                  | 0.24                 | 1565                                          | 4                     | 0           |
| 935.20.1.1                                                   | 0.04                                    | 655        | 412         | 0.65                                   | 3.7052                                 | 0.71                 | 0.0969                                  | 0.37                 | 1565                                          | 7                     | 2           |
| 935.9.1.1                                                    | 0.00                                    | 1024       | 840         | 0.85                                   | 3.6575                                 | 0.65                 | 0.0968                                  | 0.27                 | 1564                                          | 5                     | 0           |
| 935.1.1.1                                                    | 0.04                                    | 513        | 279         | 0.56                                   | 3.7144                                 | 0.76                 | 0.0968                                  | 0.42                 | 1563                                          | 8                     | 2           |
| 935.10.1.1                                                   | 0.02                                    | 866        | 637         | 0.76                                   | 3.7253                                 | 0.94                 | 0.0967                                  | 0.52                 | 1562                                          | 10                    | 2           |
| 935.13.1.1                                                   | 0.02                                    | 855        | 676         | 0.82                                   | 3.6636                                 | 1.01                 | 0.0967                                  | 0.30                 | 1561                                          | 6                     | 0           |
| 935.29.1.1                                                   | 0.02                                    | 520        | 253         | 0.50                                   | 3.6665                                 | 1.14                 | 0.0966                                  | 0.40                 | 1560                                          | 7                     | 0           |
| 935.5.1.1                                                    | 0.02                                    | 765        | 509         | 0.69                                   | 3.6132                                 | 0.67                 | 0.0966                                  | 0.31                 | 1560                                          | 6                     | -1          |
| 935.7.1.1                                                    | -0.01                                   | 749        | 546         | 0.75                                   | 3.6736                                 | 0.68                 | 0.0965                                  | 0.32                 | 1558                                          | 6                     | 0           |
| 935.16.1.1                                                   | 0.01                                    | 837        | 536         | 0.66                                   | 3.6256                                 | 1.02                 | 0.0965                                  | 0.30                 | 1558                                          | 6                     | -1          |
| 935.26.1.1                                                   | 0.01                                    | 1637       | 20          | 0.01                                   | 3.5958                                 | 0.93                 | 0.0965                                  | 0.22                 | 1557                                          | 4                     | -2          |
| 935.8.1.1                                                    | 0.03                                    | 598        | 334         | 0.58                                   | 3.7069                                 | 0.94                 | 0.0965                                  | 0.37                 | 1557                                          | 7                     | 1           |
| 935.17.1.1                                                   | 0.02                                    | 873        | 390         | 0.46                                   | 3.6364                                 | 0.91                 | 0.0964                                  | 0.30                 | 1556                                          | 6                     | -1          |
| 935.30.1.1                                                   | 0.02                                    | 648        | 337         | 0.54                                   | 3.6369                                 | 1.02                 | 0.0964                                  | 0.36                 | 1556                                          | 7                     | -1          |
| 935.18.1.1                                                   | 0.05                                    | 676        | 408         | 0.62                                   | 3.6386                                 | 0.70                 | 0.0963                                  | 0.35                 | 1554                                          | 7                     | -1          |
| 935.11.1.1                                                   | 0.14                                    | 445        | 296         | 0.69                                   | 3.8681                                 | 0.75                 | 0.0963                                  | 0.50                 | 1553                                          | 9                     | 5           |
| 935.22.1.1                                                   | 0.02                                    | 809        | 457         | 0.58                                   | 3.6451                                 | 0.67                 | 0.0963                                  | 0.31                 | 1553                                          | 6                     | -1          |
| 935.24.1.1                                                   | 0.01                                    | 761        | 381         | 0.52                                   | 3.6536                                 | 0.68                 | 0.0962                                  | 0.32                 | 1551                                          | 6                     | -1          |
| 935.19.1.1                                                   | 0.04                                    | 437        | 256         | 0.61                                   | 3.5928                                 | 0.77                 | 0.0961                                  | 0.43                 | 1550                                          | 8                     | -2          |
| 935.27.1.1                                                   | 0.03                                    | 655        | 472         | 0.74                                   | 3.6330                                 | 0.71                 | 0.0960                                  | 0.36                 | 1547                                          | 7                     | -1          |
| 935.14.1.1                                                   | 0.00                                    | 731        | 631         | 0.89                                   | 3.6506                                 | 0.68                 | 0.0960                                  | 0.32                 | 1547                                          | 6                     | -1          |
| 935.2.1.1                                                    | 0.05                                    | 812        | 642         | 0.82                                   | 3.6716                                 | 0.68                 | 0.0958                                  | 0.37                 | 1544                                          | 7                     | -1          |
| <i>Analyses &gt;5% discordant, or high common Pb (n = 2)</i> |                                         |            |             |                                        |                                        |                      |                                         |                      |                                               |                       |             |
| 935.23.1.1                                                   | 1.04                                    | 529        | 263         | 0.51                                   | 3.6850                                 | 0.72                 | 0.0972                                  | 0.93                 | 1570                                          | 17                    | 2           |
| 935.4.1.1                                                    | 0.28                                    | 603        | 173         | 0.30                                   | 3.9214                                 | 1.14                 | 0.0957                                  | 0.82                 | 1542                                          | 16                    | 6           |

1.  $^{206}\text{Pb}_c$  indicates common  $^{206}\text{Pb}$  as a percentage of the total measured  $^{206}\text{Pb}$ .

## 14. FOREST HOME TRONDHJEMITE: IWGT552

|                                                         |                                                          |
|---------------------------------------------------------|----------------------------------------------------------|
| <b>GA Sample ID:</b>                                    | <b>IWGT552</b>                                           |
| <b>GA Sample Number:</b>                                | <b>1977986</b>                                           |
| <b>Other Sample ID:</b>                                 |                                                          |
| <b>1:250,000 Sheet:</b>                                 | <b>GEORGETOWN SE5412</b>                                 |
| <b>Region:</b>                                          | <b>Etheridge Province, Queensland</b>                    |
| <b>Grid Reference (AGD66):</b>                          | <b>713760mE 7984127mN Zone 54</b>                        |
| <b>Collector:</b>                                       | <b>I. Withnall</b>                                       |
| <b>Collection Date:</b>                                 | <b>18/9/2008</b>                                         |
| <b>Formal Name:</b>                                     | <b>Forest Home Trondhjemite</b>                          |
| <b>Informal Name:</b>                                   |                                                          |
| <b>Lithology:</b>                                       | <b>biotite trondhjemite</b>                              |
| <b>Geochronologist:</b>                                 | <b>N. Kositcin</b>                                       |
| <b>Mount ID:</b>                                        | <b>GA6081</b>                                            |
| <b>Instrument:</b>                                      | <b>SHRIMP IIe Geoscience Australia</b>                   |
| <b>Acquisition Date:</b>                                | <b>19-21/3/2009</b>                                      |
| <b>U-Pb Standard &amp; reproducibility:</b>             | <b>TEMORA-2; 0.00% (1<math>\sigma</math>) [32 of 32]</b> |
| <b><sup>207</sup>Pb/<sup>206</sup>Pb Standard:</b>      | <b>OG1 (3465.4 <math>\pm</math> 0.6 Ma)</b>              |
| <b>Measured Value (<math>\pm</math>95% confidence):</b> | <b>3468.3 <math>\pm</math> 2.0 Ma [18 of 18]</b>         |
| <b>Interpreted Age:</b>                                 | <b>1564 <math>\pm</math> 7 Ma</b>                        |
| <b>IMF correction applied?</b>                          | <b>No</b>                                                |
| <b>Interpreted Age Type:</b>                            | <b>Igneous crystallisation age</b>                       |

**Sample Description and Previous Work**

Based on U-Pb zircon studies, peraluminous S-type granites of the Forsyth Supersuite were intruded in the Etheridge Province at ~1560-1550 Ma (Black and McCulloch, 1990; Murgulov et al., 2007). The Forsyth Supersuite (the main component of the Forsyth Batholith) is the largest known Mesoproterozoic S-type granite in northern Australia (Withnall et al., 1997a). Possibly contemporaneous I-type magmatism is recorded by the Forest Home Supersuite, which consists of the Forest Home and Talbot Creek Trondhjemites (Bain et al. 1985). The former (defined as Forest Home Granodiorite by Mackenzie, 1980) is made up of 15 small (less than 1-10 km long), elliptical plutons that crop out in the Black Gin Creek area to the south of Forest Home homestead (Mackenzie, 1980; Withnall et al., 1997a). The Forest Home Trondhjemite is a medium- to fine-grained (rarely coarse-grained) biotite trondhjemite. Minor amounts of secondary muscovite or sericite are present in places in



**Figure 14.1.** Outcrop photo of Forest Home Trondhjemite at the site of sample IWGT552.

some plutons (Mackenzie, 1980). Some bodies become porphyritic and progressively finer-grained towards their margins (Mackenzie, 1980; Withnall et al., 1997a).

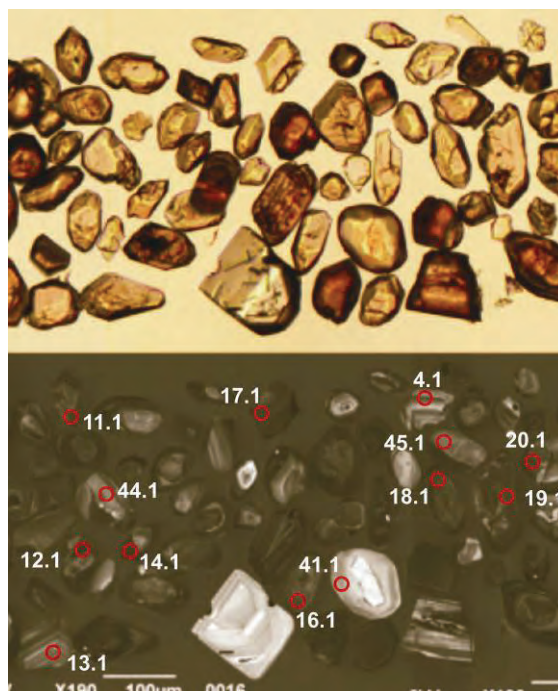
Previous age determinations include K-Ar and Rb-Sr ages of 1229 Ma (Richards et al., 1966)

and 1238 Ma (Black and Holmes, unpubl.), a Rb-Sr whole rock age of  $1553 \pm 46$  (Black and Holmes, unpubl., quoted in Black and Withnall, 1993), and a U-Pb age of  $1650 \pm 17$  Ma (Black and Withnall, 1993). The latter age, however, may be inherited, as it could be based on xenocrystic or inherited zircons. Black and Withnall (1993) suggest that the Rb-Sr whole rock isochron age of  $1553 \pm 46$  Ma (Black and Holmes, unpubl.) probably defines the time of emplacement.

The sample was collected beside the Gulf Developmental Road near Forest Home Station. The outcrop is a low-lying platformal outcrop surrounded by alluvium and consisting of pale grey, non-foliated, fine- to medium-grained, equigranular, biotite leucotonalite or trondhjemite (Figure 14.1). No xenoliths were obvious. The material sampled was from relatively fresh exfoliated shells that had recently been dislodged by passage of a large earth-moving machine.

### Zircon Description

Zircons are mostly dark brown, elongate, subhedral and range between 50  $\mu\text{m}$  and <200  $\mu\text{m}$  in length. Aspect ratios are typically 1:1 to 1:2. Most grains have weakly luminescent thin (<5  $\mu\text{m}$ ) rims surrounding distinct, volumetrically dominant cores, the latter being rounded or euhedral in appearance. Both rims and cores show a range of oscillatory zoning patterns. Several larger rounded grains exhibit a distinctive pitting texture suggesting that they have been through a cycle of erosion and transport (Figure 14.2). In cathodoluminescence images, a small proportion of grains reveal cores with a bright response; these regions are featureless, or have rare zoning patterns (Figure 14.2).

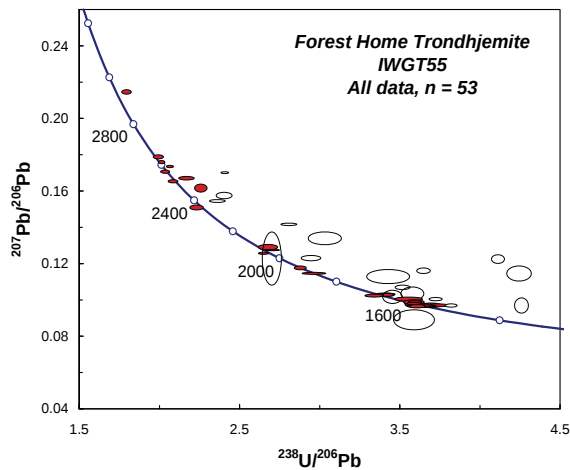


**Figure 14.2.** Representative transmitted light and cathodoluminescence images of zircons from the Forest Home Trondhjemite (sample IWGT552), with locations of some SHRIMP analyses. Scale bar is 100  $\mu\text{m}$ .

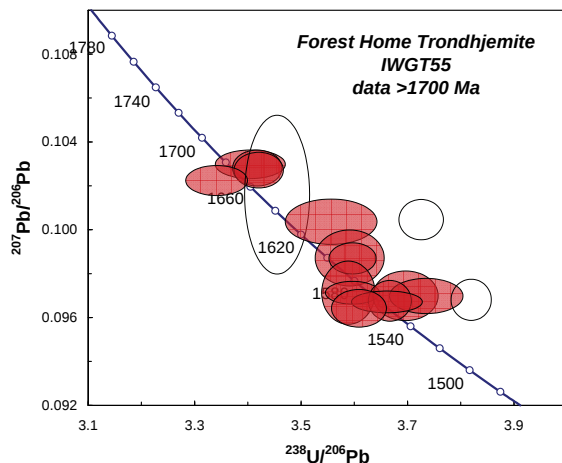
### U-Pb Isotopic Results

A total of 53 analyses were collected on 53 individual zircon grains from sample IWGT55, the results of which are presented in Table 14.1 and illustrated in Figures 14.3 and 14.4. U concentration ranges from 2205 to 74 ppm, with Th/U between 1.14 and 0.03.

Twenty-four analyses are more than 5% discordant and/or contain  $>0.5\%$   $^{206}\text{Pb}_c$ , and are rejected from further interpretation. SHRIMP spots which targeted the weakly luminescent rims returned poor data (discordant, high  $^{206}\text{Pb}_c$  and U ppm). The remaining 29 concordant analyses form a spread of ages from ~1556 Ma to ~2940 Ma (Figure 14.4).



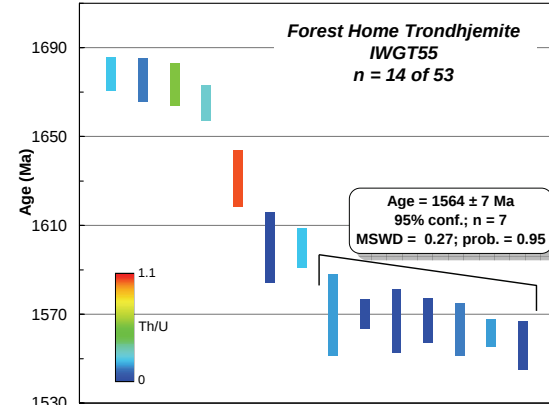
**Figure 14.3.** Tera-Wasserburg concordia diagram showing results of all zircon analyses for sample IWGT55 (Forest Home Trondhjemite). Unfilled ellipses are those >5% discordant, and/or have high common Pb, and are excluded from interpretation (six highly discordant analyses are off-scale).



**Figure 14.4.** Tera-Wasserburg concordia diagram showing results of near-concordant zircon analyses for sample IWGT55 (Forest Home Trondhjemite), younger than 1700 Ma.

The youngest 7 analyses form a coherent group with a weighted mean age of  $1564 \pm 7$  Ma (95% confidence; MSWD = 0.27; probability = 0.95, Figure 14.5). Older grains include two analyses which combine to give a weighed mean age of  $1600 \pm 16$  Ma (95% confidence), and 4 analyses group to give a weighted mean age of  $1673 \pm 9$  Ma (95% confidence). The remainder of the age spectrum are individual grains ( $1\sigma$ ) at  $1631 \pm 13$  Ma,  $1873 \pm 6$  Ma,  $1920 \pm 12$  Ma,  $2038 \pm 3$  Ma,

$2063 \pm 3$  Ma,  $2085 \pm 15$  Ma,  $2355 \pm 10$ ,  $2472 \pm 15$  Ma,  $2511 \pm 6$  Ma,  $2529 \pm 7$  Ma,  $2564 \pm 6$  Ma,  $2614 \pm 5$  Ma,  $2642 \pm 6$  Ma and  $2940 \pm 6$  Ma.



**Figure 14.5.** Mean age diagram showing  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of zircons from sample IWGT55 (Forest Home Trondhjemite), coloured according to Th/U ratio.

### Geochronological Interpretation

The majority of ages in this sample are interpreted to represent inheritance within the I-type Forest Home Trondhjemite. The youngest group of concordant analyses form a distinct cluster with a weighted mean age of  $1564 \pm 7$  Ma ( $n = 7$ ; 95% confidence; MSWD = 0.27; probability = 0.95), interpreted to record the crystallisation age of this sample.

**Table 14.1.** SHRIMP U-Pb isotopic data for zircons from sample IWGT55 (1977986), Forest Home Trondhjemite.

| Grain.area                                                    | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|---------------------------------------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| <i>Inherited grains (n = 21)</i>                              |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| 986.4.1.1                                                     | 0.12                                               | 129        | 49          | 0.395                                  | 1.7870                                 | 1.08        | 0.2146                                  | 0.37        | 2940                                             | 6            | 3           |
| 986.7.1.1                                                     | 0.08                                               | 144        | 71          | 0.507                                  | 1.9869                                 | 1.02        | 0.1788                                  | 0.38        | 2642                                             | 6            | 1           |
| 986.10.1.1                                                    | 0.03                                               | 646        | 181         | 0.289                                  | 2.0092                                 | 0.67        | 0.1759                                  | 0.33        | 2614                                             | 5            | 0           |
| 986.5.1.1                                                     | 0.11                                               | 415        | 233         | 0.579                                  | 2.0600                                 | 0.74        | 0.1735                                  | 0.25        | 2592                                             | 4            | 2           |
| 986.29.1.1                                                    | 0.03                                               | 217        | 134         | 0.636                                  | 2.0299                                 | 0.91        | 0.1706                                  | 0.33        | 2564                                             | 6            | -1          |
| 986.56.1.1                                                    | 0.00                                               | 195        | 61          | 0.323                                  | 2.1627                                 | 1.45        | 0.1671                                  | 0.39        | 2529                                             | 7            | 4           |
| 986.52.1.1                                                    | 0.00                                               | 222        | 84          | 0.391                                  | 2.0794                                 | 0.93        | 0.1653                                  | 0.35        | 2511                                             | 6            | -1          |
| 986.54.1.1                                                    | 0.15                                               | 119        | 61          | 0.527                                  | 2.2528                                 | 1.17        | 0.1616                                  | 0.92        | 2472                                             | 15           | 5           |
| 986.53.1.1                                                    | 0.04                                               | 104        | 66          | 0.658                                  | 2.2252                                 | 1.25        | 0.1508                                  | 0.57        | 2355                                             | 10           | -2          |
| 986.50.1.1                                                    | -0.10                                              | 78         | 67          | 0.896                                  | 2.6734                                 | 1.46        | 0.1290                                  | 0.83        | 2085                                             | 15           | 2           |
| 986.12.1.1                                                    | 0.01                                               | 1253       | 148         | 0.122                                  | 2.7012                                 | 1.05        | 0.1274                                  | 0.17        | 2063                                             | 3            | 2           |
| 986.47.1.1                                                    | 0.02                                               | 382        | 97          | 0.261                                  | 2.6445                                 | 0.77        | 0.1256                                  | 0.33        | 2038                                             | 6            | -2          |
| 986.37.1.1                                                    | 0.02                                               | 294        | 161         | 0.567                                  | 2.8776                                 | 0.85        | 0.1176                                  | 0.66        | 1920                                             | 12           | 0           |
| 986.1.1.1                                                     | 0.02                                               | 408        | 18          | 0.045                                  | 2.9599                                 | 1.63        | 0.1146                                  | 0.35        | 1873                                             | 6            | 0           |
| 986.44.1.1                                                    | 0.00                                               | 377        | 79          | 0.217                                  | 3.4027                                 | 1.28        | 0.1030                                  | 0.41        | 1678                                             | 8            | 1           |
| 986.25.1.1                                                    | 0.05                                               | 234        | 31          | 0.135                                  | 3.4157                                 | 0.89        | 0.1028                                  | 0.52        | 1675                                             | 10           | 1           |
| 986.55.1.1                                                    | 0.04                                               | 239        | 139         | 0.600                                  | 3.4179                                 | 0.90        | 0.1027                                  | 0.52        | 1674                                             | 10           | 1           |
| 986.34.1.1                                                    | 0.04                                               | 363        | 101         | 0.286                                  | 3.3391                                 | 1.15        | 0.1022                                  | 0.44        | 1665                                             | 8            | -2          |
| 986.13.1.1                                                    | -0.07                                              | 155        | 161         | 1.072                                  | 3.5545                                 | 1.61        | 0.1004                                  | 0.68        | 1631                                             | 13           | 2           |
| 986.40.1.1                                                    | -0.12                                              | 115        | 0           | 0.002                                  | 3.5892                                 | 1.19        | 0.0987                                  | 0.86        | 1600                                             | 16           | 1           |
| 986.2.1.1                                                     | 0.03                                               | 300        | 63          | 0.217                                  | 3.5946                                 | 0.81        | 0.0987                                  | 0.47        | 1599                                             | 9            | 1           |
| <i>Magmatic grains (n = 7)</i>                                |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| 986.17.1.1                                                    | 0.25                                               | 612        | 101         | 0.170                                  | 3.5871                                 | 0.92        | 0.0971                                  | 0.98        | 1570                                             | 18           | -1          |
| 986.41.1.1                                                    | 0.02                                               | 601        | 18          | 0.031                                  | 3.5948                                 | 0.94        | 0.0971                                  | 0.36        | 1569                                             | 7            | -1          |
| 986.36.1.1                                                    | 0.08                                               | 143        | 5           | 0.033                                  | 3.6946                                 | 1.10        | 0.0970                                  | 0.77        | 1567                                             | 14           | 2           |
| 986.31.1.1                                                    | 0.01                                               | 249        | 7           | 0.031                                  | 3.7337                                 | 1.23        | 0.0970                                  | 0.54        | 1567                                             | 10           | 3           |
| 986.35.1.1                                                    | 0.34                                               | 495        | 67          | 0.140                                  | 3.6650                                 | 0.73        | 0.0968                                  | 0.63        | 1563                                             | 12           | 1           |
| 986.32.1.1                                                    | 0.07                                               | 660        | 108         | 0.169                                  | 3.6595                                 | 1.20        | 0.0967                                  | 0.34        | 1561                                             | 6            | 0           |
| 986.33.1.1                                                    | 0.02                                               | 207        | 6           | 0.028                                  | 3.6070                                 | 0.95        | 0.0964                                  | 0.59        | 1556                                             | 11           | -2          |
| <i>Analyses &gt;5% discordant, or high common Pb (n = 25)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| 986.24.1.1                                                    | 0.12                                               | 763        | 190         | 0.257                                  | 2.4030                                 | 0.66        | 0.1701                                  | 0.21        | 2559                                             | 3            | 15          |
| 986.3.1.1                                                     | 0.16                                               | 1018       | 310         | 0.315                                  | 2.3985                                 | 1.37        | 0.1574                                  | 0.75        | 2428                                             | 13           | 9           |
| 986.18.1.1                                                    | 0.02                                               | 759        | 93          | 0.127                                  | 2.3567                                 | 1.39        | 0.1544                                  | 0.36        | 2396                                             | 6            | 6           |
| 986.16.1.1                                                    | 0.12                                               | 449        | 109         | 0.250                                  | 2.8040                                 | 1.17        | 0.1415                                  | 0.31        | 2246                                             | 5            | 14          |
| 986.22.1.1                                                    | 9.91                                               | 1175       | 219         | 0.193                                  | 5.4645                                 | 1.17        | 0.1407                                  | 1.40        | 2236                                             | 24           | 56          |
| 986.19.1.1                                                    | 0.04                                               | 527        | 141         | 0.276                                  | 3.0307                                 | 2.26        | 0.1339                                  | 1.72        | 2150                                             | 30           | 17          |
| 986.48.1.1                                                    | 0.05                                               | 74         | 51          | 0.712                                  | 2.9410                                 | 1.39        | 0.1229                                  | 0.80        | 1999                                             | 14           | 6           |
| 986.45.1.1                                                    | 1.33                                               | 147        | 127         | 0.895                                  | 2.6978                                 | 1.45        | 0.1227                                  | 7.92        | 1996                                             | 141          | -2          |
| 986.43.1.1                                                    | 6.28                                               | 737        | 281         | 0.394                                  | 4.1135                                 | 0.65        | 0.1225                                  | 1.29        | 1993                                             | 23           | 33          |
| 986.51.1.1                                                    | 2.01                                               | 447        | 90          | 0.209                                  | 3.6460                                 | 0.76        | 0.1160                                  | 0.83        | 1896                                             | 15           | 20          |
| 986.49.1.1                                                    | 3.96                                               | 341        | 108         | 0.326                                  | 4.2450                                 | 1.20        | 0.1145                                  | 2.40        | 1872                                             | 43           | 30          |
| 986.8.1.1                                                     | 0.31                                               | 629        | 105         | 0.173                                  | 3.4272                                 | 2.58        | 0.1128                                  | 2.26        | 1844                                             | 41           | 12          |
| 986.30.1.1                                                    | 37.99                                              | 2161       | 389         | 0.186                                  | 17.9988                                | 0.68        | 0.1073                                  | 4.30        | 1754                                             | 79           | 82          |
| 986.38.1.1                                                    | 0.53                                               | 258        | 135         | 0.540                                  | 3.5168                                 | 0.89        | 0.1068                                  | 0.73        | 1746                                             | 13           | 9           |
| 986.26.1.1                                                    | 38.78                                              | 2205       | 1216        | 0.570                                  | 14.9833                                | 2.10        | 0.1036                                  | 4.74        | 1689                                             | 87           | 78          |
| 986.28.1.1                                                    | 17.71                                              | 1007       | 150         | 0.154                                  | 10.9620                                | 1.95        | 0.1034                                  | 4.33        | 1687                                             | 80           | 69          |
| 986.6.1.1                                                     | 0.04                                               | 561        | 84          | 0.155                                  | 3.5781                                 | 1.33        | 0.1034                                  | 2.35        | 1686                                             | 43           | 6           |
| 986.46.1.1                                                    | 1.89                                               | 127        | 141         | 1.143                                  | 3.4531                                 | 1.17        | 0.1016                                  | 2.36        | 1653                                             | 44           | 1           |
| 986.11.1.1                                                    | 0.54                                               | 375        | 298         | 0.821                                  | 3.7239                                 | 0.75        | 0.1005                                  | 0.60        | 1633                                             | 11           | 7           |
| 986.21.1.1                                                    | 7.41                                               | 1068       | 326         | 0.316                                  | 5.4353                                 | 1.70        | 0.0994                                  | 4.25        | 1613                                             | 79           | 35          |

# SHRIMP geochronology of north Queensland: 2007-2010

| Grain.area | $^{206}\text{Pb}_c$<br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | $\frac{^{232}\text{Th}}{^{238}\text{U}}$ | $\frac{^{238}\text{U}}{^{206}\text{Pb}}$ | $\pm 1\sigma$<br>(%) | $\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$ | $\pm 1\sigma$<br>(%) | $\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$<br>Age (Ma) | $\pm 1\sigma$<br>(Ma) | Disc<br>(%) |
|------------|-----------------------------------------|------------|-------------|------------------------------------------|------------------------------------------|----------------------|-------------------------------------------|----------------------|-------------------------------------------------------|-----------------------|-------------|
| 986.27.1.1 | 22.60                                   | 2119       | 466         | 0.227                                    | 13.8896                                  | 1.16                 | 0.0990                                    | 6.17                 | 1606                                                  | 115                   | 75          |
| 986.20.1.1 | 2.16                                    | 887        | 195         | 0.227                                    | 6.2224                                   | 0.98                 | 0.0971                                    | 0.97                 | 1568                                                  | 18                    | 42          |
| 986.14.1.1 | 4.35                                    | 935        | 150         | 0.166                                    | 4.2607                                   | 0.67                 | 0.0968                                    | 2.80                 | 1564                                                  | 53                    | 15          |
| 986.23.1.1 | 0.97                                    | 820        | 117         | 0.147                                    | 3.8183                                   | 0.65                 | 0.0968                                    | 0.63                 | 1563                                                  | 12                    | 5           |
| 986.42.1.1 | 1.22                                    | 27         | 2           | 0.097                                    | 3.5877                                   | 2.35                 | 0.0889                                    | 4.12                 | 1403                                                  | 79                    | -15         |

1.  $^{206}\text{Pb}_c$  indicates common  $^{206}\text{Pb}$  as a percentage of the total measured  $^{206}\text{Pb}$ .

## 15. BRANDY HOT GRANODIORITE: IWGT342

|                                                         |                                                          |
|---------------------------------------------------------|----------------------------------------------------------|
| <b>GA Sample ID:</b>                                    | <b>IWGT342</b>                                           |
| <b>GA Sample Number:</b>                                | <b>1977987</b>                                           |
| <b>Other Sample ID:</b>                                 |                                                          |
| <b>1:250,000 Sheet:</b>                                 | <b>GEORGETOWN SE5412</b>                                 |
| <b>Region:</b>                                          | <b>Etheridge Province, Queensland</b>                    |
| <b>Grid Reference (AGD66):</b>                          | <b>748694mE 7975233mN Zone 54</b>                        |
| <b>Collector:</b>                                       | <b>I. Withnall</b>                                       |
| <b>Collection Date:</b>                                 | <b>18/9/2008</b>                                         |
| <b>Formal Name:</b>                                     | <b>Brandy Hot Granodiorite</b>                           |
| <b>Informal Name:</b>                                   |                                                          |
| <b>Lithology:</b>                                       | <b>porphyritic biotite granite</b>                       |
| <b>Geochronologist:</b>                                 | <b>N. Kositsin</b>                                       |
| <b>Mount ID:</b>                                        | <b>GA6082</b>                                            |
| <b>Instrument:</b>                                      | <b>SHRIMP IIe Geoscience Australia</b>                   |
| <b>Acquisition Date:</b>                                | <b>16-17/3/2009</b>                                      |
| <b>U-Pb Standard &amp; reproducibility:</b>             | <b>TEMORA-2; 0.00% (1<math>\sigma</math>) [17 of 17]</b> |
| <b><sup>207</sup>Pb/<sup>206</sup>Pb Standard:</b>      | <b>OG1 (3465.4 <math>\pm</math> 0.6 Ma)</b>              |
| <b>Measured Value (<math>\pm</math>95% confidence):</b> | <b>3468.2 <math>\pm</math> 2.2 Ma [17 of 17]</b>         |
| <b>Interpreted Age:</b>                                 | <b>1563 <math>\pm</math> 3 Ma</b>                        |
| <b>IMF correction applied?</b>                          | <b>No</b>                                                |
| <b>Interpreted Age Type:</b>                            | <b>Igneous crystallisation age</b>                       |

**Sample Description**

The Brandy Hot Granodiorite is the sole member of the Brandy Hot Supersuite, which intrudes the Etheridge Group, and crops out 20 km west of Georgetown (Withnall et al., 1997a). The sample is a felsic, I-type, porphyritic muscovite-biotite granodiorite.

Bain et al. (1985) interpreted the Brandy Hot Granodiorite as Proterozoic in age (c.f. Forsyth Supersuite). Work by Holmes (unpublished) and Champion and Heinemann (1994) has shown it to be distinct, both chemically and in its  $\gamma$ -ray spectrometric signature, from the surrounding granites of the Forsyth Supersuite, and to show both similarities and differences to Silurian granites in the region, which led to its classification as a separate Supersuite.

This sample was collected on the eastern side of the track to the old Cumberland gold mine, just inside the gate of the fence along the Gulf Developmental Road. It consists of pinkish grey, coarse-grained, slightly porphyritic to seriate

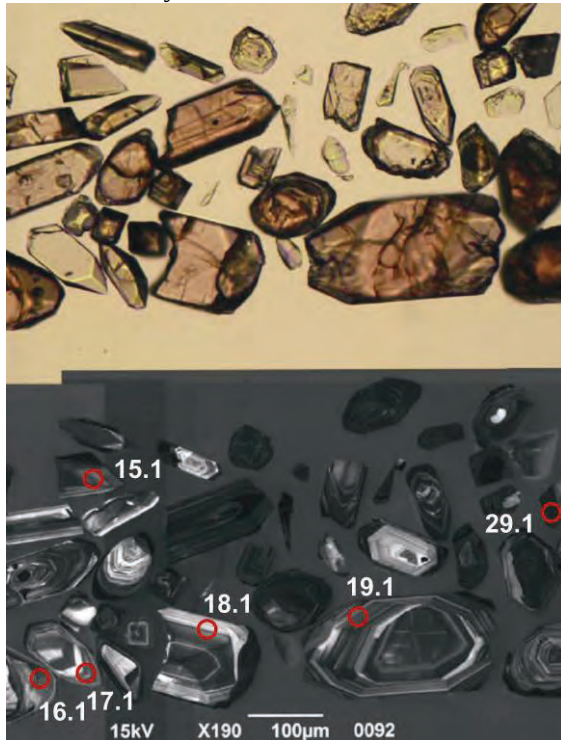
biotite granite-granodiorite with pink, subequant K-feldspar megacrysts to 2 cm.

**Zircon Description**

A range of zircon types are apparent in transmitted light (Figure 15.1). Grains are generally euhedral to subhedral, with a few rounded grains. Smaller grains are typically elongate (20-50  $\mu$ m wide, 100-120  $\mu$ m in length) and clear to colourless. The larger grains are typically of straw to red-brown in colour, and between 80-100  $\mu$ m wide and 100-400  $\mu$ m in length. Most grains are heavily fractured, and incomplete; broken fragments are common. A large proportion of grains in this sample have discernable core-rim relationships in transmitted light. Cores can be completely rounded or euhedral in appearance.

In cathodoluminescence images, a large proportion of grains have cores with a bright response; these regions are featureless, or mottled and somewhat homogeneous or have faint zoning patterns. In other cases, cores have a very poor

cathodoluminescence response and no obvious features. Some cores appear to contain several phases. Some grains have concentric, oscillatory zoned rims which apparently truncate concentric, oscillatory zoned cores (Figure 15.1). Most grains display a moderate cathodoluminescence response and reveal well defined concentric and planar oscillatory zoning. A large proportion of grains have weakly luminescent rims, but, in the majority of cases, these rims are too narrow for SHRIMP analysis.

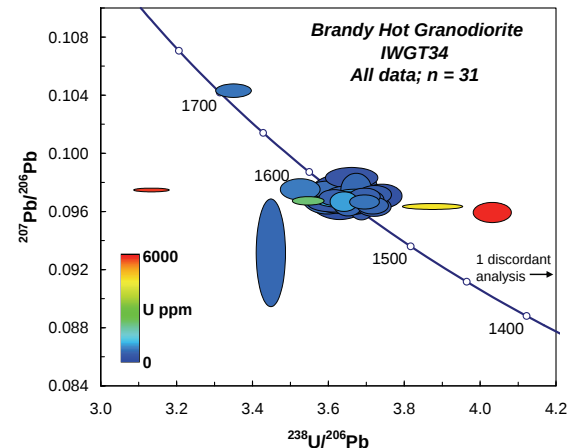


**Figure 15.1.** Representative transmitted light and cathodoluminescence images of zircons from the Brandy Hot Granodiorite (IWGT342), with locations of some SHRIMP analyses. Scale bar is 100  $\mu\text{m}$ .

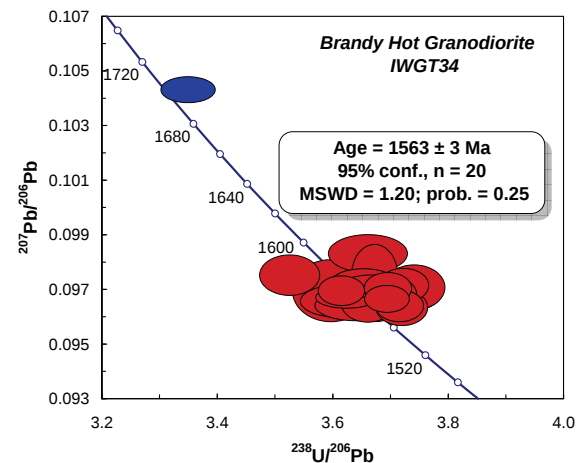
### U-Pb Isotopic Results

Thirty-one analyses were collected on 31 individual zircon grains from sample IWGT34, the results of which are presented in Table 15.1 and illustrated in Figures 15.2 and 15.3. Common  $^{206}\text{Pb}_c$  contents were between 0.01 and 14.2%. U concentrations range from 5891 to 166 ppm, with Th/U between 0.51 and 0.02. Of the 31 analyses, 10 were >5% discordant and/or contained >0.5%  $^{206}\text{Pb}_c$ , and/or have extreme U concentrations (e.g., >2000 ppm; 29.1.1; 28.1.1), and are also excluded from interpretation (Figure 15.2).

Several rims were targeted, and where concordant, there is no apparent age distinction between rims and cores. One grain is clearly inherited and has an individual age of  $1702 \pm 6$  Ma ( $1\sigma$ ). The 20 remaining analyses form a coherent group with a weighted mean age of  $1563 \pm 3$  Ma (95% confidence; MSWD = 1.20; probability = 0.25, Figure 15.3). Analyses making up this group have U concentrations between 985 ppm and 202 ppm, and Th/U ratios between 0.42 and 0.04.



**Figure 15.2.** Tera-Wasserburg concordia diagram showing all analyses for sample IWGT34 (Brandy Hot Granodiorite), coloured according to U (ppm).



**Figure 15.3.** Tera-Wasserburg concordia diagram showing near-concordant analyses for sample IWGT34 (Brandy Hot Granodiorite).

### Geochronological Interpretation

The weighted mean age of  $1563 \pm 3$  Ma is interpreted as the igneous crystallisation age of this sample.

**Table 15.1.** SHRIMP U-Pb isotopic data for zircons from sample IWGT34 (1977987), Brandy Hot Granodiorite.

| Grain.area                                                         | $^{206}\text{Pb}_c$<br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | $\frac{^{232}\text{Th}}{^{238}\text{U}}$ | $\frac{^{238}\text{U}}{^{206}\text{Pb}}$ | $\pm 1\sigma$<br>(%) | $\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$ | $\pm 1\sigma$<br>(%) | $\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$<br>Age (Ma) | $\pm 1\sigma$<br>(Ma) | Disc<br>(%) |
|--------------------------------------------------------------------|-----------------------------------------|------------|-------------|------------------------------------------|------------------------------------------|----------------------|-------------------------------------------|----------------------|-------------------------------------------------------|-----------------------|-------------|
| <i>Inherited grain (n = 1)</i>                                     |                                         |            |             |                                          |                                          |                      |                                           |                      |                                                       |                       |             |
| 987.13.1.1                                                         | 0.01                                    | 676        | 291         | 0.45                                     | 3.3485                                   | 0.93                 | 0.1043                                    | 0.30                 | 1702                                                  | 6                     | 1           |
| <i>Magmatic analyses (n = 20)</i>                                  |                                         |            |             |                                          |                                          |                      |                                           |                      |                                                       |                       |             |
| 987.18.1.1                                                         | -0.02                                   | 313        | 71          | 0.24                                     | 3.6594                                   | 1.24                 | 0.0983                                    | 0.48                 | 1591                                                  | 9                     | 2           |
| 987.27.1.1                                                         | 0.18                                    | 721        | 174         | 0.25                                     | 3.5240                                   | 0.97                 | 0.0975                                    | 0.51                 | 1576                                                  | 9                     | -2          |
| 987.8.1.1                                                          | 0.44                                    | 565        | 109         | 0.20                                     | 3.6713                                   | 0.72                 | 0.0974                                    | 0.78                 | 1576                                                  | 15                    | 2           |
| 987.1.1.1                                                          | -0.02                                   | 535        | 22          | 0.04                                     | 3.6526                                   | 1.07                 | 0.0971                                    | 0.39                 | 1570                                                  | 7                     | 1           |
| 987.6.1.1                                                          | 0.03                                    | 424        | 71          | 0.17                                     | 3.7207                                   | 0.78                 | 0.0971                                    | 0.43                 | 1569                                                  | 8                     | 2           |
| 987.23.1.1                                                         | 0.00                                    | 846        | 359         | 0.44                                     | 3.6661                                   | 0.94                 | 0.0971                                    | 0.28                 | 1568                                                  | 5                     | 1           |
| 987.17.1.1                                                         | -0.02                                   | 202        | 62          | 0.32                                     | 3.7394                                   | 0.93                 | 0.0970                                    | 0.57                 | 1567                                                  | 11                    | 3           |
| 987.9.1.1                                                          | 0.04                                    | 496        | 95          | 0.20                                     | 3.6936                                   | 0.74                 | 0.0970                                    | 0.39                 | 1567                                                  | 7                     | 2           |
| 987.12.1.1                                                         | 0.25                                    | 603        | 107         | 0.18                                     | 3.5953                                   | 1.22                 | 0.0969                                    | 0.78                 | 1565                                                  | 15                    | -1          |
| 987.15.1.1                                                         | -0.02                                   | 500        | 122         | 0.25                                     | 3.6137                                   | 0.73                 | 0.0969                                    | 0.37                 | 1565                                                  | 7                     | -1          |
| 987.31.1.1                                                         | 0.02                                    | 501        | 91          | 0.19                                     | 3.7007                                   | 0.77                 | 0.0968                                    | 0.43                 | 1563                                                  | 8                     | 1           |
| 987.24.1                                                           | 0.01                                    | 985        | 376         | 0.39                                     | 3.6227                                   | 0.97                 | 0.0966                                    | 0.27                 | 1560                                                  | 5                     | -1          |
| 987.11.1.1                                                         | 0.02                                    | 674        | 128         | 0.20                                     | 3.6925                                   | 0.70                 | 0.0966                                    | 0.34                 | 1559                                                  | 6                     | 1           |
| 987.4.1.1                                                          | 0.02                                    | 808        | 95          | 0.12                                     | 3.7043                                   | 1.30                 | 0.0965                                    | 0.31                 | 1558                                                  | 6                     | 1           |
| 987.14.1.1                                                         | 0.02                                    | 384        | 104         | 0.28                                     | 3.6140                                   | 1.30                 | 0.0965                                    | 0.42                 | 1557                                                  | 8                     | -1          |
| 987.3.1.1                                                          | 0.05                                    | 359        | 64          | 0.18                                     | 3.6725                                   | 0.82                 | 0.0965                                    | 0.49                 | 1557                                                  | 9                     | 0           |
| 987.19.1.1                                                         | 0.03                                    | 317        | 60          | 0.20                                     | 3.6598                                   | 0.83                 | 0.0964                                    | 0.48                 | 1556                                                  | 9                     | 0           |
| 987.22.1.1                                                         | 0.01                                    | 461        | 117         | 0.26                                     | 3.6401                                   | 1.31                 | 0.0963                                    | 0.39                 | 1554                                                  | 7                     | -1          |
| 987.2.1.1                                                          | 0.05                                    | 547        | 87          | 0.16                                     | 3.7141                                   | 0.74                 | 0.0963                                    | 0.41                 | 1554                                                  | 8                     | 1           |
| 987.7.1.1                                                          | 0.02                                    | 390        | 84          | 0.22                                     | 3.7184                                   | 0.80                 | 0.0963                                    | 0.46                 | 1553                                                  | 9                     | 1           |
| <i>Analyses &gt;5% discordant, or high common Pb or U (n = 10)</i> |                                         |            |             |                                          |                                          |                      |                                           |                      |                                                       |                       |             |
| 987.10.1.1                                                         | -0.23                                   | 878        | 432         | 0.51                                     | 3.1087                                   | 15.34                | 0.3516                                    | 41.11                | 3714                                                  | 626                   | 59          |
| 987.20.1.1                                                         | 0.00                                    | 5789       | 884         | 0.16                                     | 3.1327                                   | 0.98                 | 0.0974                                    | 0.09                 | 1575                                                  | 2                     | -15         |
| 987.25.1.1                                                         | 3.10                                    | 387        | 80          | 0.21                                     | 3.6853                                   | 0.79                 | 0.0971                                    | 1.21                 | 1569                                                  | 23                    | 2           |
| 987.16.1.1                                                         | 0.70                                    | 166        | 26          | 0.16                                     | 3.6276                                   | 1.50                 | 0.0969                                    | 1.06                 | 1565                                                  | 20                    | 0           |
| 987.5.1.1                                                          | 0.70                                    | 912        | 167         | 0.19                                     | 3.6390                                   | 0.66                 | 0.0966                                    | 0.46                 | 1559                                                  | 9                     | 0           |
| 987.26.1.1                                                         | 0.73                                    | 558        | 111         | 0.21                                     | 3.6493                                   | 0.71                 | 0.0964                                    | 0.57                 | 1556                                                  | 11                    | 0           |
| 987.29.1.1                                                         | 0.02                                    | 4589       | 193         | 0.04                                     | 3.8719                                   | 1.35                 | 0.0963                                    | 0.14                 | 1553                                                  | 3                     | 5           |
| 987.28.1.1                                                         | 0.00                                    | 2165       | 50          | 0.02                                     | 3.5446                                   | 0.78                 | 0.0967                                    | 0.19                 | 1561                                                  | 4                     | -3          |
| 987.30.1.1                                                         | 0.49                                    | 5891       | 220         | 0.04                                     | 4.0291                                   | 0.83                 | 0.0959                                    | 0.49                 | 1545                                                  | 9                     | 8           |
| 987.21.1.1                                                         | 14.21                                   | 569        | 156         | 0.28                                     | 3.4472                                   | 0.73                 | 0.0930                                    | 2.65                 | 1489                                                  | 50                    | -12         |

1.  $^{206}\text{Pb}_c$  indicates common  $^{206}\text{Pb}$  as a percentage of the total measured  $^{206}\text{Pb}$ .

## 16. MYWYN GRANITE: 2007167007-01

|                                                         |                                                          |
|---------------------------------------------------------|----------------------------------------------------------|
| <b>GA Sample ID:</b>                                    | <b>2007167007-01</b>                                     |
| <b>GA Sample Number:</b>                                | <b>1980483</b>                                           |
| <b>Other Sample ID:</b>                                 |                                                          |
| <b>1:250,000 Sheet:</b>                                 | <b>EINASLEIGH SE5509</b>                                 |
| <b>Region:</b>                                          | <b>Etheridge Province, Queensland</b>                    |
| <b>Grid Reference (AGD66):</b>                          | <b>730588mE 7918685mN Zone 55</b>                        |
| <b>Collector:</b>                                       | <b>D.L. Huston</b>                                       |
| <b>Collection Date:</b>                                 | <b>9/2007</b>                                            |
| <b>Formal Name:</b>                                     | <b>Mywyn Granite</b>                                     |
| <b>Informal Name:</b>                                   |                                                          |
| <b>Lithology:</b>                                       | <b>feldspar-porphyritic biotite granite</b>              |
| <b>Geochronologist:</b>                                 | <b>N. Kositsin</b>                                       |
| <b>Mount ID:</b>                                        | <b>GA6081</b>                                            |
| <b>Instrument:</b>                                      | <b>SHRIMP IIe Geoscience Australia</b>                   |
| <b>Acquisition Date:</b>                                | <b>20-21/3/2009</b>                                      |
| <b>U-Pb Standard &amp; reproducibility:</b>             | <b>TEMORA-2; 0.00% (1<math>\sigma</math>) [32 of 32]</b> |
| <b><sup>207</sup>Pb/<sup>206</sup>Pb Standard:</b>      | <b>OG1 (3465.4 <math>\pm</math> 0.6 Ma)</b>              |
| <b>Measured Value (<math>\pm</math>95% confidence):</b> | <b>3468.3 <math>\pm</math> 2.0 Ma [18 of 18]</b>         |
| <b>Interpreted Age:</b>                                 | <b>1559 <math>\pm</math> 3 Ma</b>                        |
| <b>IMF correction applied?</b>                          | <b>No</b>                                                |
| <b>Interpreted Age Type:</b>                            | <b>Igneous crystallisation age</b>                       |

**Sample Description**

The Mywyn Granite is an S-type, strongly foliated, feldspar porphyritic biotite granite, of cream-pink colour and of likely Proterozoic age (i.e., Forsayth Supersuite; Warnick and Withnall, 1985; Warnick, 1989).

The Oasis uranium prospect is hosted by a north-trending, moderately to steeply west dipping shear zone which cuts the Mywyn Granite. The Mywyn Granite has a very high background  $\gamma$ -ray spectrometric signature, and the uranium in these deposits was probably mobilised from the granite (Withnall et al., 1997a).

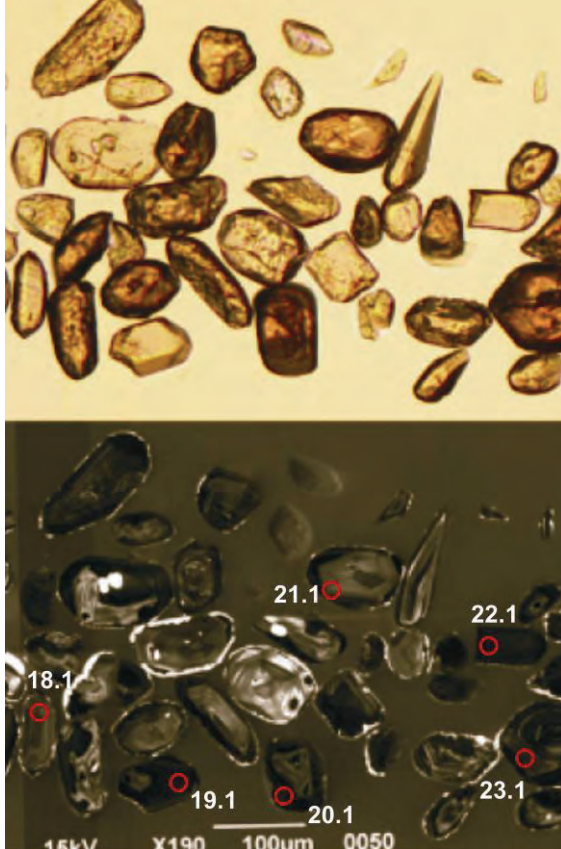
The sample, a foliated, feldspar-porphyritic biotite granite with patchy biotite-albite altered zones, was collected from drill hole LYD002 (114.4 - 118.9 m) in order to determine the emplacement age of the Mywyn Granite, and a maximum age for U mineralisation.

**Zircon Description**

A large proportion of grains have evidence of metamorphic recrystallisation, resorption and truncation of primary magmatic features, but in most cases individual zones/phases were too small to analyse (Figure 16.1). This sample has obviously experienced a degree of recrystallisation and alteration. Most grains are subhedral to rounded. The majority of grains are a light yellow or straw colour, and are 100  $\mu$ m or less in length. Larger grains (80 – <200  $\mu$ m) are straw to red-brown in colour. Aspect ratios are typically between 1:1 and 1:3.

In cathodoluminescence images, almost all grains display irregular rims (<5  $\mu$ m) which have a distinctive bright cathodoluminescence, and possibly consist of thorite and/or uraninite, which occur as multiple inclusions in a number of grains (Figure 16.1). These bright rims infill embayments and irregular grain faces. Distinctive cores, exhibiting oscillatory zoning, are recognisable in a number of grains. Inner poorly

luminescent rims and outer weakly luminescent rims are evident also. In the majority of cases, both rims and cores are disturbed such that they show a mottled/mixed appearance. The majority of rims are of weak cathodoluminescence and show no discernable features.

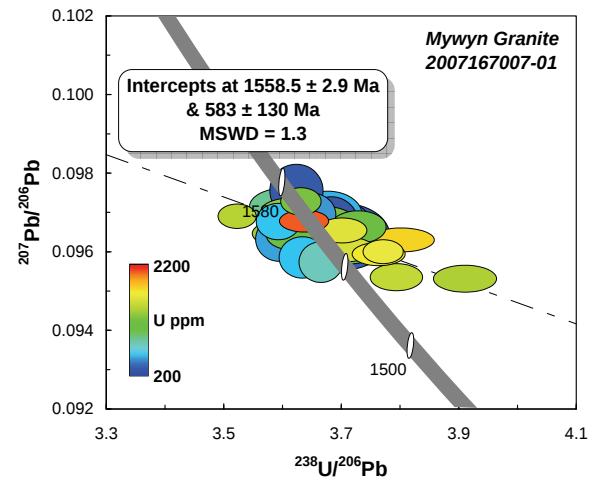


**Figure 16.1.** Representative transmitted light and cathodoluminescence images of zircons from sample 2007167007-01 (Mywyn Granite), with locations of some SHRIMP analyses. Scale bar is 100  $\mu\text{m}$ .

#### U-Pb Isotopic Results

A total of 36 analyses were collected on 36 individual zircon grains from sample 2007167007-01, the results of which are presented in Table 16.1 and illustrated in Figure 16.2. Common  $^{206}\text{Pb}_c$  contents were generally low, between zero and 0.11%. One analysis is >5% discordant. The zircons have reasonably high U concentrations between 2072 ppm and 308 ppm (median = 1168). Th/U values range between 1.73 and 0.02.

When plotted on a concordia diagram and coloured according to U content, it is evident that, in general, higher U grains tend to be slightly more discordant and have slightly younger  $^{207}\text{Pb}/^{206}\text{Pb}$  ages (Figure 16.2). All analyses define a discordia with upper and lower intercept ages of  $1559 \pm 3$  Ma and  $583 \pm 130$  Ma (95% confidence, MSWD = 1.3, probability = 0.11; Figure 16.2).



**Figure 16.2.** Tera-Wasserburg concordia diagram showing results of zircon analyses for sample 2007167007-01 (Mywyn Granite).

#### Geochronological Interpretation

Given the evidence of disturbance in this sample, the upper intercept age of  $1559 \pm 3$  Ma (MSWD = 1.3) is interpreted as the igneous crystallisation age of this rock. This age is consistent with U-Pb zircon (TIMS and SHRIMP) and Rb-Sr ages of other granites of the Forsyth Supersuite (Black and McCulloch, 1990; Black and Withnall, 1993), to which it is considered to belong. A lower intercept age defined by higher U analyses is suggestive of isotopic disturbance during the Paleozoic.

**Table 16.1.** SHRIMP U-Pb isotopic data for zircons from sample 2007167007-01 (1980483), Mywyn Granite.

| Grain.area                        | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|-----------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| <i>Magmatic analyses (n = 35)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| 483.26.1.1                        | 0.00                                               | 325        | 300         | 0.955                                  | 3.6240                                 | 0.82        | 0.0975                                  | 0.46        | 1578                                             | 9            | 0           |
| 483.33.1.1                        | 0.02                                               | 1232       | 117         | 0.098                                  | 3.6317                                 | 0.62        | 0.0973                                  | 0.24        | 1572                                             | 4            | 0           |
| 483.24.1.1                        | 0.08                                               | 868        | 1078        | 1.283                                  | 3.6036                                 | 1.09        | 0.0971                                  | 0.32        | 1570                                             | 6            | -1          |
| 483.19.1.1                        | 0.00                                               | 1317       | 111         | 0.087                                  | 3.6164                                 | 0.97        | 0.0970                                  | 0.23        | 1568                                             | 4            | 0           |
| 483.10.1.1                        | 0.01                                               | 490        | 378         | 0.796                                  | 3.6495                                 | 0.74        | 0.0969                                  | 0.37        | 1566                                             | 7            | 0           |
| 483.34.1.1                        | 0.11                                               | 534        | 864         | 1.673                                  | 3.6770                                 | 1.05        | 0.0969                                  | 0.42        | 1565                                             | 8            | 1           |
| 483.32.1.1                        | 0.01                                               | 1421       | 357         | 0.259                                  | 3.5231                                 | 0.61        | 0.0969                                  | 0.21        | 1565                                             | 4            | -3          |
| 483.27.1.1                        | 0.01                                               | 1342       | 76          | 0.059                                  | 3.6198                                 | 0.95        | 0.0968                                  | 0.23        | 1564                                             | 4            | -1          |
| 483.22.1.1                        | 0.00                                               | 1232       | 88          | 0.073                                  | 3.6712                                 | 0.91        | 0.0968                                  | 0.24        | 1563                                             | 4            | 1           |
| 483.13.1.1                        | 0.00                                               | 2072       | 165         | 0.082                                  | 3.6370                                 | 0.75        | 0.0968                                  | 0.19        | 1563                                             | 4            | 0           |
| 483.5.1.1                         | 0.04                                               | 565        | 252         | 0.461                                  | 3.5932                                 | 0.69        | 0.0968                                  | 0.32        | 1562                                             | 6            | -1          |
| 483.21.1.1                        | -0.02                                              | 455        | 304         | 0.690                                  | 3.6896                                 | 1.09        | 0.0967                                  | 0.41        | 1561                                             | 8            | 1           |
| 483.12.1.1                        | -0.01                                              | 308        | 377         | 1.265                                  | 3.6829                                 | 0.84        | 0.0967                                  | 0.49        | 1561                                             | 9            | 1           |
| 483.30.1.1                        | 0.10                                               | 1128       | 75          | 0.069                                  | 3.7287                                 | 0.85        | 0.0966                                  | 0.28        | 1560                                             | 5            | 2           |
| 483.9.1.1                         | -0.01                                              | 1209       | 111         | 0.094                                  | 3.6525                                 | 0.62        | 0.0966                                  | 0.49        | 1559                                             | 9            | 0           |
| 483.4.1.1                         | -0.01                                              | 1459       | 193         | 0.137                                  | 3.6789                                 | 0.95        | 0.0966                                  | 0.22        | 1559                                             | 4            | 1           |
| 483.7.1.1                         | 0.01                                               | 1593       | 36          | 0.023                                  | 3.7015                                 | 0.75        | 0.0965                                  | 0.22        | 1558                                             | 4            | 1           |
| 483.25.1.1                        | 0.00                                               | 1248       | 110         | 0.091                                  | 3.6576                                 | 1.14        | 0.0965                                  | 0.24        | 1558                                             | 4            | 0           |
| 483.15.1.1                        | 0.01                                               | 912        | 496         | 0.562                                  | 3.6571                                 | 1.21        | 0.0965                                  | 0.29        | 1557                                             | 5            | 0           |
| 483.35.1.1                        | -0.01                                              | 1329       | 120         | 0.093                                  | 3.5988                                 | 0.91        | 0.0965                                  | 0.23        | 1557                                             | 4            | -2          |
| 483.17.1.1                        | -0.01                                              | 582        | 461         | 0.819                                  | 3.6750                                 | 1.07        | 0.0964                                  | 0.35        | 1556                                             | 7            | 0           |
| 483.28.1.1                        | 0.02                                               | 1102       | 127         | 0.119                                  | 3.6206                                 | 0.86        | 0.0964                                  | 0.26        | 1555                                             | 5            | -1          |
| 483.31.1.1                        | 0.22                                               | 336        | 397         | 1.218                                  | 3.7025                                 | 1.43        | 0.0964                                  | 0.58        | 1555                                             | 11           | 1           |
| 483.1.1.1                         | 0.05                                               | 508        | 372         | 0.757                                  | 3.5942                                 | 0.73        | 0.0963                                  | 0.38        | 1554                                             | 7            | -2          |
| 483.16.1.1                        | 0.00                                               | 1782       | 149         | 0.087                                  | 3.8014                                 | 0.98        | 0.0963                                  | 0.21        | 1553                                             | 4            | 3           |
| 483.3.1.1                         | 0.04                                               | 503        | 868         | 1.783                                  | 3.6624                                 | 0.73        | 0.0963                                  | 0.38        | 1553                                             | 7            | 0           |
| 483.6.1.1                         | 0.01                                               | 1052       | 534         | 0.524                                  | 3.6289                                 | 1.13        | 0.0963                                  | 0.26        | 1553                                             | 5            | -1          |
| 483.2.1.1                         | 0.01                                               | 956        | 249         | 0.269                                  | 3.7090                                 | 1.09        | 0.0961                                  | 0.28        | 1550                                             | 5            | 1           |
| 483.8.1.1                         | 0.01                                               | 1561       | 209         | 0.138                                  | 3.7098                                 | 0.84        | 0.0960                                  | 0.22        | 1549                                             | 4            | 1           |
| 483.14.1.1                        | 0.00                                               | 1642       | 158         | 0.099                                  | 3.7712                                 | 0.60        | 0.0960                                  | 0.21        | 1547                                             | 4            | 2           |
| 483.11.1.1                        | 0.00                                               | 1711       | 203         | 0.122                                  | 3.7632                                 | 0.78        | 0.0959                                  | 0.20        | 1546                                             | 4            | 2           |
| 483.18.1.1                        | 0.03                                               | 561        | 669         | 1.233                                  | 3.6344                                 | 0.72        | 0.0958                                  | 0.37        | 1545                                             | 7            | -2          |
| 483.23.1.1                        | 0.13                                               | 760        | 327         | 0.445                                  | 3.6655                                 | 0.67        | 0.0957                                  | 0.36        | 1542                                             | 7            | -1          |
| 483.29.1.1                        | 0.07                                               | 1482       | 148         | 0.103                                  | 3.7937                                 | 0.77        | 0.0953                                  | 0.24        | 1535                                             | 4            | 2           |
| 483.20.1.1                        | 0.04                                               | 1384       | 163         | 0.122                                  | 3.9104                                 | 0.91        | 0.0953                                  | 0.24        | 1534                                             | 4            | 5           |
| 483.36.1.1                        | 0.04                                               | 1300       | 353         | 0.280                                  | 5.7070                                 | 31.13       | 0.0949                                  | 0.31        | 1526                                             | 6            | 34          |

1. <sup>206</sup>Pb<sub>c</sub> indicates common <sup>206</sup>Pb as a percentage of the total measured <sup>206</sup>Pb.

## 17. GILBERTON FORMATION: 2007167002-08

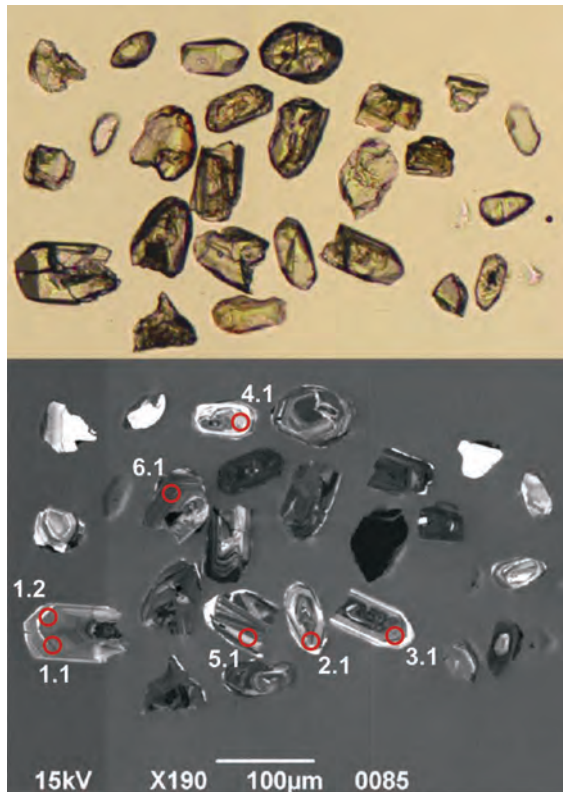
|                                                         |                                                          |
|---------------------------------------------------------|----------------------------------------------------------|
| <b>GA Sample ID:</b>                                    | <b>2007167002-08</b>                                     |
| <b>GA Sample Number:</b>                                | <b>1980538</b>                                           |
| <b>Other Sample ID:</b>                                 |                                                          |
| <b>1:250,000 Sheet:</b>                                 | <b>RED RIVER SE5408</b>                                  |
| <b>Region:</b>                                          | <b>Etheridge Province, Queensland</b>                    |
| <b>Grid Reference (AGD66):</b>                          | <b>756786mE 8008597mN Zone 54</b>                        |
| <b>Collector:</b>                                       | <b>D.L. Huston</b>                                       |
| <b>Collection Date:</b>                                 | <b>9/2007</b>                                            |
| <b>Formal Name:</b>                                     | <b>Gilberton Formation</b>                               |
| <b>Informal Name:</b>                                   |                                                          |
| <b>Lithology:</b>                                       | <b>fine-grained volcanoclastic sandstone</b>             |
| <b>Geochronologist:</b>                                 | <b>N. Kositcin</b>                                       |
| <b>Mount ID:</b>                                        | <b>GA6082</b>                                            |
| <b>Instrument:</b>                                      | <b>SHRIMP IIe Geoscience Australia</b>                   |
| <b>Acquisition Date:</b>                                | <b>18/3/2009</b>                                         |
| <b>U-Pb Standard &amp; reproducibility:</b>             | <b>TEMORA-2; 0.00% (1<math>\sigma</math>) [17 of 17]</b> |
| <b><sup>207</sup>Pb/<sup>206</sup>Pb Standard:</b>      | <b>OG1 (3465.4 <math>\pm</math> 0.6 Ma)</b>              |
| <b>Measured Value (<math>\pm</math>95% confidence):</b> | <b>3468.2 <math>\pm</math> 2.2 Ma [17 of 17]</b>         |
| <b>Interpreted Age:</b>                                 | <b>~335 Ma</b>                                           |
| <b>IMF correction applied?</b>                          | <b>No</b>                                                |
| <b>Interpreted Age Type:</b>                            | <b>Maximum depositional age</b>                          |

**Sample Description**

The most extensive outcrop area of Gilberton Formation is one of about 120 km<sup>2</sup> near Gilberton. Other occurrences are scattered through the central part of the Georgetown Region mainly preserved beneath areas of Carboniferous volcanic rocks. All outcrops lie within the Georgetown Region (Withnall et al., 1997a). This sample was collected from drillcore (DDH 9025; 32.68–32.70 m). The Late Devonian to Early Carboniferous Gilberton Formation predominantly consists of quartzose to feldspathic fluvial sandstones and conglomerates, with sparse tuffs and volcanoclastic sedimentary rocks the latter occurring locally in the Maureen area (Withnall et al., 1997a, b). Macroflora indicate deposition of the Gilberton Formation between the late Famennian and Viséan (Withnall et al., 1997a). The sample was collected in order to determine the depositional age of the unit (on the premise that the sample may represent a volcanic tuff).

**Zircon Description**

Only a small amount of material was collected. Consequently, sample 2007167002-08 returned a poor yield of 22 zircons, of which only a few were suitable for SHRIMP analysis (that is, part of grains of reasonable size and clarity, free of cracks etc., [Figure 17.1](#)). In transmitted light, the majority of grains are a light yellow or straw colour, and all are 100  $\mu$ m or less in length. Most are subhedral to rounded, extensively cracked, with some broken grain fragments. There is some evidence of resorption and truncation of primary magmatic features in a few grains. Most grains display oscillatory and/or irregular zonation patterns in cathodoluminescence images, and distinctive cores are evident in very few grains. The appearance of these grains suggests this sample is not of volcanic origin.

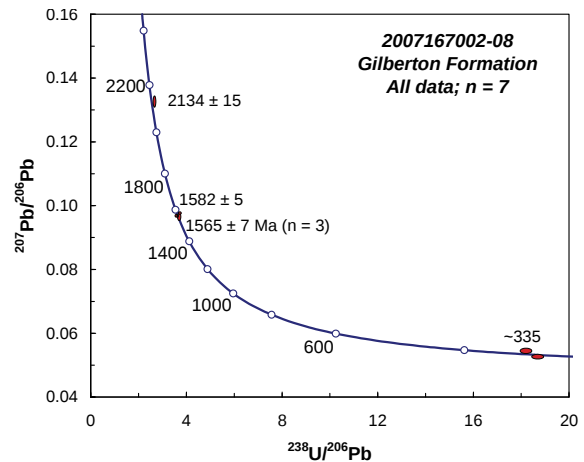


**Figure 17.1.** Transmitted light and cathodoluminescence images of all zircons extracted from sample 2007167002-08 (Gilberton Formation), with locations of SHRIMP analyses. Scale bar is 100  $\mu\text{m}$ .

### U-Pb Isotopic Results

Seven analyses were collected on 6 individual zircon grains from sample 2007167002-08 (Table 17.1). Common  $^{206}\text{Pb}_c$  contents were low, between zero and 0.52%, but generally less than 0.1%. U concentrations range between 165 and 77 ppm, with Th/U ratios between 0.73 and 0.08. No coherent age group was determined, and the analyses give a large spread of ages between  $336 \pm 3$  Ma and  $2134 \pm 15$  Ma ( $1\sigma$ ). As the majority of ages were Proterozoic, a second analysis was conducted on the young grain to confirm its age ( $344 \pm 3$  Ma,  $1\sigma$ ). Three grains combine to give a

weighted mean age of  $1565 \pm 7$  Ma (95% confidence; MSWD = 0.06; probability = 0.94), and individuals are recorded at  $2134 \pm 15$  Ma and  $1582 \pm 5$  Ma ( $1\sigma$ , Figure 17.2).



**Figure 17.2.** Tera-Wasserburg concordia diagram showing near-concordant analyses for sample 2007167002-08 (Gilberton Formation).

### Geochronological Interpretation

Although too few analyses were conducted to make any meaningful conclusions, it is likely that this sample does not represent a tuff, but is a clastic sedimentary rock of the Gilberton Formation. The  $\sim 335$  Ma age, although based on duplicate analyses on one grain, is consistent with the Late Devonian-Early Carboniferous age of the Gilberton Formation in the Maureen area, and the  $\sim 1560$  Ma ages are consistent with a provenance of the Forsyth Supersuite and similar-aged granitic rocks in the region.

**Table 17.1.** SHRIMP U-Pb isotopic data for zircons from sample 2007167002-08 (1980538), Gilberton Formation.

| Grain.area                       | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|----------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|-----------------------------------------|-------------|--------------------------------------------------|--------------|-------------|
| <i>Detrital analyses (n = 6)</i> |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| 538.2.1.1                        | 0.52                                               | 98         | 68          | 0.72                                   | 3.7221                                 | 1.17        | 0.0966                                  | 0.81        | 1560                                             | 15           | 2           |
| 538.3.1.1                        | 0.02                                               | 123        | 10          | 0.08                                   | 3.7552                                 | 0.96        | 0.0978                                  | 0.29        | 1582                                             | 5            | 4           |
| 538.4.1.1                        | 0.00                                               | 77         | 10          | 0.13                                   | 2.6832                                 | 1.50        | 0.1327                                  | 0.87        | 2134                                             | 15           | 5           |
| 538.5.1.1                        | 0.15                                               | 143        | 105         | 0.75                                   | 3.6088                                 | 0.91        | 0.0969                                  | 0.30        | 1566                                             | 6            | -1          |
| 538.6.1.1                        | 0.05                                               | 165        | 118         | 0.74                                   | 3.6514                                 | 0.63        | 0.0969                                  | 0.27        | 1565                                             | 5            | 0           |
| Grain.area                       | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>206</sup> Pb/ <sup>238</sup> U<br>Age (Ma)  | ± 1σ<br>(Ma) | Disc<br>(%) |
| <i>Youngest grain (n = 2)</i>    |                                                    |            |             |                                        |                                        |             |                                         |             |                                                  |              |             |
| 538.1.1.1                        | 0.06                                               | 117        | 56          | 0.50                                   | 18.7139                                | 0.89        | 0.0529                                  | 0.95        | 336                                              | 3            | -4          |
| 538.1.2.1                        | -0.10                                              | 116        | 55          | 0.49                                   | 18.2279                                | 0.87        | 0.0547                                  | 0.99        | 344                                              | 3            | 14          |

1. <sup>206</sup>Pb<sub>c</sub> indicates common <sup>206</sup>Pb as a percentage of the total measured <sup>206</sup>Pb.

## 18. UNNAMED SANDSTONE, JHR GLENBEDE DOWNS 1: 2010831028

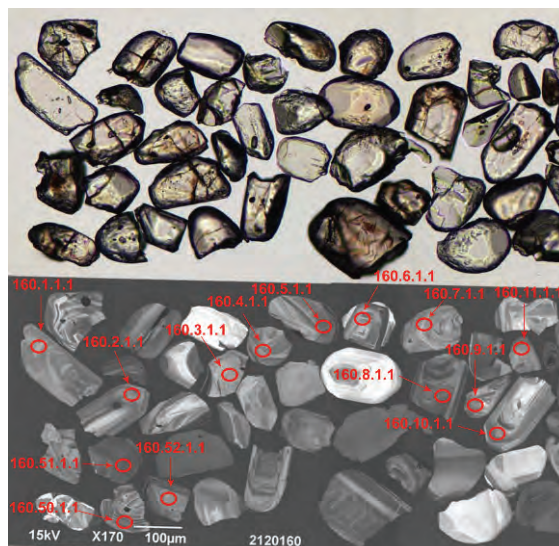
|                                                         |                                               |
|---------------------------------------------------------|-----------------------------------------------|
| <b>GA Sample ID:</b>                                    | 2010831028                                    |
| <b>GA Sample Number:</b>                                | 2120160                                       |
| <b>Other Sample ID:</b>                                 | JHR GLENBEDE DOWNS 1: 603.51 - 664.47 m depth |
| <b>1:250,000 Sheet:</b>                                 | McKINLAY SF5407                               |
| <b>Region:</b>                                          | Millungera Basin, Queensland                  |
| <b>Grid Reference (MGA94):</b>                          | 558230mE 7668439mN Zone 54                    |
| <b>Collector:</b>                                       | R.J. Korsch                                   |
| <b>Drill Date:</b>                                      | 01-AUG-1988                                   |
| <b>Formal Name:</b>                                     |                                               |
| <b>Informal Name:</b>                                   | JHR Glenbede Downs 1 sandstone                |
| <b>Lithology:</b>                                       | sandstone                                     |
| <b>Geochronologist:</b>                                 | N.L. Neumann                                  |
| <b>Mount ID:</b>                                        | GA6151                                        |
| <b>Instrument:</b>                                      | SHRIMP IIe Geoscience Australia               |
| <b>Acquisition Date:</b>                                | 5-11/1/2011                                   |
| <b>U-Pb Standard &amp; reproducibility:</b>             | TEMORA-2; 1.5% (2 $\sigma$ ) [40 of 40]       |
| <b><sup>207</sup>Pb/<sup>206</sup>Pb Standard:</b>      | OG1 (3465.4 $\pm$ 0.6 Ma)                     |
| <b>Measured Value (<math>\pm</math>95% confidence):</b> | 3460.6 $\pm$ 1.9 Ma [32 of 32]                |
| <b>Interpreted Age:</b>                                 | 1570 $\pm$ 11 Ma                              |
| <b>IMF correction applied?</b>                          | Yes - to all individual analyses              |
| <b>Interpreted Age Type:</b>                            | Maximum deposition age                        |

**Sample Description**

This sample was collected from the JHR Glenbede Downs 1 drill hole, between the 603.51 m to 664.47 m depth interval, within the Millungera Basin, Queensland. The sample was collected from drill cuttings, and was a red sandstone.

**Zircon Description**

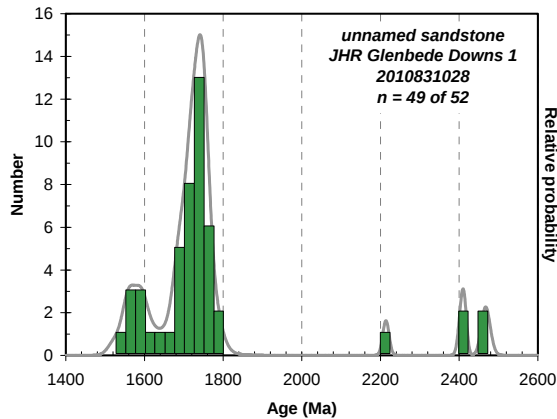
Zircons from this sample range in length from ~100  $\mu$ m to ~200  $\mu$ m (Figure 18.1). Most grains are subrounded, with some grains recording pitted surfaces, and are clear and colourless to brown in colour. In cathodoluminescence images, most grains record oscillatory zoning, whereas some record a dark cathodoluminescence response.



### U-Pb Isotopic Results

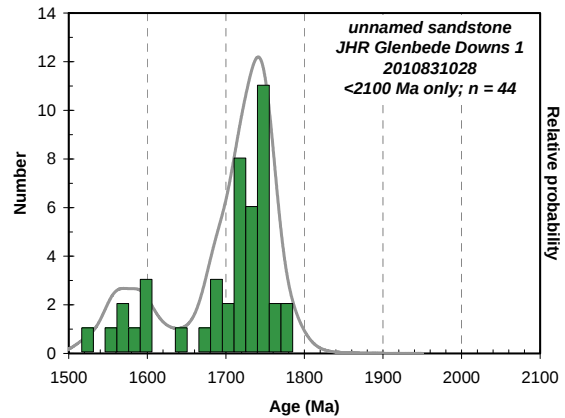
Fifty-two analyses were undertaken on zircons from this sample, the results of which are presented in Table 18.1 and illustrated in Figures 18.2 and 18.3. An IMF correction was applied to all individual  $^{207}\text{Pb}/^{206}\text{Pb}$  analyses following the methodology outlined in Stern et al. (2009). U concentrations of the analysed zircons range between 391 and 40 ppm, with Th/U ratios between 2.28 and 0.26. One discordant analysis and two grains with common  $^{206}\text{Pb}_c$  contents greater than an arbitrary value of 0.5% were removed from further consideration.

The remaining 49 analyses yield ages between ~2470 Ma and ~1527 Ma (Figure 18.2). Within the spectra, there are four ages between ~2470 Ma and ~2405 Ma, one age at ~2214 Ma and large number of ages from ~1781 Ma to ~1527 Ma.



**Figure 18.2.** Probability density diagram of zircon analyses from the unnamed sandstone, JHR Glenbede Downs 1 drillhole (2010831028).

The youngest individual age of  $1527 \pm 26$  Ma ( $2\sigma$ ) forms part of this cluster, but the MSWD value for the weighted mean age of this entire group indicates that it is not a single population (Figure 18.3). Mixture modelling (Sambridge and Compston, 1994) of this cluster based on two components provides modelled ages of  $1570 \pm 11$  Ma ( $2\sigma$ ; 19% of the cluster) and  $1732 \pm 6$  Ma ( $2\sigma$ ; 81% of the cluster). Alternatively, using the MSWD as a guide, the youngest statically coherent age group provides a weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1559 \pm 24$  Ma (95% confidence) for the youngest 5 analyses in this cluster (MSWD = 1.8; probability of fit = 0.13; Figure 18.3).



**Figure 18.3.** Probability density diagram of zircon analyses from the unnamed sandstone, JHR Glenbede Downs 1 drillhole (2010831028), yielding  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of less than 2100 Ma.

### Geochronological Interpretation

As the age determined by the mixture modelling approach is within error of the youngest weighted mean age calculated using the MSWD as a guide, the modelled age of  $1570 \pm 11$  Ma ( $2\sigma$ ) can be used to define a maximum depositional age for this sedimentary rock.

**Table 18.1.** SHRIMP U-Pb isotopic data for zircons from sample 2010831028 (2120160), unnamed sandstone, JHR Glenbede Downs 1.

| Grain.area                                                         | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb <sup>#</sup> | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age <sup>#</sup> (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|--------------------------------------------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|------------------------------------------------------|-------------|---------------------------------------------------------------|--------------|-------------|
| <i>Detrital zircon (n = 49)</i>                                    |                                                    |            |             |                                        |                                        |             |                                                      |             |                                                               |              |             |
| 160.16.1.1                                                         | 0.03                                               | 97         | 145         | 1.54                                   | 2.2281                                 | 1.3         | 0.1614                                               | 0.7         | 2470                                                          | 12           | 3           |
| 160.49.1.1                                                         | 0.03                                               | 133        | 130         | 1.01                                   | 2.0910                                 | 1.1         | 0.1610                                               | 0.6         | 2466                                                          | 10           | -2          |
| 160.19.1.1                                                         | 0.02                                               | 352        | 149         | 0.44                                   | 2.2416                                 | 0.9         | 0.1560                                               | 0.4         | 2413                                                          | 7            | 1           |
| 160.34.1.1                                                         | -0.03                                              | 239        | 62          | 0.27                                   | 2.1375                                 | 1.0         | 0.1553                                               | 0.4         | 2405                                                          | 8            | -3          |
| 160.27.1.1                                                         | 0.03                                               | 290        | 411         | 1.46                                   | 2.4397                                 | 1.0         | 0.1389                                               | 0.5         | 2214                                                          | 8            | 0           |
| 160.30.1.1                                                         | -0.17                                              | 108        | 83          | 0.80                                   | 3.2128                                 | 1.2         | 0.1089                                               | 1.1         | 1781                                                          | 20           | 2           |
| 160.15.1.1                                                         | -0.10                                              | 148        | 94          | 0.66                                   | 3.3349                                 | 1.3         | 0.1087                                               | 0.9         | 1778                                                          | 17           | 5           |
| 160.13.1.1                                                         | -0.03                                              | 265        | 67          | 0.26                                   | 3.2714                                 | 1.3         | 0.1076                                               | 0.6         | 1759                                                          | 11           | 2           |
| 160.25.1.1                                                         | -0.10                                              | 154        | 99          | 0.66                                   | 3.2811                                 | 1.1         | 0.1075                                               | 1.7         | 1758                                                          | 32           | 2           |
| 160.23.1.1                                                         | 0.03                                               | 148        | 95          | 0.66                                   | 3.3090                                 | 1.1         | 0.1072                                               | 0.8         | 1753                                                          | 15           | 3           |
| 160.3.1.1                                                          | -0.06                                              | 93         | 47          | 0.52                                   | 3.1738                                 | 1.3         | 0.1072                                               | 1.1         | 1752                                                          | 20           | -1          |
| 160.28.1.1                                                         | -0.03                                              | 157        | 91          | 0.60                                   | 3.2386                                 | 1.1         | 0.1071                                               | 0.8         | 1751                                                          | 14           | 1           |
| 160.33.1.1                                                         | 0.08                                               | 195        | 109         | 0.57                                   | 3.2848                                 | 1.0         | 0.1071                                               | 0.7         | 1751                                                          | 14           | 2           |
| 160.45.1.1                                                         | 0.01                                               | 91         | 69          | 0.78                                   | 3.2976                                 | 1.3         | 0.1070                                               | 1.0         | 1749                                                          | 19           | 2           |
| 160.8.1.1                                                          | 0.04                                               | 202        | 115         | 0.59                                   | 3.2711                                 | 1.1         | 0.1069                                               | 0.8         | 1747                                                          | 14           | 2           |
| 160.20.1.1                                                         | -0.01                                              | 254        | 158         | 0.64                                   | 3.2168                                 | 1.0         | 0.1069                                               | 0.6         | 1747                                                          | 11           | 0           |
| 160.14.1.1                                                         | -0.10                                              | 64         | 46          | 0.74                                   | 3.2858                                 | 1.5         | 0.1068                                               | 2.9         | 1746                                                          | 53           | 2           |
| 160.18.1.1                                                         | 0.07                                               | 150        | 149         | 1.03                                   | 3.2720                                 | 1.1         | 0.1068                                               | 0.9         | 1746                                                          | 16           | 2           |
| 160.43.1.1                                                         | 0.21                                               | 110        | 89          | 0.83                                   | 3.2400                                 | 1.2         | 0.1067                                               | 1.1         | 1745                                                          | 20           | 1           |
| 160.24.1.1                                                         | -0.04                                              | 166        | 94          | 0.59                                   | 3.1745                                 | 1.1         | 0.1067                                               | 0.8         | 1744                                                          | 15           | -1          |
| 160.10.1.1                                                         | 0.03                                               | 176        | 127         | 0.74                                   | 3.3076                                 | 1.1         | 0.1064                                               | 0.8         | 1738                                                          | 14           | 2           |
| 160.11.1.1                                                         | 0.21                                               | 140        | 73          | 0.54                                   | 3.2425                                 | 1.2         | 0.1063                                               | 1.0         | 1736                                                          | 19           | 0           |
| 160.29.1.1                                                         | -0.03                                              | 219        | 82          | 0.39                                   | 3.2580                                 | 1.4         | 0.1062                                               | 0.7         | 1735                                                          | 12           | 1           |
| 160.51.1.1                                                         | 0.01                                               | 391        | 191         | 0.50                                   | 3.2278                                 | 1.0         | 0.1059                                               | 0.8         | 1730                                                          | 15           | -1          |
| 160.39.1.1                                                         | 0.02                                               | 180        | 83          | 0.48                                   | 3.3019                                 | 1.1         | 0.1057                                               | 0.7         | 1727                                                          | 13           | 1           |
| 160.44.1.1                                                         | -0.14                                              | 79         | 73          | 0.95                                   | 3.2585                                 | 1.4         | 0.1057                                               | 1.3         | 1726                                                          | 24           | 0           |
| 160.4.1.1                                                          | -0.07                                              | 123        | 87          | 0.73                                   | 3.2727                                 | 1.2         | 0.1054                                               | 1.0         | 1722                                                          | 18           | 0           |
| 160.6.1.1                                                          | -0.15                                              | 86         | 62          | 0.74                                   | 3.2295                                 | 1.3         | 0.1054                                               | 1.5         | 1721                                                          | 27           | -1          |
| 160.22.1.1                                                         | 0.05                                               | 152        | 92          | 0.63                                   | 3.2858                                 | 1.1         | 0.1053                                               | 1.0         | 1719                                                          | 18           | 0           |
| 160.48.1.1                                                         | -0.02                                              | 219        | 117         | 0.55                                   | 3.2582                                 | 1.0         | 0.1052                                               | 0.7         | 1718                                                          | 12           | 0           |
| 160.12.1.1                                                         | 0.00                                               | 239        | 75          | 0.32                                   | 3.2169                                 | 1.0         | 0.1050                                               | 0.6         | 1715                                                          | 12           | -2          |
| 160.41.1.1                                                         | -0.03                                              | 81         | 180         | 2.28                                   | 3.4402                                 | 1.4         | 0.1049                                               | 1.6         | 1713                                                          | 29           | 4           |
| 160.21.1.1                                                         | 0.09                                               | 64         | 61          | 0.99                                   | 3.2779                                 | 1.5         | 0.1049                                               | 1.4         | 1712                                                          | 25           | 0           |
| 160.38.1.1                                                         | 0.12                                               | 143        | 89          | 0.64                                   | 3.2720                                 | 1.1         | 0.1048                                               | 1.0         | 1711                                                          | 18           | 0           |
| 160.52.1.1                                                         | 0.12                                               | 109        | 68          | 0.64                                   | 3.2600                                 | 1.2         | 0.1040                                               | 1.0         | 1697                                                          | 18           | -2          |
| 160.26.1.1                                                         | -0.05                                              | 189        | 79          | 0.43                                   | 3.2682                                 | 1.1         | 0.1039                                               | 0.8         | 1696                                                          | 15           | -1          |
| 160.9.1.1                                                          | 0.05                                               | 168        | 163         | 1.00                                   | 3.5175                                 | 1.1         | 0.1033                                               | 0.9         | 1685                                                          | 16           | 4           |
| 160.40.1.1                                                         | -0.03                                              | 177        | 92          | 0.54                                   | 3.3033                                 | 1.1         | 0.1033                                               | 0.8         | 1685                                                          | 15           | -1          |
| 160.32.1.1                                                         | 0.23                                               | 67         | 39          | 0.61                                   | 3.2970                                 | 1.4         | 0.1033                                               | 1.9         | 1684                                                          | 34           | -1          |
| 160.42.1.1                                                         | -0.21                                              | 40         | 22          | 0.58                                   | 3.4387                                 | 1.8         | 0.1024                                               | 1.9         | 1667                                                          | 35           | 1           |
| 160.35.1.1                                                         | -0.02                                              | 42         | 79          | 1.94                                   | 3.5203                                 | 2.5         | 0.1011                                               | 1.6         | 1644                                                          | 29           | 2           |
| 160.46.1.1                                                         | 0.14                                               | 80         | 42          | 0.54                                   | 3.4563                                 | 1.4         | 0.0989                                               | 1.3         | 1604                                                          | 24           | -2          |
| 160.7.1.1                                                          | -0.09                                              | 96         | 67          | 0.73                                   | 3.6888                                 | 1.7         | 0.0986                                               | 1.2         | 1597                                                          | 22           | 3           |
| 160.36.1.1                                                         | 0.02                                               | 227        | 184         | 0.84                                   | 3.5504                                 | 1.0         | 0.0983                                               | 0.7         | 1592                                                          | 13           | 0           |
| 160.47.1.1                                                         | 0.00                                               | 111        | 64          | 0.60                                   | 3.5801                                 | 1.2         | 0.0981                                               | 1.0         | 1589                                                          | 20           | 0           |
| 160.5.1.1                                                          | 0.00                                               | 241        | 152         | 0.65                                   | 3.5738                                 | 1.2         | 0.0972                                               | 0.7         | 1572                                                          | 13           | -1          |
| 160.31.1.1                                                         | -0.08                                              | 326        | 111         | 0.35                                   | 3.6458                                 | 1.0         | 0.0966                                               | 0.7         | 1560                                                          | 12           | 0           |
| 160.50.1.1                                                         | -0.02                                              | 257        | 156         | 0.63                                   | 3.6142                                 | 1.0         | 0.0961                                               | 0.7         | 1550                                                          | 13           | -2          |
| 160.37.1.1                                                         | 0.06                                               | 169        | 173         | 1.06                                   | 3.7410                                 | 1.1         | 0.0949                                               | 0.9         | 1527                                                          | 18           | 0           |
| <i>Analysis &gt;10% discordant (n = 1)</i>                         |                                                    |            |             |                                        |                                        |             |                                                      |             |                                                               |              |             |
| 160.17.1.1                                                         | 0.01                                               | 338        | 189         | 0.58                                   | 3.7236                                 | 1.1         | 0.1053                                               | 0.6         | 1719                                                          | 11           | 11          |
| <i>Analyses with <sup>206</sup>Pb<sub>c</sub> &gt;0.5% (n = 2)</i> |                                                    |            |             |                                        |                                        |             |                                                      |             |                                                               |              |             |
| 160.2.1.1                                                          | 2.87                                               | 126        | 120         | 0.98                                   | 3.3979                                 | 1.3         | 0.1078                                               | 4.7         | 1762                                                          | 85           | 6           |
| 160.1.1.1                                                          | 1.97                                               | 92         | 46          | 0.51                                   | 3.5831                                 | 1.4         | 0.0970                                               | 3.6         | 1568                                                          | 68           | -1          |

<sup>1</sup>. <sup>206</sup>Pb<sub>c</sub> indicates common <sup>206</sup>Pb as a percentage of the total measured <sup>206</sup>Pb.<sup>#</sup>IMF-corrected value, following the methodology outlined in Stern et al. (2009).

## 19. UNNAMED SANDSTONE, JHR HAMPDEN DOWNS 1: 2010831035

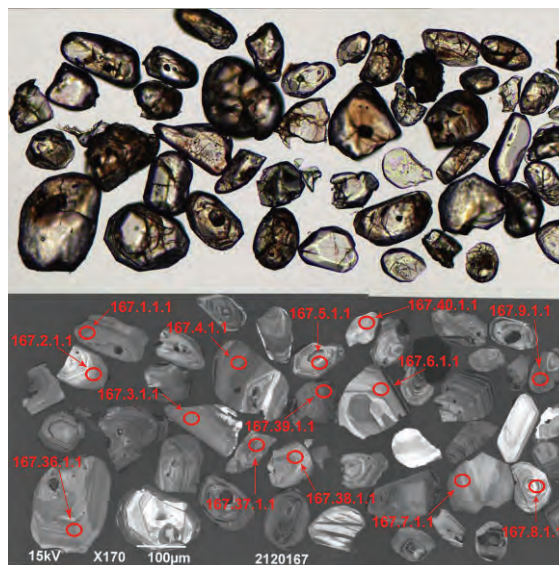
|                                                         |                                              |
|---------------------------------------------------------|----------------------------------------------|
| <b>GA Sample ID:</b>                                    | 2010831035                                   |
| <b>GA Sample Number:</b>                                | 2120167                                      |
| <b>Other Sample ID:</b>                                 | JHR HAMPDEN DOWNS 1: 658.38 - 719.34 m depth |
| <b>1:250,000 Sheet:</b>                                 | McKINLAY SF5407                              |
| <b>Region:</b>                                          | Millungera Basin, Queensland                 |
| <b>Grid Reference (MGA94):</b>                          | 567515mE 7617920mN Zone 54                   |
| <b>Collector:</b>                                       | R.J. Korsch                                  |
| <b>Drill Date:</b>                                      | 16-JUL-1988                                  |
| <b>Formal Name:</b>                                     |                                              |
| <b>Informal Name:</b>                                   | Hampden Downs 1 sandstone                    |
| <b>Lithology:</b>                                       | sandstone                                    |
| <b>Geochronologist:</b>                                 | N.L. Neumann                                 |
| <b>Mount ID:</b>                                        | GA6151                                       |
| <b>Instrument:</b>                                      | SHRIMP IIe Geoscience Australia              |
| <b>Acquisition Date:</b>                                | 5-11/1/2011                                  |
| <b>U-Pb Standard &amp; reproducibility:</b>             | TEMORA-2; 1.5% (2 $\sigma$ ) [40 of 40]      |
| <b><sup>207</sup>Pb/<sup>206</sup>Pb Standard:</b>      | OG1 (3465.4 $\pm$ 0.6 Ma)                    |
| <b>Measured Value (<math>\pm</math>95% confidence):</b> | 3460.6 $\pm$ 1.9 Ma [32 of 32]               |
| <b>Interpreted Age:</b>                                 | 1560 $\pm$ 14 Ma                             |
| <b>IMF correction applied?</b>                          | Yes - to all individual analyses             |
| <b>Interpreted Age Type:</b>                            | Maximum deposition age                       |

**Sample Description**

This sample was collected from the JHR Hampden Downs 1 drill hole, between the 658.38 m to 719.34 m depth interval, within the Millungera Basin, Queensland. The sample was collected from drill cuttings, and is a red sandstone.

**Zircon Description**

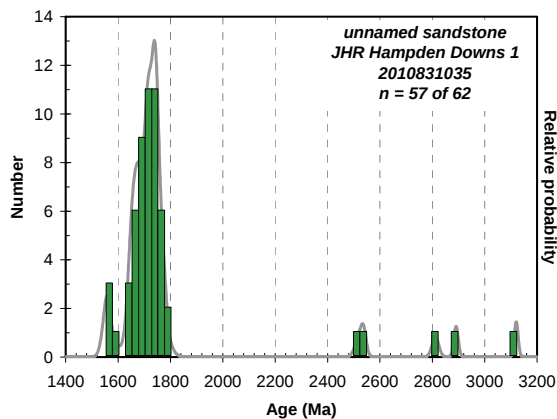
Zircons from this sample range in length from ~80  $\mu$ m to ~180  $\mu$ m, with some large grains up to ~230  $\mu$ m in length (Figure 19.1). Most grains are subrounded and record pitted surfaces with internal cracks and inclusions, whereas occasional grains preserve some prismatic crystal faces. Grains are clear and colourless to brown. In cathodoluminescence images, most grains record oscillatory zoning.



### U-Pb Isotopic Results

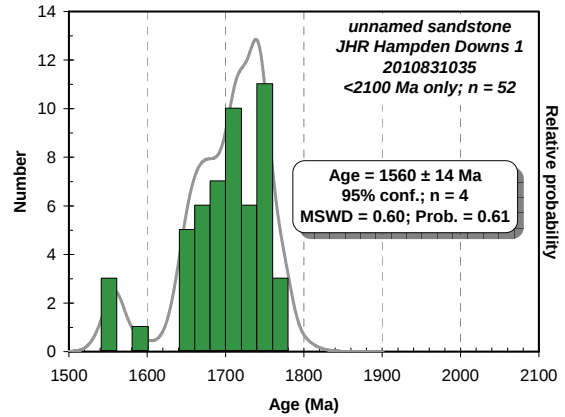
Sixty-two analyses were undertaken on zircons from this sample, the results of which are presented in Table 19.1 and illustrated in Figures 19.2 and 19.3. An IMF correction was applied to all individual  $^{207}\text{Pb}/^{206}\text{Pb}$  analyses following the methodology outlined in Stern et al. (2009). U concentrations of the analysed zircons range between 459 and 69 ppm, with Th/U ratios between 1.99 and 0.19. Five analyses greater than 10% discordant were removed from further consideration.

The remaining 57 analyses yield ages between ~3120 Ma and ~1552 Ma (Figure 19.2). Within the spectra, there is one age at ~3120 Ma, ~2890 Ma, ~2811 Ma, ~2537 Ma and at ~2518 Ma, and large number of ages between ~1780 Ma and ~1552 Ma.



**Figure 19.2.** Probability density diagram of zircon analyses from the unnamed sandstone, JHR Hampden Downs 1 drill hole (2010831035).

The youngest individual age of  $1552 \pm 32$  Ma ( $2\sigma$ ) forms part of a small cluster separate from the next youngest group (Figure 19.3), and the weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age for these 4 individuals is  $1560 \pm 14$  Ma (95% confidence; MSWD = 0.60; probability of fit = 0.61).



**Figure 19.3.** Probability density diagram of zircon from the unnamed sandstone, JHR Hampden Downs 1 drill hole (2010831035), yielding  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of less than 2100 Ma.

### Geochronological Interpretation

The weighted mean age of  $1560 \pm 14$  Ma (95% confidence) for the youngest 4 individuals can be used to define a maximum depositional age for this sedimentary rock.

**Table 19.1.** SHRIMP U-Pb isotopic data for zircons from sample 2010831035 (2120167), Unnamed sandstone, JHR Hampden Downs 1.

| Grain.area                                 | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb <sup>#</sup> | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age <sup>#</sup> (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|--------------------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|------------------------------------------------------|-------------|---------------------------------------------------------------|--------------|-------------|
| <i>Detrital zircon (n = 57)</i>            |                                                    |            |             |                                        |                                        |             |                                                      |             |                                                               |              |             |
| 167.25.1.1                                 | 0.06                                               | 125        | 58          | 0.48                                   | 1.6287                                 | 1.2         | 0.2400                                               | 0.5         | 3120                                                          | 7            | 1           |
| 167.2.1.1                                  | 0.00                                               | 114        | 131         | 1.19                                   | 1.7843                                 | 1.2         | 0.2081                                               | 0.5         | 2890                                                          | 9            | 1           |
| 167.52.1.1                                 | 0.12                                               | 69         | 36          | 0.54                                   | 1.8394                                 | 1.4         | 0.1982                                               | 0.8         | 2811                                                          | 13           | 0           |
| 167.32.1.1                                 | 0.06                                               | 114        | 56          | 0.51                                   | 2.0602                                 | 1.2         | 0.1679                                               | 0.6         | 2537                                                          | 11           | -1          |
| 167.22.1.1                                 | 0.01                                               | 143        | 121         | 0.88                                   | 2.0811                                 | 1.3         | 0.1660                                               | 0.9         | 2518                                                          | 15           | 0           |
| 167.59.1.1                                 | -0.14                                              | 96         | 69          | 0.74                                   | 3.2823                                 | 1.3         | 0.1088                                               | 1.3         | 1780                                                          | 24           | 4           |
| 167.13.1.1                                 | 0.03                                               | 383        | 72          | 0.19                                   | 3.1749                                 | 0.9         | 0.1087                                               | 0.5         | 1777                                                          | 9            | 1           |
| 167.28.1.1                                 | -0.01                                              | 140        | 70          | 0.51                                   | 3.3045                                 | 1.4         | 0.1080                                               | 1.3         | 1766                                                          | 23           | 3           |
| 167.53.1.1                                 | 0.02                                               | 284        | 163         | 0.59                                   | 3.2162                                 | 1.0         | 0.1076                                               | 0.6         | 1759                                                          | 11           | 1           |
| 167.29.1.1                                 | 0.01                                               | 205        | 141         | 0.71                                   | 3.1815                                 | 1.4         | 0.1076                                               | 0.7         | 1759                                                          | 13           | 0           |
| 167.50.1.1                                 | -0.15                                              | 138        | 123         | 0.93                                   | 3.2218                                 | 1.2         | 0.1074                                               | 1.5         | 1756                                                          | 28           | 1           |
| 167.49.1.1                                 | 0.01                                               | 337        | 113         | 0.35                                   | 3.2752                                 | 1.0         | 0.1072                                               | 0.6         | 1752                                                          | 11           | 2           |
| 167.24.1.1                                 | 0.06                                               | 134        | 91          | 0.70                                   | 3.2456                                 | 1.2         | 0.1071                                               | 1.0         | 1750                                                          | 19           | 1           |
| 167.41.1.1                                 | -0.04                                              | 254        | 151         | 0.61                                   | 3.2470                                 | 1.0         | 0.1070                                               | 0.6         | 1749                                                          | 12           | 1           |
| 167.4.1.1                                  | 0.02                                               | 227        | 92          | 0.42                                   | 3.2641                                 | 1.0         | 0.1069                                               | 0.7         | 1747                                                          | 13           | 1           |
| 167.7.1.1                                  | -0.02                                              | 155        | 61          | 0.41                                   | 3.2675                                 | 1.1         | 0.1067                                               | 0.8         | 1745                                                          | 15           | 1           |
| 167.26.1.1                                 | 0.04                                               | 459        | 235         | 0.53                                   | 3.2338                                 | 0.9         | 0.1067                                               | 0.5         | 1744                                                          | 9            | 0           |
| 167.6.1.1                                  | 0.30                                               | 90         | 79          | 0.91                                   | 3.2279                                 | 1.7         | 0.1067                                               | 1.3         | 1743                                                          | 24           | 0           |
| 167.20.1.1                                 | 0.10                                               | 89         | 81          | 0.94                                   | 3.2956                                 | 1.3         | 0.1066                                               | 1.2         | 1742                                                          | 22           | 2           |
| 167.54.1.1                                 | -0.02                                              | 408        | 228         | 0.58                                   | 3.2177                                 | 0.9         | 0.1064                                               | 0.5         | 1738                                                          | 10           | 0           |
| 167.15.1.1                                 | 0.04                                               | 263        | 148         | 0.58                                   | 3.2140                                 | 1.2         | 0.1063                                               | 0.6         | 1738                                                          | 12           | 0           |
| 167.46.1.1                                 | 0.03                                               | 419        | 178         | 0.44                                   | 3.2892                                 | 0.9         | 0.1063                                               | 0.5         | 1737                                                          | 9            | 2           |
| 167.34.1.1                                 | 0.07                                               | 143        | 54          | 0.39                                   | 3.1781                                 | 1.1         | 0.1062                                               | 0.9         | 1735                                                          | 17           | -2          |
| 167.58.1.1                                 | 0.03                                               | 216        | 99          | 0.47                                   | 3.2107                                 | 1.0         | 0.1058                                               | 0.7         | 1728                                                          | 13           | -1          |
| 167.19.1.1                                 | -0.05                                              | 178        | 129         | 0.75                                   | 3.3120                                 | 1.1         | 0.1054                                               | 0.9         | 1721                                                          | 16           | 1           |
| 167.39.1.1                                 | 0.18                                               | 425        | 129         | 0.31                                   | 3.5445                                 | 0.9         | 0.1053                                               | 0.6         | 1720                                                          | 12           | 7           |
| 167.56.1.1                                 | 0.03                                               | 178        | 196         | 1.14                                   | 3.2563                                 | 1.1         | 0.1053                                               | 0.8         | 1720                                                          | 15           | 0           |
| 167.37.1.1                                 | -0.02                                              | 223        | 197         | 0.91                                   | 3.3083                                 | 1.0         | 0.1052                                               | 0.7         | 1718                                                          | 12           | 1           |
| 167.18.1.1                                 | 0.06                                               | 229        | 86          | 0.39                                   | 3.6366                                 | 1.3         | 0.1052                                               | 0.7         | 1718                                                          | 13           | 9           |
| 167.51.1.1                                 | 0.13                                               | 180        | 151         | 0.87                                   | 3.4874                                 | 1.1         | 0.1051                                               | 0.9         | 1717                                                          | 16           | 5           |
| 167.60.1.1                                 | 0.08                                               | 201        | 98          | 0.50                                   | 3.2611                                 | 1.1         | 0.1051                                               | 1.0         | 1716                                                          | 18           | 0           |
| 167.1.1.1                                  | 0.04                                               | 303        | 142         | 0.49                                   | 3.2291                                 | 1.0         | 0.1049                                               | 0.6         | 1712                                                          | 11           | -2          |
| 167.23.1.1                                 | 0.19                                               | 134        | 63          | 0.49                                   | 3.1822                                 | 1.5         | 0.1045                                               | 1.1         | 1706                                                          | 21           | -3          |
| 167.31.1.1                                 | -0.04                                              | 178        | 163         | 0.94                                   | 3.3059                                 | 1.1         | 0.1045                                               | 0.7         | 1705                                                          | 14           | 0           |
| 167.8.1.1                                  | 0.02                                               | 89         | 111         | 1.29                                   | 3.3308                                 | 1.3         | 0.1044                                               | 1.2         | 1705                                                          | 23           | 1           |
| 167.9.1.1                                  | 0.12                                               | 287        | 251         | 0.90                                   | 3.3355                                 | 1.0         | 0.1041                                               | 1.0         | 1699                                                          | 19           | 1           |
| 167.36.1.1                                 | 0.00                                               | 151        | 94          | 0.64                                   | 3.3788                                 | 1.3         | 0.1039                                               | 0.8         | 1696                                                          | 15           | 1           |
| 167.10.1.1                                 | -0.07                                              | 109        | 92          | 0.87                                   | 3.4111                                 | 1.2         | 0.1038                                               | 1.1         | 1694                                                          | 21           | 2           |
| 167.44.1.1                                 | 0.36                                               | 78         | 69          | 0.92                                   | 3.2334                                 | 1.4         | 0.1034                                               | 1.4         | 1687                                                          | 27           | -1          |
| 167.14.1.1                                 | 0.06                                               | 107        | 78          | 0.75                                   | 3.3660                                 | 1.2         | 0.1034                                               | 1.0         | 1686                                                          | 18           | 1           |
| 167.42.1.1                                 | -0.09                                              | 107        | 205         | 1.99                                   | 3.3610                                 | 1.3         | 0.1032                                               | 1.0         | 1682                                                          | 19           | 0           |
| 167.35.1.1                                 | 0.18                                               | 124        | 56          | 0.47                                   | 3.3044                                 | 1.2         | 0.1032                                               | 1.2         | 1682                                                          | 21           | -1          |
| 167.43.1.1                                 | 0.01                                               | 159        | 110         | 0.71                                   | 3.4287                                 | 1.1         | 0.1028                                               | 0.9         | 1676                                                          | 16           | 2           |
| 167.48.1.1                                 | -0.03                                              | 220        | 128         | 0.60                                   | 3.3241                                 | 1.0         | 0.1028                                               | 1.0         | 1675                                                          | 19           | -1          |
| 167.17.1.1                                 | 0.00                                               | 149        | 148         | 1.03                                   | 3.3773                                 | 1.1         | 0.1026                                               | 0.8         | 1672                                                          | 15           | 0           |
| 167.38.1.1                                 | 0.03                                               | 133        | 93          | 0.72                                   | 3.3503                                 | 1.2         | 0.1026                                               | 0.9         | 1671                                                          | 17           | -1          |
| 167.16.1.1                                 | 0.05                                               | 210        | 121         | 0.60                                   | 3.4174                                 | 1.0         | 0.1024                                               | 0.8         | 1669                                                          | 14           | 1           |
| 167.5.1.1                                  | -0.12                                              | 111        | 117         | 1.09                                   | 3.5458                                 | 1.7         | 0.1021                                               | 1.2         | 1662                                                          | 22           | 4           |
| 167.33.1.1                                 | 0.06                                               | 259        | 179         | 0.72                                   | 3.4053                                 | 1.0         | 0.1016                                               | 0.7         | 1654                                                          | 13           | 0           |
| 167.3.1.1                                  | 0.07                                               | 145        | 69          | 0.49                                   | 3.4474                                 | 1.4         | 0.1016                                               | 1.2         | 1653                                                          | 22           | 1           |
| 167.62.1.1                                 | 0.03                                               | 220        | 171         | 0.81                                   | 3.4275                                 | 1.0         | 0.1013                                               | 0.7         | 1648                                                          | 14           | 0           |
| 167.55.1.1                                 | 0.02                                               | 190        | 126         | 0.68                                   | 3.3872                                 | 1.6         | 0.1013                                               | 0.8         | 1648                                                          | 14           | -1          |
| 167.12.1.1                                 | 0.04                                               | 113        | 112         | 1.02                                   | 3.3388                                 | 1.2         | 0.1012                                               | 1.1         | 1647                                                          | 20           | -3          |
| 167.40.1.1                                 | 0.19                                               | 152        | 98          | 0.67                                   | 3.5811                                 | 1.1         | 0.0979                                               | 1.1         | 1584                                                          | 20           | 0           |
| 167.11.1.1                                 | 0.08                                               | 431        | 137         | 0.33                                   | 3.6960                                 | 0.9         | 0.0966                                               | 0.6         | 1559                                                          | 11           | 1           |
| 167.47.1.1                                 | 0.04                                               | 215        | 86          | 0.42                                   | 3.6327                                 | 1.1         | 0.0964                                               | 0.8         | 1555                                                          | 16           | -1          |
| 167.61.1.1                                 | 0.06                                               | 194        | 62          | 0.33                                   | 3.6895                                 | 1.1         | 0.0962                                               | 0.8         | 1552                                                          | 16           | 0           |
| <i>Analyses &gt;10% discordant (n = 5)</i> |                                                    |            |             |                                        |                                        |             |                                                      |             |                                                               |              |             |
| 167.27.1.1                                 | 1.37                                               | 328        | 83          | 0.26                                   | 15.8167                                | 6.1         | 0.0989                                               | 6.1         | 1603                                                          | 114          | 75          |
| 167.57.1.1                                 | 0.04                                               | 264        | 151         | 0.59                                   | 5.5113                                 | 1.3         | 0.1057                                               | 0.8         | 1726                                                          | 15           | 38          |
| 167.30.1.1                                 | 0.48                                               | 185        | 187         | 1.04                                   | 6.0836                                 | 1.1         | 0.0976                                               | 1.6         | 1578                                                          | 30           | 38          |
| 167.45.1.1                                 | -0.04                                              | 97         | 90          | 0.96                                   | 4.3566                                 | 1.3         | 0.1056                                               | 1.2         | 1724                                                          | 22           | 23          |
| 167.21.1.1                                 | 0.12                                               | 105        | 78          | 0.77                                   | 3.7890                                 | 1.3         | 0.1055                                               | 1.1         | 1723                                                          | 20           | 12          |

1. <sup>206</sup>Pb<sub>c</sub> indicates common <sup>206</sup>Pb as a percentage of the total measured <sup>206</sup>Pb.

#IMF-corrected value, following the methodology outlined in Stern et al. (2009).

## 20. UNNAMED SANDSTONE, JHR ROSEVALE DOWNS 1: 2010831041

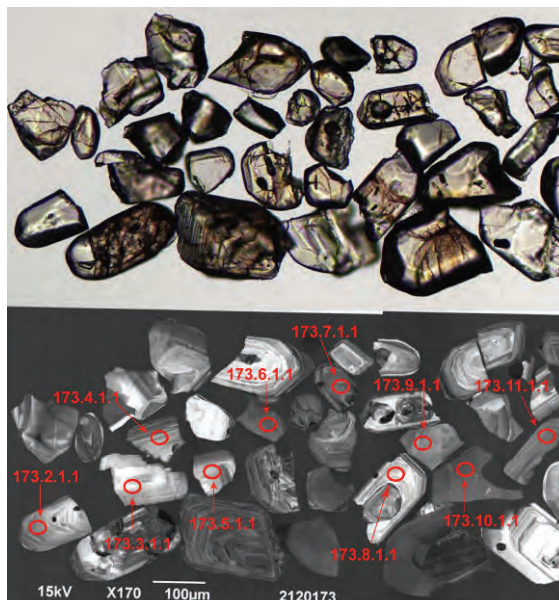
|                                                         |                                               |
|---------------------------------------------------------|-----------------------------------------------|
| <b>GA Sample ID:</b>                                    | 2010831041                                    |
| <b>GA Sample Number:</b>                                | 2120173                                       |
| <b>Other Sample ID:</b>                                 | JHR ROSEVALE DOWNS 1: 603.51 - 655.33 m depth |
| <b>1:250,000 Sheet:</b>                                 | McKINLAY SF5407                               |
| <b>Region:</b>                                          | Millungera Basin, Queensland                  |
| <b>Grid Reference (MGA94):</b>                          | 601774mE 7659312mN Zone 54                    |
| <b>Collector:</b>                                       | R.J. Korsch                                   |
| <b>Drill Date:</b>                                      | 16-JUL-1988                                   |
| <b>Formal Name:</b>                                     |                                               |
| <b>Informal Name:</b>                                   | Rosevale Downs 1 sandstone                    |
| <b>Lithology:</b>                                       | sandstone                                     |
| <b>Geochronologist:</b>                                 | N. L. Neumann                                 |
| <b>Mount ID:</b>                                        | GA6151                                        |
| <b>Instrument:</b>                                      | SHRIMP IIe Geoscience Australia               |
| <b>Acquisition Date:</b>                                | 5 – 11/1/2011                                 |
| <b>U-Pb Standard &amp; reproducibility:</b>             | TEMORA-2; 1.5% (2 $\sigma$ ) [40 of 40]       |
| <b><sup>207</sup>Pb/<sup>206</sup>Pb Standard:</b>      | OG1 (3465.4 $\pm$ 0.6 Ma)                     |
| <b>Measured Value (<math>\pm</math>95% confidence):</b> | 3460.6 $\pm$ 1.9 Ma [32 of 32]                |
| <b>Interpreted Age:</b>                                 | 1593 $\pm$ 17 Ma                              |
| <b>IMF correction applied?</b>                          | Yes - to all individual analyses              |
| <b>Interpreted Age Type:</b>                            | Maximum deposition age                        |

**Sample Description**

This sample was collected from the JHR Rosevale Downs 1 drill hole, between the 603.51 m to 655.33 m depth interval, within the Millungera Basin, Queensland. The sample was collected from drill cuttings, and was a red sandstone.

**Zircon Description**

Zircons from this sample range in length from ~90  $\mu$ m to ~160  $\mu$ m, with some larger grains up to ~210  $\mu$ m in length (Figure 20.1). Grains range from subrounded morphologies with some pitted surfaces, to euhedral grains preserving some prismatic crystal faces. Grains are clear and colourless to light brown in colour. In cathodoluminescence images, most grains record oscillatory zoning.

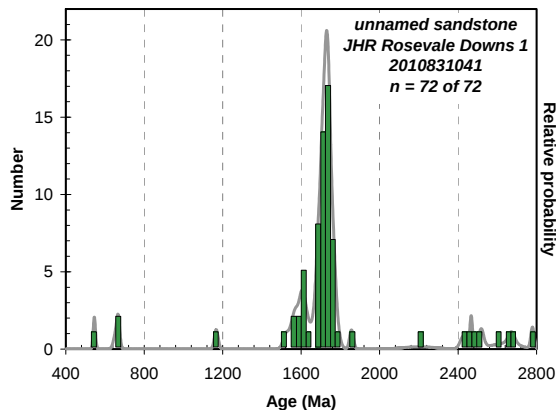


**Figure 20.1.** Representative transmitted light and cathodoluminescence images of zircons from the unnamed sandstone, JHR Rosevale Downs 1 drill hole (2010831041), with locations of some SHRIMP analyses.

### U-Pb Isotopic Results

Seventy-two analyses were undertaken on 71 zircon grains from this sample, the results of which are presented in Table 20.1 and illustrated in Figures 20.2 and 20.3. An IMF correction was applied to all individual  $^{207}\text{Pb}/^{206}\text{Pb}$  analyses following the methodology outlined in Stern et al. (2009). U concentrations of the analysed zircons range between 553 and 47 ppm, with Th/U ratios between 1.95 and 0.06.

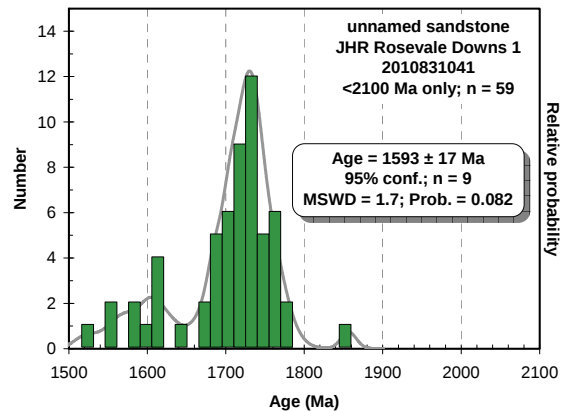
These analyses yield ages between ~2779 Ma and ~1520 Ma (Figure 20.2), with 3 younger  $^{206}\text{Pb}/^{238}\text{U}$  ages at ~1167 Ma (analysis 173.27.1.1), at ~664 Ma (analyses 173.30.1.1 and 173.30.2.1) and at ~545 Ma (analysis 173.68.1.1). As each of these younger ages were only recorded by one individual grain, and that the sample is from drill cuttings which may result in down hole contamination, the age significance of these zircons as a constraint on the maximum depositional age is difficult to interpret.



**Figure 20.2.** Probability density diagram of zircon analyses from the unnamed sandstone, JHR Rosevale Downs 1 drill hole (2010831041), displayed as  $^{207}\text{Pb}/^{206}\text{Pb}$  age for individuals >1500 Ma and as  $^{206}\text{Pb}/^{238}\text{U}$  ages for individuals <1500 Ma.

Within the Archean-Mesoproterozoic component of the detrital spectra, there are 8 ages between ~2779 Ma and ~2427 Ma, one age at ~2202 Ma and at ~1857 Ma, and large number of ages between ~1781 Ma and ~1520 Ma (Figure 20.2).

The youngest individual Mesoproterozoic age of  $1520 \pm 28$  Ma ( $2\sigma$ ) forms part of this cluster, but this analysis (from grain 173.53.1.1) has a Th/U ratio (= 1.70) which is much higher than the other zircons of this cluster. Therefore it was excluded from age calculations. Using the MSWD as a guide for the youngest statically coherent age group provides a weighted mean  $^{207}\text{Pb}/^{206}\text{Pb}$  age of  $1593 \pm 17$  Ma (95% confidence) for the 9 next youngest analyses in this sample (MSWD = 1.7; probability of fit = 0.082; Figure 20.3).



**Figure 20.3.** Probability density diagram of zircon analyses from the unnamed sandstone, JHR Rosevale Downs 1 drill hole (2010831041), yielding Mesoproterozoic  $^{207}\text{Pb}/^{206}\text{Pb}$  ages <2100 Ma.

### Geochronological Interpretation

The weighted mean age of  $1593 \pm 17$  Ma (95% confidence;  $n = 9$ ) can be used to define a maximum depositional age for this sedimentary rock.

**Table 20.1.** SHRIMP U-Pb isotopic data for zircons from sample 2010831041 (2120173), Unnamed sandstone, JHR Rosevale Downs 1.

| Grain.area                      | $^{206}\text{Pb}_c$<br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | $^{232}\text{Th}/$<br>$^{238}\text{U}$ | $^{238}\text{U}/$<br>$^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/$<br>$^{206}\text{Pb}^\#$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/^{206}\text{Pb}$<br>Age <sup>#</sup> (Ma) | $\pm 1\sigma$<br>(Ma) | Disc<br>(%) |
|---------------------------------|-----------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|----------------------|--------------------------------------------|----------------------|------------------------------------------------------------|-----------------------|-------------|
| <i>Detrital zircon (n = 72)</i> |                                         |            |             |                                        |                                        |                      |                                            |                      |                                                            |                       |             |
| 173.59.1.1                      | 0.03                                    | 125        | 53          | 0.44                                   | 1.8398                                 | 1.1                  | 0.1944                                     | 0.5                  | 2779                                                       | 9                     | -1          |
| 173.29.1.1                      | 0.02                                    | 150        | 91          | 0.63                                   | 1.9632                                 | 1.6                  | 0.1835                                     | 2.7                  | 2684                                                       | 45                    | 1           |
| 173.32.1.1                      | 0.02                                    | 166        | 113         | 0.71                                   | 1.9902                                 | 1.1                  | 0.1821                                     | 1.0                  | 2672                                                       | 16                    | 2           |
| 173.18.1.1                      | 0.03                                    | 130        | 82          | 0.65                                   | 2.1269                                 | 1.4                  | 0.1757                                     | 2.8                  | 2612                                                       | 46                    | 5           |
| 173.33.1.1                      | -0.01                                   | 279        | 143         | 0.53                                   | 2.0836                                 | 1.0                  | 0.1661                                     | 0.7                  | 2519                                                       | 12                    | 0           |
| 173.40.1.1                      | 0.06                                    | 146        | 115         | 0.82                                   | 2.0656                                 | 1.2                  | 0.1638                                     | 2.4                  | 2495                                                       | 41                    | -2          |
| 173.55.1.1                      | 0.02                                    | 338        | 86          | 0.26                                   | 2.2291                                 | 0.9                  | 0.1611                                     | 0.4                  | 2467                                                       | 6                     | 3           |
| 173.13.1.1                      | 0.02                                    | 232        | 128         | 0.57                                   | 2.3063                                 | 1.0                  | 0.1573                                     | 0.9                  | 2427                                                       | 16                    | 4           |
| 173.12.1.1                      | 0.07                                    | 150        | 184         | 1.27                                   | 2.5244                                 | 1.1                  | 0.1380                                     | 4.6                  | 2202                                                       | 81                    | 2           |
| 173.61.1.1                      | 0.03                                    | 304        | 129         | 0.44                                   | 3.0291                                 | 1.0                  | 0.1135                                     | 0.5                  | 1857                                                       | 10                    | 1           |
| 173.65.1.1                      | 0.02                                    | 147        | 129         | 0.91                                   | 3.1744                                 | 1.1                  | 0.1089                                     | 0.8                  | 1781                                                       | 15                    | 1           |
| 173.58.1.1                      | -0.06                                   | 308        | 128         | 0.43                                   | 3.2231                                 | 1.0                  | 0.1085                                     | 0.6                  | 1774                                                       | 11                    | 2           |
| 173.17.1.1                      | -0.01                                   | 281        | 238         | 0.88                                   | 3.1832                                 | 1.0                  | 0.1078                                     | 0.6                  | 1763                                                       | 10                    | 0           |
| 173.71.1.1                      | -0.03                                   | 51         | 64          | 1.29                                   | 3.3186                                 | 2.1                  | 0.1076                                     | 1.4                  | 1760                                                       | 25                    | 4           |
| 173.49.1.1                      | -0.08                                   | 130        | 73          | 0.58                                   | 3.2801                                 | 1.6                  | 0.1076                                     | 0.9                  | 1759                                                       | 17                    | 2           |
| 173.52.1.1                      | 0.12                                    | 84         | 50          | 0.61                                   | 3.0811                                 | 1.3                  | 0.1075                                     | 1.3                  | 1758                                                       | 23                    | -3          |
| 173.64.1.1                      | 0.00                                    | 325        | 179         | 0.57                                   | 3.2087                                 | 0.9                  | 0.1075                                     | 0.5                  | 1757                                                       | 10                    | 0           |
| 173.26.1.1                      | 0.02                                    | 181        | 121         | 0.69                                   | 3.1912                                 | 1.1                  | 0.1074                                     | 0.8                  | 1756                                                       | 15                    | 0           |
| 173.38.1.1                      | -0.01                                   | 223        | 69          | 0.32                                   | 3.2252                                 | 1.0                  | 0.1069                                     | 0.6                  | 1748                                                       | 12                    | 0           |
| 173.66.1.1                      | 0.06                                    | 224        | 206         | 0.95                                   | 3.1982                                 | 1.0                  | 0.1068                                     | 0.7                  | 1745                                                       | 13                    | -1          |
| 173.22.1.1                      | 0.05                                    | 259        | 149         | 0.60                                   | 3.2104                                 | 1.0                  | 0.1067                                     | 0.7                  | 1745                                                       | 12                    | 0           |
| 173.51.1.1                      | 0.03                                    | 456        | 207         | 0.47                                   | 3.3190                                 | 0.9                  | 0.1066                                     | 0.5                  | 1742                                                       | 9                     | 3           |
| 173.16.1.1                      | -0.02                                   | 81         | 57          | 0.73                                   | 3.2539                                 | 1.3                  | 0.1065                                     | 1.0                  | 1741                                                       | 19                    | 1           |
| 173.14.1.1                      | 0.07                                    | 121        | 81          | 0.69                                   | 3.1947                                 | 1.2                  | 0.1063                                     | 0.9                  | 1736                                                       | 16                    | -1          |
| 173.24.1.1                      | -0.02                                   | 81         | 40          | 0.52                                   | 3.1934                                 | 1.3                  | 0.1062                                     | 1.0                  | 1736                                                       | 19                    | -1          |
| 173.48.1.1                      | 0.01                                    | 516        | 142         | 0.28                                   | 3.4189                                 | 0.9                  | 0.1062                                     | 0.5                  | 1736                                                       | 9                     | 5           |
| 173.2.1.1                       | 0.04                                    | 250        | 145         | 0.60                                   | 3.2311                                 | 1.0                  | 0.1062                                     | 0.6                  | 1735                                                       | 11                    | 0           |
| 173.62.1.1                      | 0.00                                    | 247        | 183         | 0.77                                   | 3.2394                                 | 1.0                  | 0.1061                                     | 0.6                  | 1734                                                       | 11                    | 0           |
| 173.46.1.1                      | 0.12                                    | 148        | 93          | 0.65                                   | 3.2319                                 | 1.3                  | 0.1061                                     | 0.9                  | 1734                                                       | 17                    | 0           |
| 173.54.1.1                      | 0.05                                    | 285        | 143         | 0.52                                   | 3.1814                                 | 1.0                  | 0.1061                                     | 0.6                  | 1733                                                       | 11                    | -2          |
| 173.35.1.1                      | -0.02                                   | 253        | 404         | 1.65                                   | 3.2425                                 | 1.2                  | 0.1060                                     | 0.6                  | 1732                                                       | 11                    | 0           |
| 173.42.1.1                      | -0.01                                   | 190        | 118         | 0.64                                   | 3.1852                                 | 1.1                  | 0.1060                                     | 0.7                  | 1731                                                       | 13                    | -2          |
| 173.1.1.1                       | 0.04                                    | 177        | 117         | 0.68                                   | 3.2687                                 | 1.1                  | 0.1060                                     | 0.7                  | 1731                                                       | 14                    | 1           |
| 173.15.1.1                      | 0.10                                    | 191        | 163         | 0.88                                   | 3.2727                                 | 1.0                  | 0.1058                                     | 0.7                  | 1728                                                       | 14                    | 1           |
| 173.60.1.1                      | 0.00                                    | 376        | 147         | 0.40                                   | 3.2468                                 | 0.9                  | 0.1056                                     | 0.5                  | 1726                                                       | 9                     | 0           |
| 173.10.1.1                      | 0.03                                    | 438        | 253         | 0.60                                   | 3.3197                                 | 0.9                  | 0.1056                                     | 0.5                  | 1724                                                       | 9                     | 2           |
| 173.4.1.1                       | 0.08                                    | 160        | 90          | 0.58                                   | 3.2441                                 | 1.1                  | 0.1055                                     | 0.9                  | 1723                                                       | 17                    | -1          |
| 173.44.1.1                      | 0.15                                    | 104        | 66          | 0.65                                   | 3.2043                                 | 1.2                  | 0.1053                                     | 1.2                  | 1720                                                       | 22                    | -2          |
| 173.20.1.1                      | 0.10                                    | 244        | 138         | 0.58                                   | 3.2546                                 | 1.2                  | 0.1053                                     | 0.7                  | 1719                                                       | 12                    | 0           |
| 173.36.1.1                      | 0.12                                    | 154        | 249         | 1.67                                   | 3.2236                                 | 1.1                  | 0.1050                                     | 0.9                  | 1715                                                       | 17                    | -2          |
| 173.43.1.1                      | -0.08                                   | 102        | 74          | 0.75                                   | 3.2864                                 | 1.2                  | 0.1050                                     | 1.2                  | 1715                                                       | 23                    | 0           |
| 173.25.1.1                      | 0.04                                    | 304        | 161         | 0.55                                   | 3.2768                                 | 0.9                  | 0.1049                                     | 0.6                  | 1712                                                       | 11                    | 0           |
| 173.63.1.1                      | 0.00                                    | 191        | 114         | 0.61                                   | 3.1374                                 | 1.2                  | 0.1049                                     | 0.7                  | 1712                                                       | 13                    | -4          |
| 173.31.1.1                      | 0.07                                    | 175        | 207         | 1.22                                   | 3.2822                                 | 1.1                  | 0.1048                                     | 0.9                  | 1712                                                       | 16                    | 0           |
| 173.7.1.1                       | 0.04                                    | 270        | 199         | 0.76                                   | 3.2730                                 | 1.0                  | 0.1047                                     | 0.6                  | 1709                                                       | 11                    | -1          |
| 173.56.1.1                      | 0.01                                    | 391        | 317         | 0.84                                   | 3.5024                                 | 0.9                  | 0.1047                                     | 0.7                  | 1709                                                       | 12                    | 5           |
| 173.45.1.1                      | 0.02                                    | 380        | 234         | 0.64                                   | 3.3342                                 | 1.0                  | 0.1044                                     | 0.5                  | 1704                                                       | 10                    | 1           |
| 173.37.1.1                      | 0.03                                    | 309        | 228         | 0.76                                   | 3.3763                                 | 1.0                  | 0.1044                                     | 0.6                  | 1704                                                       | 11                    | 2           |
| 173.34.1.1                      | 0.14                                    | 117        | 112         | 0.99                                   | 3.3879                                 | 1.2                  | 0.1043                                     | 1.1                  | 1702                                                       | 19                    | 2           |
| 173.67.1.1                      | 0.31                                    | 93         | 56          | 0.63                                   | 3.1553                                 | 1.9                  | 0.1041                                     | 1.3                  | 1698                                                       | 23                    | -5          |
| 173.3.1.1                       | 0.04                                    | 47         | 88          | 1.95                                   | 3.4526                                 | 1.6                  | 0.1039                                     | 1.5                  | 1695                                                       | 27                    | 3           |
| 173.11.1.1                      | 0.11                                    | 279        | 130         | 0.48                                   | 3.2822                                 | 1.0                  | 0.1036                                     | 0.7                  | 1690                                                       | 13                    | -1          |
| 173.5.1.1                       | 0.13                                    | 115        | 86          | 0.77                                   | 3.3579                                 | 1.2                  | 0.1036                                     | 1.0                  | 1689                                                       | 18                    | 1           |
| 173.19.1.1                      | 0.26                                    | 102        | 67          | 0.68                                   | 3.2080                                 | 1.5                  | 0.1035                                     | 1.3                  | 1688                                                       | 24                    | -4          |
| 173.28.1.1                      | 0.00                                    | 553        | 31          | 0.06                                   | 3.3861                                 | 0.9                  | 0.1033                                     | 0.4                  | 1684                                                       | 8                     | 1           |
| 173.9.1.1                       | 0.07                                    | 210        | 90          | 0.45                                   | 3.3388                                 | 1.1                  | 0.1030                                     | 0.8                  | 1679                                                       | 15                    | -1          |
| 173.69.1.1                      | 0.01                                    | 101        | 92          | 0.94                                   | 3.2524                                 | 1.3                  | 0.1029                                     | 1.0                  | 1677                                                       | 18                    | -3          |
| 173.6.1.1                       | 0.03                                    | 401        | 64          | 0.16                                   | 3.2992                                 | 0.9                  | 0.1009                                     | 0.9                  | 1640                                                       | 17                    | -4          |
| 173.50.1.1                      | 0.02                                    | 284        | 204         | 0.74                                   | 3.5978                                 | 1.0                  | 0.0997                                     | 0.8                  | 1618                                                       | 16                    | 2           |
| 173.47.1.1                      | 0.07                                    | 128        | 63          | 0.51                                   | 3.5648                                 | 1.2                  | 0.0993                                     | 1.0                  | 1611                                                       | 19                    | 1           |
| 173.41.1.1                      | 0.00                                    | 143        | 67          | 0.48                                   | 3.5751                                 | 1.1                  | 0.0993                                     | 0.9                  | 1611                                                       | 16                    | 1           |
| 173.8.1.1                       | 0.12                                    | 74         | 46          | 0.64                                   | 3.4874                                 | 1.4                  | 0.0992                                     | 1.4                  | 1610                                                       | 26                    | -1          |
| 173.57.1.1                      | 0.01                                    | 287        | 241         | 0.86                                   | 3.5392                                 | 1.0                  | 0.0988                                     | 0.6                  | 1601                                                       | 12                    | 0           |
| 173.21.1.1                      | 0.07                                    | 140        | 42          | 0.31                                   | 3.5826                                 | 1.1                  | 0.0976                                     | 1.0                  | 1578                                                       | 19                    | -1          |

SHRIMP geochronology of north Queensland: 2007-2010

| Grain.area | $^{206}\text{Pb}_c$<br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | $^{232}\text{Th}/^{238}\text{U}$ | $^{238}\text{U}/^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/^{206}\text{Pb}^\#$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/^{206}\text{Pb}$<br>Age <sup>#</sup> (Ma) | $\pm 1\sigma$<br>(Ma) | Disc<br>(%) |
|------------|-----------------------------------------|------------|-------------|----------------------------------|----------------------------------|----------------------|--------------------------------------|----------------------|------------------------------------------------------------|-----------------------|-------------|
| 173.70.1.1 | 0.03                                    | 158        | 116         | 0.76                             | 3.5431                           | 1.1                  | 0.0974                               | 0.9                  | 1575                                                       | 16                    | -2          |
| 173.23.1.1 | 0.31                                    | 190        | 171         | 0.93                             | 3.7891                           | 1.1                  | 0.0965                               | 1.1                  | 1558                                                       | 20                    | 3           |
| 173.39.1.1 | 0.05                                    | 186        | 125         | 0.69                             | 3.5810                           | 1.1                  | 0.0965                               | 1.0                  | 1558                                                       | 19                    | -2          |
| 173.53.1.1 | -0.02                                   | 206        | 340         | 1.70                             | 3.7363                           | 1.4                  | 0.0946                               | 0.8                  | 1520                                                       | 14                    | -1          |
| Grain.area | $^{206}\text{Pb}_c$<br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | $^{232}\text{Th}/^{238}\text{U}$ | $^{238}\text{U}/^{206}\text{Pb}$ | $\pm 1\sigma$<br>(%) | $^{207}\text{Pb}/^{206}\text{Pb}^\#$ | $\pm 1\sigma$<br>(%) | $^{206}\text{Pb}/^{238}\text{U}$<br>Age (Ma)               | $\pm 1\sigma$<br>(Ma) | Disc<br>(%) |
| 173.27.1.1 | 0.00                                    | 426        | 168         | 0.41                             | 5.0387                           | 0.9                  | 0.0799                               | 1.1                  | 1167.1                                                     | 9.7                   | 2           |
| 173.30.1.1 | 0.02                                    | 230        | 322         | 1.45                             | 9.1595                           | 1.2                  | 0.0625                               | 2.2                  | 668.0                                                      | 7.6                   | 3           |
| 173.30.2.1 | -0.15                                   | 297        | 484         | 1.68                             | 9.3384                           | 1.9                  | 0.0606                               | 1.2                  | 655.8                                                      | 11.8                  | -5          |
| 173.68.1.1 | -0.14                                   | 253        | 247         | 1.01                             | 11.3188                          | 1.1                  | 0.0599                               | 1.6                  | 545.8                                                      | 5.9                   | 9           |

1.  $^{206}\text{Pb}_c$  indicates common  $^{206}\text{Pb}$  as a percentage of the total measured  $^{206}\text{Pb}$ .

<sup>#</sup>IMF-corrected value, following the methodology outlined in Stern et al. (2009).

## 21. UNNAMED GRANITE, JHR GLADEVALE DOWNS 1: 2010831046

|                                                |                                                |
|------------------------------------------------|------------------------------------------------|
| GA Sample ID:                                  | 2010831046                                     |
| GA Sample Number:                              | 2120178                                        |
| Other Sample ID:                               | JHR GLADEVALE DOWNS 1: 496.83 - 551.69 m depth |
| 1:250,000 Sheet:                               | JULIA CREEK SF5403                             |
| Region:                                        | Etheridge Province, Queensland                 |
| Grid Reference (MGA94):                        | 651463mE 7754784mN Zone 54                     |
| Collector:                                     | R.J. Korsch                                    |
| Drill Date:                                    | 15-AUG-1988                                    |
| Formal Name:                                   |                                                |
| Informal Name:                                 | Gladevale Downs 1 granite                      |
| Lithology:                                     | granite                                        |
| Geochronologist:                               | N.L. Neumann                                   |
| Mount ID:                                      | GA6151                                         |
| Instrument:                                    | SHRIMP IIe Geoscience Australia                |
| Acquisition Date:                              | 5-11/1/2011                                    |
| U-Pb Standard & reproducibility:               | TEMORA-2; 1.5% (2 $\sigma$ ) [40 of 40]        |
| <sup>207</sup> Pb/ <sup>206</sup> Pb Standard: | OG1 (3465.4 $\pm$ 0.6 Ma)                      |
| Measured Value ( $\pm$ 95% confidence):        | 3460.6 $\pm$ 1.9 Ma [32 of 32]                 |
| Interpreted Age:                               | 347.0 $\pm$ 2.6 Ma                             |
| IMF correction applied?                        | Yes - to all individual analyses               |
| Interpreted Age Type:                          | Magmatic crystallisation age                   |

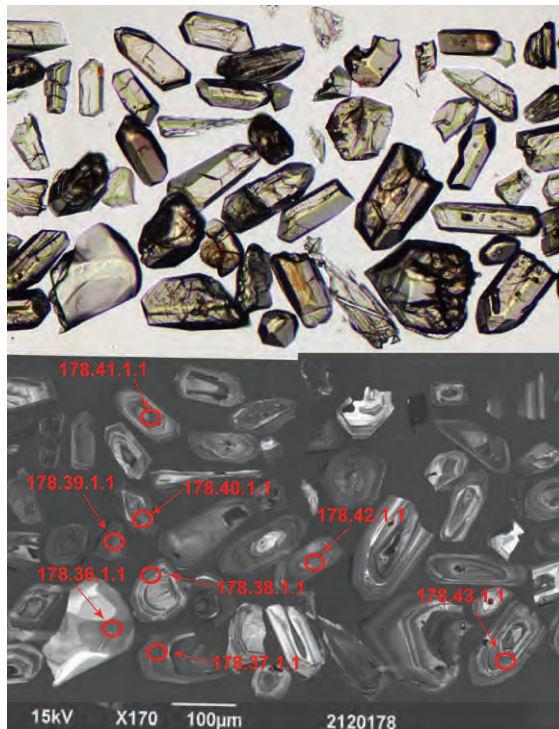
**Sample Description**

This sample was collected from the JHR Gladevale Downs 1 drill hole, between the 496.83 m to 551.69 m depth interval, to the east of the Millungera Basin, Queensland, within the Etheridge Province. The sample was collected from drill cuttings, and was a pink granite.

**Zircon Description**

There are two different groups of zircons within this sample based on size and morphology. The first group range in length from  $\sim 90$   $\mu\text{m}$  to  $\sim 140$   $\mu\text{m}$ , with some larger grains up to  $\sim 250$   $\mu\text{m}$  in length (Figure 21.1). These grains are glassy and elongate, with most crystal faces preserved, are clear and colourless, and record oscillatory zoning in cathodoluminescence images.

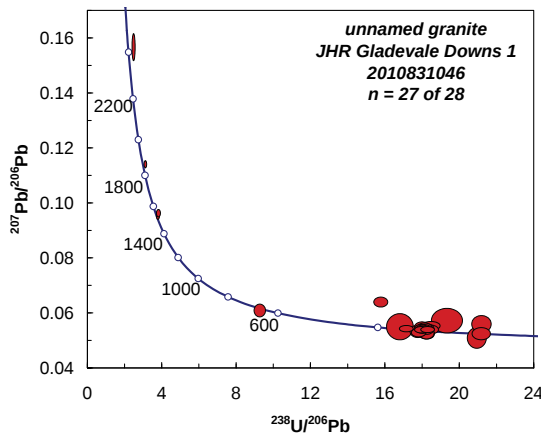
**Figure 21.1 (right).** Representative transmitted light and cathodoluminescence images of zircons from the unnamed granite, JHR Gladevale Downs 1 drill hole (2010831046), with locations of some SHRIMP analyses.



The second group of zircons range in length from ~100  $\mu\text{m}$  to ~150  $\mu\text{m}$  and have a rounded morphology with some crystal faces preserved (Figure 21.1). In cathodoluminescence images, these grains record oscillatory zoning, or zoned dark cathodoluminescence responses.

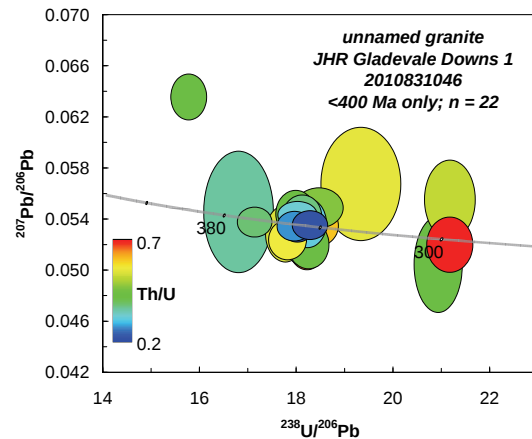
### U-Pb Isotopic Results

Twenty-eight analyses were undertaken on this sample, the results of which are presented in Table 21.1 and illustrated in Figures 21.2 to 21.4. An IMF correction was applied to all individual  $^{207}\text{Pb}/^{206}\text{Pb}$  analyses following the methodology outlined in Stern et al. (2009). U concentrations of the analysed zircons range between 1466 and 178 ppm, with Th/U ratios between 0.70 and 0.16. One analysis with common  $^{206}\text{Pb}_c$  contents higher than an arbitrary value of 0.5% was removed from further consideration.



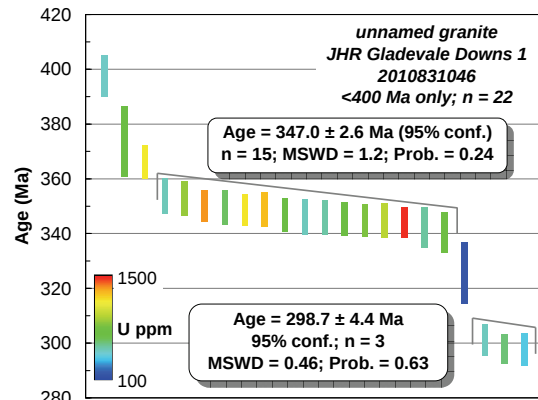
**Figure 21.2.** Tera-Wasserburg concordia diagram showing results of zircon analyses from the unnamed granite, JHR Gladevale Downs 1 drill hole (2010831046).

The remaining 27 analyses yield ages between ~2419 Ma and ~298 Ma (Figure 21.2), and includes individual  $^{207}\text{Pb}/^{206}\text{Pb}$  ages at ~2419 Ma, ~1861 Ma, ~1545 Ma and at ~1530 Ma, and an individual  $^{206}\text{Pb}/^{238}\text{U}$  age at ~667 Ma. These ages may represent inherited ages within the granite. The remaining analyses range in age between ~397 Ma and the youngest individual age at ~298 Ma (Figure 21.3). Within this youngest component of the spectra, three grains combine to give a weighted mean  $^{206}\text{Pb}/^{238}\text{U}$  age of  $298.7 \pm 4.4$  Ma (95% confidence; MSWD = 0.46; probability of fit = 0.63; Figure 21.4).



**Figure 21.3.** Tera-Wasserburg concordia diagram showing results of zircon analyses from the unnamed granite, JHR Gladevale Downs 1 drill hole (2010831046) with ages <400 Ma, coloured according to Th/U ratios.

There is one age at ~325 Ma, which is separate from the next group of analyses, which provide a weighted mean  $^{206}\text{Pb}/^{238}\text{U}$  age of  $347.0 \pm 2.6$  Ma (95% confidence,  $n = 15$ ; MSWD = 1.2; probability of fit = 0.24). There are three individuals older than this weighted mean group, with ages of ~366, ~373 and ~397 Ma (Figure 21.4).



**Figure 21.4.** Mean  $^{206}\text{Pb}/^{238}\text{U}$  age diagram showing ages <400 Ma from the unnamed granite, JHR Gladevale Downs 1 drill hole (2010831046), coloured according to U content.

Both of the weighted mean ages reported include the session-specific standard error on the U-Pb mean value of Temora-2 reference zircon, in this case, 0.34% ( $2\sigma$ ).

### **Geochronological Interpretation**

There are two possible interpretations for the magmatic crystallisation age of this granite - either the 3 youngest grains at ~299 Ma or the larger group of 15 ages at ~347 Ma. The zircons from both populations record elongate morphologies with prismatic crystal faces and simple oscillatory zoning, and so cannot be used to distinguish different events. Both groups also have Th/U ratios which are  $>0.20$ , and so are consistent with a magmatic rather than a metamorphic origin for the zircons.

Given that the sample was collected from drill cuttings, and that contamination with higher (and younger) stratigraphic units of the Eromanga and Galilee Basins is possible, the age of  $347.0 \pm 2.6$  Ma (95% confidence) calculated from the largest population of zircons is the preferred interpretation for the magmatic crystallisation age of this granite.

**Table 21.1.** SHRIMP U-Pb isotopic data for zircons from sample 2010831046 (2120178), Unnamed granite, JHR Gladevale Downs 1.

| Grain.area                                                          | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb <sup>#</sup> | ± 1σ<br>(%) | <sup>207</sup> Pb/ <sup>206</sup> Pb<br>Age <sup>#</sup> (Ma) | ± 1σ<br>(Ma) | Disc<br>(%) |
|---------------------------------------------------------------------|----------------------------------------------------|------------|-------------|----------------------------------------|----------------------------------------|-------------|------------------------------------------------------|-------------|---------------------------------------------------------------|--------------|-------------|
| <i>Inherited <sup>207</sup>Pb/<sup>206</sup>Pb ages (n = 4)</i>     |                                                    |            |             |                                        |                                        |             |                                                      |             |                                                               |              |             |
| 178.46.1.1                                                          | 0.00                                               | 579        | 138         | 0.25                                   | 2.3625                                 | 1.6         | 0.1565                                               | 1.3         | 2419                                                          | 22           | 6           |
| 178.29.1.1                                                          | 0.00                                               | 338        | 142         | 0.43                                   | 2.9934                                 | 1.1         | 0.1138                                               | 0.5         | 1861                                                          | 9            | 0           |
| 178.40.1.1                                                          | 0.02                                               | 341        | 55          | 0.17                                   | 3.6963                                 | 1.1         | 0.0959                                               | 0.6         | 1545                                                          | 11           | 0           |
| 178.35.1.1                                                          | 0.05                                               | 308        | 47          | 0.16                                   | 3.6792                                 | 0.9         | 0.0951                                               | 0.6         | 1530                                                          | 12           | -1          |
| Grain.area                                                          | <sup>206</sup> Pb <sub>c</sub><br>(%) <sup>1</sup> | U<br>(ppm) | Th<br>(ppm) | <sup>232</sup> Th/<br><sup>238</sup> U | <sup>238</sup> U/<br><sup>206</sup> Pb | ± 1σ<br>(%) | <sup>207</sup> Pb/<br><sup>206</sup> Pb <sup>#</sup> | ± 1σ<br>(%) | <sup>206</sup> Pb/ <sup>238</sup> U<br>Age (Ma)               | ± 1σ<br>(Ma) | Disc<br>(%) |
| <i>Inherited <sup>206</sup>Pb/<sup>238</sup>U ages (n = 4)</i>      |                                                    |            |             |                                        |                                        |             |                                                      |             |                                                               |              |             |
| 178.36.1.1                                                          | -0.06                                              | 504        | 339         | 0.70                                   | 9.1781                                 | 1.4         | 0.0604                                               | 1.6         | 666.7                                                         | 8.6          | -8          |
| 178.38.1.1                                                          | 0.02                                               | 473        | 195         | 0.43                                   | 15.7269                                | 1.0         | 0.0635                                               | 1.2         | 397.4                                                         | 3.8          | 45          |
| 178.42.1.1                                                          | 0.05                                               | 720        | 251         | 0.36                                   | 16.7629                                | 1.8         | 0.0545                                               | 3.6         | 373.5                                                         | 6.4          | 5           |
| 178.41.1.1                                                          | -0.05                                              | 1160       | 427         | 0.38                                   | 17.1012                                | 0.9         | 0.0537                                               | 0.9         | 366.3                                                         | 3.1          | -2          |
| <i>~347 Ma ages (n = 15)</i>                                        |                                                    |            |             |                                        |                                        |             |                                                      |             |                                                               |              |             |
| 178.33.1.1                                                          | 0.09                                               | 497        | 261         | 0.54                                   | 17.7362                                | 1.0         | 0.0528                                               | 1.7         | 353.6                                                         | 3.3          | -10         |
| 178.31.1.1                                                          | 0.09                                               | 885        | 487         | 0.57                                   | 17.7822                                | 0.9         | 0.0523                                               | 1.2         | 352.7                                                         | 3.1          | -18         |
| 178.28.1.1                                                          | 0.03                                               | 1342       | 352         | 0.27                                   | 17.9311                                | 0.8         | 0.0534                                               | 0.9         | 349.8                                                         | 2.8          | -2          |
| 178.5.2.1                                                           | 0.05                                               | 628        | 251         | 0.41                                   | 17.9559                                | 0.9         | 0.0543                                               | 1.4         | 349.4                                                         | 3.2          | 9           |
| 178.34.1.1                                                          | 0.06                                               | 1168       | 229         | 0.20                                   | 17.9879                                | 0.9         | 0.0536                                               | 1.1         | 348.8                                                         | 2.9          | 1           |
| 178.37.1.1                                                          | -0.01                                              | 1264       | 396         | 0.32                                   | 17.9959                                | 0.9         | 0.0543                                               | 0.8         | 348.6                                                         | 3.2          | 9           |
| 178.3.2.1                                                           | -0.06                                              | 729        | 265         | 0.38                                   | 18.0887                                | 0.9         | 0.0542                                               | 1.2         | 346.9                                                         | 3.1          | 8           |
| 178.30.1.1                                                          | 0.10                                               | 491        | 106         | 0.22                                   | 18.1388                                | 1.0         | 0.0530                                               | 1.7         | 345.9                                                         | 3.2          | -5          |
| 178.44.1.1                                                          | 0.16                                               | 537        | 136         | 0.26                                   | 18.1394                                | 0.9         | 0.0523                                               | 1.6         | 345.9                                                         | 3.2          | -17         |
| 178.25.2.1                                                          | 0.13                                               | 691        | 448         | 0.67                                   | 18.1873                                | 0.9         | 0.0521                                               | 1.7         | 345.0                                                         | 3.0          | -19         |
| 178.32.1.1                                                          | 0.23                                               | 831        | 251         | 0.31                                   | 18.1969                                | 0.9         | 0.0536                                               | 1.5         | 344.9                                                         | 3.0          | 3           |
| 178.7.2.1                                                           | 0.06                                               | 970        | 401         | 0.43                                   | 18.2176                                | 1.0         | 0.0519                                               | 1.5         | 344.5                                                         | 3.2          | -22         |
| 178.39.1.1                                                          | 0.05                                               | 1466       | 312         | 0.22                                   | 18.2522                                | 0.8         | 0.0534                                               | 0.9         | 343.8                                                         | 2.8          | 1           |
| 178.6.2.1                                                           | -0.02                                              | 548        | 324         | 0.61                                   | 18.3479                                | 1.1         | 0.0534                                               | 1.3         | 342.1                                                         | 3.7          | 1           |
| 178.2.2.1                                                           | -0.06                                              | 772        | 349         | 0.47                                   | 18.4385                                | 1.1         | 0.0548                                               | 1.2         | 340.5                                                         | 3.7          | 16          |
| <i>~325 Ma age (n = 1)</i>                                          |                                                    |            |             |                                        |                                        |             |                                                      |             |                                                               |              |             |
| 178.11.2.1                                                          | -0.34                                              | 178        | 96          | 0.56                                   | 19.3066                                | 1.8         | 0.0567                                               | 3.2         | 325.5                                                         | 5.6          | 32          |
| <i>~299 Ma ages (n = 3)</i>                                         |                                                    |            |             |                                        |                                        |             |                                                      |             |                                                               |              |             |
| 178.15.2.1                                                          | 0.45                                               | 486        | 201         | 0.43                                   | 20.9199                                | 1.0         | 0.0504                                               | 3.1         | 301.0                                                         | 2.9          | -42         |
| 178.45.1.1                                                          | 0.10                                               | 600        | 403         | 0.69                                   | 21.1602                                | 0.9         | 0.0519                                               | 1.7         | 297.7                                                         | 2.7          | -6          |
| 178.18.2.1                                                          | -0.29                                              | 393        | 198         | 0.52                                   | 21.1644                                | 1.0         | 0.0555                                               | 2.3         | 297.6                                                         | 3.0          | 31          |
| <i>Analysis with <sup>206</sup>Pb<sub>c</sub> &gt; 0.5% (n = 1)</i> |                                                    |            |             |                                        |                                        |             |                                                      |             |                                                               |              |             |
| 178.43.1.1                                                          | 2.38                                               | 680        | 200         | 0.30                                   | 18.3415                                | 1.1         | 0.0534                                               | 6.3         | 342.2                                                         | 3.8          | 1           |

1. <sup>206</sup>Pb<sub>c</sub> indicates common <sup>206</sup>Pb as a percentage of the total measured <sup>206</sup>Pb.<sup>#</sup>IMF-corrected value, following the methodology outlined in Stern et al. (2009).

## References

- Bain, J.C.H., Withnall, I.W., Oversby, B.S. and MacKenzie, D.E. 1985. Geology of the Georgetown region, Queensland, 1:250 000 Map Sheet. Australian Bureau of Mineral Resources, Canberra.
- Bain, J.H.C. and Draper, J.J. (eds) 1997. North Queensland Geology. Bulletin of the Australian Geological Survey Organisation 240, and Queensland Department of Mines and Energy Geology 9, 600pp.
- Black, L.P. and McCulloch, M.T. 1990. Isotopic evidence for the dependence of recurrent felsic magmatism on new crust formation; an example from the Georgetown region of northeastern Australia. *Geochimica et Cosmochimica Acta* 54, 183-196.
- Black, L.P. and Withnall, I.W. 1993. The ages of Proterozoic granites in the Georgetown Inlier of northeastern Australia, and their relevance to the dating of tectonothermal events. *Australian Geological Survey Organisation Journal of Geology and Geophysics* 14/4, 331-341.
- Black, L.P., Gregory, P., Withnall, I.W. and Bain, J.H.C. 1998. U-Pb zircon age for the Etheridge Group, Georgetown region, north Queensland: Implications for relationship with the Broken Hill and Mt Isa sequences. *Australian Journal of Earth Sciences* 45, 925-935.
- Black, L.P., Kamo, S.L., Allen, C.M., Davis, D.W., Aleinikoff, J.N., Valley, J.W., Mundil, R., Campbell, I.H., Korsch, R.J., Williams, I.S. and Foudoulis, C. 2004. Improved  $^{206}\text{Pb}/^{238}\text{U}$  microprobe geochronology by the monitoring of a trace element-related matrix effect; SHRIMP, ID-TIMS, ELA-ICP-MS and oxygen isotope documentation for a series of zircon standards. *Chemical Geology* 205, 11 5-140.
- Black, L.P., Withnall, I.W., Gregory, P., Oversby, B.S. and Bain, J.H.C. 2005. U-Pb zircon ages from leucogneiss in the Etheridge Group and their significance for the early history of the Georgetown region, north Queensland. *Australian Journal of Earth Sciences* 52, 385-401.
- Camuti, K. and Young, D. (eds) 2009. Northern Queensland Exploration and Mining 2009 and North Queensland Seismic and MT workshop. Australian Institute of Geoscientists Bulletin 49, 202pp.
- Carson, C.J., Hollis, J.A., Glass, L.M., Close, D.F., Whelan, J.A. and Wygralak, A. 2010. Summary of results. Joint NTGS-GA geochronology project: East Arunta, Pine Creek and Murphy Inlier regions July 2007 – June 2009. Northern Territory Geological Survey, Record 2010-004.
- Claoué-Long, J.C., Compston, W., Roberts, J. and Fanning, C.M. 1995. Two Carboniferous ages: a comparison of SHRIMP zircon dating with conventional zircon ages and  $^{40}\text{Ar}/^{39}\text{Ar}$  analysis. In: Berggren, W.A., Kent, D.V., Aubry, M-P. and Hardenbol, J. (eds) *Geochronology, time scales and global stratigraphic correlation*. Society for Sedimentary Geology Special Publication 54, 3-21.
- Champion, D.C. and Heinemann, M.A. 1994. Igneous rocks of northern Queensland: 1:500 000 map and explanatory notes. Australian Geological Survey Organisation Record 1994/11.
- Compston, W., Williams, I.S. and Meyer, C. 1984. U-Pb geochronology of zircons from lunar breccia 73217 using a sensitive high mass-resolution ion microprobe. *Journal of Geophysical Research* 89, Supplement B, 525-534.
- Denaro, T.J. Withnall, I.W., Bain, J.H.C. and Mackenzie, D.E. 1997. Mineral resource assessment, Georgetown-Croydon area. Queensland Minerals and Energy Review Series 1997, 228pp.
- Dodson, M. H., Compston, W., Williams, I. S. and Wilson, J. F. 1988. A search for ancient detrital zircons in Zimbabwean sediments. *Journal of the Geological Society of London*, 145, 977-983.
- Korsch, R.J., Withnall, I.W., Hutton, L.J., Henson, P.A., Blewett, R.S., Huston, D.L., Champion, D.C., Meixner, A.J., Nicoll, M.G. and Nakamura, A. 2009a. Geological interpretation of the deep seismic reflection line 07GA-IG1: the Cloncurry to Croydon transect. *Australian Institute of Geoscientists Bulletin* 49, 153-158.
- Korsch, R.J., Henson, P.A., Champion, D.C., Blewett, R.S., Huston, D.L., Withnall, I.W., Hutton, L.J., Henderson, R.A., Fergusson, C.L and Collins, W.J. 2009b. Geodynamic implications of the deep seismic reflection profiles in North Queensland. *Australian Institute of Geoscientists Bulletin* 49, 181-184.
- Korsch, R.J., Struckmeyer, H.I.M., Kirkby, A., Hutton, L.J., Carr, L.K., Hoffmann, K.L., Chopping, R., Roy, I.G., Fitzell, M., Totterdell, J.M., Nicoll, M.G. and Talebi, B. 2011. Energy potential of the

- Millungera Basin: a newly discovered basin in north Queensland. *APPEA Journal* 2011, 295-332.
- Kositcin, N., Champion, D.C. and Huston, D.L. 2009. Geodynamic Synthesis of the North Queensland Region and Implications for Metallogeny. *Geoscience Australia Record* 2009/30, 196pp.
- Ludwig, K.R., 2001a. SQUID 1.02: a user's manual, Berkeley Geochronology Centre Special Publication 2.
- Ludwig, K.R., 2001b. Isoplot/Ex, Version 2.49. A geochronological toolkit for Microsoft Excel. Berkeley Geochronology Centre Special Publication 1a.
- Ludwig, K.R. 2003. User's Manual for Isoplot 3.6 (April 2008 revision). Berkeley Geochronology Center Special Publication 4, 77pp.
- Ludwig, K.R. 2009. Squid 2, A User's Manual (revision 2.50, April 2009). Berkeley Geochronology Center Special Publication, 100pp.
- Mackenzie, D.E. 1980. New and redefined igneous rock units in the Forest Home–North Head region, Georgetown Inlier, North Queensland. *Queensland Government Mining Journal* 81, 208-214.
- Murgulov, V., Beyer, E., Griffin, W.L., O'Reilly, S.Y., Walters, S.G. and Stephens, D. 2007. Crustal evolution in the Georgetown Inlier, North Queensland, Australia: a detrital zircon grain study. *Chemical Geology* 245, 198-218.
- Nasdala, L., Hofmeister, W., Norberg, N., Mattinson, J.M., Corfu, F., Dörr, W., Kamo, S.L., Kennedy, A.K., Kronz, A., Reiners, P.W., Frei, D., Kosler, J., Wan, Y., Götze, J., Häger, T., Kröner, A. and Valley, J.W. 2008. Zircon M257 – a homogeneous natural reference material for the ion microprobe U-Pb analysis of zircon. *Geostandards and Geoanalytical Research* 32, 247-265.
- Page, R.W. and Hoatson, D.M. 2000. Geochronology of the mafic-ultramafic intrusions. In: Hoatson, D.M. and Blake, D.H. (eds), *Geology and economic potential of the Palaeoproterozoic layered mafic-ultramafic intrusions in the East Kimberley, Western Australia*. Australian Geological Survey Organisation Bulletin 246, 163-172.
- Pidgeon, R.T., Furfaro, D., Kennedy, A.K., Nemchin, A.A. and Van Bronswijk, W. 1994. Calibration of zircon standards for the Curtin SHRIMP II. In: *Eighth International Conference on Geochronology, Cosmochronology and Isotope Geology*, Berkeley, USA. Abstracts Volume, U.S. Geological Survey Circular 1107, 251.
- Richards, J.R., White, D.A., Webb, A.W. and Branch, C.D. 1966. Isotopic ages of acid igneous rocks in the Cairns hinterland, North Queensland. Bureau of Mineral Resources, Australia, Bulletin 88.
- Sambridge, M.S. and Compston, W. 1994. Mixture modelling of multicomponent data sets with application to ion-probe zircon ages. *Earth and Planetary Science Letters* 128, 373-390.
- Stacey, J.S. and Kramers, J.D. 1975. Approximation of terrestrial lead evolution by a two stage model. *Earth and Planetary Science Letters* 26, 207-221.
- Stern, R.A., Bodorkos, S., Kamo, S.L., Hickman, A.H., and Corfu, F. 2009. Measurement of SIMS instrumental mass fractionation of Pb-isotopes during zircon dating. *Geostandards and Geoanalytical Research* 33 (2), 145-168.
- Vermeesch, P. 2004. How many grains are needed for a provenance study? *Earth and Planetary Science Letters*, 224, 441-451.
- Warnick, J.V. 1989. Pre-Carboniferous geology of the Mount Surprise-Einasleigh region. Queensland Department of Mines Report 2, 103-129.
- Warnick, J.V. and Withnall, L.W. 1985. New and revised names for intrusive units in the Einasleigh region. *Queensland Government Mining Journal* 86, 102-105.
- Withnall, I.W. 1996. Stratigraphy, structure and metamorphism of the Proterozoic Etheridge and Langlovale Groups, North Queensland. *Australian Geological Survey Organisation Record* 1996/15.
- Withnall, I.W., Bain, J.H.C., Draper, J.J., Mackenzie, D.E., Oversby, B.S. 1988. Proterozoic stratigraphy and tectonic history of the Georgetown Inlier, northeastern Queensland. *Precambrian Research* 40-41, 429-446.
- Withnall, I.W., Mackenzie, D.E., Denaro, T.J., Bain, J.H.C., Oversby, B.S., Knutson, J., Donchak, P.J.T., Champion, D.C., Wellman, P., Cruikshank, B.I., Sun, S.S. and Pain, C.F. 1997a. Georgetown Region. In: Bain, J.H.C. and Draper, J.J. (eds) *North Queensland Geology*. Bulletin of the Australian Geological Survey Organisation 240, 19-69.

- Withnall, I.W., Draper, J.J., Mackenzie, D.E., Knutson, J., Blewett, R.S., Hutton, L.J., Bultitude, R.J., Wellman, P., McConachie, B.A., Bain, J.H.C., Donchak, P.J.T., Lang, S.C., Domagala, J., Symonds, P.A. and Rienks, I.P. 1997b. Review of geological provinces and basins of north Queensland. In: Bain, J.H.C. and Draper, J.J. (eds) North Queensland geology. AGSO Bulletin 240, 449-528.
- Withnall, I.W., Hutton, L.J., Garrad, P.D., Jones, M.R., Blight, R.K.J. 2002. North Queensland Gold and Base Metal Study Stage 1 – Georgetown GIS. Geological Survey of Queensland, Department of Natural Resources and Mines, digital data (including explanatory notes) released on CD-ROM.
- Withnall, I.W., Korsch, R.J., Blewett, R.S., Henson, P.A., Hutton, L.J., Holzschuh, J., Saygin, E., Fergusson, C.L., Collins, W.J., Henderson, R.A., Huston, D.L., Champion, D.C., Nicoll, M.G., Blenkinsop, T.G. and Wormald, R. 2009a. Geological interpretation of deep seismic reflection line 07GA-GC1: the Georgetown to Charters Towers transect. Australian Institute of Geoscientists Bulletin 49, 163-168.
- Withnall, I.W., Neumann, N.L. and Lambeck, A. 2009b. Palaeoproterozoic to Mesoproterozoic geology of North Queensland. Australian Institute of Geoscientists Bulletin 49, 129-134.