Organised by the Northern Territory Geological Survey,
Department of Primary Industry, Fisheries and Mines

Supported by Mining and Petroleum Services,
Department of Business, Economic and Regional Development
MINISTER’S FOREWORD

Welcome to the Northern Territory and to our ninth Annual Geoscience Exploration Seminar, which once again showcases the rich mineral potential of the Territory.

Mining remains the Territory’s most important industry, accounting for 25% of GSP in 2006–07, and the resources industry underpins much of the Territory’s current strong economic growth. However, vast and prospective areas of the Territory remain under-explored, and tremendous opportunities remain for new world-class discoveries. AGES remains a critical element of the Territory Government’s strategy to spread this message and to grow and develop the Territory’s exploration and mining industry.

In recognition of the importance of new mineral discoveries in sustaining the Territory’s economy into the future, the Territory Government has committed to a new 4-year, $12 million exploration investment attraction initiative, Bringing Forward Discovery. This initiative aims to stimulate exploration through new generation pre-competitive geoscience, including a major program of regional gravity surveys, with a focus on promoting greenfields exploration. Bringing Forward Discovery is also providing resources to assist in facilitating land access for explorers and to promote the Territory’s prospectivity in an internationally competitive environment.

AGES is used by my Department of Primary Industry, Fisheries and Mines as a key platform to communicate the results and significance of its targeted geoscience programs, as well as collaborative geoscience undertaken by partner organisations. It also acts as the premier networking forum for the Territory’s exploration industry. For the third year, through co-operation with the Department of Business, Economic and Regional Development, a Mining Services Expo is being held concurrently with AGES, to showcase central Australian businesses and their capability to support the exploration and mining industry.

Welcome to Alice Springs, and I hope you enjoy your stay in central Australia. I trust that you find AGES stimulating and enjoyable, and that it will assist in bringing forward your next discovery in the Territory.
Site Plan

AGES and Mining Services EXPO, Alice Springs Convention Centre

17 – 19 March

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<td>Registration &amp; Ice Breaker - sponsored by Cameco Australia Pty Ltd and Paladin Energy Ltd</td>
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## DAY 2
### Tuesday 18 March

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<tbody>
<tr>
<td>8:00–8:30</td>
<td>Registration</td>
</tr>
<tr>
<td>8:30–8:40</td>
<td>Traditional Welcome to Country</td>
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<tr>
<td>8:40–8:50</td>
<td>Minister Natt AGES Opening Address</td>
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### Session 1

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Topic</th>
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<tbody>
<tr>
<td>8:50–9:10</td>
<td>Ian Scrimgeour</td>
<td>Bringing Forward Discovery</td>
</tr>
<tr>
<td>9:10–9:30</td>
<td>John Dunster</td>
<td>NT Exploration overview 2007</td>
</tr>
<tr>
<td>9:30–9:50</td>
<td>Steve Tatzenko</td>
<td>New mining developments in the NT</td>
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<tr>
<td>9:50–10:40</td>
<td></td>
<td>Morning tea</td>
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### Session 2

<table>
<thead>
<tr>
<th>Time</th>
<th>Speaker</th>
<th>Topic</th>
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<tbody>
<tr>
<td>10:40–11:10</td>
<td>David Huston</td>
<td>Proterozoic geodynamics and metallogeny</td>
</tr>
<tr>
<td>11:10–11:30</td>
<td>Uramet Minerals</td>
<td>Overview of NT exploration projects</td>
</tr>
<tr>
<td>11:30–11:50</td>
<td>Eloise Beyer</td>
<td>New insights into the Alcoota region</td>
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<tr>
<td>11:50–12:00</td>
<td>Tracey Rogers</td>
<td>STRIKE / Geophysical Image Web Server overview</td>
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<td>12:00–1:00</td>
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<td>Lunch</td>
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### Session 3

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<tr>
<th>Time</th>
<th>Speaker</th>
<th>Topic</th>
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<tbody>
<tr>
<td>1:00–1:20</td>
<td>Jo Whelan</td>
<td>Geology and mineralisation of the Entia Dome</td>
</tr>
<tr>
<td>1:20–1:40</td>
<td>NuPower Resources</td>
<td>Overview of NT exploration projects</td>
</tr>
<tr>
<td>1:40–2:00</td>
<td>Dorothy Close</td>
<td>Mineralisation styles in the eastern Arunta</td>
</tr>
<tr>
<td>2:00–2:20</td>
<td>Energy Metals</td>
<td>Overview of NT exploration projects</td>
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<tr>
<td>2:20–3:00</td>
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<td>Afternoon tea</td>
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### Session 4

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<tr>
<th>Time</th>
<th>Speaker</th>
<th>Presentation Title</th>
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<tbody>
<tr>
<td>3:00–3:20</td>
<td>Roger Clifton</td>
<td>Using NTGS geophysical data</td>
</tr>
<tr>
<td>3:20–3:40</td>
<td>Benedict Scambary</td>
<td>Sacred sites in the NT and AAPA’s processes for site registration</td>
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<tr>
<td>3:40–4:40</td>
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<td>Session on Titles and Land Access issues</td>
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**AGES Official Dinner**

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<tr>
<th>Time</th>
<th>Event Description</th>
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<tbody>
<tr>
<td>6:30–7:00</td>
<td>Pre-dinner drinks sponsored by Emmerson Resources Pty Ltd</td>
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<tr>
<td>7:00–late</td>
<td>Dinner wine sponsored by Arafura Resources Ltd and NuPower Resources Ltd</td>
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<td></td>
<td>Dinner Speaker – Dr Neil Williams, Chief Executive, Geoscience Australia</td>
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### DAY 3  Wednesday 19 March

#### Session 1

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<tr>
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<th>Speaker</th>
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<tbody>
<tr>
<td>9:00–9:20</td>
<td>Uranium Equities Overview</td>
<td>Uranium Equities</td>
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<tr>
<td>9:20–9:40</td>
<td>The discovery of an Archean inlier in Arnhem Land</td>
<td>Julie Hollis</td>
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<tr>
<td>9:40–10:00</td>
<td>Alligator Rivers uranium modelling project</td>
<td>Peter Schaubs</td>
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<tr>
<td>10:00–10:40</td>
<td>Morning tea</td>
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#### Session 2

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<thead>
<tr>
<th>Time</th>
<th>Topic</th>
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<tbody>
<tr>
<td>10:40–11:00</td>
<td>Exploring through regolith in the Tanami</td>
<td>Lisa Worrall</td>
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<tr>
<td>11:00–11:20</td>
<td>Overview of NT exploration projects</td>
<td>Westgold Resources</td>
</tr>
<tr>
<td>11:20–11:40</td>
<td>Accessing NTGS information</td>
<td>Tracey Rogers</td>
</tr>
<tr>
<td>11:40–12:00</td>
<td>The NT Government’s China Investment Strategy</td>
<td>Steve Tatzenko</td>
</tr>
<tr>
<td>12:00–1:00</td>
<td>Lunch</td>
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#### Session 3

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<thead>
<tr>
<th>Time</th>
<th>Topic</th>
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<tbody>
<tr>
<td>1:00–1:20</td>
<td>Mineral systems in the Calvert Hills region</td>
<td>Andrew Wygralak</td>
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<tr>
<td>1:20–1:40</td>
<td>Overview of NT exploration projects</td>
<td>Bondi Mining</td>
</tr>
<tr>
<td>1:40–2:00</td>
<td>Onshore energy security programs in the NT</td>
<td>David Maidment</td>
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<tr>
<td>2:00–2:20</td>
<td>Overview of NT exploration projects</td>
<td>Toro Energy</td>
</tr>
<tr>
<td>2:20–2:30</td>
<td>Closing remarks</td>
<td>Ian Scrimgeour</td>
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**End AGES 2008**
NT MINERAL EXPLORATION OVERVIEW 2007

John Dunster

Exploration expenditure

Expenditure on mineral exploration in Australia went from $1.24 billion during 2005/06 to $1.71 billion during 2006/07. Only 36% of this was spent on greenfields exploration. In 2006/07, expenditure in the Northern Territory was on a par with Victoria. The Northern Territory has been overtaken by New South Wales and South Australia. All states and the Northern Territory have been losing market share to South Australia. The Northern Territory is endeavouring to redress this and to claw back to its previous best of 10% in 1990, from its present ~6% Australian market share.

Tenement situation

At the end of 2007, 28% of the Northern Territory landmass was covered by 1076 granted exploration titles. This was more than double the granted area at the end of 2005. Currently, a record 46% of the Territory is under application, compared with 30% in 2005. The number of grants per year is also at record levels and the 1000 granted EL benchmark was passed during 2007. This is a result of momentum building steadily, since large tracts of land were granted in 2002/03, particularly for exploration under cover. However, the northern McArthur Basin, an area the size of Tasmania, has a low proportion of granted titles and a disproportionate number in moratorium. Likewise, the southwest of the Territory, including the Musgrave Province and the western Arunta Region through to the Tanami Region, contains EL applications of roughly the same land area as the whole of Victoria. The Department is monitoring and encouraging the turnover of ground in all of the Territory’s important geological provinces and that situation is also slowly improving.

Exploration highlights by geological province

The McArthur Basin is one of the Territory’s most prospective provinces and, with over 142 400 km² exposed, it is also one of largest. The basin is ‘elephant country’ with a >20-year history of world-class mining, worth >$3B, and it is prospective for base metals, uranium, diamonds and phosphate. Xstrata continued with its open cut operation at the McArthur River Mine; Redbank Mines continued to build a resource at it namesake operation, with some intercepts of about 60 m at 1.5% to 2.5% Cu. Gravity Diamonds continued to evaluate the Abner pipe and surrounds, and explored regionally for diamonds. North Australian Diamonds is looking to reinvigorate the Merlin field. Sandfire Resources tested a McArthur River look-alike target. Legend International Holdings explored mainly for diamonds and phosphate. Rox and Admiralty are new players in the area.

The Tanami Region is a mature gold province with proven gold production, and is also being explored for uranium. It is one of the Territory’s smallest geological provinces and is covered by a relatively low number of titles, but has a good record of turnover of ground. The big two explorers (Newmont Australia and Tanami Gold) have been joined by the junior explorers, Ord River Resources/Supplejack, Excalibur/Palace, Washington and Deep Yellow.

The Arunta Region is a highly complex metamorphic province and NTGS has been working for a number of years to unravel that complexity. It is truly a multi-commodity province, with targets that include base and precious metals through to garnet and vermiculite. Highlights for 2007 include Arafura Resource’s ongoing work at the Nolans (formerly Nolans Bore) rare earth-phosphate-uranium deposit and in regional exploration. Intercepts reported from Nolans include 5.4 m at 23.8% REO and 4.7 lb/t U³O₈ and 8.3 m at 11.4% REO, 2.2 lb/t U³O₈. Thor Mining reported intercepts of 10 m at 0.61% MoS₂, 1.04% WO₃, and has the Molyhil project under feasibility study. Reward Minerals continued their long-term drilling at the Jervois base metals project with good intercepts of 13 m at 2.25% Cu and 26 g/t Ag, and 4 m at 5.73% Zn.

The Pine Creek Orogen has over 1000 documented mineral occurrences and is one of the Northern Territory’s most mature provinces in terms of exploration. It is renowned for gold and high-grade uranium. The Pine Creek Orogen contains 20% of the World’s low-cost uranium and this alone makes it currently some of the most desirable real estate anywhere. Gold mining is currently dominated by GBS Gold’s activities. Other key projects include Territory Iron at the Frances Creek iron ore deposits and Compass Resources’ work on the Browns base metals and Mount Fitch uranium deposits. Compass reported separate drilling intercepts of 1 m at 6.68 lb/t U³O₈; 43 m at 1.97% Cu, 0.30% Co, 0.20% Ni and 43 g/t Ag; 10 m at 6.61% Cu, 0.46% Co, 0.33% Ni, 165 g/t Ag and 3.8 lb/t U³O₈; and 55 m at 5.1% Pb. Atom Energy intersected uranium at three previously known prospects: 10 m at 1490 ppm U³O₈ at Twin; 12 m at 345 ppm at Cliff; and 9 m at 2004 ppm at Dam. The Stevens prospect was drilled by a Uranium Equities/Cameco JV. They reported 8 m at 2.57 g/t Au, 1.02 g/t Pd, and 0.88 g/t Pt, and 1 m at 0.19% U³O₈. ERA continued mining at Ranger and is working to increase resources and reserves. The company intersected 17 m at 0.257% eU₃O₈ outside the pit.

The Tennant Region is another highly prospective multi-commodity province at a moderately mature state of exploration. The region includes the central Warramunga Province and unconformably overlying Palaeo- to Mesoproterozoic North Australian Platform Cover successions of the Davenport and Tomkinson Creek (formerly Ashburton) provinces, to south and north, respectively. The traditional target of Warramunga Formation iron-oxide gold ± copper has been a mainstay of exploration for over 100 years and the high-grade gold has been a company-maker. New exploration methods and new target commodities have seen exploration activity increase to a point where expenditure in the Tennant Region has surpassed that in the Tanami Region for the first time in over a decade. Emmerson Resources has the commanding landholding and has recently been floated with a promise of active exploration.

1 Northern Territory Geological Survey, GPO Box 3000, Darwin NT 0830. Email: john.dunster@nt.gov.au.
to begin in the coming field season. Westgold Resources and Adelaide Resources have separately reinvigorated the Rover field and surrounds to the west of Tennant Creek, with some good base metals ± gold intercepts. These include 73 m at 4.3% Zn + Pb and 10.7 g/t Ag, and 64 m at 4.8% Zn, 4.1% Pb and 40.4 g/t Ag at Explorer 108. OM Holdings has continued its exploration and development work at the Bootu Creek manganese mine. Brumby Resources has begun exploring to their north. Other juniors active in the Tennant Region include Truscott, Excalibur and Prosperity. Considerable potential exists for targets in extensions to the province under cover and NTGS are taking the lead in acquiring gravity data over these areas.

The Musgrave Province extends over Western Australia, South Australia and the Northern Territory. It is a relatively complex metamorphic region that contains nickel, PGE, gold, uranium and lead-zinc-silver targets. Despite a high level of activity in the adjacent states and recent work by NTGS, much of the Northern Territory portion is yet to be explored. The Musgrave Province was largely ignored during previous exploration booms and currently most of the Northern Territory portion is still under application.

The Murphy Inlier is an east-trending 1835 km² inlier of Palaeoproterozoic metasediments, volcanics and felsic intrusives that extends into Queensland. The NT portion is prospective for uranium, gold, and copper and tin-tungsten. The western third is being explored by Lagoon Creek Resources, Uranium West and Murphy Uranium/Bondi Mining. The eastern portion is still mostly under application, but NuPower has a granted EL on the Queensland border.

The onshore Bonaparte Basin extends from the Northern Territory into Western Australia. Both portions contain clusters of Mississippi Valley-type base metal deposits. Tennant Creek Gold has resurrected several lead-zinc deposits as part of their Sandy Creek/Manbarrum project. Their reported grades are typical for a Mississippi Valley-style deposit. Drilling intercepts reported during 2007 include 85 m at 5.46% Zn eq and 130 m at 4.0% Zn + Pb and 18.0 ppm Ag.

The uranium exploration boom has led to a massive resurgence of interest in central Australian basins. The Ngalia Basin, home to several known uranium prospects, including Bigryli (Energy Metals JV), has gone from being almost entirely vacant to almost entirely pegged in the space of two years. Similarly, the Amadeus Basin, mostly thought of as a petroleum province, was only being explored for evaporites, copper and gold prior to 2006. There are now over 100 uranium titles. The central Australian basins should not be seen as just being prospective for uranium. They warrant more systematic exploration for other metals using modern techniques.

The Territory’s Mesozoic and Cenozoic basins are finally getting the recognition they deserve from the explorers. There is some work on coal in the Pedirka Basin, but elsewhere, the focus is almost exclusively on secondary uranium. Toro/Deep Yellow are proving-up such a resource at New Well/Napperby. However, Matilda Minerals (zircon sands), Olympia Resources (garnet sands) show that there are other target commodities.

Conclusion

The minerals commodity boom continued during 2007 and exploration expenditure has increased in the Northern Territory. Despite a record numbers of exploration titles, the Northern Territory still has some way to go to recover its previous share of Australian expenditure. Important resources of iron, uranium, copper, gold, lead-zinc, and rare earths are being, or have been proved-up. Grass roots exploration has been dominated by uranium, with a lot of activity now starting in frontier younger basins.

THE GEODYNAMICS AND METALLOGENESIS OF THE NORTH AUSTRALIA CRATON

David Huston1,2, Ian Scrimgeour3, Ian Tyler4 and Laurie Hutton5

The Proterozoic North Australian Craton is one of the mostly richly mineralised provinces in the world, containing two of the ten largest known Zn-Pb-Ag deposits (HYC and Hilton-George Fisher, as well as important uranium (Alligator Rivers and South Alligator Valley), copper (Mount Isa), copper-gold (Tennant Creek and Ernest Henry) and gold (Pine Creek and Tanami) districts. These resources are the direct or indirect results of convergence and collision of provinces within the North Australia Craton, as well as interactions with the South Australian Craton and, particularly, the West Australian Craton. Importantly, mineralising events in many cases did not occur at the convergent margin, but inboard, either in zones of back-arc spreading behind arcs, or well inboard as a consequence of the reactivation of pre-existing structures by collision-related changes in stress.

Analysis of potential field data, seismic traverses, and geological, geochronological and isotopic data suggests that the North Australian Craton is composed of five blocks made up of one or more provinces: the Kimberley-Pine Creek, Tanami-Tennant Creek, Aileron, Warumpi and Georgetown blocks. The boundary between the Tanami-Tennant Creek and Georgetown blocks formed an important locus for the development of overlying basins of the North Australian Basin System.

Although Neoarchean to earliest Palaeoproterozoic nuclei are known in both the Pine Creek Orogen and Tanami Region (Worden et al in press, Page et al 1995), the earliest known mineralising event occurred in overlying 2020 Ma rocks (Worden et al in press). The best example of this event is the Namoona Zn-Pb prospect, which, based on a lead isotope model age of 2000 Ma (Ahmad and Wygralak 2006), is interpreted as a syngenetic or early diagenetic deposit.

1 Geoscience Australia, GPO Box 378, Canberra ACT 2601.
2 Email: david.huston@ga.gov.au.
3 Northern Territory Geological Survey, GPO Box 3000, Darwin NT 0830.
4 Geological Survey of Western Australia, 100 Plain Street, East Perth WA 6004.
5 Geological Survey of Queensland, Department of Natural Resources and Mines, Block A, 80 Meiers Road, Indooroopilly QLD 4068.
The next set of mineralising systems was associated with convergence between the Tanami-Tennant Creek and Kimberley-Pine Creek blocks between 1870 and 1840 Ma, terminating with collision during the 1840–1805 Ma Tanami and Halls Creek orogenies. Convergence between these blocks was complex, involving initial north-dipping subduction (Sheppard et al 1999), forming 1870–1860 Ma back-arc basins that host VHMS deposits in the Pine Creek Orogen. Between 1860 and 1845 Ma, subduction was southeast dipping, forming the Tickalara island arc. Extension within the arc resulted in the emplacement of layered mafic-ultramafic intrusions that host both orthomagmatic Ni-Cu and PGE deposits. At 1845 Ma, the polarity of subduction switched again, resulting in rifting of the Tickalara island arc (Sheppard et al 1999). The rifted arc host layered intrusion Ni-Cu deposits, VHMS deposits and porphyry Cu deposits. This change in the polarity of subduction may be related to a collision between the Tanami-Tennant Creek and Aileron blocks, as discussed below. According to our interpretation, the boundary between Tanami-Tennant Creek and Kimberley-Pine Creek blocks extends to the east below the Victoria River and McArthur basins, raising the possibility of similar styles of mineralisation at depth.

The 2005 Tanami seismic survey indicated that the Willowa Gravity Ridge is associated with a east–west- to east-southeast–west-northwest-trending suture between the Tanami Region and Aileron Province (Goleby et al 2006). As turbiditic sedimentary rocks of the Tanami–Lander Rock package overlie this suture, its age must be older than 1840 Ma. A possible, though speculative timing for collision is 1850–1845 Ma, a period of N-verging compression and granite emplacement in the 1865 Ma Warramunga basin. This basin and the 1865 Ma Stubbins basin to the west in the Tanami Province, may be back-arc basins (eg Bagas et al in press), associated with the convergence between the Tanami-Tennant Creek and Aileron blocks. In this interpretation, the Tennant Creek iron-oxide copper-gold deposits are a consequence of this collision, and potential for similar styles of mineralisation exists to the north of the boundary between these two blocks.

Preliminary results of the 2007 Mount Isa–Georgetown seismic traverse suggest that the Georgetown Province and Tennant Region were juxtaposed along a west-dipping zone. Differences in seismic character and variations in radiogenic isotopes across this zone suggest it is a major suture that predated initiation of the North Australian basin system at 1790 Ma. Although not directly associated with known mineralisation, this interpreted suture may have localised later basin development and iron-oxide copper-gold deposits.

After the collision between the Tanami-Tennant Creek and Kimberley-Pine Creek blocks at 1840–1820 Ma, the locus of convergence shifted to the southern margin of the North Australia Craton, resulting in a series of southward-younging magmatic events associated with a north-dipping subduction zone that steepened with time. Lode-gold mineralising events at 1810–1800 Ma in the Pine Creek Orogen and Tanami Region are interpreted to be inboard manifestations of this convergence, and similar-aged volcanic-hosted massive sulfide deposits formed in back-arc basins developed above the subduction zone.

Collision between the North Australian and West Australian cratons during the Capricorn and Yapungku orogenies at 1790–1760 Ma (Cawood and Tyler 2004, Bagas 2004) caused a change in the direction of convergence from broadly north–south to more northwest–southeast, resulting in a convergent margin that may have extended along the northeast margin of the West Australian Craton to the eastern margin of the North Australia Craton. Granite with arc-like geochemical signatures of the Inkamulla Suite in the southeast Aileron Province formed at 1770–1750 Ma and are associated with northwest-dipping subduction along this margin. However, further to the north and east, the North Australian basin system developed as a consequence of back-arc extension (Gibson et al in press). Although initial extension was not associated with known mineral deposits in the basin system, it set up an architecture exploited by later Mount Isa-type Zn-Pb and iron-oxide copper-gold deposits. Moreover, W and W-Mo deposits associated with 1730–1710 Ma granites in the eastern Aileron Province and Tennant Region may be inboard expressions of this geodynamic system.

Deposition of sedimentary rocks that make up the North Australian zine belt began at 1670 Ma with deposition of the Cannington deposit and finished at 1575 Ma with deposition of the Century deposit. Two quite different types of Zn-Pb deposits formed during this period: Mount Isa-type and Broken Hill-type. Broken Hill-type deposits (eg Cannington and Pegmont) formed earliest (1690–1675 Ma) in a deep-water-turbidite-dominated setting with active magmatism, possibly ensialic rifts. In contrast, Mount Isa-type deposits formed in platformal or sag basins that lacked active magmatism. Formation of these deposits corresponds to major changes in the apparent polar wander paths, suggesting they are inboard responses to major plate reorganisations. Periods of Zn-Pb mineralisation correspond, in many cases, with periods of unconformity-style U deposition. As an example, the HYC Mount Isa-type deposit, several unconformity U deposits and the Browns Pb-Cu-Ni-Co deposit correspond with the Liebig Orogeny and a U-turn in the apparent polar wander path at 1640–1630 Ma, suggesting that these deposits are inboard manifestations of the accretion of the Warumpi Province along the southern margin of the North Australian Craton.

The last major series of Proterozoic mineralising events in the North Australian Craton involved U ± REE and Cu ± Au deposition between 1555 and 1500 Ma in rocks of the North Australian basin system. At 1550 Ma, metasomatic U deposits at Mary Kathleen and in the Valhalla districts formed (Perkins et al 1999); at 1520 Ma, the Cu orebodies of the Mount Isa deposit formed (Perkins et al 1999); and at 1500 Ma (Perkins and Wyborn 1998), iron-oxide copper-gold deposits formed above the inferred suture between the Tennant Region and Georgetown Province. These deposits formed during the second phase of the Isan Orogeny, possibly related to the collision to the east with Laurentia (Betts et al 2006).

After the Isan Orogeny, mineralising events in the North Australian Craton were not as extensive, though
more exotic. For example, orthomagmatic Ni-Cu-PGE mineralisation is hosted by a layered ultramafic phase that forms part of the 1130 Ma Mordor alkaline igneous complex in the south-central Aileron Province (Hoatson et al. 2005), and weathering of biotite alteration associated with the 730 Ma (Black and Gulson 1978) Mud Tank carbonatite has resulted in a vermiculite deposit. Lode gold deposits in the Arltunga field formed at 300 Ma (J Dunlap, Geoscience Australia pers comm 2007) are associated with late stages of the intracratonic Alice Springs Orogeny. The most enigmatic deposit is the Nolans REE-P-U deposit in the central Aileron Province. Although this deposit has the potential to become a world-class mine, its origin and age are poorly constrained.

References


PRELIMINARY INVESTIGATIONS IN THE CENTRAL ARUNTA REGION

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In 2007, NTGS commenced work on a new project in the central Arunta Region, initially focused in the southwest of the Alcoota 1:250k mappoint. This project incorporates work by NTGS in 2002 in the central northern 1:100k mappoint (Woodgreen) of Alcoota (Haines and Scrimgeour 2007). The central Arunta is critical to furthering the development of an integrated framework of the Arunta Region, and builds on NTGS work since 2000 in the southwestern, northern and eastern Arunta. The project will add important information to the emerging picture of the evolution and tectonic context of the amalgamation of this complex terrane.

Aileron Province

Lander Package

The central Arunta comprises elements of the oldest part of the Aileron Province; granulite-facies equivalents of the Lander Rock Formation are exposed in the eastern extension of the Reynolds Range in the SW of Alcoota. The Lander Rock Formation has maximum deposition

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ages in the range 1860–1830 Ma and underwent early metamorphism and deformation during the 1810–1800 Ma Stafford Event. A major intrusive episode occurred during the 1790–1770 Ma Yambah Event and, most likely, was accompanied by deformation and by generally greenschist-facies metamorphism.

**?Strangways Metamorphic Complex**

The majority of the central Arunta Region has been considered to be part of the Strangways Metamorphic Complex of the Aileron Province. In Alcoota, named rock units include the granulite-facies Kananda Granulite and Bleechmore Granulite, and the amphibolite-facies Mapata Gneiss, Delmore Metamorphics and Delny Metamorphics. The Kananda Granulite, Mapata Gneiss and Bleechmore Granulite have a significant mafic component in addition to metasedimentary rocks, with less common felsic orthogneiss. The Delmore and Delny metamorphics are dominantly siliciclastic metasedimentary rocks with a lesser mafic component.

Geochronology is somewhat limited, but suggests that the metamorphic packages described above may form a distinct, slightly older succession than the Ongeva Package of the main Strangways Metamorphic Complex. The Kananda Granulite, Delmore Metamorphics and Delny Metamorphics give maximum deposition ages of about 1820 Ma, with considerable inheritance back to about 2500 Ma (Srimgeour and Raith 2001, Bodorkis unpublished data, J Claué-Long, Geoscience Australia, unpublished data). The detrital spectra for these units indicate a provenance from the North Australian Craton (NAC), not unlike that of the Lander Rock Formation, although lithologically the successions are dissimilar. The Ongeva Package has maximum deposition ages of between 1810–1800 Ma, with no to very little inheritance of older zircons (Hussey et al. 2005, Claué-Long et al. in press). The Bleechmore Granulite is slightly anomalous, as it gives a maximum deposition age of about 1800 Ma, but shows a smear of inheritance back to about 2500 Ma (Maidment et al. 2005), suggesting input from the NAC.

Newly acquired geochronological data records the presence of an un-named felsic gneiss in association with rocks of the Harts Range Metamorphic Complex of the Irindina Province. This gneiss has an older inheritance component and a unimodal cluster of 14 zircon cores at about 1795 Ma, suggesting a possible volcanic or volcanioclastic origin.

**Ledan Package**

The Ledan Package in the central Arunta Region comprises the upper greenschist–lower amphibolite-facies Ledan Schist (with overlying Utopia Quartzite) and Mendip Metamorphics, plus the granulite-facies metasedimentary rocks of the Anira Metamorphics. The Ledan Schist comprises a succession of quartz-muscovite ± biotite ± andalusite schist, and metapsammite with minor amphibolite, which is unconformable on the Delmore Metamorphics, and which has a maximum deposition age of 1775 Ma (Maidment et al. 2005). Metapelite and metapsammite of the Anira Metamorphics in central north Alcoota have a maximum deposition age of 1795 ±19 Ma (Claué-Long, unpublished data). The Mendip Metamorphics comprise metasedimentary rocks, gneiss and amphibolite; this unit is interpreted to be unconformable on the Bleechmore Granulite and has a maximum deposition age of 1770 Ma (Maidment et al. 2005).

The Ledan Package is a probable correlative of the unmetamorphosed upper Hatches Creek Group of the Davenport Province to the north. Together, these packages constitute part of an intracratonic basin that formed to the north of a plate margin during rollback of a north-dipping subduction system; to the south and southeast, this event also produced the magmatic-dominated Oonagalabi (host to carbonate-replacement base metals deposits) and Albarta successions (Srimgeour 2006).

**Strangways Orogeny (1735–1690 Ma)**

The Strangways Orogeny was the major tectonic event in the eastern and central Arunta Region, where it affected both the older metasedimentary successions and the Ledan Package. Metamorphic grade is predominantly granulite facies in older rocks, and varies from granulite facies (Anira Metamorphics) to predominantly upper greenschist facies (Ledan Schist) in the Ledan Package. The nearest metamorphic data comes from the east, where P-T conditions in the Kananda Granulite were calculated to be 770–850°C and 5–7 kbar (Srimgeour and Raith 2001). Zircon rims in the Bleechmore Granulite record a smear of ages from 1790 Ma to 1710 Ma, interpreted to represent a mix of ages from an earlier event at about 1780 Ma (Yambah Event) and the Strangways Orogeny at 1730 Ma (Maidment et al. 2005). From the Ledan Package, both the Anira Metamorphics and Mendip Metamorphics record zircon rims at about 1724 Ma (Claué-Long unpublished data, Maidment et al. 2005). Newly acquired data from this project on an un-named 1795 Ma felsic gneiss from within the contact zone between the Aileron and Irindina provinces includes analysis of two Palaeoproterozoic rims, which give an age of about 1698 Ma, after being corrected for isotopic disturbance during the overprinting Laraapinta Event at about 490 Ma.

Deformation and metamorphism of the Kananda Granulite during the Strangways Orogeny is characterised by a protracted granulite-facies M1 metamorphism, with D1/D2 formation of an S/S′ gneissic fabric, magmatic melt migration, granite intrusion and northwest- to north-northwest-trending D3 refolding. The tectono-metamorphic relationships developed in the Mapata and Delny gneisses are interpreted to mirror those in the Kananda Granulite, with similar fabric-overprinting relationships, melt generation and intrusive histories.

In the domain dominated by the Delmore Metamorphics and the Ida and Copia granites, it may be possible to distinguish the effects of the earlier Yambah Event from those of the Strangways Orogeny. In the Delmore Metamorphics, upper-amphibolite-facies, west-northwest-
to northwest-striking migmatitic (S<sub>1</sub>) gneiss and schist are folded by steeply southeast- to east-plunging F<sub>3</sub> folds, with a steep east–west-striking, axial-planar S<sub>2</sub> fabric and melt. The S<sub>1</sub> fabric and melts are co-planar to a gneissic fabric in granites that are interpreted to have intruded at 1770 Ma and 1730 Ma; it remains possible that the S<sub>1</sub> fabric elements may be due to the earlier Yambah Event and that the overprinting east–west-trending S<sub>1</sub> fabric elements are related to the Strangways Event. The Delmore Metamorphics, which has a west-northwest– to northwest-striking S<sub>1</sub> schistosity and gneissosity in epidote-silica altered meta-volcanic rocks and muscovite-rich felsic gneiss, is unconformably overlain by the Ledan Schist. The Ledan Schist and Utopia Quartzite experienced progressive deformation involving regional shearing (D<sub>1a</sub> with respect to the Ledan Schist, and involving regional thrusting?) closely followed by (D<sub>1b</sub> folding. The L<sub>1</sub> stretching lineation and F<sub>1a</sub>, fold axes generally trend east-southeast, though considerable deviation from this trend across the region is due to reorientation by D<sub>2</sub> and D<sub>1b</sub> refolding. The angular unconformity at the base of the Ledan Schist is locally intensely deformed, and the strong mylonitic fabric and stretching lineation is probably related to the development of early D<sub>1a</sub> high-strain zones within the overlying Ledan Package.

The granulite-facies Anira Metamorphics show no pervasive fabric development, and are characterised by large volumes of melt, typical of high-T low-P regional 'aureole'-style metamorphism (Haines and Scrimgeour 2007).

Chewings Orogeny (1590–1560 Ma)

The Lander Package in the Reynolds Range and in the southwest Alcoota is overprinted by high-T low-P granulite-facies metamorphism belonging to the 1590–1560 Ma Chewings Orogeny (Hand and Buick 2001). The Mendip Metamorphics recorded a few thin zircon rims at 1572 Ma (Maidment et al. 2005), although zircon rim data of this age was not determined in the underlying Bleechmore Granulite. Further work is required to determine the extent and character of the Chewings Orogeny in the central Arunta Region.

Igneous rocks

Intrusive rocks in Alcoota outcrop predominantly in the eastern half of the mapsheet, and occur as dominantly syn-tectonic plutons, intruding rocks of older metasedimentary successions and the Ledan Package. The granites fall into two main groups, based on the classification scheme developed by Zhao and McCulloch (1995). The older of the two groups is referred to the "Low Al" sub-division of Zhao and McCulloch’s "Main Group" and includes the Copia, Crooked Hole and Queenie Flat granites. This subdivision is defined by a granite age range of 1780–1750 Ma. The granites are characterised by LREE-enriched patterns with deep Eu anomalies, and their trace element patterns show a negative slope with negative anomalies in Ba, Sr, Nb, Ti and P.

The second group intrudes the Main Group and belongs to the "High Heat Production Group (HHP)" sub-division of Zhao and McCulloch”. Granites in this group include the Mount Ida and Mount Swan Granites, and those of the Woodgreen Granite Complex, and have an age range of 1730–1700 Ma. The HHP granites are enriched in heat-producing elements such as U, Th and K, as is shown by their trace element patterns which show elevated abundances of these elements compared to granites from the Main Group. The HHP Group also shows enrichment in LREE, Zr, Nb and Y relative to granites from the Main Group.

Geochemical and Nd isotopic signatures of granites from the central Arunta suggest that their sources are heterogeneous, and contain at least two main components: a Palaeoproterozoic mantle-derived component and an older crustal component evidenced by inherited zircons with ages ranging back to the early Archaean. According to Zhao and McCulloch (1995), the formation of the Main Group granites may have involved partial melting of modified arc-related underplates, though not necessarily in a subduction environment. The geochemistry of the HHP granites points to a felsic or granite source, the most likely candidate being older Main Group granites.

Irindina Province

The northeastern limit of the Irindina Province is exposed in the southeastern corner of Alcoota. The Harts Range Metamorphic Complex there comprises granulite-facies metapelite, metapsammite, mafic rocks, and calc-silicate of Neoproterozoic to Cambrian age; these are time equivalents of the adjacent Amadeus and Georgina Basins (Maidment 2005). A zone of orthogneiss near the northern margin of outcrop, previously mapped as Harts Range Group, has been found to be Palaeoproterozoic in age, and is therefore part of the Aileron Province.

The Corkwood Hill granite was intruded at about 387 Ma (Buick et al. 2001). This granite is geochemically very different to the Palaeoproterozoic granites – it is high in Al<sub>2</sub>O<sub>3</sub> and Na<sub>2</sub>O, but very low in K<sub>2</sub>O. It also has an unusual REE pattern with a strong negative slope, depleted HREE, and no Eu anomaly.

Larapinta Event (510–460 Ma)

The Larapinta Event in Alcoota reached peak metamorphic conditions of 705–810°C and 8–12 kbar (Miller et al. 1997) and occurred between 480 and 460 Ma (Buick et al. 2001). This high-grade metamorphic event is thought to have occurred during regional extension, accompanying mafic magmatism and the formation of the overlying Amadeus and Georgina Basins (Mawby et al. 1999, Buick et al. 2001, Scrimgeour and Raith 2001). Deformation and metamorphism are characterised by a steeply dipping, regional east–west-trending gneissosity (D<sub>2</sub>/D<sub>1b</sub>), defined by peak metamorphic, transitional granulite-facies assemblages that formed at 476 Ma (Mawby et al. 1999), which in turn experienced deformation, transposition and re-melting accompanying development of shallowly east–west-plunging, steep, tight D<sub>1a</sub> folds.
Generally, the Larapinta Event is not recorded in the surrounding Palaeoproterozoic rocks of the Aileron Province, with the exception of a single record in the eastern Arunta, where Maidment (1995) reported a 474 Ma metamorphic zircon overgrowth from a 1745 Ma megacrystic gneiss. In ALCOOTA, a felsic migmatitic gneiss on the northern margin of the Harts Range Metamorphic Complex records a maximum deposition age of 1795 Ma, older rims at 1698 Ma, and several younger rims calculated to be 489±10 Ma, slightly older than the metamorphic ages calculated for metasedimentary rocks of the Harts Range Metamorphic Complex in the same area (see above). This Palaeoproterozoic gneiss shows the same deformational fabrics as the adjacent Harts Range Metamorphic Complex rocks. The absence of Larapinta metamorphic ages in adjacent Palaeoproterozoic rocks indicates they were juxtaposed after the Larapinta Event, during subsequent Palaeozoic deformation (eg see Maidment 2005). However in this case, the geochronological and structural evidence indicate that the Harts Range Metamorphic Complex and Aileron Province rocks were in close association prior to the onset of the Larapinta Event.

**Palaeozoic deformation (450–300 Ma)**

Compressional tectonics began in the eastern Arunta at about 450 Ma and focused on regionally extensive shear zones, the most prominent in the northern region being the Entire Point Shear Zone (EPSZ), which marks the northern boundary of the Irindina Province. To the east, the EPSZ is a discrete structure with upper amphibolite-facies mylonites (700°C, 7 kbar) reworking the Kanandra Granulate at 445 Ma (Scrimgeour and Raith 2001). In Alcoota, local mylonitisation of the Harts Range Metamorphic Complex, subsequent to the metamorphic peak, occurred at conditions of 680–730°C and 5.8–7.7 kbar (Miller et al 1997), and may relate to compression at 450 Ma.

The major expression of the Alice Springs Orogeny in the area mapped to date is in the northwest-striking faults that form the western extension of the Delny Fault Zone (DFZ). To the east, the DFZ is a major, steeply south-dipping, north-vergent, 2–4 km-wide mylonite zone, which varies from mid-amphibolite facies to greenschist facies (Scrimgeour and Raith 2001). In Alcoota, the zone is represented by discrete, quartz-filled fault planes of low grade, with strong quartz-mylonite development and associated steeply plunging mineral stretching lineation. Locally-preserved kinematic indicators on faults that cut the Woodgreen Granite Complex are consistent with the north vergence described above.

**Mineral potential and exploration activity**

Metasedimentary successions and granite are intruded by Sn-Ta-bearing pegmatites of probably similar age to the 1730 Ma W-Sn-bearing granites of the Davenport Province. These deposits have been historically mined.

The Delmore Metamorphics contain rocks interpreted to be volcanioclastics, and show mineral assemblages (quartz-cordierite rocks, cordierite-anthophyllite rocks) characteristic of the Ongeva Package, which in the Strangways Range, host VAMS and epigenetic base metals occurrences (Hussey et al 2005). Warren and Shaw (1985) and Hussey et al (2005) suggested that this alteration took place prior to metamorphism.

Copper deposits are present in Georgina Basin sediments at Mount Skinner and are currently being assessed by Uramet Metals Pty Ltd. Drillhole intercepts with elevated base metals occur in the Delmore/Delny metamorphics.

Minor vermiculite and REE are associated with carbonate in the Mount Bleechmore granulite, north of the Mud Tank granulite field. Potential for Nolans'-style vein hosted REE mineralisation exists within the Lander Rock Formation in the southwest and its probable eastward extent undercover.

Exploration activity in western Alcoota is largely focused on palaeochannel or calcrite-hosted uranium, associated with the Cenozoic Ti Tree/Aileron Basin.

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### OVERVIEW OF THE GEOLOGY AND MINERAL POTENTIAL OF THE ENTIA DOMES, EASTERN ARUNTA REGION

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The Arunta Region comprises a 200 000 km² basement inlier in central Australia that has undergone multiple tectonothermal events in the period spanning the Palaeoproterozoic to the Carboniferous. The inlier is divided into the Aileron, Warumpi and Irindina provinces, on the basis of differences in the sedimentary and igneous protolith ages (Scrimgeour 2004). The Entia Dome is located in the eastern Arunta Region and forms part of the Aileron Province, a window of Palaeoproterozoic basement rocks in an area dominated by the Neoproterozoic to Palaeozoic Irindina Province. The basement rocks are separated from the structurally overlying Cambro–Ordovician Harts Range Metamorphic Complex by a mylonitised sheet-like body of granite, the Bruna Detachment Zone.

### Tectonothermal events in the Entia Dome

This document focuses on four of the seven tectonothermal events that have been recognised in the Eastern Arunta Region (Scrimgeour 2003, Hand and Maidment 2007): the Palaeoproterozoic Yambah (1780–1770 Ma; previously Early Strangways) and Strangways (1730–1700 Ma) events, and the Palaeozoic Larapinta (480–460 Ma) and Alice Springs events (450–300 Ma).

The 1780–1770 Ma Yambah Event is associated emplacement of voluminous felsic and lesser mafic intrusives. Granitoids and orthogneisses of the Ambulbinya Igneous Suite (new name; incorporates some of the gneisses of the Entia Gneiss Complex, and Huckitta and Inamullala suites) form part of the calc-alkaline-trondhjemite (CAT) suite of Zhao and McCulloch (1995). These have an arc-like geochemical signature and have been interpreted to have been generated in a subduction zone setting (Foden et al 1998, Zhao and McCulloch 1993, Zhao and McCulloch 1995), through either fractionation and/or partial melting of arc related magmas or underplates. Magmatism was accompanied by compressional deformation and has been interpreted to represent the closure of a back-arc basin and the development of a continental arc (Scrimgeour 2006).

The 1735–1690 Ma Strangways Event is characterised by high-grade (upper amphibolite- to granulite-facies) metamorphism and is the dominant tectonothermal event in the eastern Aileron Province. Metamorphism is high-T, low-P and was locally accompanied by partial melting and the intrusion of felsic magmas in the eastern Arunta (Scrimgeour 2003). The Strangways Orogeny has been interpreted as the final stage of plate-margin tectonism in the southeastern Arunta (Scrimgeour 2006).

The 480–460 Ma Larapinta Event is characterised by high-grade (up to granulite-facies) metamorphism (Miller et al 1998, Mawby et al 1999, Buick et al 2005, Maidment 2005), and is accompanied by the intrusion of mafic dykes and the deposition of fine-grained sediments in an extensional environment (Mawby 1999, Hand and Maidment 2007). The 450–300 Ma Alice Springs Orogeny spans a major period of extensional and compressional deformation in central Australia. Characterised by north–south- to northeast–southwest-directed intraplate shortening, this orogeny was at its most intense in the Entia Dome and Harts Ranges. There, amphibolite-facies metamorphism was accompanied by felsic magmatism, including the intrusion of voluminous pegmatites, and the Harts Range Metamorphic Complex was exhumed and thrust southwards over Palaeoproterozoic basement. (Hand and Maidment 2007).

### Palaeoproterozoic magmatism within the Entia Dome

Basement rocks of the Entia Dome are dominated by the Ambulbinya Igneous Complex. This complex is characterised by orthogneiss and granitoids, ranging in composition from ultramafic through to granitic/plitic, and is associated with a lesser supracrustal succession, consisting of pelites, rare psammites, calc-silicate rocks and marble, and both ortho- and para-amphibolites. At the centre of the Entia Dome, two ‘lobe-like’ low-strain boudins, of dominantly granodiorite composition, preserve primary igneous textures in places. High-strain gneisses of the Ambulbinya Igneous Complex wrap around these boudins and are of tonalite, granodiorite and granite composition. These gneisses are geochemically similar to the granitoids and are thought to represent higher-strain equivalents (Foden et al 1988, Maidment 2005); they are also consistent with the CAT suite of Zhao and McCulloch (1995). The Huckitta and Inamullala granodiorites intruded at 1760 and 1770 Ma, respectively (Maidment et al 2005) and have geochemical affinities with I-type Cordilleran

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suites. Voluminous pegmatites intrude the basement rocks, particularly throughout the southwestern and northeastern Entia Dome.

Recently acquired geochemical data is consistent with the generation of the Ambulbinya Igneous Complex in a subduction zone setting. Both the granodiorites and orthogneisses are strongly metaluminous, ranging to weakly peraluminous with increasing differentiation. Felsic rocks of the Ambulbinya Igneous Complex are geochemically similar to 1770 Ma felsic gneisses and granitoids from the Alberta Metamorphic Complex and the Atneequa Granitoid Complex, both located to the south of the Entia Dome. The two domains are separated by the Illogwa Schist Zone, which is an east–west-trending package of intensely sheared felsic gneiss, with lesser ultramafic rock and granodiorite. The Bruna Gneiss separates these rocks from the Harts Range Metamorphic Complex and, in contrast to the I-type granitoids described above, has A-type geochemical affinities and an igneous crystallisation age (zircon ID TIMS) of 1747 ± 2 Ma (Cooper et al. 1988).

The dominant fabric in the Entia Dome is a pervasive north–south- to northwest–southeast-trending foliation produced by the Alice Springs Orogeny. Reworking of the rocks during this time has obscured older fabrics and, as a consequence, no evidence of the Ordovician Larapinta Event has been observed in basement rocks to date. Low-strain boudins, such as the Huckitta and Inkamulla boudins or those located along the margins of the dome, may preserve such evidence. High-T, low-P metamorphism, associated with the Strangways Orogeny, lead to the production of rare migmatites in the Entia Dome, typically associated with the supracrustal succession in the northwest of the dome. Recent U-Pb SHRIMP studies on metamorphic rims from detrital zircon in a granulite-grade migmatitic metapelite has yielded a Strangways age (1717 ± 10 Ma) for peak metamorphism and a Yambah (1774 ± 7 Ma) maximum depositional age. Wade et al. (in press) reported evidence of Strangways metamorphism in amphibolite-grade rocks from elsewhere in the dome, a 1730 Ma age for metamorphic zircon in a calc-silicate rock from the southeastern Entia Dome, and 1719 ± 9 Ma for metamorphic monazite from a kyanite-bearing metapelite in the western part of the dome. However these two ages are the only reported evidence of metamorphism during the Strangways Event in the basement rocks. In situ monazite studies on upper amphibolite-grade metasediments from the eastern Alberta Metamorphics also record Strangways age (1729 ± 3 Ma) metamorphism (Carson et al in prep).

**Dating of metasedimentary packages within the Entia Dome**

Recent detrital zircon studies on metasedimentary rocks within the Entia Gneiss Complex have identified two distinct provenance patterns. Wade et al. (in press) reported maximum depositional ages of either 1780–1760 Ma or 2470–2460 Ma. The metasediment dated in this study falls into the first group. A maximum depositional age of 1780–1760 Ma suggests these gneisses are likely to have been derived locally from the Ambulbinya Igneous Complex, whereas a proximal Archaean source is not currently recognised.

**U and REE potential**

Voluminous pegmatites containing anomalous U and REEs intrude both the basement rocks of the Entia Gneiss Complex and the Palaeozoic Harts Range Group. Collectively, these pegmatites are informally named the Entia Pegmatite Field (Hussey 2003) and they form the eastern extent of a corridor of elevated U and REEs that extend northwest to Nolans REE, U, Th deposit. The Entia Pegmatite Field is thought to have intruded over a period of time, as is shown by variations in the mineralogy, geochemistry, orientation and degree of deformation of pegmatite bodies during the Alice Springs Orogeny; however, the number of generations is uncertain (Hand et al. 1999, Mawby 2000, Maidment 2005). Sodic and potassic varieties have been identified (Joklik 1955, Hussey 2003); the former is generally hosted in the Harts Range Group and the latter in gneisses of the Ambulbinya Igneous Complex. Both types are known to host REE minerals, such as monazite (LREE), samarskite (HREE), allanite (LREE), fergusonite (LREE, Y, Nb) and formanite (Y, Ta). PNC Exploration Australia identified REE occurrences in the Entia Dome on the basis anomalously high La, Ce and Y (as a proxy for HREE) within the Harts Range region. These are commonly associated with anomalously high U, particularly where HREE enrichment occurs (Hussey 2003). Apart from U associated with HREE occurrences, most REE anomalies are also enriched in one or more of Th, Nb, Ta, P, Ba, Fe, Ti or Zr.

**Revised geology for the Entia Dome**

The preliminary findings of this work suggest that at least some of the gneisses in the Entia Gneiss Complex are part of a magmatic system that includes the Huckitta and Inkamulla granodiorites, now collectively referred to as the Ambulbinya Igneous Complex. Depositional ages of 1780–1760 Ma maximum for some of the metasediments in the dome, are coincident with the intrusion of voluminous felsic and mafic magmatism with arc-like signatures and metamorphic monazite growth, suggesting that not only are some of the metasediments in the Entia Dome locally derived, but deposition and metamorphism happened in a short period of time and were most likely related to the intrusion of this large magmatic system. Interestingly, the closest known Archaean basement outcrops in the Tanami Region, the 2514 Ma Billabong Complex. The occurrence of an Archaean detrital signature in metasediments of the Entia Dome raises the possibility of undiscovered Archaean basement within the vicinity of the eastern Arunta.

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**MINERALISATION STYLES IN THE EASTERN ARUNTA REGION**

Dorothy Close1,2 and Ian Scrimgeour1

The current NTGS focus on the Arunta Region aims to characterise metamorphic, intrusive and deformational overprints in the region, with the objective of seeing through these events to determine the nature of the protolith packages, in terms of age, provenance and tectonic setting. This framework is then being integrated with an understanding of known mineralisation styles within the Arunta Region, combined with extensive new geochronological datasets, in order to develop new mineral system concepts and assist in opening up previously underexplored areas. The current NTGS project in the southeastern Arunta Region (Illogwa Creek, Hale River and Hay River 1:250k mapsheets, an area that includes sections of the Proterozoic Aileron Province and the Neoproterozoic Palaeozoic Irindina Province), is applying these principles to better understand this highly prospective region. New findings have included a redefinition of the spatial extent of 1770 Ma arc-like magmatism, the identification of distinct metamorphosed sedimentary packages, including possible back-arc basins, and a newly identified succession with a largely Archean signature (Whelan et al. 2008). Furthermore, a previously unmapped and underexplored Palaeoproterozoic basement inlier (Casey Inlier) has now been placed in context within the Arunta Region framework, and has attracted exploration interest for Ni, Cu and REE.

The eastern Arunta differs from most of the Territory’s Proterozoic basement in that large areas were affected by significant deformation and fluid flow during the Palaeozoic, particularly during the long-lived, episodic Alice Springs Orogeny (450–400 Ma). Fluid flows associated with the many phases of this event are distinctive in their relationship to mineral systems, which include REE and/or uranium mineralisation along with Au, Cu ± Pt and Pd associations.

**Uranium**

A thorough analysis of the uranium potential of the Entia region was undertaken by PNC Exploration (Australia) Pty Ltd in the mid 1990s, identifying many prospects and various styles of uranium mineralisation, relating to either localised metasomatic processes or pegmatite intrusion. SHRIMP 207Pb/206Pb dating of uranium-bearing mineral phases from all identified prospects consistently yielded Palaeozoic ages ranging 640 to 335 Ma (Drake-Brockman et al. 1996).

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REE

The Arunta Region already has proven REE prospectivity and the significant Nolans REE-U-P deposit is currently being developed by Arafura Resources Ltd. Within the Entia area, Hussey (2003) analysed geochemical data from PNC Exploration (Australia) Pty Ltd and identified two types of alkaline pegmatite composition associations: LREE/thorium enriched and HREE/uranium enriched. These pegmatites are pervasive within the Entia region, forming up to 11% of the rock mass (M Hand, School of Earth and Environmental Sciences, University of Adelaide, pers comm 2008). Crosscutting field relationships suggesting multiple phases of pegmatite intrusion. SHRIMP U-Pb zircon and monazite dating of the pegmatites indicate emplacement coeval with phases of the Alice Springs Orogeny (Drake-Brockman et al 1996, Hand et al 1999, Mawby 2000). Further work on these pegmatites is required to determine relative timing and compositional relationships.

Northeast–southwest-trending siliceous vein sets, containing anomalous REE and elevated copper geochemistry, have been identified in the Casey Inlier in the southern section of the eastern Arunta. These veins are yet to be dated, but are most likely to be Neoproterozoic to Palaeozoic.

Cu-Au±Pt, Pd

High-grade Pt-Pd-Au-Cu mineralisation occurs within felsic-carbonate veins, hosted by amphibolite units of the Irindina Province south and southeast of Mount Riddoch. Four prospects have been defined, associated with the Florence-Muller Shear Zone, which is a major structure that juxtaposed the Irindina and Aileron provinces at 450–440 Ma. The Kongo Prospect, 4 km northwest of the Copper Queen mine in the eastern Arunta Region, consists of mineralised quartz-carbonate-tourmaline veins associated with chlorite-haematite-altered amphibolite. The veins contain up to 0.6 ppm Pt, 1.4 ppm Pd, 5.8 ppm Au, 6.8% Cu and 12 ppm Ag (Hoatson et al 2005). High-grade mineralisation (maximum of 38.5 ppm Au, 4.8 ppm Pd, 0.1 ppm Pt) has also been reported at the Copper King (800 m southeast of Kongo), Pegma and Copper Hill (both 2.4 km southeast of Kongo) prospects. The polymetallic character of the vein systems, an associated Fe alteration and erratic metal ratios are features common to other hydrothermal Au-PGE deposits, such as Coronation Hill and El Sherana in the Pine Creek Orogen.

Ni

The Irindina Province, which is a metamorphosed Neoproterozoic to Cambrian rift succession containing both metabasalts and a number of generations of mafic intrusions, has significant and largely untested potential for mafic intrusion-hosted nickel sulphide mineralisation. Promising nickel values in very poorly exposed mafic rocks, along with significant new EM targets, will be followed up and drill tested by Mithril Resources during 2008, in partnership with BHP Billiton and Arafura Resources. Other areas of this terrane remain unexplored for nickel. This region has the potential to emerge as a significant new nickel province, and NTGS is working on acquiring and interpreting additional geochemistry on mafic rocks in the region, as well as redefining the stratigraphy of the metamorphosed rift succession. The nickel potential of the Casey Inlier, which has a high proportion of anomalously Ni- and Cr-rich Palaeoproterozoic mafic rock, remains largely untested.

Conclusions

The eastern Arunta Region is a prospective and underexplored region, and existing evidence suggests that it experienced long-lived deformation, fluid flow and multiple mineralising events during the Palaeozoic. This is likely to have occurred at the same time as REE-U fluorapatite veining at Nolans in the central Arunta Region, suggesting a regional REE-enriched fluid-flow event(s). The existence in the eastern Arunta Region of Palaeoproterozoic arc-like rocks and a Neoproterozoic to Cambrian rift succession, both overprinted by large-scale Palaeozoic fluid-flow processes, has implications in that the prospectivity of the region needs to be viewed differently to other parts of the North Australian Craton. Ongoing work by NTGS will aim to further define the geological framework, including investigating the timing, nature and mineral associations of Palaeozoic fluid-flow events.

References


ARMCHAIR EXPLORATION USING THE INTERNET

Roger Clifton

Simple reconnaissance exploration can be performed on the internet, using an ordinary browser and public domain data available on the NTGS website.

The procedure is recommended for users when first studying a new area or a new commodity. It is simple enough for naïve explorers, such as investors, to investigate assertions of prospectivity. Conversely, if you have proprietary knowledge of an area, it may interest users to know how easily outsiders can look into their tenement. The presentation demonstrates what can be deduced from the perspective of an outsider, perhaps a stockbroker in Toronto.

Any member of the public can log on to the NTGS’ Internet GIS at http://apps.minerals.nt.gov.au/strike, load up the vector layer, “Mineral Occurrences”, select a group of occurrences, then underlay it with geophysical images, one by one.

Most people associated with mining have at least a little knowledge of how a commodity associates with the geophysical properties of the surrounding country. With that insight, a newcomer can find associations of the selected commodity with one or more of the geophysical layers, form a hypothetical model, and test for it elsewhere on the image. Thus armed, the newcomer is enabled to explore across the same image for prospective areas elsewhere.

From the variety of commodities available in the NTGS’ Mineral Occurrences database, uranium has been chosen to demonstrate the facility.

For example, Rum Jungle is famous for its uranium occurrences. However, a new user, who knows no more than this, can nevertheless track uranium-rich rock units, characterised by blue, across the image seen in Figure 1. With the overlay of uranium occurrences switched on, as seen in Figure 2, a newcomer can see his or her area of interest, the presence of uranium-rich rock and, in this case, two exposures of a granite, split and displaced by a large fault. Two possibilities should occur to the newcomer. One hypothesis is that high uranium values coincide with uranium-rich rocks, so it might be possible to trace the blue uranium-rich rocks outside this image and expect to find more occurrences and prospective ground. Alternatively, other appearances of granites might be targeted for the same associations. Using the latter model, a new user would, for example, be able to quickly locate the uranium occurrences associated with the Mount Bundey granite (Figure 3).

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With the naive eye of an outsider, this presentation explores uranium occurrences across the Northern Territory and their associations with other geophysical image layers including magnetic, uranium and relief.

**THE DISCOVERY OF AN ARCHAEO INLINER IN ARNHEM LAND**

Julie Hollis1,2, Chris Carson1 and Linda Glass1

Archaean basement rocks in the North Australian Craton are uncommon. Within the Pine Creek Orogen, Archaean rocks include the Rum Jungle (2534–2520 Ma) and Waterhouse (2545–2535 Ma) domes, the Nanambu Complex (2470 Ma) and the sub-cropping Woolner Granite (2675 Ma). In the Tanami Region, Archaean rocks form the Billabong Complex (2514 Ma). Although known mineral occurrences within Archaean rocks are minor, there are strong spatial associations of uranium and base metal occurrences in the oldest Palaeoproterozoic strata (P1 and P2 subdivisions of Ahmad 2001), which immediately overlie the Archaean basement. For example, in the East Alligator Rivers region, the Cahill Formation, which overlies the Archaean Nanambu Complex, is host to world-class uranium deposits at Ranger, Jabiluka, Koongarra and Nabarlek. Therefore, the identification of Archaean basement has potentially important ramifications for mineral prospectivity. On the basis of recent NTGS regional geological mapping and from geochronology conducted in collaboration with Geoscience Australia, a new area of exposed Archaean basement in west Arnhem Land has been identified (Figure 1). The Archaean rocks comprise part of the Caramal Inlier (and possibly also the Myra Falls Inlier) within the Nimbuwah Domain of the Pine Creek Orogen.

The Pine Creek Orogen comprises a thick succession of Palaeoproterozoic sedimentary and volcanic strata deposited onto sparsely outcropping Neoproterozoic basement. In broad terms, the orogen has been subdivided into three regions (eg Carson et al 2008). These are the greenschist-facies Central Domain, and the higher-grade Litchfield Province to the west and Nimbuwah Domain to the east. The relatively little-studied Nimbuwah Domain is the focus of current NTGS mapping in west Arnhem Land. There, the Palaeoproterozoic strata were deformed and metamorphosed to mid-amphibolite facies or higher, most likely in response to emplacement of the voluminous, granodioritic Nimbuwah Complex at 1862 Ma. The Tin Camp and Nabarlek granites were emplaced after the cessation of ductile deformation at 1846 Ma and 1818 Ma, respectively. These units are unconformably overlain by Palaeoproterozoic Kombolgie Formation sandstone and volcanic rocks of the McArthur Basin, which were subsequently intruded by sills of the Oenpelli Dolerite at 1725 Ma.

The Myra Falls and Caramal inliers largely comprise amphibolite-facies metasedimentary rocks of the Kakadu Group and Cahill Formation. Detailed correlations between the stratigraphy of this area and the well defined stratigraphy of the Central Domain of the Pine Creek Orogen are complicated by poor exposure, differences in metamorphic grade and structural complexity. However, prominent ridges of quartzite act as a marker horizon, which enables structural and stratigraphic models to be applied.

The Kudjumarndi Quartzite of the Kakadu Group comprises quartzite and quartzofeldspathic schist, and represents the deepest level of exposed Palaeoproterozoic strata in this region. It preserves two phases of isoclinal folding, the second of which controls the kilometre-scale outcrop pattern of overturned isoclinal shallow east-northeast- and west-southwest-plunging F2 folds. The Kudjumarndi

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Quartzite is structurally overlain by interlayered mica schist and psammite, banded amphibolites, and subordinate carbonates and ultramafic rocks of the Cahill Formation. These hold a strong S2 schistosity deformed by shallow east-northeast-plunging F3 crenulations. A fourth deformation phase locally generated upright north-striking kink bands and fracture zones with limited offsets.

Structurally below the Kudjumarndi Quartzite are multiply-deformed, felsic biotite-plagioclase-K-feldspar-quartz gneisses exposed over approximately 65 km². These show strong compositional layering and strain variation at outcrop scale. Based on textures in low-strain zones, they are interpreted as deformed felsic magmatic basement to the Palaeoproterozoic strata. Samples of these gneisses from the Caramal and Myra Falls inliers were targeted to test the hypothesis that they are Archaean basement.

New SHRIMP U-Pb zircon age data were obtained for a leucocratic layered gneiss from the Caramal Inlier, interpreted in the field as a granodioritic orthogneiss. A zircon separate comprised stubby to slightly elongate, partly resorbed grains, exhibiting concentric, but indistinct and diffuse oscillatory-zonation. Of the 32 analyses, three were rejected on the basis of excessive discordance (>5%). The remaining 29 analyses yielded a unimodal weighted mean 207Pb/206Pb age population of 2510 ± 4 Ma (95% confidence, MSWD = 1.6). The preferred interpretation of the data is that this age represents the magmatic crystallisation age of a felsic magmatic protolith. This is supported by relatively uniform Th and U contents and uniform, intermediate Th/U values (0.5–0.7). A complementary sample of a similar, multiply deformed granodioritic gneiss from structurally below the Kakadu Group in the Myra Falls Inlier will also be targeted for SHRIMP U-Pb zircon geochronology to test the extent of exposed Archaean basement rocks.

The recognition of Archaean basement in west Arnhem Land raises the possibility that near-surface Archaean basement to Palaeoproterozoic strata may be more extensive than previously thought, which has implications for ore deposit models in this region.

### References


### ALLIGATOR RIVERS URANIUM FIELD NUMERICAL MODELLING PROJECT: DEFORMATION, FLUID FLOW AND GEOCHEMICAL CONTROLS ON THE GENESIS OF UNCONFORMITY–RELATED URANIUM DEPOSITS

**Peter Schaubs**1,2 and **Louise Fisher**1

This project investigates uranium deposits in the Alligator Rivers area of the Northern Territory using 3D deformation-fluid flow, geochemical modelling and 2D reactive transport modelling (computational simulation) of ore forming processes. The objective of this effort is to develop a predictive understanding of the processes and factors that control the formation of these uranium deposits and attempt to predict the relative favourability for the location of new deposits.

Three-dimensional deformation–fluid flow models for the Ranger and Nabarlek deposits are presented and highlight the role that rheological contrasts and the presence of specific rock types have in controlling the localisation of potentially uranium-hosting faults and the direction and magnitude of

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flow within these faults. Given the appropriate geochemical conditions, this has implications as to where sites of fluid–rock interaction or fluid mixing may occur and whether uranium mineralisation might be expected to occur above or below the unconformity between undeformed sandstone and deformed basement rocks. Geochemical modelling of unconformity-related uranium deposits in the Alligator Rivers Uranium Field provides insights into deposit genesis. The simulations tested a genetic model in which saline, oxidised, U-bearing basinial fluids, sourced from the overlying sandstone succession, penetrate the basement through faults or zones of brecciation and are reduced by reaction with reduced basement rocks (chlorite/graphite), depositing uraninite.

Deformation–fluid flow simulations of the Ranger deposits investigate whether specific geologic units are necessary for localising faults, the relative importance that different rheologic contrasts have in localising faults and the effect of the dip of geologic contacts on localisation. Model results show that faults are most likely to form along the contact between strong footwall units such as the Nanambu Complex (granitoids) or Lower Mine Sequence (carbonate rocks) and hangingwall units such as the weaker schist (Upper Mine Sequence) and within the Upper Mine Sequence itself (Figure 1). Areas where the units dip 40° appear to be most conducive for localising faults.

Models of the Nabarlek deposit are aimed at determining the effect of the presence or absence of the Oenpelli Dolerite, Nabarlek Granite and amphibolite units on the location of sites of dilation, as well as fluid flow direction and magnitude in pre-existing faults. Results show that models with all three of these units allow for the greatest fluid flow through the fault that hosts the mineralisation. The presence of the Oenpelli Dolerite appears to be most important as models without it have significantly reduced flow rates. The presence of the dolerite also controls whether fluid flows up or down the fault. Models with the dolerite allow for downward flowing fluid sourced from the sandstone to meet with upward moving basement-derived fluids within the fault in the vicinity of the dolerite, whereas models lacking the dolerite allow fluid to penetrate deeper into the basement.

In all cases, maximum dilation occurs where the fault intersects the unconformity. Maximum fluid flow and dilation occurs when faults are at right angles to the shortening direction, indicating that situations where reverse (as opposed to strike slip) faulting has occurred are more likely to create conditions favourable for fluid mixing and the formation of uranium deposits.

Geochemical fluid infiltration models run, using HCh software (developed by Shvarov and Bastrakov 1999), predict that as oxidising ore fluid infiltrates basement lithologies, uraninite is deposited at a redox front within the basement. As infiltration continues, the buffering capacity of the host rock is consumed and the redox front migrates. As the basement rocks are progressively oxidised, uraninite is stripped from the rock and redeposited at the new redox front. The HCh models predict the formation of chlorite alteration zones adjacent to mineralisation.

Simulations of the flow of the ore fluids back into the overlying sandstone, after interaction with the basement lithologies, predict significant alteration of the sandstone layer by both pre- and syn-ore fluids and indicate that precipitation of uraninite within the sandstone would be expected in such a fluid flow environment – the redox front moving from the basement into the altered sandstone along the fluid flow path. The absence of documented uranium deposits or prospects above the unconformity in the Alligator Rivers Uranium Field may be considered evidence for fluid flow environments dominated by downward-moving flow, such as are simulated with the deformation–fluid flow models. Therefore, such fluid flow scenarios have been used in reactive transport simulations and include density gradients as the flow driver. Reactive transport modelling incorporates the coupling between fluid flow, heat, transport and chemical reaction processes, and allows predictions to be made on the distribution patterns of alteration zones and uranium mineralisation. The modelled geometry is 2 km by 2 km, with a faulted basement unconformably overlain by two sandstone units. Pressure and temperature conditions are modelled so that the unconformity is effectively at 5 km depth, and porosities and permeabilities are modelled so that sandstone > fault > basement. Two-stage reactive transport models were run, with 50 000 years of pre-ore fluid flow, followed by 50 000 years of syn-ore fluid flow from an evaporitic environment, through uraninite-bearing sandstone into quartz-mica schist basement. The results predict alteration of the basement with destruction of K-feldspar and the formation of amphibole and chlorite alteration zones. As the model progresses, deposition of uraninite along the unconformity is observed (Figure 2).

However, in this model, the transport of uranium into the basement is limited, even though modelling the flow of a tracer shows that fluid is transported into the fault. Modelling the basement with a haematite-bearing palaeo-regolith zone immediately below the unconformity does not increase the volume of uraninite deposited within the basement fault zones. Further modelling and evaluation of different genetic scenarios is thus required to explain the formation of the Alligator Rivers deposits.

![Figure 1](image-url) East-west cross-section through generic 3D deformation – fluid model showing maximum shear strain localisation at carbonate–schist contact.
the regolith. The project collaborators are CRC LEME, Geoscience Australia, Northern Territory Geological Survey, Geological Survey of Western Australia, Tanami Gold NL, Newmont Asia Pacific and Anglo American.

Project activity will culminate in June 2008, with the release of a Guide to mineral exploration through the regolith in the Tanami. This Guide will be freely available for download from the CRC LEME (www.crcleme.org.au) or NTGS (www.nt.gov.au/dpifm/Minerals_Energy/Geoscience/) websites.

The guide forms part of a CRC LEME series of guides on mineral exploration through the regolith and is specifically designed to assist mineral explorers working in the Tanami. It provides a basic introduction to the regolith and landscape history of the region, as well as advice on appropriate exploration strategies and techniques. This presentation will foreshadow the release of the Guide by describing the key components of that advice.

ACCESSING NTGS INFORMATION

Tracey Rogers

Information projects undertaken or started in the last year include production of an NT-wide GIS dataset, STRIKE offline, transcription of seismic and well log data from old 9-track tapes to modern high-density media, further improvements to both the minerals and petroleum Industry Reports Management System (IRMS) records, and building and testing of a spatial relational database for geological mapping and geochemistry.

Web delivery systems

The Geophysical Image Web Server (GIWS) had 2967 visits in 2007, a 10% increase over 2006. Preliminary images of the 2007 Tanumbirini airborne magnetic and radiometric survey were available on GIWS from September 2007 and the final images were published in February 2008. New NT-wide stitches incorporating the Tanumbirini data are due for release in mid-March.

Two new index layers for Aster and Landsat data that are available from NTGS were added to STRIKE in October 2007 and a petroleum wells layer in December. Updates to the NTGS and company airborne geophysical survey indexes were uploaded in October and a second update for the company airborne geophysical index in December 2007. STRIKE registered 3517 visits from January to July 2007, which is similar to the numbers for the same period in 2006, and 3953 visits from July to December 2007, an increase of 26% over the same period in 2006.

Spatial data and geochemical data capture

The project to convert older GIS datasets into the current NTGS data dictionary has continued at a slow pace. A number

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Figure 2. Uraninite concentrations from 2D reactive transport simulation.

Reference


EXPLORING THROUGH THE REGOLITH IN THE TANAMI REGION

Lisa Worrall1,2, Martin Smith1,3, Nathan Reid4, Brad Pillans4,5, Anna Petts4,5, Dirk Kirste6, John Joseph1,3, Steve Hill1,3 and Tony Eggleton1,7

The Tanami Region, which straddles the Northern Territory and West Australian border approximately 700 km northwest of Alice Springs, is host to a number of significant gold deposits including the world-class Callie deposit. Exploration of this region is hampered by the extensive development of regolith, which is composed of both in situ and transported materials and which may be over 200 m thick.

A collaborative regolith research project “Exploring through the cover in the Tanami” was established in mid 2005 to develop a cost-effective means of exploring through
of datasets have been converted, but still require further attribution and QC. New dataset releases have priority and four are scheduled to be released in March 2008.

Due to resourcing issues, only 800 records were added to the NTGS geochemistry and drill collar database in the last 12 months, giving a total of 355,980 records. All of this data was included in an updated Digital Information Package (DIP 001) released in September 2007 and is also available via STRIKE. Exploration data capture by TerraSearch over the entire McArthur Basin has been completed and all open file data will be available to explorers via STRIKE and as part of an updated DIP 001 in March 2008. The data capture over the McArthur Basin includes 5226 surface samples and 1447 drill collars. In addition, data from over 400 company reports has been collated and it is planned to migrate this data into the database over the next few months.

The final version of DIP 007, Geology and Mineral Resources of the Southern Georgina Basin, was released in October 2007. This comprehensive GIS dataset includes geology, structure, drilling, geophysics, geochronology and satellite imagery layers.

Compilation of an NT-wide GIS dataset for release as DIP 008, STRIKE Offline: NT geoscience GIS dataset, is complete and quality control processes are underway. This new product, containing geological, geophysical, geochronology, drilling and index layers is due for release in March 2008.

Reports and data management

A project to update the content of IRMS Minerals continued and a total of 1035 records were upgraded during 2007, including work to standardise the names of mines, prospects and occurrences between databases. Another 857 reports, including 68 legacy reports, were also added to IRMS between March 2007 and mid-February 2008.

A total of 1213 mineral reports were scanned in 2007, including 199 small reports which were scanned in house. Scanning of all non-digital open file reports was scheduled to be finished by June 2007, but it is now envisaged that scanning of the remaining 1000 or so reports will be completed by December 2008.

The focus for petroleum data management during 2007 was the transcription of onshore digital data. Over 100 onshore seismic surveys are currently being transcribed from 9-track reels and Exabyte cartridges to SEG Y format and output to high-density, industry-standard 3590 cartridges or CD/DVD. Onshore analogue data, acquired from seismic surveys in the 1960s, has been identified and one survey, the 1966 Simpson Desert B Seismic Survey, has been transcribed. The survey is currently being processed, so the usefulness of this old data is still unknown. The well logs for over 20 onshore wells are also being transcribed from 9-track reels and Exabyte cartridges for output to high-density modern media. This digital data is now being properly catalogued into IRMS.

There have been 330 new records added to IRMS Petroleum since March 2007, including 228 legacy reports/
scanned/digital mineral exploration company reports; provision of company geophysical data; NTGS website and the provision of company geochemistry and drillhole data.

The survey indicated a very high satisfaction with the overall performance of MEIC staff, with respect to their knowledge and attitude, and the efficiency, quality and timeliness of service. About 50% of clients rated each of these areas at the highest level of satisfaction, and at 83%, timeliness was the only area below a combined total of 90% for ratings of 4 and 5. No client rated MEIC service levels as unsatisfactory (below 3).

MINERAL POTENTIAL OF THE MURPHY INLIER AND SURROUNDING AREA

Andrew Wygralak1,2 and Terrence Mernagh3

The Murphy Inlier is probably one of the least studied parts of the Palaeoproterozoic North Australian Craton. This basement outcrop separates Mesoproterozoic successions of the McArthur Basin to the north from those of the South Nicholson Basin to the south. The area of the project covers Calvert Hills 1:250k mapsheet. It contains several styles of mineralisation including:

- U ± Au veins in Cliffordale and Seigal volcanics (eg Eva Mine, Cobar II)
- U associated with faulting in Seigal Volcanics and/or Westmoreland Conglomerate (eg El Hussen, Jim Beam)
- U in ‘reduction front’ lenses in the Westmoreland Conglomerate (eg Namalangi); economically the most important type of U mineralisation
- U associated with fracturing in Murphy Metamorphics (eg Anomaly 1)
- Cu in breccia pipes hosted by felsic volcanics (eg Redbank)
- Cu associated with veins in Nicholson Granite (eg Norris)
- Sn and W in Nicholson Granite-hosted greisens (eg Crystal Hill)
- stratiform Cu in carbonate rocks (eg Mountain Home in McDermott Fm)
- stratiform Zn-Pb in carbonate rocks (eg Karns prospect in Karns Dolomite)
- Mn occurrences in Karns Dolostone
- palaeoplacer Au in Westmoreland Conglomerate
- potential for diamonds.

NTGS conducted a metallogenic study of the Murphy Inlier in the 1980s. In the last few years, there has been renewed interest in mineral (in particular uranium) exploration in this region. A lack of modern geochronology and recent advances in the study of mineral systems have prompted NTGS to embark on a new project aimed at studying the mineral systems present in the Murphy Inlier region and fully assessing its mineral potential.

The project is in its initial stage. Due to prolonged negotiations to obtain permission to enter Aboriginal land, which forms a core part of the project area, only limited work was conducted during the 2007 field season. More work is planned for the 2008 and 2009 seasons.

Several samples from the lower part of the Tawallah Group (McArthur Basin succession) were taken for zircon geochronology. These samples included: base and top of Westmoreland Conglomerate; Murphy Metamorphics; Carolina Sandstone Member of Seigal Volcanics; and Sly Creek Fm. A sample of Wire Creek Sandstone (South Nicholson Basin succession) was also collected. The results are expected in the first half of 2008 (except for three samples; see below).

The Westmoreland Conglomerate returned ages ranging from 1858 ± 1 Ma (basal part?) to 1843 ± 4 Ma (top part). Of particular interest to geochronological sampling was a persistent, 50 mm-thick tuff-like horizon in rocks mapped as Westmoreland Conglomerate, located two metres above the contact with the Palaeoproterozoic basement. Dating of primary zircons from this horizon would document the beginning of sedimentation in the McArthur Basin. Subsequent study of this sample has so far raised more questions than answers. A thin section study of its mineralogy could not clearly prove or disprove its tuffaceous origin. Its chemical analysis revealed an unusual composition including 3.7% Sr, 1089 ppm Zr, 152 ppm As and 129 ppm U. SHRIMP dating of zircons from this sample returned results ranging from ca 1840 Ma to ca 410 Ma (with the whole range in between). Contamination, which would be the simplest explanation for such a large age span, is considered unlikely (the same equipment was used directly before this sample to separate zircons from a Palaeoproterozoic rock). At this stage, the reason for such a young age is uncertain.

Stable isotope and fluid inclusion work on chalcopyrite-bearing veins in the Redbank breccia pipes returned δ18O values in the range 16.5 to 17.5‰ and δ34S values in the range -4.0 to -3.9‰. Such values could indicate a magmatic (carbonatitic) or hydrothermal origin. However, fluid inclusion data indicate a low temperature (120°C), high salinity (22 wt % CaCl2, eq) brine. It is possible that the studied fluid inclusions are secondary and further work is required to reconcile these results.

A preliminary study of the Seigal Volcanics has revealed that this formation consists of ten lithofacies. Basalts of the formation show widespread K-metasomatism and alteration indicating hydrothermal activity. The study has also shown that copper mineralisation in historical small mines (St Barb and Dianne) is also hosted by breccia pipes, similar to those in Redbank. A sample of ore from the Dianne mine returned (apart from 10.5%Cu) 0.4 g/t Au. An initial fluid inclusion study disclosed ore fluid parameters similar to those at Redbank (temperature 100°C, salinity 15 wt% CaCl2, eq).

An interesting style of copper mineralisation was noted in drill core from the Seigal Volcanics near the NW.

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Westmoreland uranium prospect. There, chalcopyrite mineralisation occurs in quartz-K-feldspar veins. Fluid inclusion work suggests a relatively hot (250–400°C), low salinity (5–8 wt% NaCl eq) fluid, similar to fluid from lode gold deposits in the Tanami Region. K-Ar dating of the K-feldspar returned unexplainably young ages ranging from 165–53 Ma. This is another case, as well as the ‘tuff’ described above, where the obtained age is much younger than expected. It could indicate previously undetected and much younger hydrothermal activity. Note that the Merlin kimberlites, intruding the McArthur Basin succession, 200 km to the northwest, have also a relatively young age of 380 Ma.

Palaeoplacer gold in the top unit of the Westmoreland Conglomerate (which consists of four upward-fining fluvial cycles) was firstly detected in Queensland by the German company Urangeschelshaft, while exploring for uranium in 1983. In the following year, NTGS discovered similar mineralisation on the NT side of the border. In 2007, NTGS sampling also confirmed the presence of detrital gold in the lowest cycle of the Westmoreland Conglomerate; a single sample collected on the Queensland side of the border contained 0.12 g/t Au. Gold occurs in the matrix of conglomeratic horizons, but its distribution is erratic and subsequent samples taken further west (in NT) were barren. Palaeocurrent directions indicate that the primary source of gold is located towards the northeast, in an area currently covered by younger sediments.

Fieldwork planned for the 2008 and 2009 field seasons will include:

- a study of the mineral potential of the Seigal and Clifdale volcanics
- a study of mineral systems in the Murphy Inlier
- an assessment of the base metal potential of the McDermott Formation (McArthur Basin) and Walford Formation (South Nicholson Basin)
- an assessment of the palaeoplacer gold potential of the Westmoreland Conglomerate
- the preparation of a 1:100k map (Nicholson River special)
- work on the structural relationship between the Murphy Inlier and McArthur Basin.

INITIAL RESULTS FROM GEOSCIENCE AUSTRALIA’S ONSHORE ENERGY SECURITY PROGRAM

David Maidment1, 2 (on behalf of James Johnson3)

In August 2006, Geoscience Australia was allocated $59 million to undertake a five-year Onshore Energy Security Program as part of the Federal Government’s Energy Security Initiative. This program is designed to deliver precompetitive geoscience data and scientifically based assessments of the potential for onshore energy resources, including oil, gas, hot rocks (geothermal energy), uranium and thorium. The work is being undertaken in collaboration with State and Territory Geological Surveys and will finish in June 2011.

Data acquisition for the Australia Wide Airborne Geophysical Survey (AWAGS2), a geophysical tie-line survey, was completed in December 2007. This survey will allow radiometric surveys across the country to be levelled with respect to each other, allowing direct comparisons of K, Th and U values to be made between widely separated areas. The National Geochemical Survey of Australia has also commenced, with more than 25% of 1390 catchments sampled by State and Territory geological surveys in conjunction with Geoscience Australia. This survey will provide a geochemical dataset of 60+ elements, with consistent sample media and analytical procedures, providing a baseline for more detailed geochemical surveys.

Geophysical data to be acquired in the Northern Territory as part of the Onshore Energy Security Program include a regional airborne electromagnetic survey to be conducted in the Pine Creek and Arnhem Land regions in 2008. This survey will collect data with line spacings of 1.7–5 km, with the aim of delineating geological features relevant to uranium exploration, such as the geometry of unconformities and basement structures, and the presence of alteration systems. Acquisition of deep-crustal seismic data is scheduled to commence in 2008–09, targeting basement and basin architecture in order to better understand uranium, thorium and hydrocarbon mineral systems.

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