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Mineralisation in NE Qld
FUTORES II Conference Report
Cover photo: Outcropping skarn, Red Cap area, Chillagoe district, north-east Queensland. Photo courtesy of Kalem Wright.
The FUTORES II conference (4-7 June 2017, Toowoomba, Queensland, Australia), EGRU’s flagship event this year, was highly successful. The conference attracted 280 delegates from 16 countries. It featured excellent talks on deposit research, exploration methods, regional geology and metallogeny, and industry strategies and management, many given by leaders in their fields. The Queensland Minister for Natural Resources and Mines and Minister for State Development, the Honourable Dr. Anthony Lynham, also addressed the audience from a government perspective. In total there were 120 oral presentations and 17 poster presentations. The conference also organized four pre-conference workshops and two post-conference field trips, plus a SEG Student Chapter trip to visit epithermal and porphyry deposits in Fiji shortly after FUTORES II. We appreciate the strong support from conference sponsors, professional societies, the Queensland Government and James Cook University.

One of the major EGRU research projects, Characterising and Assessing Prospectivity of Intrusion-Related Hydrothermal Mineral Systems in north-east Queensland, sponsored by the Queensland Department of Natural Resources and Mines / Geological Survey of Queensland under the Future Resources Program, is close to completion. The team is synthesizing the data and writing the final report. At the same time, new research opportunities are emerging for the coming years.

EGRU’s program of short courses is continuing to offer professional development training to both students and industry geologists. In recent months there have been two Masters level short courses, Advanced Techniques in Mining and Exploration Geology and Advanced Field Training, and an Honours level short course, Exploration Geophysics. Early next year EGRU will offer a number of courses and workshops, including two Masters level short courses: Integrated Spatial Analysis and Remote Sensing of Exploration Targets, and Business and Financial Management for the Minerals Industry. The annual Cloncurry District Mineral Systems symposium and field trip will also be held in the town of Cloncurry in March. Additional short courses scheduled for next year are included in the Calendar of Professional Development Courses on the back cover of this issue of the EGRU Newsletter.

The undergraduate 2+2 program with China University of Geosciences, Wuhan (CUG), has been finalized, and I visited the university in May to promote the program. More collaboration opportunities were raised during the visit. Indeed five CUG students and one staff member came to north Queensland and participated in the third-year undergraduate Field Mapping and Field Skills field-based course in early July (1–18 July). More collaboration in both teaching/learning and research will be implemented.

There has also been continuing progress with the laboratory analytical facilities and capabilities. Dr. Yue Wang has completed the setup and testing of the Cu isotope analysis methodology at the Advanced Analytical Centre (AAC), and a detailed report about the technique and its applications will be included in the next issue of the EGRU Newsletter. The Fe isotope analysis capacity is now also established, and the testing of the Zn isotope standards is ongoing.

In the last few months EGRU has enjoyed presentations by visitors from industry and academia worldwide. Jesse Clark from BHP Billiton, also the Australian representative on the SEG Young Professionals Committee, presented on the Olympic Dam deposit. John Mizens, an EGRU alumni, talked about Entrepreneurship and Geoscience. Prof. Gerald Dickens from Rice University, USA, discussed the Tasman frontier subduction.

EGRU appreciates the support of our continuing members, and welcomes the return of the Geological Survey of Queensland as a member and new industry member Signature Gold.
Overview of Sn-W-Mo Mineralisation in north-east Queensland

Zhaoshan Chang, Gavin Clarke, Yanbo Cheng, Jaime Poblete, Kairan Liu (EGRU - JCU)

Introduction

Tin (- tungsten) mineralisation in north-east Queensland was discovered in the 1880’s. Since then there has been intermittent exploration for, and mining of, both hard rock and alluvial resources. The north-east area is characterised by a large number (many hundreds) of Sn and W deposits, indicating geological conditions favourable for Sn-W-Mo mineralisation. While the deposits are generally small (particularly when compared to, for example, the giant deposits of China) the area has been one of Australia’s major sources of Sn and W.

Most of the Sn-W mineralised districts in north-east Queensland, and the largest known deposits, are located within the Siluro-Devonian Mossman Orogen in the east. To the south, the relatively small Sn deposits of the Kangaroo Hills district straddle the boundary between the Mossman and the Neoproterozoic–Ordovician Thomson Orogen. In the west, scattered Sn and W deposits occur within the Paleoproterozoic–Mesoproterozoic Etheridge Province of the North Australian Craton (Figure 1); here the larger deposits are placer deposits.

The North Australian Craton, and the Thompson and Mossman Orogens, were intruded by Carboniferous–Permian plutons of the extensive Kennedy Igneous Association (KIA), and covered by roughly coeval volcanic rocks (Figure 1). The KIA mainly comprises I-type magmatic rocks, with local S-type intrusions to the north-east of a NW trending line that passes through Atherton and Innisfail, and minor scattered A-type rocks south-west of the Atherton-Innisfail line.

Sn-W-Mo mineralisation of north-east Queensland is closely associated with these Carboniferous-Permian igneous rocks of the KIA.

Deposit Classification

The Sn-W-Mo deposits of north-east Queensland have different metal associations and can be classified as W-dominant, W-Mo-Bi deposits, and Sn-dominant deposits. These subgroups have characteristic features and time-space distributions.

W-dominant deposits

These are represented by the Mt Carbine and Watershed deposits north-west of Cairns. Both deposits are hosted in siliciclastic rocks and mineralisation occurs mainly in sheeted quartz +/- feldspar +/- muscovite veins, with local disseminated mineralisation at Watershed. Tungsten mineralisation at Mt Carbine is dominantly wolframite with minor later scheelite, while at Watershed scheelite is the only tungsten ore mineral. Wall rock alteration around veins at Mt Carbine is mainly chlorite-ililitic, whereas wallrock alteration at Watershed comprises skarn assemblages (including garnet, pyroxene, clinozoisite and amphiboles). Mineralisation in the Mt Carbine - Watershed area has been dated at 287 - 253 Ma (this project; Higgins et al., 1987).

W-Mo-Bi deposits

This group of deposits occurs mainly in the NNE-trending Wolfram Camp - Bamford Hill corridor, and is represented by the Wolfram Camp and Bamford Hill deposits. The characteristic features of this group are:

- Mineralisation is confined to granitic intrusions.
- Ore occurs in pipe-like bodies and discontinuous pockets of quartz +/- minor calcite, which grade outwards to quartz-rich greisen. The pipes and pockets are located in the roof zone and upper side margins of plutons, and oriented parallel to intrusion margins.
- The main W mineral is wolframite, with minor scheelite replacing wolframite. Molybdenite is the main Mo mineral, locally occurring intergrown with wolframite. Minor cassiterite, bismuthinite and native bismuth post-date the wolframite.
- Most alteration ore minerals are coarse- to very coarse-grained (wolframite crystals can be up to 50 cm long).
- Molybdenite from both Wolfram Camp and Bamford Hill has been dated at 308 - 306 Ma.

Sn-dominant deposits

Deposits with Sn as the dominant economic metal cluster in the Collingwood, Herberton and Kangaroo Hills districts (Figure 1). The deposits can be subdivided into two groups based on host rocks, and further subdivided based on alteration assemblages and distribution.

Group 1 deposits are hosted in metasedimentary rocks, whereas Group 2 deposits occur in fractionated microgranites and/or in coarse-grained batholithic granite adjacent to microgranites. Variations in alteration allow the group to be subdivided into the following sub-types:

1A Mineralisation hosted in carbonate wall rocks resulting in skarn alteration assemblages. The typical ore assemblage is cassiterite - magnetite - fluorite - wollastonite - pyroxene. The skarn Sn deposits are typically larger than other sub-types.

Figure 1. Geology of north-east Queensland showing the distribution of W and Sn deposits (GDA 94).
### Tin Deposits

<table>
<thead>
<tr>
<th>Metal Association</th>
<th>Deposit Style</th>
<th>Sub-Style</th>
<th>Resources (Mt)</th>
<th>Grade Sn (%)</th>
<th>Production Sn (t)</th>
<th>Total Sn (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pinnacles</td>
<td>Skarn: wriggle with cassiterite-bearing magmatic bands is common</td>
<td>1A</td>
<td>7.035</td>
<td>0.30</td>
<td>11,520</td>
<td>11,520</td>
</tr>
<tr>
<td></td>
<td>Veins and pipes in granite rocks</td>
<td>2B</td>
<td>Combined figures for three adjacent deposits</td>
<td>11,903</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gillian</td>
<td>Skarn: wriggle with cassiterite-bearing magmatic bands is common</td>
<td>1A</td>
<td>2.53</td>
<td>0.78</td>
<td>19,734</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2B</td>
<td>0.643</td>
<td>1.19</td>
<td>5,133</td>
<td>12,793</td>
</tr>
<tr>
<td>Collingwood</td>
<td>Sheared quartz-tourmaline and greisen veins in granite</td>
<td>2B</td>
<td>Combined figures for three adjacent deposits</td>
<td>11,903</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great Northern Cully</td>
<td>Veins and pipes in granite rocks</td>
<td>2B</td>
<td>Combined figures for three adjacent deposits</td>
<td>11,903</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tommy Burns*</td>
<td>Steeply dipping pipes hosted in altered sandstone</td>
<td>1C</td>
<td>11,520</td>
<td>11,520</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vulcan</td>
<td>Pipes in siliciclastic metasediments</td>
<td>1D</td>
<td>10,993</td>
<td>10,993</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jeannie River</td>
<td>Veins in sheared sediments*</td>
<td>1D</td>
<td>2.24</td>
<td>0.47</td>
<td>10,583</td>
<td></td>
</tr>
<tr>
<td>Sailor Tin</td>
<td>Sub-horizontal lenticular bodies of greisen in granite*</td>
<td>2B</td>
<td>10^</td>
<td>0.88</td>
<td>7,874</td>
<td></td>
</tr>
<tr>
<td>Station Creek</td>
<td>Placer</td>
<td>46 M m^3</td>
<td>180 g/m^3</td>
<td>6,520</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tate River</td>
<td>Placer</td>
<td>9.76 M m^3</td>
<td>587 g/m^3</td>
<td>1,256 alluvium</td>
<td>6,154</td>
<td></td>
</tr>
<tr>
<td>Mount Holmes</td>
<td>Quartz-feldspar and pegmatite veins in chert*</td>
<td>1D</td>
<td>10^</td>
<td>0.055</td>
<td>5,654</td>
<td></td>
</tr>
<tr>
<td>Baal Gammon*</td>
<td>Veins and breccia pipe</td>
<td>1E</td>
<td>2.8^</td>
<td>0.20</td>
<td>5,600</td>
<td></td>
</tr>
<tr>
<td>Windermere</td>
<td>Skarn: massive magnetite-hematite*</td>
<td>1A</td>
<td>2.04^</td>
<td>0.27</td>
<td>5,308</td>
<td></td>
</tr>
</tbody>
</table>

### W-Mo Deposits

<table>
<thead>
<tr>
<th>Metal Association</th>
<th>Deposit Style</th>
<th>Sub-Style</th>
<th>Resources (Mt)</th>
<th>Grade WO3 (%)</th>
<th>Production WO3 (t)</th>
<th>Total WO3 (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mt Carbine</td>
<td>Deeply dipping veins, largely hosted in silstone - shale</td>
<td>1A</td>
<td>59.3^</td>
<td>0.12</td>
<td>12,546</td>
<td>83,706</td>
</tr>
<tr>
<td>Watershed</td>
<td>Shorited veins and disseminations largely hosted in skarn altered sediments</td>
<td>1B</td>
<td>49.2^</td>
<td>0.14</td>
<td>70,400</td>
<td></td>
</tr>
<tr>
<td>Wolfram Camp - Bamford Hill</td>
<td>Quartz pipes and pockets in the roof zones and margins of phonons</td>
<td>1C</td>
<td>2.39^</td>
<td>0.29</td>
<td>5,253</td>
<td>12,260</td>
</tr>
</tbody>
</table>

### Age of Mineralisation

The age of Sn-dominant mineralisation varies from district to district, with the earliest Sn mineralisation occurring in the Kangaroo Hills district (345-339 Ma), and with younger Sn mineralisation in the Herberton-Emuford-Mt Garnet district (327-317 Ma). W-Mo-Bi deposits located in a north-south corridor west of the herberton tin field formed at 308-306 Ma.

Age dates from the W-dominant mineralisation in the Mt Carbine - Watershed area north of the Herberton District are in the range 287-253 Ma, and may be broadly synchronous with the Collingwood Sn mineralisation further north. At Collingwood, the mineralisation age should be younger than ~276 Ma, the age of the host granite, although accurate mineralisation ages for the Collingwood district are yet to be obtained.

### Prospective

The setting and style of Sn-W-Mo mineralisation in north-east Queensland suggests that:
- Carbonate rocks are the most favourable host rocks for forming larger deposits.
- Siliciclastic wall rocks, extensive chlorite alteration seems to indicate higher grade Sn mineralisation.
- Granitic wall rocks, white mica greisen is more favourable to mineralisation than topaz-bearing greisen and felspathic alteration.
- Mineralisation confined within intrusions may indicate the magma did not exsuffice sufficient water to rupture the carapace and such deposits may have limited tonnage potential.

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* Tommy Burns also produced 700 t scheelite and 670 t wolframite
* Mt Carbine has also produced 8 t Sn.
* Baal Gammon also contains 2.8 Mt resources averaging 1% Ca. 40 ppm Ag and 39 ppm In.
* Includes both past production and current identified resources.
Previous drilling and mining operations in the north-east Queensland Sn-W-Mo districts have generally been fairly shallow. Elsewhere in the world, vein-type W mineralisation may transition to skarn or massive greisen-related mineralisation at depth (e.g. southern Jiangxi, China - see Xu, 2008). Consequently, in north-east Queensland the potential for mineralisation at depth is considerable, and Sn and W vein and breccia style mineralisation hosted in wall rocks should be priorities in future exploration.

Please Note: A more detailed and comprehensive review of Sn-W-Mo mineralisation will be included in the upcoming volume: Australian Ore Deposits, to be published by the Australasian Institute of Mining and Metallurgy.

References


Mineralisation in the Herberton - Mt Garnet Mineral Field  

Mineralisation in NE Qld  

Mineralisation in Pipes within Roof-Zones of Granite Stocks  

The mineralisation at Bamford Hill, 20 km NNW of Emuford and outside the designated confines of the Herberton - Mt Garnet Mineral Field shown in Figure 1, is characteristic of this type of mineralisation. The Bamford Hill W-Mo-Bi deposits are contained within the high-level, silica-rich Permian-aged Bamford Granite which has intruded the Carboniferous Featherbed Volcanics. The bulk of the payable grade came from pipe-like orebodies occurring in extensively greisenised granite, and infilled with quartz, wolframite, molybdenite, bismuth and bismuthinite. The mining of these structures delivered more than 2,000 tonnes of wolframite concentrate, 170 tonnes of molybdenite, and 20 tonnes of bismuth/bismuthinite (Pollard, 2013).

The pipe-like structures occur intermittently over a distance of 1300m, within an 80m wide zone of greisenised granite (Gregory et.al. 1980). They exhibit a gross structural control consistent with contraction jointing in a cooling pluton (Blevin, 1989). Individual pipe ranges in diameter from several metres to several hundreds of metres, and can extend for more than 200 metres. With depth, they tend to pass into silicified greisen. Blevin (op. cit.) noted that subsequent propagation veining of conjugate vertical fracture sets led to the replacement of wolframite by scheelite, bismuthite by chlorite, muscovite by sericite / kaolinite, plus the precipitation of iron and base-metal sulphides, comb quartz, fluorite, calcite, chalcedony and, finally, laumontite. Similar styles of mineralisation occur at Eight Mile Hill, Captain Morgan and Wolfram Camp. Wolfram Camp, in particular, is reported to have 250 irregular branching pipes, some up to six metres wide, in an area 3.2km long by 800m wide and 170m deep (Pollard, 2013). Locating similar mineralised granite systems at depth most likely entails recognizing the alteration imprint they impart to the overlying host rocks. According to Blevin (op. cit.) the fieldsparks within rhodacite immediately overlying the Bamford Granite have been locally replaced by quartz-cordierite which has then been further altered to a quartz + andalusite + Mg-biotite + Zn-hercynite assemblage. Further fluid interaction then resulted in partial muscovitisation and development of late chlorite – carbonate – sulphide veining. These are all hydrothermal features whose presence within areas of Featherbed Volcanics may signal the presence of a mineralised granite below.

Mineralisation Hosted in Altered Batholithic Granites

Feldspathic Alteration Types

Feldspathic alteration can occur as albisation or microclinisation wherein pre-existing feldspars are converted to secondary albite or microcline; the alteration can be both pervasive and locally intense. In tinfields around the world albisation appears to be far more prevalent and extensive than microclinisation (Taylor, 1979). Granite host rock adjacent to albised zones usually appears much the same as distant unaltered examples of the same granite. Except that biotite is completely altered to muscovite (Pollard, 1984; Figure 3), with the overall texture of the granite generally preserved. In the Herberton – Mt Garnet region albite alteration has been recognised at several mineralised sites. Tin mineralisation typically occurs as swarms of subparallel quartz-cassiterite +/- fluorite veinlets associated with zones of albised granite and albite rock (Pollard, 2013).

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Mineralisation within Topazite affiliated with Topazitic Aplites

Four kilometres north-west of Innot Hot Springs there are outcrops of an irregular pod-like body (3m across) of topazite known as the Wilcox Silexite. This structure contains large inward radiating quartz and topaz crystals (Figure 2) that are enclosed in fine-grained vughy rock composed of quartz, topaz, minor albite laths and muscovite shreds, plus a smattering of cassiterite (Johnston & Chappell, 1992). Adjacent to this occurrence are the Gibbon’s Gully Aplites - small-scale aplistic dykes and sills that commonly contain topaz, have selvedges and ‘clots’ of pegmatite, and are often albite/oligoclase – enriched (Donnellan, 1991). From various geochemical trends, both Johnston (1984) and Donnellan (1991) conjecture that a fluorine-rich fluid eventually escaped from the crystallising aplite and was instrumental in the formation of topazites such as the Wilcox Silexite. Mine workings around these features are predominantly small pits and shafts but, according to Johnston & Chappell (1992), there are other topazites elsewhere within the Coolgarra Batholith, exhibiting the characteristics of pegmatites or quartz pipes, and these may indicate the presence of an extreme magmatic differentiate somewhere below.

Mineralisation in Altered Rocks

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Mineralisation Hosted in Altered Batholithic Granites

Feldspathic Alteration Types

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Sericite ‘/Greisen’ – Type Deposits

By far and away the most common form of alteration associated with mineral deposits in granites of the Herberton – Mt Garnet region is that designated as ‘greisen’. However, this designation can include development of obvious muscovite (e.g. Figure 7) through to ultra-fine muscovitic or illitic material, and the alteration assemblage may also include various amounts of topaz, fluorite, apatite and tourmaline. The category also includes a wide variety of structural features - from fractures with greisenised sidewalls and greisen-bordered veins, through to veinlet swarms or quartz pipes in greisenised granite, greisenised breccia zones, or irregular greisen patches of indeterminate structural affinity (Pollard, 1984). Moreover, the associated ore can be of one or several minerals including wolframite, cassiterite, and various sulphides such as pyrite, arsenopyrite, chalcopyrite, and sphalerite. Further subgrouping of greisen deposits is therefore required and has been done in terms of specific ore

Mineralisation in NE Qld

Table 1: Summary of Deposit Types in the Herberton - Mt Garnet Mineral Field

<table>
<thead>
<tr>
<th>Regional Host</th>
<th>Deposit Host Rocks</th>
<th>Deposit Style</th>
<th>Ore &amp; Alteration Minerals</th>
<th>Districts &amp; Deposits: Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineralised Microgranites and affiliated Differentiates</td>
<td>Pegmatites and Microgranites</td>
<td>wolframite, molybdenite, cassiterite</td>
<td>Margins of Billings Granite (Emudford district)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quartz Pipes</td>
<td>molybdenite, wolframite, topaz, albite</td>
<td>Moomin Sill offshoots (north of Herberton)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Topazic Pipes</td>
<td>cassiterite, topaz, fluorite, feldspar, muscovite, monazite</td>
<td>Wilcon Siletite, Mt Gibson (Innot Hot Springs area)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Roof Zones of Granite Stocks</td>
<td>wolframite, scheelite, molybdenite, biotite, native bismuth, feldspar, muscovite (greisen)</td>
<td>Bamford Hill, Wolfcamp, Eight Mile Hill</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quartz Pipes enclosed in Greisen</td>
<td>cassiterite, fluorite, albite / mica</td>
<td>Emudford district - Royal Standard Upper Emu Creek - Great Divide, Mt Tin / Mt Misery, All Rose, Eeloo</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intrusive Rocks</td>
<td></td>
<td>Gurrumba district: Adelaide lode</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altered Batholithic Granites</td>
<td>Feldspathic (esp. albite) Alteration: disseminated plus sub-parallel quartz veins / veinlets</td>
<td>cassiterite, fluorite, albite / mica</td>
<td>Emudford district - Royal Standard Upper Emu Creek - Great Divide, Mt Tin / Mt Misery, All Rose, Eeloo</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(may be locally overprinted by muscovite greisens)</td>
<td>Gurrumba district: Adelaide lode</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Structuraly defined Alteration Zones in Batholithic Granites</td>
<td>Wolframite – Li mica + quartz +/- topaz</td>
<td>Lodes clustered around late granite intrusions in the Eastern Tate Batholith and in “Phase 1 &amp; 3” zones of the Nettle Granite</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>fine muscovite, sericite (often ferruginous) +/- quartz</td>
<td>Lodes clustered in and around small late-stage granite, e.g. Specimen Tray (Herberton), Gibson Granite (via Innot Hot Springs), or larger strongly fractionated granites, e.g. Go Sam Granite</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>sericite - clay + quartz</td>
<td>Copper Firing Line, north of Herberton</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chlorite-Quartz Lodes: quartz pipes, veins</td>
<td>Herberton Hill area: Good Friday, Old Monarch</td>
<td></td>
</tr>
</tbody>
</table>

1984; Figure 4). The deposits are commonly spatially associated with the marginal zones of late stage granites (Pollard, op cit.). Locally, quartz + muscovite + cassiterite +/- fluorite veins of the greisen type (see following section) can occur – typically associated with muscovite alteration of albite; in some cases where the muscovite alteration becomes intense, the albitedised rocks are converted to greisens, thus masking the presence of the albite style of mineralisation (Pollard, 1984; Charoy & Pollard, 1989; Figure 5). In fact, according to Pollard (1984) it is the overlay of greisen-type mineralisation that brings feldspathic mineralisation into the realms of potential mine feasibility.

Deposits of this type may have some economic potential.

In the 1980’s Western Mining Corporation identified a non-JORC compliant resource (assuming a cutoff grade of 0.2%) of between 100 and 140 kilolitres of mineable ore at a grade of 0.4% to 0.6% Sn to a depth of 100m at the Mt Tin / Mt Misery prospect in the Upper Emu Creek area (Champion & McKay, 2012).

Sericite ‘/Greisen’ – Type Deposits

By far and away the most common form of alteration associated with mineral deposits in granites of the Herberton – Mt Garnet region is that designated as ‘greisen’. However, this designation can include development of obvious muscovite (e.g. Figure 7) through to ultra-fine muscovitic or illitic material, and the alteration assemblage may also include various amounts of topaz, fluorite, apatite and tourmaline. The category also includes a wide variety of structural features - from fractures with greisenised sidewalls and greisen-bordered veins, through to veinlet swarms or quartz pipes in greisenised granite, greisenised breccia zones, or irregular greisen patches of indeterminate structural affiliation (Pollard, 1984). Moreover, the associated ore can be of one or several minerals including wolframite, cassiterite, and various sulphides such as pyrite, arsenopyrite, chalcopyrite, and sphalerite. Further subgrouping of greisen deposits is therefore required and has been done in terms of specific ore
Mineralisation in the Herberton - Mt Garnet Mineral Field

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Mineralisation in the Herberton - Mt Garnet Mineral Field cont’d

Cross-cutting relationships suggest the development of chlorite lodes at Herberton may post-date the sericitic lodes (Georgees, 1974; Williamson, 1984). In addition, locally there appears to be at least two generations of cassiterite – a predominant dark brown magnetic cassiterite, overprinted by a lighter brown non-magnetic form. This suggests there may be more than one generation of mineralisation in the Herberton Hill area, and may explain the high density of lodes within the one hill. Over 64,000 tons of SnO₂ have been extracted from that one hill (Georgees, 1974); it seems feasible to say that such a mineralised feature be discovered today (well away from any township), then with present technology and a more buoyant tin price it would be possible to profitably extract much of the ore by open-pit mining.

DEPOSITS IN NON SKARN-FORMING METASEDIMENTS ADJACENT TO GRANITE CONTACTS

Microgranite / Porphyry Dyke – ‘Greisen’ Associations

In some localities clusters of greisenous lodes appear to occur nearly a kilometre away from the closest exposed granite contact. Pollard (1984) noted that some of these deposits are spatially associated with dykes of pegmatic microgranite or quartz-feldspar porphyry. Of much greater significance is the larger-scale sericitised poly-metallic Baal Gammon deposit located in the Watsonville district. Initially mined in the 1880’s as a cluster of small high-grade tin-bearing chloritic lodes, the deposits of what is now the Baal Gammon / U. N. A. lease area were found to grade down into complex sulphide lodes at depth (Blake, 1972). Mining operations for tin, copper and silver were intermittent during last century, and operations recommenced in 2011 after drilling by Kagara gave an indicated resource of unmined ore of 2.77 Mt at 1% Cu, 40 g/t Ag, 0.2% Sn and 38 g/t In (Champion & McKay, 2012). Intermittent mining was suspended in April 2014 following heavy rainfall associated with Cyclone Ita, and the mine placed on care-and-maintenance.

Drilling and mining revealed mineralisation at Baal Gammon occurs within and adjacent to a mainly quartz-sericite altered quartz-feldspar porphyry sill that intrudes arenaceous metasediments. Mineralisation occurs mainly as sulphides and cassiterite infilling a pervasive complex network of micro-fractures and vughs, and locally as pods and lenses several metres long of coarse-grained sulphide-rich assemblages (Fraser et al., 1981; Figure 9). All forms of mineralisation contain fragments of altered porphyry and metasediments variously replaced by fine grained sulphides (Fraser et al., 1981). The deposit exhibits characteristics similar to porphyry-type tin systems, and analogous to those at Ardlethan in NSW (Clarke, 1979) or tin systems in Bolivia (Kelly & Turneaure, 1970).

So far the Baal Gammon deposit has been considered to be one of a kind, but this assumption has not been seriously tested, as several other deposits show similar characteristics (e.g. the Stella and Lancelot deposits).

DEPOSITS IN SILICICLASTIC METASEDIMENTS

Tourmalinised Metasediment Lodes

Cassiterite-bearing quartz-tourmaline lodes are almost entirely confined to the metasediments of the Hodgkinson Formation and tend to occur in distinguishable clusters. Tourmalinatic lode types occur in at least three forms, sometimes within the same lode system:

- Pods / pipes: cassiterite-bearing massive quartz with minor tourmaline to massive tourmaline with minor quartz (Moore, 1981).
- Sheeted veins/veinlets designated ‘steaky ore’, made up of alternating bands of quartz, tourmaline and cassiterite (Pollard & Taylor, 1983). Several generations of cross-cutting veinlet swarms can give rise to locally intense veinlet networks (Figure 10).
- Tourmaline and quartz fragments in clay following fracturing and overprint of argillic alteration.

Chloritised Metasediment Lodes

Chlorite - quartz lodes are the most widespread form of mineralisation within the metasediments of the Herberton – Mt Garnet Mineral Field. They generally occur as pipes and veins localized in steeply dipping fracture/shear zones, and collectively account for more than half the total lode tin produced in this region, as well as a significant amount of the copper (Blake, 1972). Most of these lodes tend to occur in clusters, although scattered individual deposits are also evident. Chloritic lodes have been mined for both tin and base metals, and the distribution of the economic metals is typically zoned with respect to intrusive contacts. For example, in the Emudford district the clusters of chloritic lodes overlap with, and arc around, the cluster of tourmaline lodes (Figure 1). The chlorite lodes within 1 km of the northern (faulted) boundary of the Eastern Tate Batholith produced cassiterite and little else. Between 1 km to 2 km from the northern boundary cassiterite and minor copper ores (sulphides & secondary) were mined, whereas beyond 2 km base-metal ores (especially of Cu and Pb) with minor
tin have been extracted from quartz-sulphide lodes weakly haloed by silicic +/- chloritic alteration (Figure 1). For the elongate chlorite lode cluster north-west of Bakerville the cutoff into tin-bearing and those exploited for base-metals is around 2 km out from the nearest producer, whereas just west of Herberton it is the actual (faulted) contact. The vast majority of chlorite-lode tin mines in the region have been small, relatively high-grade producers. However, larger bodies of more diffuse mineralisation have been found recently in chloritized metasediments. For example, the Dalcoch prospect, located almost in the middle of the Brownville - Coolgarra ‘mega-cluster’ of chlorite lodes, fine anastomosing quartz-cassiterite veins and vein stockworks permeate three strongly chloritized zones. The main zone is over 350m in strike length, up to 130m wide, continuous to at least 100m depth, and recent drilling has identified a resource comprising 495,000 tonnes at 0.31% Sn (MGT Resources, 19/4/2016). Drilling has also intersected a rhythmic intrusion spatially associated with the three mineralised zones.

Silicified Metasediment Lodes
In addition to quartz + ore lodes enclosed with sericitic, tourmalinic or chloritic alteration, there are lodes where the associated alteration is either more difficult to discern or main form of alteration. Mineralisation associated with such lodes seems to vary considerably with regards distance from either source granite or to margins of caldera subsidence.

Tin and Tungsten Lodes
Tungsten ores embedded in quartz with little in the way of distinctive associated hostrock alteration are occasionally evident in structures cutting hornfelled metasediments close to, or within, contacts with metasalcatitic granite. Tin ores embedded in quartz with little in the way of distinctive associated hostrock alteration are far more common than tungsten lodes. In many cases they are intermingled with lodes enclosed in distinguishable forms of alteration (sericitic, tourmalinic, or chloritic) that cluster in metasediments adjacent to small-scale, late-stage, fractionated (micro) granites dotted around the margins of a batholith (Figure 1). Blake (1972) noted that many of the quartz lodes grade imperceptibly into chlorite-quartz or quartz-tourmaline lodes at depth. Most instances of this lode form are recorded as having been quite small producers of bonanza-type ores.

Base-Metals Lodes
In broad perspective, along the outer flank of tin-bearing lodes in metasediments lie a smattering of metasediment hosted base-metal – quartz lodes. That is, base-metal – quartz lodes flank cassiterite-bearing quartzitic and chloritic lodes, which in turn flank and intermingle with tin-bearing tourmaline lodes (Figure 1). In many instances the mineralisation below the water table is the be a complex mix of base-metal and arsenical sulphides. Past miners sought only the Cu, Pb, and Zn sulphides and their secondary enrichment derivatives, including secondary native silver (Blake, 1972), and tended to only mine what was available above the water-table. At the Isabel deposit, near Herberton, sulphides and quartz occur as breccia in a tectonic breccia. The sulphide assemblage includes base metal sulphides and stannite, along with minor cassiterite (Figure 11). At the Comeno Mine, base metal mineralisation has been deposited as crustiform bands of alternating sphalerite-rich and galena + chalcopyrite-rich layers, which are cut by later chalcopyrite and quartz-sulphide-siderite veins (Woodward, 1976; Figure 12). These features are somewhat similar to mineralisation designated by Corbett (2002) as occurring in the quartz – base-metal sulphide zone beneath an epithermal system. Similarly, deposits on Montalbion Hill (NE of Comeno) also have features that suggest deposition in an environment similar to the older levels of an epithermal system (Corbett, 2002), including chaledonic silica in veins and alteration, pervasive argillic alteration, small intrusive breccia pipes, and crustiform bands of fine-grained sulphides (Woodward, 1976; Figure 13). Mineralisation is cut by later veins of quartz-pyrite, then ferruginous carbonate, and the early silica alteration is overprinted by pervasive kaolinisation. The Montalbion Hill deposits are pipe-like and associated with breccias.

Antimony – Quartz Lodes
Small quantities of antimony have been mined at several deposits known for tungsten and/or tin mineralisation. The predominant lithologies within the Hodgkinson Province are sandstone, greywacke and siltstone. However, the Province’s western margin comprises of limestone from a few metres up to three-quarters of a kilometre across are locally intercalated with the sedimentary sequence (Askins, 1975). Skarns are often evident where these limestone strata have come into contact with granitic intrusions.

Carbonate-Hosted Skarn Deposits
According to Kwak (1987), the four most common proximal tin skarn assemblages are: (i) magnetite with minor tin, (ii) andradite + wollastonite, (iii) magnetite + fluorite + vesuvianite, and (iv) forsterite + pyroxene +/‐ spinel. Of these, the first and third types are evident in the western part of the Hodgkinson Province, where tin skarns have been identified in the Pinnacles, Ironstone, Munderra, Red Hill and Gillian areas. Where associated with strong fluorite precipitation, magnetite-rich skarn can develop a ‘wriggite’ structure (Figure 14), consisting of rhythmic finely crenulated layers made of magnetite lamellae (+ minor cassiterite) alternating with lamellae of fluorite + fluoro-vesuvianite (Kwak & Askins, 1981). Such deposits have been viewed as a carbonate analogue of a greisen system (Taylor, 1979).

In north-east Queensland, a good example of this type of deposit is the long explored Pinnacles prospect which, according to a 2013 announcement by Consolidated Tin Mines Ltd, has a total (Indicated + Inferred) resource of 5.39Mt at 0.45% Sn equivalent, and 5.39 Mt at 6.6% F at a cut-off grade of 0.3 g/t Au. Seven kilometres north-west of Triple Crown is the Nymsbolk gold prospect. According to an MGT Prospectus report (2012) mineralisation occurs within sheeted quartz veins and breccias associated with a complex of felsic porphyry bodies that have intruded the contact zone between two granitoids. Drilling revealed the presence of approximately 2.4 Mt of oxidised mineralisation containing around 0.3 – 1.0 g/t Au (av. – 0.7 g/t), easily extractable via heap leaching, with the better grades being associated with intense quartz veining and extensive silicification (Pyper, 2012). The Nymsbolk gold prospect and nearby Ambrose Gully gold prospect lie adjacent to areas of known tin mineralisation, leading to speculation as to whether or not the gold and tin deposits share a common derivation. Before such a notion is summarily dismissed, it should be noted that flotation test work done on mine dump samples of sulphide ore from the bottom of the nearby Smiths Creek Tin Mine produced a concentrate containing 35% Cu and 500 g/t Au. It should also be noted that according to Thompson and associates (1999), it is not uncommon for intrusion-related gold deposits to occur within magmatic provinces best known for tungsten and/or tin mineralisation.
Mineralisation in the Herberton - Mt Garnet Mineral Field

Infilling between (and partially replacing) crystalline quartz banding of galena-rich and sphalerite-rich layers encrusted fine sulphide spots (black). The sample is cut by marcasite on a quartzitic sandstone fragment (top), within breccia silicified rock flour (black- &-white photo from thesis by Woodward, 1976).

The sample is cut by marcasite on a quartzitic sandstone fragment (top), within breccia silicified rock flour (black- &-white photo from thesis by Woodward, 1976).

Figure 14. Typical example of a wriggilitic skarn from the Pinnacles area, north of Mt Garnet. Photo from Taylor (1979).

Figure 15. Sample of strongly altered breccia from the Jack-in-a-wolframite (black) segregations in chlorite (green) + garnet (orangy to dark brown) lode overprinting predominantly biotite and almandine garnet alteration of a metabasalt. (Photo from thesis by Moore, 1981).

Conversely, holes drilled through the Hole 16 skarn deposit in the Ironstone area about 10km south-west of Mt Garnet have revealed the presence of a thin body of garnet skarn immediately above an Elizabeth Creek type granite which outcrops just over three kilometres to the west of the Mt Garnet skarn.

Possible affinities between this more conventional sulphide-bearing skarn, and the mostly tin-bearing wriggilitic type discussed previously are difficult to discern. Askins (1975) postulated the hydrothermal fluids responsible for skarn formation at Mt Garnet actually emanated from a completely different granitic source, that being the Hammonds Creek Granodiorite which outcrops just over five kilometres to the east of the Mt Garnet skarn.

METABASALT-HOSTED DEPOSITS

Along with a monotonous flysch succession of shale, siltstone, greywacke, and greywacke-type conglomerate, the Hodgkinson Formation also includes sporadic intercalated bands / lenses of mafic igneous rock and associated cherts interpreted to be submarine lava flows (Fawckner, 1975), typically capped by stratified lava flows.

Mafic Skarns

At the Magnum Bonum tin mine in the Silver Valley district, mineralisation is centred in a highly brecciated and altered basalt intercalated with flysch-type metasediments. According to Obiji (1979) the basaltic unit has been brecciated, veined and altered to assemblages typical of an iron-rich skarn system (e.g. pyroxene, amphibole, magnetite, fluorite, cassiterite, sulphides). Close by to the east, and potentially beneath, is the highly mineralised Go Sam Granite, which is therefore most likely the source of heat and mineralising fluids.

Progenitors of Chlorite – Garnet Lodes

Pinkish red to reddish brown almandine garnets up to 5mm in diameter have been found in a number of cassiterite-bearing chlorite lodes located in metasediments. Where such lodes have not been augmented by other forms of mineralisation exploiting the same structural conduits (such as tourmalinitic lodes in the Irwinbank area), production from such lodes has been quite meagre. For example, at the Jumna Mine the disseminated cassiterite within the chlorite-garnet lodes seldom gave grades greater than 1% Sn, but the overprinting quartz-tourmaline zones tended to be considerably richer with up to 25% Sn (Milburn, 1980). According to Milburn (op cit.) much of the chlorite appeared to have been derived from the alteration of a garnet-bearing biotite precursor rock. Likewise, at the Jack-in-a-box mine in the Irwinbank area, much of the supposed ‘chlorite lode’ was eventually determined to be metabasalt replaced by biotite, almandine garnet, hercynitic spinel and intermittent corundum, which had been partially chloritized where transected by lodes containing tourmaline, quartz and cassiterite (Moore, 1981, Figure 15). Once again, the best grades occur where the overprinting lodes of cassiterite-rich quartz-tourmaline and clay-tourmaline occur (Moore, 1981).

At the Tommy Burns mine, (in the Emuford district outside of area covered by Figure 1), hydrothermal fluids moving through a fault-related breccia zone caused extensive wallrock alteration in a mafic volcanic unit (Figure 16), and partial alteration of the adjacent metasediments (Pollard, 1978). As a result, altered mafic rocks that consist of cordierite, anthophyllite, biotite and almandine garnet occur in close association with cassiterite-bearing cordierite-cummingtonite rocks of definite hydrothermal origin (Pollard, 1978, 1981). The cordierite and cummingtonite have subsequently been replaced by chlorite - almost completely in the lower levels of the main lode, but only partially in the upper levels (Goulevitch, 1990). In addition, the ore mineralogy also changes with depth, from cassiterite dominant in the upper part, through cassiterite + wolframite, to cassiterite + wolframite + scheelite some 250m below the discovery outcrop (Goulevitch, 1990).

The main object lesson presented by this deposit is that where minerals such as cordierite, anthophyllite and cummingtonite are encountered in a confined area of mafic rock, it should not be assumed they are just local perturbations of regional metamorphism.
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DEPOSITS IN LATE CARBONIFEROUS VOLCANICS
Silver-lead deposits within the Featherbed Volcanics occur as two clusters of lodes in the Mt Weinert – Orient Camp district. The lodes seem to be associated with shallow to steeply dipping shear zones within pyrophyllitic felsic pyroclastics (Blake, 1972). Below the water-table the lodes consist of argilligentic galena intermingled with other base-metal sulphides. Above the water-table most associated sulphides had oxidized, and the argillitogenic galena had partially oxidized to lead carbonates with native silver. As a result, most lodes were mined down to ground water level and then abandoned. The deepest level of mining was around 36 metres at the East Orient (Blake, 1972), so clearly there is still unmined primary mineralisation in existence at these sites.

In 2013, Monto Minerals reported that soil sampling north of the Orient Camp group of workings outlined a strong Sn–Pb–Zn–As–Ag anomaly 60km wide over a strike length of 2.2 kilometres within the felsic volcanics (Proactive Investors, 18-10-2013). Thus there appears to be further potential for the discovery of argentiferous base-metal mineralisation within the Featherbed Volcanics.

SYNTHESIS
Mineralising Granites
A significant advance since Blake compiled the geological maps of the Herberton – Mt Garnet region in 1972, has been the classification of two main granitic supersuites in areas previously considered to be ‘Elizbeth Creek Granite’ (Champion, 2003, 2013). The identification of the supersuites was based on detailed mapping, sampling and petrological analysis by ICU PhD students (e.g. Pollard, 1984, 1988; Johnston, 1984; Johnston & Black, 1988; Witt, 1985, 1988; Blevin, 1989; Clarke, 1990).

Mineralisation in Granites
Tungsten mineralisation typically manifests as crystalline wolframite, in places partially replaced by scheelite, intergrown with infill quartz in either pegmatites/pipes associated with microgranites, or in vein/pipe-like structures enclosed in silicous to micaceous greisen within coarser granitized granite. Where evident in Ootann Supersuite granites, tungsten minerals are typically associated with Mo and Bi minerals within quartz pipes in the apical portions of a granite intrusion. Where affiliated with O’Brien Supersuite granites, tungsten minerals are more likely to be associated with fluorite, cassiterite, and minor sulphide minerals (including molybdenite). Within the Eastern Tate Batholith, mineralisation with this assemblage typically occurs within, or as satellite clusters encircling later-stage, more fractionated, small-scale granite intrusions. Within the Coolgara Batholith, they tend to occur within the more fractionated fringing phases of the Nettle granite intrusion suite, as is noted by Johnston (1984).

Table 2: Mineralisation characteristics of the two main supersuites in the Herberton - Mt Garnet Mineral Field

<table>
<thead>
<tr>
<th>Supersuite</th>
<th>Age</th>
<th>Characteristics (mineralized areas)</th>
<th>Metal Associations</th>
<th>Tungsten Deposits</th>
<th>Tin Deposits</th>
<th>Deposit Settings</th>
<th>Alteration Associations</th>
<th>Deposit Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>O’Brien Creek</td>
<td>Mid – Late Carboniferous</td>
<td>Granites</td>
<td>Sn +/- W</td>
<td>W associated with</td>
<td>CaS + quartz +</td>
<td>Pipes within apical</td>
<td>Dominantly sodic to hydrolytic &amp; silicic</td>
<td>From small and high-grade to moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strongly fractionated Reduced</td>
<td></td>
<td>fluoride, cassiterite, minor sulphides</td>
<td>+ fluoride</td>
<td>zones in siliceous</td>
<td>greisen, albite, chrysoberyl</td>
<td>and bulk mineable</td>
</tr>
<tr>
<td>Ootann</td>
<td>Latest Carboniferous</td>
<td>Graniodiortes, Granite stocks</td>
<td></td>
<td></td>
<td>No significant</td>
<td>within medium-grained</td>
<td>Dominantly potassic to hydrolytic &amp; silicic</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-type</td>
<td></td>
<td></td>
<td>tin deposits</td>
<td>granite</td>
<td>greisen, incipient and pervasive K-feldspar</td>
<td></td>
</tr>
</tbody>
</table>

Mineralisation in Adjacent Metasediments
Within Hodgkinson Formation metasediments that enclose granite batholiths, the types of deposit and associated mineralisation relate to both the distance from granitic source and the metasediment rock types. These associations have been summarized in Table 1 and are briefly outlined below.

Pods of limestone often occur intercalated with the usual siliciclastic sedimentary sequences, particularly along the province’s western margin (Askins, 1975). Proximal to a mineralising granite, carbonate-hosted skarn deposits can be expected, as in the Mt. Garnet district. Close to highly fractionated O’Brien Supersuite Specimen Hill plutons, towards the east they occur in an area of coarse-grained granite that has been intruded by small bodies of often granophyric +/- pegmatitic microgranite (Clarke, 1990). In both these localities the greisen-type tin deposits are joined / cross-cut by additional cassiterite-bearing pipes and intrusive breccia boudins with affliliated chloride alteration (Williamson, 1984).

The key association in all these areas is the presence of late-stage highly fractionated granite differentiates within / around areas of tin-bearing alteration and / or greisenisation. Presumably, future detailed mapping and sampling will also reveal similar associations for areas of mineralisation that the granite masses presently designated as Jumna Granite and Lass O’Gowrie Granite.

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Mineralisation in NE Qld
Mineralisation in the Herberton - Mt Garnet Field cont’d

granites, the skarns are typically cassiterite-bearing
wriggite and tin-rich magnetite types. In addition,
base-metal skarns with major sphalerite are also
evident, perhaps produced by fluids from a granitoid
of Ootann Supersuite derivation. Distal to a source
pluton, mineralising fluids are more likely to produce
carbonate replacement type deposits. Deposits of this
type have yet to be identified in the Herberton – Mt.
Garnet mineral field, possibly due to erosion removing
all vestiges of carbonate strata overlying granite plutos.
Within the otherwise monotonous flysch succession
of Hodgkinson Formation, there are also sporadic
intercalated bands / lenses of mafic igneous rock and
affiliated cherts. In close proximity to a mineralising
granite, metabasalt-hosted mafic skarn deposits can be
expected, as at the now abandoned Magnum Bonum
Mine. At slightly lower temperatures (4000 – 500°C:
Pollard, 1978), the mafic units may be altered to
rocks that consist of cordierite, anthophyllite, biotite
and almandine garnet as at the Tommy Burns mine.
Alternatively, replacement of mafic units by biotite
containing almandine, hercynite and intermittent
corundum has also been identified in the region,
although discernable mineralisation is usually only
evident where the biotite has been chloritised. Further
afield, altered metabasalts are more likely to be altered
to chlorite (Lagat, 2009). Likewise, all three higher
temperature forms of alteration mentioned above are
likely to be altered to chloride + garnet by later cooler
stages of fluid ingress, which occurs at the Magnum
Bonum (Obiji, 1979), Tommy Burns (Pollard, 1978),
Jumna (Milburn, 1980), and Jack-in-a-box (Moore,
1981) mines.

According to Pirajno (2010), there are many cases where
country rocks surrounding greisenised granite cupolas
have undergone some degree of tourmalisation, with
tourmaline particularly abundant in zones of fracturing.
Fluid inclusion data from tourmaline breccia pipes
associated with vein-type tin deposits indicate that
hydrothermal tourmaline commonly forms at depths
from between 1 and 3 km, and at temperatures in excess
of 300°C from highly saline fluids (Kirwin, 1985). Such
conditions are comparable to those required to form
albitisation in granites of the Herberton – Mt. Garnet
region (Witt, 1988).

It is therefore highly relevant to note that in the Emuford
district, tin deposits immediately to the south of the
Emuford Fault occur in granite that has been albitised
and/or greisenised, whereas those immediately north
of that fault occur in siliclastic meta-sediments that
have undergone some degree of tourmalisation. It
is difficult to comprehend how these adjacent forms of
tin mineralisation would have developed, side by side,
from two separate mineralising systems that have not
in some way overlapped or interfered with each other.
More likely is that north-side-down relative movement
on the Emuford Fault has offset two parts of the same
mineralising system, and mineralisation now seen on
the down-set northern side was once also present on
the southern side but has since been eroded away to
reveal the underlying granitic roots of the system. More
importantly, what is now seen on the northern side of
the Emuford Fault is most likely underlain by granite-
related deposits similar to those seen on the southern
side, as shown in Figure 17.

South of Emuford, tourmaline is an accessory mineral
in the highly fractionated Denford Granite, occurs in
pegmatite at the margins of the Billings Granite, and
is also present in a couple of the local greisen-style
deposits (Pollard, 1984). The fact that tourmaline is
not more prevalent in the Emuford granites may relate
to the volatility at high temperatures of boron - its
fundamental constituent (Menard et al., 2013). This
would also explain the appearance of tourmaline in what
would have been cooler overlying metasediments, such
as those outcropping immediately north of Emuford.
If this assumption is correct then the multitude of
tourmalinated metasediment lodes around Irvinebank,
along with lesser clusters south and north-east of Hales
Siding plus just east of the Glenlimdale Granite, should
also be perched immediately above stanniferous granite
intrusions.

Chloritic lodes in metasediments generally overprint
or arc around areas festooned with tourmalinitic lodes,
typically on the side opposite to the exposed granites.
These flanking chloritic lodes most likely developed
further away from the intrusions that exsolved
mineralising fluids, and thus formed at somewhat lower
temperatures (Lagat, 2009). If this is correct then the
intrusion(s) responsible for tin mineralisation associated
with chloritic lodes through the Brownville – Coolgarra
area must be located at greater depth than those
beneath the tourmalinitic deposits in the Irvinebank
area and north of Emuford. Further afield, lodes nested
in silicified metasediments most likely formed at even
lower temperatures, particularly along the outer reaches
where the silica tends to be chalcedonic, and the main
ore components are sphalerite and argentiferous galena
deposited as relatively fine-grained crustiform bands
(Corbett, 2002).

In tandem with the sequencing of wallrock alteration
types with progression away from the perceived
location of a mineralising intrusions, there is also
gradual change in ore minerals. Tungsten orebodies,
which are common in granites, are virtually absent
from metasediments, although tungsten minerals are
Mineralisation in NE Qld

Mineralisation in the Herberton - Mt Garnet Field cont’d

often present in predominantly Sn and Cu deposits. Cassiterite is the main ore mineral in tourmalinised deposits, although minor wolframite and sulphides of Fe +/- As and Cu may also be present. Closer to mineralising granites and sites of tourmalinised metasediment, chlorite and quartzitic lodes are most likely to contain cassiterite with minor wolframite and sulphides of Fe, As and/or Cu. With increasing distance, however, the relative proportion of tin mineralisation decreases, with some of the tin occurring as stannite, while sulphides become far more significant, and complex - including Pb and Zn forms as well. With further progression onwards, the relative proportions of sulphides present continues relatively unchanged, but the relative proportions change considerably: arsenopyrite and chalcopyrite become far less dominant, while sphalerite and argentiferous galena become much more significant within outer zone siliceous orebodies. Thus there is a zoning pattern but the zones are transitional rather than occurring in discrete bands.

This inner to outer progression in deposit alteration and mineralisation types is similar to that seen in major tinfields elsewhere in the world, such as in Freeberg (Baumann, 1965), Cornwall (Hosking, 1964; Guibert & Park, 1986), Loe Boulter (Collier, 1982, 1990). Such a progression is generally interpreted to be due to changes in fluid reactivity related to decreases in temperature +/- pressure, with the solution producing minerals in reverse order of their solubilities. However, as noted by Blake (1992), such deposits appear to exhibit reversed zoning, with cassiterite mineralisation giving way to complex mixtures of sulphides at depth! Such deposits typically comprise several episodes of mineralisation, with successive stages having limits to their extents. In most cases, the minerals produced in successive stages can also be attributed, at least in part, to successively declining temperatures and pressures of formation.

Mineralised stockwork / breccia zones also occur in this mineral field and are commonly associated with felsic porphyry dykes. Clusters of greisenous lodes can occur near a kilometer away from the closest exposed granite contact and, where mapped in detail such as in the Emuford district, these clusters in metasediment are typically affiliated with microgranite or quartz-feldspar porphyry dykes (Pollard, 1984). At Watsonville the UWA / Baal Garnet system initially manifested as small intermittent high-grade tin-bearing chloritic to sericitic lodes clustered between porphyry dykes less than a kilometre out from granite. Subsequent drilling and mining has shown these lodes to be crowning projections of a much larger tin + sulphides orebody within a sericitised breccia mass in an older porphyry dyke, that is cross-cut by later near-vertical dykes (Fraser et al., 1981). Similarly, east of the Stannary Hills at Abergowrie, a roof pendant of sericitised metasediment has also, in places, been extensively brecciated and the breccia zones intruded by quartz porphyries. Tourmalinised lodes proximal to porphyry dykes are often associated with zones of brecciation (e.g. Moore, 1981), most of which are assumed to be products of faulting and fracturing. Located almost in the middle of the Brownsville - Coolgarra 'mega-cluster' of chloride lodes, the Dalcotch prospect has been extensively drilled to reveal the presence of tin-bearing stockwork systems affiliated with extensive chloritisation, and spatially associated with a chalcopyritic intrusion. At several sites in the Nymboid district, gold mineralisation has been found affiliated with siliceous breccia systems that are typically spatially associated with intrusions of felsic porphyry / porphyritic microgranite. Finally, in close proximity to the Featherbed Caldera Complex of volcanics and associated porphyry dykes, the Montalbion Ag-bearing base-metal deposits are centered in siliceous breccia systems.

This association seems somewhat similar to the close association between mineralised stockwork / breccia zones and porphyry dykes / spires in many porphyry copper systems, where both have formed in particular association with a magmatic or crustal weak zone and, sourced from a large, sequentially crystallised parent magma chamber below (Sillitoe, 2010; Li et al., 2010). However, as noted above, the Herberton - Mt Garnet Mineral Field exhibits the felsic igneous equivalent, with the petrology of the late-stage porphyry dykes giving indications as to physico-chemical developments that occurred in the parent magma chamber below, and the sitting of several such porphyry dykes giving indication as to where stockwork / breccia-related bulk low grade deposits may lie. Testing this supposition would require more attention being paid to locating and assessing the porphyry dykes within this region.

REASONS FOR FURTHER RE-ASSESSMENT

Limited Past Perceptions of Deposit Geology

It should be emphasized that in the late 1800s / early 1900s, when most of the known deposits were discovered, prospectors typically sought lodes of obvious bonanza-type mineralisation. Moreover, where extensive porphyry dykes or orogenic gold (i.e. gold) were usually mined by several small separate mining ventures rather than by one mining entity / group. As a result, exploration thinking (and expenditure) has tended to be straight-jacketed by the assumption that small-scale bonanza-type deposits are the only ore types to be found. Where perspectives have changed, exploration has revealed the presence of broader-scale bulk low-grade deposits (e.g. the Baal Garnet breccia and Dalcouth stockwork deposits).

Limited Extent of Past Mine Development

Small-scale mining operations with limited financial resources commonly ceased mining when faced with a significant impediment, such as water problems or complex ore beneath the water table level, a major constriction / truncation in an ore shoot, or indeed a tragic accident. As a result, there remains considerable potential for locating more extractable ore, either as extensions of the lodes mined, or as haloes areas of lower grade ore.

Smiths Creek Tin Mine is a good example. Discovered in 1901 and mined from 1903 to 1909, this mine was developed on a 6 – 10m wide quartz-tourmaline pipe which was worked to 152m depth, and produced 1,561 tons of SnO₂ (Blake, 1972). According to an MGT Resources Prospectus (Pyper, 2012), the average grade was 4% Sn, and locally up to 15% Sn. The miners struck copper-sulphide ore but worked on to 167m depth, at which point mining stopped and the mine was abandoned due to a major accident. An additional 23,773 tons of ore with an average grade of 0.7% Sn was also extracted from an adjacent open-cut pit (Pyper, 2012). The full extent of low-grade ore has not been fully assessed, nor have other surface tin anomalies (e.g. open pit) been traced to significant depths, and underground mining is known to have stopped in high-grade Cu + Sn ore. Exploration drilling done by MGT in 2013 has revealed the presence of a further inferred resource of 200,000 tons at an average grade of 1.68% Sn. If ever there is a case of ‘unfinished business’ it is this one, but this is just one of many in the region! Moreover, prior to the 1990s the Queensland Government had reserved considerable areas, particularly around the Mt Garnet district, for development by only small-scale miners. Since then such restrictions have mostly been removed, so that it is now feasible for companies with substantial capital and high level of expertise to apply for and obtain large EPMs (Pyper, 2012). As a result, large areas of relatively low grade can be sought and developed, or conversely several smaller deposits within a broad area can be developed sequentially to maintain ongoing production from a decent sized mill. Such a model of development seems to have motivated MGT Resources to take up several extensive EPMs in the region, and refurbish the Mt Veteran tin processing plant (MGT Resources, 2013, 2016).

Limited Past Perceptions of Inherent Commodities

Most initial discoveries of mineralisation were done by prospectors who assessed potential lodes in terms of visible mineral extracts. Today there are a range of present and rare commodities that can be present at low minable concentrations yet not be visible to the human eye. As a result, a systematic survey for such commodities has not been done on deposits in the Herberton – Mt Garnet region, even though associations demonstrated elsewhere around the world, and analyses done at specific sites in the region, indicate their presence is to be expected.

According to Thompson and associates (1999), it is not uncommon for intrusion-related gold deposits to occur within magmatic provinces best known for tungsten and/or tin mineralisation. In this respect, the Smiths Creek Tin Mine once again springs to mind. As noted previously, flotation test work done on mine dump samples of sulphide ore from the bottom of this mine produced a concentrate containing 500 g/t Au. There are in fact several such ‘reversed zoned’ tin mines in the region that were abandoned upon reaching ‘complex sulphide’ ore (Blake’s terminology, 1972), including the Baol Garnet.

Another highly valued commodity affiliated with tungsten and/or tin magmatic provinces is indium. The Herberton tin-polymetallic mineral field is amongst the largest known indium-enriched ore provinces (Seifert and Sandmann, 2006), and indium mineralisation has also been discovered in the tinfields of Cornwall (O’Callaghan, 2011), the tin – tungsten – base-metal deposits of the Canadian Appalachians (Geoddeke et al., 2015), and the Gejiu tin – polymetallic deposit in Yunnan, China (Li et al., 2015). In each case the main indium-bearing mineral is sphalerite, although in the Pinguino deposit in Argentina, indium has also been found in association with tin minerals such as cassiterite and ferrokerstelite (Jovic et al., 2016). The Baal Garnet deposit near Watsonville is already recognised as a potential source of indium, but there are all the other ‘complex sulphide’ ore deposits listed by Blake (1972) that are of potential interest. Moreover, close to Herberton there is the Ischel base-metal deposit where the gossanous material yielded approximately 450 ppm In, although the unweathered sphalerite contained around 130 ppm In (Greaves, 1975). Finally, there are all the sphalerite-bearing ores from the more distal margins of the mineral field for which there is virtually no analytical data available. A reconnaissance sampling survey of residual ores on rock dumps at abandoned mines that once produced base-metal sulphides is surely warranted.
Newly Discovered Deposit Types

Since 1990 several new deposits, not previously identified by the early prospectors, have been discovered in the Herberton – Mt Garnet mineral field. These have the potential to be used as templates for further exploration in the region. For example, there are the apparent intrapair intrusive related gold deposits located west of Mt Garnet, which have yet to be examined in detail, and compared to other auriferous systems in northern Queensland such as those at Kidston and Chillagoe. Then there is the reported metalliferous anomaly located in the Featherbed Volcanics - the obvious assumption would be that it signals the presence of a deposit similar to those of Orient Camp, but even those have not been fully examined in any detail. Moreover, the list of anomalous metals includes tin - something that obviously requires further evaluation.

Clearly there is much that can be done, and further possibilities for discovering even more mineralisation in the Herberton – Mt Garnet region.

References


Mineralisation in the Herberton - Mt Garnet Field


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EGRU News March 2017

Mineralisation in NE Qld


EGRU would like to acknowledge and thank speakers and poster presenters, short course presenters, and field trip leaders for their contributions. We are also grateful for the support of our conference sponsors: Mount Isa Mines (a Glencore company), South32, Newmont, HiSeis, and Geoscience Australia. The generous assistance of our industry and professional association supporters is also gratefully acknowledged: SEG, SGA, Aranz Geo, AusIMM, Evolution Mining, Carpentaria Gold / Resolute Mining, Minjar Gold, Consolidated Tin Mines, Auctus Minerals, Lantana Exploration and Wolfram Camp Mining. Special thanks to all the students who provided invaluable help before and during the conference.

EGRU's flagship FUTORES conference was held in Townsville in June this year. FUTORES II built on the success of the inaugural FUTORES conference in 2013, and brought together researchers, explorers and government agencies to address issues related to the sustainable supply and utilisation of mineral and energy resources. The conference was opened by Professor Iain Gordon, ICU Deputy Vice Chancellor, Tropical Environments and Societies, and welcomed the Honourable Dr Anthony Lynham, Queensland Minister for State Development and Minister for Natural Resources and Mines.

FUTORES II attracted 280 delegates from 16 countries, including global leaders in the fields of economic geology research and resource exploration. The delegates gathered to present papers and contribute to discussions about recent developments in the exploration and understanding of major types of mineral deposits, and the key issues and techniques critical to future minerals and energy exploration.

Over 130 conference presentations, during three days of three concurrent sessions, covered a wide range of resource types, geological settings, and exploration technologies. Presentations by plenary speakers, Richard Sillitoe and Dan Wood, tackled some of the major technical and management issues that face explorers targeting world class deposits. A keynote presentation by legendary explorer, Doug Kirwin, traced the changing world of exploration and highlighted the frustrations and challenges of exploring in the 21st century. The warm sunny days and balmy evenings, typical of Townsville in winter, encouraged informal (and vigorous) discussions during breaks and social sessions to spread from the conference rooms to the verandahs.

The conference was preceded by several short courses and followed by field trips to deposits in north-east Queensland. Field trip reports are included on pages 36-37.

Associate Professor Zhaoshan Chang (EGRU Director), Trevor Shaw (MM, EGRU Chairman), Professor Iain Gordon (ICU Deputy Vice Chancellor, Tropical Environments and Societies), and Honourable Dr Anthony Lynham, Queensland Minister for State Development and Minister for Natural Resources and Mines. (Photo by Bob Holm)

EGRU News March 2017

Mineralisation in the Herberton - Mt Garnet Field
After the successful completion of the FUTORES II conference, EGRU organized a 3-day field trip to some of the major gold deposits south of Townsville. The field trip was led by Paul Dirks, Zhaoshan Chang, Isaac Corral and Fredrik Sahlström from EGRU, and attracted 12 industry and academic geologists, hailing from Australia, Asia and Europe.

On the first day we visited the Mt Carlton high-sulphidation Au-Ag-Cu epithermal deposit in the northern Bowen Basin, operated by Evolution Mining. The participants first enjoyed a tour of the open pits, where they got a chance to observe the spectacular extensional deformation features which have overprinted the Mt Carlton deposit. This was followed by lunch and interesting presentations about Mt Carlton and the nearby prospects in the district. The day was finished off by a visit to the core shed where we inspected and discussed a variety of interesting ore textures from the Mt Carlton deposit.

On the second day we drove to the historical mining town of Ravenswood to visit the Carpentaria Gold mining operation. The day started with presentations where about the different breccia hosted gold deposits in the Ravenswood area. These were followed by visits to one of the open pits and to the core shed, and all participants got to collect a few samples to bring home. The day finished with a hill climb where we observed some of the different host rocks for the Ravenswood deposits.

After spending the night in Charters Towers, we drove to the Pajingo gold mine operated by Minjar Gold. After presentations introducing the local geology we visited the core shed to see some of the spectacular features of the Pajingo deposit which, amongst others, include sinter horizons with fossilized algae. We finished the day by visiting one of the mineralized outcrops where participants could collect samples. After a drive back to Townsville the group parted ways for the time being, with everyone happy after a successful field trip.
In June a group of eight embarked on a trip to visit and learn about the geology of Fiji, with a focus on epithermal and porphyry style gold. The group included five students (one undergraduate, two honours and two PhD), two industry professionals and EGRU Director Dr. Zhaoshan Chang.

The trip was funded by the James Cook University Society of Economic Geologists Student Chapter. This trip would not have been possible without the generosity of the mines and sites we visited, and the financial sponsors. We would particularly like to thank the folks from Lion One Metals, Vatukoula Gold Mines and Newcrest who took the time to show us around their deposits.

The first stop was Tuvatu gold mine owned by Lion One Metals, on the north east of the main island, Viti Levu. (Viti Levu is Fijian for large break, describing the pioneers who had to break through the thick Fijian jungle). The deposit is a low sulphidation epithermal system, hosted by a variably brecciated and altered monzonite. We spent half a day in the core shed looking at samples and chats with the pioneer Mohammed. Gold was first found in the 1930’s by a bloke panning gold in the creek (pictured). The deposit is located on the western rim of a huge caldera (approx. 25km diameter) that collapsed at approximately 4.5Ma. Brownfield exploration is driven by soil sampling and drilling, and magnetic surveys have also been successful at highlighting areas of fluid flow. Mine production is often driven by exploration cycles, explaining a closure in 2006-2008, as well as cycles not coinciding with government support. Due to the sporadic nature of high grade narrow vein mining, there is no mechanised mining system and production use airleg drills, a very labour intense option. As such, workers operate in three eight hour shifts a day. Rehabilitation is not amongst the greatest challenges, as the mining method is reasonably efficient, and the environment forgiving.

Most of the day was spent in the core shed looking at another unique low sulphidation system. The host rock is a basalt with tuffaceous layers. There were spectacular examples of varying quartz phases, from opaline quartz, chalcedony and lattice texture bladed quartz. Interestingly the major faults (shattered breccia, shear and fault zones known locally as flat makes) are subhorizontal, related to the Caldera collapse. Learning about fluid chemistry with examples on hand was a great experience.

Taking the ferry over to Vatu Levu, we were unable to visit Mt Kasil due to ongoing rehabilitation. On the way to Savusavu, however, there were plentiful opportunities for roadside geology. There was some spectacular iron - Ni lateritic weathering on the coastal road, explained by Zhaoshan Chang. Everyone on the trip was loaded with questions, and the more experienced members of the group ready to explain or point us in the right direction.

Our day in Savusavu was spent poring over a roadside example of advanced argillic alteration and discussing porphyry systems. This was a great opportunity to summarise what we’d learnt about porphyries and how the various alteration systems translate into either low, high or intermediate sulphidation. In the afternoon we hunted out a young coastal carbonate unit, to the east of Savusavu township. Here we found spectacular fossils, weathering patterns, and evidence for Holocene uplift.

On the second to last day we visited Newcrest’s Namosi project, on the southeastern side of Viti Levu. It is a porphyry system of 2.12 billion tonnes at 0.35% Cu and 0.11g/t Au in the prefeasibility stage of development. Placeer gold was noted in the area in the early 1960’s and has since been explored by eleven different companies. The main site consisted of a camp, offices and sheltered core area. An extensive drilling program had finished by the time we arrived, with the current focus on environmental studies for the feasibility requirements. It was a fascinating and rare opportunity to be on the scene of a project in this stage of its life, and a startling look at the challenges of taking a deposit from discovery to mine. Quite a contrast to exploring in north Queensland; I’ve not yet come across any endangered fish in the Cloncurry district. The core itself was also fascinating and complex, with host rocks of andesite and andesitic basalt. We saw classic examples of the porphyry alteration stages, fresh unaltered intrusions and intrusive contacts.

In summary this SEG trip was a unique opportunity, particularly for someone of my limited experience. It was an eye opening look at the challenges, technical geology and exciting prospects of our industry in another country with entirely different climate, politics and social licence. One of the most admirable things about the industry in Fiji was the pride in their work and deposits, and the ability to work amicably and collaboratively between companies. I would like to thank the SEG once again for making this trip possible. Thank you, Fiji, for the equally beautiful hospitality and landscape.
Field Mapping Course

Third Year Students
Course Leaders: Dr Ioan Sanislav, A/Prof. Zhaoshan Chang, Prof Paul Dirks (EGRU - JCU)

The third year field mapping course was run between 1st July and 18th of July in Cloncurry, NW Queensland. The field trip had 34 students including 30 JCU students and 4 students from the China University of Geoscience in Wuhan. The Chinese students were accompanied by one of their lecturers, Dr Zhanke Li. This is the first time that students from China have joined our field mapping course, and it marks the inaugural event linked to a recently signed MOU between JCU and Wuhan. We hope to grow this partnership in future.

Mapping exercises were carried out in an area north of the Snake Creek Anticline, along the contact between the calcisilicate rocks of the Corella Formation and the turbiditic sequence comprising the Mt Norna Quartzite and the Llewellyn Creek Formations. The area contains a large variety of rock types and structures, is easy to access, and it is well-exposed. On top of that, the area contains Whiffs of Cu mineralization and was affected by an alteration style similar to that encountered in the Ernest Henry mine north of Cloncurry. There are also numerous outcrops with beautiful, coarse-grained metamorphic and alteration minerals, which get many of the students excited.

The field trip ended with a visit to the Mount Isa Mines exploration office where the students were received by the Senior Exploration geologist, Peter Rea. Students were introduced to the local geology, the mining methods and were shown representative core samples through the Mt Isa ore body and stratigraphy.

Because we are currently shifting our field camp at Roxmere station from the station house to a location in the middle of the mapping area, we could not camp out in the field this year, but instead stayed in the caravan park in Cloncurry. Access to internet and TV did result in some distractions, especially around the final State of Origin test, but the caravan park did provide excellent facilities and was very welcoming to our students. However, next year we expect the camp to be back in the bush, under the great southern sky.

From the 20th to 29th of June 2017 the Advanced Field Training course took place in Cloncurry, NW Queensland. Participants included JCU MSc students along with mineral industry geologists. The Cloncurry region contains a high number of world class IOCG and skarn related Cu, U and REE deposits hosted within well-exposed mid-Proterozoic multiply deformed and metamorphosed rocks. This makes the area ideal for training in geological mapping with a focus on mineral exploration techniques.

The field trip started with two days of mapping along the Cloncurry Fault where different types of breccias associated with widespread hematite alteration are beautifully exposed. The students were asked to map intrusive breccia outcrops and identify the structural setting, the rock types and the alteration styles characteristic of the IOCG deposits in the region.

The next five days included mapping of the Eloise Doherty prospect, near the Mt Colin copper mine, which contains outcropping Cu mineralization in close spatial relationship to intense skarn alteration. This allowed the students to apply the knowledge gained from Mary Kathleen in an open pit, to similar styles of mineralization in outcrop.

The next Advanced Field Training course is scheduled for June 2019. However, if there is sufficient interest from industry the course may be run in 2018.
Application of Fluid Inclusion Studies in Economic Geology

Beijing September 16 - 17, 2017
(associated with the 2017 SEG Meeting)

Presenters:
Jan Marten Huizenga (JCU)
Lorena Ortega (University of Madrid)

This two-day workshop will focus on the fundamentals of fluid inclusion studies, including fluid inclusion petrography, phase diagrams of single and multicomponent systems (H,O, CO₂, H,O-NaCl, H,O-NaCl-CaCl₂, H,O-CO₂), use of the heating-freezing stage, microthermometry, data collection and data presentation, and the use of data processing software.

Jan Marten Huizenga visited the China University of Geoscience (Beijing) in June to discuss fluid inclusion research collaboration with Professor Shengrong Li and Dr Sida Niu. During his visit he presented a fluid inclusion short course that was attended by 35 economic geology postgraduate students.

The course content included fluid inclusions associated with metamorphism and with mineralisation. Future cooperative activities will include the development of a collaborative fluid inclusion website to enhance fluid inclusion research collaboration, focussing on economic geology.

The second day was organised by the Geoscience discipline at JCU (Carl Spandler and Jan Marten Huizenga) and included practical exercises on rock and mineral identification, and on magmatic and volcanic processes.

The two-day workshop was attended by 13 teachers from eight different high schools. The feedback from the teachers was very positive and it is clear that there is a need for these types of courses on different Earth Science topics. More of these PD courses will be offered in near future.

A two-day Earth Science professional development workshop for high schools in the Townsville region was offered in April at James Cook University (JCU) in collaboration with the Teacher Earth Science Education Programme (TESEP). The first day, organised by TESEP and presented by Philip Sansom, included two sessions: the first session focussed on the rock cycle and the second on plate tectonics.

The feedback from the teachers was very positive and it is clear that there is a need for these types of courses on different Earth Science topics. More of these PD courses will be offered in near future.
Postgraduate Student Research Projects

Helge Behnsen (PhD)
Magma fertility related to Au-Cu mineralization in north Queensland, Australia - evaluating the potential for linked porphyry Cu Au (±Mo) deposits at depth.
Supervisors: A/Prof. Carl Spandler, Prof. Paul Dirks

Tegan Beveridge (PhD)
Geochemical characterisation of bentonites combined with high-precision geochronology for correlation and provenance in the Cretaceous Strata of North America.
Supervisors: A/Prof. Eric Roberts, A/Prof. Carl Spandler

Alex Brown (PhD)
Base Metal Genesa, Stratigraphy and Structural Evolution of the Central Tommy Creek Domain, Mt Isa Inlier.
Supervisors: A/Prof. Carl Spandler, Prof. Tom Blenkinsop, Prof. Paul Dirks

Michael Calder (PhD)
Zonation, paragenesis and fluid evolution from the root to top of the Far Southeast Lepanto porphyry-epithermal system, Mankayan district, Philippines.
Supervisors: A/Prof. Zhaoshan Chang, A/Prof. Carl Spandler, Dr Jeffrey Hedenquist, Dr Antonio Arribas

George Case (PhD)
Ore genesis and alteration paragenesis of the E1 group and Monakoff IOCG deposits, Cloncurry region, north-west Queensland.
Supervisors: A/Prof. Carl Spandler, A/Prof. Zhaoshan Chang

Robert Coleman (PhD)
Evolution of the Tommy Creek Domain and associated rare earth mineralisation.
Supervisors: A/Prof. Carl Spandler, A/Prof. Zhaoshan Chang

Kelly Heilbron (PhD)
Establishing a tectonic framework for the Cretaceous break-up of eastern Gondwana.
Supervisors: Dr James Daniell, Dr Rob Holm, A/Prof. Carl Spandler, A/Prof. Eric Roberts

Peter Illig (PhD)
Magma related hydrothermal gold and base metal deposits in the Chillagoe district, NE Queensland, Australia: relationships, transitions and controls.
Supervisors: A/Prof. Zhaoshan Chang, A/Prof Carl Spandler, Dr Jeffrey Hedenquist, Dr Antonio Arribas

Leigh Lawrence (PhD)
Geochemical investigation of Oligocene-aged alkaline volcanic events in the Rukwa Rift Basin, southwestern Tanzania.
Supervisors: A/Prof. Carl Spandler, A/Prof. Eric Roberts

Xuan Truong Le (PhD)
Geological setting and mineralisation characteristics of the Pac Lang Au-W deposits, Bac Kan Province, northeastern Vietnam.
Supervisors: A/Prof. Zhaoshan Chang, Dr Jan Martin Huizenga

Kairan Liu (PhDI)
Geochronology and formation conditions of the Wolfram Camp W-Mo-Bi deposit, Qld.
Supervisors: A/Prof. Zhaoshan Chang, Dr Yanbo Cheng

Asish Mishra (PhD)
Rates of Erosion and Weathering in the Tropics.
Supervisors: Dr Christa Placzek, Prof. Michael Bird

Stephanie Mrozek (PhD)
Uplift History, Intrusive Sequence, and Skarn Mineralisation at the Giant Antamina Deposit, Peru.
Supervisors: A/Prof. Zhaoshan Chang, A/Prof. Carl Spandler, Prof. Lawrence Meinert

Teimoor Nazari Dehkordi (PhD)
The origin and evolution of heavy rare earth element mineralisation in the Browns Range area, Northern Australia.
Supervisors: A/Prof. Carl Spandler, Prof. Nick Oliver, Prof. Paul Dirks

Prince Owusu Agymang (PhD)
Mesozoic detrital zircon provenance of Central Africa: implications for Jurassic-Cretaceous tectonics, paleogeography and landscape evolution.
Supervisors: A/Prof. Eric Roberts, A/Prof. Carl Spandler, Dr Rob Holm

Alexander Parker (PhD)
Fluids in the lower crust: storage and mobilization.
Supervisors: Dr Jan Martin Huizenga, Dr Ioan Sanislav

Jaime Poblete Alvarado (PhD)
Geological characteristics and origin of the Watershed W Deposit, North Queensland, Australia.
Supervisors: A/Prof. Zhaoshan Chang, Prof. Paul Dirks, Dr Jan Martin Huizenga

Jessie Robbins (PhD)
Understanding the genesis and patterns of cave fill across the Cradle of Humankind, South Africa.
Supervisors: A/Prof. Paul Dirks, A/Prof. Eric Roberts

Behnam Sadeghi (PhD)
Quantification of uncertainty in univariate geochemical anomalies for mineral exploration.
Supervisors: A/Prof. John M. Carranza, Prof. Paul Dirks, Dr Arianne Ford, Dr Jan Marten Huizenga, Prof. Jel Caers (Stanford University).

Fredrik Sahlsströmd (PhD)
Mt Carlton high-sulphidation epithermal deposit, Queensland Australia: Geological characteristics, genesis and implications for exploration.
Supervisors: A/Prof. Zhaoshan Chang, Prof. Paul Dirks

Paul Slezak (PhD)
Evolution and origin of the Gifford Creek Carbonatite Complex: understanding rare earth element mobility in the continental crust.
Supervisors: A/Prof. Carl Spandler

Christopher Todd (PhD)
Sedimentary history of the Porcupine Gorge National Park and application of U Pb detrital zircon geochronology for correlation of Cretaceous and Jurassic strata in northern Queensland.
Supervisors: A/Prof. Eric Roberts, A/Prof. Carl Spandler

Michal Wenderlich (PhD)
Seismic Stratigraphy of the Great Barrier Reef.
Supervisor: Dr James Daniell

Jelle Wiersma (PhD)
Cave sedimentation processes, geochronology, and the distribution of hominins at Rising Star Cave, Cradle of Humankind, South Africa.
Supervisors: A/Prof. Eric Roberts, Prof. Paul Dirks

Matthew Van Ryt (PhD)
Geochemical characterisation of gold mineralisation in Geita Hill, Geita Greenstone Belt, Tanzania.
Supervisors: Dr Ioan Sanislav, Dr Jan Martin Huizenga

Christopher Yule (PhD)
Seismic Stratigraphy and Petroleum Systems of the Mentelle Basin, south west Western Australia.
Supervisor: Dr James Daniell

Postgraduate Student Research Projects

Tegan Beveridge (PhD)
Establishing a tectonic framework for the Cretaceous break-up of eastern Gondwana.
Supervisors: Dr James Daniell, Dr Rob Holm, A/Prof. Carl Spandler, A/Prof. Eric Roberts

Jesse Clarke
SEG Young Professional / BHP Billiton
Presentation: Update on Geology of Olympic Dam

John Menzies
CMI Capital, Cambodia
Presentation: Entrepreneurship & Geoscience

Gerald Dickens
Rice University, Houston
Presentation: Tasman Frontier Subduction Initiation and Paleogene Climate Change

Visitors

Visitors
EGRU Membership 2016

Level 1
Evolution Mining
Mount Isa Mines
South 32, Cannington

Level 2
Newmont Asia Pacific

Level 3
Carpentaria Gold Pty Ltd
Mount Isa Mines
South 32, Cannington

Level 4
CSA Global
Gnomic Exploration Services
Lantana Exploration Services (new 2016)
Mantle Mining
Sandfire Resources (new 2016)
Teck Australia Pty Ltd

Level 5
11 Individual members

Staff Update
Promotions
Eric Roberts to A/Prof.

Conferences/Meetings
attended by staff and students
Goldschmidt Conference
Yokohama, Japan
Carl Spandler, Isaac Corral
Helge Behnsen, Fredrik Sahlsström
Paul Steak, John Wardell
Tesmoor Nazari Dehkordi

IOCG and Other Mineral Systems in the Cloncurry Region: New Advances in Exploration and Deposit Understanding
Zhaoshan Chang, Kaylene Camuti
Jacob Harvey, Mike Rubenach
Peter Illig, Kairan Liu
Mark Sedgman, Peter Illig

AESC Conference Adelaide, South Australia
Zhaoshan Chang, Yanbo Cheng
Jaime Poblete

Palaeontological Society of Sth Africa
Stellenbosch Sth Africa
Eric Roberts, Paul Dirks
Cassy Mteleta
Geological Society of America, MIT Boston USA
Eric Roberts
Geological Society of Australia Meeting
Brisbane QLD
George Case

Digging Deeper, Brisbane QLD
Zhaoshan Chang, Paul Dirks
Gavin Clarke, Isaac Corral
Ariane Ford, Bob Henderson
Helge Behnsen, Fredrik Sahlsström
Jaime Poblete

INTRAW - EU Research Project
2nd Panel of Experts Workshop
Falmouth, Cornwall UK

Jaime Poblete

Industry & Academic Liaison
AMIRA P1162A: Unlocking Australia’s Hidden Mineral Potential Stage 2 Workshops Perth and Adelaide
Zhaoshan Chang, Carl Spandler
Geoscience Australia, Canberra
Zhaoshan Chang, Paul Dirks
Science Academy Canberra
Zhaoshan Chang
Evolution Mining
Zhaoshan Chang

QEC: Exploration Outside the Box
Zhaoshan Chang, Paul Dirks
University of Johannesburg
Jan Huizenga
University of Queensland
Jan Huizenga

Qld Government Resources Reception
Trevor Shaw, Kaylene Camuti
Chinese Academy of Science
Zhaoshan Chang

Anglogold Ashanti, Tanzania
Paul Dirks, Ioan Sanislav

Visiting Speakers
Alan Wilson
International Exploration Manager
Antofagasta Minerals
Nicky White
Cambridge University
David Champion
Geoscience Australia
Patrick Haymen
Southern QLD AusIMM
Julius Kruttitschmidt Lecturer
Pat Williams
Chump Mountain Geoscience
Erik Ramamasooda
CSIRO
Daniel Wood
SEG Student Chapter speaker
Murray Hitzman
Haddon Forrester King Lecturer & SEG International Exchange Lecturer

EGRU Short Courses/Workshops/ Seminars: held at JCU

Ore Textures and Brecia: Recognition Techniques
Gavin Clarke, Eric Roberts
Business and Financial Management for the Minerals Industry
Andrew White, Nick Franey
Integrated Spatial Analysis and Remote Sensing of Exploration Targets
Zhaoshan Chang, Ariane Ford
Carsten Laukamp (CSIRO)
Understanding of, and Exploration for, Epithermal and Porphyry Deposits
Jeffrey Hedenquist
Drill Core, Structure and Digital Technologies (AusIMM & AIG)
Julian Yearncombe

EGRU Short Courses/Workshops: off-campus

IOCG and Other Mineral Systems in the Cloncurry District - Cloncurry QLD

Coordinators - Zhaoshan Chang & Richard Lilly

Structural Geology Short Course - MIM
Ioan Sanislav

Ore Deposit Models & Exploration, Guiyang, China
Zhaoshan Chang
Research Grants

Continuing Grants
Grantee: Paul Dirks, Tom Blenkinsop, Joan Sanislav
Source: AngloGold Ashanti Geita Gold Mine Ltd, Contract Research
Title: Geological Services Geita Gold Mine
Commencing year: 2011
Completing Year: 2016
Amount: $1,818,729.00
Grantee: Carl Spandler
Source: Australian Research Council - Discovery – Future Fellowships
Title: Rare earths unearthed: resolving the mystery of how rare earth elements are mobilised and concentrated in continental crust
Commencing year: 2012
Completing Year: 2016
Amount: $71,099.00
Grantee: Zhaoshan Chang
Source: Compania Minera Antamina S.A.
Title: Investigating the source of enigmatic Pliocene-Quarternary Magnetism in PNG
Commencing year: 2013
Completing Year: 2016
Amount: $200,250.00
Grantee: Zhaoshan Chang, Paul Dirks, Carl Spandler, John Carranza, Jan Huizenga, Bob Henderson
Source: Qld Dept of Natural Resources and Mines, Future Resources Program
Title: Characterising and assessing prospectivity of intrusion-related hydrothermal mineral systems in north-east Queensland
Commencing year: 2014
Completing Year: 2017
Amount: $1,779,736.00
Grantee: Paul Dirks, Eric Roberts, Carl Spandler, Tom Blenkinsop
Source: Australian Research Council – Discovery Projects Grant
Title: Life and death of Australopithicus sediba: how a potential ancestor ended up dead in a cave in world heritage site in South Africa
Commencing year: 2014
Completing Year: 2017
Amount: $254,000.00
Grantee: Zhaoshan Chang, Paul Dirks, Christa Placzek

Source: Evolution Mining Contract Research
Title: Geological Characteristics and Genesis of Mt Carlton High-Sulfidation Epithermal Deposit, and the Implications for Exploration
Commencing year: 2014
Completing Year: 2017
Amount: $150,000.00

New Grants
Grantee: Joan Sanislav, Jan Huizenga, Thomas Blenkinsop
Source: Mount Isa Mines
Title: Geology of the Tommy Creek Block Mount Isa Inlier
Commencing year: 2016
Completing Year: N/A
Amount: $30,000.00
Grantee: Robert Holm
Source: JCU Rising Star
Title: Investigating the the source of enigmatic Pliocene-Quaternary Magnetism in PNG
Commencing year: 2016
Completing Year: N/A
Amount: $30,000.00

Postgraduate and Honours Courses

MGM Postgraduate Courses
EA5024 Business and Financial Management for the Minerals Industry
Andrew White, Nick Fennery
EA5029 Integrated Spatial Analysis and Remote Sensing of Exploration Targets
Zhaojun Chang, Arumue Pond
Carsten Laukamp (CSIRO)

Honours Coursework
Ore Textures and Breccias: Recognition Techniques
Gavin Clarke
Analytical and Optical Mineralogy
Jan Huizenga, Carl Spandler
Geology of Australia
Bob Henderson
Geology of Australia Field Work
Ioan Sanislav
Exploration Geophysics
James Daniel

Student Awards
PhD Candidates

Muhammad Rehman Murtaza Shahm Sadeghi
International Assoc for Mathematical Sciences - travel grant
Ashish Mishra
CSTE 1st prize Seminar Day Best Poster

Honours Candidates
Oliver Fennwick Ross: EGRU Honours Scholarship
Robert Coleman: AusIMM Ian Morley Prize
Tegan Beveridge: AIG Geoscience Honours Bursary

Student Field Trips
SEG Student Chapter – Argentinian and Chilean Patagonia

New PhD Students
Robert Coleman
Kelly Heilbron
Peter Illig
Truong Le
Alexander Parker
Jew Robbins
Jella Wiesema
Mathew van Ryt

PhD Completions
Hannah Hilbert Wolf
Quaid Kahn Jadoon
Shima Kovelva
Cassy Miedela
Qihan Shu

Honours Completions
Tegan Beveridge
Klaudia Diets
Tamara Everall
Oliver Fennwick Ross
Leigh Lawrence
Natalie McIver
John Wardell
Christopher Yule

Professional Development Training, Honours & Masters Courses

Professional Development Training - Industry Enrolments

<table>
<thead>
<tr>
<th>Year</th>
<th>Business &amp; Financial Management</th>
<th>Advanced Field Training</th>
<th>Advanced Techniques in Mining &amp; Exploration Geology</th>
<th>Integrated Spatial Analysis &amp; Remote Sensing of Exploration Targets</th>
<th>Ore Textures Recognition Techniques</th>
<th>IOCG and Other Mineral Systems</th>
<th>Understanding of &amp; Exploration for Epithermal &amp; Porphyry Deposits</th>
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<tr>
<td>2016</td>
<td>3 N/A</td>
<td>N/A</td>
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<td>3 N/A</td>
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Honours & Master Minerals Geoscience Courses - Student Enrolments

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Undergraduate Courses

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<td><strong>Other Professional Services</strong></td>
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<td><strong>TOTAL EXPENSES</strong></td>
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<td><strong>Closing Balance December 2016</strong></td>
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<td><strong>Member Benefits Spent 2016 (workshops)</strong></td>
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<td><strong>2016 Publications</strong></td>
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EGRU 2017

EGRU 2017

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RU News August 2017

5 - 16 February 2018
JCU Townsville

Course Leader
Dr Nick Franey

Course Content
Goals, Strategies and Tactics
- Global and local commercial and political contexts for developing appropriate strategies and tactics in all facets of the minerals business.

Management of People
- Team management,
- Self management,
- Structuring and managing a creative enterprise for success in exploration.

Economic and Financial Management
- Discounted cash flow analysis as a tool for valuation, Project risk ranking,
- Financial risk management,
- Options for mining finance and linking these options with strategy.

Operations Management and Planning
- Organisational management in the resources sector, incorporating budgeting and financial control
- Technical data management and auditing of technical performance
- Management of environmental, legal, business ethics and community issues.

8 - 18 January 2018
JCU, Townsville

Course Leader
A/Prof Zhaoshan Chang

Course Content
This 10 day course is divided into modules. It can include, but is not exclusive to, the following topics:

Spectral Remote Sensing for Mineral Exploration
- Spectral remote sensing with spaceborne/airborne images
- SWIR (short wavelength Infra-Red) spectral techniques and applications

Exploration Geochemistry & GIS-based Prospectivity Analysis
- Geochemistry in mineral exploration
- Univariate analysis of exploration geochemical data

Business & Financial Management for the Minerals Industry
5 - 16 February 2018
JCU Townsville

Course Leader
Dr Nick Franey

Course Content
Goals, Strategies and Tactics
- Global and local commercial and political contexts for developing appropriate strategies and tactics in all facets of the minerals business.

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Operations Management and Planning
- Organisational management in the resources sector, incorporating budgeting and financial control
- Technical data management and auditing of technical performance
- Management of environmental, legal, business ethics and community issues.

- Organisations and regulations affecting the minerals industry.

- Environmental and social issues.

The 2018 calendar of EGRU PD courses and workshops is included on the back cover of this issue.

For further information contact: Judy Botting egru@jcu.edu.au

EGRU Facilities/Equipment

ICP-MS: 2 quadrupole ICP-MS units.
LA (Laser Ablation): GeoLas 200 Excimer Laser Ablation System (193nm)
MC-ICP-MS (Multi-collector-Inductively Coupled Plasma-Mass Spectrometer):
Clean Lab: class 350 clean lab
Microprobe: Jeol JXA8200 “Superprobe” – SWDS, EDS, BSE, SE, CL
SEM: with cathodoluminescence imaging capacity: Jeol JSM5410LV
XRD: Siemens D5000 Diffractometer (XRD)
ICP-AES: Varian Liberty Series II
SWIR spectral instruments: PIMA-SP and specTERRA
Raman microspectrometry facility
Fluid inclusion stage: Linkam MDS600 freezing/heating stage
Melt inclusion / fluid inclusion stage: Linkam TS1500 heating stage
Lapidary/Mineral Separation Laboratory Equipment available includes - RockLabs crusher and splitter, Temeer and Disc mills, Franz magnetic separator, Wilfley table, and dental drill for micro-sampling. Magnetometer: GeoMetrics G 816/826A
Photomicrography set 1: Leica DM2500P microscope + Leica DFC420 C Camera
Photomicrography set 2: Leica DM RXP microscope + Leica DC 300 v2.0 Camera
Magnetic susceptibility meter: Fugro GMS-2 (Serial No: 1942)
Microscopes: Transmitted light + reflected light optical microscopes, including a Nikon Eclipse E400 POL, a Nikon Labophot2 POL, and ~45 Leica microscopes
Gigapan robotic camera
3D visualisation laboratory

EGRU Analytical Capabilities

SWIR (Short Wavelength Infra-Red) spectral analysis
Thermometric measurements of fluid inclusions and melt inclusions
Composition of individual fluid/melt inclusions
Mineral major element compositions by EDS and/or WDS on a Jeol ‘Superprobe’ electron microprobe
Cathodoluminescence (CL), Back-Scattered Electron (BSE) and Secondary Electron (SE) imaging, using SEM and electron microprobe
Full CL wavelength spectra analysis by electron microprobe equipped with a CL spectrometer (XCLent)
Mineral trace element composition
Mineral elemental mapping
Stable isotope analysis (C, O, Cu)
Geochronology (U-Pb on zircon, titanite, monazite, xenotime)
Radiogenic isotope analysis
In situ Lu-Hf and Sm-Nd isotope analyses
High pressure / temperature experiments

For information on EGRU analytical services contact A/Prof. Carl Spandler: carl.spandler@jcu.edu.au
EGRU Members receive discounted registration for EGRU conferences, short courses and workshops.

Membership information is available at http://www.jcu.edu.au/egru/

Delegates attending EGRU conferences, short courses and workshops may earn Professional Development points from their professional bodies.

For further information contact:
Judy Botting, egru@egru.edu.au

2018 Calendar
Professional Development Courses

8 - 18 JANUARY
Integrated Spatial Analysis
JCU, Townsville, Qld

23 - 25 JANUARY
Ore Textures Recognition Techniques
JCU, Townsville, Qld

29 - 30 JANUARY
Core Logging Techniques
JCU, Townsville, Qld

5 - 16 FEBRUARY
Business & Financial Management
JCU, Townsville, Qld

13 - 16 FEBRUARY
Analytical Mineralogy
JCU, Townsville, Qld

19 - 21 FEBRUARY
Optical Mineralogy
JCU, Townsville, Qld

13 - 16 MARCH
IOCG Workshop
Cloncurry, Qld

18 - 26 MARCH
Exploration Geophysics
JCU, Townsville, Qld

9 - 13 APRIL
Geology of Australia
JCU, Townsville, Qld