Intrusion-Related Gold Systems of north Queensland & new ideas from Charters Towers Province

Gregg Morrison & Simon Beams
Intrusion-Related Gold Deposit (IRGD)
A deposit spatially and temporally related to an intrusion where Au (Ag) is the only commodity

Intrusion-Related Gold System (IRGS)
The area of intrusions and hydrothermal features (alteration, breccias, mineralisation) that may enclose a deposit

Intrusion-Related Mineral System (IRMS)
The clan of magmatic hydrothermal systems with a variety of metals (Cu Mo W Sn)
System Components
Mount Leyshon

- 1km diameter deposit 3.5Moz
- 2km diameter breccia pipe with multi-phase intrusions and mineral occurrences
- 3km reverse magnetic anomaly magnetite-biotite alteration on an inferred diorite stock
- 4km long chargeability anomaly due to pyrite - sericite alteration
- 4km x 2km intrusion-centred magmatic-hydrothermal system all components 290+/5 Ma
- **Systems more common than deposits**
Metal Zoning
(Kidston)

• Polymetallic system
• Classical zoning on a Thermal gradient
• Au only in one zone with Pb-Zn-Cu
• Mo-W-Bi Core
• Exposed distal BM

CLASSIFY
PINPOINT AU
IRGS NQ: *metal zoning patterns for different core associations*

<table>
<thead>
<tr>
<th>METAL ZONING</th>
<th>general</th>
<th>Cu-Au</th>
<th>Cu-Mo</th>
<th>Mo-W-Bi</th>
<th>Sn-W</th>
<th>Sn-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>MARGINAL</td>
<td>Ca, F</td>
<td>Ca</td>
<td>Ca</td>
<td>F, U</td>
<td>F, Ba, Se, Hg, U</td>
<td>F</td>
</tr>
<tr>
<td>DISTAL (As)</td>
<td>As Sb</td>
<td>Au As Sb</td>
<td>(As, Sb, Au)</td>
<td>(As Ag Sb Au)</td>
<td>As (Au)</td>
<td>As</td>
</tr>
<tr>
<td>DISTAL (BM)</td>
<td>Pb, Zn, Ag,</td>
<td>Pb Zn Ag Au (Cu Mo Te)</td>
<td>Pb Zn Ag (Au, Bi)</td>
<td>Zn Cu Pb Bi Au</td>
<td>Pb Ag Zn</td>
<td>Zn Pb Ag</td>
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<tr>
<td>PROXIMAL (BM)</td>
<td>Cu Mo</td>
<td>Cu (Zn)</td>
<td>Cu Au Ag (Bi Te)</td>
<td>Cu (Au Bi Te)</td>
<td>Cu Mo Bi</td>
<td>Cu Bi Mo (W)</td>
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<tr>
<td>CORE</td>
<td>core</td>
<td>Cu Au (Te)</td>
<td>Cu Mo</td>
<td>W Mo Bi</td>
<td>Sn W</td>
<td>Sn B (W)</td>
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<tr>
<td>Example</td>
<td>Goonumbla</td>
<td>Mount Leyshon</td>
<td>Kidston</td>
<td>Herberton</td>
<td>Cooktown</td>
<td></td>
</tr>
</tbody>
</table>

- Broadly similar patterns of metal zoning **core → Cu → Zn-Pb → As-Sb → Ca**
- Progression of core associations siderophile to lithophile, mafic to felsic
- Diagnostic metals  **Te mafic, Bi-Te intermediate, Bi felsic, Sn-W min melt**
- Best gold is more distal in zoning for more lithophile associations
IRGS NQ: *igneous type - core metal mapping*

Phil Blevin redox-fractionation plot links igneous rock type to core associations. Dave Champions maps show the distribution of igneous types.

→ Maps that identify prospective areas for core metal associations.
IRGS NQ: wide range of emplacement levels & styles

NQ IRGS MODEL

Crustal range for levels of emplacement reflected in intrusion form

Porphyry level dominant in NQ

Plutonic level in Yukon & Braidwood

Vein & breccia styles dominant reflects qz-fs basement

3 metal associations reflect fluid conditions
## IRGS NQ

### NQ Au total and >1Moz deposits

<table>
<thead>
<tr>
<th>CLAN</th>
<th>TOTAL Moz</th>
<th>Deposit Moz</th>
<th>DEPOSIT</th>
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<tbody>
<tr>
<td>IRGS</td>
<td>19.3</td>
<td></td>
<td>5.0 Kidston</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>4.8 Ravenswood</td>
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<td></td>
<td></td>
<td></td>
<td>3.5 Mt. Leyshon</td>
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<tr>
<td></td>
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<td>2.1 Red Dome</td>
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<tr>
<td></td>
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<td>1.1 Mungana</td>
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<td></td>
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<td>1.1 Mt. Wright</td>
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<tr>
<td>Epithermal</td>
<td>8.9</td>
<td></td>
<td>3.6 Pajingo</td>
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<td>1.4 Mt. Carlton</td>
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<td>1.1 Wirralie</td>
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<tr>
<td>Orogenic granite-hosted</td>
<td>8.6</td>
<td>6.8</td>
<td>Charters Towers</td>
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<td></td>
<td></td>
<td>1.0</td>
<td>Croydon</td>
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<tr>
<td>Orogenic turbidite-hosted</td>
<td>1.3</td>
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<td>Hodgkinson</td>
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<td>Placer (estimated)</td>
<td>~4</td>
<td>1.6</td>
<td>Palmer River alluvials</td>
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<tr>
<td>VMS total</td>
<td>0.3</td>
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</tbody>
</table>

**For NQ**

- >40Moz total endowment
- Nearly half IRGS
- Mostly since 1985
- Some bi-product Cu
- But no major Cu deposits

**So NQ is an IRGS Province**

one of only a few in the world
**Townsville Mornington Island Belt**

is oblique to the arc
Cauldron subsidence => extension
K-rich rhyodacite magma
Crustal melts by under-plating
Au-Sn-W-Mo-U metallogeny
IRGS dominant

**Connors arc**

extensive under Bowen Basin
Andesite stratovolcanoes
Cu-Mo-Au metallogeny
Porphyry Cu dominant

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**Legend**

- Igneous Province
- Subduction Complexes
- Forearc
- Volcanic Arc
- Continental Basin
- Basement

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**KLONDIKE**
IRGS NQ  IRGS CAMPS ON KENNEDY IGNEOUS

- 320-310Ma
- 340-330Ma
- 300-290Ma scattered
- 310-300Ma

Kennedy Igneous Association
- Intrusive Unit
- Volcanic Unit

Deposit depth zone
- Epizonal
- Mesozonal
- Hypozonal

Towns

Map showing the locations of camps on the Kennedy Igneous Association with different age ranges and deposit depth zones.
CT IRGS: Setting of ChartersTowers Province

- CT is the best exposed part of the Cambro-Ordovician Thomson Orogen
- Proterozoic metased basement under TO & Mossman Orogen to north
- Cambro-Ordovician sediments, felsic volcanics & felsic granitoids
- Siluro – Devonian granitoids
- boundary faults to Dev-Carboniferous basins
- E boundary tectonic obscured by Carb-Permian Kennedy Province
CT IRGS: basement geology domains

Separate Ordovician and older felsic granitoids and meta-sediments
From Siluro-Devonian granodiorite in Ravenswood domain
Concentrated Au & basemetal in Ravenswood Domain (Sil-Dev granodiorite) Basemetal Mt Windsor belt (Ord) & Cu-Mo porphyry in Ravenswood (Dev) Oweenee stitching pluton brings Sn-W(Carb)
### CT Metallogenic: Mineral System Classification

<table>
<thead>
<tr>
<th>Clan</th>
<th>Deposit Type</th>
<th>Geochem Type</th>
<th>Epoch</th>
<th>Type Example</th>
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</thead>
<tbody>
<tr>
<td>Orogenic (granitoid hosted)</td>
<td>lode hypozonal</td>
<td>Au-BM-As</td>
<td>S-D</td>
<td>Hadleigh Castle</td>
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<tr>
<td></td>
<td>lode mesozonal</td>
<td>Au-BM</td>
<td>S-D</td>
<td>Charters Towers</td>
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<tr>
<td>Intrusion-related (reduced)</td>
<td>vein hypozonal</td>
<td>Au-PM-Te</td>
<td>C-P</td>
<td>Brookville</td>
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<td>lode mesozonal</td>
<td>Au-PM-Te</td>
<td>C-P</td>
<td>Ravenswood</td>
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<td>breccia mesozonal</td>
<td>Au-PM-Bi</td>
<td>C-P</td>
<td>Mt Leyshon</td>
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<tr>
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<td>breccia epizonal</td>
<td>Au-As</td>
<td>C-P</td>
<td>Antimony Dam</td>
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<tr>
<td></td>
<td>Vein network epizonal</td>
<td>Au-PM-Bi</td>
<td>C-P</td>
<td>Far Fanning</td>
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<tr>
<td></td>
<td>vein epizonal</td>
<td>Au-PM-Bi</td>
<td>C-P</td>
<td>Wellington Springs</td>
</tr>
<tr>
<td>Intrusion-related (oxidized)</td>
<td>stockwork hypozonal</td>
<td>Cu-Mo</td>
<td>S-D</td>
<td>Titov</td>
</tr>
<tr>
<td></td>
<td>High-sulfidation epith.</td>
<td>Au-PM-Bi</td>
<td>P-Tr</td>
<td>Mt Carlton</td>
</tr>
<tr>
<td>Epithermal</td>
<td>Low-sulfidation vein</td>
<td>Au-BM</td>
<td>C-P</td>
<td>Pajingo</td>
</tr>
<tr>
<td></td>
<td>Low-sulfidation hotspring</td>
<td>Au-As</td>
<td>C-P</td>
<td>Wirralie</td>
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<tr>
<td>Volcanogenic</td>
<td>Au-rich VMS pipe</td>
<td>Au-BM</td>
<td>E-O</td>
<td>Highway</td>
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<tr>
<td>Placer</td>
<td>Au-rich VMS stratiform</td>
<td>Au-PM</td>
<td>E-O</td>
<td>Thalanga</td>
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<tr>
<td></td>
<td>Alluvial</td>
<td>Au</td>
<td>Rec</td>
<td>Leyshon view</td>
</tr>
</tbody>
</table>

**Diagram:**

- Triassic
- Permian
- Carboniferous
- Devonian
- Silurian
- Ordovician
- Cambrian
- Neoproterozoic

**Mineral Systems:**

- Orogenic Au
- Epithermal Au
- Porphyry Au

**Locations:**

- Mt Carlton
- Burra-Mina Camp
- Oxford Mt
- Laguna Mt
- Ravenswood
- Charters Towers
- Wellwasser
- Neoproterozoic Metamorphism
CT IRGS: Gold Camps by Clan
CT IRGS: main commodity for Permo-Carb Camps on Domains
CT IRGS: Basement domains control IRGS type

Legend:
- Epithermal Camps
- Intrusive Camps
- PermoCarb Volcanic Units
- PermoCarb Intrusive Units
- Domain Boundaries
- Drummond Basin Boundary

Map showing the distribution of different geological features such as Stocks-dikes, plutons, and the Mo-WCu-Mo plutons. The basement domains control the type of IRGS.
CT IRGS: Reverse mag anomalies
Three Sisters System reverse magnetic anomaly
Related to biotite- magnetite alteration around an inferred dioritic intrusion

N Lisowiec, Resolute Mining
IRGS CT:  Three Sisters geology

N Lisowiec, Resolute Mining
IRGS CT: Three Sisters metal zoning
IRGS CT  Mt Wright soil and rock metal zoning

- 3km diameter soil anomaly Zn, Bi, Au only 5ppb on hill

- 1km tall system, well zoned
  - Au 0.1ppm at surface
  - Best Au ore 500-800m below
**Classification using multi-metal data**

Based on 13 metal set Au Ag As Sb Pb Zn Cu Bi Te Mo W Sn
Normalised to host or related intrusion
Classified in terms of relative enrichment
Scheme based on ~100 examples from Charters Towers region

**CLASSIFICATION SCHEME**

<table>
<thead>
<tr>
<th>AU+BM (NO BI +/-AS, TE)</th>
<th>OROGENIC GRANITE-HOSTED TYPE e.g. Charters Towers</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU BI TE AS SB (+/-BM)</td>
<td>PLUTONIC IRGS TYPE and or mafic intrusion e.g. Ravenswood</td>
</tr>
<tr>
<td>AU-BI-BM +/-TE</td>
<td>PORPHYRY AU TYPE and or intermediate intrusion e.g. Mt Leyshon</td>
</tr>
<tr>
<td>AU BI MO W +/- BM</td>
<td>PORPHYRY AU TYPE with felsic intrusion e.g. Mt Remarkable, Kidston</td>
</tr>
<tr>
<td>AU AG TE</td>
<td>LOW SULFIDATION EPITHERMAL VEINS e.g. Pajingo</td>
</tr>
<tr>
<td>AU AG AS</td>
<td>EPITHERMAL HOTSPRING DEPOSITS e.g. Wirralie</td>
</tr>
<tr>
<td>AU AG TE AS +/- BM</td>
<td>HI-SULFIDATION EPITHERMAL e.g. Mt Carlton</td>
</tr>
</tbody>
</table>
- A distinct NQ IRGS province with +20Moz
- Existing work defines >150 systems
- ~30 explored well
- In current climate good targets can be identified in system interpretation
- Especially via system facies geometry & multi-element geochemistry