Pathways between skarns and porphyry deposits – A New South Wales Perspective

David Forster
Cadia Skarns

*Skarns were important to the discovery of Cadia
*Recognition of skarn alteration helped to focus exploration at Cadia toward the largest porphyry system in Australia.
Pathways between skarns and porphyry deposits – A NSW Perspective
# Pathways between skarns and porphyry deposits

## Skarn : Porphyry Ratio

**Table 1.** Examples of porphyry and skarn deposits

<table>
<thead>
<tr>
<th>Skarn Name &amp; Location</th>
<th>Porphyry Resource (wt%Cu, ppm Au)</th>
<th>Skarn Type &amp; Skarn Resource</th>
<th>Porphyry:Skarn Ratio</th>
<th>Skarn Protolith</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Cadia and Little Cadia* NSW Australia</td>
<td>'Cadia Hill &amp; 'Cadia Quarry 352Mt @ 0.16% Cu &amp; 0.63 ppm Au; '40Mt @ 0.21% Cu &amp; 0.4 ppm Au</td>
<td>FeCuAu</td>
<td>1:12</td>
<td>Volcanic sandstone &amp; conglomerate, limestone blocks</td>
</tr>
<tr>
<td></td>
<td>Cadia East 220Mt @ 0.37 Cu &amp; 0.43 Au</td>
<td>Little Cadia 8Mt @ 0.5% Cu &amp; 0.3 ppm Au</td>
<td>1:28</td>
<td>Volcanic sandstone</td>
</tr>
<tr>
<td>Ingerbelle BC, Canada²</td>
<td>Simikameen skarn+² porphyry 141Mt @ 0.47% Cu &amp; 0.13%Cu³</td>
<td>CuAu 42.6Mt @ 0.45% Cu, 0.63 ppm Au²</td>
<td>1:21</td>
<td>Calcareous mass flow deposits</td>
</tr>
<tr>
<td>Ok Tedi Papua New Guinea</td>
<td>439Mt@0.59% Cu &amp; 0.51Au³</td>
<td>AuCu 28.8M @ 1.58 ppm Au, 1.25% Cu</td>
<td>1:15</td>
<td>Limestone</td>
</tr>
<tr>
<td>Big Gossan Indonesia</td>
<td>Porphyry not defined</td>
<td>34.7M @ 2.69% Cu</td>
<td>n.a.</td>
<td>Limestone, dolostone siltstone</td>
</tr>
<tr>
<td>Kucing Liar AuCu Indonesia</td>
<td>Au-Cu 220M @ 2,796M @ 0.97ppm Au &amp; 0.09% Cu⁴</td>
<td>Au-Cu 1.57ppm Au, 1.42%Cu (much more ore in “heavy sulfide” zones)</td>
<td>1:12</td>
<td>Limestone</td>
</tr>
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Pathways between skarns and porphyry deposits

Photo P Downes
Pathways between skarns and porphyry deposits

Ok Tedi Mine- Rush & Seegers, 1990)
Porphyry-Skarn Ratio 15:1
Pathways between skarns and porphyry deposits

Skarn : Porphyry Ratio ~1:12

Pathways between skarns and porphyry deposits
Pathways between skarns and porphyry deposits

Big Cadia Cu & Au distribution - 13000E

Lithology
- Lapilli volcaniclastics
- Conglomerate & volcanic breccia
- Limestone
- Fine-grained phric volcanic rocks, & feldspar & pyroxene intrusions

Calccheous volcaniclastic sandstone
Fault inferred
Au >0.5 ppm
Cu >5000 ppm
Au 0.2-0.5 ppm
Cu 2000 - 5000 ppm

See Fig. 4A for geology of southern area

PC40 Fault Zone

Exploration in the House Thursday, June 18, 2009 NSW Parliament House Theatrette
Interpretive cross section - Alteration - Cadia Quarry - Big Cadia 13050 +/- 40m

Cadia Quarry

Big Cadia

[Diagram of geological cross section]

[Note: The image includes a geological cross section diagram with various layers and features labeled, along with related images of rock samples.]
PATHWAYS! Big Cadia Skarn Zonation = Fluid Evolution In Space... AND Time

- Alteration zonation is reflected by temporal skarn development
- Alteration matches at all scales

Zoned Garnet-Rich Vein
Pathways between skarns and porphyry deposits

Key
Stage-1
- Garnet (zoned)
Stage-2
- Epidote
- Magnetite-Quartz
- Savage peach Quartz

Magnetite-Quartz (Wallrock style)

Late fluid egress from vein

Stage 1

Stage 2
Progressive replacement of hematite to magnetite to pyrite ADVANCE OF SKARN FRONT ($fO_2$ decline) with time then $T$ increase so effective pH decline
Interpretive cross section - Alteration Cadia East - Little Cadia 15600 +/- 100m

Drill Holes - see Fig. 4A
Cadia Quarry — Big Cadia
Mass-Balance Change
Measured gains and losses for Skarn Zones
Pathways between skarns and porphyry deposits

Cadia Mass-Balance Change — Cu

Cadia Quarry (Porphyry)  Big Cadia (Skarn)

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EARLY-STAGE SKARN FORMATION
CADIA

Cadia Mass-Balance Change  (Methodology by Gresens, 1967)
Pathways between skarns and porphyry deposits

EARLY-STAGE SKARN FORMATION
CADIA

Cadia Mass-Balance Change (Methodology by Gresens, 1967)
Sources of Fe (as Fe\textsubscript{2}O\textsubscript{3}) – Big Cadia

1) Volcanic Sandstone 7%
2) Conglomerate ~8%
3) Fine-grained volcanic rocks 9%
4) CIC

~10% Fe\textsubscript{2}O\textsubscript{3}
(Or 6% for mineralising phase)
Cadia Mass-Balance – Implications

- The Source of Fe for Big Cadia Fe-Cu-Au skarn – (~45 Mt of (tot) Fe) source must have been the CIC
- The volume Fe mobilised from about 108 M m³ of altered CIC quartz monzonite, presently identified at Cadia Quarry (Cadia Extended), assuming 6 wt % Fe₂O₃
- This is accounts for ~1/3 of the (tot) Fe contained in the distal Big Cadia iron skarn alone (not including modest addition of Fe in more proximal skarn zones!)
- Additional source(s) of Fe are speculative, but could include the Cadia Hill system and/or…….
- Include additional, unidentified zones of alteration?
  e.g. Cadia Hill+Cadia Extended / Big Cadia = ~1:12
### Pathways between skarns and porphyry deposits

#### Skarns vs Associated Porphyry Deposits

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Skarns can be key to understanding fluid dynamics in the porphyry environment

Therefore: Not only do skarns provide vectors to ore but they may provide clues as to scale of blind porphyries

Recognition of skarn mineralisation at Big Cadia was important to the recognition of the large Cadia Porphyry System.

Don’t forget the poor “little” skarns at your porphyry!
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With permission of the Director General –
Department of Primary Industries, New South Wales
Big Cadia (Iron Duke)

From ~1850-1945 mining was focused on the Cadia skarns (and Little Cadia)
Largest skarns in Australia

Production of Cu totaled ~140 000 t @ 5-7% and >1.5Mt Fe
The skarns are key to understanding the genesis of the Cadia district