Architectural controls on Palaeozoic porphyry Au-Cu mineralisation in the Cadia Valley, NSW

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### Cadia district - resources

<table>
<thead>
<tr>
<th>Deposit</th>
<th>Resource (Mt)</th>
<th>Au (g/t)</th>
<th>Cu (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alkalic porphyry Au–Cu</strong></td>
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<tr>
<td>Cadia East</td>
<td>2,347</td>
<td>0.44</td>
<td>0.28</td>
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<tr>
<td>Cadia Hill</td>
<td>427</td>
<td>0.43</td>
<td>0.12</td>
</tr>
<tr>
<td>Ridgeway</td>
<td>152</td>
<td>0.77</td>
<td>0.39</td>
</tr>
<tr>
<td>Cadia Quarry / Extended</td>
<td>53</td>
<td>0.39</td>
<td>0.22</td>
</tr>
<tr>
<td><strong>Magnetite Cu–Au skarn</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big Cadia</td>
<td>37</td>
<td>0.34</td>
<td>0.47</td>
</tr>
</tbody>
</table>

**District total:** 44 Moz Au, 7.98 Mt Cu
Evolving low-relief, multiple vent volcanic complex developed across an area of active marine sedimentation

• Vents comprised mafic to intermediate lava flows, cryptodomes, dykes and sills
• Stacked lava sequences, including hyaloclastites, massive lavas and their reworked equivalents, are up to 1 km thick
Ordovician volcanism and sedimentation

- The volcaniclastic units contain rare mid-Darriwilian (Da2-3) to late Gisbornian (Gi2) graptolites (reworked?)
- There are also conodonts, brachiopods, fragmentary coral and trilobites
- Detrital zircons from the Weemalla Fm have U-Pb ages ~454 Ma
- Faunal ages that are diagnostically Eastonian (Ea3 - ca. 452 Ma) have been recognized in the upper parts of the FRV
- The Forest Reefs Volcanics were deposited during the Eastonian, between 454 and 452 Ma
Magmatism and mineralisation

- Mineralisation and alteration was centred on monzonite pipes at Ridgeway, and dykes at Cadia East
- Mineralisation occurred within larger monzonite plutons at Cadia Hill and Cadia Quarry
- Quartz - sulfide - carbonate veins are the predominant mineralisation style (sheeted and stockwork)

• The Cadia district has been dismembered by steeply-dipping faults, some with offsets of 100s of metres...

• This has juxtaposed different levels of the magmatic-hydrothermal system, and disrupted the cover sequence
Silurian sedimentation and later deformation

- Deformed Silurian sub-basins cover the dismembered Cadia Hill deposit
- Scale of thrust-related movement differs between the basement and cover rocks

Washburn (2008)
Cadia East - a 33 Moz gold resource

- Largest known gold deposit in eastern Australia
- World’s sixth largest porphyry deposit in terms of contained Au
- Total resources of 2.3 billion tonnes at 0.44 g/t Au and 0.28 % Cu
- Contains more than 70% of the Cadia district Au resource

- Mineralised zone ~2 km long, 600 m wide and >1500 m in vertical extent
- Significant variations in mineralisation and alteration styles with depth

Ore shell projected to surface from 5430mRL; bulk ore grade models (data from Newcrest Mining Ltd.)
Host rocks:
- Polymict volcanic conglomerates and intermediate to basic lavas and associated autobreccia

Pre-mineralisation intrusions:
- Basaltic-andesite dikes and sills

Mineralising intrusions:
- Early Silurian (c. 437 Ma) alkalic monzonite - monzodiorite dikes surrounded by concentric zones of mineralisation and alteration

Styles of mineralisation:
- Deep-level W-NW- trending sheeted quartz-sulphide vein array
- Shallow level, disseminated stratabound orezone
Sheeted vein-style mineralisation (deep level)

- W- to WNW-striking orebody
- Sheeted quartz – calcite – feldspar veins with bornite – chalcopyrite ± molybdenite
- High grade veins dip steeply N and S
- K-feldspar – magnetite – biotite ± actinolite alteration halos

Gold grades projected to surface from 4260mRL grade model (data from Newcrest Mining Ltd.)
Replacement-style Cu – Au mineralisation (shallow level)

- Disseminated Cu – Au – Mo mineralisation forms large NW-striking ore zone
- Associated with biotite – tourmaline – chlorite ± albite – chalcopryite alteration
- Lithologically controlled with preferential development in polymict breccias

Gold and copper grades projected to surface from 5430mRL grade model (data from Newcrest Mining Ltd.)
Stratigraphic marker horizons - upper Forest Reefs Volcanics

Planar laminated volcanic siltstone:
- 5 to ~40 m thick unit deposited in a below wave-base environment
- Extensively ab-ser-chl-py altered

Polymict volcanic breccia:
- Abundant subaqueous debris flows; some beds up to 30 m thick
- Early bi-tm-cp alt; late qz-ab-or-cc-ser-tm

Calcareous volcanic sandstone:
- Laterally extensive, 5 to 70 m thick unit
- Extensively epi-gt-chl-cal-py ± cp altered
• Geometrical modelling by Newcrest geologists suggest that active fault-bounded sub-basins localised sedimentation of calcareous sandstone and feldspathic siltstone units in the upper Forest Reefs Volcanics.
Five NNE-oriented cross-sections show sequential offset of the calcareous volcanic sandstone

- *Half graben geometry defined at the eastern end of Cadia East*
- *Graben geometry defined at the western end*

Sections taken from wireframe model of bedded units (Newcrest Mining Ltd.)
Gold mineralisation

- Early Silurian monzonites intruded pre-existing basin-bounding faults
- High grade sheeted veins are oriented sub-parallel to the monzonites, and generated a ~2 km long, E-trending orebody
Copper mineralisation

- Lower grade disseminated mineralisation developed in graben infill (polymict breccias)
- This unit was permeable to magmatic derived hydrothermal fluids during mineralisation and subsequent alteration

Copper grades projected to surface from 5430mRL grade model (data from Newcrest Mining Ltd.)

Silurian cover
Calcereous volcanic sandstone

Section 15220mE

Cu Grade
- >0.1 % Cu
- >0.3 % Cu
- >0.5 % Cu
Restoration of the deformed state cross sections allow for an improved understanding of syn-mineral structure.
1-2 km

2-3 km

444 Ma surface

Structural Reconstruction
Ordovician-Silurian Alteration Distribution

439 Ma surface

1-2 km

2-3 km

437 Ma surface

~300°C
10 wt.% NaCl eq.

~600°C
10 wt.% NaCl est.
High CO₂

Alteration Facies
Potassic and Sedic Alteration Assemblages
- K-feldspar-magnetite
- K-feldspar-albite - chlorite-magnetite (calcite-epidote)
- albite - chlorite-magnetite (hematite-epidote)

Propylitic Alteration Assemblages
- chlorite - hematite (calcite-epidote-albite)
- chlorite (calcite-epidote)

Phyllic Alteration Assemblages
- sericite-quartz-pyrite (albite)

Calc-silicate Alteration Assemblages
- garnet (pyroxene-calcite-epidote)
- magnetite (pyrite)
- epidote
System preservation

Skarn clasts in boulder conglomerate covering Cadia East

2 m.y. approx. 1-2 km of erosion
0.5mm/yr (1km)
Conclusions

- The FRV and Weemalla Formation are proximal and distal volcanic facies that accumulated in a marine basin on the flank of the Macquarie Arc during the Eastonian (454 - 452 Ma).
- Porphyry emplacement occurred in the Late Ordovician and Early Silurian during the Benambran Orogeny, associated with periods of basin inversion and relaxation.
- Facies architecture and deformation localised and strongly influenced the styles of hydrothermal alteration and mineralisation.
Conclusions

Silurian cover sequence, Cadia Hill

- The Cadia district was exhumed in the Early Silurian and buried again in the mid-Silurian
- Basin inversion helped to localize these world-class porphyry ore deposits, and also dictated the tectonic and surficial processes that ultimately lead to their preservation
Thanks to Newcrest Mining Ltd for their on-going support and for permission to give this presentation.