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

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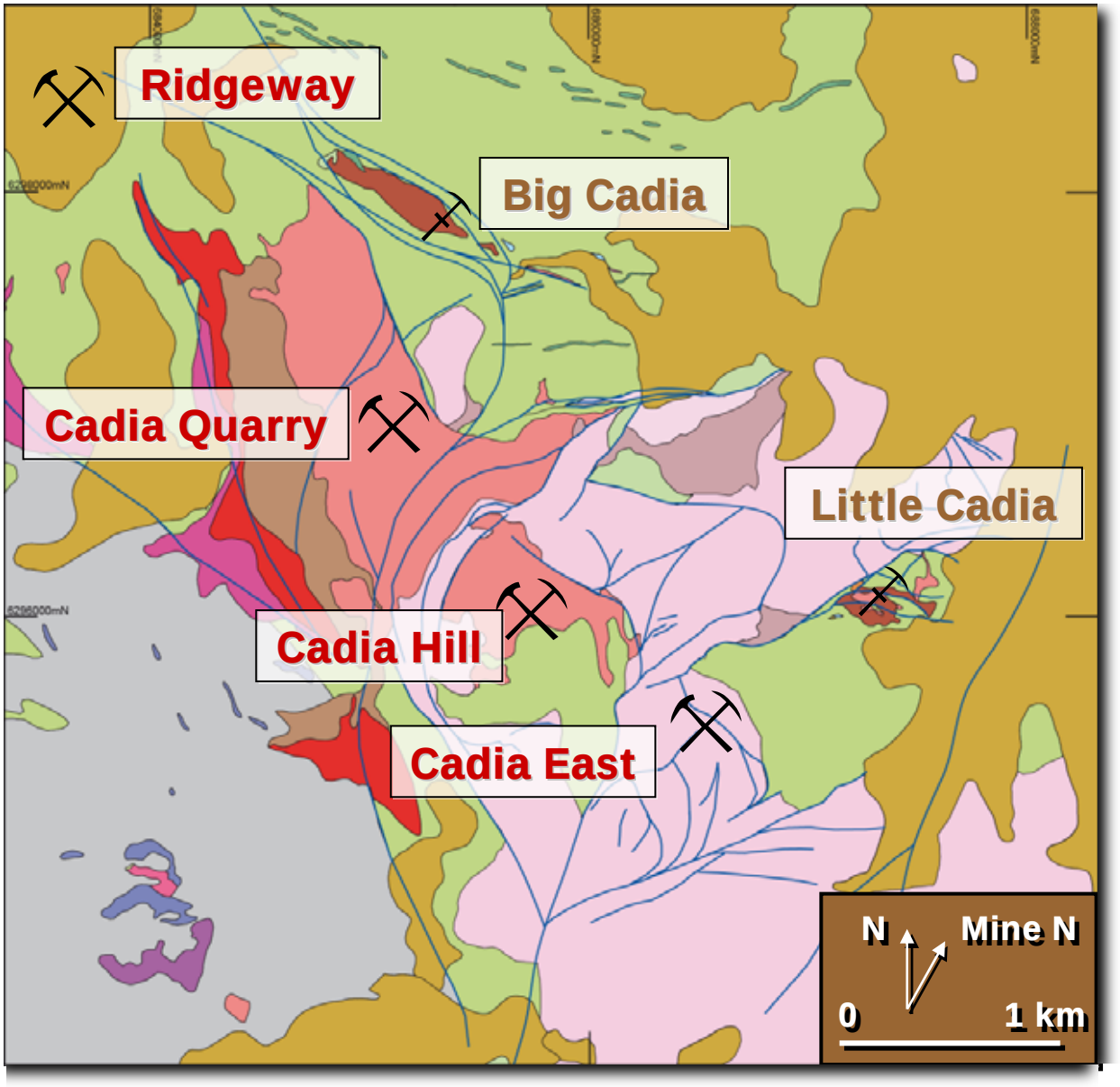
Cadia district – resources

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

District total: 44 Moz Au, 7.98 Mt Cu

Cadia district – geology



Tertiary

- Basalt

Middle Silurian

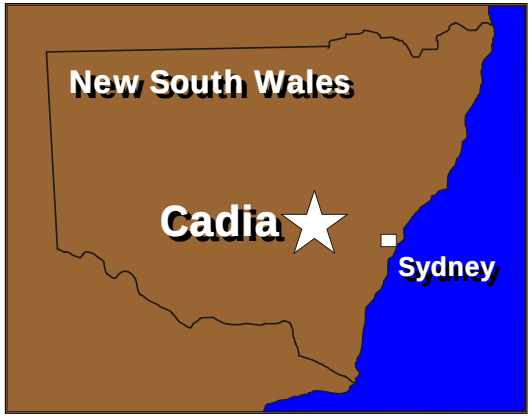
- Waugoola Group

Ordovician - Silurian

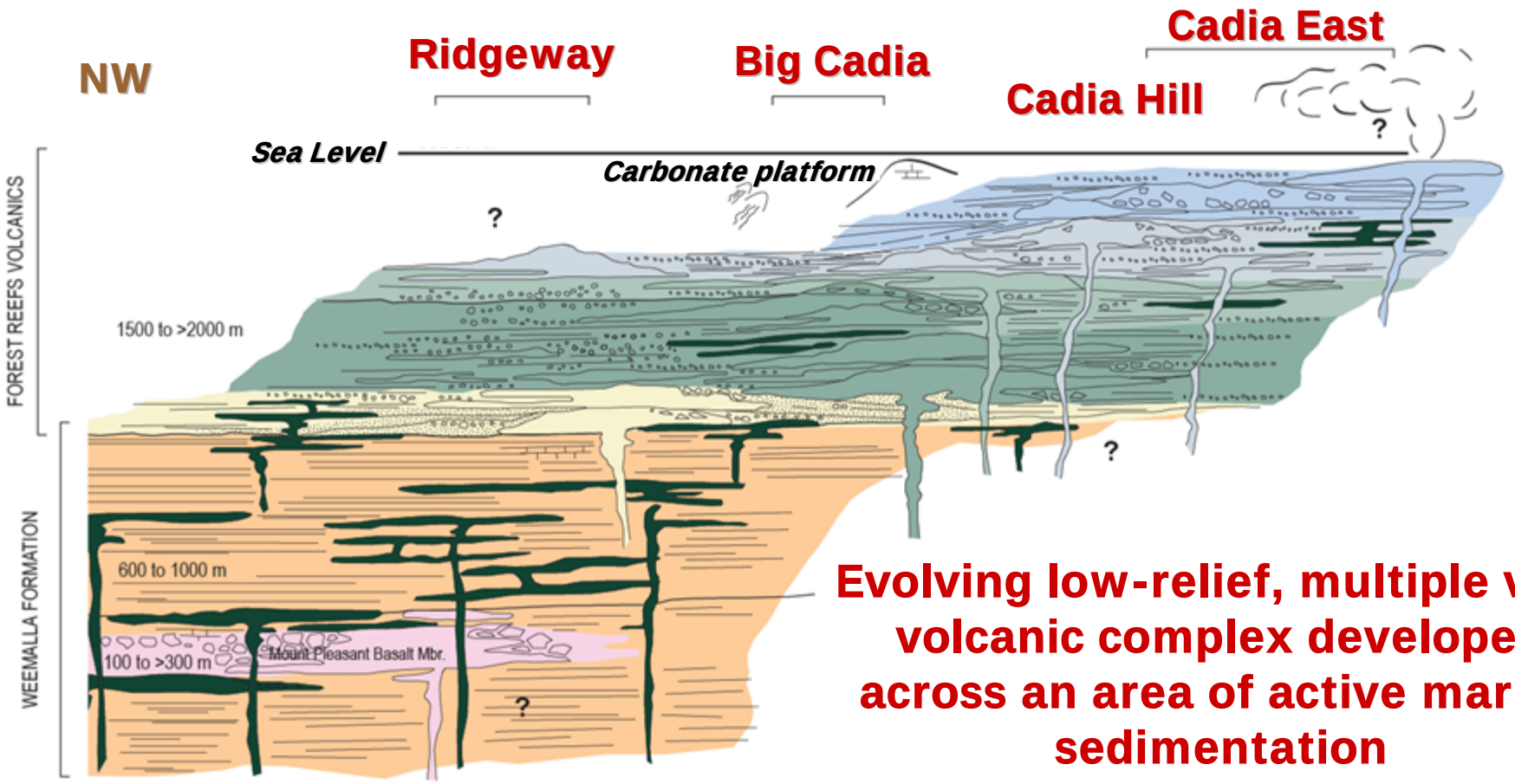
- Cadia Intrusive Complex

Ordovician

- Forest Reefs Volcanics
- Weemalla Formation

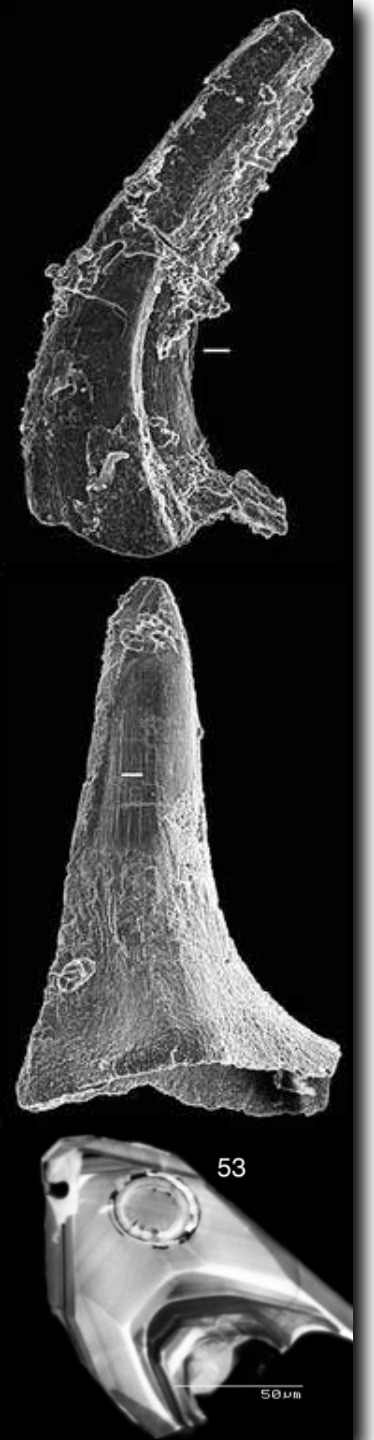


Volcanic architecture



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**

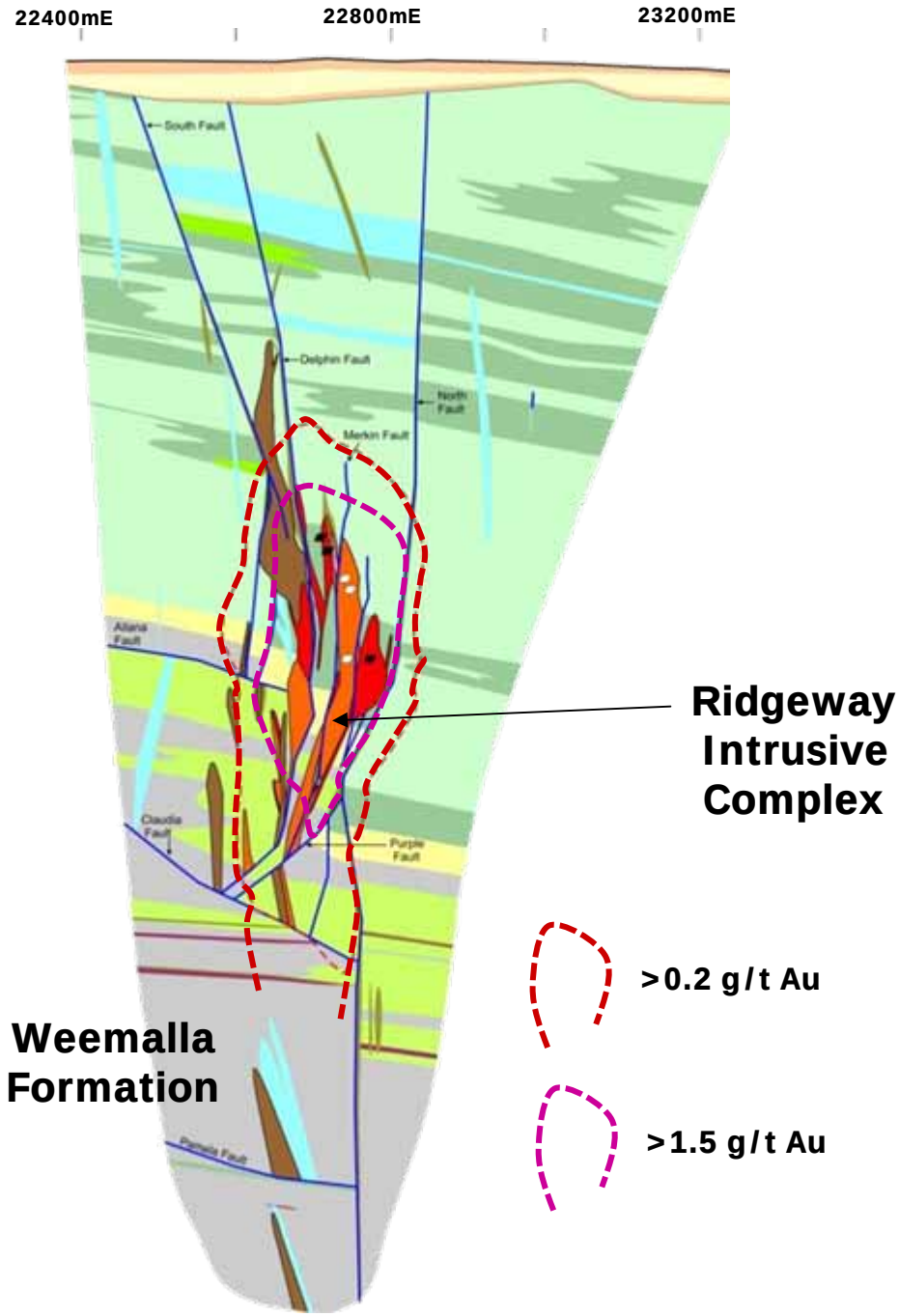


Ordovician volcanism and sedimentation

- 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)



Ridgeway Section 11050E - unpubl. Cuison (2010)

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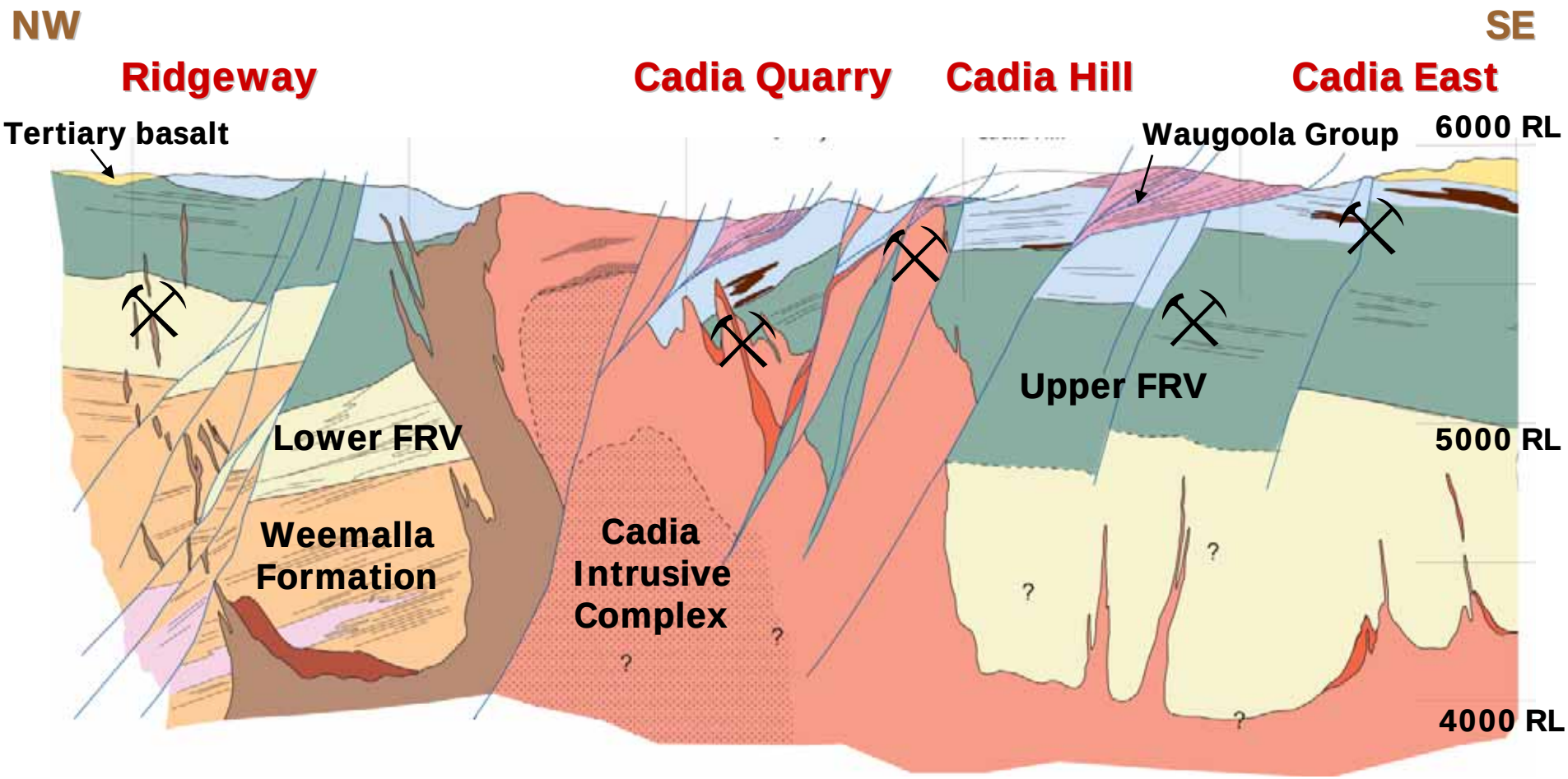
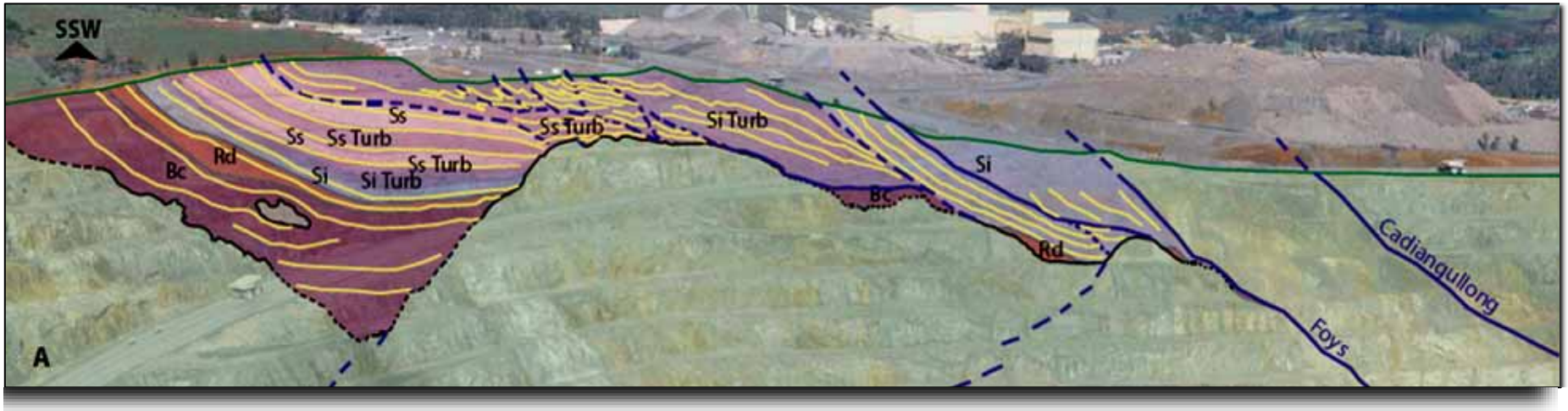
Cadia district – long section



- **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

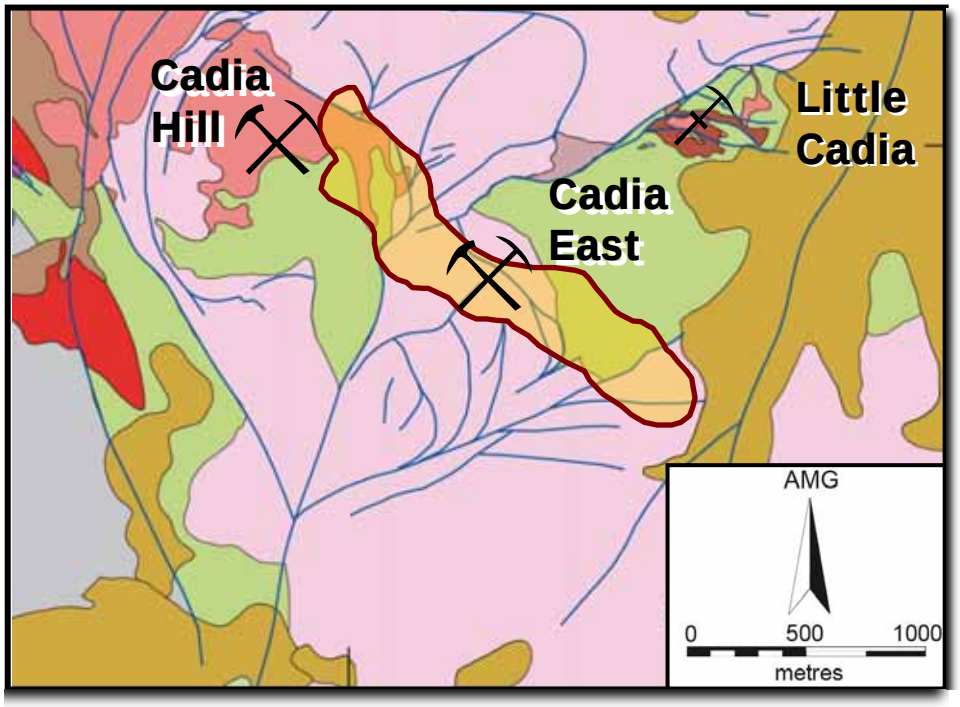
- Deformed Silurian sub-basins cover the dismembered Cadia Hill deposit



- 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.)

Cadia East – Geology

Host rocks:

- Polymict volcanic conglomerates and intermediate to basic lavas and associated autobreccia

Pre-mineralisation intrusions:

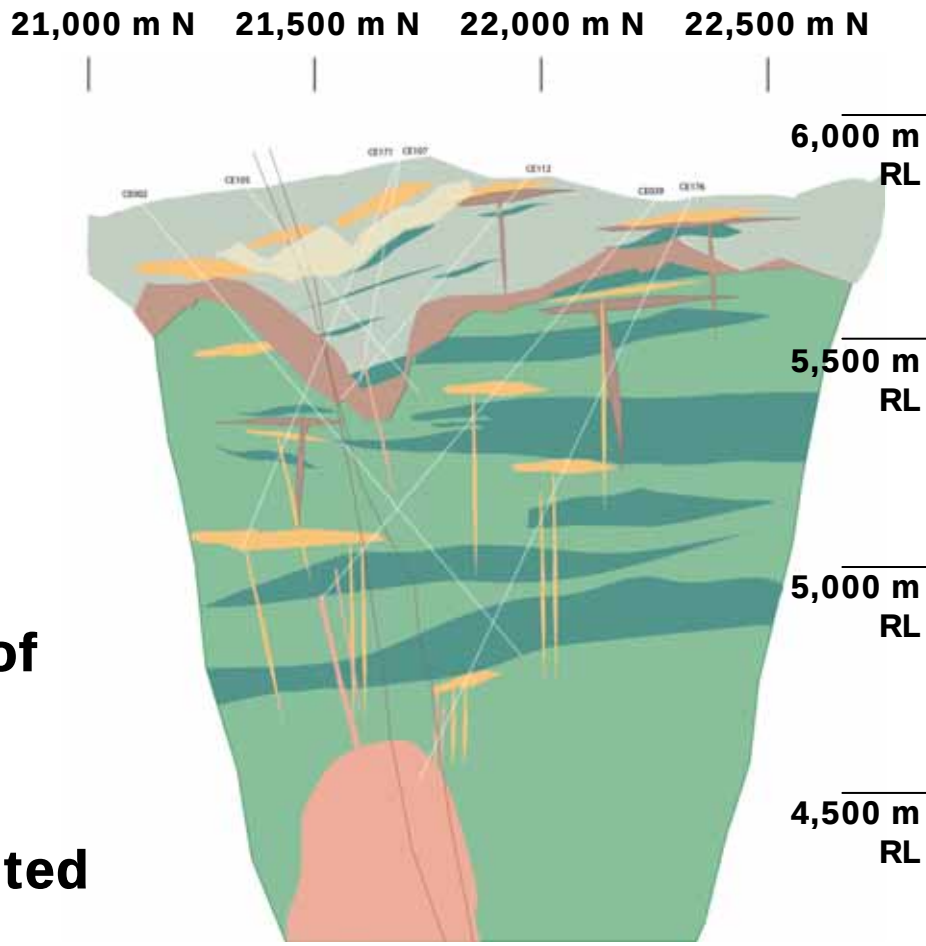
- Basaltic-andesite dikes and sills

Mineralising intrusions:

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

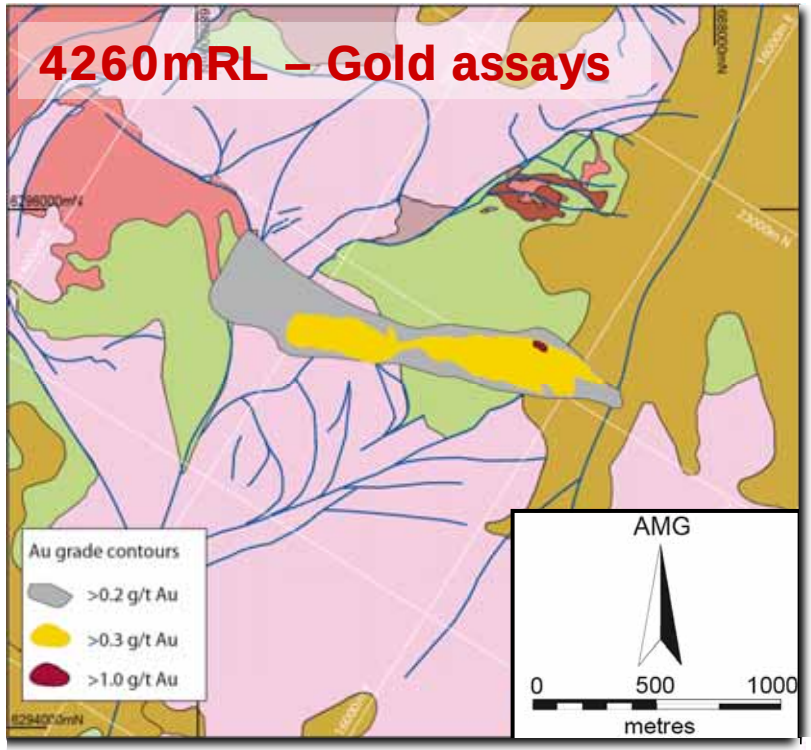
Styles of mineralisation:

- Deep-level W-NW- trending sheeted quartz-sulphide vein array
- Shallow level, disseminated stratabound orezone



Cadia East section 15220mE; Fox et al., 2009

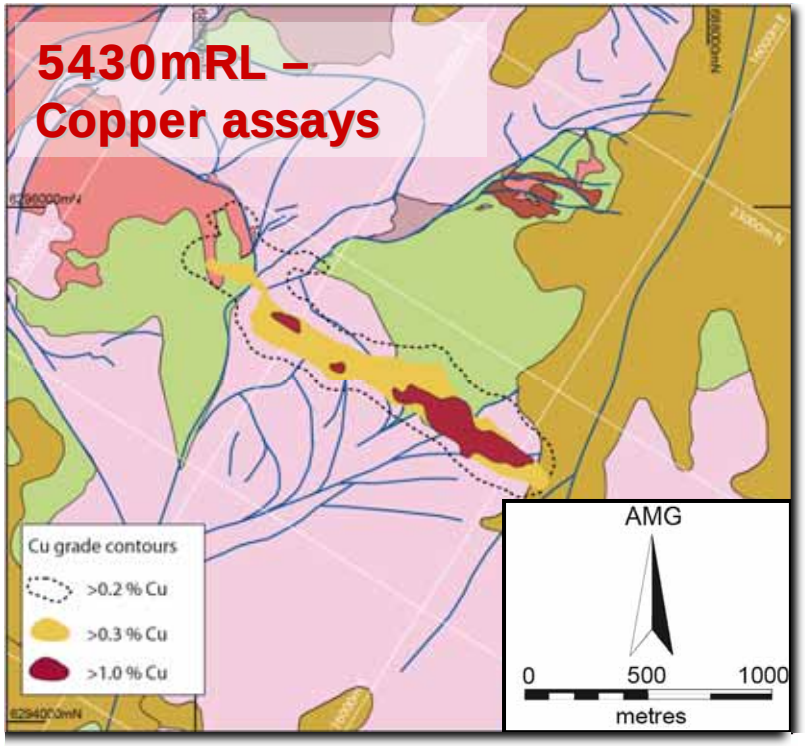
Sheeted vein-style mineralisation (deep level)



- 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)



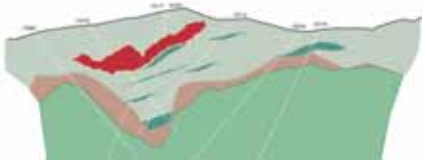
- **Disseminated Cu – Au – Mo mineralisation forms large NW-striking ore zone**
- **Associated with biotite – tourmaline – chlorite ± albite – chalcopyrite alteration**
- **Lithologically controlled with preferential development in polymict breccias**

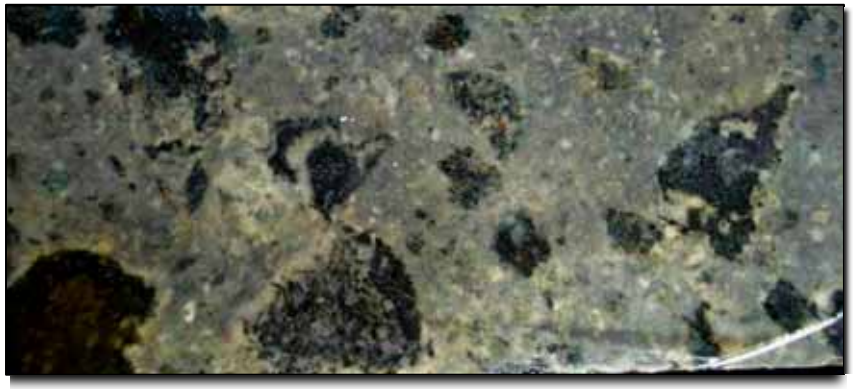
Gold and copper grades projected to surface from 5430mRL grade model (data from Newcrest Mining Ltd.)

Stratigraphic marker horizons – upper Forest Reefs Volcanics

Planar laminated volcanic siltstone:

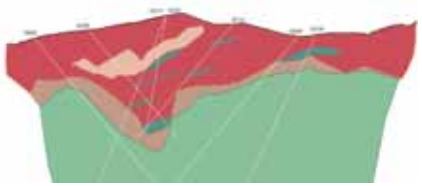
- 5 to ~40 m thick unit deposited in a below wave-base environment
- Extensively ab–ser–chl–py altered





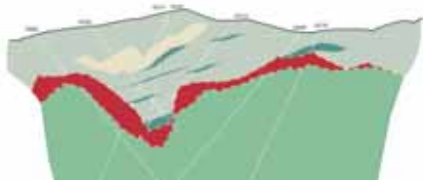
Polymict volcanic breccia:

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



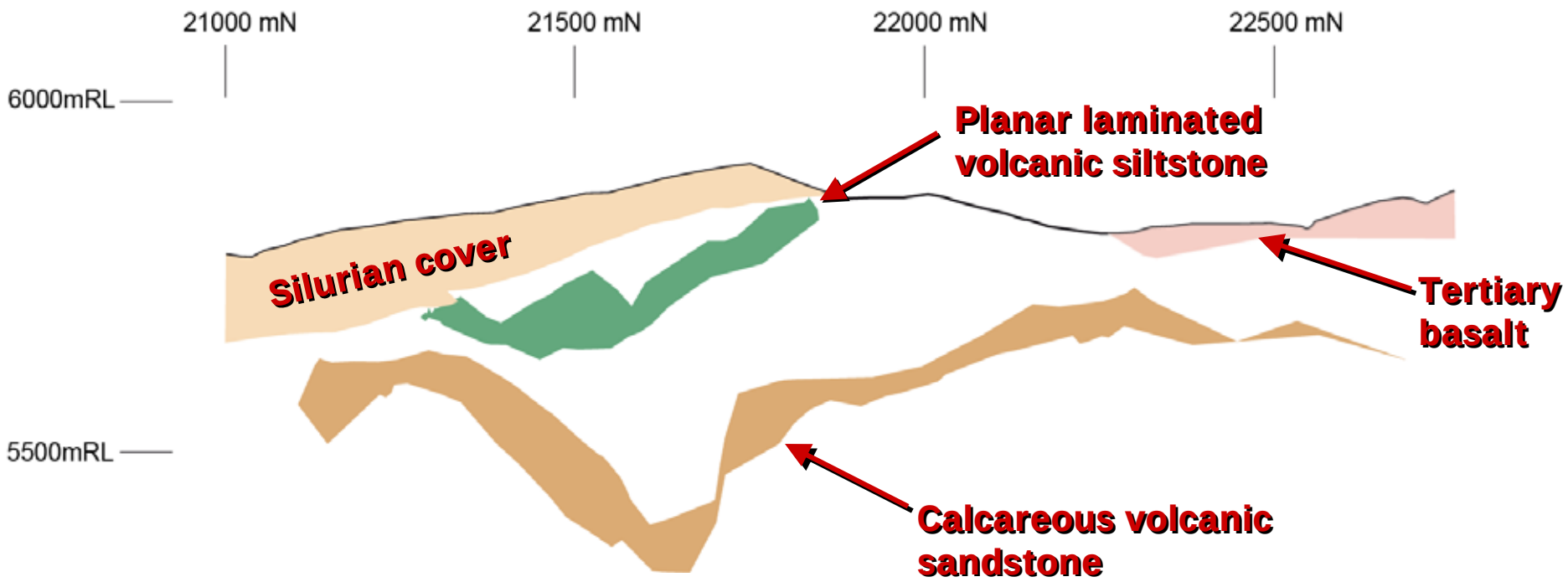
Calcareous volcanic sandstone:

- Laterally extensive, 5 to 70 m thick unit
- Extensively epi–gt –chl–cal–py ± cp altered



Cadia East section 15220mE

Stratigraphic marker horizons – upper Forest Reefs Volcanics

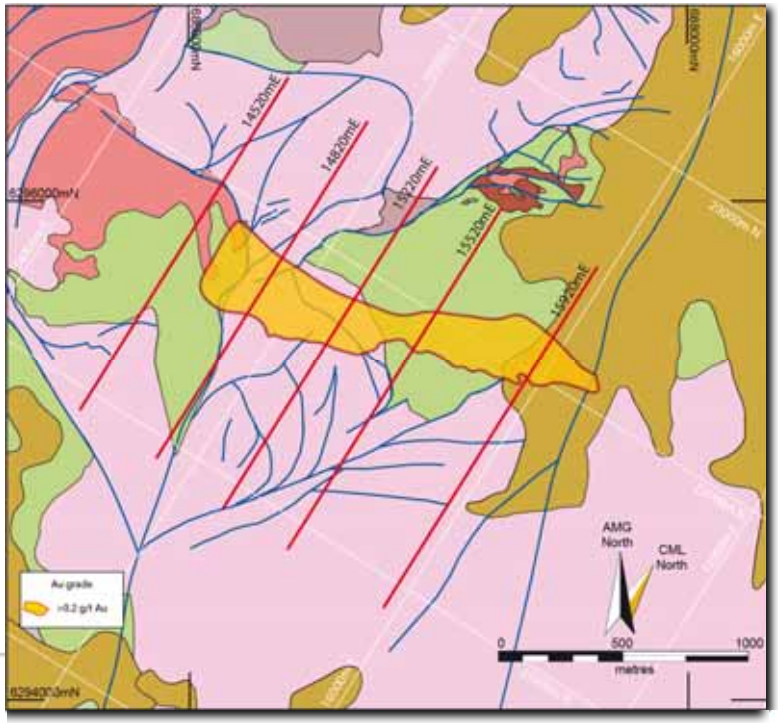


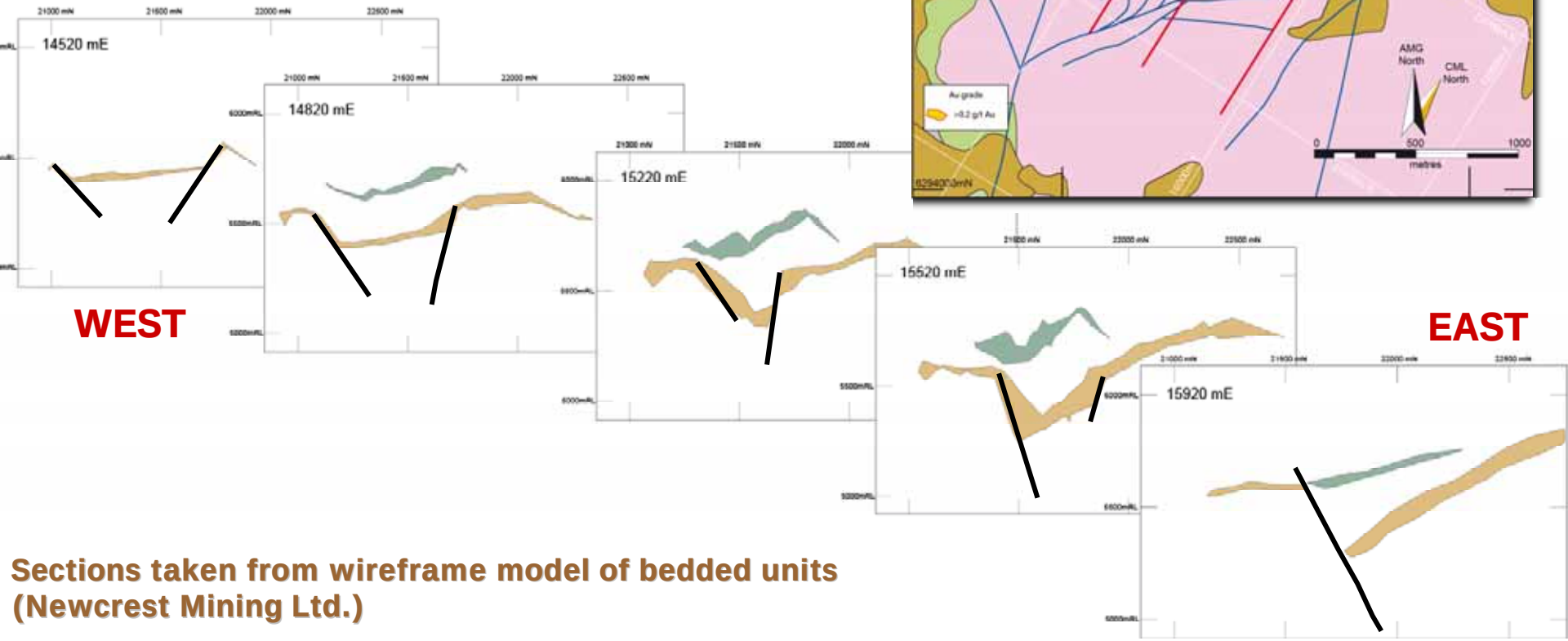
- **Geometrical modelling by Newcrest geologists suggest that active fault-bounded sub-basins localised sedimentation of calcareous sandstone and feldspathic siltstone units in the upper Forest Reefs Volcanics**

Section 15220mE

Sub-basin geometry

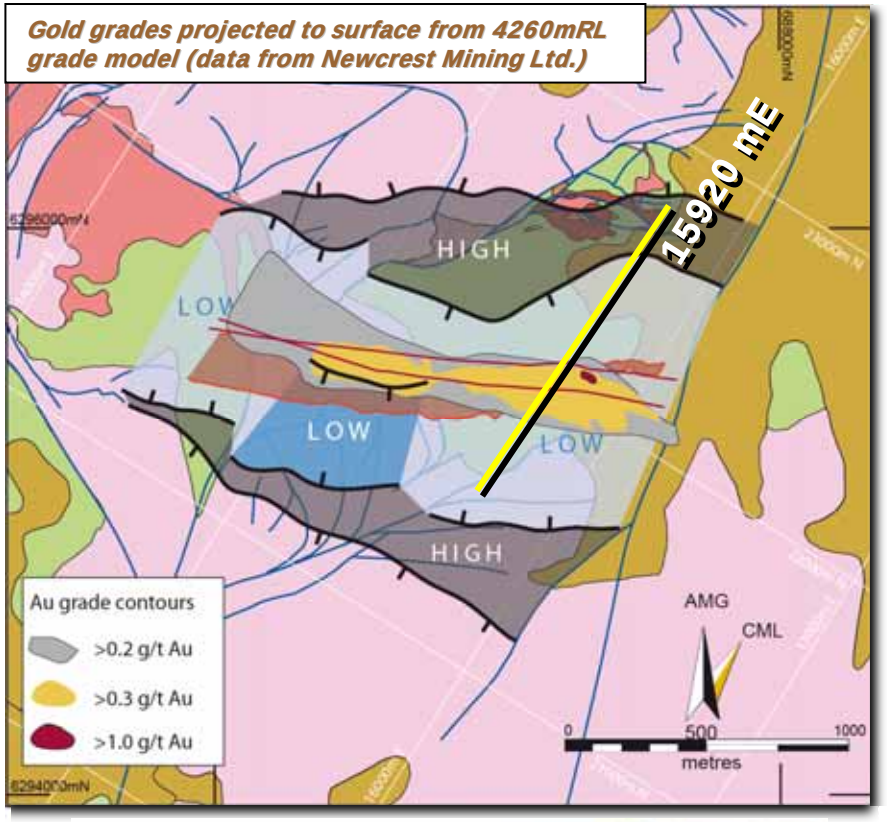
- **Five NNE- oriented cross-sections show sequential offset of the calcareous volcanic sandstone**
  - ***Half graben geometry defined at the eastern end of Cadia East***
  - ***Graben geometry defined at the western end***



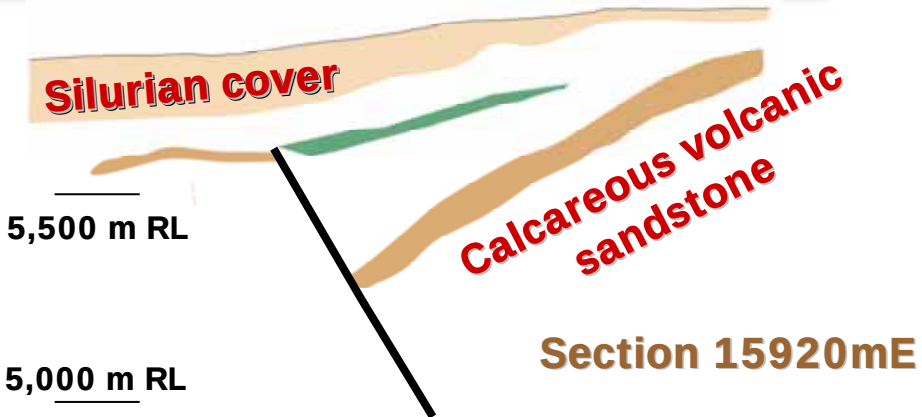


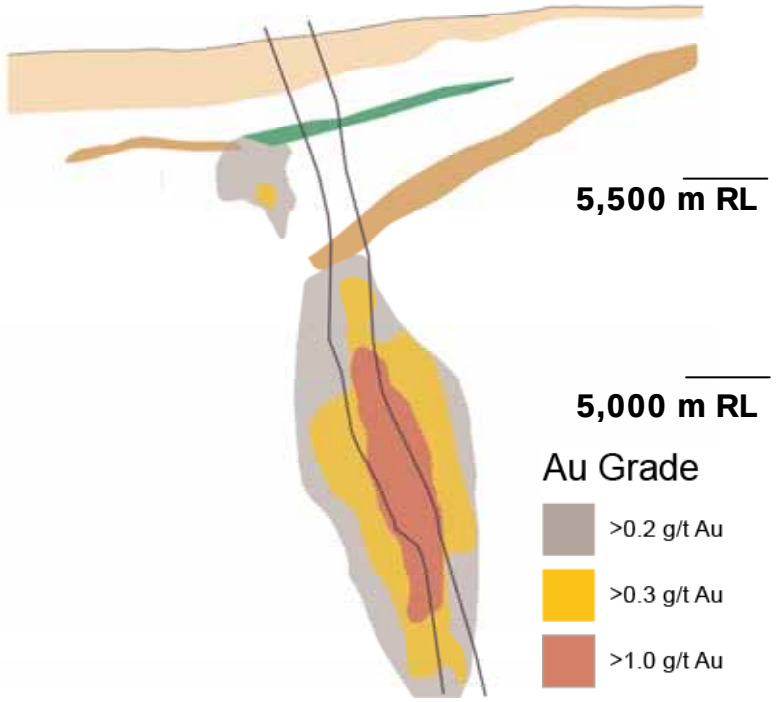
Sections taken from wireframe model of bedded units (Newcrest Mining Ltd.)

Gold mineralisation

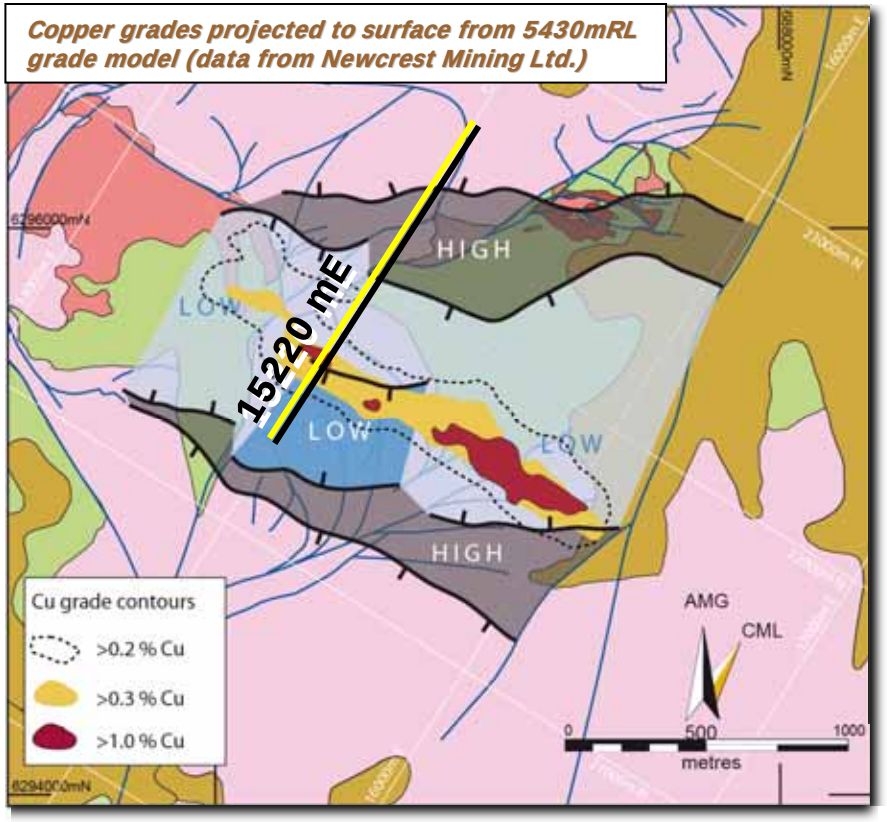


- **Early Silurian monzonites intruded pre-existing basin-bounding faults**
- **High grade sheeted veins are oriented sub-parallel to the monzonites, and generated a ~2 km long, E-trending orebody**

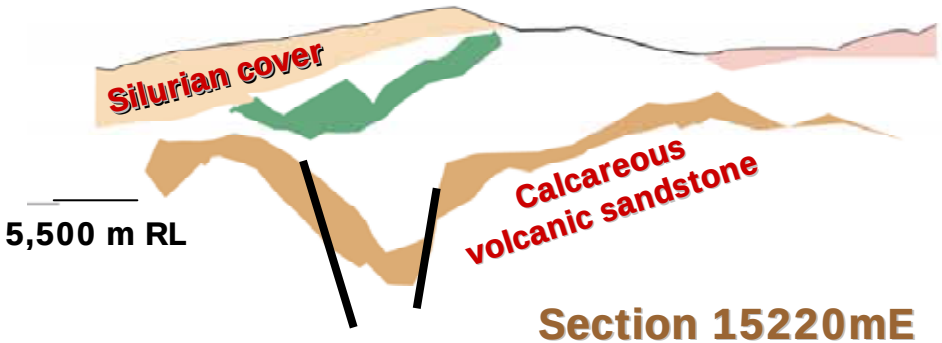




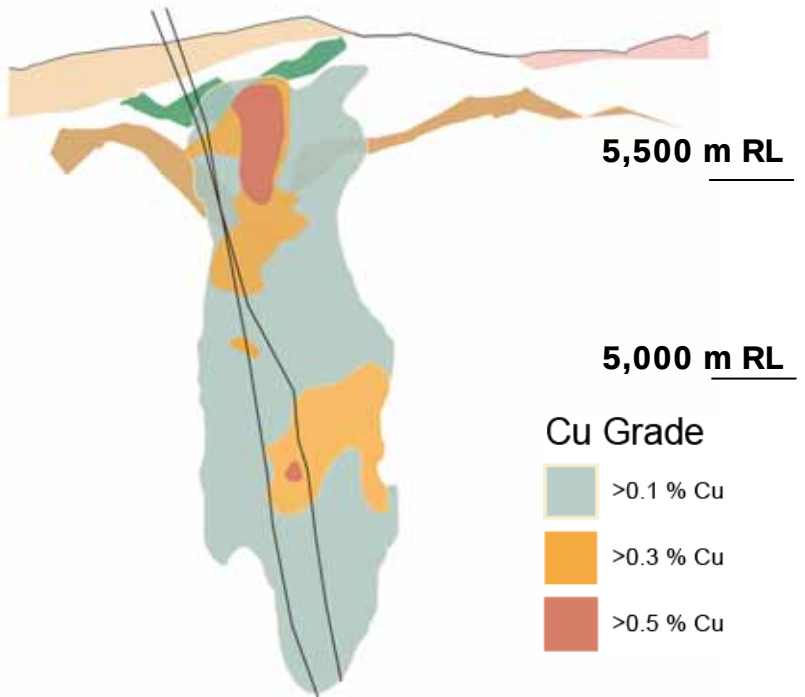
Copper mineralisation



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

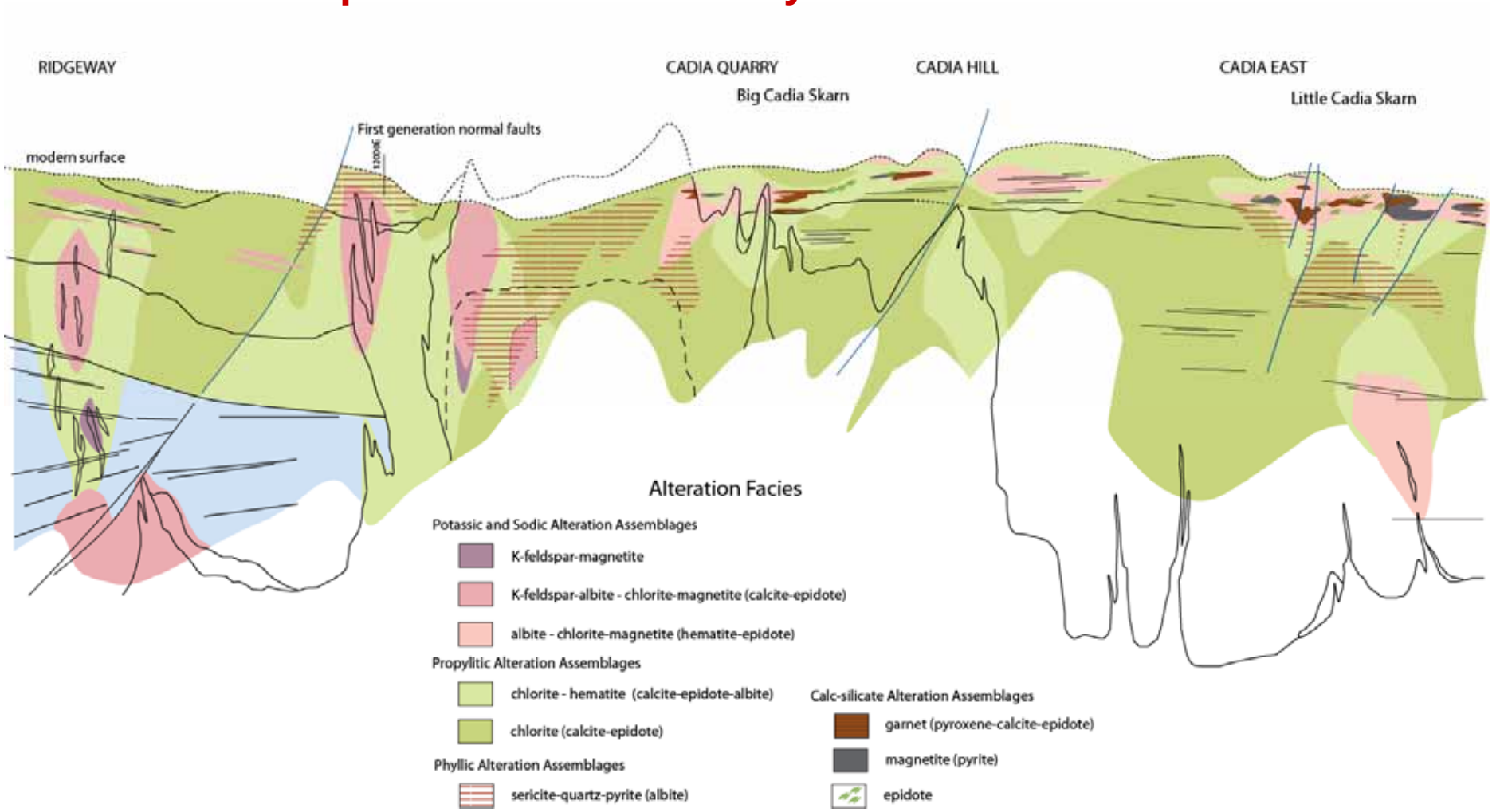


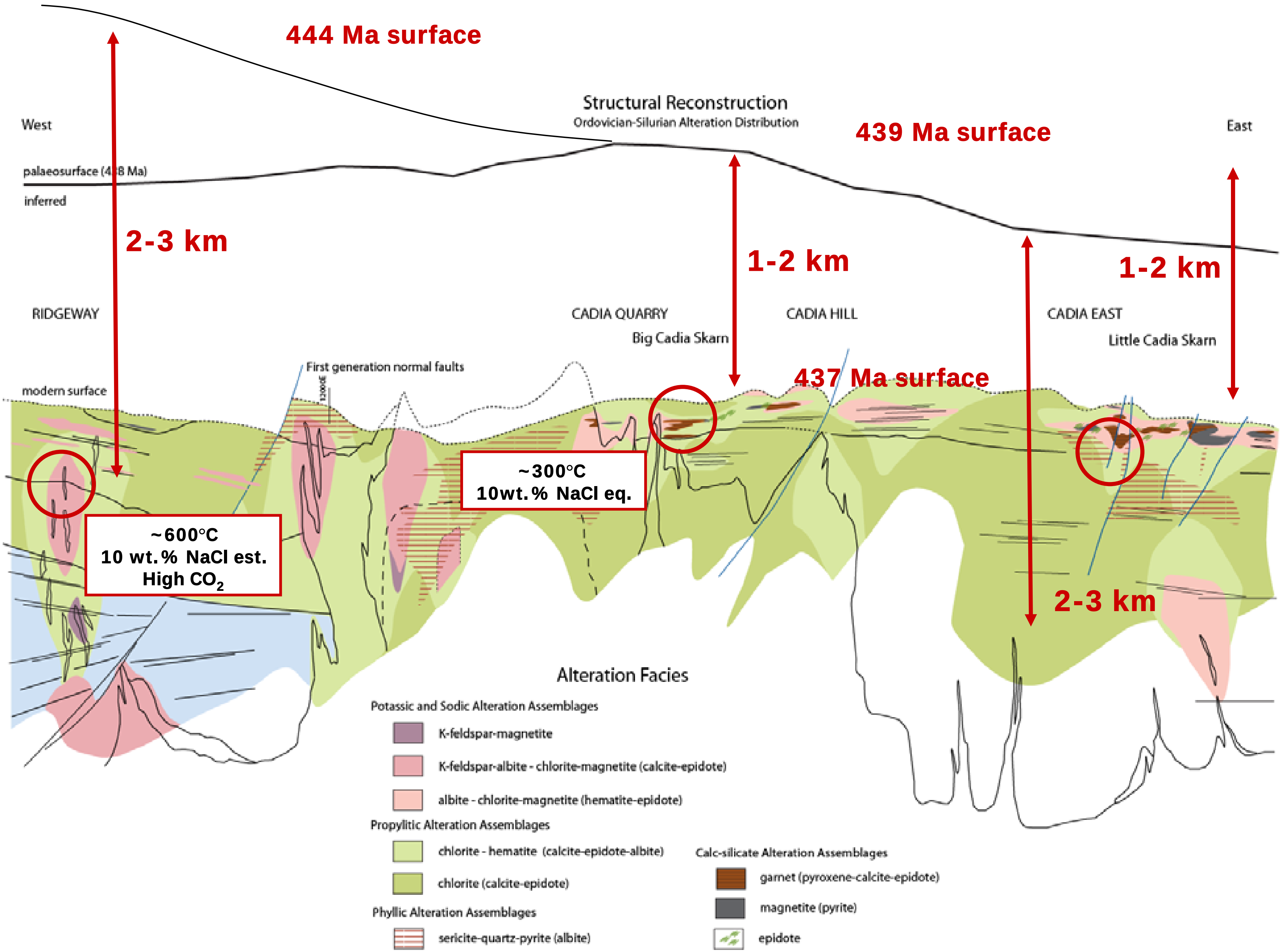
Section 15220mE



Cadia district - Architecture

Restoration of the deformed state cross sections allow from an improved understand of syn-mineral structure





444 Ma surface
Structural Reconstruction
Ordovician-Silurian Alteration Distribution
West
East
439 Ma surface
palaeosurface (438 Ma)
inferred
2-3 km
1-2 km
1-2 km
RIDGEWAY
CADIA QUARRY
Big Cadia Skarn
CADIA HILL
CADIA EAST
Little Cadia Skarn
First generation normal faults
437 Ma surface
modern surface
~300°C
10wt.% NaCl eq.
~600°C
10 wt.% NaCl est.
High CO2
2-3 km
Alteration Facies
Potassic and Sodic 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

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