



Australian Government

Geoscience Australia

IOCG mineralisation and alteration

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Government of South Australia
Primary Industries and Resources SA

IOCG Workshop
Adelaide, 24 February 2006



Geoscience Australia

Outline

1. Summaries of IOCG deposits:

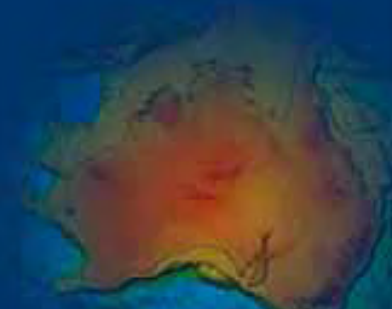
Olympic Dam

Prominent Hill

Carrapateena

2. Regional & deposit alteration

3. Targeting higher grade Cu-Au



Fe oxide Cu-Au (IOCG) deposits:

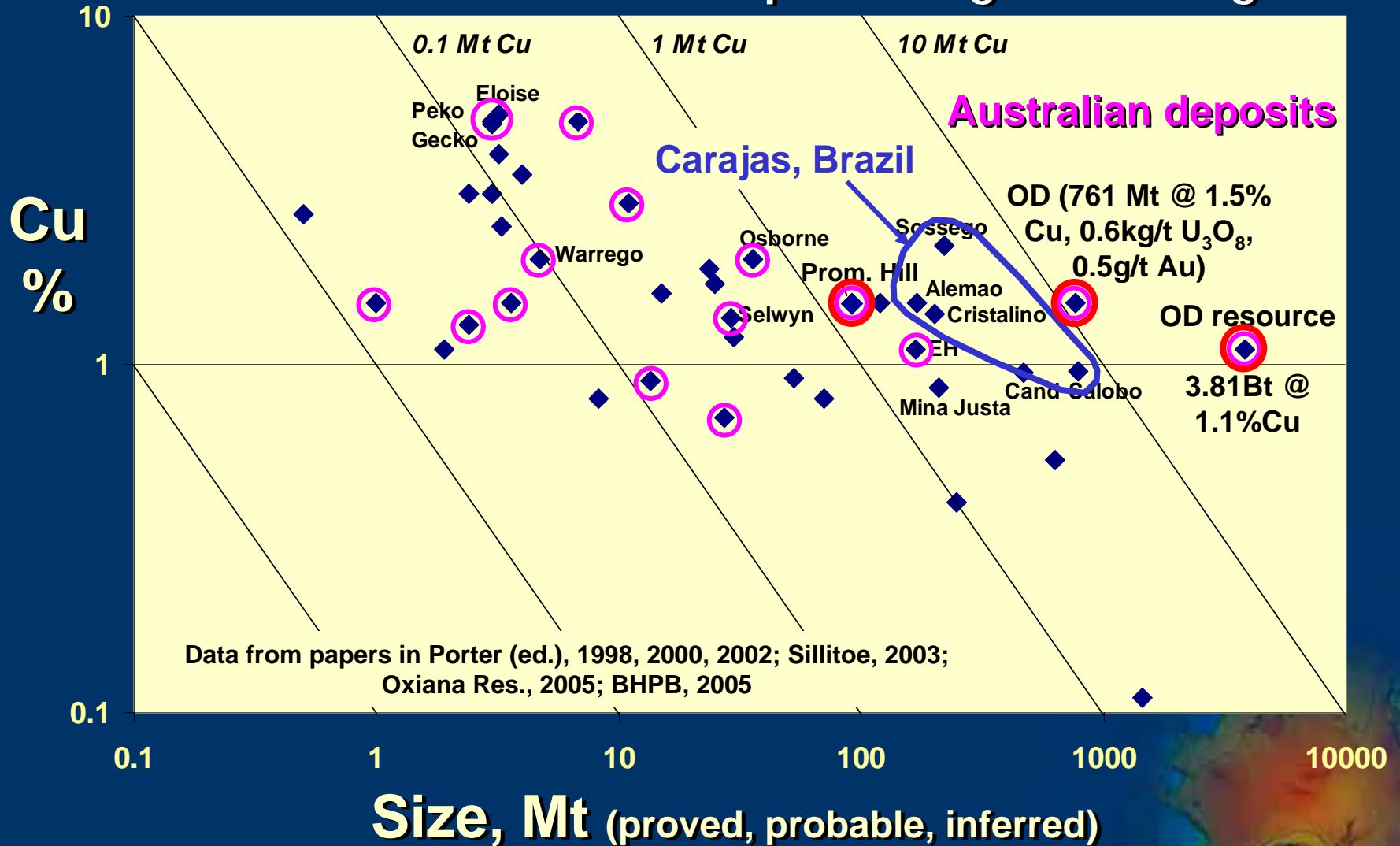
A descriptive definition of a diverse class

- **Cu, Au, \pm U, LREE, Ag, CO₃, F, P, Ba, Co association**
- **Cu-Fe sulfides & Au spatially assoc with abundant (>10%) magnetite and/or hematite**
- **Hydrothermal quartz \ll Fe-oxides; sulfides \ll Fe-oxides**
- **Local alteration is potassic (Kfs, bt), hydrolytic (ser, chl), and/or carbonate; regional alteration is Na-Ca**
- **Epigenetic, structurally-controlled hydrothermal replacements, vein stockworks, breccias**
- **Distal from coeval igneous intrusions; various hostrocks**
- **Fluids: hypersaline, & separate lower salinity brines, \pm CO₂**
(based on Hitzman et al., 1992; Hitzman, 2000; Haynes, 2000)

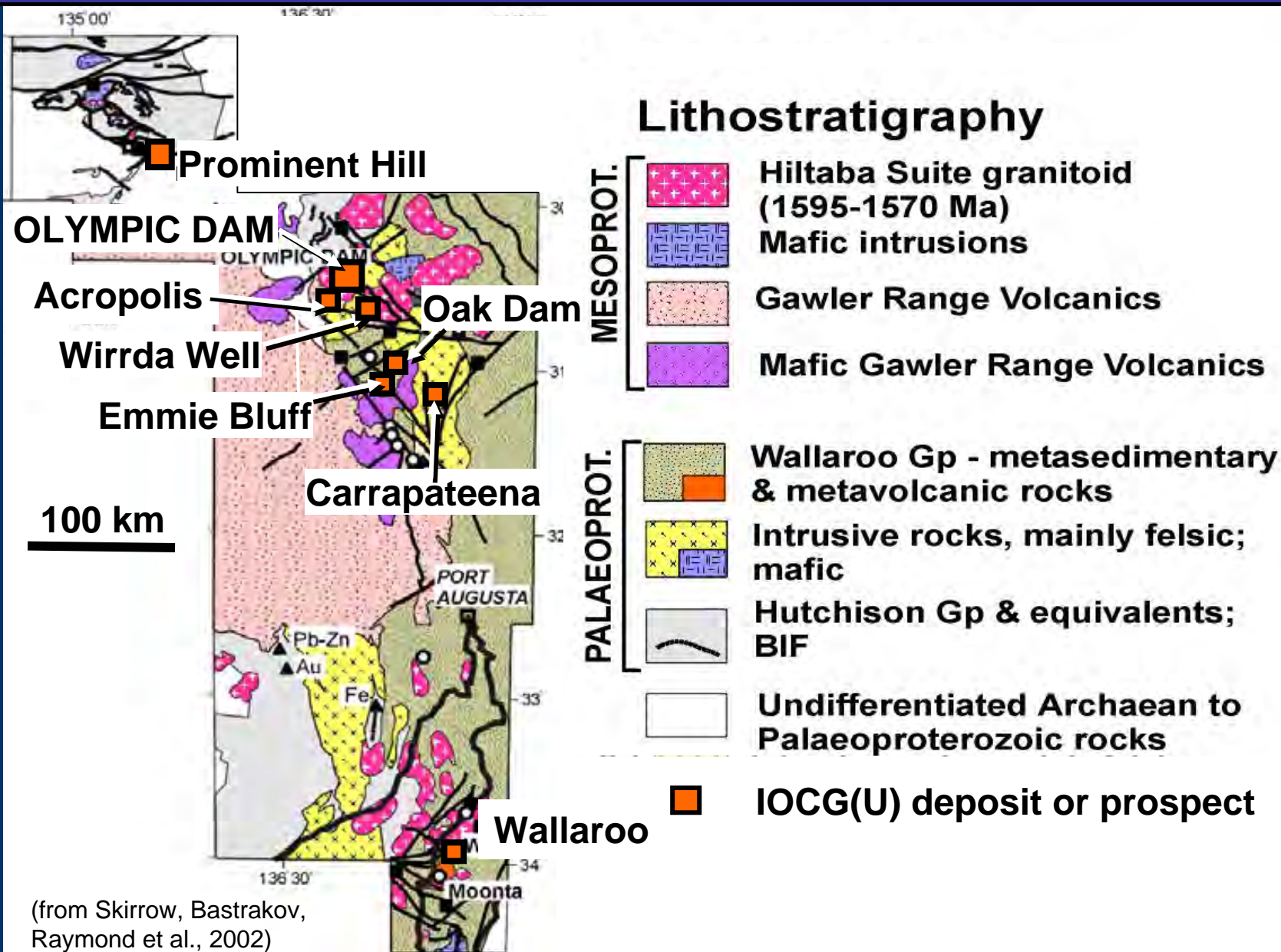
Prominent Hill (Minotaur
Exploration website)

Gawler IOCG deposit grade-tonnages in perspective

Global & Australian IOCG deposits Cu grade-tonnage



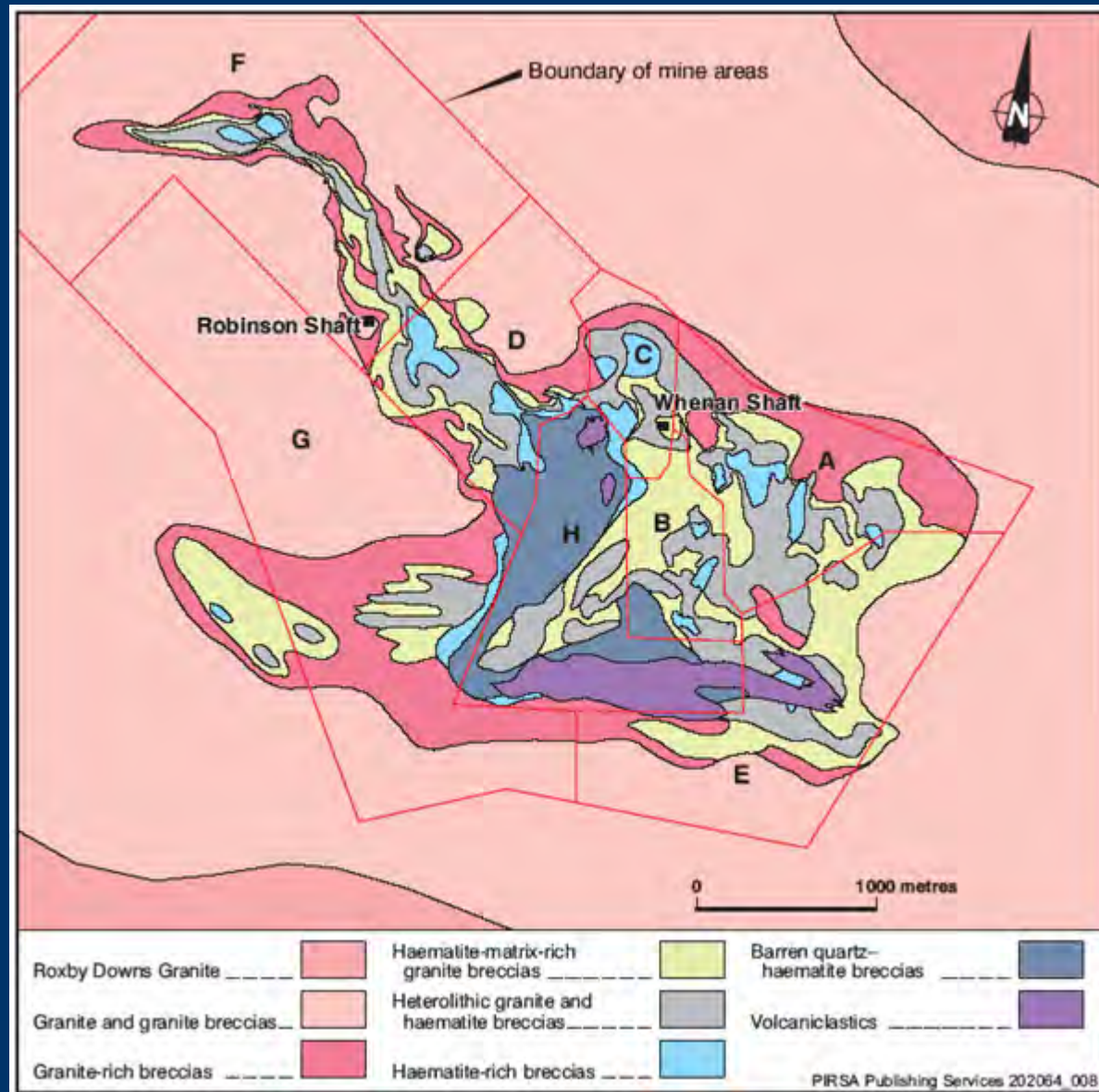
Olympic Cu-Au province: IOCG deposits & prospects



1. Summaries of IOCG deposits of the Gawler Craton

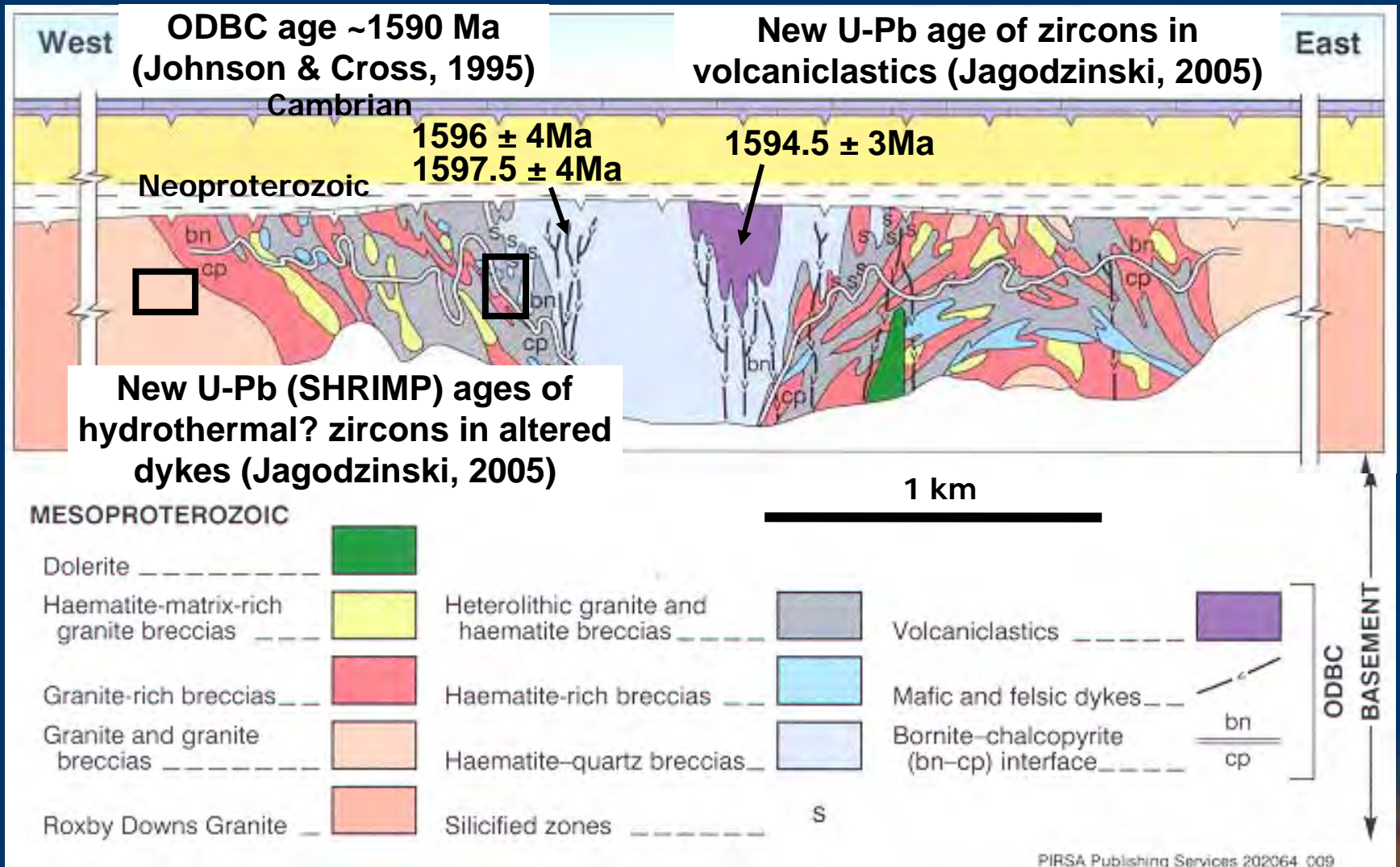


Olympic Dam – geology map



After Reynolds (2000)

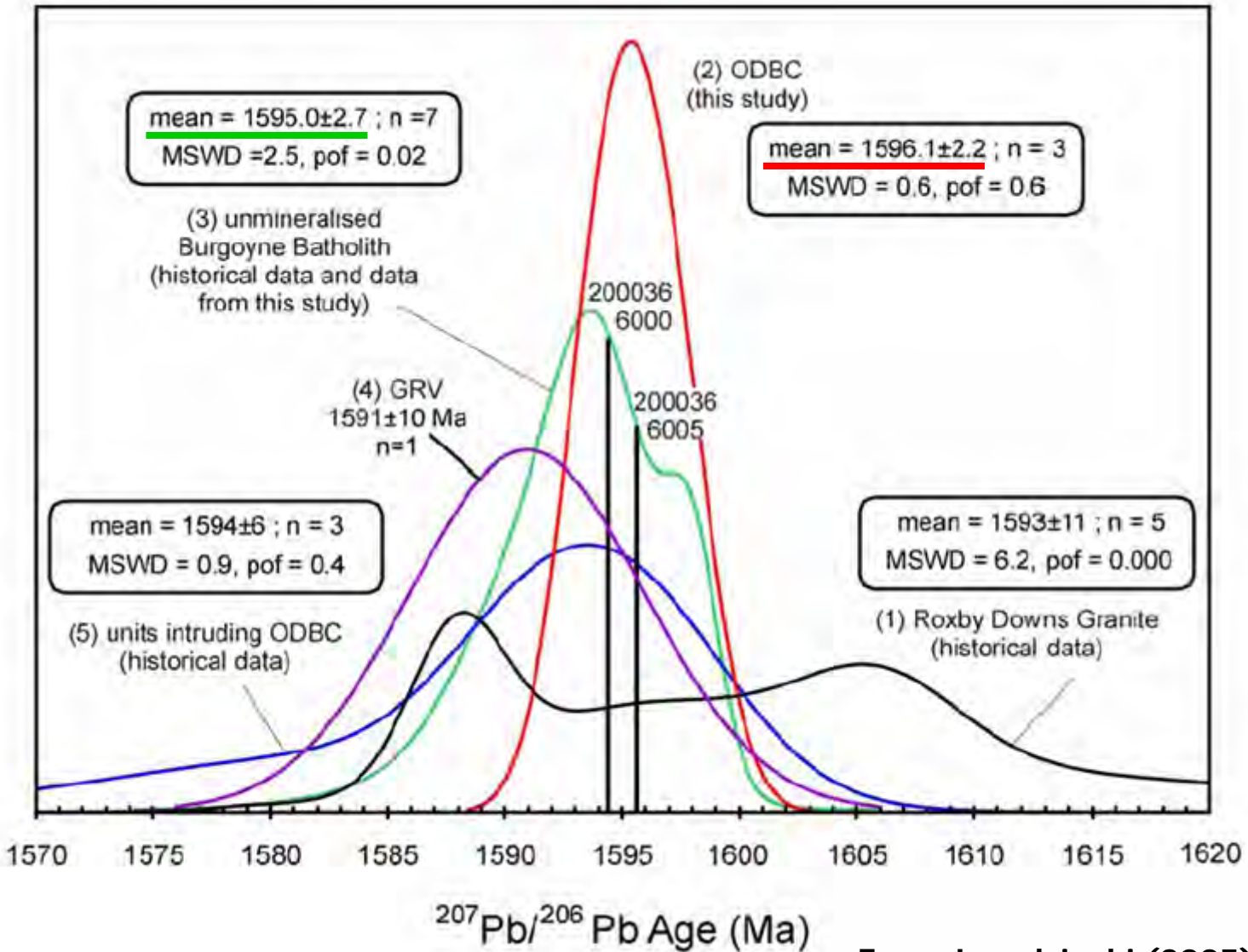
Olympic Dam Cu-U-Au deposit - section



PIRSA Publishing Services 202064 009

After Reynolds (2000)

Olympic Dam geochronology



From Jagodzinski (2005)

Olympic Dam 1: fracturing & incipient brecciation of granite host



Olympic Dam breccia-hosted Cu-U-Au

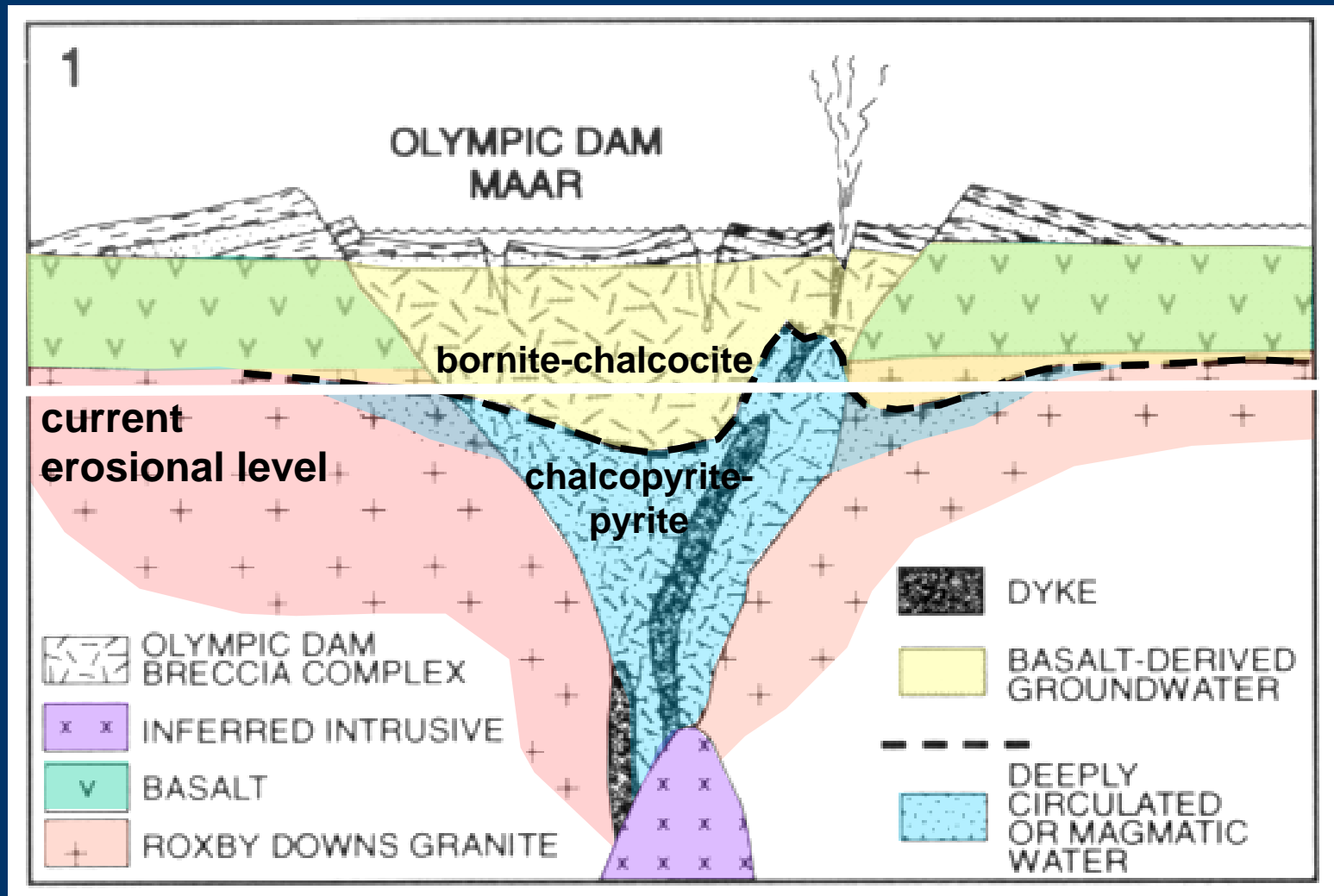
Copper ore



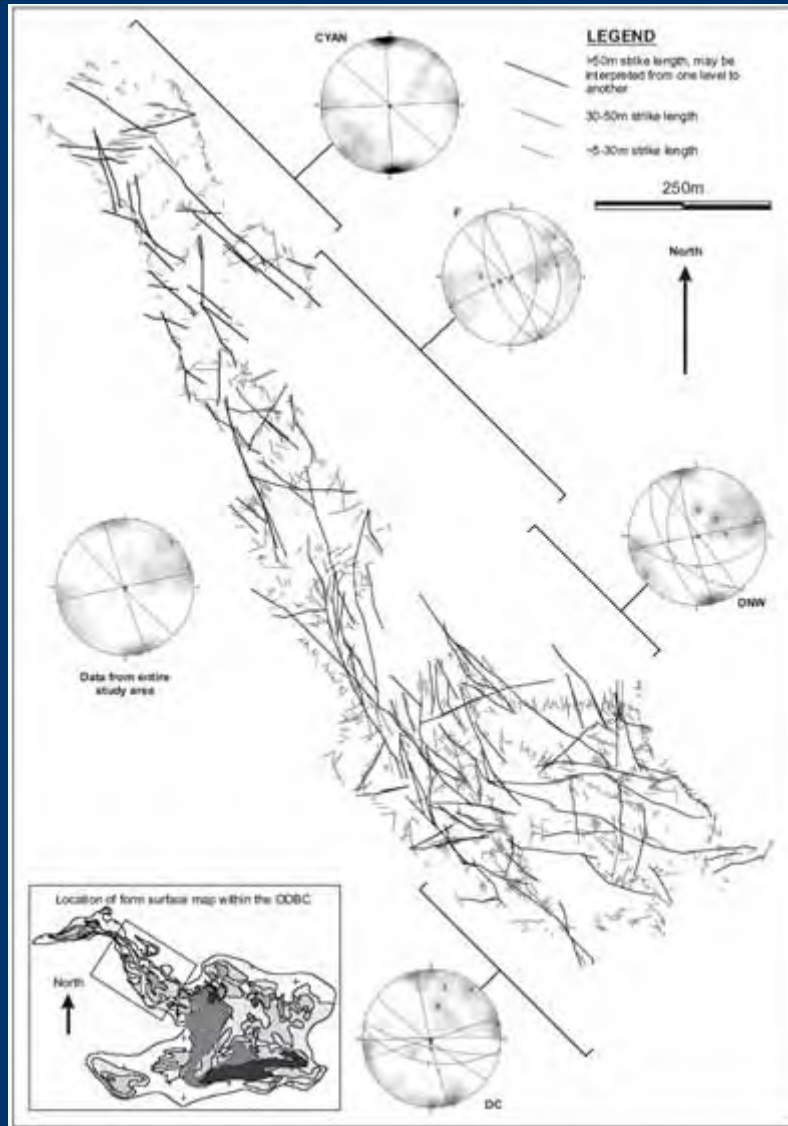
Heterolithic, multistage breccias



Olympic Dam: formation model (Haynes et al., 1995)



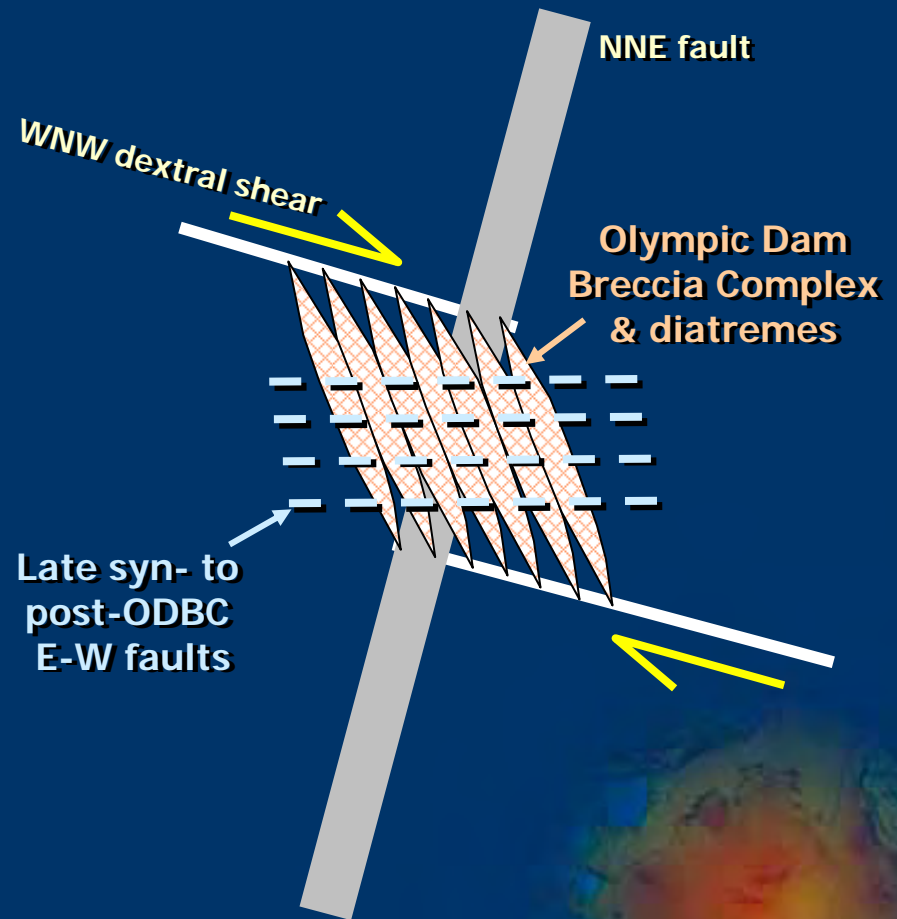
Olympic Dam faults



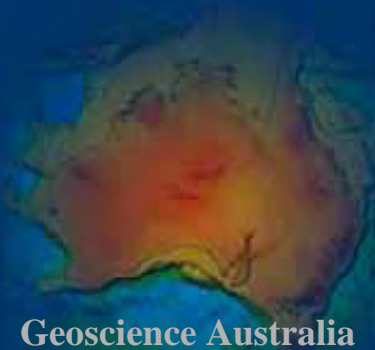
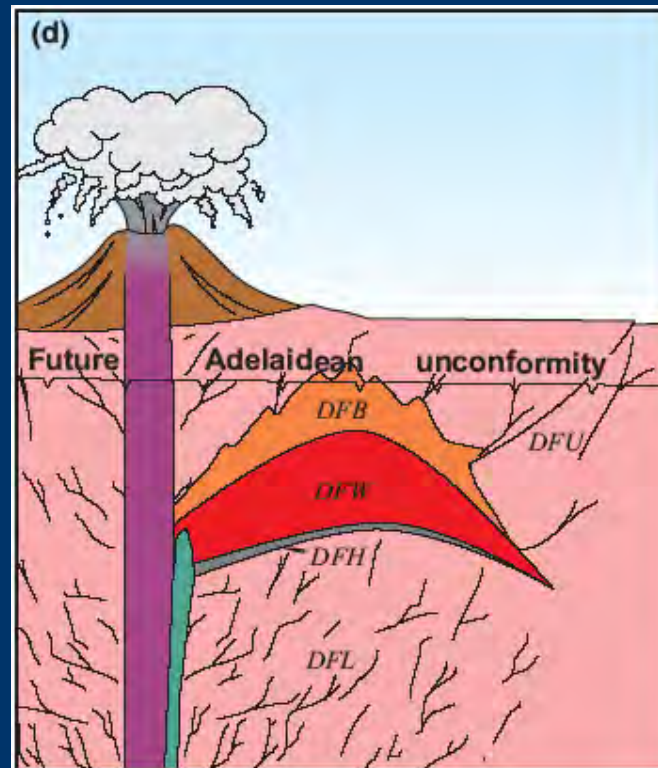
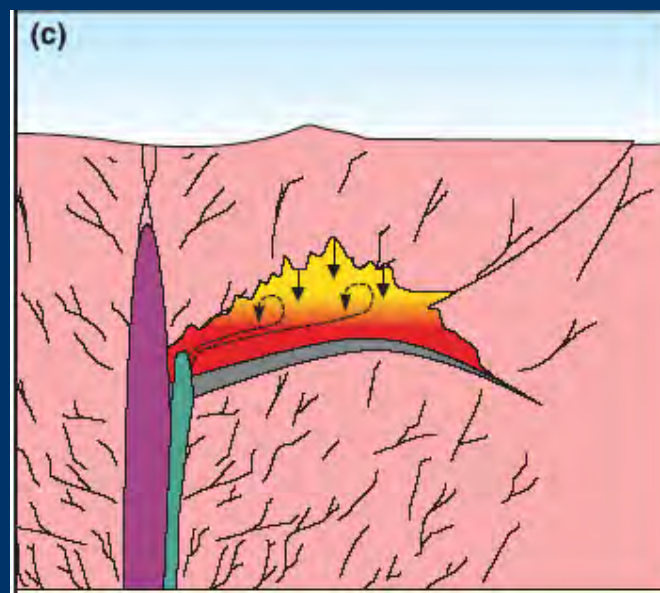
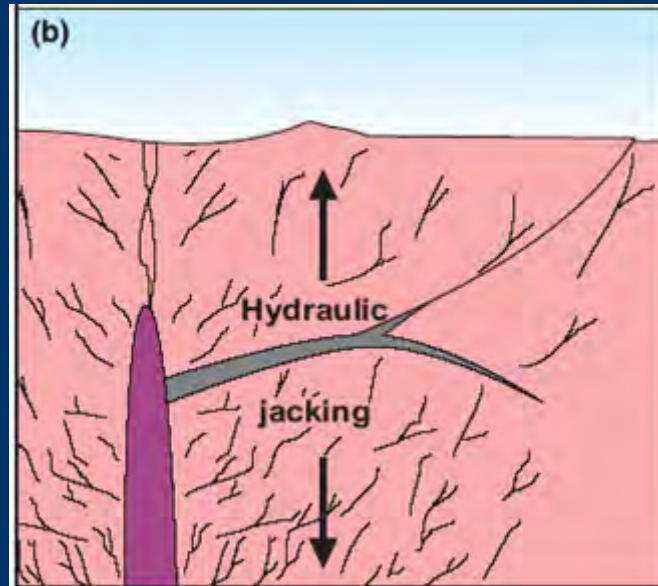
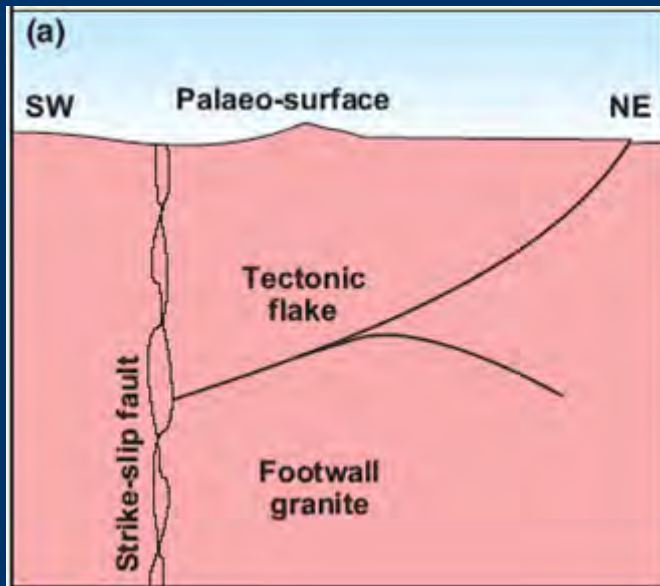
From Widdup et al. (2004)

Regional & deposit structure

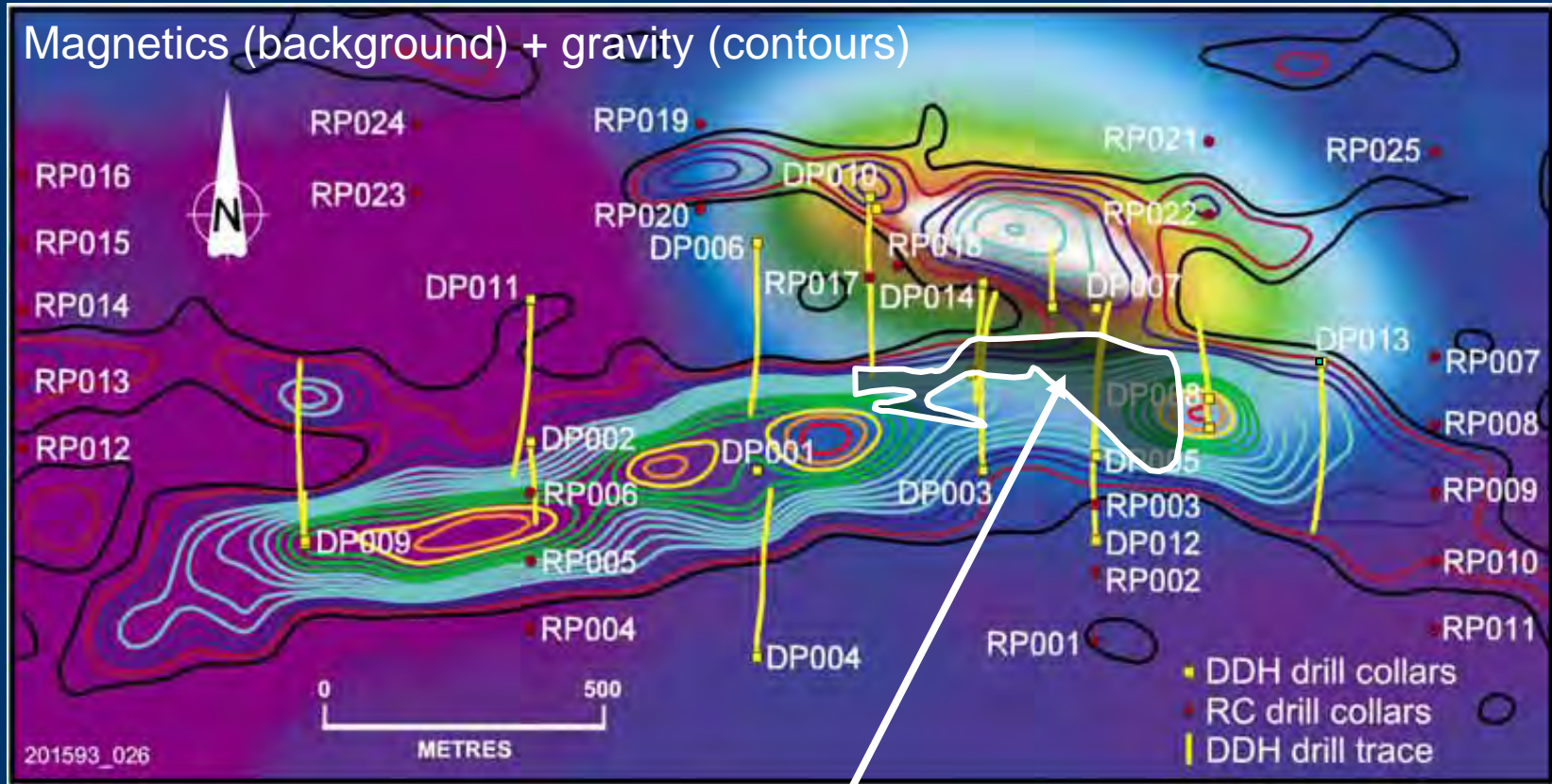
(based on Sugden, 1992; Cross et al. 1993; Widdup et al. 2004)



Model for Mine Area A breccias (from Conor, 2004)



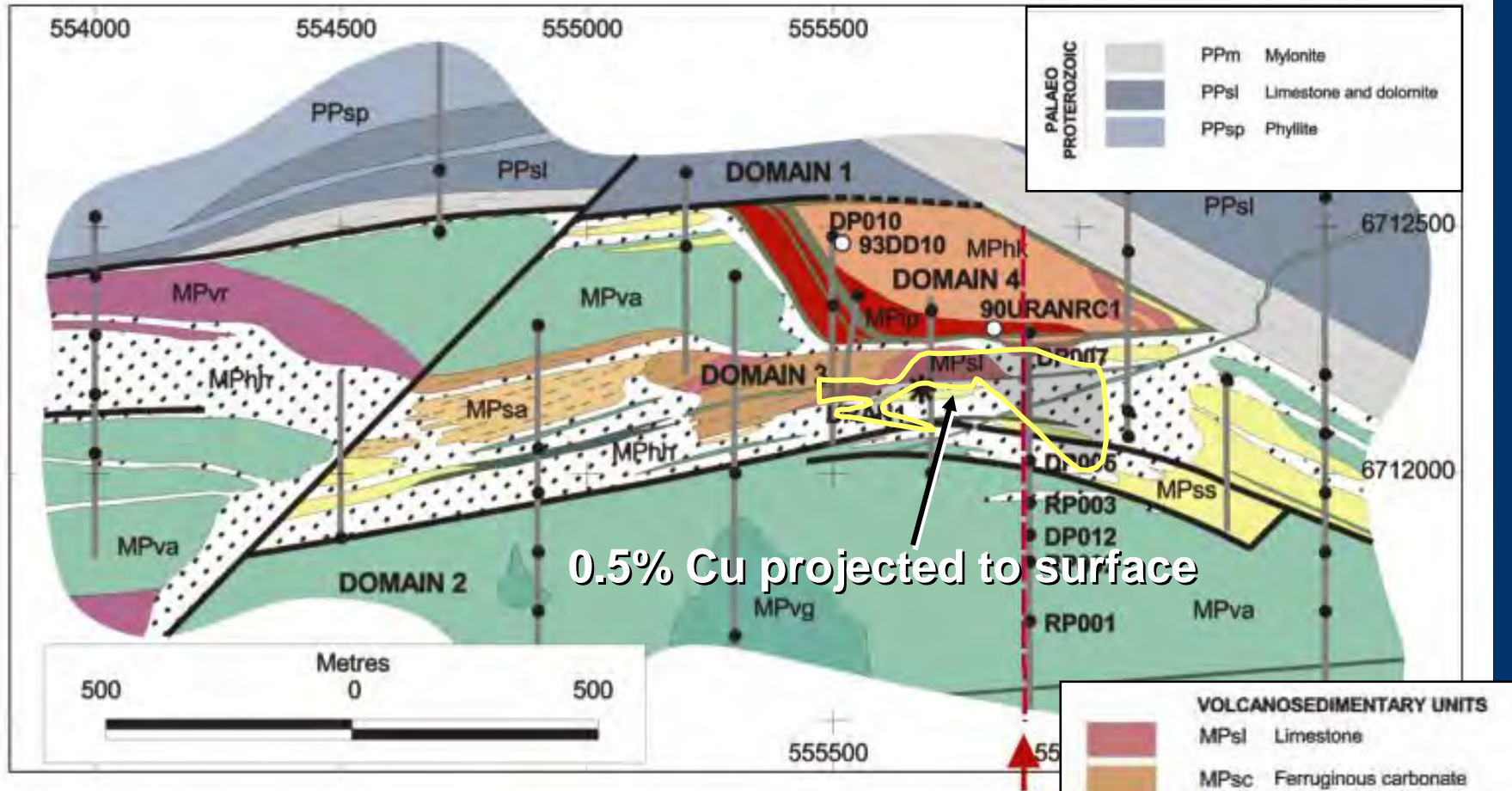
Prominent Hill discovery 2001: 101 Mt @ 1.5% Cu 0.55 g/t Au + 21 Mt @ 1.2 g/t Au



Sources: Minotaur +
MESA Journal (January 2003)

>0.5% Cu, projected to surface

Prominent Hill - plan geology and alteration (courtesy PIRSA & Minotaur)



PALAEO PROTEROZOIC	
PPm	Mylonite
PPsl	Limestone and dolomite
PPsp	Phyllite

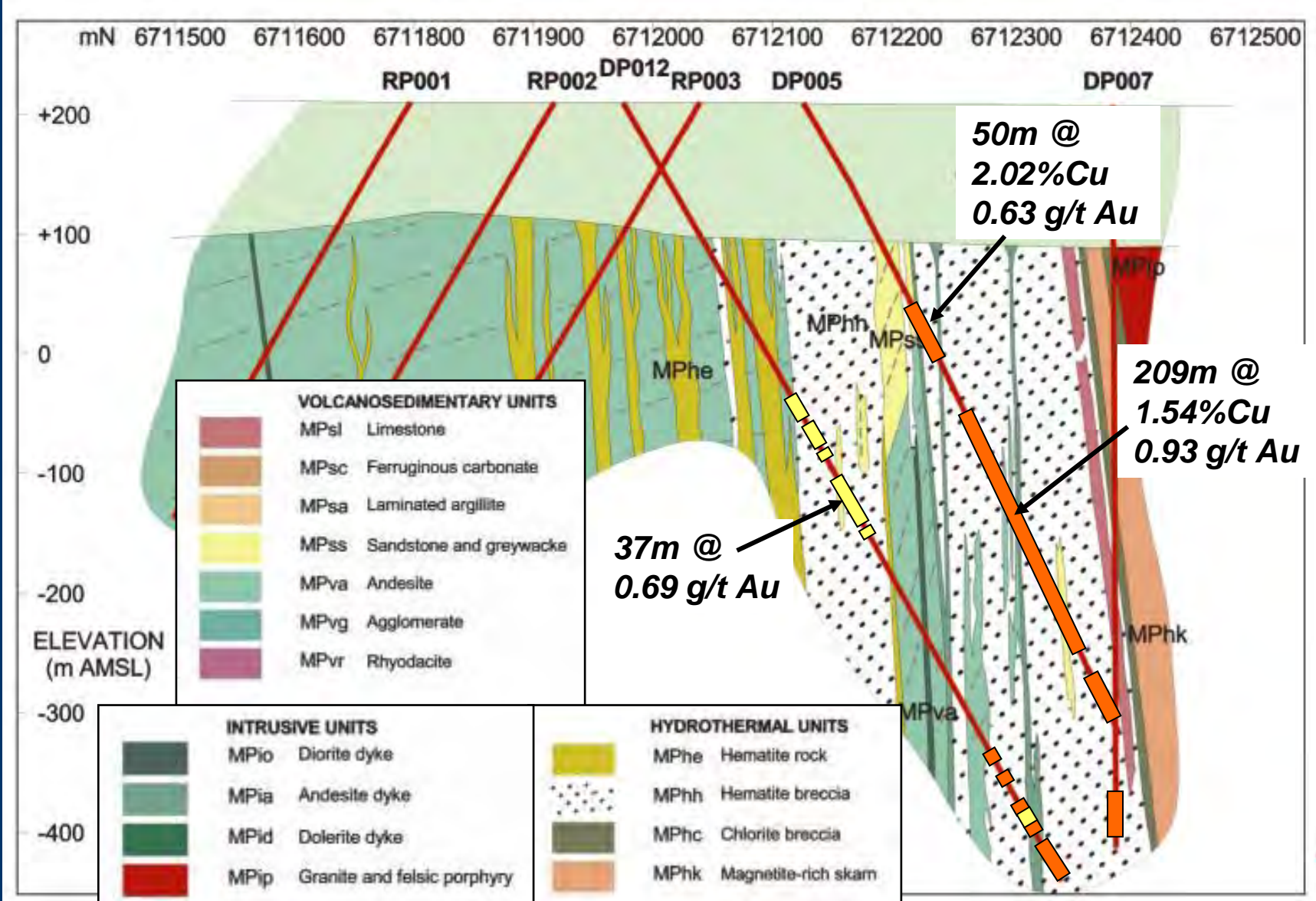
VOLCANOSEDIMENTARY UNITS	
MPsl	Limestone
MPsc	Ferruginous carbonate
MPsa	Laminated argillite
MPss	Sandstone and greywacke
MPva	Andesite
MPvg	Agglomerate
MPvr	Rhyodacite

HYDROTHERMAL UNITS	
MPhe	Hematite rock
MPhh	Hematite breccia
MPhc	Chlorite breccia
MPhk	Magnetite-rich skarn

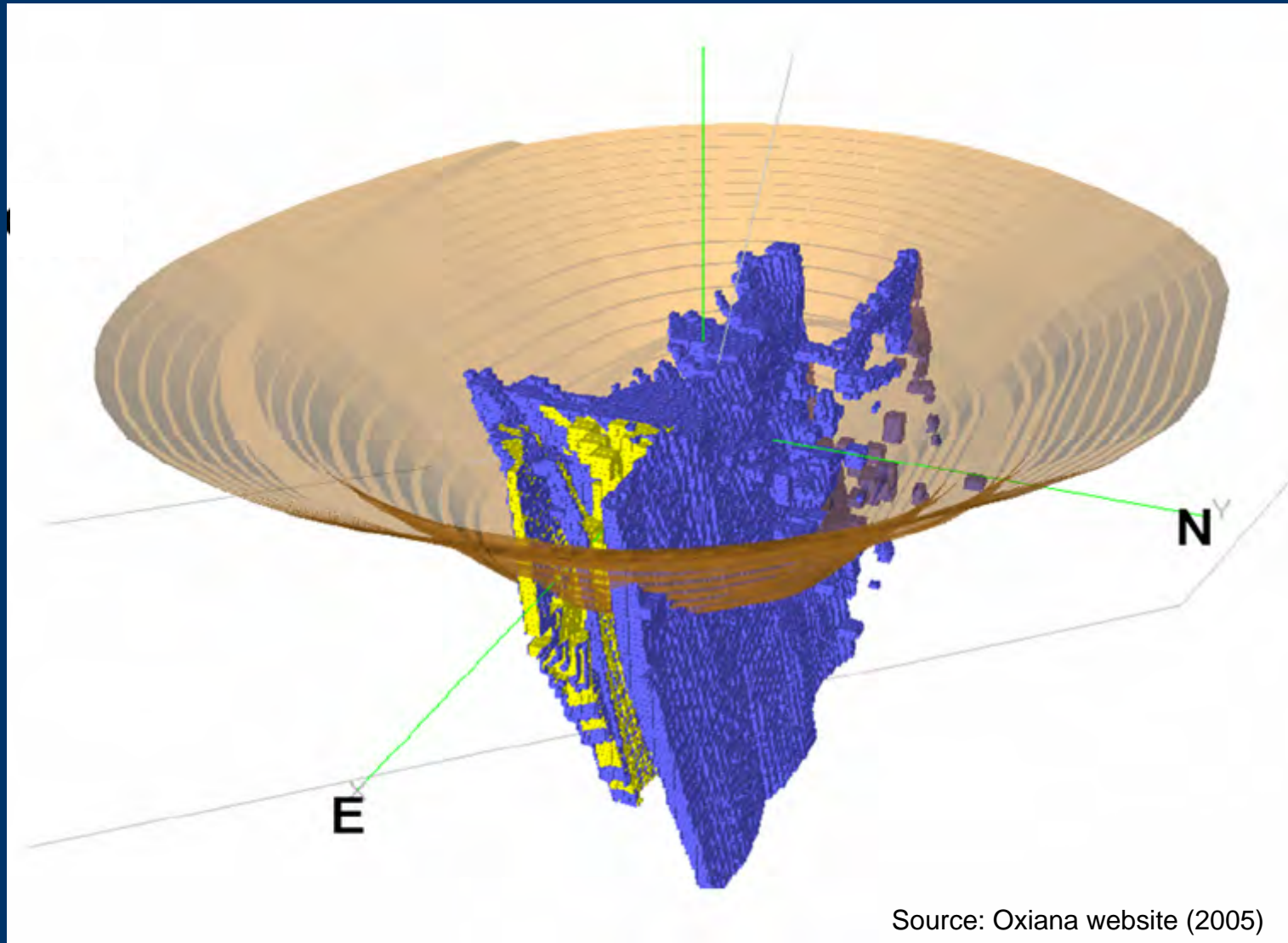
INTRUSIVE UNITS	
MPio	Diorite dyke
MPia	Andesite dyke
MPid	Dolerite dyke
MPip	Granite and felsic porphyry

Prominent Hill – section geology and alteration

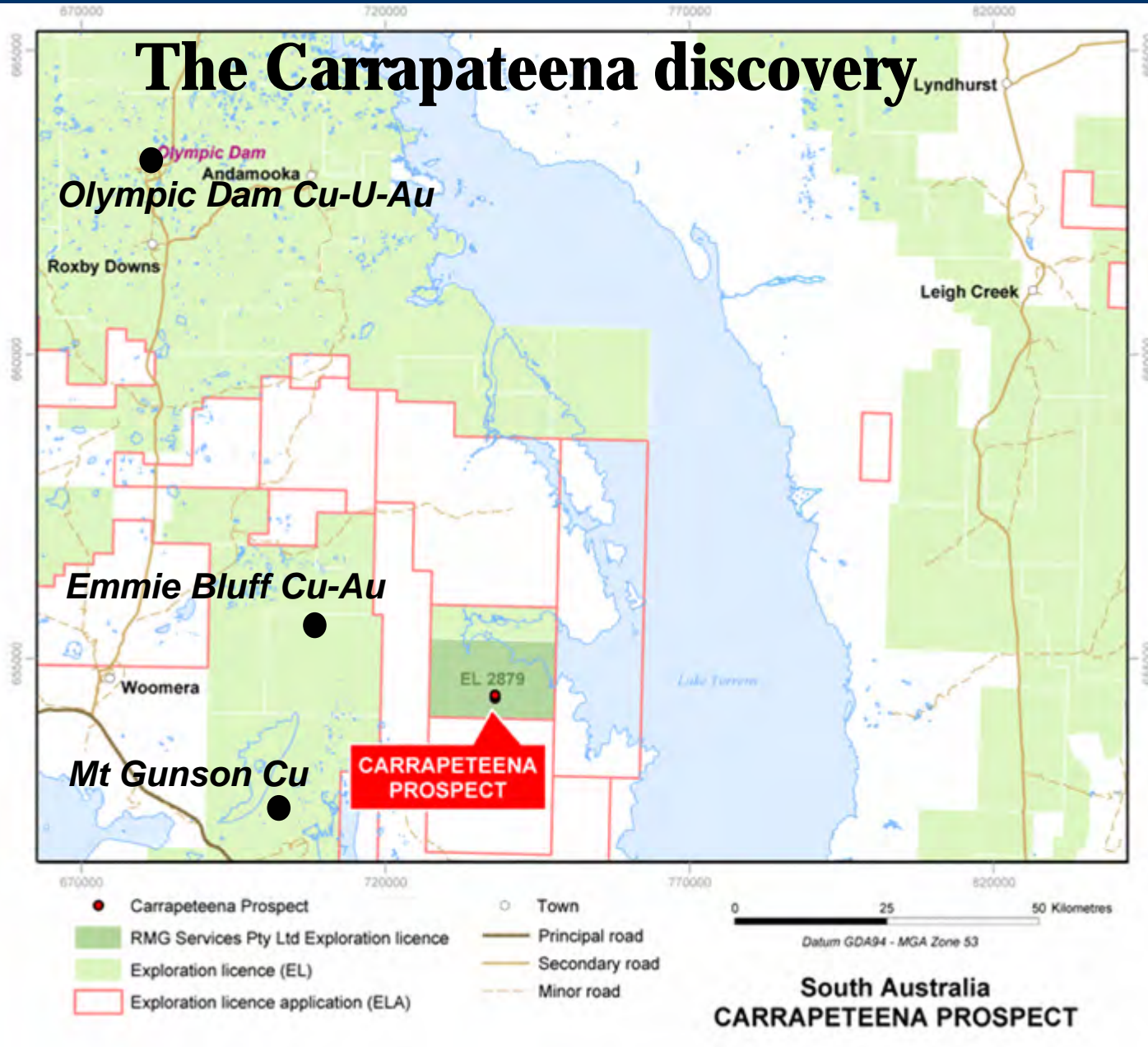
(courtesy PIRSA & Minotaur)



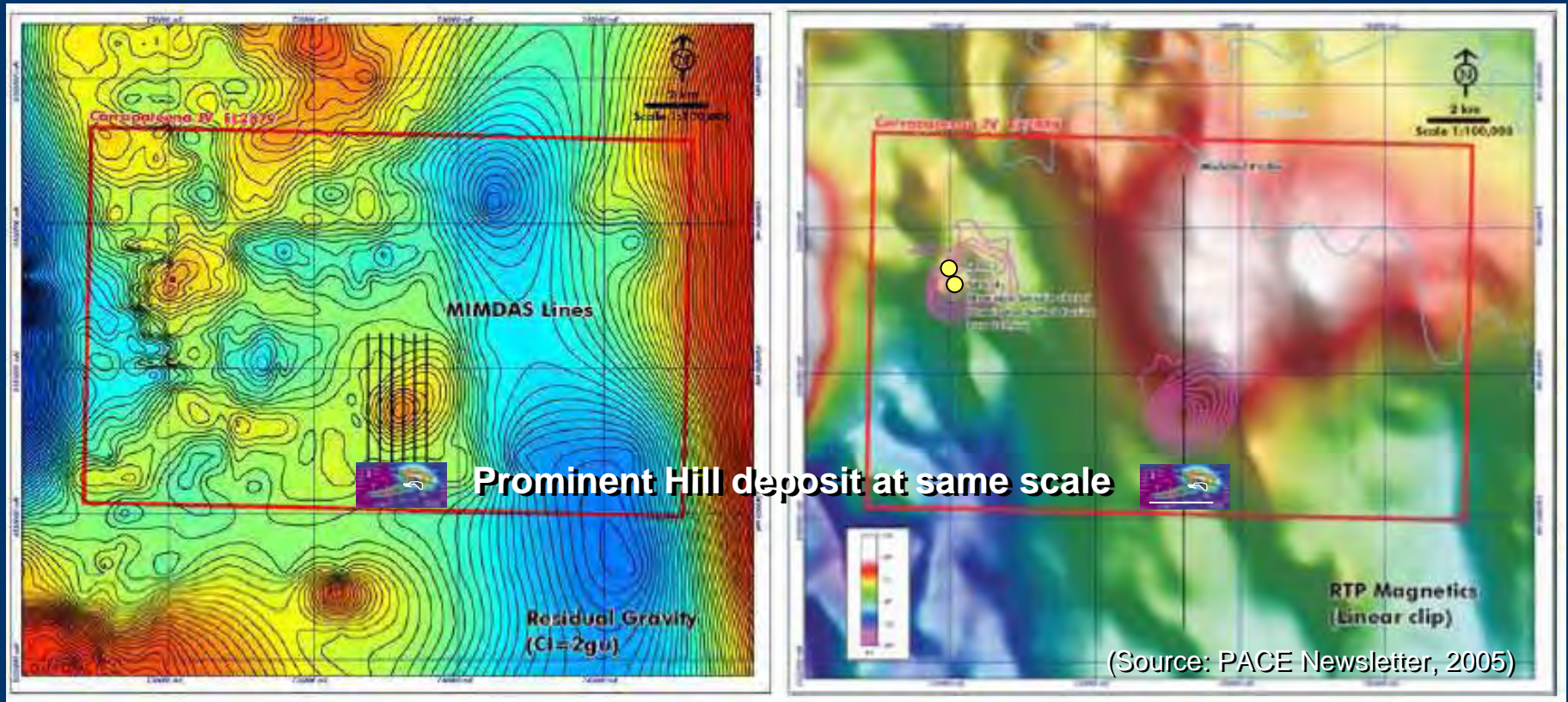
Prominent Hill planned open cut mine; production in 2009



The Carrapateena discovery

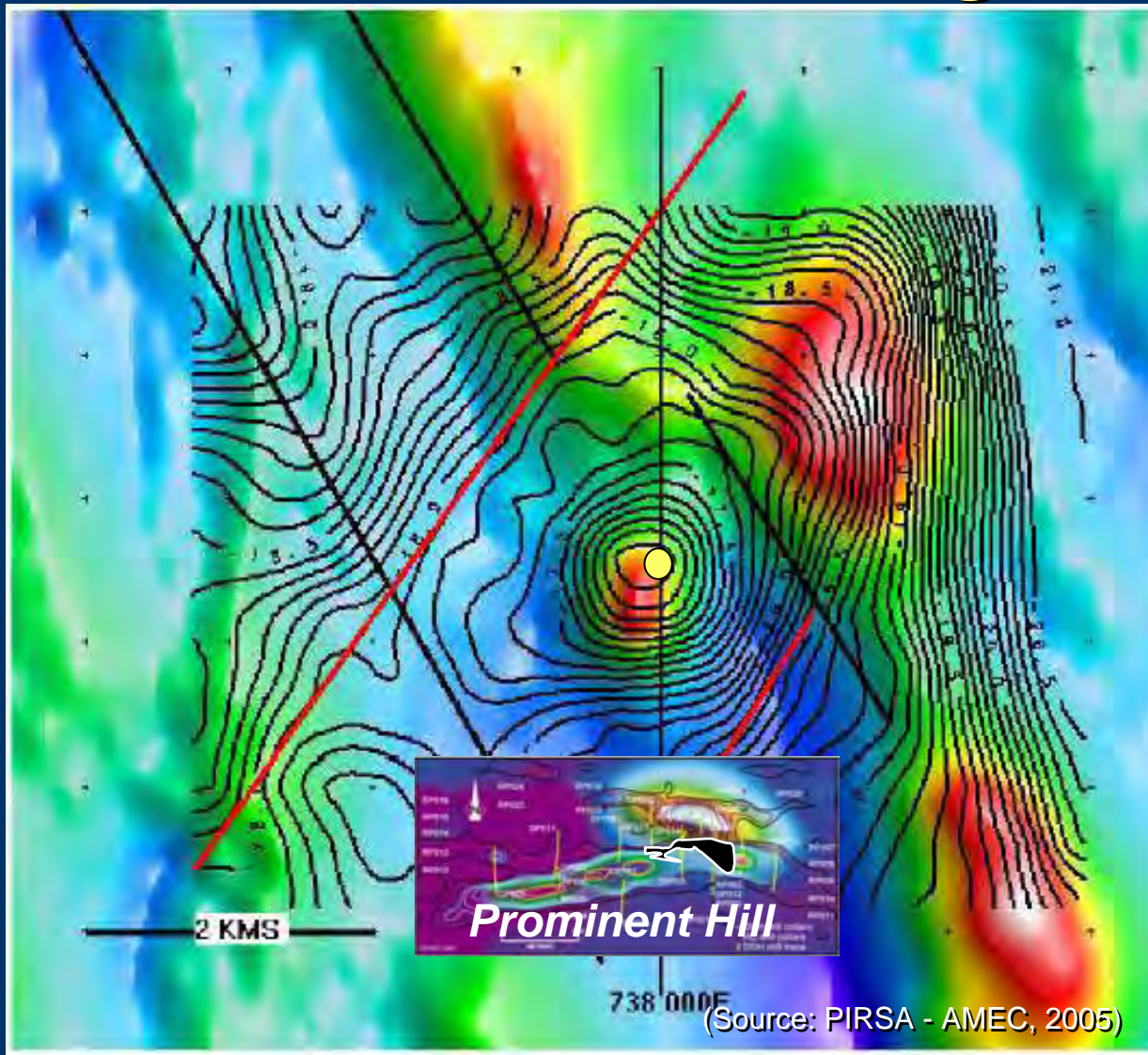


Carrapateena – gravity and magnetics



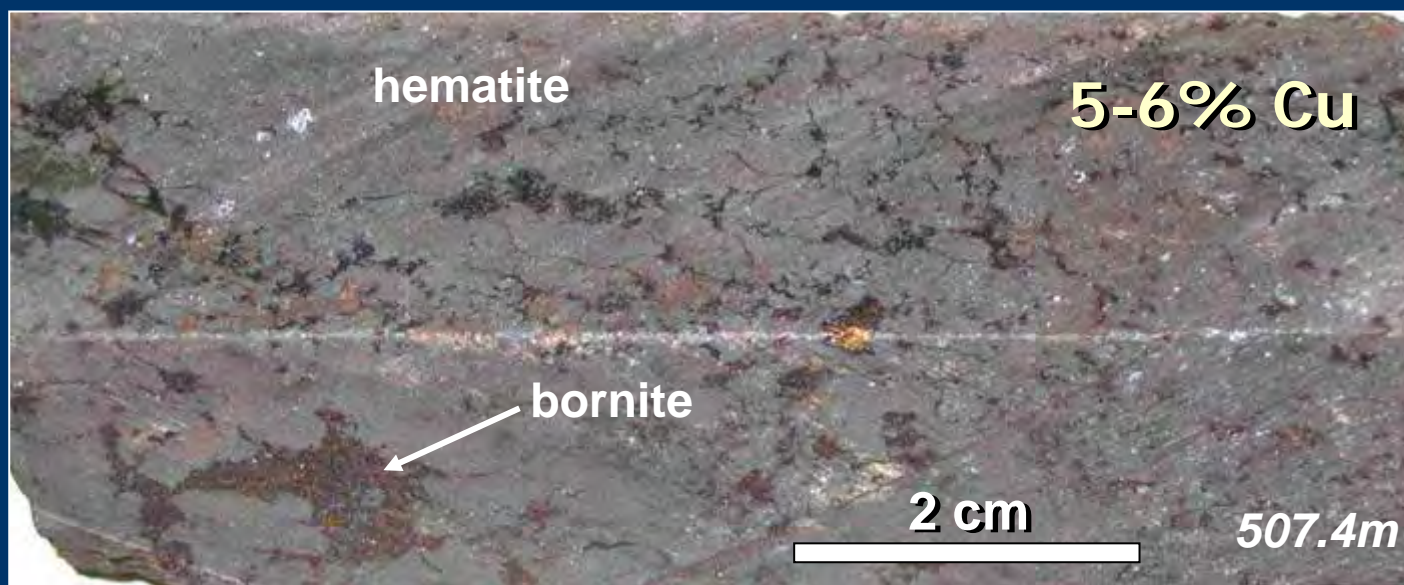
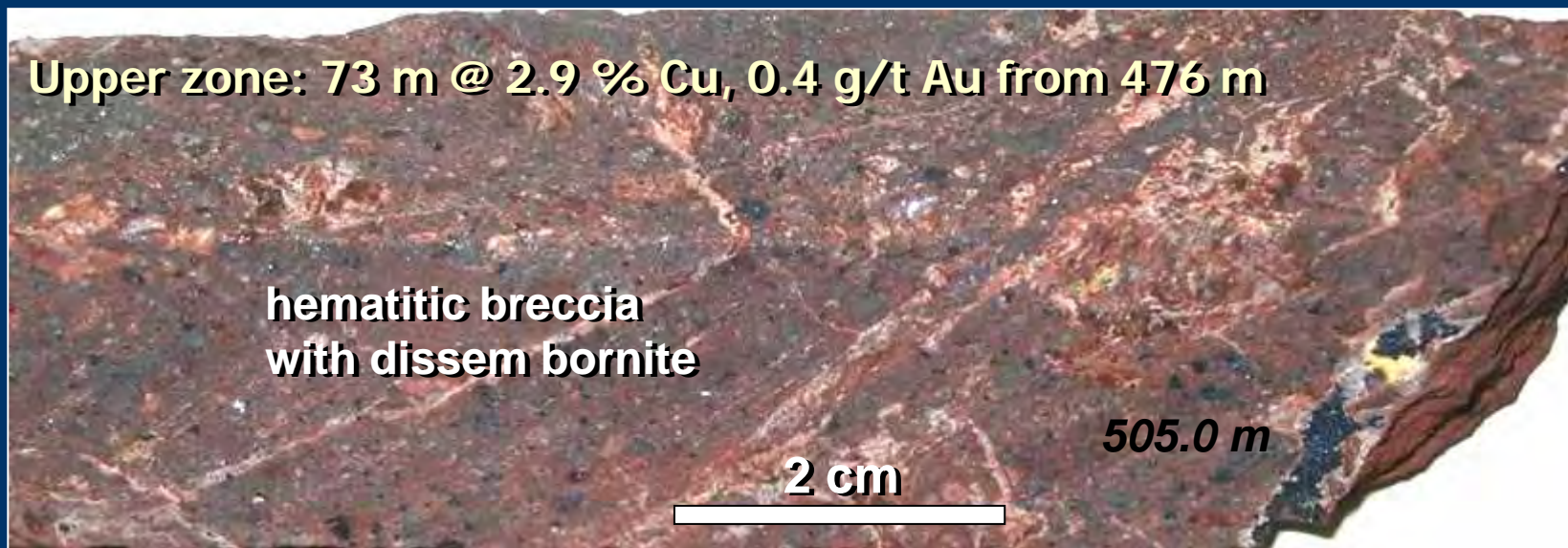
- MIM drilled Salt Creek anomaly to NW in 1970's; hm-ser alt'n
- MIM re-entered in JV with Terramin Aust Ltd & Rudy Gomez; defined Carrapateena gravity anomaly in 2002-2003
- MIMDAS survey looked discouraging; MIM pulled out

Carrapateena – gravity contours (0.1 mgal) and residual magnetics



- Early 2005 – RMG Services drills CAR1 and CAR2, co-funded by PACE
- Oct 2005 - TeckCominco takes ownership
- \$18m to be spent on drill-out

Carrapeteena CAR02: 178 m @ 1.83% Cu, 0.6 g/t Au



(photos with permission of TeckCominco; assay results from RMG Services, PACE, 2005)

Carrapeteena CAR02: 178 m @ 1.83% Cu, 0.6 g/t Au

Lower zone: 33 m @ 1.5 % Cu, 0.7 g/t Au to 641 m
(chalcopyrite zone)

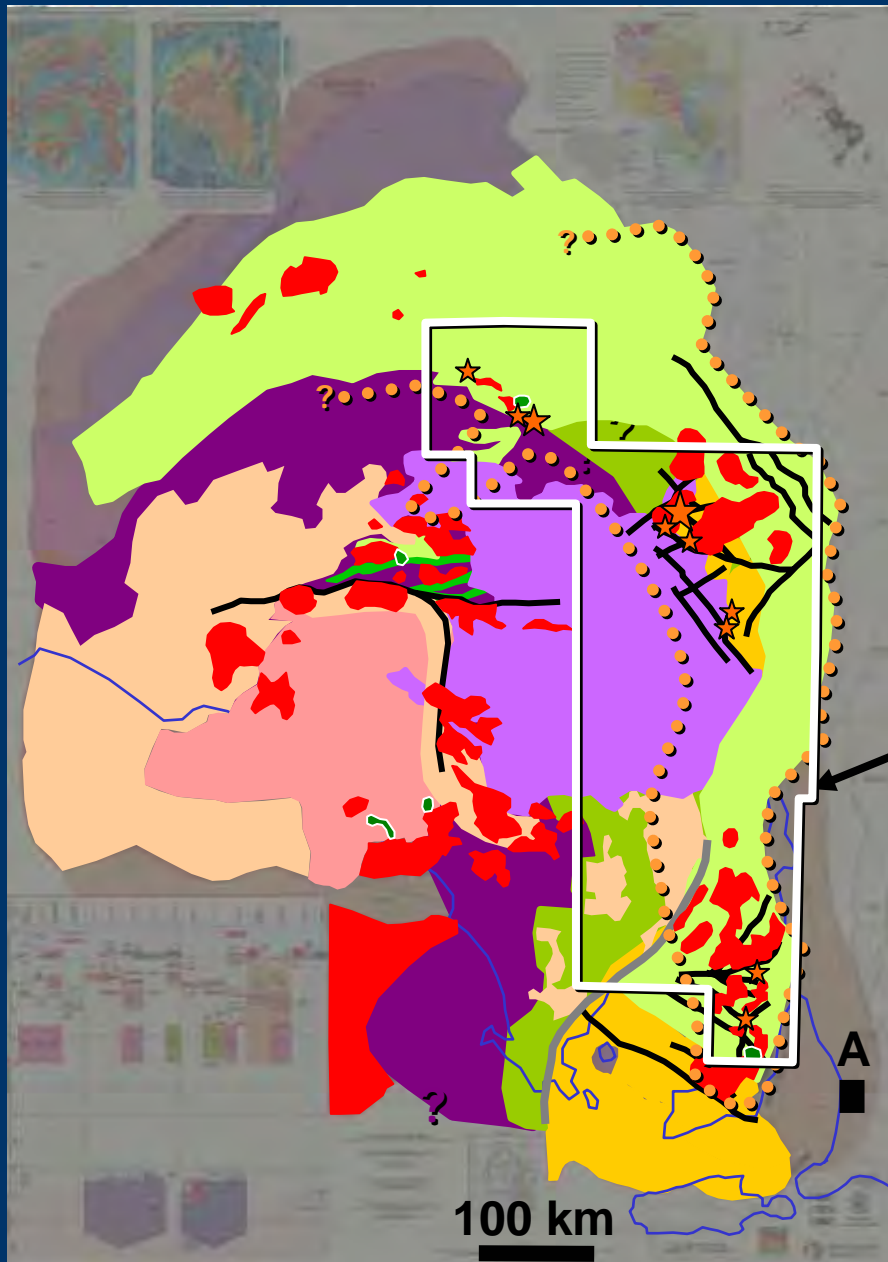


(photos with permission of TeckCominco; assay results from RMG Services, PACE, 2005)

2. Regional and deposit alteration

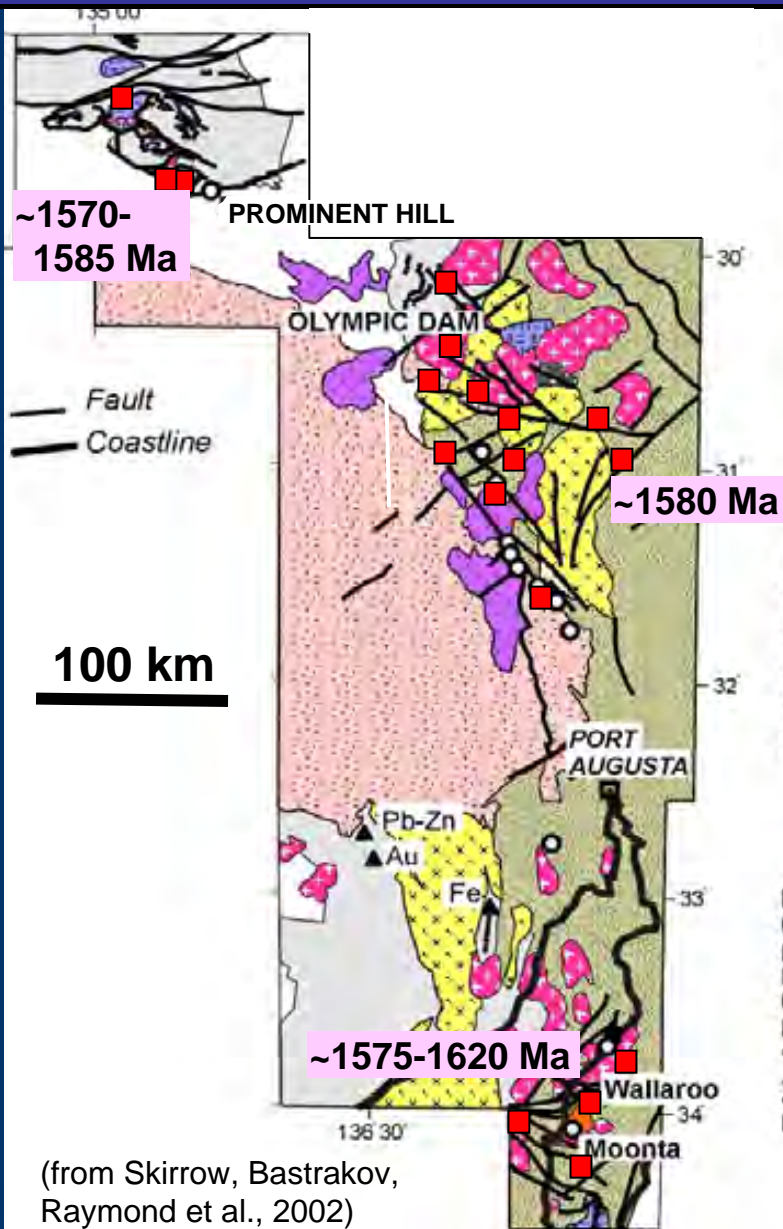


Olympic Cu-Au province, eastern Gawler Craton



Area of next slide

Regional to deposit-scale alteration

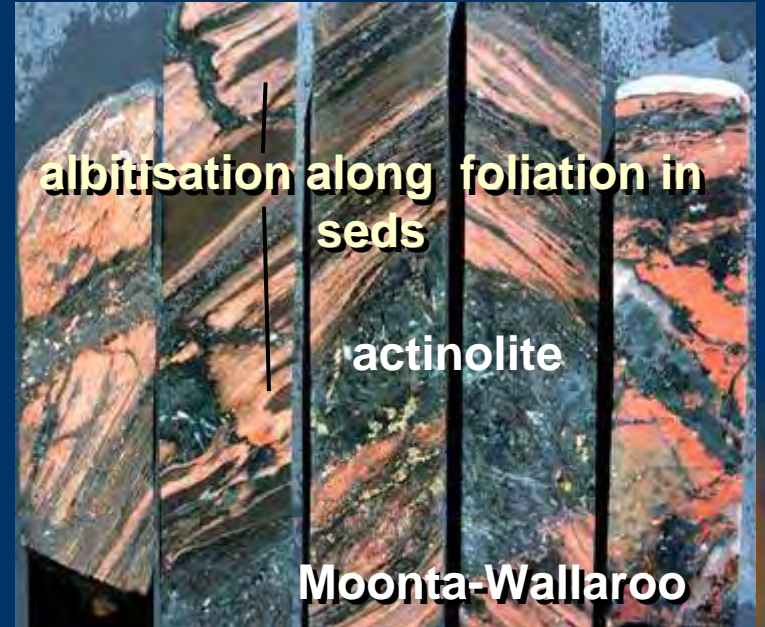
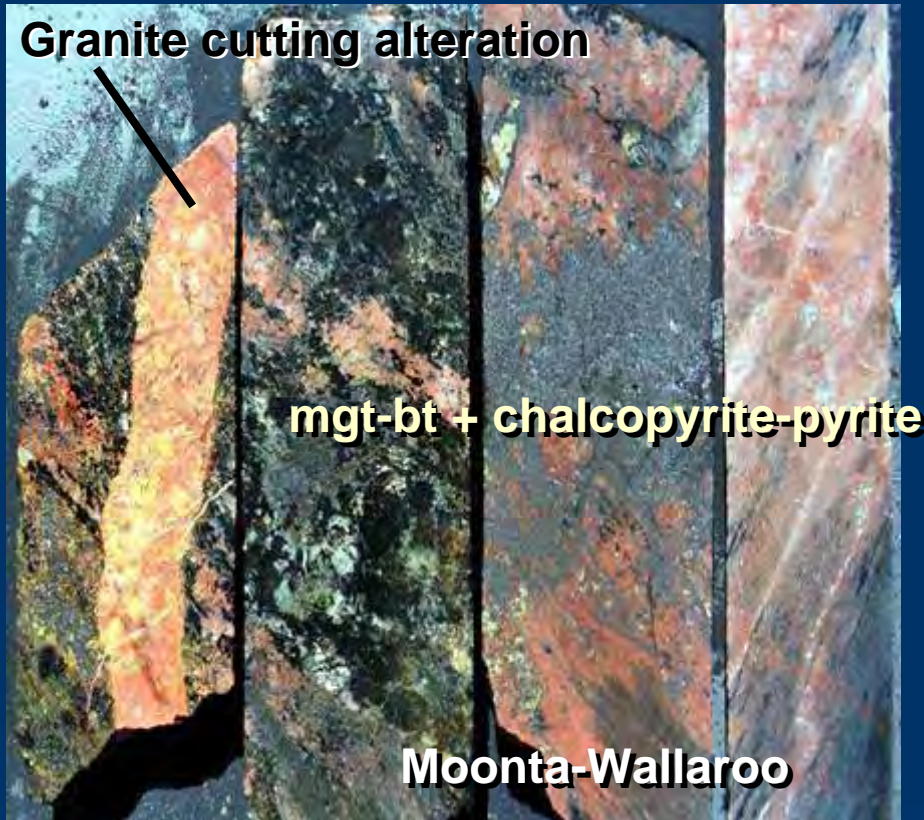


- Magnetite-alk feld-calcsil ± Cu-Au
- Magnetite-biotite ± Cu-Au

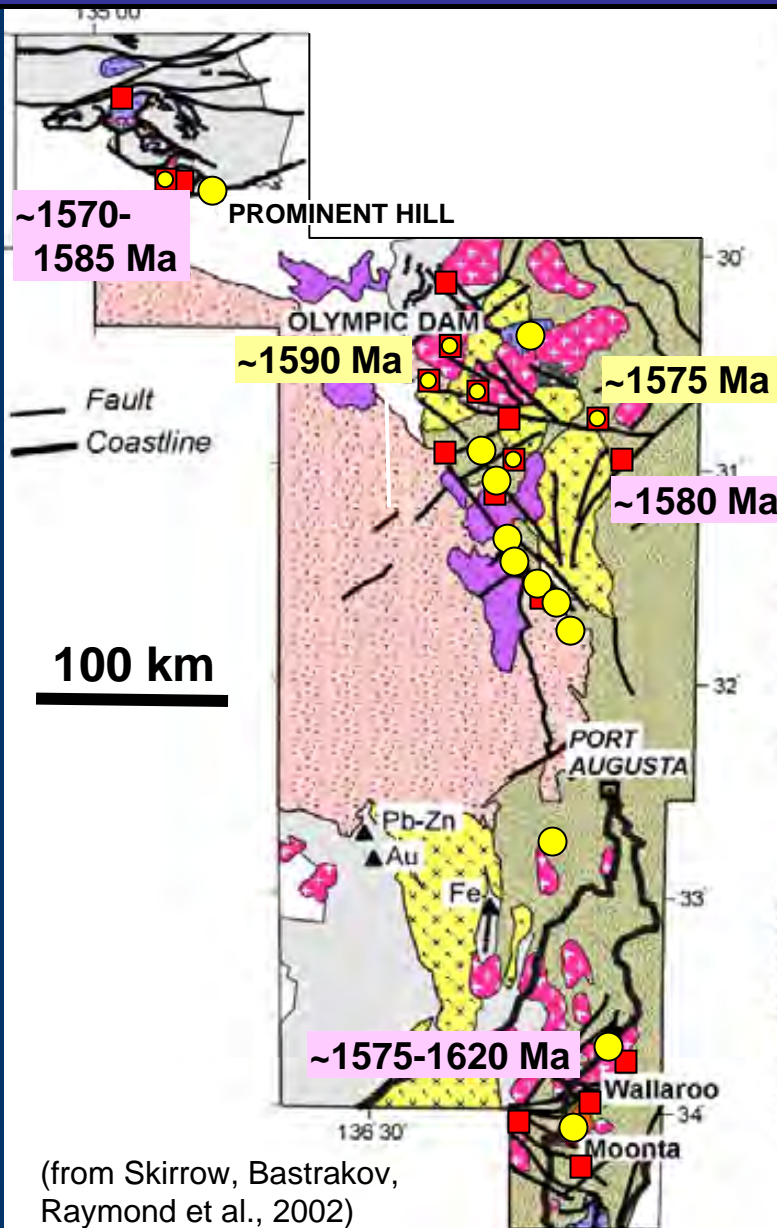


(from Skirrow, Bastrakov, Raymond et al., 2002)

Regional- to deposit-scale magnetite alteration, minor Cu



Regional to deposit-scale alteration



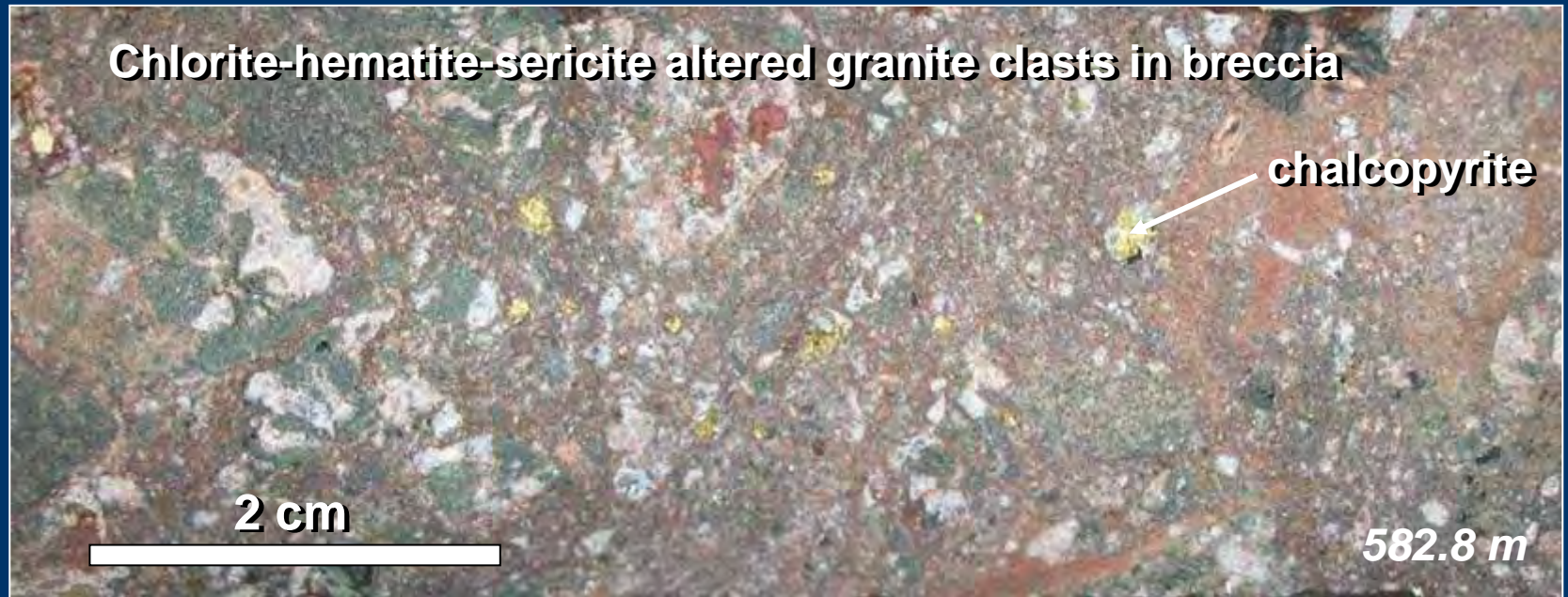
- Magnetite–alk feld–calcsil \pm Cu–Au
Magnetite–biotite \pm Cu–Au
- Hematite–ser–chl–carb
 \pm Cu–Au–U
- ◼ Hm overprinting magnetite
(but synchronous at OD; Haynes et al., 1995)



(from Skirrow, Bastrakov,
Raymond et al., 2002)

Carrapeteena CAR02: 178 m @ 1.83% Cu, 0.6 g/t Au

Middle zone: 58 m @ 0.9 % Cu, 0.9 g/t Au
(granite-chalcopyrite zone)



(photo with permission of TeckCominco; assay results from RMG Services, PACE, 2005)

District- to deposit-scale hematitic alteration & Cu-Au

Prominent Hill

hematite-sericite
alteration + Cu-sulfides,
Au (LREE, U)



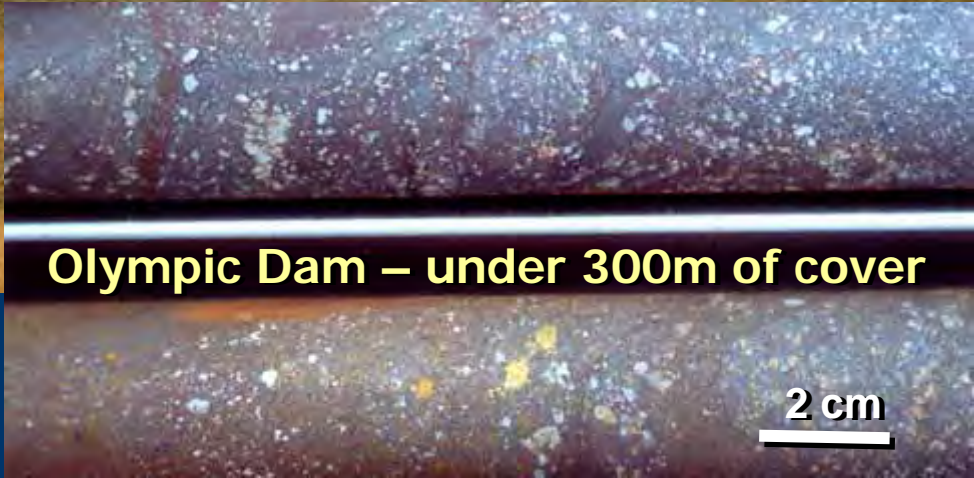
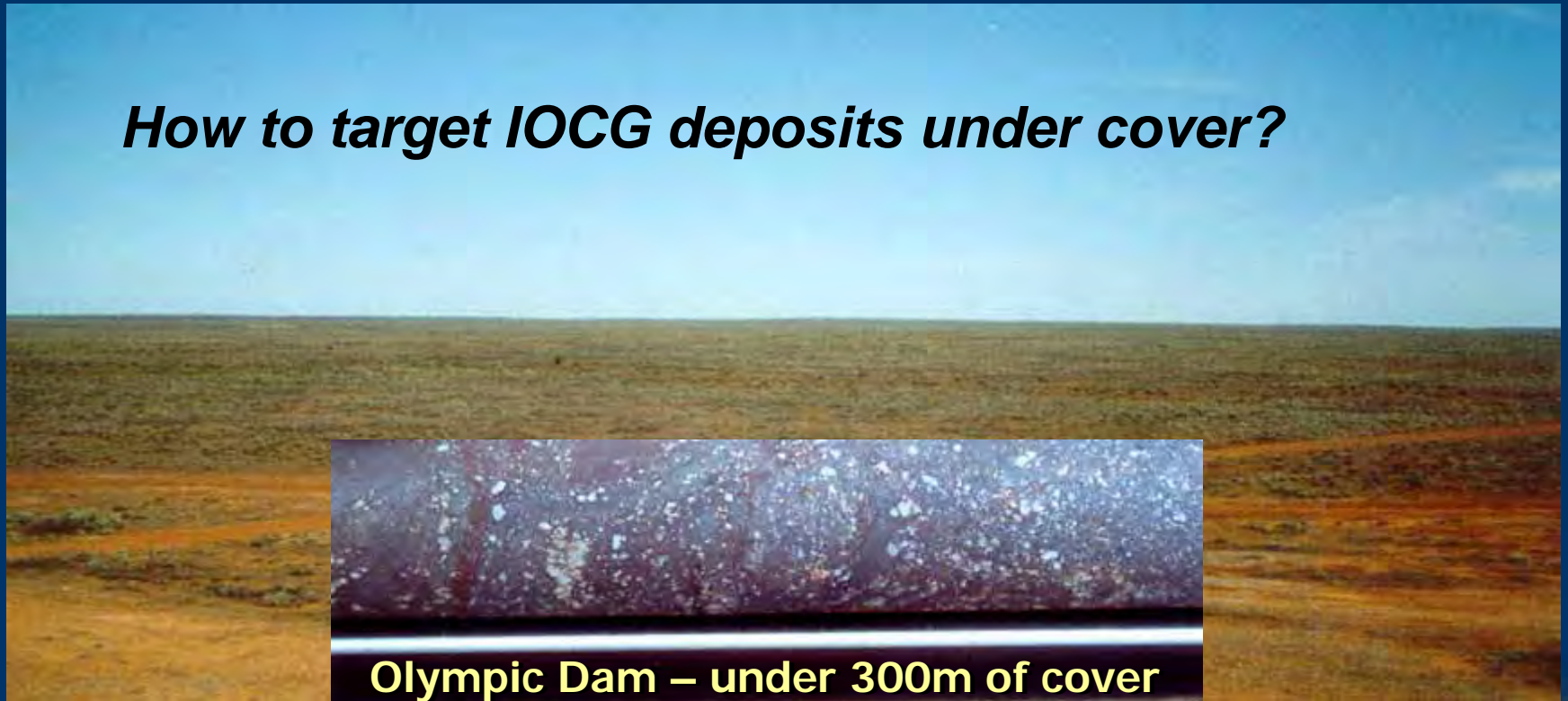
*IOCG districts have
mgt, but hm-ser is
better for OD / PH style*

DP003 463-464m: 30% Fe, 2.9% Cu, 0.9 g/t Au, 8g/t Ag
Chalcocite and Bornite within flow banded haematite breccia

Source: Minotaur Resources
website, 2003

3. Targeting higher grade Cu-Au

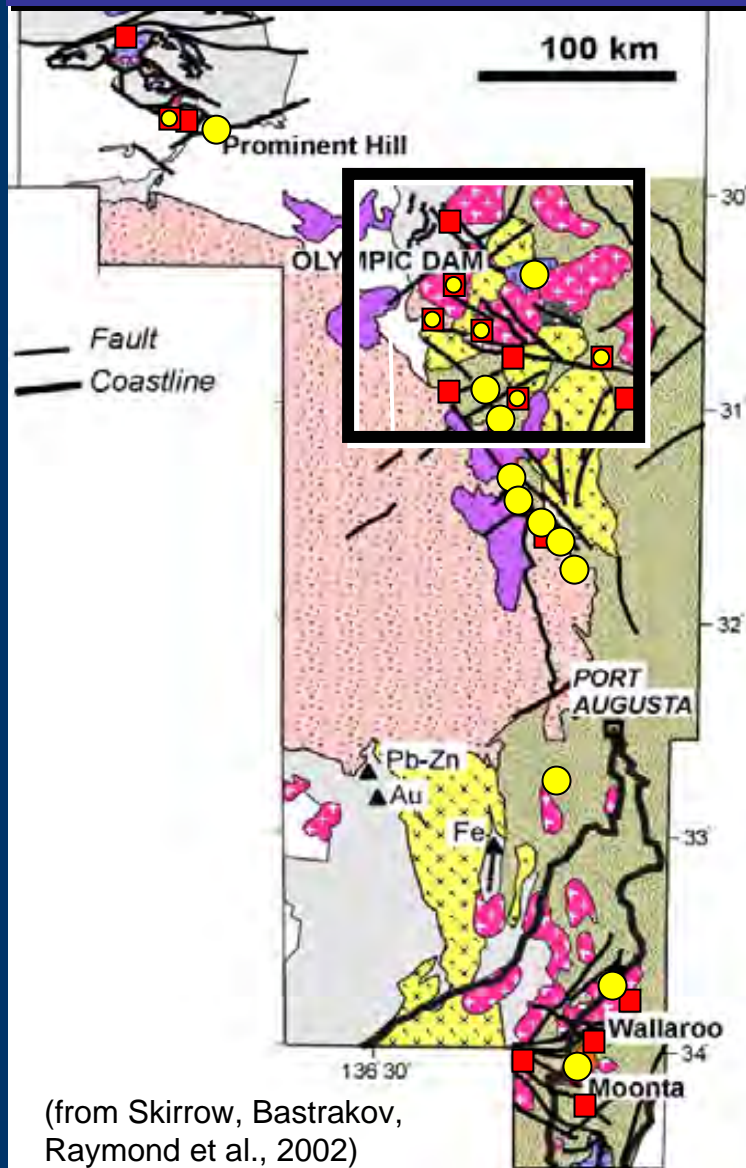
How to target IOCG deposits under cover?



Olympic Dam – under 300m of cover

2 cm

Mapping alteration undercover with potential-field inversion modelling



Olympic Cu-Au province alteration

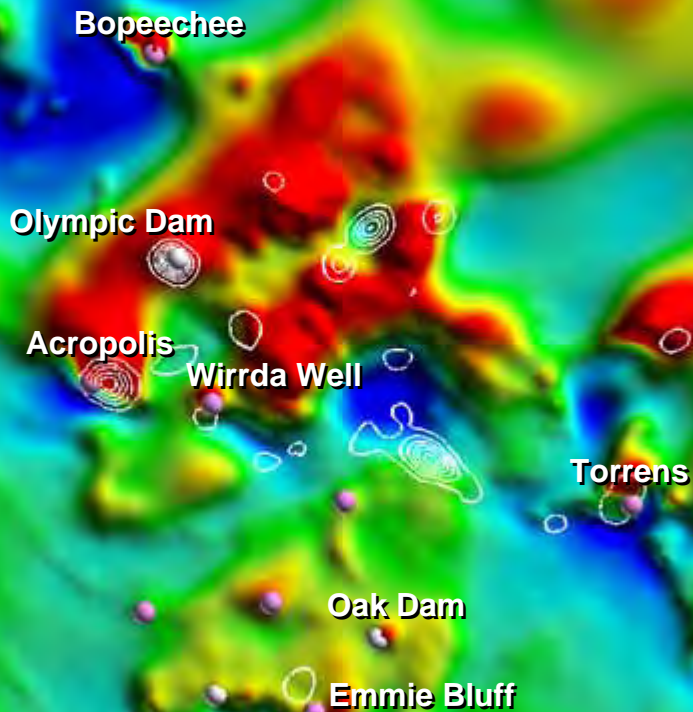
- Magnetite–alk feld–calcsil \pm Cu-Au
Magnetite–biotite \pm Cu-Au
- Hematite–ser–chl–carb \pm Cu-Au-U
- ◐ Hm overprinting magnetite



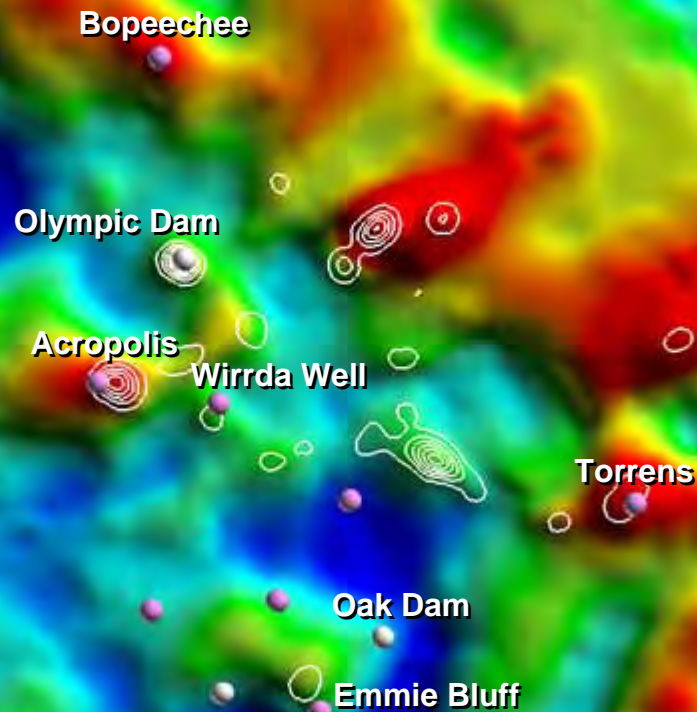
(from Skirrow, Bastrakov, Raymond et al., 2002)

District scale targeting: mapping alteration using inversion modelling (Nick Williams, GA)

Total Magnetic Intensity



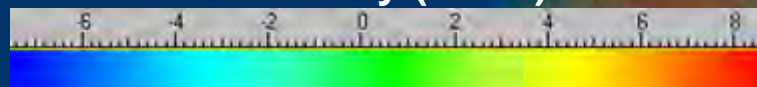
Gravity



Total magnetic intensity (nT)



Gravity (mGal)



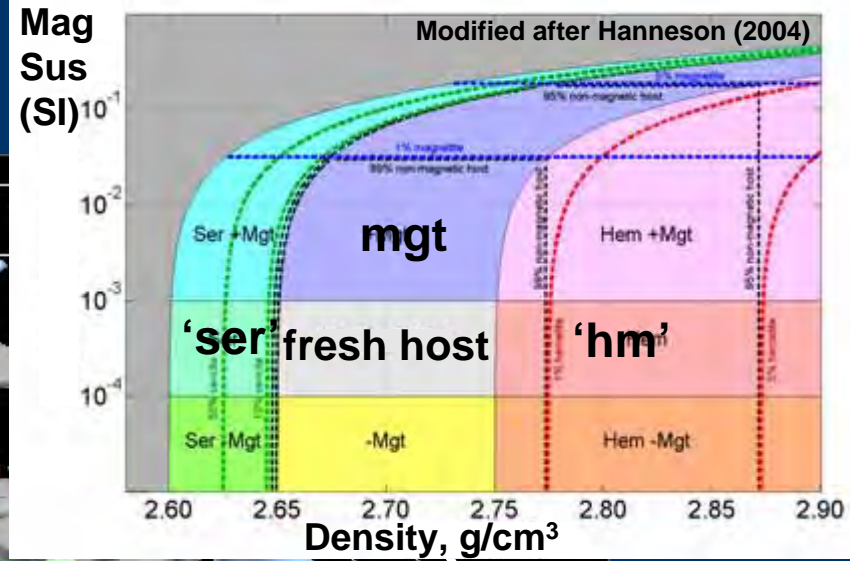
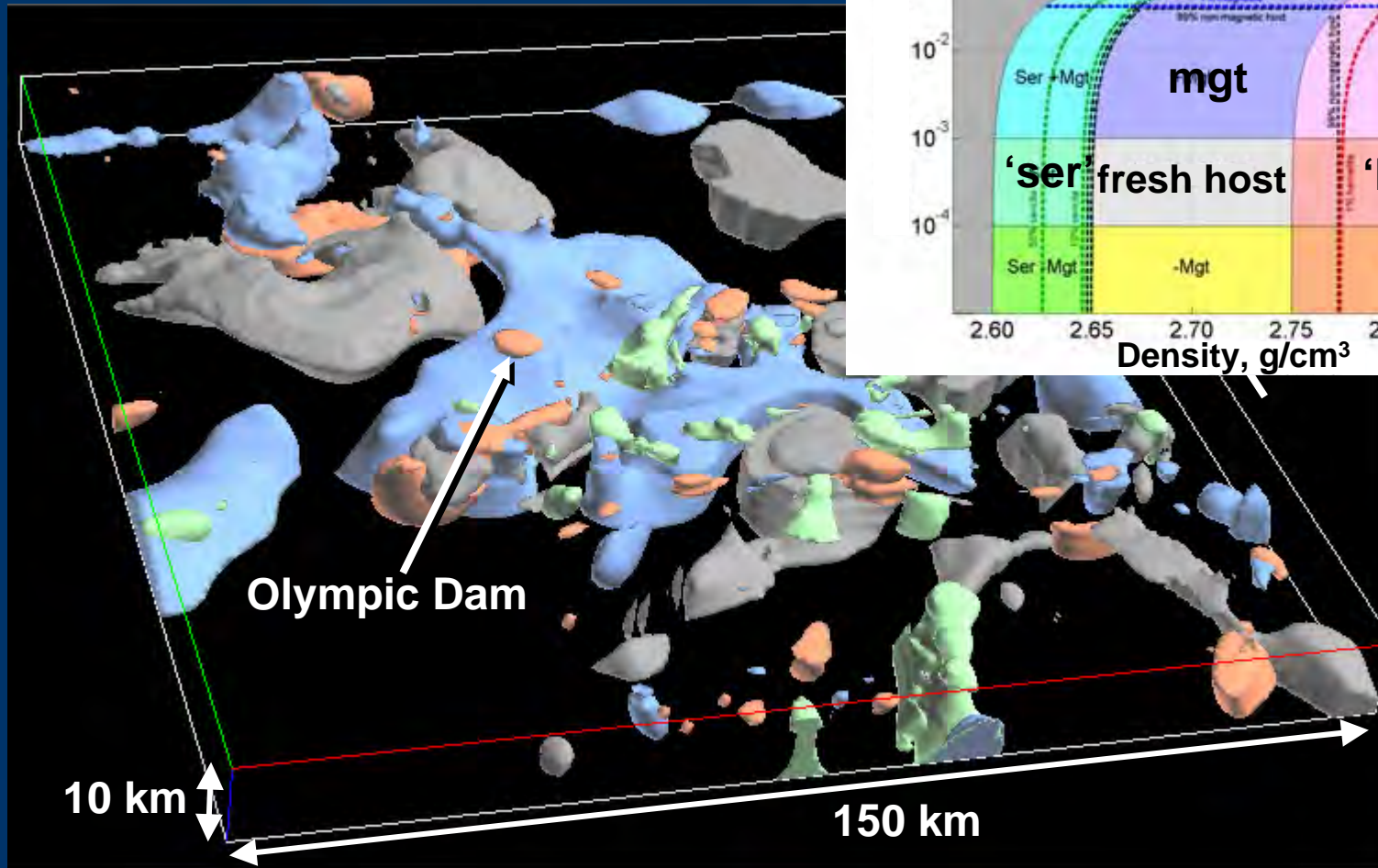
Contours of 0.5% 'sulfides+hematite' at -500 m

● Cu Deposits

● Cu Prospects

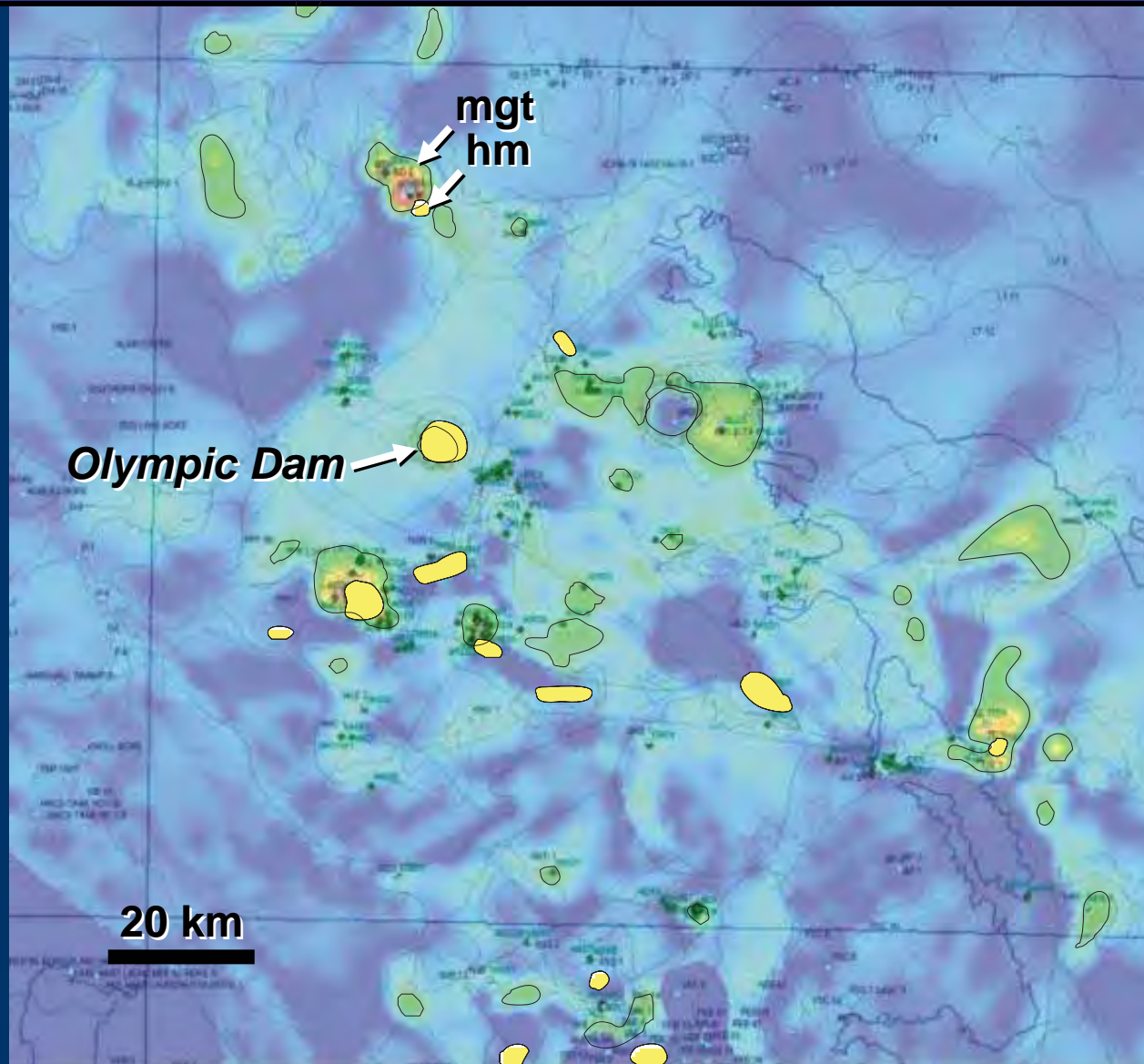


Mapping alteration undercover by 3D inversion of magnetic and gravity data



Voxels:
1 x 1 x 0.5 km

Mapping alteration undercover by 3D inversion of magnetic and gravity data

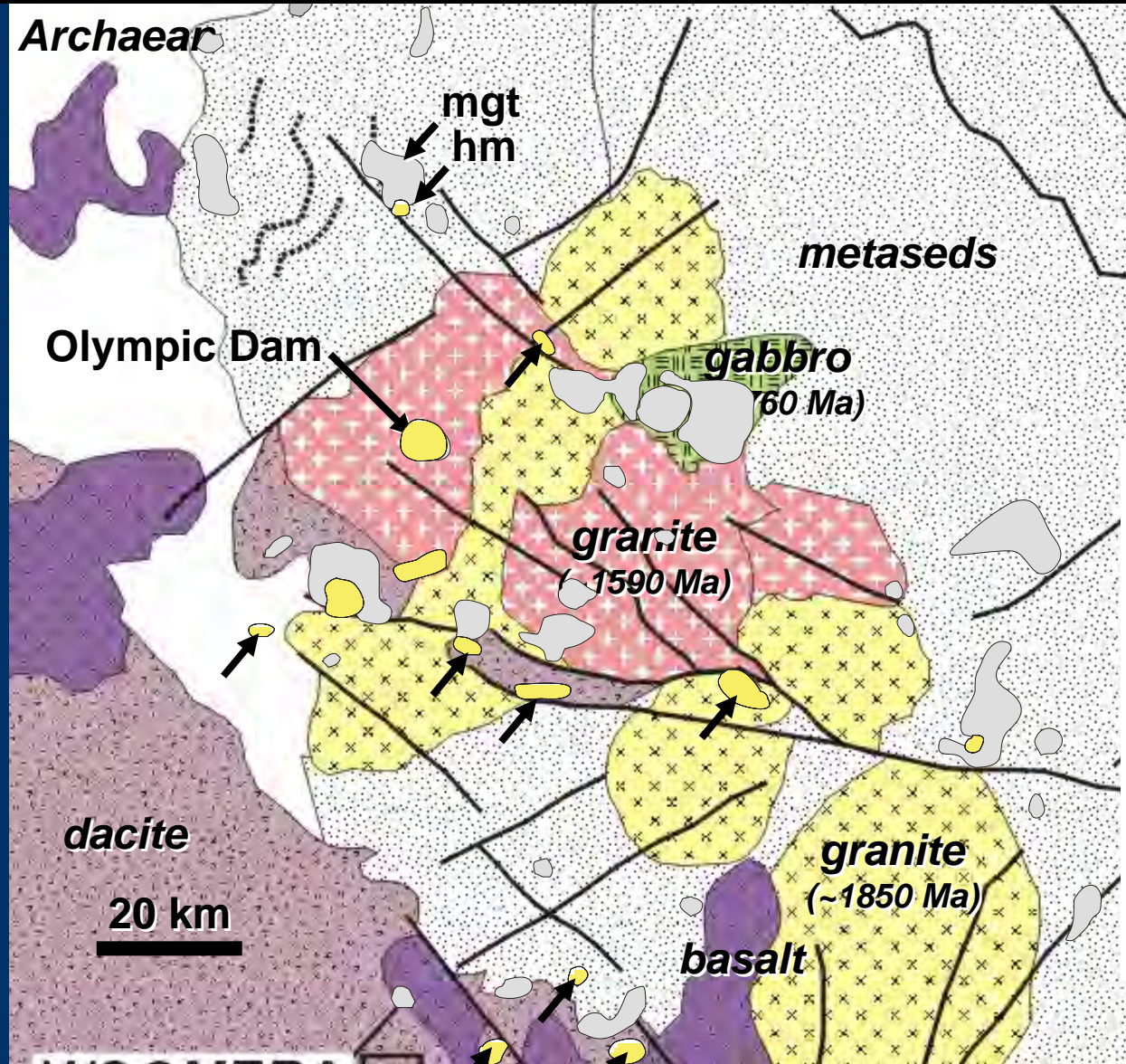


2D slice of 3D inversion model for mgt at ~-500m

Anomalous Magnetite (contour for > ~2% vol.)

Anomalous 'hematite' (contour for > ~2% vol.)

Mapping alteration undercover by inversion of magnetic and gravity data



Basement geology

Anomalous magnetite (> ~2% vol.)

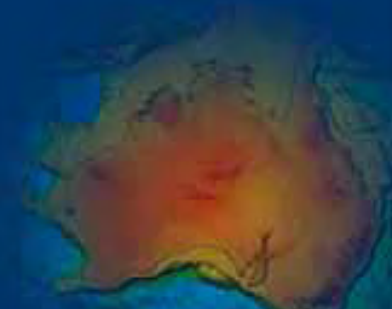
Anomalous hematite (> ~2%)

💡 **IOCG alteration controlled by major NW-WNW fault zones (less so by lithology); & Many untested 'hm' anomalies**

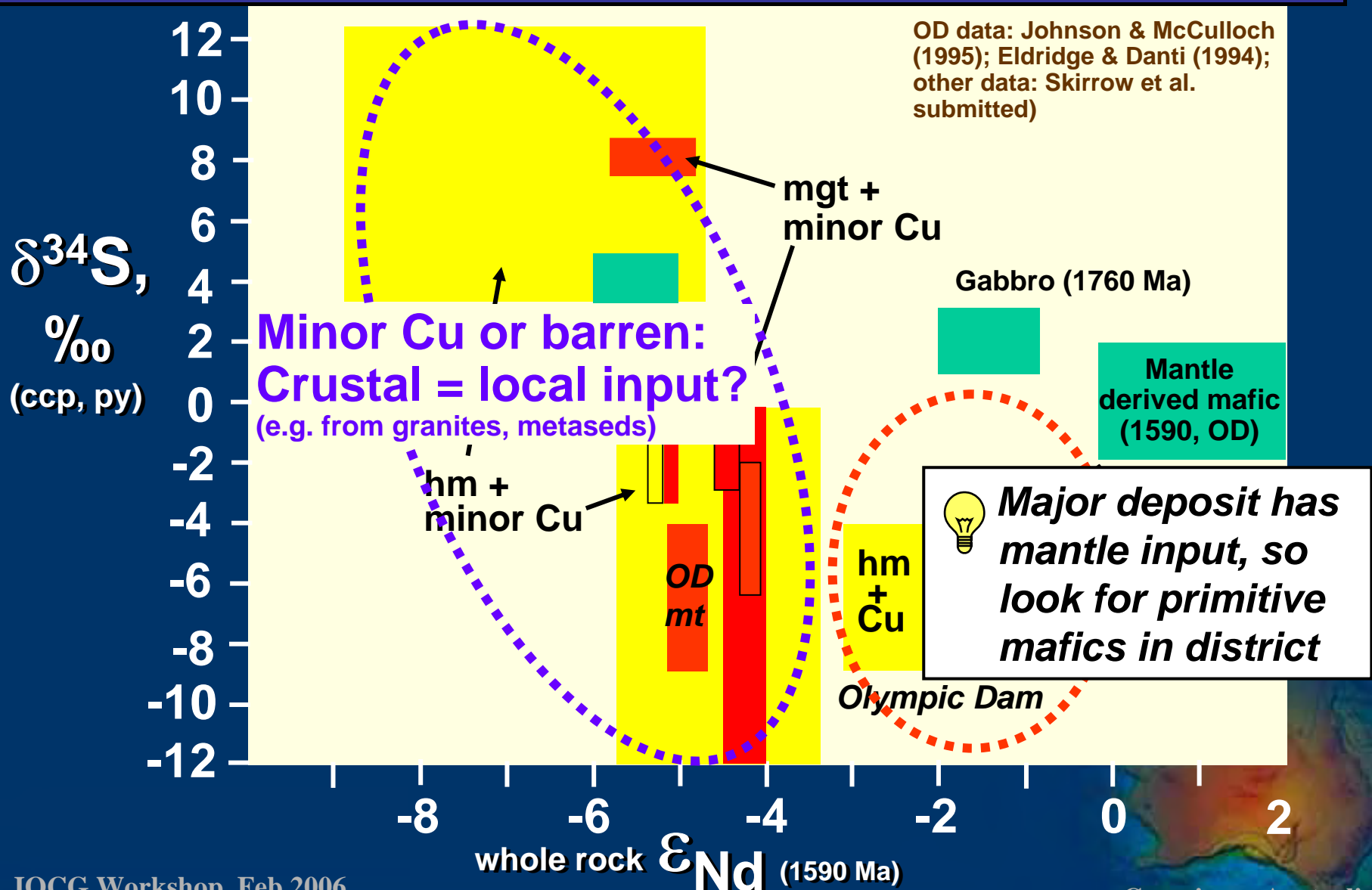
OK, but which 'hematite' anomalies have potential for major IOCG?

And, which parts of these alteration systems might contain higher grade Cu-Au mineralisation?

Turn now to geochemistry for deposit scale targeting.

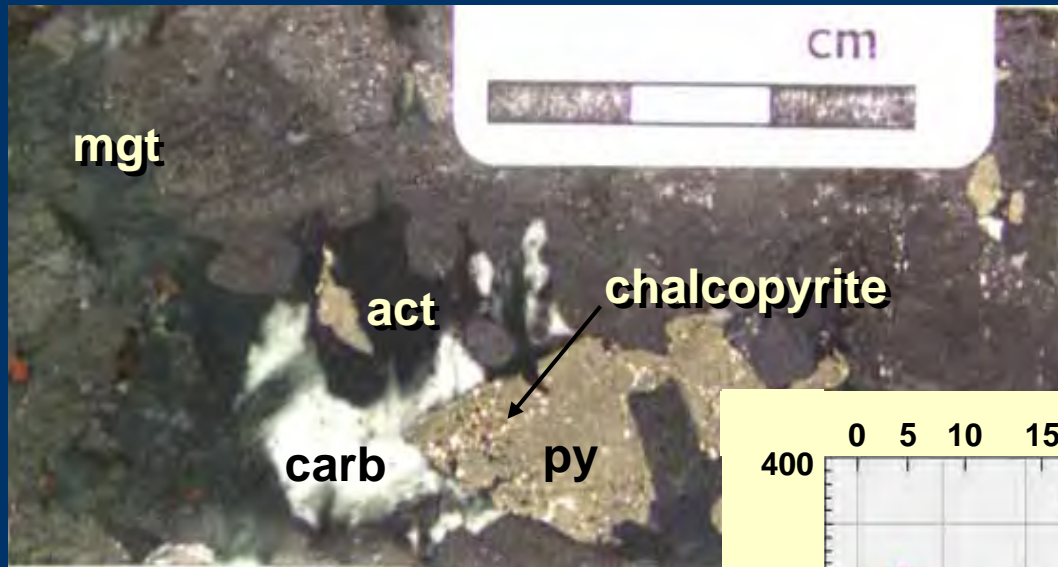


Discriminating fertile from minor alteration systems & deposits using neodymium & sulfur isotopes

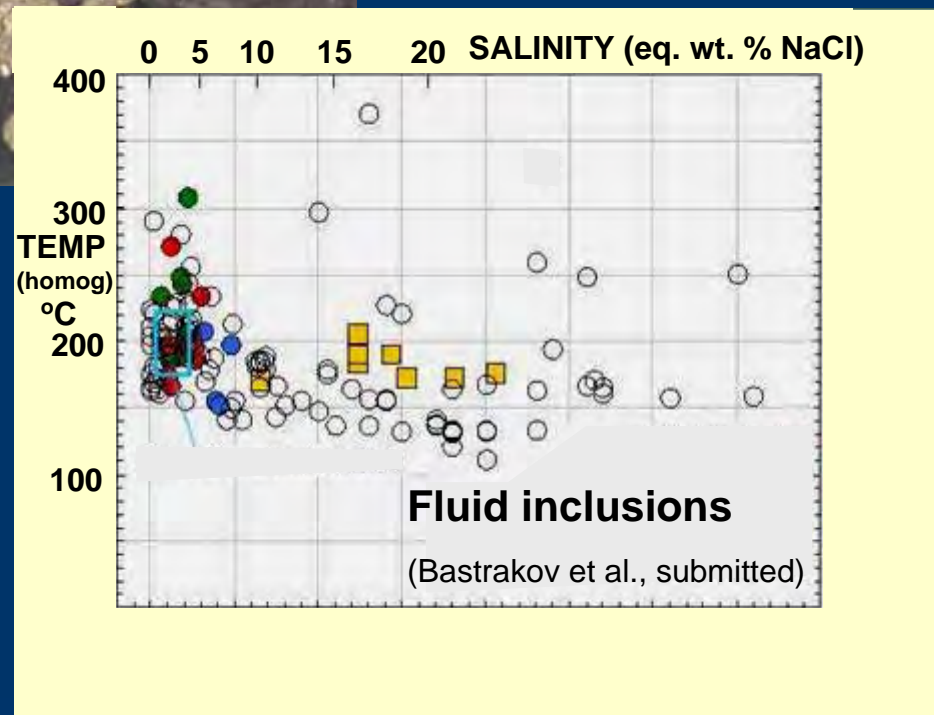


Deposit scale targeting: higher grade Cu-Au zones

Magnetite-rich alteration with minor chalcopyrite like this . . .

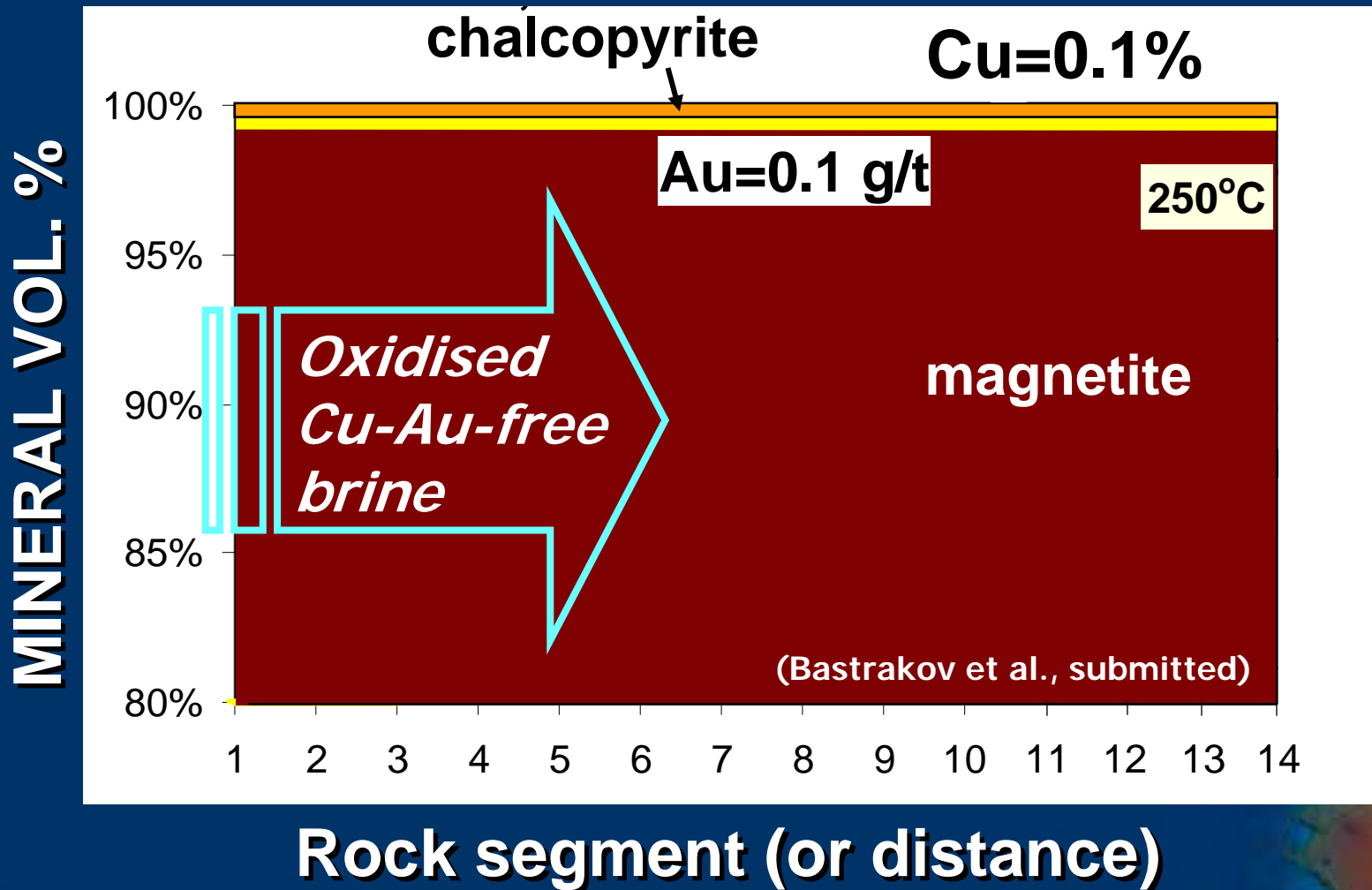


is commonly altered to hematite-chlorite-sericite by fluids like this . . .

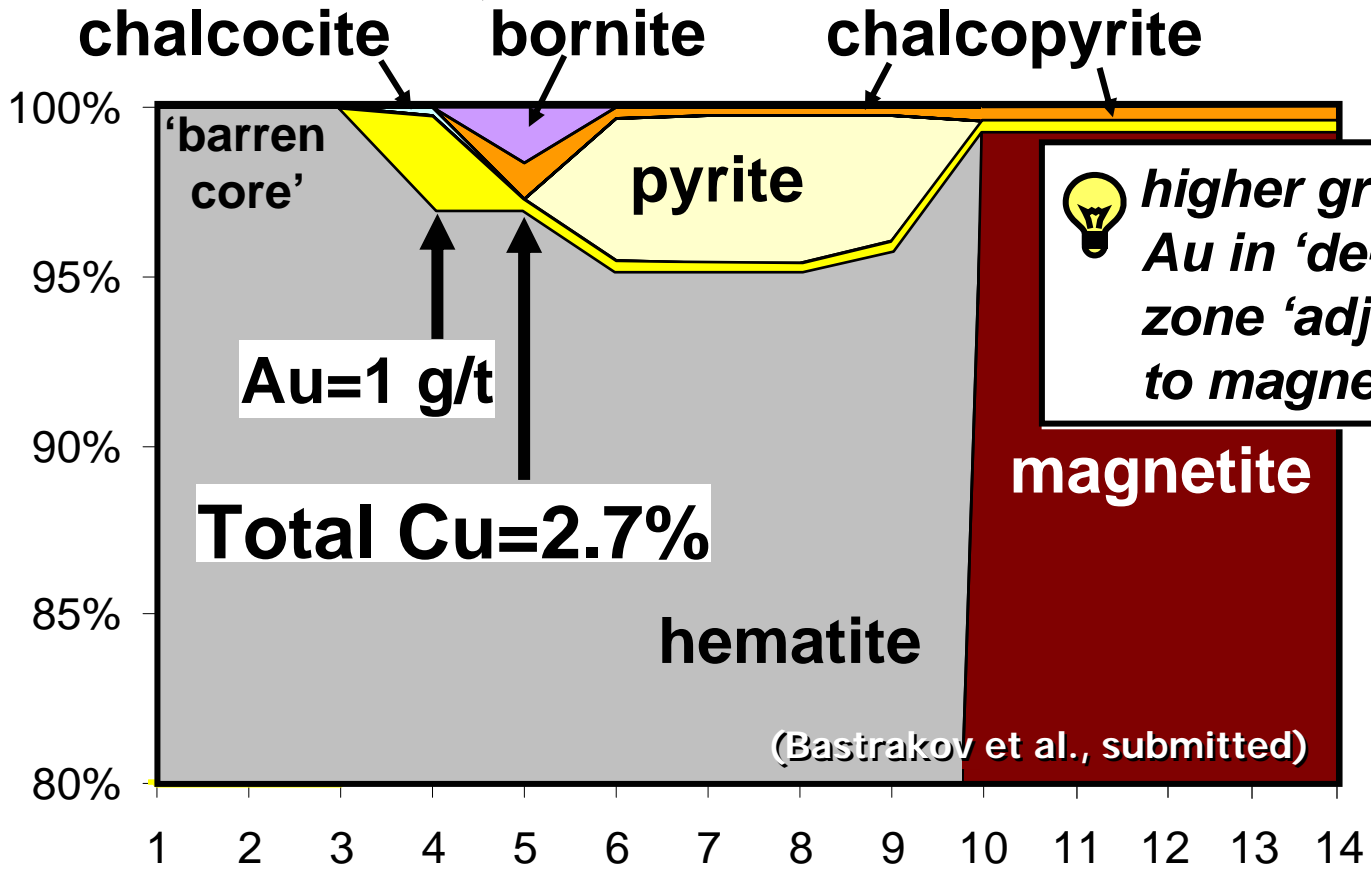
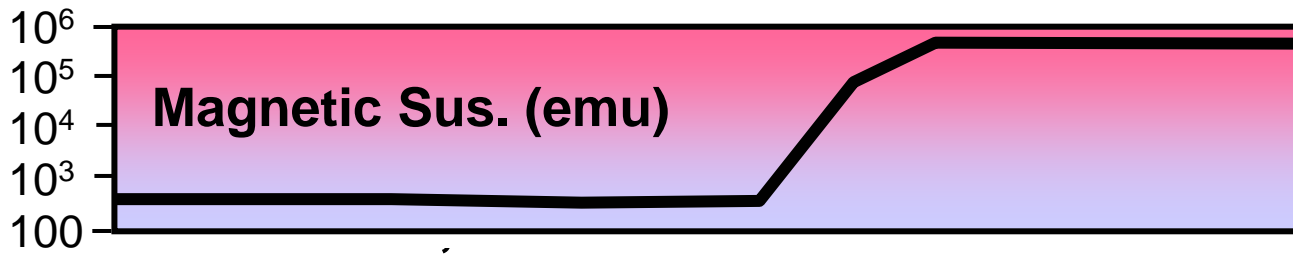


Deposit scale targeting: higher grade Cu-Au zones

What if we chemically model this scenario?



MINERAL VOL. %

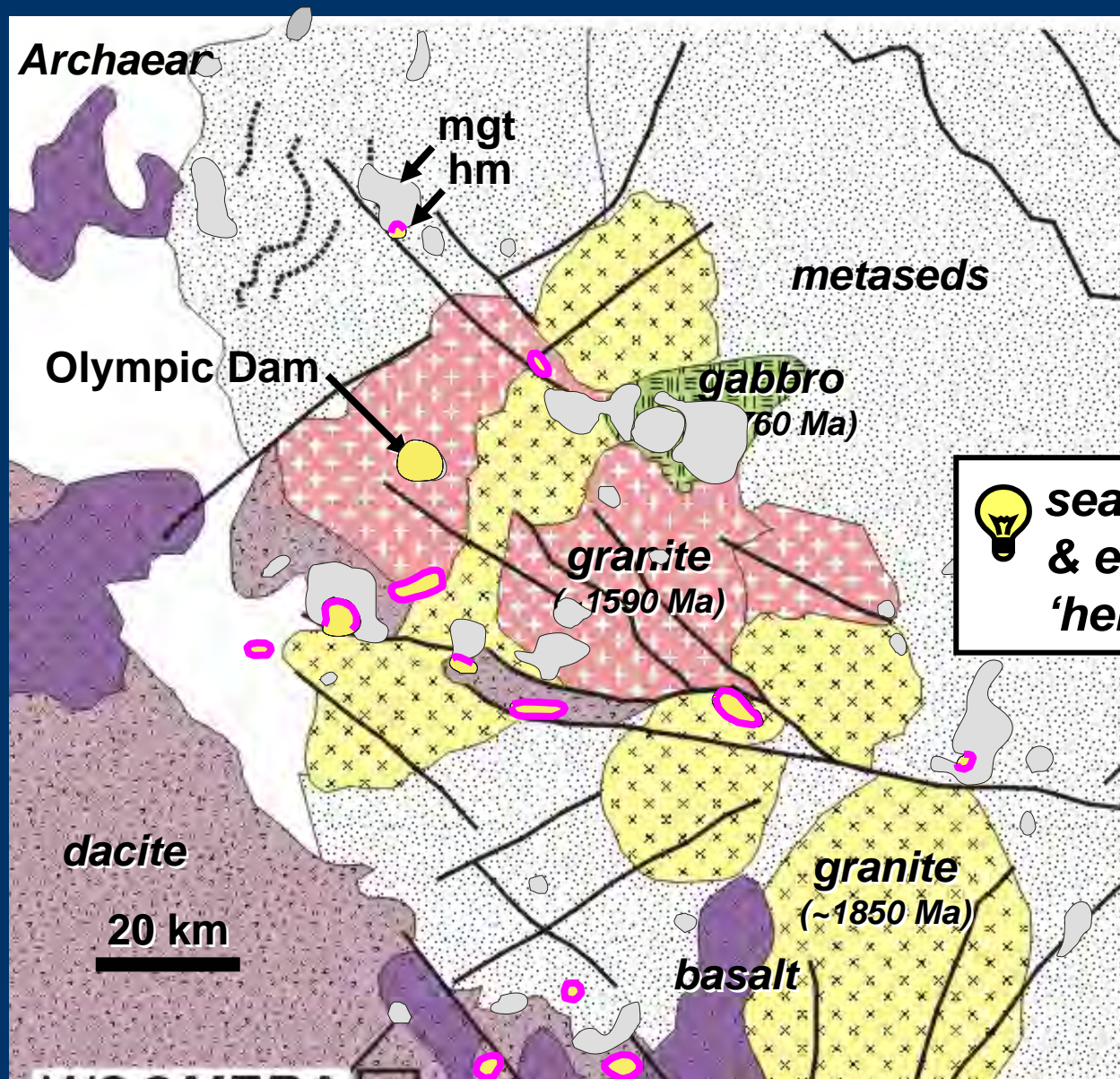


💡 higher grade Cu-Au in 'de-mag' zone 'adjacent' to magnetite

Au=1 g/t
Total Cu=2.7%

Rock segment (or distance)

Deposit scale targeting: higher grade Cu-Au zones



Basement geology

Anomalous magnetite (> ~2% vol.)

Anomalous hematite (> ~2%)



search contacts & edges of 'hematite' zones

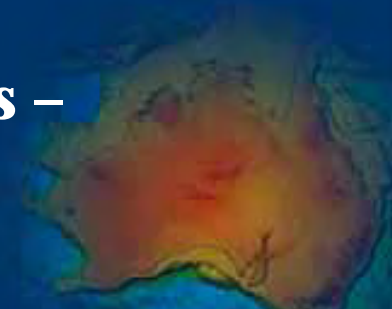
Conclusions – targeting IOCG mineralisation

New methods (inversion modelling; geochemical tools) can reduce risk in IOCG exploration in covered terranes.

Hematite-sericite-chlorite-carbonate alteration with or without 'earlier' magnetite-bearing alteration is a key ingredient for shallow-crustal (OD, PH, Car) style IOCGs.

District to deposit scale targeting: gradients are good! Search contact zones of hematitic alteration in 'fertile' systems (e.g. those with syn-alteration mafic dykes).

Look out for other associated(?) mineralisation styles – epithermal, porphyry, skarn.





Australian Government Geoscience Australia

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University of Tasmania

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Minotaur Expl., Oxiana Res., RMG Services, Stellar Res., Tasman
Res., TeckCominco, WMC Res.

