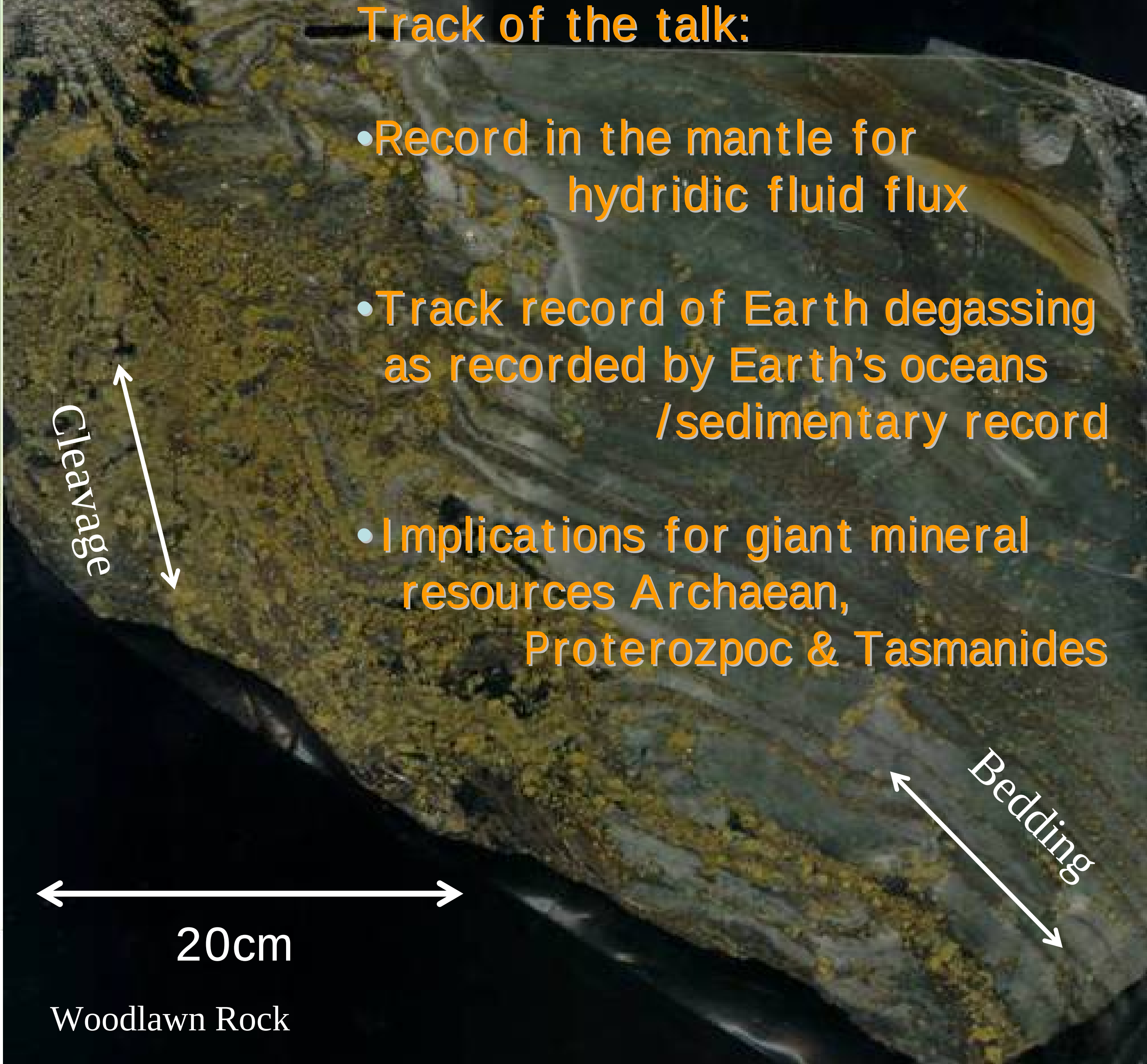
Mineral Systems in the Tasmanides: The Global Perspective

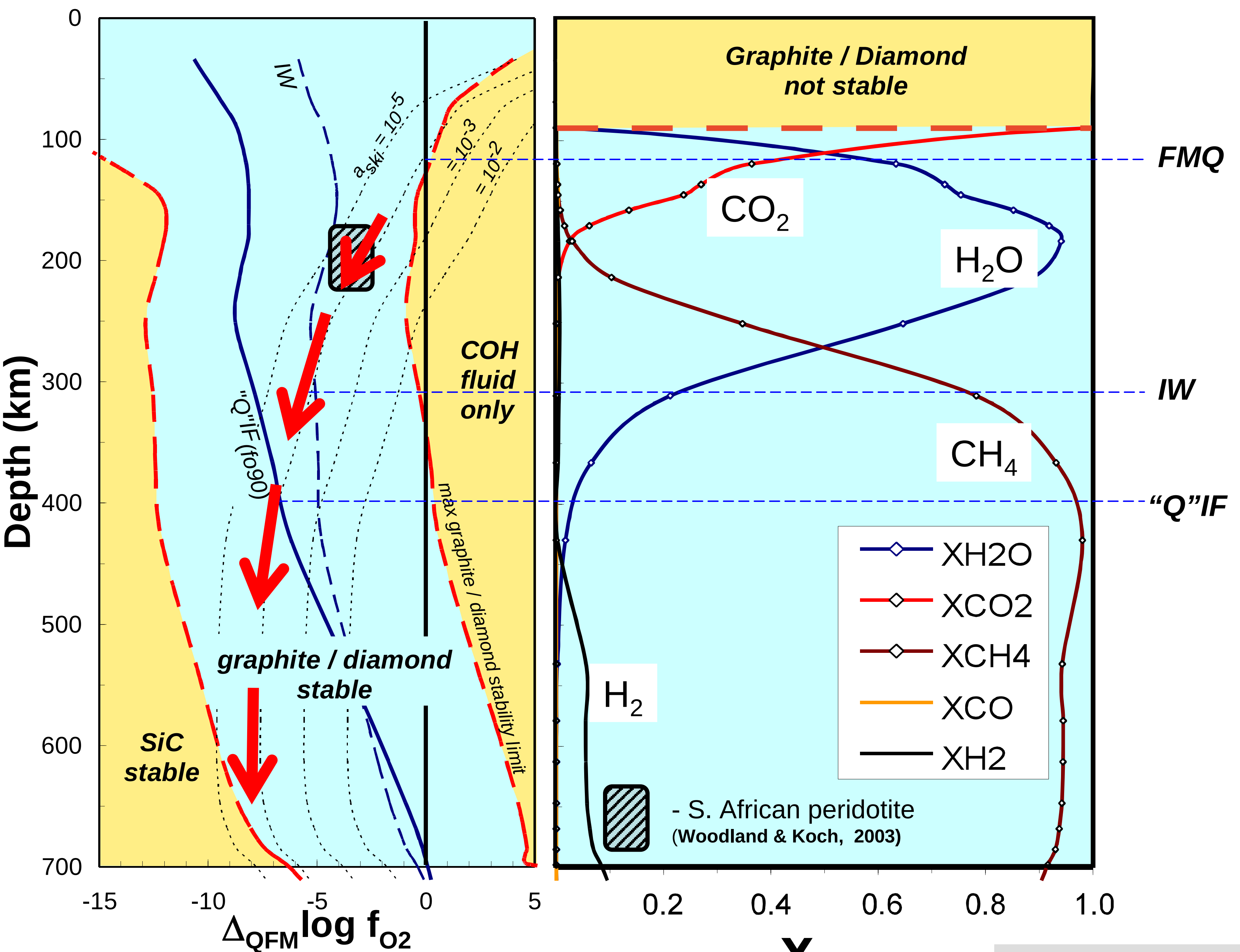
A color enhancement of an ultraviolet photograph of the spectrum of the upper atmosphere of the Earth and geo-corona.
The bright horizontal line is far ultraviolet emission of hydrogen extending 40,000 miles either side of the Earth.
UV camera was operated by Astronaut John W. Young on the Apollo 16 lunar landing mission

predictive mineral discovery

Track of the talk:

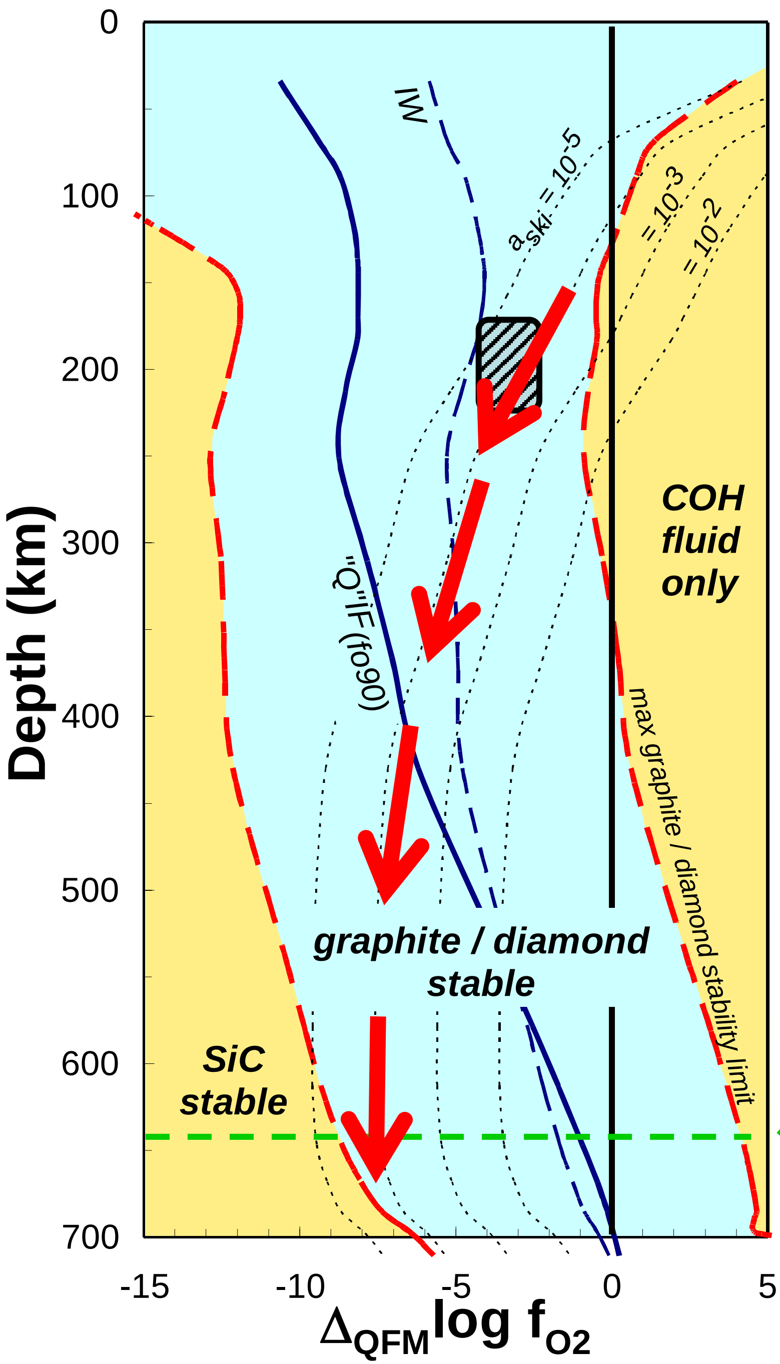
- Record in the mantle for hydridic fluid flux
- Track record of Earth degassing as recorded by Earth's oceans /sedimentary record
- Implications for giant mineral resources Archaean, Proterozpoc & Tasmanides

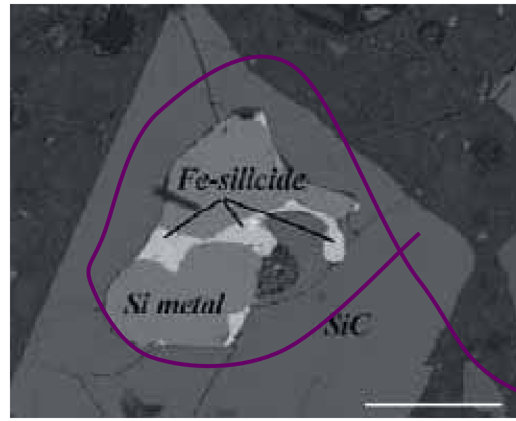




2Fe2+3Fe3+2Si3O4(gt) = 4Fe2SiO4(ol) + 2FeSiO3(px) + O2; Gudmundsson & Wood,1995

Ed Mikucki, 2006

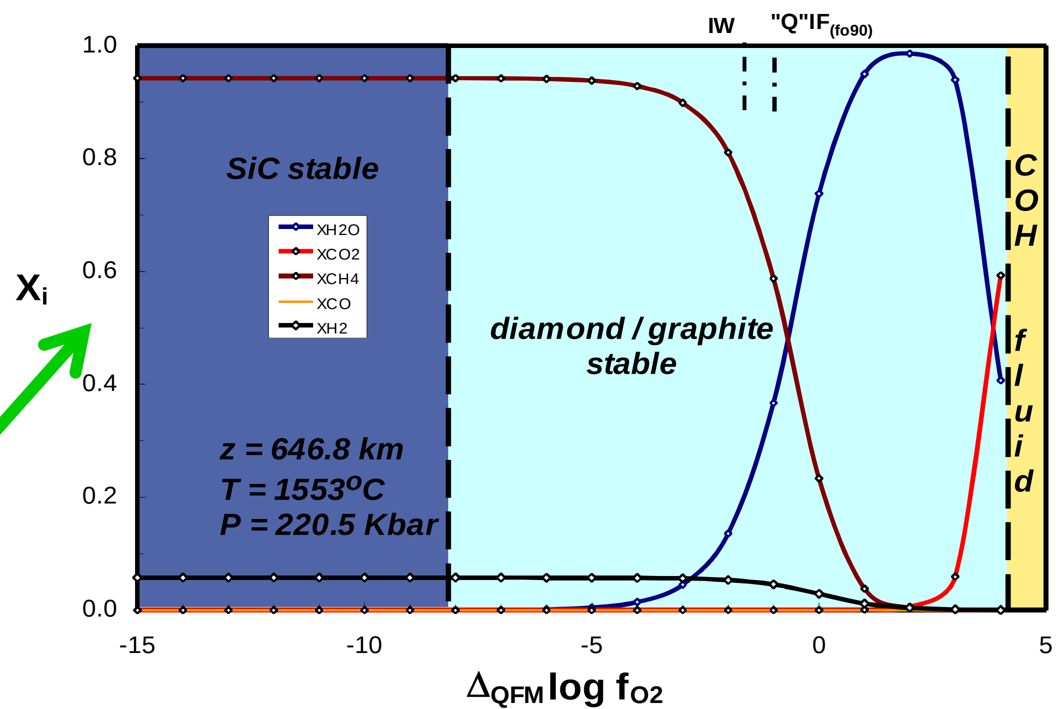


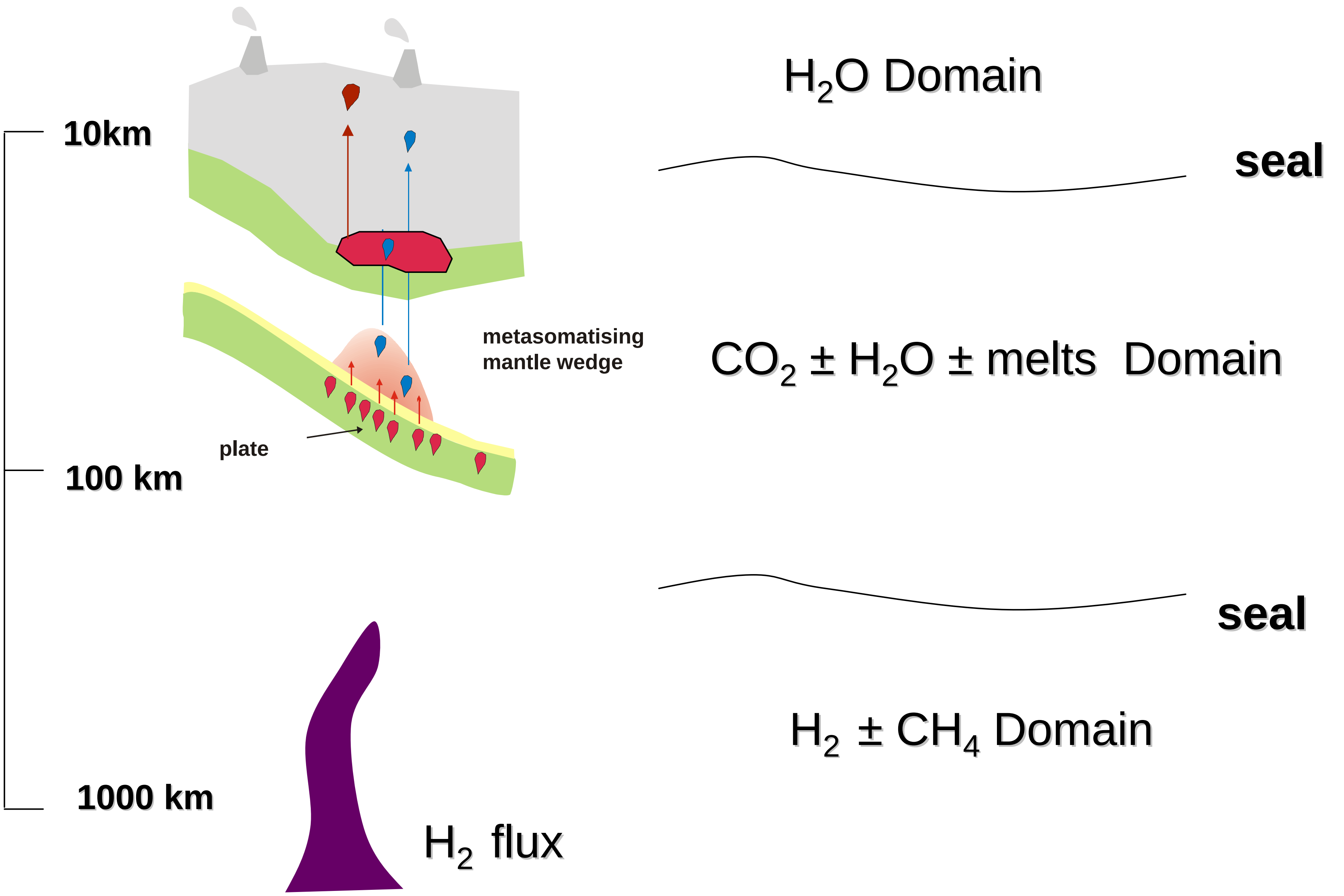


Di Pierro et al, 2003

Si
$FeSi_2$
Fe_3Si_7
$CaSi_2$
Si_2N_2O
Fe-Ti silicides
REE silicates

Hydrogen flux from Earth's core

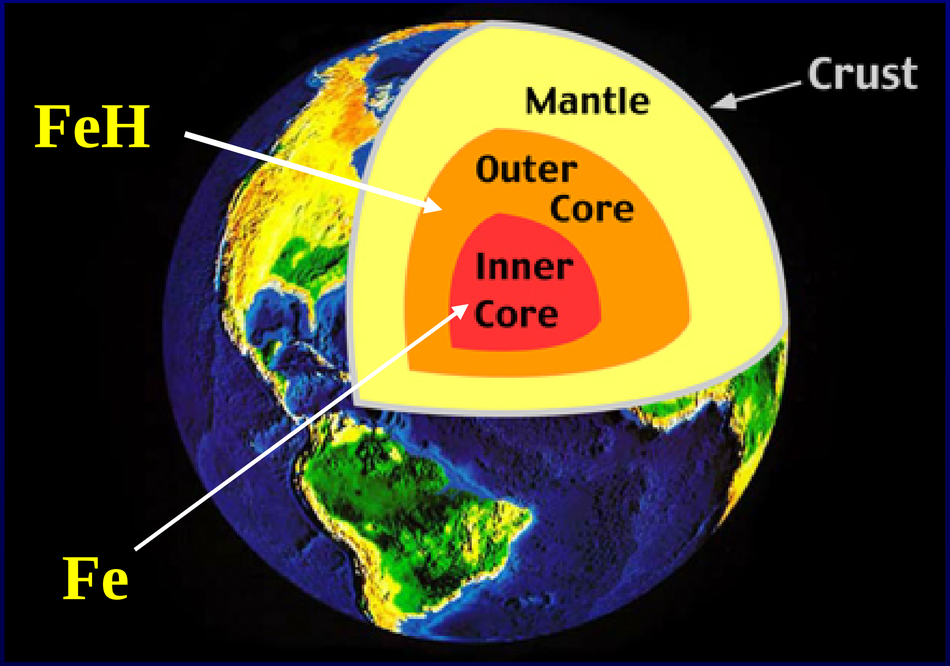



H_2O Domain
10km
seal
metasomatising
mantle wedge
$CO_2 \pm H_2O \pm$ melts Domain
plate
100 km
seal
$H_2 \pm CH_4$ Domain
1000 km
H_2 flux

Nature of gas flux through Earth history?

It is possible to identify:

- epochs of high rates of H2 diffusion
- epochs of advective loss of reduced, CH4-rich gases
- epochs of advective loss of oxidized CO2-rich gases



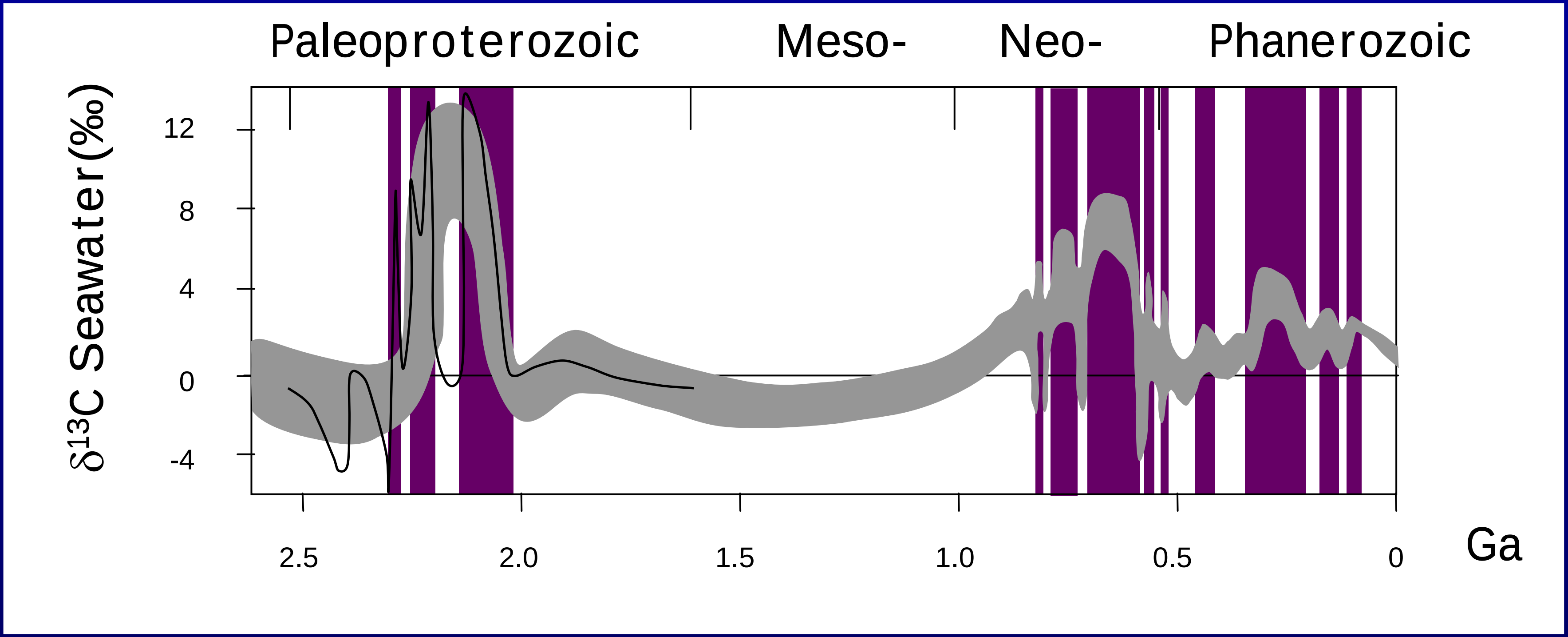
These epochs relate to the flux of hydridic fluids from the Earth's core.

Hydridic fluid flux drive redox-relate processes Earth's mantle, crust, hydroshere, atmosphere

e.g. mass extinction & metallogenesis ....

Williams & Hemley (2001); Okuchi T (1997); Larin (1993)

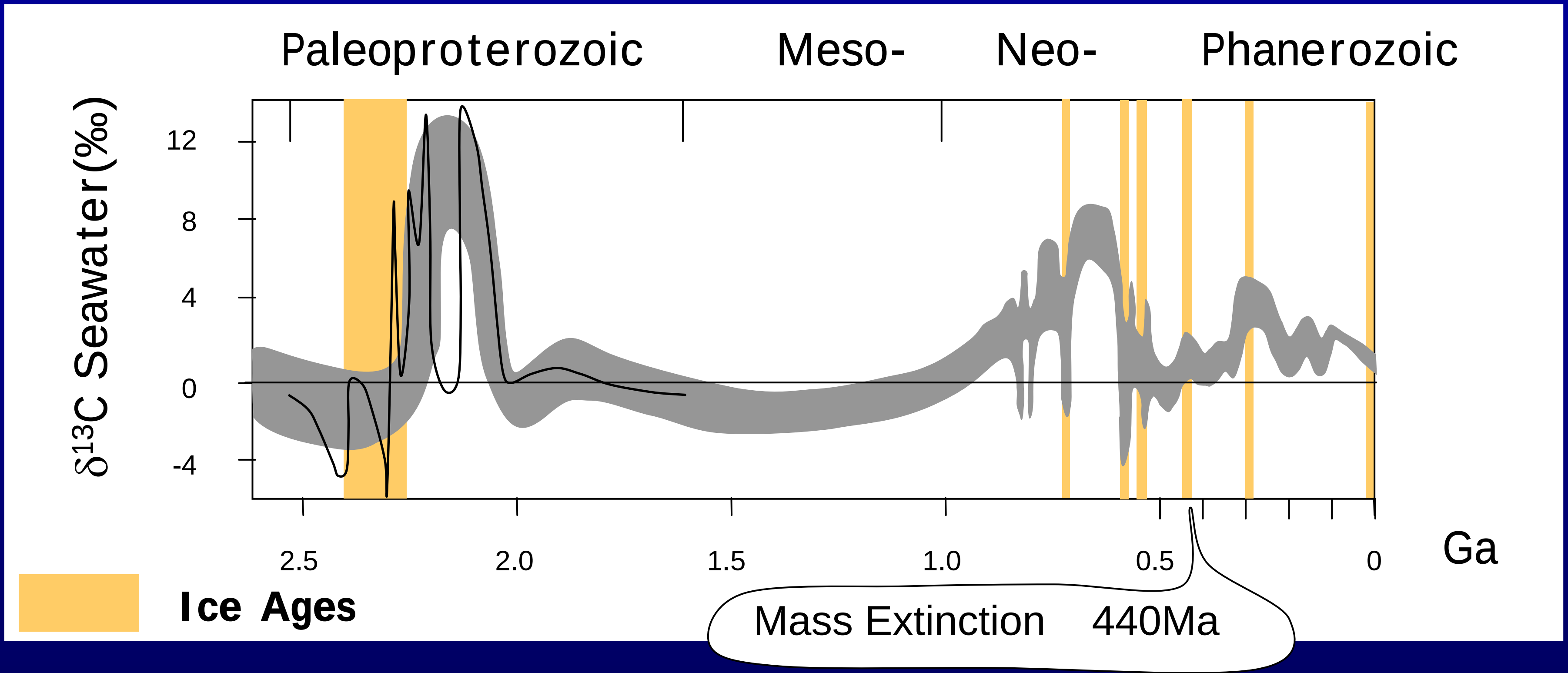
Major Epochs of H2 Diffusion



- Defined by positive deviations in $\delta^{13}C$ seawater
- CO_2atmos ➡ CO_2sw + H_2 ➡ CH_4 + H_2O: methanogenesis
- $\delta^{12}C$ ➡ CH_4 and CO_2sw enriched in $\delta^{13}C$
- CH_4 ➡ fixed as organic matter/methane clathrate
- CO_2type methanogens: H_2 flux fuels methanogenesis

Sources of data
Holland (2005)
Melezhik et al. (2005)

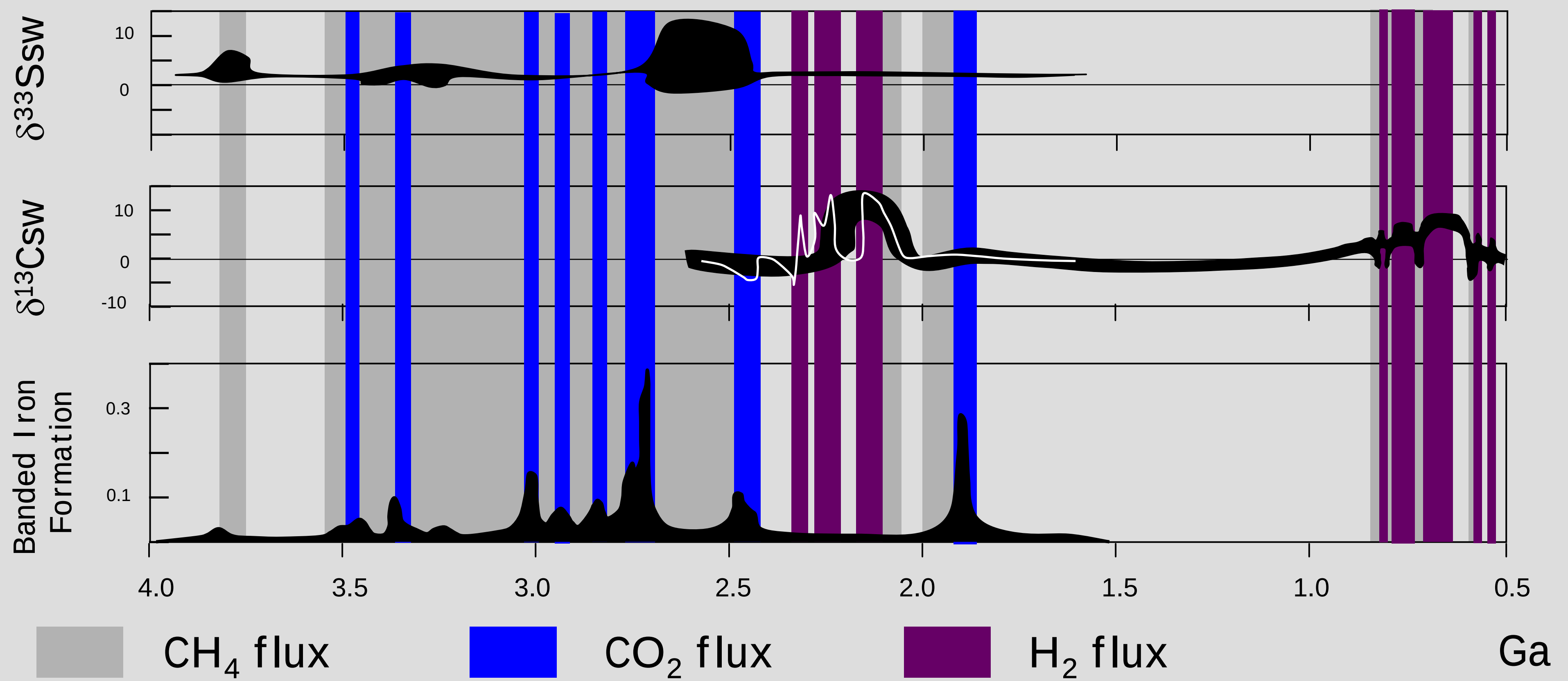
Ice Ages & Epochs of H2 Diffusion



- Positive $\delta^{13}C$ excursions commonly predate cooling/glaciation Neoproterozoic & Phanerozoic
- Overall draw down in greenhouse gases leads to Earth cooling : Kaufman et al. (1997)
- H_2 flux fuels methanogenesis & reduction of greenhouse gases

Sources of information
Melezhik et al. (2005), Holland (2005), Kaufman et al (1997), Veizer et al. (1999), Saltzman & Young (2005)

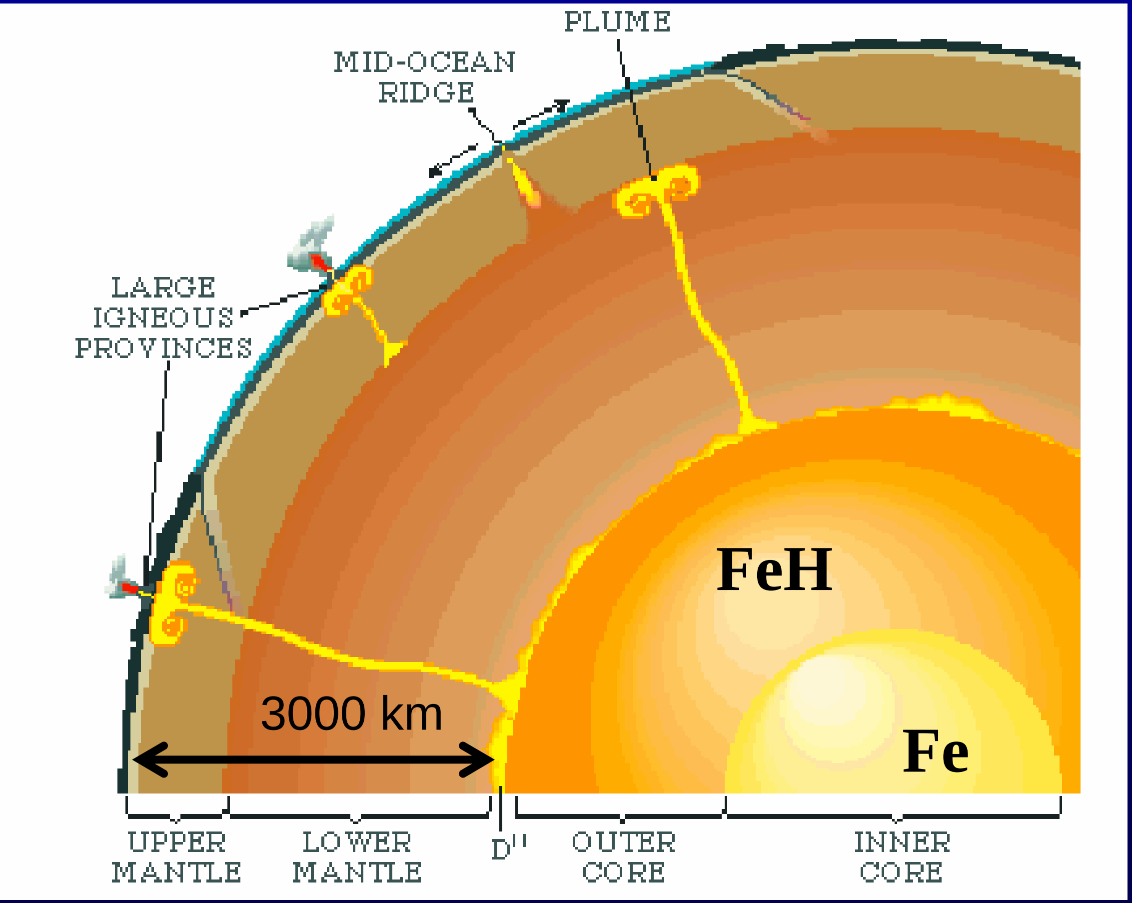
Epochs of CH_4 & CO_2 Flux



- Define high CO_2 ± SO_2 flux from distribution of banded iron formation
- Defined high CH_4 ± H_2 ± H_2S by negative deviations in $\delta^{13}C$ seawater; $\delta^{33}S$anomalies; global anoxia

Sources of information
Melezhik et al. (2005), Canfield (2005), Holland (2005) & references therein

Metal transport with deep – Earth hydridic fluids



H2
S, N, C
Halogens
Na, Li

Au
Cr, Ni
PGEs
Pb, Zn
U

Complexes of halides, chlorides, amines, carbonyls, cyanides

Williams & Hemley (2001); Okuchi T (1997); Larin (1993)

100- 200 ºC; Sedimentary/basin environment

Deep –fluids
Influence
pH, redox, salinity
temp

Pb-Zn sedimentary deposits

Most Au deposits

Porphyry Cu deposits

Hydrous

500-600ºC

Anhydrous

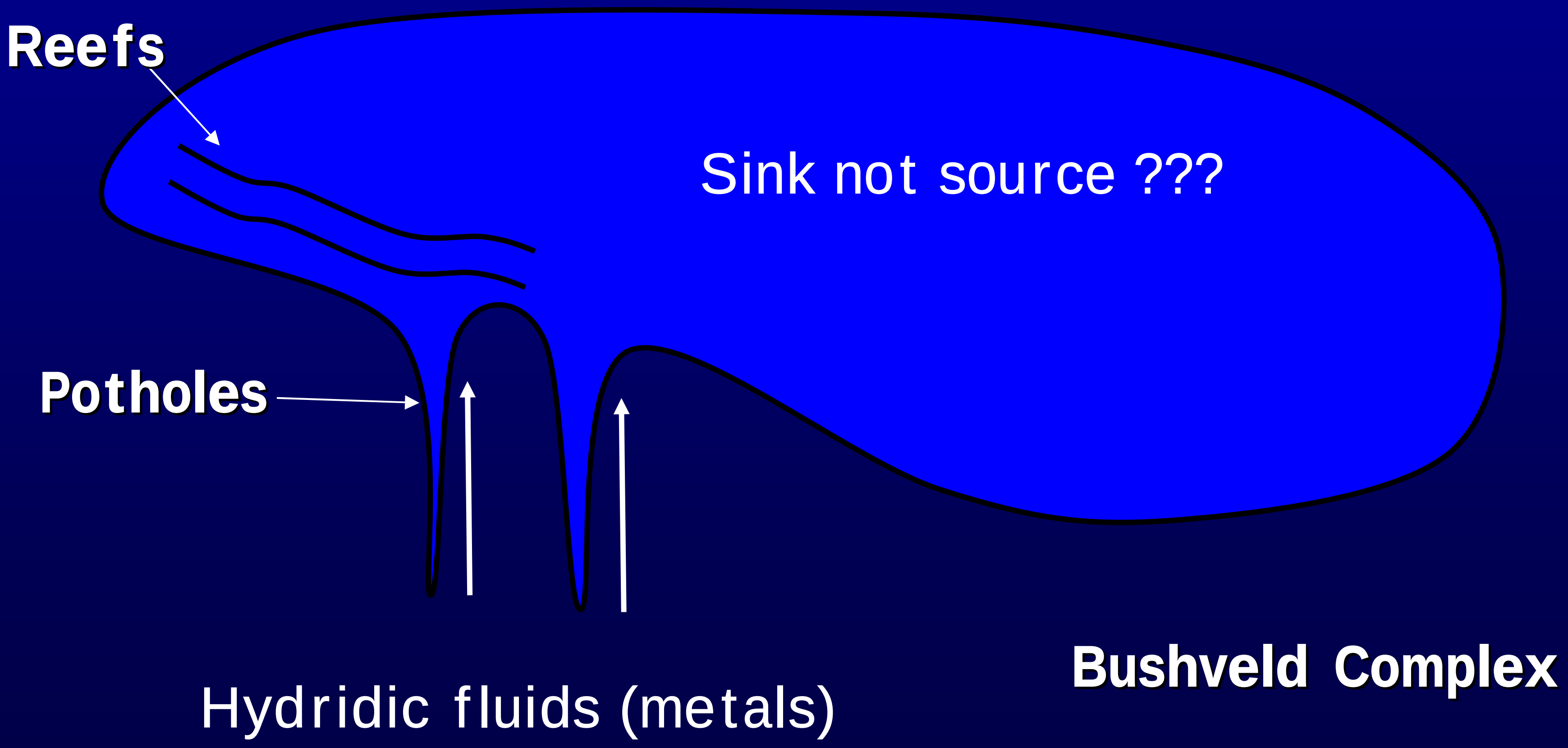
Au — Challenger; formed with melt

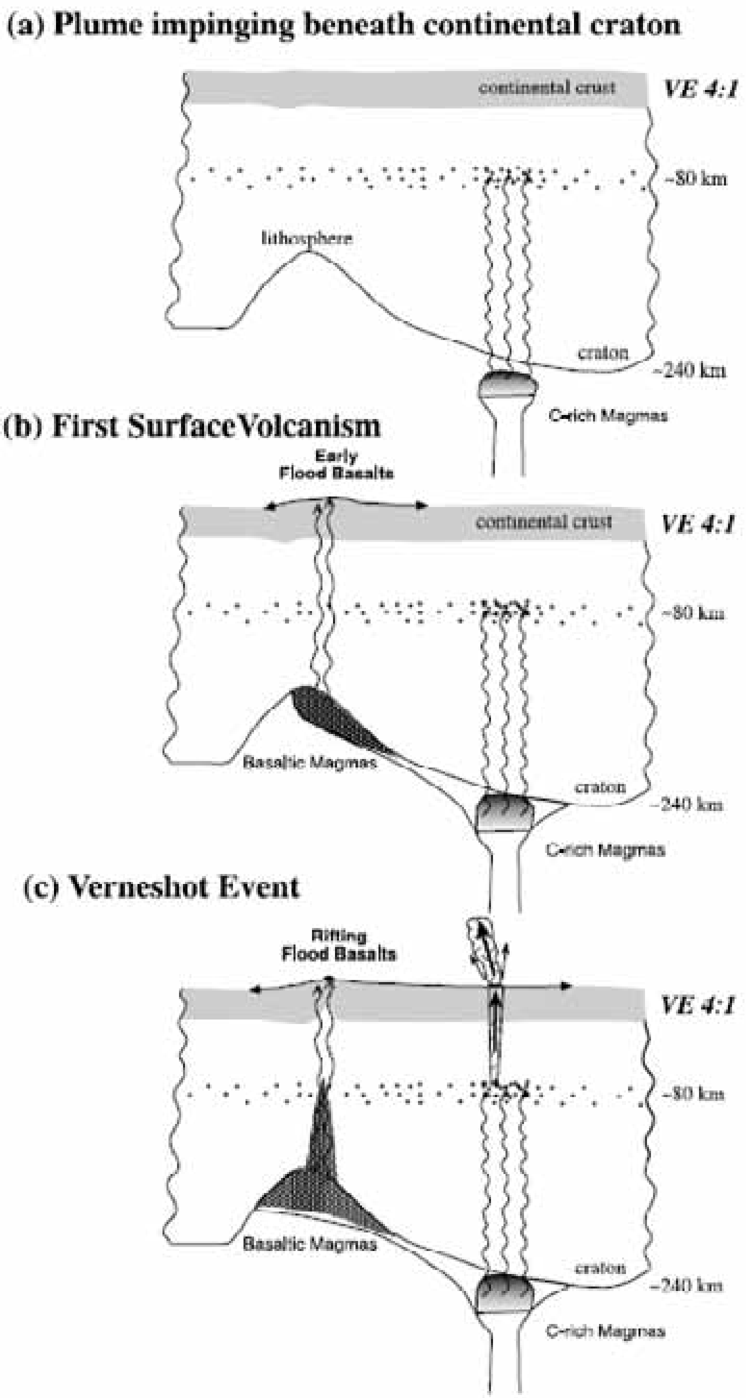
Pb, Zn; Cu — Broken Hill (BHTs)

Cr, Ni, PGEs, Au — Bushveld; Sudbury; Komatiitic Ni

800-1000 ºC; Magmatic Conditions

Magmatic deposits: Silicate melts act as trap medium for metals in hydridic fluids; not transport medium





Q: What is the mechanism of advection of $CO_2 \pm CH_4$ through the crust

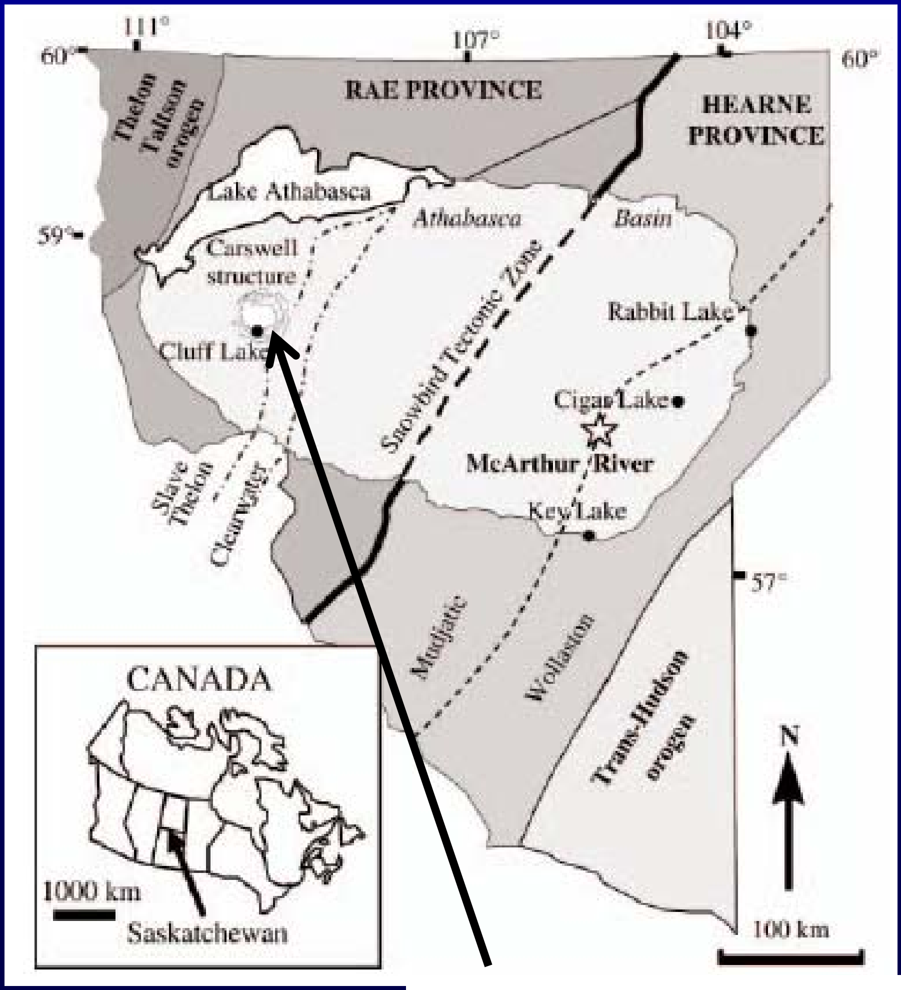
A: Transient,
Deep-lithospheric blasts of gas,

or Verneshots

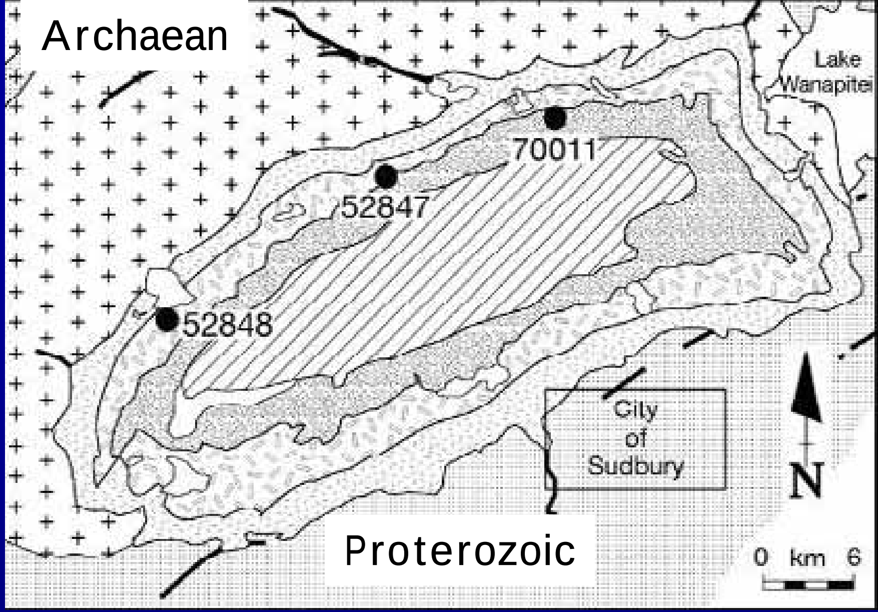
Sufficient energy to produce shocked quartz & shattercones

J. Phipps Morgan et al, EPSL 217 (2004) 263-284

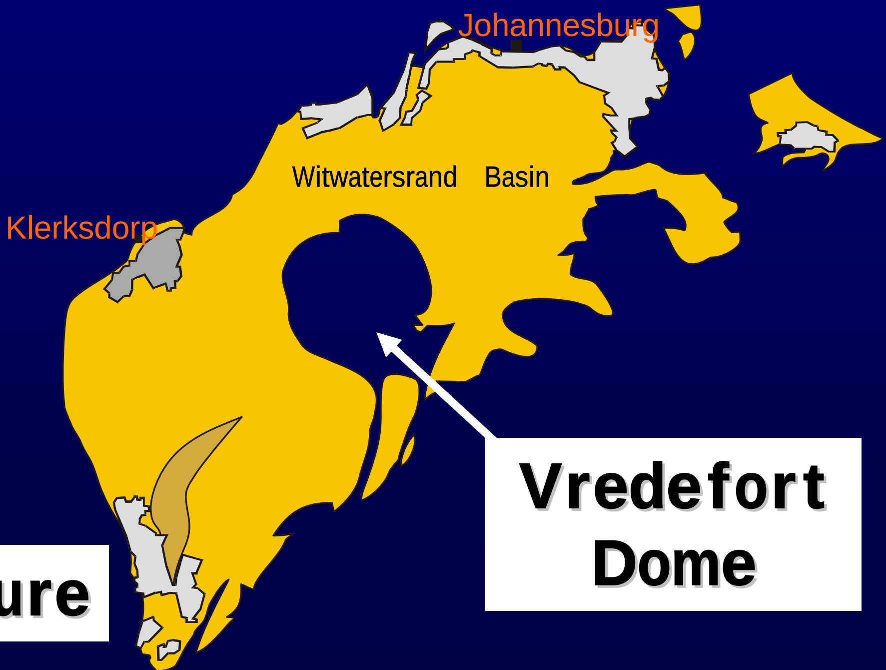
Verneshots in major mineral provinces



Carswell structure

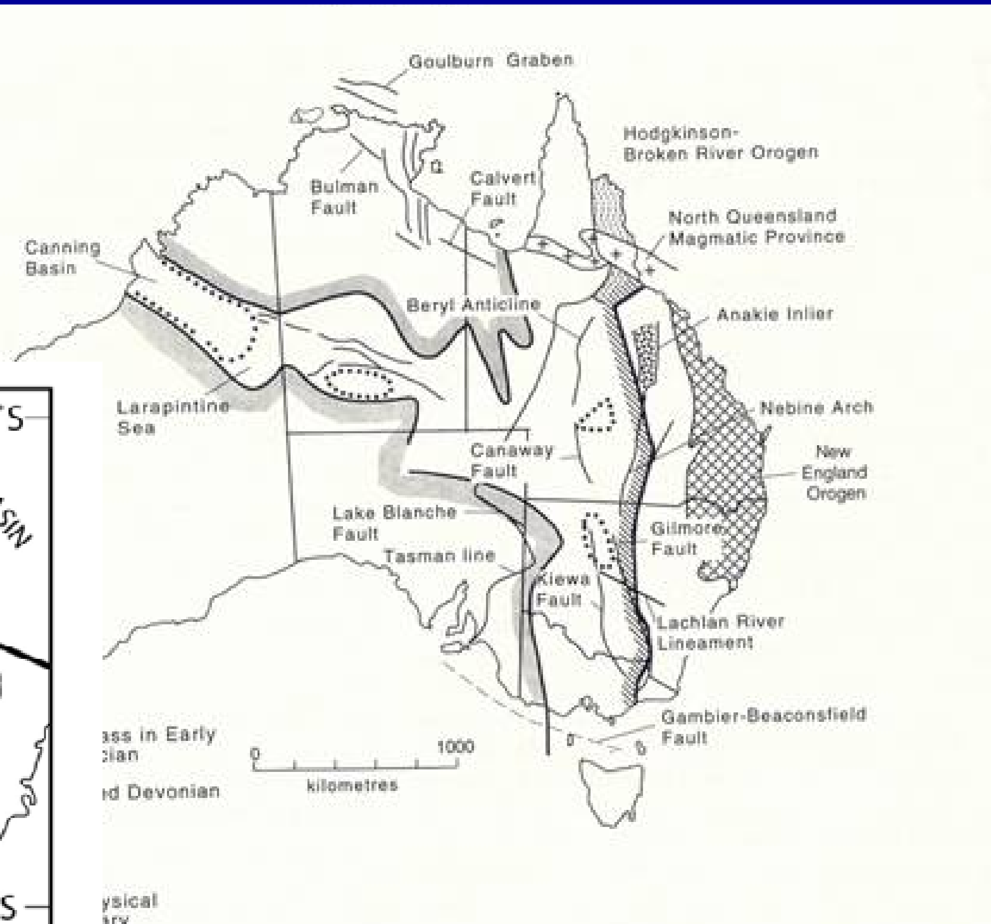


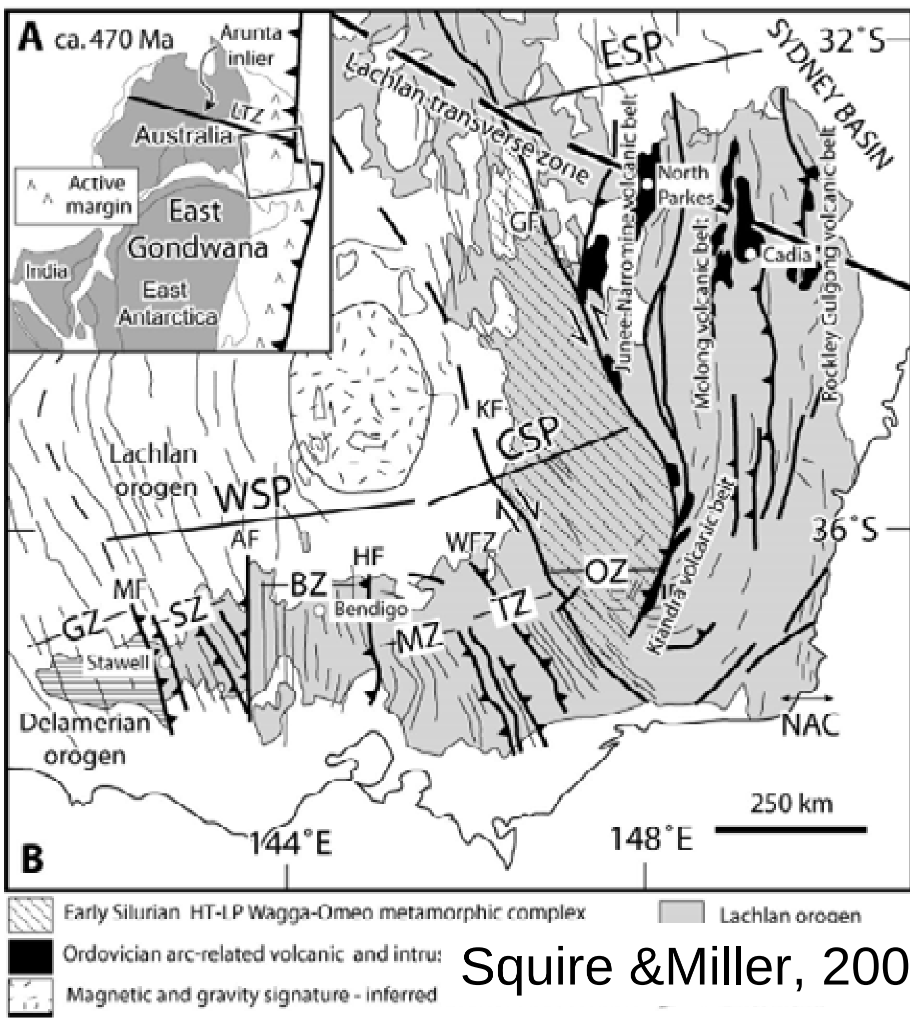
Sudbury “Impact”



Vredefort Dome

Pathways from the mantle ???



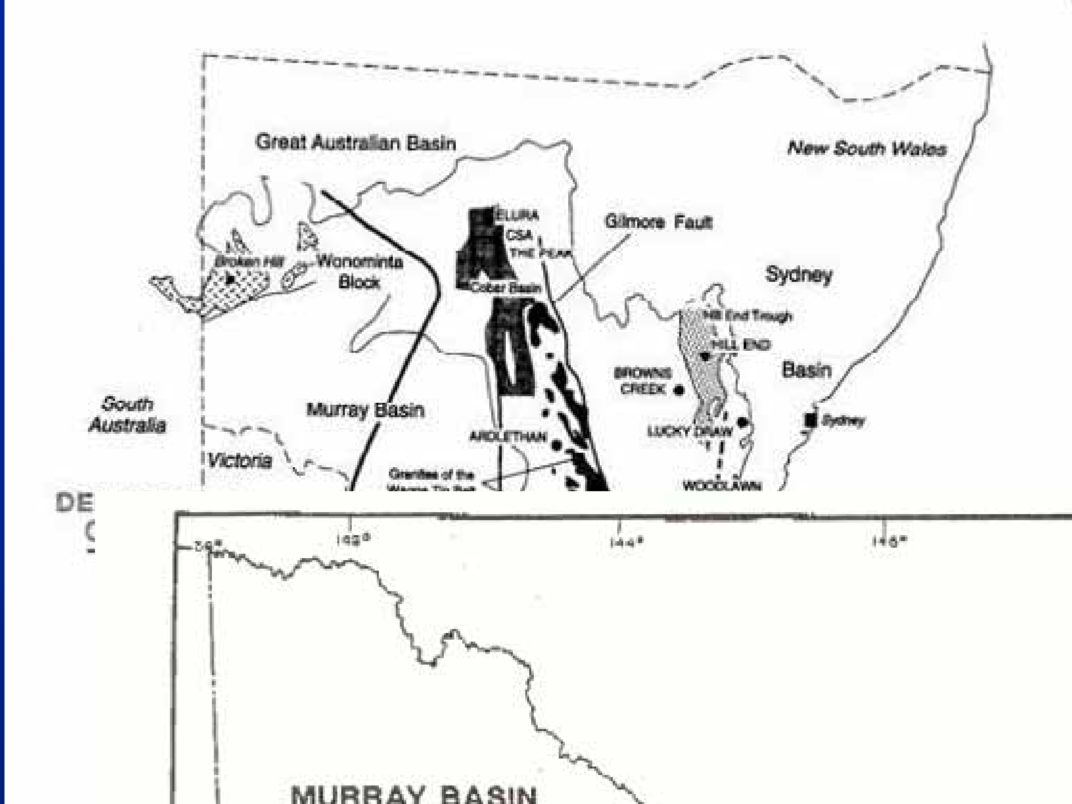


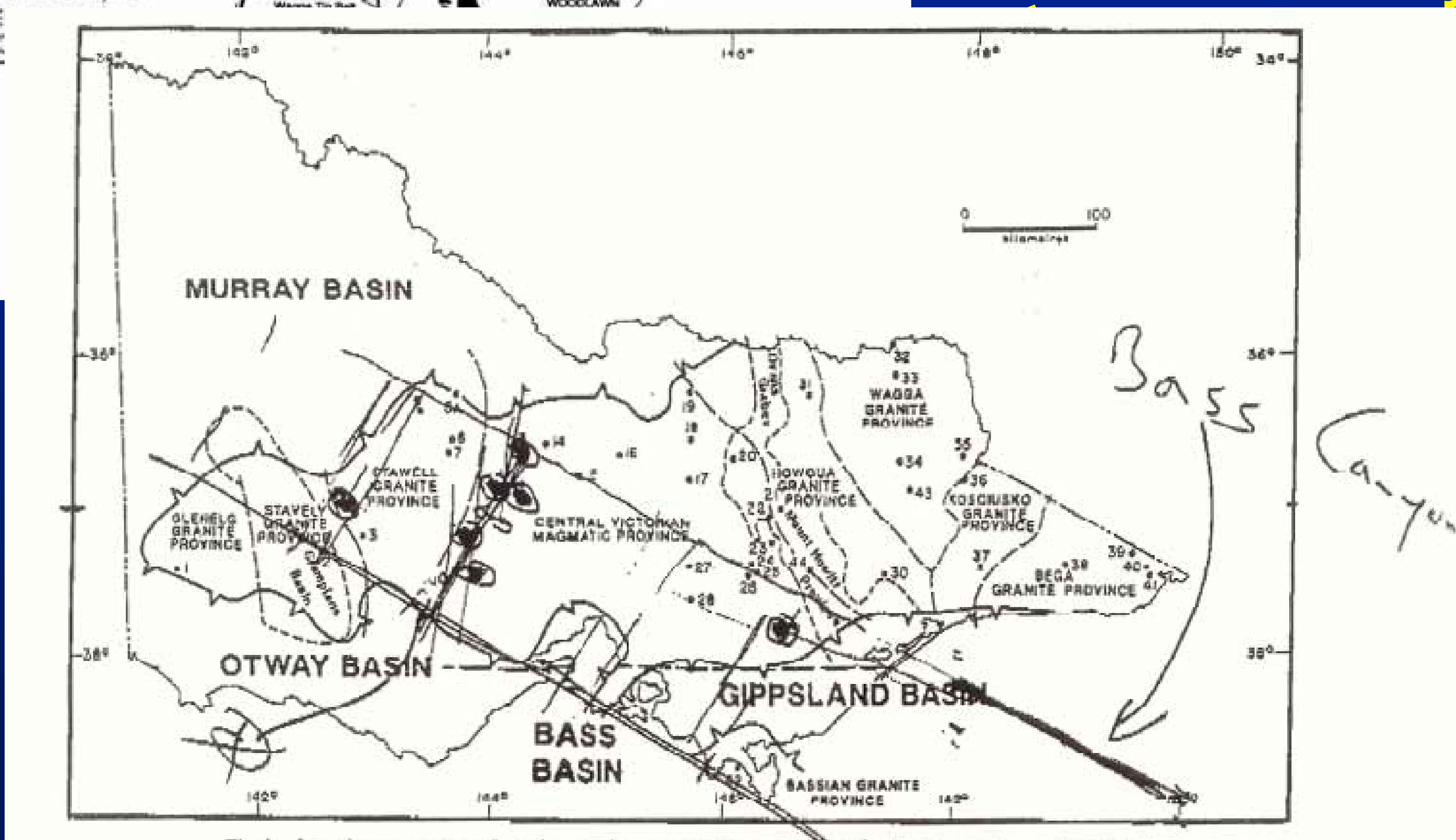
Squire &Miller, 2003

Cross-Arc Structures & Lachlan Tectonic Zone

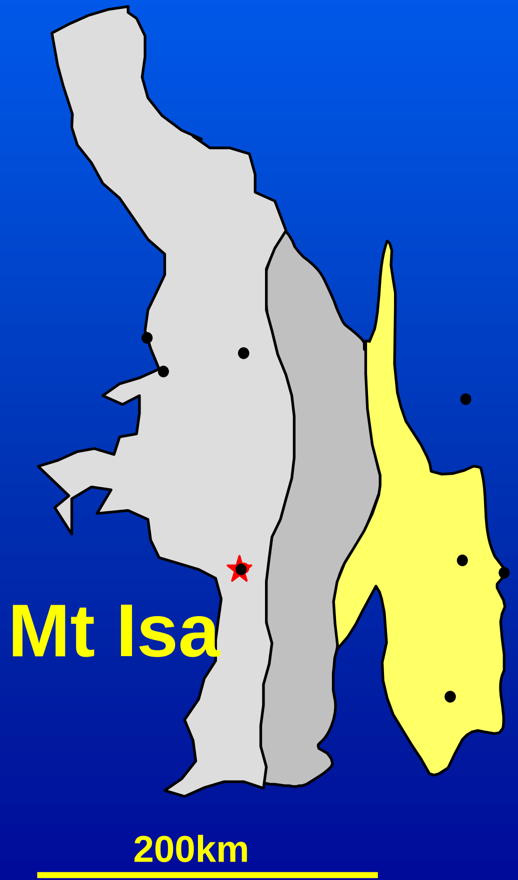
Cross-Arc Structures

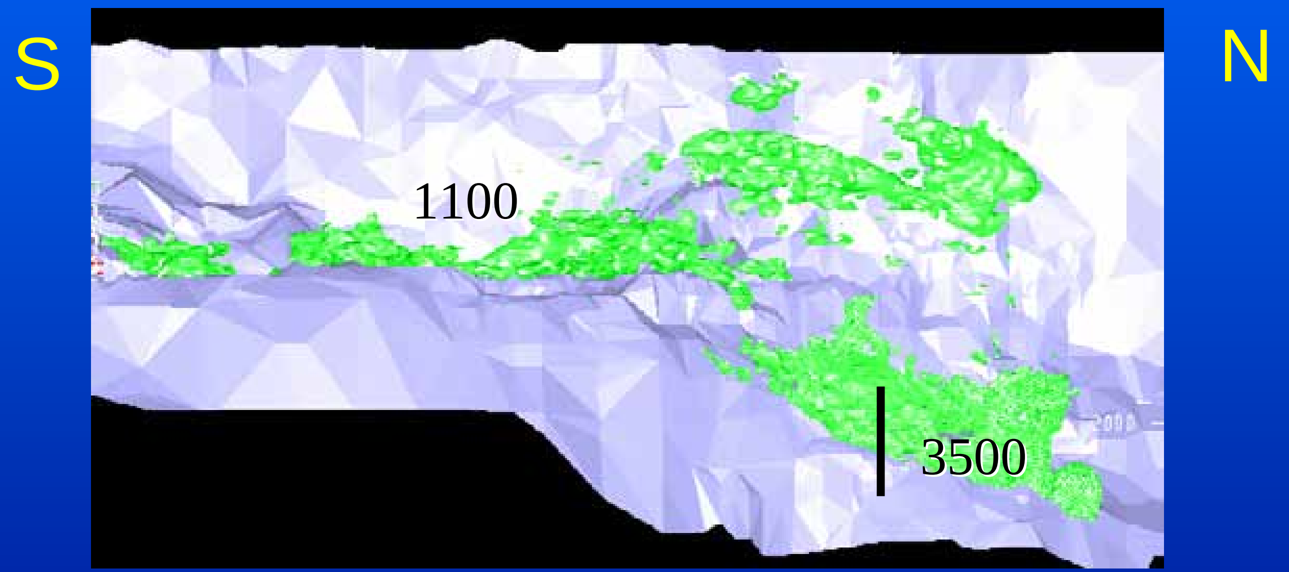
Bass Canyon



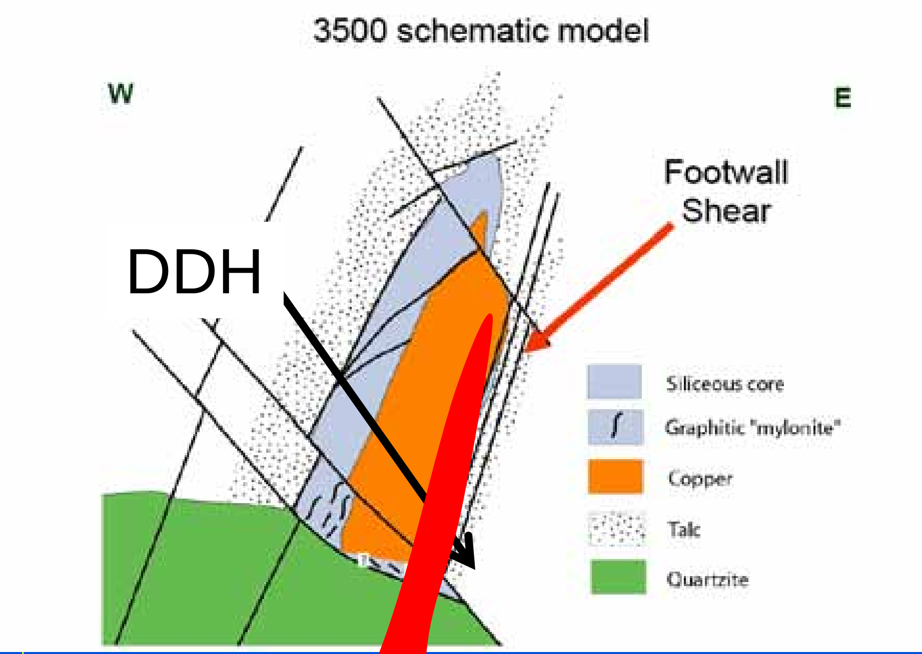


Tracking pathways of deep-Earth Fluids: Mt Isa Cu Orebodies

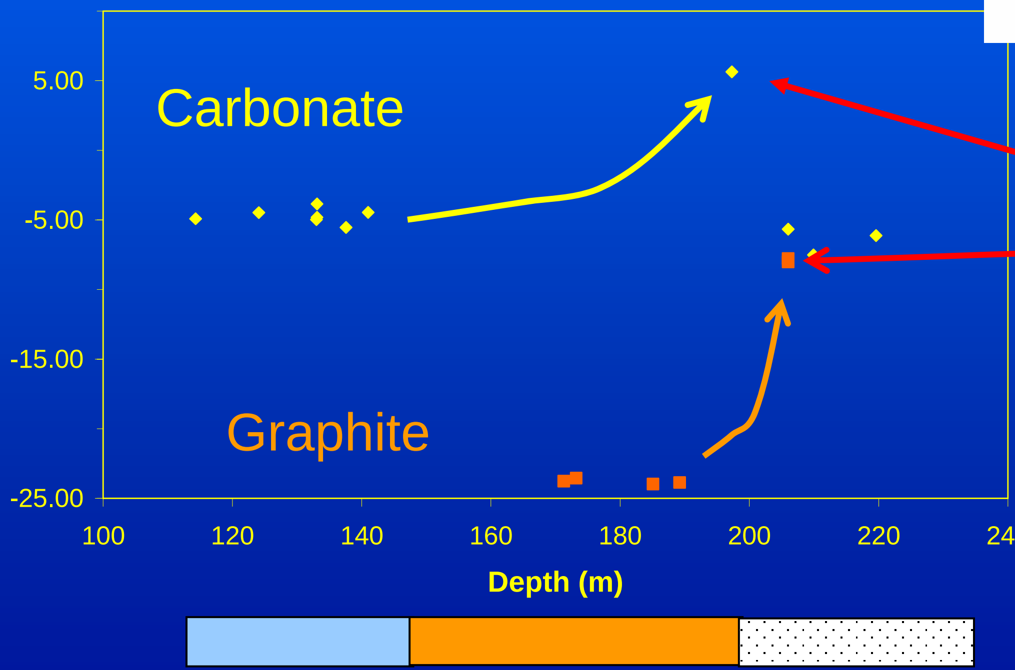




Positive deviation $\delta^{13}C$ – H_2 reducing CO_2



$\delta^{13}C$

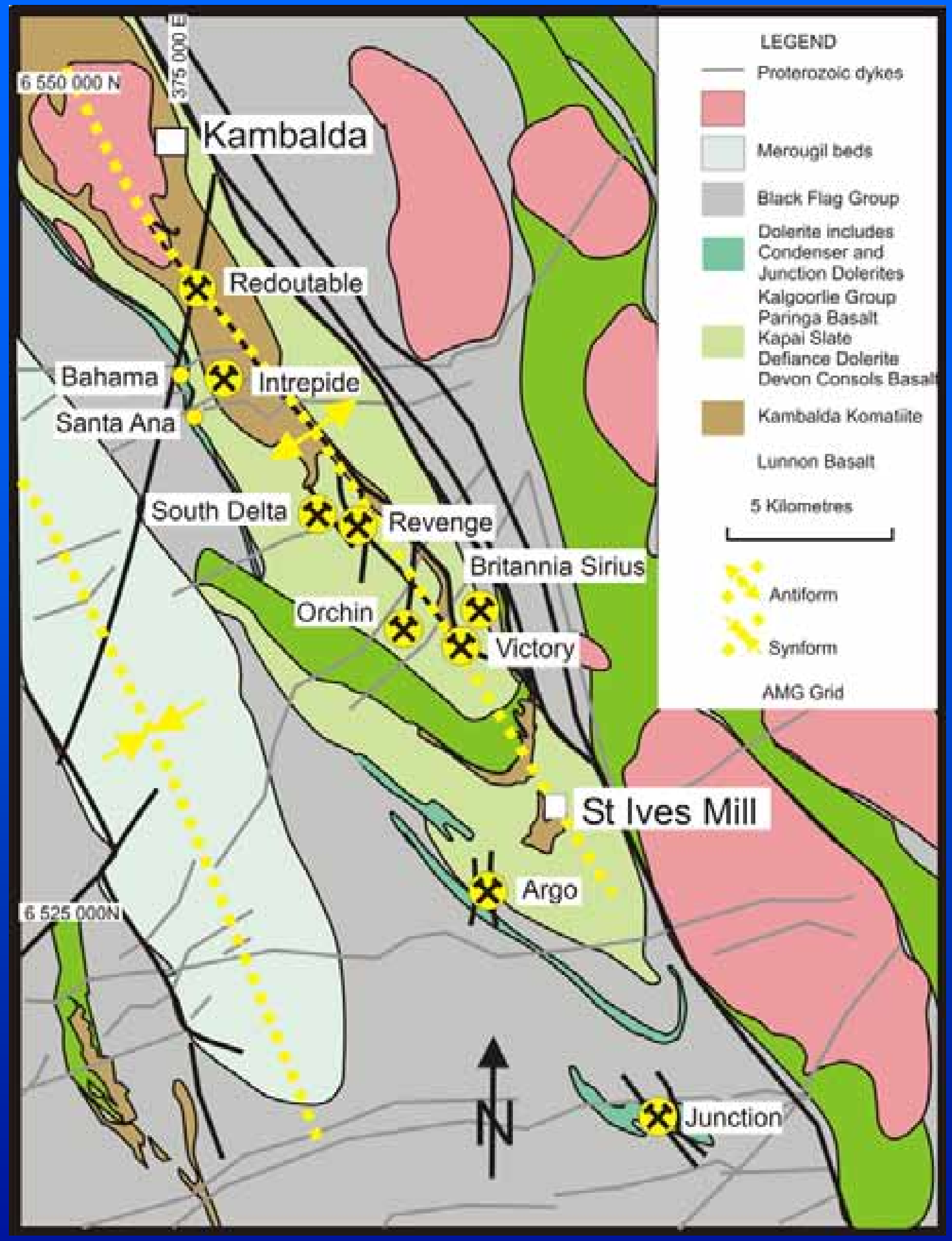


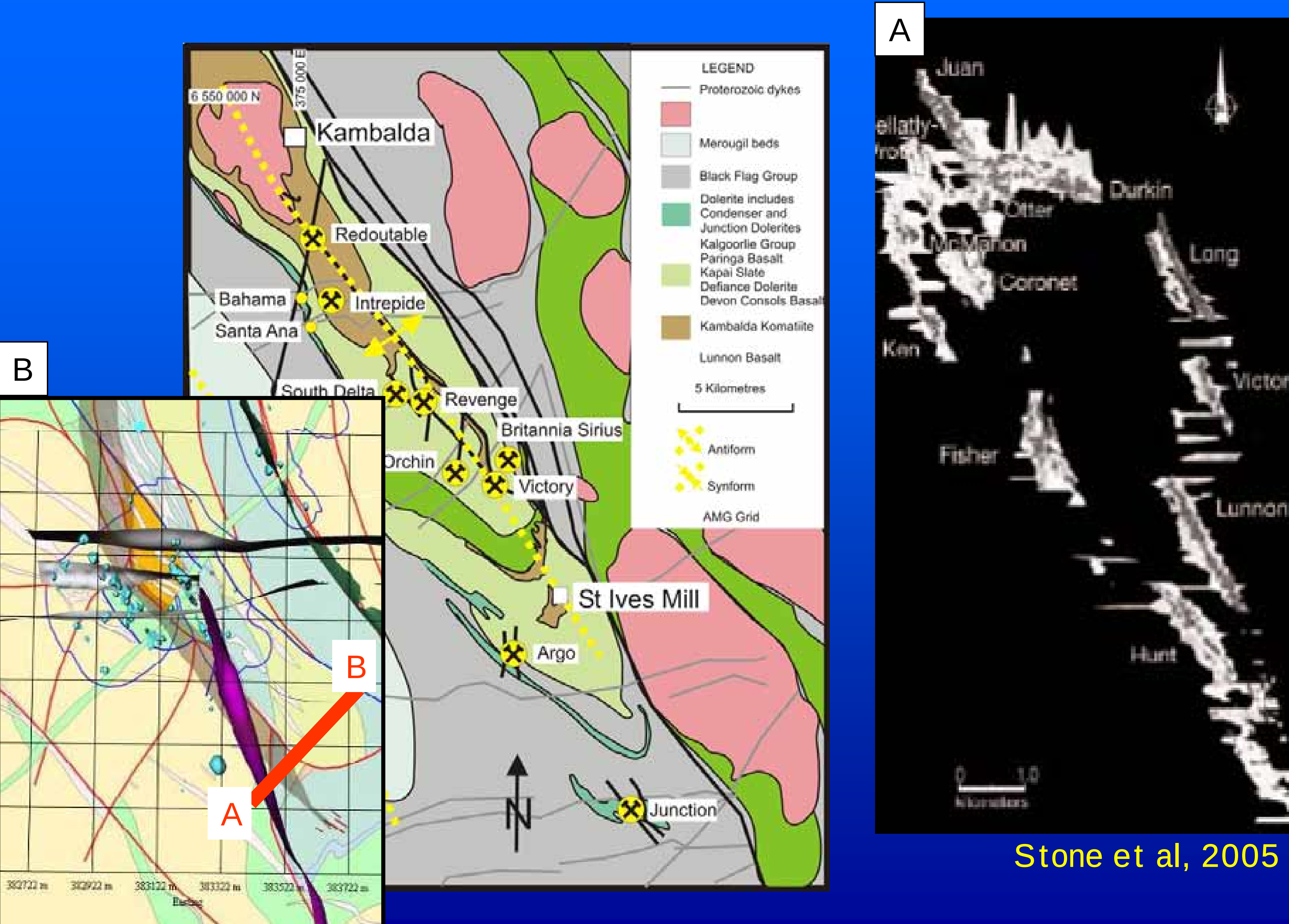
H_2 Flux

$$CO_2 + 4H_2 = CH_4 + 2H_2O$$

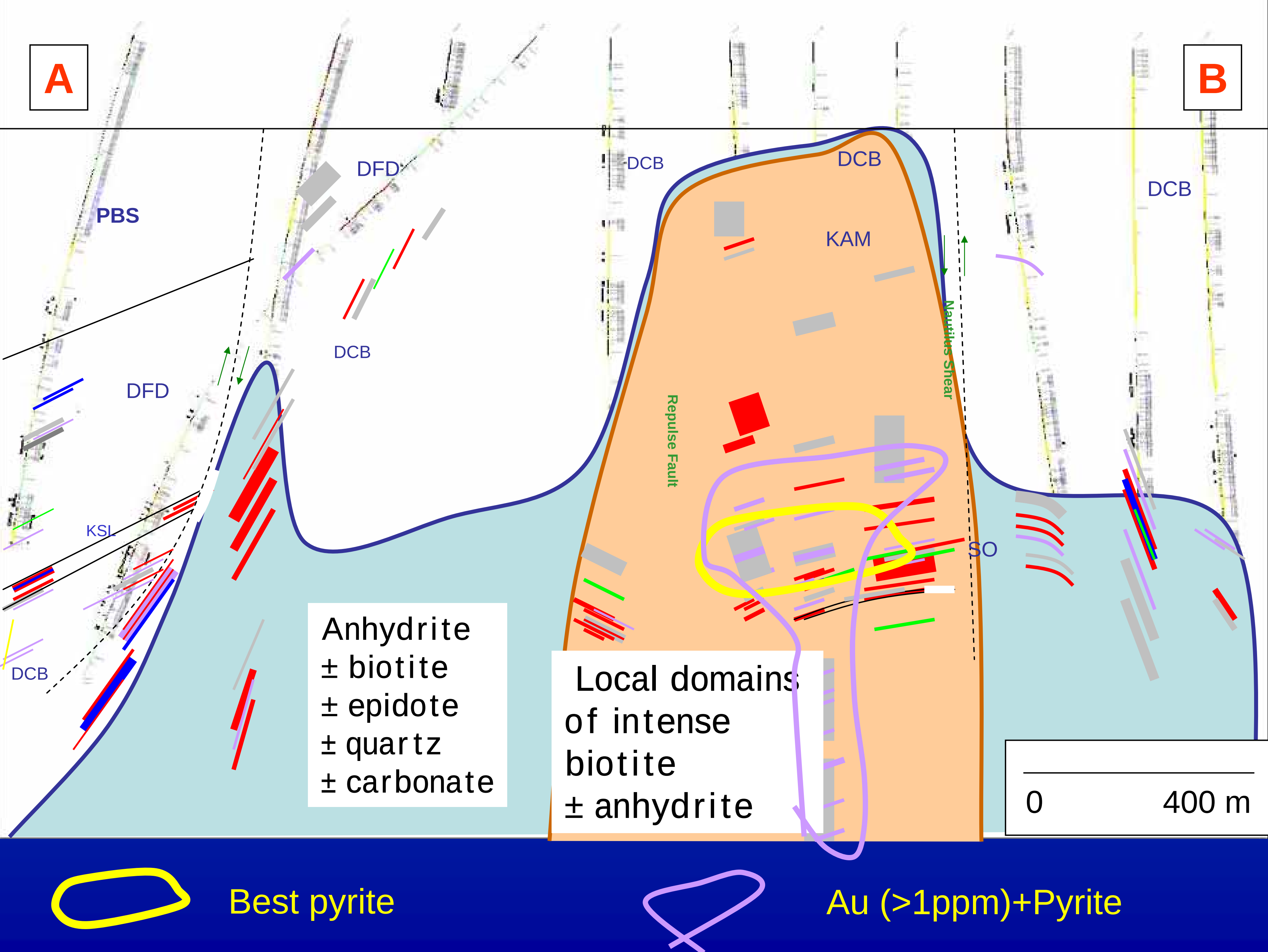
Clues from Archaean Au & Ni? deposits

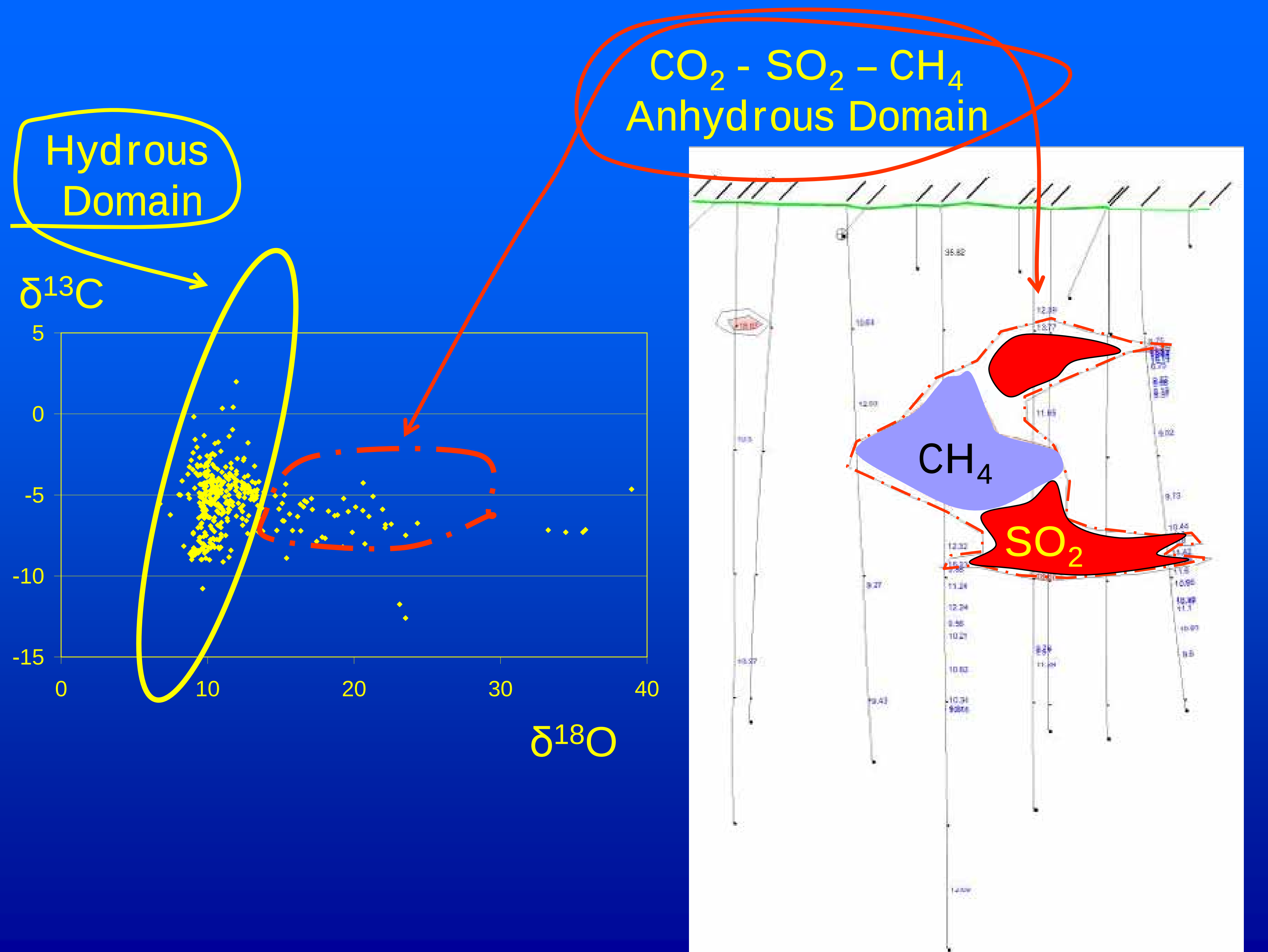
Geological map of the St. Ives gold camp Yilgarn WA





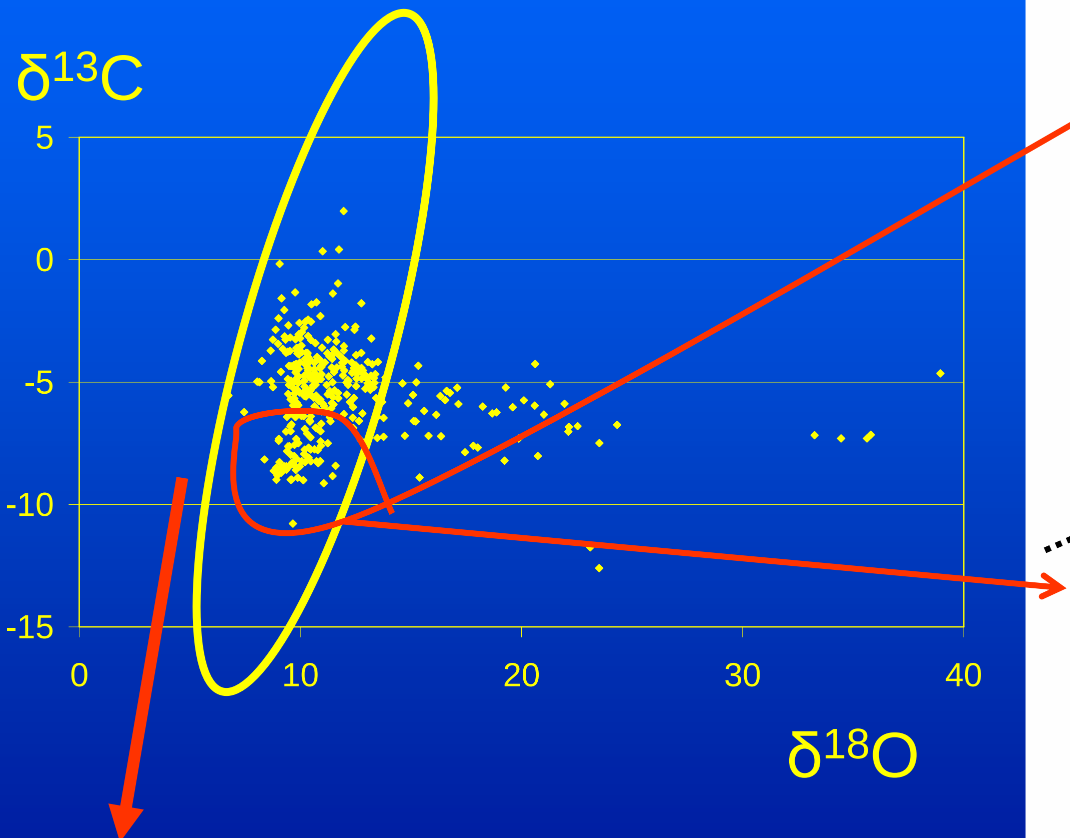
Stone et al, 2005

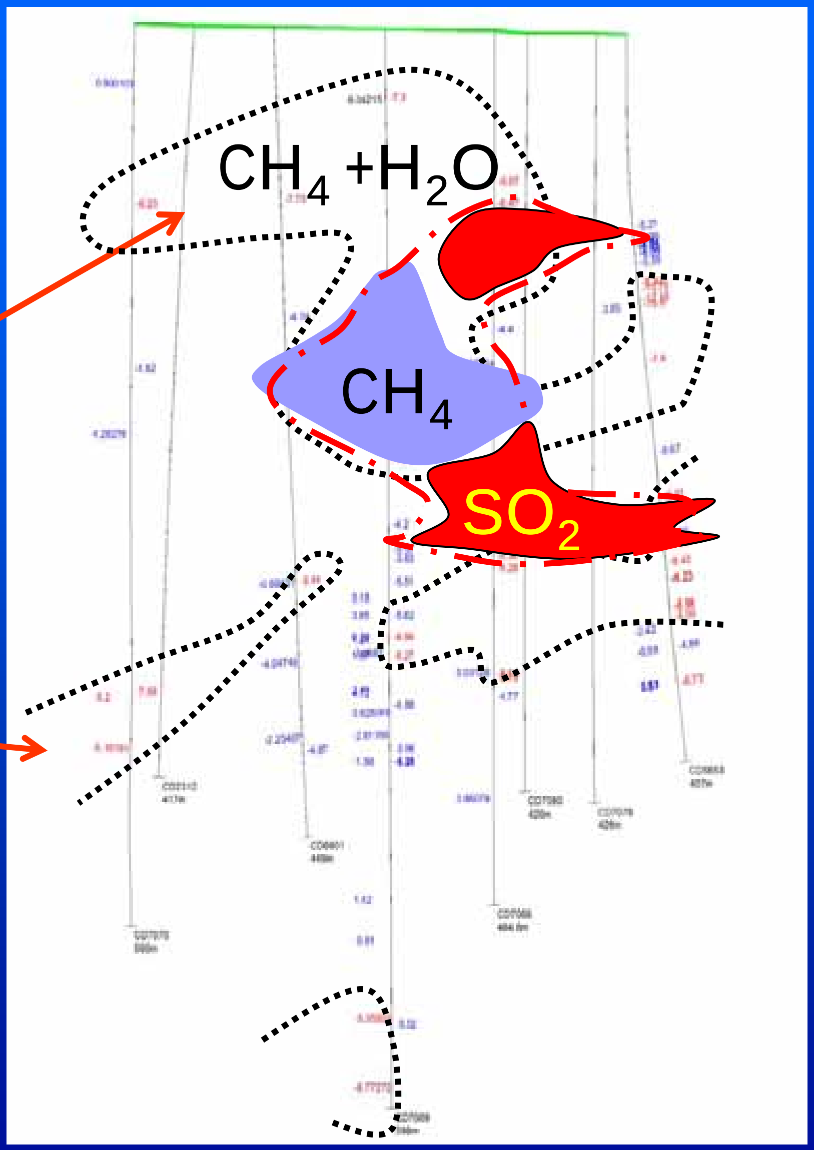

A
B
PBS
DFD
DCB
KAM
DFD
DCB
KSL
DCB
Repulse Fault
Nautilus Shear
SO
Anhydrite
± biotite
± epidote
± quartz
± carbonate
Local domains of intense biotite
± anhydrite
0
400 m
Best pyrite
Au (>1ppm)+Pyrite



Hydrous Domain
CO_2 - SO_2 – CH_4
Anhydrous Domain
$\delta^{13}C$
5
0
-5
-10
-15
0
10
20
30
40
$\delta^{18}O$
CH_4
SO_2

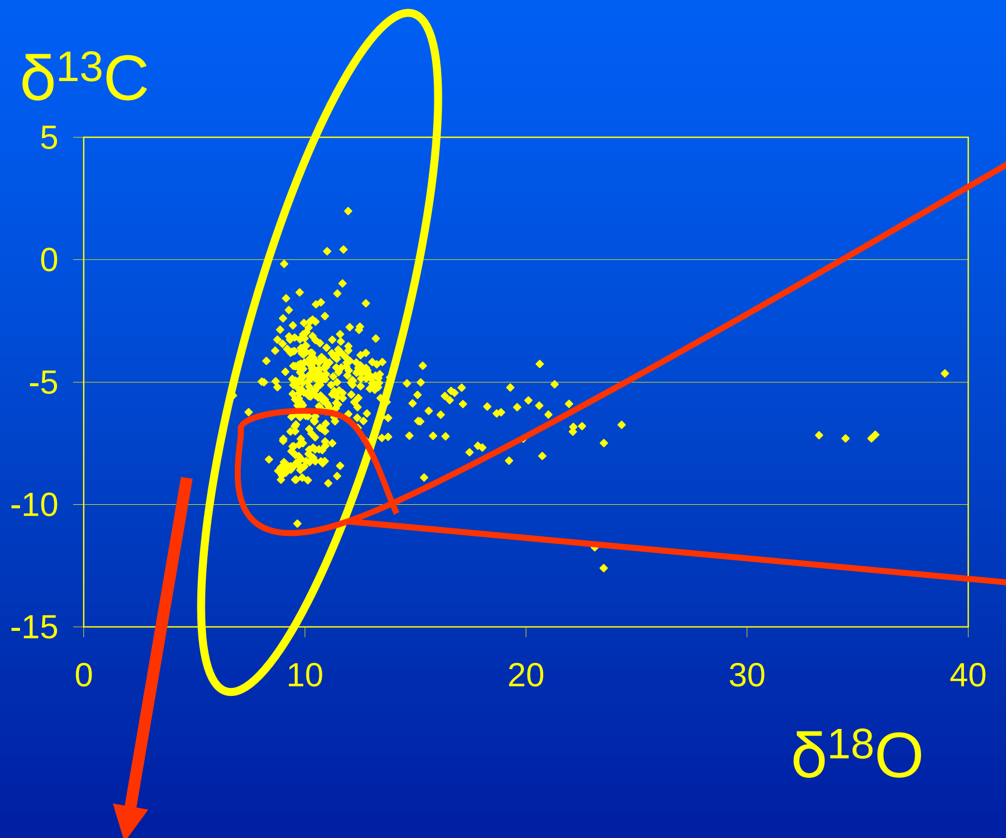
Negative deviation $\delta^{13}C$ – SO_2 oxidizing CH_4

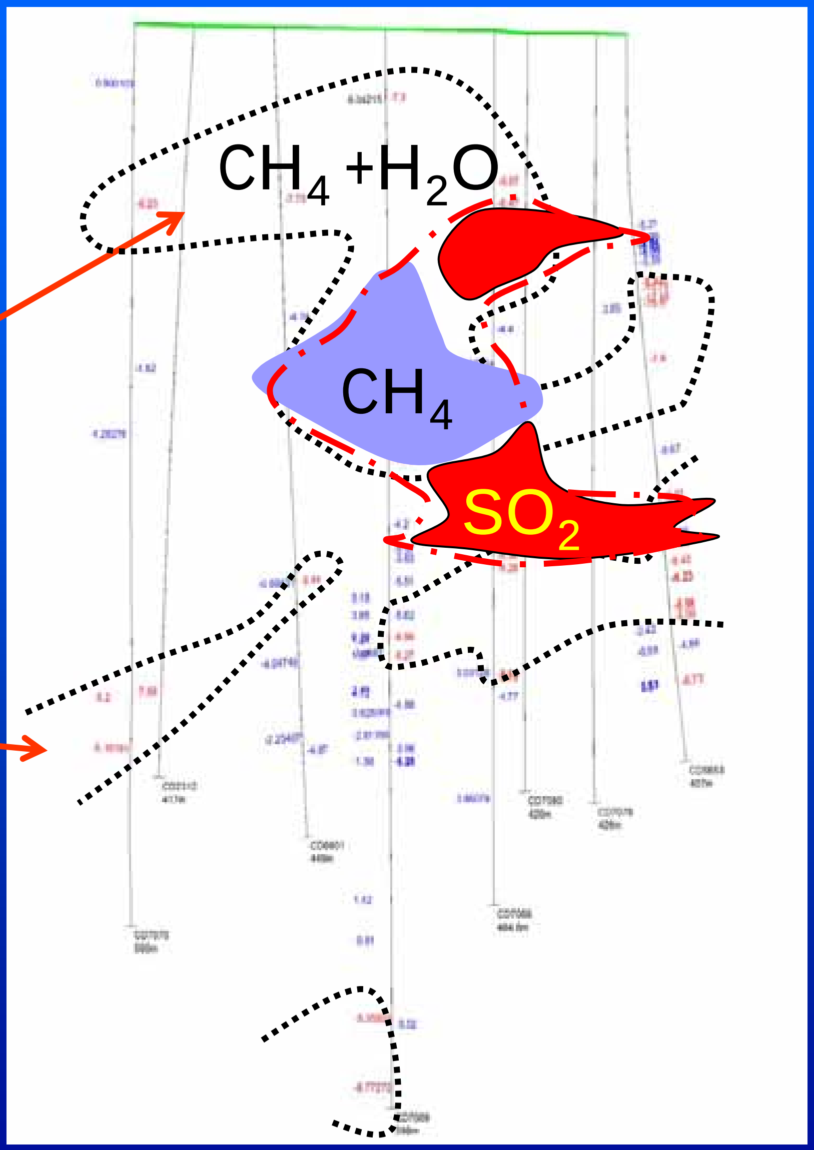




$3CH_4 + 4SO_2 = 3CO_2 + 2H_2O + 4H_2S$

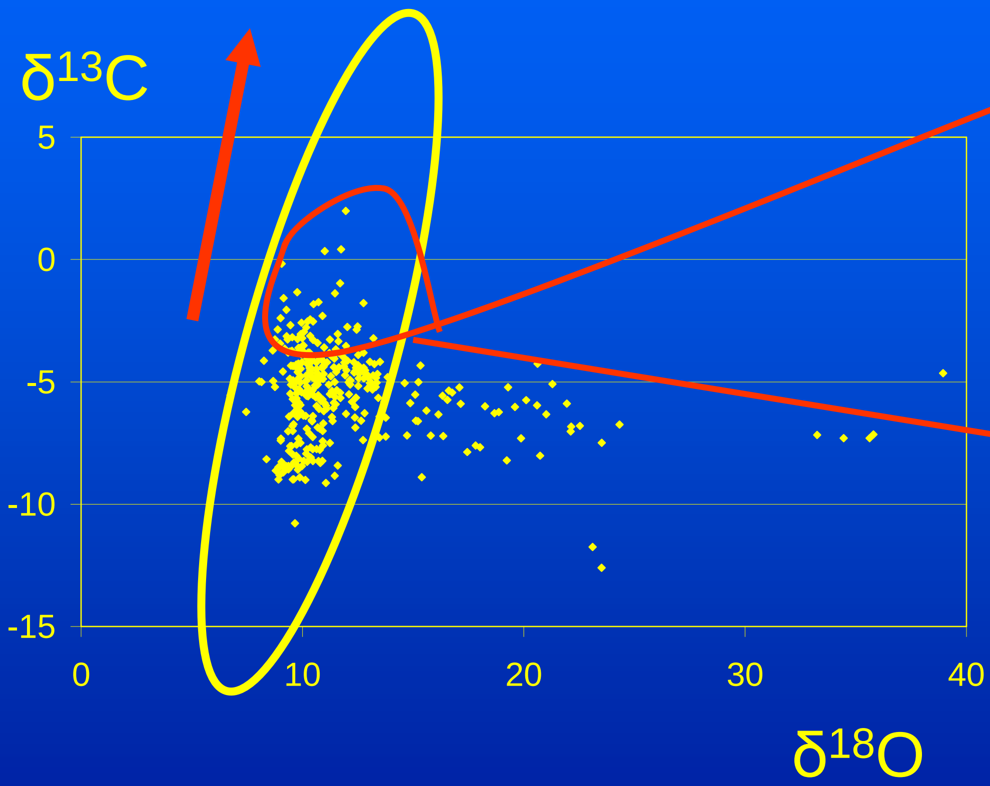
Negative deviation $\delta^{13}C$ – SO_2 oxidizing CH_4

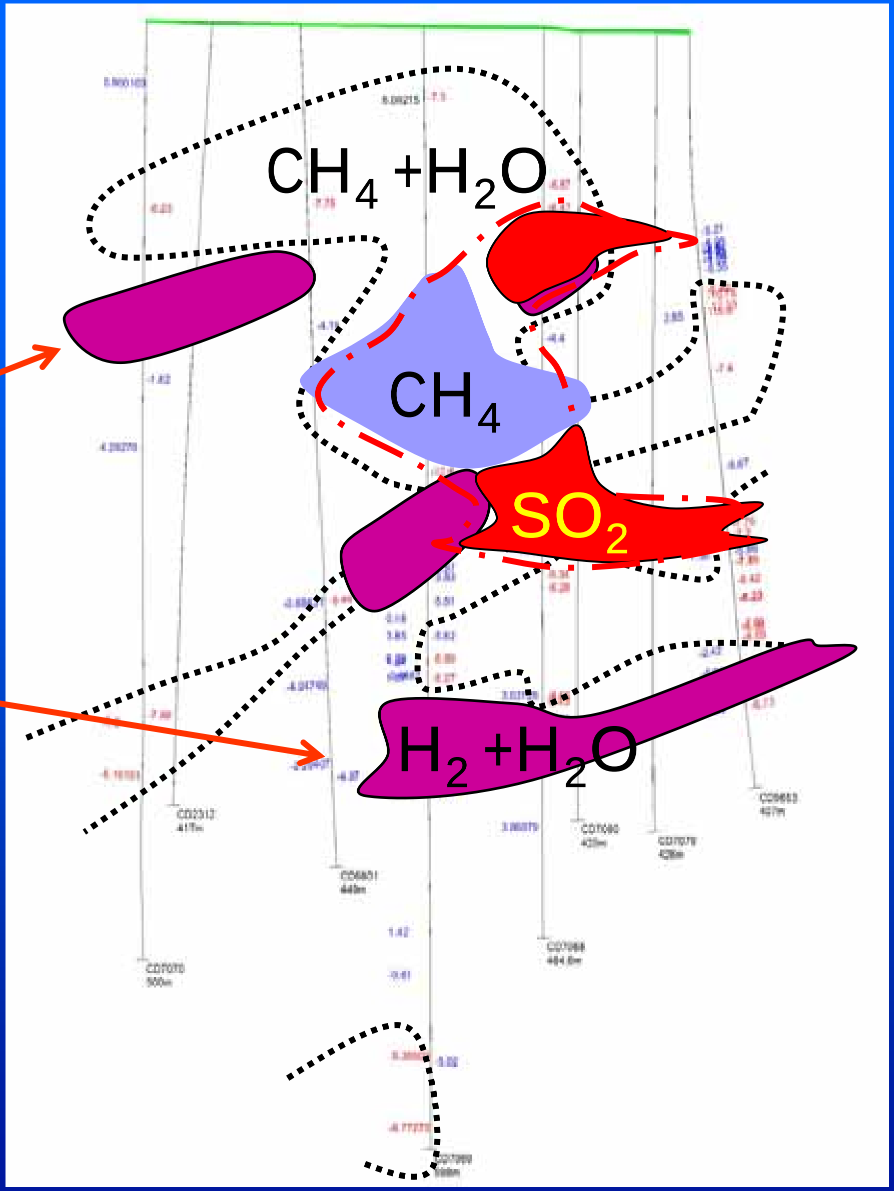




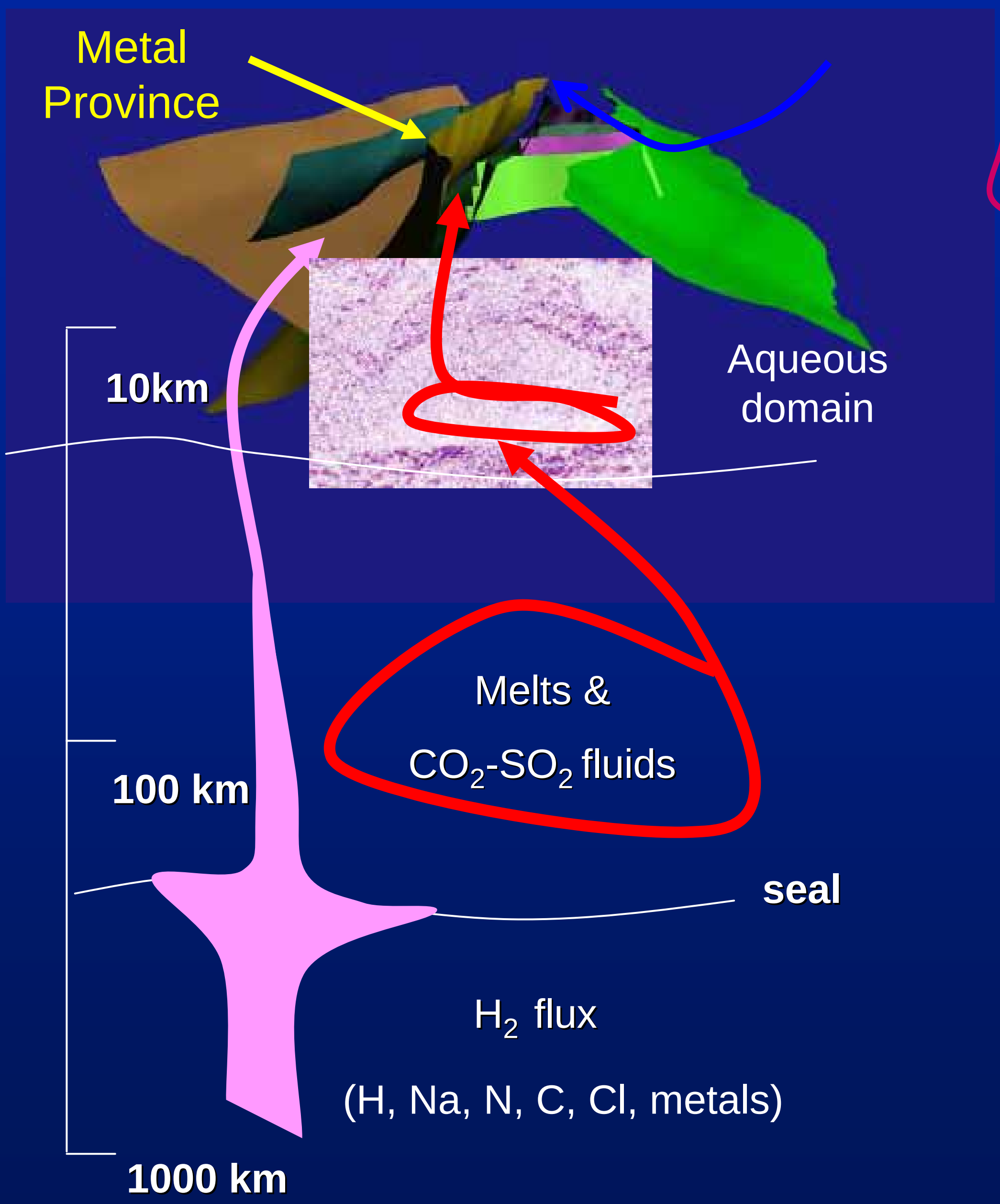
$3CH_4 + 4SO_2 = 3CO_2 + 2H_2O + 4H_2S$

Positive deviation $\delta^{13}C$ – H_2 reducing CO_2

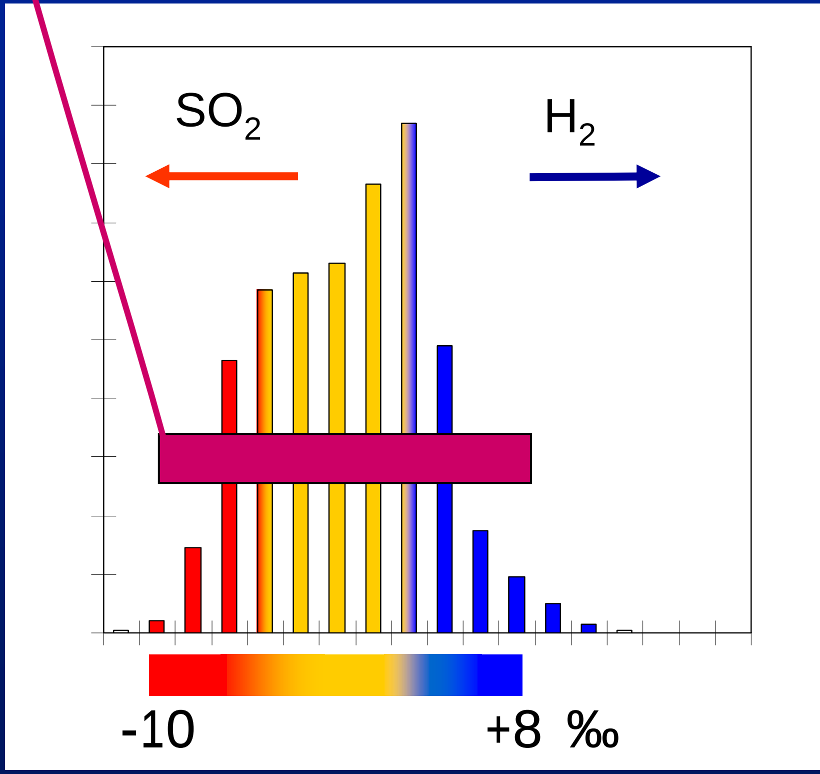




$CO_2 + 4H_2 = CH_4 + 2H_2O$



$\delta^{34}S$ variation
in volcanic hosted Ni?

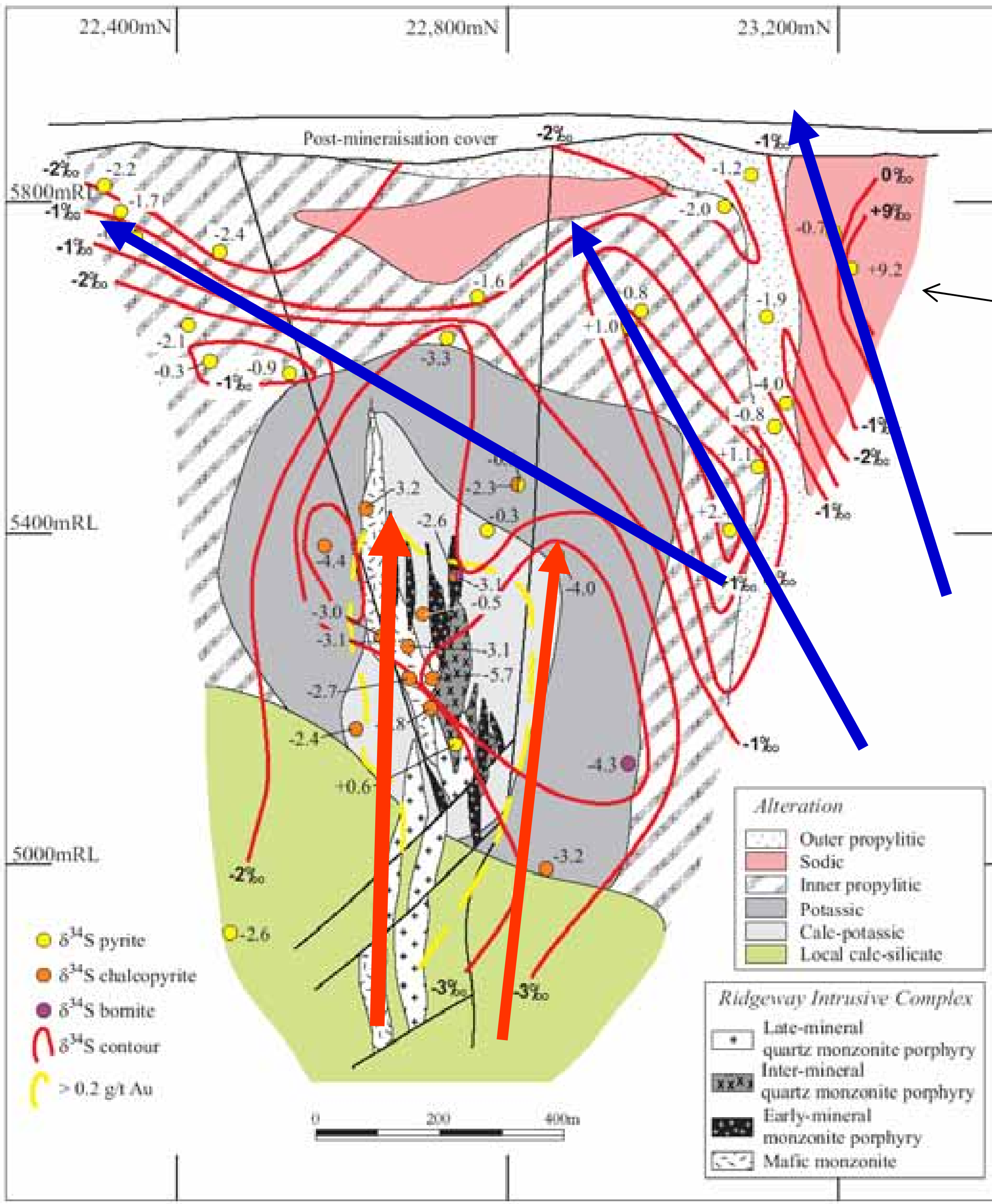


$\delta^{34}S$ pyrite Au deposits

Ridgeway

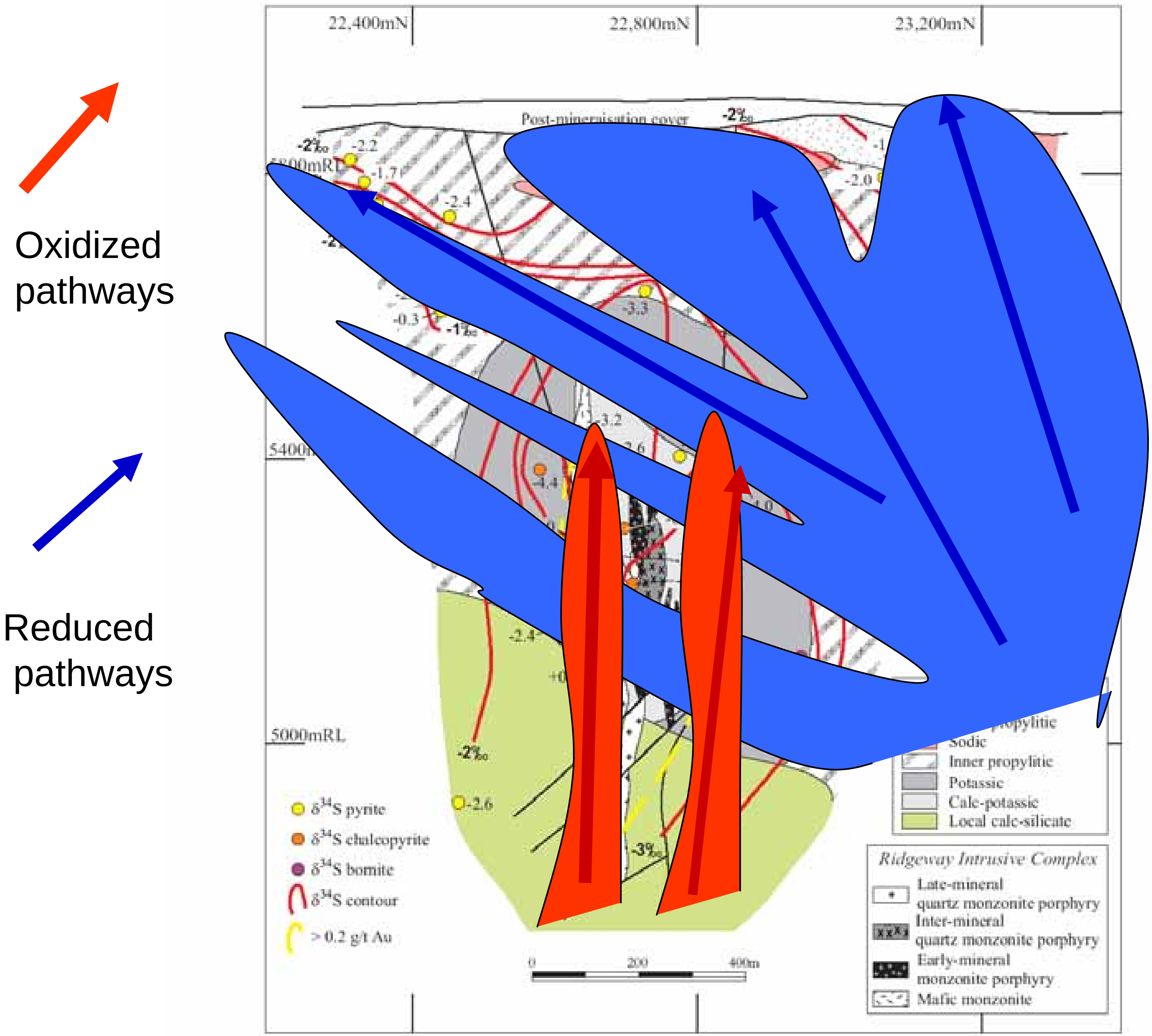
Oxidized pathways

Reduced pathways



Extreme reduction of magmatic sulphate in the sodic alteration zone

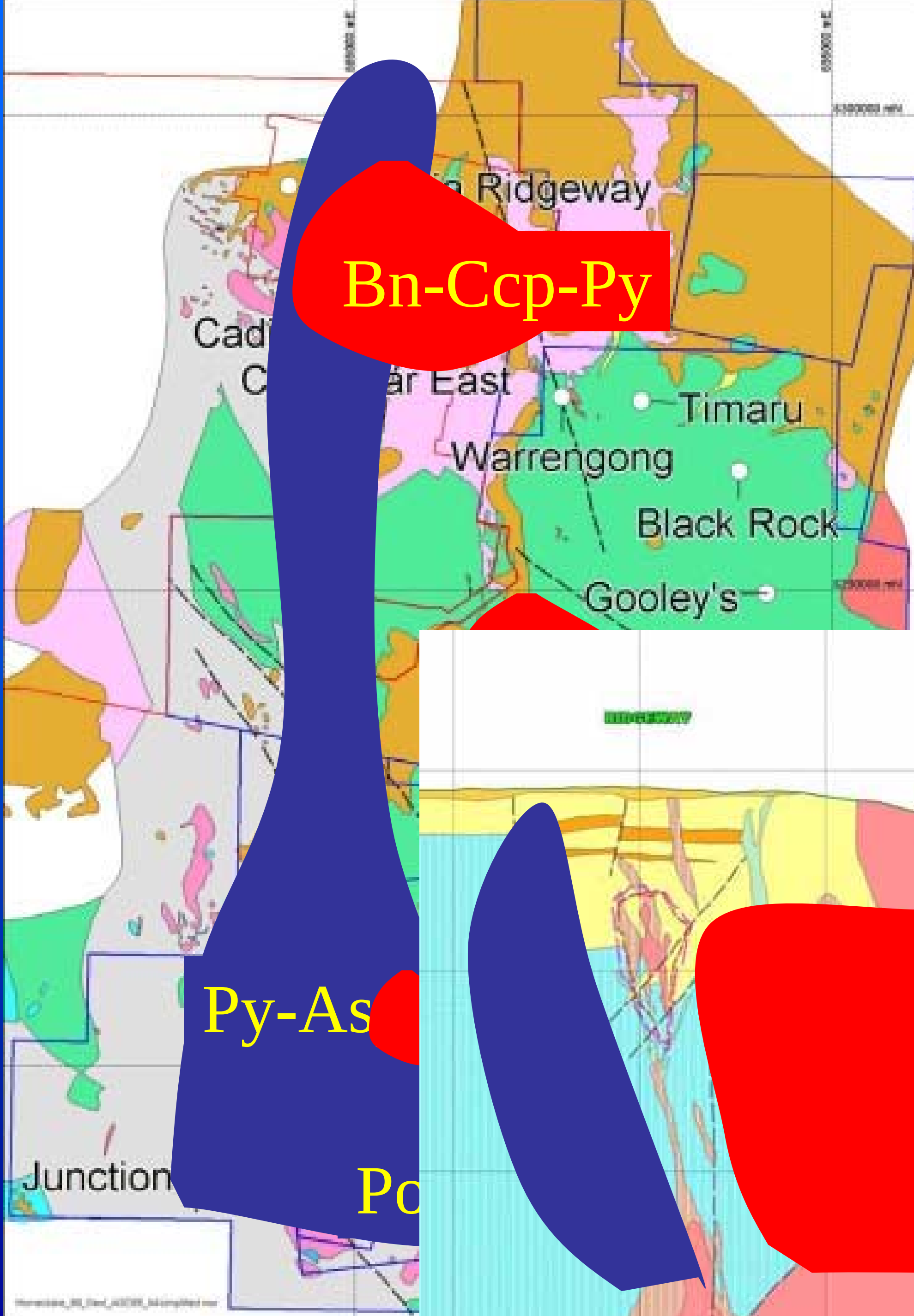
Wilson et al., 2004

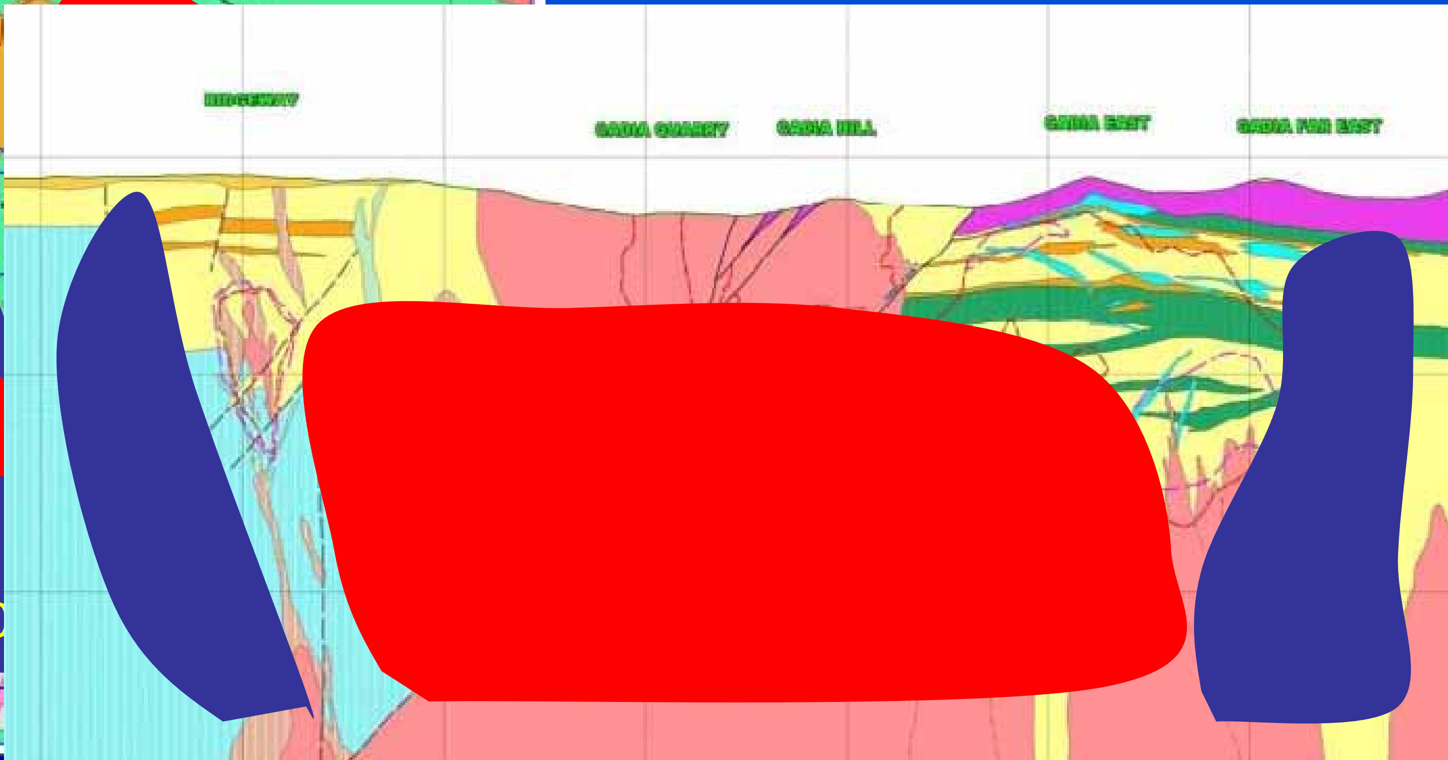


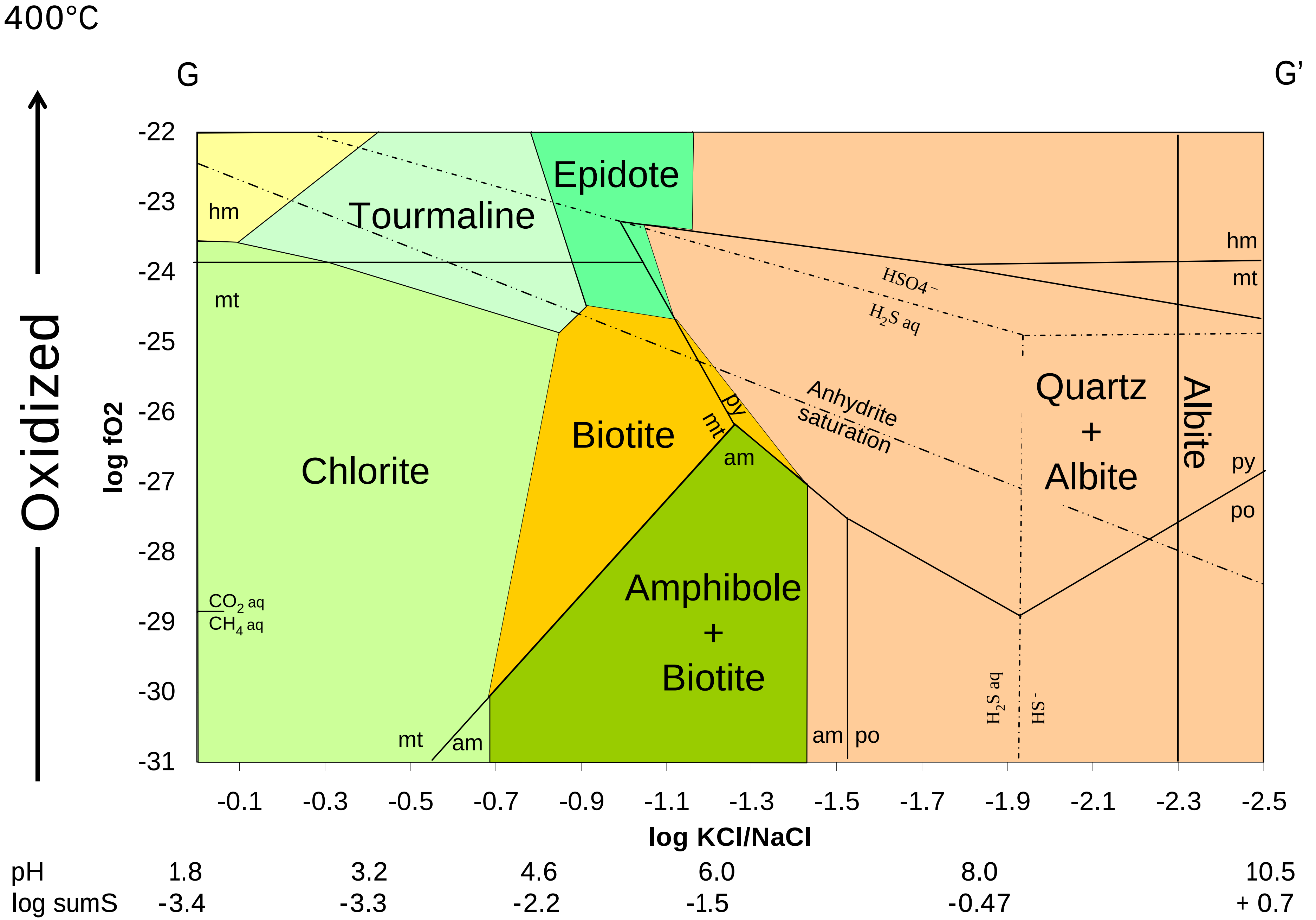
Oxidized pathways
Reduced pathways
22,400mN
22,800mN
23,200mN
Post-mineralisation cover
5400mRL
5000mRL
δ34S pyrite
δ34S chalcopyrite
δ34S bornite
δ34S contour
> 0.2 g/t Au
Sodic
Inner propylitic
Potassic
Calc-potassic
Local calc-silicate
Ridgeway Intrusive Complex
Late-mineral quartz monzonite porphyry
Inter-mineral quartz monzonite porphyry
Early-mineral monzonite porphyry
Mafic monzonite
0
200
400m

Cadia & environs: Redox mapping in porphyry environment

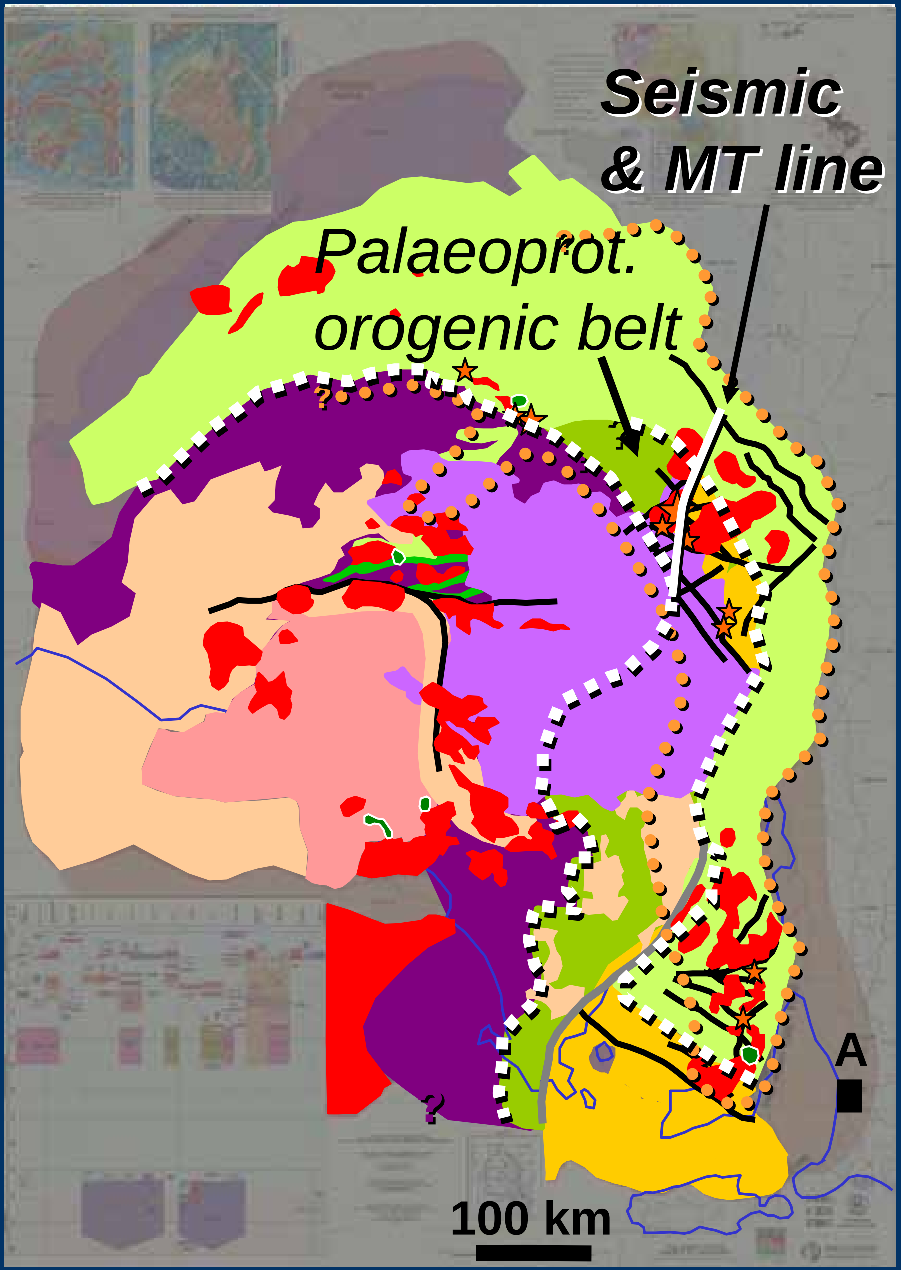
Aid to near mine exploration





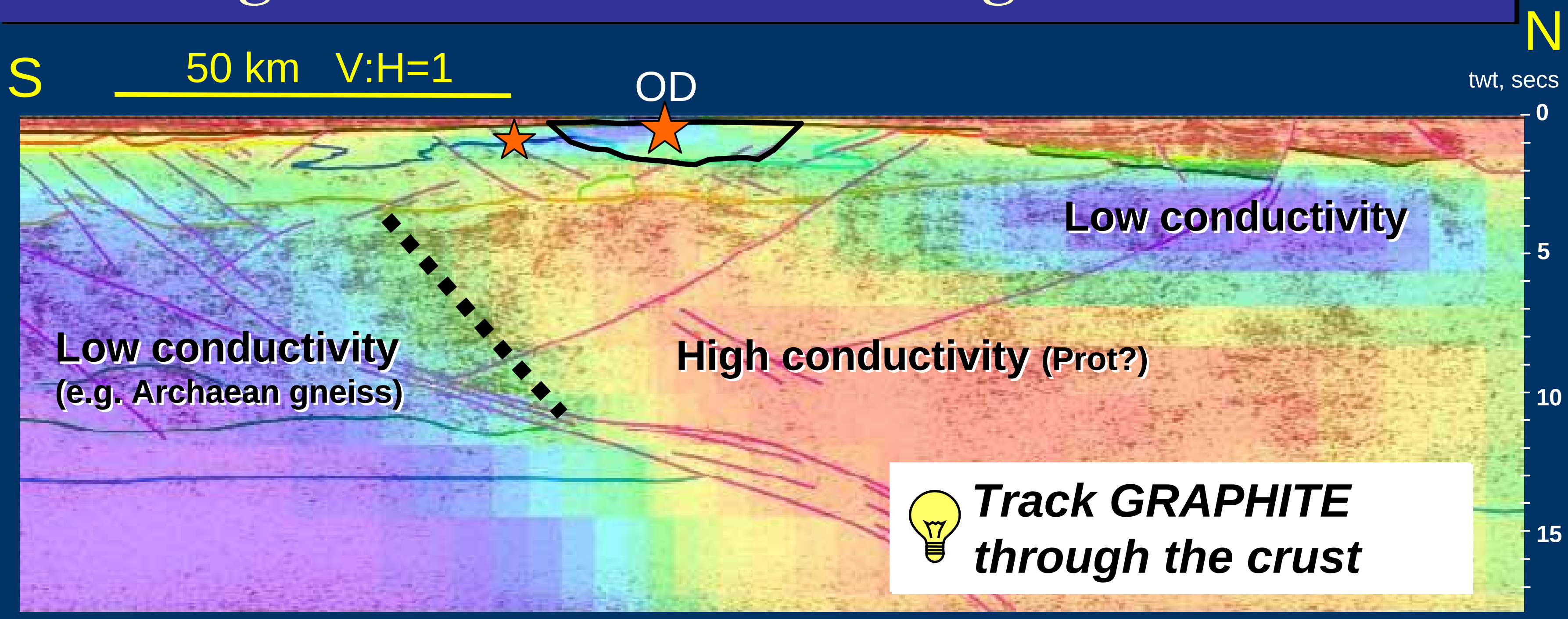

400°C
G
G'
Oxidized
log fO2
-22
-23
-24
-25
-26
-27
-28
-29
-30
-31
hm
mt
Tourmaline
Epidote
Chlorite
Biotite
Amphibole
+
Biotite
Quartz
+
Albite
Albite
hm
mt
HSO4⁻
H2S aq
Anhydrite
saturation
py
mt
am
py
po
CO2 aq
CH4 aq
mt
am
am
po
H2S aq
HS⁻
-0.1
-0.3
-0.5
-0.7
-0.9
-1.1
-1.3
-1.5
-1.7
-1.9
-2.1
-2.3
-2.5
log KCl/NaCl
pH 1.8 3.2 4.6 6.0 8.0 10.5
log sumS -3.4 -3.3 -2.2 -1.5 -0.47 + 0.7

IOCG crustal setting



- ~1590 Ma: Gawler Range Volcanics (bimodal, mainly felsic)
- ~1595-1575 Ma: Hiltaba Suite granitoid and mafic intrusions;
- faults
- ~1590-1575 Ma: Olympic Cu-Au province;

Crustal architecture of the Olympic Dam region: magneto-telluric transect along seismic line



Coloured MT image courtesy R. Gill, G. Heinson, N. Direen at The University of Adelaide, and published in Thiel et al., (2004).
MT image overlays GA-PIRSA seismic data with early interpretive linework by GA-PIRSA-UofA.

Earth-system models

Potential to explain

- Time scales
- Length scales
- Province scale alteration
- Build genuine mineral system models