Mineralized Terranes

Eastern Goldfields Superterrane (EGST)

The 5 Questions

A legacy for mineral exploration science

Key Parameter → Mineral System → Exploration

is reflected in

scale-dependent translation

A. Gradient in hydraulic potential

B. Permeability

C. Solubility sensitivity to P, T, C

D. Spatial gradient of P, T, C

E. Time (duration)

5 Questions

1. Geodynamics
2. Architecture
3. Fluid reservoirs
4. Flow drivers & pathways
5. Deposition

Terrain Selection

Area Selection

Drill Targeting

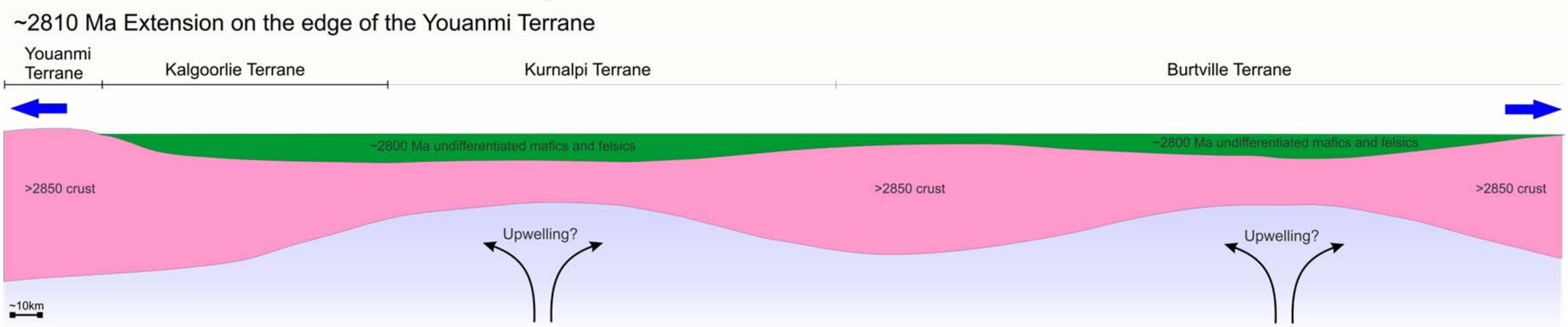
Slide after: A. Barnicoat

Geodynamics

2810 Ma extension on the edge of the Youanmi Terrane

Set up of NNW striking deep crustal architecture which controls the εNd model age map

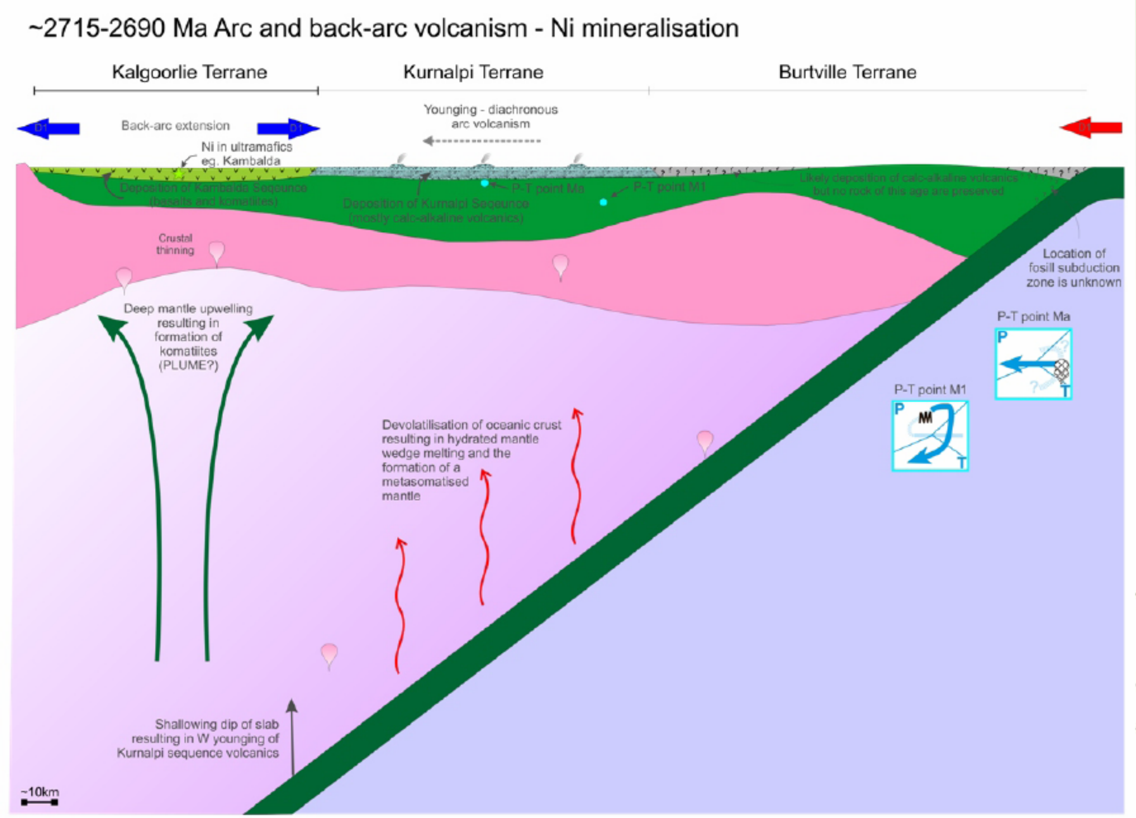
Thinned continental lithosphere



Czarnota et al 2007

Geodynamics

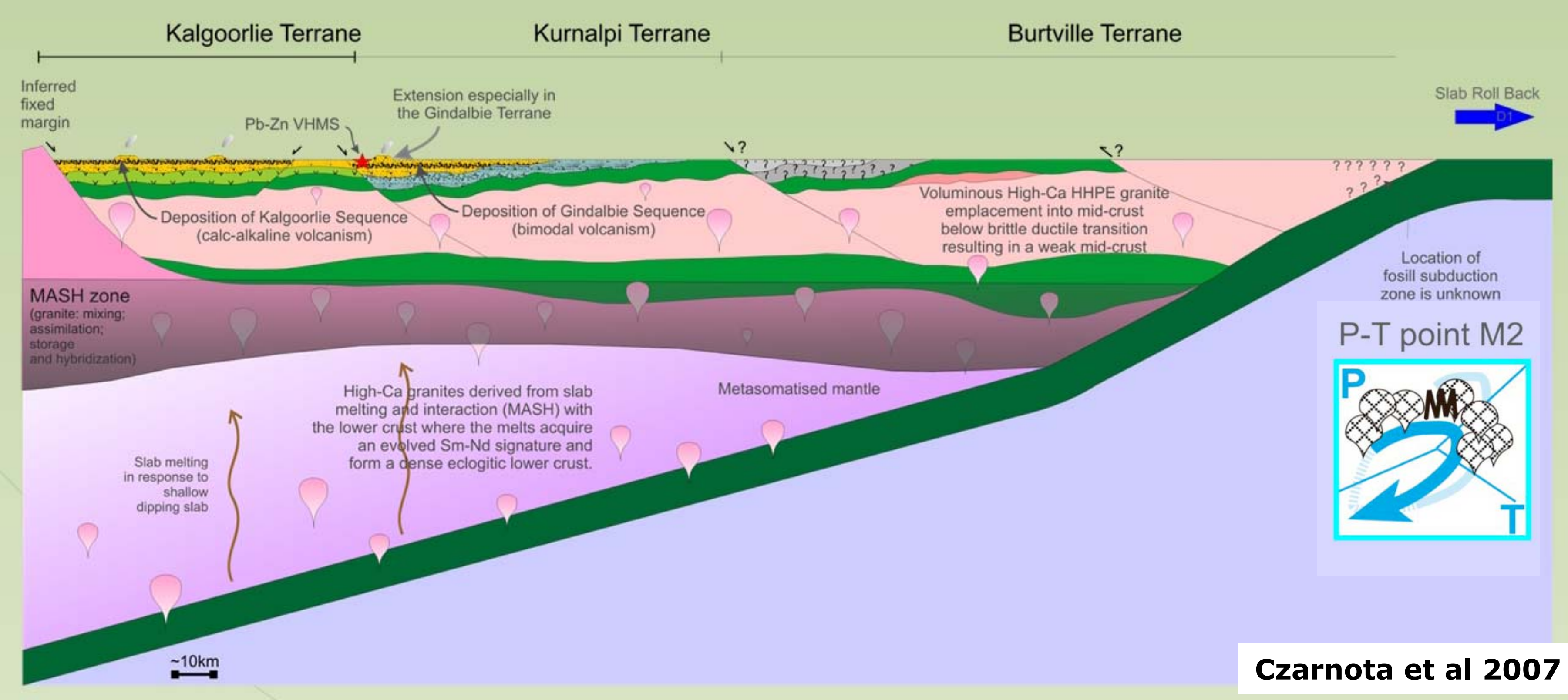
2715-2690 Ma Initiation of West dipping subduction: arc and back-arc volcanism; Ni mineralization



Czarnota et al 2007

Geodynamics

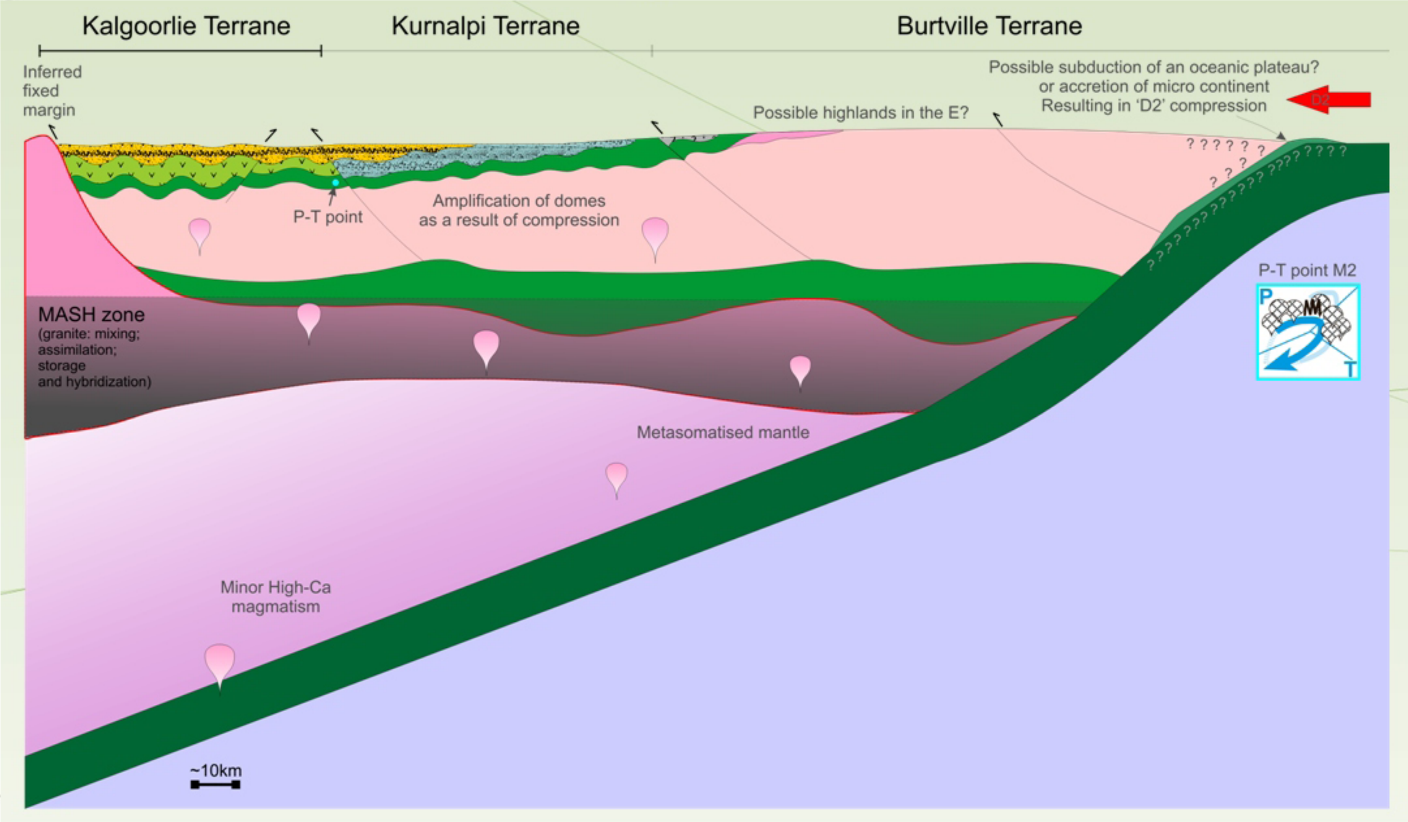
2690-2670 Ma: bimodal volcanism; high-Ca granite magmatism; VHMS mineralization



Czarnota et al 2007

Geodynamics

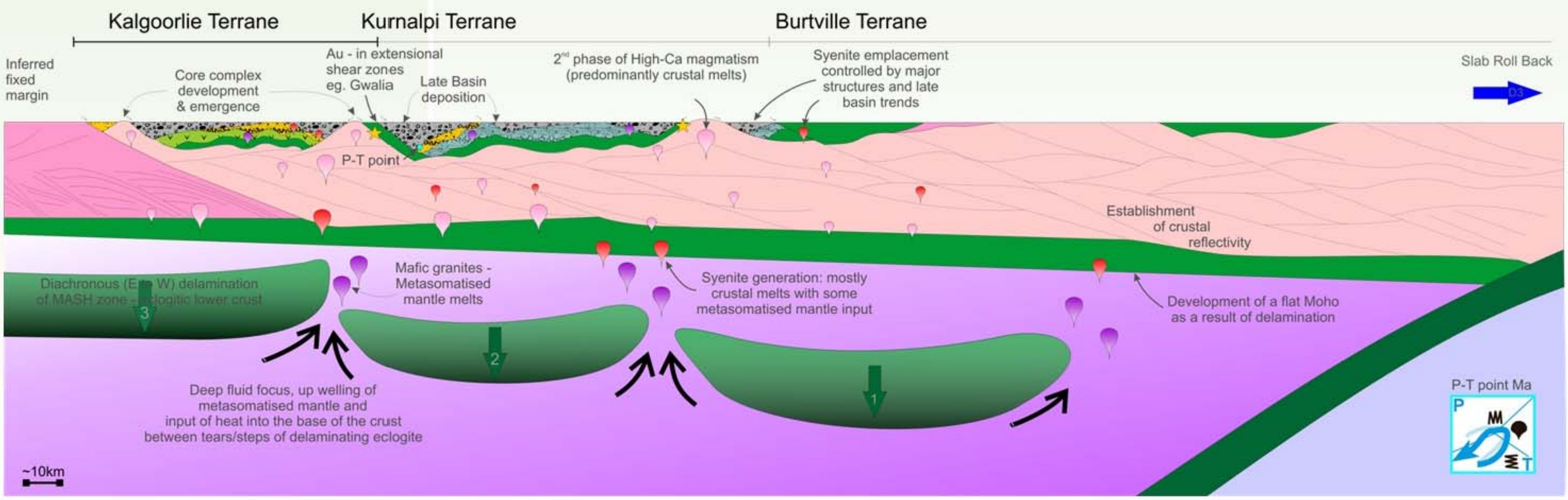
2670-2663 Ma: diachronous ‘D2” compression; crustal thickening; termination of volcanism; trigger for deformation



Czarnota et al 2007

Geodynamics

2665 to ~2652 Ma: diachronous lithospheric extension and delamination associated with: Core complex development, metasomatised mantle and the start of major EGST Au mineralization

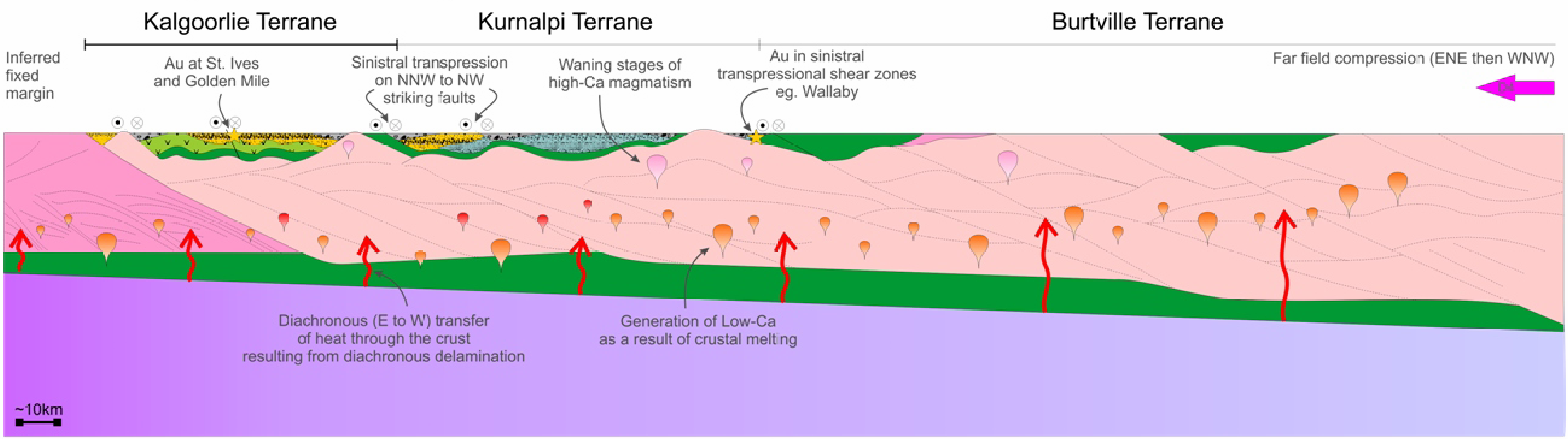


Czarnota et al 2007

Geodynamics

~2650 Ma: sinistral transpression on NNW-striking shear zones

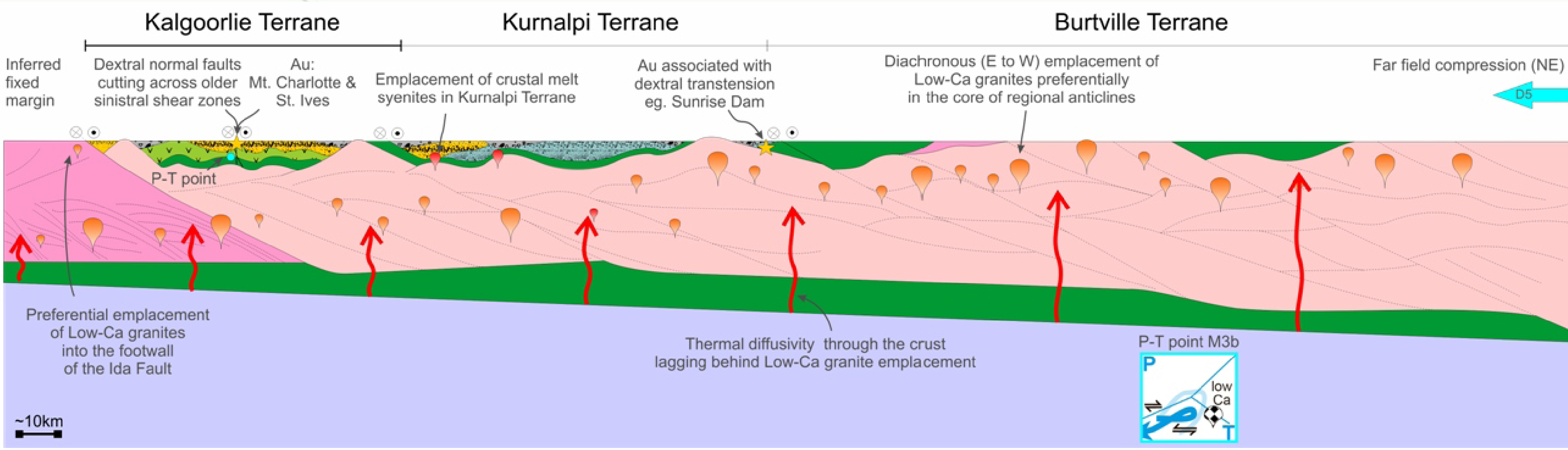
High- to low- Ca magmatism switch, main Au event



Czarnota et al 2007

Geodynamics

~2650-2620 Ma: dextral strike-slip on N to NNE striking shear zones, Low-Ca granite emplacement and cratonisation - Au



Czarnota et al 2007

Structural History and Au

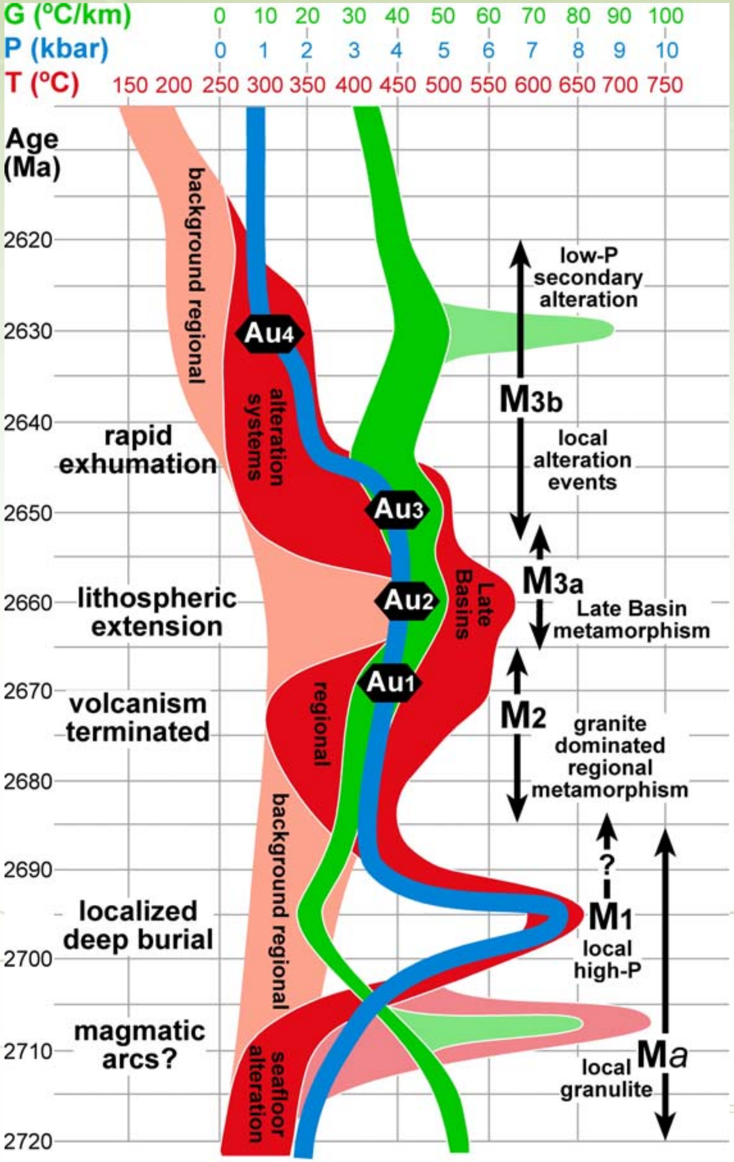
Blewett & Czarnota 2007			Swager 1997	Blewett *et al.* 2004b	Miller 2006
Minor contraction		D7			
Minor extension		D6	Collapse	Late De	
Dextral transtension		D5	D4	(D3)	D4
Sinistral transpression		D4b	D3	(D3)	D3
		D4a	D2	D2b	D2
Extensional doming	Stage 2 Late Basins	D3b	DE	D2e	
	Stage 1 Late Basins	D3a			
Upright folding and reverse faulting		D2	D2	D2a	D1
Extension with intermittent compression		D1	DE	De, D1, D1e	

Au

Metamorphic events

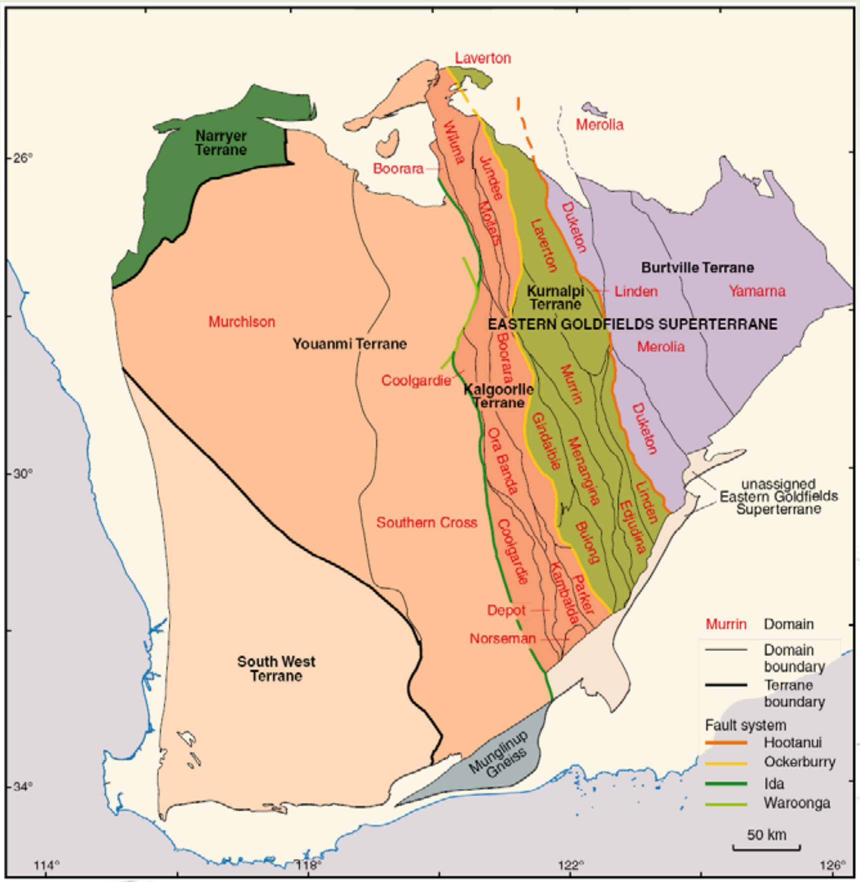
- Ma, M1, M3a and M3b metamorphic events are local events of restricted spatial distribution.
- Unlike the punctuated evolution of deformation events; metamorphic parameters evolve along a continuum.

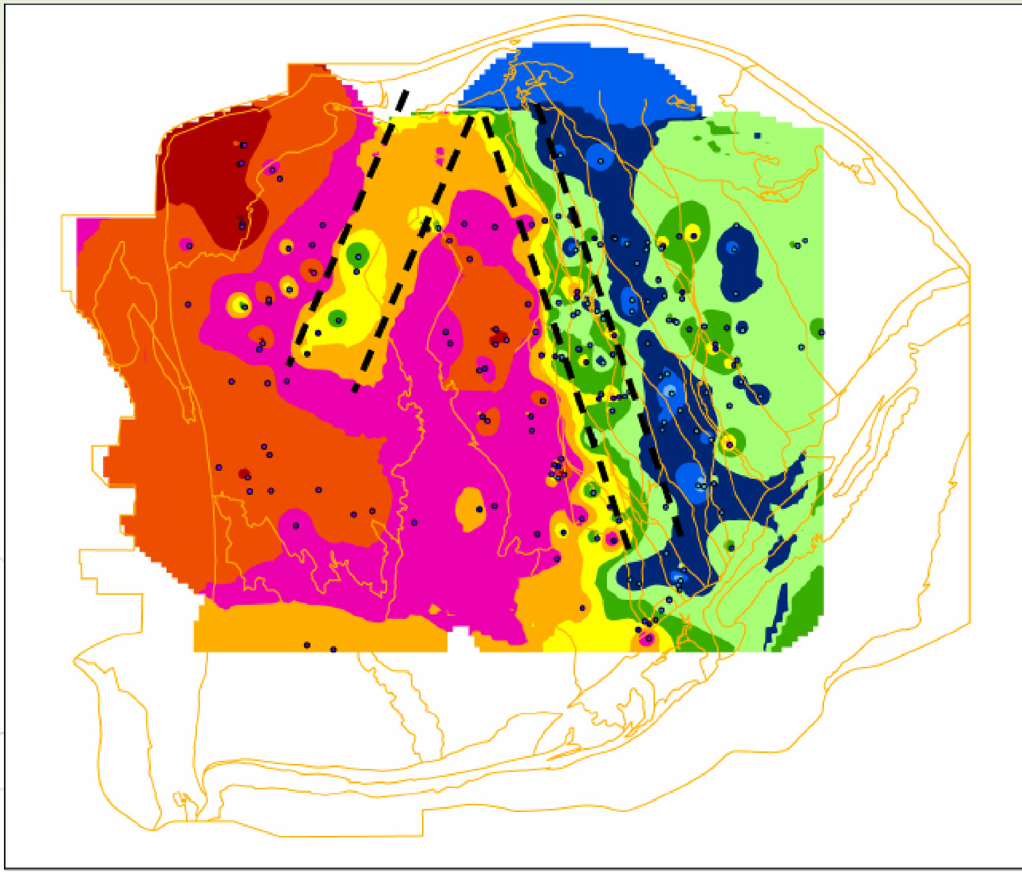
Red = T
Blue = P
Green = T/depth (thermal regime)



Slide from: B. Goscombe

Architecture – large scale

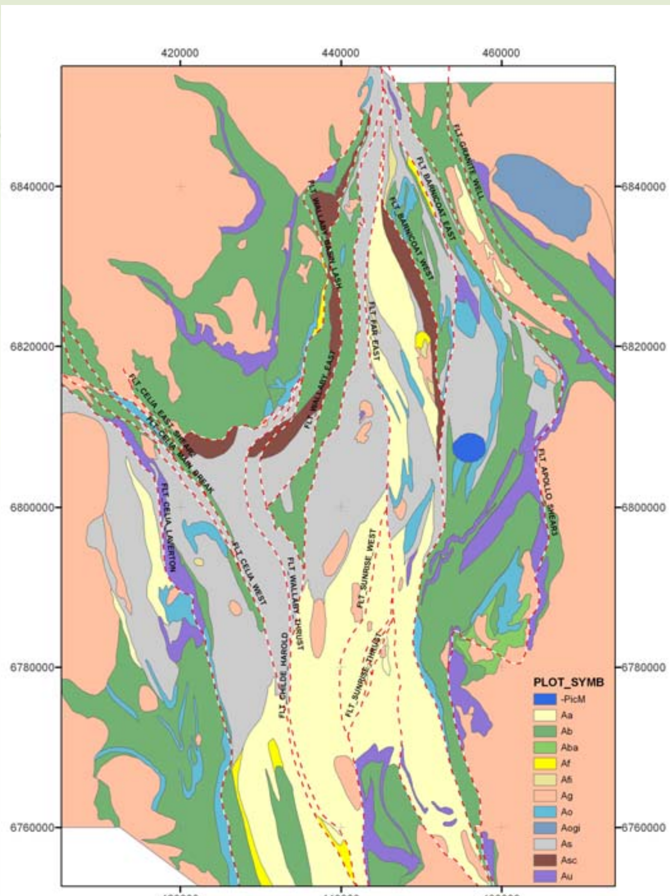




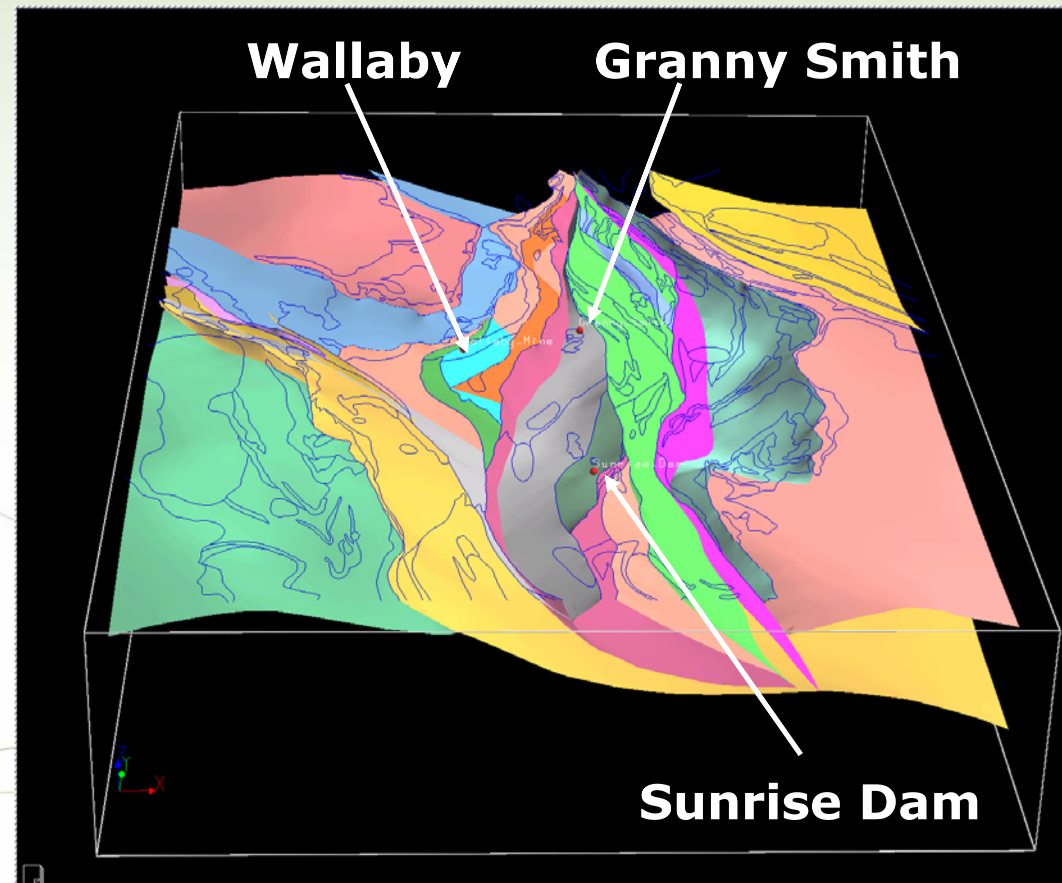
Cassidy et al (2006)

Champion and Cassidy (2007)

Architecture – regional

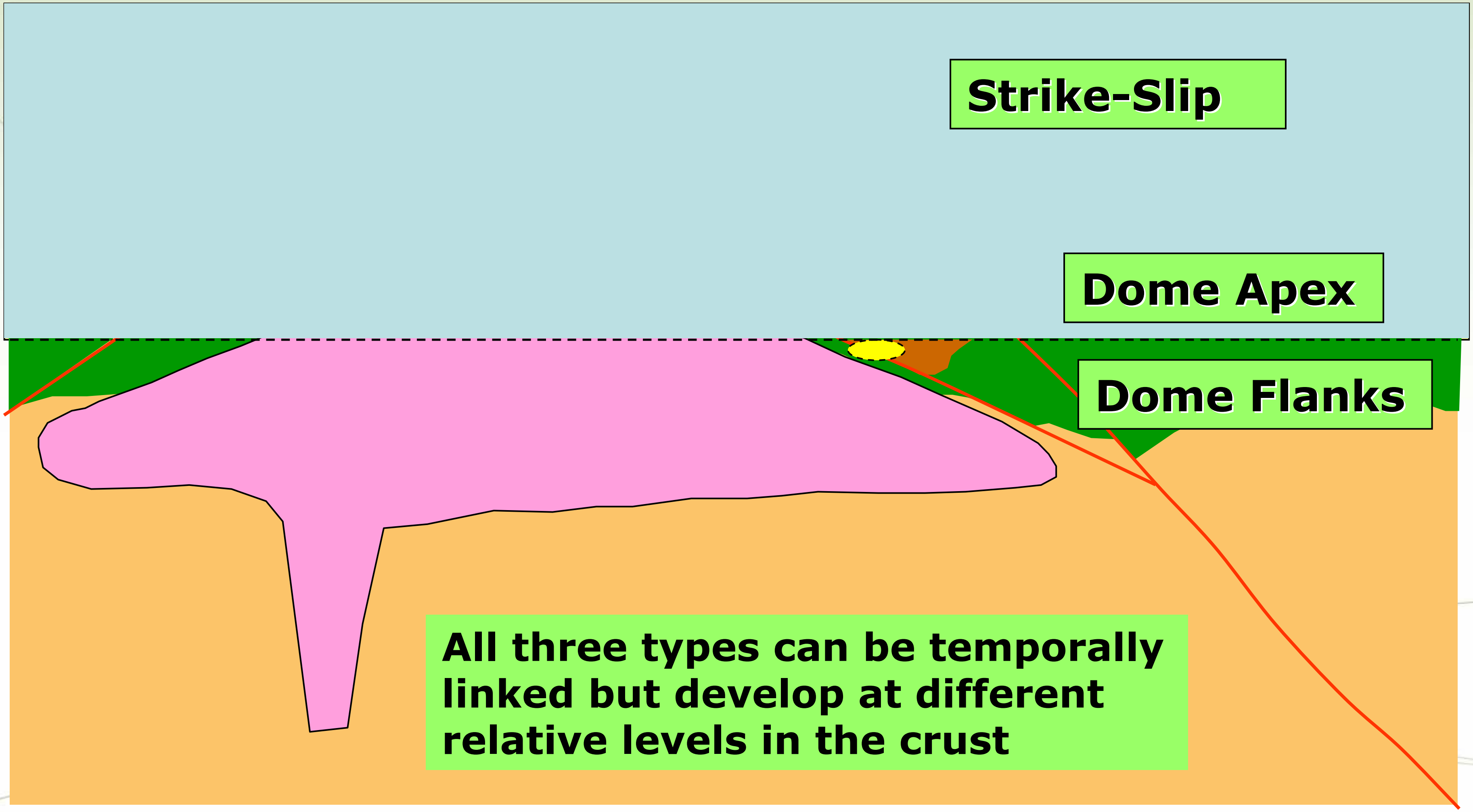


Henson et al (2007)



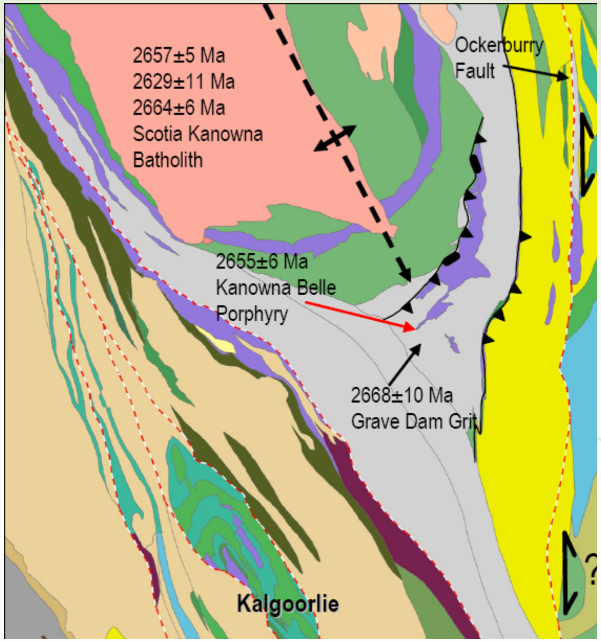
Slide after: P. Henson

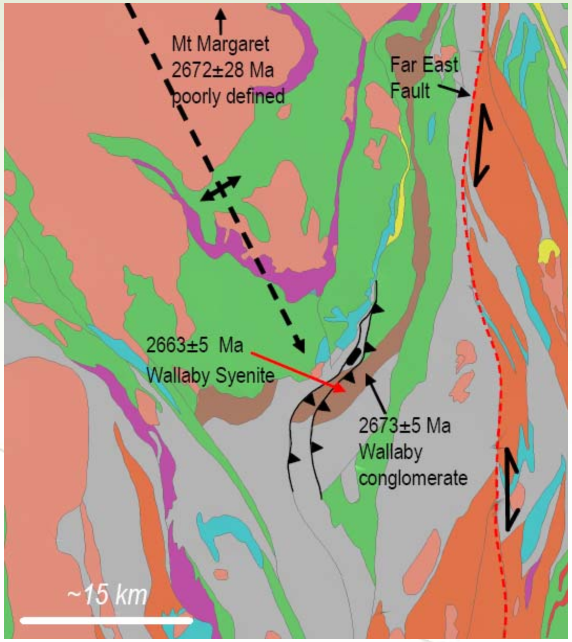
Architecture – camp scale

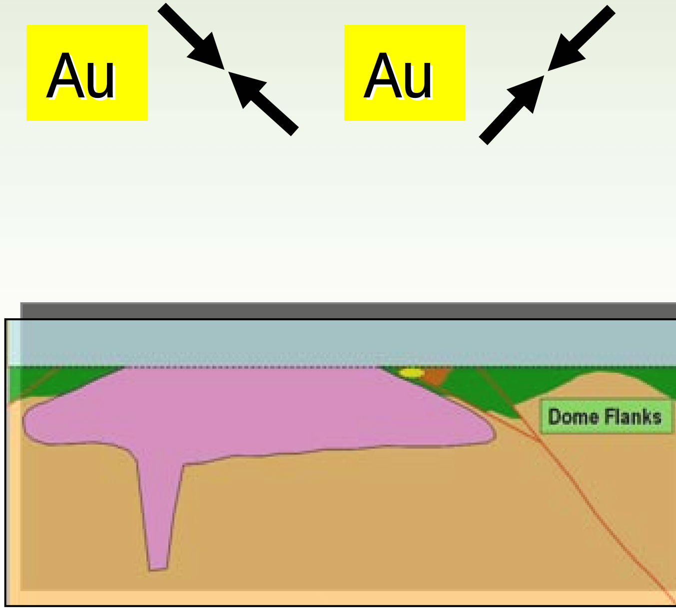


Slide after: P. Henson

Architecture – camp scale



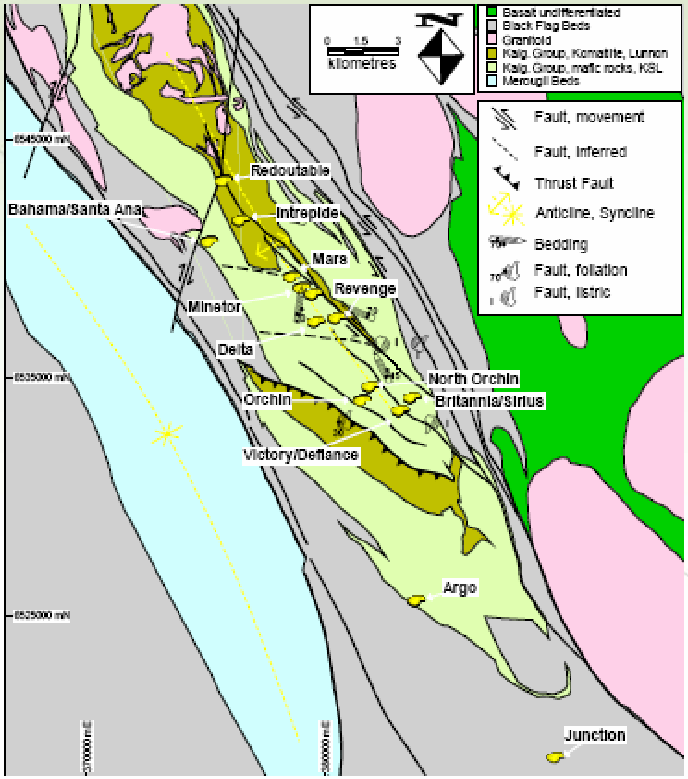


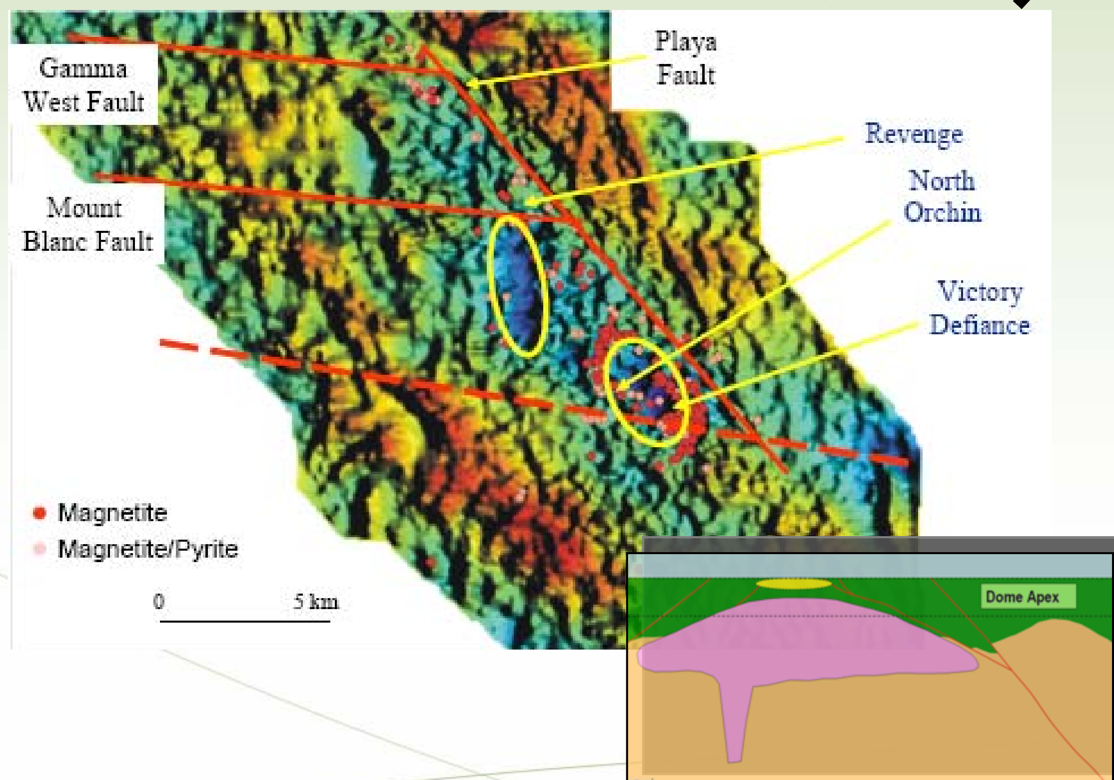


Domes projecting under Kanowna Belle in Kalgoorlie and Wallaby in Laverton focus fluids/ melt into splays off reactivated normal faults

Architecture – camp scale

Au Au

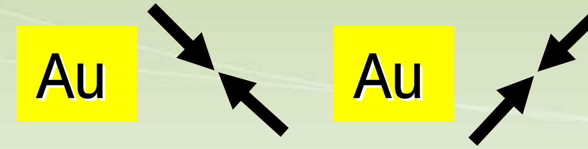


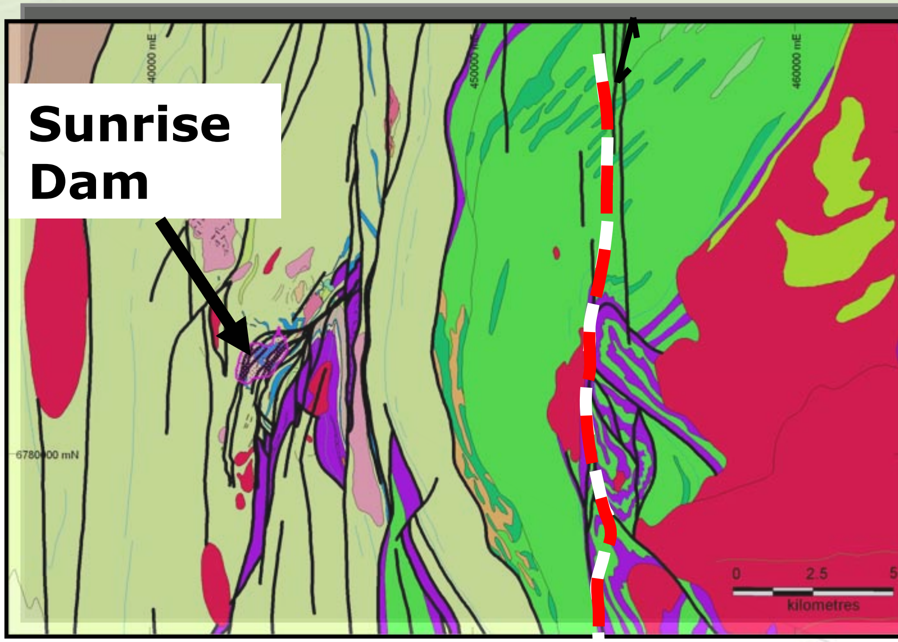


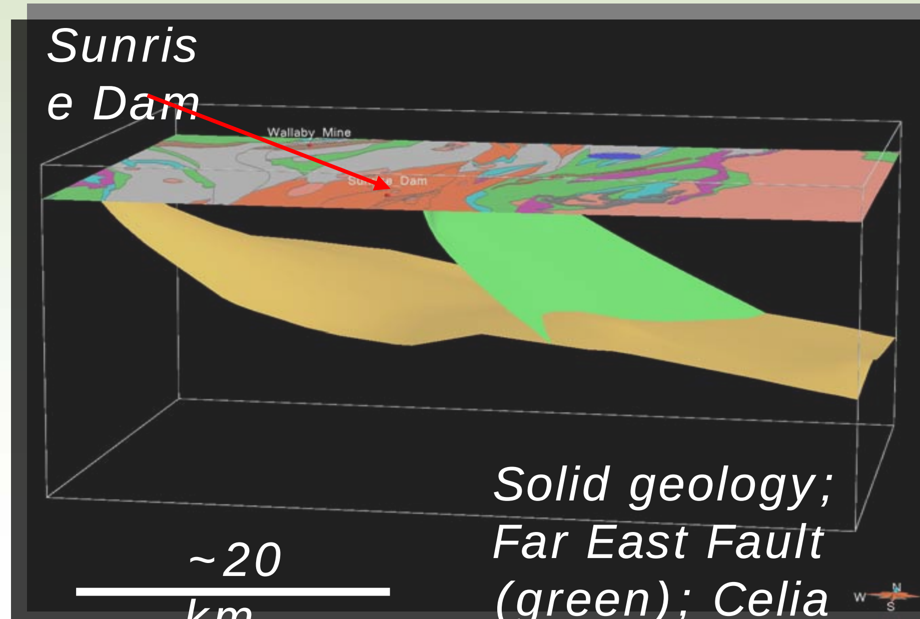
Victory Defiance mine located above a granite dome (focussing fluid/ melts) and in the footwall of the strike slip reactivated normal Playa Fault acting as a seal

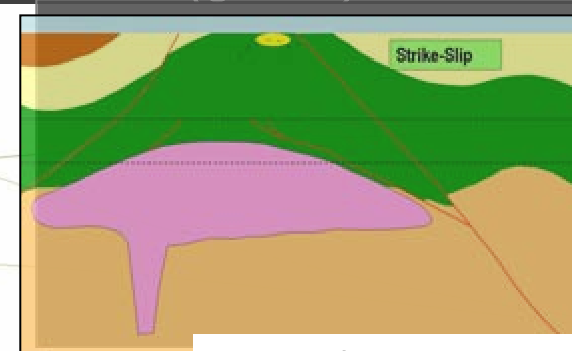
Slide after: P. Henson

Architecture – camp scale







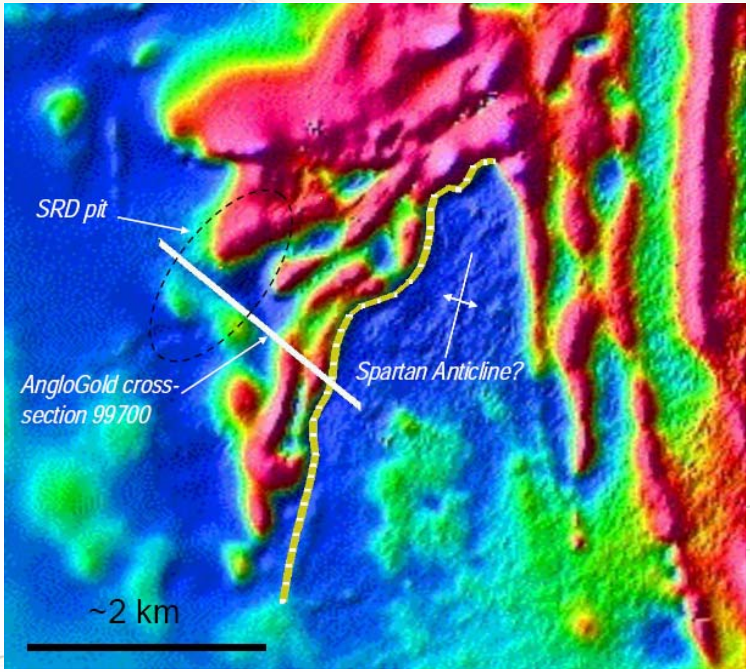


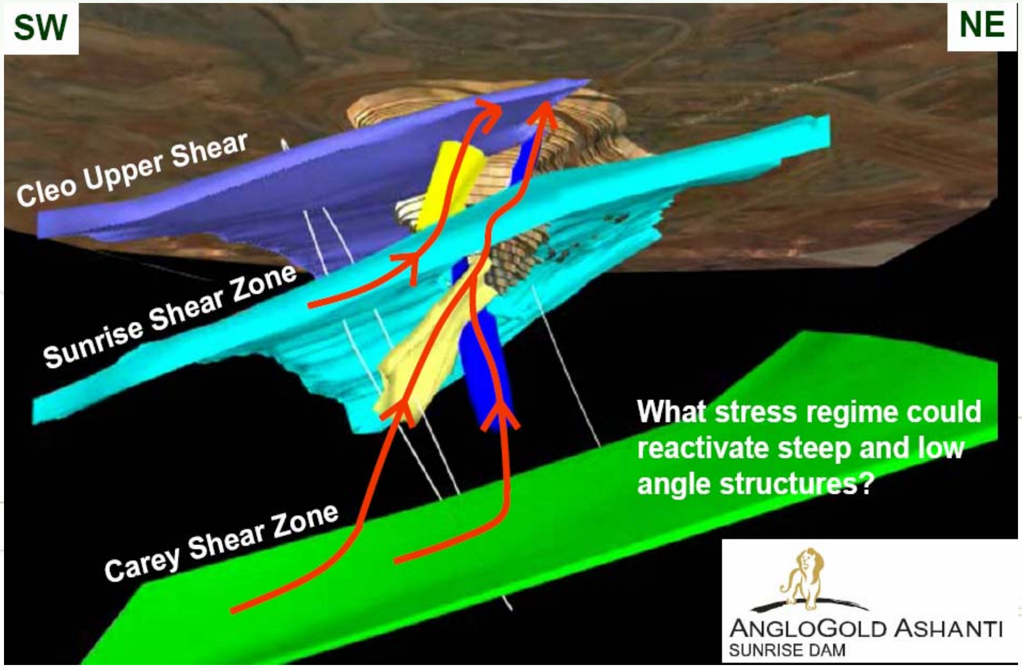
Major deposits (Golden Mile & Sunrise Dam) occur proximal to strike-slip reactivated normal faults determined from lithological distributions and offsets

Slide after: P. Henson

Architecture – Deposit scale

1. **Fluid/ melt focussing occurs at sites where the folding produces plunging anticlines**
2. **Shear zones at Sunrise Dam mine act as both fluid pathways and seals during the migration of mineralised fluids. Shear zones interact with local rheology contrasts to influence fluid/ migration.**



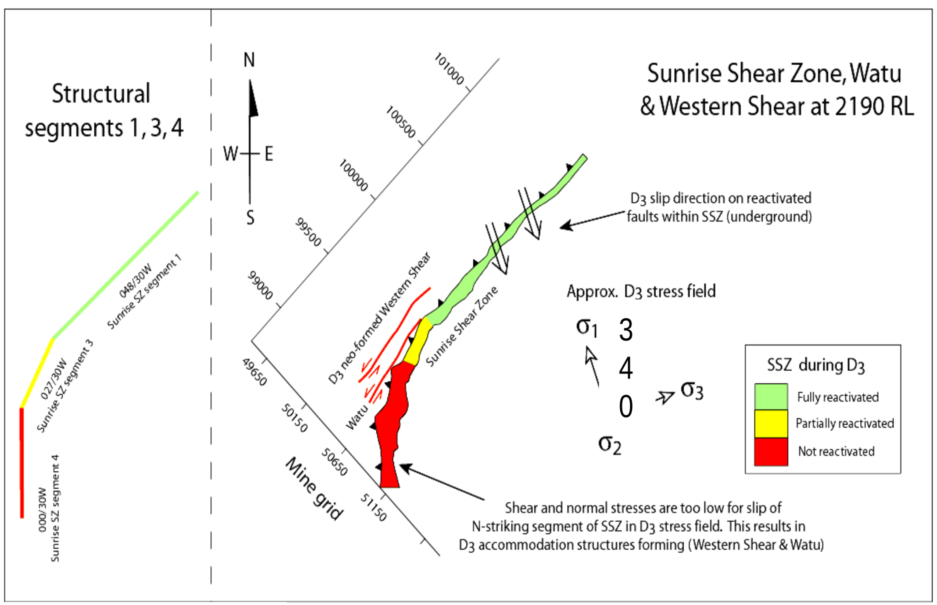


Architecture – Ore scale

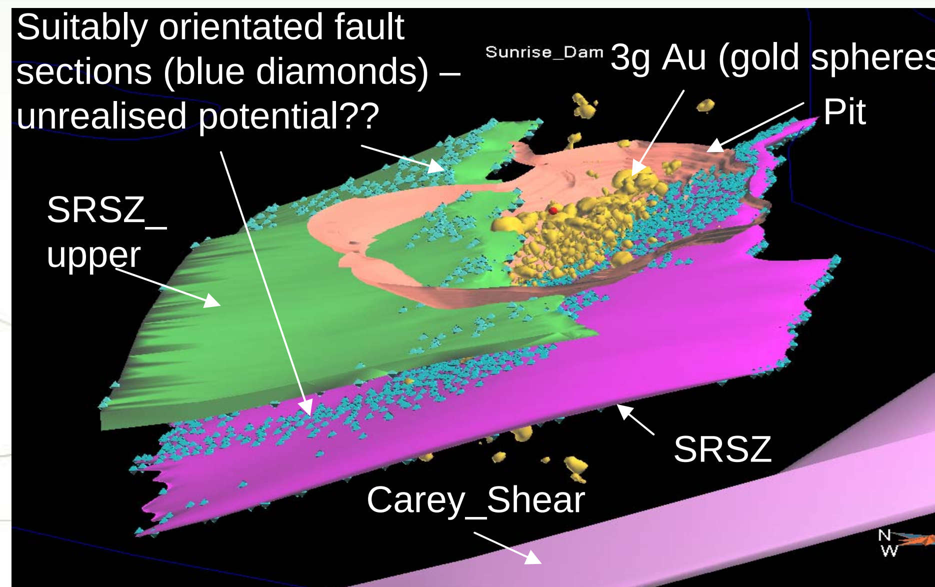
Sunrise Dam

Detailed structural analysis of the Sunrise Dam deposit

Statistical analysis of 3D fault orientations delineates spatial regions that will preferentially reactivate/ dilate



J. Miller 2006

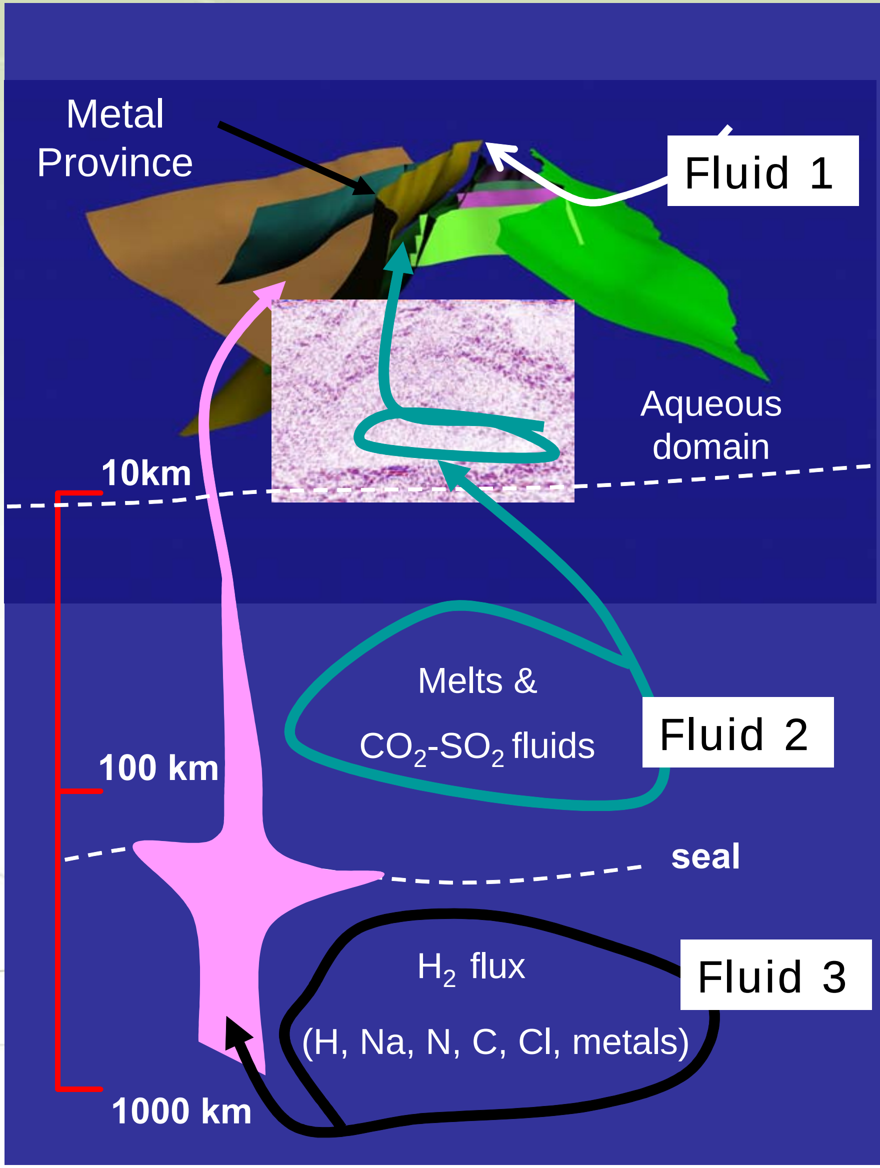


J. Miller

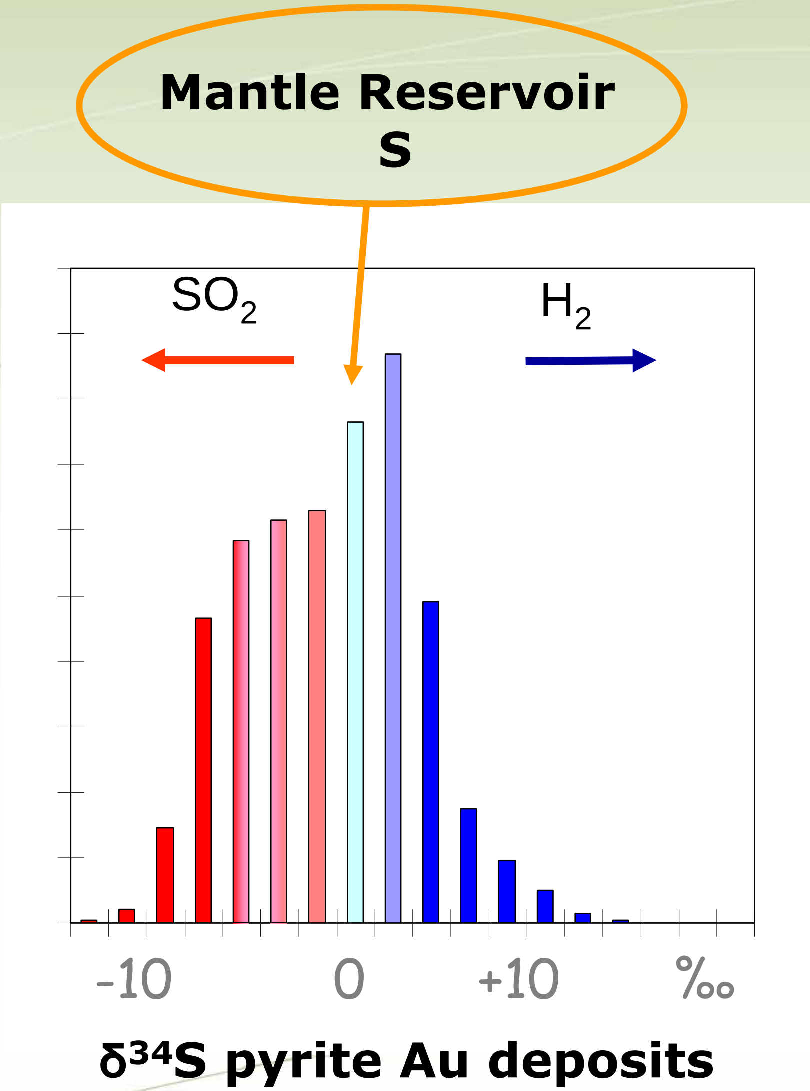
Fluid reservoirs

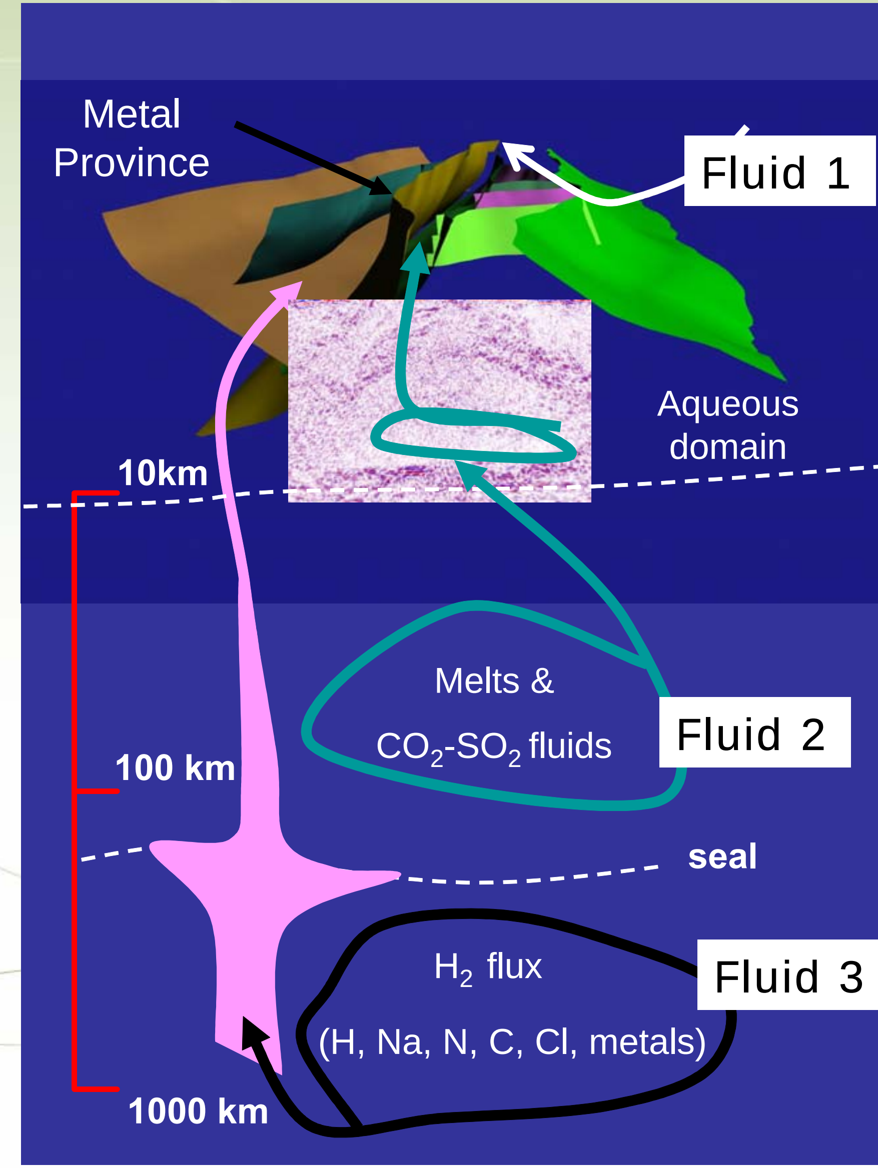
3 end-member fluids:

1) **ambient crustal aqueous fluid, with low concentrations of salt and volatiles**
2) **magmatic, dominated by CO2 and SO2**
3) **'deep-earth', highly reduced CH4 - N2 - H2 - fluid**
   - **acid volatiles (H2S, HCl ±HF),**
   - **noble gases (Ne and Ar) of mantle origin,**
   - **possibly metal hydrides (e.g. NaH, MgH2, AlH3 and SiH4)**
   - **and probably Au**



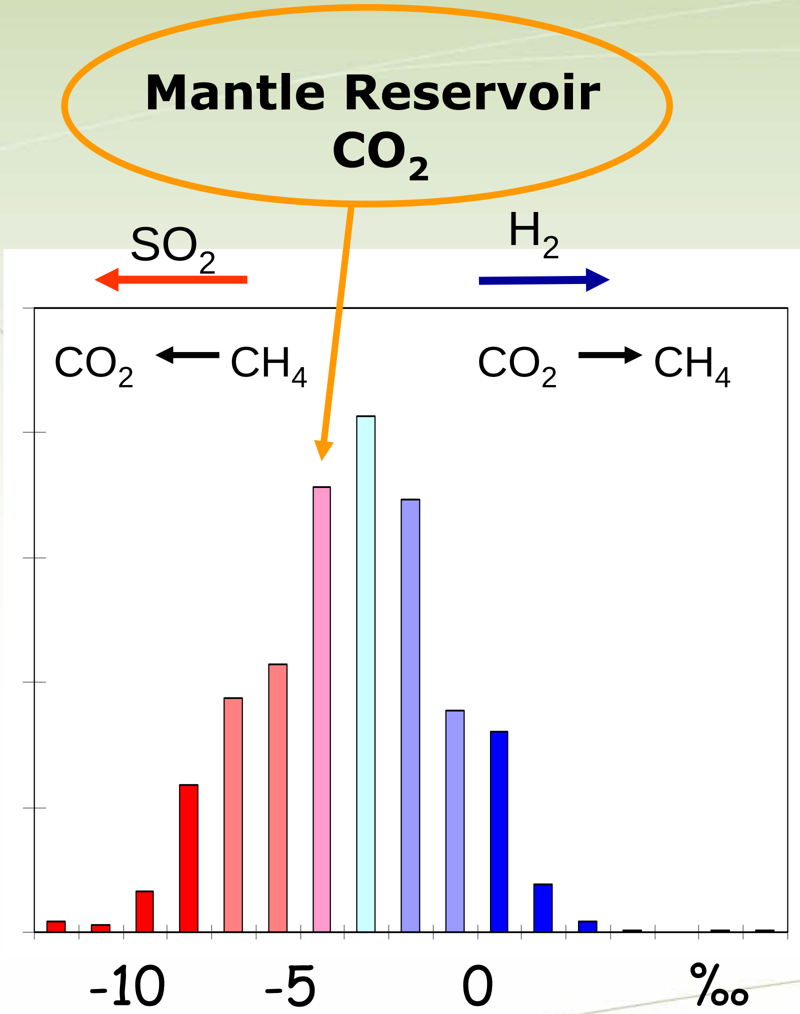
Walshe et al



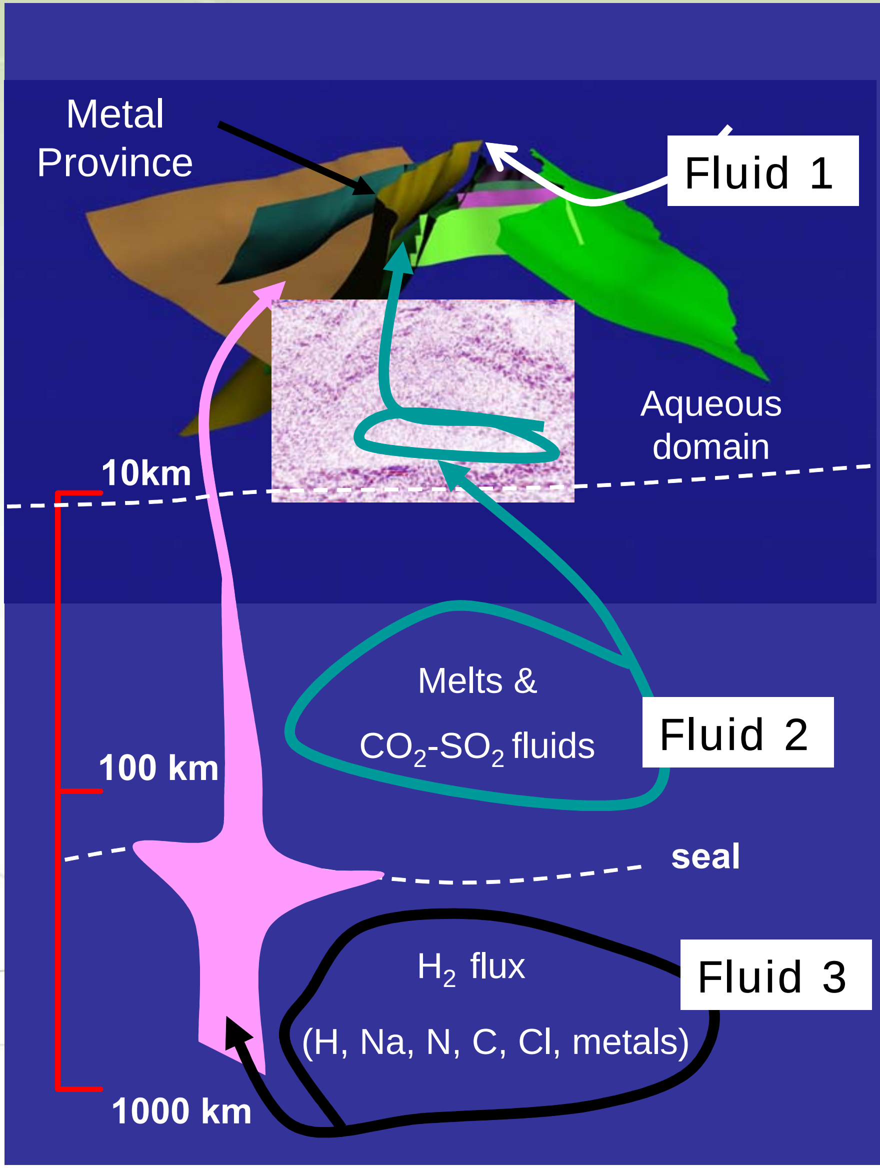


Slide after: J. Walshe

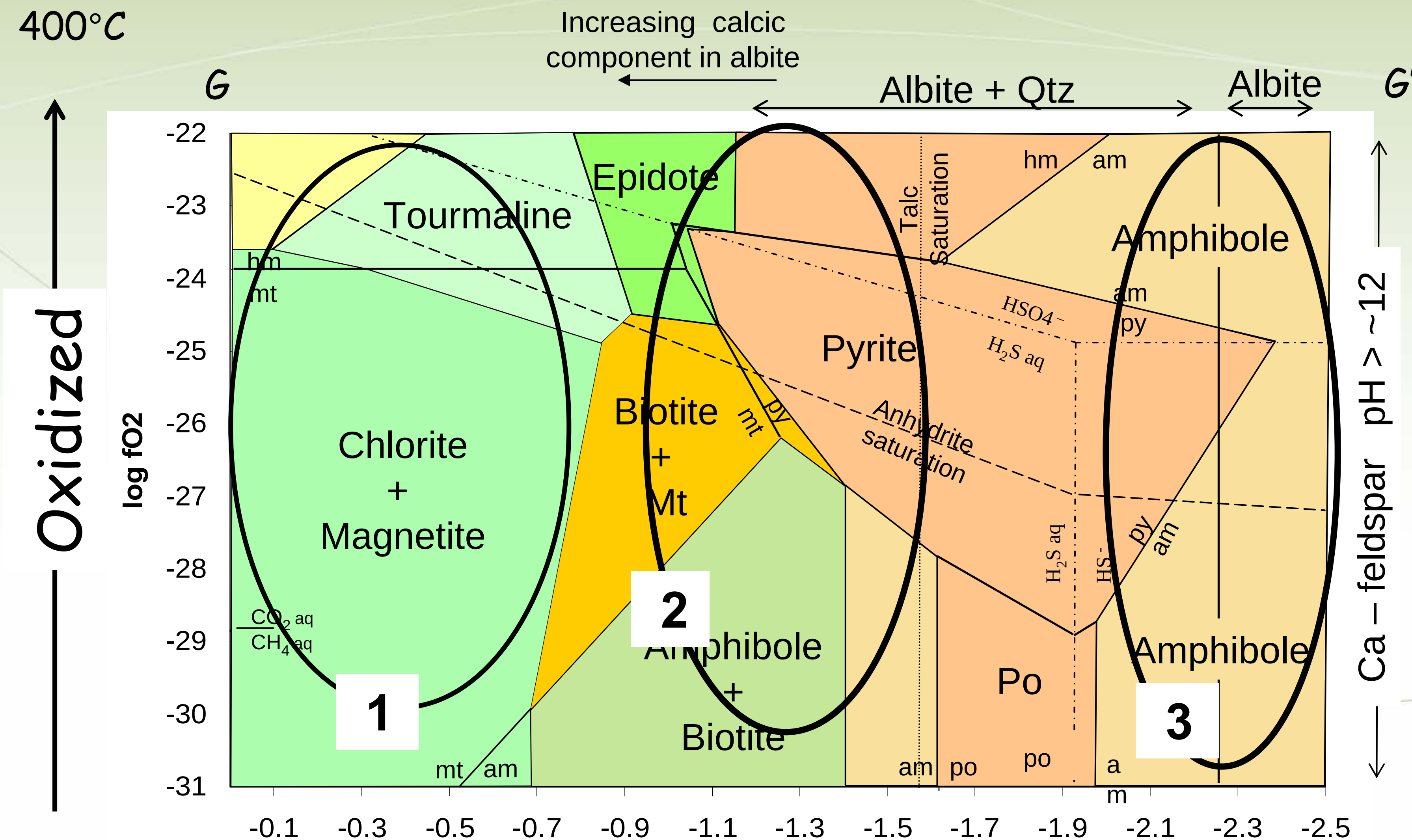
A legacy for mineral exploration science



δ¹³C carbonate Au deposits

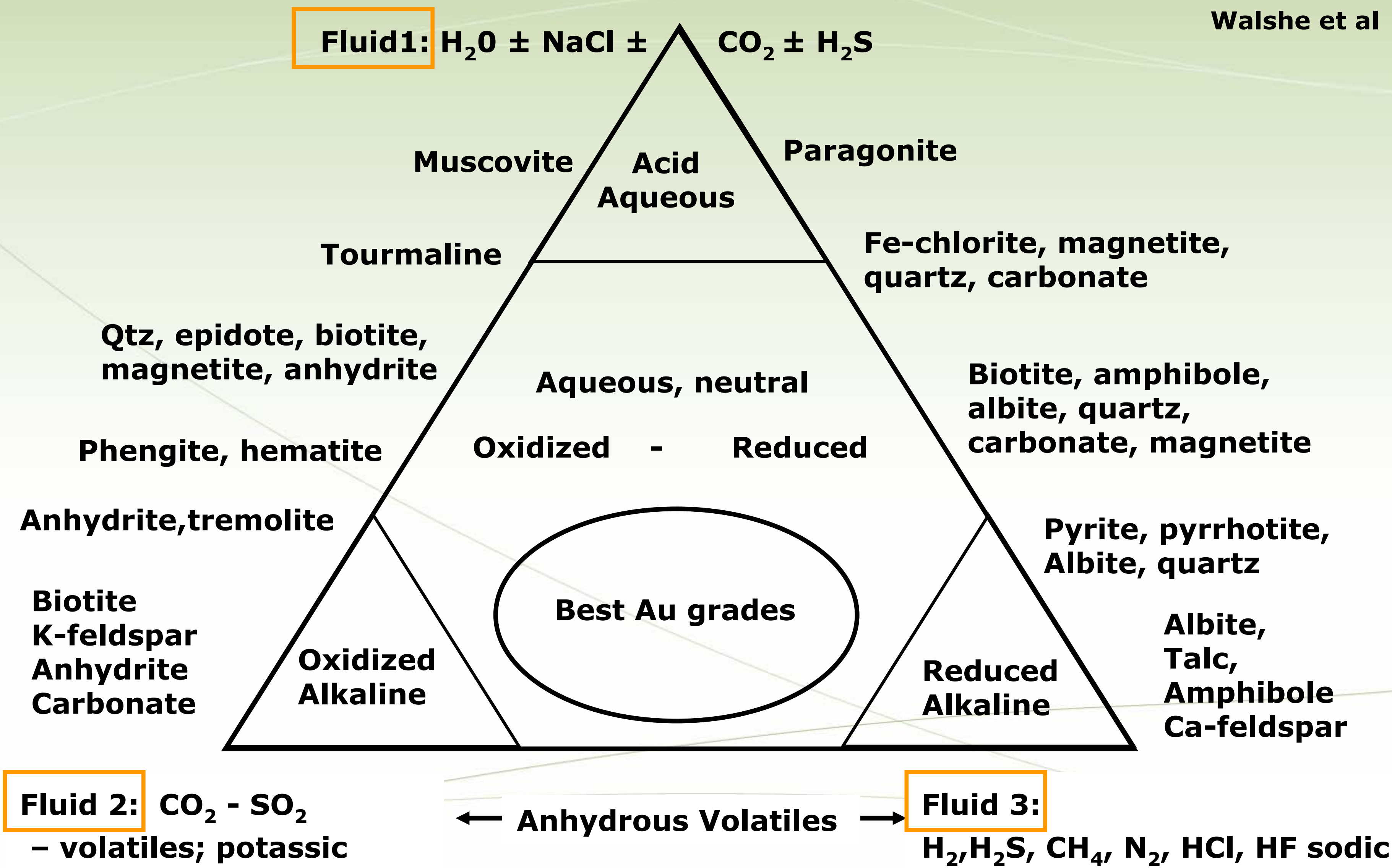


Slide after: J. Walshe

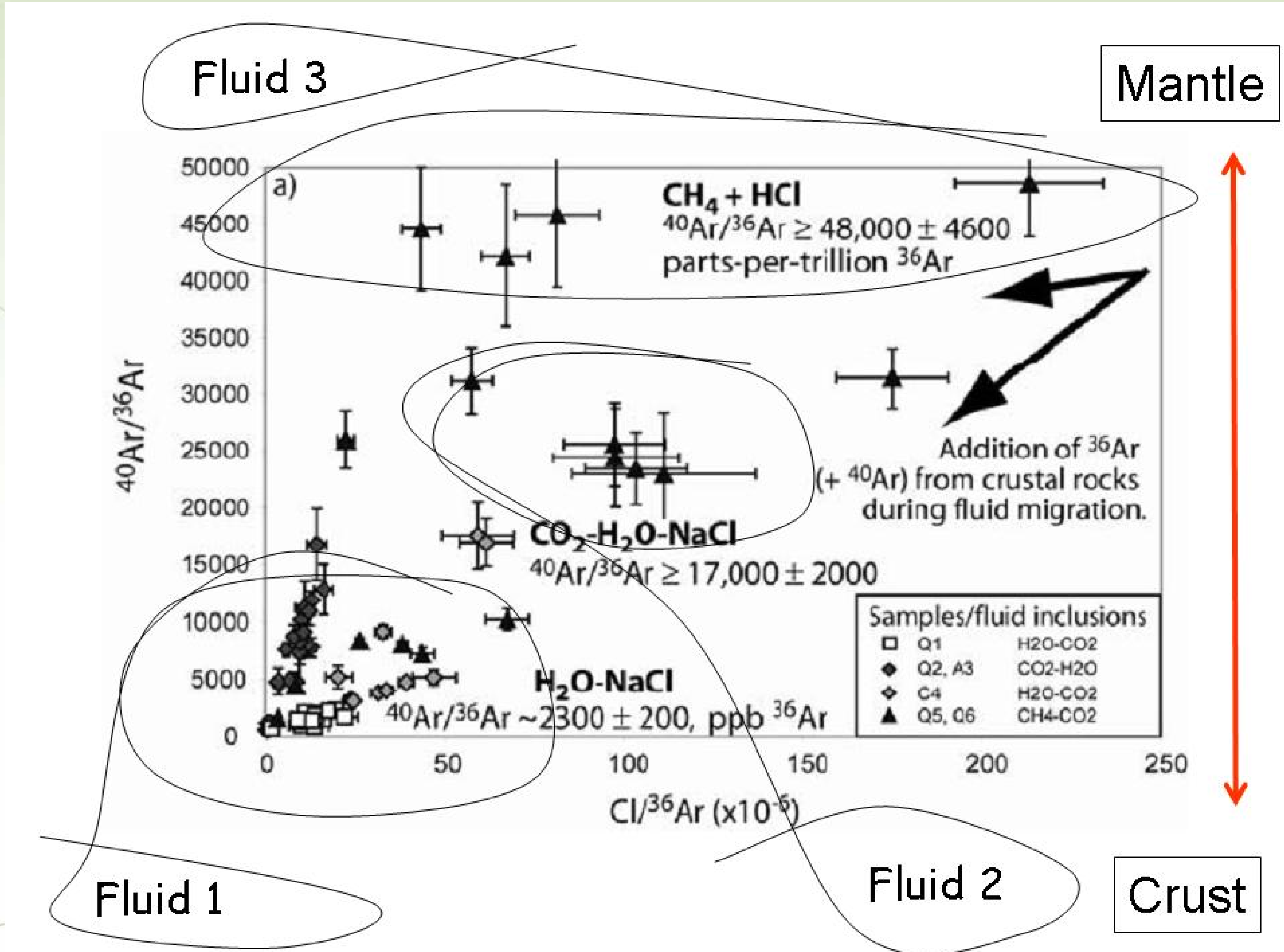

400°C
Increasing calcic component in albite
G
Albite + Qtz
Albite
G'
Oxidized
log fO2
-22
-23
-24
-25
-26
-27
-28
-29
-30
-31
Tourmaline
Epidote
Talc saturation
hm
am
Amphibole
hm
mt
am
py
HSO4−
Pyrite
H_2S aq
Biotite + Mt
mt
py
Anhydrite saturation
Chlorite + Magnetite
H_2S aq
HS-
py
am
CO_2 aq
CH_4 aq
2
Amphibole + Biotite
Amphibole
1
Po
3
mt
am
am
po
po
a
m
-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
Ca – feldspar pH > ~12

Walshe et al

A legacy for mineral exploration science



Fluid inclusion 40Ar/36Ar versus Cl/36Ar



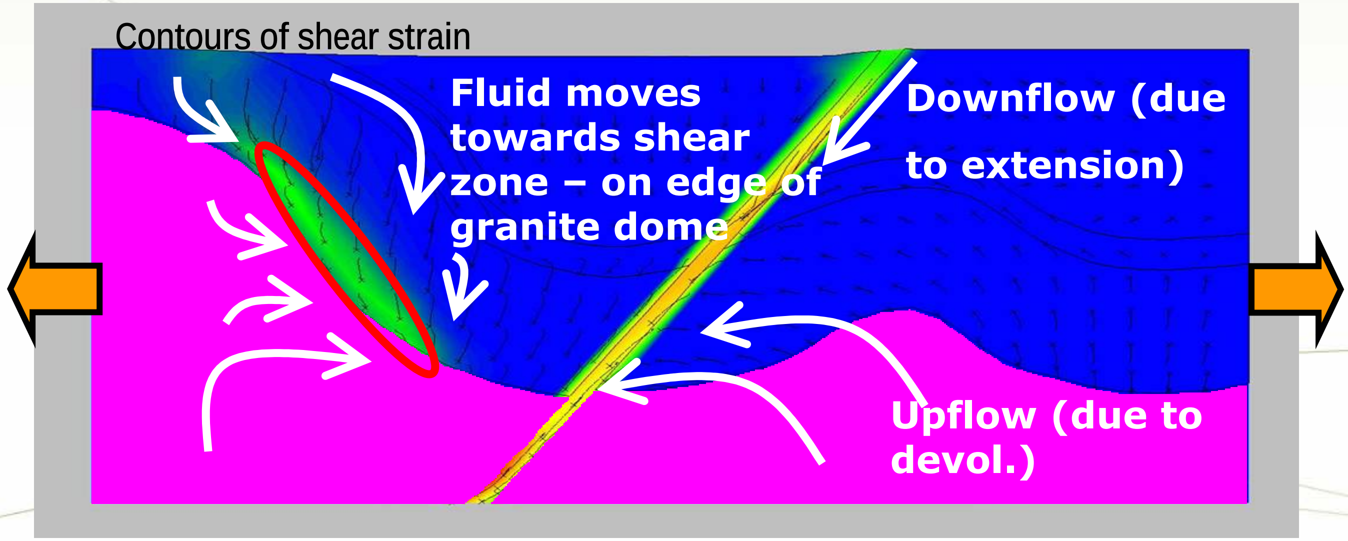
Kendrick et al 2008

Fluid pathways and drivers

Deformation

Competing drivers: Extension and metamorphic fluid production

Pathways: Faults/ shear zones

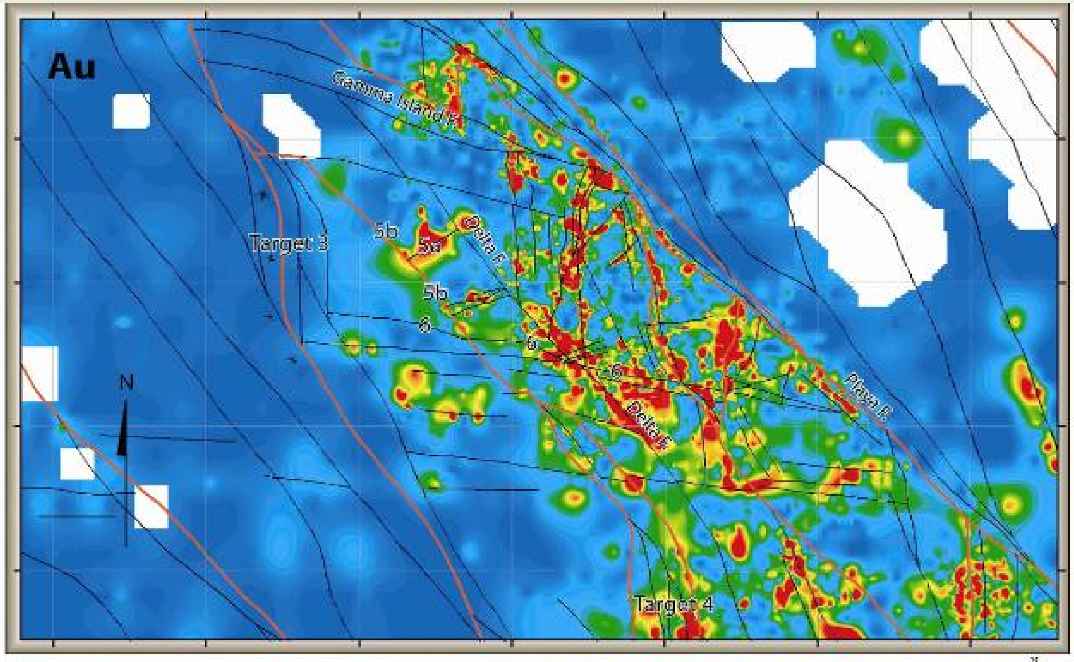


Devolatilisation during extension

H. Sheldon

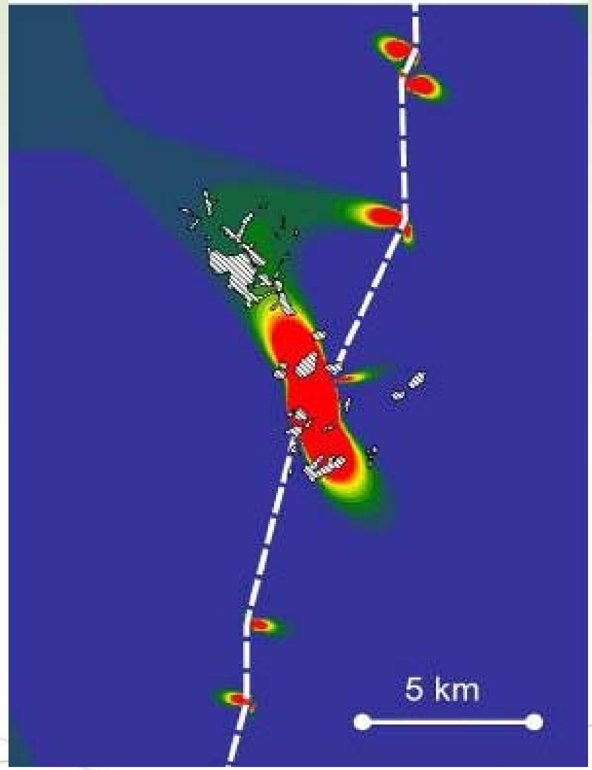
Fluid pathways - Faults

Miller 2007



Association between alteration and faults

Sheldon and Micklethwaite 2007



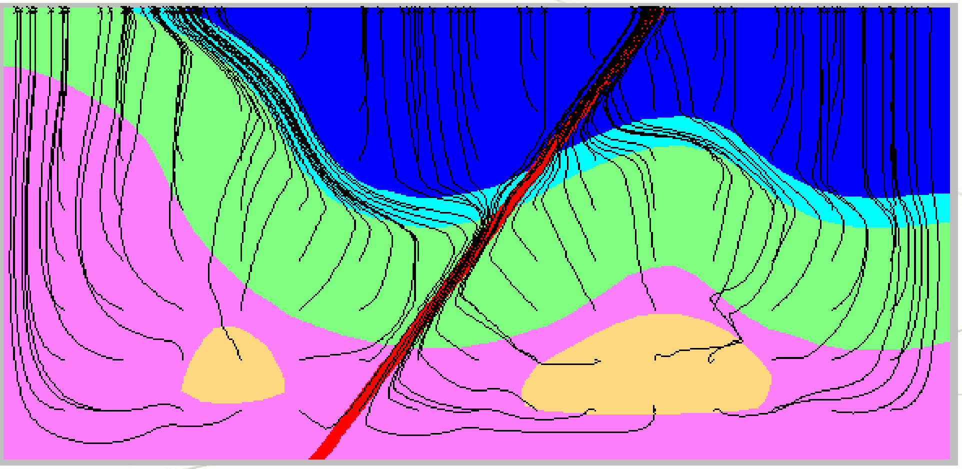
Permeability enhancement at jogs and bends (contractional <u>and</u> dilational)

Fluid pathways and drivers

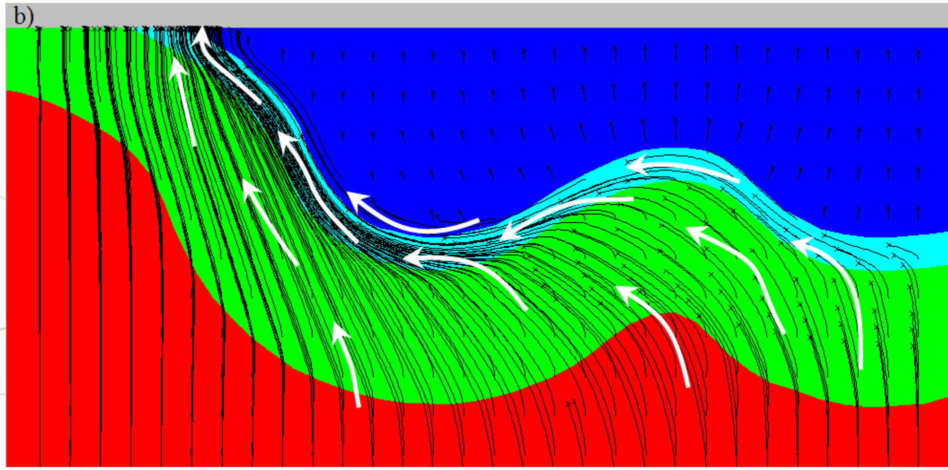
Plutonism and metamorphism

Driver: Magmatic/metamorphic fluid production

Pathways: Permeable fault, variations in permeability (domes, late basins)



Sheldon et al 2007



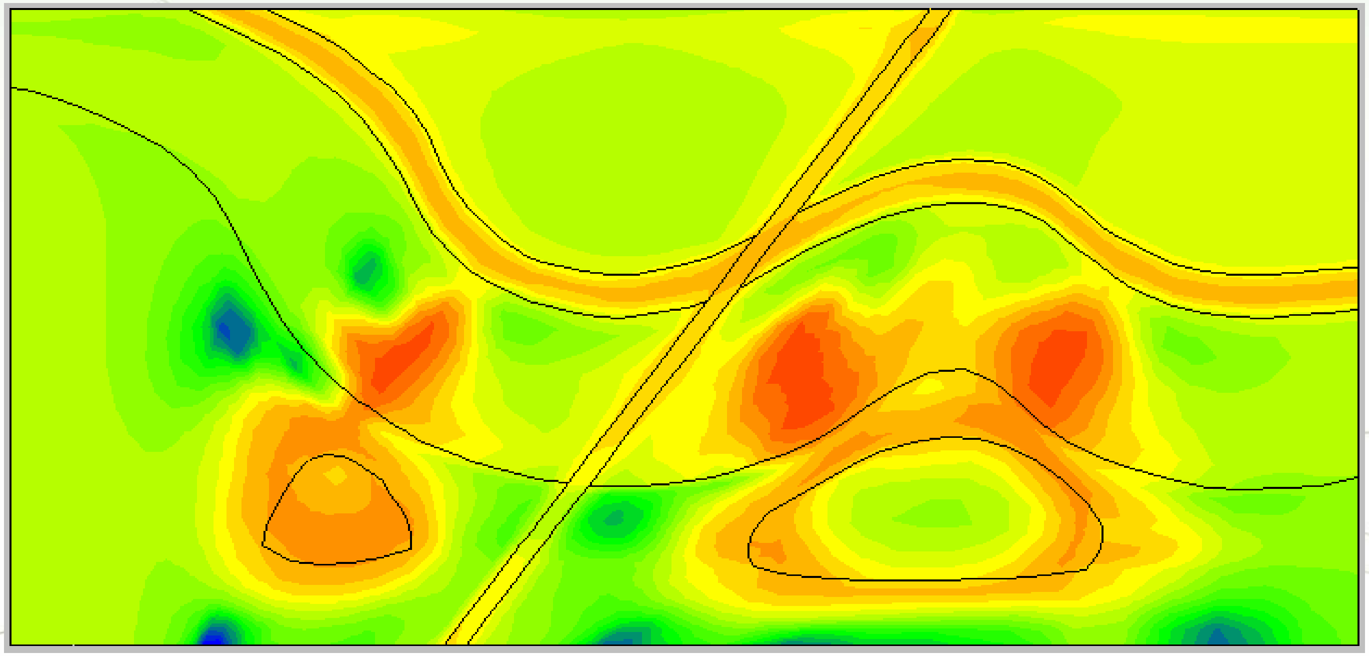
Sheldon 2007

Fluid pathways and drivers

Plutonism and metamorphism

Driver: Magmatic/metamorphic fluid production

Pathways: increase of permeability due to fluid production



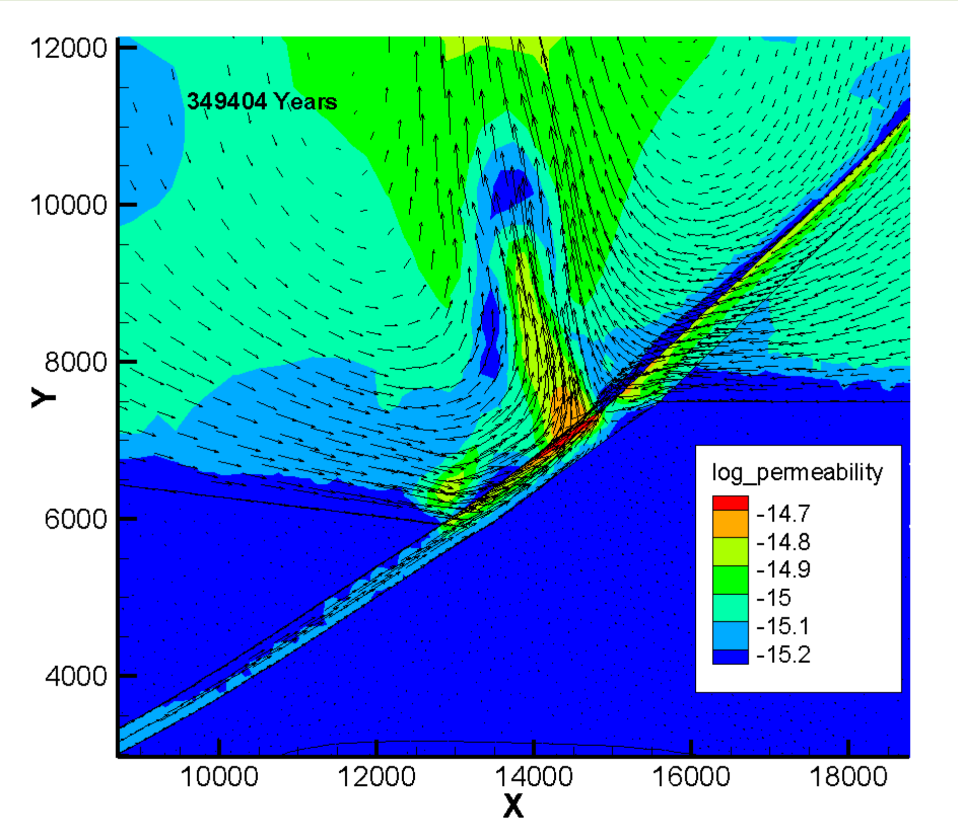
Sheldon et al 2007

Fluid pathways and drivers

Plutonism and metamorphism

Driver:
Magmatic/metamorphic fluid production

Pathways:
changes in permeability due to chemical reactions (Precipitation or dissolution)



Cleverley 2008

Deposition

Main controls on Au solubility:
- Temperature
- Redox
- pH
- Total Sulfur
- H2O activity

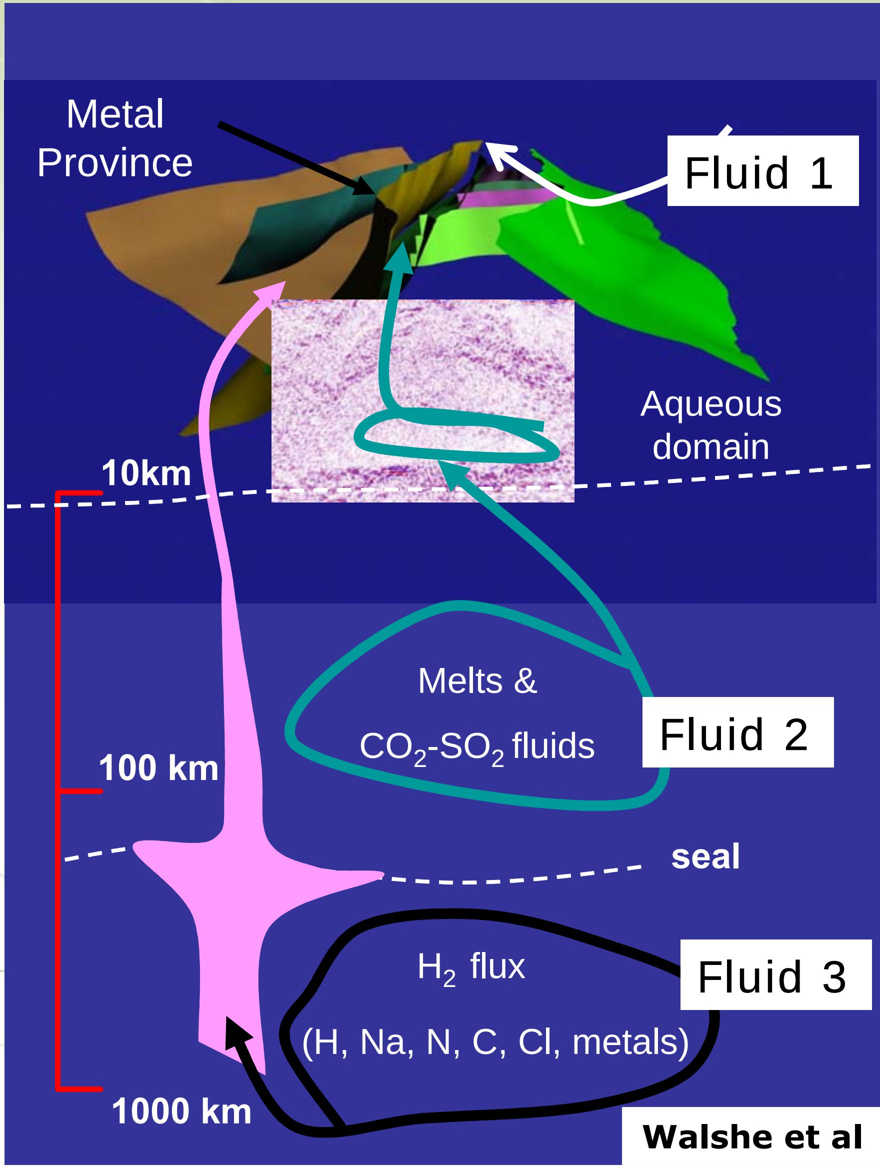
Mechanisms potentially controlling Au solubility
- Fluid-rock/ fluid-fluid interaction (pH, redox, total S)
- Phase separation (redox, total S, H2O)
- Vapour condensation (redox, total S, H2O)
- Fluid mixing (T, redox, total S, pH, H2O)

Deposition

Au deposition in anhydrous domain involving fluids 2+3 (changes in redox, sulphur activity…)

Au deposition involves little water (lack of alteration)

Fluid mixing most efficient

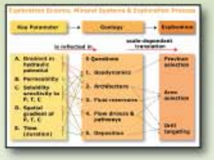


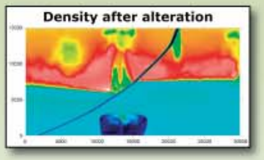
Walshe et al

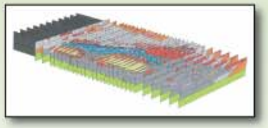

A
B
C
S084

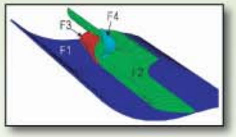
predictive mineral discovery*Cooperative Research Centre

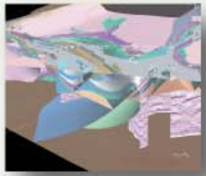
A legacy for mineral exploration science

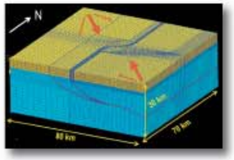


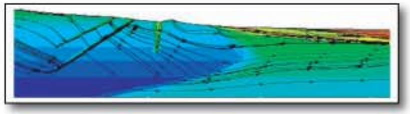


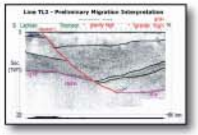












pmd*CRC working with industry

pmd*CRC research areas

pmd*CRC research nodes

pmd*CRC working with State/Territory Surveys

www.pmdcrc.com.au

pmd*CRC

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