Mineral Systems

Q4 Fluid flow drivers & pathways

A legacy for mineral exploration science

Key Parameter → is reflected in → Mineral System → scale-dependent translation → Exploration

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

Fluid drivers

What drives fluid flow?

Flow is driven by gradients in hydraulic head (related to fluid pressure)

Darcy's Law

$$q = -\frac{k}{\mu}\left(\nabla P - \rho_f g\right)$$

- q: **Fluid flux**
- k: **Permeability**
- μ: **Viscosity**
- ρ_f: **Fluid density**
- ∇P: **Fluid pressure gradient**

Fluid pathways

Fluid pathways are governed by variations in:

- **permeability which reflect the distribution of rock types**
- **the deformation/stress regime**
- **chemical reactions**

Permeability

Permeability Creation

Deformation
- Extensional and compressional

Chemical reaction

Permeability Destruction

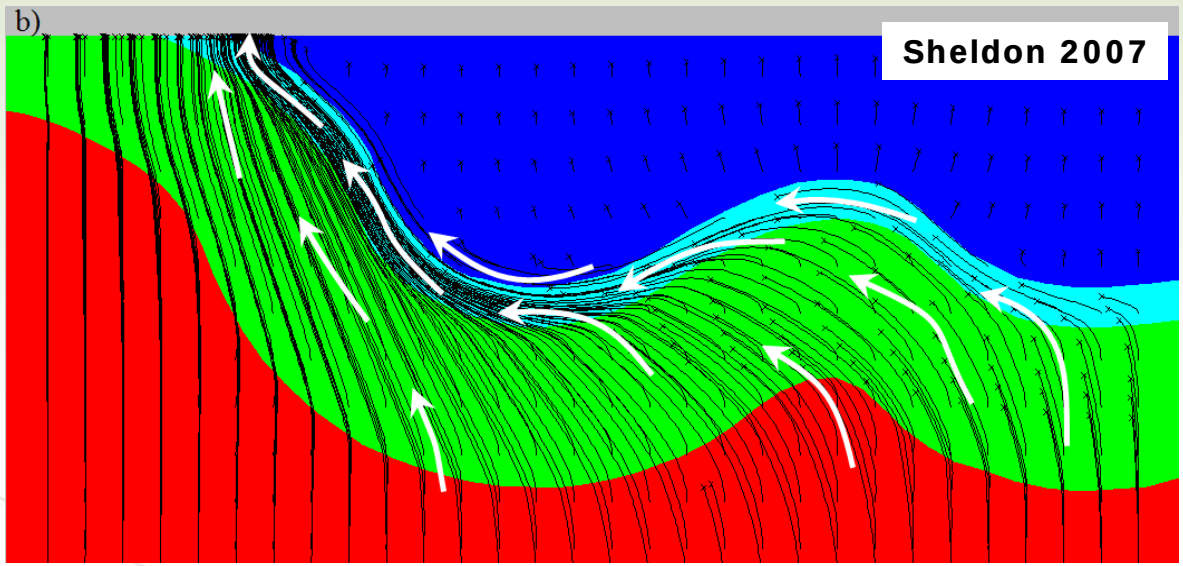
Compaction

Mineral precipitation

Permeability

Domes:

Fluid is focused into shear zones on flanks of granite domes



Late basins:

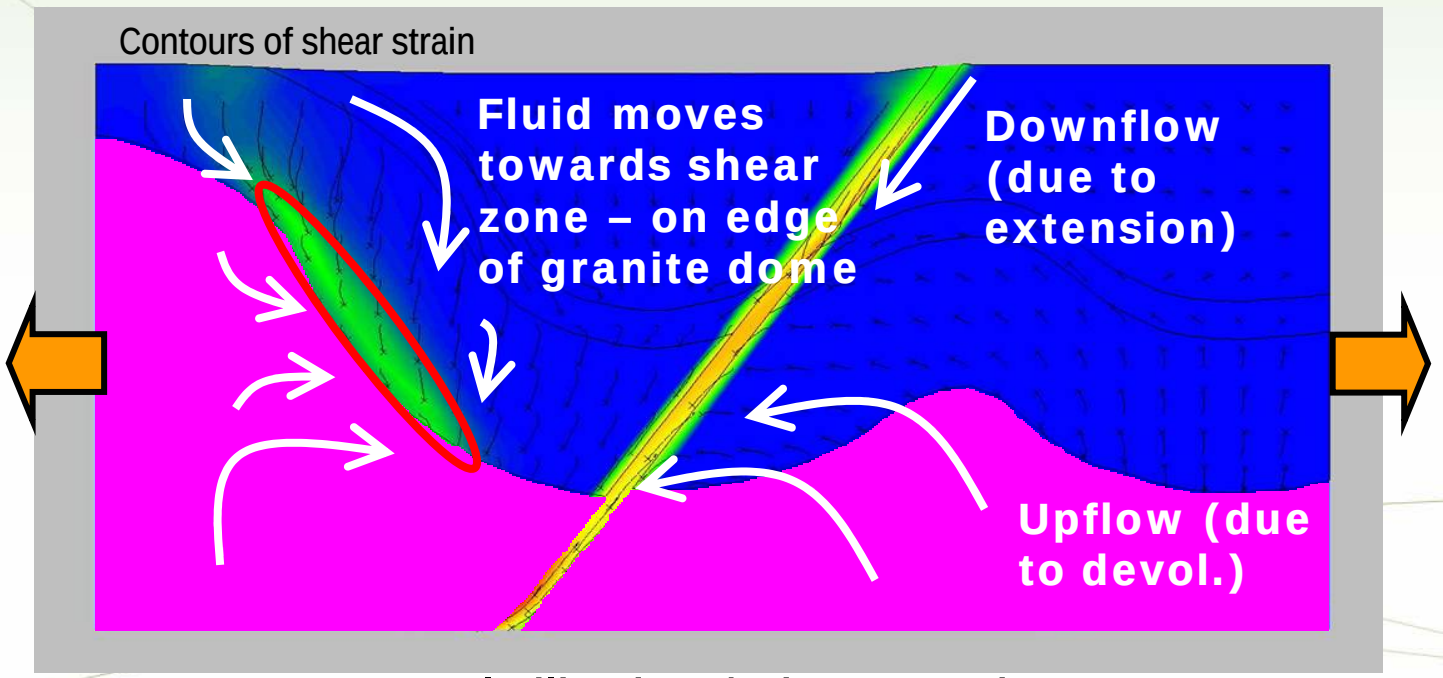
Act as local seals

Fluid is channelled around edges of basins.

Basins indicate location of long-lived faults that have acted as fluid pathways

Deformation

Extension drives downward flow. Magmatic/ metamorphic fluids retained in crust; mixing with shallow-sourced fluids



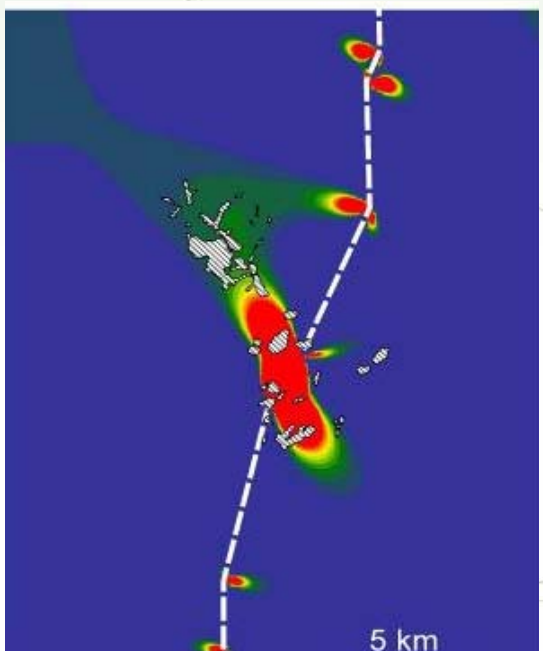
Devolatilisation during extension

H. Sheldon

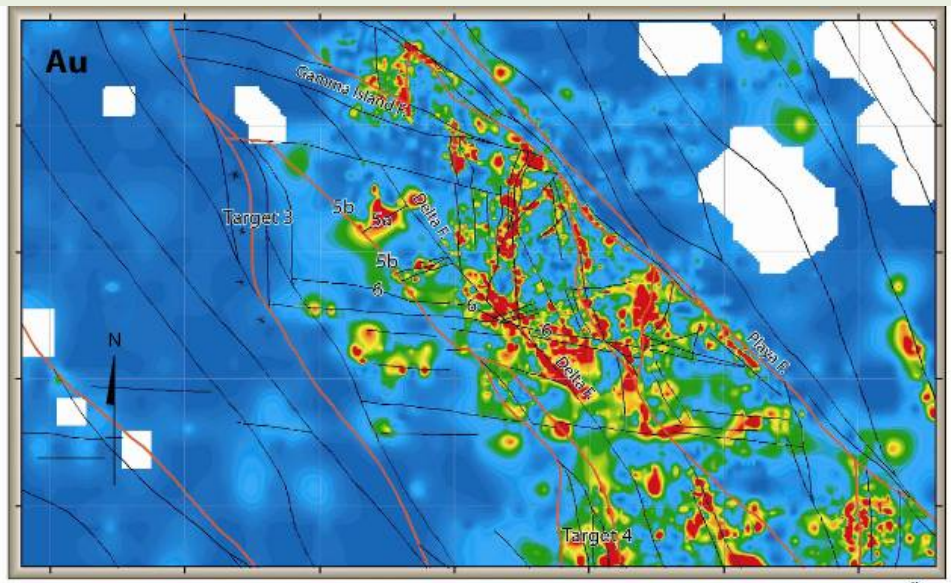
Deformation

Faults act as fluid pathways

Association between alteration and faults



Sheldon and Micklethwaite 2007



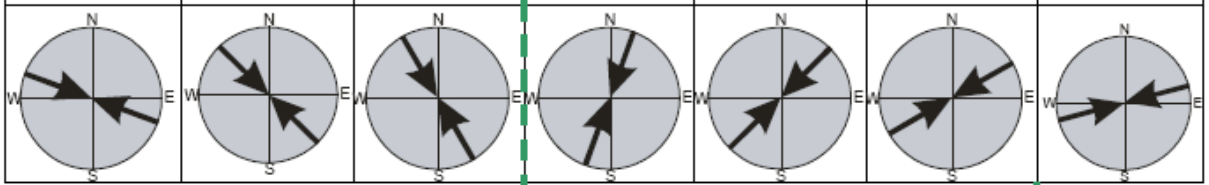
Miller 2007

Permeability enhancement at jogs and bends (contractional and dilational)

Deformation

"Stress switching"

activates different fluid pathways, thus allowing tapping of different fluid reservoirs

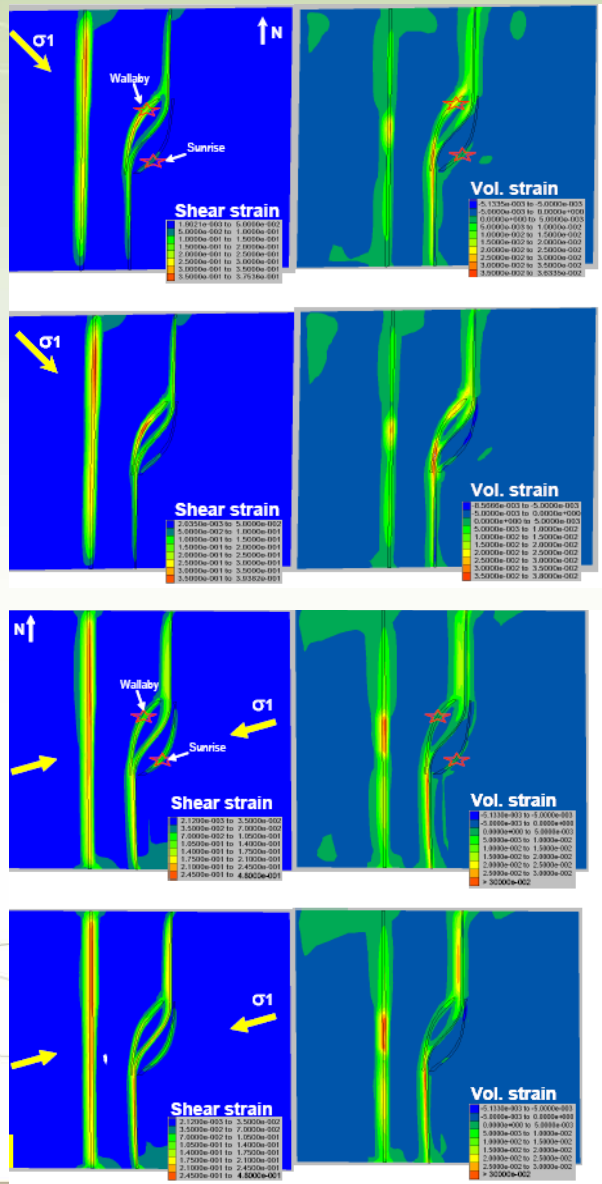
NW-SE orientations			NE-SW orientations			
1	2	3	4	5	6	7
WNW-ESE	NW-SE	NNW-SSE	NNE-SSW	NE-SW	ENE-WSW	ENE-WSW
290°-110°	315°-135°	300°-150°	20°-200°	45°-225°	60°-240°	75°-255°
						

Structurally more favourable for Wallaby and, to a less extent for Sunrise

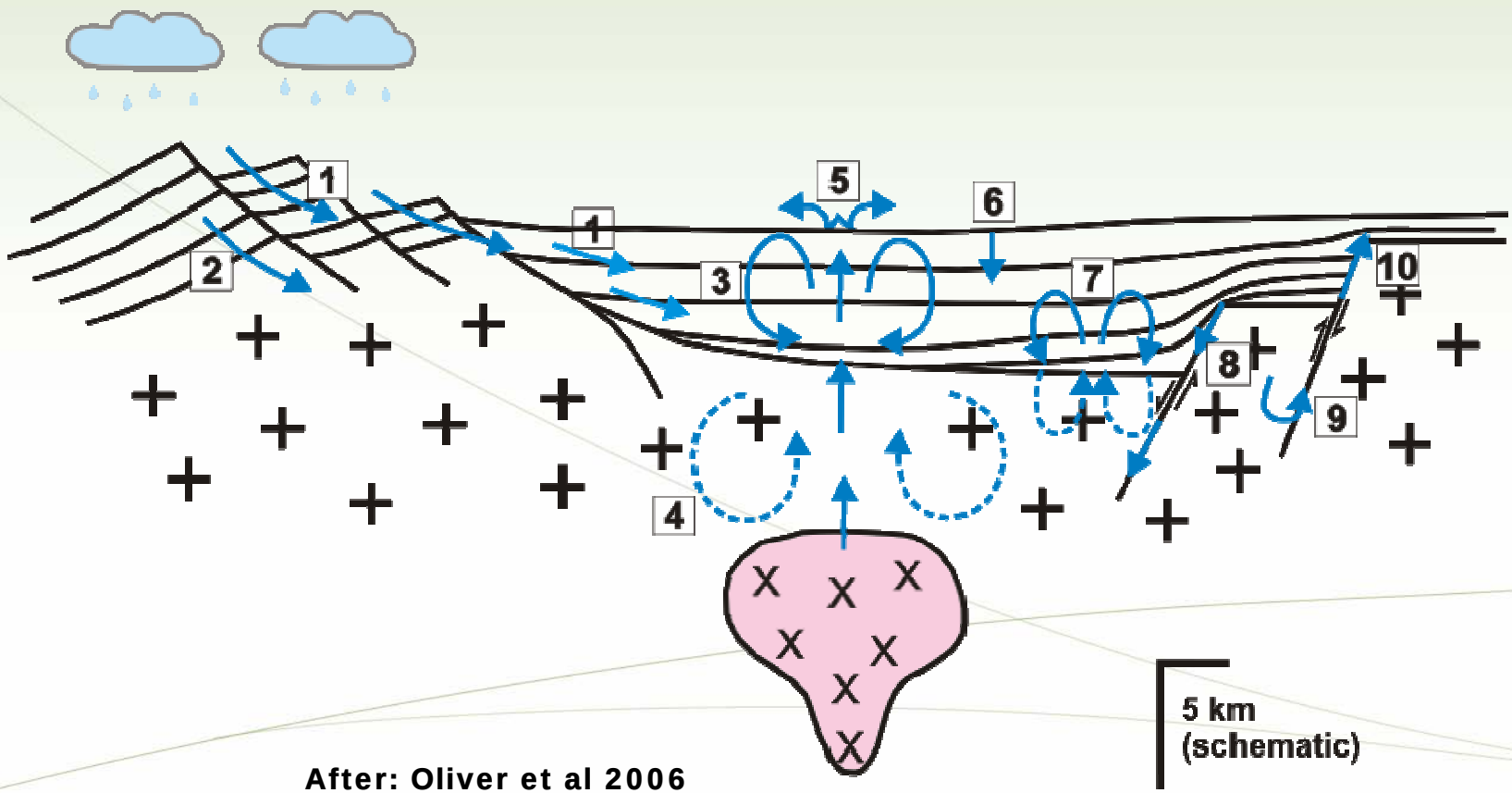
Unfavourable orientations for Wallaby and Sunrise structures

Enhanced at Sunrise
Weakened at Wallaby

Henson et al 2007



Fluid flow (basin related)



After: Oliver et al 2006

Deformation

Fluid migration during basin development

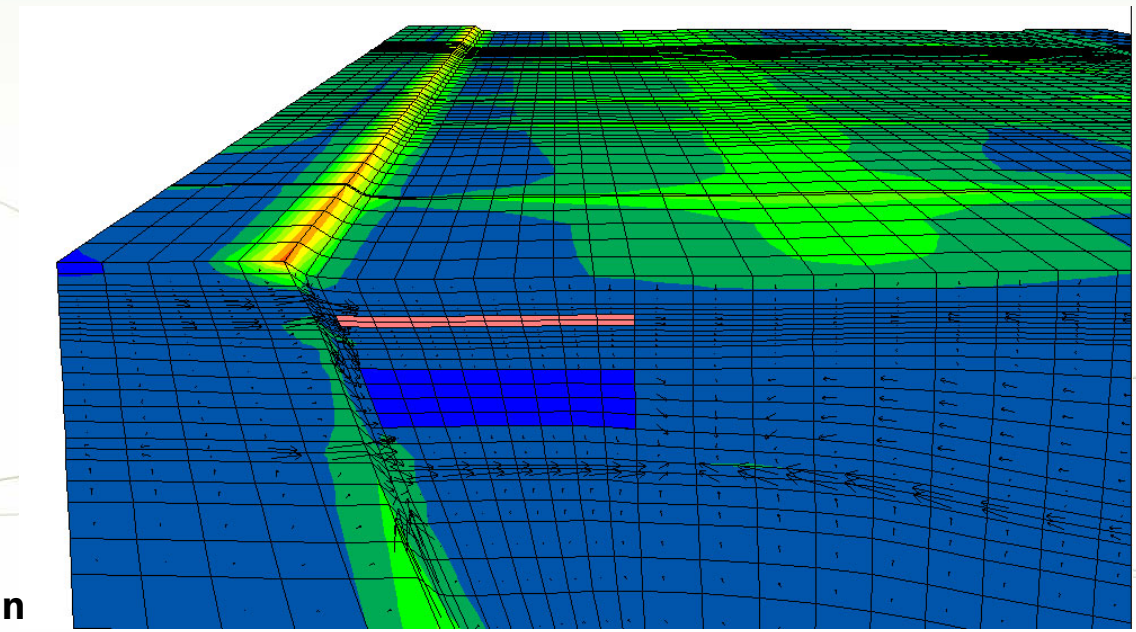
Downward migration of surficially derived fluids and brine reflux due to extension

- **Extension or topography**

Shallow fault as pathways

Permeable sediments

- **Lateral transport within Basin**
- **Fluid storage**



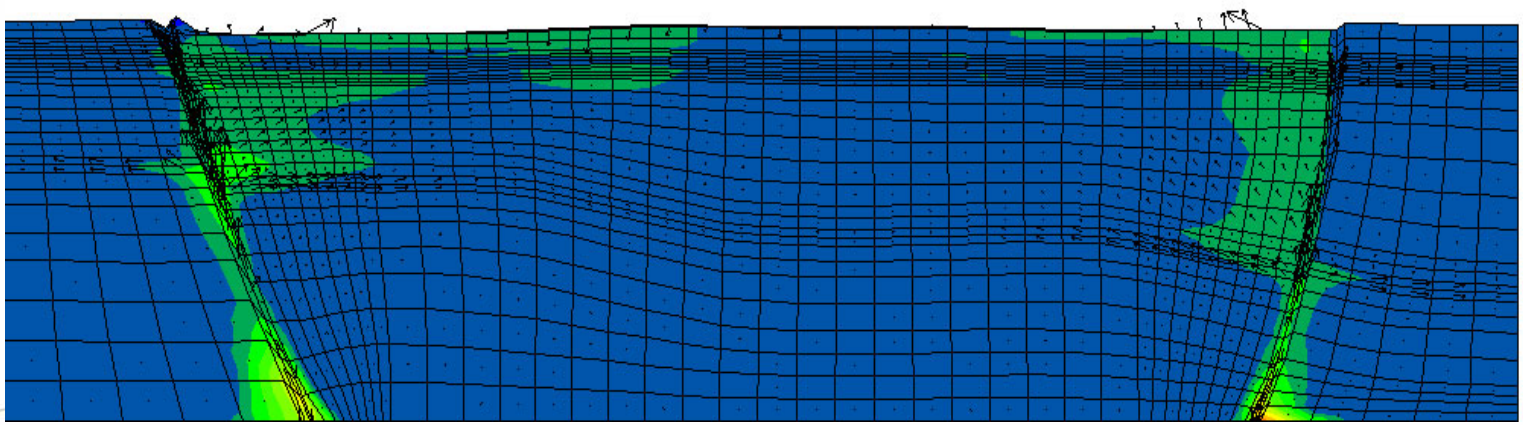
J. McLellan

Deformation

Fluid migration during Isan Orogeny

Particularly during compressive tectonic events, such as basin inversion, basin bounding faults are important fluid conduits

Fluid flow is generally focussed into the hanging wall sediments during compression (within LRFT)

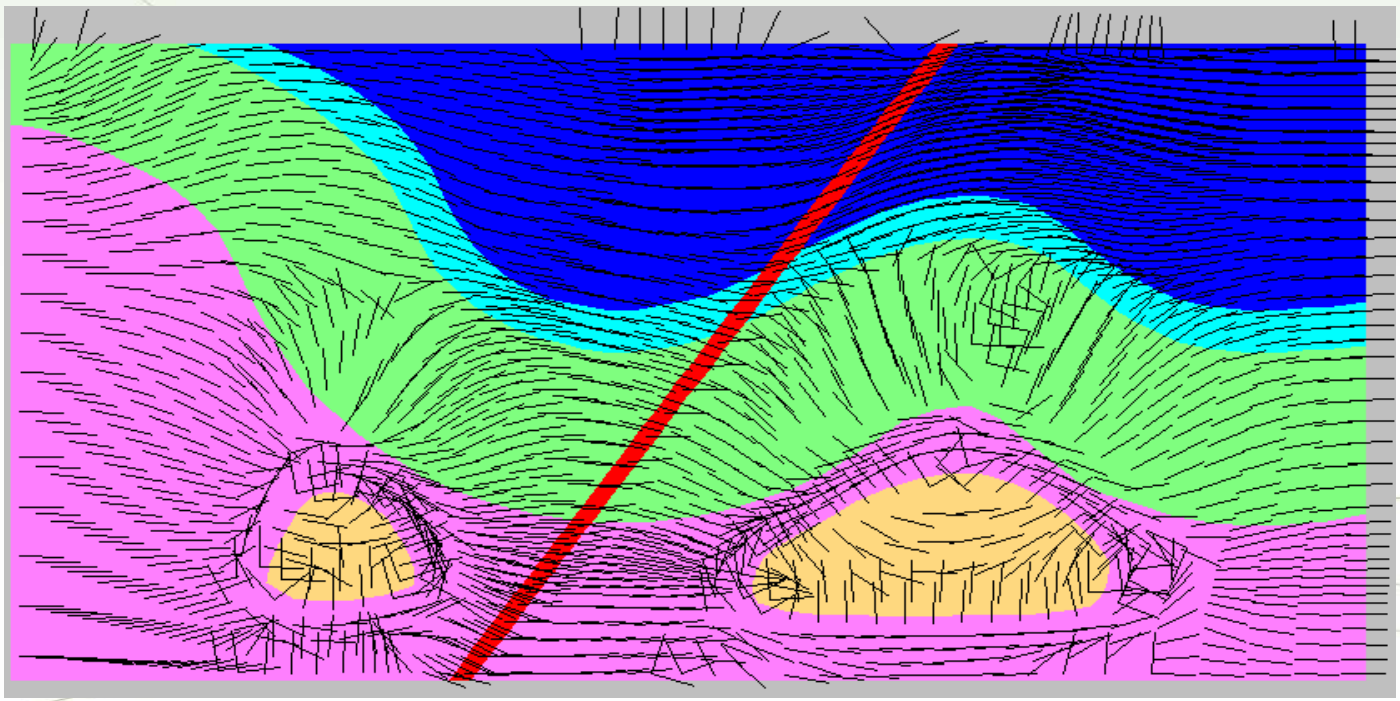


J. McLellan

Plutonism

Intrusions

cause local change in stress regime

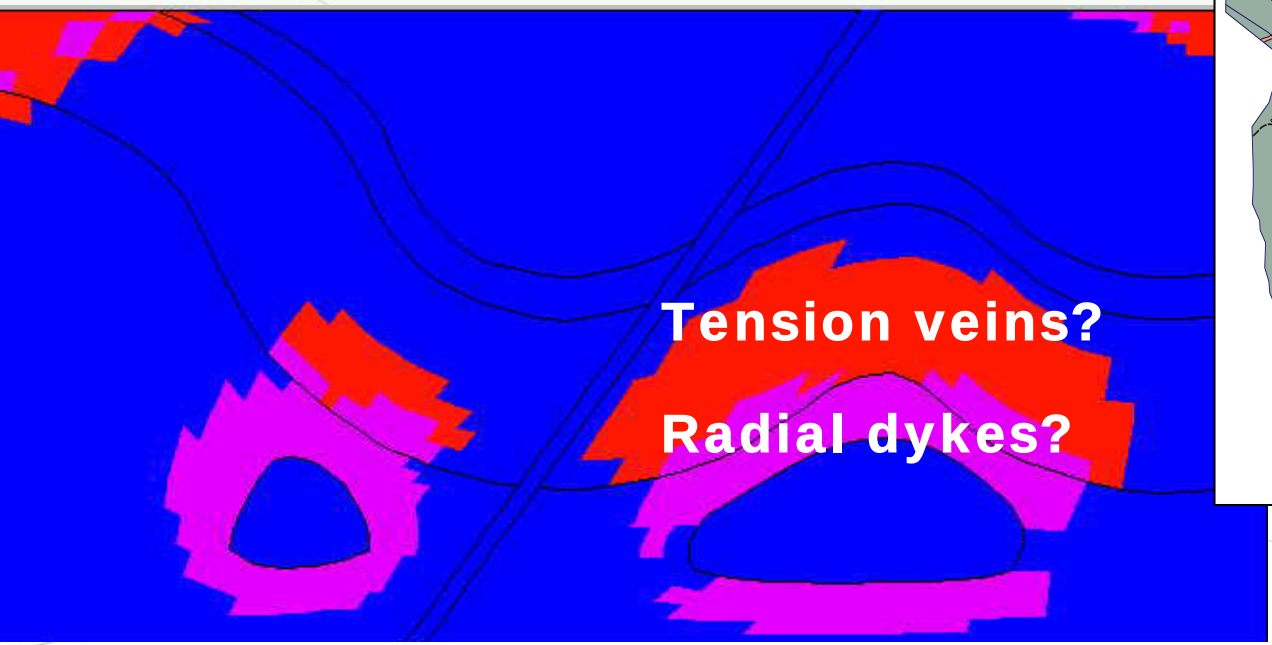


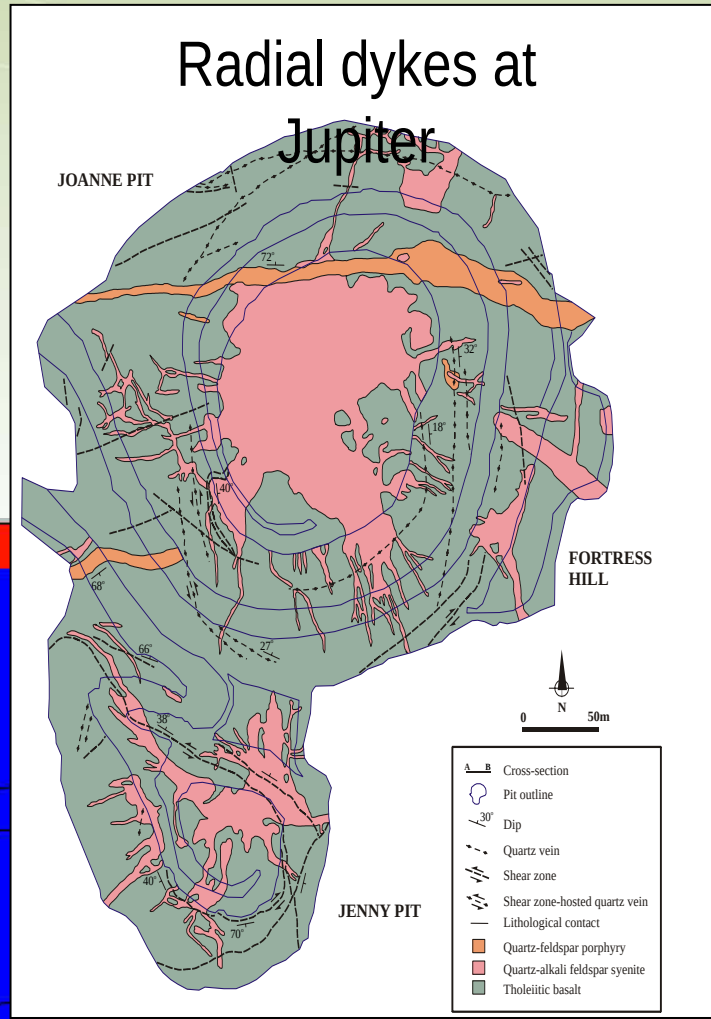
Sheldon et al 2007

Plutonism

Intrusions

fluid pathways radiate away from intrusions



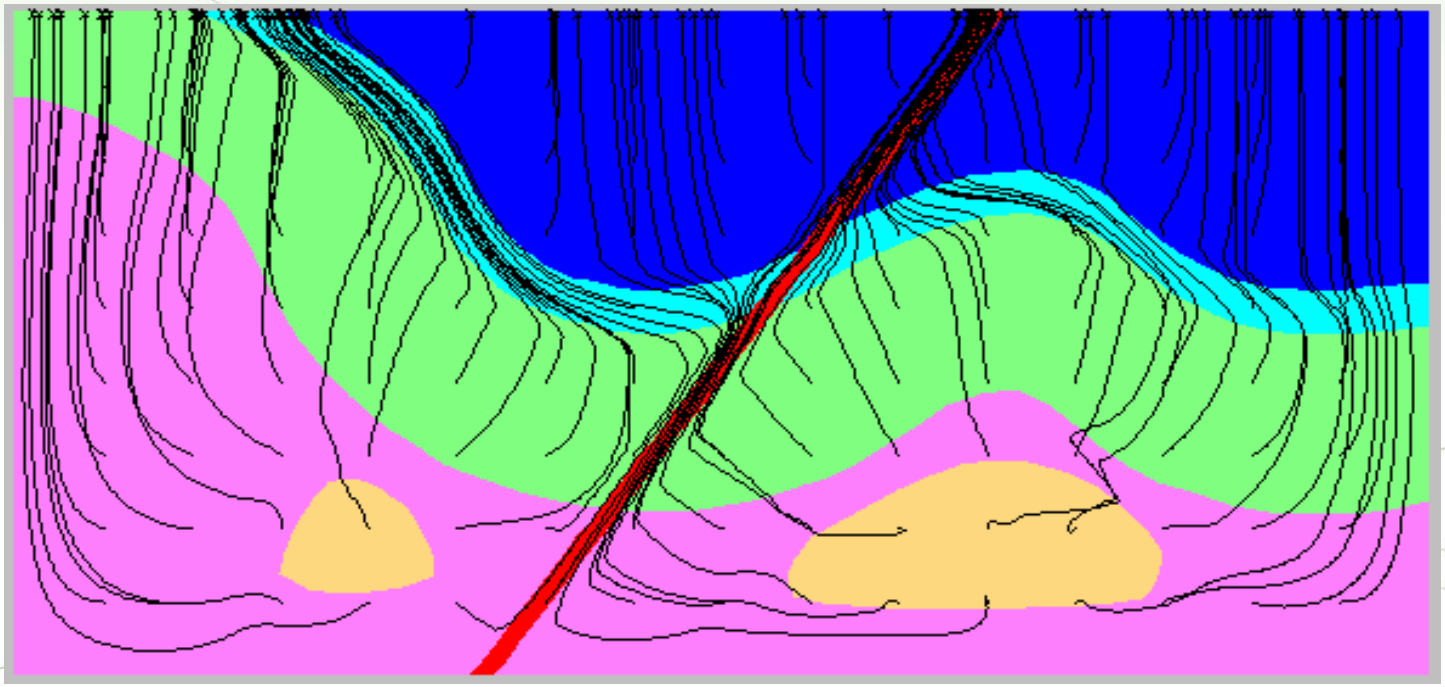


Plutonism and metamorphism

Magmatic/ metamorphic fluid production

overrides convection;

fluid is driven away from intrusions in early stages of cooling

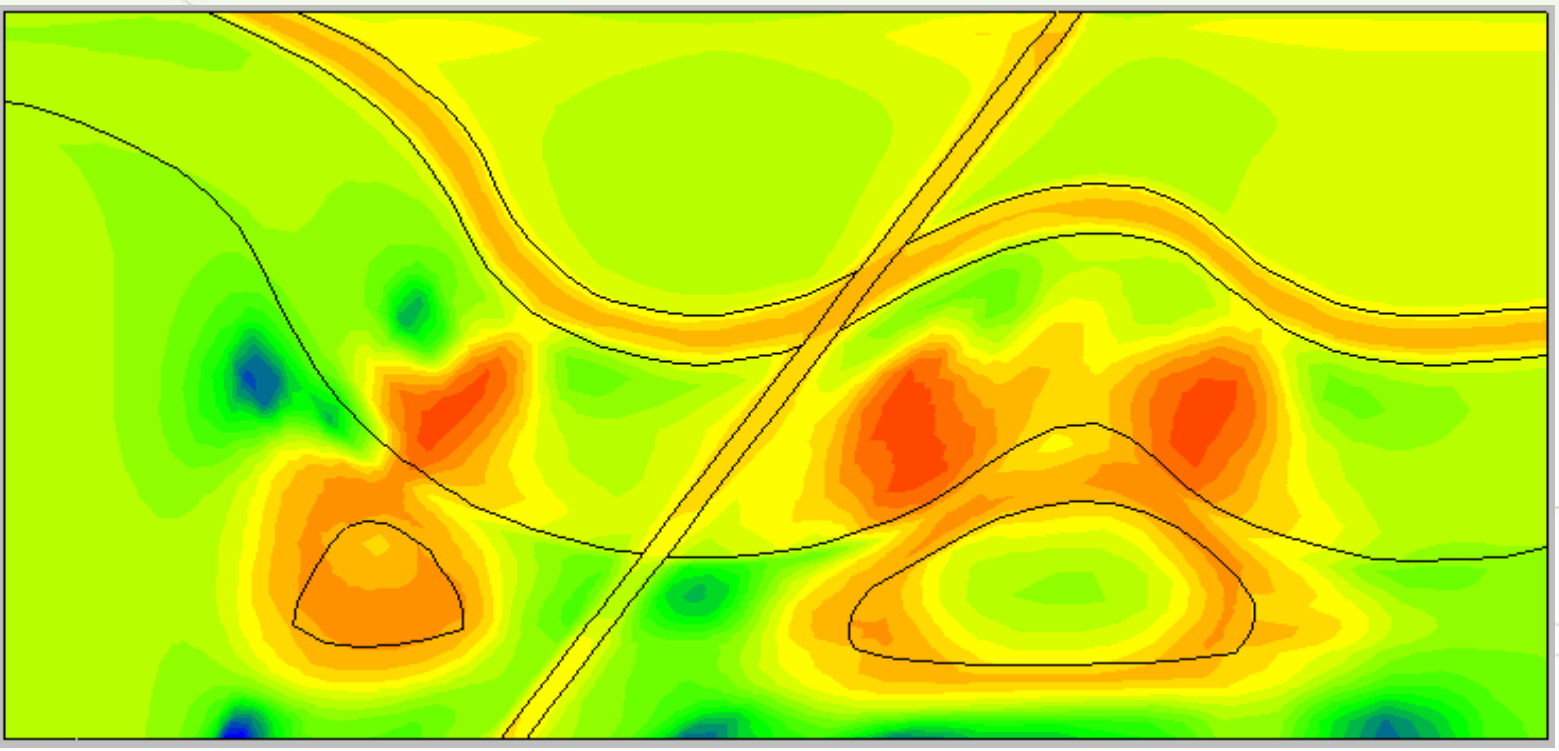


Sheldon et al 2007

Chemical reactions

Magmatic or metamorphic fluid production:

permeability increases



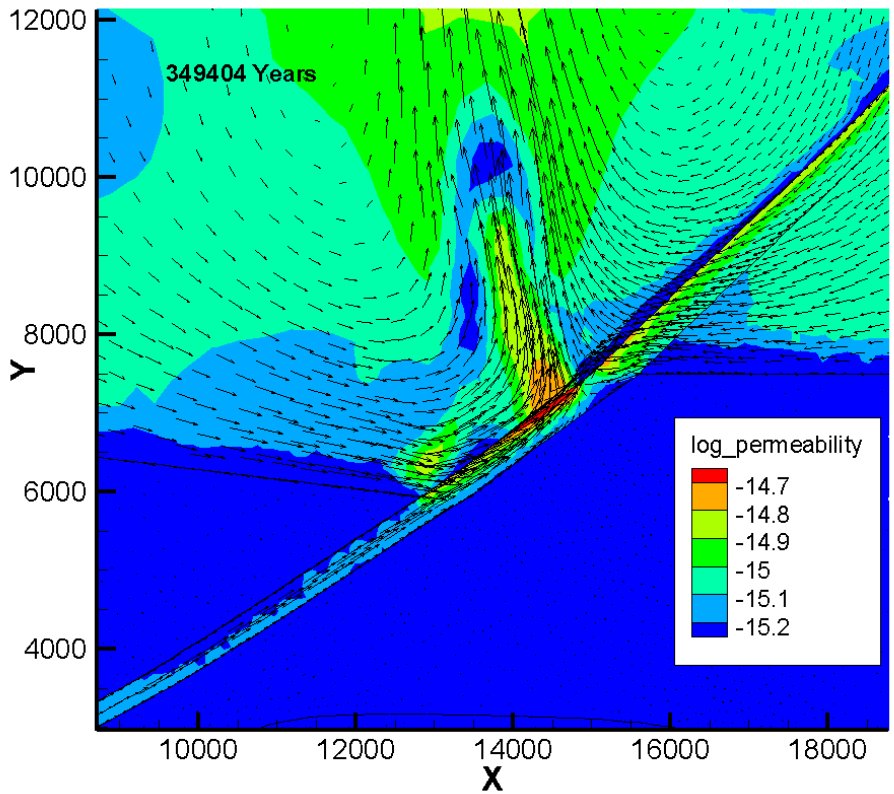
Sheldon et al 2007

Fluid pathways and drivers

Plutonism and metamorphism

Driver:
Magmatic/metamorphic fluid production

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



Cleverley et al 2006

How is this predictive?

Faults cutting through late basins are important fluid pathways

Extension and/or retrogression → downflow → fluid mixing

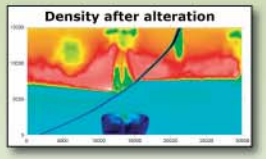
Shear zones around domes are sites of fluid mixing

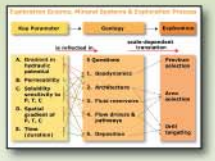
Late granites have important effects:

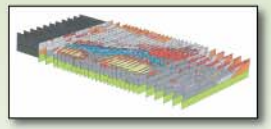
- Fluid + heat source
- Devolatilisation
- Radial tensile failure
- Downflow

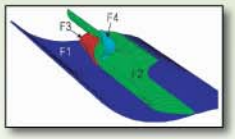
*predictive mineral discovery*Cooperative Research Centre*

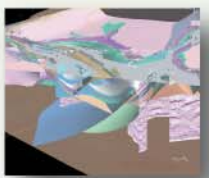
A legacy for mineral exploration science

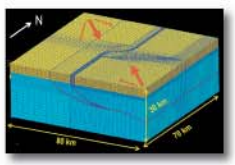


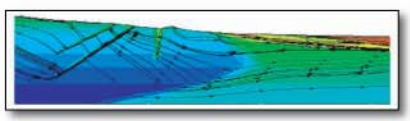


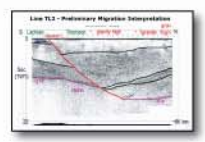












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References

Oliver, N. H. S., McLellan, J. G., Hobbs, B. E., Cleverley, J.S., Ord, A. & Feltrin, L. (2006). "100th Anniversary Special Paper: Numerical Models of Extensional Deformation, Heat Transfer, and Fluid Flow across Basement-Cover Interfaces during Basin-Related Mineralization." Economic Geology 101(1): 1-31.

Sheldon, H. A., and Micklethwaite, S. (2007). "Damage and permeability around faults: Implications for mineralization." Geology(35): 903-906
Miller, J. (2007). Structural targets in the Dome to Victory corridor. pmd*CRC Project Report: Project Y4, Additional final reports for Y4 subprojects: 21p.

Sheldon, H. A., Zhang, Y., and Ord, A. (2007). Archaean gold mineralisation in the Eastern Yilgarn: Insights from numerical models. pmd*CRC Y4 Project Contribution to section III of the final report: 17p.

Sheldon, H. A. (2007). Integrated numerical models of fluid flow for generic and site specific scenarios in the Yilgarn Craton. pmd*CRC Y4 Project Deliverable 11: 55p.

References

Henson, P. A., Miller, J. McL.,Zhang, Y., Blewett, R.S. (2007). The 4D architecture of the Laverton camp, Eastern Yilgarn Craton. pmd*CRC Project Report: Project Y4, pmd*CRC.