Enabling Technologies

Advanced Geochemical Techniques

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

Why geochemistry?

Predict the processes that led to formation of certain mineral deposits.

Predict possible alteration assemblages and mineral paragenesis.

Understand which are the most important or effective processes in mineral deposit formation.

Start to build computer models of mineral deposit formation, and

Combine fluid-flow, deformation and geochemistry codes to produce a predictive tool for mineral deposit exploration.

Slide after:
Cleverley & Oliver

Hyperspectral methods

PIMA (Portable Infrared Mineral Analyser)

field-based alteration mapping

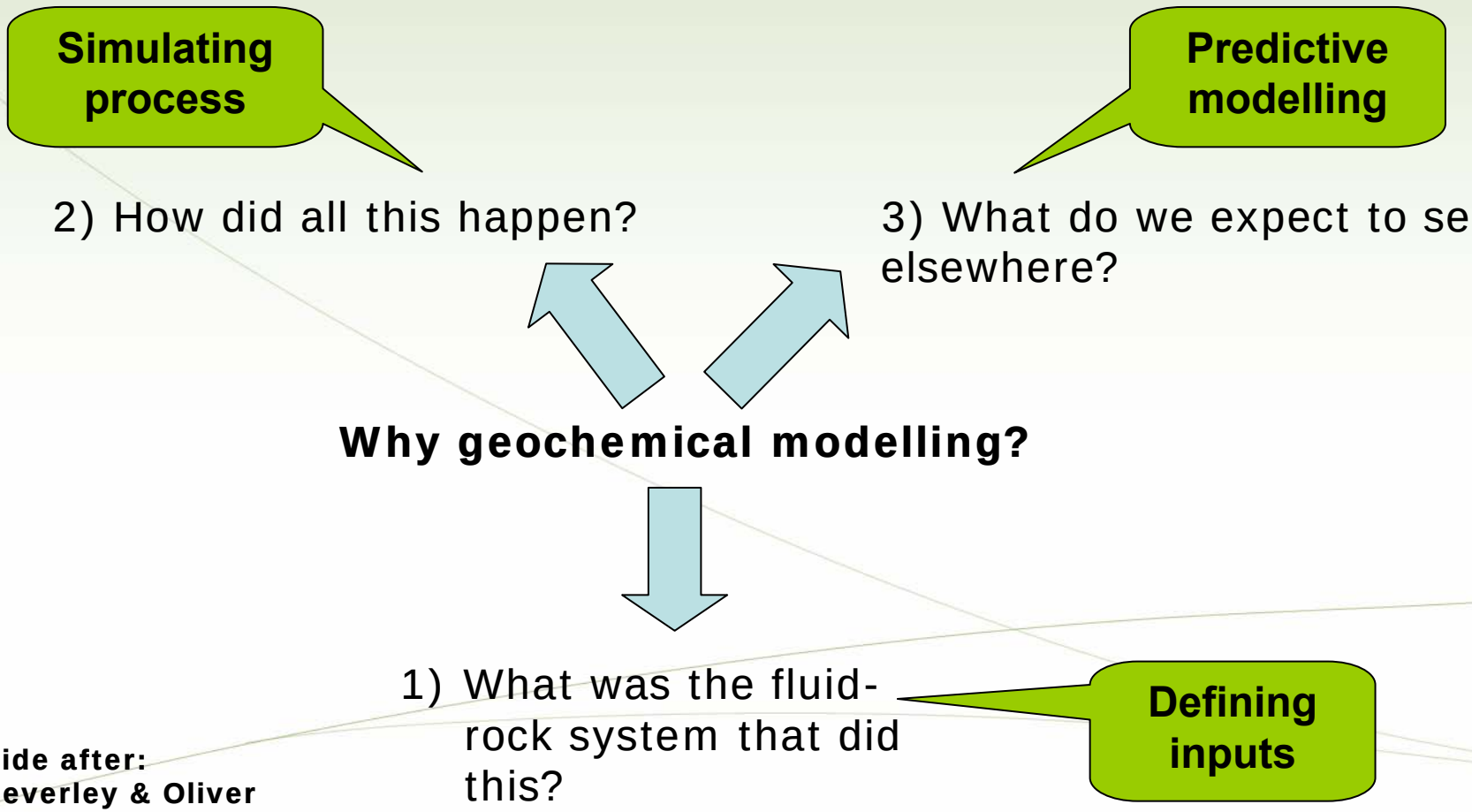
HyMap

airbourne alteration mapping
regolith, lithological and alteration related imagery
mineral(s) absorption features
e.g. iron oxides, AlOH, chlorite/epidote, chlorite chemistry, green vegetation and dry vegetation

HyLogger

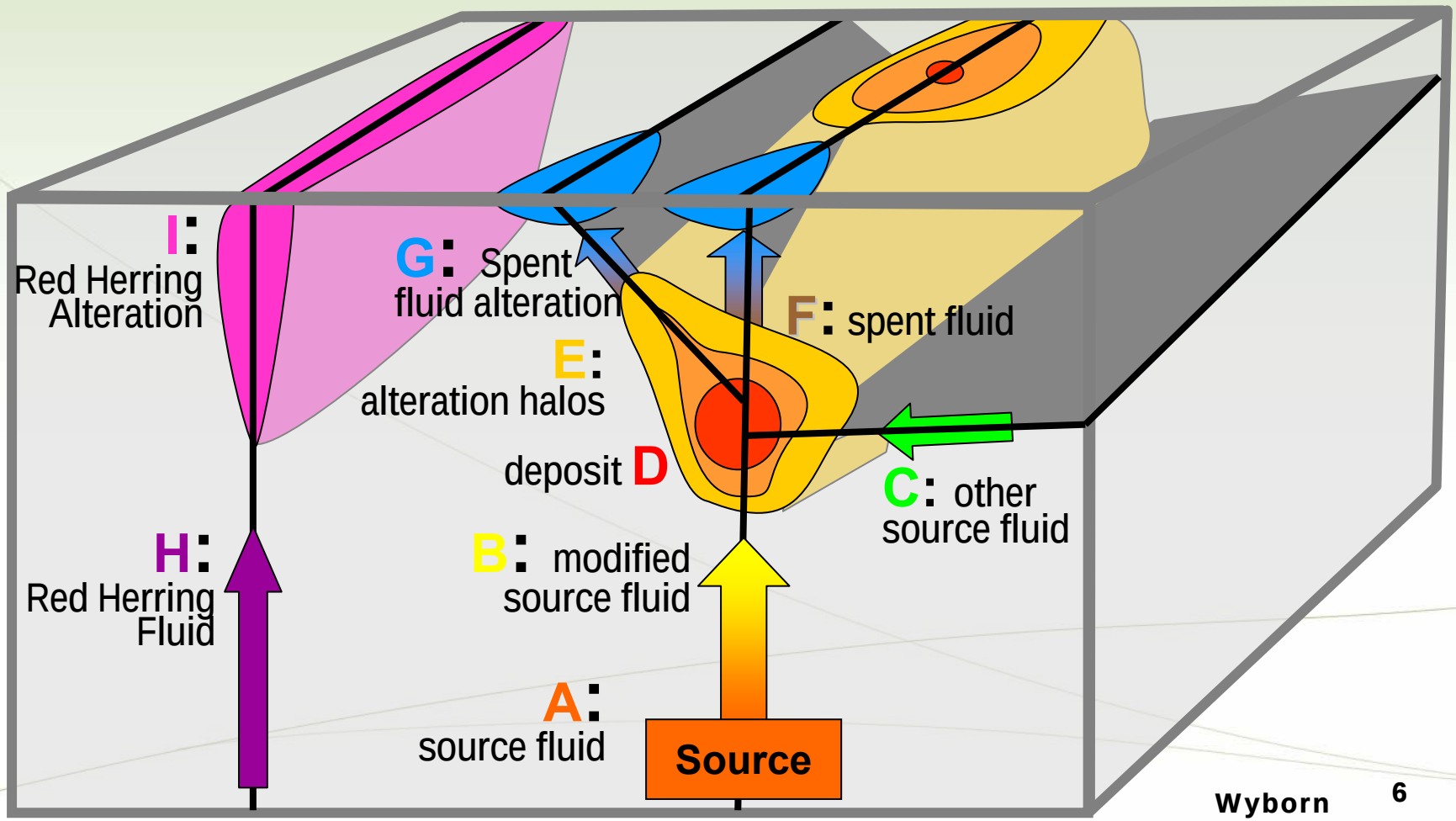
drillhole-based alteration mapping
to map the downhole distribution of alteration minerals

Why geochemical modelling?



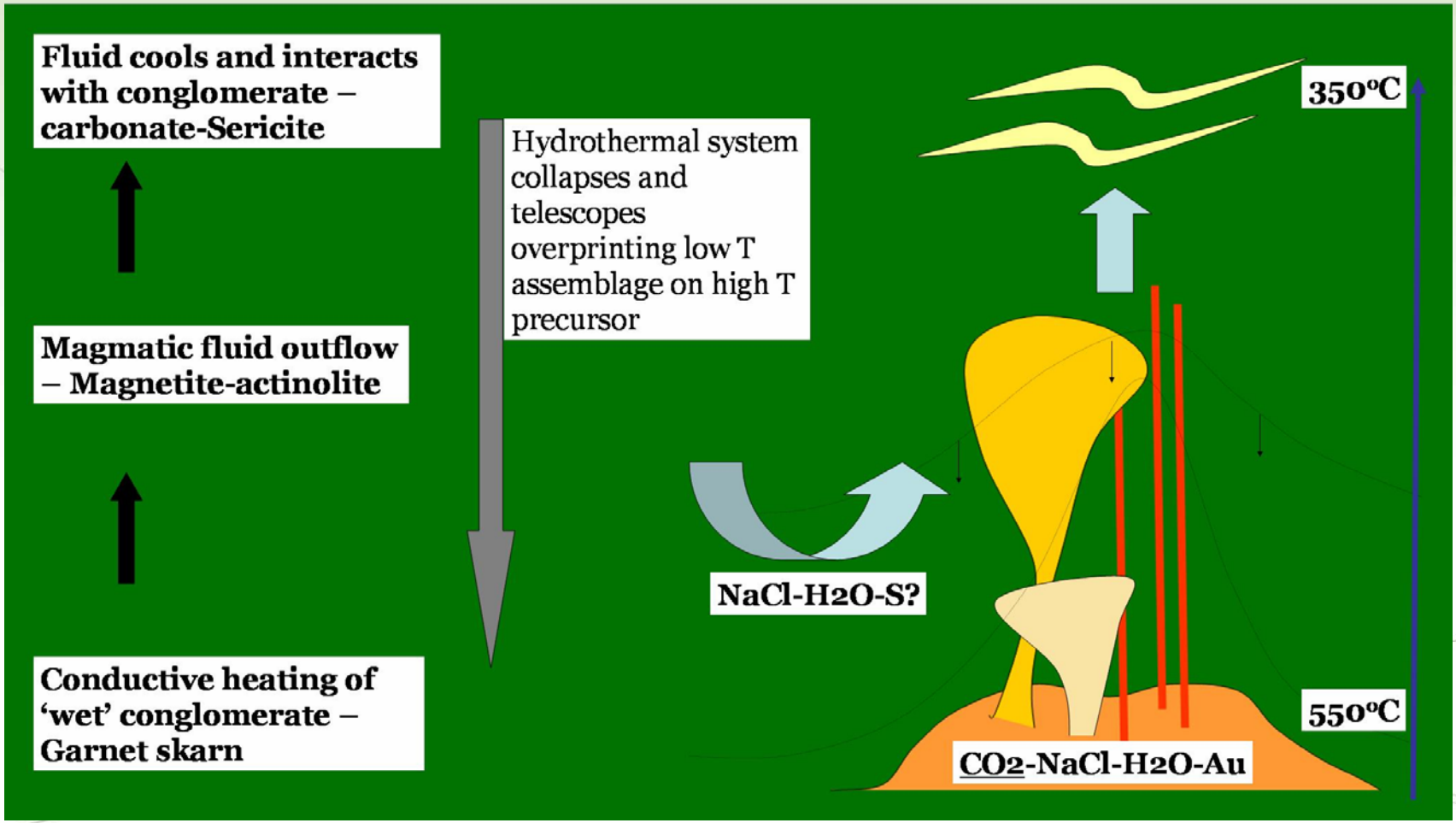
Slide after:
Cleverley & Oliver

Fluids and their signatures



Example Wallaby

Cleverley et al 2005



Example Wallaby

Wallaby Alteration System

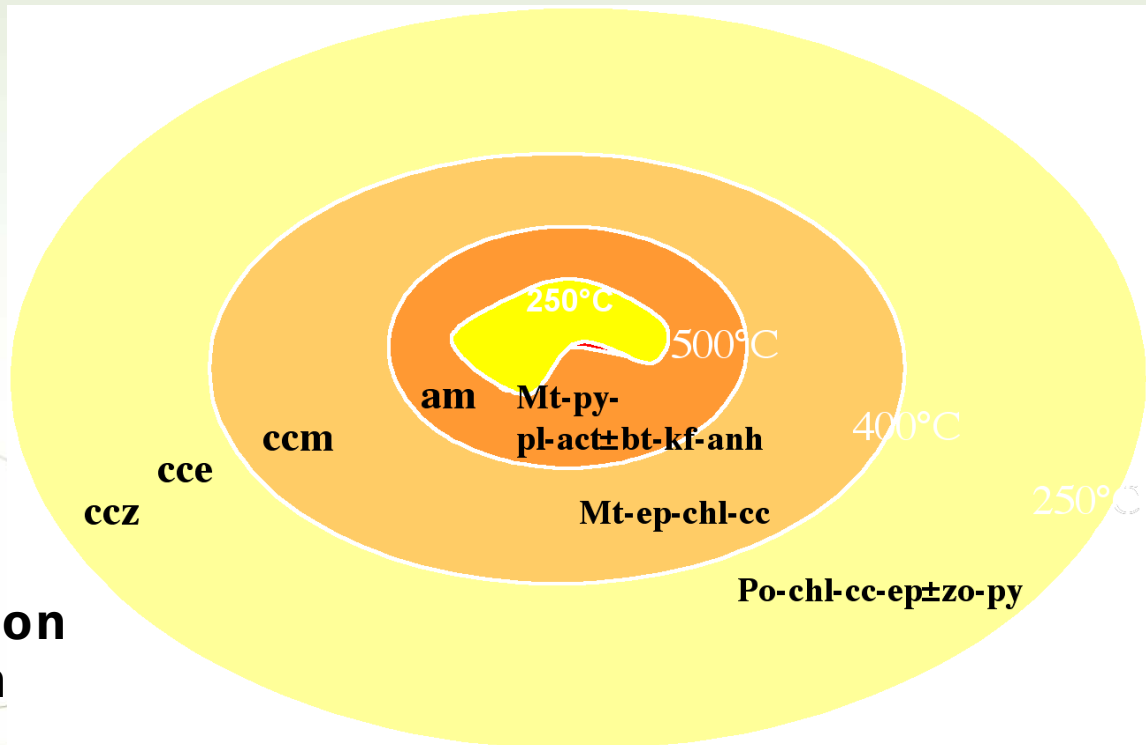
Intrusion-related aureole style alteration zonation

Syenitic rocks in core

Proximal magnetite alteration

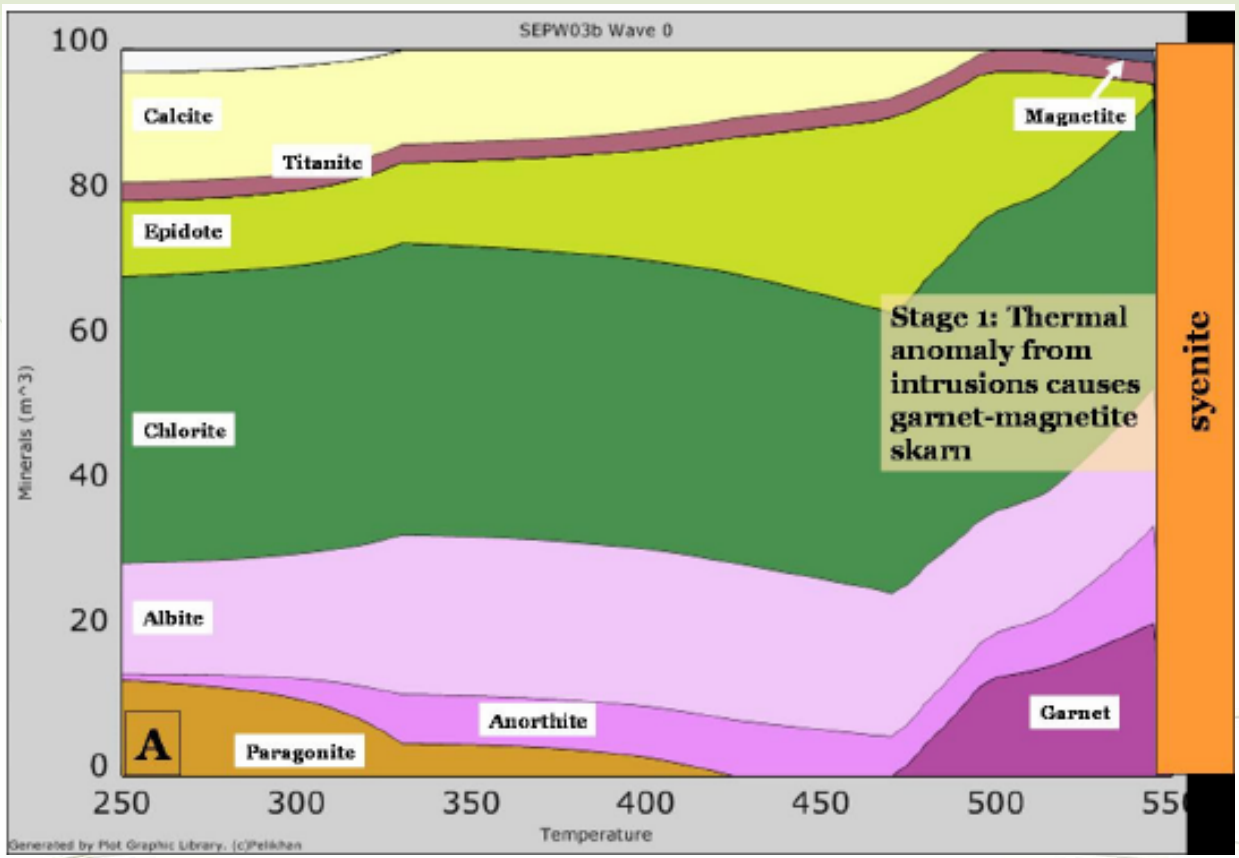
Grades outwards to

pyrrhotite-bearing alteration
Chlorite-bearing alteration
Mafic conglomerates



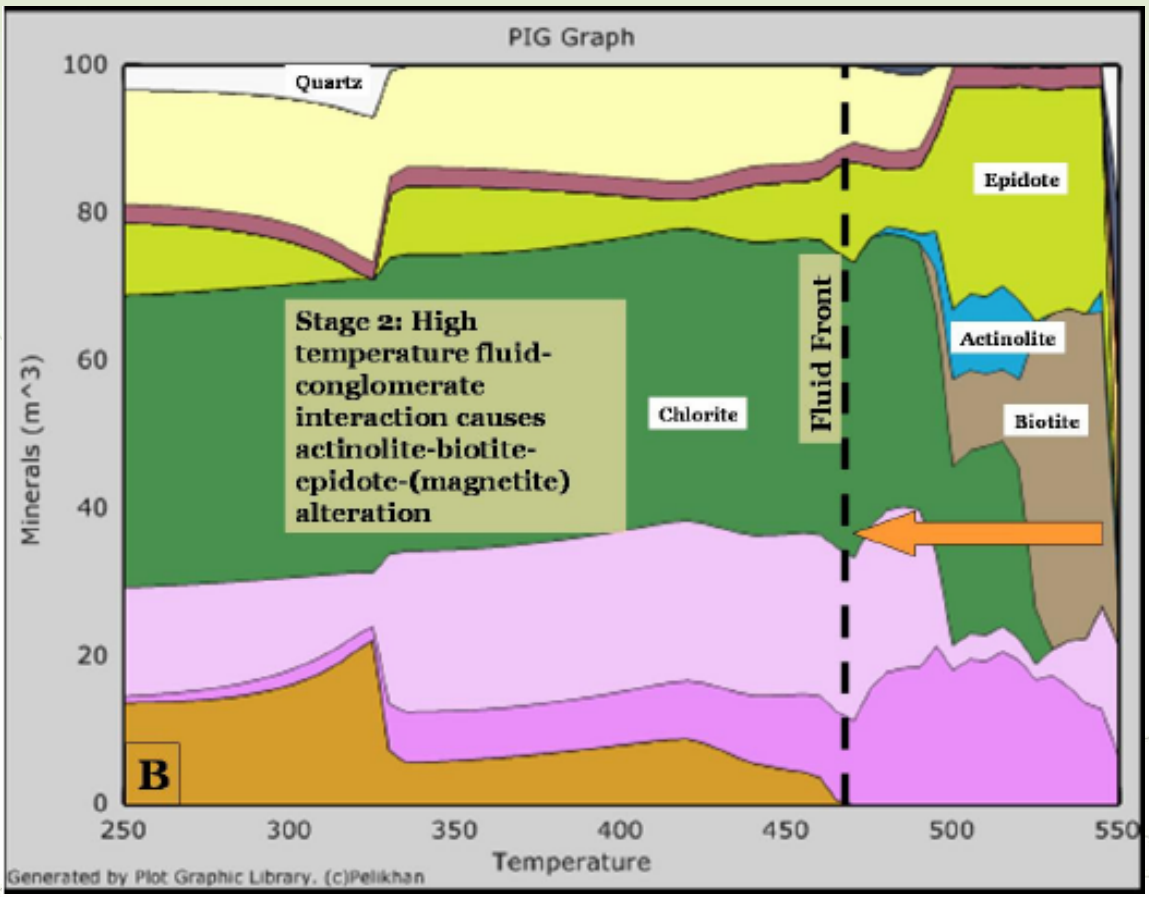
Cleverley et al 2005

Example Wallaby



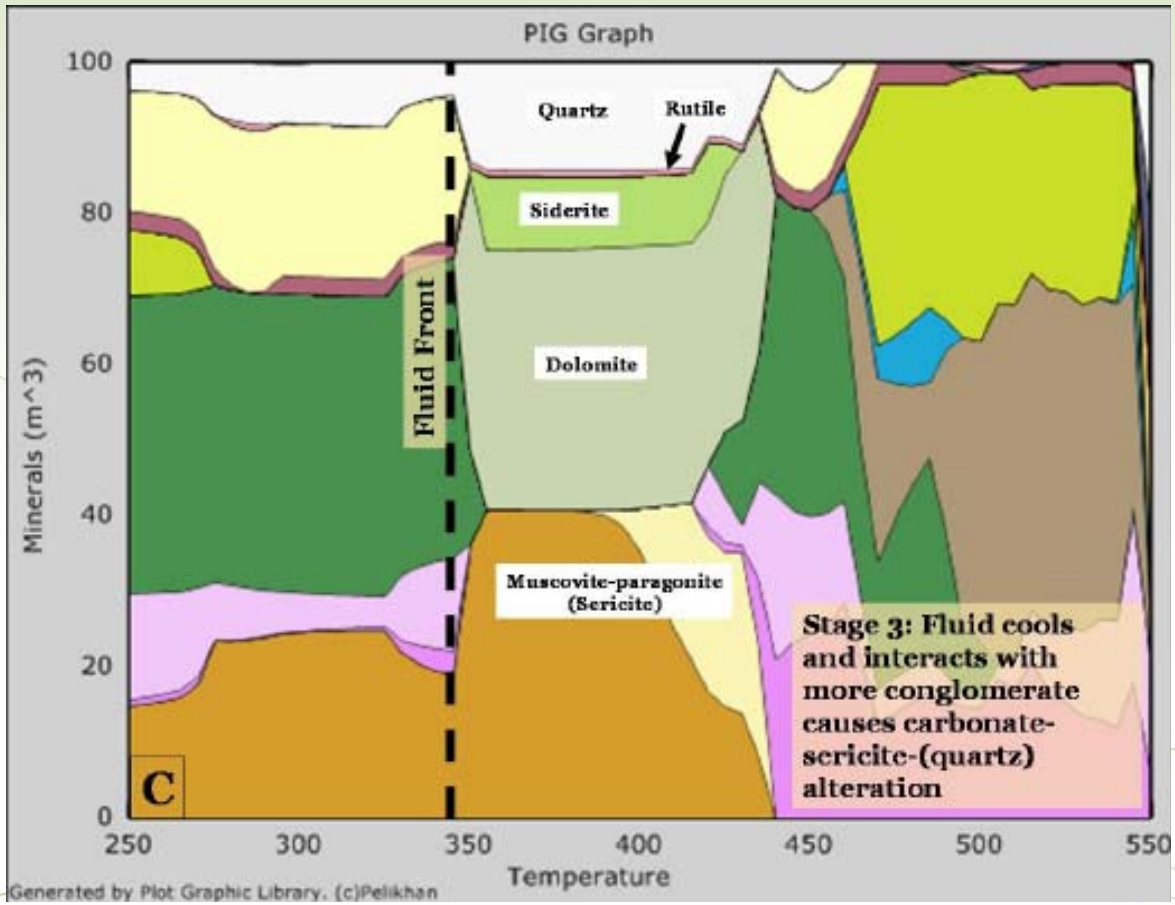
Cleverley et al 2005

Example Wallaby



Cleverley et al 2005

Example Wallaby



Cleverley et al 2005

Fluid / melt inclusions

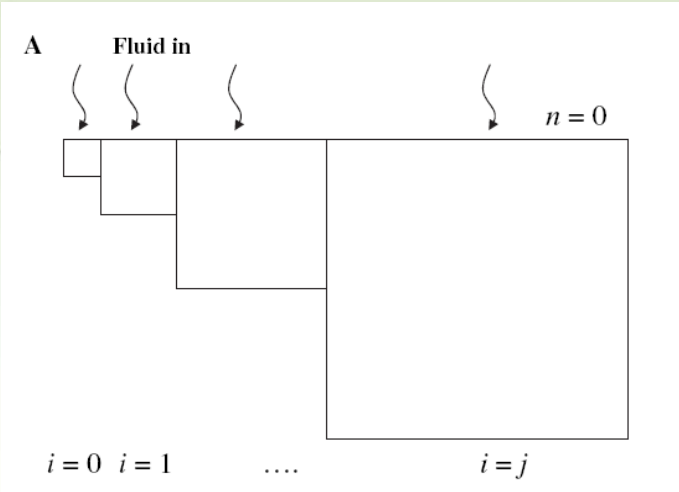
record of fluid-rock interactions

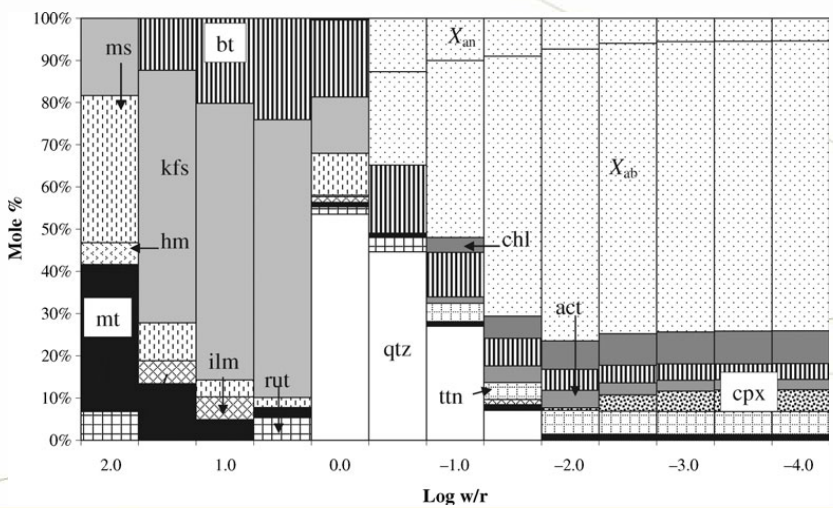
modelling of fluid-rock reactions

- Fluid and metal source region
- Predeposit fluid–rock interactions (inflow zone)
- Ore deposit formation
- Deposit proximal alteration
- Deposit distal alteration (outflow zone)
- Outflow alteration of fluids not responsible for ore deposition (the 'red-herring' fluid)

→ Predictive geochemical modelling

Fluid-rock interaction models





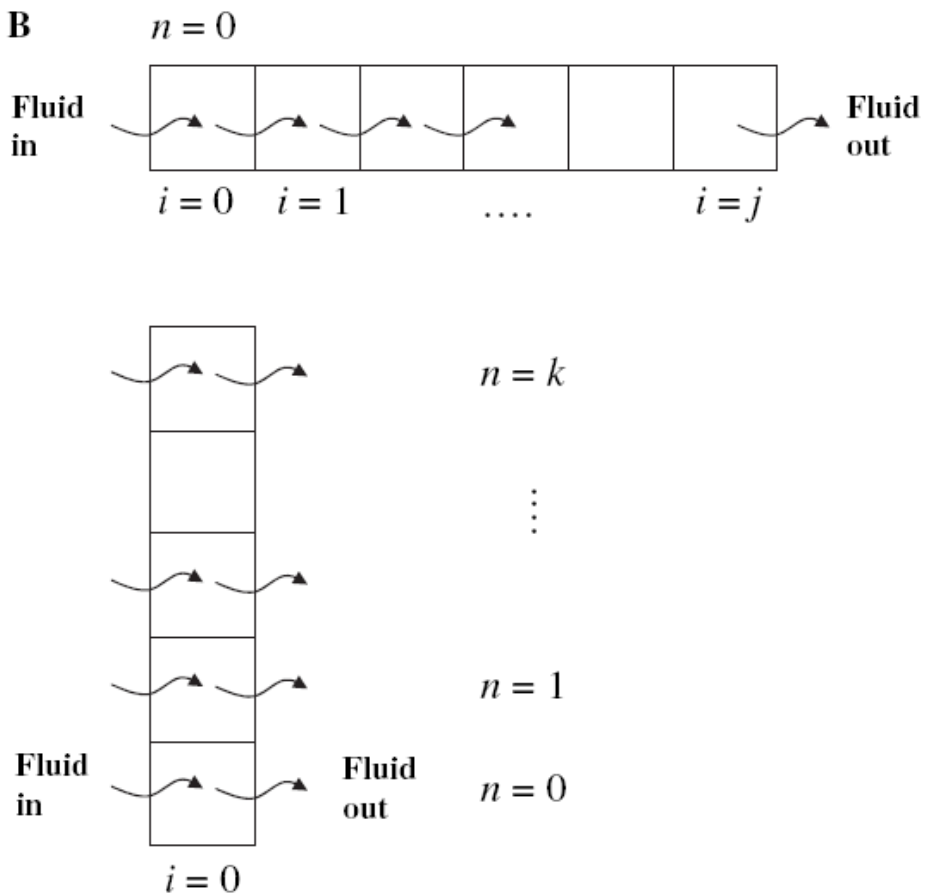
1) Static closed system models

- static fluid, no mass transfer between steps
- rock titration model

'What is the predicted mineral assemblage if the fluid reacts with a known mass of rock, and what is the change in the predicted mineral assemblage as the system changes from fluid dominated to rock dominated?'

Cleverley 2005

Fluid-rock interaction models



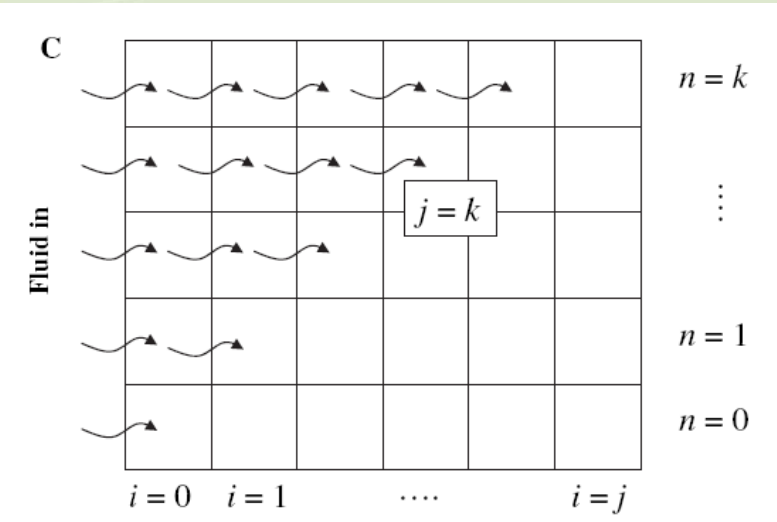
Cleverley 2005

2) Flow-through models

- a portion of the chemical system (fluid or rock) is passed on as input to the next step along the reaction path
- fluid is allowed to become modified by the rock

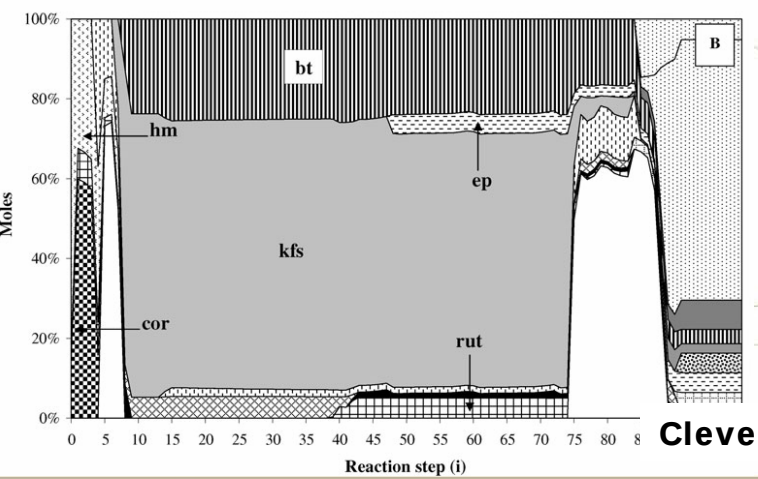
'What is the assemblage related to outflow pulses from a complex ore-forming system?'

Fluid-rock interaction models



Fluid infiltration model:

- fresh fluid is always added to one side of the rock column
- fluid front moves through the rock column
- during reaction progress fluid and the rock are both allowed to become modified
- temporal and spatial dependency



Cleverley 2005

'What is the predicted spatial zonation of metasomatic alteration produced by brine infiltrating the volcanic host sequence at Ernest Henry?'

Fluid / melt inclusions

PIXE (Particle induced x-ray emission)

non-destructive elemental analysis technique

An energy dispersive detector is used to record and measure these x-rays and the intensities are then converted to elemental concentrations.

High Sensitivity, Multi-element capability, measurements at atmospheric pressure

Fluid / melt inclusions

LA-ICPMS (Laser-ablation inductively-coupled-plasma mass spectrometry)

trace element and isotopic analysis

Direct analysis of different types of solids

reduced risk of contamination and sample losses

Analysis of very small samples

Determination of spatial distribution of elements

Fluid inclusions

record of fluid-fluid interactions

2 types:
- mixing of chemically contrasting fluids
- seperation of immiscible fluids

→ chemical driving force for selective element enrichment

dissolution, transport, reprecipitation

shallow geothermal systems

Fluid inclusions

Noble gas and halogen analyses of fluid inclusions - what do they tell us?

Fluid Inclusion geochemistry:

- Ar and He ratios to determine hydrosphere vs crust vs mantle contributions.

- Cl (^{38}Ar), Br (^{80}Kr), I (^{128}Xe) to determine source of salinity (e.g. mantle, meteoric, bittern brines, halite dissolution, etc).

$^{40}Ar/^{39}Ar$ dating of fluid inclusions:

- Requires 3D isochron plots using ^{40}Ar, ^{36}Ar K, Cl
- K-rich fluid inclusions - max ages
- Inclusions with trapped mica - cooling ages

Halogens and Noble Gases

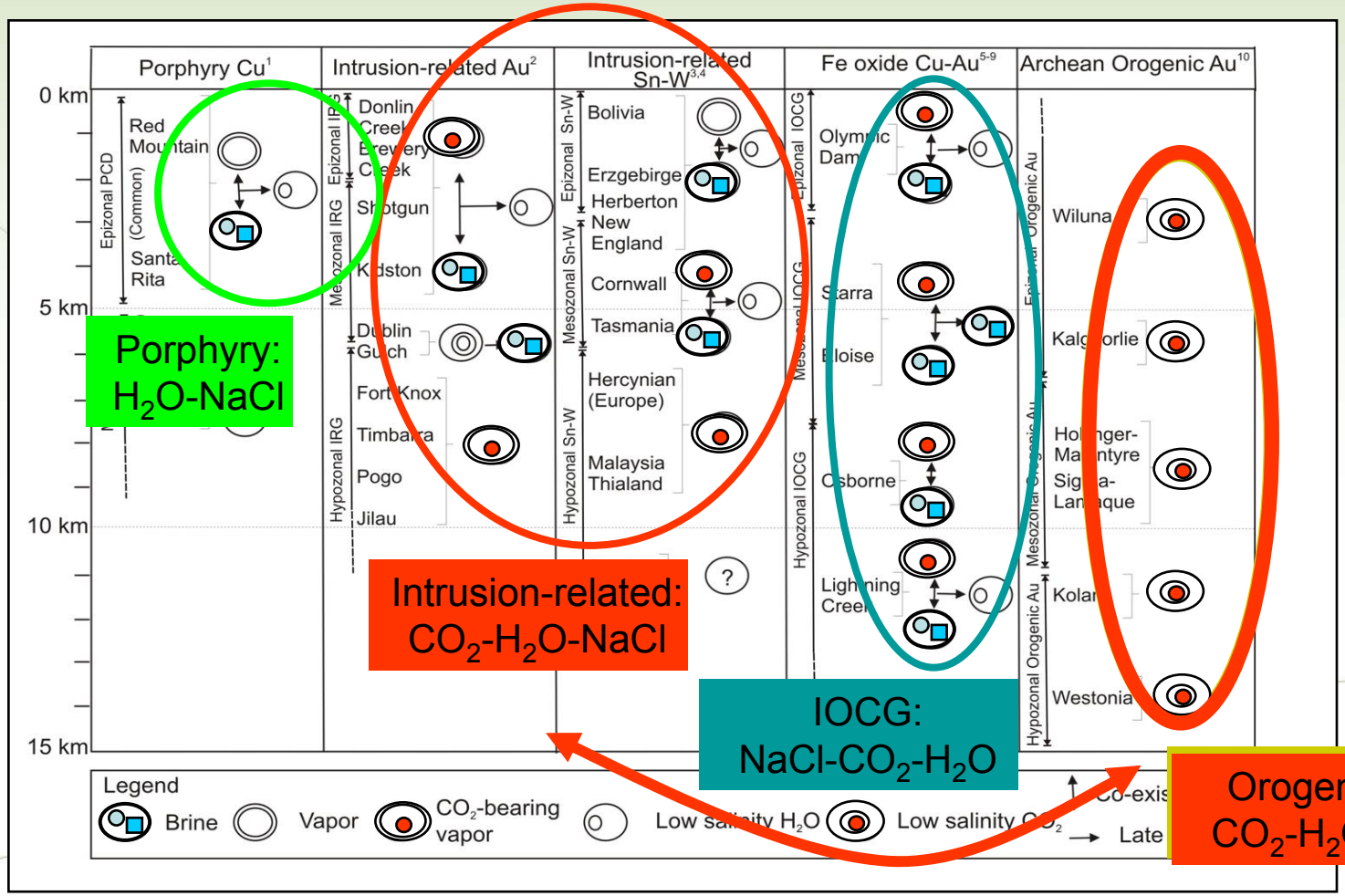
for fluid pathway detection

partition strongly into the fluid and will be least modified along the fluids' flowpath

retain information about the origins of at least a component of the fluid

Halogens, because they do not partition into common rock-forming minerals, are little affected by fluid-rock interaction (except apatite and scapolith)

Fluid inclusion types

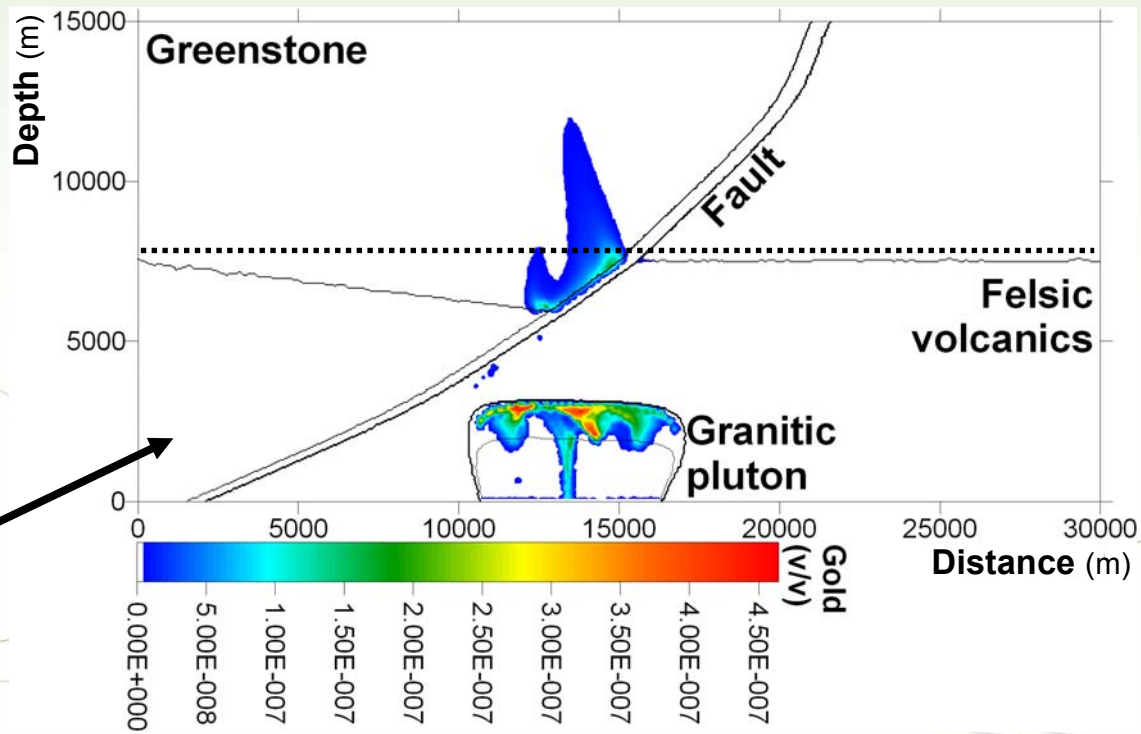


RT Models

attempts to couple the simulation of key ore forming processes: fluid flow, heat and chemical transport and chemical reactions

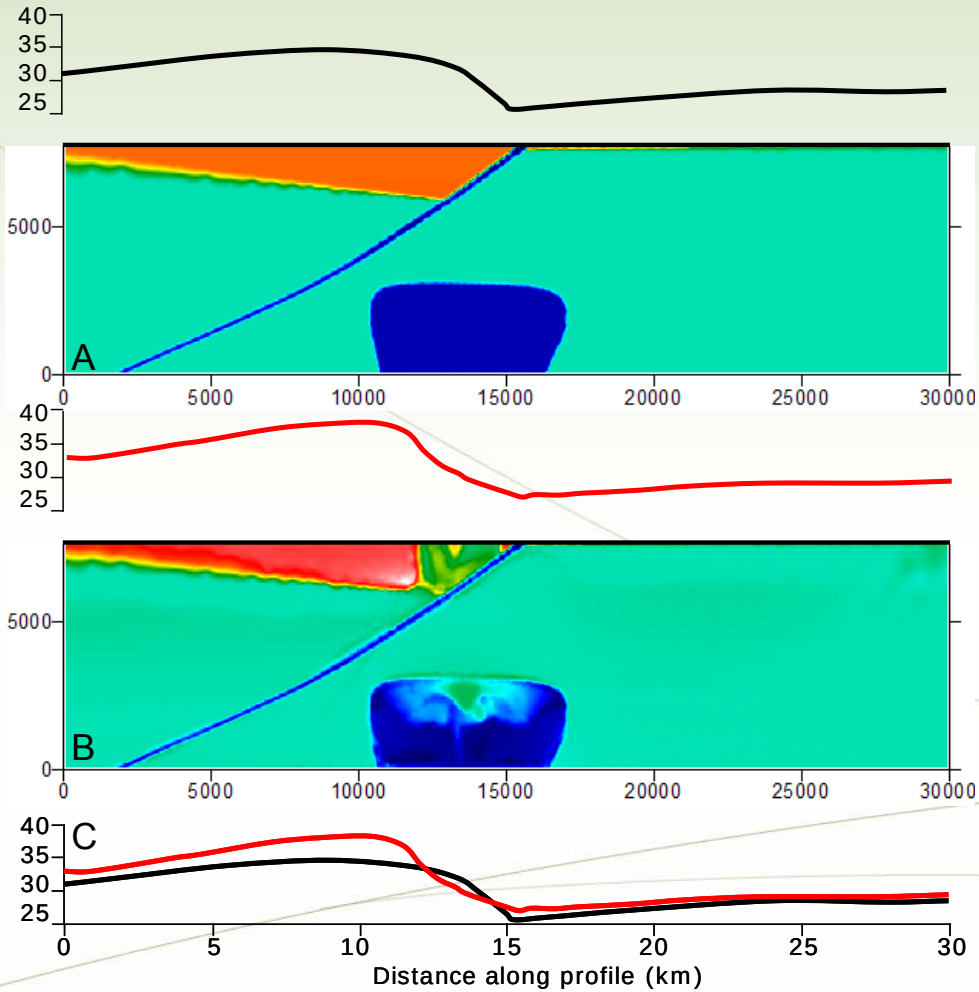
Can be used to simulate geophysical responses, allowing direct targeting from chemical models

Listric fault model



Cleverley et al. (2006)

RT Models – geophysical signatures



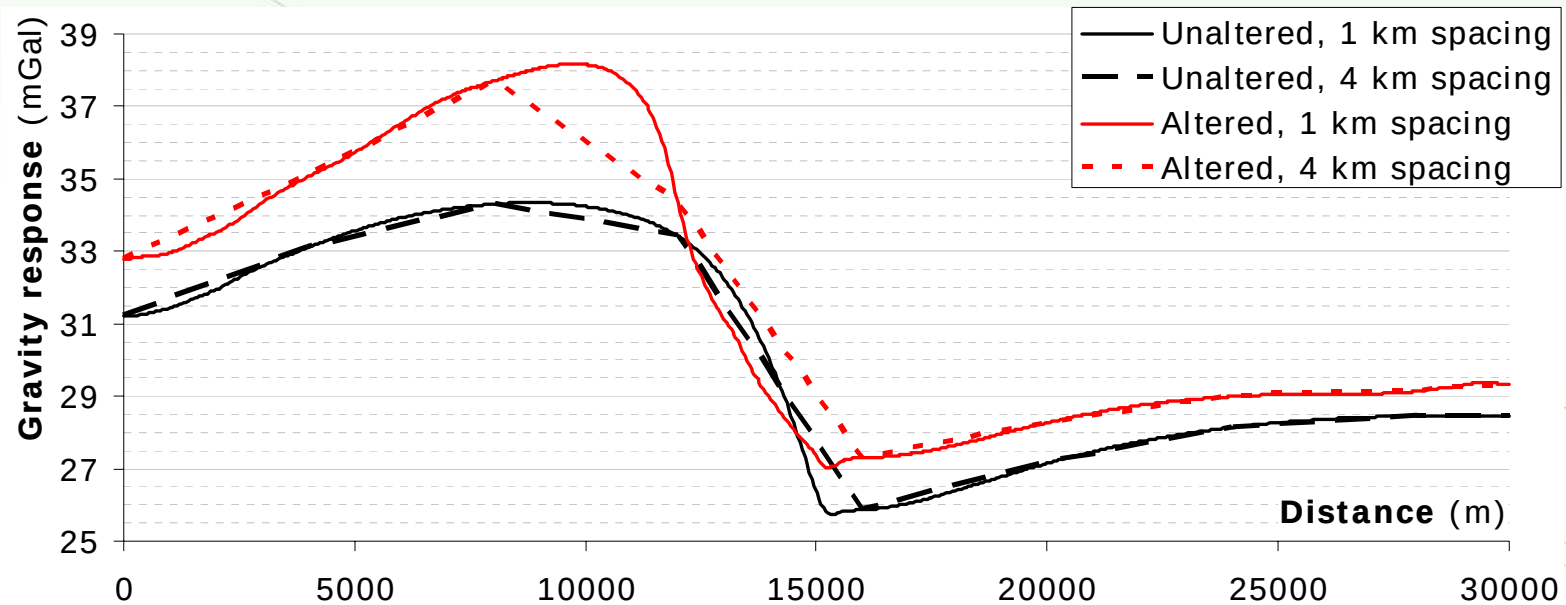
decrease in density directly associated with the ore deposit

low-density inflow and outflow material

Chopping (2007)

RT Models – geophysical signatures

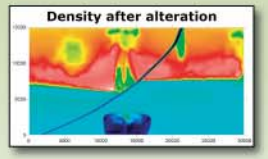
Differing station spacings

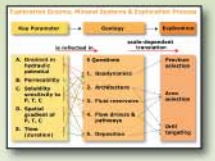


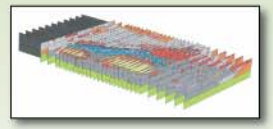
Chopping (2007)

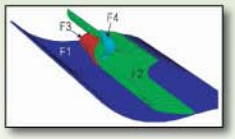
*predictive mineral discovery*Cooperative Research Centre*

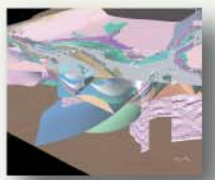
A legacy for mineral exploration science

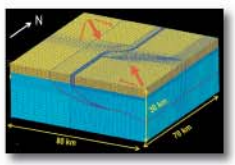


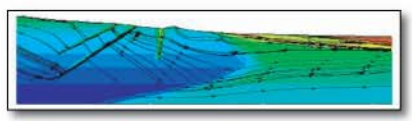


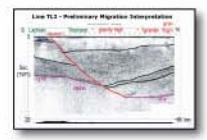












*pmd*CRC* working with industry

*pmd*CRC* research areas

*pmd*CRC* research nodes

*pmd*CRC* working with State/Territory Surveys

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References

- Cleverley, J., Oliver, N.H.S. and Placer Dome (Asia Pacific) Granny Smith (2005). Chapter 6: Geochemical Modelling of the Wallaby Ore system, Yilgarn Block, Western Australia. pmd*CRC Fluid Processes and Geochemical Modelling F1-2 Project. Final Project Report. N. Oliver: 103-107.
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