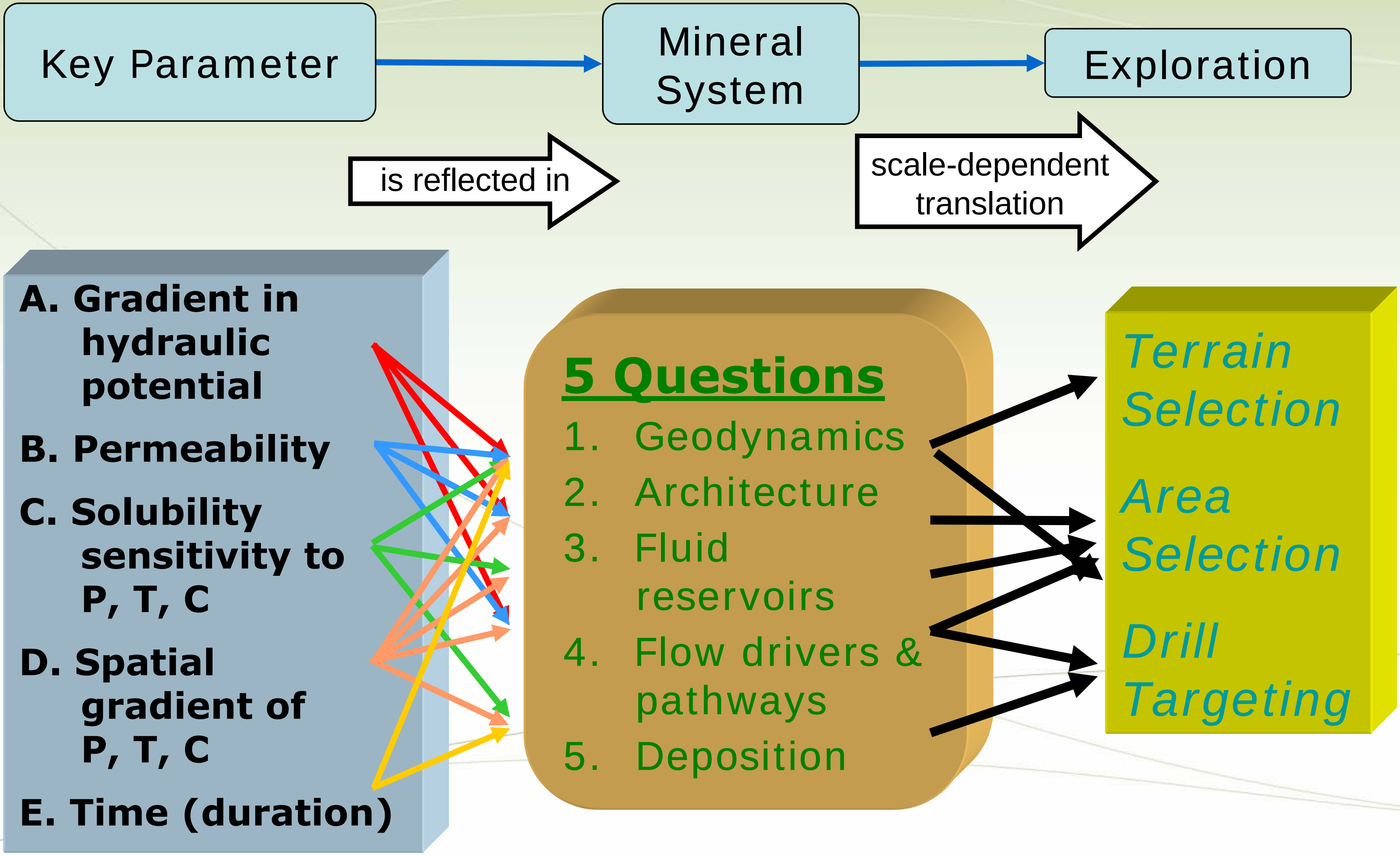
Enabling Technologies

Thermal Modelling

A legacy for mineral exploration science



Heat Transfer

Geologically relevant are only conduction and advection

Conduction is a diffusive process: "heat will flow from hot to cold"

Advection is a transport process, whereby heat is transported by a solid, fluid or gas

Advection is faster than diffusion

Normal geothermal gradient generally too small for convection (requires local heat source or high permeability)

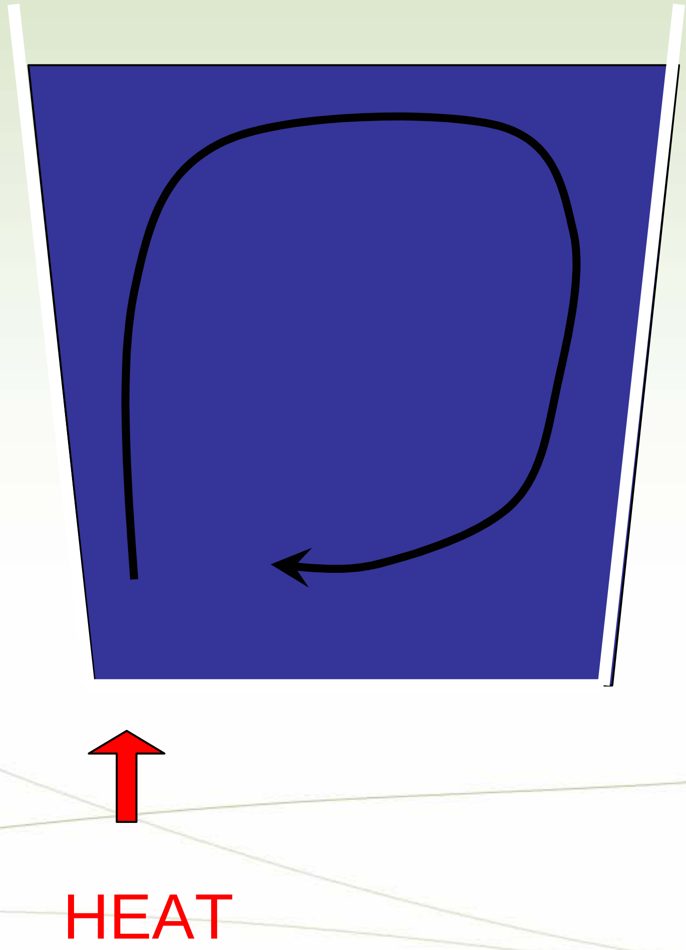
Heat Transfer

Convection

Density-driven flow

Density varies with P, T, and chemistry

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



Convection in geological systems

Critical Rayleigh number

Height of system

Temperature difference

Permeability

$$Ra = \frac{\rho_f^2 c_p \alpha k H \Delta T g}{\mu K}$$

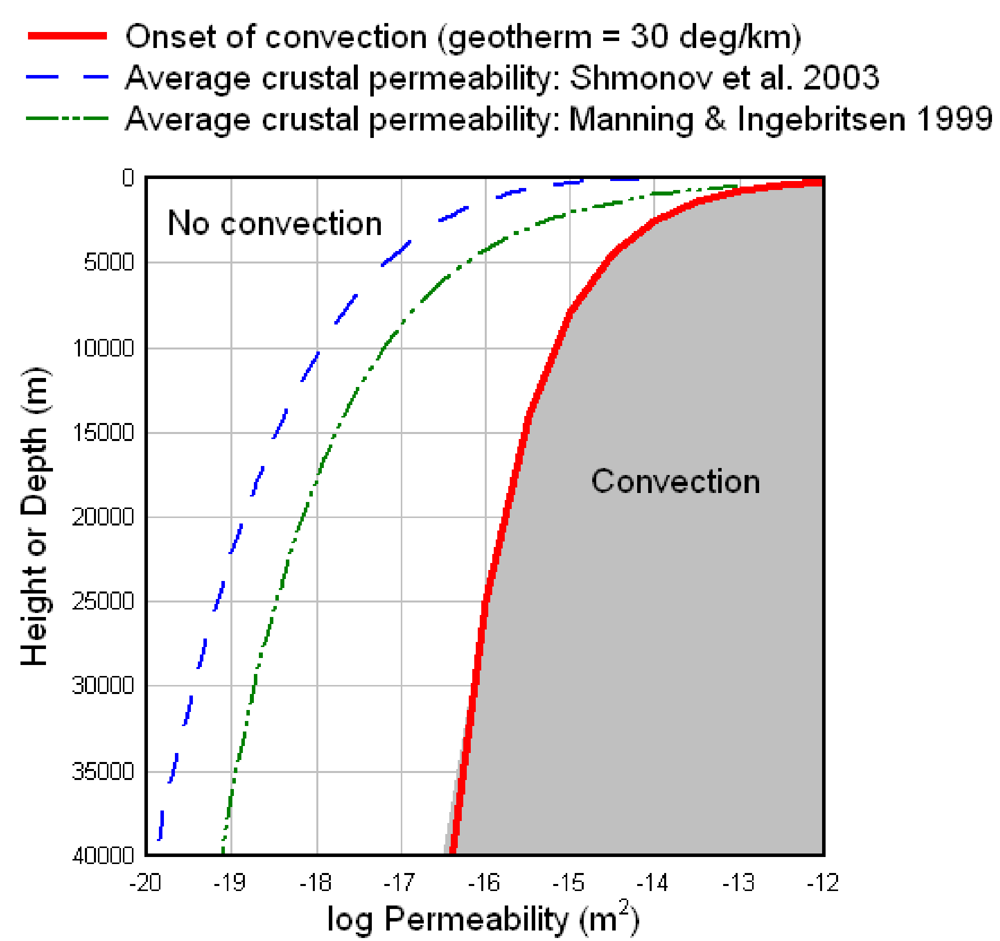
Convection occurs when Ra > critical value
Ra critical = $4p^2$ ~ 39.5 (fixed T boundaries)

Heat Transfer

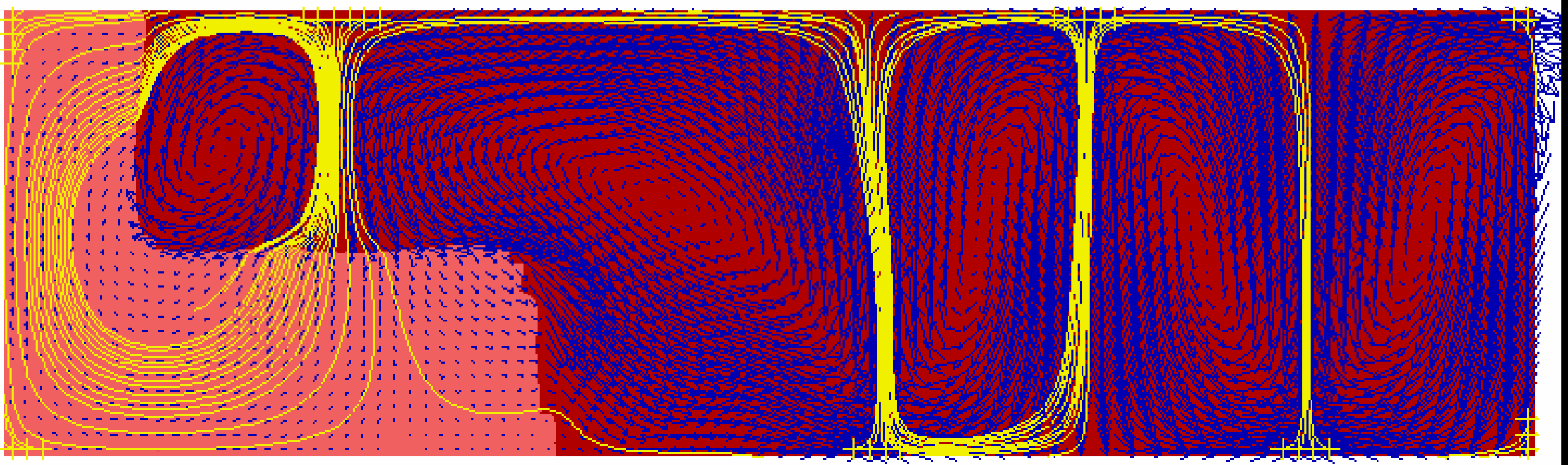
Is thermal convection possible?

Average crustal permeabilities too low for convection

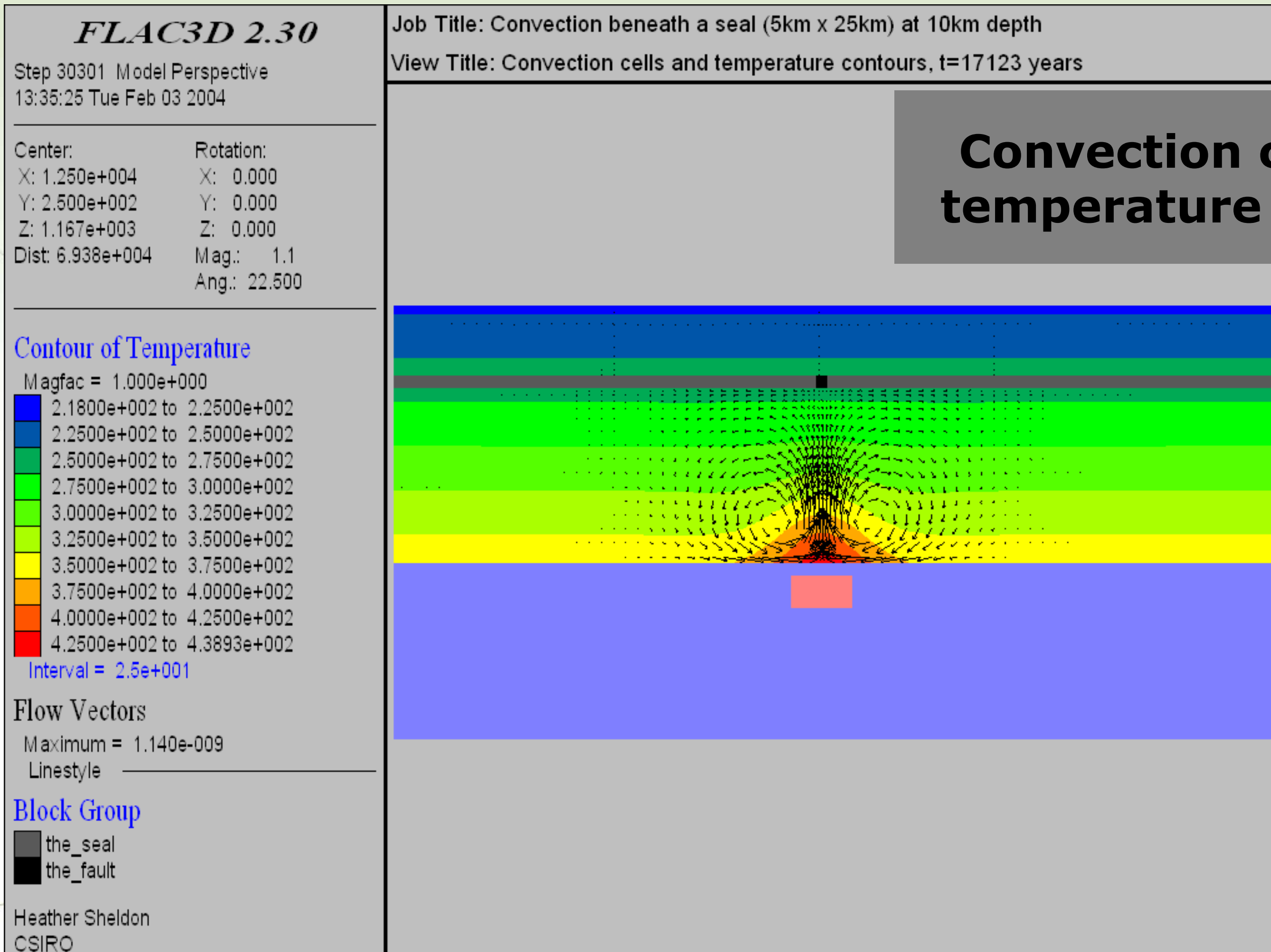
Convection may occur where permeability is abnormally high (e.g. faults), or where geothermal gradient is abnormally high (e.g. intrusions)



Modelling Convection

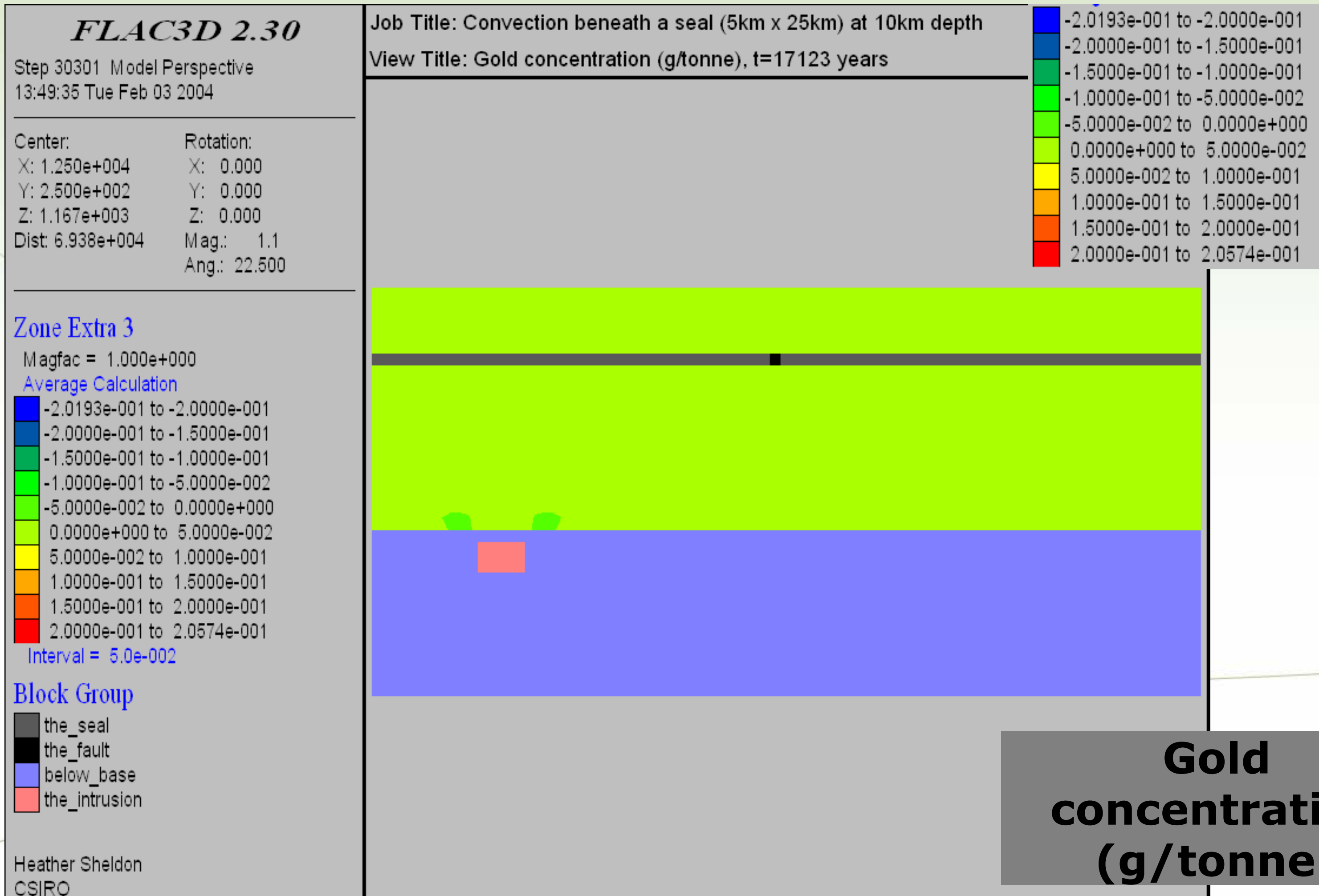


Modelling Convection



Convection cells and temperature contours

Modelling Convection



Gold concentration (g/tonne)

Heat Transfer

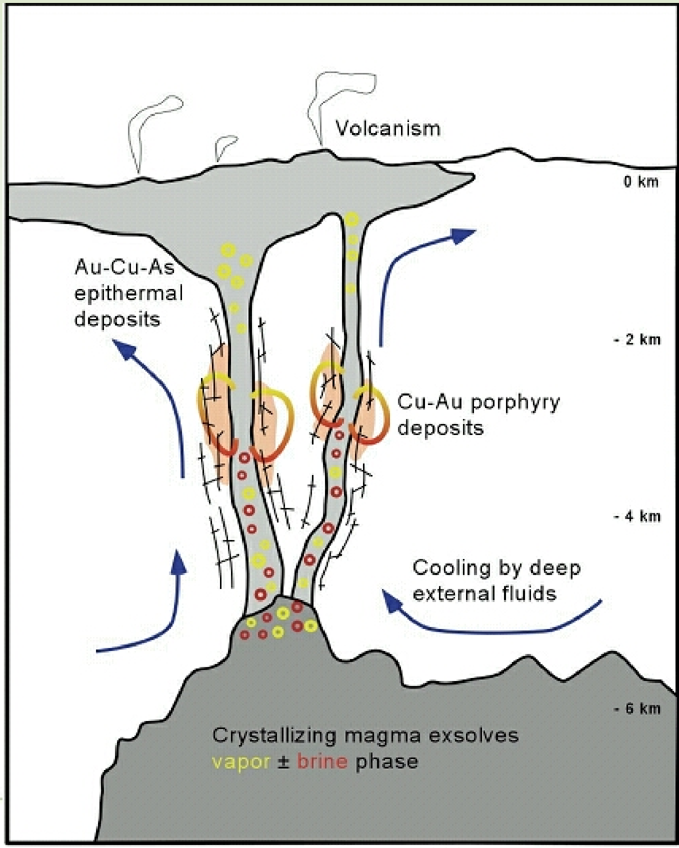
Intrusions and hydrothermal ore deposits

Heat from intrusions drives convection

- Collect ("scavenge") metals from wide source area
- Deposit metals in the narrow, upwelling region
- But flux is rather small

Heat drives dehydration reactions in the wall rocks

Cooling magma releases volatiles (fluids)



Sebastian Geiger
(http://n.ethz.ch/student/sgeiger/)

Dehydration and magmatic fluids are probably more important for generating ore deposits.

Heat Transfer

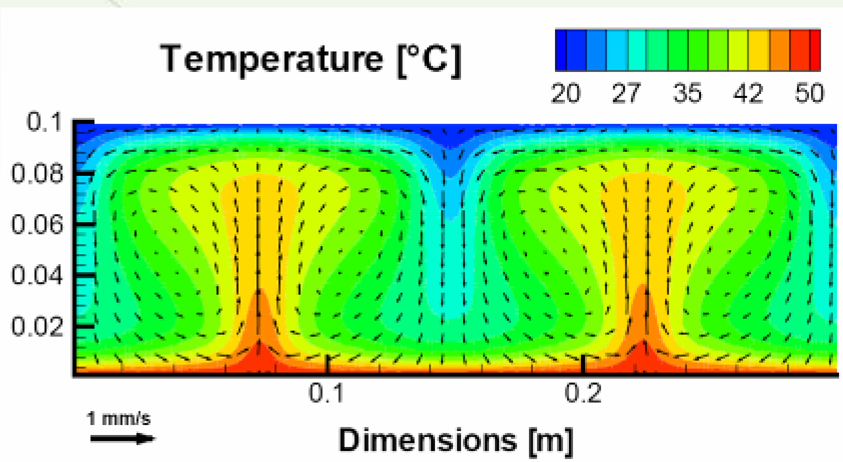
Precipitation and dissolution due to convection

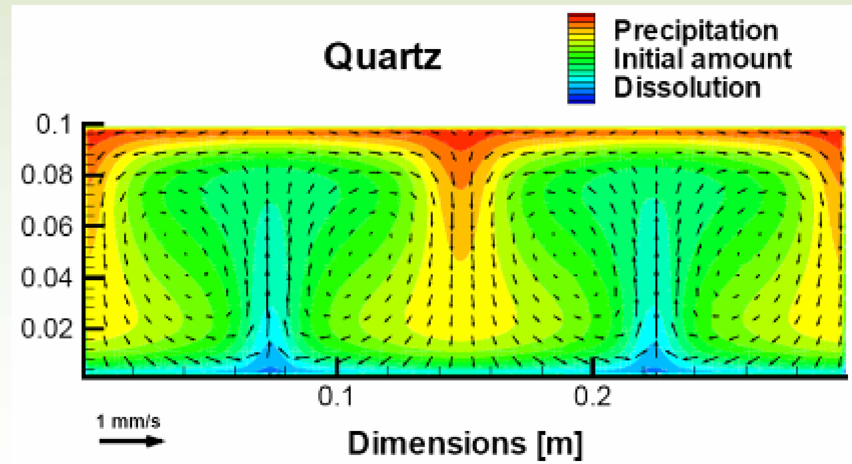
Reaction rate = Fluid flux x gradient in solubility

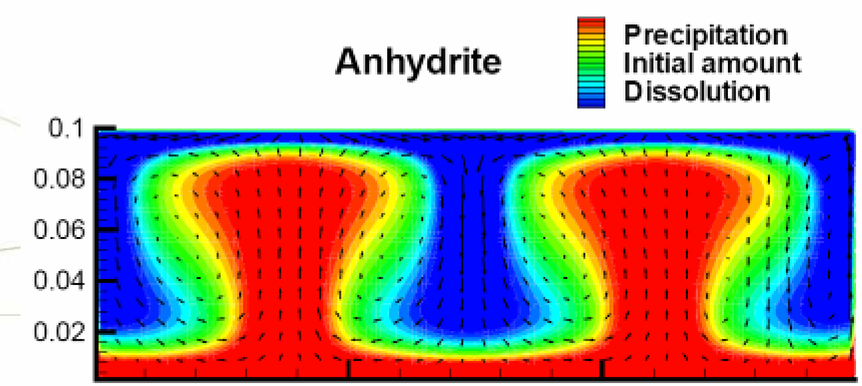
$$R \approx \mathbf{q} \cdot \nabla C$$

… due to gradients in T, P, rock composition etc.

Reactions within thermal gradients







Thermal Rock Properties

Specific heat capacity (c)

$$c = c / M = \Delta Q / (\Delta T\ M)$$

Thermal conductivity (λ)

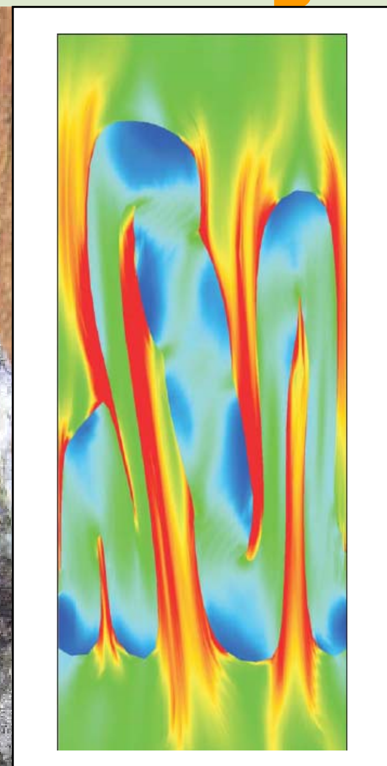
$$q_i = -\lambda_{ij} \frac{\partial T}{\partial x_j}$$

Thermal diffusivity (κ)

Thermal capacity (ρ c)

$$(\rho\ c) = \lambda / \kappa$$

Thermodynamics of Folding

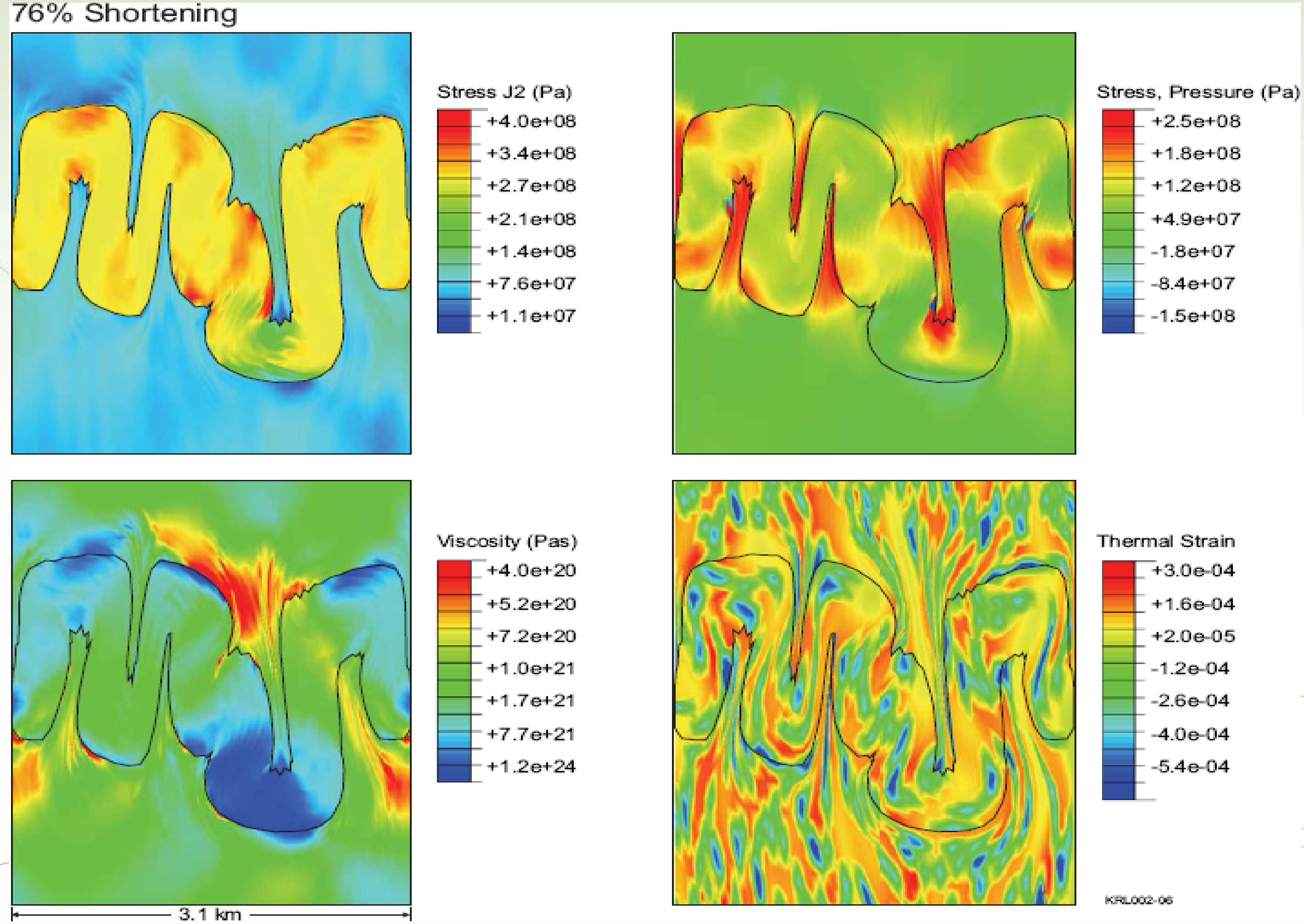


Thermo-dynamic Simulation

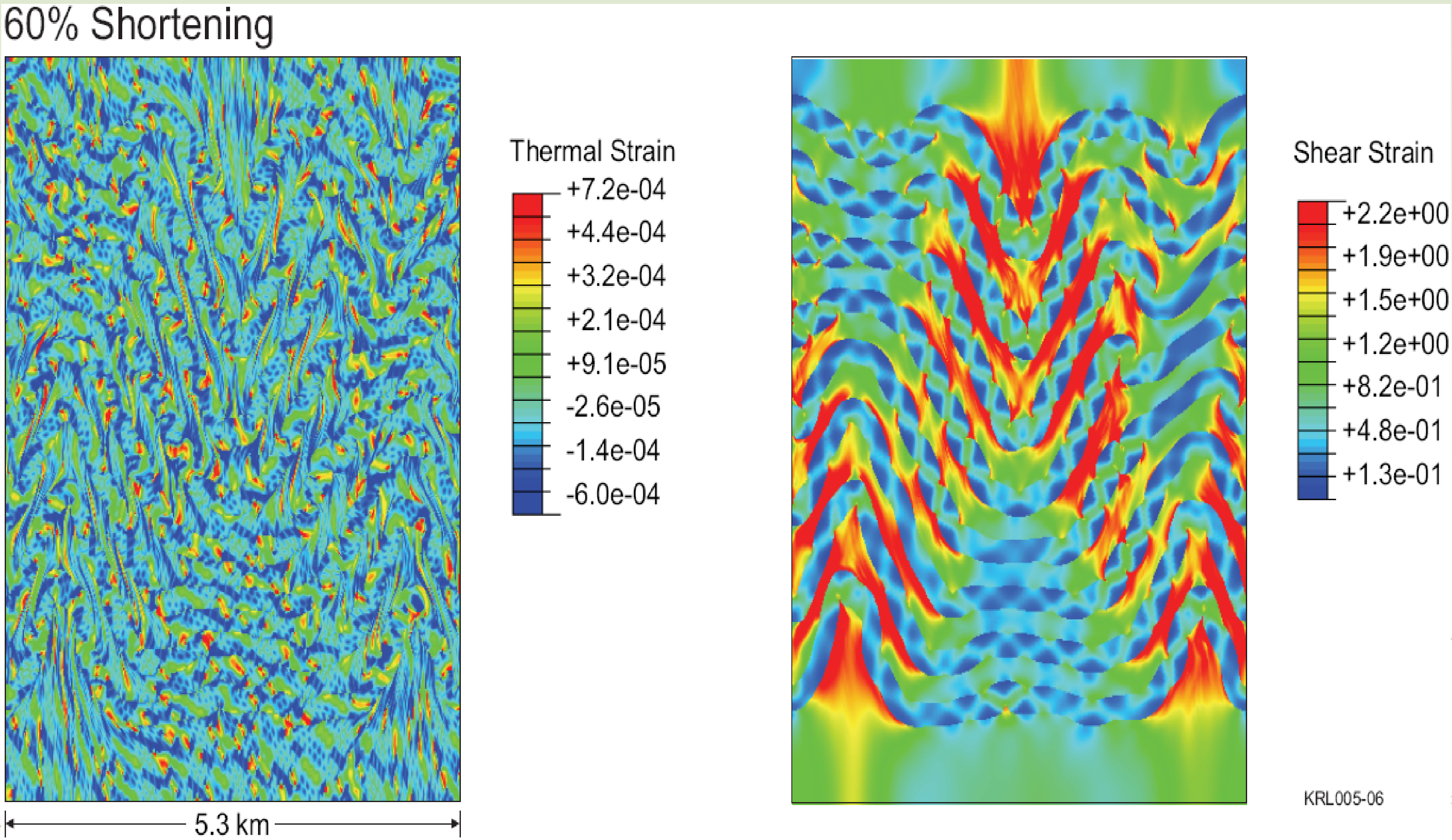
Manuscript Geology (in press) available

Folded meta-quartz vein in Challenger Deposit: courtesy of Andy Tomkins (Monash)

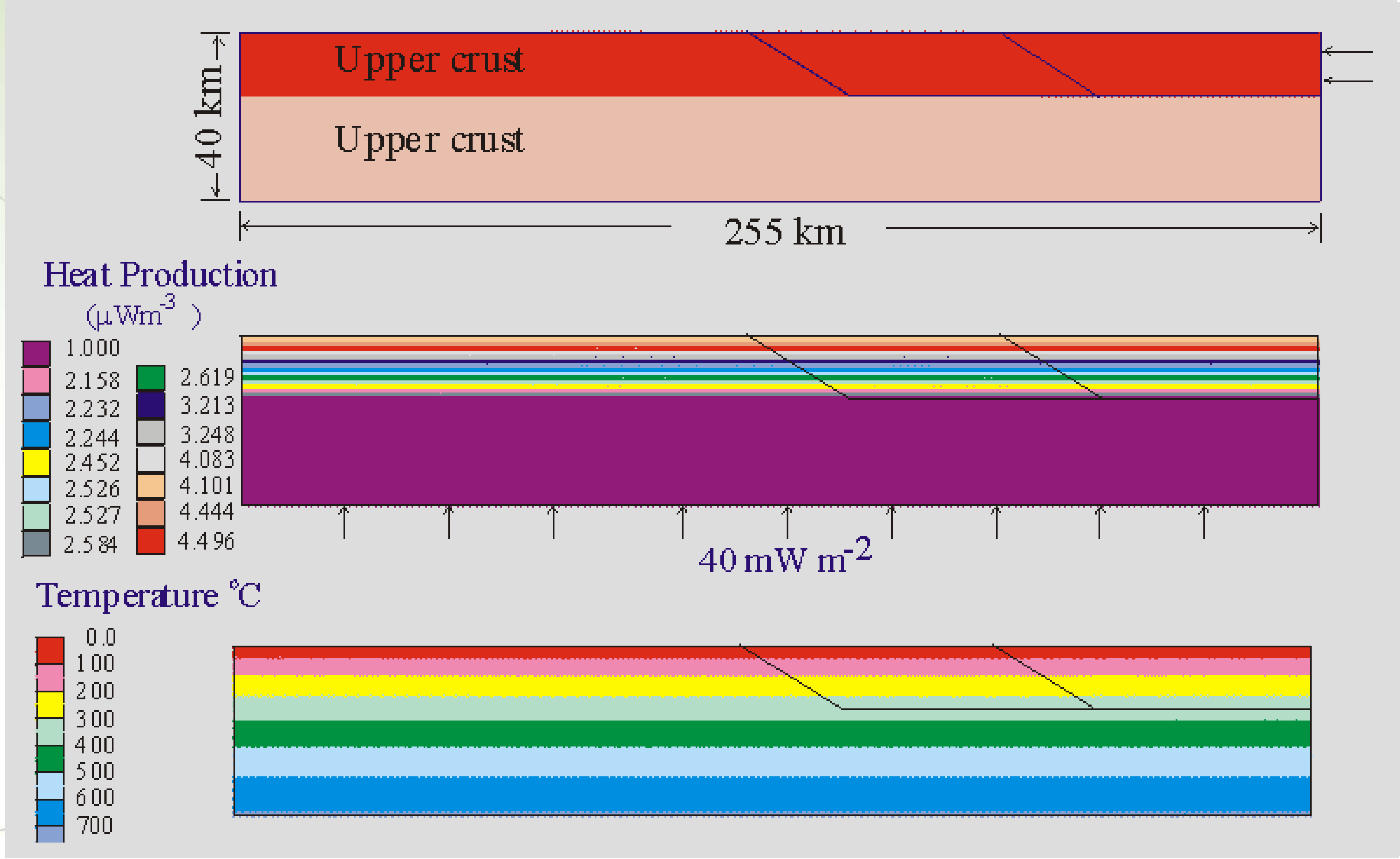
Thermodynamics of Folding



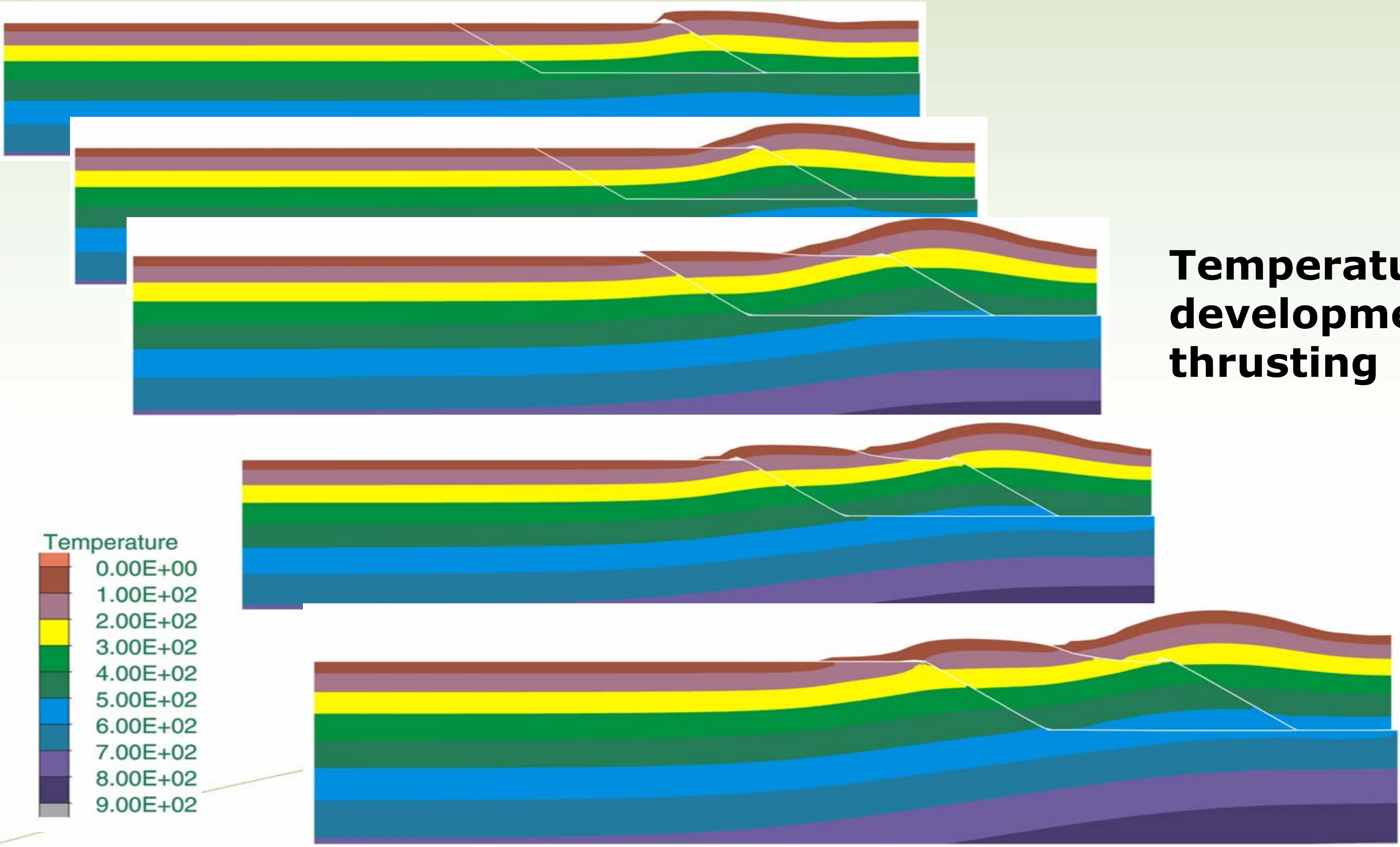
Thermodynamics of Folding



Coupled thermal-mechanical models

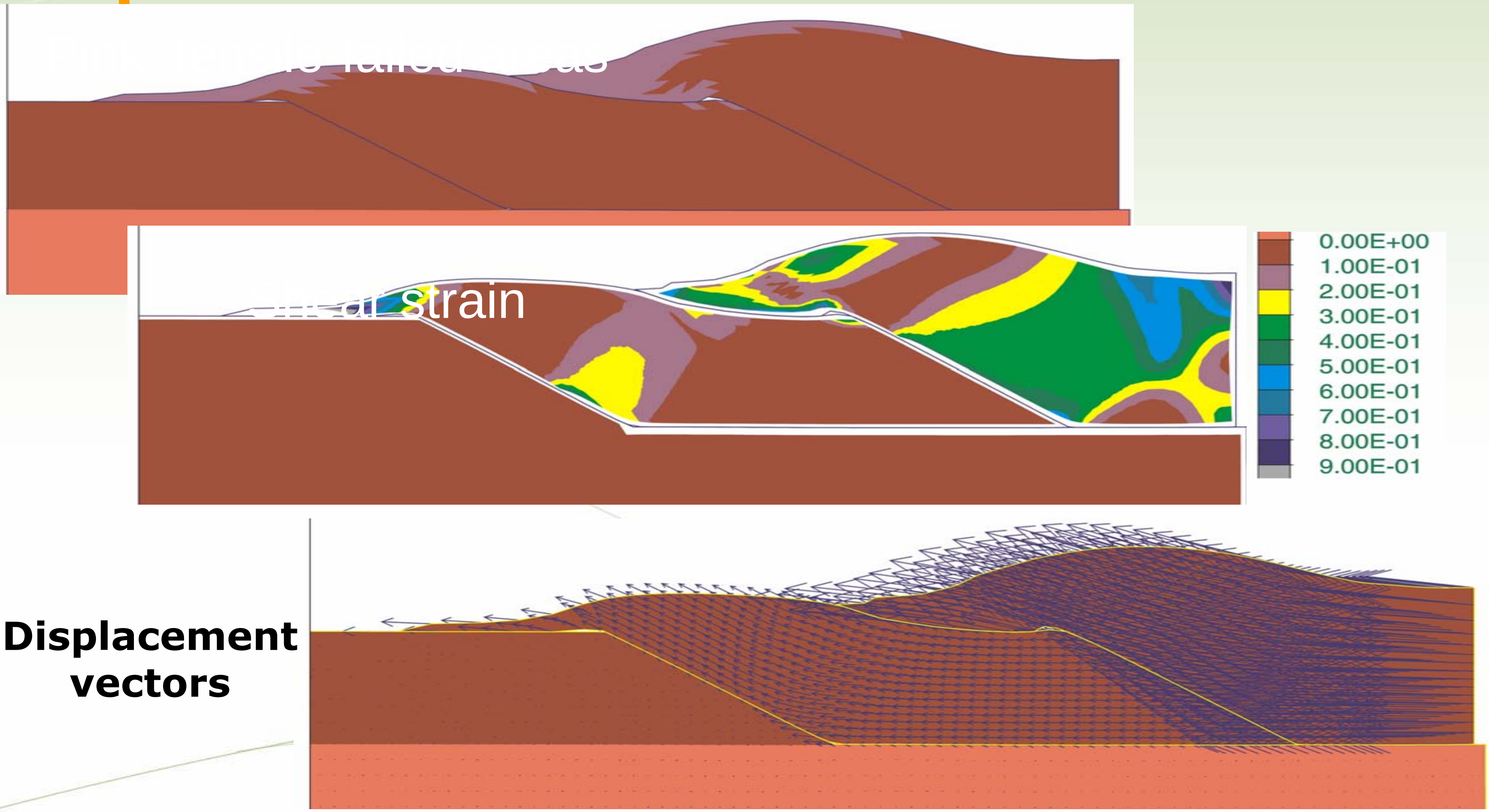


Coupled thermal-mechanical models



Temperature development with thrusting

Coupled thermal-mechanical models



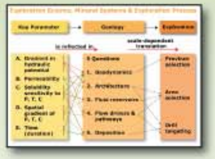
Displacement vectors

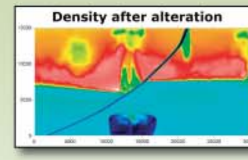
Thermal Modelling

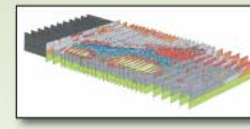
CAN BE USED TO UNDERSTAND THE HEAT DISTRIBUTION IN THE LITHOSPHERE, AND BY INFERENCE ASPECTS OF ITS MECHANICAL AND HYDRAULIC ARCHITECTURE.

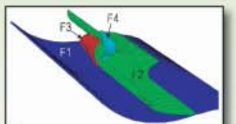
predictive mineral discovery*Cooperative Research Centre

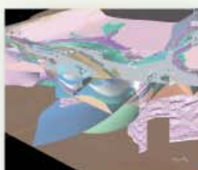
A legacy for mineral exploration science

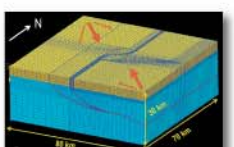


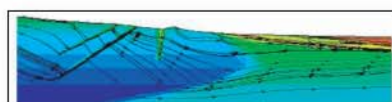


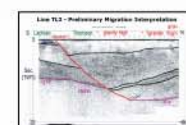


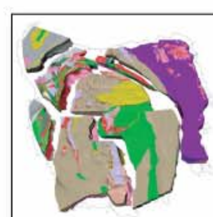












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