Faulting in Porous Sediments

Background

In petroleum systems, faults commonly act as barriers to fluid flow whilst in ore systems, they are the principal pathways along which fluids flow.

Some models of Pb-Zn ore formation infer focussed fluid flow to the surface in recently deposited sediments (Fig. 1), but deformation experiments and observations of natural fault rocks suggest that faults in porous sediments are unlikely to act as fluid pathways.

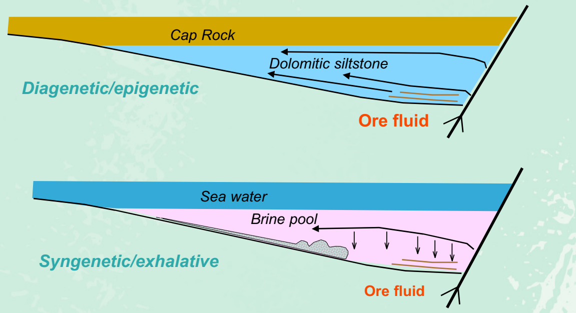

Figure 1 – Conceptual models for Pb-Zn deposits: some (bottom) infer focussed fluid flow to the surface. Is this realistic?

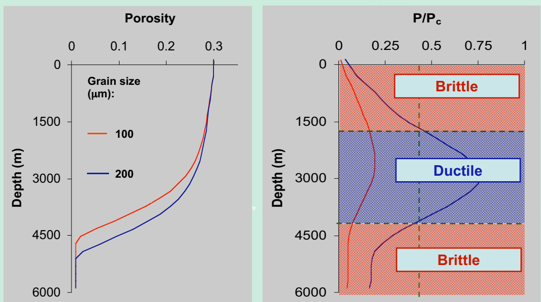

Figure 2 –Porosity and P/Pc versus depth in sandstone

Deformation Processes

At low confining pressure (P), sandstones deform by localised dilatant shear failure.

At high P, sandstones deform by distributed cataclasis.

The transition from dilation to compaction occurs at P/Pc ~ 0.45, where Pc increases with decreasing porosity and grain size. P and Pc vary with depth, hence deformation style varies with depth (Fig. 2).

Permeability Evolution during Deformation

During compaction (either elastic or cataclasis):
- Permeability decreases

During dilatant shear failure:
- Permeability increases if porosity < 15%
- Permeability decreases if porosity > 15%

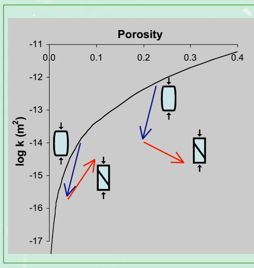

Figure 3 – Porosity-permeability relationship in undeformed sandstone (black curve), during elastic loading (blue arrows) and during shear failure (red arrows). Permeability reduces during dilatant shear failure at high porosity.

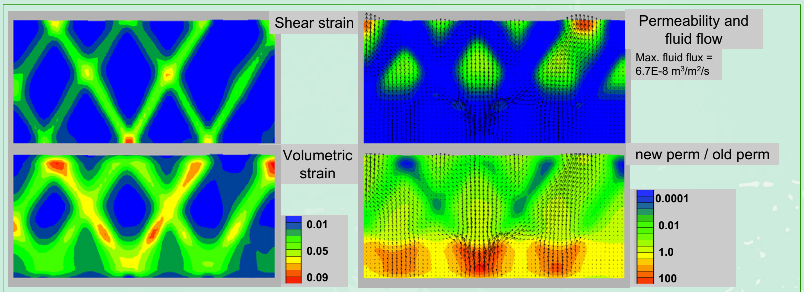

Figure 4 – Numerical model of extension in sandstone. Model size = 12 km x 6 km.

Numerical Modelling

- 4.8% extension
- Deeper material is compacted and hence lower porosity: deforms by dilatant brittle failure; permeability *increases*
- Shallower material has higher porosity, dilates during deformation but permeability *decreases*

Implications

- Focussing of fluids is unlikely near-surface, unless porosity is abnormally low.
- In sandy rock packages that are not overcompacted, the depth to permeable faults depends on the geothermal gradient and grain size *via* control on cementation
- Understanding of the basinal history and timing of fluid flow is critical for predicting prospectivity

References

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