Permeability heterogeneity during sandstone compaction

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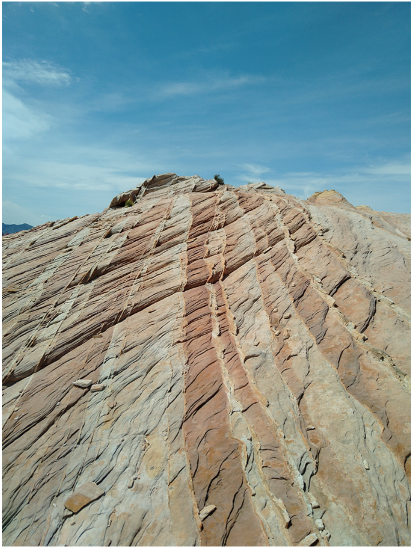
Sandstone compaction

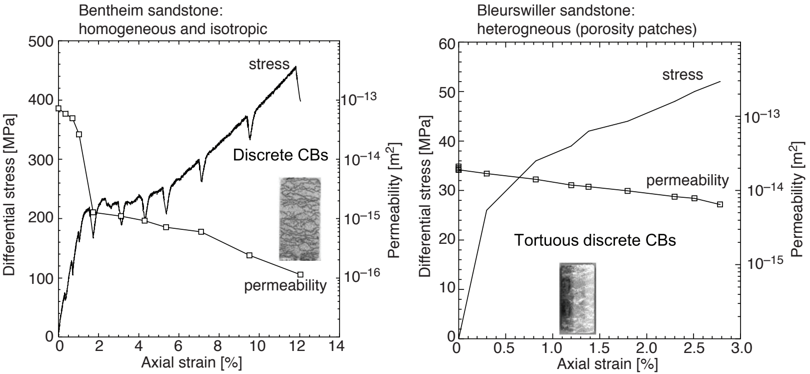


(Photo: Mark Jefferd)

- Compaction in porous sandstones can be localised in bands.
- Strong decrease in porosity ($\sim 14\%$) due to cataclasis.
- Decrease in permeability across band.

Transport properties

Compaction bands induce decrease in permeability, but quantitative impact is very variable. Seems to depend on band geometry.



(Baud et al., JGR 2012)

Motivation

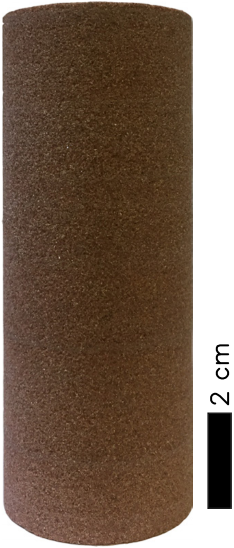
Goals

- Determine precisely contribution of compaction bands to permeability,
- Determine impact of CB geometry on permeability structure.

Method

- Triaxial deformation tests,
- Combine AEs, ultrasonics, and *local* measurements of permeability during deformation.

Sample material

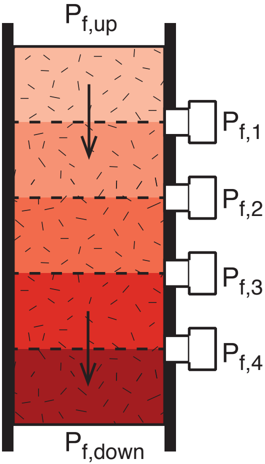


- Locharbriggs sandstone (Mair et al., JSG 2000),
- porosity ≈ 24%,
- quartz rich (88%).

Experimental setup

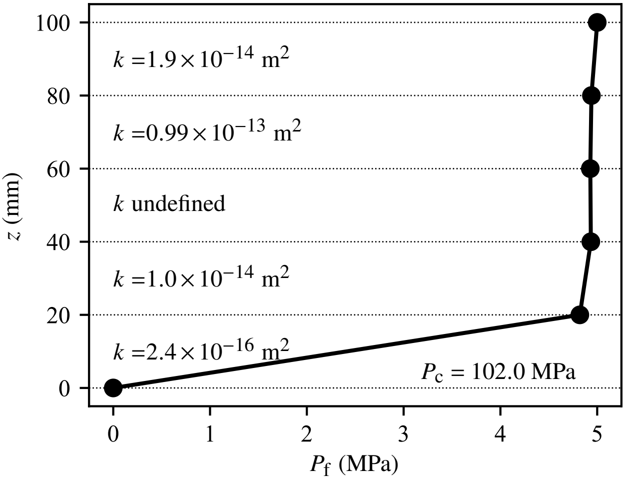
- 4 local pore pressure transducers (Brantut, EPSL 2020),
- 16 piezoelectric transducers,
- $P_{\mathrm{c}} = 100$ MPa, $P_{\mathrm{f}} = 2$ MPa,
- deformation at 10^{-5} s^{-1}.

Pore pressure measurements



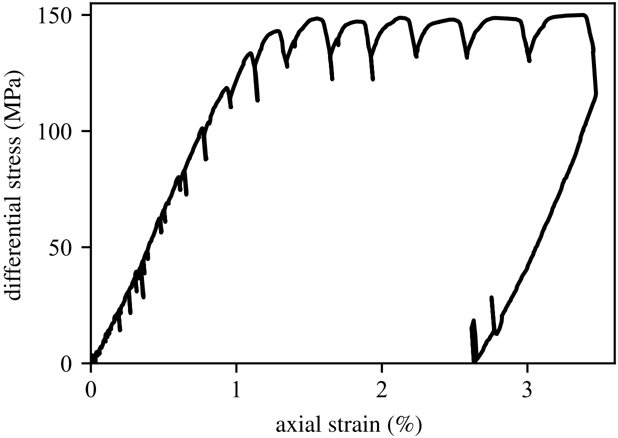
- Stop deformation regularly and impose constant flow rate,
- Measure local pore pressure and flow rate,
- Get local permeability in 5 zones.

Sample characterisation



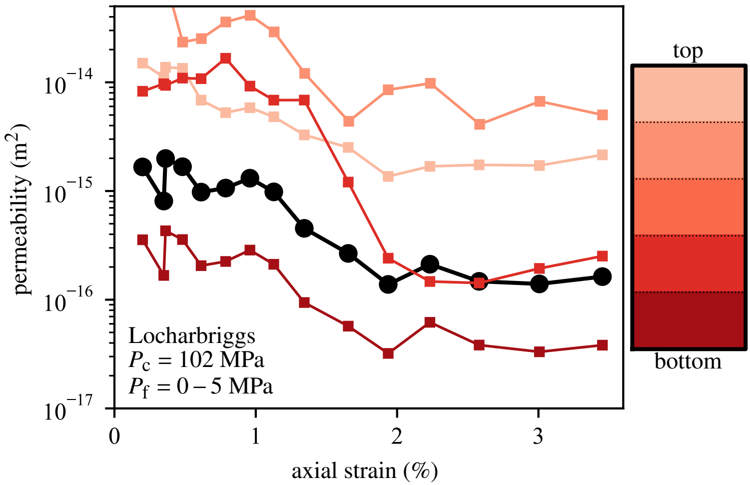
Initial permeability very heterogeneous: low permeability layer at the bottom.

Mechanical data



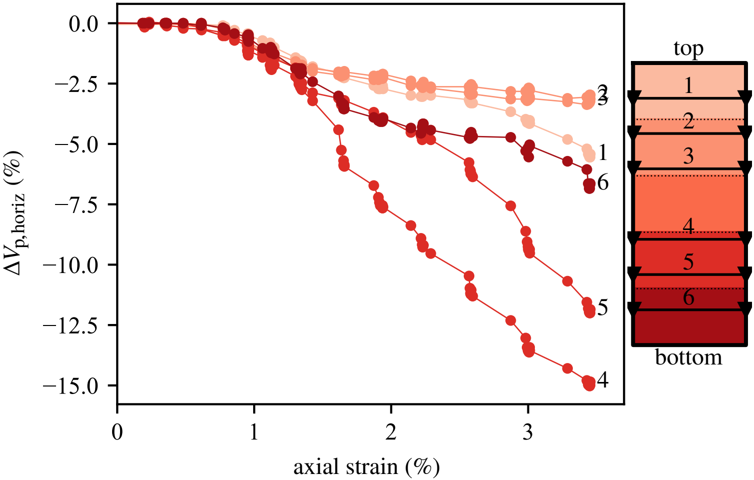
Typical of compactant cataclistic flow in porous sandstones. Large stress drops are due to relaxation during permeability measurements.

Permeability evolution



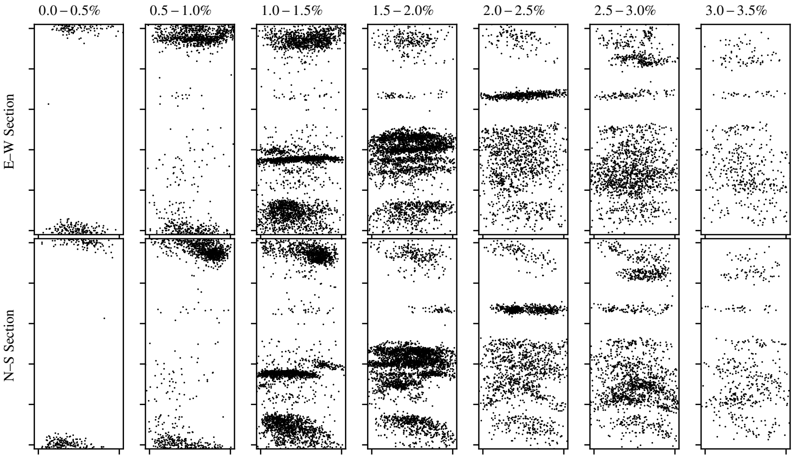
Black curve is average across sample. Overall decrease, but one layer experiences much larger drop (by around a factor 80).

Wave speed evolution



Average horizontal P wave speed across different paths. Large, early drops observed at positions 4 and 5, where permeability drop was largest.

Acoustic emissions



Interpretations

- initial sample quite heterogeneous,
- localised compaction $\rightarrow$ local drop in permeability,
- bands need to be complete or connected across whole sample to have any significant effect,
- cumulative effect of multiple bands,
- average permeability still dominated by initial low permeability layer!

Implications

- compaction redistribute permeability structure. No effect unless continuous bands form,
- direct observation of compartmentalisation of the rock, at sample scale,
- how to upscale? strongly depends on connectivity and 3D geometry of bands.