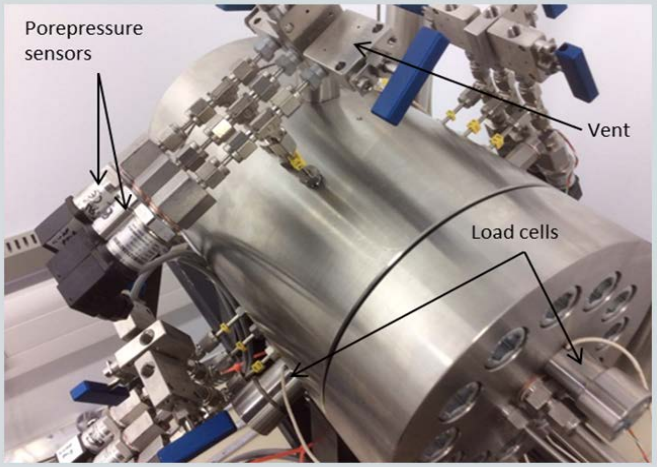
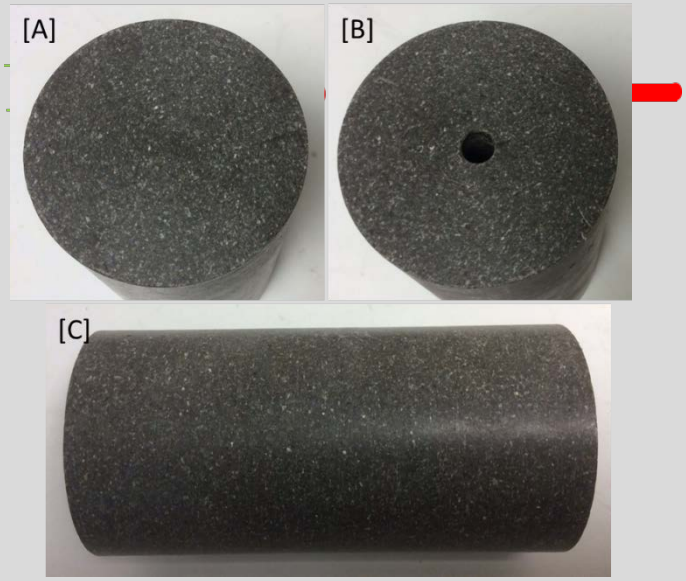
Understanding the homogenisation behaviour of bentonite: Laboratory and field observation 3-4/11/15

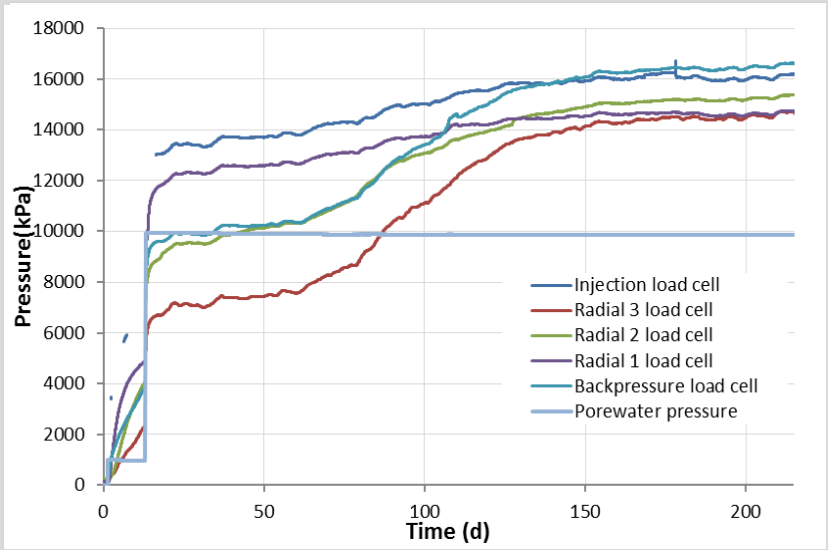
Jon Harrington,

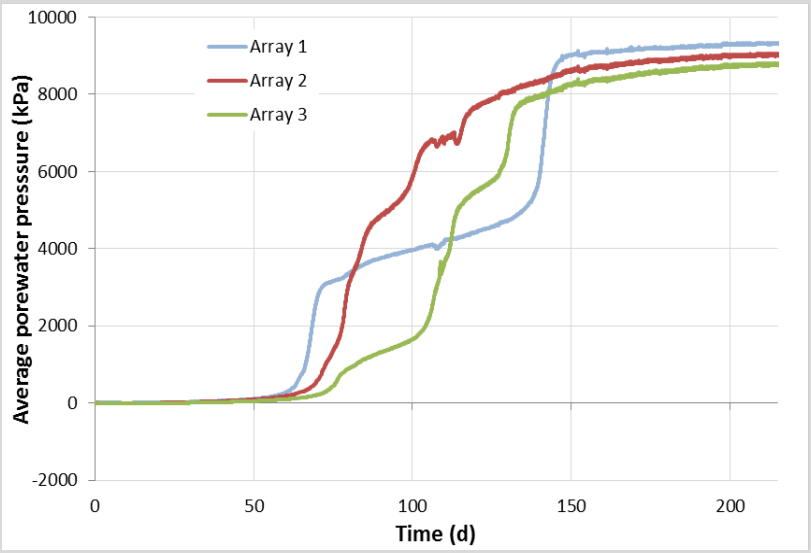
Rob Cuss, Caroline Graham, Tony Milodowski and Andrew Wiseall

Laboratory experiments – homogenisation of porewater and stress



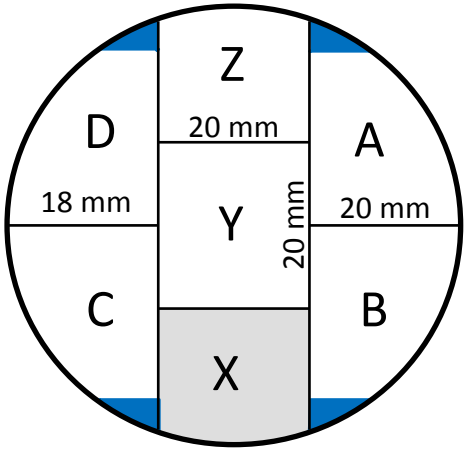


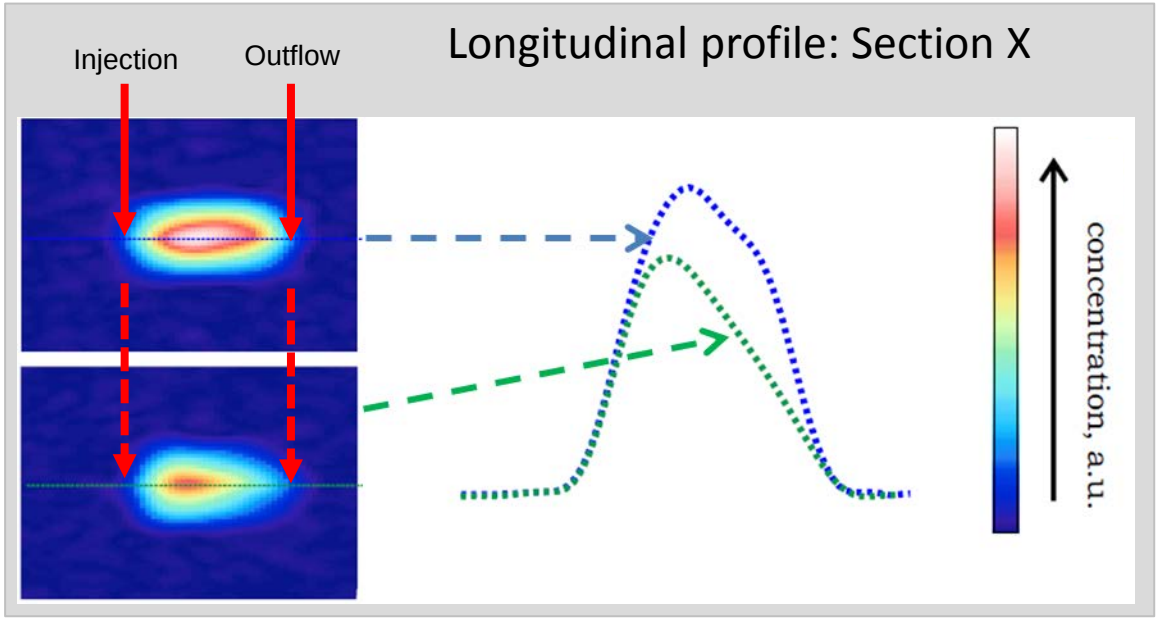


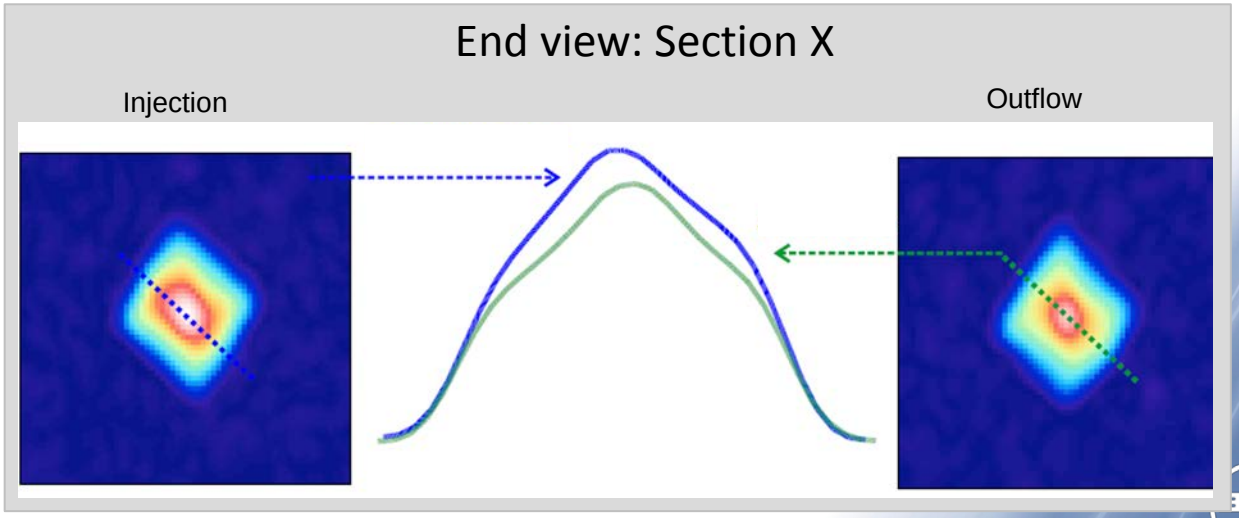


Porewater flow tracking

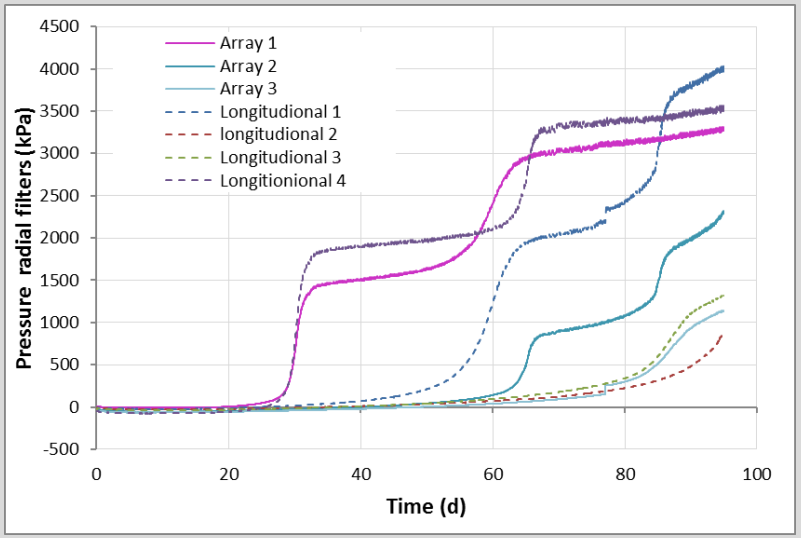
Sample sections

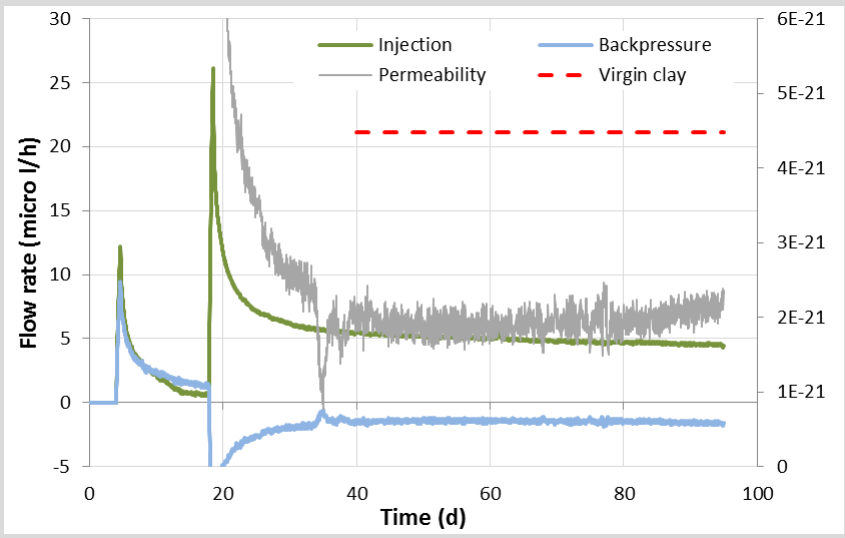


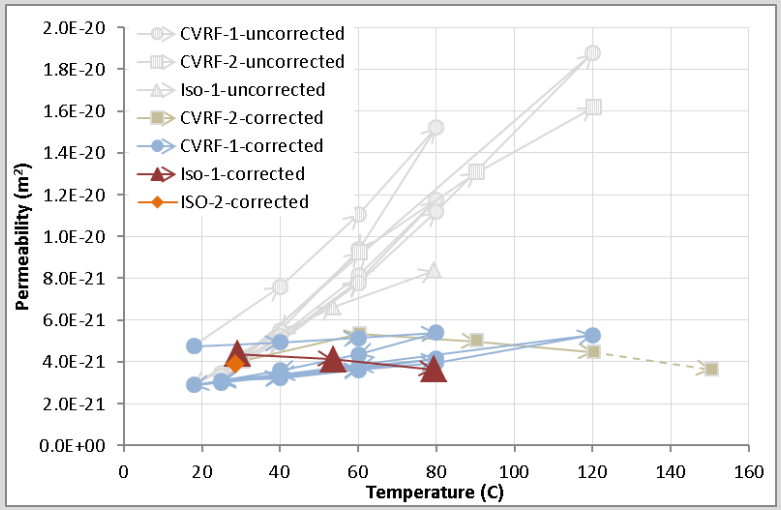




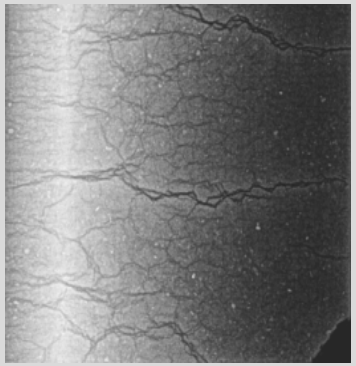
Laboratory experiments – homogenisation of permeability and thermal influences



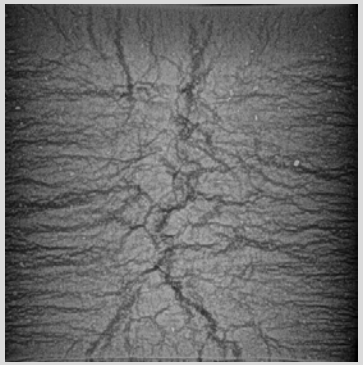




Untested



Tested

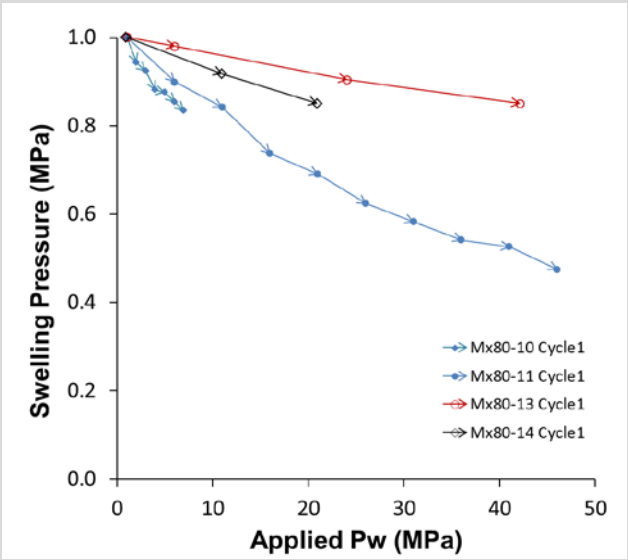


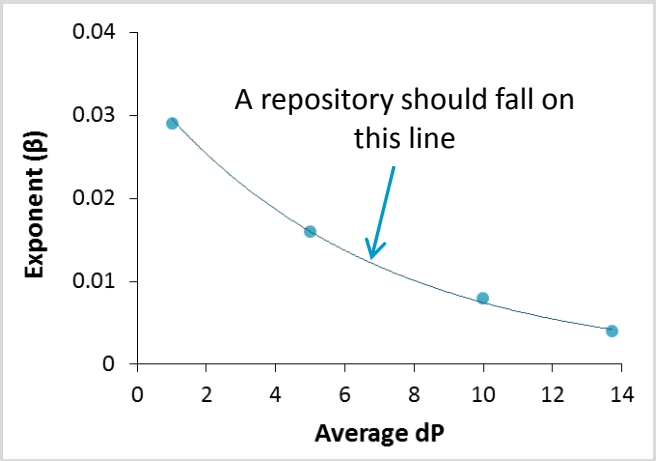
inlet

outlet

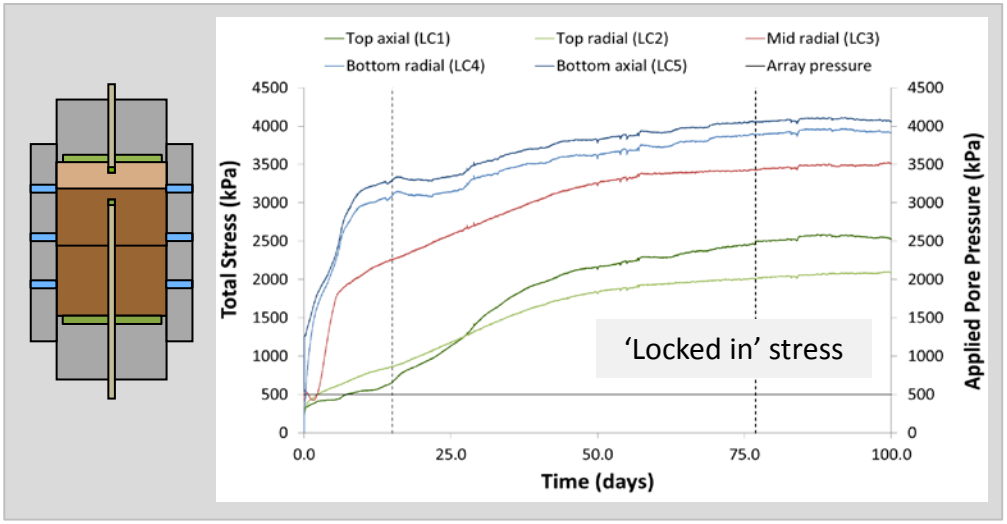
Heterogeneity in distribution of micro-fracturing in post-test bentonite bares no relationship to original bentonite clast “domain” fabric

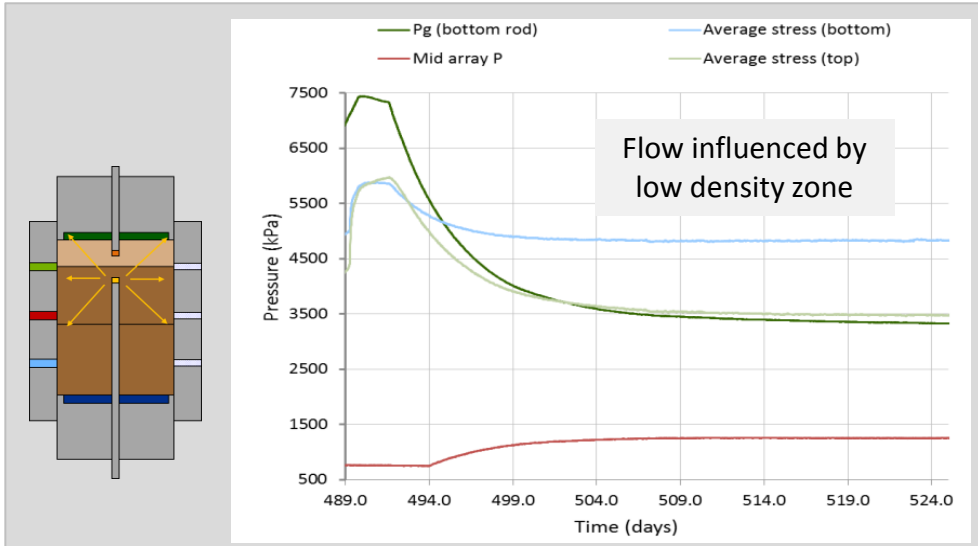
Laboratory experiments – homogenisation under different hydraulics gradients and coupling in dual density systems



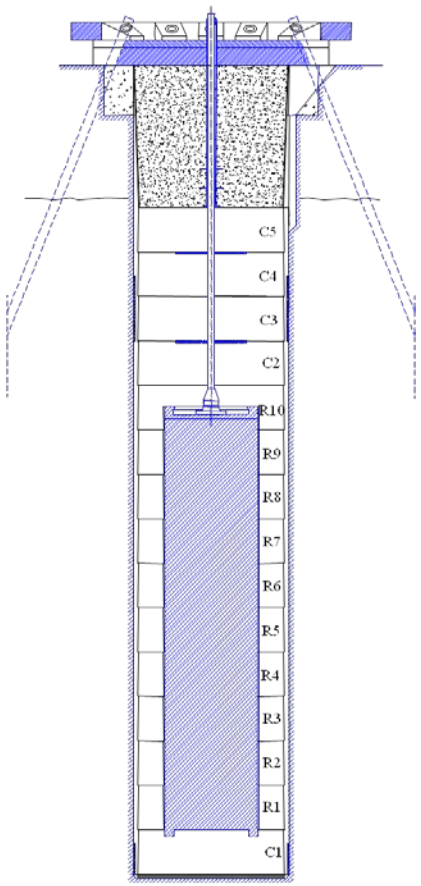


$$\sigma = p_w + \pi_0 \, e^{-\beta p_w}$$

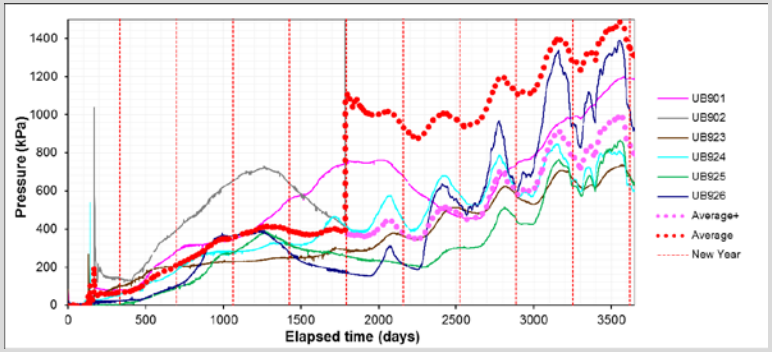




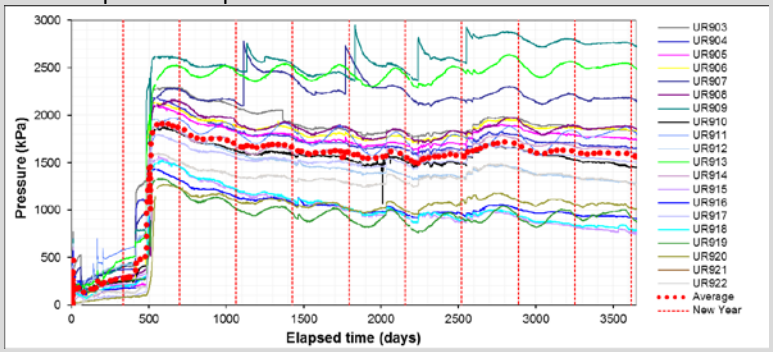
Field-scale observations (Lasgit)



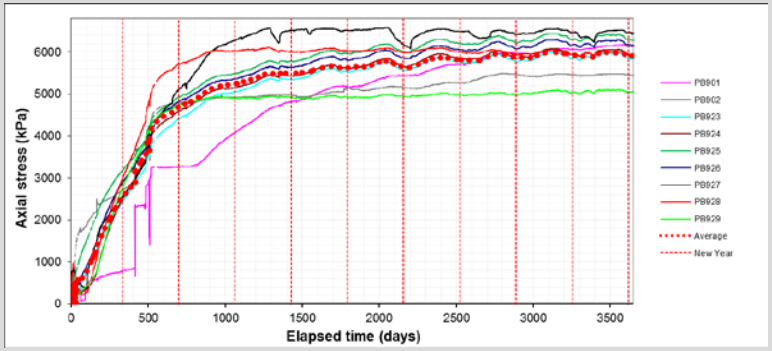
Internal porewater pressure



External porewater pressure

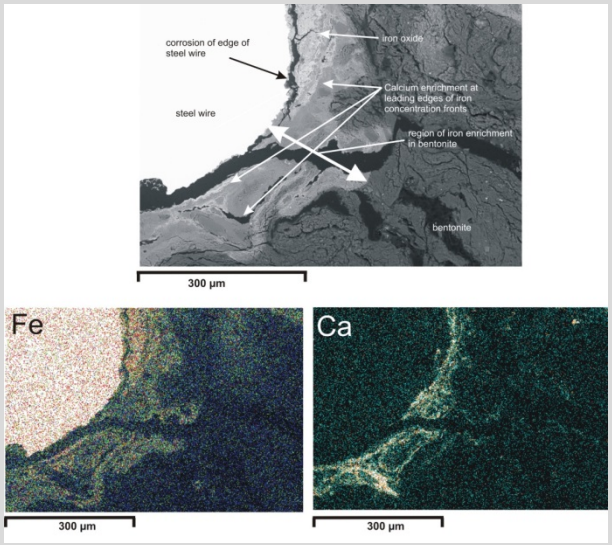


Internal stress



- Complex porepressure history
- Stress development not linked to internal porewater pressure (poor proxy for hydraulic equilibrium)
- After 10 years stress and pore pressure yet to reach equilibrium

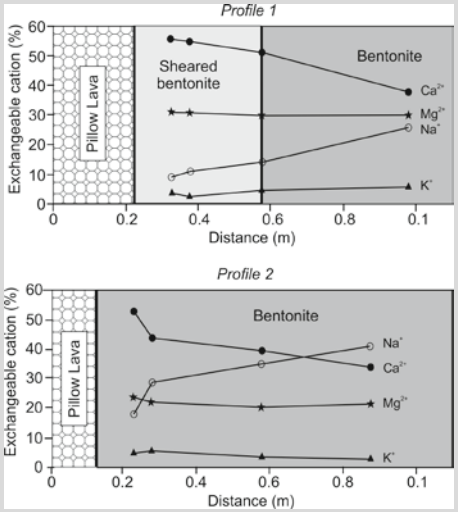
Chemical heterogeneity: steel corrosion



- Alteration of bentonite induced by the corrosion of steel produces chemical heterogeneity in exchangeable cation distribution
- Potential for heterogeneity in distribution of physical properties related to cation exchange capacity and exchangeable cation chemistry: e.g. swelling, shrinkage, microfracturing

Milodowski et al., 2009. SKB Report TR-09-03

Chemical heterogeneity: high pH cement pore fluids



- Hyperalkaline groundwater discharges through fractured Pillow Lavas into bentonite
- Bentonite shows only minimal mineralogical alteration
- However, significant heterogeity in exchangeable cations is observed over metre-scales, induced by exchange of Na^{+} by Ca^{2+} cations

Alexander & Milodowski et al., 2015. Posiva Report WR2014-02

Summary and way forward

- Multiscale laboratory experiments provide an essential route to explore key fundamental processes governing bentonite behaviour:
  - Evolution in density from emplacement to saturation
  - Temporal and spatial development of stress, porewater pressure and swelling response (importance of local vs average values)
  - Distribution, availability and pressure gradients of interstitial fluid (wetting history) during hydration and its impact on bentonite behaviour
  - Impact of thermal load on mechanical and transport behaviour
  - Impact of chemical alteration (e.g. cation distribution when exposed to Fe) on physical properties
  - Development of heterogeneities and their impact on swelling pressure (e.g. loading of retaining plugs)

- Undertake multiscale experiments, in support of numerical modelling, to assess the influence of hydration processes on homogenisation efficiency and its impact on safety function