# Upscaling laboratory measurements: Quantifying the role of hydrothermal alteration in creating geothermal and epithermal mineral resources

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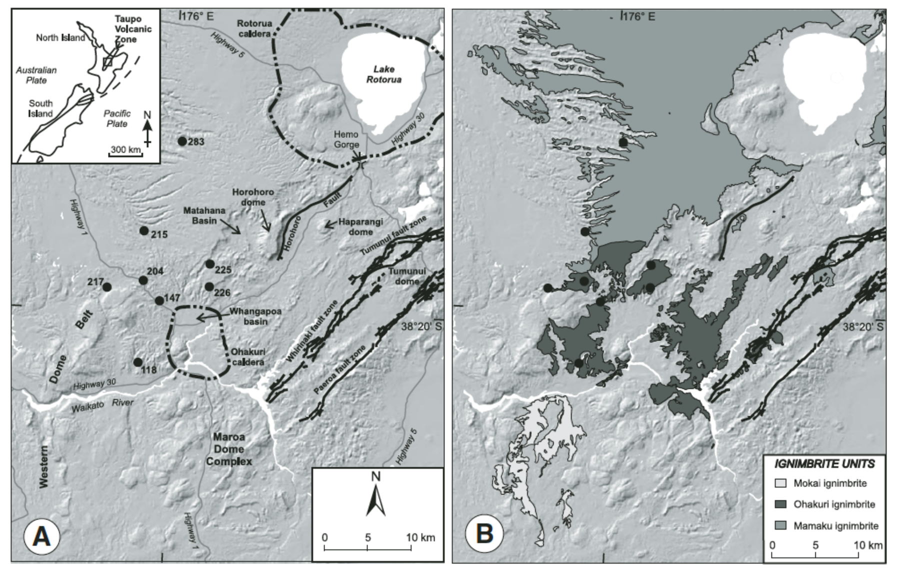
## 1 Introduction

Large-scale hydrothermal convection, driven by magmatic heat, can create economically viable geothermal and epithermal mineral resources. Geothermal energy exploitation is most efficient at high temperatures and high flow rates and requires a high-permeability reservoir and a low-permeability cap. High-grade epithermal deposits typically form in high-flow (high permeability) zones and, in particular, when the flow of hydrothermal fluids is focussed within fractures.

Our goal here is to understand, from a physical property perspective, how geothermal and epithermal mineral resources can develop in an ignimbrite. Our case study site is the Ohakuri ignimbrite (Taupō Volcanic Zone, New Zealand), which hosts a palaeo-hydrothermal system that is now accessible for sampling. We provide physical property measurements for a range of variably altered samples and show how alteration can provide both a permeable reservoir and a low-permeability cap.

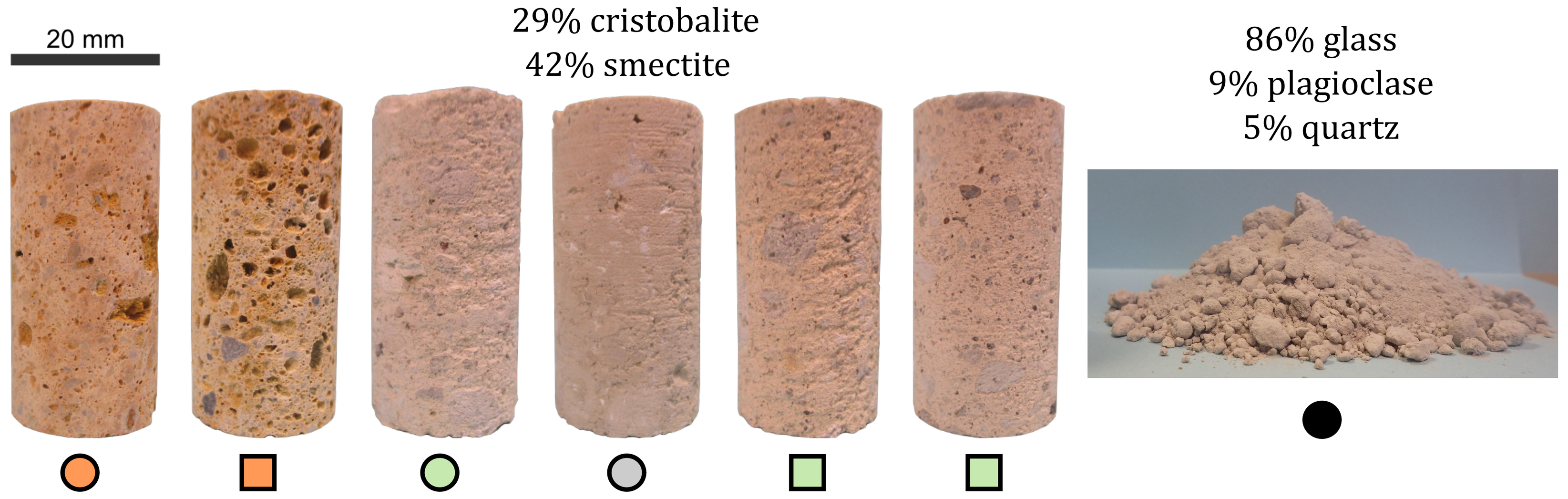



Maps showing the location of the Ohakuri ignimbrite
(Gravley et al., 2007; doi: 10.1130/B25924.1)

## 2 Experimental materials

Highly-altered, dense rock close to the Ohakuri Dam

Unaltered and unlithified parent material




23% plagioclase
6% quartz
29% cristobalite
42% smectite

86% glass
9% plagioclase
5% quartz

53% adularia
47% quartz

74% glass
21% plagiolcase
5% quartz

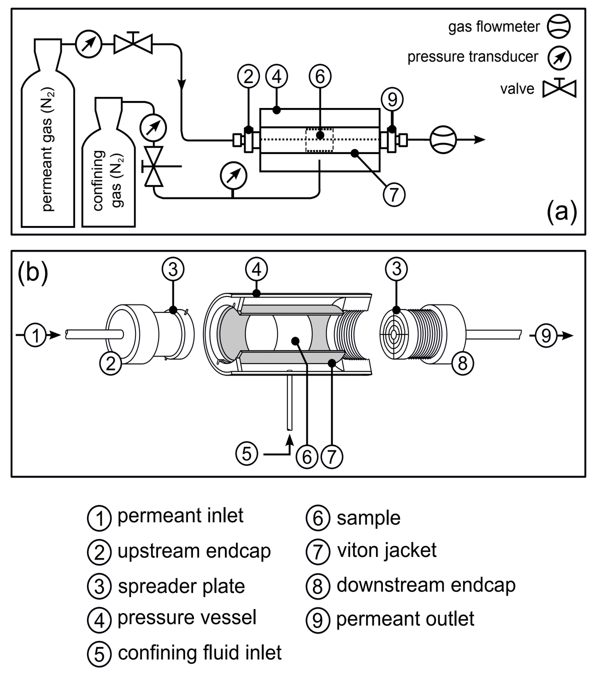
## 2 Experimental methods

Porosity measured using a helium pycnometer

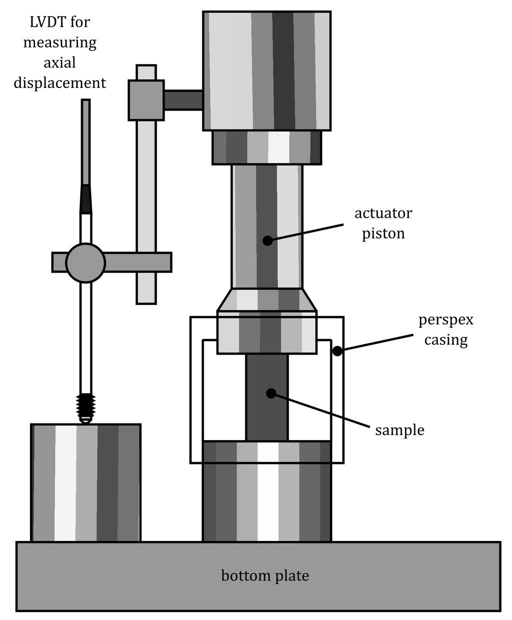
Permeability measured using nitrogen gas at a confining pressure of 1 MPa at at room temperature

Uniaxial compressive strength measured using a uniaxial loadframe

Young's modulus calculated from stress-strain data

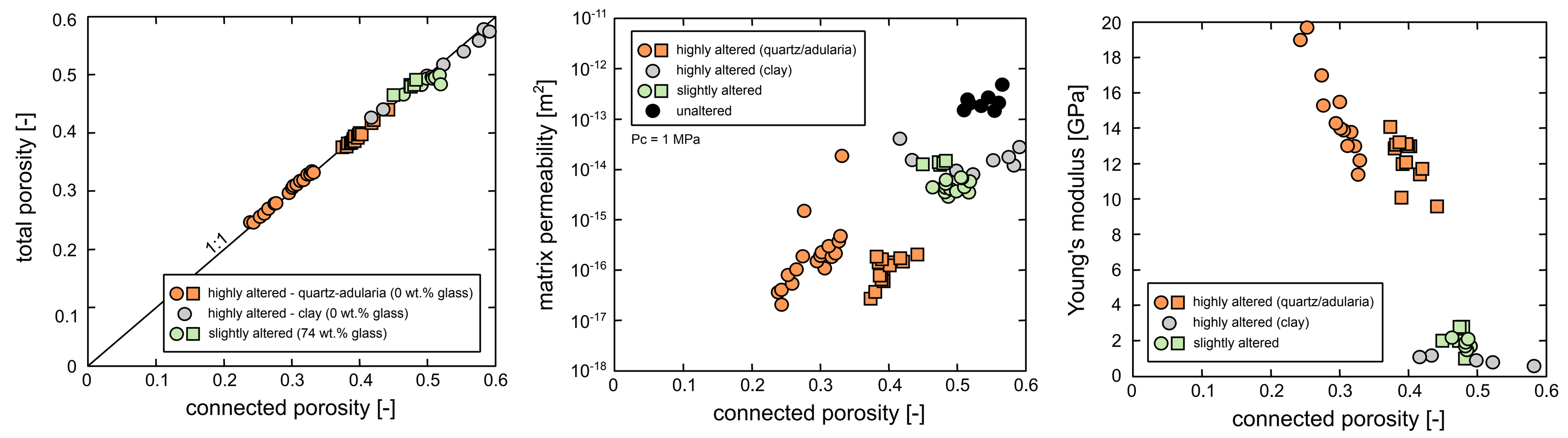



Permeameter
(modified from Heap and Kennedy, 2016; doi: 10.1016/j.epsl.2016.05.004)




Uniaxial loadframe
(Heap et al., 2020; doi: 10.1016/j.jvolgeores.2019.106684)

## 3 Results

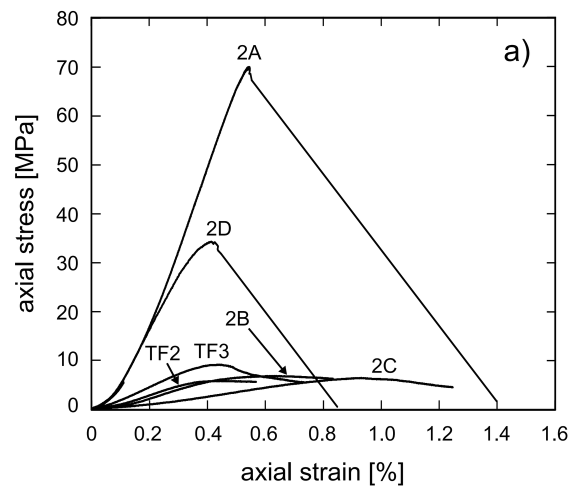



There is no isolated porosity in the studied materials

Permeability is reduced by up to four orders of magnitude as a result of alteration

Young's modulus increases by up to a factor of ten as a result of alteration

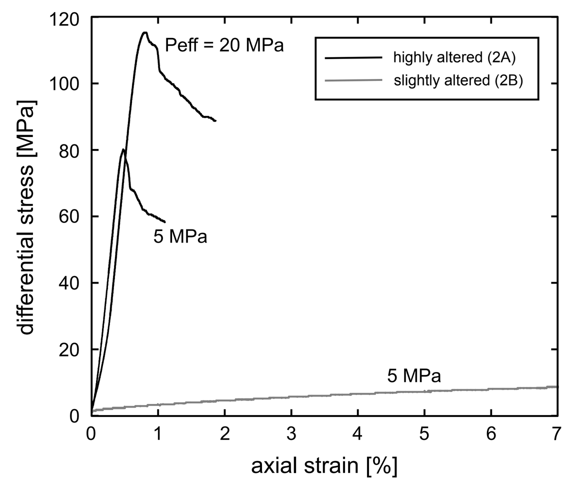
Uniaxial compressive strength increases by up to a factor of ten as a result of alteration

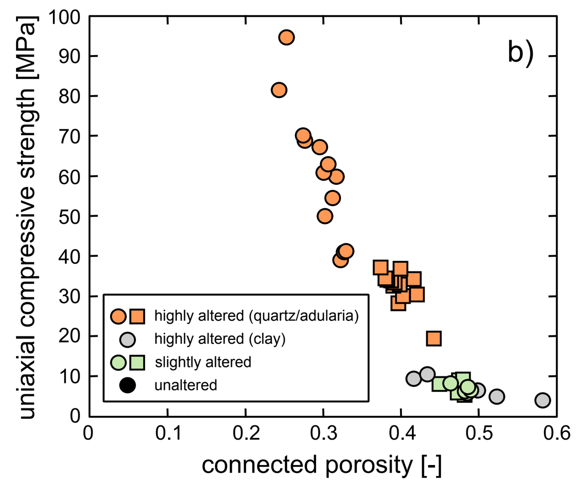



We also performed triaxial deformation experiments

Highly-altered samples are brittle over a range of pressures (depths)

Slightly-altered samples are ductile at low pressure (depth)




## 4 Discussion

Hydrothermal alteration (silicification) significantly reduces matrix permeability

Slight alteration or alteration to smectite does not significantly change matrix permeability

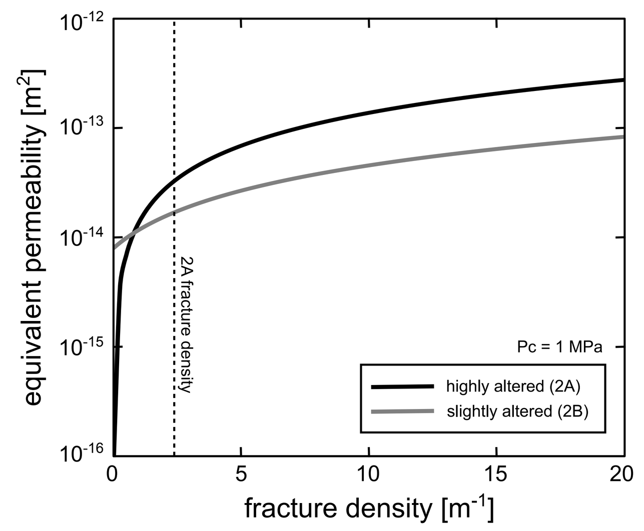
Our results also show that silicification increases the propensity for permeability-enhancing fracture formation. Indeed, we see many fractures in the highly-altered deposit, and essentially no fractures in the unaltered, parent material

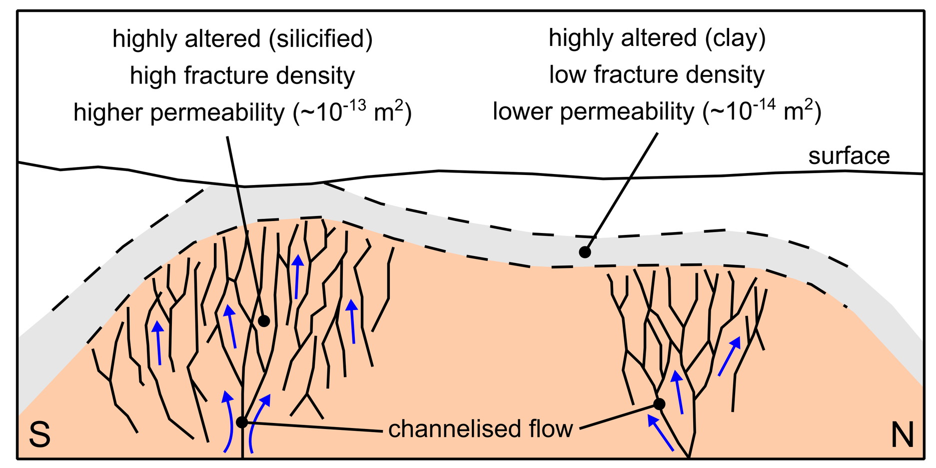
We use a simple two-dimensional model that considers flow in parallel layers (see Heap and Kennedy, 2016) to upscale our laboratory data

We find that highly-altered rock masses are more permeable (despite their low matrix permeability) than moderately-altered rock masses or rock masses characterised by smectite alteration

Large fractures in the highly-altered deposit
Photo credit: M.J. Heap

We therefore show, from a rock physical property perspective, how hydrothermal alteration can produce a high-permeability reservoir and a low-permeability cap required for a viable geothermal resource and the focussed flow required for a viable epithermal mineral resource




**We show using laboratory physical property measurements, and some simple upscaling considerations, that hydrothermal alteration can create economically viable geothermal and epithermal mineral (Au-Ag) resources**