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Experimental And Numerical Modelling Of Thermal Stimulation In Geothermal Core Studies

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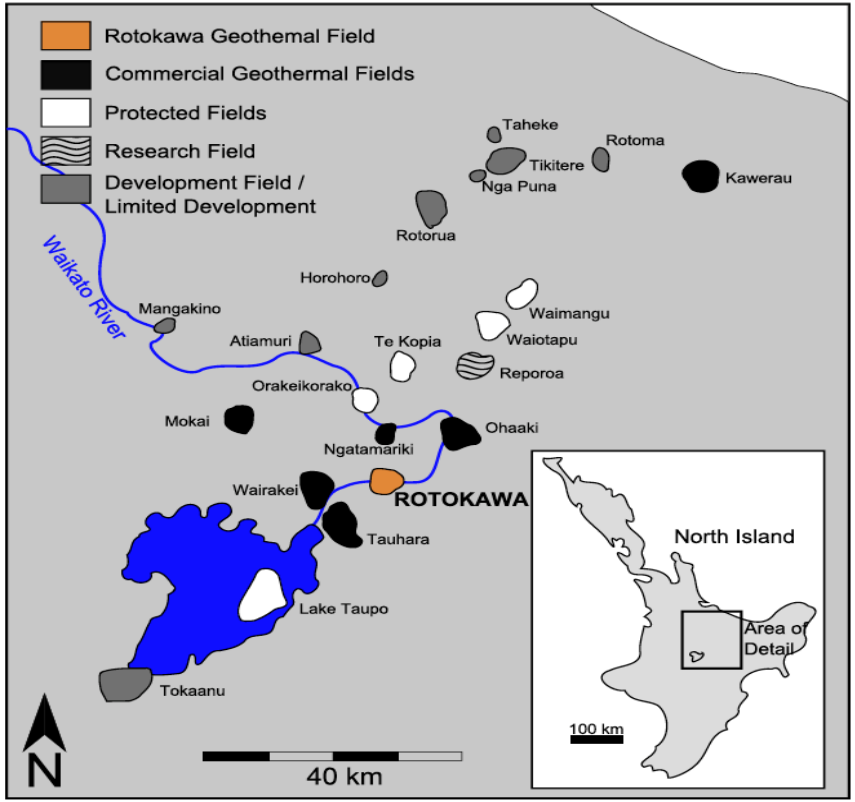
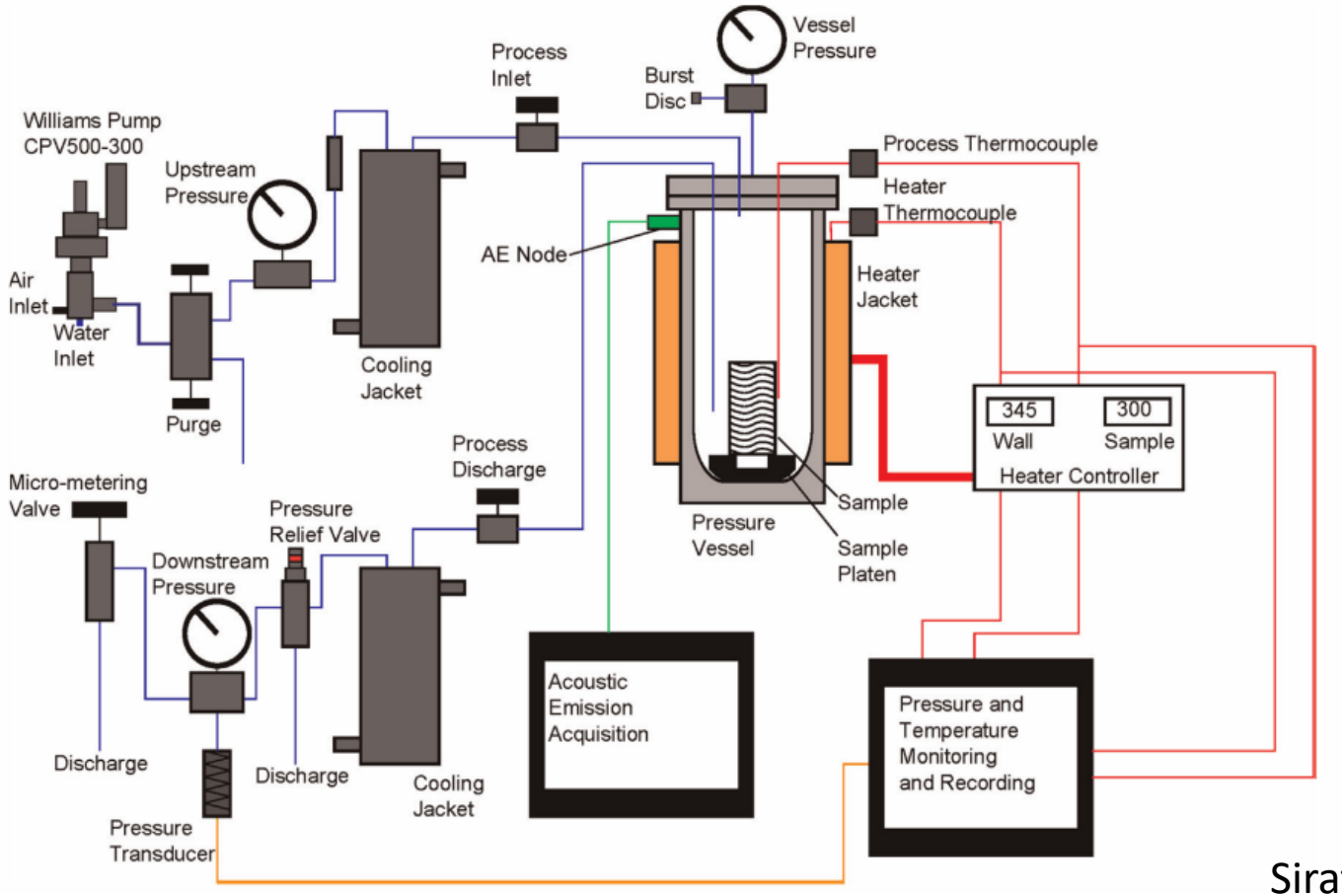
Thermal Stimulation for Geothermal Energy

- New Zealand Geothermal fields: Taupo Volcanic Zone (TVZ)
- Stimulated rock sourced from Rotokawa: Rotkawa Andesite



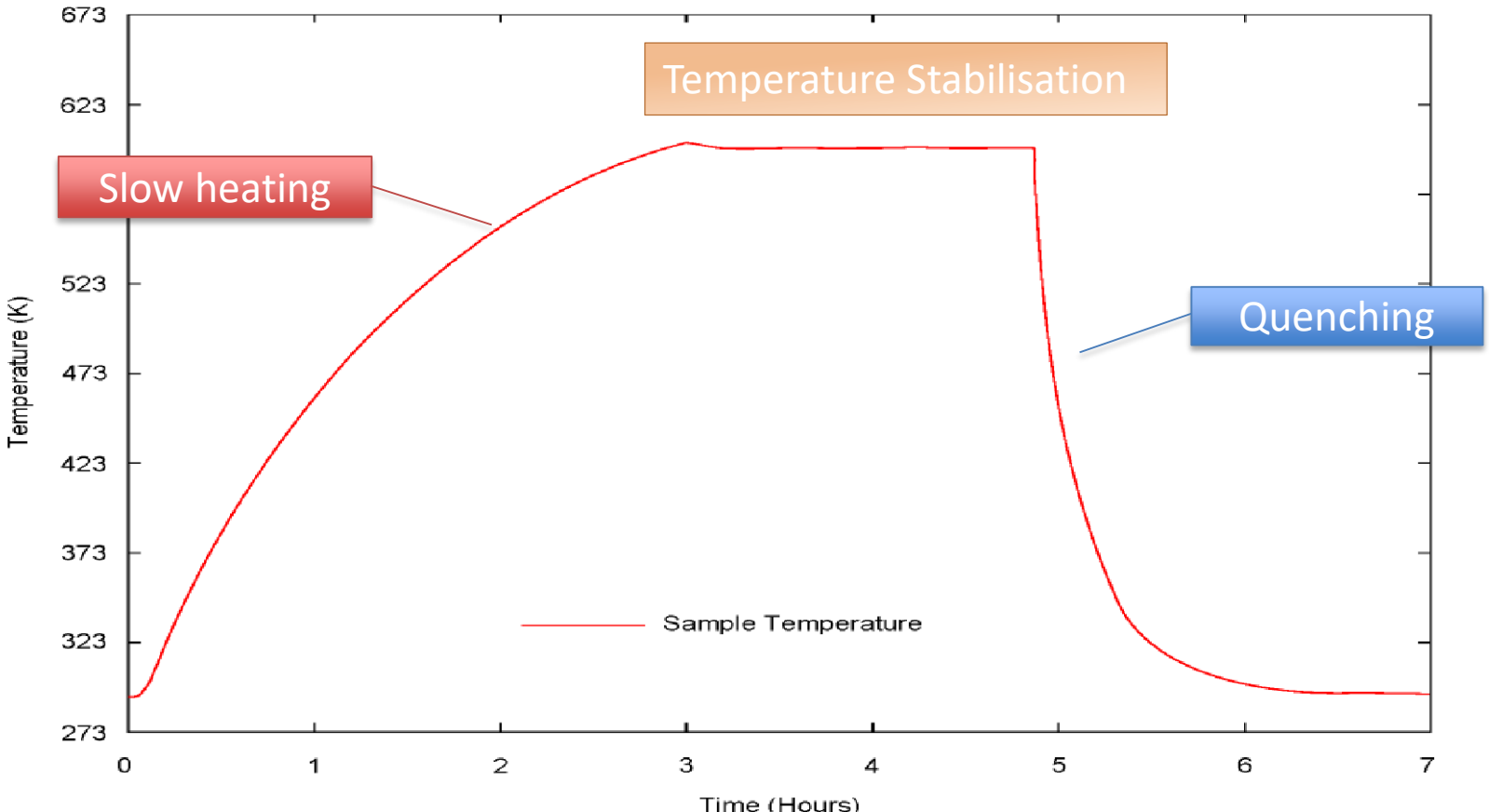
Siratovich et al., 2014

Thermal Stimulator



Siratovich et al., 2015

Thermal Stimulation Curve for Rotokawa Andesite



Numerical Model of Rotokawa Andesite – Mineralogy and Texture

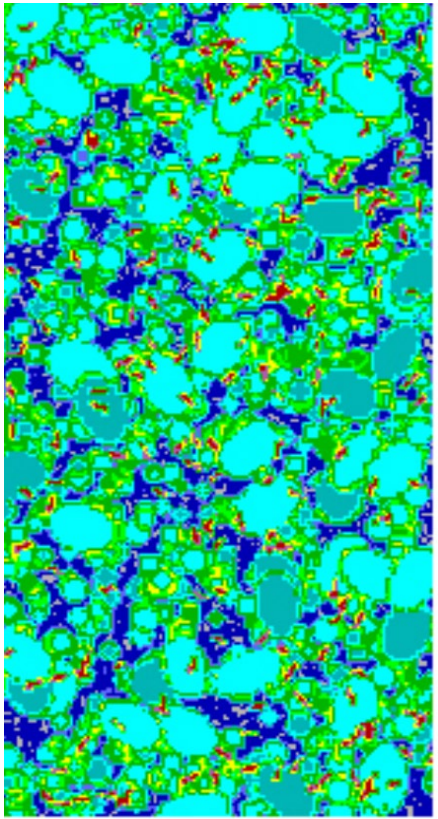
Feldspar

Pyroxene

Chlorite

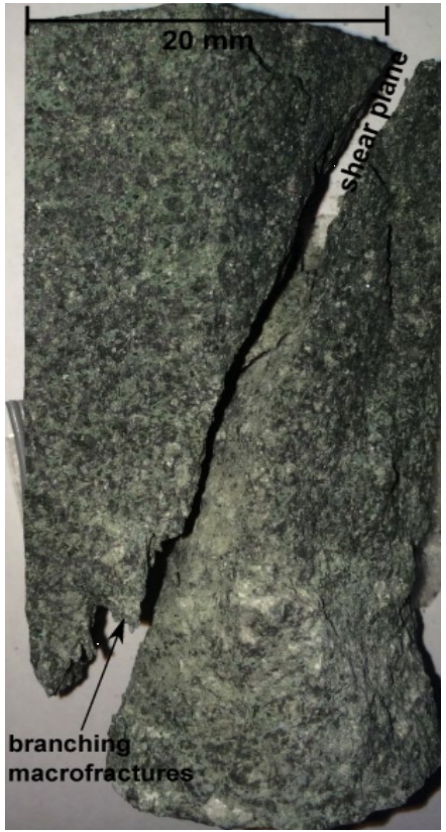
Void

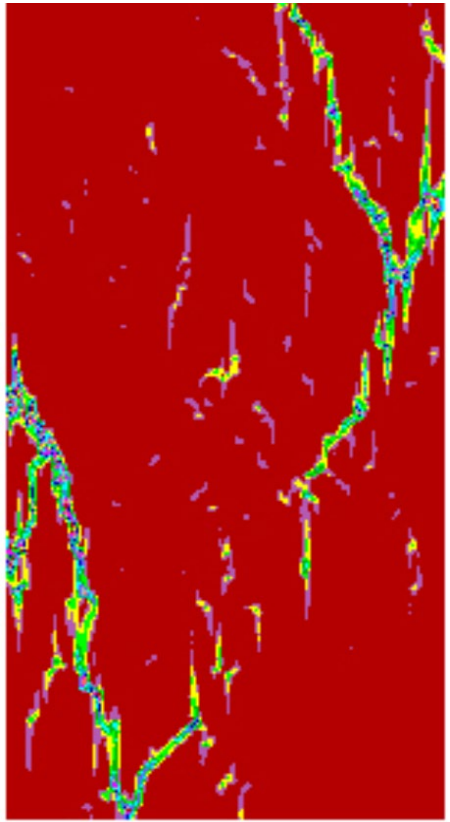
- Mechanical & Physical parameters +
  - Conductivity
  - Linear expansion
  - Specific heat



Numerical Model of Rotokawa Andesite – Mechanical Calibration

Sample	Laboratory	Simulated
UCS (MPa)	105-126	102-108
Young's Modulus (GPa)	31.2-38.9	69-71
Poisson's Ratio	0.19-0.23	0.33-0.36



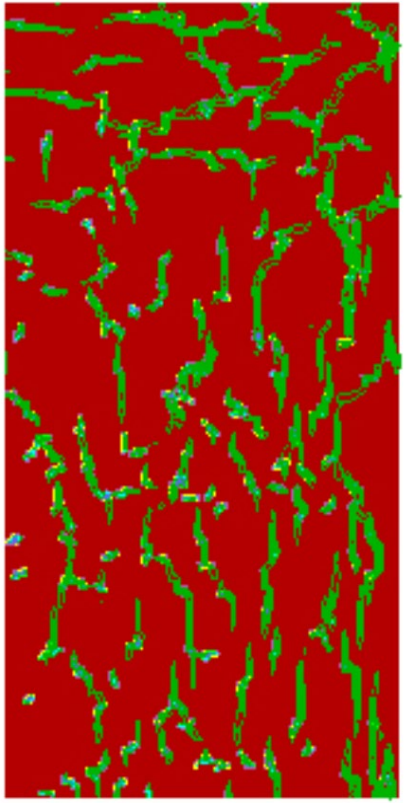


Numerical Model of Rotokawa Andesite – Thermal Calibration

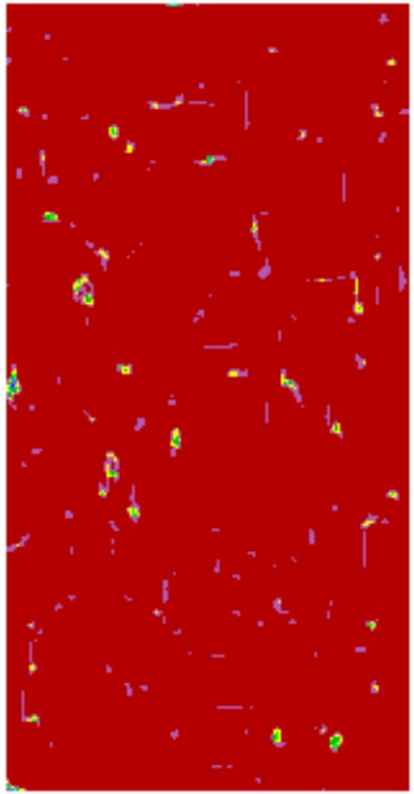
Sample	Linear Thermal Expansion (10^{-6} K^{-1})
Laboratory	8.3 (Rotokawa Andesite average 9 at 300K)
Simulated (initial)	19
Simulated (final)	10.6

Linear Expansion (10^{-6} K^{-1}) for water:
Initial – 69
Final – 1×10^{-7}

Initial – closed porosity

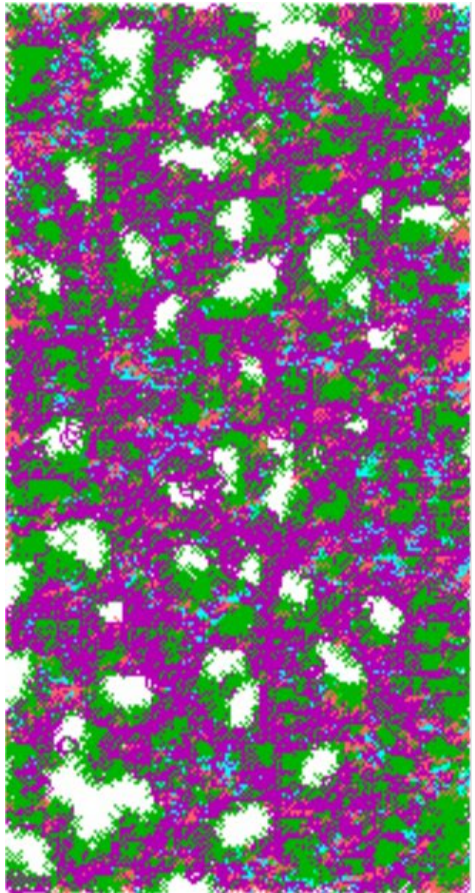


Final – open porosity

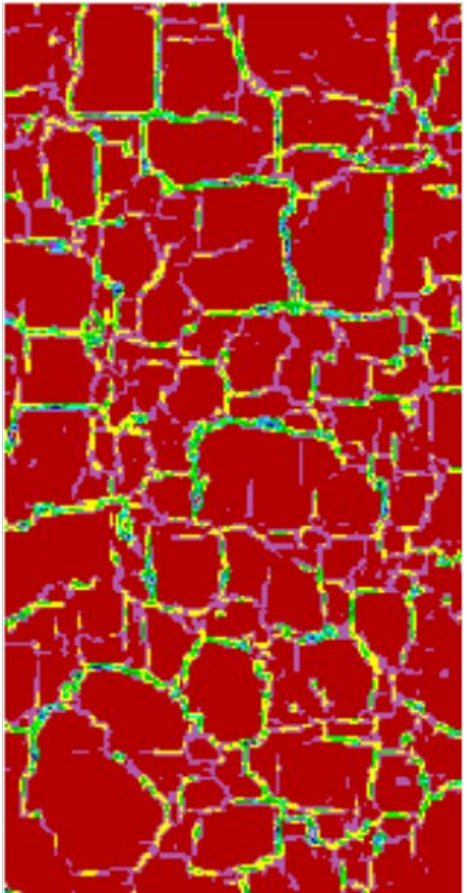


Thermal Stimulation Model Results

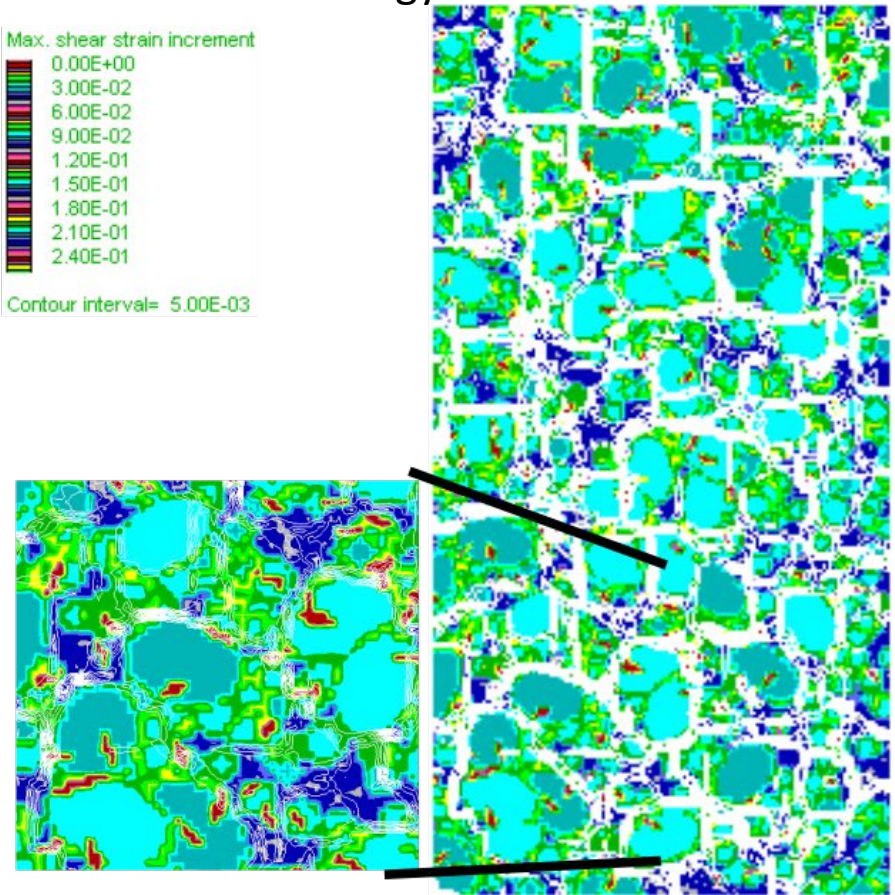
Failed elements



Strain

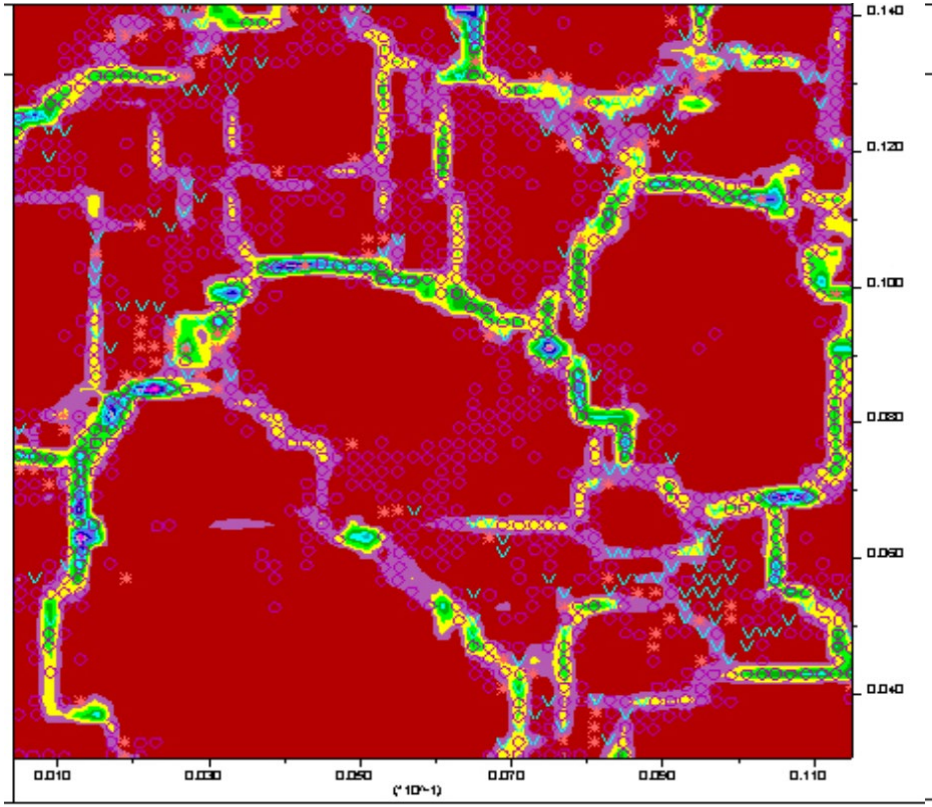


Mineralogy + strain

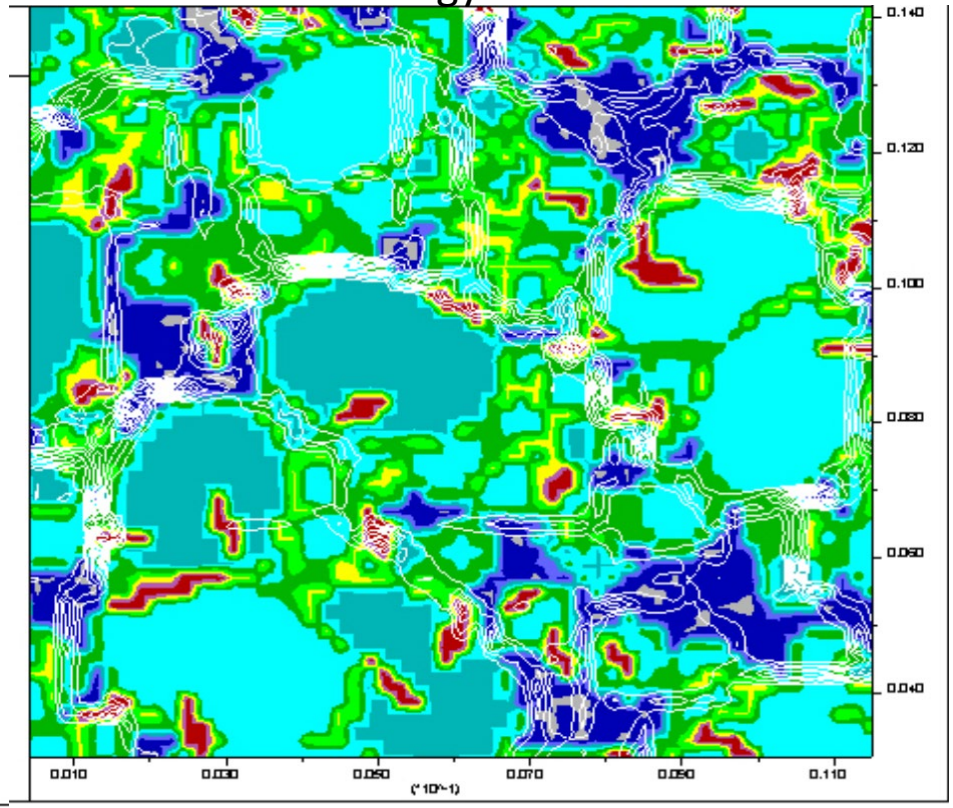


Thermal Stimulation Model Results

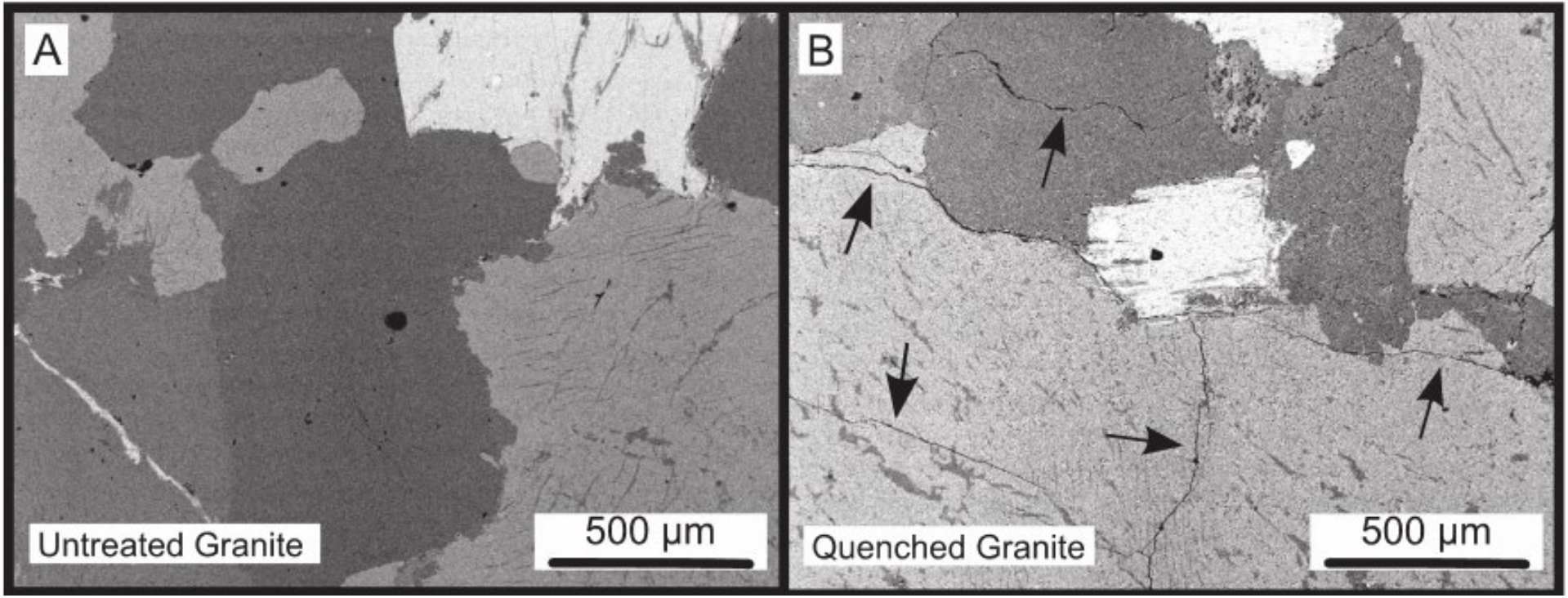
Failed elements + strain



Mineralogy + strain



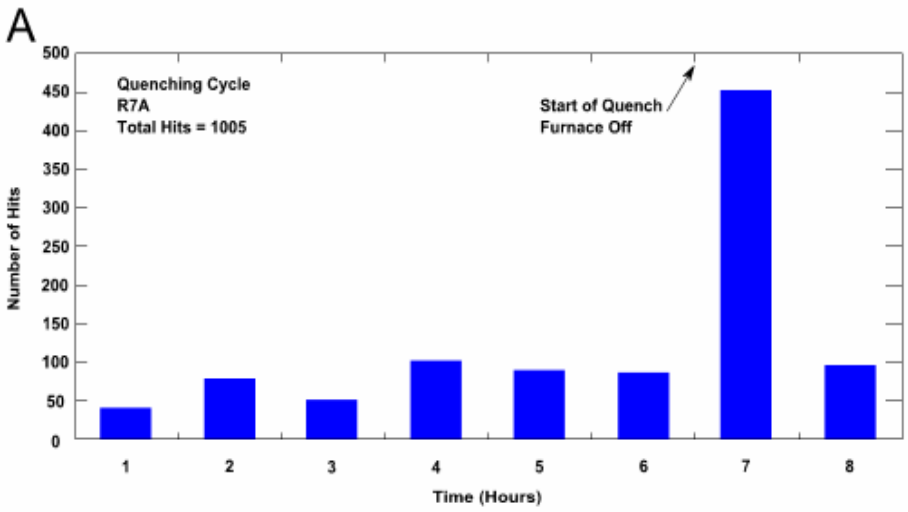
Thermal Stimulation Results



Siratovich et al., 2015

Thermal Stimulation Outcomes

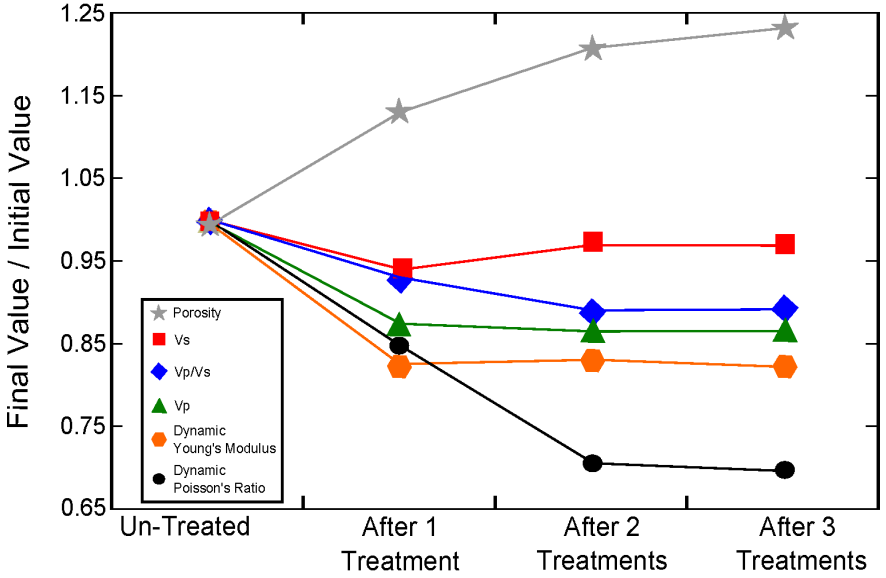
- Can simulate strength and thermal stimulation behaviour
- Varying linear expansion for water simulates closed or open porosity
- Can observe the fracture patterns at the grain scale
- Can examine the development of the fractures with respect to element yield type, minerals, stress state, displacements, temperature variations, etc., all of which can be plotted, queried and output to spreadsheets for quantitative analysis



Siratovich et al., 2015

Thermal Stimulation Future Work - Input

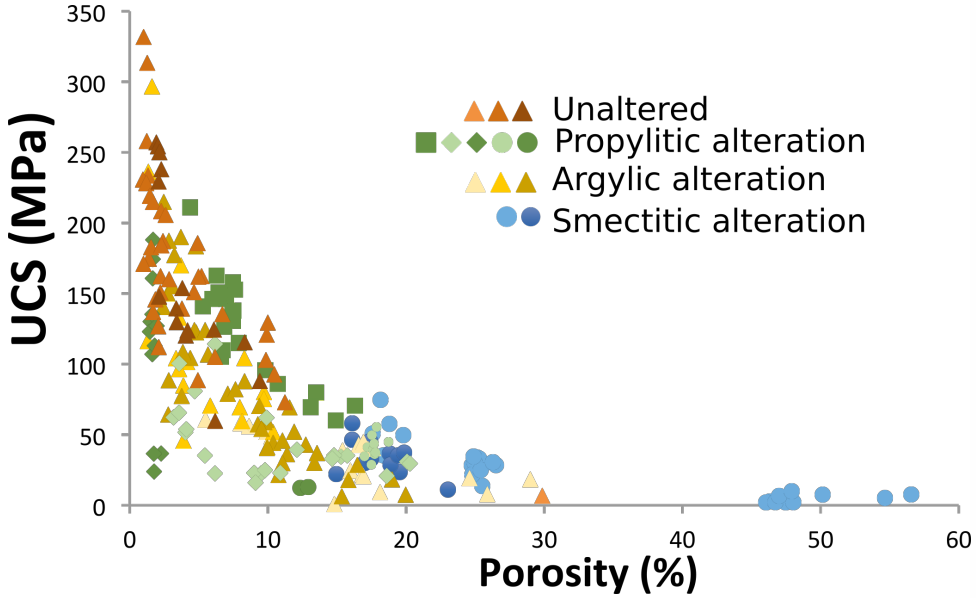
- Incorporate strain-dependent stiffness to better simulate Young's Modulus and Poisson's ratio
- Incorporate temperature-dependent thermal properties to better simulate fracture behaviour as sample is heated, then cooled
- Derive more mineral-specific input parameters



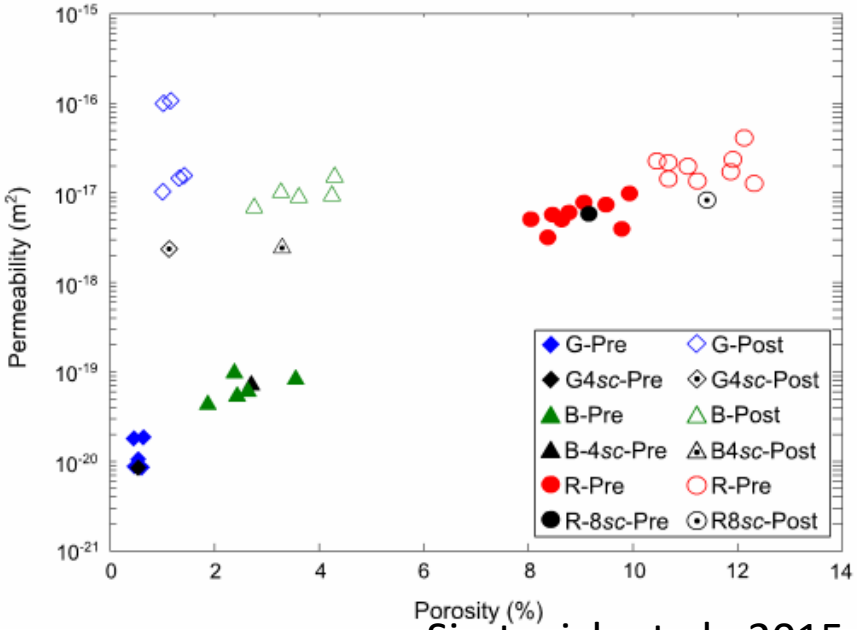
Siratovich, 2013

Thermal Stimulation Future Work - Input

- Derive function to determine changes in porosity
- Couple with water flow model (i.e. Tough2 - FLAC) for permeability



Villeneuve et al., 2019



Siratovich et al., 2015

References

Siratovich, P.A. 2013. Thermal Stimulation of the Rotokawa Andesite: A Laboratory Approach. PhD Thesis, University of Canterbury.

Siratovich, et al. 2014. Physical property relationships of the Rotokawa Andesite, a significant geothermal reservoir rock in the Taupo Volcanic Zone, New Zealand. *Geothermal Energy*, 2:10

Siratovich, et al. 2015. Saturated heating and quenching of three crustal rocks and implications for thermal stimulation of permeability in geothermal reservoirs. Int J Rock Mech Min 80, 265–280.

Villeneuve, M., Kennedy, B., Gravley, Mordensky, Heap, Siratovich, P., Wyering, L., Cant, J., 2019. Characteristics of altered volcanic rocks in geothermal reservoirs. ISRM Symposium, Foz do Iguassu, Brazil.