An insight into Whakaari's conduit:

How altered tuffs and subsurface pressures can control volcano dynamics

Shreya Kanakiya[1*], Ludmila Adam[1], Michael C Rowe[1], Jan Lindsay[1], and Lionel Esteban[2]
[1]University of Auckland, School of Environment, Auckland, New Zealand
[2]CSIRO-Energy, Perth, WA, Australia

This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

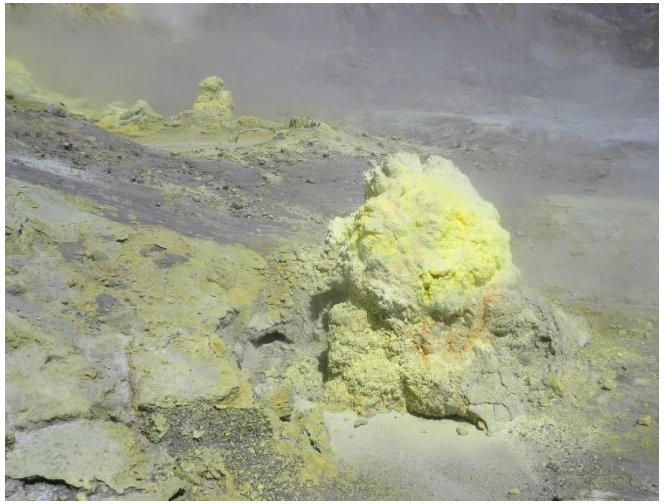
Whakaari (White Island)

New Zealand’s most active volcano

- Most recent eruption in 2019.
- Phreatic eruptions are most common at Whakaari. Eruptions have also been of phreatomagmatic, strombolian, or dome-forming nature.
- At least two collapses have occurred in the past.

Whakaari (White Island)

Has a dynamic hydrothermal system



Sulfur flows & mud pools

Persistent degassing

Widespread rock alteration

OUR GOALS

To aid monitoring of alteration on volcanoes

OUR GOALS

Hydrothermal alteration related petrophysical changes in rocks

Changes in mineralogy and fluid pathways of representative rocks due to alteration.

Effect on volcano dynamics

Effects of petrophysical changes on overall volcano dynamics, such as predisposition to eruptions or slope failures.

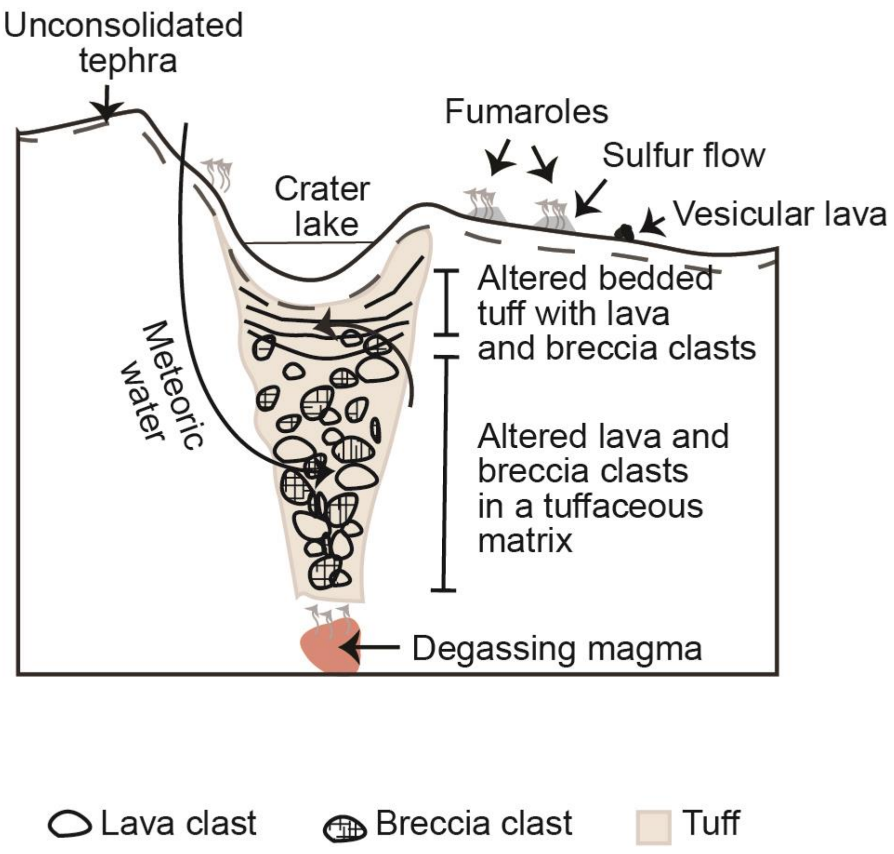
Effect on geophysical signatures

Effects on elastic rock properties with implications for interpreting geophysical monitoring data.

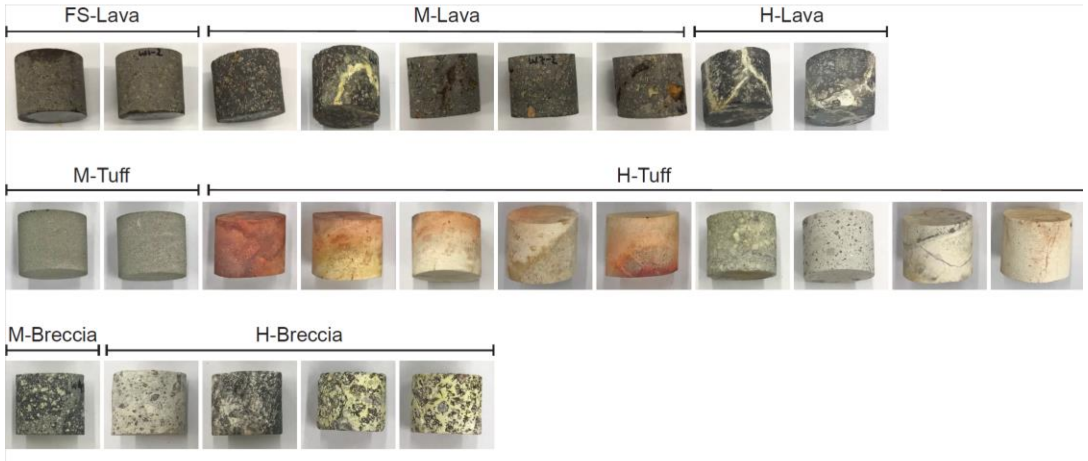
Methods

Field sampling – Whakaari (White Island) in 2018

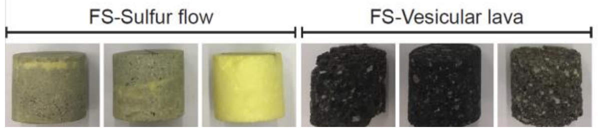
Schematic of White Island



Subsurface (ballistics)



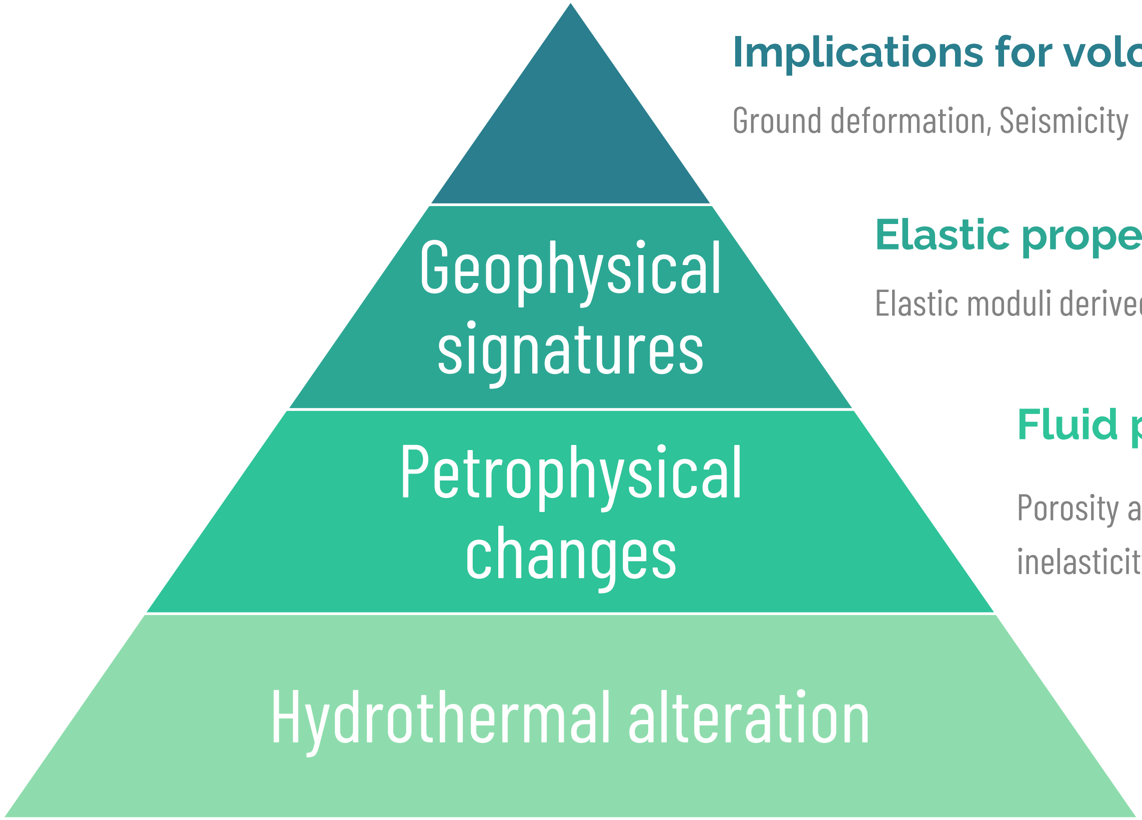
Surface (outcrops)



Kanakiya et al. (2021a, 2021b)

Methods

Experimental and Computational



Implications for volcano monitoring

Ground deformation, Seismicity

Elastic properties

Elastic moduli derived from P- and S-wave velocity at atmospheric and varying pore and hydrostatic pressures.

Fluid pathways

Porosity and permeability at atmospheric and hydrostatic pressures, onset of inelasticity, back-scattered electron imaging.

Mineralogy

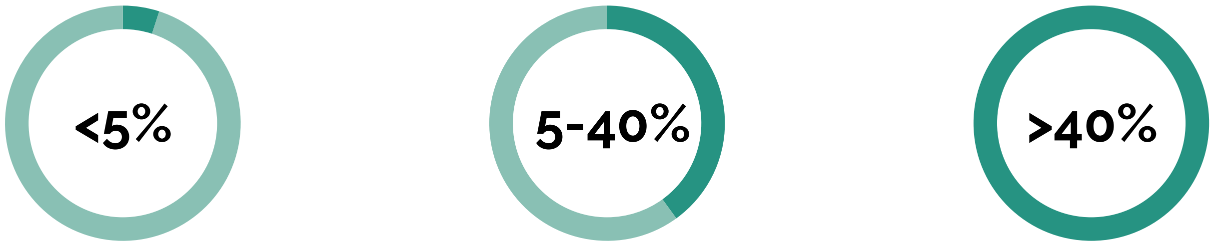
X-ray diffraction analysis, AMORPH, thin section analysis, back-scattered electron imaging, and energy dispersive spectroscopy.

Kanakiya et al. (2021a)

Methods

Nomenclature

Hydrothermal alteration intensity
(based on amount of secondary phases)

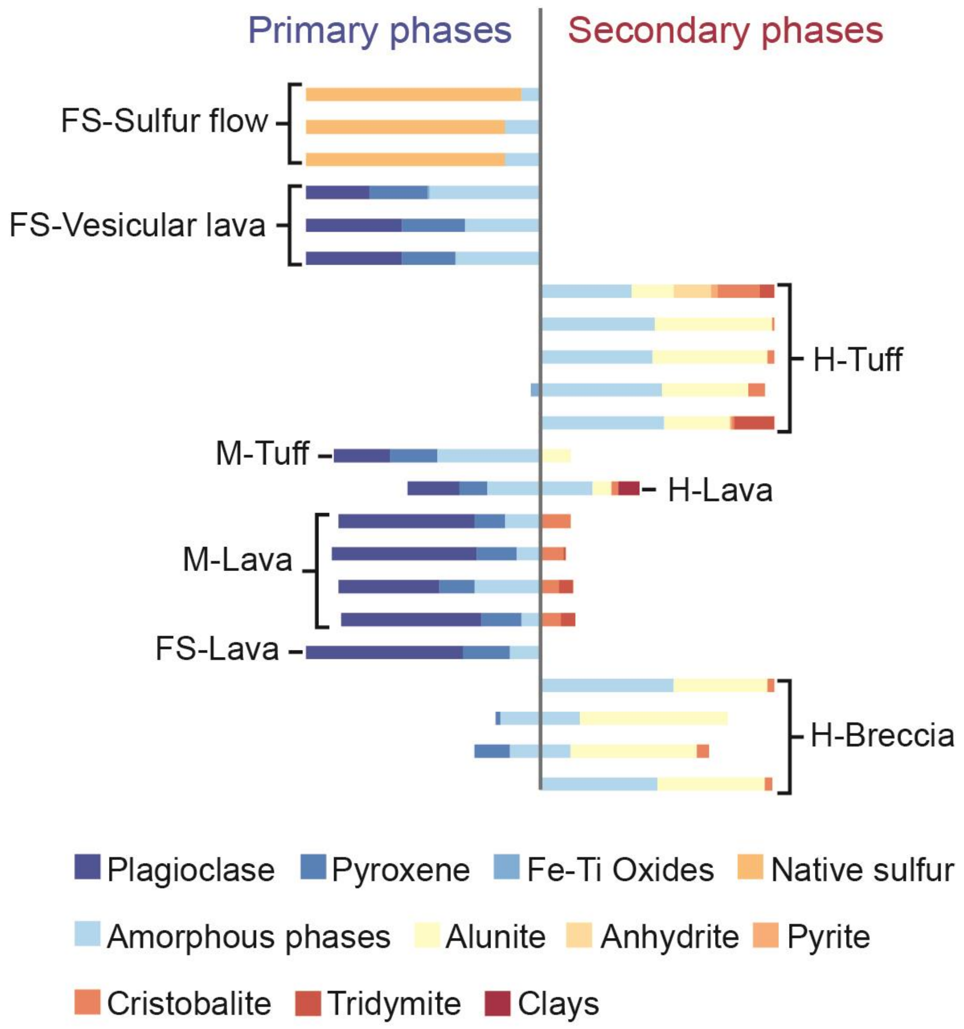


Fresh-slightly altered (FS-) | Moderately altered (M-) | Highly altered (H-)

Kanakiya et al. (2021a)

Acid-sulfate alteration

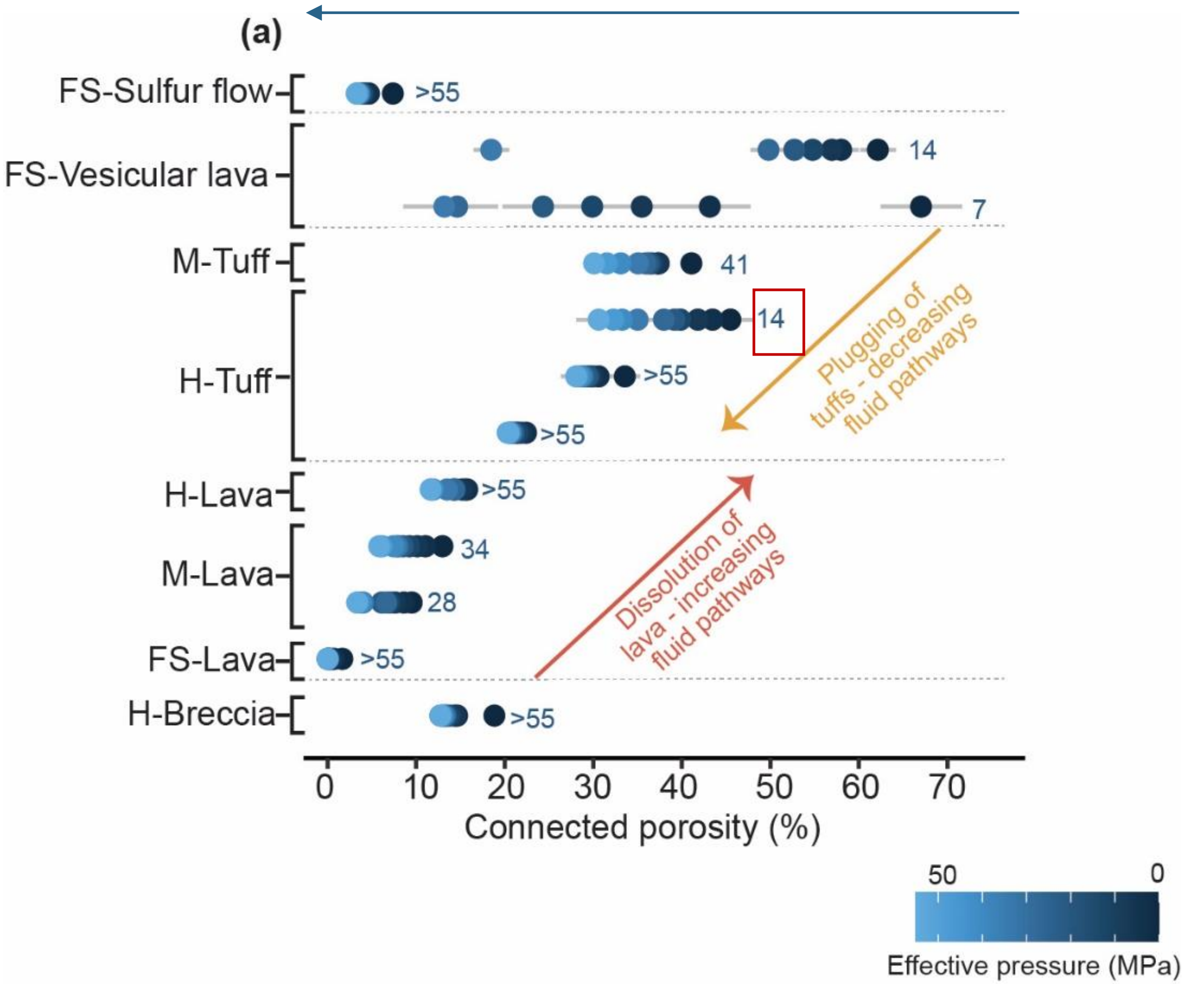
- Rocks are altered by hot (< 400ºC) SO_2-rich fluids.
- Dissolves primary rock-forming minerals.
- Precipitates secondary minerals.



Kanakiya et al. (2021a)

Changes in fluid pathways & onset of inelasticity

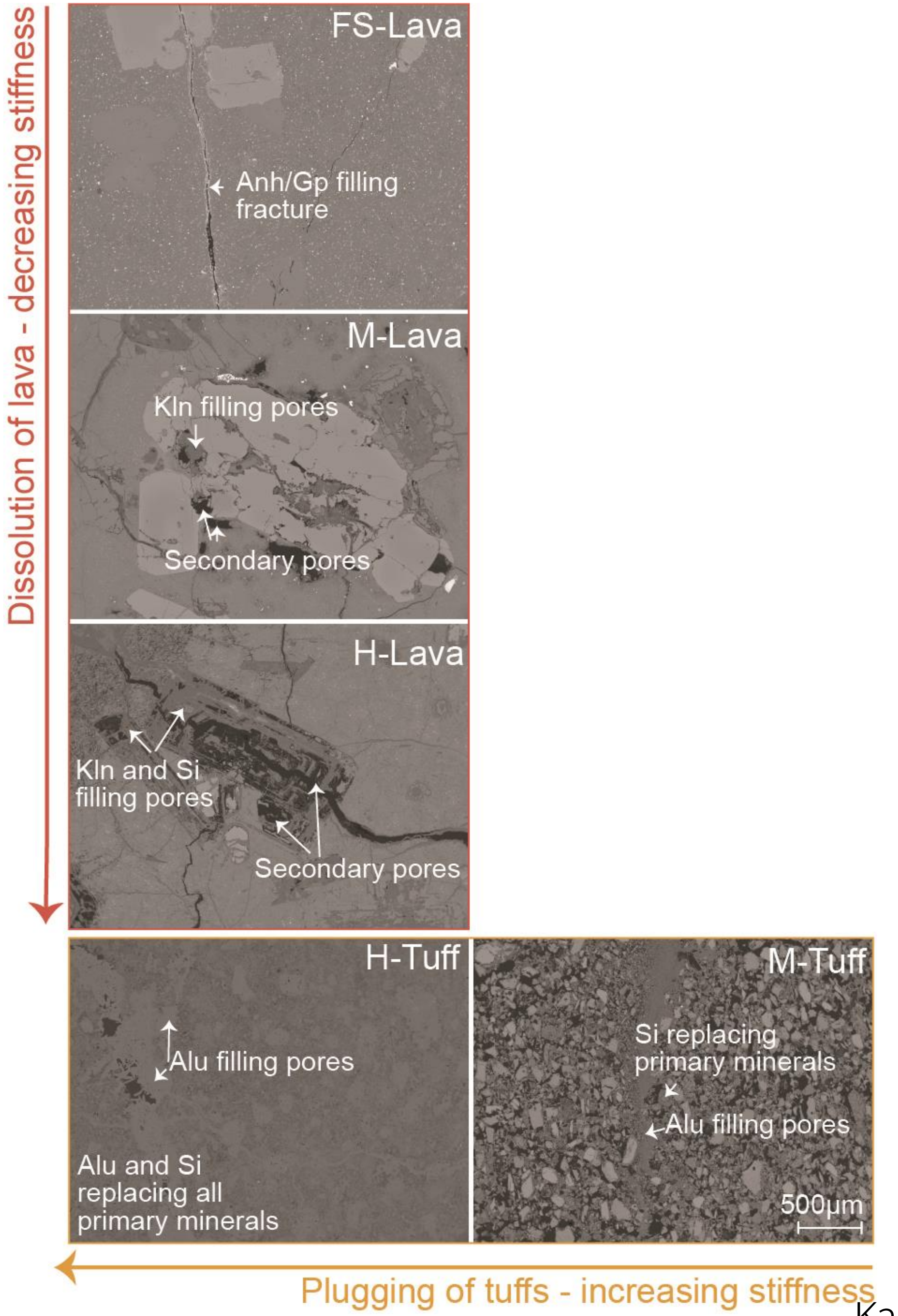
- Porosity decreases with increasing effective pressure.
- Contrasting changes in fluid pathways through lava and tuff with increasing alteration.
- Inelastic compaction begins as low as 14 MPa (< 1 km depth) in tuffs.



Kanakiya et al. (2021a)

Changes in fluid pathways & onset of inelasticity

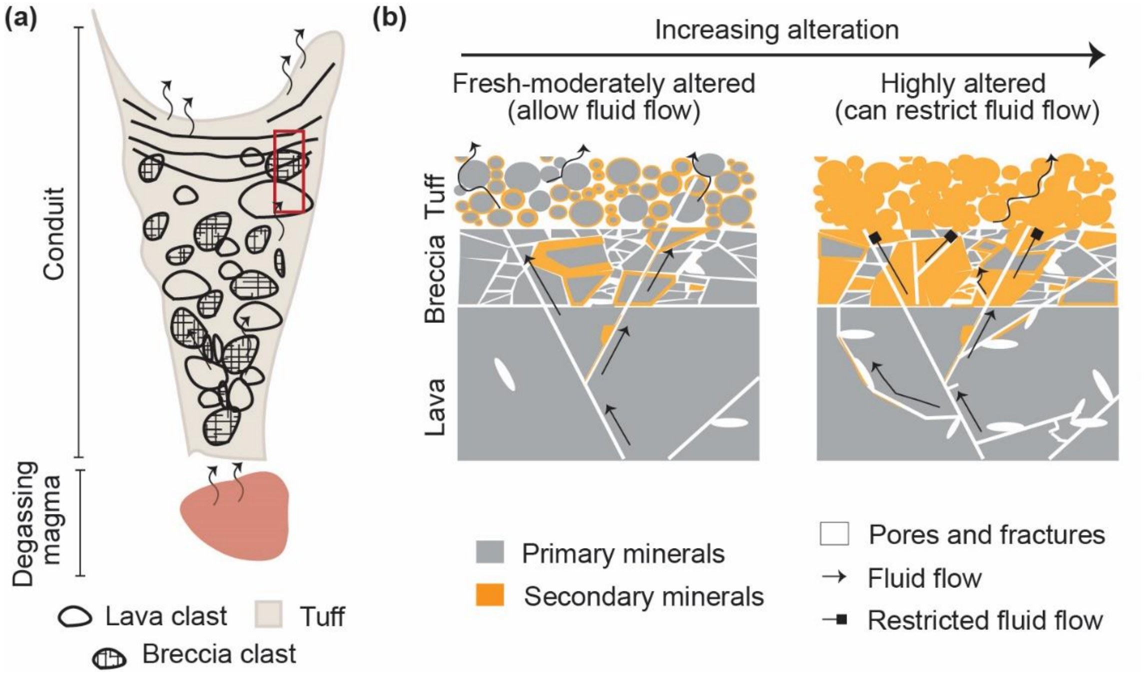
- Porosity decreases with increasing effective pressure.
- Contrasting changes in fluid pathways through lava and tuff with increasing alteration
- Inelastic compaction begins as low as 14 MPa (< 1 km depth) in tuffs.



Kanakiya et al. (2021a)

Volcano dynamics

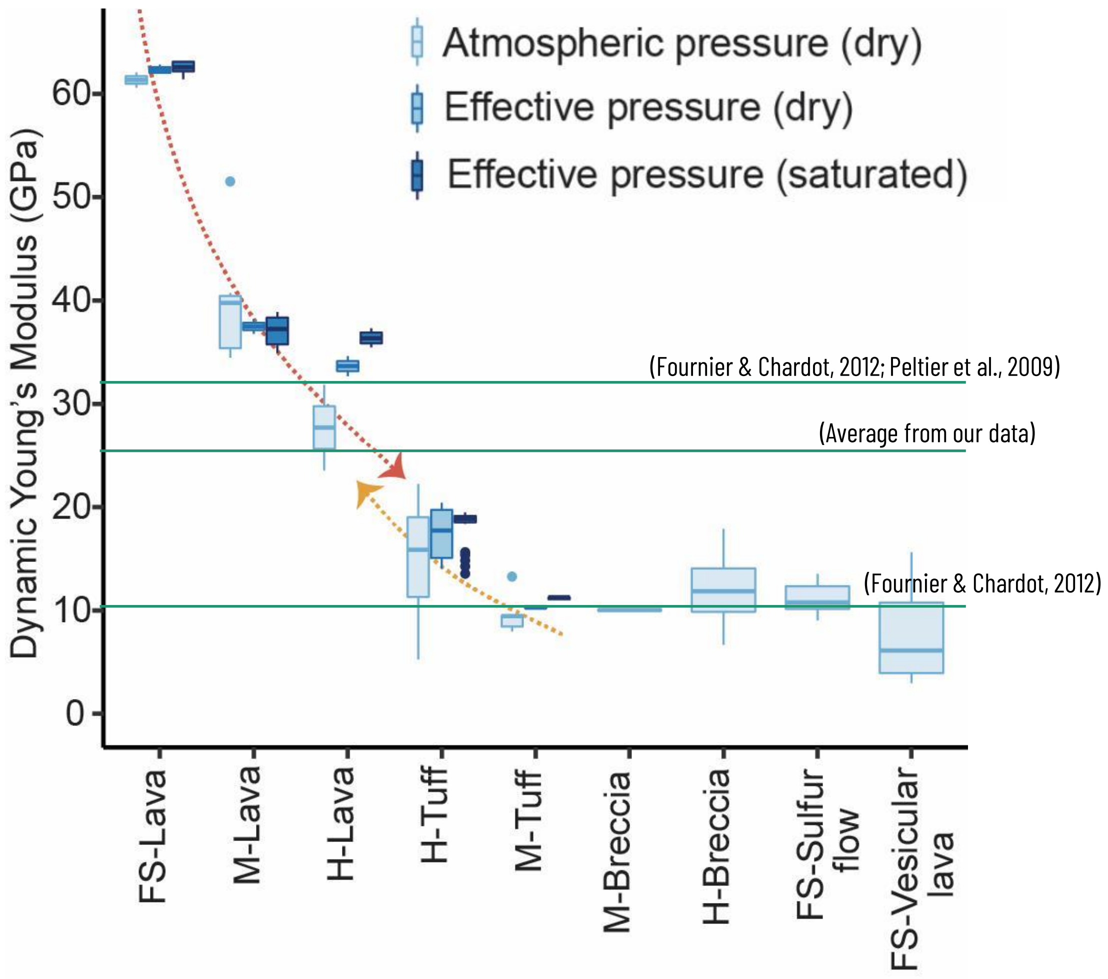
- Subsurface pressures reduce fluid pathways by crack closure in lavas and breccias and compaction, especially in tuffs.
- Over months to years: Hydrothermal alteration, reducing overall pathways for fluids to degas.
- Other sealing mechanisms: solid-state sintering, welding, viscous behavior of sulfur.
- Partially sealed hydrothermal system forms.
- If fluid injection rates are high, the volcano can be predisposed to an eruption.



Kanakiya et al. (2021a)

Elastic properties

- Dynamic Young's moduli varies between 5-63 GPa.
- Elastically heterogeneous subsurface.
- Lavas: Stiffness decreases with alteration.
- Tuffs: Stiffness increases with alteration.



Kanakiya et al. (2021a)

Summary

Key findings

Hydrothermal alteration

- The rocks studied underwent acid-sulfate alteration.
- Alunite and silica (cristobalite/ tridymite) are the major secondary mineral phases observed.
- In volcanic conduits, lavas undergo net dissolution and tuffs net secondary mineral precipitation.

Volcano dynamics

- Inherently porous and permeable tuffs, when compacted and highly altered, can form low permeability zones within volcanic conduits.

Geophysical properties

- The subsurface of Whakaari is elastically heterogeneous.
- The data generated in this study can be used as constraints to incorporate heterogeneity into future ground deformation source modelling studies.

Thank You

For more information contact – skan887@aucklanduni.ac.nz

AGU ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters

RESEARCH LETTER
10.1029/2021GL095175

The Role of Tuffs in Sealing Volcanic Conduits

Shreya Kanakiya[1], Ludmila Adam[1], Michael C. Rowe[1], Jan M. Lindsay[1], and Lionel Esteban[2]

[1]University of Auckland, School of Environment, Auckland, New Zealand, [2]CSIRO-Energy, Perth, WA, Australia

Key Points:

- In volcanic conduits, lavas undergo net dissolution and tuffs net secondary mineral precipitation
- The elasticity of conduit-filling lavas and tuffs also changes due to alteration
- Inherently porous and permeable tuffs, when compacted and highly altered, can form seals within volcanic conduits

Supporting Information:

Supporting Information may be found in the online version of this article.

Correspondence to:

S. Kanakiya,
s.kanakiya@auckland.ac.nz

Abstract Acid-sulphate alteration commonly changes the physicochemical properties of volcanic conduits. Although several conduit pressurization models suggest hydrothermal sealing, little experimental evidence exists from conduit-filling rocks on the development of such a seal. Here we show that acid-sulphate alteration affects conduit-filling lavas and tuffs differently, with implications for their role in sealing the conduit. In lavas, alteration creates fluid pathways and decreases rock stiffness by dissolving primary minerals. In contrast, in the inherently porous tuffs, alteration reduces fluid pathways and increases rock stiffness by precipitating secondary minerals. Compaction of tuffs under subsurface pressures together with such alteration-related sealing can form low porosity and low permeability zones within the conduit. Such zones could promote fluid-pressure build-up and predispose the volcano to explosive eruptions. We discuss our results in the context of observed seismicity and ground deformation and suggest using our elastic properties data to constrain geophysical inversions of acid-sulphate altered volcanic conduits.

Findings of this presentation - Kanakiya et al. (2021a)

AGU ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters

RESEARCH LETTER
10.1029/2021GL095732

High Remanent Magnetization Measured in Hydrothermally Altered Lavas

Shreya Kanakiya[1], Gillian M. Turner[2], Michael C. Rowe[1], Ludmila Adam[1], and Jan M. Lindsay[1]

[1]University of Auckland, School of Environment, Auckland, New Zealand, [2]Victoria University of Wellington, School of Chemical and Physical Sciences, Wellington, New Zealand

Key Points:

- Natural remanent magnetization dominates induced magnetization in volcanic rocks from Whakaari
- Hydrothermally altered lavas can carry higher remanent magnetization than fresh lavas
- Both induced and remanent magnetizations should be used to interpret field-scale data

Supporting Information:

Supporting Information may be found in the online version of this article.

Correspondence to:

S. Kanakiya,
s.kanakiya@auckland.ac.nz

Abstract Magnetic surveys are used to identify and monitor hydrothermally altered regions on volcanoes. Commonly such magnetic data are interpreted on the premise that hydrothermal alteration consumes Fe-Ti oxides in the host rocks, reducing their total magnetization. Here, we report a contrasting observation from Whakaari (White Island) volcano in New Zealand. We study the magnetic properties of 42 conduit-filling and surficial lithologies that have undergone varying degrees of acid-sulfate alteration. We find that while the induced magnetization of lavas decreases with hydrothermal alteration, some altered lavas have an order of magnitude higher remanent magnetization than fresh lavas. We discuss plausible mechanisms by which altered lavas can retain high remanent magnetization including the importance of magnetic mineralogy and grain size. Our results urge caution in correlating reduced magnetization with hydrothermally altered regions. Furthermore, they highlight the importance of measuring both the induced and remanent magnetization of samples used to interpret field-scale data.

Related publication - Kanakiya et al. (2021b)

Acknowledgements

Funding

- European Geosciences Union
- New Zealand Earthquake Commission
- University of Auckland
- Royal Society of New Zealand
- American Geophysical Union
- Geoscience Society of New Zealand