Volcanic and Magmatic Studies Group 60th Annual Meeting

University of Bristol

3-5th January 2024

Schedule

Wednesday 3rd January

09.00	Workshops
09.30	
10.00	
10.30	
11.00	
11.30	
12.00	Registration
12.30	
13.00	Welcome & Session 1
13.30	
14.00	
14.30	
15.00	Break
15.30	Session 2
16.00	
16.30	
17.00	Poster Session 1
17.30	
18.00	
18.30	Icebreaker
19.00	

Thursday 4th January

08.30	Session 3
09.00	
09.30	
10.00	Break
10.30	Session 4
11.00	
11.30	
12.00	Lunch
12.30	
13.00	PhD Forum
13.30	Session 5
14.00	
14.30	
15.00	Break
15.30	ECR Forum
16.00	Poster Session 2
16.30	
17.00	
17.30	
18.00	Pre-dinner event
18.30	
19.00	Conference Banquet til late

Friday 5th January

08.30	Session 6
09.00	
09.30	
10.00	Break
10.30	Session 7
11.00	
11.30	
12.00	Lunch
12.30	
13.00	Award talks
13.30	
14.00	
14.30	Break
15.00	EDI Forum
15.30	AGM
16.00	
18.00	Outreach event at the Watershed

Contents

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Sponsors

We are greatful to the following sponsors for their support of the conference and VMSG prizes.

About

The Volcanic and Magmatic Studies Group (VMSG) is a joint Special Interest group of the Mineralogical Society of Great Britain and Ireland, and the Geological Society of London. The Volcanic Studies Group of the Geological Society was formed in December 1963 by ATJ Dollar and GPL Walker, and first met in 1964 and became the VMSG on affiliating with the Mineralogical Society in 1997.

The group has hosted scientific meetings, workshops and field trips in support of the community cinse its inception, with the symposium and annual general meeting held at a different institution each year. 2024 marks 60 years of continuous activity by the group, which is one of the largest special interest groups of the both host societies.

This meeting seeks to celebrate that legacy and look forward to the groups future, with an unprecedented number of associated pre-conference workshops, as well as a post-conference field trip. As has become a badge of merit for the group, the schedule highlights the very best of the work carried out in our community, with a focus on hihglighting the work of our student and ECR members.

Alongside the scientific schedule we are pleased to be hosting the first of the 60th Anniversay Seminar Series. This will take place before the conference banquet on Thursday night, where Bristol volcanologist, long time member (and one-time chair!) of VMSG Professor Sir Steve Sparks FRS will talk a little about the legacy and future of our group.

We are delighted to welcome you here, and hope you have an enjoyable, interesting, and thought-provoking time.

The local organising committee
Pete Rowley
Juliet Biggs
Sam Mitchell
Ailsa Naismith
Matt Watson

The scientific committee
Edna Dualeh
Sam Mitchell
Ailsa Naismith
Gregor Weber

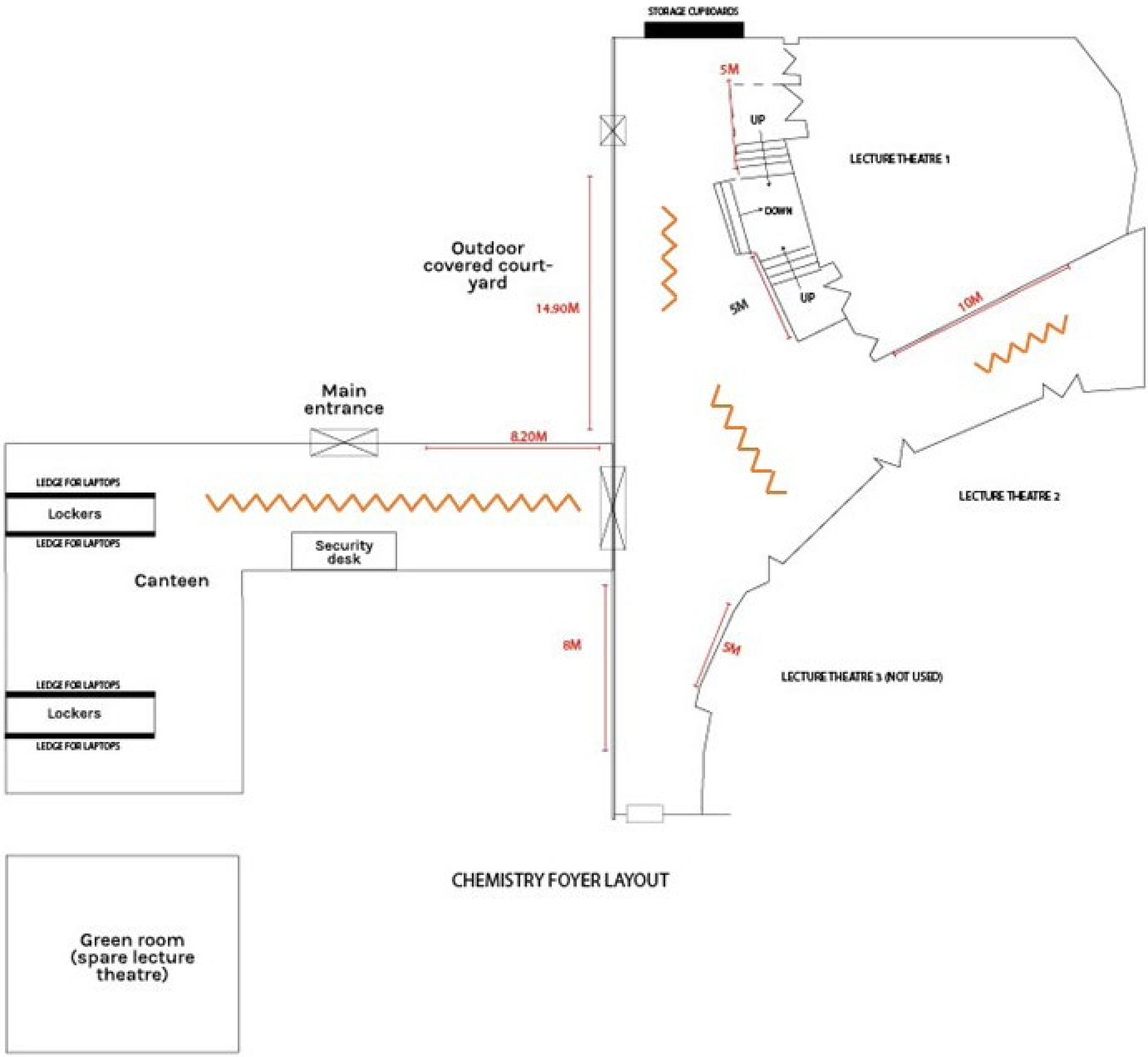
VMSG

Venue information

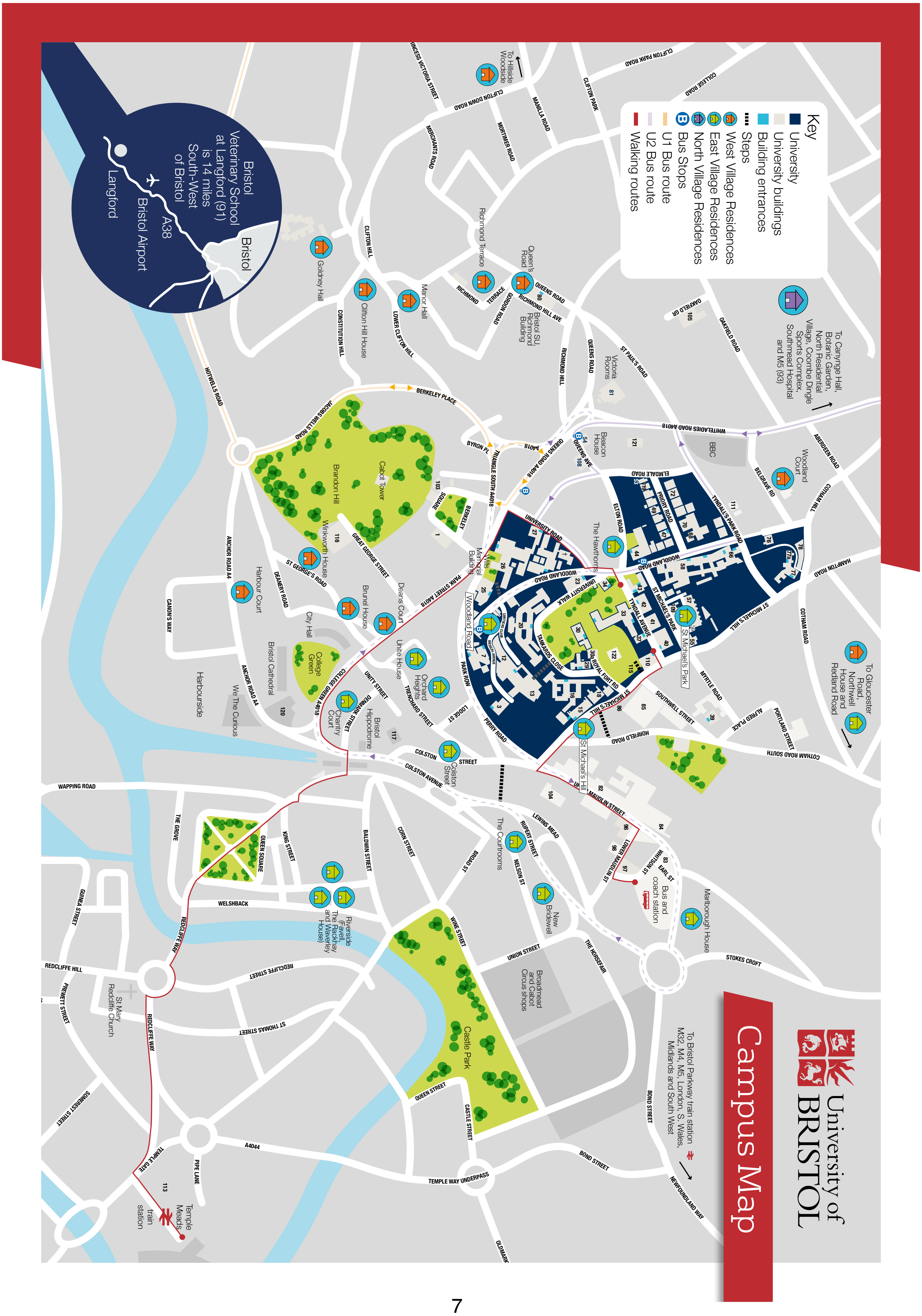
The conference will take place in the Chemistry Building, Cantock's Close, BS8 1TS.

The conference banquet will take place in Wills Memorial Building, Queens Road, BS8 1RJ

All accessibility information can be located here:
https://www.accessable.co.uk/university-of-bristol/access-guides/chemistry
https://www.accessable.co.uk/university-of-bristol/access-guides/wills-memorial-building



Campus Map



Key
University
University buildings
Building entrances
Steps
West Village Residences
East Village Residences
North Village Residences
Bus Stops
U1 Bus route
U2 Bus route
Walking routes
University of BRISTOL
Campus Map
Bristol Veterinary School at Langford (91) is 14 miles South-West of Bristol
Bristol
A38
Bristol Airport
Langford
To Canynge Hall, Botanic Garden, North Residential Village, Coombe Dingle Sports Complex, Southmead Hospital and M5 (93)
To Gloucester Road, Northwell House and Redland Road
To Bristol Parkway train station M32, M4, M5, London, S. Wales, Midlands and South West
To Hillside Woodside
Goldney Hall
Clifton Hill House
Manor Hall
Richmond Terrace
Queen's Road
Bristol SU, Richmond Building
Victoria Rooms
Beacon House
BBC
Woodland Court
The Hawthorns
Brandon Hill
Cabot Tower
Winkworth House
Harbour Court
Brunel House
Deans Court
City Hall
College Green
Bristol Cathedral
We The Curious
Harbourside
Unite House
Orchard Heights
Chantry Court
Bristol Hippodrome
Colston Street
Memorial Building
Woodland Road
St. Michael's Park
St Michael's Hill
The Courtrooms
New Bridewell
Bus and coach station
Marlborough House
Riverside (Favell, The Rackhay and Waverley House)
Broadmead and Cabot Circus shops
Castle Park
St Mary Redcliffe Church
Temple Meads train station

Conference Banquet

Following the close of sessions on Thursday 4th December, we will move across to the Reception Room on the first floor of Wills Memorial Building, where Professor Sir Steve Sparks FRS will give the first of the VMSG 60th Anniversary Seminar Series.

We will move through to the Great Hall to sit for 7.15 pm.

The banquet menu is fully vegetarian. Other dietary requirements will be provided for by table. Please ensure you use the allocated table (see below). A non-alcoholic welcome drink will be provided, and all other drinks will be available from the bar.

The Menu

Starters
Pan fried polenta, smoked aubergine caponata,
marinated mushrooms, tarragon oil

Sharing mains
Sourdough pitta
A Très Vegan Cassoulet
Lebanese Zaatar & chana masala chickpea
Patatas bravas, green sauce and sour 'cream'
Dressed spinach & green bean salad

Awards

Dessert
Glasses of poached pear & chocolate mousse
Tea & Coffee from the bar

Departure by 11.30pm.

Table allocations are detailed on the following page. Please note that the arrangement of tables on this page does not reflect the arrangement of tables in the banquet venue.

Olympus Mons

Clive Oppenheimer
Daniel Bowden-Haynes
Hazel Knight
Katie Baumber
Kerys Meredew
Man Mei Chim
Richard Taylor
Steve Sparks
Tamsin Mather

Etna

Alex Stewart
Alex Walton-Keeffe
Beitris Morrison-Evans
Isabelle Taylor
Jade Hrintchuk
James Hickey
Lara Mani
Tegan Havard
Thomas Jones

Nabro

Alexander Riddell
Bence Horányi
Ella Webber
Hannah Ellis
Jordan Chenery
Joshua Brown
Melina Hoehn
Rahul Subbaraman
Sofia Della Sala
Thomas Austin

Colima

Alison Rust
Daniel Manns
Ella Curtis
Jeremy Phillips
Jinheum Park
Marie Zedler
Marjorie Encalada Sim-baña
Tom Gernon
William Hutchison

Popcatépetl

Claire Horwell
David Colby
David Neave
Dee Cirium
Emma Nicholson
Eric Newland
Frankie Butler
Jess Bassett
Rahma Hassan
Ritwick Sen

Holuhraun

Amy Myers
Daniela Vitarelli
David Pyle
Emma Horn
Gabriel Adler
Janine Kavanagh
Juliet Biggs
Megan Taylor
TiVonne Howe

Fuego

Ailsa Naismith
Ben Esse
Kate Williams
Liz Gaunt
Matthew Varnam
Natasha Dowey
Owain Smith
Paul Albert
Sophie Baldwin
Wasim Mustafa

Cordón Caulle

Amy Kember
Brendan McCormick Kilbride
Ed Llewellin
Fathia Lutfiananda
Hugh Tuffen
Lin Way
Marie Edmonds
Mike Cassidy
Yahaya Mohammed Danjuma

Campi Felgrei

Christopher Kilburn
Claire Harnett
Jack Bronziet
Jacob Nash
Kate Wale
Matt Watson
Peter Rowley
Philip Benson
Sophie Jackson

Hunga Tonga-Hunga Ha'apai

Alice Hopkins
Felix Boschetty
Isobel Yeo
James Dalziel
Matthew Horstwood
Mike A Clare
Rebecca Williams
Sam Bright
Sebastian Watt
Tianyuan Zhu

La Soufrière

Ben Latimer
Eilish Brennan
Emma Hadré
Gilles Seropian
Martin Mangler
Natalia Lipiejko
Nemi Walding
Paul Cole
Samuel Mitchell

Anak Krakatau

Eshbal Geifman
Fay Amstutz
Francesca Haywood
Jenni Barclay
Josh Yonish
Katie Preece
Ryan Hill
Sacha Lapins
Sally Gibson
Jingwei Zhang

Axial Seamount

Megan Campbell
Madeleine Humphreys
Geri Peykova
John Maclennan
Zoltan Taracsak
George Cooper
Wenting Huang
Louis Chambers
Roxane Buso
Sami Mikhail

Erebus

Amanda Lindoo
Ben Ireland
Caitlin Chalk
Edward McGowan
Elisa Biagioli
Gabriele Radzeviciute
Leah Gingell
Milan Lazecky
Samantha Engwell
Thomas Aubry

Pacaya

Alexandra Morand
Callum Pearman
Charlotte Gordon
Kendra Ní Nualláin
Mark Bemelmans
Matthew Johnson
Owen Weller
Rami Alshembari
Thomas Johnston
Timothy Davis

Kīlauea

Annie Matthews
Hannah Calleja
Jessica Rawlings
Joshua Shea
Julia Neukampf
Magali Verkerk
Morgan Bugler
Oliver Higgins
Ri Cao

Ngauruhoe

Jasmine Dibben
Katharine Gilchrist
Katy Chamberlain
Lindsay Young
Matias Clunes
Norbert Toth
Rebecca Tanner
Sam Mitchinson
Alison Hunt

Hekla

Lorenzo Mantiloni
Adam Stinton
Alexandra Daniels
Charlie Bates
Chetan Nathwani
Fiona Gardner
Frances Beckett
Megs Watfa
Rhian Meara
Tyrone Stafford

Unzen

Alexander Nies
Ana Martinez
Emma Watts
Jamie Farquharson
Jane H. Scarrow
Janina Gillies
Linda Sobolewski
Rebecca Hughes
Ryan Bailey

Ol Doinyo Lengai

Abate Melaku
Alastair Hodgetts
Barbara Bonechi
Bridie Verity Davies
Molly Flynn
Nick Mappin
Priya Minhas
Sally Law
Sarah MacDonald

Redoubt

Adam Welsh
Ceri Allgood
Edna Dualeh
Elliot Carter
Gregor Weber
Helen Thornhill
Max Van Wyk de Vries
Michael Stock
Rachel Bilsland

Scientific Programme

Eruption and transport processes
Remote sensing and geophysics
Hazard, risk, and society
Petrology and geochemistry

Oral presentations - Wednesday 3rd January

Time		Presenter	Title
13.15		Tegan Havard	Analogue experiments to investigate magma mixing in dykes
13.30		Magali Verkerk	Large-ensemble simulations of volcanic impacts on climate throughout the last 9000 years.
13.45		Elisa Biagoli	Magma ascent dynamics and lava flow propagation: a numerical modelling approach with examples from the 2021 Cumbre Vieja and 2014 Fogo eruptions.
14.00		Charlotte Gordon	The textural record of extreme disequilibrium crystallisation
14.15		Ben Ireland	Towards a systematic catalogue of volcano deformation source parameters from Sentinel-1 InSAR data.
14.30		Eilish Brennan	Insights into the magmatic source of Kozelsky Volcano, Kamchatka including Boron and B-Sr-Nd isotopes as tracers of FME and volatile enrichments in the mantle source.
14.45		Ed Llewellin	Emplacement of a complex lava flow field on Kīlauea, Hawaii, USA

Time		Presenter	Title
15.30		Isobel Yeo	Diverse impacts of marine volcanic eruptions on Pacific Island communities
15.45		Hannah Calleja	Inclined conduits promote flow recirculation in shallow open vent volcanic systems.
16.00		Maximillian Van Wyck de Vries	Monitoring hazard at ice-clad volcanoes: remote mapping of summit ice cap volumes.
16.15		Beitris Morrison-Evans	Source depth of basaltic-andesite magma beneath La Soufrière, St Vincent
16.30		Ceri Allgood	Particle alignment and bubble deformation in solidifying flows.
16.45		Man-Mei Chim	Disproportionate Impacts of the COVID-19 Pandemic on Early Career Researchers and Disabled Researchers in Volcanology.

Oral presentations - Thursday 4th January

Time		Presenter	Title
08.30		Claire Horwell	'All four engines have failed!': The psychological and behavioural impacts to passengers and crew on flight BA009 which flew through the 1982 Gallungung ash cloud
08.45		Thomas Aubry	Using the Independent Volcanic Eruption Source Parameter Archive (IVESPA) to calibrate and evaluate a 1D volcanic plume model.
09.00		Morgan Bugler	Examining the role of continental collision magmatic activity in Phanerozoic continental crustal growth
09.15		Mark Bemelmans	Robust Observation of Volcano Displacement Using Sub-Pixel Offset Tracking on High-Resolution Satellite SAR
09.30		Abate Melaku	The origin and magnitude of gas emissions at a major Ethiopian Rift volcanic system.
09.45		Elliot Carter	Rapid temperature fluctuations in the early Iceland plume revealed by olivine-spinel and melt thermometry

Time		Presenter	Title
10.30		Amy Myers	A global analysis of lava dome and lava spine geometries
10.45		Megan Campbell	Evaluating the role of complex topography on ground deformation modelling at marine volcanoes
11.00		Callum Pearman	Temporal Variations In North Atlantic Mid-Ocean Ridge Magmatism and Plume-Ridge Interaction: Insights from IODP Expedition 395C.
11.15		Nemi Walding	The effect of moisture on cohesion of pyroclastic material: implications for deposit architecture and flow behaviour.
11.30		Jamie Farquharson	International volcanology: some publishing perspectives.
11.45		Gabriele Radzeviciute	Populations on Volcanic Islands: Life in the Shadow of Stromboli, Aeolian Islands, Italy

Time		Presenter	Title
13.30		Chetan Nathwani	A zircon case for super-wet arc magmas
13.45		Janina Gilies	Formation of Pele's hair by stretching of bubbly magma
14.00		Ben Esse	Quantifying daily volcanic SO2 emissions on a global scale.
14.15		Ri Cao	Formation of volcanic domes on Venus and the mobilization of crystal mush: Insights from the Troodos Ophiolite, Cyprus
14.30		Hazel Knight	Assessing models for Large Igneous Province formation using a new magma productivity record spanning the North Atlantic Igneous Province
14.45		Marjorie Simbana	Sensors as a tool to understanding hazards and connecting people in hazard-prone zones.

Oral presentations - Friday 5th January

Time		Presenter	Title
08.30		Owen Weller	New thermodynamic models for alkaline-silicate magmatic systems
08.45		Emma Horn	New insights into the magmatic systems feeding caldera-forming eruptions from juvenile nodules in lag breccias.
09.00		Jenni Barclay	Volcanologists as Storytellers: the explanatory power of stories told about volcanic crises
09.15		Timothy Davis	A theory for mega-dyke propagation as driven by hotspot topography.
09.30		Barbara Bonechi	Direct observation of degassing and crystallisation of magma via HP-HT X-ray transparent Internally Heated Pressure Vessel
09.45		Michael Clare	When volcanoes meet the internet: The variable drivers and impacts of volcanic hazards on subsea telecommunications networks

Time		Presenter	Title
10.30		Matias Clunes	Artistic expressions of volcanoes in Chile: a pathway to understanding their social significance
10.45		Roxanne Buso	CO2-rich primary magmas in continental intraplate domains: Insight from olivine-hosted melt inclusions from Bas-Vivarais (French Massif Central)
11.00		Thomas Gernon	A multi-million-year legacy of volcanism in the Earth system
11.15		Bridie Davies	Volcanology in a vacuum? How lessons from the archives can help us unify perspectives on volcanic crises.
11.30		David Neave	Iron valence systematics in clinopyroxene from oceanic basalts: revisiting stoichiometric estimates of ferric iron content.
11.45		Rami Alshembari	Modelling Surface Deformation from Melt Injection to a Poroelastic Reservoir at Soufrière Hills Volcano, Montserrat

VMSG Award Talks - Friday 5th January

Time	Presenter	Title
13.00	Edna Dualeh	WIlly Aspinell Award - Quantifying the rapid increase in extrusion rate from Synthetic Aperture Radar backscatter: 2021 dome growth at La Soufrière, St Vincent.
13.20	Martin Mangler	Zeiss Postdoctoral Keynote - Plagioclase shape variability reveals textural maturation of crystal mush due to resorption
13.40	Clive Oppenheimer	Thermo Fisher Scientific VMSG Award

Conference Schedule

Wednesday 3rd January

09.00	Workshops
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12.00	Registration
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15.00	Break
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17.00	Poster Session 1
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18.00	
18.30	Icebreaker
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Thursday 4th January

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Friday 5th January

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14.30	Break
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15.30	
16.00	
18.00	Outreach event at the Watershed

Poster Session 1 - Wednesday 3rd January

Please note that posters are associated with a posterboard number. Odd-numbered posters will be presented on Wednesday, and even number posters will be presented on Thursday.

- Eruption and transport processes
- Remote sensing and geophysics
- Hazard, risk, and society
- Petrology and geochemistry

No.	Presenter	Title
1	Gabriel Adler	Tracking Mush Disaggregation During the 1783 CE Laki Eruption.
3	Ceri Allgood	Complex dyke architecture suggests flow localisation during magma propagation.
5	Ryan Bailey	New insights into past and present volcanic activity of Socorro Island, Mexico
7	Sophie Baldwin	Trace element systematics at Etinde, Cameroon Volcanic Line.
9	Juliet Biggs	Analogue experiments show that fracturing around magma reservoirs can cause variation in surface uplift rates even at constant volumetric flux.
11	Samuel Bright	Bizarre magmatic compositions at Volcán Ceboruco, Trans Mexican Volcanic Belt, Mexico
13	Ella Curtis	Chemical and isotopic tracers of the transition between oceanic and continental lithosphere in the Canary Islands
15	Jordan Chenery	'Can you stop a PDC?' Assessing the impact of topography on analogue fluidized, dense granular flows.
17	Tanvi Chopra	Modelling lahars at Merapi (Indonesia) and Rainier (USA) volcanoes using Titan2D and LaharZ computer models
19	Leah Gingell	Developing a method to investigate waxing and waning behaviors in analogue pyroclastic density currents and their impact on deposit architecture.
21	Sofia Della Sala	Volcanism, Sedimentation and Hydrothermal Activity in Santorini, Greece
23	Jasmine Dibben	Seismically inferred reservoir geometry deformation model for Soufrière Hills Volcano, Montserrat.
25	Hannah Ellis	The Porosity of Shallow, Hot Granites
27	Molly Flynn	Refining the marine tephrostratigraphy of the central Mediterranean (40-90 ka): New insights into Late-Pleistocene Campanian explosive volcanism
29	Fiona Gardner	Volcanic units of the early centres of the Palaeogene Mull volcano
31	Katharine Gilchrist	Magma Mixing in Dykes and Chambers
33	Alexandra Daniels	Understanding pyroclastic density current timescales and evacuation timescales at Volcán Fuego and Volcán Santiaguito, Guatemala.
35	James Hickey	Social sensing the Kīlauea 2018 volcanic eruption
37	Rahma Hassan	The formation of the lower crust in oceans: a study from the Lizard ophiolite in Cornwall.
39	Frankie Haywood	What mechanisms control transitions in explosive-effusive eruptions for pantellerite volcanoes?
41	Oliver Higgins	Identifying distinct pre-eruptive composition-H_2O-time trends using plagioclase
43	Alastair Hodgetts	Volcanism in the Mexico City region: extending our knowledge of past eruptions over the past 400 ka.
45	Alice Hopkins	Detecting Submarine Volcanic Eruptions from Space
47	Bence Horanyi	Experimental Constraints on the Genesis of Lithium-rich, Felsic Melts
49	TiVonne Howe	Deep CO_2 systematics at La Soufriere Volcano, St Vincent
51	Wenting Huang	Reconstructing volatile exsolution in a porphyry ore-forming magma chamber: Perspectives from apatite inclusions.
53	Rebecca Hughes	Using pyroclast textures to investigate a change in explosivity within a low-intensity basaltic eruption.
55	Thomas Johnston	What Can Block and Ash Flow Deposits Tell Us About Lava Dome Collapse Dynamics?
57	Amy Kember	Investigating transitions in eruption style using textural analysis of tephra samples: a case study from Fagradalsfjall 2021
59	Sally Law	The formation of silicic magmas on young planetary bodies in an Iceland-like setting

61	Fathia Lutfiananda	Systematic Review of Forecast-based Early Actions (FbEA) in Response to Volcanic Hazards: Insights from Merapi Volcano, Indonesia
63	Daniel Manns	Towards Dynamic Poroelastic Numerical Analysis of Volcano Ground Deformation at Bárðarbunga Volcanic System, Iceland
65	Lorenzo Mantiloni	Stress Inversion in Calderas with a Simplified Model of Dyke Pathways: Towards a Physics-based Forecast of Eruptive Vent Locations.
67	Lorenzo Mantiloni	From Mush to Dyke: Insights into Reservoir Failure and Dyke Nucleation in Dynamic Magma Mush Reservoirs.
69	Nick Mappin	Fluid interaction in nepheline syenite, Stjernøya, Norway
71	Ed McGowan	A geochemical reevaluation of caldera-forming eruption deposits in the Upper Borrowdale Volcanic Group, English Lake District.
73	Priya Minhas	Evolution, Eruptive Recurrence Rates and Behaviour of Monogenetic Volcanism in Central Armenia
75	Sam Mitchell	The Middle Hope Volcanics: Reconstructing the eruptive history of a Carboniferous marine volcanic sequence in modern-day Somerset, UK.
77	Jacob Nash	What do volcaniclastic sediments produced by submarine flows tell us about the largest volcanic eruption this century?
79	Kendra Ni Nuallain	Volcanic dome collapse: exploring post-emplacement stability as a function of hydrothermal alteration
81	David Pyle	Vesuvius: the Model Volcano.
83	Jessica Rawlings	Constraining ascent velocities of diamond bearing kimberlite magmas using diffusion chronometry
85	Alexander Riddell	New gas analyser for high frequency, simultaneous measurements of volcanic gas species.
87	Jane Scarrow	What can zircon tell us about volcanic processes?
89	Gilles Seropian	Towards volcanic jet noise theory
91	Adam Stinton	Long-term fumarole temperature monitoring with aerial and ground-based techniques
93	Isabelle Taylor	Measurements of sulfur dioxide (SO_2) emissions from volcanoes with the Infrared Atmospheric Sounding Interferometer (IASI) for 2007 to 2021.
95	Matthew Varnam	Low fO_2 magmatic gases released during lunar mare eruptions.
97	Daniela Vitarelli	Chemical characterization of Carboniferous age Irish volcanics.
99	Megan Watfa	Petrology and geochemistry of the Kula Volcanic Province.
101	Sebastian Watt	Volcano distribution and hazards associated with a passive continental rift: a re-evaluation of submarine volcanism in the Sicily Channel
103	Emma Watts	Afar triple junction fed by single, heterogeneous mantle upwelling
105	Rebecca Williams	Quantifying the sedimentation of ignimbrites – progress and challenges in analogue flume modelling of pyroclastic density currents and their deposits
107	Rebecca Winstanley	Generation, storage, and eruption of an intermediate composition magma on Ascension Island
109	Joshua Yonish	Development of an assessment framework for volcanic tsunami hazards at partially submerged caldera systems
111	Jingwei (David) Zhang	Records of prolonged ash-venting at a rhyolitic volcanic system, Torfajökull, Iceland
113	Tianyuan Zhu	Long-term deformation of seasonal snow-covered calderas: A case study at Laguna del Maule, Chile
Exhibiton	Anya Lawrence	Decolonising UK Earth Science pedagogy - a toolkit for all

Poster Session 2 - Thursday 4th January

Eruption and transport processes — Hazard, risk, and society — Remote sensing and geophysics — Petrology and geochemistry

2	Fay Amstuz	Isotopic constraints on volcano tectonically controlled assimilation at Campi Flegrei caldera.
4	Thomas Austin	Benchmarking a Distinct Element Method model of volcanic deformation
6	Charlie Bates	Modelling Volcanic Umbrella Ash Clouds for Aviation Purposes
8	Katie Baumber	Relating Changes in Melt Genesis to Dynamic Conditions of the Demise of a Continental Arc: Antarctic Peninsula Arc
10	Frances Beckett	Conducting Multi Agency Volcanic Ash Cloud Exercises: Practicing forecast evaluation procedures and the pull-through of scientific advice to the London VAAC
12	Rachel Bilsland	Modeling Surface Deformation due to Magma Migration through Mush Zones
14	Daniela Bowden-Haynes	Bang, spatter, and plop: welding dynamics of proximal ignimbrite agglomerates.
16	Jack Bronziet	Magmatism and Mineralisation Along the Great Glen Fault, NW Highlands
18	Joshua Brown	A complex magmatic plumbing system beneath Bagana volcano, Papua New Guinea
20	Frankie Butler	The Rheological Feasibility of Magma Mixing at the Drumadoon Sill, Isle of Arran.
22	Caitlin Chalk	Deciphering flux-driven dyke dynamics with experimental and numerical models.
24	Dee Cirium	Volatiles and their Sources in the Afro-Arabian LIP
26	Matias Clunes	Dike-induced strain and stress field influenced by dipping heterogeneous crustal layers: insights from analogue modelling
28	David Colby	Unlocking volatile budgets at Santorini, Greece using Apatite
30	Edna Dualeh	Separating volcanic deformation signals using ICA: Corbetti Caldera, Ethiopia
32	Sam Engwell	The North Atlantic Volcanic Hazards Partnership: An Introduction
34	Eshbal Geifman	Geochemical Tracers of Assimilation in North Atlantic Paleogene Dykes
36	Janina Gillies	Evolution of highly vesicular basaltic pyroclasts during fountaining
38	Emma Hadre	Geomorphometric analysis and semi-automatic classification of blocks and cones in a volcanic flank collapse debris field offshore Fogo, Cape Verde.
40	Claire Harnett	Introducing ROTTnROCK: a new project to explore the role of hydrothermal alteration in unpredicted volcanic hazards
42	Ryan Hill	Comparing and interpreting the mechanics of formation of collapse calderas on Io and on Earth
44	Melina Hoehn	Petrological and geochemical characterisation of eruption products from the Rabaul Caldera Complex, Papua New Guinea
46	Jade Hrintchuk	Investigating magma flow dynamics in a dyke: a microstructural study of the Budj Bim Volcanic Complex, Australia
48	Matthew Johnson	Experimental modelling of thalwegs in pyroclastic density currents - the dynamic influence of progressive aggradation upon a migrating flow axis
50	Thomas Jones	Accretionary lava balls record the Pāhoehoe to `A`ā transition.
52	Ben Latimer	Magma mush remobilisation during replenishment of granitic intrusions: evidence from localised fabric heterogeneity
54	Milan Lazecký	Current Volcanic Activity at Azores Islands Observed by Sentinel-1 and GNSS
56	Amanda Lindoo	Plagioclase shape: implications for magma mush dynamics
58	Natalia Lipiejko	Permeability of granular mixtures under shearing conditions: implications for pyroclastic density currents.
60	Natalia Lipiejko	Experimental and numerical rheometer: insights into the flow properties of fluidised and non-fluidised granular mixtures.
62	Ariane Loisel	The evolution of a basaltic fissure eruption
64	Sarah MacDonald	Carbonatite-syenite interaction and assimilation, Stjernøya, Norway.
66	Ana Martinez-Garcia	Model of the shallow crustal density distribution of the Krafla Volcanic System

Analogue experiments to investigate magma mixing in dykes

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A wide range of behaviour can be displayed by basaltic fissure systems during their eruptive episodes, posing danger to people and infrastructure in the vicinity. Magmas can physically and chemically interact when stored in the subsurface plumbing systems that feed basaltic fissure eruptions. There is also evidence that physically distinct magmas can mix during ascent, the success and extent of this interaction a factor in determining eruption longevity and the nature of the eruptive products. The majority of previous analogue experiment studies investigating magma interaction of plumbing systems have used pipe-like or chamber-like geometries (i.e. cylindrical or cuboidal respectively) and immiscible fluids representing magma mingling. There are difficulties extrapolating these findings to high aspect ratio, dyke geometries that characterise fissure systems and to situations where magmas are miscible and mixing. Therefore, to better explore the dynamics of mixing in high aspect ratio geometries, we use miscible fluids in a novel analogue experimental setup.
We present results from seven scaled analogue experiments investigating the fluid interactions in a dyke-like geometry, each of a different miscible fluid pair representing two magmas of differing composition. The lower density fluid is placed above the higher density fluid in the tank in a stable configuration before the apparatus is inverted to initiate the interaction between fluids. Throughout the experiment, images were captured and later processed to quantify the spatiotemporal evolution of mixing in the system and the Reynolds number (Figure 1). Fluid samples were collected to complement the image suite and examine the evolution of the fluid physical properties (density, viscosity). We relate these experimental results to (1) evolving physical and chemical properties of magma during subsurface magma replenishment and eruption, (2) to a natural composite fissure system in Iceland that displays chemical and physical interaction of multiple magmas, and (3) to gelatine analogue experiments investigating magma mixing during dyke emplacement.

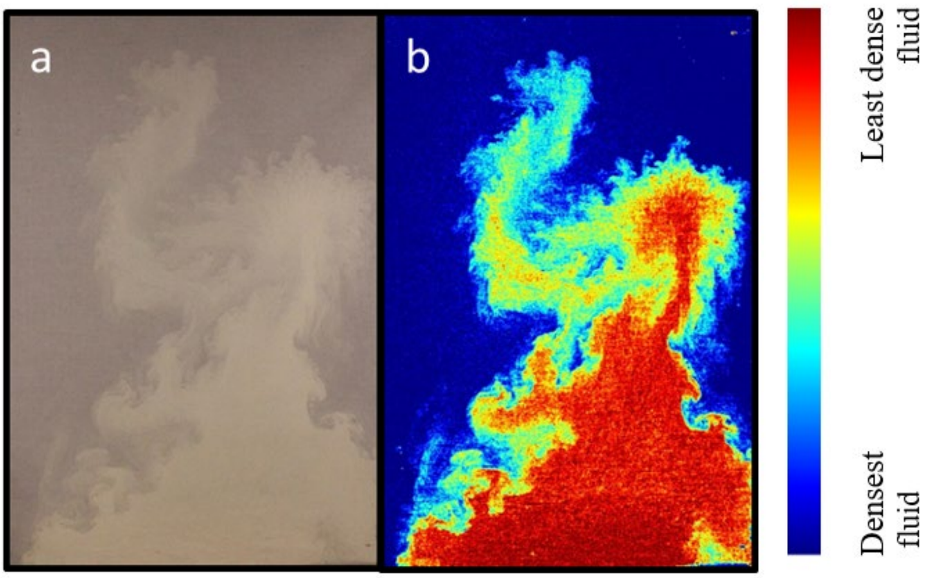

Figure 1: Example of processed image showing conversion from (a) the original image to the (b) colourmap determined by the light intensity value, a proxy for the density of the fluid. The blue end of the spectrum represents denser fluid and red represents less dense fluid.

Large-ensemble simulations of volcanic impacts on climate throughout the last 9000 years.

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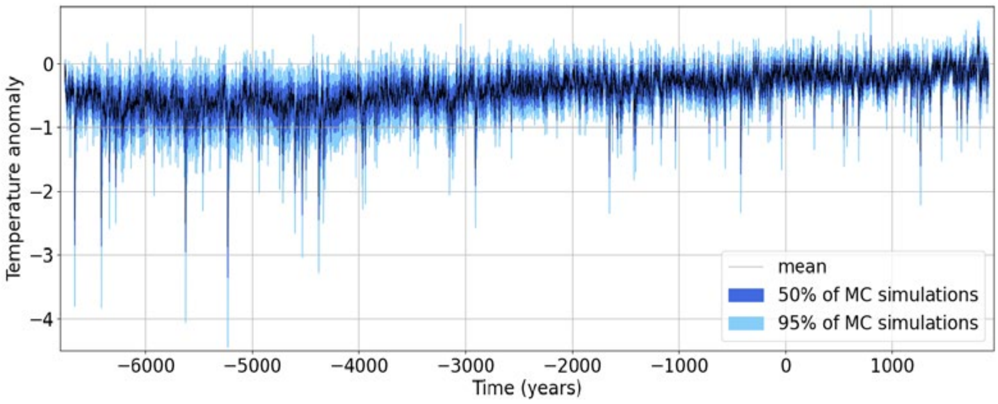
Large explosive volcanic eruptions are one of the most important drivers of climate variability and result in global cooling. Our understanding of their impact is based either on proxy reconstructions or on climate model simulations. These two methods tend to present discrepancies, with a stronger cooling in simulations than proxy reconstructions.
To address this problem, we quantify how uncertainties on eruption source parameters, uncertainties on volcanic aerosol and climate models, and natural climate variability affect the simulated surface temperature response to volcanic eruptions for the last 9000 years. As the computational cost of full-blown Earth System models is prohibitive to quantify uncertainties for such long simulations, we employ simple models instead. We first use ice-core derived estimates of Holocene volcanic stratospheric sulfur emissions and a simple aerosol model (EVA_H) to obtain volcanic aerosol optical properties and radiative forcing. This volcanic forcing and forcing from key greenhouse gases and the Sun are then used to run a simple climate model (FaIR) providing global mean surface temperatures. Thanks to the inexpensive nature of the model used, we run an ensemble of 1000 simulations to propagate all uncertainties and the effect of natural climate variability.
Our results show a time averaged volcanic cooling of -0.17±0.15°C over our nearly 9000-year studied time period, with the cooling reaching -2.33±0.42°C for the strongest eruption of the period. Our simulations show excellent agreement with the latest tree ring-based reconstructions since 750 CE on the mean temperature response to volcanic eruptions. On a millennial scale, we obtain a good agreement between simulations and the state-of-the-art Last Glacial Maximum reanalysis. However, on a centennial scale, our simulations do not show a transition from the Medieval Warm Period to the Little Ice Age apparent in tree ring records.



We discuss how accounting for other forcings (e.g., land use) and using simple climate models emulating regional scale temperatures instead of global mean surface temperature might resolve this discrepancy.
Figure: Holocene temperature anomalies obtained with our modelling framework, the black curve is the mean temperature response over a 1000 Monte Carlo Simulations, shading indicates envelopes containing 50% and 95% of the simulations.

Magma ascent dynamics and lava flow propagation: a numerical modelling approach with examples from the 2021 Cumbre Vieja and 2014 Fogo eruptions.

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This presentation focuses on investigating volcanic processes with a numerical modelling approach. We employ a 1D model to elucidate the dynamics of magma ascent within volcanic conduits and a separate 2.5D model to investigate the propagation of lava flows on the Earth's surface. The former encapsulates the complex interactions between magma properties, gas exsolution, crystallization, and disequilibrium processes, providing a thorough understanding of how magma rises from the the crust to the surface [1,2]. With this model, we aim to shed light on the factors leading to volcanic eruptions and eruptive style transitions. The latter model explores the complexities of how lava spreads across the landscape, accounting for topographical features, lava rheology, and thermal heat exchanges with the environment [3,4]. Both models are combined with, and validated by, observations of the natural system, and petrological data coming from experimental and analytical work. The presentation will illustrate results from 2 case studies, the 2021 explosive eruption of Cumbre Vieja (Canary Islands) and the 2014 effusive eruption of Fogo (Cape Verde).

While these two models are not directly integrated yet, their combined insights offer a holistic perspective on explosive and effusive activity, from magma ascent to lava flow propagation. Our numerical modelling approach allows us to advance our understanding of volcanic process and provides a tool for improving hazard assessment and risk mitigation to be used for communities living in volcanic regions.

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The textural record of extreme disequilibrium crystallisation

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Magmatic systems experience phases of extreme thermodynamic disequilibrium, when rapid changes in pressure, temperature or volatile content outpace the kinetic ability of the system to respond. Understanding disequilibrium crystal growth is crucial for interpreting mineral geochemistry, as supersaturation influences element partitioning. The degree of disequilibrium experienced by a magma also provides information about its transport and storage history. However, extreme events may be poorly represented in the crystal record, as they either trigger crystal dissolution or the rapid growth of unstable crystals with high-energy shapes. We investigate the textural record of the latter to seek characteristics that may be reliable markers of disequilibrium in the rock record.

Crystals that grow rapidly under extreme disequilibrium conditions can incorporate systematic errors during their growth, resulting in high dislocation densities and curved or twisted crystal lattices. These warped crystals may be obvious or very subtle in visible light, but electron backscatter diffraction (EBSD) allows detailed and precise quantification of the lattice rotations present. We investigate unequivocal case studies where igneous crystals have incorporated lattice curvatures during growth, including examples of feldspars and clinopyroxenes from komatiites and orbicular rocks. Using EBSD, we quantify the lattice curvatures present and demonstrate that each mineral displays curvature around specific misorientation axes, due to the preferential incorporation of specific types of dislocations during rapid crystal growth.

Finally, we consider examples from the plutonic record where crystals that at first glance appear relatively ordinary contain evidence for an origin under conditions of extreme disequilibrium. These crystals have experienced protracted cooling in a plutonic setting and therefore commonly show evidence of euhedral overgrowth, recovery, and static recrystallisation. However, even in samples that have almost reached textural equilibrium, some evidence of the original dislocation-rich growth can still be found in the microstructure, where low-angle subgrain boundaries retain characteristic misorientation axes. It is likely that curved crystals may be under-represented in the geological record due to preservation bias, and that subtle evidence of disequilibrium crystal growth is frequently overlooked.

Towards a systematic catalogue of volcano deformation source parameters from Sentinel-1 InSAR data.

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Understanding the global patterns and spatio-temporal characteristics of volcanic deformation is important for improved eruption forecasting through identifying analogue behaviours and commonalities between volcanoes. They can also be useful for comparing or validating models of magmatic systems. Previous metadata catalogues are incomplete and biased by methodological differences in data and modelling, and are also difficult to compare with other catalogues of e.g. SO2 emissions or erupted volumes, because of such differences. However, the large archive of systematically acquired and processed Sentinel-1 data now provides the opportunity to overcome these limitations and construct the first systematic volcano deformation catalogues.

Here, we systematically extract deformation characteristics from Sentinel-1 InSAR datacubes, focussing on source parameters extracted through inversion modelling (Figure 1). We adapt GBIS, a Bayesian non-linear inversion software, to run in an automated fashion. We use synthetic examples to explore pre-processing options, focusing on downsampling, initial model geometry, and bounding boxes. We first apply a Mogi model to all the signals and then try alternate source geometries, comparing the improvements in fit using Akaike's Information Criterion.

We find that a polygon-based coarse-fine downsampling approach is both efficient and effectively reduces noise and find that the fine polygon containing the signal can be delimited in real interferograms using multi-level Otsu Thresholding. We test our approach using Sentinel-1 datacubes from the East African Rift containing signals previously classified as dike intrusions, restless calderas, lava flow subsidence, pore-pressure changes, or post-eruptive deformation. We use GBIS to invert for the source parameters in each signal and compare these to the previously reported literature: most signals are best fit with a Mogi or sill-like source, whilst others can be best fit by an Okada source.

Complications arise when there are multiple signals per interferogram, either from the same or multiple volcanoes. We combine the extracted source parameters with those describing their temporal behaviour to produce a regional catalogue. This approach has the potential to be applied globally to produce a systematic volcano deformation catalogue which can be used for eruption forecasting.

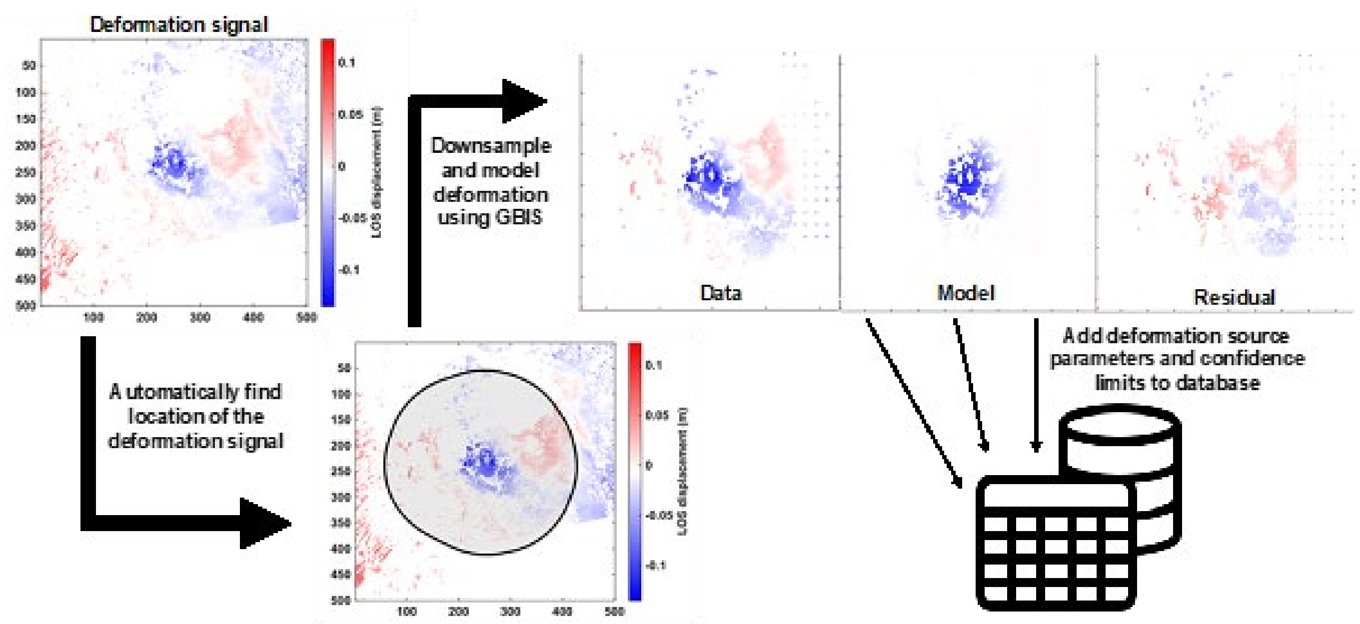

Figure 1: Schematic showing a simplified example of the automatic source parameter extraction framework.

Insights into the magmatic source of Kozelsky Volcano, Kamchatka including Boron and B-Sr-Nd isotopes as tracers of FME and volatile enrichments in the mantle source.

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The voluminous magmatic outputs from the old, cold and altered Pacific slab under the Kamchatka Peninsula creates an ideal environment to trace volatile release across a subduction zone and improve our understanding of subduction processes driving extensive volcanic activity. Here we report new petrological and geochemical results (XRF, EMPA, SEM, ICP-MS, and TIMS) from the forearc-situated Kozelsky and Avachinsky volcanoes (Avacha Group) with respect to other mafic bearing Kamchatkan volcanoes.

We will present whole rock and mineralogical overview of Kozelsky volcano, which samples a depth to slab of <90km [1]. The suite ranges from hornblende dacites to olivine basalts and expresses a wide range of textures interpretive of the magmatic history. The sampled olivine-phyric basalts from the Avacha Group record high MgO (5-15 wt%), Ni (15-250 ppm) and Cr (60-800 ppm) abundances. The whole rock $^{87/86}$Sr and $^{143/144}$Nd ratios of these volcanoes show narrow ranges (~0.70335 and ~0.51305, respectively), revealing dominantly mantle wedge (non-crustal) magma sources.

New whole rock B and B isotope data reveals serpentinite-forearc mélange influenced outputs [e.g. high B and heavy δ^{11}B (up to >+2 to +5‰)]; this deviates from the expected deep sourced slab melt contribution (+2‰ [3]) which whilst has an influence, alone cannot source these magmas. This is also in contrast to AOC (altered oceanic crust) melt dominating mantle metasomatism in the arc belts with deeper subducting slabs (i.e. Tolbachik [3,4,5]). Therefore, such excess, non-sediment sourced B and enriched δ^{11}B should be derived from dehydrated and with heavy δ^{11}B AOC [6] or forearc, serpentinite, mélange rocks associated with the subducting slabs, supporting the mélange model of slab material transport [7]. Our results will evaluate if systematic variations in B-Sr-Nd isotopes and trace element ratios can be linked to across arc change in depth to slab of the magma source and/or reveal details about the prevailing geodynamic regime.

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Emplacement of a complex lava flow field on Kīlauea, Hawaii, USA

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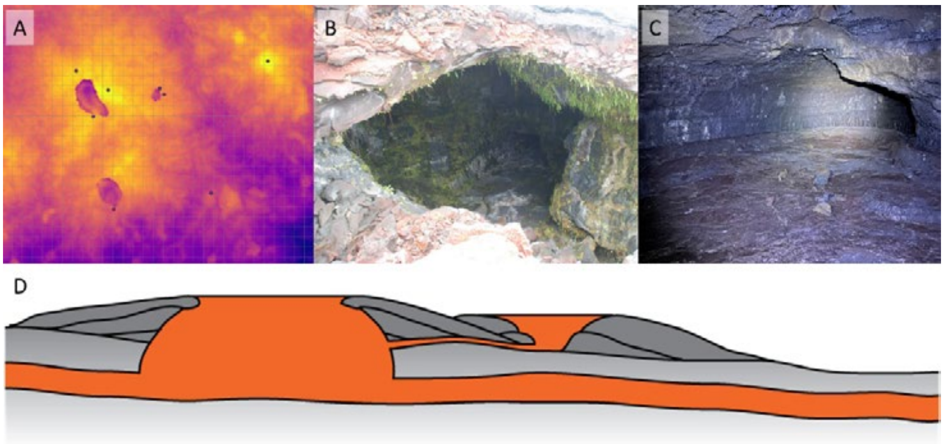
Basaltic eruptions can construct complex lava flow fields over days to years. Flow fields comprise an interconnected network of lava channels, tubes, and inflated lava pads that store lava and mediate its transport to the active flow front. Hence, flow-field geometry has a profound influence on the rate of propagation of lava flows and on their hazard potential. Here we investigate the proximal part of a lava flow field produced by the Puʻuʻōʻō eruption of Kīlauea in 2003-4. The flow field is characterized by a series of rootless shields – shield-like perched lava-ponds – and the lava tubes over which they form. We used hand-held LiDAR, field observations, and an existing airborne LiDAR Digital Elevation Model (DEM), to reconstruct the surface and interior geometry of the drained shields and lava tubes. The drained shields have a large interior void space 10–20 m high and 50–150 m in diameter, with a lobate internal geometry that we infer reflects the pre-existing ground topography. Some shields sit over a deeper lava tube which apparently fed their construction. In many cases, interior lobes connect to shallow lava tubes, which feed further shields down-slope. Based on our analysis, we propose the following formation sequence: skylight overflow forms a surface flow >> topography causes flow to pond >> pond overflows build a lava-filled shield >> hydrostatic head within the pond increases causing lava to intrude through the shield flank, forming a 'seep' >> seep feeds a surface flow >> topography causes flow to pond >> etc. Rootless shields can hold $>10^5$ m^3 of fluid lava, acting as a buffer that modulates variations in eruption flux, and posing an acute hazard during rapid seep events.



A) DEM of rootless shield field; grid has 10 m spacing. B) View into collapsed shield. C) Lava tube interior. D) Cartoon showing construction of lava flow field.

Diverse impacts of marine volcanic eruptions on Pacific Island communities

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Volcanic eruptions pose many direct and indirect hazards, including pyroclastic density currents, ash fall, lahars, landslides and lava flows, that may disrupt water supply, communications and food security. Where volcanoes are located in the ocean or near coastlines hazards can be compounded by other phenomena, such as volcanic tsunamis and pumice rafts, or made more hazardous, for example by the generation of long runout surges over water, produced when pyroclastic density currents reach the ocean. Thus, hazards posed by eruptions in or near the ocean, and their community impacts, can vary widely, even between different eruptions at the same volcano. The Southwest Pacific is a remote volcanically and tectonically active region. A few volcanoes have formed islands or are in the process of becoming emergent, while many others lie completely underwater and those known have only been mapped in the last few decades, while many are unmapped. Historic activity reveals a spectrum of eruptions, from Volcanic Explosivity Index (VEI) 0 (e.g. 2019 Late'iki), to explosive eruptions (e.g. 2012 Havre, 2006 Home Reef) that can have global consequences, most recently the VEI 5-6 eruption of Hunga Volcano in 2022. Lower VEI eruptions likely occur every few years (but are not all observed or recorded), while larger events may recur on centennial to millennial timescales. Thus, communities are exposed to a range of volcanic hazards and impacts on varying temporal scales.

Southwest Pacific nations are geographically and culturally diverse and can be impacted differently by the same eruption. Here, we discuss the variability of marine volcanic hazards and vulnerability across the Southwest Pacific with reference to two case studies that represent distinct and contrasting impacts arising from shallow marine volcanic eruptions: the 2022 eruption of Hunga Volcano and the VEI 2-3 2019 eruption of Volcano-F/0403-091. Despite their differing magnitudes, we show how these eruptions both had widespread and enduring community impacts. We find that the nature and extent of impacts recorded differ according to the methodology used to report them, and that some may be entirely missed without direct community engagement. For example, impacts of pumice rafting experienced by small island communities following the 2019 Volcano-F eruption went unreported, in contrast to widespread reporting of financial and human impacts from the 2022 Hunga Volcano eruption. Finally, we provide an overview of volcanic hazards in the region generally and highlight the importance of understanding and recording hazards at all spatial and temporal scales.

Inclined conduits promote flow recirculation in shallow open vent volcanic systems.

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Knowledge of open-vent volcanic eruption styles and eruption forecasting relies on our understanding of the multiphase behaviour of magmas in shallow plumbing systems. Eruption dynamics are primarily driven by the rise and burst of gas from within volcanic conduits, and low viscosity magmatic systems exhibit a variety of activity over different timescales. Specific bubble regimes are attributed to the onset of specific eruption types, and conduit geometry is a major control on their ascent dynamics in the upper <1 km of the system.

While there is an awareness of complex flow conditions within real volcanic plumbing systems, the theoretical consideration of these is sparse. It is thus vital to expand our existing experimental framework to accommodate more complex geometries. Here, we use analogue experiments to examine the combined effects of varied conduit inclination (vertical i.e. 0°, to 70°) and viscosity (0.001-1.412 Pa·s) on the ascent parameters of single bubbles in the spherical cap and slug regimes.

Dimensionless parameters (Fr, Re, Eo, Mo, N_f) are derived to enable comparison between specific flow characteristics at laboratory and volcanic scales, and to demonstrate the viability of current framework for true-scale application to complex, gas-rich, open systems (e.g., Stromboli). Initial results, and previous studies for different bubble regimes, indicate that conduit inclination promotes recirculation behaviour and faster bubble ascent up to a maximum within the range of 40°-60°. This has implications for the longevity of inclined conduits at volcanic scale: can an inclined conduit remain thermally viable and thus longer-lived for a given gas fraction than a vertical conduit?

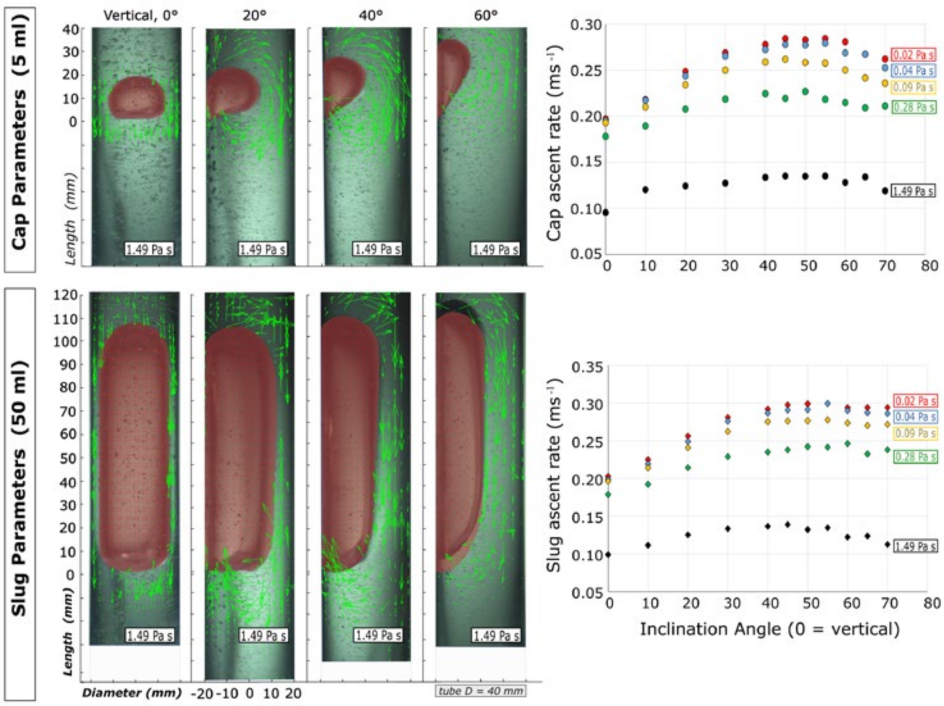

Figure 1: Ascent parameters for spherical cap (top) and slug (bottom) flow regimes. Bubble morphology (red shapes) and fluid behaviour (green arrows) are shown to change with increased deviation from vertical inclinations. Bubble ascent rates are shown to increase, reach a maximum, then decrease in all cases.

Monitoring hazard at ice-clad volcanoes: remote mapping of summit ice cap volumes.

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Ice-clad volcanoes are associated with some of the most hazardous regions on our planet, and were the source of the deadliest volcanic disaster of the past 50 years, the 1985 Armero tragedy in Colombia. Some of the most dangerous ice-clad volcanoes are located in the tropical Andes, where glacier melt also provides valuable water to headwater communities. Climate warming is projected to remove many of these glaciers within the coming century. Understanding their futures requires an accurate record of their thicknesses and volumes, which is lacking in many regions. We calculate present-day (2015–2021) ice-thicknesses for all volcanic ice caps in Colombia and Ecuador using six different methods, and combine these into multi-model ensemble-mean ice-thickness and -volume maps. We compare our results against available field-based measurements, and show that current ice volumes in Ecuador and Colombia are 2.49 ± 0.25 km3 and 1.68 ± 0.24 km3 respectively. We detected no motion on any remaining ice in Venezuela. The overall ice volume in the region, 4.17 ± 0.35 km3, is half of the previous best estimate of 8.11 km3 but greater than 0.5 km3 remains and contributes to high flood and lahar hazard on several active volcanoes. We input these ice-thickness data to a numerical flow model to provide preliminary runout estimates for different eruption and ice-melt scenarios. We conclude that satellite imagery enables glacier thickness and volume to be monitored in near-real time which, through new interdisciplinary collaboration, can be integrated into volcanic hazard assessments in all glacierised regions.

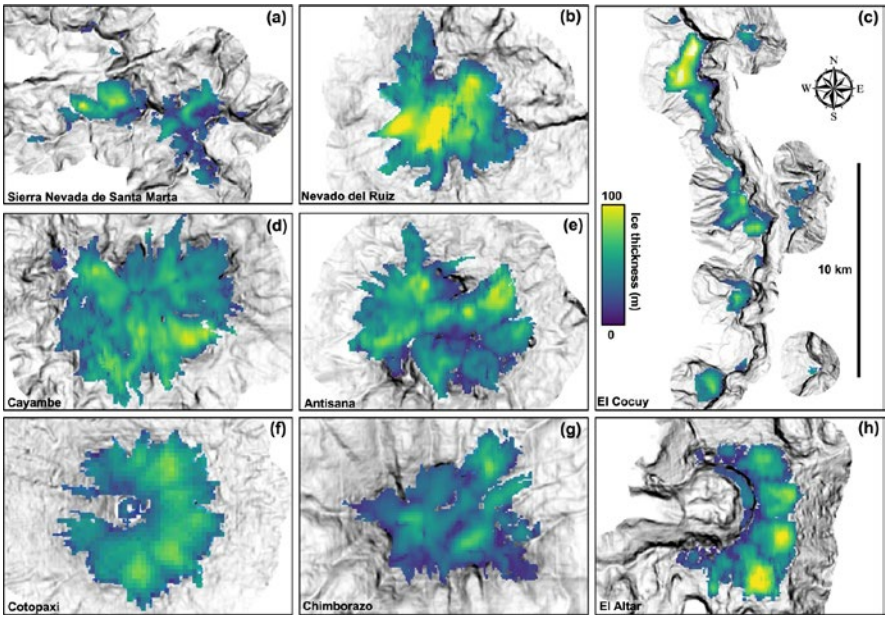

Figure 1: Ice thickness maps of selected glaciers in Ecuador and Colombia, including volcanic ice caps, computed using new satellite remote sensing workflows (source: Van Wyk de Vries et al., 2022).

Source depth of basaltic-andesite magma beneath La Soufrière, St Vincent.

Beitris Morrison-Evans[1], Elena Melekhova[1], & Jon Blundy[1].

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Many volcanoes erupt a limited compositional range of magmas over their lifetime. The composition of these erupted magmas is thought to be buffered by the crystal-rich mush from which melts are sourced (Blundy, 2022). Identifying the origin of erupted magmas helps us to constrain possible locations of melt accumulation in the mush and improve our interpretation of geophysical signals at restless volcanoes.

Melt extracted from a mush will be multiply-saturated on its liquidus with the mush mineral assemblage at the P-T-fO_2-XH_2O conditions at the time of segregation. In a system with relatively low thermodynamic variance, for example, five or six *independent* chemical components (as determined by principal component analysis), a large number of coexisting mineral phases (e.g. plag+cpx+amph+oxides) and a well-constrained fO_2, multiple saturation can be reduced to an invariant point on the liquidus of the melt in P-T-H_2O space. Identifying points of liquidus multiple saturation for volcanic rocks offers a novel magma source thermobarometer and hygrometer. We use this approach to explore the origin of the 2020-2021 basaltic-andesite magma from La Soufrière volcano, St Vincent (Eastern Caribbean). A series of near-liquidus, high-pressure and high-temperature experiments were performed at 4-8 kbar and 980-1200ºC, fO_2 ≈ Ni-NiO buffer, with initial H_2O contents of 2-10 wt%. Five-phase multiple saturation at the liquidus (melt fraction ≥85%) was found for initial H_2O contents of 8-10 wt%, at 6 kbar pressure (~15-18 km depth) and temperatures of 1000-1030ºC (Figure 1, pink shading). The saturating assemblage is a hornblende gabbro (cpx+plag+amph+Fe-Ti oxides) consistent with the mineralogy of plutonic xenoliths from historic eruptions of St Vincent (Tollan et al., 2012; Fedele et al., 2021). Mineral compositions in these multiply-saturated runs (e.g. very calcic plagioclase An_{75-85}) are similar to those in the xenoliths. Temperatures agree with mineral geothermometry estimates of Weber et al. (2023) for the 2020-21 eruption, suggesting little cooling of the magma during ascent from its source region. Seismicity prior to the 2020-21 eruption is also consistent with mid-crustal source depths (Joseph et al, 2022). Magmas sourced from similar depths can account for the limited compositional diversity of La Soufrière over its volcanic history (Fedele et al., 2021).

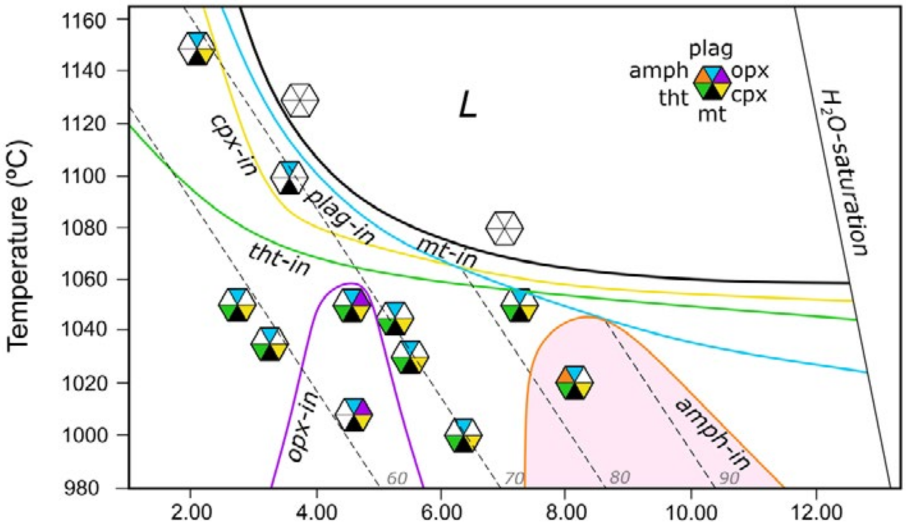

Figure 1: 6 kbar phase relations of 2020-21 basaltic-andesite from La Soufrière, St Vincent. H_2O calculated by-difference. Solid lines represent phase boundaries; dashed grey lines are An contours. Pink shading denotes multiple saturation of basaltic-andesite melt with hornblende-gabbro. L-liquid, plag-plagioclase, opx-orthopyroxene, cpx-clinopyroxene, mt-magnetite, tht-titanohematite, amph-amphibole.

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Particle alignment and bubble deformation in solidifying flows.

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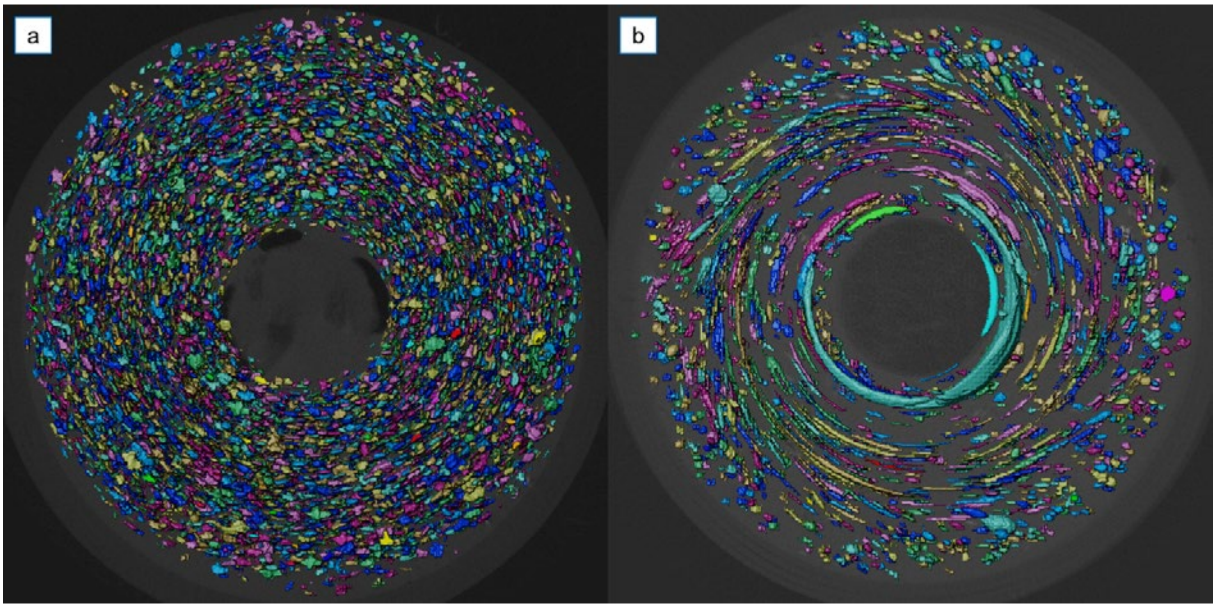
Crystal and vesicle textures are commonly used to infer flow directions within dykes, sills and lava flows. The rotation and collision of particles and the deformation of bubbles within flows have both been studied extensively in order to infer flow processes from rock textures; however, previous theoretical analyses and analogue experiments have assumed that the suspending fluid has uniform and constant viscosity. This assumption is unlikely to hold true in dykes and lava flows, which cool and solidify progressively inwards from their margins while their interior continues to flow. The magma therefore develops a viscosity gradient, which is likely to impact the rotation and collision of crystals, and the deformation of bubbles, influencing the final rock texture. The effects of this viscosity gradient will be most pronounced at the fast-cooling flow margins, which are the regions most often sampled in efforts to determine flow directions. Here, we present results of analogue experiments in which particle and bubble suspensions are sheared within progressively solidifying fluids. We use mica flakes as an analogue for phenocrysts, air bubbles as an analogue for volatiles, and molten sugar as an analogue for the melt. Suspensions are sheared as they cool progressively inwards. 3D x-ray computed tomography scans of our samples reveal that vesicle textures are strongly influenced by the balance between cooling and deformation rates, but that crystal textures appear unaffected. Our experiments therefore demonstrate the importance of cooling rates and viscosity gradients, with implications for the way we interpret rock textures in dykes and lava flows.



Three-dimensional reconstructions of a) particles and b) bubbles from CT scans of analogue samples composed of solid sugar, mica flakes and air bubbles. View is downwards from the top of the sample, which has been stirred in a clockwise direction as it solidified progressively inwards from its edge.

Disproportionate Impacts of the COVID-19 Pandemic on Early Career Researchers and Disabled Researchers in Volcanology.

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The COVID-19 pandemic has brought unprecedented challenges to researchers worldwide, and extensive studies have demonstrated that its impacts since March 2020 have been unequal, including across research discipline, gender, and career status. In 2023, as we navigate the post-pandemic times, questions persist regarding potential disparities and enduring effects faced by volcanology researchers, whose activities range from remote field work to laboratory experiments and numerical modelling. In this study, we explore the multifaceted impacts of the pandemic on volcanology researchers through an online survey distributed globally from January to March 2023. Our survey findings reveal that a considerable fraction of volcanology researchers (44-62%) face longer-term challenges from the pandemic that continue to impact their research, with a notably higher proportion among early career researchers (62%) and researchers with disabilities (76%). In addition, over half (52%) of researchers indicated that they had left or considered leaving academia due to pandemic-related factors. A significantly higher proportion of disabled researchers (56-70%) had left or considered leaving academia compared to researchers without disabilities (42%). Our findings underscore the pandemic's long-lasting and disproportionate impacts on early career and disabled volcanology researchers. We emphasise the need for concerted efforts by research organisations and funding bodies to mitigate the pandemic's enduring impacts and stress the importance of making conferences accessible to support disabled researchers' participation. As the pandemic's long-lasting impacts ripple across the broader scientific community, the insights from this research can be used for fostering equitable practices and shaping policies beyond volcanology to other research disciplines.

‘All four engines have failed!’: The psychological and behavioural impacts to passengers and crew on flight BA009 which flew through the 1982 Gallungung ash cloud

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Flight BA009, which was en route from London to Auckland, unknowingly flew through an ash plume from Mt Galunggung, Indonesia on 24 June 1982. As ‘smoke’ filled the cabin, one by one each of the four engines failed. Over 13 minutes of gliding descent, in which the flight deck crew tried, initially unsuccessfully, to restart the engines, many passengers believed they would crash into the ocean. The flight crew managed to restart 3 engines, as the plane descended out of the plume, allowing a safe emergency landing at Jakarta airport.

Twenty semi-structured interviews were conducted with passengers and crew of flight BA009, to investigate how they responded (thought, felt, behaved) to the sensory signs of the incident (e.g., ‘smoke’ in the aircraft, sounds and movements related to engines failing and restarting attempts and the descent, light phenomena on the windows, wings and engines), whether they experienced any acute or chronic psychological or physiological health impacts and whether crew announcements and behaviour influenced passenger behaviour. The interviews also explored whether the experience impacted their lives since the event.

The interview data, together with secondary data from documentaries and a book written by a passenger, are being analysed using reflexive thematic analysis. The findings will be used to inform civil aviation training, risk assessments and scenario planning in relation to pilot reticence, route planning, and consumer confidence, and will provide valuable evidence on behaviour of passengers in aviation crises.

Using the Independent Volcanic Eruption Source Parameter Archive (IVESPA) to calibrate and evaluate a 1D volcanic plume model.

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Volcanic plume models are critical to our understanding of explosive eruption dynamics and to initialize of ash forecasts during eruptive crises. The simplest form of volcanic plume model is an empirical power-law linking the mass eruption rate at the vent to the height reached by the plume. In addition to being widely used, this empirical relationship has been shown to outperform more sophisticated plume models including analytical scalings and one-dimensional (1D) plume models accounting for the role of atmospheric conditions such as wind speed and atmospheric stratification.

Here, we use the Independent Volcanic Eruption Source Parameter Archive (IVESPA) to evaluate the Geneva 1D plume model. IVESPA is a community database gathering all eruption source and atmospheric parameters required to evaluate volcanic plume models for 134 well-observed volcanic events. It includes uncertainties on all parameters, and the provided data has been independently vetted by two members of the international working group curating the database.

We demonstrate that the Geneva plume model better predicts plume height when employing relatively low values of entrainment coefficients and ignoring the impact of water phase changes on the plume buoyancy flux. This suggests that more efforts are needed to accurately capture water phase changes impact on plume dynamics in 1D plume models. Furthermore, we show that when accounting for uncertainties and excluding the least constrained events in IVESPA, the 1D plume model outperforms the empirical power-law relationship. Accounting for uncertainties and continued resources for high-quality eruption source parameter datasets is thus key for future plume model development and evaluation.

Examining the role of continental collision magmatic activity in Phanerozoic continental crustal growth

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Evolution of Earth's continental crust has a large influence on Earth and ocean systems, but the mechanisms and rates of continental growth over geological time are debated. Studies of long-term growth are largely based on the zircon record, which is informative, but biased by various processes. In addition, the zircon record does not directly address the mechanisms and sites of continental growth. It is generally assumed that the majority of continental crustal growth takes place in arc-type tectonic settings, although these are also the primary sites of crustal recycling into the mantle. In contrast, continental collision zones are generally considered to be sites of crustal recycling with minimal growth. However, this view is largely based on a study by Scholl & Von Huene [1] which did not directly measure crustal growth in collision zones, but assumed a value based on a comparison with Andean-type magmatism.

We are examining the role continental collisional zones have played in crustal growth by studying the volcanics of Eastern and Central Turkey over the past 30 Myr as a case study. This region is being used as it has a wealth of geochronological, geochemical and petrological data. These data show that there is widespread volcanism associated with post-collisional tectonics largely driven by asthenospheric upwelling within the region. The transition is reflected in the volcanic activity; with an evolution from calc-alkaline to high potassic magmatism to more recent sodium-rich basalts, reflecting the change from subduction to the continent-continent collision. Initial studies of the volcanic history of this area have concentrated on an age frequency-based approach. We are developing an approach, using geochronological and geochemical data to initially develop a model of the volcanic area as a function of age, which will then be developed further to calculate magmatic volumes through time. The initial step has been to correctly locate all the published data. The data is then assigned to areas of volcanic rocks mapped by the Turkish Geological Survey (MTA). Following this, we have developed a model which provides an accurate history for over 50% of the volcanic area in the study area. Comparison of the geochemical and petrological data from dated and undated areas then allows us to present a complete history of the area of volcanic rocks erupted in the study area over the past 30 Myr. The implications of these results will be discussed at the meeting.

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Robust Observation of Volcano Displacement Using Sub-Pixel Offset Tracking on High-Resolution Satellite SAR

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Large flank movements at volcanoes can lead to devastating landslides and volcanic eruptions; monitoring such motion can help reduce the impact of these disasters. Ground monitoring is often missing or too sparse to capture the extent and magnitude of slope displacement. Fortunately, satellite SAR can retrieve flank motion through Interferometric Synthetic Aperture Radar (InSAR), or Sub-Pixel Offset Tracking (SPOT). SPOT is more suitable than InSAR for detecting large-magnitude displacements with an achieved precision of approximately 1/10th of the pixel dimensions. High-resolution SAR data therefore allow for 1-10 cm level precision. Vegetation and steep slopes degrade the data quality of InSAR and SPOT. We propose a method for robust displacement estimation from pixel offset tracking in steep-sloped and vegetated areas. To test, we use high-resolution satellite SAR data over Merapi volcano (Indonesia), which experienced complex cm-m scale displacements in late 2020. For our procedure, we first estimate pixel offsets using multiple window sizes. Next, we detect and remove outliers in the offset data. We evaluate the outlier detection performance of 5 methods (median difference, Local-Outlier-Factor, HDBSCAN, GLOSH, and a combination of median difference and HDBSCAN) using the area-under-the-curve (AUC) of receiver-operator-characteristic (ROC) curves. We find that the median difference filter with a filter radius of 7 pixels performs best for small window sizes and the combination of the median difference filter and HDBSCAN (with a minimum cluster size of 300 and minimum samples of 1) performs best for larger window sizes, with AUC values of 0.92 and 0.90, respectively. Additionally, we find that large window sizes misrepresent the position of sharp boundaries in the displacement field and smooth out small displacement features. Therefore, large window sizes are only suitable for smooth displacement signals. Finally, we average multiple window sizes on a pixel-by-pixel basis. The resulting offset maps improve the precision over vegetated areas from 0.09 m to 0.05 m in range, and from 0.23 m to 0.09 m in azimuth. Over the non-vegetated areas, the precision slightly degrades because of the inclusion of the multiple window sizes going from 0.010 m to 0.027 m in range and 0.026 m to 0.048 m in azimuth. The resulting offset maps also preserve sharp boundaries associated with lava flow edges. The proposed procedure can be performed in addition to other specific filtering techniques and can be applied in steep and vegetated terrain with applications for volcano flank motion and landslide areas.

The origin and magnitude of gas emissions at a major Ethiopian Rift volcanic system.

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The Ethiopian Rift valley hosts numerous restless silicic volcanic centres. At the surface, these volcanoes are typified by fumaroles and hot springs, and there is good evidence that they contain significant reserves of untapped geothermal Energy. Despite this potential, major uncertainties remain about the deep architecture of their magmatic-hydrothermal systems, as well as origin and magnitude of their gas emissions (and whether it is significant from a global perspective). Here, we combine a high-spatial resolution soil CO_2 survey and gas geochemical study to better understand volcano-tectonic structures and quantify gas emissions at the Tulu Moye volcanic complex, Ethiopia's most promising geothermal site, located in the Central Main Ethiopian Rift. The soil CO_2 degassing shows highest fluxes along major NNE-SSW rift-aligned normal faults. Interestingly, NW-SE faults, at high angle to the major rift-aligned faults, are also identified as sites of high CO_2 and we hypothesise that these are linked to pre-rift faults. These observations highlight the significant role that tectonic faults play in controlling the uplfow of volatiles and hydrothermal fluids. The total magmatic CO_2 emission is calculated to be 390–450 kt y^{-1}, a value that is comparable to C emissions from persistently active arc volcanoes and makes Tulu Moye the highest known site of C emission in the Ethiopian Rift Valley. The soil CO_2 -$\delta^{13}C$ values range from -1 to -6 ‰, suggesting that magmatic outgassing is the dominant CO_2 emission source. Finally, fumarole gases samples show exceptionally high He isotope ($^3He/^4He$) of 13 – 17 R_A. These too are among the highest He isotopes ratios measured in gas samples from Ethiopia and require a deep mantle plume source for the volatiles, with limited crustal overprinting of the primitive He isotope ratio. These new results allow us to develop a detailed understanding of the deep architecture of the Tulu Moye volcanic system, and by extension other major volcanic-geothermal systems of Ethiopia. They emphasise a deep mantle plume input, high levels of magmatic intrusion within the crust, and an important role of tectonic faults at directing the flow of gas and hydrothermal fluids towards the surface.

Rapid temperature fluctuations in the early Iceland plume revealed by olivine-spinel and melt thermometry

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The Antrim Lava Group (Northern Ireland) is among the largest and earliest-formed surface expressions of the British and Irish Paleogene Igneous Province (BIPIP), which comprises part of the larger North Atlantic Igneous Province [1]. Despite this, it remains comparatively little-researched, with very few geochemical or petrological investigations undertaken in the past 30 years. Addressing this shortcoming represents an excellent opportunity to develop our understanding of the melting conditions and crustal interactions associated with initiation of large igneous province (LIP) volcanism in the North Atlantic.

The ALG consists of two main lava sequences (the Lower and Upper Basalt Formations) separated by <30m thick laterites which mark a pronounced hiatus in volcanism. This sequence has been cored through its thickness for mineral exploration at multiple sites. These allow detailed sampling and logging of a continuous stratigraphically-controlled succession. Each flow from this section has been sampled, totalling 67 samples, and analysed for whole rock major and trace element geochemistry. Melting temperatures have been assessed through the succession by two inpedendent methods: olivine-spinel Al exchange thermometry and whole rock olivine back-fractionation using PRIMELT3 [2]. Back calculation to remove the effects of ubiquitous clinopyroxene fractionation on whole rock temperatures has been achieved using a novel Monte Carlo approach. This provides a uniquely detailed record of melting temperature during LIP volcanism.

Both temperature records indicate substantial (100-120°C) variation in melting temperature over a relatively short stratigraphic interval in the Lower Basalt Formation (LBF). This contrasts with the later Upper Basalt Formation (UBF) which shows much less variation in melting temperature, suggesting intial instability or pulsing of mantle/plume temperature stabilised with time. Variability in melting temperature is mirrored by proxies for crustal and volcanic processes; Ni contents of olivine are elevated in the same interval as the lowest melting temperatures indicating mixing of primary and more evolved (MgO > 6%) melts. This suggests low magmatic flux into the crust in this interval. The ubiqutity and thickness of red weathering horizons capping lava flows is also significantly higher in the LBF indicating prolonged repose periods between eruption and a stop-start rhythm to volcanism. This suggesting that variabilty in mantle temperature through the LBF may have ultimately driven the tempo of volcanism at the surface. Finally, in this context the pronounced hiatus between LBF and UBF sequences may relate too to even more significant fluctuations in mantle temperature.

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A global analysis of lava dome and lava spine geometries

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The geometries of lava extrusions in nature exist on a spectrum and can be most easily characterised by their aspect ratio, calculated as height divided by width. When highly viscous magma extrudes, it either piles up to form a lava dome, or extrudes as a solid lava spine. This behaviour has been observed at over 200 volcanoes globally, but the quality and quantity of measurements made in these locations is highly varied and the full range of extrusion geometries remains poorly characterized. The need to monitor and understand the growth of viscous extrusions persists since structures become increasingly unstable as their aspect ratio increases. To better understand factors influencing extrusion geometry and growth, we have collated 323 measurements of height, width, and composition from 46 volcanoes globally, including five time series records. We found that extrusion geometry is sensitive to age, with extrusions > 250 years old showing lower heights for a given width compared with younger extrusions. Furthermore, we found that our collated dataset contains insufficient records from basaltic, trachytic, and rhyolitic extrusions to include these in statistical analyses. Across the three compositions with sufficient sample sizes (basaltic-andesitic, andesitic, and dacitic), we found that extrusion height and width do not exhibit a statistically significant dependence on composition. Lastly, we found that height and width of lava domes and spines are well approximated by a Weibull distribution and scale according to a truncated power law. We therefore suggest that the probability distributions of these first-order geometric parameters can form a basis for probabilistic hazard forecasting. Importantly, our dataset also serves as validation for analogue and numerical modelling studies that explore the temporal evolution and factors controlling dome and spine growth. The dataset presented here is open access and we encourage members of the volcanology community to use and contribute to this resource, which can be found at [https://theghub.org/resources/4988], or scan the QR code below.

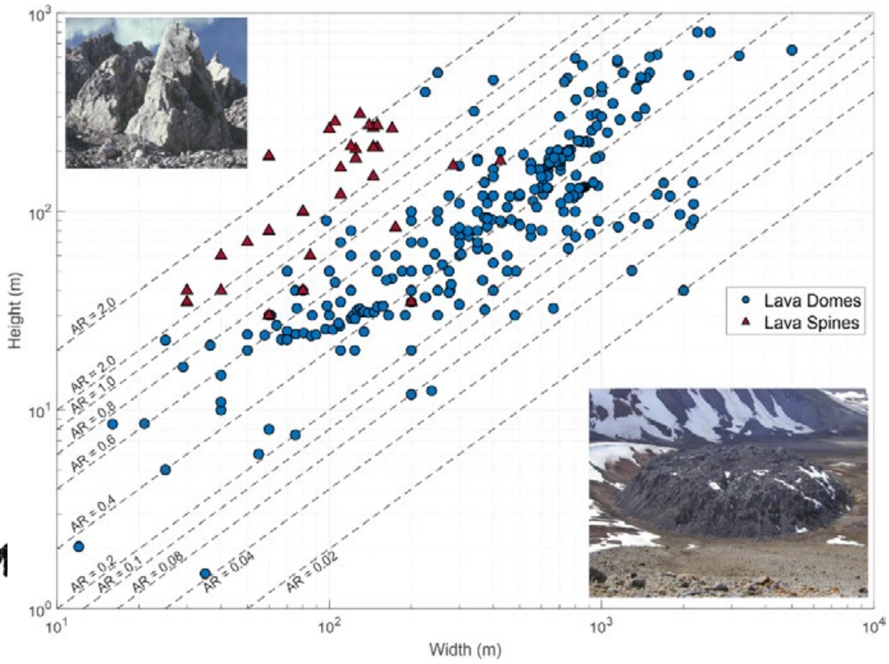

Figure: Log-log plot of height and width of measured viscous extrusions where the characterisation as either a lava dome or spine is taken from the source publication. Dashed lines represent lines of equal aspect ratio. Photographs show typical lava dome (Novarupta, USA; USGS) and lava spine (Santiaguito, Guatemala; Bill Rose).

Evaluating the role of complex topography on ground deformation modelling at marine volcanoes

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Marine volcanoes have significant topographical relief considering their extent above and below sea-level. For example, Moana Loa (Hawaii) rises to 4170m above sea level and down to 6000m below sea level, extending over 10,000m in total, surpassing the largest mountains on Earth. So far, the effect of topography has commonly been neglected in volcano deformation modelling which has proven to lead to significant misinterpretations of surface displacements for axisymmetric volcanoes. Compared with subaerial volcanoes, marine volcanoes have a more complex geomorphometrical classification as they consider both the subaerial and submarine portions of an edifice. Therefore, it can be said that a symmetric topography is not completely accurate for these cases. In this study, we aim to evaluate the effect of using asymmetric representations of topography in simple deformation modelling and quantify how this impacts surface displacements at marine volcanoes.

We investigate this effect by using an analytical solution, where the deformation source is simulated by triangular dislocations. First, we test a set of synthetic topographic cases to determine the influence of important geomorphometrical parameters – asymmetry and steepness - on surface displacements. Secondly, we apply the same approach at case study volcanoes, which exhibit different edifice geometries: El Hierro (Canary Islands), Mount Etna (Italy) and Stromboli (Italy). We use freely available DEMs and bathymetry to create the topographic surface. To evaluate the effect at all synthetic and real cases we compare the difference between the displacements generated from the model with topography and without.

We find a threefold overestimation of vertical displacements in shallow sloped and symmetric volcano models without topography. Conversely, steep and asymmetric cases underestimate maximum vertical displacements by at least ~30% in the absence of topography. Therefore, highlighting the importance of including topography in modelling scenarios as results are dependent on the shape of the volcano. Additionally, we find that radial deformation can occur beyond the shoreline at real cases which can have implications for future modelling of shoreline crossing geodetic datasets. These results can help define the importance of including topography in kinematic modelling of marine volcanoes worldwide.

Temporal Variations In North Atlantic Mid-Ocean Ridge Magmatism and Plume-Ridge Interaction: Insights from IODP Expedition 395C.

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The Reykjanes Ridge is one of the best 'window samplers' into plume-ridge interaction on Earth, as it samples asthenospheric mantle in the immediate vicinity of the Icelandic mantle plume. The dynamics of this subcrustal interaction remain poorly constrained, but are vital to understand if we are to develop our comprehension of the mechanics of mantle plumes and mid-oceanic spreading systems. The Reykjanes V-shaped ridges (VSRs) and troughs (VSTs) are time-transgressive linear crustal anomalies that straddle the Reykjanes Ridge south of Iceland, that are thought to represent the progressive sampling by the ridge axis of mantle temperature anomalies advecting away from the Icelandic plume conduit. Therefore, the V-shaped ridges are likely a direct manifestation of plume-ridge interaction, and so act as a natural laboratory where transient mid-ocean ridge processes can be probed. To this end, International Ocean Discovery Programme Expedition 395C drilled into two VSRs and VSTs along a plate-spreading flow line 600 km south of Iceland in Summer 2021. Over 400 m of basalt was recovered, representing an archive of basaltic magmatism at the ridge axis over 15 Ma of plate spreading, a fixed distance from the Icelandic plume conduit. Joint petrological, petrophysical, and geochemical analysis of the recovered basalt has yielded significant insights into the magmatic processes operating at the axis. Observations of volcanic morphology has shown that VSRs contain significantly more sediment, peperite and pillow lavas in comparison to VSTs, which contain abundant sheet flows. This implies that the transitions from VSR to VST formation are accompanied by fundamental changes in axial eruptivity. Measurement of major and trace elements over the entire recovered sections of each borehole reveal distinct changes both within and between sites. Furthermore, measurement of 50 Nd isotope compositions of the basaltic whole-rock samples reveal ƐNd has changed from approximately 7.5 to 10.5 over the last 14 Ma, with a linear relationship, that implies a gradual dilution of Icelandic plume material present within the mantle source of melting at this latitude. This dilution is counter intuitive as it has occurred synchronously with the entire timeframe of VSR formation and anticorrelates with seismically constrained changes in crustal thickness. Therefore, this isotopic, and allied petrological and geochemical, data has the potential to transform the way we understand the relationship between mantle source composition and crustal production, at the mixing front between the mid-ocean ridge system and what is argued to be the largest mantle plume on Earth.

The effect of moisture on cohesion of pyroclastic material: implications for deposit architecture and flow behaviour.

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Pyroclastic density currents (PDCs) are hazardous, multiphase currents of heterogeneous volcanic material and gas. Moisture can enter a PDC through external (e.g., interaction with bodies of water) or internal (e.g., from phreatomagmatic eruptions) processes. The effects that moisture has on PDC transport, deposition and remobilisation of material remains poorly understood. This project aims to understand how moisture alters the properties of pyroclastic material and the resulting impact on PDC propagation and sedimentation. This research enhances our understanding of PDC dynamics, how they react to variations in internal and external conditions, and the factors that control the depositional record of PDCs. Improved interpretation of PDC deposit architecture is pivotal in improving volcanic hazard prediction and assessment.

Analogue experiments were conducted to investigate the behaviour of static pyroclastic material with increasing moisture addition. Our results showed that 1) the cohesivity of pyroclastic material changes with the addition of small amounts of moisture, 2) moisture changes can impact gas transport pathways and material fluidisation and 3) gas flow through a deposit can result in moisture profiles, leading to mechanical heterogeneity within the deposit. Material property experiments demonstrate that the addition of even slight (<0.50 %) moisture increments had an impact on the cohesive and frictional behaviours of pyroclastic material. Such changes may significantly affect the ability of a PDC to transport, deposit and erode material, consequently impacting depositional architectures.

Fieldwork in Tenerife and Lipari was conducted to investigate examples of volcanic stratigraphies in which moist syn-depositional conditions have been previously inferred. In Tenerife, fine-grained ash layers in the 273 Ka Poris succession showed varying resistance to erosion and remobilization by subsequent PDCs. This is though to be due to changes in apparent strength, which may be attributed to moisture content and cohesivity. In Lipari, moist, ash rich dilute PDCs of the Brown Tuff succession appear to have compressed, sheared, and remobilized underlying deposits. To understand these field observations, we are conducting analogue flume experiments looking at PDCs propagating over loose substrates with varying moisture content. Shear tests will also be used to explore ash strength and shearing behaviour at varying moisture contents. Together, these experiments will help elucidate how moisture governs deposit erosion and substrate remobilisation.
Our research has revealed that increasing moisture within a PDC system transforms material flowability, transitioning from free-flowing to a non-flowing behaviour. This potentially has implications for PDC dynamics and sedimentation of material. Further planned experiments will investigate dynamic flow behaviour under small variations in moisture.

International volcanology: some publishing perspectives.

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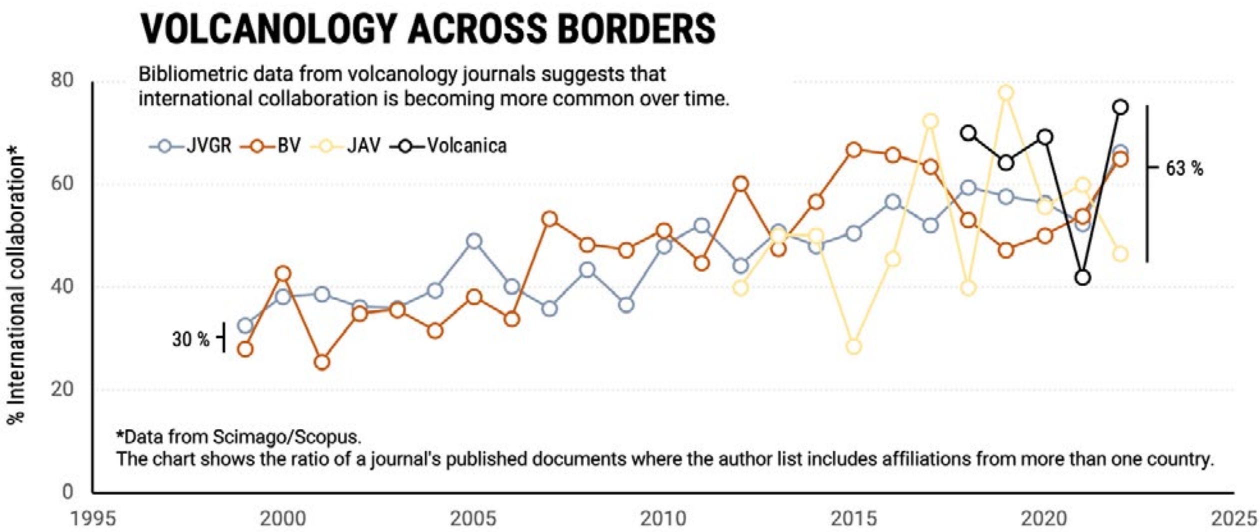

Volcanoes do not care about borders. This is reflected in the increasingly international nature of volcanology as a discipline, using bibliometric data as a proxy for international collaboration. We look at the percentage of articles in different journals which include affiliations from two or more countries. Research in volcanology-specific venues (*Journal of Volcanology and Geothermal Research*, *Bulletin of Volcanology*, *Journal of Applied Volcanology*, *Volcanica*) demonstrate a progressive rise in this metric over 1999–2022, from around 30% in 1999 (*JVGR*, *BV*) to averages of around 60% over 2020–2022. This is notably higher than generalist journals such as *Nature* and *Science* (from 12–15% to 24–27%).

The apparent increase in international collaboration is positive; nevertheless, there still remain substantial disparities in published work from country to country. In particular, the use of English as the default language of scholarly publishing constitutes a significant barrier to maximising the contribution of non-native English speakers to volcanological research. Studies have highlighted time costs (e.g. increased time taken to read and write manuscripts, conduct reviews and editorial tasks, or prepare presentations) and financial costs (e.g. requirements to engage editing or translation services). Anecdotally, articles by non-native English speakers are more likely to be desk-rejected or subject to discriminatory reviews on the basis writing quality, constituting a “career cost” as well. Additional factors include reduced opportunities to review and edit English-language research. We aim to collate survey data from researchers writing in English for whom English is not their first language, providing an invaluable dataset for evaluating the scale of the setbacks faced by non-native English speakers.

Volcanica has implemented language-related initiatives aimed at improving research accessibility, including the option to provide abstracts in languages other than English, and a fully bilingual special issue. The bilingual special issue involved simultaneous publication of translated works (English, Spanish), affording a unique look at article access solely as a function of language. Article downloads were broadly comparable for both versions of the manuscripts, with the Spanish-language version typically downloaded more often. The possibility of simultaneous publication of research in multiple languages may be a step towards better valorising the contribution of volcanologists around the world as well as facilitating both local and global objectives and application of volcanological research.

Populations on Volcanic Islands: Life in the Shadow of Stromboli, Aeolian Islands, Italy

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Stromboli is one of two active volcanoes in the Aeolian Archipelago, with its continuous eruptive activity dating back to 8th century AD. The island itself has been inhabited on and off since the Copper Age (4000-3800 BC), with a population reaching its peak in the 1890s (2,700), yet dramatically declining between the 1900s to 1970s (450 in 1970), due to a complex mixture of socioeconomic and environmental factors. At present day, Stromboli is home to a community of ~500 Strombolians, however, during the high tourist season between June and September, the population can reach up to 5,000.

In 2002-2003, 2007 and 2019 Stromboli experienced larger than usual paroxysmal eruptions posing higher hazard risk and danger to the communities of the two small villages on the opposite sides of the volcano, given their proximity to the volcano. The increased risk of large-scale paroxysm events mean that the population is now not only exposed to volcanic, but also to tsunamigenic landslide hazards, which can have devastating effects, especially to Stromboli village that lies very close to the sea. Due to incandescent pyroclastic materials reaching further down the slopes of the volcano during the large-scale paroxysms, Stromboli is now more prone to wildfires, as seen during the 2019 paroxysm event. In the last couple of years, significant damage and loss of vegetation around volcano slopes from wildfires also made villages on Stromboli more prone to flooding and debris flows after intense rainfall.

Although Stromboli is one of the most intensely monitored volcanoes in the world, barely any research has been conducted on hazard risk perceptions of the local Stromboli communities, and their vulnerability and resilience to all the potential large-paroxysm-induced hazards. Therefore, the main purpose of this PhD project is to understand and evaluate how the Stromboli population perceives the risks of paroxysm, tsunamigenic, wildfire, flooding and other hazards present on the island, whilst also assessing the overall vulnerability and resilience of the community. The project also examines various stakeholders' engagement in DRR and hazard mitigation strategies on Stromboli. Since this project is very interdisciplinary with various disciplines converging, complex human-environment relationships, as well as social, cultural historical and other external factors, must be evaluated and addressed for multiperspectivity, depth and rigour. Therefore, a bricolage approach is used to allow methodologies from different disciplines to be combined, to address the interdisciplinarity, multiperspectivity and complexity of the nature of the project and its aims.

A zircon case for super-wet arc magmas

Chetan Nathwani[1,2,3], Simon Large[2], Jon Blundy[4], Matt Loader[2], Jamie Wilkinson[2,3], Yannick Buret[2] Lorenzo Tavazzani[1] & Cyril Chelle-Michou[1].

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[3] Department of Earth Sciences, University of Oxford, UK

Magmas emplaced in subduction zones have elevated contents of dissolved water relative to those emplaced in other tectonic settings. Measurements of water in glassy melt inclusions suggest that most mafic arc magmas which feed arc volcanoes contain 2-6 wt.% H_2O. This restricted range of arc melt inclusion water contents, regardless of melt differentiation, is at odds with the water contents produced by fractional crystallization of a 2-4 wt.% H_2O primitive basalt (6-11 wt.% H_2O). A growing body of evidence points towards higher concentrations of water dissolved in intermediate to felsic arc magmas at mid- to deep-crustal levels (>8 wt.%). Whether such super-wet magmas are commonplace or eventually reach the upper crust remains unknown. One mineral that can potentially survive ascent from deeper magma reservoirs and escape re-equilibration at shallow crustal levels is zircon. Here, we investigate the controls of initial magma water contents on zircon saturation in arc magmas using thermodynamic modelling and experimental constraints on zircon saturation. We show that increasingly wet magmas have markedly lower liquidus temperatures and thus different crystallization trends. As a result, super-wet magmas (8 wt.% H_2O, 400 MPa) saturate zircon early in the crystallisation sequence (30% crystallinity) and at low temperatures (780°C). Therefore, zircons crystallized from super-wet magmas will result in homogeneous and low Ti concentrations.
We test the idea of early, low temperature zircon saturation in super-wet arc magmas by presenting new zircon data from porphyry Cu districts. In all cases, porphyry Cu deposits show homogeneous and low zircon Ti. Host precursor batholiths show higher and diverse Ti concentrations which transition to lower concentrations over time. This suggests a transition from damp to super-wet arc magmatism coincident with porphyry Cu deposit emplacement. We also find that zircons from magmatic systems previously posited to contain high water contents contain similar low, homogeneous zircon Ti concentrations. Our findings hint that super-wet magmas are common products of mature arc magmatism and have paramount importance in ore deposit formation and shaping modern continental crust.

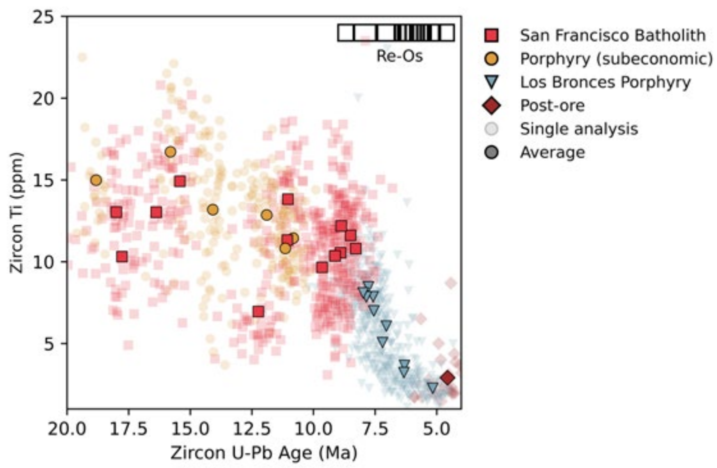

Figure: LA ICP-MS data from 19 intrusive rocks from the Los Bronces porphyry Cu deposit, Central Chile showing a marked change in zircon Ti concentrations in coincidence with porphyry Cu mineralisation (8-5 Ma)

Formation of Pele's hair by stretching of bubbly magma

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Pele's hair – long, thin, hair-like strands of volcanic glass – is a common product of explosive basaltic eruptions. It has been proposed that strands of Pele's hairs are formed when small droplets of lava are deformed by strong jets of magmatic gas, which stretch them into long filaments. However, Pele's hair is also found in large, tangled clumps which do not appear to have formed as individual hairs. Here, we demonstrate a new mechanism for the formation of Pele's hair by the stretching of bubbly lava during eruption. We reproduce Pele's hair experimentally by pulling apart a foam of molten art glass in a custom-built apparatus employing a pulley mechanism. The molten, bubbly glass solidifies as it cools, replicating behaviour in the natural system which is not captured by isothermal analogues.
As the analogue is stretched, junctions between bubbles are deformed and eventually produce long, thin strands of glass. Samples at high bubble fraction (~90 vol.%) produced long, intertwined strands of glass, as thin as 4 μm in diameter. Many strands contain long tube-vesicles, as found in some natural samples. The hairs are connected to less deformed regions of glass containing bubbles that are more spherical. Samples at low bubble fraction (~20%) produced thin glass ribbons containing tube-vesicles, and occasional hair-like strands. While bubble-free samples produced a continuous, thin glass sheet with triangular ridges. These represent the range of textures present across a wide spectrum of deformation that may occur in basaltic pyroclasts. These experiments reveal an alternative formation mechanism for Pele's hair, where they may form during weakly explosive or fountaining eruptions, from bubbly lava fragments that separate as they are erupted, deforming the vesicles and stretching to form long strands of glass that cool almost immediately.

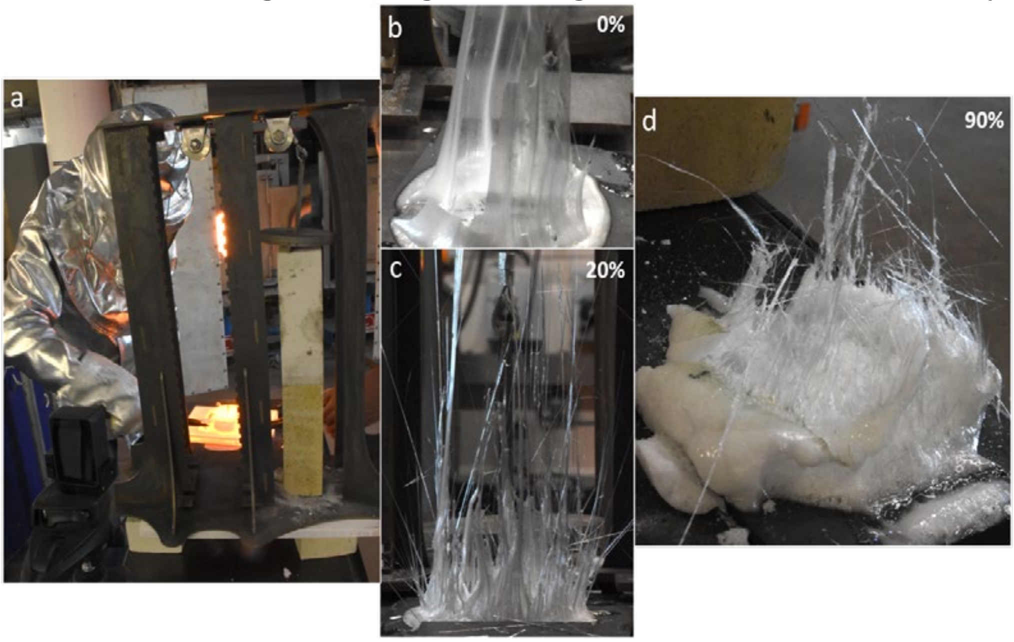

Figure 1. a) Loading molten glass foam into pulling apparatus. b) continuous glass sheet formed from ~0% gas fraction pulled glass. c) glass ribbons and hairs produced from ~20% gas fraction glass. d) thin hairs produced from ~90% gas fraction pulled glass foam.

Quantifying daily volcanic SO_2 emissions on a global scale.

Ben Esse[1], Mike Burton[1], Catherine Hayer[2]

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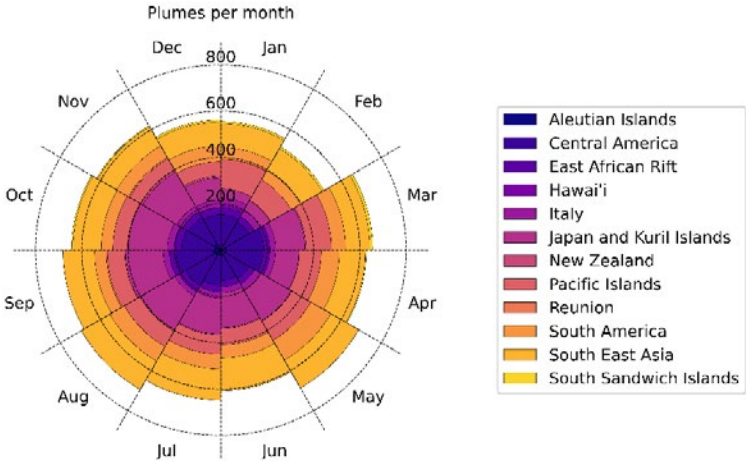
The expression of volcanic activity at the Earth's surface is accompanied by the emission of a cocktail of different gases, including water, carbon dioxide, sulphur species, halogens and metals. The composition and magnitude of these emissions reflects the state of magmatic systems, providing insights into volcanic processes and key hazard monitoring information. Many of these products also have serious health implications for local communities and are important species for the global climate. The primary target species for quantification of volcanic emissions is SO_2, due to its high prevalence in volcanic emissions, its low typical atmospheric concentration and the ability to detect it remotely using UV and IR spectroscopy from both ground and space. Satellite instruments provide a global view of volcanic activity through a combination of geostationary and polar orbiting platforms. This is particularly useful for remote or difficult to reach volcanoes, as well as for identifying eruptions from those which have not been historically active. Most previous satellite work has focused on explosive eruptions due to the decreased sensitivity of satellites to SO_2 lower in the atmosphere, however recent advances in instrumentation and processing algorithms have opened the possibility of detecting and quantifying passive emissions in the troposphere.

Here, we combine daily SO_2 imagery from the TROPOMI satellite instrument with the PlumeTraj back-trajectory analysis toolkit developed at the University of Manchester to detect and quantify daily SO_2 emissions as a function of time and altitude from volcanoes globally throughout the year 2020. We consistently detect more than 20 degassing volcanoes per day, with an average total non-explosive global emission rate of ~14 kt/day. The emissions seen are predominantly effusive, being emitted at or around vent altitudes, though several explosive eruptions are also captured.

These results demonstrate the ability of TROPOMI and PlumeTraj to provide daily automatic SO_2 emissions for volcanoes globally. In the future, this analysis will be extended to the full TROPOMI dataset (from 2018 to present) as well as to the development of a near real-time processing workflow. This will generate an invaluable dataset of volcanic degassing for investigating volcanic processes and characterising SO_2 emissions as a function of latitude and altitude, an important input for global climate modelling. Finally, the near real-time analysis will provide a key monitoring tool for volcano observatories worldwide.



The total number of volcanic plumes (explosive and effusive) identified per month for separate regions around the world.

Formation of volcanic domes on Venus and the mobilization of crystal mush: Insights from the Troodos Ophiolite, Cyprus

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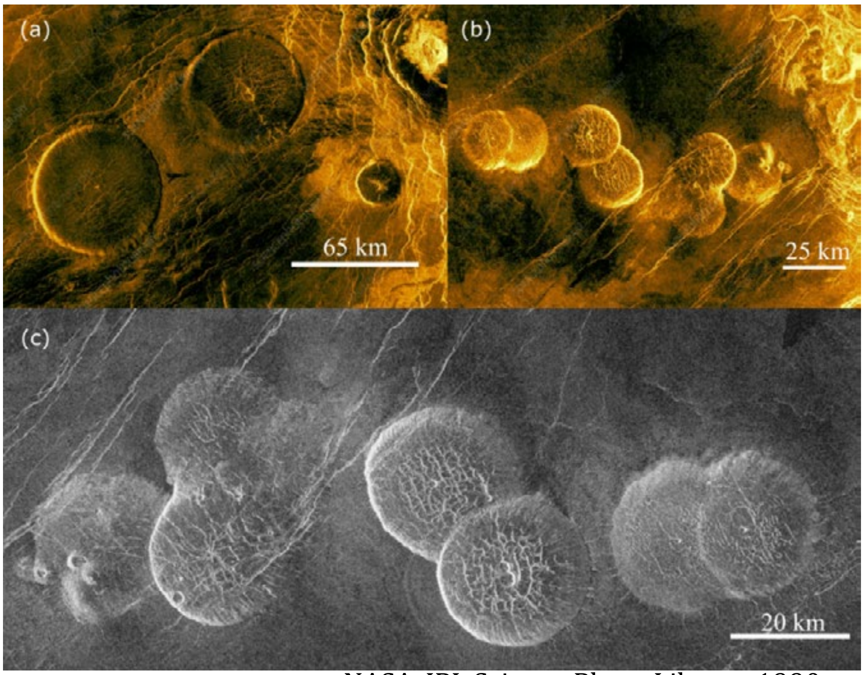
Steep-sided domes are prominent volcanic landforms on Venus that are postulated to require eruption of highly viscous magma. They are pivotal in (1) deciphering the range of magmatic processes operating on Venus, and (2) elucidating geological evolution of stagnant lid regime planets. We have investigated potential mechanisms for the formation of Venusian domes by constraining the viscosity of liquids formed by batch melting (BM) of Venusian crust or by fractional crystallisation (FC) of primary magmas.

We executed numerous simulations using the Rhyolite-MELTS Matlab interface to model magma compositions using bulk compositions inferred from Venera 13 (alkaline basalt) and Venera 14 (low alkali basalt) lander data at different pressures (0.01-1GPa), temperatures (800-1400°C), water content (0-1 wt.%), from which we subsequently calculated viscosities. Those viscosities were then compared to published physical models of Venusian dome formation. FC and BM processes alone fail to produce magmas with viscosities required to account for formation of steep-sided domes. Presence of water during BM can substantially modify magma composition, but only results in a substantive increase in liquid viscosity if magmas are unexpectedly water-rich and extensively degas prior to eruption. Crystal content may also markedly increase viscosities by an order of magnitude towards those needed in physical models, although required crystal contents exceed 50%, again suggesting that magmatic processes cannot easily account for steep-sided dome formation.

To investigate constraints on the eruption of crystal-rich lavas we have investigated olivine-rich (>50 vol%) picritic lavas from the Marki region, Cyprus. Geochemical data from these picrites and volcanic glasses across the Troodos ophiolite have been used to constrain conditions of olivine crystallisation, and the context of picrite formation within wider magmatic processes. As such, although picrites demonstrate the feasibility of eruption of crystal-rich lavas, they again imply that steep-sided dome formation on Venus required an unusual set of processes.



NASA, JPL Science Photo Library, 1990.

Figure: Venusian volcanic pancake domes, based on radar data from Magellan spaceraft. (a) and (b) are stemmed from Eistla region, and Eastern edge of the Alpha region, Venus, respectively.

Assessing models for Large Igneous Province formation using a new magma productivity record spanning the North Atlantic Igneous Province

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Large Igneous Provinces (LIPs) represent dramatic events in Earth history and are frequently linked with significant environmental change. LIP formation models can broadly be split into four categories: bottom-up convection (e.g. mantle plumes), top-down convection (e.g. basal lithospheric instabilities), compositional difference (e.g. mantle fertility) and external driving forces (e.g. meteorite impacts). Despite these models predicting distinct patterns of magmatic productivity and surface uplift the lack of complete records across an entire LIP cycle, from initiation to final emplacement, has hindered attempts to assess their validity.
At volcanic passive margins, oceanic crustal thickness as measured by seismic refraction profiles can be directly interpreted as a record of magmatic productivity. However, due to the well-known association between LIPs and continental break-up, the onset of seafloor spreading usually post-dates LIP initiation. Therefore, almost all existing oceanic crustal records are missing the first half of the LIP formation cycle. The North Atlantic Igneous Province (NAIP) provides an exciting opportunity because break-up in the south preceded LIP onset, allowing us to accsess a record of the full waxing and waning cycle of LIP formation. In May 2021, the PORO-CLIM project acquired a new seismic refraction profile across the Rockall Plateau margin (NE Atlantic) that contains the first continuous record of magmatic productivity during the entire formation cycle of any of the world's LIPs. This dataset shows a long-term (>5 Myr) increase in crustal thickness from earliest-Paleocene to a peak around the Paleocene-Eocene boundary, followed by decreasing thickness in the earliest-Eocene. Shorter-term 'pulses' of increased thickness are superimposed on this long-term trend, comparable to the peaks in surface uplift recorded in the adjacent continental margin. The need for a mechanism to explain coupled changes in oceanic crustal thickness and widespread surface uplift strongly favours a mantle plume initiation (i.e. bottom-up) model for the NAIP, with the shorter term fluctuations lending support to more specific 'pulsing plume' models.

Sensors as a tool to understanding hazards and connecting people in hazard-prone zones.

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Citizen Science projects have been developed and applied to create collaborations with people without formalised science training in risk zones and thus contribute to Disaster Risk Reduction (DRR). However, a focus on the collection of data to define hazard behaviour is important but not all that is needed for DRR.

In this presentation, we explore a research project that involves a different kind of citizen science, that is 'people-centred', focused on the knowledge, interests, and needs of communities at risk. The methodology begins with meetings, and different participatory workshops. These are designed to foster relationships between the participants creating a shared understanding of hazards, their monitoring, and their impacts. At this point sensors (Seismometers, weather stations) were installed by the communities in collaboration with scientists, implementing their new knowledge. This acted to not only enrich and deepen the conversation about the hazards they are exposed to but integrate the experiences, and perspectives of community members. Then everyone had a wider understanding of the expectations that each of the actors in risk areas have about the sensors, but also about the data, its history, its use, its application, and its importance for both scientists and non-scientists. It is our aim that all participants have more tools for decision making before, during and after the occurrence of an adverse event related to geological hazards, and there are open channels of communication between the different actors as a consequence of this approach.

New thermodynamic models for alkaline-silicate magmatic systems

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Alkaline-silicate magmatic systems are geologically and economically important, for example as small fraction metasomatic melts and hosts of rare earth element (REE) deposits. While phase equilibria modelling is an increasingly popular tool for the analysis and contextualisation of igneous systems, currently it is not possible to model most alkaline compositions. This limitation is due to the absence of an appropriate activity-composition model for alkaline-silicate melts, as well as a dearth of models for their crystalline products.

Here we present a new model for alkaline-silicate melts in the Na_2O–CaO–K_2O–FeO–MgO–Al_2O_3–SiO_2–H_2O–TiO_2–O_2–Cr_2O_3 (NCKFMASHTOCr) model system along with new models for nepheline, kalsilite, leucite and melilite. The models are calibrated with experimental information and benchmarked against six independent experimental datasets (e.g., Figure 1) encompassing a range of pressure (0–22 kbar), temperature (680–1350 °C), oxygen fugacity (log fO_2 ΔFMQ-3 to +1), total alkali (5–16 wt%) and silica (37–70 wt%) conditions. The calculated pseudosections successfully reproduce experimental crystallisation sequences and phase compositions across this spectrum of conditions, indicating that the models are well calibrated within these ranges.

We apply our models to average alkaline-silicate bulk compositions (e.g., nepheline syenite, syenite), yielding solid assemblages consistent with those reported for these compositions in each case, including model analogues to common exsolution textures. Analysis of the liquid line of descent reveals that for silica-undersaturated compositions the final melt fraction evolves to extremely alkali-rich compositions, potentially explaining the source of 'fenitised' zones of alkali metasomatism commonly observed around intrusions of these compositions. We also use our models to predict residual REE enrichment in alkaline-silicate systems based on mineral-melt partitioning to explore the roles of bulk composition and crystallisation conditions in generating REE-rich melts.

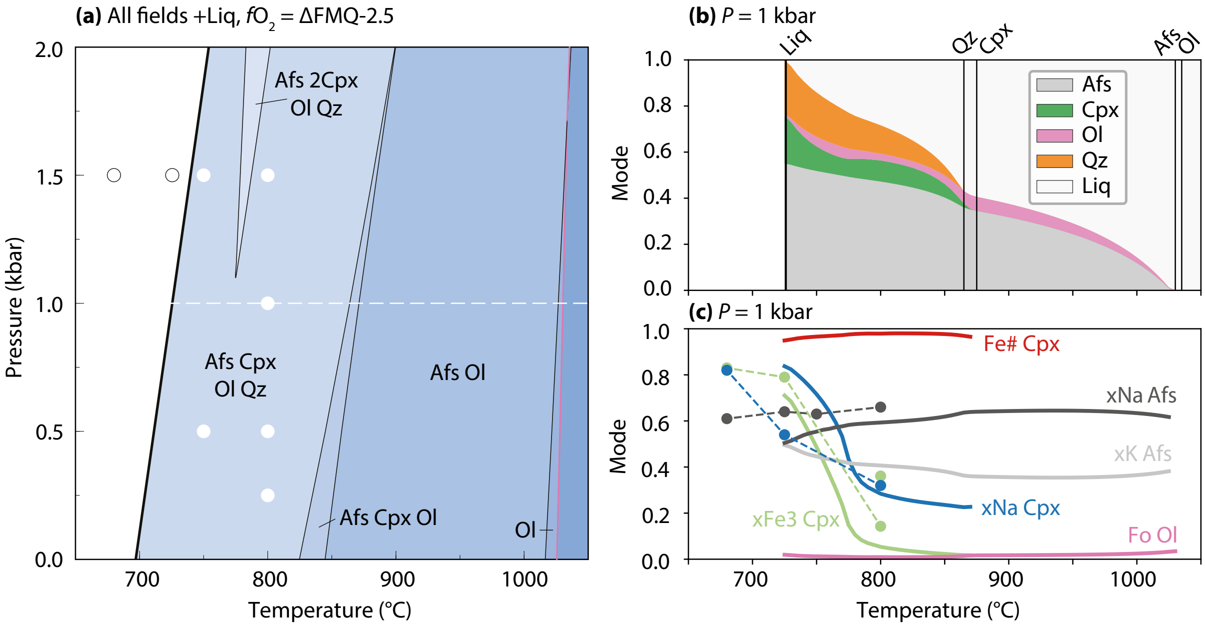

Figure 1: Example benchmark of sample PAN (a pantellerite) from Di Carlo *et al.* (2010). (a) P-T pseudosection. White dots show experimental conditions. (b) Modebox at 1 kbar. (c) Selected compositional parameters at 1 kbar, overlain by compositions (filled circles) from experiments.

New insights into the magmatic systems feeding caldera-forming eruptions from juvenile nodules in lag breccias.

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[2] Research Laboratory for Archaeology and the History of Art, University of Oxford, Oxford, OX1 3TG, UK
[3] Department of Earth Sciences, Science Site, Durham University, Durham DH1 3LE, UK
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Ocean island volcanoes like the Canary Islands provide valuable insights into deep magmatic processes, offering well-preserved eruptive records and close proximity to mantle sources. Tenerife, a long-lived ocean island, has experienced diverse eruptive styles and compositional variations over 2 million years. However, the architecture and interactions of magma reservoirs beneath Tenerife remain unclear, necessitating comprehensive data from past events. Our research focuses on explosively fragmented juvenile nodules from Tenerife's pyroclastic deposits, providing snapshots of the reservoir before caldera-forming events. These fragmented nodules represent various crystallisation stages of the alkaline system, with the groundmass being supra solidus before eruption, containing ~26% melt (Horn et al., 2022). We utilize petrological and geochemical analyses, including major and trace elements, and Pb isotopes of melts and crystals, to explore the underlying mush-bearing reservoir.

The isotopic and trace element compositions of individual phonolite eruptions during this explosive period are distinct, indicating isotopic evolution was occurring in the reservoir between major eruptions. We assess the ability of the crystal mush to preserve or homogenise mantle-derived heterogeneities emerging from the Canary plume, utilising the existing Pb isotopic record (Taylor et al., 2020). The nodules contain interstitial basanite melts, offering novel insights into the magma mush reservoir during specific explosive eruptions. These melts differ in Pb isotopes from juvenile phonolite pumice in corresponding ignimbrite deposits, suggesting separate crustal magma reservoirs. The Pb isotopes support the presence of well-mixed, melt-dominated phonolite bodies homogenising melts from an underlying, heterogeneous crystal-mush reservoir. Our integrated dataset of Pb isotope analysis and detailed petrological investigations on these nodules advances our understanding of magma mush reservoir dynamics and the complex systems contributing to caldera-forming eruptions. This study offers new insights into the internal structure and heterogeneity of crystal mush reservoirs at well-defined points in time, plus the relative timescales of magma integration, thereby enhancing our understanding of ocean island volcanoes and their crustal magma reservoirs.

References:
Emma L Horn, Rex N Taylor, Thomas M Gernon, Michael J Stock, E M Ruth Farley, Composition and Petrology of a Mush-Bearing Magma Reservoir beneath Tenerife, *Journal of Petrology*, Volume 63, Issue 10, October 2022, egac095, https://doi.org/10.1093/petrology/egac095
Taylor, R. N., Davila-Harris, P., Branney, M. J., Farley, E. R., Gernon, T. M. & Palmer, M. R. (2020). Dynamics of a chemically pulsing mantle plume. *Earth and Planetary Science Letters* 537, 116182. https://doi.org/10.1016/j.epsl.2020.116182.

Volcanologists as Storytellers: the explanatory power of stories told about volcanic crises

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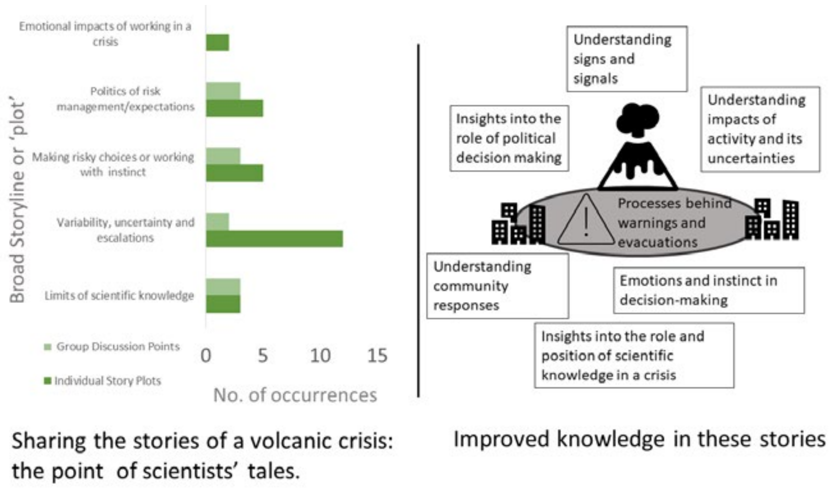
This is not a presentation about the 'story' of research findings but about the sharing of experience and important knowledge relevant to managing and coping with volcanic crises. Narratives or stories are the descriptive sequencing of events to make a point. In comparison with scientific deduction, the point (plot) of a story can be either implicit or explicit, and causal links between events in the story are interpretative, rendering narrative a looser inferential framework. We demonstrate how storytelling functions to share and to shape knowledge, particularly when scientific knowledge is uncertain during a volcanic crisis.

We explore how storytelling (the process) and stories (or narratives) involving scientists can make sense of volcanic crises, where conditions change rapidly and natural, social, and scientific systems collide. We use the example of the Soufrière Hills volcanic eruption (Montserrat), and scientists' experiences of the events during that time. We used 37 stories gathered from seven semi-structured interviews and one group interview (5 scientists). We wanted to understand whether these stories generate or highlight knowledge and information that do not necessarily appear in more conventional scientific literatures produced in relation to volcanic eruptive crises, and how that knowledge explicitly or implicitly shapes future actions and views (Figure).

Through our analysis of the value these stories bring to volcanic risk reduction we argue that **scientists** create and transmit important knowledge about risk reduction through the stories they tell one another, and that this could be better used. In our example storytelling and stories are used in several ways: (1) evidencing the value of robust long-term monitoring strategies during crises; (2) exploring the current limits of scientific rationality, and the role of instinct in a crisis and (3) the examination of the interactions and outcomes of wide-ranging drivers of population risk. More broadly these stories allowed for the emotional intensity of these experiences to be acknowledged and discussed; the actions and outcomes of the storytelling are important. We suggest that storytelling frameworks could be better harnessed in both volcanic and other contexts.



Summary diagram of the key points (plots) of stories told and the new types of knowledge created.

A theory for mega-dyke propagation as driven by hotspot topography.

Timothy Davis[1], Richard Katz[1].

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How can mega-dykes propagate hundreds of kilometres laterally through the crust? These blade-shaped dykes are enormous geological structures characterised by widths up to 100 metres. It has been shown that mega-dykes propagate radially from a point at the centre of the dyke swarm. The magma for such dykes is believed to originate from a hotspot beneath the base of the lithosphere, and this process typically precedes rifting events. Current models do not adequately explain the mechanisms driving the propagation and termination of mega-dykes. We hypothesise that mega-dyke propagation is driven by the gradient in gravitational potential energy associated with the topography of a hotspot swell.

We present an analytical theory linking the length of a mega-dyke to the dimensions of the topographic swell from which it originates. Our model accounts for various energy sources, including magma-source pressure and gravitational potential energy, and energy sinks such as viscous dissipation, elastic wall-rock deformation, and fracturing at the dyke tip. We define the ground surface deformation above a hotspot using an analytical model. The final dyke length is computed by finding the point at which the sum of energy sources becomes less than the energy sinks. We verify this model using numerical solutions computed with PyFrac. Furthermore, we explore the trade-offs between parameters controlling the swell size and the final length of a mega-dyke. We tentatively apply our findings to observed mega-dyke swarms and investigate the hot-spot sizes required to produce the observed lengths of these structures.

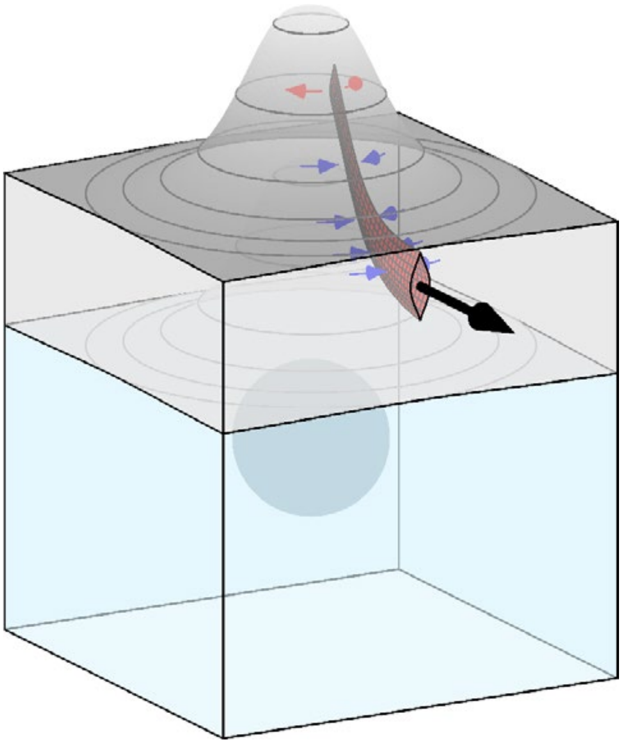

Figure caption: Schematic diagram of a density-trapped mega-dyke propagating away from the ground uplift due to a hotspot head impinging on the base of the crust. The dyke (red) cuts through the crust (grey) that has been uplifted due to the hotspot head (sphere) rising through the mantle (blue).

Direct observation of degassing and crystallisation of magma via HP-HT X-ray transparent Internally Heated Pressure Vessel

Barbara Bonechi[1], Margherita Polacci[1], Fabio Arzilli[2], Giuseppe La Spina[3], Jean-louis Hazemann[4], Richard A. Brooker[5], Elisa Biagioli[1], Robert Atwood[6], Sebastian Marussi[7], Peter D. Lee[7,8], Roy A. Wogelius[1], Jonathan Fellowes[1], & Mike Burton[1].

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Transitions in eruptive style during volcanic eruptions are strongly dependent on how easily gas can decouple from magma during ascent. Stronger gas-melt coupling favours highly explosive eruptions, whereas a weaker coupling promotes lava fountaining and lava flows. However, the mechanism fostering the transition from closed- to open-system degassing is still poorly understood, due to a lack of direct observations of bubble dynamics under natural magma ascent conditions. We combined X-ray synchrotron radiography with a novel high-pressure/high-temperature X-ray transparent Internally Heated Pressure Vessel apparatus to directly observe and quantify in 2D bubble growth and coalescence from 100 MPa to the surface, in real-time. We found that for low-viscosity basaltic magmas, bubbles coalesce and recover a spherical shape within 3 s, implying that, for lava fountaining activity, both gas and melt remain coupled during the ascent up to the last hundred metres of the conduit. For higher viscosity magmas, instead, the recovery time becomes longer, promoting connected bubble pathways leading to some degree of decoupling that we directly observed as bubbles expand until they connect to an open pathway and then contract as gas escapes.

Together with degassing, also crystallisation processes play a key role in determining transitions in eruptive style by affecting the rheological properties of magma and, hence, its ability to move and rise in the crust and erupt. For this reason, we combined fast synchrotron x-ray microtomography with our X-ray transparent Internally Heated Pressure Vessel to simulate magma storage conditions within the crust at pressures ≤100 MPa and temperatures of ≤1200 °C in presence of volatiles (H_2O). These experiments allowed us to capture, visualise and quantify in 4D (3D + time) crystallisation and vesiculation kinetics in a tephritic magma at pre- and syn-eruptive conditions, which are fundamental to improve our understanding of magma behaviour and mitigating the volcanic risk associated with tephritic systems like the one that fed the 2021 Tajogaite eruption (Canary Islands).

This apparatus opens a new frontier in unravelling the processes which control volcanic eruptions, leading to improve the current numerical models by integrating new constraints, hazard assessment and risk mitigation.

When volcanoes meet the internet: The variable drivers and impacts of volcanic hazards on subsea telecommunications networks

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When the first transoceanic telegraph cables were laid in the mid-1800s, rapid communication between continents became possible. The advent of fibre-optic submarine cables in the 1990s, catalyzed a global digital revolution. Today a network of more than 1.4 million kilometres of fibre-optic cables crosses the oceans, carrying more than 99% of all digital data traffic worldwide and trillions of dollars in financial transactions. These arteries of the global internet underpin so many aspects of our daily lives, and are particularly important for remote island communities that rely on submarine cables for telemedicine, e-finance and online education. However, these same remote island communities, that are often in seismically and volcanically-active regions, can be highly prone to natural hazards, which threaten their critical subsea communication infrastructure. This vulnerability was acutely exposed in January 2022, when the collapse of the eruption plume of Hunga Volcano triggered a fast-moving density current that damaged Tonga's only international submarine cable; cutting off an entire nation from global communications in the midst of a volcanic crisis. Here, we present a new analysis of historical instances of damage to subsea communications cables by volcanic events from around the world, and document their diverse impacts. Examples include: i) severing of the only telegraph cable by seafloor density currents created during the 1883 Krakatau eruption; ii) ocean-entering pyroclastic density currents, lahars and landslides during the 1902 eruptions of Mount Pelée; iii) destruction of a cable landing station on Montserrat by a pyroclastic density current in 1997; iv) submarine slope failures triggered by the 2015 eruption of Kick 'Em Jenny in the Caribbean; v) complete loss of the telecommunications network due to power outages following the 2000 eruption of Miyake-jimi, Japan; vi) disruption to subsea cables during the 2020/21 eruption of La Soufrière; and vii) unprecedented damage to seafloor cables from ocean-entering pyroclastic fluxes delivered during the 2022 Hunga volcano eruption. We find that the root causes of damage can be varied and typically relate to cascades of hazards, rather than the primary eruption itself. Based on these diverse case studies, we present lessons learned for enhancing telecommunications resilience, and discuss how subsea cables themselves can be used as sensors to improve understanding and early warning of volcanic hazards, filling a monitoring blind spot for remote island communities.

Artistic expressions of volcanoes in Chile: a pathway to understanding their social significance

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The separation between nature and society has been a concern within the social sciences and interdisciplinary discussions, a division that often characterizes the way we perceive our environment. The arts have played an important role in demonstrating the entanglement of Earth and society through their ability to frame and shape the dynamics of the Earth across sensations. This have been achieved through various explorations of the artistic language, delving into colors, shapes, sizes, compositions, and more. However, this capacity is often underestimated. Through an examination of artistic representations in Chile, we seek to unveil how the proximity of Chilean society to the majestic presence of volcanoes has been eloquently conveyed through various artistic styles throughout different historical epochs. Our study extends from the birth of the Chilean nation in 1818 to the present day, examining a wide variety of artistic representations that encompass national symbols, image-making techniques, sculpture, art installations, poetry, music, and audiovisual works. Our research represents a pioneering effort to explore the diverse representations of volcanoes in Chile and has uncovered a remarkable diversity of artistic expressions that reflects the deep connection between Chilean society and volcanic processes and landscapes. Ever-present and often breathtaking, volcanoes have served as enduring symbols of national identity and sources of inspiration for artists across diverse disciplines and aesthetic sensibilities. This study can provide the basis for detailed analyses focusing on the temporal and spatial contexts in which the artworks presented were developed. We also highlight how art can frame the complex relationship between volcanoes and society, emphasizing its vital role in disaster risk reduction drawing on global examples, and highlighting the importance of interdisciplinary collaboration in building more resilient communities.

CO_2-rich primary magmas in continental intraplate domains: Insight from olivine-hosted melt inclusions from Bas-Vivarais (French Massif Central)

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The amount of carbon contained in magmas directly affects the volcanic eruption style and the evolution of Earth's atmosphere via magmatic degassing. There is growing evidence of volatile-rich primary magmas, with CO2 contents reaching several weight percent, in intraplate domains such as oceanic islands and continental rifts. However, in most cases, these high CO2 contents are inferred but not directly measured, because the erupted products are strongly degassed. Quantifying the initial CO2 contents of magmas is difficult and requires analysis of crystal-hosted melt inclusions, including the volatiles stored in their associated bubble. Here, we quantify the pre-eruptive CO2 contents of magmas in a continental intraplate context using the olivine-hosted melt inclusions from a series of young basanites from the Bas-Vivarais volcanic province (Massif Central, France). We characterized the glass phase of the melt inclusions by electron probe microanalysis (major elements, Cl, F and S) and Raman spectrometry (H2O and CO2), and obtained basanitic compositions with high volatile contents (ranging from 0.8 to 2.5 wt% H2O and up to 1.9 wt% CO2 dissolved in glasses). However, in addition to the silicate glass, melt inclusions systematically contain CO2-rich bubbles whose walls are covered by microcrystals (mainly carbonates). Thus, to assess the total CO2 content at the time of melt inclusion entrapment, we developed a new technique of homogenization at high pressure and temperature in a piston-cylinder on olivine-hosted melt inclusions. After homogenization, we report unusually high CO2 concentrations of up to 4.8 wt% (3.4 wt% on average), among the highest ever measured to date. Our results indicate that in continental intraplate settings, the primary melts and their mantle sources can be extremely rich in carbon dioxide. Because of their high carbon contents, our results also highlight that even small-volume basaltic eruptions can release large amounts of CO2 in the atmosphere. Finally, we propose that intraplate volcanoes may contribute much more to global CO2 flux than their size would suggest.

A multi-million-year legacy of volcanism in the Earth system

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Volcanism has long been implicated, either directly or indirectly, in driving climatic and environmental chaos at various points in Earth's history. Notable examples include the Palaeocene-Eocence Thermal Maximum, during which a massive transient injection of magmatic carbon triggered global warming, and the Cretaceous-Paleogene (K-Pg) boundary, when Deccan Traps volcanoes may (or may not) have contributed to the extinction of non-avian dinosaurs. Typically, when examining volcano-climate interactions, we focus on relatively short timeframes, ranging from years in the case of direct sulfate or greenhouse gas emissions to many thousands of years in the case of e.g., magmatic responses to deglaciation. In this talk, I'll explore some much longer-term responses of the Earth system to volcanism and tectonism, with lag times spanning millions to tens of millions of years. My specific focus will be on the geological legacy of continental rifting and supercontinent breakup, which initiates a cascade of effects in the mantle that persist long after continental breakup is complete. Specifically, I will present various lines of evidence that support dynamic feedbacks between rifting, mantle convection, and surface processes across many continents, which shaped ancient environments on land and in the oceans. For example, we suggest that during the breakup of the Pangaea supercontinent, dynamic mantle-surface interactions led to widespread uplift, exhumation, and chemical weathering. Global biogeochemical models show that these events were potent enough to drive multiple episodes of oceanic anoxia in the Cretaceous world. Finally, I will highlight the importance of lead-lag relationships in Earth system studies, as well as the need for a functional mechanism(s) when identifying correlations between volcanic, magmatic, and/or tectonic phenomena and environmental upheaval.

Volcanology in a vacuum? How lessons from the archives can help us unify perspectives on volcanic crises.

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For volcanologists to fully understand critical impacts of activity we must engage in research that determines the value and importance of how different strands of research intersect and interact – particularly in times of crisis. In the volcanological community it is now widely accepted that we need to include the social, political and economic contexts in which these physical phenomena occur, when understanding drivers of risk. We must also consider how our experiences (or lack thereof) and biases can impact our views during crises, and in decision-making. Whose voices are deemed trustworthy in recounting events during a crisis? What are our motivations for engaging with active systems and how do they align with the needs of communities, in which we are working? How do frameworks and structures in which we operate come into conflict with other stakeholders? And most importantly, do we recognise this?

One way to answer these questions is to explore how power structures, attitudes and interactions between stakeholder groups played out (and were recorded) in the past. The Curating Crises project, in collaboration with the University of the West Indies Seismic Research Centre, The Montserrat Volcano Observatory and The National Archives (UK) explored UK and US archive materials relating to geophysical hazards in the Caribbean over the last 200 years. The archival material shed light on how colonial practices and attitudes of institutions and scientists working in the Caribbean impacted how knowledge and data were and still are circulated, who took ownership of it and who benefitted. Via an online platform and associated outreach activities we highlighted and celebrated voices previously unacknowledged or "hidden" from narratives of volcanic hazard and risk in the Caribbean, as well as identified some key lessons. The exhibit "Sensing Volcanoes", presented at the Royal Society Summer Science Exhibition 2023, showcased some of this learning and provided an opportunity to observe the public, scientists and policy makers making decisions during a simulated volcanic crisis. Discussions of uncertainty and timescales, and what happens when there is a mismatch between policy and reality were sparked – mirroring some accounts recorded in the archives.
We present some lessons learned during the Curating Crises project, using stories from the archives and the conversations they excited. We also reflect on how we can use these to improve our understanding of volcanic crises and how to mitigate their impacts.

The names of observers of the onset of the 1902 eruption of Soufriere, St Vincent from the archived notebooks of John Flett (blue) and the names of the seismic observers from 1936-1945 on Montserrat (green). These observers are unacknowledged in the scientific literature until now.

Iron valence systematics in clinopyroxene from oceanic basalts: revisiting stoichiometric estimates of ferric iron content.

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Clinopyroxene is a major constituent of most upper mantle and crustal rocks across all tectonic settings. The general formula for clinopyroxene is $M2M1T_2O_6$, where M2 is a distorted octahedral site, M1 is a regular octahedral site and T is a tetrahedral site, allowing it to incorporate diverse major cations. This makes clinopyroxene particularly valuable for estimating the thermochemical conditions under which magmas form and crystallise, as well as the timescales over which these processes occur. However, the abundance of ferric iron (Fe^{3+}) in magmatic clinopyroxene crystals and the substitution mechanisms by which it is incorporated remain highly uncertain, including in the oceanic basalts that dominate global magma fluxes. The few direct determinations of Fe valence by Mössbauer spectroscopy that do exist suggest that ratios of Fe^{3+} to total Fe (i.e., $Fe^{3+}/\Sigma Fe$) are well above zero in many clinopyroxene crystals and can reach up to 0.6 in mafic alkaline rocks, implying Fe^{3+} is a major but cryptic constituent of clinopyroxene in many systems. To address these uncertainties we performed Mössbauer spectroscopy and high-precision electron probe microanalysis (EPMA) on end-member and single crystal clinopyroxene grains to critically re-evaluate the potential for determining clinopyroxene $Fe^{3+}/\Sigma Fe$ by stoichiometry, an accessible but discredited approach of determining $Fe^{3+}/\Sigma Fe$. We find that stoichiometric determinations following Droop (1987) reproduce Mössbauer results within uncertainty ($1\sigma \sim 0.03$). We then performed high-precision EPMA on clinopyroxene crystals in oceanic basalts from Iceland and the Azores that range from tholeiitic basalts to alkaline tephrites to generate an internally consistent dataset clinopyroxene compositions and $Fe^{3+}/\Sigma Fe$ systematics. Clinopyroxene $Fe^{3+}/\Sigma Fe$ ranges from 0 to 0.3 in tholeiitic basalts but extends up to 0.5 in tephrites. Our results suggest that most Fe^{3+} is incorporated as esseneite ($CaFe^{3+}AlSiO_6$) rather than aegirine ($NaFe^{3+}Si_2O_6$). Finally, we explored how these clinopyroxene $Fe^{3+}/\Sigma Fe$ contents relate to apparent magmatic oxygen fugacities recorded by olivine-liquid equilibria. Olivine-liquid equilibria suggest that the tholeiitic samples from Iceland evolved at close to FMQ+1 while the more alkaline samples from the Azores evolved nearer to FMQ+2.5, which is consistent with literature data from similar systems elsewhere. Clinopyroxene $Fe^{3+}/\Sigma Fe$ contents thus correlate to some extent with estimated magma oxygen fugacities, suggesting that the valence state of iron in clinopyroxene could potentially serve as a magma redox probe.

Droop (1987). Min Mag 51, 431–435.

Modelling Surface Deformation from Melt Injection to a Poroelastic Reservoir at Soufrière Hills Volcano, Montserrat

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Volcano deformation studies have traditionally considered melt-dominated magma reservoirs, thus neglecting the role of poroelastic mush in modulating surface deformation patterns. In this study, we analyse the deformation at Soufrie re Hills Volcano (SHV) during its ongoing intra-eruptive unrest, emphasizing the role of a mush-dominated, poroelastic magma reservoir. We used a 3D Finite Element model combined with optimization techniques to investigate the causes of recent observed deformation, comparing with data from fourteen continuous GPS stations. Considering bulk magma properties, we found that the deformation is driven by ongoing melt injection into a low permeability (4.7 x 10^{-10} m^2) mush reservoir with a base at 16.5 km below sea level. The models show that the melt injection rate decreased linearly from 1.9 to 0.3 m^3/sec between 2010 and 2022, derived from fitting the recorded decreasing GPS displacement rates. Forward modelling suggests complete cessation of melt injection could occur around July 2024 ± 2 years, but poroelastic melt diffusion will continue, redistributing melt, deforming the surface, and potentially impacting reservoir stability. To extend our research, we will incorporate dynamic changes in magma properties to account for volatile behaviour in our deformation models. By integrating existing thermodynamic models into our Finite Element deformation models, we aim to better represent the time, temperature, and pressure-dependent changes in magma properties. Our research provides insights into understanding deformation patterns at volcanoes, particularly those with crystal-rich magma reservoirs like SHV.

Willy Aspinall Award

Quantifying the rapid increase in extrusion rate from Synthetic Aperture Radar backscatter: 2021 dome growth at La Soufrière, St Vincent.

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Satellite-based radar has been shown as a useful tool to provide unique information about volcanic eruptions, especially when other datasets may be limited. Lava domes in particular can be challenging to measure due to the hazards associated with ground-based measurements, and restricted accessibility and visibility that may limit other remote-sensing datasets (e.g., photogrammetry, airborne or space-based observations). For these reasons extrusion rates are not often measured with a high temporal resolution. However, quantifying the extrusion rate of lava domes is critical for understanding the progression and development of an eruption.

We present an approach to estimate volcanic topography from single SAR backscatter images to calculate extrusion rates during the 2021 eruption of La Soufrière, St. Vincent. At the end of December 2020, a new lava dome began to grow within the crater of La Soufrière. This effusive phase lasted 3-months before the eruption transitioned from effusive to explosive in April 2021. Using data from multiple SAR sensors (TerraSAR-X, COSMO-SkyMed, Sentinel-1) accessed through the CEOS Working Group on Disasters Volcano Demonstrator, we construct a temporally dense timeseries of dome volumes and extrusion rate during the effusive phase of the 2021 eruption at La Soufrière, St. Vincent. We measured a steady extrusion rate of 1.8 m^3s^{-1} between December 2020 and March 2021 before observing a rapid increase to 17.5m^3s^{-1} two days prior to the explosive eruption on 9 April. Based on the topography extracted from SAR images, we extrapolate a final dome volume of 19.4 million m^3. Approximately 15% of this total extruded volume was emplaced in the two days before the explosive eruption.

The dome volumes we retrieve from SAR backscatter complements other measurements made during the eruption (e.g., photogrammetry, seismicity, and SO_2) and provides an insight into the transition from effusive to explosive. We demonstrate that SAR backscatter can be a powerful tool that can provide quantitative measurements of topographic changes during a volcanic eruption.

Zeiss Postdoctoral Keynote Award

Plagioclase shape variability reveals textural maturation of crystal mush due to resorption

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Crystal morphology has long been recognised to reflect magmatic conditions during nucleation and growth. Specifically, crystal shapes are often used to assess magma undercooling, with higher undercoolings thought to result in increasingly elongate morphologies based on crystallisation [1,2]. However, a deeper understanding of the petrological significance of crystal shapes has been hampered by the difficulty of constraining 3D crystal shapes from 2D thin section data. Here, we present *ShapeCalc*, a new tool to robustly estimate 3D crystal morphologies based on 2D intersection lengths and widths [3]. We use *ShapeCalc* to produce an inventory of plagioclase phenocryst shape variability at Mt. St. Helens volcano (USA), which sheds new light on magma storage conditions in its plumbing system.

We analysed plagioclase shapes in a 1982 dome dacite and a Castle Creek age basalt, as well as in several quenched magmatic inclusions and mush enclaves. Plagioclase crystals in quenched inclusions are generally unresorbed and have tabular, elongate shapes, similar to unresorbed phenocrysts in the dacite and basalt. By contrast, plagioclase from mush enclaves are typically resorbed (dissolution surfaces and sieving) and show more prismatic, compact crystal shapes, similar to zoned phenocrysts in the 1982 dacite that have one or more resorption horizons. We therefore speculate that episodes of resorption (for example, due to recharge-induced temperature fluctuations) are a primary cause for changes in plagioclase phenocryst shapes in the magma reservoir. To test this, we conducted high-T temperature cycling experiments during which we grew and then resorbed plagioclase crystals in a haplodacite melt. The experiments confirm that resorption progressively reduces crystal aspect ratios, producing more equant plagioclase morphologies. This has important implications for magma rheology and, ultimately, eruptibility, as crystal shape controls the packing density and permeability of a crystal mush [4]. We therefore hypothesise that a texturally mature mush with more prismatic, compact crystals due to multiple resorption events will be more readily remobilised than an immature mush comprised of unresorbed, tabular, elongate crystals.

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Thermo Fisher VMSG Award

Volcanoes and their lovers

Clive Oppenheimer

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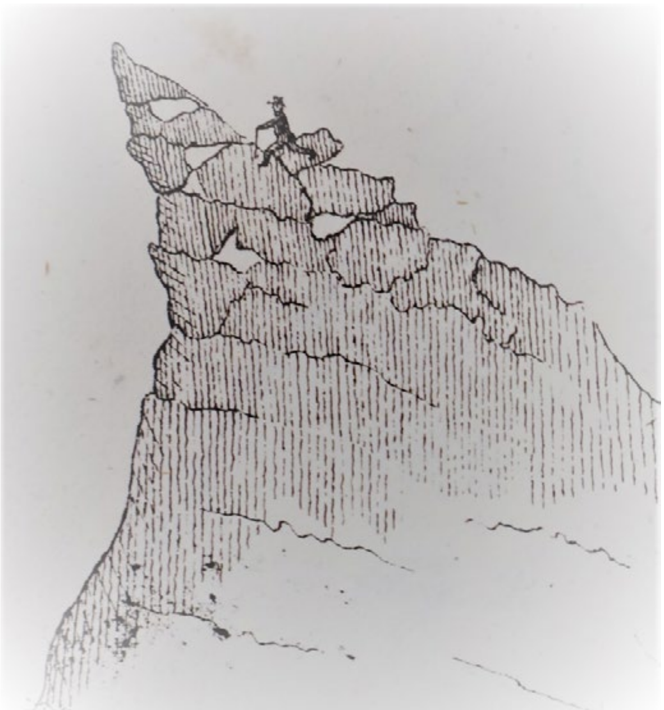
Whenever I read works on volcanology from the late 18th or 19th centuries, I am usually struck and humbled to discover that the pioneers of our discipline grappled with many of the same fundamental questions that engage us today. What animates volcanoes? Why do they erupt in particular ways? How can we leverage on microscale observations to understand the macroscale? What is going on down there?

The first volcano observatory was established in the 1840s on Vesuvius, heralding the systematization of data collection, and invention of new ways of listening to volcanoes. By the early 20th century, monitoring efforts were increasingly motivated by the goal of disaster prevention.

Here, I will introduce several volcanological heroes whose empirical and experimental studies I particularly admire. Then I will share a few of my own experiences in the field. Bring your own sulphur.



Franz Junghuhn (1809–1864) exploring a Javanese volcano before the era of risk assessments. From Junghuhn, F.W. (1845), Reise durch Java.

Tracking Mush Disaggregation During the 1783 CE Laki Eruption.

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A key goal of igneous petrology is to use volcanic rocks to better understand the development and evolution of large and damaging eruptions. The 1783 CE Laki eruption in Iceland had widespread public health and societal impacts and notable excess mortality. Understanding the timescales of magmatic events through quantitative textural work is therefore important to improve hazard response to geophysical signals of magma movement in the crust.
We use a new deep learning model[1], to produce segmented maps of plagioclase crystal shapes and sizes of 42 thin sections of lava and tephra samples from Laki. This method uses stitched thin section images obtained from circular polarised microscopy. The output crystal shapes can then be processed to obtain aspect ratios and Crystal Size Distributions (CSDs), which can be compared with previous x-ray mapping work results from a small subset of these samples[2]. These textural quantifications of the Laki samples contain information about the cooling and crystallisation history of the Laki magma both in the subsurface and during cooling in the lava flow. Diffusion chronometry will also be used to explore the timescales of magmatic processes associated with Laki. We will present estimates of the timescale between mush disaggregation and eruption based on Mg zonation near the rims of plagioclase macrocrysts[3].
Modal proportions of plagioclase and other phases can be obtained from the processed thin-section images, improving the accuracy of quantification of the relationships between crystal cargo and bulk-rock composition first identified by Passmore et al., 2012[4]. These new observations will be used to test models of the mechanisms of mush disaggregation prior to the Laki eruption. If the deep learning approach can reliably provide accurate estimates of these properties, this will allow for quicker processing of large sample sizes and could greatly speed up our understanding of the timescales of magmatic events.

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Isotopic constraints on volcano tectonically controlled assimilation at Campi Flegrei caldera.

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Campi Flegrei volcano, central Italy, has produced >60 eruptions since the last caldera forming eruption at 15 kyr. These span a wide range of eruptive styles (lava domes to Plinian events) and compositions (basanites to phonolites)1. These eruptions occurred in different spatial/structural locations within the larger caldera system, with early vents often located on the structural boundary of the pre-existing caldera system and later eruptions migrating towards the centre of the caldera2. Geophysical and petrological data support multi-level magma storage beneath Campi Flegrei, with post-15 kyr eruptions primarily fed by mid- to lower-crustal storage zones and ephemeral shallow sills3. Several authors have identified that the major element compositions of Campi Flegrei magmas cannot be produced through simple fractional crystallisation, and instead suggest that country rock assimilation must play a significant role in controlling their compositional evolution4. Despite this, the role of assimilation has yet to be systematically investigated in post-15 kyr eruptions, and the type/composition of the assimilant and extent of contamination are poorly defined.

The isotopic composition of volcanic rocks can provide insights into mantle and crustal processes prior to their final ascent and eruption. In particular, combined radiogenic and stable isotopes afford unique insights into the type and extent of crustal assimilation5. In this study, we characterised the oxygen, strontium and neodymium isotopic compositions of mineral and glass separates from post-15 kyr Campi Flegrei eruptions alongside potential basement rocks. The eruptions cover the full range of spatial, temporal, and compositional variability to assess the crustal controls on assimilation dynamics.

We find variability in the δ18O, 87Sr/86Sr and 143Nd/144Nd compositions of post-15 kyr Campi Flegrei eruptions, outside the range expected for typical mantle-derived magmas evolving through fractional crystallisation. Instead, our data point to an important role of assimilation in the Campi Flegrei sub-volcanic system and differences in the isotopic composition of individual eruptions attest to variations in either the amount or type of assimilated material. Isotopic differences correlate with the vent location within the pre-existing caldera structure; eruptions along caldera rim faults have isotopic compositions which deviate further from typical mantle source values than those erupted from the centre of the caldera or along regional tectonic faults, consistent with more extensive assimilation. Comparison with the isotopic compositions of potential basement rocks suggest that Hercynian metamorphic basement or shallow flysch sequences are the most likely crustal contaminants at Campi Flegrei, in contrast with the extensive limestone assimilation at nearby Vesuvius6.

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Complex dyke architecture suggests flow localisation during magma propagation.

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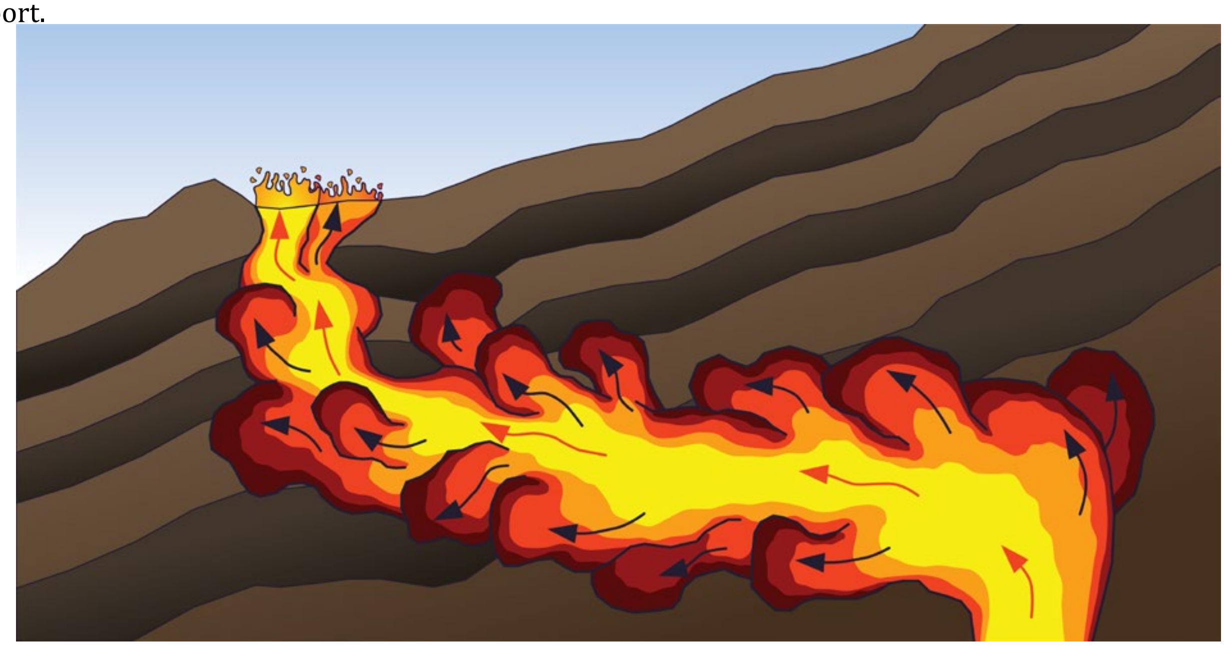
Dyke architecture is a product of interactions between magma and host rock. The structure of a dyke reflects the development of subsurface flow pathways, which would have influenced the location and behaviour of basaltic fissure eruptions. Dykes are commonly found to be segmented along their length, but their true, three-dimensional architecture often remains unknown, with interpretations hindered by limited exposure. Here we present observations from a dyke with segmentation on both horizontal and vertical exposures, providing a rare insight into its complex, three-dimensional architecture and associated flow pathways. The dyke consists of branching, overlapping, plate-like lobes, reminiscent of pahoehoe flow field. We propose that such a structure is likely to have arisen due to preferential flow pathways developing within a dyke advancing on multiple fronts, producing a network of linked segments and dead-end branches. Our findings suggest that dyke emplacement not only involves interactions with the host rock, but thermal feedback within the narrow dyke tip. Such complex behaviour has implications for the way we view dykes in the field and for our understanding of dyke propagation, and provides context for the interpretation of seismicity associated with subsurface magma transport.



Schematic representation of complex dyke architecture. The dyke propagates on multiple fronts and develops preferential flow pathways, similar to a pahoehoe flow field. When the dyke is eventually exposed at the surface, these pathways present themselves as segments.

Benchmarking a Distinct Element Method model of volcanic deformation

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During periods of unrest, the migration of magmatic material beneath volcanoes commonly causes measurable surface deformation. This deformation can generate complex fracture networks and reactivate existing faults. Modelling the generation and reactivation of faults during these periods of unrest is crucial in determining potential pathways for future volcanic and geothermal activity. Current numerical modelling of volcanic deformation typically assumes a purely elastic or a viscoelastic host rock. This allows for comparison with various analytical solutions. Such continuum-based modelling limits exploration of complex faulting associated with inflation/deflation cycles – for example during caldera collapse or resurgence. By using the 3D Distinct Element Method (DEM), one can simulate the transition from elastic to non-elastic (frictional-plastic) behaviour as the breakage of elastic bonds between modelled elements, allowing for the investigation of fracture localization, propagation, and orientation.

Here we benchmark a new three-dimensional DEM model with pressure boundary conditions against existing analytical solutions and a Finite Element Method model. We consider a simple spherical magma chamber in a homogenous, elastic host rock. We then implement an overpressure of 1 MPa and record surface displacements. We explore the validity of our DEM model at key conditions (e.g. by varying magma reservoir depth and shape). This benchmarking shows that the DEM yields reasonable solutions for displacement in the low strain, elastic phase. Benchmarking provides a firmer physical basis for application of DEM models to discontinuous, large strain volcanic deformation, such as caldera collapse, caldera resurgence, manga intrusion, and volcano flank collapse.

New insights into past and present volcanic activity of Socorro Island, Mexico

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Socorro Island, Mexico, is a volcanically active Island located ~700km off the west coast of Mexico. In an abandoned ridge setting, Socorro has a complex eruptive history: shifting from a basaltic shield-building phase, to explosive peralkaline rhyolite eruptions, with potential caldera collapse, and most recently, basaltic scoria cone forming eruptions. An offshore eruption in 1993, and an active fumarolic zone, suggests magmatic activity is ongoing [1]. This silicic peralkaline activity makes Socorro unique in the Pacific Basin. Geological maps of varying scales exist, however, inaccessibility to areas of the island often means maps are incomplete or include inferred descriptions, with many volcanic deposits yet to be dated or chemically analysed. The understanding of the scoria cone eruptions is limited, with only one sub-arial date of 5500 BP [2], and published data for the hydrothermal zone is limited to fluid analysis [3]. Therefore, repeated geological field surveys have been performed since the last published geological map in 2016 [4] to: understand the geological history of the island, monitor the hydrothermal zone, assess the landslide risk, and analyse the scoria cones in the southeast.

Field surveys from Colima de Intercambio en Investigación en Vulcanología (CIIV) have attempted to improve the current geological maps, focusing primarily in Playa Norte and Playa Blanca, with updated maps every year. CIIV has established frequent monitoring of the hydrothermal zone, employing systematic methods to obtain thermal images and individual fumarole temperatures, allowing for analysis through time, a range of temperatures for typical activity, and identifying major zones of hydrothermal activity. Areas of major landslide risk have been identified within the hydrothermal zone, with a landslide occurring at the summit in 2022, performing interviews with island residents to infer when and how the landslide occurred. New scoria cones have been identified throughout the southeast of the island, with basic morphometric analysis suggesting a migration of activity from summit to coast in the last 150ka. Socorro Island presents opportunities for a range of research ideas, with many projects currently ongoing through CIIV, and many challenges remain unsolved.

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Modelling Volcanic Umbrella Ash Clouds for Aviation Purposes

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The aim of this project was to look at modelling ash deposits from volcanic umbrella clouds, specifically looking at the Calbuco eruption in Chile 22nd April 2015. Initially, governing equations for the umbrella cloud scheme were analysed. The uncertainty of these equations was assessed, and it was found that various factors including the chosen coefficients, the weather (such as wind shear) and the accuracy of measurements taken led to high uncertainty in estimating the volume flow rate of the umbrella cloud and the radius of the umbrella cloud after certain times.

The Met Office NAME model was used to simulate deposition outputs of the Calbuco eruption in Chile 22nd April 2015. This eruption had two phases, with Phase 1 lasting approximately 90 minutes, and phase 2 lasting around 6 hours. NAME modelled deposition outputs were plotted and compared to Ash3d modelled outputs produced by Mastin and Van Eaton (2020). It was found that NAME modelled deposition outputs agree well with Ash3d modelled deposition outputs. The depth of the umbrella cloud was varied form 1-4km in NAME model simulations, and it was found that varying the depth of the umbrella cloud had minimal effect on the deposition output. Non-umbrella cloud scheme models also agreed well with Ash3d modelled simulations for non-umbrella clouds. There was no significant difference in non-umbrella cloud plots for varying depths of non-umbrella clouds. Various umbrella cloud schemes were compared using NAME and it was found that the Rooney scheme (2014) was the only scheme to plot the observed 32mm isopach line seen in Ash3d models.
Model simulations were compared to observational data collected by Van Eaton et al. (2016). 25 sample locations were taken, where the thickness of the collected deposits was compared to the thickness of the NAME modelled deposition for varying parameters. For umbrella cloud schemes there was a weak positive correlation with all correlations being within the range of 0.05-0.3. For non-umbrella cloud schemes a slightly stronger correlation was found with one combination of parameters having a correlation of 0.696, and all other non-umbrella cloud simulations being in the range of 0.141-0.460. Reasons for the discrepancies between NAME modelled thickness values and the observational data are discussed. Ash resuspension and ash compaction may have played a factor in altering deposit thickness, as the thickness measurements were taken 3-8 July in some locations, which is two and a half months post the initial eruption.

Trace element systematics at Etinde, Cameroon Volcanic Line.

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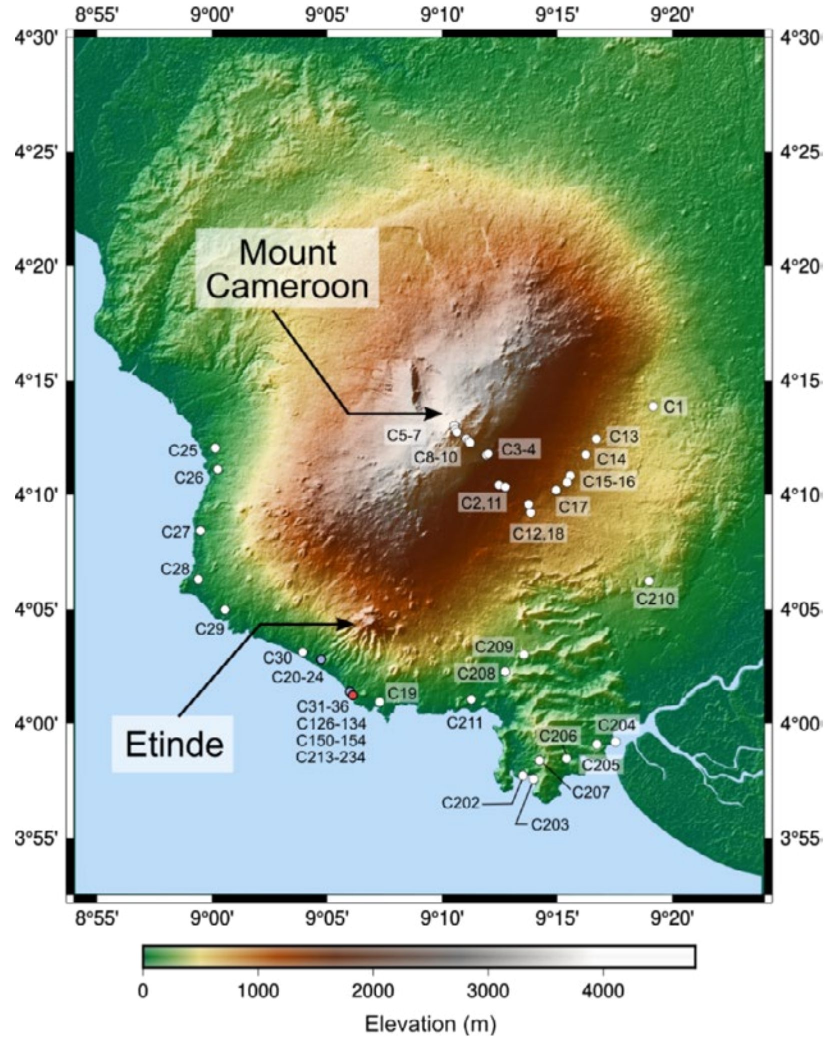
The Cameroon Volcanic Line (CVL) is a 1600km long intraplate magmatic province that spans the passive continental margin of West Africa. The CVL lacks linear age-progression along strike with the youngest magmatic activity in the centre of the line. There is also a notable lack of primordial geochemical signatures, such as high 3He/4He. Etinde is a volcano of the CVL which is remarkably enriched in incompatible elements. It is situated on the western flank of the recently active Mount Cameroon and is composed almost entirely of feldspar-free nephelinite ranging in composition from mafic (olivine-phyric) to felsic (schorlomite- and nosean-phyric) types. Better understanding the nature of geochemical enrichment at Etinde could facilitate new insights into magmatism and enrichment at the CVL.

The source of geochemical enrichment at Etinde is enigmatic, and volatile- and incompatible-element signatures cannot be explained solely by small-degree melting of asthenospheric mantle. For example, niobium concentrations vary from ~100 ppm in the most mafic samples (MgO ~ 8wt.%) to >300 ppm in the more felsic samples (MgO ~ 2wt.%). Furthermore, the LREE (e.g. La, Nd and Ce) display drastic shifts in compatibility, behaving mostly incompatibly (their abundance increases with decreasing MgO) though across the most evolved samples switch to compatible behaviour (their abundance decreases with decreasing MgO below ~2.5wt.%).

In order to address this enigmatic behaviour, we investigate the influence of fractionation of lesser-discussed mineral phases such as perovskite and schorlomite. We present a suite of perovskite partition coefficients for Etinde, calculated by measuring coexisting trace element abundances in perovskite crystals and host glass. We then discuss how fractionation of perovskite modulates trace element systematics in this highly enriched system.



A map of the Cameroon Volcanic Line, colour-coded for elevation. The ocean-continent boundary zone location of Etinde, the volcano which forms the focus of this work, is labelled.

Relating Changes in Melt Genesis to Dynamic Conditions of the Demise of a Continental Arc: Antarctic Peninsula Arc

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The Antarctic Peninsula preserves the life-cycle of a continental arc from initiation to demise, and its volcanic rocks hold the secret to a better understanding of the tectonic processes which precede the demise of an arc. The Antarctic Peninsula is located on the western side of the Antarctic, and was the site of an active continental arc from 200Ma – 10Ma (Smellie, et al. 2021). The Phoenix Plate was progressively subducted beneath the Antarctic plate, producing volcanism along the Peninsula between 135Ma - 20Ma (Leat and Riley, 2021a). The arc began to shut-down approximately 50Ma, as a result of the subduction of the Antarctic-Phoenix spreading ridge. The ridge subduction began in the south, near Alexander Island, and progressed northwards to the South Shetland Islands at the other end of the arc. Today there is no more subduction and the various stages of ridge-subduction, with subsequent slab-window formation, are preserved along the length of the Peninsula (Hole, 2021).
Over the last century the British Antarctic Survery have conducted numerous field expiditions to the Peninsula and amassed the Legacy Collection. From this work, the distribution of arc-related volcanic rocks, their geochemistry and more infrequently their age, have been documented. Despite this, there are many open questions and vast stretches of outcrop with no data. However, recent work (Leat and Riley, 2021b) has classified 4 main geochemical groups across the arc: calc-alkaline; high-Mg andesites; adakites and high-Zr. An understanding of the petrogenesis of these groups has enabled speculation on the progression of mantle dynamics. This project will be looking to examine the chronological and geochemical relationships between the different groups and build up a more-indepth understanding of the mantle dyanamics. Alongside this, the project will create a geodynamic model to better understand slab-window formation and ridge-trench interactions. The first step for this project is to conduct a thorough dating program with these questions in mind, as well as to gather additional geochemical data to help bring the arc together as a single location of study as opposed to focussing on individual localities.

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Analogue experiments show that fracturing around magma reservoirs can cause variation in surface uplift rates even at constant volumetric flux.

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Many volcanoes show continuous but variable deformation over timescales of years to decades. Variations in uplift rate are typically interpreted as changes in magma supply rate and/or an anelastic response of the host rock. Here we conduct analogue experiments in the laboratory to represent the inflation of a silicic magma body at a constant volumetric flux, and measure the chamber pressure and resulting surface displacement field. Dyke intrusions radiating from the magma body cause a decrease in the peak uplift rate, but do not significantly affect the spatial pattern of deformation or spatially averaged uplift rate. We identify 4 distinct phases: 1) elastic inflation of the chamber, 2) a gradual decrease in the rate of uplift and pressurisation, associated with the formation of visible cracks 3) propagation of a dyke by mode 1 failure at the crack tip and 4) a pressure decrease within the chamber. Phase 2 can be explained by either a) crack damage, which reduces the elastic moduli of the surrounding rock or b) magma filling pre-existing cracks. Thus these experiments provide alternative mechanisms to explain observed variations in uplift rate, with important implications for the interpretation of deformation patterns at volcanoes around the world.

Conducting Multi Agency Volcanic Ash Cloud Exercises: Practicing forecast evaluation procedures and the pull-through of scientific advice to the London VAAC

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Practising and testing emergency procedures are fundamental for ensuring an effective operational response to a crisis. We have developed a new series of exercises which test the multi-agency response needed to produce volcanic ash forecasts at the London Volcanic Ash Advisory Centre (VAAC). Our exercises have been specifically designed to practice our ability to interpret and evaluate model simulations and observations, the pull through of international scientific expertise into the London VAAC, and decision-making procedures under uncertainty.

We will describe our exercise methodology, this includes the development of simulated observations for exercise conditions, and a framework for comparing transport and dispersion simulations generated using different model setups (multi-model ensemble). We will also discuss how we practice the necessary interactions between scientists supporting the London VAAC and external collaborators, which may include experts at volcano observatories, national/state geological or geophysical institutions, and volcano research institutions. We will present case-studies of exercises for hypothetical events in Iceland and outline the lessons learnt. Our Exercises have not only improved our ability to respond to a volcanic ash cloud event but have also driven scientific and technical improvement of the forecasts, and strengthened the relationships between collaborators and responders, with the aim of providing the best possible advice to the London VAAC.

Bizarre magmatic compositions at Volcán Ceboruco, Trans Mexican Volcanic Belt, Mexico.

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Subduction zones are important areas for understanding mantle re-enrichment. The Trans Mexican Volcanic Belt (TMVB) is one of the most compositionally diverse subduction arcs on Earth, and is therefore a prime location for investigating the generation and evolution of arc magmas in tectonically complex settings. Ceboruco is one of a handful of active volcanoes in the western part of the TMVB, while also being part of one arm of three shallow crustal rift zones separating the 'Jalisco Block' from the North American Plate. Ceboruco's eruptive history is diverse, ranging from mafic to felsic products, including at least one caldera-forming eruption within the last 1000 years. Volcanic products are enriched in HFSE, as in nearby associated Nb-enriched basalts, but unlike other TMVB stratovolcanoes. The origins of this enrichment, along with the controls on the compositional diversity of magmas at Ceboruco, remain unclear.

Here we present our initial findings collected on a selection of Ceboruco lavas, along with an assessment of both new and published geochemical data. We address possible causes for Ceboruco's unusual chemical signatures, which bear mixed characteristics of subduction and rift zone magmas. These include varying abundances of LIL and light REE elements, along with distinctive negative Ti anomalies. Major and trace element data suggest that fractional crystallisation (e.g. Mg# of 0.25 – 0.41) and possible crustal contamination (e.g. high La/Sm ratios) played a major role in the evolution of Ceboruco's magmas. Additionally, Dy/Yb ratios imply the involvement of amphibole, though the scarcity of volatile-bearing minerals in erupted products suggests the occurrence of cryptic fractionation. However, this would not explain the high Nb (20-30 ppm) at Ceboruco, serving to highlight the geochemical complexity. These apparently conflicting trends will be addressed in a larger-scale project, consisting of a field-based analysis of the volcanic stratigraphy, along with a geochemical and petrographic study (whole rock and *in-situ* analyses of phenocryst phases) of Ceboruco's Pleistocene-Holocene products. This is done to gain a better understanding of the conditions leading to the formation of the volcano's wide range of volcanic products, its magmatic plumbing system (or systems), and to ultimately be able to apply our findings to volcanic systems located at the interface of subduction and rifting zones.

Modeling Surface Deformation due to Magma Migration through Mush Zones.

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Interpreting ground deformation at volcanoes is key for understanding the processes occurring in the system below. By studying the spatial and temporal evolution of surface patterns, we can learn to characterise the geometry of the deformation source, as well as to track magma migration. Most numerical models used to interpret surface deformation assume a purely elastic rheology, or more complex rheological properties but limited to a spherical reservoir. However, these assumptions are inconsistent with the most widely accepted concept of magmatic plumbing, the Trans-Crustal-Magmatic-System (TCMS).

The TCMS model represents a widely heterogeneous thermal system, primarily comprised of magma mush: a porous crystalline matrix saturated with interstitial viscous melt and fluids. How these different fluids interact in the system and how this affects surface deformation is not yet fully understood. Previous models have shown that incorporating mush rheologies can both augment and depress the magnitude of deformation, depending on injection rate and volume, which can misinform forecasting processes.

Using numerical modelling, here we simulate the mechanical complexity of the TCMS by introducing the mush components as poro- and visco-elasticity. Each rheology contributes its own time-dependent distortion to deformation when injecting or ejecting melt from the system. Here we investigate a melt lens within a vertically elongated mush zone, injecting melt as mass into the lens. Particularly, we study how the lens position within the mush can impact the development of geodetic signals, and further how deformation can be be affected by the viscosity of both the mush and the melt.

As the resolution of geodetic monitoring improves, so does the importance of incorporating mush properties into volcano deformation interpretation. This is critical for identifying new intrusions of magma, assessing their volume and aiding migration forecasting and hazard management.

Chemical and isotopic tracers of the transition between oceanic and continental lithosphere in the Canary Islands

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The Canary Islands transect the West African passive continental margin, providing opportunities for unique insight into the nature of continental lithospheric input into the Canarian mantle plume. The Canary Islands overlie a mantle hotspot from which their volcanic activity originates. By combining isotopic and chemical data, the compositions and origins of the mantle components contributing toward Canarian volcanism will be constrained.

Comparison of the compositions of mantle-derived volcanic rocks from ocean islands located at varying distance from the continental margin will provide context for variations in the isotopically enriched 'EM1' mantle signature in Canarian volcanics (fig. 1). The origin of this enriched signature remains undetermined but is often attributed to entrainment of continental material into the plume [1,2,3]. If this signature does in fact originate from a continental source, then the influence of the enriched component would be expected to decrease with greater distance from the continental margin. This is reflected in preliminary data from this project. Major-, minor- and trace-element olivine compositions from Lanzarote, Tenerife and La Palma suggest that the mantle source of the eastern islands, which lie closer to the African continental margin, is more pyroxenitic than that of the western islands. This is consistent with greater addition of silicic melts derived from recycled continental material[4]. Helium isotope data also collected during this study supports this hypothesis of greater addition of continentally-derived material towards the east, with a more dominant deep plume signature towards the west. Constraining the source of the isotopic enrichment in the mantle source of the Canary Islands may help to identify the sources of similar EM1 mantle signatures in other ocean island settings. Analysis of isotopic (Sr-Nd-Pb) compositions of olivine-hosted melt inclusions (MI) from Canarian volcanic beach sands with well-constrained provenance will help to constrain the origin and nature of compositional heterogeneity in the mantle source of the Canary Islands, which is key to understanding the evolution of both the Earth's mantle and Canarian magmatism. This project will utilise new 10^{13} Ω resistors with the University of Leeds Thermal Ionisation Mass Spectrometer to collect precise isotope ratio measurements of nanogram quantities, which will be combined with major and trace element compositions of both MI and host olivine. Preliminary MI data will be presented, including the first Sr-Nd-Pb isotope measurements from MI in the Canary Islands, in order to constrain the nature and origin of mantle heterogeneity in the mantle beneath the Canary Islands.

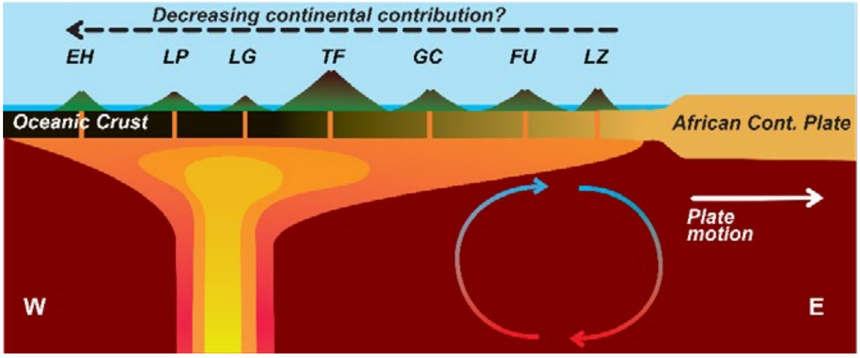

Figure 1 - The Canary Islands transect an area where the crust transitions from continental to oceanic. This provides unique insight into the nature of a continental component in the mantle, and how this varies with distance from the continent.

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Bang, spatter, and plop: welding dynamics of proximal ignimbrite agglomerates.

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Very hot pyroclasts from volcanic eruptions can weld, agglutinate, and coalesce to form coherent lava-like deposits, in which original clast outlines are obliterated. The origins of intensely welded, lava-like pyroclastic deposits can be difficult to discern. This contribution is part of a wider study aimed at discovering key textural criteria for inferring the emplacement mechanisms of highly welded deposits.

'Typical' welded ignimbrites range from mildly sintered lapilli-tuffs to intensely welded, lava-like deposits. Welding in ignimbrites is thought to occur by either: (1) rapid, syn-depositional agglutination of pumice and shards, commonly accompanied by rheomorphic deformation as the pyroclasts deposit through a thin ductile shear zone (Branney and Kokelaar 1992), and/or by (2) slow post-depositional burial compaction of pumice during cooling (Smith 1960). Many large ignimbrite sheets also contain proximal agglomerates: very coarse-grained deposits dominated by large fluidal magma rags (bombs). They are associated with a range of geodynamic settings and magma compositions but are commonly found with lithic breccias at large flooded calderas (Mellors and Sparks 1991; Branney and Kokelaar 2002). Agglomerates vary from incipiently to intensely welded and may locally become lava-like.

We present detailed field characterization of two remarkably welded ignimbrite agglomerates, found as the proximal facies of two caldera-forming eruptions (Upper Scoriae 2 and Campanian Ignimbrite). Textural characteristics, componentry, and quantitative measurements of clast flattening have been documented in detail as each grades from nonwelded to lava-like. In both examples, increases in welding occur without significant clast compaction or deformation via syn-depositional shearing. Unlike in most 'typical' ignimbrites, measurements of clast deformation do not increase markedly with welding, and clasts are often markedly 'flat' or elongate across all welding intensities. Increases in welding are marked principally by the blurring (agglutination) and merging (coalescence) of clast outlines, commonly accompanied by decreases in lithic and/or matrix abundance. In the most welded sections, both agglomerates become intensely lava-like, with remnant clast outlines only locally preserved by trails of small lithic clasts. In neither case is there evidence for significant syn-depositional shearing (rheomorphism) in these lava-like facies. We suggest that welding in these proximal ignimbrite agglomerates is primarily achieved by adhesion and necking between large bombs, with lesser influence of compaction or rheomorphism.

'Can you stop a PDC?' Assessing the impact of topography on analogue fluidized, dense granular flows.

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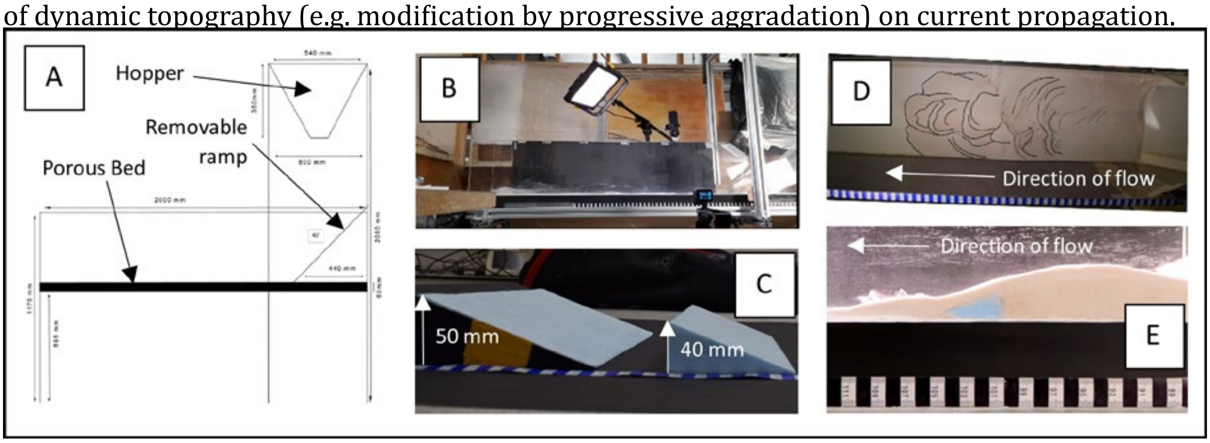
Pyroclastic density currents (PDCs) are hazardous volcanic flows that can travel at high velocities (of up to 700 kmh^{-1}) over great distances (in excess of 10-100 km) and have the potential to surmount topographic highs. Topography can also deflect or reflect PDCs, and topographic barriers are sometimes used to delineate inundation areas in hazard assessment. However, how PDCs interact with topography is not yet fully understood. Past experimental studies have found that all or some of an unfluidized, analogue current can overtop topographic barriers depending on the ratio of flow thickness to barrier height, and the momentum of the flow . But the effect of topography on fluidised currents has not been investigated.

Here, we set out a new project that aims to quantify the effects of different topographic barriers (varying in morphology, height and angle) on the velocity and runout length of aerated to fully-fluidised dense-granular currents in a new flume facility (Fig 1A and 1B). Further, analysis of depositional processes and the resultant analogue deposits will explore (1) the effects of different barriers on PDC deposit architecture and (2) the effect of dynamic topography (e.g. modification by progressive aggradation) on current propagation.



Preliminary work has demonstrated that topographic obstacles (Fig 1C) affect the flow characteristics of a dense-granular current as well as the resultant bedform deposits (Fig 1D and 1E) and that the overall runout length of the current is shorter if it has been impeded by a topographic obstacle. The greater the obstacle height (Fig 1C) in relation to the flow thickness, the slower the current travels after being impinged by the obstacle. Next steps will involve a series of experimental runs to quantify the influence of the ratio of topographic obstacle height to current thickness, topographic shape, and obstacle location relative to flow axes, upon a range of flow characteristics of a gas-fluidised, channelised granular current . Improved understanding of how topography affects the flow characteristics of PDCs will better inform hazard modelling and management strategies.

Figure 1: Schematic diagram (A) and photo (B) of the flume. (C) Examples of topographic obstacles (wedges). Top-down and side-on view of resultant deposits after different currents have been impeded by an obstacle of 5 mm high at 90° angle (D), and 20 mm high at 90° angle (E).

Magmatism and Mineralisation Along the Great Glen Fault, NW Highlands.

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The green transition has emphasized the need for a better understanding of the behaviour of critical metal enrichment in both the mantle and the crust so that regional exploration can be targeted more effectively. In the Caledonides of northern Britain the 'Newer Granite' intrusions contain historically important sources of porphyry-style Cu-Mo-Au-As mineral enrichments, as well as more unusual enrichments in W, Sn and Mo, and in recent years there has been a resurgent interest in these as prospects for precious metal exploration and mining at sites such as Cononish, Scotland and Curraghinalt, Northern Ireland. Yet although a broad correlation between the Newer Granites and mineralization has long been suggested, genetic relationships remain poorly constrained.

Associated with a number of the Newer Granites are a suite of relatively small, alkali-rich, appinitic intrusions. These are particularly common near the deep-seated Great Glen Fault and are considered to originate as small-fraction melts of metasomatized sub-continental lithospheric mantle (SCLM). Previous isotopic studies reveal that the appinite suite magmas sample two geochemically distinctive SCLM sources, one on either side of the Great Glen Fault. However, the trace metal and volatile element signatures of these mantle domains, and the role that small-fraction melts and their associated magmatic fluids played in transporting and concentrating trace metals from the mantle into economically important mineral resources both require further in-depth investigation.

In this study we are investigating the magmatic history and provenance of the Caledonian appinites and late orogenic lamprophyres. We are using a combination of XRF, XRD, SEM, EPMA and fluid inclusion geochemistry to decipher the petrological and geochemical evolution of these distinctive metal-bearing small-fraction melts. We aim to establish the links between magma genesis and the temporally correlated cessation of subduction at the end of the Caledonian orogeny. Ultimately, our work will provide new insights into the tectono-magmatic controls on formation of mineral resources associated with similar magmato-tectonic settings on a global scale.

Modelling lahars at Merapi (Indonesia) and Rainier (USA) volcanoes using Titan2D and LaharZ computer models.

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Lahars are considered one of the most dangerous volcanic hazards that can have devastating impacts on surrounding environments and communities [1]. They are difficult to predict and study, making them even more hazardous. In order to better understand the extent and potential impacts of lahars, this study develops digital simulations and GIS technology to model lahar activity at Mount Merapi in Indonesia and Mount Rainier in the United States.

This study utilizes two computer codes, Titan2D [2] and LaharZ [3], in combination to generate visual outputs for GIS systems. Titan2D is used to model near volcano hazards, such as pyroclastic density currents, using a Digital Elevation Model (DEM) of the volcano. These outputs are then remobilized as lahars and extended along valleys using LaharZ, resulting in outputs that mimic real-life scenarios.

Both Mount Merapi and Mount Rainier are located near densely populated settlements and have the potential to generate lahars, posing a significant hazard to surrounding populations. Using a 30 metre DEM and varying parameters, this study simulates lahars of varying volumes ranging from 125,000 m3 to 16,000,000 m3 in order to identify the extent of the hazard.

Both Titan2D and LaharZ have been tested individually by researchers in the past [3] [4] [5] and have been found to accurately recreate past events. This study tests their combined use as a tool for producing hazard maps viewable in GIS, which can aid in hazard prediction and analysis. The resulting hazard maps for both Mount Merapi and Mount Rainier are found to be comparable to existing hazard maps for these volcanoes, indicating that the combination of Titan2D and LaharZ is an effective tool for hazard analysis.

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A complex magmatic plumbing system beneath Bagana volcano, Papua New Guinea

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Bagana is a persistently active stratovolcano located on Bougainville Island, Papua New Guinea. Characteristic activity consists of prolonged lava effusion over months to years, with occasional shifts to explosive eruptions which threaten surrounding communities. Despite persistent and potentially hazardous activity, no previous geophysical, petrological, or geochemical studies have constrained the magma storage conditions and reservoir processes at Bagana. To address this knowledge gap, we present new bulk rock major, trace element and radiogenic isotope data, plus mineral phase major element compositions, for Bagana lavas erupted in 2005 and 2012. We use our new data to understand the magmatic processes controlling the typical effusive activity and provide the first estimates of magma storage conditions beneath Bagana.

Our Bagana lavas have basaltic andesite bulk rock compositions (56-58 wt % SiO2), which reflect accumulation of a plagioclase + clinopyroxene + amphibole + magnetite + orthopyroxene crystal cargo by andesitic-dacitic (57-66 wt % SiO2) carrier melts. Constraints from clinopyroxene and amphibole thermobarometry, amphibole hygrometry and experimental petrology suggest that the high-An plagioclase + clinopyroxene + amphibole + magnetite assemblage crystallizes from basaltic-basaltic andesitic parental magmas with 4-9 wt % H2O, at ~1100-900 °C and ~9-21 km depth. Continued crystallization in this mid-crustal storage region produces andesitic-dacitic residual melts, which ascend towards the surface, entraining a diverse crystal cargo through interaction with melt-rich and mushy magma bodies en-route. Degassing of carrier melts during ascent results in crystallization of low-An plagioclase and the formation of amphibole breakdown rims. The radiogenic isotope and trace element compositions of Bagana lavas suggest that parental magmas feeding the system derive from an enriched mantle source modified by subducting slab components.

Our findings suggest that the prolonged lava effusion and persistently high gas emissions that characterise Bagana's activity in recent decades are sustained by a steady state regime of near-continuous ascent and degassing of magmas from the mid-crust. Our characterisation of the Bagana magmatic plumbing system during effusive activity provides a valuable framework for interpreting ongoing monitoring data, and for identifying any differences in magmatic processes during any future shift to explosive activity.

Developing a method to investigate waxing and waning behaviors in analogue pyroclastic density currents and their impact on deposit architecture.

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Pyroclastic Density Currents (PDCs) are high-speed, multiphase currents driven by gravitational forces and are widely associated with explosive volcanism. PDCs are inherently unsteady; physical characteristics such as velocity, thickness and concentration can all vary at a given point in the current through time. This has been inferred from interpreting deposits that appear to show evidence of transient current conditions, and through observations of sustained PDCs that appear to show pulsatory behaviour.

The generation mechanisms of PDCs are inherently unsteady and unsteadiness in PDC dynamics is often attributed to fluctuations in mass flux at source. For example, a pulsatory and variably collapsing eruption column may wax and wane in supply to PDCs as the eruption progresses. Waxing and waning conditions in a sustained pyroclastic density current are thought to affect the distance a pyroclastic density current can travel, its ability to deposit and erode through time, and the nature of the deposit it leaves behind. However, simulating these conditions in analogue experiments has so far proved challenging.

This study develops a method to control and steadily change mass flux of the input material in analogue flume experiments of aerated, granular currents. A modified hopper was developed with a motorised release gate that had interchangeable inserts with different shaped apertures; these controlled the discharge of the analogue material into the flume and simulated waxing and waning conditions. Three different aperture shapes were used: (1) a wedge which could be rotated to test either a waxing or a waning mass flux (depending on the orientation it was inserted); (2) a diamond to test waxing to waning conditions, and (3) an hourglass to test waning to waxing conditions. Poly-disperse mixtures of glass ballotini were used to investigate whether these changes in mass flux could generate normal-, reverse- or lateral-grading patterns in the resultant deposits. Work is underway to calculate the change in velocity and run out of the experimental currents created, to determine the effect of changing mass flux at source. Initial image analysis of the resultant deposits shows a consistent difference in deposit morphology and internal sedimentary structures across the different mass flux conditions. Continuing work will quantify bedforms and grading patterns to correlate these to changes in velocity of the currents. This work contributes to our understanding of how bedforms in the field are translated into interpretations of PDC dynamics.

The Rheological Feasibility of Magma Mixing at the Drumadoon Sill, Isle of Arran.

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The rheological feasibility of magma mixing is an under researched area of volcanology. Holistic models of emplacement are impossible to reconstruct without considering the rheology of the magmatic components involved. These models are integral for effective hazard management of polymodal volcanic systems e.g., Eyjafjallajökull, Iceland and Campo de Flegri, Italy. Magma mixing influences the explosivity of eruptions, knowing the rheological feasibility of mixing can contribute towards mitigation of hazards. Paleo-igneous systems such as the Drumadoon Sill Complex on the Isle of Arran have often only been considered from a chemical petrological background to describe emplacement theories and the feasibility of magma mixing.

This dissertation used the Giodarno et al., 2008 viscosity calculator to assess the rheological feasibility of magma mixing between significant Basalt and Rhyolite samples from the Drumadoon Sill Complex under varying % wt H_2O. The results of this study show that there is a theoretical zone where the viscosity of magmas intersect and the viscosity ratio is the same; which this study termed, 'Goldilocks zone'. Dry basalt and wet rhyolite of 2.91-5.21 % wt H_2O were found to have the same viscosity at over a temperature range of 850-1000°C and therefore it is rheologically feasible for these magmas to mix at Drumadoon. The model further shows that it is rheologically infeasible at specific compositions and temperatures, in part explaining the presence of mingled and not mixed samples at Drumadoon. These calculations combined with Meade et al., 2009 petrological analysis, hand sample and thin section data allowed for the construction of a holistic schematic for magma emplacement at the Drumadoon Sill Complex.

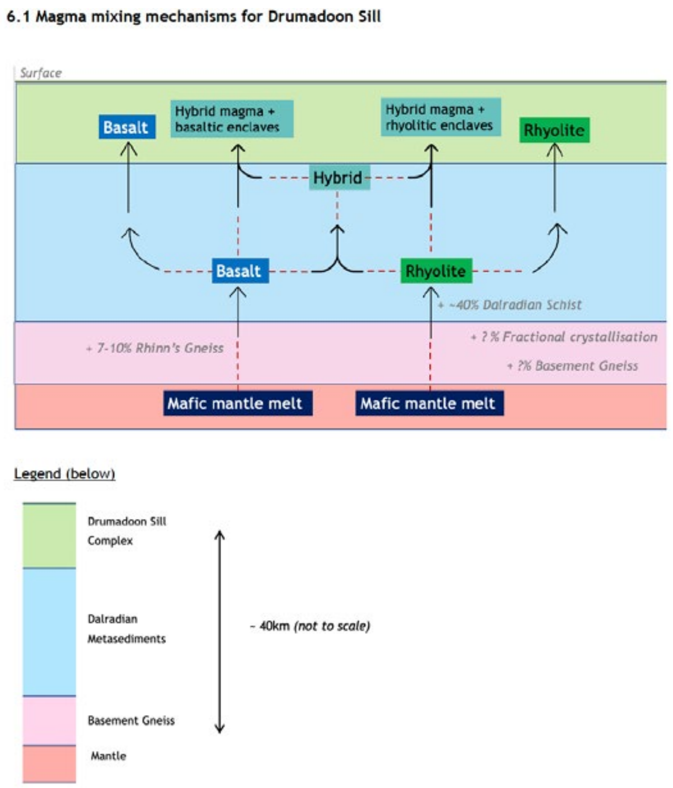

Figure 1. Schematic diagram for possible Drumadoon Sill emplacement mechanism that accounts for presence of each rock type present in the Drumadoon Sill outcrop. This model is combined with Meade et al., 2009 petrological data, hand samples and thin sections.

Volcanism, Sedimentation and Hydrothermal Activity in Santorini, Greece

Sofia Della Sala[1], Joost Frieling[1], David Pyle[1], Timothy Druitt[2], Steffen Kutterolf[3], Thomas Ronge[4] & Expedition 398 scientists

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Santorini is one of the most violent and well-known volcanoes in the world, and its pre-caldera history has been very well studied. However, the post-caldera evolution of the volcanic system, specifically the influence of hydrothermal activity in known volcanic events remains largely unknown. Better understanding of island-arc volcanism and the associated hazards requires further research into what affects the volcanism and how it interacts with other systems, such as hydrothermal fields. Santorini is ideally suited to address this relationship as the volcanic history is well documented and its known to exhibit hydrothermal activity.

This study focuses on the lithological and chemical analysis of sediment and volcaniclastic samples from cores containing post-caldera volcanic/sedimentary fill that were drilled during International Ocean Discovery Program (IODP) Expedition 398. The core material acquired by X398 represents the first accessible record of intra-caldera sedimentation over the post-caldera interval. Samples from six cores were selected to obtain a comprehensive reconstruction of activity since the last caldera forming eruption in the Late Bronze Age ca.1650 BCE. The sediment record is hypothesized to include subaerial erupted products of the Kameni islands (two volcanic islets that have progressively grown in the caldera since the Late Bronze Age eruption) and an older unit that is thought to have developed during the submarine phase of the Kameni islands' growth.

The main aim of our study is to assess episodes of heightened hydrothermal activity within Santorini's flooded caldera by examining whether distinctive (caldera-wide) trace-metal-enrichment horizons occur within the accumulating sediments. Sedimentary enrichments of elements that are typically enriched in hydrothermal fluids are interpreted as periods of elevated hydrothermal activity and compared to the historical record of volcanic activity at Santorini. We will present preliminary results for down-core concentrations of elements that are strongly enriched in hydrothermal fluids, in particular sedimentary mercury (Hg).

Figure 1: Site locations of IODP Expedition 398 in the Santorini Caldera.
Holes are indicated by A, B, C.

Deciphering flux-driven dyke dynamics with experimental and numerical models.

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Dyke propagation is a complex, solid-fluid (rock-magma) interaction problem controlled by multiphysical processes involving fluid dynamics and the mechanics of fractured solids. As opposed to buoyancy-driven dykes, flux-driven dykes propagate due to the continuous injection of magma in solid rock, leading to high internal fluid pressures. Pressure is distributed and dissipated by the internal flow, and the fluid dynamics during flux-driven dyke propagation control the propagation velocities, host-rock erosion, and eruptive style. To understand and predict dyke behaviour, it is essential to understand the internal fluid dynamics, and their coupling with fracture mechanics and solid host deformation. As these dynamic processes are naturally hidden from view, experimental and numerical models are essential for deciphering dyke processes in real-time. Combining these two approaches – by numerically simulating analogue dyke experiments – is rarely done, yet has great potential to advance knowledge of subsurface processes.

I will present new experiments of a fluid, magma analogue being injected into a solid host rock analogue (gelatine), where a state-of-the-art laser imaging system was used to quantify material behaviour from injection to eruption. Seeder particles – which fluoresce in laser light – were suspended either in the fluid or gelatine to observe the coupled fluid flow and solid deformation during fracture propagation. Different flow conditions were created by varying the viscosity and flux of the injected fluid. The overall fracture tip propagation velocity is a simple linear function of the flux, yet the internal flow dynamics exhibit a complex, recirculating pattern. This complex flow pattern is clearly reflected in the associated deformation of the solid host, and has significant implications for interpreting natural dyke data.

Numerical models can enhance experimental data sets by simulating a much wider parameter space than is possible with physical experiments. Furthermore, analogue experiments provide invaluable dynamic data sets for validating numerical models. Current numerical models are based on simplifying assumptions (for example, considering a fully developed dyke with unidirectional magma flow) and simulating analogue dyke experiments remains a key challenge. I will present ongoing work on the development of a new numerical model – utilizing a phase field approach – for simulating analogue dyke propagation from initiation to eruption.

Seismically inferred reservoir geometry deformation model for Soufrière Hills Volcano, Montserrat.

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Volcano observatories and volcanologists worldwide use deformation models in an effort to improve hazard assessment by simulating magmatic system dynamics that may be causing observed surface displacement. Traditionally, simplified spherical or ellipsoidal magma reservoir (i.e., deformation source) assumptions are used to inform the model, failing to represent the irregular reservoir geometries often identified in geophysical surveys. Uncertainties regarding the influence of irregular reservoir geometry on surface displacement limit the effectiveness of using deformation models to interpret unrest signals in volcanically active areas. Here, we aim to determine the feasibility of using a geophysically derived magma reservoir in a volcano deformation model for Soufrie re Hills Volcano, Montserrat, using a low velocity anomaly from a seismic tomography survey. To evaluate the new method, 3D deformation models were created to simulate displacement using a seismically-derived isovolume reservoir, in contrast with a traditional ellipsoid reservoir. Each model includes a Montserrat digital elevation model to incorporate the influence of topography on deformation and a heterogenous Young's Modulus, accounting for regional differences in subsurface properties. The results of each model were optimized against observed displacement from 2010-2022 using 14 GPS stations across Montserrat, included in the Montserrat Volcano Observatory deformation monitoring network, to identify the best-fit reservoir geometry and pressure combinations. We also tested a "hybrid" model that combined the seismically-inferred model upper section with an ellipsoidal base. Results show that different reservoir geometries change the horizontal and vertical displacement fields across the island. The ellipsoid best reproduced vertical displacement magnitude and the hybrid model best simulated the direction of horizontal displacement and spatial distribution of maximum vertical deformation. Overall, the ellipsoid-shaped reservoir still provides the best-fit to the observed data, but this could be a biased result due to the years of optimization that have previously helped constrain the ellipsoid shape, size and location. Our methods could be applied to other volcanoes worldwide where 3D reservoir geometry has been identified using geophysical methods, and a time series of deformation has been recorded.

Volatiles and their Sources in the Afro-Arabian LIP

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The eruptions of Large Igneous Provinces (LIPs) are strongly correlated with mass and minor extinction events, which in turn are driven by complex short-term sulphur mode cooling and long-term carbon mode warming from volatile outgassing (Black et al, 2018). The Afro-Arabian LIP (30Ma) has been implicated in cooling and faunal turnover at the Oligo-Miocene boundary, though in order to assess these correlations, pre-eruptive volatile contents must be constrained for the main stages of LIP volcanism. In Ethiopia, this volcanism exhibits a transition from compositionally zoned tholeiitic flood basalts in the Oligocene to alkaline shield volcanoes in the Miocene. These lavas sample a heterogenous mantle enriched in volatiles via metasomatic agents derived from a) the Afar Plume, b) slab components from the Pan-African subduction event 600-700Ma and c) carbonatitic fluids, related to either ancient subduction events or recent plume activity (Nelson et al, 2016; Rooney et al, 2017).

We investigate a series of lavas in the NW Ethiopian Plateau across the flood–shield transition using whole rock, phenocryst, and preliminary melt inclusion data, in order to examine magma sources and volatile contents, and how these change over time. Trace element signatures differ between flood basalts and shield volcanoes, reflecting different mantle sources and depths of magma generation. To further corroborate this, we present new constraints on pressure and temperature using cpx-liquid thermobarometry. We additionally present early estimates of pre-eruptive volatile contents using a range of proxy methods, including ol-liquid hygrometry, the FeO-S proxy for sulphur, and the CO2-S proxy for CO2, and discuss how these compare to our EPMA pilot study on MI volatile contents. Future work will involve extensive EPMA and SIMS to perform volatile and trace element analysis in melt inclusions in order to constrain the full suite of magmatic volatiles (CO2, H2O, S, F, Cl) in the spatially and temporally variable lavas of the Afro-Arabian LIP.

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The Porosity of Shallow, Hot Granites

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The range of porosities and permeabilities of hot granitic rocks in the shallow crust has implications for interpreting geophysical signals of unrest beneath volcanoes, exploiting geothermal systems, and understanding magma outgassing and types of ore deposition. Both geophysical and petrological studies indicate that granites are capable of transporting fluids and can store fluids with high electrical conductivity. This study investigates the physical features on a microscopic scale that allow granites to be porous and permeable, using two sets of samples that were brought from depth to ambient conditions rapidly: cores drilled into hot granite of the Kakkonda geothermal field (Japan), and granite lithic clasts erupted by Laguna del Maule volcano (Chile). Depths and temperatures of the Kakkonda granites were obtained during drilling and Laguna del Maule granitic magma conditions were estimated from geothermobarometry. The studied granites occupy depths of 2-5Km at 650-800°C, consistent with the estimated conditions of hydrothermal and geothermal systems from previous work on these case studies. A variety of techniques to quantify porosity were applied to cover a range of pore sizes and ensure a representative sample volume. Helium pycnometry data on 2” core samples indicate a connected porosity range of ~5-8 vol.%. 2D Scanning Electron Microscopy (SEM) on polished samples and 3D X-ray tomography imaging show a range of intragranular pores, cavities, fractures and miaroles connected by an intergranular pore network. The porosity is dominated by connected space along grain boundaries (i.e. intergranular), most of which has widths <5μm based on Euclidean distance maps. Image analysis also indicates a total porosity range of ~47 area%, similar but slightly smaller than porosities determined by helium pycnometry, suggesting that the finest pores were not resolved. Additional imaging by FEG SEM resolves intergranular pore space with widths as fine as 0.007μm. We conclude that some granites can store ~4 vol.% magmatic fluids in 0.007-25μm intergranular pore space, which is consistent with electrical resistivity anomalies under volcanoes. Permeability simulations remain for future work, however, flow capabilities are inferred from the 5-8 vol.% connected porosity and the chemical footprint of fluids in the studied samples. The permeability at low porosities could facilitate the final stages of magma outgassing as granite solidifies and have implications for geothermal resources.

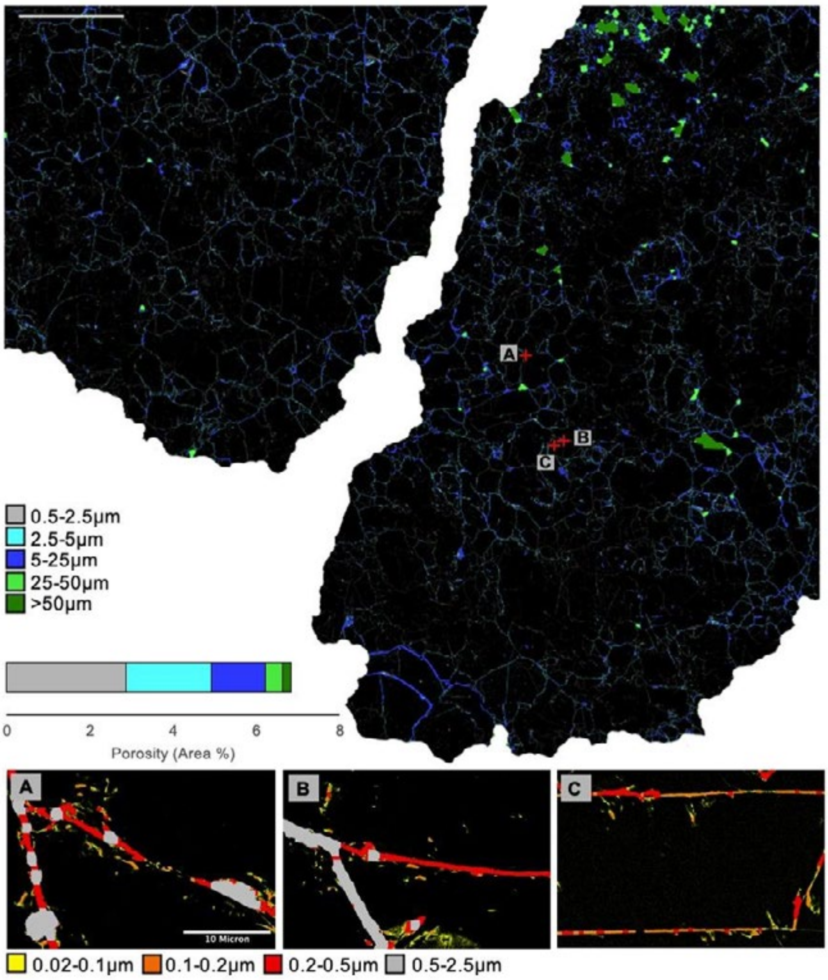

Figure 1. Euclidean distance map (EDM) of sample BTK1 (Kakkonda) showing an interconnected plexus of pores associated with felsic grain boundaries (0.5μm/pixel). A., B., and C. EDMs of pore networks at higher resolutions (0.02μm/pixel). Sample minimum connected porosity value from Helium pycnometry is ~7%.

Dike-induced strain and stress field influenced by dipping heterogeneous crustal layers: insights from analogue modelling

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Most analogue experiments of dyke propagation in gelatine simulate the crust either as a homogeneous solid or as heterogeneous with horizontal layers. This is a simplification for areas that have undergone orogenesis and crustal folding, and generally for magma intrusions propagating through dipping layers in volcanic edifices. Here we present the results of novel experiments in which water was injected into a layered elastic analogue crust. The two gelatine layers were of contrasting stiffness and separated by a weakly or strongly bonded interface dipping at 45°. This interface was in the path of the dyke or away from it. Dyke growth was monitored using HD video cameras and gelatine stress evolution during dyke propagation was visualised using polarised light. Dyke-induced surface elevation changes were measured using an overhead laser scanner and subsurface strain evolution was monitored using particle image velocimetry in gelatine seeded with fluorescent passive tracer particles that were illuminated by a laser sheet.

We observed vertical dyke propagation always occurred when the lower layer was stiffer than the upper layer and the interface was strong and for the models in which the interface was away from the dyke propagation path. In this scenario, the experimental dyke narrowed in width when crossing the interface. Sill formation from dyke deflection along the interface occurred when the interface was weak, regardless of the stiffness contrast between the layers. When the upper layer was stiffer than the lower layer, a decrease in dyke velocity was observed and this was associated with dyke widening during deflection parallel to the weak interface until interface intrusion, at which point the velocity increased and width reduction occurred. When the lower layer was stiffer than the upper layer, the dyke first deflected away from the interface and then intruded into the weak interface. Dyke deflection was also observed when the upper layer was stiffer than the lower layer and the interface was strong. Dyke-induced strain and stress were asymmetrically distributed around the dyke tip. The surface elevation profiles were also asymmetric, as observed in numerical and analogue models for inclined sheets propagating into a non-layered crust. These results highlight the importance of considering heterogeneous dipping layers in volcano monitoring studies which characterise sources of deformation by inversion of ground deformation signals.

Refining the marine tephrostratigraphy of the central Mediterranean (40-90 ka): New insights into Late-Pleistocene Campanian explosive volcanism.

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Volcanic hazard assessments rely heavily on the investigation of tephra deposits preserved in near-source volcanic settings. However, these eruption records which provide insights into past explosive activity are often fragmentary due to burial and erosional processes, particularly problematic for older, low-to mid-intensity explosive eruptions, but that extends to larger magnitude events as well. This has major implications on forecasting future eruption scenarios. Fortunately, tephra deposits recovered from distal sedimentary archives can provide a long continuous ash-fall record and, therefore, are a crucial tool for filling the gaps in long-term eruption records.

In this contribution, we examine tephra deposits preserved in Mediterranean marine sediment cores DED87-07 and DED87-08 (Tyrrhenian Sea) and MD909-16 (Adriatic Sea) to better constrain the timing, scale, and ash dispersal patterns of the densely populated Campanian volcanoes Ischia and Campi Flegrei (Southern Italy). A particular focus is on better resolving the long-term eruptive history leading up to, during and following the caldera-forming Monte Epomeo Green Tuff (MEGT) eruption of Ischia. The islands near-source record is not extensively preserved on land, limiting our understanding of activity leading up to and during one of the largest Late Quaternary explosive eruptions of the central Mediterranean. Here major and trace element geochemical fingerprinting of the marine tephra layers (glass) are used to integrate the distal and near-source eruption records, while placing this refined eruption record into the context paleoenvironmental change as revealed by a new high-resolution oxygen isotope record developed for DED87-07.

Unlocking volatile budgets at Santorini, Greece using Apatite

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Magmatic volatiles (H2O, CO2, F, Cl) play a major role in the development and eruption of stored magma; however, their role in the mobilisation of crystal-rich magma mush remains unclear[1]. To assess this, accurate information on volatile contents and the magma's saturation state is needed, ideally spanning a broad portion of its evolutionary history. Traditionally, this is achieved through analysis of melt inclusions; however, these may not capture the volatile budgets of magmas across a wide evolutionary range and are commonly affected by post-entrapment processes.

Apatite [Ca5(PO4)3(OH, F, Cl)] is a highly useful tool to determine volatile contents (H2O, Cl, F) in magmas as they are incorporated directly into the crystal structure through non-ideal mixing on the channel site. Detailed analysis of apatite micro-phenocrysts and inclusions in various mineral phases allows for robust estimates of volatile contents in magmas across its evolutionary history.

Here, we focus on magmas erupted from Santorini volcano, Greece, which have fed a range of eruptive styles from large-scale, caldera-forming eruptions to smaller inter-Plinian events. We incorporate analysis of apatite from several of these eruptions with a novel non-ideal forward model and sensitivity analysis of apatite and fluid fractionation to investigate the evolution of volatile contents and the onset of saturation within these magmas.

Preliminary data show that apatites record high halogen contents of between 1.5 - 3 wt.% F and 0.6 - 1.5 wt.% Cl and demonstrate there are distinct volatile signatures between the major eruptive units at Santorini. These data will help constrain the evolution and storage of the magma system at Santorini and provide insight into the role that volatiles play in the lead-up to large-scale explosive eruptions.

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Volcanic units of the early centres of the Palaeogene Mull volcano

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Volcanic units associated with activity from the Early Mull centres are found in a range of locations both within and outwith the early caldera on the Isle of Mull. During two periods of fieldwork, the nature of these units across the island have been studied. Further fieldwork and geochemistry will continue examine their formation and eruptive histories, within the context of activity and timescales associated with the formation of the early centres and caldera on Mull.

The volcaniclastic deposits range from dominantly fine grained and flow banded units to very coarse, poorly sorted polymictic breccias. On some slopes, extensive and complex volcaniclastic successions can be found. The internal relationships of these deposits are often hard to discern due to later intrusion and reworking of material during subsequent activity from the Mull volcanic complex. The nature of the inclusions and matrix of the volcaniclastic units differ across the south and east of the island, with some places showing a wide variation in deposits across a small area. These variations may result from topographic effects on the flows as they were deposited, or from displacement such as faulting during later stages of activity within the central complex. Numerous well-defined and well exposed outcrops of basaltic pillow lavas can also be found within the early caldera, often lying just within the proposed margin of the caldera. Across many areas, these pillow basalts are found overlying a brecciated basaltic unit and in close proximity to volcaniclastic units. This indicates an eruptive history that likely transitioned between basaltic effusive events into large bodies of water on land, likely caldera lakes, and explosive silicic eruptions, likely subaerial in nature, forming large pyroclastic density currents.

Further geochemical examination of the pillow basalts will assess compositional changes between the pillowed units and the underlying associated intrusive layers across the early caldera, where they are often found near the margins. Optical microscopy and SEM will be used to examine breccias and clast rich lapilli tuffs to assess the nature and composition of the included clasts. The outcomes of this work will increase our understanding of the nature of volcanic events associated with the early igneous centres on Mull and contribute to our knowledge of the petrogenesis and timing of the volcanism of the British Palaeogene Igneous Province, building on other recent works on the volcanism of the province- e.g., on Arran [1], Eigg [2], and Skye [3].

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Separating volcanic deformation signals using ICA: Corbetti Caldera, Ethiopia

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The increase in the availability of frequent and open-access satellite-based radar data over the last decade, through missions such as ESA's Sentinel-1, has revealed the wide range of deformation patterns at volcanic systems that were not previously observable. However, the deformation at a volcano are complex signals that contain contributions from different processes (e.g., volcanic, tectonic, hydrothermal, structural, anthropogenic etc.) as well as noise sources (e.g., atmospheric, orbital, etc.). We present a study using Independent Component Analysis (ICA) to differentiate deformation patterns associated with the magmatic and hydrothermal at Corbetti Caldera, Ethiopia.

Corbetti Caldera has been showing steady uplift since mid-2009, with of approximately 4.8 cm yr^{-1} of uplift observed in the satellite's line-of-sight (LOS) between 2015 – 2022. We apply ICA to displacement maps constructed using Sentinel-1 interferograms spanning 8 years (2015-2023), processed through the automated COMET-LiCSAR system and LiCSBAS timeseries analysis package. Our ICA results separate the deformation signal into three primary components, (1) the dominant uplift signal related to magmatic processes, (2) a structurally controlled signal that correlates with the shallow fault-bound hydrothermal system at Corbetti Caldera, as well as (3) deformation patterns affected by seasonal variation. As these processes are potentially linked in time, we are applying spatial ICA to better constrain the spatial distribution of individual components. Based on the assumption that different processes have distinctive spatial patterns, although potentially mixing through time. We, therefore, cannot resolve for entirely independent temporal patterns for each component.

This study demonstrated how ICA can be used both to (1) improve the signal-to-noise ratio of dominant deformation signal by identifying and removing noise sources and (2) uncover deformation signals that may be hidden by a larger signal. By understanding the deformation contributions from different processes, we can better understand the subsurface architecture of a volcanic system.

Magma Mixing in Dykes and Chambers

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Magma mixing may occur during the interaction of compositionally distinct magmas, where material properties and environment conditions are sufficient to initiate chemical exchange and the formation of a homogenous body. This process occurs during the intrusion of dykes into magma chambers and is widely accepted as a triggering mechanism for volcanic eruptions. This study uses analogue models to investigate how variation in source geometry and injection rate (flux) controls mixing efficiency as an intrusion interacts with a fluid chamber of differing density, in both buoyant and non-buoyant scenarios. Analogue experiments are carried out in a 40 x 40 x 40 cm^3 tank. A fluid is injected into the base of the tank directly into another fluid in the case of point source experiments, or through a gelatine layer to form a dyke. For a given flux under non-buoyant conditions, plume velocities are significantly higher, around 0.15-0.2 m/s, for dyke intrusions compared to point source, around 0.050.07 m/s. Larger plume radii, around 30-32 mm, are also seen for non-buoyant dyke source experiments, in comparison to 20-25 mm for point source. A similar source geometry-radii relationship is observed within buoyant experiments, with a reduction in overall mixing compared to the non-buoyant equivalent. Mixing efficiency can be quantified by collecting geometric and velocity data and calculating dimensionless Reynolds and Froude numbers, with larger plumes and higher velocities suggest greater mixing efficiency. The flux of magma into a chamber and the geometry of the intrusion can be suggested as variables dictating how much mixing may occur between ambient and injected magmas.

The North Atlantic Volcanic Hazards Partnership: An Introduction

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The North Atlantic Volcanic Hazard Partnership was established during the 2010 eruption of Eyjafjallajökull, to provide a coordinated approach to operational response to volcanic unrest and eruptions in the North Atlantic, specifically in Iceland and Jan Mayen. The partnership is underpinned by a Memorandum of Understanding between the Icelandic Meteorological Office, the UK Met Office, the National Centre for Atmospheric Science and the British Geological Survey. The primary objectives of the partnership are to: a) enhance capabilities for the monitoring, measurement and modelling of pre-eruptive and eruptive activity in Iceland and Jan Mayen and resultant characteristics of eruptive plumes and volcanic clouds and b) to facilitate the provision of coordinated volcanic hazard related science advice and services to domestic and international stakeholders in civil protection, aviation, media and other sectors.

Since 2010, the partnership has met twice yearly, comprising an in-person meeting in the Autumn, and an online meeting in the Spring. During these meetings, the Iceland Meteorological Office provides an update on Icelandic volcanic activity, with each partner then providing progress reports on their respective capabilities for volcanic and eruptive plume monitoring, modelling and underpinning science. The partnership also undertakes joint activities to advance capabilities. A notable example spanning science and operations is the partnerships ongoing work linked to exercises. These form an important aspect of preparedness and are based on a pre-determined eruption scenario using enhanced sudo-observations. Exercises are designed to trigger discussion and modelling of eruptive activity, ultimately resulting in the development and testing of science protocols to ensure efficient and effective support to operational colleagues.

During our 2023 Autumn meeting, we reflected on the significant progress that has been made by the partnership in ensuring that the hazard associated with Icelandic volcanic eruptions are better communicated to stakeholders, for example to UK government. We also reflected on improvements over the last decade or so in satellite-based monitoring of volcanic emissions, and new techniques being employed to incorporate this data into volcanic plume modelling initialisation and operational forecasting procedures. Finally, we reflected on the importance of involving early career scientists and researchers in discussions, both to provide different perspectives and for career development. We gratefully acknowledge the contributions of many scientists and technicians over the last 13 years.

Understanding pyroclastic density current timescales and evacuation timescales at Volcán Fuego and Volcán Santiaguito, Guatemala.

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PDCs are one of the deadliest volcanic hazards, owing to their high mobilities and complexity of mitigation strategies. On June 3rd, 2018, a paroxysmal eruption at Volcán de Fuego (Guatemala) triggered a PDC which killed as many as 2,900. On May 9th, 2014, a dome collapse at Volcán Santiaguito (Guatemala) produced a PDC with a runout of 7 km, passing Vincas and Santiaguito's observatory. Both events highlight the potential for loss for communities situated in the path of PDCs. This study combines VolcFlow-simulated PDCs with timed evacuation routes and local perspectives to understand risk and evacuations around Fuego and Santiaguito. Simulated PDCs reached maximum speeds of 250 km/h at Fuego and 200 km/h at Santiaguito, with PDCs at Fuego reaching communities closest to the volcano in 8 minutes 40 seconds (Figure 1). Maximum evacuation speeds (on foot) for communities were much slower than PDC timescales, reaching 4 km/h at both Fuego and Santiaguito. No community at Fuego or Santiaguito can outpace a PDC (assuming communities evacuate the same time that PDCs initiate). Simulated PDCs start at a higher point on each volcano than the selected communities, yet still greatly outpace evacuated communities, demonstrating the rapid mobilities of PDCs which communities must evade if they are to reach safety. Communities may evade loss if evacuations therefore begin before PDC descent. PDCs reach more distal runouts at faster speeds at Fuego than Santiaguito, as Fuego's narrow barrancas constrain PDCs, increasing speeds and runouts. Santiaguito's ríos are wider and shallower, producing slower PDC speeds of smaller runouts. Local perspectives highlight barriers to timely evacuations and the role of national institutes INSIVUMEH and CONRED in aspects of risk mitigation. Future mitigation should consider PDC timescales in informing evacuation timescales, with Vindings highlighting the importance of coordination between mitigation groups and communities, to reduce volcanic vulnerability. This study integrates qualitative and quantitative data, bridging the gap between social and physical science, to better understand volcanic hazard and risk mitigation in Guatemala.

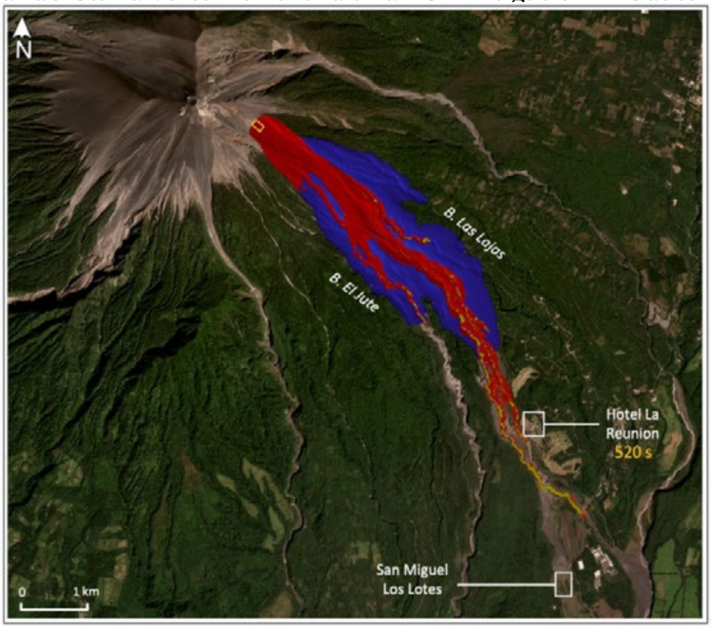

Figure 1 - VolcFlow-simulated PDC for Barranca Las Lajas at Volcán de Fuego, Guatemala. The pyroclastic Vlow is marked red, and pyroclastic surge marked blue. The PDC passes Hotel la Reunión 520 seconds after its initiation. The VolcFlow simulation is overlaid onto a Planet Labs base map for February 2023.

Geochemical Tracers of Assimilation in North Atlantic Paleogene Dykes

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Assimilation can have significant effects on the composition and behaviour of crustal magmas and is integral to the formation of many mafic/ultramafic sulphide deposits. During the Paleogene, the north of Ireland was subject to extensive magmatism and volcanic activity driven by mantle melting where the proto-Iceland plume impacted on the base of the lithosphere. This included the emplacement of numerous km-scale dykes, which are associated with the British and Irish components of the North Atlantic Igneous Province (NAIP). The dykes have been mapped in detail using aero-magnetic data captured for the Tellus geophysical survey [1], and six major swarms have been identified, with relative age constraints provided by their cross-cutting relationships. We have sampled and geochemically characterised 68 dykes from the North of Ireland.

Our data show that the dykes can be split by two distinct Rare Earth Element (REE) trends: the first is characterised by light REE depletion and a convex-down spider diagram profile, while the second is enriched in LREEs and displays a slight convex-up profile. This dual trend is prevalent in magmas across the entire NAIP [2, 3]. Geochemical evidence points to the possibility that varying amounts of assimilation is the cause of the two trends; enrichment in LREE's also correlates with magmatic evolution in these dykes, indicating a coupling of assimilation and fractional crystallisation. Importantly, our data show that REE trends might act as a geochemical indicator for the presence of assimilated country rock in magma. These two trends exist across different terranes in the North Atlantic, possibly indicating a relatively constant assimilant during initial rifting of the North Atlantic. These findings provide the potential for this concept to be applied as a tool to assist exploration for magmatic sulphide deposits in the North Atlantic.

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Social sensing the Kīlauea 2018 volcanic eruption

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Protecting lives and livelihoods during volcanic eruptions is the key challenge in volcanology, conducted primarily by volcano monitoring and emergency management organizations, but complicated by scarce knowledge of how communities respond in times of crisis. Social sensing, the systematic analysis of publicly available social media data to observe and analyse real-world events, is a rapidly developing practice that can be adapted for volcanology. Here, we use social sensing of Twitter posts to track changes in social action and reaction throughout the 2018 eruption of Kīlauea, Hawai'i, by analysing tweet frequency, sentiment, geolocation, and content. We note that Twitter has rebranded as "X", but we use the term Twitter (and tweets) as that was its name in 2018. The volume of relevant tweets explodes in early May, coincident with the beginning of the eruption; automated sentiment analysis shows a simultaneous shift towards more negative scores that reflect more negative emotions being expressed in the posts. Temporal trends in topics of local Twitter conversations reflect patterns in volcanic activity, civil protection actions, and socioeconomic pressures. We find evidence of social action around sharing official warnings in the eruption's lead up and early stages and sharing official mitigation actions later during the eruption. This is a positive outcome for volcano monitoring and emergency management organizations that are responsible for the official messaging. We generally show how hazard and risk information is discussed and reacted to on Twitter. Our study demonstrates the potential for real-time social sensing analyses to inform our understanding of community response actions and aid in situational awareness for risk-reduction professionals during volcanic crises.

Evolution of highly vesicular basaltic pyroclasts during fountaining

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The vesicularity of basaltic pyroclasts varies widely, from fully dense glass to 95–99 vol.% vesicular reticulite. The final vesicularities of basaltic pyroclasts are influenced by a range of processes acting on them prior to, and during, cooling. These process, which include vesiculation and bubble growth, bubble coalescence, collapse, and outgassing, are often difficult to disentangle from the textures in the final products. In this study, we analyse highly vesicular pyroclasts that have preserved evidence of these processes, and which fall between typical scoria and reticulite in the continuum of basaltic pyroclasts. The 2021 Fagradalsfjall eruption produced highly vesicular (75-88 vol.%) pyroclasts which can be separated into two different groups based on temporal and textural variations: texturally simple pyroclasts, likely erupted in late-May, are characterised by primarily sub-spherical, large vesicles and a low crystallinity (<5%); whereas texturally more complex pyroclasts, erupted between early April and early May, are characterised by relatively smaller vesicles, with a large variation in vesicle shapes, from spherical to highly irregular. Interactions between cooling, bubble growth, capillary relaxation and coalescence processes, have altered these pyroclasts while they remained hot in the fountain and have contributed to their final texture. Texturally simple pyroclasts are primarily composed of a stable foam and appear to have undergone relatively little bubble film failure and coalescence prior to cooling. Texturally complex pyroclasts, however, capture the textures of a breakdown in the foam as bubble films failed; we conclude that they represent a more mature stage in the textural evolution of these vesicular pyroclasts. The subsequent retraction and relaxation of the bubble films are clearly preserved in different stages throughout the pyroclasts in this group, providing insight into the breakdown process that is often lost in highly vesicular pyroclasts.

The formation of the lower crust in oceans: a study from the Lizard ophiolite in Cornwall.

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The Lizard ophiolite of SE England formed at a spreading ridge within the Rheic Ocean during the Middle Devonian and was shortly obducted onto the southern continental margin of the Avalonia plate (now forming the central-southern part of Britain) during the Variscan orogeny. In the eastern portion of the Lizard Peninsula, along the coast between Coverack and Godrevy Cove, there are extensive exposures of the gabbro sequence of the ophiolite, which is intruded locally by a dyke swarm.

Ophiolites are exposed relics of oceanic lithosphere and as such can be used as a structural analogue for and provide a window to study the formation of oceanic crust. The aims of this study are (1) to analyse the petrofabric of the gabbro sequence to test the hypothesis that during formation of the lower part of oceanic crust minerals align horizontally and parallel to the spreading direction, and (2) to reconstruct the orientation of the palaeo-spreading ridge at which the Lizard ophiolite formed. The petrofabric of the gabbros and palaeomagnetic directions recorded within the dykes that intrude them were analysed in the Palaeomagnetic Unit and Magnetic Anisotropy (PUMA) lab at the University of Birmingham (UK). The anisotropy of magnetic susceptibility (AMS) of 172 gabbro specimens (from 33 oriented hand samples collected from 6 sites) was measured using the KLY-4S Kappabridge to calculate the orientation-distribution (i.e. alignment) of the minerals within it and hence its petrofabric. Since this may inform on the palaeo-3low direction of gabbro melts during sea3loor spreading, it was in turn used to reconstruct the palaeo-ridge orientation (assuming the 3low was perpendicular to it). All gabbro and 138 dyke specimens (from 31 samples collected from 5 sites) were demagnetised using alternating 3ield (AF) method and their remanence measured using a JR-5A spinner magnetometer.

Palaeomagnetic directions were calculated through standard principal component analysis using online software www.paleomagnetism.org. The dykes were restored to their original orientation at the time of their injection, providing an alternative method to determine the orientation of the spreading ridge (assuming the dykes were intruded vertically). The results provide a spreading ridge orientation constrained by new AMS and palaeomagnetic data, which improved our understanding of the tectonic and structural context in which the Lizard ophiolite formed and was obducted.

Gabbro from the lower crustal sequence of the Lizard ophiolite in Coverack intruded by a dyke.

Geomorphometric analysis and semi-automatic classification of blocks and cones in a volcanic flank collapse debris field offshore Fogo, Cape Verde.

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Oceanic island volcanoes are a source of multiple hazards, including hazards related to the instability of volcanic edifices and flanks. Collapse events as a result of flank instability are potentially tsunamigenic with devastating impacts, especially in the near field. An example of an unstable volcano with a history of tsunamigenic collapses is Fogo, one of the southern Cape Verde islands. Seismic and geological field evidence revealed a major collapse event, the Monte Amarelo collapse of the eastern flank of Fogo c. 73ka ago, that triggered a mega-tsunami and left behind a scar still visible in the island's morphology today. Unravelling the mechanisms active during the collapse event and modelling the subsequent tsunami requires information about the volume of failed material. Because erosion and recent volcanic activity obscure the subaerial scar, the volume cannot be easily interpolated from the onshore post-collapse morphology. The offshore record, in contrast, is better preserved and yields more robust information. Research cruise M155 on *R/V METEOR* investigated the well-preserved volcaniclastic apron and debris avalanche deposit from the Monte Amarelo collapse. Seismic and sub-bottom profile data reveal its thickness and lateral extent. The high-resolution multibeam bathymetry data reveal a field of debris blocks and intermittent volcanic cones in the volcanic debris avalanche deposit region, which are only partially resolved in the seismic data. An estimate of the volume of these blocks may improve the overall volume estimate, as well as the understanding of the failure mechanism, significantly.

We develop a workflow to automatically map morphological features of the seafloor (blocks and volcanic cones) and conduct a geomorphometric analysis of the individual elements. On the basis of selected parameters, we separate blocks and cones so that only blocks may be considered for the volume estimation of the collapse. Pre-existing tools and workflows share a common deficiency: they perform poorly on steep-sloped surfaces such as volcanic flanks and fail to accurately map seafloor features in these regions. Using our innovative workflow, we are able to characterize the blocks and derive a robust volume estimate to be used in tsunami modelling of the Monte Amarelo flank collapse. In addition, the geomorphometric characterization of the block field reveals information about the collapse and transport dynamics based on the size and distribution of the blocks.
The workflow is tailored to application on volcanic flanks but, with slight modifications, presents a promising tool for application in other landslide and steep coastal regions.

What mechanisms control transitions in explosive-effusive eruptions for pantellerite volcanoes?

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Pantellerites are rhyolitic magmas with excess alkali contents characterised by anomalously low viscosity melts. Despite their low viscosity, pantellerite volcanic centres are known to produce significant caldera-forming Plinian eruptions. Deposits commonly show continuous transitions between clearly explosive and apparently effusive eruptions, including signs of hybrid episodes. There is, however, evidence that 'effusive' deposits in the form of lava-like obsidians are in fact welded units with a clastogenic- or spatter-fed origin. Although factors such as bulk composition or volatile content have been investigated, the exact mechanism/s that control changes in eruptive style remain unclear. This evidence suggests that poorly understood, active pantellerite volcanoes (including those found in Ethiopia, Italy and the China-North Korea border) could switch unpredictably in eruption style, representing a significant hazard in case of future unrest. Here, we present research from Tūhua (Mayor Island) a pantellerite volcano in New Zealand, where the stratigraphic context is well-constrained. An array of pumice (explosive) and obsidian (apparently effusive) samples were collected within complex eruption sequences to explore the various eruption styles and their underlying mechanisms. We analyse vesicle textures and micro-/nanolite abundances in natural samples to inform on eruption processes. Furthermore, we consider the possibility that apparently effusive deposits on Tūhua may be welded units with a pyroclastic origin. If lava deposits are produced by welding, this may provide a viable explanation for apparent changes in eruption styles as it does not require changes in bulk magma compositions.

Introducing ROTTnROCK: a new project to explore the role of hydrothermal alteration in unpredicted volcanic hazards

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More than 10% of the world's population are at risk to the direct impacts of volcanic eruptions. Volcano monitoring aims to detect and correctly interpret volcanic hazards and to provide early and accurate warnings of impending eruptions. Yet, despite technical and scientific advances, volcanoes still produce unexpected explosive eruptions or sudden flank collapses. Each year, such unpredictable events result in volcanic disasters that devastate unprepared communities and destroy unprotected infrastructures. Previous work suggests that unexpected volcanic hazards are caused by hydrothermal alteration, which progressively and imperceptibly changes the chemical and physical state of rocks inside a volcano, creating a soft and unstable (or "rotten") interior. However, the link between "soft" volcanoes and unpredictable volcanic events remains enigmatic. The ROTTnROCK project aims to understand the hydrothermal alteration processes that act inside active volcanic systems. Specifically, we will identify where and at which scales alteration occurs, explore the chemical fingerprint of alteration and effects on rock properties and strength using laboratory methods, and develop 4D volcano stability simulations and, therefore, an innovative and optimised hazard assessment workflow (WP3). The ROTTnROCK project combines innovative approaches from traditionally distinct geoscience disciplines (remote sensing, mineralogy and chemistry, rock mechanics, and modelling). This project will pave the way for strategies to forecast and mitigate unexpected volcanic events caused by hydrothermal alteration and circumvent disasters at volcanoes worldwide.

Here, we launch our new project funded by the European Research Council, and introduce new PhD and postdoc positions opening up around Europe (based in Dublin, Sweden, France, and Germany) in the coming few years.

Identifying distinct pre-eruptive composition-H_2O-time trends using plagioclase

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In oceanic arcs, such as the Lesser Antilles in the Eastern Caribbean, the fractionation of magmatic melts is strongly influenced by the crystallisation of plagioclase throughout the crustal column. Consequently, chemical-textural information recorded in zoned plagioclase provides insights into the environments in which the melts feeding volcanic eruptions are generated. Here we present a statistical study of plagioclase zoning from 15 eruptions, spanning three stratigraphic sections, erupted from the Mount Liamuiga stratovolcano (Saint Kitts, Lesser Antilles).

To accurately capture the chemical-textural variability within individual samples we have applied a novel image-segmentation approach to 2-dimensional geochemical maps of thin sections (1). This largely unsupervised method is fundamentally based on the principle of superpixels, such that crystals are classified into spatially coherent zones that are akin to those identified by the averaging effect of the petrologists' eye. Zones are correlated within and between samples to identify a set of common chemical building blocks which we term "zoning groups". Our results show that individual stratigraphic sections are characterised by distinct zoning groups, but that subtle zoning commonalities exist between many erupted magmas across the three sections. For example, larger volume, pumice-rich eruptions on the island are associated with distinct plagioclase textures and magma chemistry. Using a combination of whole rock and plagioclase chemistry we demonstrate that the chemical and textural differences between stratigraphic sections are related to variations in pre-eruptive water contents. We show that magmas were stored under water-saturated conditions throughout the middle and upper crust, in line with independent findings from Saint Kitts using xenolith geochemistry (2) and nearby Montserrat using nominally anhydrous minerals (3). By linking whole rock chemistry, plagioclase textures, and eruptive dynamics on Saint Kitts, we reconstruct the temporal and spatial architecture of a magmatic system that lacks a detailed record of geophysical monitoring.

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(2) Melekhova et al., 2017, Contributions to Mineralogy and Petrology
(3) Edmonds et al., 2016, Lithos

Comparing and interpreting the mechanics of formation of collapse calderas on Io and on Earth.

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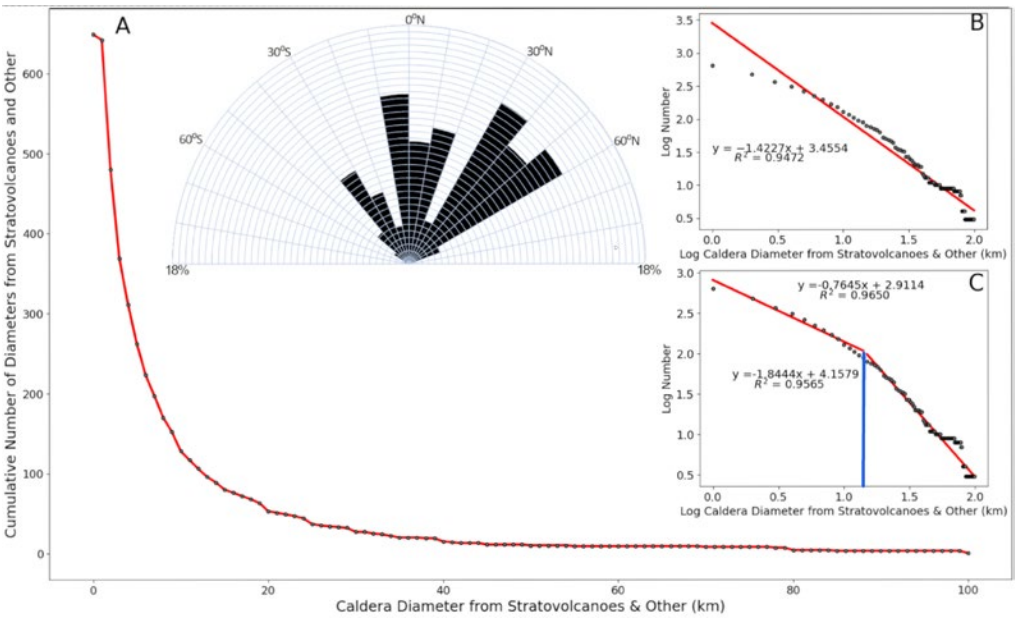
Collapse calderas are a large volcanic depression which form by land collapsing into a magma chamber after a partial or full ring fault is formed, they're very common on Earth and on Io, a moon of Jupiter. These caldera structures share similar properties, a key similarity is all types of caldera measured in this study; shield volcano, stratovolcano and Ionian calderas all share a power law distribution. This means that smaller calderas, the minimum diameter being 1km, are more frequent and the largest on Earth being 100km are rarer. Although they share a lot of similar features, Io's calderas tend to be larger and more rectangular, we do not know if they are associated with a collapse into a magma chamber, so they're referred to as patera. Even on Earth, we do not fully understand the main pull mechanics which drive caldera formation from an associated eruption and how these mechanics differ between sizes and systems. Here, I present numerical modelling for the mechanics behind the formation of each kind of caldera from diameter measurements; 139 shield volcano, 649 stratovolcano and 417 Ionian caldera measurements. I collected data using Google Earth and a database of Ionian patera measurements which were put together in a database from multiple spacecraft missions since 1979 starting with Voyager 1. The break in the straight line represents a change in condition for forming the caldera's particular property (diameter, area and subsidence). Using the coefficient of determination (R^2) calculations we are able to gather how reliable the results are at interpreting a shift in mechanics of formation. I show that calderas which form by stratovolcanoes there is a shift in mechanics when a caldera reaches a diameter of 15.85km, I interpret this as the local geology being favourable for larger caldera formation as stratovolcanoes will have surge deposits. Calderas from shield volcanoes have a best fit of two breaks at 4.67km and 12.59km which I interpret as the caldera shape influencing caldera shape, as basaltic edifices tend to have rounder calderas and an explosive eruption for formation mechanics respectively. On Io we see the break at a value of 53.7km which I interpret this as the regional tectonics having a greater impact on caldera shape than is mostly seen on Earth, as caldera shape is controlled mostly by the magma chamber except for graben calderas in the Andes.



Caldera diameters from stratovolcanoes A) Cumulative plot of a total 649 stratovolcano caldera diameters. The first bin represents all calderas with a diameter x > 0km. B) Bi-logarithmic plot of the diameter of calderas under one formation mechanic. C) Similar plot but with two formation mechanics represented by blue line.

Volcanism in the Mexico City region: extending our knowledge of past eruptions over the past 400 ka.

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The Mexico City region is home to over 25 million people, making it one of the largest populations in the world. This densely populated megacity is also surrounded by numerous active and long-lived (polygenetic) volcanoes, such as Popocatépetl and Nevado de Toluca, as well as a highly active volcanic field, comprising over 200 shorter-lived (monogenetic) volcanoes visible at the surface today. Due to being a fiercely built-up area, the eruptive histories of these hazardous volcanoes are poorly constrained, containing only the largest eruptions of the past 40,000 years.

Here, new research will be presented which provides a near-complete record of explosive volcanism which has impacted the Mexico City region over the past 400,000 years, a tenfold increase on what is currently known. This record contains eruptions from both polygenetic and monogenetic volcanoes as well as more distal caldera volcanoes outside of Mexico City and Mexico.

Through the use of a deep (over 500 m-long) sediment core collected from a lake on the south-eastern edge of Mexico City (Lake Chalco), combined with new fieldwork, geochemistry and geochronology; a detailed volcanic stratigraphy of diverse eruptions impacting the Mexico City region can be reconstructed over a timeframe that is comparable to the lifetimes of many of the surrounding volcanoes. Here, a new age-depth model is presented for the core, using newly acquired $^{40}Ar/^{39}Ar$ and ^{14}C ages and known large explosive events which have been correlated to tephras in the core through major and trace element glass geochemistry. Lacustrine sedimentation is now known to have initiated ~400 ka and the oldest dated volcanics in the core are ~1.3 Ma. This has permitted the first long-term frequency assessment of potentially devastating eruptive events in the region.

In addition to the identification and corroboration of tephrostratigraphic markers, new major element glass geochemistry is presented from the core which allows us to assess which volcanoes have impacted Mexico City over the past ~400 kyrs and will likely do so again in the future. The eruptive styles and processes involved in these past eruptions also allow us to assess the magnitude and durations of eruptions that may impact the megacity in future eruptive events.

Petrological and geochemical characterisation of eruption products from the Rabaul Caldera Complex, Papua New Guinea

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Rabaul is a large caldera system located at the northeastern tip of the island of New Britain, Papua New Guinea. Historically, it has been the most active volcano in Papua New Guinea. Rabaul is capable of large volume, high intensity caldera-forming eruptions (high risk, low probability events occurring every ca. 2 ka, most recently the Rabaul Pyroclastics event ca. 1400 years ago) and lower intensity but more frequent intra caldera eruptions. All eruptions at Rabaul pose a significant risk to nearby populations and settlements [1,2].

Rabaul's volcanic rocks vary in composition from basaltic andesite to rhyolite and mostly lie on a common liquid line of descent, controlled by fractional crystallization under reducing conditions [1,2,3,4.] Magma mixing and mingling are common, evidenced by basaltic enclaves and mafic minerals in andesitic and dacitic eruption products [1,2,4]. These enclaves signify regular mafic recharge of the main dacitic reservoir, which primes the system for eruptions [4]. Seismic tomography imaging suggests the presence of an extensive, tabular magma body at a depth of 3-6 km with a volume of about 15150 km^3 [5,6].

The main goal of this study is to develop a comprehensive petrological and geochemical characterisation of Rabaul eruption products. We aim to discover how the petrology and geochemistry vary between magmatic products erupted from different intervals in the caldera cycle of Rabaul volcano. In addition, we aim to get a better understanding of the primitive magmas that feed and sustain volcanism at Rabaul.

Here, we present EPMA mineral analysis and thermobarometry model outputs for products of the 1937, 1994 and 2014 eruptions as well as for the most mafic eruption products known, the Kombiu basalts. Our thermobarometry data complement existing geophysical observations of the structure of Rabaul's magma plumbing system. Furthermore, we present SEM imagery to reveal how mineral textures (zoning, resorption, grain size, grain boundaries) in samples from different eruptions at Rabaul reflect magma chamber processes such as mafic recharge, magma mixing and crystallisation.

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Detecting Submarine Volcanic Eruptions from Space

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It is thought that around three-quarters of the volcanoes on Earth are underwater, [1], yet they are relatively understudied in comparison with their terrestrial counterparts. Studies in the past have been limited by the inaccessibility of submarine volcanoes and difficulty of observing these remote processes. Eruptions are often only detected due to passing ships or aeroplanes, [2,3], and so it is likely that many erupt undetected. With the vast expansion of remote sensing data now available, there is the potential to greatly improve our observations and monitoring of submarine eruptions.

There are many techniques used for the monitoring of subaerial volcanoes, but no such approaches currently available to monitor submarine volcanism due to the intervening ocean. However, submarine volcanic eruptions can have effects on or above the ocean surface that are observable with sufficiently high-resolution satellite imagery. These include the production of pumice rafts, subaerial eruptive plumes and seawater discolouration (due to the release of particulates into the ocean and phytoplankton blooms in response to this release). The advent of free access global satellite imagery datasets, such as that of Sentinel-2, brings new opportunities to improve our understanding of underwater volcanism and allow for the monitoring of short-term, small-scale processes globally.

Here, we present a case study of the August 2019 eruption of Volcano F, Southern Pacific Ocean. This eruption, like many other submarine eruptions, occurred undetected and wouldn't have been noticed had a ship not passed its erupted pumice raft. This pumice raft floated for months and both subaerial and submarine plumes were erupted that dispersed in under a week, all observable from satellite imagery. These images are spectrally analysed, with the use of machine learning techniques, to show the temporal and spatial evolution of the submarine plume and pumice raft. This is combined with analysis of pumice samples that washed up on surrounding islands post eruption. This study demonstrates not only that spectral satellite analysis is a viable method for the study of submarine eruptions but also shows that, often, it is the only method we can use to detect eruptions that would otherwise go unnoticed.

This leads into the proposed future work to develop an automatic detection algorithm to significantly improve current observation methods for active submarine volcanism and greatly increase our capacity to remotely detect submarine eruptions.

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Investigating magma flow dynamics in a dyke: a microstructural study of the Budj Bim Volcanic Complex, Australia.

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In order to understand the style, longevity and hazards of volcanic fissure eruptions, we need to understand the dynamics that govern their feeder dykes. To achieve this, the analysis of rock microstructures through optical microscopy and scanning electron microscopy may be used to observe the crystal alignment, shape and size from dyke samples to investigate magmatic fluid flow and deformation processes during the ascent of magma. Here we examine oriented samples of a basaltic dyke from the Budj Bim Volcanic Complex (BBVC), the only known fissure-fed eruption in the Newer Volcanics Province (NVP), south east Australia. Extensive quarrying has provided excellent exposure of the internal architecture of a dyke which fed a scoria cone in the BBVC (known as Little Mount). Optical microscopy data show the dyke samples typically comprise zoned olivine phenocrysts (<0.5 mm diameter, 20%), pyroxenes (<0.1 mm diameter, 20%) and a fine-grained plagioclase-rich groundmass with oxides (<0.05 mm diameter, 5%). Microscale observations show the dyke also contains rare and texturally complex quartz crystals (0.1-0.5 mm diameter, <5%) with microcrystalline rims of potassium silicate and pyroxene. Electron backscattered diffraction (EBSD) of plagioclase microlites shows they share a crystallographic preferred orientation (CPO). CPO in plagioclase can be used as an indicator of magma flow, as elongate crystals may align parallel to flow direction. The plagioclase microlites also exhibit intracrystalline distortion, which indicates they have experienced deformation during magma flow. This could potentially be due to the interactions between microlites, or with the magma during the final stages leading to eruption. It is of utmost importance to understand the physical and chemical processes involved in historic fissure eruptions such as the BBVC as they can facilitate risk mitigation and hazard assessment from future fissure eruptions worldwide.

Experimental Constraints on the Genesis of Lithium-rich, Felsic Melts

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Peraluminous rare-metal granites are enriched in fluxing elements (Li, B, P, F) and rare-metals, such as Li, Cs, Ta, W, and Rb. Among these metals, Li is particularly important for modern-day technologies and the net-zero transition, therefore it is imperative to understand the processes responsible for its enrichment in peraluminous rhyolitic systems. Lithium enrichment by fractional crystallization can be modelled by using mineral-melt partition coefficients; however, at present these are poorly constrained in peraluminous systems. In order to better constrain mineral-melt partition coefficients, crystallization experiments were performed on peraluminous rhyolites in an internally-heated pressure vessel at 300 MPa and 600-675°C. The effect of temperature, melt aluminosity, , and the concentration of fluxing elements (F and P), on the partition coefficients was also investigated. Mineral-melt partition coefficients of rare-metals (e.g., Li, Cs, Ta, W, Rb) were obtained for quartz, plagioclase, k-feldspar, biotite, and muscovite (Figure 1). Variations in partition coefficients are primarily a function of temperature, and to a lesser extent the melt aluminosity. These results were largely unaffected by the fluxing elements and . The partition coefficients were used to model the enrichment of rare-metals in the Macusani volcanics in S.E. Peru, which are considered to be the extrusive equivalent of rare-metal granites. The model focuses on the fractional crystallization of the Macusani tuffs (700-800 ppm Li), which represent the parental magma of the 'macusanite' glasses (up to 3400 ppm Li) [1] and thus provides a unique insight into the magmatic processes responsible for Li enrichment. Fractional crystallization of the tuffs by 75-85% produced trace element concentrations that are consistent with the macusanite glasses, thus demonstrating that fractionation can further the enrichment of Li and other rare-metals in felsic magmatic systems.

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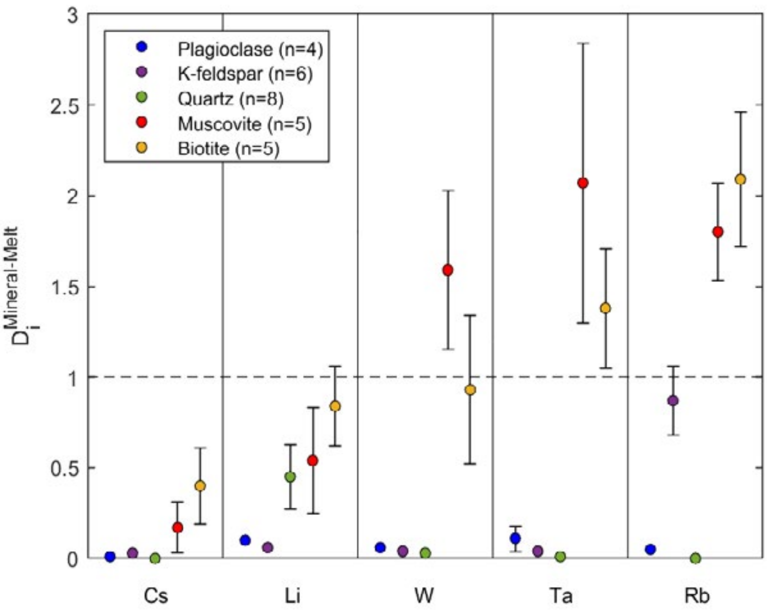

Figure 1: Mineral-melt partition coefficients of selected rare-metals (Cs, Li, W, Ta, Rb). Standard deviations are shown by the error bars. High standard deviations in the micas is primarily a function of temperature.

Experimental modelling of thalwegs in pyroclastic density currents - the dynamic influence of progressive aggradation upon a migrating flow axis

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Pyroclastic density currents (PDCs) deposit a diverse range of ignimbrite stratigraphy that can be analysed to interpret how these catastrophic flows behave in time and space. However, the difficulties in observing the physical characteristics of PDCs in real-time create uncertainty in the relationships between stratigraphic bedforms and the current behaviours that generated them. Analogue modelling can provide crucial insights into these linkages, with implications for our understanding of volcanic hazards. Sustained pyroclastic density currents are inherently unsteady and non-uniform. When flowing across plains, the main flow axis ('thalweg') may shift laterally, with implications for the balance of deposition, non-deposition and erosion at a location through time. Thalweg migration has the potential to significantly change the nature of hazard - for example by increasing velocity/run out in certain areas - but the various factors that likely influence it (such as channelisation, topography, substrate, unsteadiness, and modification of topography during progressive deposition) have not previously been examined using analogue modelling. In this study, two experimental setups were developed to investigate the influence of deposit aggradation on thalweg development and migration in channelised, gas-fluidised analogue PDCs. Two gas-fluidised flumes, 15cm and 30cm wide, were used to explore the effects of changing channel width.

In both experiments, deposition forms planar beds at first, which build into steeper backset bedforms that diverts the thalweg. Even steeper backset bedforms can grow that are prone to upstream collapse. The collapse of these backsets can rapidly divert the thalweg, potentially forming new channels. Thalwegs in the narrow channel experiments follow broadly straight vectors, which supports the overall assumption of narrow channels behaving in a largely "2D" manner (albeit with considerable sidewall effects). In the wider channel experiments, the marginal areas of the current are more likely to begin to be diverted, forming clear thalwegs of flow that do not propagate uniformly along the channel. The migration of these thalwegs is related to rapid deposition within the current, and these areas are typically marked with the onset of shallow backset deposition.

This work finds that thalweg migration is evident in gas-fluidised granular currents in even moderately wide flume experiments, and that there is a clear relationship between deposited bedforms and lateral current migration. Further work to improve analogue models will improve our ability to interpret field examples of ignimbrite stratigraphic architecture, enabling improvements to risk models and hazard mitigation.

Deep CO_2 systematics at La Soufriere Volcano, St Vincent

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Volatile species including CO2 can migrate from magma reservoirs towards the Earth's surface. Characterisation of the fluxes of magmatic volatiles and their ratios can provide key constraints on magmatic processes. As volatiles can be exsolved and released at volcanoes before eruption of their parent magma, they provide useful information in terms of forecasting and hazard mitigation, especially at island arc settings, as these volcanoes are characterised by dome building and explosive eruptions and are therefore highly hazardous.

The eruption of La Soufriere volcano, St Vincent lasted approximately four months, beginning with lava dome building at the end of December 2020 and culminating in a series of explosive events in April 2021[1, 2]. Volatile species analysis via Raman spectroscopy, SIMS and EPMA carried out on melt inclusions is shedding light on the controls of the explosive phase by providing pre-eruptive volatile concentrations for individual stratigraphic units within the eruption.

Melt inclusions (MI) hosted in olivine, plagioclase, orthopyroxene and clinopyroxene phenocrysts are basaltic to andesitic in composition, with whole rock products across the units being basaltic andesitic in nature, ranging from 53.64 – 54.81 wt.% SiO_2. While all MI contained bubbles, only 8% of measured bubbles contained volatiles, indicating that volatiles in the vast majority of inclusions are held solely in the glass. H_2O contents range from 2.42 – 5.48 wt.%, broadly consistent with other eruptions at La Soufriere [5] and CO_2 from 3 – 6414 ppm. There are no differences in volatile content throughout the units. Storage depths inferred from solubility models place 87% of inclusions at < 10km, generally agreeing with deformation modelling and focus of seismicity [3, 4], and the remaining 13% ranging between 10 – 36 km. Ongoing work is relating inferred storage depths and degassing systematics to geophysical signals and evolving eruption dynamics.

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Accretionary lava balls record the Pāhoehoe to `A`ā transition.

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Mafic lavas are a widespread product of effusive volcanism. They typically erupt as pāhoehoe flows and transition to `a`ā as they propagate away from the vent. Pāhoehoe flows have a smooth, near continuous surface and are capable of engulfing large areas. While `a`ā flows have a surface crust that is fragmented and rough, they also can self-channelize, form levees and push over structures. These vastly different surface morphologies also give rise to different thermal characteristics, where `a`ā with a disrupted crust exhibits greater heat loss. Thus, determining when different lava flow morphologies form and the physical processes behind morphological transitions is important for hazard mapping and lava flow modelling. Here, we present a series of detailed field observations and laboratory analyses on accretionary lava balls that formed at, or very close to, the pāhoehoe to `a`ā transition. The lava balls were spatially mapped belonging to the most recent effusive products from Tseax (*Sii Aks*) volcano, British Columbia, Canada. They have a low-density, vesicular core comprised of pieces of pāhoehoe crust and are coated by multiple thin layers of denser, microlite-rich, poorly vesicular lava. We discuss the physics behind their construction and how they can be used to infer lava flow dynamics, especially the transition between pāhoehoe and `a`ā lava flow morphologies.

Reconstructing volatile exsolution in a porphyry ore-forming magma chamber: Perspectives from apatite inclusions.

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Porphyry-type deposits in the shallow crust (3-5 km) are formed from metal-rich fluids exsolved from underlying magma chambers (5-15 km). However, a direct volatile record of the fluid exsolution in the magma chamber is commonly lacking. Here, we analyse the compositions of apatite inclusions (in biotite and plagioclase phenocrysts, fully-/partly-included in zircon microphenocrysts) and the apatite in groundmass from the largest Cretaceous Luoboling porphyry Cu–Mo deposit in South China. In combination with thermodynamic models, we reconstructed the volatile behaviour in the ore-forming magma. The analysed apatites are magmatic in origin without hydrothermal overprint, as indicated by their homogeneous cathodoluminescence (CL) and higher Cl and REE contents than typical hydrothermal apatite. Apatite inclusions fully enclosed in zircon show decreasing X_{Cl}/X_{OH} (1.5-0.1) with increasing X_F/X_{OH} (0.4-3.3) and X_F/X_{Cl} (0.5-21), and display a steep drop in X_{Cl} at approximately constant X_{OH} in the ternary F–Cl–OH plot. These trends follow the modelled compositional trajectories of isobaric H_2O-saturated crystallisation, indicating volatile exsolution during/or before zircon crystallisation in the magma chamber. Groundmass apatite crystals, phenocryst-hosted apatite inclusions and apatite inclusions, which are partially enclosed by zircon microphenocrysts, have comparable volatile compositions, with much higher X_F/X_{OH} (1.7-78.8) and X_F/X_{Cl} (2.3-37.5) but lower X_{OH} and X_{Cl} than those fully enclosed in zircon. Compositional similarities between these crystals in different textural associations indicate that the phenocryst-hosted apatite inclusions do not preserve their original volatile records at the time of entrapment, and the volatile compositions were overprinted by later re-equilibration with the residual melt and the exsolved magmatic fluids. Given the porphyry magma is highly oxidized, and the sulfides phases would be unstable in such circumstance, we suggest that volatile exsolution in the magma chamber is essential for Cl, Cu and Mo extraction from the melts and thereby the porphyry mineralization. In this study, only zircon-hosted apatite inclusions appear to best record the magmatic volatile compositions in a porphyry system faithfully. Therefore, using apatite hosted in other minerals or groundmass compositions to unravel magma volatile contents in porphyry copper system should be conducted with caution.

Figure 9

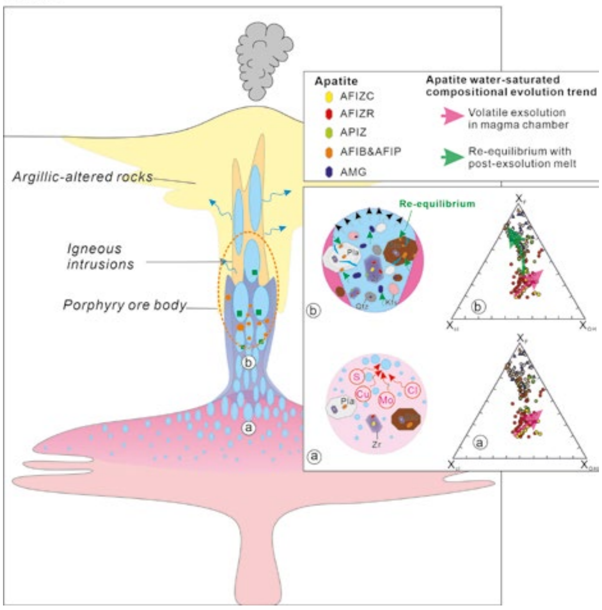

Figure caption Schematic diagram summarising the volatile evolution during porphyry Cu ore formation, based on the apatite composition (modified after Richards, 2016). The F–Cl–OH ternary diagram illustrates apatite composition changes during different magmatic processes in the porphyry ore system.

Magma mush remobilisation during replenishment of granitic intrusions: evidence from localised fabric heterogeneity

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Igneous intrusions may archive strain arising from internal magmatic and external tectonic processes that occur during emplacement. Throughout the emplacement process, magma replenishment zones (MRZ) act as a conduit where new magmas inject into, reheat and remobilise host magma. MRZs therefore may archive strain from multi-stage crystal mush processes, from low viscosity flow through to grain-grain contact strain in near-solid crystal frameworks, preserving processes as microtextures and mineral fabrics. Rock fabric studies tap into this archive to provide unique insight on the magma rejuvenation mechanisms within magmatic systems. This study examines a MRZ within the Fanad Pluton, NW Ireland to investigate fabric variation associated with the interaction between newly injected and remobilised host magma. The pluton contains multiple MRZ areas each tens of metres wide showing mafic enclaves and sheets included in a coeval host quartz monzodiorite, with a range of magma contacts providing an ideal test site for the study. A representative MRZ exhibiting a series of NW-SE trending mafic sheets and enclave swarms injected parallel to the steep petrofabric of the pluton was chosen for cm-scale mapping. Mixing and mingling textures within the zone are interpreted to show the mafic sheets have interacted with and remobilised the host magma, which records a gradational loss of foliation to become unfoliated approaching the MRZ.

Fabric orientation and strength were quantified using anisotropy of magnetic susceptibility (AMS), measured from drilled samples along four 25-60m traverses that traverse sheets and enclaves across the MRZ. Initial results highlight distinct transitions in magnetic fabric orientation and corrected degree of anisotropy (Pj) across each traverse. Mafic sheets record a sub-horizontal NW-SE trending magnetic foliation and Pj (strength of fabric) that is lower than the host intrusion that is indicative of internal magma flow. Host magma shows a loss in mineral alignment, but sharp rises in Pj within 5m of mafic sheet contacts, reflecting the observed complex mixing/mingling mechanisms. A marked decrease in Pj is observed up to 30 m away from the contact, coinciding with siting of mixing/mingling in the field and is interpreted to represent the limit of magma remobilisation proximal to the injected mafic sheets.

Our results highlight fabric heterogeneity from competing magmatic processes at MRZs and the extent of crystal mush remobilisation within the host intrusion. Supplementary analyses are required to further constrain this extent and refine the petrographic and magnetic fabric transitions associated with magma replenishment zones.

Using pyroclast textures to investigate a change in explosivity within a low-intensity basaltic eruption.

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Low-intensity basaltic eruptions are the most common expression of subaerial volcanism. They are characterised by fluctuations in explosivity within eruptions. Potential driving factors for these fluctuations can involve changes in magmatic properties including ascent rate, magmatic composition and volatile content. Alternatively, extrinsic factors such as changes in vent morphology by localisation or narrowing may also affect explosivity. Previous textural studies of pyroclasts combining vesicularity, petrographic and compositional analyses have provided valuable insights into such factors and thus variations in explosivity. However, comprehensive studies have overwhelmingly focused on Kilauea, Stromboli and Etna.
Here, we used a textural study of pyroclasts to investigate the increase in explosivity from initial weak spattering to peak fountaining in the first week of the 2022 eruption of Fagradalsfjall, Iceland. Clasts produced by initial weaker activity are moderately vesicular, with euhedral olivine, spinel and plagioclase phenocrysts, glomerocrysts of plagioclase, olivine and pyroxene, and anhedral plagioclase hopper microlites. Clasts produced by peak fountaining are extremely vesicular, with similar phenocryst populations except for the absence of microlites. No significant change in glass or phenocryst composition with increased explosivity was detected. However, the absence of plagioclase microlites in clasts produced by later peak fountaining indicates an increased magmatic ascent rate. A change from moderate to extreme vesicularities is interpreted to reflect greater residence time in higher fountains enabling post-fragmentation expansion, and potentially suggests an increased volatile content that could have driven a greater magmatic ascent rate. This study demonstrates the value of combining vesicularity, petrographic and compositional analyses to investigate low-intensity basaltic explosivity.

Current Volcanic Activity at Azores Islands Observed by Sentinel-1 and GNSS

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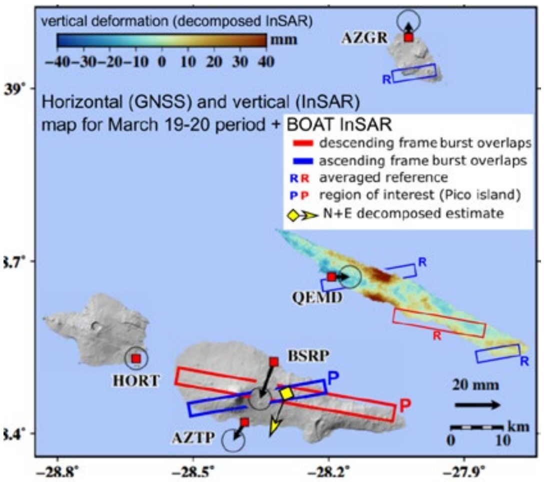

Eruptions at long-inactive volcanoes are usually preceded by days to months of unrest as magma migrates gradually to shallower depths. This is built into plans by civil protection agencies for societal response. On 19th March 2022, at São Jorge, Azores Islands, after 60 years of repose, magma reached almost the surface in a vertical dyke intrusion within a few hours of the seismicity onset with no previous precursory signals. Recent eruptions at São Jorge have produced pyroclastic density currents, and the potential for an eruption to occur with little warning poses a great hazard to the population. We captured the surface deformation due to the dyke intrusion using Sentinel-1 InSAR and GNSS and monitored the post-event dynamics closely with additional instruments but the intrusion did not continue to the surface. We established a model based on measurements of seismicity and land surface deformation that attempts to explain this volcanic unrest. Deformation was high in the first day of activity (>5 cm of uplift) and significantly decreased afterwards. It reached other neighbouring islands over a distance of at least 45 km away from São Jorge, expanding the region with approximately north-south displacements in magnitude of up to 2 cm, partly captured by both GNSS measurements and an InSAR method incorporating spectral diversity in burst overlaps along the track (BOAT) of the Sentinel-1.

Although unrest continued for weeks, subsequent magma intrusion after the first day was below 4 km deep. São Jorge lies in a rift zone where extensional stress is expected to be built over time to accommodate magma at depth. We interpret the cause of the initial shallow injection to be due to the deviatoric stress there being so high that the suction due to opening was greater than the force required to reach a greater height. After relaxing the stress field at shallow levels, the next most energetically favourable location for magma injection was deeper. This implies that an eruption was unlikely during the first hours, despite reaching such shallow depth. The São Jorge event indicates that elastic strain accumulated from long-term periods of tectonic spreading at dormant volcanoes can be released by sudden, episodic shallow dyking events triggering the activity of deeper magmatic processes.

The current unrest at Azores however did not conclude by this event, as since the end of June 2022, an increase in seismic activity started to appear in Terceira Island below the Santa Barbara volcano. Since then, seismic activity has remained persistent, sometimes with a few dozen events per day. Last eruptions related with this volcano occurred in 1761 and in 1867, the last being a submarine one. We observed surface deformation of Terceira by sparse network of GNSS stations, possibly capturing an expansion below Santa Barbara. The current results of Sentinel-1 InSAR processing using updated LiCSAR processing chain, GACOS atmospheric correction data and modified LiCSBAS time series supported by a signal separation routine ICASAR estimate deformation signal obscured by signal due to atmosphere and bring forward a possibility of an expansion of Santa Barbara by ~2 cm in E-W direction. This contribution shows significance of using satellite InSAR to support observation of volcanic areas and importance of covering volcanoes considered inactive.

What Can Block and Ash Flow Deposits Tell Us About Lava Dome Collapse Dynamics?

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Lava domes form when viscous lava accumulates at an active volcanic vent. Timescales for lava dome growth prior to collapse can range from hours to years. Lava domes can be generated by a wide range of magma compositions; however, most are andesitic to dacitic. Lava domes are divided into four main morphologies; upheaved plugs, Peléean domes, low lava domes, and coulees, where the distinction depends on the material properties. Lava domes consist of a ductile core, transitional carapace, and brittle talus outer region. This talus zone consists of the solid outer part of the dome and slopes of disaggregated material. This talus can influence the dome growth and morphology.

Lava domes are unstable and prone to collapse, with several collapse mechanisms proposed, including thrust forces, gas overpressurisation, oversteepening of the slopes, seismic triggering, and rainfall. Dome collapses generate block-and-ash flows (BAFs), which are typically low volume (<0.5 km3) and contain a proportion of dense, juvenile blocks with non-pumiceous ash. To date, there has been limited work done on linking the original dome structure to BAF formation, or whether the deposits can be used to understand collapse dynamics.

This project aims to address three key questions: (1) How and when is ash generated within a BAFs? (2) Can the nature of the blocks within BAFs inform us about the dome and collapse process? (3) To what extent can the BAF deposit be used to infer conditions in the dome? To do this we will carry out field observations, stratigraphic analysis; lab analysis of the blocks and ash, such as geochemistry, vesicularity, and rock strength testing; and modelling, using numerical models and an analogue flume to link the deposits to original dome conditions. By improving our descriptions of BAF deposits it will be possible to better address how they sit within the broader spectrum of PDC literature, and refine our interpretations about triggering, propagation, and deposition. Improving the understanding of lava dome collapse dynamics will allow for improvements in hazard and risk assessment of lava domes.

Plagioclase shape: implications for magma mush dynamics

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Volcanic, petrological, and geophysical studies reveal that magma storage regions are primarily composed of a crystalline mush with a small volume of melt [1]. Crystal shape plays a significant role in influencing mush rheology. Elongate crystals form a rigid network at low concentrations (e.g., 30 volume %), while equant grains require higher concentrations (e.g., > 50 vol. %) [2]. Given the well-established sensitivity of plagioclase shape to undercooling (i.e., Tliq-T), we can utilize plagioclase shape to estimate the rate at which a crystal mush developed [3]. Therefore, we investigated the evolution of plagioclase shapes under low to moderate (10-50°C) nominal undercooling, within the interface-controlled regime, at both low- and high-pressure conditions [4]. We examined the effects of different cooling methods on crystal textures using isothermal, single-step, and continuous cooling procedures (fig 1). Plagioclase 3D crystal shapes were obtained from back-scattered electron images, processed using ShapeCalc [5].

Our study found no clear correlation between crystal shape and absolute values of undercooling, consistent with previous experimental research [4]. We observed a range of crystal shapes regardless of cooling rate, as illustrated in the figure below. As crystals grew larger, their shapes transitioned from prismatic to tabular, a pattern that aligns with the proposed growth model of Mangler et al., 2023[4]. However, deviations in our data from the expected model trend hint at a more complex interplay between crystal shapes and variations in melt diffusivity. Our experiments show that even the most texturally immature accumulating mafic mushes likely contain diverse crystal shapes in varying proportions. Mushes that host a mix of tablets and prisms would require a higher crystallinity before reaching a rheologically locked state [6]. As a result, a crystal mush characterized by a combination of crystal shapes could potentially maintain a more favourable state for eruption than one with a single population of elongate crystals. In summary, our findings emphasize the significance of considering crystal shapes, as well as the specific conditions under which they form, when seeking to understand the behaviour of crystal mushes and their potential for remobilization.

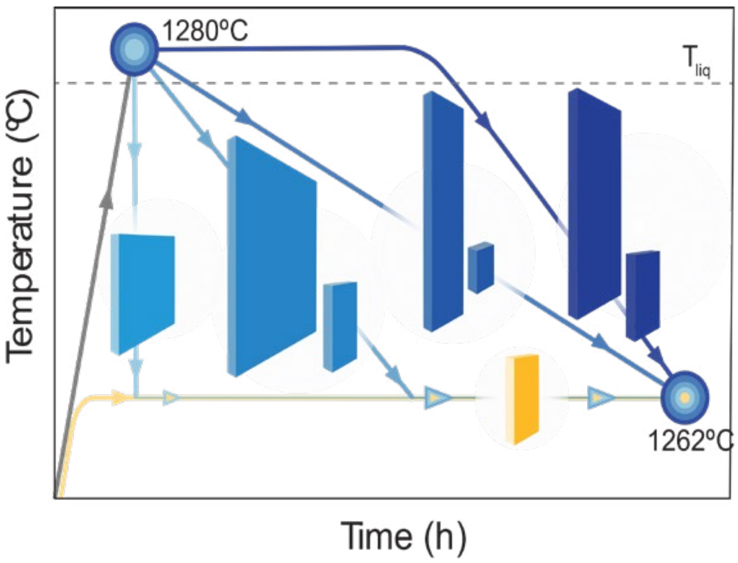

Figure caption. Schematic of different experimental pathways and resulting crystal population(s) shapes.

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Investigating transitions in eruption style using textural analysis of tephra samples: a case study from Fagradalsfjall 2021

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The 2021 Fagradalsfjall eruption in southwest Iceland exhibited significant changes in eruptive style. Following eruption onset on 19 March, initial stages consisted of low, near-continuous effusive activity with mild intermittent lava fountaining from multiple fissures. By 28 April sustained lava fountaining had been confined to a single vent. After 2 May, activity became intensely pulsatory, where periods of inactivity alternated with intense lava fountaining ejecting jets of magma almost 500 m above sea level [1].

The changes in eruption style were likely driven by the behaviour of magmatic volatiles in the volcanic conduit. Volatile exsolution and degassing in magmatic conduits are not directly observable at the surface, and have proved difficult to understand from geophysical signals and geochemical studies of gases emitted at active volcanoes. Vesicles in erupted tephra samples preserve a textural record of volatile exsolution during magma ascent.

We present 2D vesicle abundance, size and shape distributions from tephra clasts erupted before and after a major transition in eruptive style. X-ray computed microtomography experiments have been conducted to reconstruct and visualise textures in 3D for selected clasts. By integrating 2D and 3D textural analysis, quantitative investigations of the proportions, spatial distributions and interconnected porosity of the vesicles will reveal insights into the degassing processes which were operative in the volcanic conduit during the distinct phases of the eruption.

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Permeability of granular mixtures under shearing conditions: implications for pyroclastic density currents.

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Pyroclastic density currents (PDCs), gravity-driven hot gas-particle mixtures, are one of the most lethal geophysical flows. One of the reasons for the hazardous and devastating nature of PDCs is their ability to travel great distances on slopes of just a few degrees. Detailed information about the mobility of PDCs is required to effectively forecast the flow path and the run-out distance of PDCs, and inform the hazard maps. This high mobility has been often attributed to the presence of positive internal pore pressure, which enhances the flowability of granular mixtures. The generation mechanisms and the conditions required to sustain and mediate the pore pressure are not fully understood. We know that internal pore pressure is reduced by permeable gas flow within the PDC.

Our current knowledge of gas-particle permeability is mainly limited to static conditions, however, PDCs are dynamic phenomena, and parameters such as the shear rate can change with time and space as the flows propagate away from the volcanic vent. This research studies the effects of the shear rate on the permeability of gas-particle mixtures through novel experiments where the granular mixture is simultaneously sheared and fluidised whilst the gas flow rate and pressure are measured. The permeability and the fluidisation behaviour are investigated in terms of the applied shear rate, the content of fine particles, and the timescales associated with the particle segregation.

The formation of silicic magmas on young planetary bodies in an Iceland-like setting

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Four billion years ago, Earth's surface was covered with a thick basaltic crust and, similar to other rocky planets and potentially our own moon, parts of this basaltic crust subsequently underwent partial melting to produce silicic crust. On Earth, this silicic crust grew into the continents. An analogue of a pre-subduction early Earth and rocky planetary bodies is found in Iceland where poorly understood granitic rocks are encased in thick basaltic crust away from any active subduction zone. Here, we investigate these Icelandic granitoids to understand the mechanisms that generated the Earth's oldest continents, and potentially similar silicic rocks on Mars and Venus. Here, we present new geochemical data from the four largest silicic Icelandic intrusions, located in southeast Iceland. We investigate the formation of these intrusive rocks using models of partial melting and fractional crystallisation. Our data show that the granitic intrusions are compositionally unlike early Earth continental material. We show that intra-crustal partial melting of thick Icelandic basalt can potentially form silicic material on other planetary bodies but cannot produce the first continents on Earth.

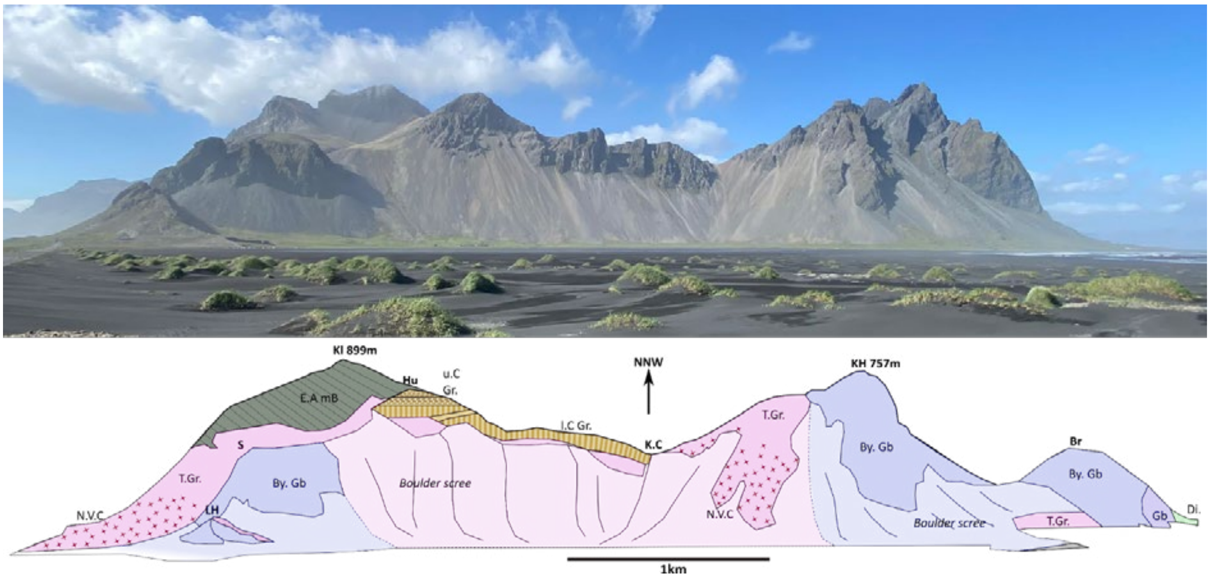

Figure 1. The Vestrahorn intrusion in southeast Iceland with accompanying 'cross section'. Intrusions of silicic rock are in yellow (central granites) and pink (granodiorites). Areas with red crosses are hybrid 'net-vein' complexes. Later intruded gabbros are in blue and purple. Roof basalts are in dark green. Icelandic plutons can inform about petrogenetic processes that produce silicic magmas in thick oceanic plateaus.

Experimental and numerical rheometer: insights into the flow properties of fluidised and non-fluidised granular mixtures.

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Pyroclastic density currents (PDCs) are hot gas-particle mixtures travelling away from the volcanic vent, transporting particles from micron-sized ash to clasts larger than a metre. PDCs range from dilute turbulent suspensions to dense fluidised granular flows. Most PDCs contain aspects of both of these end members, which makes their internal structure particularly complex. Due to the destructive nature of the flows, direct observations of PDCs are incredibly difficult and PDCs remain as one of the least understood volcanic phenomena. Advances in understanding of the internal dynamics and the rheology of PDCs are mainly based on deposit studies, experimental and numerical modelling of gas-particle mixtures.

Here, we perform novel rheological measurements of a fluidised and a non-fluidised column of Ballotini glass beads and compare these physical laboratory results with a DEM (Discrete Element Method) simulation of the experiments. Although granular flows comprising monodisperse and uniform density particles allow for relatively easy implementation in the numerical simulations and the comparison with the experimental results, these simplifications might not be capturing the complex internal structure of natural PDCs. Therefore, the present work constitutes only the first part of the project, and the findings will be used to inform large-scale simulations of fluidised granular flows comprising particles of various sizes and shapes, propagating over non-uniform topographies.

Systematic Review of Forecast-based Early Actions (FbEA) in Response to Volcanic Hazards: Insights from Merapi Volcano, Indonesia

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The Forecast-based Early Action (FbEA) is an approach that consists of precise guidelines and automatic activation of predefined protocols based on forecasted hazardous conditions. This innovation is mainly applied by non-governmental organizations (NGOs) to proactively anticipate disaster impact, commonly due to climate-hydrometeorological hazards. However, despite technological advancements, the practical implementation and programmatic viability of the FbEA strategy against volcanic hazards remain challenging. This research provides a comprehensive literature review focused on FbEA application in addressing Merapi's volcanic hazards in Indonesia. This study employs CARI's portal to access several repositories, including Portal Garuda, an Indonesian research repository by the Ministry of Education, Culture, Research, and Technology, Directory of Open Access Journal, and Scopus. Utilising well-defined English and Bahasa Indonesia keywords based on Merapi's specific volcanic hazards, location, and disaster management approaches, this study collated 477 relevant publications. Through multi-stage selections and review process, our preliminary findings are 1) the majority of these publications are centered on forecasting volcanic hazards, with implications for decision-making, planning, and timely response actions; 2) pyroclastic flows emerge as the most extensively studied type of volcanic hazard, closely followed by lahars and volcanic ash, while other hazards including lava flow remain limited; 3) merely around one-third of the compiled publications directly studied FbEA application pertain to specific geographic areas, (e.g., villages, cities or regencies). Hence, our initial conclusion suggests that the FbEA programs and their execution by national actors, such as the National Agency for Disaster Management or Badan Nasional Penanggulangan Bencana (BNPB) in Indonesian, along with local stakeholders, including the Local Agency for Disaster Management or Badan Penanggulangan Bencana Daerah (BPBD), in mitigating volcanic hazards for communities in Merapi, are at an early developmental phase, especially in the delivery and financing of FbEA, the studied hazards diversity, and the practical application within the local context.

Keywords: Volcanic hazards, Forecast-based early action, Merapi, Anticipatory, Systematic review

The evolution of a basaltic fissure eruption

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Basaltic eruptions produce lava flows that have the potential to destroy local infrastructure and emit toxic gas and particles that may adversely impact public health. Predicting their style and evolution is therefore a key goal in volcanology. This requires an understanding of the multiphase flow processes that operate within the sub-volcanic system.

Field observations of both solidified and erupting basaltic fissures at Kīlauea volcano (Hawaiʻi, USA) are synthesised with laboratory analogue experiments to determine the evolving organisation of gas-driven flow patterns within basaltic feeder dyke systems, and their effects on eruptions. Our laboratory kit was designed to perform scaled analogue experiments of bubbly flows in a 3.0 x 2.0 x 0.03 m glass-walled slot. This geometry mimics the geometry of dykes that feed most basaltic eruptions, whereas previous experimental studies have usually assumed a cylindrical conduit. The role that localization of fissure segments plays in shaping eruption behaviour is explored by occluding parts of the top of the slot. We also consider the role played by flooding of the vent with lava, focussing on long-lived systems that are reproduced by a conical vent geometry. We collate the imagery acquired during our analogue experiments with recent monitoring datasets and a detailed field investigation of the spatial organization of vents and drain-back structures on solidified fissures at Kīlauea to improve our understanding of the controls on the eruptive behaviour of basaltic systems. This study will help interpret the underlying flow patterns within feeder dykes from real-time gas and erupted lava flux measurements.

Towards Dynamic Poroelastic Numerical Analysis of Volcano Ground Deformation at Bárðarbunga Volcanic System, Iceland

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Measuring and modelling ground deformation of volcanic regions can provide a key insight into the geophysical processes operating within the crust and improve our understanding of magma system dynamics. Our capacity to model the ground deformation produced by volcanic systems has improved signi icantly in the last two decades, largely due to the advances in the capability and processing power of computer-based models, and simultaneous improvements in volcano geodetic monitoring capacity. Contemporary inite element (FE) models have begun to incorporate poroelastic behaviour in crystalrich magma-mush reservoirs, with additional inclusion of poroviscoelastic reservoir behaviour and thermo-viscoelastic crustal behaviour also feasible. The addition of these rheological parameters is believed to facilitate a more realistic representation of magmatic systems, and in turn improve our ability to constrain volcano deformation signals. Thus far however, these models are yet to be tested by applying them to real-world volcanic systems. The eruption of the Bárðarbunga volcanic system in 2014-2015 was accompanied by a gradual caldera collapse of up to 65 m, due to approximately 1.9 km^3 of magma being extruded from a source under the caldera into a propagating dyke. Post-eruptive geodetic observations indicate that the volcano began in lating again as early as July 2015, an observation accompanied by a mirror-image reversal in the polarity of earthquake focal mechanisms on the Bárðarbunga caldera ring fault system. The in lation has been attributed to a combination of viscoelastic relaxation and renewed magma in low, and as of ~May 2023 has shown an acceleration in deformation velocity. We will use dynamic poroelastic-reservoir volcano deformation models to reproduce the observed post-eruptive deformation of the Bárðarbunga caldera, in an attempt to more robustly and realistically constrain magma supply and storage characteristics. The parameters of the existing, generic models will be tailored to the Bárðarbunga volcanic system by incorporating independent geological, geochemical, and geophysical data. Primary model veri ication when constraining system parameters will be provided by simulating recorded geodetic data (ground-based GNSS and satellite-based InSAR) and optimising a solution between observations and model predictions.

Carbonatite-syenite interaction and assimilation, Stjernøya, Norway.

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The Lillebukt Alkaline Complex (LAC, 570 – 520 Ma) Stjernøya, Norway, consists of a miaskitic nepheline syenite body, calcite carbonatite, nepheline syenite pegmatites, and mafic dykes of various origins [1]. The complex remains relatively unstudied, with little research conducted since the 1980s [2][3].

Previous research has given evidence for contamination of carbonatites from xenoliths of calcite syenite in drill core at the Kaiserstuhl Volcanic Complex, Germany, the process has been shown to play an important role in the evolution and REE potential of carbonatites in recent years [4]. This study details textural evidence for assimilation and disequilibrium between alkaline rocks (nepheline syenite) and the associated carbonatite magma in the LAC.

Field observations present a spatially heterogeneous calcite carbonatite, that towards contacts with the syenite increases in dark mica abundance. Xenoliths of syenite and xenocrysts of nepheline and feldspar entrained from the nepheline syenite have rims of dark mica and range from euhedral to anhedral (rounded).

The modal abundance, along with atypical size (decimeter crystals) of mica observed in the Lillebukt carbonatites exceed those of silica activity capable in primary carbonatites, thus, we hypothesize these features result from reaction and assimilation with the syenite body [4]. We suggest syenite xenoliths and xenocrysts with mica reaction rims represent the process of assimilation and reaction. Whereas, at the interfaces between the bodies, a mica-rich (>70% dark mica) "glimmerite" occurs, indicating complete reaction and armoring. The abundance of syenite xenoliths/wall rock to carbonatite magma appears to have a strong influence on the resulting mineralogy of the carbonatite. The main syenite body is cross-cut by meter-scale micarich dykes containing calcite and anhedral xenocrysts of syenite, we suggest these represent carbonatite dykes that have reacted fully due to the relatively low abundance of carbonatite magma to syenite.

From field evidence the following hypotheses were devised, 1) the carbonatite has been contaminated by the rock it intrudes into (syenite). 2) Fenitisation occurs at contacts between the carbonatite and syenite host [5]. Alternatively, textures represent 3) immiscible contacts between iron-poor and ironrich magmas.

The project aims to investigate these observed textural and mineralogical relationships using thin section microscopy and mica chemistry via electron microprobe analysis. The field localities described exhibit carbonatite-syenite interaction and assimilation from hand specimen to outcrop scale, spanning hundreds of meters, providing an excellent opportunity to study these processes.

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Stress Inversion in Calderas with a Simplified Model of Dyke Pathways: Towards a Physics-based Forecast of Eruptive Vent Locations.

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Forecast of vent opening locations in volcanic areas typically relies on purely data-driven approaches, where the spatial density of past eruptive vents informs the probability maps of future vent opening. As sophisticated as they may be, such methods are difficult to apply to settings with scarce and spatially sparse data, or where the factors driving magma pathways may change over time. An alternative approach is to combine physics-based models of magma propagation with statistics to, first, understand the controls on past vent patterns and, secondly, exploit such information to forecast future vent locations. Such an approach was recently proposed and tested with two-dimensional models. Here, we extend it to three dimensions (3D) and lay out a framework for stress inversions and vent forecast in calderas. First, we present a numerical model of crustal stress accounting for tectonic processes and gravitational loading/unloading associated to topography. Then, we introduce a simplified but computationally-efficient model of dyke pathways in 3D, which can also backtrack dykes from a vent down through the crust. We use these models to calculate synthetic scenarios inspired by real calderas, producing sets of dykes and vents for a given stress field and magma reservoir. Then, we use such scenarios to test a stress inversion strategy such that dyke trajectories backtracked from the known vents are consistent with the assumed location and size of the magma storage volume. Eventually, we discuss how to combine the outcomes of stress inversions and our dyke propagation model to forecast the opening locations of future vents.

Model of the shallow crustal density distribution of the Krafla Volcanic System.

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The Krafla Volcanic System (KVS) in the Northern Volcanic Zone (NVZ) in Iceland is composed of a restless caldera of 10 km wide, an array of scoria cones along a fissure swarm covering 5-9 km wide. It is among the best-studied volcanic systems due to the exploitation of its geothermal potential. The KVS last erupted between 1975 and 1984, during an eruptive period called “the Krafla Fires”. These nine eruptions were associated with the intrusion of an extensive network of basaltic sills and dikes in the central part of the caldera at depths of between 3-7 km. The unexpected drilled rhyolitic magma body at 2.1 km depth by the Icelandic Deep Drilling Project (IDDP) in 2009 shows the importance of characterising the magmatic architecture in the shallow crust of the Krafla Volcanic System.

Static gravity measurements provide insight into subsurface mass-density distributions based on spatial variations in the Earth’s gravitational field. This technique is used in volcanic areas to determine the local subsurface density architecture, such as the depth of caldera infill, the dimensions of magma feeder pipes, and the extent of hydrothermal activity. We have assembled a gravity dataset comprising previous studies, along with 76 new gravity measurements across the KVS caldera, and compute the Bouguer anomaly (BA) for the region.

Similarly to previous studies, the broad pattern we observe is a positive gravity anomaly around the outside of the caldera, with a negative gravity anomaly in the centre. The density contrast between different rock units and the background density generates these anomalies. In order to probe the sub-caldera magmatic system down to 5km in more detail, we invert our BA values for subsurface density variation using GROWTH 3.0. The future interpretation of the 3D model will provide us with a better understanding of the magmatic processes and intrusion distribution in a rift tectonic environment, we can identify potential magmatic bodies that were previously unrecognised, while also exploring correlations between density anomalies and potential geothermal areas.

From Mush to Dyke: Insights into Reservoir Failure and Dyke Nucleation in Dynamic Magma Mush Reservoirs.

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Assessing the stability of magma reservoirs is critical to understand the conditions that may lead from unrest to eruption in volcanoes. In particular, reservoir failure can initiate the propagation of magmatic intrusions towards the surface, often in the form of dykes. The last decade has seen a shift of paradigm from the widely employed static models of melt-dominated magma chambers to trans-crustal magmatic systems (TCMS), envisioning a mush zone that includes melt-dominated lenses and can be considered as a poro-(visco)-elastic medium. Recent studies have also investigated the dynamic processes of magma injection or withdrawal in magma mush reservoirs. However, there has been little investigation of reservoir failure within such new approaches. At the same time, modelling of three-dimensional dyke propagation has advanced considerably in recent years, both in terms of calculations of dyke pathways in a static stress field and in terms of dyke growth and velocity under different assumptions on fluid properties and injection rate. The models at both ends are now mature for an investigation into the process of dyke nucleation from mush reservoirs. Here I present some preliminary results in that direction, and outline the objectives and steps of my future research within the recently-started NERC-funded DV3M (Deforming Volcanoes with Dynamic Magma Mush Models) project. Specifically, I focus on modelling strain-rates produced in coupled solid and fluid mechanics mush reservoirs of different geometries undergoing magma recharge, employing Finite-Element numerical models. I also study the evolution of stresses induced in the surrounding rocks when considering the viscoelastic response of the crust, and how it may affect dyke pathways.

Eldfell, 1973: Reconstructing the eruption night using archived documents and personal accounts.

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The 1973 Eldfell eruption is the only Icelandic eruption to have occurred in an urban setting since the early settlement of the main island in 876 AD. A volcanic fissure opened on the eastern side of the island of Heimaey, c. 100 meters from the nearby Kirkjubær farm, posing immediate danger to residents, livestock, property, and the harbour. Within 6 hours c. 5,000 islanders were evacuated to the Icelandic mainland, utilising the 60-boat fishing fleet that was in dock overnight (Fig. 1). Around 300 people stayed behind to begin rescue work and damage control.

This research reconstructs the events of the first night of the Eldfell eruption. Archived documents including weather reports, seismic records, ships logs, photographs, and newspaper articles, are combined with written personal accounts and interviews. We investigate the reactions to the eruption, the communication and planning involved in the evacuation, and the experiences of individuals during the event, including but not limited to children, pregnant women, sailors, and emergency service workers. Understanding the community response to the 1973 eruption can help present and future generations of islanders, scientists, and emergency responders to understand and prepare the community for future eruptions on the island and further afield.

Figure 1: The fishing boat Sólfari AK 170 evacuating islanders to the mainland on the 23rd of January 1973. Photograph: Sigurgeir Jónsson.

Fluid interaction in nepheline syenite, Stjernøya, Norway.

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The Nabarren nepheline syenite deposit is an intrusive body in the south of the Lillebukt Alkaline Complex (LAC). It comprises two predominant, syenite types, defined by the accessory mafic mineralogy: biotite- and pyroxene-nepheline syenite, and is currently mined for nepheline and feldspar. The distinguishing factor of the two variants has previously been attributed to fractional crystallisation, zonation linked to volatile content, and hydrothermal alteration facilitated by faulting [1][2][3].

This study aims to assess the extent of hydrothermal alteration, using cathodoluminescence, XRF, EPMA, and textural evidence to evaluate the following hypotheses. a) The mineralogy and petrology of the nepheline syenite is altered by metasomatism from mafic intrusions, which were once carbonatitic.
b)Ore quality is reduced in proximity to the intrusions, with the release of chemistry-altering fluids. c) The primary nepheline syenite forms from a phonolitic melt which initially crystallized pyroxenite, contrary to previous work, stating alkali-pyroxenites intruded as separate events [4].

A zone of alteration occurs around the dykes (described as diabase orvogesite[5]), with biotite in proximity, and pyroxene increasing distally. Nepheline is depleted in the biotite-type, with concentrations as low as 5%, and zoned by albite, with partial replacements of cancrinite. The pyroxene-nepheline syenite has an increased nepheline abundance (up to 35%), larger crystal size, and contains titanite. We infer nepheline was replaced by secondary processes, the syenite initially had a pyroxene-rich mafic mineralogy, and due to the spatial relationship between the dykes and the biotite- nepheline syenite, the intrusions are hypothesized to instigate alteration.

Carbonatite to the north of the nepheline syenite ore body has distinctive disequilibrium features at contacts with syenite, where field evidence shows nepheline and feldspar breaking down, and the rock becoming mica-rich [6]. Therefore, it is hypothesized the dykes have formed via a similar process to the carbonatite, on a smaller scale, where they have interacted and assimilated the syenite, changing the composition.

The magmatic origin of the nepheline syenite is inferred through the identification of a cumulate sequence, with pyroxenite progressively evolving to a leucocratic nepheline syenite. We hypothesize the nepheline syenite formed during phonolitic melt evolution, initially crystallizing pyroxenite. If correct, this updates the magmatic history of the LAC.

We present evidence for the genesis of the primary nepheline syenite, and the alteration processes responsibleforthereducingorequality,allowingorebeneficiationtobeenhanced, andtheprocesses responsible for ore degradation to be understood and implemented in future exploration.

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Magmatic Memories: Eldfell, 1973.

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2023 marked the 50th anniversary of the 1973 Eldfell eruption on the island of Heimaey, Iceland (Fig. 1). The eruption began unexpectedly at 1.50 am on the 23rd of January 1973, and the 5,300 residents had to be evacuated to the Icelandic mainland by fishing fleet. The eruption is synonymous with the islanders' fight to save their town by spraying cold seawater onto the advancing lava flows. Previous research has focused on the physical volcanology and igneous petrology of the eruption and the wider Vestmannaeyjar Volcanic System, however very little research has focused on the social impacts of the eruption. Fieldwork identified how the 1973 eruption is remembered and commemorated by the residents of Heimaey both in public and private settings. Over 50 memorials are discussed including artworks, sculptures, museum exhibitions, in-person events and online digital repositories that highlight connections to the eruption itself and to life before the eruption. Interviews and surveys with the local community draw attention to the on-going impacts of the eruption, for example traumatic responses to present-day hazard events such as the Eyjafjallajökull eruption in 2010. A predominantly positive community narrative of the event has persisted for several decades. The narrative depends on the belief that no deaths were caused by the eruption, the successful rebuilding and recovery of the town, and the resilience of the residents. The last ten years, however, have seen a drastic change in how the community discuss their experiences of the eruption, with a new focus on the loneliness, bullying, isolation, danger, and trauma experienced during the event.

Figure 1: Fire fountains at the Eldfell volcano during the 1973 eruption taken from the northwest of the island near the Harbour. Photo: Sigurjón Einarsson.

A geochemical reevaluation of caldera-forming eruption deposits in the Upper Borrowdale Volcanic Group, English Lake District.

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Caldera-forming eruptions are amongst the most catastrophic events to affect the Earth's surface. However, research of caldera volcanoes is greatly hindered at modern examples due to critical features such as caldera faults, eruption conduits, and caldera fill deposits being concealed. Therefore, to better understand these disastrous eruptions, we must turn to ancient calderas that have been uplifted and exhumed, providing internal examinations.

The upper portion of the Borrowdale Volcanic Group (BVG) of the English Lake District is dominated by large-scale caldera-forming deposits that have been tectonically uplifted and dissected by glacial erosion. Each of the BVG calderas has the potential to provide a wealth of knowledge regarding how calderas erupt, collapse, and continue to shape geological processes when their explosive activity ceases.

Scafell Caldera is one such BVG caldera that provides world-class internal exposures, gaining international interest on the subject. However, due to intense faulting, alteration, and impersistent exposure in other parts of the Lake District, similar in-depth research at other BVG calderas has been prevented using standard field-mapping techniques. This leaves most of the understanding for the overall nested caldera complex to be inferred.

This investigation utilizes whole-rock geochemistry as the primary method to establish correlations between potential large-scale, caldera-forming pyroclastic deposits across large distances. Once the extent of each deposit was determined, they were individually traced back to their source vents. Detailed fieldwork was then conducted to identify characteristic caldera-forming features, such as rapid thickness changes over volcanotectonic faults, and extensive intercalated mesobreccia deposits.

Geochemical analysis shows significant changes in critical immobile element abundances, including Nb, Th, Y, and Zr, in potential caldera-forming deposits at around the Haweswater and Helvellyn areas. This suggests that the deposits have been misidentified across localities and are instead part of separate eruption events. Subsequent fieldwork supports these claims, with stratigraphical and facies changes occurring with the geochemical variations. Investigations for critical caldera-forming characteristics in these new deposits also brings forth new interpretations of the volcanic centers within the BVG. A distinct lack of these characteristics at Haweswater 'caldera' suggests no collapse occurred. However, at the Helvellyn 'basin' there is strong evidence for two collapse events, and the possibility of a third caldera collapse around the Ambleside area. The discovery of three new calderas within close proximity to Scafell and Langdale calderas can help to improve the understanding of how individual calderas impact the development of future collapses within nested caldera complexes.

The relationship between volcano growth, eruption style and instability at Anak Krakatau, Indonesia.

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Edifice destabilisation is a common volcanic process and although relatively infrequent, large-scale gravitational collapses can occur across all volcano-tectonic settings. Growing evidence suggests that cycles of edifice growth and destruction, through variable loading of the underlying magma reservoir, influence magma storage conditions and eruptive behaviour on a range of timescales. However, difficulties in developing high-resolution reconstructions of pre- to post-collapse volcanic activity limit our understanding of these relationships.

In December 2018, Anak Krakatau underwent a substantial failure of its south-western flank, following a period of heightened but not atypical eruptive activity. Unlike most historical lateral collapses, this major structural failure occurred just 91 years after Anak Krakatau's emergence above sea-level in 1927. As a result, the volcano offers a uniquely well-documented record of a complete cycle of edifice construction, failure and subsequent regrowth.

This work combines remote sensing, 3D reconstructions and analysis of past eruption records to examine Anak Krakatau's volumetric evolution at 33 points since its initial formation. Results indicate that following collapse Anak Krakatau entered an accelerated ongoing phase of regrowth, with 4-years of rapid volumetric increase equivalent to 62-years of historical growth (1950-2012). Evaluating this structural development provides an analogue for understanding edifice growth and stability at other volcanoes globally, and is key to constraining the future growth and stability of Anak Krakatau itself. This is critical in developing improved hazard management strategies in this densely populated region, where a challenging set of cascading hazards results from the partially submerged setting and frequent eruptions.

Evolution, Eruptive Recurrence Rates and Behaviour of Monogenetic Volcanism in Central Armenia

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The Gegham Volcanic Highlands, central Armenia consists of a dense cluster of 127 Pleistocene-Holocene monogenetic scoria cones and lava domes. The vents were mostly formed during strombolian to violent strombolian eruptions, which produced extensive lava flows, scoria, and spatter with predominantly trachybasalt, basaltic trachyandesite and trachyandesite compositions [1,2].

The timing of monogenetic volcanism in the Gegham Volcanic Highlands is uncertain, due to the lack of geochronological age information available for individual volcanic vents. K-Ar dating of past eruptive activity in the region has yielded ages between 700 ka and < 50 ka, with uncertainties for the youngest eruptions approaching ± 100 % [2,3]. However, archaeological evidence suggests eruptive activity may be as young as ~3.5 ka [4]. Recent studies suggest that seismic swarms in the Gegham Volcanic Highlands can be linked to an active magmatic system, indicating the possibility of future volcanic eruptions, which pose a significant threat to the Armenian capital city Yerevan and its population of 1.1 million people [1]. With uncertainty regarding the timing of the last eruption and the potential threat of future volcanism, high precision $^{40}Ar/^{39}Ar$ ages for past eruptions are critical to underpin spatial and temporal volcanic modelling of the region, to understand possible future eruption scenarios.

This project will utilise $^{40}Ar/^{39}Ar$ geochronology to determine the spatio-temporal evolution and eruptive recurrence rates of monogenetic volcanism in the Gegham Volcanic Highlands. New $^{40}Ar/^{39}Ar$ ages will be used to inform statistical modelling forecasting the location and timing of potential future eruptions. In addition, constraints on magma ascent and eruptive behaviour will be gained from textural analysis using Scanning Electron Microscopy and X-ray micro-CT/microscopy. Overall, the results from this project will be used to inform hazard assessment in Armenia and provide insight into the evolution of monogenetic volcanic fields in continental-collision zones worldwide.

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Identifying earthquake swarms at Mt. Ruapehu, a Machine Learning approach

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Mt. Ruapehu is an active andesitic stratovolcano, consisting of several peaks with the summit plateau at 2,797m, making it the largest active volcano in New Zealand. The extent of the volcano spreads 40km across with a series of complex faults encompassing almost the entire base of the volcano. In a period between 1994-1995, a series of earthquakes occurred 20km west the summit of Mt. Ruapehu near the small town of Erua. Five months later, the 1995/1996 major volcanic eruption sequence began [1]. Petrological studies of the erupted materials have suggested a magma mixing event which coincides temporally with the increased seismicity prior to the eruption [2]. The timing and depth of the earthquakes suggest a process of fresh magma being fed into the magma reservoir from a deeper source, creating a change in stress loading in the neighbouring rock and resulting in the observed earthquake swarm. It has been proposed that earthquake swarms at distal faults may be useful medium-term signals for eruptions at Mt Ruapehu [2],[3]. We use unsupervised machine learning clustering to answer the question of whether the Erua earthquake swarm could have been a reliable forecasting tool for the major magmatic eruption of Mt. Ruapehu in 1995. To do this, we statistically, and without bias or a priori knowledge, define anomalous earthquake swarms in the region and determine whether the Erua swarm was unique by identifying key characteristics in space, time, and magnitude distribution.

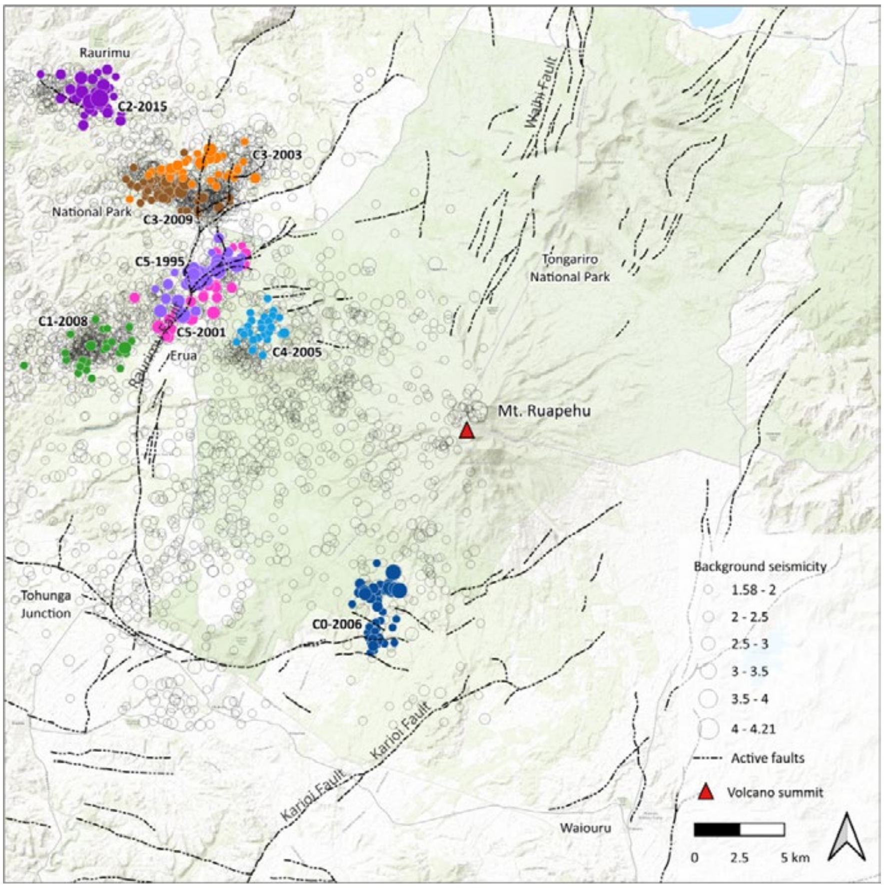

Figure 1. A map of Mt. Ruapehu with active fault lines [4] and earthquake data downloaded from the GNS earthquake catalogue [5] from 1995-2023, showing eight individual earthquake sequences detected in space and time, using HDBSCAN and DBSCAN.

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The Middle Hope Volcanics: Reconstructing the eruptive history of a Carboniferous marine volcanic sequence in modern-day Somerset, UK.

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Sand Point, Somerset, is home to a rare and well-preserved exposure of volcaniclastics from the Lower Carboniferous circa 350 Ma. This period of volcanic activity can be found – albeit in limited exposure – across SW England and S Wales, capped either side by the Black Rock Limestone and Dolomite series, when this region was sat submerged on a warmer marine continental shelf. However, very little scientific research has been conducted on one of the best exposures of this volcanic activity since the late 1980s. New permissions from the National Trust and Natural England have allowed us the first sampling in decades of this site. The best exposure is found at several beach outcrops, called the Middle Hope Volcanics, which comprise a sequence of: volcaniclastic ash tuffs, lapilli tuffs, very poorly sorted "flow-like" deposits, interlaying limestones, fossiliferous assemblages, bioturbated fine sediments, and coherent lavas with possible lava-sediment interactions. A combination of recent field observations, stratigraphic logging, and petrographic and microtextural analysis, permits new detailed analysis of this volcaniclastic eruptive sequence and its origins. We present possible evidence of several periods of local volcanic activity from a mafic volcanic center in a coastal- to very shallow-marine environment, with the modern deposits perhaps only within a km or few hundreds of meters of the original volcanic vent. Numerous lapilli with particle morphologies and vesicles (now amygdales) well-preserved in calcite cement reveal a variety of vesicularities and bubble number densities throughout an eruptive sequence. Our combined evidence implies mafic explosive eruptions with a combination of unsteady fallout and flow deposits with some post-volcanic reworking and remobilisation upon marine deposition. Subsequent geochemical analysis of these sequence may further elucidate the number of volcanic sources for these deposits.

Exposure of Carboniferous ash/lapilli tuffs underneath pebbles at Middle Hope Cove beach. Hammer is 30 cm long. Exposure shows normal grading of volcaniclastic deposits now bound by a calcite cement.

Upscaling host rock strength in Discrete Element Method models of viscous magma intrusion.

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Inflation of viscous magma intrusions in the shallowest 1-2 km of the Earth's crust often induces fracturing and compaction within the host rocks and dome-shaped ground deformation. Most models that simulate magma-induced deformation assume a homogeneous and isotropic medium wherein stress patterns indicate the potential for failure. However, magma intrusion takes place in heterogeneous host rocks which are already fractured and frequently layered. We use a two-dimensional Discrete Element Method (DEM) to model viscous magma emplacement in heterogeneous host rocks. In the DEM, the medium is discretised by an assemblage of circular rigid particles bonded by force contact laws. Bonds can break at any timestep, and thus fractures can propagate during the magma intrusion simulation. We investigate two different methods to transcribe host rock heterogeneity through the example of small-volume, Permian trachyandesite magma bodies intruded in the Permian sedimentary succession of the Intra-Sudetic Synclinorium, in SW Poland. First, we numerically simulate magma injection into an unfractured non-layered host rock, calibrated to the mechanical strength obtained from intact rock samples. Secondly, we simulate magma injection into host rock where the intact rock sample strength has been upscaled to a lower bulk crust strength by using the Geological Strength Index (GSI). Third, we test upscaling to the bulk crustal strength by introducing pre-existing cracks, i.e. pre-cracked bonds, into the model. We show that both methods for upscaling intact rock sample strength to the – lower – strength of the bulk crust impact the final magma-induced displacement, strain and fracture pattern. Whereas using the GSI results in a higher amount of magma-induced fracturing, the presence of pre-existing cracks concentrates magma-induced deformation in more narrow zones within the host rock while leading to higher amounts of surface displacement. Simulations of intrusion into a layered model which represents the basin-scale architecture of the Intra-Sudetic Synclinorium further demonstrate the effects of layering on the spatial distribution of the deformation. Our simulations indicate that the presence and nature of mechanical heterogeneities (fractures, layering) should be carefully considered when selecting a method of rock strength upscaling in DEM models of magma-induced deformation.

What do volcaniclastic sediments produced by submarine flows tell us about the largest volcanic eruption this century?

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On January 15th, 2022, the partially-submerged Hunga Volcano (HV), Kingdom of Tonga, erupted. The eruption, the most explosive volcanic event this century, generated atmospheric shockwaves, triggered tsunamis, and damaged seafloor telecommunication cables cutting communication across the Kingdom of Tonga. During the eruption, large volumes of erupted material entered the ocean generating exceptionally fast (>100 km/hr) volcaniclastic density currents that were topographically channeled down steep 45° chutes on the submarine flanks of HV and across the seafloor, modifying the seafloor topography and damaging the two subsea telecommunications cables that connect Tonga to the global Internet[1,2].

Explosive submarine eruptions are mostly poorly constrained, due to the sparsity of available observations and measurements. The HV deposits are unique in recording the most explosive volcanic event ever recorded with modern instrumentation and are fundamental for reconstructing the eruption and the volcanic processes that drove it, as well as providing insights into the nature of these exceptional submarine flows.

We present images and logs of sediment cores collected three months after the eruption that sampled the submarine volcaniclastic density current deposits, maps evidencing the pathways of the volcaniclastic density currents on the seafloor, and initial Scanning Electron Microscopic (SEM) characterisation of the deposit material. We identify the volcaniclastic density current deposits in all cores, extending more than 100 km away from the HV edifice, including at both sites of subsea cable damage. Minimal deposition is recorded on the slopes of HV. Proximally, several lobate deposits, < 40 m thick, are found ~5 km away from the HV edifice at breaks in seafloor slope downstream of gullies on the HV flanks. Extending away from HV the deposits thin, with the most distal deposits > 80 km from HV attaining decimetre thicknesses. The density current deposits comprise sand-to-granule sized volcanic material (predominantly scoria) that is overlain by a thin ashfall deposit, and in distal cores, record a sharp basal contact with pre-eruption hemipelagic sediments.

These preliminary findings provide new insights into the behaviour and nature of incredibly fast, long-runout, and destructive submarine volcanic currents generated during the 2022 HV eruption. Building upon these results we aim to further develop our understanding of current dynamics, constrain their context within the 2022 HV eruption, and their implications for submarine volcanic eruption models and hazard assessment. This new knowledge will aid future hazard assessment and the identification of volcanoes that pose similar hazards.

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Preliminary textural and petrological insights from recent eruptive products of Fuego and Pacaya volcanoes, Guatemala

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Magmatic water content influences the physical and chemical properties of silicate melts. Consequently, it is a key control on the timing and pressure of vapour saturation and the conditions under which magmas and co-existing fluids are stored in the crust. To investigate the relationship between primary water content ($H_2O_{(o)}$) in magmas and the partitioning behaviour of metallic trace elements, we have selected two contrasting yet closely-located volcanoes based on compiled literature $H_2O_{(o)}$ data from melt inclusions. Fuego and Pacaya volcanoes, Guatemala, are separated along the same segment of the Central American Volcanic Arc by only ~30 km. However, despite their proximity, these two volcanoes exhibit high and low maximum $H_2O_{(o)}$ relative to typical arc values, respectively.

Preliminary work characterising the texture and geochemistry of bombs erupted during Strombolian activity at Pacaya in February and November 2017 (n=12) shows consistent phase volumetric proportions between the eruptive periods, with aggregated means of 39.4% plagioclase, 3.6% olivine, 0.9% augite, 0.3% titanomagnetite, and 54.8% glassy groundmass. Phenocrysts exhibit normal (olivine and plagioclase) and oscillatory (plagioclase only) zoning over a range of crystal sizes; reverse zoning is less common. EPMA data estimate that plagioclase and olivine compositions span An_{49-90} and Fo_{65-69} (mol%).

Future laboratory work will involve preparing glass (melt inclusions and matrix) from both volcanoes for Raman spectroscopy, SIMS, EPMA and LA-ICP-MS, to constrain volatile and trace element evolution throughout the crystallisation interval. Trace element systematics in erupted tephra will be compared with aerosol compositions in the outgassed plume to determine element volatilities, and linked via petrological and thermodynamic modelling to track partitioning behaviour during magma storage and ascent.

Volcanic dome collapse: exploring post-emplacement stability as a function of hydrothermal alteration

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Volcanic domes are inherently unstable structures as they grow incrementally, with varied extrusion rates, material properties, and directions of flow. These instabilities can bring about volcanic dome collapse, leading to turbulent and hot avalanches of material that can devastate communities surrounding a volcano, as well as affecting the volcano's eruptive dynamics.

The objective of this research is to investigate the effect of hydrothermal alteration on dome stability, where hydrothermal alteration typically results in mechanical weakening of volcanic rock. The internal structure of the La Soufriere de Guadeloupe dome was mapped by Heap et al. (2021), whereby electrical conductivity surveys were carried out to obtain the rock porosity and therefore the density variation within the dome. The density contrasts were correlated with mechanical parameters (i.e., uniaxial compressive strength of volcanic rock) to obtain a 3D internal strength map of the volcano. We designed a novel methodology to input this geophysical data into a new 3D Particle Flow Code (PFC) model. This involves creating a digital elevation model from satellite data and interpolating the geophysical data to assign strengths to each PFC particle.

We show here the results of alteration scenario testing. This involves weakening/strengthening rock properties in an alteration zone, changing its location (i.e., a lateral/ central zone, or on a steep flank), and changing its size by varying the proportion of altered material. This allows us to make predictions on potential for collapse and direction of material flow, quantify collapse volumes, and test from small-scale to large-scale failures. To date, no 3D dynamic models of stability exist and therefore these models are key to forecasting volcanic hazards as a result of hydrothermal alteration.

Once Upon A Time In The West: Communicating volcanic disaster through participatory arts-based methods

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Disasters disproportionately affect vulnerable people, whose experiences of the disaster are often unrecorded. Disaster research increasingly recognizes the importance of these missing voices and promotes methods that broadcasts those experiences. Arts-based methods can communicate crisis research democratically as people affected by disaster shape how their story is told (Sou & Hall, 2023). Communicating crisis using these methods requires a trusting relationship between disaster-affected people and researcher. However, building this relationship requires significant investment of time and presence in the disaster-affected communities, resources which are often scarce in academia. This study presents my process in making a zine that tells a collective story of disaster from people who experienced a series of eruptions of Fuego volcano (Guatemala) in the 20th century. These eruptions devastated communities on Fuego's SW flanks as large volumes of tephra destroyed agricultural crops and collapsed houses; however, these impacts have been mostly unreported. This zine reflects a relationship I have built with the people of Fuego since 2017, through my PhD and postdoc. My priority in creating it was to create a research product that ethically and respectfully represents the experiences of people who lived through volcanic disaster. This study builds on research that promotes arts-based methods as a democratic process that makes research accessible to both participants and the public. The zine also shows how to communicate disaster research through the voices of people who experienced it, rather than methods in mainstream media or academia that may homogenize disaster-affected people (Sou & Douglas, 2019). Finally, the zine also illustrates the deep relationship that can build between a researcher and research participants in a case study; a relationship that has value to both but is rarely articulated. This study encourages other researchers who work persistently in a research area to consider communicating their research in a similar way.

Figure 1: a participatory exercise in the village of Panimaché Dos, on Fuego's SW flanks, to share experiences and memories of Fuego's past eruptions through images and text (Credit: Ailsa Naismith)

Vesuvius: the Model Volcano.

David M. Pyle[1]

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In the 18th and 19th centuries, Vesuvius was the most active volcano in Europe. It was accessible to day-trippers, travellers and natural historians and being ‘not so small as to be contemptible not so great as to be unapproachable’, it features prominently in written and visual records of visitors from across Europe.
By the late-18th century, Vesuvius was a model for the concepts of the sublime; and so widely cited, that it was regarded by some as a ‘tired metaphor’. In the early 19th century, Vesuvius became a laboratory for natural scientists; and a physical observatory. In parallel, visual representations of Vesuvius in eruption found a ready market among tourists, with grandiose gouache representations of fire and smoke by day and night; and as an agent of catastrophe in popular novels.

But to what extent did this exposure help to shape European audiences’ views of volcanoes, around an imagined ideal? And to what extent are the visual and textual records of Vesuvius faithful to what was happening at the volcano, or curated for particular audiences? Using letters, diaries, paintings and sketches, we explore depictions of phenomena at Vesuvius in the 18th and 19th centuries. Some common themes are influenced by the social and cultural setting: whether through deference to authoritative voices, or to meet the expectations of the recipient. In contrast, records of some phenomena that were intimately linked to Vesuvius’ physical state contributed to the emerging narrative ‘natural history’ of the volcano, and the search to understand their causes.

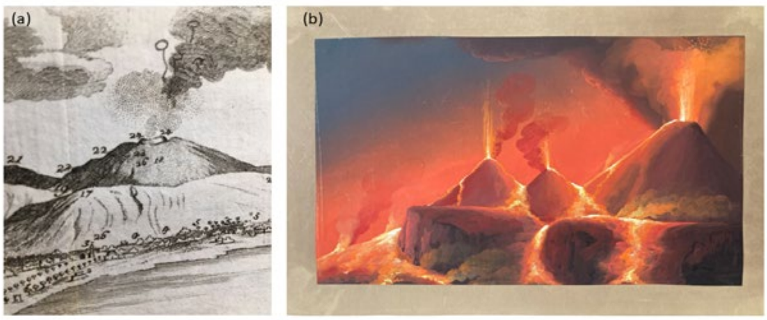

Figure – (a) ‘Smoke rings’ or vortex rings depicted from a 1733 eruption of Vesuvius by Della Torre (1768, Storia e fenomeni del Vesuvio. Bodleian Libraries GG 33 Art. (b) Unattributed and undated 19th century painting of an eruption from the Gran Cono of Vesuvius. Gouache on paper, ‘Neapolitan school’. Ashmolean Museum, Western Art Print Room.

Post-eruptive mobility of lithium in plagioclase

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Over the past decades lithium (Li) has become an important raw material and receives increasing attention as a potential tracer of metamorphic, hydrothermal and magmatic processes. Despite increasing numbers of studies focused on magmatic processes, there is only limited knowledge on the post-eruptive mobility of Li in volcanic rocks. A pioneering study showed that Li concentrations and isotopic compositions in minerals of welded ignimbrites from the Yellowstone–Snake River Plain magmatic province (USA) can be severely modified by post-eruptive processes. The phenocrysts from slowly cooled microcrystalline ignimbrite interiors have been shown to carry significantly more Li than their rapidly quenched, glassy, counterparts[1].

Here we present data of Li concentrations and isotopic composition of plagioclase crystals, glass and bulk rock samples from three rhyolitic lavas, namely Sheep Creek, Shoshone Falls and Dorsey Creek, from the Yellowstone–Snake River Plain magmatic province. Samples were taken from the top vitrophyres and from the interior of the lava flows (in 3- to 5-meter steps). All minerals and groundmass glass were analysed for major (EPMA) and trace element contents (LA-ICP-MS); Li concentrations and isotope compositions of mineral phases and glass separates were obtained using solution ICP-MS and MC-ICP-MS, respectively. The Li concentrations in plagioclase crystals from the vitrophyres are lower compared to the plagioclase crystals from the devitrified part. Plagioclase crystals from the vitrophyres show a decrease in Li concentration towards the crystals rims whereas crystals from the interior of the flow either display an increase of Li concentration towards the rims (samples taken closer to vitrophyres) or are homogeneous in concentration (samples taken further away from vitrophyres). Plagioclase crystals from the interior of the lavas are isotopically lighter (2.6±0.3‰) compared to crystals from the vitrophyres (3.2±0.1‰); similar behaviour can be observed for the bulk samples (8.3±0.2‰ vs. 13.8±0.2‰, respectively). These differences in Li content and isotopic composition are most likely related to the degassing of the lava flow.

We show that Li remains mobile in lavas long after eruption and passes into phenocrysts via diffusion as groundmass crystallisation increases the Li concentration in the remaining melts. Lithium isotopic measurements reveal that degassing of the lavas affects the Li content and isotopic compositions of the phenocrysts and the bulk rock. Further, it highlights that Li is concentrated in the phenocrysts rather than in the metastable glass, which has implications on the formation of Li deposits.

Ref.: 1. Ellis et al. 2018, Nat. Commun. 9, 3228.

Constraining ascent velocities of diamond bearing kimberlite magmas using diffusion chronometry

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Kimberlites are enigmatic igneous rocks which can transport diamonds to Earth's surface. Their magma is sourced from depths of >150km and ascends rapidly due to its high volatile content. Despite their scientific and economic importance, many aspects of kimberlite formation, ascent and eruption remain unknown. The aim of this PhD project is to constrain ascent velocities of kimberlite magmas using diffusion chronometry, as estimates in literature currently vary between 0.02-30 m/s, and many of these values are based on indirect methods such as melt fluid dynamics or textural evidence. Providing improved constrains on kimberlite ascent velocities will allow us to better understand how diamonds are delivered to Earth's surface, whilst giving us further insight into mantle dynamics.

This project analyses lavas from the Igwisi Hills Volcanoes (IHV), Tanzania. Being the youngest known kimberlites in the world (~12.6 ka), these lavas are exceptionally fresh. Automated mineralogy and scanning electron microscopy (SEM) imaging has revealed complex zoning in olivine crystals from the IHV lavas. Geochemical transects for forsterite (Fo, = Mg/[Mg + Fe]*100) acquired using electron probe micro analysis (EPMA) illustrate that most crystals feature a 1) xenocrystic core, 2) internal zone formed due to metasomatism or interaction between the xenocrystic core and a proto-kimberlite melt, 3) magmatic rim, 4) magmatic rind and 5) magmatic outermost rind. Strong sigmoidal diffusion profiles are seen on transects taken between cores and internal zones, and internal zones and rims. Preliminary transects of Li using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) also reveal multiple zones, and diffusion profiles.

Electron back scatter diffraction (EBSD) analysis will be carried out to determine the crystallographic orientation of transects. Secondary Ion Mass Spectrometer (SIMS) analysis will also be conducted to gather further profiles for Li, taking advantage of both the low spatial resolution and detection limit of the instrument. Diffusion of Fe-Mg (expressed as Fo), and Li in olivines from the IVH lavas will then be modelled, using recently released, sophisticated programs such as that of Mutch *et al.,* 2021 and Wu *et al*., 2022.

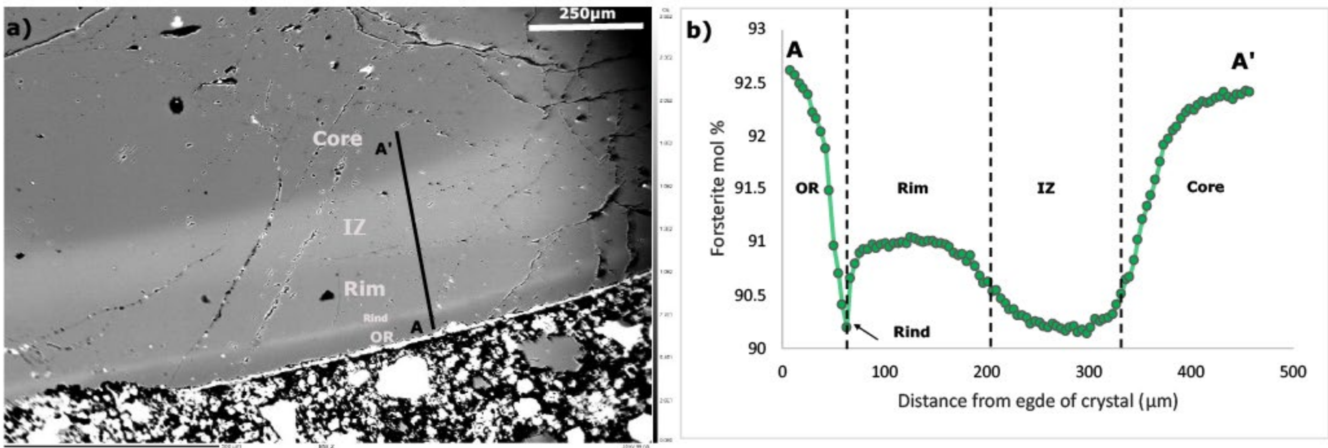

Figure 1. a) BSE image with location of profile on IHV olivine crystal. b) Fo profile. IZ = internal zone. OR = out-most rind.

A novel model of volcanic plume evolution from high-temperature chemistry to reactive halogen processing in the atmosphere

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The first seconds of the interaction of volcanic gases with the atmosphere have so far often been drastically simplified, e.g., by assuming thermochemical equilibrium. In this period, hot and reduced magmatic gases mix with ambient air and undergo rapid cooling. The in-mixture of atmospheric oxygen triggers fast oxidation processes which depend on the dynamic interplay of chemical kinetics, mixing and cooling.

We investigate these processes with a chemical box model accounting for chemical kinetics alongside cooling and mixing of the plume. We focus on the evolution of halogen radicals, which significantly influence atmospheric chemistry on a regional scale. Furthermore, we build a connection to an atmospheric chemical model to investigate the influence of the high-temperature initializations on ambient-temperature plume chemistry to capture for example the catalytic destruction of ozone by bromine chemistry in the cooled volcanic plume.

The model is based on a chemical mechanism from combustion chemistry and has added sub-mechanisms for halogens, reactive nitrogen and mercury. In addition, it is fast and flexible to test many different emission temperatures, mixing scenarios and gas compositions.

This modeling study aims to investigate the chemical conversions, which occur during the first seconds, minutes to hours of plume evolution and thereby contributes to the understanding of the impacts of halogens on the atmosphere and supports the interpretation of remote sensing data of the cooled and diluted plume. In the future, the model can be utilized to study other plume phenomena such as aerosol formation by SO_2-sulfate transformation, mercury and NO_x-nitrate chemistry.

New gas analyser for high frequency, simultaneous measurements of volcanic gas species.

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Volcanic degassing transports volatiles from Earth's interior to the atmosphere and plays a critical role in global geochemical cycles, and can impact local, regional and global climate. Volatile species drive volcanic eruptions, play a key role in controlling magma ascent processes and play a key role in controlling the style of eruptive activity. For these reasons, monitoring and quantification of magmatic gas emission fluxes and composition is a key part of volcanological research.

Remote sensing of volcanic plumes was initially developed in the 1970s using correlation spectrometers (COSPEC) to measure SO_2. Since then the development of miniaturised UV-spectrometers has greatly reduced the instruments size and weight and now many volcanoes are monitored with scanning ultraviolet spectrometers to measure SO_2 flux. Open path Fourier transform infrared spectroscopy allows quantification of many magmatic gas species in volcanic plumes, including CO_2, H_2O, SO_2, HCl and HF, but is expensive, heavy and requires careful positioning of the plume and radiation source. Multi-Gas instruments provide in-situ measurements of some species, typically S and CO2, however, their combination of both electrochemical and optical sensors can pose challenges due to the different frequency responses of the sensors, and sensitivity to pressure and temperature changes, resulting in calibration issues. Thus, there is a need for improved gas sensing technology.

We developed a new gas analyser for high frequency, simultaneous measurements of volcanic gas species in order to address some of the limitations outlined above. The analyser comprises multiple instruments, but all use an open-path multipass cell measuring ambient air with no pumping, and use optical absorptions to quantify gas amounts at a frequency of 1-4 Hz. The first instrument uses two near infrared tunable diode laser systems to measure CO2 and HF, the second uses a mid-infrared laser to measure HCl and H2O, while a UV-LED provides a radiation source for an SO2 instrument, using a UV spectrometer. The system is called an optical multi-gas, OMG.

The OMG was deployed on the 18th of May 2017 where it made 6 passes through a plume at Soufriere Hills Volcano (SHV), Montserrat, on board a helicopter. The analyser successfully captured the plume abundances for CO_2, SO_2 and HCl during traverse through the plume. Here we report on the results from these measurements and examine processes controlling degassing at SHV.

Estimating volcanic ash plume heights using buoyancy waves

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The explosive phase of the 2021 eruption of La Soufrière on the island of St Vincent consisted of a series of eruptive events occurring over 14 days. Ash clouds from these explosions were observed with the Advanced Baseline Imager (ABI) onboard the Geostationary Operational Environmental Satellite 16 (GOES 16). A commonly used method for obtaining the height of volcanic ash is to compare the brightness temperature measured in the 11.2 μm channel with a temperature profile. However, this can often result in two possible solutions: one in the troposphere and one in the stratosphere. For part of the eruption, the instrument provided mesoscale scans over the volcano, providing data every minute. This high temporal resolution allowed the tracking of the explosion plumes and the observation of buoyancy waves in the umbrella region. These buoyancy waves oscillate at a frequency which depends on the ambient conditions.

A novel method for estimating plume height was developed that mapped the oscillation frequency to an altitude using the temperature and pressure profiles from ECMWF ERA5 data. This method was applied to a range of events from the 2021 La Soufrière eruption and the results closely matched estimates obtained through other methods. All clouds reached heights of 16-19 km, placing them at or slightly above the tropopause. The novel method presented here has the advantage of providing a single solution for clouds near the tropopause. Moreover, it is not limited to daylight observations as direct imaging is. Combining the results with start times determined from seismic data, allowed for the estimation of ascent rates.

The insights gained from this analysis contribute to our understanding of volcanic eruption dynamics and hazard management and demonstrate the usefulness of high-frequency satellite data.

What can zircon tell us about volcanic processes?

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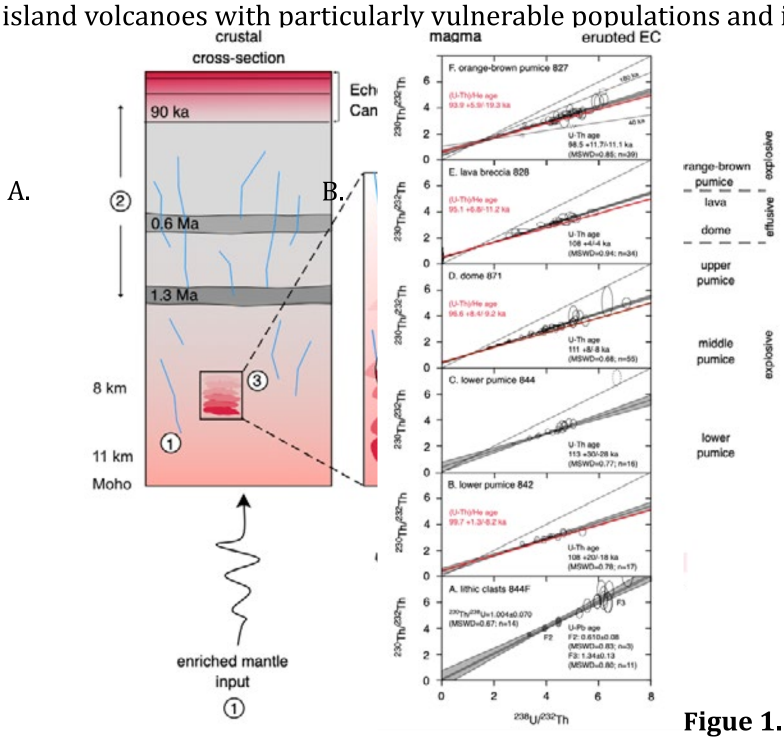
Novel combination of zircon trace element and O isotope compositional data with double-dating (disequilibrium ^{238}U–^{230}Th and (U–Th)/He) can decipher the timescales and dynamics of magmatic processes. The Echo Canyon (EC) sequence, Ascension Island, South Atlantic, comprises small-volume explosive-effusive eruptions of trachyte that tapped a compositionally zoned magma system. Zircon U–Th–Pb dating of lithic lava clasts has revealed recurrent evolved volcanism at 1.34 and 0.6 Ma, and 95 ka that had previously gone undetected. The (U–Th)/He zircon cooling ages indicate that most of the EC explosive-effusive sequence erupted in a brief episode at ca. 95 ka. Additionally, uniform ^{238}U–^{230}Th zircon crystallisation ages suggest moderately protracted magma storage with melt present at depth for at most 10^3–10^4 years before eruption. The enriched character of zircon trace element compositions without a continental crustal signature in the oxygen isotope values ($\delta^{18}O$ range 2.67–5.63‰), suggests an enriched component in the EC magma source. Furthermore, low $\delta^{18}O$ zircon compositions imply assimilation of high temperature hydrothermally altered country rock by the source magma. Significantly, zircon crystals were preserved both as macrocryst inclusions and in the groundmass of EC explosive and effusive deposits. Magma evolution by fractional crystallisation led to pre-eruptive compositional stratification with progressively deeper tapping of less evolved magma from discrete lenses recorded in whole-rock compositions and zircon Zr/Hf values. This information is relevant for assessing hazards and informing monitoring and forecasting efforts to assist in managing associated risks for small ocean island volcanoes with particularly vulnerable populations and infrastructure.



Figue 1.

A. Zircon U/Th crystallisation (grey lines) and (U-Th)/He eruption ages (red lines), ZDD, of explosive—effusive eruption deposits from Ascension Island. B. Insights into timing and processes in the magma system: mantle input, melt evolution and position of previous eruptive products relative to the main sequence.

The Story So Far: Impacts and prospective hazard analysis of rainfall-triggered lahars on St. Vincent 2021-2022

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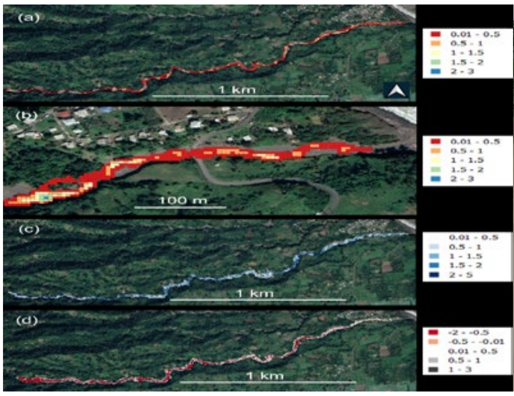
Lahars are energetic flows of loosely consolidated volcanic debris and water, which have occurred frequently after rainfall events on St Vincent in the Eastern Caribbean since the April 2021 explosive phase of the 2020-21 eruption of La Soufriere volcano. Using scientific observations and information from social media, we have constructed a detailed timeline of the 25 lahar events that occurred during 2021, and summarised lahar impacts and losses. 20 mm daily rainfall on a river catchment is (and remains) sufficient to result in a lahar. We used this threshold, with field estimates of lahar volumes, to conduct both an island-wide assessment of potentially impacted locations using the LAHARZ model, and a detailed reconstruction of one lahar event, using the dynamic model LaharFlow. A simplified catchment hydrology approach with runoff ratios typical for the Caribbean showed good agreement with observations of flow properties near the coast.

Lahars will continue to be an important hazard in St Vincent into the future, and our modelling approach can assess future lahar impacts and provide early warnings. Social media provided key information about lahars and impacts, and allowed communities to alert each other. Future hazard mitigation should strengthen links between communities and with national risk management.



Left - A lahar at the Overland river crossing, October 2022 (shared on the Changing Landscapes WhatsApp group); Right – LaharFlow model simulations of lahars at the Overland crossing: (b) flow depth (m), (c) flow speed (m/s)

Towards volcanic jet noise theory

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Sustained explosive volcanic eruptions produce vast quantities of acoustic energy, generally referred to as jet noise. Jet noise can be easily recorded in the field using cheap microphones. The resulting frequency spectra will depend on multiple parameters related to the eruption dynamics (e.g. gas and magma exit velocity, mass eruption rate), magma properties (e.g. particle size and density), crater topography, and observer's location (e.g. distance and angle to the vent). Being able to extract information on the eruption parameters from jet noise would be extremely useful for eruption crisis management. For instance, mass eruption rate is one of the key, yet most poorly constrained, parameters used in ash dispersal models. However, current classical jet noise theory is limited to pure-air jets and hinders any application to volcanic jets, which contain significant quantities of ash. In the project presented here, we will build an experimental apparatus to investigate ash-laden jet noise in a laboratory setting, and to characterize the influence of some of the main eruption parameters on the resulting frequency spectrum. The apparatus will resemble a sandblasting device and will allow the experimentalist to control the jet speed and mass eruption rate. We introduce the prototype design of the apparatus, as well as the different analysis techniques that will be employed and the current limitations and challenges. We also demonstrate how the laboratory-derived results may then be applied to natural scenarios. Ash-laden jet noise theory is still in its infancy, and we welcome all interested to participate in this novel project.

Distinct but linked magma storage zones fed the 1975-1984 Krafla Fires eruptions

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The 1975-1984 Krafla Fires event in northeast Iceland was the first plate-boundary rifting episode to be tracked using seismic and geodetic monitoring. Geophysical observations from this episode have driven the development of conceptual models of magma transport during plate spreading. For instance, the lateral flow model of melt supply from shallow magma chambers to fissure eruptions was inspired in part by these observations. Complementary petrological data could provide an important test of these models, but has not been available to date. In order to address this knowledge gap, we studied the petrology and geochemistry of all nine Krafla Fires basaltic eruptions. Our large dataset of new whole-rock, matrix glass and mineral analyses from samples collected during or shortly after each eruption reveal a clear compositional bimodality that persisted across the episode, with evolved quartz tholeiite (MgO = 5.7–6.4 wt.%) erupted inside Krafla caldera, and more primitive olivine tholeiite (MgO = 6.4–8.7 wt%,) erupted north of the caldera margin. Barometric calculations indicate tapping of these magmas from distinct reservoirs: a primitive lower-crustal reservoir at a most probable depth of ~14 – 19 km, and a more evolved, shallower reservoir at a most probable depth of ~7-9 km beneath the caldera. These reservoirs were often tapped simultaneously, at times without any mixing of the two magmas. Diffusion modelling indicates that primitive magma erupted in 1984, in the final and largest eruption, rose from lower-crustal depths over timescales of a few months at most – well within the duration of the decade-long rifting event. These observations are not consistent with the widely-held view that the eruptions were entirely fed by lateral magma outflow from the shallow reservoir. They instead require some decoupling of the flow paths of the two magma types: the primitive magma either bypassed the sub-caldera reservoir laterally, or ascended vertically from beneath the northern vents. Gradual inflation of the caldera between rifting events may indicate continuous flow of deep-sourced melt into the shallow storage zone. Comparison of the Krafla Fires with other rifting events and eruptions highlights key differences between events and sets out the requirements for any generalized models of rift-zone magmatism. Integration of petrologic, geochemical and geophysical data is required to provide a holistic view of future rifting events in Iceland and at other spreading centres.

Long-term fumarole temperature monitoring with aerial and groundbased techniques.

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Fumaroles are a crucial source of information on the state of a volcanic system before, during and after periods of activity. A variety of techniques have been applied at many volcanoes around the world to monitor fumarole chemistry and temperatures for the purposes of understanding hydrothermal systems, identifying trends that might be precursory to eruptive activity.

The Soufriere Hills volcano, located on Montserrat in the NE Caribbean, has experienced a series of eruptive phases characterized by the growth and collapse of a series of large lava domes. Since the end of the last phase of eruptive activity in February 2010, fumarole activity has been one of the main visual indicators of a system still in unrest. Since 2013, the Montserrat Volcano Observatory has used thermal imagery acquired with a handheld FLIR camera during helicopter flights to monitor the temperature of fumaroles on the large lava dome. More recently, this has been supplemented by in-situ monitoring of a few low-temperature fumaroles in accessible areas located away from the lava dome.

The data collected via thermal imagery, which has been collected on average 2-3 times a month depending on cloud conditions over the volcano, has yielded some insight into the state of the volcanic system through the interpretation of long-term trends. Temperatures were initially as high as 580 °C and decreased steadily for several years, but then, depending on the location of the fumaroles being monitored, some localized difference in trends was observed. Currently temperatures are still in the range 250-400 °C, more than 14 years since the end of the last effusive phase of activity. The in-situ temperature record is shorter and data collected at a much higher rate of every ten minutes. One of the main outcomes of this is the identification of short-term (hours to days) impacts of rain on some of the low temperature fumaroles.

Using both aerial- and ground-based monitoring techniques has enabled the MVO to identify both long- and short-term trends in temperature caused by different processes.

Spontaneous unsteadiness and resulting particle size mixing in PDCs and their deposits.

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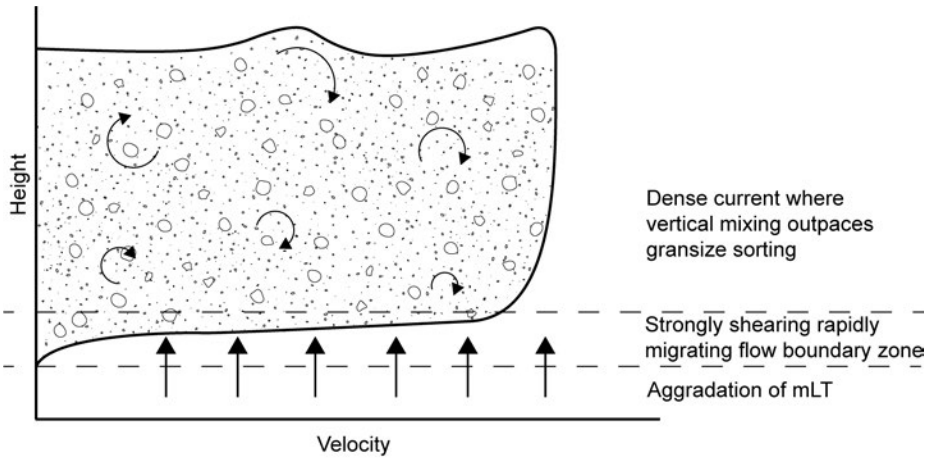
Pyroclastic density currents (PDCs) pose substantial risk to populations living on and around active volcanoes, but their structure and internal dynamics are poorly understood. Much of this understanding is derived from interpretation of their widespread deposits. Scaled experiments are able to probe different conditions, to explore how changing flow dynamics relate to the wide variety of depositional styles observed in nature. Here we present two suites of work, first exploring the generation of spontaneous unsteadiness, and how it can impact the partitioning of sediment between dense granular under-currents, and over-riding dilute particle clouds. Second, we introduce grainsize variation to the dense granular regime and explore the formation of grading patterns. We demonstrate that unsteadiness in flow can be important in capturing different grading structures in deposits, and that granular sorting mechanisms are highly effective in thin fluidized grainflow. We conclude that this may raise challenges for the interpretation of common poorly sorted lithofacies (massive lapilli tuff) in natural deposits, as it must require substantial vertical mixing within these grainflows.



Model of mLT aggradation where rapid migration of the flow boundary zone suppresses shear-driven sorting processes, and vertical mixing in the bulk of the current counterbalances kinetic sieving.

Measurements of sulfur dioxide (SO_2) emissions from volcanoes with the Infrared Atmospheric Sounding Interferometer (IASI) for 2007 to 2021.

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Satellite data offers numerous advantages for studying volcanic clouds of ash and sulfur dioxide (SO_2) including that they can be used to detect emissions from across the globe and track emissions as they are transported away from the source. The Infrared Atmospheric Sounding Interferometer (IASI) onboard the MetOp satellites has sensitivity to both SO_2 and ash. This sensitivity can be used to detect and quantify information about the clouds, providing information that is critical for aviation safety and for investigating the impacts of volcanic eruptions on the environment and climate.

The Earth Observation Data Group (EODG) at the University of Oxford has multiple methods for studying SO_2 emissions from volcanoes. The first of these is a linear retrieval which is able to quickly identify pixels which contain SO_2. The speed of this tool means that it can be applied in Near Real-Time, and these results are displayed on a data portal managed by the Centre for Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET) (https://comet.nerc.ac.uk/iasi/COMET_IASI_portal.html). The second technique, an iterative retrieval, is applied to SO_2 flagged pixels to quantify information about the plume including the SO_2 column amount and height of the gas, and the associated errors. These retrievals have been used to study the plumes from multiple eruptions, with recent examples including Raikoke, La Soufrière (St Vincent) and Hunga Tonga–Hunga Haʻapai in 2019, 2021 and 2022 respectively.

The first IASI instrument was launched in 2006 with data first becoming available in mid-2007, and additional instruments were launched in 2012 and 2018. The Oxford SO_2 retrievals have been applied to generate a comprehensive dataset on SO_2 for 2007-2021. The results from the dataset consist of several large eruptions (the largest SO_2 emission in the time period being from Nabro in 2011) and also includes emissions from smaller eruptions and persistent degassing. Additionally, a number of anthropogenic sources are identified. The IASI instrument will continue for a number of years and is set to be joined by the next generation of IASI instruments (IASI-NG) and a similar instrument on a geostationary platform, promising exciting opportunities for studying volcanic plumes in the future.

Estimation of Volatile Degassing during Deccan Traps Eruption

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Deccan Traps is one of the largest and best-preserved continental flood basalt provinces in the world. It hosts extensive lava flows which erupted within a million years approximately 66 million years ago. Owing to the temporal association, previous researchers have proposed a link between the Deccan eruption and the Cretaceous-Tertiary mass extinction. The volatile concentration and degassing efficiency of the Deccan basaltic lava pulses will provide direct evidence for the causative relationship between Deccan eruption and end Cretaceous mass extinction.

This study primarily aims to estimate the volatile budget associated with the Deccan Traps lava flows. It is done by investigating the mineralogical, petrological, and textural characteristics of the two basaltic lava flows of the younger Wai Subgroup of Deccan Traps from the Koyna-Warna region in Maharashtra, India. Melt inclusions preserved in the phenocryst phases of plagioclase, olivine, and clinopyroxene will be analysed to get a quantitative estimate of the primary volatile content in the magma reservoir. The trace element proxy for volatile content in the magma method will also be used to get an empirical estimate and verification of the volatile concentration of the lava flows. The minimum volatile concentration in the Deccan basaltic magma reservoirs can then be estimated.

Further, to estimate the efficiency of volatile degassing from the Deccan basaltic lava flows, the vesicle content, network and interconnectivity in the basaltic flows will be studied using 3D X-ray Computed Microtomography. By integrating the quantification of the volatile concentration from melt inclusions and the degassing efficiency from the three-dimensional textural analysis of the vesicles, we intend to generate a model of the volatile degassing from the Deccan Traps around the Cretaceous-Tertiary boundary 66 million years ago. i)

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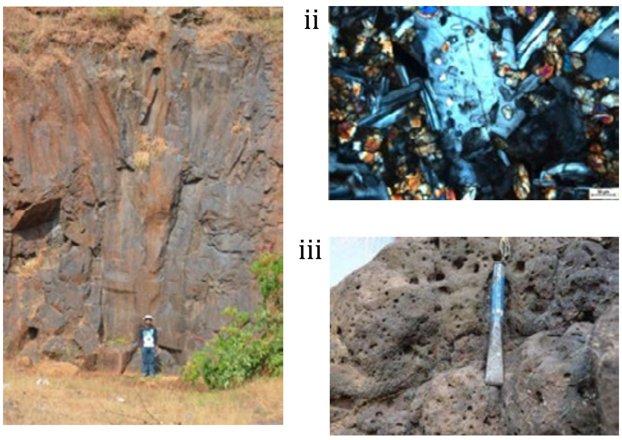

Figure 1- i) Columnar jointing in the lava flow core; ii) Photomicrograph of the plagioclase phenocryst hosting melt inclusions; iii) Vesicular basalt flow top. All pictures are of the Wai subgroup Deccan basalt.

Low fO_2 magmatic gases released during lunar mare eruptions.

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The lunar mare are basaltic lava flows which erupted from 4.0–1.2 Ga. Some researchers propose that volatiles degassed during these eruptions fed a collisional secondary lunar atmosphere [1], though this is debated [2]. The composition and speciation of the emitted volatiles would govern the formation, lifespan, and dissipation of the atmosphere [3], as well as influencing the eruption dynamics.

On Earth, the three most abundant species in a hot volcanic gas are, in order, H_2O, CO_2 and SO_2. However, *Apollo* samples suggest the Moon is more reduced than Earth, with the lunar mantle between 0–2 log units below the iron-wüstite (IW to IW-2) buffer [4] compared to IW+1.5 to IW+5.5 for Earth. Due to the more reduced magma, researchers have variously posited H_2, H_2O, CO, or CO_2 as the chief constituent of lunar magmatic gas. We examine lunar sample data to determine the concentration of C-O-H-S-F-Cl elements degassed, then use thermodynamical modelling to assign speciation.

The most reliable estimates derive from *Apollo 17* orange glass beads, which contain olivine-hosted melt inclusions [5,6]. Comparing volatile contents of inclusions to groundmass compositions, we observe that H was the most abundant element in the lunar volcanic gas, followed by O. Using thermodynamical software, we model the equilibrium species expected at fragmentation during lunar eruptions (Figure). Above about IW-1, H predominantly forms H_2O, while below IW-1, it forms more H_2. These two molecular species have very different behaviours in a proposed lunar atmosphere. Specifically, H_2 is easily lost to space. In contrast, H_2O may deposit from a temporary atmosphere, and could potentially persist in permanently shadowed regions.

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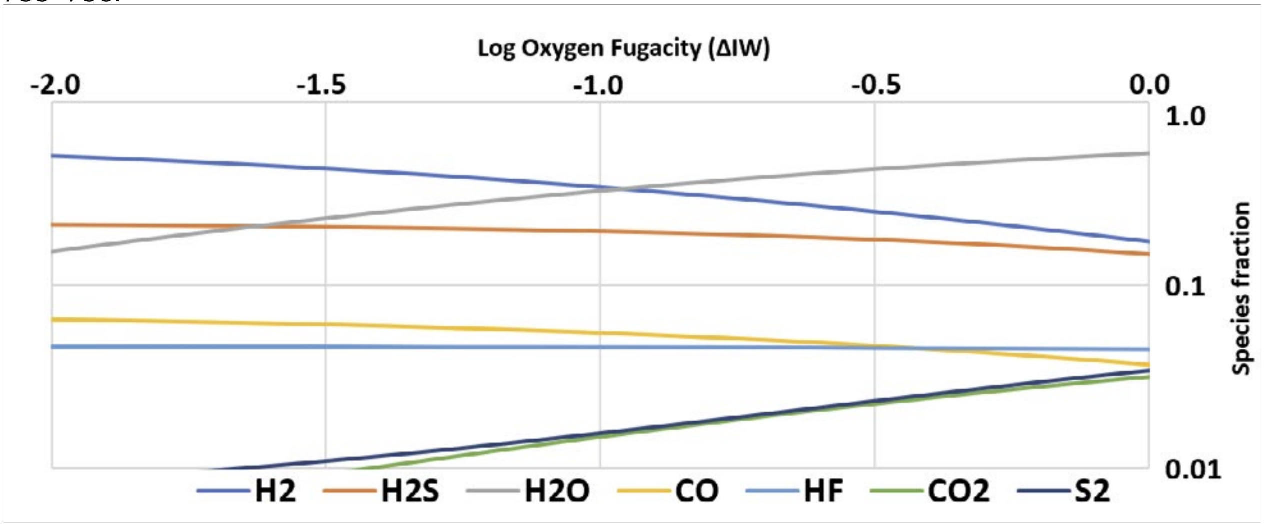

Figure. Thermo-Calc results showing the changing equilibrium species with oxygen fugacity for volatiles degassed by the *Apollo 17* orange glass beads for 1MPa and 1450 °C.

Post-eruption lava dome development in the crater of Mount Saint Helens, Washington (USA)

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Although the 2004-2008 lava dome growth at Mount Saint Helens was studied in detail, the post-eruption time has received little attention to date and no studies of long-term morphological changes and thermal evolution exist. Although constantly monitored, a comprehensive and overall picture of dome development following the end of the last eruption cycle is missing. We combine data from recent field campaigns including surveys of glaciovolcanic cave systems, measurements of fumarole temperatures, and drone flights, complemented by geochemical data. In addition, we make use of remote sensing data such as ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) images and LiDAR (Light Detection and Ranging) data.
The results presented in this work are useful to understand how lava domes can change years after an eruption ended. This might be relevant for hazard assessments as domes are often affected by hydrothermal alteration which reduces permeability and hinders outgassing. Our observations furthermore document the development of Mount Saint Helens in specific, the most active volcano in the Cascade Volcanic Arc, and illustrate the unique interplay of the lava dome with the growing glacier. Mount Saint Helens is particularly suitable to investigate the long-term development of a lava dome. Apart from being accessible, the numerous studies of lava dome growth between 2004 and 2008 resulted in a large number of diverse datasets, allowing for direct comparisons between the eruptive phase and the post-eruption time.

2004-2008 lava dome in the crater of Mount Saint Helens in July 2022. Photo: Linda Sobolewski.

Chemical characterization of Carboniferous age Irish volcanics.

Daniela C. Vitarelli[1], Emma L. Tomlinson[1]

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High levels of magmatic activity occurred throughout the Carboniferous period in northern England, Scotland, and Ireland (e.g., Timmerman, 2004). Many of these volcanic centres are spatially related to the Iapetus Suture zone.

We report micro-bulk rock major and trace element data collected via LA-ICP-MS for volcaniclastic diatreme samples from Cork (North Cork, Ballygiblin Quarry and Castle Clare areas), Limerick (Stonepark and Ballywire areas; access to samples provided for by Group Eleven), and Offaly (Croghan Hill). Samples show variable degrees of alteration, seen as high Ca, high Fe, and/or high Ti and so are classified using trace element discriminators. In Limerick, diatreme compositions range from alkali basalts to basanites and are similar to the Carboniferous aged Knockroe and Knockseefin lava flows in the area, with which they are spatially associated. Volcaniclastics erupted in Limerick are broadly lapilli tuffs and pyroclastic breccias composed of rounded vesicular clasts in a fine, ashy matrix. They are lithic-rich with abundant carbonate clasts as well as secondary alteration and the addition of sulphides and Ti-rich minerals. At Croghan Hill, volcaniclastic tuffs and agglomerates are associated with alkali basaltic lavas.

This research aims to characterise Carboniferous age volcanics within Ireland and examine their temporal and geochemical relationship to better studied volcanics in Scotland (e.g., Upton et al., 2007; Upton et al., 2020), as well as examine regional implications of their emplacement in relation to regional extension in the Laurentian continent.

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Imaging and visualising mesoscale 3D mush textures.

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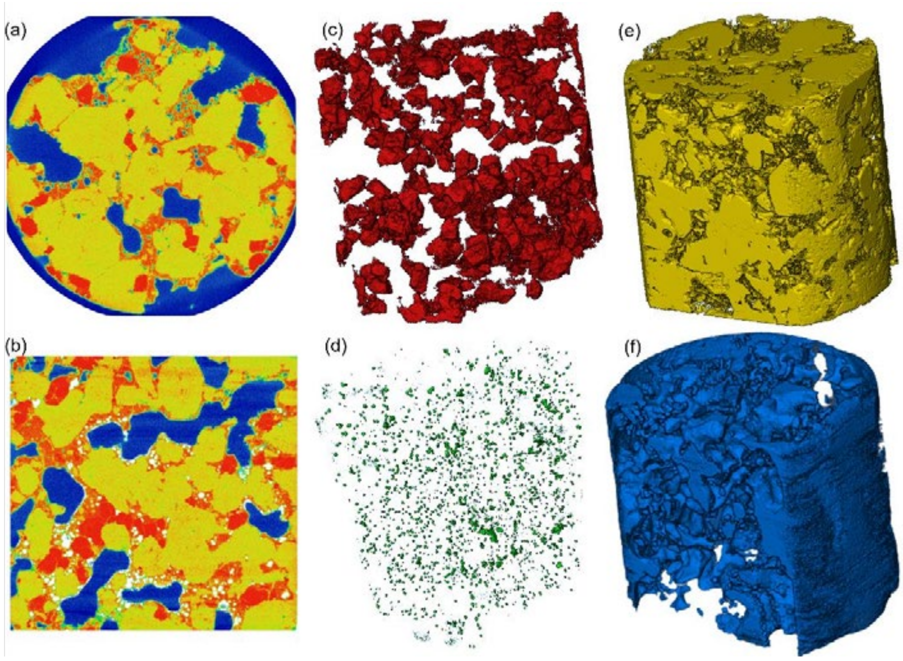
Active volcanoes are increasingly understood to be fed by vertically extensive magma plumbing systems that extend through much of the crust and are dominated by cohesive frameworks of solid crystals – crystal mushes – through which melts percolate and coalesce to form small and ephemeral but eruptible magma bodies. Studying the properties of crystal mushes is crucial for improving models of magma storage and ascent, since the mush plays a central role in mediating volcanic behaviour and determining the resulting hazards. Studying the pre- and syn-eruptive textures of crystal mushes is extremely challenging, because mush-derived clots of crystals disaggregate during magma ascent, while the mushes preserved in fossil magma reservoirs are overprinted by post-emplacement physical and chemical processes. Also, while there are numerous studies on the 2D structure of mush fragments and mush-derived crystal clusters in basalts, the 3D structure of mushes still remains to be investigated in detail. The aim of this project is to develop a better understanding of how the physicochemical properties of mushes evolve with time and how melt-rich and crystal-rich environments control the evolution and behaviour of deep magma plumbing systems. To do this, we have identified fragments of erupted mushes (gabbro nodules; also referred to as cognate xenoliths or crystalline enclaves in literature) from Gí go ldur in the Northern Volcanic Zone of Iceland, that preserve mush textures and provide ideal windows into the petrology of an actively evolving mush system. X-ray computed microtomography (XCT) is performed on cylindrical rock cores prepared from representative samples containing vesicles, volcanic glass, plagioclase feldspar, clinopyroxene, olivine, and melt inclusions within them. By combining the results of the XCT with subsequent geochemical microanalysis, we will present the first comprehensive description of 3D textural and chemical variability in mushes from an active volcanic plumbing system. This will provide new insights into magma plumbing system behaviour, especially concerning the feedback between melt infiltration, chemical reactions, and mush disaggregation in the run-up to potentially hazardous eruptions.



Preliminary reconstruction and segmentation of a cylindrical sample scanned at 16 microns. (a) circular, and (b) vertical cross section of reconstructions colour coded for different phases and segmented – glass [cyan and orange], (c) mafics [red], (d) oxides [green], (e) plagioclase [yellow], and (f) vesicles [blue].

Petrology and geochemistry of the Kula Volcanic Province.

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Small-scale monogenetic volcanic systems are the most widespread type of volcanism we experience on Earth and occur in a range of different tectonic settings, including intraplate, extensional, and subduction-related plate tectonics. Formed by multiple surface eruptions where small batches of magma erupt effusively and explosively, these features present a range of characteristics, including eruption frequency, volume, and duration, which can be linked to local and regional tectonic regimes. This volcanism is represented by tens to hundreds of associated volcanic vents where lava can unexpectedly penetrate the crust, with a new vent forming in an unknown location. Monogenetic volcanic fields (MVFs) are important to study, as each vent represents the pathway for magma from the upper mantle to the surface. These structures however are surprisingly understudied in terms of volcanic eruptive histories, and questions about the origin, longevity, and spatial distribution of vents are subject to uncertainty. An excellent example of where this can be investigated is the Kula Volcanic Province in western Turkey. Exhibiting three periods of Quaternary basaltic volcanism from 2 Ma and 10 Ka, the Burgaz, Elekçitepe, and DivlitTepe Volcanics have been identified as silica-undersaturated alkaline volcanism. This work presents a comprehensive qualitative and quantitative investigation using optical microscopy, and a range of advanced analytical techniques for an inclusive textural, chemical, and elemental approach to evaluate magma chamber dynamics, as well as temporal and spatial variations of volcanic cones. Optical microscopy will enable the constituent minerals and their textures to be identified, as well as a classification for the samples. This will be accompanied by XRD to identify mineral phases, XRF for bulk mineral composition, SEM for a thorough textural analysis, and EPMA and LA-ICP-MS for a detailed core-to-rim analysis of major and trace elements in the main mineral phases, including plagioclase, clinopyroxene, and olivine. Overall, this work will contribute to understanding future volcanic scenarios for monogenetic volcanism which can be applied to other comparable intraplate environments. This is a fundamental rationale for understanding magma generation, magma evolution, crystallisation pathway, and likely tectonic environment for volcanic hazards.

Research Outlook: Towards multi-method estimates of the intensity of explosive volcanic eruptions

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The dynamical evolution of volcanic plumes has important implications for the prediction of ash cloud formation and dispersal, and its associated hazards. Volcanic ash transport and dispersion models rely on input eruption source parameters, including the eruption intensity, often termed mass eruption rate (MER). Two of the most popular methods to estimate MER are: (i) inverting from plume height using a volcanic plume model, most commonly a simple empirical relationship between MER and height; (ii) reconstruction after the eruption from the duration and the deposit-derived total mass of tephra. Estimates of MER from these methods commonly differ by 1-2 order of magnitude, limiting our understanding of volcanic plume dynamics. Here, we discuss the potential of a third method to shed new light on volcanic plume dynamics. Previous work has shown that MER can be estimated from the growth rates of the volcanic umbrella cloud, derived from plan-view satellite images. Despite its potential to be applied to a large number of eruptions, it has only been used for a select few to date.

The methods developed also often do not account for the effects of wind, air entrainment and humidity. This research project aims to improve the methodology to estimate the MER from umbrella cloud growth rate methods and apply it to a range of different eruptions. We will systematically compare the umbrella cloud-derived MER estimates to those derived from plume height and deposit using the Independent Volcanic Eruption Source Parameter Archive (IVESPA) database which contains eruption source parameters for 134 well-observed eruptive events. This should lead to further constraints on MER, which can be used to develop and improve existing plume models, ultimately leading to better forecasting of ash dispersal during explosive volcanic eruptions.

Volcano distribution and hazards associated with a passive continental rift: a re-evaluation of submarine volcanism in the Sicily Channel

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The Sicily Channel marks a complex zone of extension between Sicily and north Africa, containing three main rift grabens that mark the principal zones of crustal thinning, alongside a complex array of oblique strike-slip faults. Volcanism has developed in close association with these tectonic structures, including the focused sites of long-lived volcanism at the islands of Pantelleria and Linosa, which close to the western ends of the Pantelleria and Linosa grabens, respectively. The distribution of volcanism elsewhere in the region is less well characterised, but interpretation are based on the presence of several confirmed and postulated submarine volcanic landforms. Aspects of these interpretations are based on very limited morphological evidence and as a result, patterns of submarine volcanism in the region remain uncertain, hindering our capacity to determine the relationship between tectonic controls and magma generation, to explore the relative timing, flux and distribution of volcanism, and to fully evaluate present-day submarine volcanic hazards in the area.

The M191 research expedition (RV Meteor) surveyed the Sicily Channel in July-August 2023, seeking to provide a more comprehensive framework for evaluating coupled tectonic and magmatic processes in the region. A combination of high-resolution seafloor mapping, sub-bottom profiles and magnetic data, alongside dredge sampling, was used to identify the location and morphology of volcanic structures in the area, to determine the overall spatial distribution of igneous bodies, and to provide a spatially comprehensive sample set that can advance knowledge of volcanism in the area. Here, we present initial results that provide an updated view of volcanism in the region, providing the foundation for more detailed chronological, geochemical and tectonic studies. We distinguish between monogenetic and polygenetic centres, evaluate the relative age and style of volcanism based on morphological indicators, including indicators of water depth, and remove previously uncertain volcanic locations that have clouded past reconstructions. Our results imply a more limited distribution of centres than has been implied in some previous studies, with the main focus of recent volcanism being offshore Pantelleria and Linosa, and in a broadly N-S alignment between the Graham volcanic field and the Sicilian shoreline. Several large volcanic landforms occur away from the main grabens, but show varying extents of degradation and may represent volcanic manifestations during earlier stages of rift development.

The sulfur content and isotopic composition of the subarc mantle.

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Over the last two decades, the study of magmatic volatile contents in melt inclusions revealed that many arc magmas have elevated sulfur contents compared to those erupting at mid-ocean ridges. However, how these high S contents relate to that of the subarc mantle has not been studied on a global scale. Here we present estimates of subarc mantle S contents for 26 volcanic systems, covering 10 volcanic arcs, from which major element data, oxygen fugacity values, melt inclusion S and H_2O contents were available. These values are all required to estimate the S content of primitive arc melt and their melting degree; the latter is calculated by determining the H_2O content-dependent solidus temperature and the P-T conditions of melting for arc whole-rock samples with >5 wt% MgO.

Globally, the sulfur content of the subarc mantle varies from 180 ppm (Lassen volcanic complex, Cascades) to 880 ppm (Shishaldin, Aleutian Islands). Out of the 26 studied systems, 20 have mantle S content estimates between 300 and 600 ppm (Fig. 1). Therefore, the mantle wedge is enriched in sulfur compared to normal upper mantle (which contains 100-200 ppm S) on global scale, and a significant amount of S is transferred from the subducting slab to the mantle wedge. This is also confirmed by the estimated sulfur isotopic composition ($\delta^{34}S$) of undegassed arc magmas, which is uniformly enriched in ^{34}S relative to the upper mantle. However, no global correlation can be observed between mantle S content and arc magma $\delta^{34}S$. There is no significant correlation between subarc mantle S content or $\delta^{34}S$ with traditional slab tracers (Ba/La), indicators of mantle heterogeneity (La/Yb), or oxidation state ($Fe^{3+}/\Sigma Fe$). Nonetheless, we estimate the highest mantle S contents for highly oxidised magmas. A combination of parameters, such as subducting plate age, slab thermal structure, sediment input, and pre-existing mantle heterogeneity may influence the S content of the subarc mantle together, ultimately controlling the magnitude of S degassing at arc volcanoes.

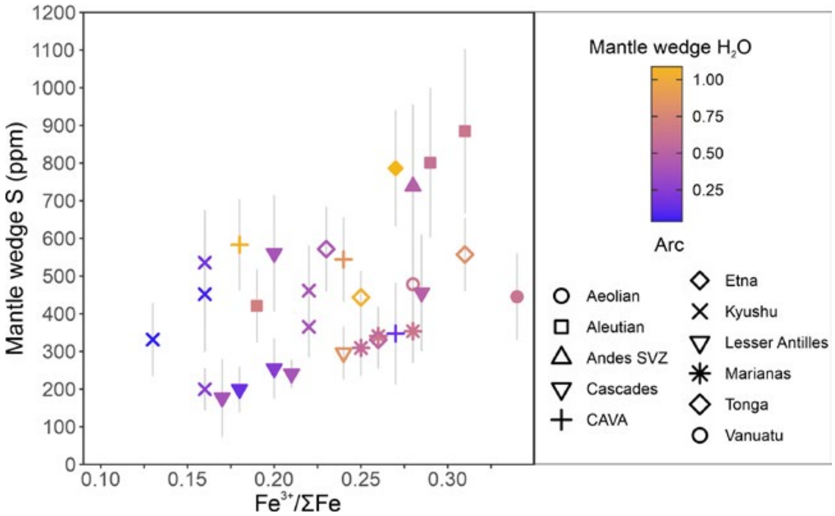

Figure 1: Sulfur content of the mantle wedge vs. iron speciation of the studied samples. The colour gradient corresponds to the estimated H_2O content of the mantle wedge under each volcano.

Afar triple junction fed by single, heterogeneous mantle upwelling.

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The arrival of hot upwellings within the mantle from Earths deep interior are commonly observed worldwide, but their role in driving volcanism during continental breakup has long been debated. Given that only a small fraction of Earth's upwellings are situated under continents and a limited number of them are associated with active continental rifting, our understanding of these processes remains incomplete.

Here, we investigate the interplay between continental breakup and mantle upwellings using the classic magma-rich continental rifting case study of the Afar triple junction in East Africa. The mantle structure beneath Afar is highly debated, with some studies previously proposing that the region is underlain by mantle upwelling(s), yet others argue for limited involvement of mantle plumes. Several discrete segments of the rift have been studied in terms of magma petrogenesis. However, until now, a paucity of high-precision geochemical data across the broader region has hampered our ability to test the above models and evaluate the spatial characteristics and structure of this major mantle upwelling in the recent geologic past.

Within this study, we present extensive new geochemical and isotopic data spanning the region and integrate these with existing geochemical and geophysical datasets to shed light on the spatial characteristics of the mantle beneath Afar. By combining geophysics and geochemistry using statistical approaches, our multi-disciplinary approach shows that Afar is underlain by a single, asymmetric heterogeneous mantle upwelling. Our findings not only validate the heterogeneous characteristics of mantle upwellings, but also demonstrates their susceptibility to the dynamics of the overriding plates. This integrated approach yields valuable insights into the spatial complexity of mantle upwellings.

Precise determination of melt inclusion volumes using micro-XCT analysis

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Melt inclusions (MIs) are small (typically <100 μm) pockets of magmatic liquid (now silicate glass) trapped inside crystals. Micro-analysis of MIs has been pivotal in constraining the fluxes of volatile species (mainly H2O and CO2) from volcanic systems as they are protected from the low-pressure degassing that affects erupted magmas. Most CO2 bearing inclusions are, however, polyphase, comprising both silicate glass and a CO2 rich vapour bubble. These bubbles typically form after entrapment during syn-eruptive decompression and can host a significant fraction of the CO2 (>40%) that was initially dissolved in the included melt [1]. Determining total MI CO2 contents therefore requires analysis of both the glass and bubble phase, usually by ion microprobe and Raman spectroscopy respectively. A crucial factor in the reconstruction of total MI CO2 using glass and bubble CO2 data is knowledge of the volume ratio between the inclusion glass and bubble. This is because the mass of CO2 in the bubble, determined from density data, must be converted to the equivalent concentration of CO2 in the MI. Current methods to determine MI and bubble volumes typically rely on 2D optical microscopy and introduce uncertainties of >40% on total CO2 determinations, although this may be far larger for irregular shaped MIs [2].

In this study we demonstrate the use of micro-X-Ray Computed Tomography (μXCT) to produce 3D maps of melt inclusion and vapour bubbles from an arc volcano in Southern Chile (Mocho Choshuenco). Once processed, this 3D data allows for precise volumetric constraints on the MIs. Our preliminary μXCT scans show that this approach can improve total MI CO2 reconstructions by 10-50%, dependent on glass CO2 concentration and MI size and shape. By adding this method to our analytical workflow for MI analysis we will create precise MI CO2 constraints for suites of inclusions from several post-glacial eruptions of Mocho Choshuenco.

Figure shows a 3D μXCT-generated image of an olivine crystal (green) containing melt inclusions (brown) with shrinkage bubbles (blue) and spinel inclusions (black). Scan pixel size: 5.7μm3

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Quantifying the sedimentation of ignimbrites – progress and challenges in analogue flume modelling of pyroclastic density currents and their deposits.

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Pyroclastic density currents (PDCs) are deadly flows of ash, gas and rocks that form during volcanic eruptions. They can travel up to 200 km/h with temperatures up to 1000°C. They pose one of the greatest volcanic hazards to populations near active volcanic centres and are directly responsible for over 90,000 deaths since 1600 AD. Understanding how these currents form and what affects their dynamic flow behaviour in time and space is fundamental to improving our predictive models that underpin hazard assessments. Our understanding of these currents is largely driven by our analysis of the deposits they leave behind (and indeed, where they do not deposit and even erode). Despite significant advances in our understanding of PDCs, there are still fundamental gaps in our understanding of their physical processes, how these change with time and space, and how this results in their high mobility and destructive behaviour. Numerical and analogue models aim to address this lack of understanding.

Our work has been advancing our understanding of the linkages between process (PDC) and product (their deposit) through analogue flume experiments designed to quantify sedimentation. Our experiments have generated deposits with complex grading patterns within bedform packages of planar, shallow backset and steep backset beds. We can relate these packages to changes in velocity, and rapidly evolving Froude numbers. We present examples of a range of bedforms and processes, including the impact of fluidisation and grain size on bedform morphology, and grading in volcanic stratigraphy. However, we have faced challenges in benchmarking our analogue experiments with sufficiently large and varied field datasets.

Models that test the relationships between deposit properties and the currents that formed them are critical, but are hindered by a lack of systematically collected, comparable, quantified datasets of field deposits to both inform and validate against. To continue to drive our understanding of PDCs, a change of approach is needed to (1) enable the collation of field data into interrogatable databases (2) to collect field data that reveals quantitative data on process (3) to collect the types of data required by modellers and (4) to use rigorous, state-of-the art quantitative methodologies. We conclude by launching FIAMME - a global network project aimed at closing this gap by creating a 'Framework for Ignimbrite Analysis Methodologies for Modelling and hazard Evaluation'.

A three-dimensional insight into Icelandic magmatic mush.

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Most processes operating within melt reservoirs beneath volcanoes remain poorly constrained[1] due to our inability to directly observe them. Crystalline nodules found within the erupted products of volcanoes provide a snapshot of their reservoirs at the time of entrainment[2]. They are an important key to unravelling the mysteries of deep magmatic systems. Through a combination of textural and chemical information, petrologists have long been able to quantify the nature and timescales of these processes. However, these data have largely been constrained to studies on sectioned samples that require extrapolating to three dimensions.

Using samples collected from Miðfell, Iceland, we aim to overcome such biases and approximations in section-based studies by directly imaging the 3D structure of gabbroic xenoliths using X-ray computed tomography[3]. Data was acquired for large scale samples (>4cm diameter) using a TESCAN CoreTOM instrument with 30-40 µm voxel sizes. Five of those were chosen to make 1cm thick cuboids for further data acquisition using a ZEISS Versa instrument with 10 µm voxel sizes. Phase segmentation is performed using X-ray absorption contrast thereby localising the different mineral phases in the volume.

Physical characteristics can be extracted from the individual phase masks and more crucially, the exact 3D mineral relationships can easily be quantified and even compared to traditional section-based measurements. These may include modal mineralogies and textural measurements, such as CSDs, aspect ratios and preferred crystal orientations. Comparison of three-dimensional and section-based measurements will be used to assess true uncertainties in conventional measurements. The three-dimensional interconnection of melt and the different mineral phases provide crucial insights into the architecture of magmatic mush bodies, including their permeabilities to percolating melt within the mush pile. Furthermore, physical properties such as bulk and shear moduli, as well as density, may be calculated; these provide important constraints to seismic studies of volcanic centres.

Combined with chemical information derived from electron microscopy and our machine learning subroutines, we will have unprecedented insights into the structure of these xenoliths and underlying mush pile at the time of eruption at Miðfell, Iceland. This we expect will help our overall understanding of the triggering and evolution of large basaltic eruptions. In time, this can be taken a step further and the segmented volumes can form the basis of simple porous melt flow models to better model the behaviour of magmatic mush bodies.

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Generation, storage, and eruption of an intermediate composition magma on Ascension Island

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Ascension Island is a Holocene, intraplate volcanic island in the South Atlantic Ocean. The island exhibits a wide compositional range of basalt-trachybasalt-basaltic trachyandesite-trachyandesite-trachyte-rhyolite(1) magma, but intermediate products make up <5% of the surface deposits. Here, we focus on the 1.3 km long, trachyandesite Devil's Ink Pot fissure (DIP), located in the south east corner of the island, and one of the youngest and best-preserved intermediate composition eruption on the island. We use a combination of petrological and geochemical data collected from juvenile components and present whole rock major and trace element data, crystal textures, and compositions, melt inclusion data and associated modelling of intensive variables to understand the genesis and triggers of intermediate melts, and relate this to the processes of magmatic evolution at low-flux ocean island volcanoes. Whole rock and trace element analyses show that the erupted magma is chemically uniform. However, petrological, and geochemical analysis of plagioclase and olivine crystals identified textural and chemical variations. MELT's modelling from the least evolved Ascension Island deposits is not able to reproduce the same intermediate composition of the Devil's Ink Pot fissure. Previous island wide studies have shown that intermediate melts formed by fractional crystallisation, but MELTs modelling and eruption specific studies suggest that additional processes are involved in the generation of intermediate melts.

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Coupling long-term magma evolution and short-term volcano deformation: Implications for uplift-subsidence patterns

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Volcanoes deform over timescales of months to decades, but such signals are likely shaped by the long-term thermo-mechanical evolution of magmatic systems occurring over hundreds of thousands to millions of years. This coupling has received limited attention in the past. Here we integrate thermal models of crustal-scale magma system evolution with finite element simulations of surface deformation. Our aim is to quantify how variation in the long-term magma flux, the duration of magmatism over 100s kyrs, and the depth of an overpressure source influence the short-term spatial and temporal patterns of viscoelastic deformation over timescales of years.

The simulations reveal that deformation stemming from deep overpressure sources at depths of 10 or 15 km follows a consistent time evolution. This deformation tends to dissipate within a few years, with minor dependence on magma flux or lifespan of the magmatic system. On the contrary, temporal deformation patterns linked to shallow crustal overpressure sources at a depth of 5 km strongly depend on magma flux and the duration of the magma system's existence. In most simulations involving shallow pressure sources, a distinct pattern emerges: initial co-intrusive uplift followed by subsidence and subsequent uplift. This early subsidence is attributed to downwards viscoelastic creep from the shallow overpressure source into the underlying hot crustal rocks. This mechanism could explain observations of subsidence following intrusions, which has previously been attributed to degassing or a hydrothermal response (e.g. Okmok and Aluto).

Our simulations yield two crucial findings. Firstly, the duration of magmatism over 100s kyrs and the rates of long-term magma supply significantly affect temporal trends of surface deformation over timescales of years, while the growth of viscoelastic shells surrounding magmatic systems has only a minor impact on spatial deformation patterns. Secondly, our results suggest a novel mechanism for characteristic temporal patterns of co-intrusive uplift, followed by subsidence and uplift at volcanoes. In conclusion, understanding the interplay between long-term magmatic processes and short-term volcanic deformation is essential for enhancing our capacity to monitor and interpret signals of volcanic unrest.

Development of an assessment framework for volcanic tsunami hazards at partially submerged caldera systems

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This project aims to create a framework by which tsunami hazard at partially submerged calderas can be assessed and evaluated where sector collapse, submarine explosions, caldera-forming eruptions, and other related processes can interact directly with the ocean. Examples of this exist at Krakatau in Indonesia, Rabaul in Papua New Guinea, and Hunga Tonga-Hunga Ha'apai (HTHH) in Tonga, where reliable accounts of volcanic tsunamis exist during episodes of relatively recent historic volcanism. However, many volcanoes of this type are not well studied despite the risk posed by them, with Banda Api in the Banda Islands of Indonesia being a key example. Although this volcano displays documented evidence of structural instability and the potential for catastrophic tsunamigenic sector collapse originating from a post-caldera volcanic edifice, the dynamics of the potential hazard and the risk posed to the population of the surrounding islands and their populations are poorly understood.

Using historical reports, accounts, and observations from recorded tsunamigenic eruptions, as well as morphological and bathymetric data from these types of volcanoes, this project will build a protocol for evaluating relative hazard and potential scenarios at shallow submarine and emergent caldera settings, and aid in assessment of how tsunamigenic eruptive processes and human vulnerability vary across some of the world's most dangerous volcanoes.

Emplacement Processes of the Whin Sill, Northern England – insights from macroscopic and microscopic structure observations

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Magma is transported through the crust in an interconnected series of sheet intrusions such as dykes, sills, and inclined sheets. Understanding how such bodies are emplaced and magma transported over long distances is key to improving the reliability of magma transport timescales and potentially eruptible magma volumes associated with different volcanic systems. The syn- and post-emplacement processes can also have a large impact on mineralization processes and the location of precious ore minerals around intrusions.

The Whin Sill is a large sill within the Great Whin Sill Complex in Northern England that has been studied extensively over the last 100 years. It is a quartz-microgabbro sill that intruded 295±6 Ma into Carboniferous-aged sedimentary strata, underlying 4500km^2 of Northern England. In this study, three key techniques, namely a detailed field study of mesoscale structures, quantitative microstructural analysis (measuring shape and crystallographic preferred orientations), and magnetic fabric analysis (anisotropy of magnetic susceptibility (AMS) and anisotropy of anhysteretic remanent magnetization (AARM)), are applied to the same Whin Sill localities and samples in order to compare and validate local emplacement process interpretations derived from these techniques. The main constituent phases and oxides observed in these specimens were analyzed using energy dispersive spectroscopy (EDS) and electron backscatter diffraction (EBSD) in a scanning electron microscope (SEM) to determine their chemical signature, as well as any crystallographic preferred orientations. Mineral phases within the samples include plagioclase feldspar (50%), clinopyroxene (10%), amphibole (5%), quartz (2%), and oxides (10%), which include ilmenite, magnetite, titanomagnetite pyrite and pyrrhotite.

There is limited evidence of any crystallographic preferred orientations within the plagioclase feldspar laths, which is the main mineral whose orientation would be expected to be modified by magma flow. Analysis of the rock magnetism identified fine-grained, single domain magnetite as the main magnetic carrier, with minor amounts of titanomagnetite identified through analysis of the curie temperature of the samples. The AMS and AARM results show there is a magnetic fabric likely recorded in a fine-grained (titano)magnetite phase in all samples. High-resolution backscatter electron (BSE) images and EDS highlight the complex textures of the iron oxides within the samples, such that establishing a link between crystallographic and magnetic fabrics proves challenging. We suggest that the magnetic fabric originates from post-emplacement processes and is not related to primary magma flow. This study therefore highlights the care that needs to be taken when utilizing individual methods in isolation to make interpretations of emplacement processes.

Records of prolonged ash-venting at a rhyolitic volcanic system, Torfajökull, Iceland

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Silicic volcanic eruptions are increasingly recognized to be predominantly hybrid in nature, incorporating simultaneous explosive and effusive activities. A key observation in support of this model is the persistent ash-venting that occurred throughout lava effusion during the 2011-2012 eruption of Cordon Caulle, Chile. Pathways which facilitated such ash-venting have been recognized in the 2011-2012 Cordon Caulle lavas, the interior surfaces of which are coated by partially-sintered, micron-sized volcanic ash[1]. The presence of these "nozzles" in lavas from past eruptions, therefore, indicate similar hybrid-style activity had occurred[2].

Here, we present a suite of nozzle samples from Hrafntinnuhraun (HRN), a series of rhyolitic lavas and pyroclastic deposits attributed to a ~900 CE eruption (VEI~4), within the Torfajökull volcanic complex, Iceland[3]. These samples record a broad spatial- and temporal range of ash-venting activity during the HRN eruption. We use TGA/SEM-EDX to characterize the compositions and morphologies of these nozzle materials, with comparisons to similar samples from Cordon Caulle.

We note that nozzle materials were observed *throughout* the lava components of HRN, including at flow-fronts up to ~1.5km from the edifice. This indicates that ash-venting at HRN persisted throughout the timeframe of its lava emplacement, which we estimate to have been ~months-years[4]. The possibility of such prolonged output of fine- to ultrafine volcanic ash has important implications to hazard assessment and mitigation in the region.

Figure: (top left inlay) location of the Torfajökull complex in Iceland; (left) nozzles hosted in vesicular lava, HRN; (right) SEM image of an HRN nozzle sample.

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The Petrogenesis of Virgin Island Granitoids: Implications for the growth of early-Earth-like continental material.

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The oldest preserved continental crust dates to the Eoarchaean and Palaeoarchaean eras (4.0 Ga–3.5 Ga) and is principally formed of a tonalite-trondhjemite-granodiorite (TTG) suite. Nevertheless, the tectonic processes responsible for the generation of these ancient TTG's remains hotly contested with intracrustal and subduction mechanisms commonly suggested as possible explanations.

In the northeast corner of the Caribbean lies the Virgin Islands (VI). The VI have a crust composed of 15-20 km thick oceanic plateau material from the Caribbean oceanic plateau, as well as Island Arc Basalt (IAB)- type volcanic and plutonic rocks related to oceanic island arc magmatism in the Caribbean region.
Since ~60Ma, the thick Caribbean plateau has been underthrusting and subducting beneath the North American plate. Ultimately, this has resulted in two distinct tectonic environments underling the VI; specifically, an intraplate environment in the south with ~30km of stacked ocean plateau and IAB material, and secondly a deeper subduction environment (from the oceanic plateau) to the north.

Granitoids with TTG compositions have been identified throughout the VI at several localities. Therefore, the VI provide a unique setting to determine whether these early-Earth like TTGs were derived from metamorphosed IAB and oceanic plateau material from the southerly intraplate setting and/or the northerly subduction environment.

Here, we present preliminary field observations and relationships between these TTGs and surrounding country rock throughout different localities within the VI alongside initial whole rock major and trace element analyses.

Long-term deformation of seasonal snow-covered calderas: A case study at Laguna del Maule, Chile

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Over the past three decades, InSAR technology has been increasingly applied to monitoring volcanic deformation because it provides continuous and high spatial-resolution data. However, at many volcanoes, InSAR measurements are challenged by technical difficulties such as phase unwrapping complexities, coherence loss, topographic shadowing and atmospheric influence. We focus on Laguna del Maule (LdM) in the Southern Volcanic Zone (SVZ), Chile, which is a large, deforming caldera with strong seasonal snow cover and steep-sided lava flows. Since 2007, LdM has started its ongoing unrest characterized by a significant uplift[1].

Here, we generated the time series of deformation of LdM by LiCSBAS between Oct 2014 to Jun 2023 using 2434 interferograms generated from 234 Sentinel-1 satellite images from COMET LiCSAR/LiCSBAS system. However, interferograms of winter months are typically incoherent reducing the total number of useable interferograms to 1117 and inducing network gaps, which reduce the accuracy of time series. Therefore, we then processed additional summer-summer acquisitions to make interferograms to fill the network gaps. Unfortunately, the longer time span summer-summer interferograms contain several unwrapping errors, which can be identified by calculating the loop closure phase for each pixel[2]. We applied a new unwrapping algorithm[3], which applies a Goldstein filter using coherence based on spectral magnitude to increase the coverage of unwrapped pixels and reduce the unwrapping error. Loop closure check results show that the number of unwrapping errors has been significantly reduced. However, a small unwrapping error caused by a topographic shadow, which was not identified by loop closure, has not been solved. The preliminary results confirmed that at the time of writing, the uplift of LdM was ongoing, and the maximum uplift had reached c. 2.1 m in the line of sight of track 083D since 2014.

Next, we test whether using external datasets such as the Normalized Difference Snow Index (NDSI) provided by MODIS and Sentinel-2 to identify snow-covered images a priori can be used to improve the efficiency of the processing system. As expected, both the coherence of the interferograms and the average NDSI of Laguna del Maule show strong and seasonal trends. Volcanoes with seasonal snow cover are common at high latitudes and high altitudes globally (e.g., Alaska, USA; the Kamchatka Peninsula, Russia; the Andes, South America and Iceland) and many of them are active and experiencing significant deformation[4]. However, snow-covered volcanoes are often not included in the global compilations. Therefore our results have important implications for understanding patterns of deformation on a global scale.

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Decolonising UK Earth Science pedagogy - a toolkit for all

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The foundations of a discipline shape the way in which knowledge is created, by whom, for what, and dictates who is allowed to generate knowledge. The historical roots of modern Earth Science lie in early colonial principles, when geological exploration for resource extraction was a powerful tool in colonial expansion. This era saw the rise of the predecessor to the British Geological Survey, The Geological Society of London and many of the university departments that continue to teach Earth Science today. The dominance of western institutions in Earth Science disciplines reinforces imperial and colonial power relations, where 'powerful knowledge' continues to ignore, belittle or erase other systems of knowledge. The founding and growth of these institutions during colonialism dictated who was allowed to practise geology. Those whose class, gender, race, or disability did not fit were excluded, and this has left a legacy of inequity in our discipline today. There is a documented diversity crisis in UK Higher Education Earth Science. However, Earth scientists of various underrepresented and intersecting identities have always existed; their histories have just been hidden. It has been argued that any action to increase diversity, equity, and inclusion needs to start with an examination of the historical roots of contemporary experiences of exclusion and specifically to acknowledge the colonial past of the discipline. Here, we exhibit the Decolonising UK Earth Science pedagogy project aimed at tackling the legacy of colonialism in the Earth Science discipline. We present a package of open access pedagogical resources to enable sector-wide recognition, learning, and conversations around the historical legacy of Earth Science and modern inequities. This comprehensive toolkit will help us towards our goal to decolonize UK Earth Science.

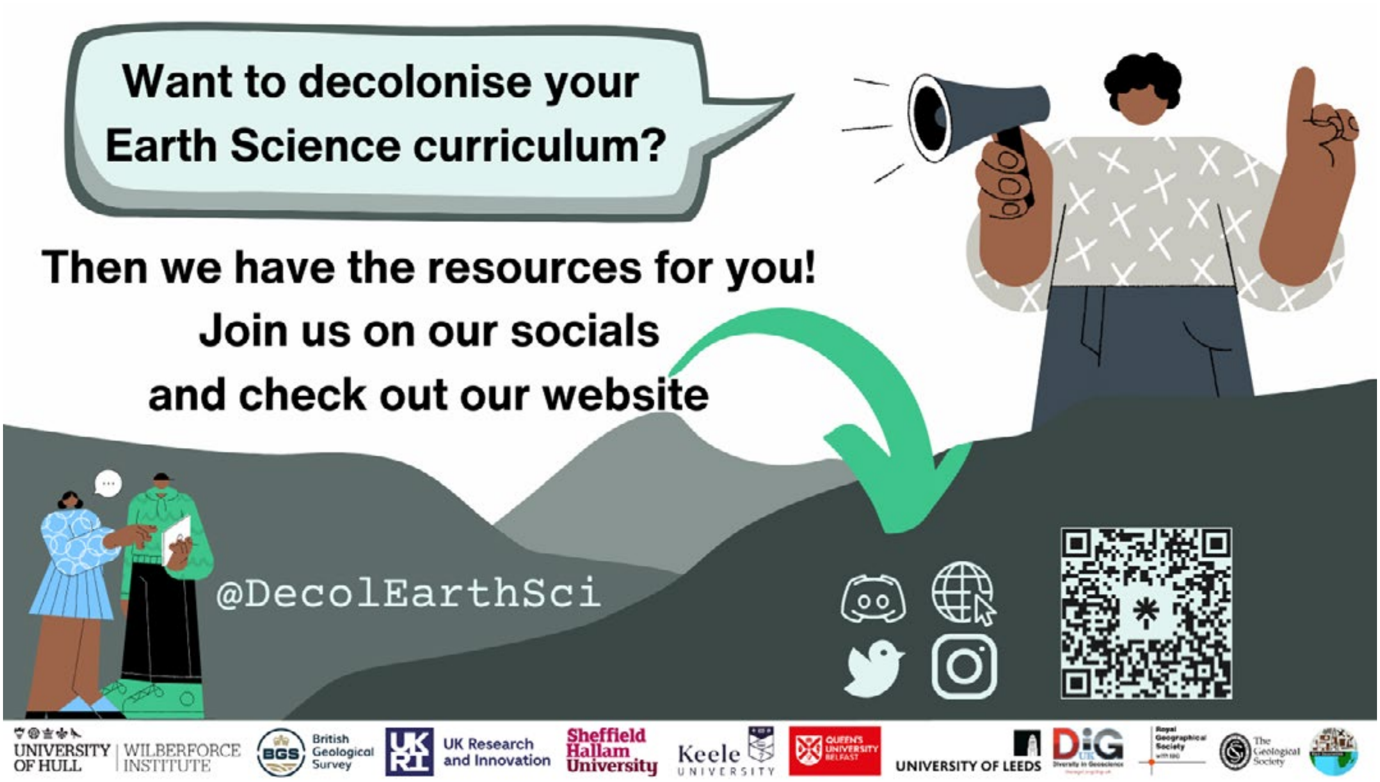

Figure: Find us in the exhibition space to grab our infographic on Decolonising the Earth Science curriculum and to explore the wide range of infographics freely available from our website. Scan the QR code to join a community of Earth Scientists discussing decolonizing curriculums and research on our Discord or follow us on X/Twitter and Instagram.