Scientific Programme

Volcanic and Magmatic Studies Group Meeting

Leeds 3rd-5th January 2018

Conference Programme

Tuesday 2nd January 2018

17:00 – 20:00	Meet-and-greet and pre-registration at the Cuthbert Brodrick pub

Wednesday 3rd January 2018

09:00 – 10:00	Registration at the Leeds City Museum
10:00 – 10:15	Welcome Address
10:15 – 10:30	VMSG Award Winner: Hugh Tuffen
10:30 – 11:00	Keynote 1: Madeleine Humphreys et al.
11:00 – 11:30	Break
	VOLCANIC ARCS
11:30 – 11:45	González-García et al.
11:45 – 12:00	Morgado et al.
12:00 – 12:15	Higgins et al.
12:15 – 12:30	Di Salvo et al.
12:30 – 13:30	Lunch break
13:30 - 13:45	Sugden et al.
13:45 - 14:00	Burton-Johnson et al
14:00 – 14:15	Bain et al.
14:15 – 14:30	McCormick Kilbride et al.
14:30 – 14:45	Albino et al.
14:45 – 15:00	Poster briefing – Volcanic Arcs
15:00 – 15:30	Break
	EXPLOSIVE IDEAS
15:30 – 15:45	Gaddes et al.
15:45 – 16:00	Hepworth & O'Driscoll
16:00 – 16:15	Kelly et al.
16:15 – 16:30	Ball & Neufeld
16:30 – 16:45	Hughes et al.
16:45 – 17:00	Poster briefing – Explosive Ideas
17:00 – 19:00	Poster Session A – Icebreaker Drinks

Thursday 4th January 2018

	RIFTS
09:00 – 09:30	Keynote 2: Willy Aspinall Prize Winner: William Hutchison
09:30 – 09:45	Moore et al.
09:45 – 10:00	Iddon et al.
10:00 – 10:15	Nowacki et al.
10:15 – 10:30	Woods et al.
10:30 – 11:00	Break
11:00 – 11:15	Seidel et al.
11:15 – 11:30	Mutch et al.
11:30 – 11:45	Giniaux et al.
11:45 – 12:00	Ágústsdóttir et al.
12:00 – 12:15	MacLennan
12:15 – 12:30	Poster briefing – Rifts
12:30 – 13:30	Lunch break [student forum]
13:30 - 13:45	Rodrigo et al.
13:45 - 14:00	Bennett et al.
14:00 – 14:15	Gibson & Richards
14:15 – 14:30	Gooday et al.
14:30 – 14:45	Roberts et al.
14:45 – 15:00	Poster briefing – Rifts
15:00 – 15:30	Break
	EXPLOSIVE IDEAS
15:30 – 15:45	Mangler et al.
15:45 – 16:00	Harnett et al.
16:00 – 16:15	Kazahaya et al.
16:15 – 16:30	Marsden et al.
16:30 – 16:45	Barclay et al.
16:45 – 17:00	Poster briefing – Beyond the Vent
17:00 – 19:00	Poster Session B – Pre-dinner Drinks

20:00 – 01:00	Conference Dinner – Leeds Marriott Hotel

Friday 5th January 2018

	EXPLOSIVE IDEAS
09:00 – 09:15	Satow et al.
09:15 – 09:30	Buchs et al.
09:30 – 09:45	Lachowycz et al.
09:45 – 10:00	Farquharson & Wadsworth
	BEYOND THE VENT
10:00 – 10:15	Esse et al.
10:15 – 10:30	Ray et al.
10:30 – 10:45	Wanmer et al.
10:45 – 11:15	Break
11:15 – 11:30	Ilyinskaya et al.
11:30 – 11:45	Heap et al.
11:45 – 12:00	Hayer et al.
12:00 – 12:15	Flower & Kahn
12:15 – 12:30	Student prize-giving
12:30 – 13:00	VMSG AGM
	Conference closes

	WRITING WORKSHOP
13:30 – 15:00	Part 1: Olga Degtyareva
15:00 – 15:30	Break
15:30 – 16:30	Part 2: Paul Cumine
16:30 – 17:00	Part 3: Melissa Plail

Saturday 6th January 2018

	Workshops at School of Earth and Environment, University of Leeds
09:00 – 16:00	An introduction to diffusion modelling in crystal systems: volcanic timescale recovery
09:00 – 16:00	Volcano Seismology
09:00 – 16:00	InSAR 101: Interpreting interferograms for volcanologists

The 54th Annual Volcanic and Magmatic Studies Group Conference

3-5th January 2018

Leeds City Museum

Leeds

Programme & Abstracts

Local Organising Committee

Dr Vern Manville (Technical Convenor) & Professor Juergen Neuberg (Scientific Convenor)

Dr Dan Morgan (webmaster and administration)

Dr Susi Ebmeier, Dr Dave Ferguson, Prof Andy Hooper, Prof Juergen Neuberg, Dr Ivan Savov, (Scientific Committee)

Dr Dave Ferguson (Corporate Supporters and Trade Displays)

Dr Mark Thomas (Social Programme)

Dr Susi Ebmeier (original artwork),

&

Student helpers (led by Claire Harnett)

Members of the VMSG Committee

On behalf of the Local Organising Committee we would like to extend a warm welcome to all delegates and visitors to Leeds

Disclaimer: Please note that all information in this volume was correct at the time of going to press. However, due to late changes and unforeseen circumstances, some abstracts presented here may have been withdrawn, while other presentations may be lacking abstracts.

Bibliographic references: A.N. Author (2018) What I did in my holidays. *In*: Manville, V. (ed.) Programme and Abstracts, VMSG 54th Annual Conference, Leeds, UK, January 2018, pg. xyz.

Table of Contents

Welcome

Local Organising Committee

On behalf of the Scientific Convenor, Professor Jurgen Neuberg, and the Technical Convenor, Dr Vern Manville, we are delighted to welcome you to the 54th annual conference of the Volcanic and Magmatic Studies Group, hosted by the University of Leeds.

Chair of the VMSG

On the behalf of the VMSG Committee, it is a pleasure to welcome you to our Annual Conference in this, the 54th year of our Special Interest Group (SIG). The different SIGs exist under the auspices of the parent bodies of the Mineralogical Society of Great Britain and Ireland, and/or the Geological Society of London, and represent crucial components contributing to the visibility of vibrancy of our Geoscience communities within the UK, Ireland, and carry their influence further abroad.

We are delighted to be hosted by Leeds University for our 2018 Annual Meeting, and in particular we extend our gratitude to the local organising team from the Department of Earth Sciences here at Leeds. The organisation and delivery of the annual VMSG meeting for c. 200 delegates is a truly major undertaking, requiring an efficient local organising committee and considerable coordinated effort by its team members.

This year the Committee is delighted to announce that the 2018 VMSG Award winner is Dr Hugh Tuffen, Reader in Volcanology at Lancaster University. It is conferred in recognition of his research contribution to the understanding glacio-volcanological interactions and silicic eruption dynamics; his enthusiastic leadership and support of the annual 'Volcano-Ice' meeting that has encouraged PhD and post-doctoral researchers to deliver their research in a subject-appropriate and academically supportive forum, and for raising the profile of UK volcanology at the national and international level.

Whilst the VMSG award allows us to celebrate the success and contribution of colleagues such as Hugh, we also wish to acknowledge the passing of key members of our community. This year, we report the loss of two Geoscientists who have long been a part of our wider volcanic and magmatic community; firstly Prof. Hazel Pritchard (Cardiff) in early January and, most recently in November, Prof. Henry Emeleus (Durham). Both leave behind a considerable body of published research and, importantly, a legacy through the imparting of their knowledge and experience to generations of undergraduate students and postgraduate researchers.

Henry was widely acknowledged as a leading expert on the formation of igneous rocks in North West Britain and Greenland and was an outstanding talent as a field geologist. In 2016 The Geological Society of London honoured his 60 years of achievements by awarding him the Prestwich Medal – this Medal is awarded every three years to persons '*who shall have done well for the advancement of the science of geology*'. Henry was a great proponent of the value of meticulous fieldwork, and argued powerfully and eloquently in its support.

Hazel was a graduate of Hull University, completed her PhD at Newcastle, and was a long-time member of Cardiff University staff. Over the years afterward her contribution to Exploration Geology at this latter institution was profound and enduring. Based on her work in the Shetland Islands Hazel was one of the first to discover that ophiolites, traditionally

considered to be platinum-poor, could be strongly enriched in this noble metal. More recently Hazel's research focus turned towards understanding the complex dispersion routes of anthropogenic PGE released into the environment from catalytic converters fitted to vehicle exhausts. Her contribution at the academic/industry interface was recognised in 2004through the Royal Society Senior Brian Mercer Award for innovation. Her passion for undergraduate industrial placement was infectious, and it supported many young geologists, who are now themselves prominent industrialists.

As ever, VMSG remains forward-looking and aims to respond to the rapidly developing new ideas and techniques that are influencing the way in which we do science. Programmes such as the recent BBC Volcano – offer wider public exposure to both the science we conduct, and also to the manner in which and understanding volcanology can assist communities affected by the threat of eruption. Most importantly, VMSG has as one of its core aims the encouragement of young scientists. Accordingly, our annual meeting aims to provide a friendly and supportive platform and environment for the next generation of geoscientists to showcase their research, and to discuss their work with established researchers and leaders in their field. It is this collaborative and supportive approach that has made it an engine for positive contribution, collaboration and discussion across the generations.

Like a constantly fractionating magma chamber VMSG remains a 'melting pot' of ideas and scientific discovery – it continually evolves and develops – new ideas crystallize and novel technique precipitate ever more detailed and interesting data. A key factor to this success has been the willingness of members to contribute and become involved - achieved through the social media links on our website, through our field trips, and by working on VMSG Committee. If you wish to become involved with the committee, then opportunities arise annually for nomination and election. Positions arising are advertised in advance on our website and include 'ordinary members of Committee (3 year term), Student representative (1 year term): we encourage nominations and applications – for 'early' , 'mid', or 'late'(!) career scientists.

This Leeds VMSG annual meeting will be my last as VMSG Chair. As a long-standing member of Committee, this venue will also bring to a close two decades of involvement with this vibrant SIG. I am delighted to hand over the role to Dr Sally Gibson, Reader in Petrology and Geochemistry at Cambridge University – and a long-time supporter and past Committee member of VMSG. So, I'd like to record my heartfelt thanks for the support and camaraderie of the current VMSG Committee, and to all of those with whom I have served on VMSG Committees over the years: '*Colleagues and friends, it has always been a joy, and a pleasure*!'

Finally, the VMSG Committee are looking forward to seeing old friends - some of you have been making the 'annual pilgrimage' to our meeting for many years - and have contributed as postgraduates, and now as Readers and Professors. Most importantly, we are delighted to have so many young geoscientists here, and we particularly look forward to meeting those of you for whom VMSG is still a novel experience. Welcome to our 'scientific family' - we sincerely hope this forum will play a positive and inspirational role at the start of your own scientific journey.

Mike Widdowson (Chair of the VMSG)

Volcanic and Magmatic Studies Group

The Volcanic and Magmatic Studies Group is a joint special interest group of the Mineralogical Society of Great Britain and Ireland and the Geological Society of London. It is the main hub for the UK community of scientists working in igneous, volcanic and magmatic disciplines.

The Volcanic Studies Group was initially founded at Birkbeck College, University of London in December 1963, before becoming formally associated with the Geological Society of London in early 1964 as its first specialist group. Two one-day colloquiums were held for the next 3 years on various topics before meetings adopted a two-day format and began the tradition of being hosted by a different university geology department each year. Somehow the group survived without an AGM until 1967 when its first committee was elected. *This information was sourced from the official VMSG website (www.vmsg.org.uk).*

General Information

The 2018 meeting has been put together by staff and students in the School of Earth and Environment at the University of Leeds, with the assistance of the VMSG Committee. With your assistance as delegates and presenters we have put together a diverse and exciting scientific programme built around the themes of 'Volcanic Arcs', 'Rifts, Islands and Intraplate Volcanism', 'Beyond the Vent' and 'Explosive Ideas'. These highlight the latest developments and advances in volcanology, showcasing the cutting edge of cross-disciplinary research in the UK geosciences and with a strong emphasis on research student contributions. Oral and poster sessions commence in the Leeds City Museum on Millennium Square on Wednesday 3rd January and continue until lunchtime on Friday 5th January. Post-conference workshops for students and Early Career Researchers include a PhD writing and publishing workshop held in the Leeds City Museum on Friday afternoon, while on Saturday 6th the School of Earth and Environment hosts a number of technical workshops on diffusion modelling in crystal systems, volcano seismology, and InSAR theory, practice and applications..

At the time of going to press, registration stood at 195 with 48 oral and 85 poster abstracts submitted.

Venue

The conference will be held at the Leeds City Museum in the heart of Leeds City Centre on Millennium Square. Designed by Cuthbert Brodrick, the Victorian architect responsible for many of the city's iconic buildings, including the Town Hall and Corn Exchange, the former Mechanic's Institute was built in 1860-65 before becoming home to the Leeds City Museum in 2008. Oral sessions will be held in the circular Brodrick Hall with trade displays and morning and afternoon teas and lunches provided around the periphery. Speaker-ready facilities are available at the AV/IT desk in the main hall. Poster sessions will be held on the Lower Ground Floor in the Denny and Thoresby Rooms, please be careful on the stairs: lifts are also available. Luggage storage facilities are provided in the Boardroom on the Lower Ground Floor: access will be supervised by a student helper.

Please note that although we have booked parts of the building the Leeds City Museum remains open to the public between the hours of 10 am – 5 pm. Wear your lanyard and name badge at all times and be aware of your personal property. We cannot take responsibility for any loss or damage.

Registration Desk

Most participants ought to have already registered and paid for the conference and will only need to report to the registration desk to collect their delegate pack. We request that all oral presenters upload their presentations at this time. If you are yet to pay for the PhD writing and publishing workshop you may do so at this time (£20). Should day registrants and walk-ins decide to attend the conference dinner a limited number of additional tickets will be available for £35.

The registration desk will be open at:

- The Cuthbert Brodrick pub on Millennium Square on Tuesday 2nd January from 5 pm – 8 pm.
- At the Leeds City Museum foyer during the rest of the conference, 9 am – 7 pm.

Information for Speakers

See pages 13-16 for the programme of talks. Speakers should be prepared to upload their presentations at the registration desk when they first arrive at the conference. Presentations should be in one of the following file formats: ppt., pptx., or pdf. and able to be presented on a Windows-based machine. Check any animations, video files or GIFs. Personal laptops cannot be used for presentations. Mac user please note!

Speakers (other than invited keynotes) will be allocated 15 minutes for their presentation: we recommend that you allow 10-12 minutes for speaking and 3-5 minutes for questions, but the actual breakdown is at your own recognisance.

Information for Poster Presenters

See pages 17-21 for a list of poster presentations. Posters will be up for viewing for the whole of the conference, but presenters should be prepared to stand by their posters during the dedicated poster viewing sessions as follows: posters for Volcanic Arcs and Explosive Ideas may be viewed on Wednesday, while posters for Rifts and Beyond the Vent may be viewed on Thursday. Poster presenters are requested to put their posters up as soon as possible and remove them before morning tea on Friday. We encourage people to take advantage of the scheduled morning and afternoon tea and lunch periods for additional viewing and discussion time. Posters should be prepared in portrait format to a minimum size of A0 (841 mm x 1189 mm) and a maximum size of 914 mm wide (36 inches) x 1400 mm long, although our poster boards should be 1 m wide x 2 m high. Please affix your poster to the allocated board using supplied Velcro hooks.

The 1 minute/1 slide poster pitches that you were invited to submit after the registration deadline closed have been organised into groups and you will be called on to stand up and speak from the floor at some point during the meeting to advertise your poster to the whole conference (see the programme for details).

Prizes

Prizes will be offered for: (i) the best student oral presentation in each session; (ii) the best student poster presentation; and (iii) the best overall student oral presentation. Prizes are sponsored by VMSG, Tescan and the Geological Society of London.

Trade Displays

The success of any conference depends to a large part on the support of industrial and academic service providers, companies and institutions. Please show your thanks by visiting the trade displays offered by our corporate supporters, including Tescan, Nikon and COMET. Tescan are planning to demonstrate some of their equipment on Friday.

Trade displays from our corporate supporters will be available for viewing around the periphery of the main Brodrick Hall throughout the conference.

Refreshments

Your registration fee includes morning and afternoon teas and lunches, which are provided in the main Brodrick Hall on Wednesday and Thursday (morning tea but no lunch is provided on Friday): please identify yourself to the serving staff if you have any food allergies or intolerances. We have done our best to accommodate these with our caterers. Alternatively, the Leeds City Museum has a café on site on the Lower Ground Floor, while there are a number of cafes, bars and dining establishments within easy walking distance of the venue. Please note that because of venue limitations the caterers will be using disposable cups, we therefore request that you bring your own reusable travel mugs if you want to be more sustainable.

Social Events

Meet-and-greet

Tuesday 2nd January, from 5 pm – 8 pm in the Cuthbert Brodrick pub on Millennium Square, next to the conference venue. All welcome. A registration desk and facilities for uploading your presentation will be available. A single drinks voucher per attendee will be provided.

Icebreaker and Poster Session

Wednesday 3rd January, from 5 pm – 7 pm in the Life on Earth Gallery and Thoresby and Denny Rooms, Leeds City Museum. Vouchers for drinks are provided in your delegate pack. A selection of local beers and non-local white wines and soft drinks will be offered, as well as a range of canapes. Unfortunately as it's a museum we are barred from having red wine…

Poster Session and Pre-dinner Drinks

Thursday 4th January, from 5 pm – 7 pm in the Life on Earth Gallery and Thoresby and Denny Rooms, Leeds City Museum. Vouchers for drinks are provided in your delegate pack. A selection of local beers and non-local white wines and soft drinks will be offered, as well as a range of snacks

Conference Dinner and Party

Thursday 4th January, from 8 pm – 1 am at the Leeds Marriott Hotel. The cost of the dinner is included in the full conference fee and dinner tickets are provided in your delegate pack. This includes a welcome drink (sparkling wine or a non-alcoholic option) and drinks during dinner. There will also be a cash bar. We will not be providing a seating plan. A disco will follow dinner: the planned evening ends at 1 am, but for those with the stamina to continue there are numerous bars and clubs nearby on Call Lane. Day registrants and walk-ins may purchase a dinner ticket from the registration desk for £35.

Getting there: the dinner venue is within easy walking distance from Leeds City Museum. The address is 4 Trevelyan Square, Boar Lane, Leeds LS1 6ET [0113 236 6399].

Menu:

Starter

Chef's Homemade Tomato Soup

Or

Baked Field Mushroom with Wilted Spinach, Mozzarella & Refried Beans on toasted Croute (v)

Main Course

Parmesan Glazed Chicken, Crushed New Potato with Creamed Leek & Bacon & Balsamic Jus

Or

Aubergine Mille Feuille with Chickpeas, Spinach & Cherry Tomato Fondue (v)

Dessert

Lemon Tart with Chantilly Cream & Raspberry Jus

Or

Chocolate Fudge Cake with Chocolate Sauce, Chocolate Shards & Chantilly Cream (v)

All to be followed by Tea and Coffee

We have made every effort to liaise with the dinner venue to accommodate food allergies/intolerances. Please identify yourself to the waiting staff if this applies to you.

Social Media Policy and Wi-Fi

VMSG supports open science and welcomes discussion around its annual meeting on social media. All presenters have been asked to add a 'no tweet' logo to their oral presentations and posters if they do not wish information to be shared on social media. Please respect this and tweet responsibly. Ask permission before you share photographs or other material on social media platforms. The official conference hashtag is #VMSG2018.

The conference venue provides free Wi-Fi: login details will be provided at the venue.

Student Forum

Noon on Thursday 4th January during the lunch break.

Annual General Meeting (AGM)

Noon on Friday 5th January after the last oral presentation.

Leeds Information

Leeds Area Guide

The third largest city in the UK, Leeds grew during the 17th and 18th Century from its medieval market town origins to become a major centre for the production and trading of wool. The industrial revolution transformed Leeds into a major mill town, alongside engineering, iron

foundries, printing and other industries until today it is the most diverse economy of all of the UK's main employment centres with major strengths in finance, insurance, manufacturing, retail and the arts. The city is served by 4 universities, and has the 4th largest student population and urban economy in the country. Leeds is also a transport hub, with a busy railway station and airport and forms the hub for regional public transport, rail and road networks. Sports are strong with Leeds City FC based at Elland Road and Headingly Stadium hosting cricket and rugby. The city centre has a large pedestrian zone based on the Briggate, Headrow and Victoria Quarter, with many bars, cafés and restaurants concentrated in the surrounding couple of blocks, between Millennium Square and Call Lane.

Taxi Services

Speedline Taxis 0113 244 1444
Blue Line Taxis 0113 263 9999
Amber Cars 0113 202 2117
City Cabs 0113 246 9999
Leeds Taxis 0113 320 1500
And of course Uber!

Bars and Restaurants

This is just a small selection of the bars and restaurants available in central Leeds: consult the map on the inside back cover. Check out www.leeds-city-guide.com for a comprehensive listing including by genre.

A) All Bar One. Several of these around the city centre, including in the Electric Press building opposite the conference venue. LS2 3AD,
B) Revolution. 41 Cookridge Street, Millennium Square, LS2 3AW.
C) Red Chili. 6 Great George Street, LS1 3DW.
D) Spice Quarter. One of a number of restaurants and bars in the Electric Press building opposite the conference venue. Great George Street, LS2 3AD.
E) Nation of Shopkeepers. Artsy bar with a large heated courtyard area. 25-27 Cookridge Street, LS2 3AG. Tel: 0113 203 1831.
F) Thai Edge. 7 Calverly Street, LS1 3DA.
G) The Victoria Hotel. Classic Victorian-era drinking establishment. 28 Great George Street, LS1 3DL.
H) Shenanigans. Recently rebranded Irish pub. 26 Great George Street, LS1 3DL.
I) Costa Coffee. Part of the generic chain, many outlets.
J) The Tiled Hall Café. Leeds City Art Gallery, The Headrow, LS1 3AB.
K) Veritas Ale and Wine Bar. 43 Great George Street, LS1 3BB.
L) Shooters Sports Bar. 123 The Headrow, LS1 5RD.
M) The Bierkeller. 1 South Parade, LS1 5DA. Tel: 0113 245 8063
N) Mr Foleys Cask Alehouse. Award-winning ale and cider pub. 159 The Headrow, LS1 5RG.
O) Ibérica. Spanish tapas bar. 17A East Parade, LS1 BH. Tel. 0113 403 7007.
P) Sukhothai. Award-winning Thai food. 15 South Parade, LS1 5QS.
Q) Starbucks. Various branches of the giant Seattle covfefe chain dotted around the city.
R) Gauchos. Argentinian steakhouse. 21-22 Park Row, LS1 5FJ.
S) Slug & Lettuce. 14 Park Row, LS1 5NR.
T) Piccolino. Italian Restaurant. 11 Park Row, LS1 5NR.

U) Jamie's Italian. 35 Park Row, LS1 5JL.
V) Café Nero. Another of the chain coffee outlets for caffeine addicts.
W) Banyan Bar & Kitchen. Fusion food. 2 City Square, LS1 2ES.
X) The Alchemist. Home of the beautiful people, gold-diggers and marginally sub-lethal £12 cocktails. Yorkshire House, Greek Street, LS1 5SH.
Y) Friends of Ham. Charcuterie and craft beers and wines. 4 Station Street, LS1 3BB.
Z) The Brewery Tap. Leeds premier brew pub. 18 New Station Street, LS1 5DL.

Keynote Speakers

The ThermoFisher Scientific VMSG Award Winner: Dr Hugh Tuffen

Hugh became fascinated by rocks as a kid growing up amongst the Cumbrian fells, and caught the volcano/magma bug from David Pyle and Sally Gibson as a dishevelled geology undergraduate at Cambridge. After a Masters in Volcanology at Clermont-Ferrand, Hugh relished a fascinating PhD project supervised by Dave McGarvie (OU), alongside Harry Pinkerton and Jennie Gilbert at Lancaster, which investigated the enigmatic products of rhyolitic eruptions beneath Icelandic glaciers. Stints busking in Devon and assisting Magnús Guðmundsson with geophysical surveys in Iceland were followed by research fellowships in Munich, UCL and Lancaster, where Hugh studied magma fracture, healing and degassing alongside Don Dingwell, Peter Sammonds and others. He was then be awarded a Royal Society University Research Fellowship at Lancaster in 2010, with a little assistance from Eyjafjallajökull, which erupted the day before his interview. Hugh is now a Reader in Volcanology and primarily works on conduit processes in rhyolitic eruptions, volcano-ice interactions and lava flow emplacement. He has directed Lancaster's successful MSc in Volcanology and Geological Hazards since 2010 and is thrilled to see so many alumni join the volcanology community. Outside of work Hugh loves spending time with his three children, playing cello and riding his bike, occasionally a little too fast!

The ThermoFisher Scientific VMSG Award is bestowed annually on an individual who is deemed to have made a significant contribution to our current understanding of volcanic and magmatic processes.

The 2018 ThermoFisher Scientific VMSG award winner is Dr Hugh Tuffen. Edited excerpts from the award nomination are as follows: "Hugh is an outstanding volcanologist who has made his mark from the excellence of his work, for his eagerness and for his dedication to volcanology and the research community in the UK and Worldwide. He has made significant contributions to several strands of volcanology, from the occurrence of brittle processes in shallow conduits, degassing-driven crystallisation in liquids and glasses, and lava flow emplacement, to the interaction between magma and ice, and its use as a paleoenvironmental marker. Hugh's efforts to integrate field observations and meticulous geochemical analyses have established the paradigm that magma may rupture and heal, even several times, during ascent and eruption. In 2003, Hugh introduced a conceptual model describing fracture and healing cycles in magma (Tuffen et al., *Geology* 2003), an hypothesis which he consolidated

via detailed textural analysis (Tuffen and Dingwell, *Bulletin of Volcanology* 2005) and innovative laboratory experiments (Tuffen et al., *Nature* 2008). Alone, these three studies have been cited over 375 times; amongst which, collaborations with geophysicists and geochemists have resulted in the integration of this concept into a magma ascent model capable of explaining geophysical (Neuberg et al., *JVGR* 2006) and geochemical (Castro et al., *EPSL* 2012) data monitored during volcanic unrest. In his 16 years of activity, Hugh has collaborated with 102 co-authors, resulting in over 50 peer-reviewed studies which have been cited some 1800 times. Hugh's etiquette makes him an excellent collaborator (as alluded by his supporters) as he engages himself fully in the work he undertakes with others; whilst also excelling at raising a growing family and acting as Director of the MSc. program in volcanology at the University of Lancaster. In closing, I hope you will agree with our view that Hugh is an excellent volcanologist who has contributed immensely to our knowledge of volcanic processes and who will continue to do so and act as an ambassador for the UK volcanology for years to come."

Unfortunately Hugh suffered a serious cycle accident in November last year and is still recuperating. As a result, he is unable to give his planned keynote presentation **"Rhyolitic conduits: from Icelandic fossils to Chilean eruptions"** the abstract of which is included in this volume. However, we are hoping he will be able to attend in person to collect his award and make a short acceptance speech. We hope you will join us all in wishing Hugh a full and speedy recovery.

The Willy Aspinall Prize Winner: Dr William Hutchison

Since completing his Ph.D. at Oxford University on 2015, where he studied silicic peralkaline volcanism in the Main Ethipian Rift, Will has continued his interest in applied volcanology and has moved to undertake a post-doc in St Andrews working with the HiTech AlkCarb project to develop new geochemical prospecting tools for rare earth element resources at alkaline igneous complexes.

The Willy Aspinall Prize may be made annually to the lead author of an Outstanding Paper on Applied Volcanology published (in English) within three years of the lead author being awarded a PhD at a university in the UK. The Prize is named in honour of Professor Willy Aspinall, a distinguished professor at the University of Bristol and a hazard and risk science consultant. His main research interests are in volcano geophysics, monitoring of volcanoes, early warning, volcanic hazards and risk assessment.

The 2018 Prize Winner is Dr William Hutchison. Edited excerpts from the nomination are as follows: "Will was awarded his Ph.D. from Oxford in 2015, publishing 4 papers from his Ph.D. work on silicic peralkaline volcanism in the Main Ethiopian Rift (MER), inspired in part by the assessment of Willy Aspinall who identified them as amongst the least studied on Earth (Aspinall et al., 2011). The nomination is based on Will's 2016 paper in *Geochemistry, Geophysics, Geosystems* entitled **'Causes of unrest at silicic calderas in the East African**

Rift: New constraints from InSAR and soil-gas chemistry at Aluto volcano, Ethiopia'. In this paper Will analysed satellite (InSAR) data to reveal the temporal and spatial characteristics of the 2008-2010 ground deformation episode, in order to place new constraints on the plumbing of Aluto and yield broader insights into the behaviour of rift volcanic systems. He showed that deformation time-series revealed pulses of accelerating uplift that transition to gradual long-term subsidence. New measurements of the geochemistry of gases escaping along the major fault zone of Aluto showed high CO_2 flux, and a clear magmatic carbon signature (CO_2-$\delta^{13}C$ of -4.2‰ to -4.5‰): i.e. new and compelling evidence that the magmatic and hydrothermal reservoirs of the complex are physically connected. Will suggested that a coupled magmatic-hydrothermal system can explain the uplift-subsidence signals and hypothesized that magmatic fluid injection and/or intrusion in the cap of the magmatic reservoir drives edifice-wide inflation while subsequent deflation is related to magmatic degassing and depressurization of the hydrothermal system. Taken together (Hutchison et al., 2015, 2016b, 2016c), his work represents a significant advance in understanding volcanic processes and hazards on a regional scale, transforming our understanding of Aluto's eruptive history and its current unrest. The work also establishes the context of the broader volcanic hazards and processes present in the MER more generally, where Aluto can be regarded as a 'type' volcano. His work directly underpinned elements of the RiftVolc NERC large grant that is now working in this area and catalysed 4 'follow-on' MSc projects and several PhD projects.
At this meeting, Will's keynote presentation is **"New geophysical and geochemical constraints on the plumbing of Ethiopia's restless rift volcanoes"**, the abstract of which is presented in this volume.

Keynote Speaker: Dr Madeleine Humphreys

completing her PhD on magmatic processes and eruption dynamics at Shiveluch Volcano at the University of Bristol in 2006, Madeleine's research interests have lain in petrology, geochemistry and volcanology. She focuses on understanding magma generation, migration and storage, and the role of volatiles in the generation, evolution and eruption of magmas, using the chemistry of the rock record to answer fundamental questions relating to the formation and differentiation of the Earth's crust through volcanic processes. Dr Humphries has particular interests in understanding the role of volatiles in subduction zone volcanism; and in constraining and tracking oxidation state during magma fractionation and ascent. Current projects include developing methods for using apatite volatile chemistry to produce quantitative, thermodynamically-based interpretations of pre-eruptive magmatic volatile systematics; and identifying signatures of repetitive magma intrusion, open-system degassing and hybridisation in volcanic systems using amphibole chemistry.

The title of her keynote presentation is **"Amphibole reveals the hidden complexity of lower crustal magma plumbing systems at arcs"**, and her co-authors are George F. Cooper, Jing Zhang, Matthew Loewen, Colin G. Macpherson and Jon P. Davidson.

Subduction zone volcanoes overlie complex plumbing systems in which magmatic components interact during magma storage at a range of pressures. This shallow magma assembly obscures information about deeper crustal processes, and bulk rock compositions therefore hide complexity that can inform us about the structure and composition of the continental crust. Melt inclusions provide an effective window onto the uppermost 10-15 km of sub-volcanic plumbing systems but it remains challenging to understand processes operating in the lower crust, as identified by geophysical anomalies.

We present a new multiple regression analysis of trace element partitioning in amphibole, which allows us to invert the measured trace element compositions of amphibole crystals to find the compositions of their parent melts, here applied to Mount St Helens volcano, USA. Evolved melts crystallised Mg-hornblende and are in equilibrium with the least evolved, plagioclase-hosted melt inclusions. Melts that crystallised Mg-hastingsite reflect an earlier stage of amphibole-dominated fractionation at high pressures (>300 MPa).

A wide variability of Nb, Zr and REE concentrations in the calculated amphibole equilibrium melts indicates assimilation of partially-remelted, older intrusive material containing biotite + zircon + apatite at mid-crustal levels. This emphasises the importance of repeated episodes of intrusion and remobilisation during the formation of arc magmas, and demonstrates how efficiently the different magmatic components are homogenised during shallow-pressure magma assembly.

Conference Programme

Tuesday 2nd January 2018

17:00 – 20:00	Arrival, pre-registration and meet-and-greet at the Cuthbert Brodrick pub, Millennium Square, Leeds. *See inside back cover for directions.*

Wednesday 3rd January 2018

09:00 – 10:00	Arrival, registration and meet-and-greet at the Leeds City Museum, Millennium Square, Leeds. *See inside back cover for directions*
10:00 – 10:15	Welcome Address
	House-keeping and questions
10:15 – 10:30	Thermo Fisher Scientific VMSG Award Winner: HUGH TUFFEN
	Thematic Session: Volcanic Arcs 1 *Chairs: Dan Morgan & Patrick Sugden*
10:30 – 11:00	Keynote 1: MADELEINE C.S. HUMPHREYS ET AL., Amphibole reveals the hidden complexity of lower crustal magma plumbing systems at arcs.
11:00 – 11:30	Tea/coffee break and posters
11:30 – 11:45	DIEGO GONZÁLEZ-GARCÍA ET AL., Diffusion of trace elements during mixing of shoshonitic and rhyolitic magmas: an experimental study.
11:45 – 12:00	EDUARDO MORGADO ET AL., What happens before a no-warning explosive eruption? The 2015 Calbuco Volcano eruption, Southern Chile.
12:00 – 12:15	MICHAEL D HIGGINS ET AL., Evolution of the Kameni Islands volcanic centre (Greece) from chemical and textural studies.
12:15 – 12:30	SARA DI SALVO ET AL., Unravelling magmatic system dynamics through *in situ* isotopic micro-analyses: insights into the Campanian Ignimbrite activity (Campi Flegrei, Italy).
12:30 – 13:30	Lunch break and posters
	Thematic Session: Volcanic Arcs 2 *Chairs: Dan Morgan & Eduardo Morgado*
13:30 - 13:45	P.J. SUGDEN ET AL., Volcanism in continental collision zones can sample ambient mantle heterogeneity.
13:45 - 14:00	ALEX BURTON-JOHNSON ET AL., A tectonic control on the timing, chemistry and scale of voluminous pulsed intrusive magmatism: Evidence from the Lassiter Coast, Antarctic Peninsula.
14:00 – 14:15	AMELIA A. BAIN ET AL., Insights on the dynamics of cyclic vulcanian explosions from textural, SO_2 and seismic data from Galeras volcano, Colombia.

14:15 – 14:30	BRENDAN T. MCCORMICK KILBRIDE ET AL., Satellite observations of lava and gas fluxes from Bagana volcano.
14: 30 – 14:45	FABIEN ALBINO ET AL., Analysis of ground deformation signals before and during the 2017 Agung eruption: Insights from InSAR data and numerical modelling.
14:45 – 15:00	Poster briefing – Volcanic Arcs
15:00 – 15:30	Tea/coffee break and posters – *supported by Nikon*
	Thematic Session: Explosive Ideas *Chairs: Jurgen Neuberg & Rodrigo Contreras-Arratia*
15:30 – 15:45	MATTHEW GADDES ET AL., Automatically isolating and monitoring signals of volcanic unrest in InSAR time series.
15:45 – 16:00	LUKE N. HEPWORTH & BRIAN O'DRISCOLL, Braided peridotite sills in the Rum Layered Suite, Scotland.
16:00 – 16:15	AMY P. KELLY ET AL., Linking precious metal enrichment and halogen cycling in the Rum Layered Suite, NW Scotland
16:15 – 16:30	THOMASINA V. BALL & JEROME A. NEUFELD, Modelling Laccoliths: Fluid-Driven Fracturing in the Lab.
16:30 – 16:45	ERY C. HUGHES ET AL., Measuring Fe oxidation state of silicate glasses using EPMA: Time-Dependent Ratio Flank Method.
16:45 – 17:00	Poster briefing – Explosive Ideas 1
17:00 – 19:00	Poster Session A – Icebreaker Reception

NB Student presentations are shaded.

Thursday 4th January 2018

	Thematic Session: Rifts 1 *Chairs: Dave Ferguson & Luke Marsden*
09:00 – 09:30	Keynote 2: Willy Aspinall Prize Winner: WILLIAM HUTCHISON, New geophysical and geochemical constraints on the plumbing of Ethiopia's restless rift volcanoes
0930 – 09:45	CHRIS MOORE ET AL., InSAR Observations of the On-going 2017 Eruption of Erta 'Ale Volcano, Afar.
09:45 – 10:00	FIONA IDDON ET AL., Missing Melts: Examining Across Rift Variations in Magma Storage at Aluto and Butajira, Main Ethiopian Rift.
10:00 – 10:15	ANDY NOWACKI ET AL., Hydrothermal fluid pathways beneath Aluto volcano, Main Ethiopian Rift, from seismic anisotropy.
10:15 – 10:30	JENNIFER WOODS ET AL., Long-period seismicity reveals magma pathways above a propagating dyke during the 2014-15 Bárdarbunga rifting episode, Iceland.
10:30 – 11:00	Tea/coffee break and posters
	Thematic Session: Rifts 2 *Chairs: Dave Ferguson & Chris Moore*
11:00 – 11:15	R.G.W. SEIDEL ET AL., Identification of Primary Tephra Layers on the SW Icelandic Shelf.
11:15 – 11:30	EUAN J. F. MUTCH ET AL., Rapid magma transport from the lower Icelandic crust.
11:30 – 11:45	JEANNE M. GINIAUX ET AL., The Askja magma plumbing system (Iceland), an interesting puzzle.
11:45 – 12:00	THORBJÖRG ÁGÚSTSDÓTTIR ET AL., The 2014-15 Bárðarbunga-Holuhraun magmatic rifting event: A seismic study.
12:00 – 12:15	JOHN MACLENNAN, Rapid Cooling and Protracted Storage in Thin Lower Crustal Sills.
12:15 – 12:30	Poster Briefing – Rifts

12:30 – 13:30	Lunch break and posters [student forum]
	Thematic Session: Rifts 3 *Chairs: Dave Ferguson & Jeanne Giniaux*
13:30 – 13:45	RODRIGO CONTRERAS ARRATIA ET AL., Curved Seismic Sources for LP Events in Volcanic Environments: Model and Radiation Patterns.
13:45 – 14:00	EMMA N. BENNETT ET AL., The significance of plagioclase textures in mid-ocean ridge basalt.
14:00 – 14:15	SALLY A. GIBSON & MARK A. RICHARDS, Delivery of deep-sourced, volatile-rich plume material to the global ridge system.
14:15 – 14:30	ROBERT GOODAY ET AL., The Palaeogene magmas of Arran: genesis, storage, and emplacement.
14:30 – 14:45	EMMA ROBERTS ET AL., The heterogeneity of the Miocene Iceland mantle plume.
14:45 – 15:00	Poster briefing – Rifts
15:00 – 15:30	Tea/coffee break and posters – *supported by Nikon*
	Thematic Session: Explosive Ideas 2 *Chairs: Jurgen Neuberg & Dinko Sindija*
15:30 – 15:45	MARTIN MANGLER ET AL., Recharge, recycle, repeat: The steady-state plumbing system of Popocatépetl volcano, Mexico.
15:45 – 16:00	CLAIRE HARNETT ET AL., A discrete-element approach to modelling lava dome stability.
16:00 – 16:15	RYUNOSUKE KAZAHAYA ET AL., Pre-eruptive inflation caused by gas accumulation: Insight from detailed gas flux variation at Sakurajima volcano, Japan.
16:15 – 16:30	LUKE MARSDEN ET AL., Causes and relievers of stress: Coupled flow and deformation modelling to explain observed deformation at silicic volcanoes.
16:30 – 16:45	JENNI BARCLAY ET AL., More alike than different: volcanologists as storytellers.
16:45 – 17:00	Poster briefing – Beyond the Vent
17:00 – 19:00	Poster Session B – Pre-dinner drinks reception

20:00 – 01:00	Conference Dinner – Leeds Marriott Hotel

Friday 5th January 2018

	Thematic Session: Explosive Ideas 3 *Chairs: Susi Ebmeier & Claire Harnett*
09:00 – 09:15	C. SATOW ET AL., Do Sea Level Changes Influence Eruptive Activity on Island Volcanoes?
09:15 – 09:30	DAVID M. BUCHS ET AL., Non-Hawaiian lithostratigraphy of Louisville seamounts and the formation of oceanic islands and guyots.
0930 – 09:45	STEFAN M. LACHOWYCZ ET AL., Statistical analysis of volcano monitoring time-series.
09:45 – 10:00	J.I. FARQUHARSON & F.B. WADSWORTH, Introducing Volcanica: a paradigm shift in academic publishing.
	Thematic Session: Beyond the Vent 1 *Chairs: Susi Ebmeier & Claire Harnett*
10:00 – 10:15	BEN ESSE ET AL., IFRiT: a new tool for measuring volcanic SO_2 flux from scattered solar UV light.
10:50 – 10:30	MELANIE RAY ET AL., A new view of Ritter Island Volcano, Papua New Guinea.

10:30 – 10:45	SAPPHIRE WANMER ET AL., A bug's death: PDC-water interactions indicated by diatom-bearing ash aggregates in the Columbia River Flood Basalt Province.
10:45 – 11:15	Tea/coffee break and posters
11:15 – 11:30	EVGENIA ILYINSKAYA ET AL., Unseen but not unfelt: resilience to persistent volcanic emissions (UNRESP). Case study from Masaya volcano, Nicaragua.
11:30 – 11:45	MICHAEL J. HEAP ET AL., 50 shades of ignimbrite: How hydrothermal alteration modifies permeability and strength.
11:45 – 12:00	C. HAYER ET AL., Comparison of satellite observations of atmospheric emissions from the April 2015 eruption of Calbuco volcano.
12:00 – 12:15	VERITY J. B. FLOWER & RALPH A. KAHN, Interpreting volcanic eruptions using space-borne remote sensing instruments.
12:15 – 12:30	Student prize-giving
12:30 – 13:00	Volcanic and Magmatic Studies Group AGM Conference Closes

End of Conference

For those staying on for the workshops, information is as follows

13:30 – 15:00	Writing Workshop part one (Olga Degtyareva)
15:00 – 15:30	Tea/coffee break
15:30 - 16:30	Writing Workshop part two (Paul Cumine)
16:30 – 17:00	Writing Workshop part three (Melissa Plail)

POSTERS – Wednesday 3rd January

Volcanic Arcs

1	Late Cretaceous magmatism in central Tibet: evidence for orogenic delamination and crustal thickening prior to India-Asia collision? LI-LONG YAN, KAI-JUN ZHANG & ANDREW C. KERR
3	Identifying molybdenum isotope variations in slab-derived fluids at the Izu arc, Japan. J. VILLALOBOS-ORCHARD, M. WILLBOLD, H. FREYMUTH & B. O'DRISCOLL
5	Protracted near-solidus storage and pre-eruptive rejuvenation of large magma reservoirs. DAWID SZYMANOWSKI, JÖRN-FREDERIK WOTZLAW, BEN ELLIS, OLIVIER BACHMANN, MARCEL GUILLONG & ALBRECHT VON QUADT
7	The Role of the Mantle and Crust in High-Volume Silicic Volcanism. J.E. HUTCHINSON, M.K. REICHOW & T. BARRY
9	Formation and Eruption of Silicic Magmas by Crustal Melting. ALEXANDRA F. GUTAI, ANDREW WOODS & MARIE EDMONDS
11	The influence of temperature on permeability evolution in Volcán Chaitén rhyolite: An experimental approach. AMY L. CHADDERTON, PETER SAMMONDS, PHILIP MEREDITH, ROSANNA SMITH & HUGH TUFFEN
13	Diamondite-formation reveals subduction-related carbonaceous melt metasomatism in the sub-continental mantle beneath Orapa, Botswana. MIKHAIL, S., MCCUBBIN, F.M., JENNER, F.E., RUMBLE, D. & SHIREY, S.B.
15	Magmatic activity during subduction initiation along the Caribbean oceanic plateau. JOANNA C. BRIMS, DAVID BUCHS & ANDREW C. KERR & ARKIN TAPIA
17	Magma – crust interaction at Gunung Guntur, west Java, Indonesia. COLIN MACPHERSON, ROBERT HALL, CAROLINE EDWARDS, MATTHEW THIRLWALL & MARTIN MENZIES
19	Magma mixing at Campi Flegrei caldera detected from high-resolution trace element mapping. REBECCA L. ASTBURY, TERESA UBIDE, MAURIZIO PETRELLI, ILENIA ARIENZO, MASSIMO D'ANTONIO & DIEGO PERUGINI
21	An Ash Shape and Componentry Study of the 2015 – 2016 Eruption of Momotombo, Nicaragua. YANNICK WITHOOS & KATHARINE CASHMAN
23	Plutonic Xenoliths from Santorini Volcano, Aegean Arc, Greece. SEAN WHITLEY, RALF HALAMA, RALF GERTISSER, THOR HANSTEEN & MATTHIAS FRISCHE
25	Alkaline magmas in collision zone settings: Age and petrogenesis of the Tezhsar Alkaline Complex, Armenia. KRZYSZTOF SOKOL, RALF HALAMA, KHACHATUR MELKSETIAN, IVAN SAVOV & MASAFUMI SUDO
27	The Role of Accurate Earthquake Locations in the Mapping of a Volcanic Plumbing System. JADE H. W. EYLES, JESSICA H. JOHNSON, PADDY J. SMITH & JENNI BARCLAY
29	Experimental and isotopic constraints on the deep magmatic plumbing system of the Taupo Volcanic Zone, New Zealand. SALLY LAW, KATE SAUNDERS, GEOFF BROMLEY, GEOFF KILGOUR, ADRIAN BOYCE & NICCI POTTS
31	Plutonic xenoliths provide evidence for differentiation and storage in a volatile rich, polybaric mush beneath Statia, Lesser Antilles Volcanic Arc. GEORGE F. COOPER, JON D. BLUNDY , COLIN G. MACPHERSON & JON P. DAVIDSON
33	Dyke propagation paths in heterogeneous volcanoes. KYRIAKI DRYMONI, JOHN BROWNING & AGUST GUDMUNDSSON
35	InSAR investigation into the 2014 eruption of Kelud volcano.

Explosive Ideas

POSTERS – Thursday 4th January

Rifts

2	Tracing volatiles in Earth's mantle using He-C-N isotopes in garnet-bearing diamondites. JAMES CROSBY, SAMI MIKHAIL, FIN STUART & FEARGUS ABERNETHY
4	Insights into subvolcanic architecture from magnetic techniques. CHARLOTTE GORDON & WILLIAM MCCARTHY
6	Evidence for largescale melt interaction in Rum Igneous Complex. ELOISE BRETAGNE & JULIEN LEUTHOLD
8	Fenitization as a Window into Processes at Ol Doinyo Lengai, Tanzania. FELIX BOSCHETTY, ADRIAN JONES & EMMA HUMPHREYS-WILLIAMS
10	Isotopic and field evidence for the crustal interaction of alkaline rift magmatism in the Gardar Province, South Greenland. ANDREW JAMES WHYTE, WILLIAM HUTCHISON & ADRIAN A. FINCH
12	The structure and eruptive dynamics of three peralkaline rift volcanoes using high-resolution digital elevation models. JONATHAN A. HUNT, TAMSIN A. MATHER & DAVID M. PYLE
14	Halogen heterogeneity in the Icelandic mantle source. EMMA C. WATERS, MARGARET E. HARTLEY, RAY BURGESS, ALISON PAWLEY, SÆMUNDUR A. HALLDÓRSSON & OLIVER SHORTTLE
16	The younger volcanic units of the Central Atlantic Magmatic Province: implications for reconstructing distal effects of Large Igneous Provinces. LAWRENCE M.E. PERCIVAL, JESSICA H. WHITESIDE, S.T. KINNEY, A.R. PHILPOTTS, PAUL E. OLSEN & TAMSIN A. MATHER
18	Crystal Cargoes of the Mauna Ulu Eruption (1969-74), Kilauea Volcano. PENNY WIESER, MARIE EDMONDS & JOHN MACLENNAN
20	Characterizing of a dike intrusion and its interaction with a volcano centre in Main Ethiopian Rift. TESFAYE T. TESSEMA, JULIET BIGGS & ELIAS LEWI
22	Recycled volatiles in supra-subduction zone melt channels from the Leka Ophiolite Complex, Norway. ELLIOT CARTER, BRIAN O'DRISCOLL, RAY BURGESS & PATRICIA CLAY
24	A Petrogenetic Study of East Siberian Intrusives and their Links with the Siberian Large Igneous Province. JOSEPH P. GREEN, MARC K. REICHOW & TIFFANY L. BARRY
26	Geothermal activity at Bárdarbunga, Iceland, following the 2014–15 caldera collapse, investigated using geothermal system modelling. HANNAH I. REYNOLDS, MAGNÚS T. GUDMUNDSSON & THÓRDÍS HÖGNADÓTTIR
28	Influence of crustal processing on the identification of mantle heterogeneity. MATTHEW L.M. GLEESON, SALLY A. GIBSON & MICHAEL J. STOCK
30	Critical eruptive controls of an intraplate volcano: Ascension Island. BRIDIE V. DAVIES, KATY CHAMBERLAIN, JENNI BARCLAY, RICHARD BROWN & KATIE PREECE
32	Gutanasar Volcanic Complex, Armenia: Evolution, Eruption and Hazards. THOMAS OLVER & CHRISTINA J. MANNING
34	Evaluating oxygen fugacity proxies in basalts from the Reykjanes Ridge, Iceland. D. NOVELLA, J. PRYTULAK, J. MACLENNAN, O. SHORTTLE & B.J. MURTON
36	Petrological and geochemical evolution of Arthur's Seat Volcano. HUA, X., CORTÉS, J.A., SAUNDERS, K.E. & POTTS, N.J.
38	Primordial and recycled geochemical signatures in the Icelandic mantle: A noble gas perspective.

Beyond the Vent

76	The dispersion pattern of sulphate, fluoride and chloride released by the degassing of Masaya Volcano, Nicaragua and the impact on soil, water and rain composition. ISOBEL E. MANNION, EVGENIA ILYINSKAYA, SEBASTIAN NOBERT, XOCHILT HERNANDEZ LEIVA & HILARY FRANCIS
78	Characterising and spatialising the interactions between people, animals, volcanic hazards, and local perceptions and responses to Popocatépetl volcano, Mexico. MIHAIELA L. SWIFT, AMY DONOVAN & CHIARA MARIA PETRONE
80	Assessment of suitable Particle Size Distributions (PSDs) for modelling ash dispersal of magmatic and phreatomagmatic Icelandic eruptions. EVEANJELENE SNEE, ALISON RUST, KATHERINE CASHMAN & FRANCES BECKETT
82	Emplacement of an andesitic hyaloclastite-lava lobe complex and implications for paleoenvironment at pre-160 ka Ruapehu Volcano, NZ. ROSIE P. COLE, JAMES D.L. WHITE, DOUGAL B. TOWNSEND & GRAHAM S. LEONARD
84	Characterising the explosive episodes of flood lava eruptions: 10th century Eldgjá, Iceland. WILLIAM M. MORELAND, THOR THORDARSON, BRUCE F. HOUGHTON & GUDRUN LARSEN
86	Pyroclastic Density Currents: the influence of variable aeration on deposit formation. GREGORY M. SMITH, REBECCA WILLIAMS, PETER ROWLEY & DANIEL J. PARSONS
88	Spectral Emissivity of eruptive products using laboratory based FTIR and Thermal Remote Sensing analysis of same area targets. NIKOLA ROGIC, FABRIZIO FERRUCCI, HAZEL RYMER & STEPHEN BLAKE
90	Aftermath of the 2015 Calbuco eruption, southern Chile: complex morpho-sedimentary responses to explosive volcanism. VERN MANVILLE, ROBBIE JONES & ELIZA CALDER
92	Using trace element chemistry to correlate distal ignimbrite outflow sheets from Langdale Caldera, English Lake District. EDWARD MCGOWAN, GREGOR HAHN, BEN CLARKE, PHIL LEAT & MICHAEL J. BRANNEY
94	Geochemical correlation of ancient pyroclastic sheets from the nested calderas of the Borrowdale Volcanic Group, N.W. England. GREGOR HAHN, MIKE J. BRANNEY, PHILIP T. LEAT & BEN CLARKE
96	The Pulsatory Nature of Bagana Volcano, Papua New Guinea. REBECCA COUCHMAN-CROOK, GEOFF WADGE & JULIA CRUMMY
98	Evaluating alternative scenarios for the 1973 Heimaey Eruption. CARA PEDLEY, EMILY LEWIS, LAURA SMITH, SARAH THOMAS, GRAHAM FERRIER, DAVID MILAN & MIKE WIDDOWSON
100	Acid dissolution of volcanic rocks: the evolution of strength and permeability. J.I. FARQUHARSON, B. WILD, M. HEAP, B. KENNEDY & P. BAUD

NB Student presentations are shaded. Presenter is underlined.

Workshops

Workshop 1: PhD writing and how to get your paper published

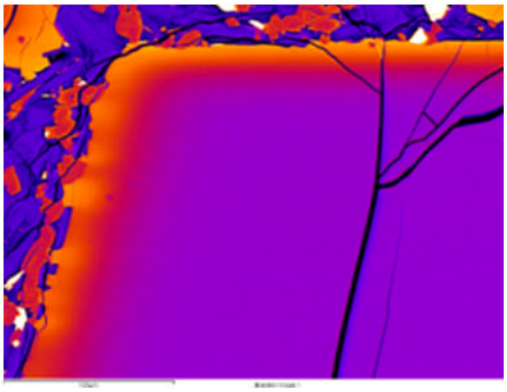
Led by: Dr Olga Degtyareva (olgadegtyareva@gmail.com) Productivity for Scientists Ltd., Paul Cumine, publisher of the Journal of Volcanology and Geothermal Research, Elsevier, and Melissa Plail, Associate Editor, Nature Communications
Venue: Leeds City Museum, Denny Room
Time: 1:30 pm - 5 pm Friday 5th January 2018
Places available: 30
Cost: £20

Part 1: Do you need to write up your thesis or research paper but keep getting stuck with it? You are not alone, many researchers struggle. Even when we know we should be writing we find it difficult to actually sit down to write. Instead we get ourselves busy with all the other things we have on our plate. When we finally find time for writing, we struggle to make a start. We worry that we have not read enough, that the supervisor won't like it, that it will take too long and that it won't be good enough. And then we don't write. Week after week (and sometimes months and years) go by and that abstract, paper or thesis is still not written. Sound familiar? Well, in this workshop we are going to discuss these exact challenges and the strategies to overcome procrastination and to start writing. You'll get step-by-step guidance so that you too can start writing, grow content fast and stay on track until completion. Come to this workshop to get the strategies and motivation to start writing, get your questions answered and actually get some writing done.

Part 2: arranged by Elsevier, will provide an introduction to journal publishing with a focus on the peer-review process and how to prepare your manuscript for submission. It will cover the nuts and bolts of writing an article, with tips on how to prepare a manuscript, how to choose the right journal, and suggestions on how to deal with comments from reviewers. There will also be the chance to discuss matters such as author rights, open access publishing, publication ethics, getting your paper noticed, and impact metrics.

Part 3: Melissa Plail, an Earth Science Editor at, Nature Communications, will give a presentation about publishing with *Nature Research* journals. Melissa is a volcanologist and is responsible for the solid Earth and Planetary Science content at *Nature Communications*. The presentation will include information about the editorial process at *Nature* journals, how to pitch high impact research and what makes a good cover letter, title and abstract.

Workshop 2: An introduction to diffusion modelling in crystal systems: volcanic timescale recovery

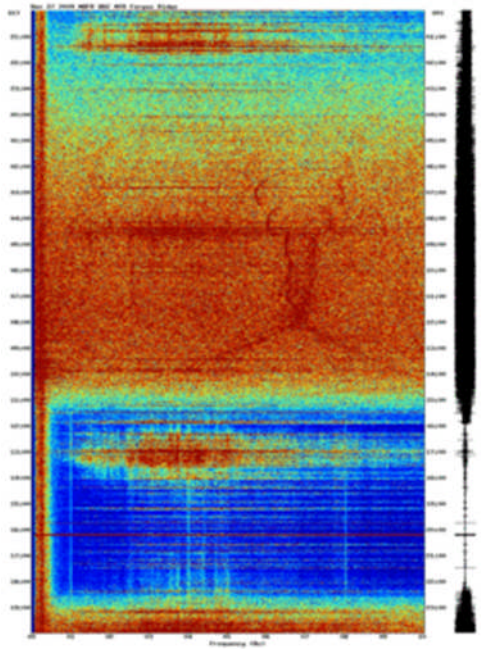


Led by: Dr Dan Morgan, SEE, University of Leeds (d.j.morgan@leeds.ac.uk)
Venue: School of Earth and Environment, Earth Visualisation Laboratory (level 10)
Time: 9 am – 4 pm Saturday 6th January 2018
Places available: 20
Cost: Free

This short workshop provides an introduction to modelling diffusion profiles in volcanic phenocrysts, via a combination of recorded lectures and hands-on workshop sessions. It is intended for those who have not undertaken such a course before and includes the rationale, basic methods and simple modelling, and might be suitable preparation for a more intensive course (such as the annual courses held in Bochum). Some course materials will (hopefully) be made available as interactive PDF's before the workshop, giving time to ask questions. The workshop itself will cover:

- Defining, building and executing simple models based on analytical solutions,
- Complexities such as anisotropy and composition dependence
- Generation and identification of "false positives", integration with other data sets, and calculation of uncertainties.

Workshop 3: Volcano Seismology



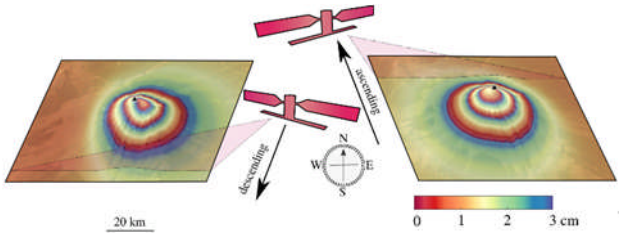
Led by: Professor Jurgen Neuberg, SEE, University of Leeds (j.neuberg@leeds.ac.uk)
Venue: School of Earth and Environment, 9.162B
Time: 9 am - 4 pm Saturday 6th January 2018
Places Available: 30
Cost: Free

This one-day workshop will focus on two types of seismic signal that are particularly important in volcanic environments: Very Long Period seismic signals (VLPs) and low-frequency (or long-period) volcanic earthquakes (LPs). These transient signals are thought to be generated by magma or gas movement and fill the gap between deformation monitoring and classic (short-period) seismic monitoring and can shed light on magma properties and conduit geometry as well as playing a role in

the forecasting of dome collapse and dome eruptions. Although the growing availability of broadband seismometers makes it now possible to detect ground motion with periods of up to 1000s, such signals are often neglected because of the additional processing required. The workshop is suitable for post-graduate level non-seismologists, however, a basic mathematical understanding of spectral analysis, differentiation and integration would be helpful. The workshop itself will cover:

- A brief theoretical introduction to VLP and LP seismic signals,
- Hands-on computer exercises utilising the processing steps needed to detect and identify VLP and LP events,
- Further exploration of the character of these seismic signals and their interpretation.
-

Workshop 4: InSAR 101: Interpreting interferograms for volcanologists



Led by: Dr Susi Ebmeier, SEE, University of Leeds (s.k.ebmeier@leeds.ac.uk)
Venue: School of Earth and Environment, 9.162A
Time: 9 am – 4 pm
Saturday 6th January 2018
Places Available: 10
Cost: Free

This workshop is suitable for those who have never used InSAR before but are interested in understanding the method better, either to make use of new global displacement data, or simply to examine interferograms that other people have created with a critical insight. This workshop will include:

- Introductory level lectures on how InSAR works, how it is used for various applications in volcanology and how to interpret interferograms.
- Practical exercises introducing (1) how to find and download InSAR data to analyse, and (2) GBIS software for inverse deformation modelling.

ABSTRACTS

In alphabetical order by first author

The 2014-15 Bárðarbunga-Holuhraun magmatic rifting event: A seismic study

THORBJÖRG ÁGÚSTSDÓTTIR*[1], JENNIFER WOODS[1], ROBERT S. WHITE[1], TIM GREENFIELD[2], BRYNDÍS BRANDSDÓTTIR[3], THOMAS S. HUDSON[1]

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On 16 August 2014 an unusual sequence of earthquakes began near the SE rim of the ice-covered Bárðarbunga caldera in central Iceland. Over the course of 2 weeks a dyke propagated 48 km beneath the glacier northeastwards and into the Holuhraun lava field, where it erupted for 6 months. It became the largest eruption in Iceland for 230 years. During this time, a gradual, incremental caldera collapse took place at the central volcano. We use accurate relative earthquake locations of ~48,000 earthquakes to analyse the seismic response to the event, both due to the dyke propagation, and the subsequent caldera collapse. We define the thickness of the seismogenic crust under Bárðarbunga as ~ 7 km, based on the depth extent of observed seismicity. The bulk of the seismicity directly beneath the volcano is located at 1-4 km below the surface, whereas the dyke exited the caldera at 4-6 km depth, propagating at ~ 6-8 km b.s.l..

Approximately 5,000 of the recorded earthquakes are associated with the caldera collapse, delineating faults accommodating the subsidence and showing good correlation with geodetic data. The seismicity reveals activation of both inner and outer caldera faults with ~60° inward dipping planes, but with an order of magnitude difference in the cumulative seismic moment on the northern and southern sides. Detailed analysis of the source mechanisms shows that ~90% of the events can be explained by double couple failure. We find the dominant failure mechanism during the collapse to be steep normal faulting, with sub-vertical P-axes, and fault planes striking sub-parallel to the caldera rim. The southeastern part of the caldera, whilst experiencing less activity, shows a mixture of failure mechanisms, owing to the interaction of the caldera collapse and the dyke exit. We suggest a complex asymmetric caldera collapse, not controlled by a single caldera ring fault.

Analysis of ground deformation signals before and during the 2017 Agung eruption: Insights from InSAR data and numerical modelling

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Starting in late November, 2017, Agung volcano, located in Bali, erupted, ending more than 50 years of quiescence. A rapid increase in seismicity in late September led to the evacuation of over 100,000 people for several weeks. The eruption itself started with a phreatic phase rapidly followed by a magmatic phase producing an ash plume reaching about 2-4 km above the crater. The previous eruption in 1963 killed several thousand people, and for the current eruption the economic losses associated with the airport closures and evacuations are still being counted. Ground-based monitoring is limited in spatial resolution, thus satellite data have played a key role in monitoring the evolving unrest and eruption. We report on InSAR data at Agung volcano from April 2017 to December 2017, from the Sentinel and ALOS-2 satellites. Agung lies in a humid, coastal region and has steep topography. Atmospheric artefacts therefore occur in most interferograms, which led to several false, but alarming, reports on Twitter of apparent deformation. In this study, we use the GACOS (Generic Atmospheric Correction Online Service) atmospheric corrections generated from high resolution ECMWF weather data. Starting in late September 2017, ALOS and Sentinel interferograms show an uplift signal on the north flank of the edifice, reaching ~ 10 cm just before the eruption. During the eruption, this signal switched to subsidence, totalling 2-3 cm by the end of November. Since the deformation pattern is asymmetric with respect to the peak, and in an area of steep topography, we use numerical modelling to infer the magmatic source(s) responsible for the pattern of observed ground deformation.

Investigating the geochemistry of the interglacial lavas from the Lýsuskarð volcanic system, Iceland

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Located on the off-rift Snæfellsnes peninsula in the west of Iceland, Lýsuskarð is a polygenetic volcano active over the Quaternary. Its products are basalts and hawaiites, with some rhyolites. Samples exhibit some of the highest values for Nb/Zr and La/Yb on the entire peninsula which, when combined with relatively high Dy/Yb, suggest potentially small degree melting in equilibrium with garnet.

Unlike elsewhere in Iceland, the Lýsuskarð samples do not exhibit the expected end-member isotopic enrichment. Instead, a unique negative correlation between increasing incompatible element enrichment and Sr-Pb isotopic ratios is observed in lavas from Lýsuskarð, which does not conform to relationships seen elsewhere in Iceland.

Lead is an effective indicator for identifying potential source components and mixing processes producing the lavas at Lýsuskarð, because mixing relationships in Pb-Pb isotopic space are linear. Icelandic lavas have unusually low $^{207}Pb/^{204}Pb$ for their $^{206}Pb/^{204}Pb$ (negative $\Delta^{207}Pb$) which, when combined with low K/Nb, has been interpreted to be the result of a component of subducted uranium-rich, Palaeozoic oceanic crust, which is tapped by upwelling of the mantle plume (Thirlwall et al., 2004). Samples from Lýsuskarð, despite having intermediate $^{206}Pb/^{204}Pb$, display some of the most negative $\Delta^{207}Pb$ values in Iceland, which would require significantly older recycled crust than inferred by Thirlwall et al., 2004.

Thirlwall, M. F. et al., 2004. Geochimica et Cosmochimica Acta. 68: 361-386

Magma mixing at Campi Flegrei caldera detected from high-resolution trace element mapping.

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The Astroni volcano, located within the Agnano-Monte Spina volcano-tectonic collapse zone, formed 3.88 – 3.82 ka BP, during the third epoch of activity of the Campi Flegrei caldera (CFc), Italy. The evolution of Astroni deserves further study because, unlike other documented activity within the CFc, which is mainly monogenetic, the preserved tuff ring of the volcano formed from seven eruptions, of varying magnitude, over a relatively short timescale.

Of particular interest, the penultimate eruption of Astroni (Astroni 6; 3.83 ka BP) began with a Plinian phase not present in the rest of the sequence. Hazard forecasting studies for the CFc area have postulated that the style and magnitude of a future medium-sized explosive event would be similar to the Astroni 6 eruption.

In this study, we focus on the composition of discrete growth zones within individual crystals from Astroni 6 to provide an in-depth understanding of the volcano's dynamic history, with implications to the evolution of the CFc. Samples for this investigation were taken across the stratigraphy, to gauge the evolution of the eruption over time. High-resolution trace element maps of phenocrysts and antecrysts, produced using laser ablation-inductively coupled plasma-mass spectrometry, highlight discrete zonations enriched in compatible elements for both feldspar (e.g. Sr and Ba) and pyroxene (e.g. Cr and Ni). These zones of enrichment indicate influxes of new magma into the system, and typically occur at the crystal rim, suggesting magma mixing may have triggered phases of the Astroni 6 eruption.

Insights on the dynamics of cyclic vulcanian explosions from textural, SO_2 and seismic data from Galeras volcano, Colombia

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Volcanic activity characterised by cyclic vulcanian explosions is a common eruptive style at arc volcanoes. If this activity occurs in populated areas, it may lead to prolonged volcanic crises that are challenging to manage. In intermediate composition magmas, vulcanian explosions are thought to result from the emplacement and explosive destruction of a degassed, densified and highly crystalline plug in the shallow conduit as a result of modest ascent rates. Continued crystallisation and degassing then generate the high pore pressures needed to drive vulcanian explosions.

We present a conceptual model of intermediate magma plug dynamics at Galeras volcano, Colombia, focussed on microlite crystallisation regimes, informed by textural data and SO_2 and seismic monitoring data. We differentiate between more explosive nucleation-dominated plugs and less explosive growth-dominated plugs driven by differences in effective undercooling. Explosion sequences resulting from nucleation-dominated plugs are characterised by larger ejected volumes, decreasing repose times and a more viscous melt phase. Explosion sequences resulting from growth-dominated plugs are characterised by lower ejected volumes, increasing repose times, a less viscous melt phase and may culminate in the extrusion of lava domes. We find that nucleation-dominated plugs are associated with lower SO_2 fluxes and rates of VT seismicity prior to explosions. Conversely, growth-dominated plugs are associated with higher SO_2 fluxes and rates of VT seismicity prior to explosions.

Our observations suggest that growth-dominated plugs allow more efficient outgassing, resulting in a lower frequency of explosions and lower ejected volumes, and are more likely to transition to effusive styles of volcanism. Nucleation-dominated plugs allow less efficient outgassing, resulting in a higher frequency of explosions and higher erupted volumes.

Modelling Laccoliths: Fluid-Driven Fracturing in the Lab

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Current modelling of the formation of laccoliths neglects the necessity to fracture rock layers for propagation to occur (Michaut, 2011). In magmatic intrusions at depth the idea of fracture toughness is used to characterise fracturing, however an analogue for near surface intrusions has yet to be explored (Bunger & Cruden, 2011) We propose an analytical model for laccolith emplacement that accounts for the energy required to fracture at the tip of an intrusion. For realistic physical parameters we find that a lag region exists between the fluid magma front and the crack tip where large negative pressures in the tip cause volatiles to exsolve from the magma. Crucially, the dynamics of this tip region controls the spreading due to the competition between viscous forces and fracture energy. We conduct a series of complementary experiments to investigate fluid-driven fracturing of adhered layers and confirm the existence of two regimes: viscosity dominant spreading, controlled by the pressure in the lag region, and fracture energy dominant spreading, controlled by the energy required to fracture layers. Our experiments provide the first comparison between an analytical prediction for the lag length and an experimental analogue. These experiments and our simplified model provide insight into the key physical processes in near surface magmatic intrusions with applications to fluid-driven fracturing more generally.

Michaut, C., 2011. *J. Geophys. Res.*, 116: 1–19.
Bunger, A.P. & Cruden, A.R., 2011. *J. Geophys. Res.*, 116: 1–18.

Understanding Basaltic Plinian Eruptions

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Plinian eruptions are very large magnitude events in which several cubic kilometres of volcanic material is produced in a brief time, with catastrophic impacts on the local environment around the volcano, as well as potentially profound impacts on global climate. Most Plinian eruptions have been produced by quite evolved, silica-rich magmas. However, a minority are produced by basaltic volcanism (Coltelli et al., 1998). The mechanisms driving basaltic Plinian eruptions are poorly understood. The aim of this project is to develop a new model of the driving processes which transform a relatively benign basaltic volcano into a Plinian system.

To address this issue, we will take a multidisciplinary approach, using a range of analytical, experimental and numerical techniques to examine and test diverse hypotheses on the triggering mechanisms of basaltic Plinian eruptions. Field studies of Plinian eruptions at Masaya Volcano (Nicaragua) will be undertaken to collect samples and constrain eruption timescales and mechanisms. Two Pleistocene examples of Plinian eruptions have been identified at Masaya, the Fontana Lapilli and Masaya Triple Layer. We will collect new tephra samples from these eruptions, providing a great opportunity to compare pre-eruptive volatile contents and vesicle distributions between eruptions. We will investigate crystal and vesicle textures in the erupted products in order to reconstruct vesicle size distributions and their evolution in magmas, and determine the relationship between porosity and permeability. Experimental data will then be modelled by numerical simulations in order to formulate a calibrated model of bubble nucleation and growth during magma ascent. Finally, the experimental and numerical models will be compared with the natural samples to constrain the conditions that trigger basaltic Plinian eruptions.

Coltelli, M. et al., 1998. Geology. 26(12): 1095-1098.

More alike than different: volcanologists as storytellers

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It is a truth universally acknowledged that a scientist in possession of the facts must be in want of the ability to communicate. It is time that this universal 'truth' is challenged more fully.

In volcanic crises, scientists struggle with partial, uncertain information, dynamic volcanic behaviour and trying social situations all of which present significant challenges to rapid and clear communication. Yet, significant lessons have been drawn from actions and recollections of past volcanic crises within the academic community. Even richer insights are revealed when these are combined with the 'informal' stories that pass between scientists. These convey lessons about risk-taking, precaution, the acquisition of key knowledge and confronting challenging social situations. In their structure these narratives bear strong resemblances to models for both folktales (Propp, 1968), and the narrative oral histories shared by communities impacted by volcanic activity.

In contrast, when stories told in popular culture around volcanic crises (films, documentaries, and stories) focus almost monotonically on the 'Hero's Journey' where a hero (usually a volcanologist) is called upon to save an unwitting public from certain destruction or single-handedly acquire vital new knowledge. We present our analyses of these popular stories and contrast them with the narratives of experience told by community members and volcanologists of actions and events surrounding volcanic activity.

We argue that the singular drive to narrate the 'Hero's Journey' contributes to the distance between volcanologists and the realms of normality in the popular imagination in a similar way to the usual cliché of a scientifically literate but socially awkward nerd. Further, while the creation of the journeying hero is an engaging way to tell stories it is not the only way and is not the only way lessons from past eruptions are shared. Further analysis of the stories told by both volcanologists and citizens about their real adventures, will not only reveal new ways to engage the general public but uncover important and exciting ways to communicate volcanic risk.

V. Propp. (1968) Morphology of the Folktale. University of Texas Press.

Crystal Size Distribution Analysis of Apollo 15 Mare Basalts

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A third of the lunar samples returned by the Apollo 15 mission were mare basalts. Based on differences in SiO_2, FeO and TiO_2 wt%, the Apollo 15 mare basalts can be split into a quartz-normative and an olivine-normative suite (Chappell and Green, 1973). Samples are further designated as parents, fractionates and cumulates on the basis of their whole-rock chemistry. The petrogenetic relationship between the two suites has proven to be controversial. Current theories suggest the quartz-normative suite underwent crystallisation in a series of magma chambers within the lunar crust, whilst the olivine-normative suite predominantly crystallised in lava flows on the lunar surface (Schnare et al., 2008). The aim of this study is to use crystal size distribution (CSD) analysis to better understand the magma storage, transport and eruption processes that produced the Apollo 15 mare basalts.

CSD analysis was undertaken by collecting optical and backscattered electron (BSE) images of thin sections and tracing around the boundaries of olivine, pyroxene and plagioclase crystals. The 2D traced crystal images were processed using ImageJ, CSD*slice* (Morgan and Jerram, 2006) and CSD*corrections* (Higgins, 2000) to obtain equivalent 3D crystal lengths.

Here we present CSD graphs (crystal population density vs. crystal length) for samples from both the quartz-normative and olivine-normative suites. We find several inconsistencies between CSD trends and the allocation of samples as parent, fractionates or cumulates. The quartz-normative sample 15475,15 is designated as a fractionate, yet the plagioclase CSD shows a convex-upward trend indicative of plagioclase accumulation and entrainment into the carrier melt prior to eruption. Samples which show textures that are in conflict with their designation as parent, cumulate or fractionate will also be targeted for future CSD analysis. These petrological data will provide new insights into the petrogenesis of lunar mare basalts.

Chappell & Green, 1973. EPSL 18:237–246.
Higgins, 2000. Am Min 85:1105-1116.
Morgan & Jerram, 2006. JVGR, 154:1-7.
Schnare et al., 2008. GCA 72:2556–2572.

The significance of plagioclase textures in mid-ocean ridge basalt

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Processes occurring within mid-ocean ridge plumbing systems, especially at the slowest spreading MORs, are poorly constrained. Here we use textural and compositional data from >1400 plagioclase crystals in MOR basalt from the Gakkel Ridge to investigate the physiochemical conditions and processes occurring within the sub-volcanic system of an ultraslow-spreading mid-ocean ridge.

Gakkel basalts contain complex crystal cargo, typically with both individual and poly- and mono-glomerocrysts, the glomerocrysts showing either high angle or planar component contacts. Some basalts have high modal proportions of plagioclase phenocrysts (up to ~50%), and a positive correlation is present between plagioclase mode and total phenocryst mode. Individual samples contain diverse textural (e.g., zoning and habit) and compositional plagioclase groups that have experienced contrasting magmatic histories. Extensive physical and chemical evidence of disequilibrium is present in the form of crystal resorption and plagioclase-melt disequilibrium. Disequilibrium growth forms also occur in the form of low anorthite skeletal crystals and matured skeletal crystals that possess low-An geometric cores surrounded by reversely zoned rims. Multiple lines of evidence, including the observed disequilibrium and juxtaposition of diverse textural and compositional groups in a single sample, suggest that the crystal cargo, on the whole, is not phenocrystic in origin. Rather, it suggests that plagioclase cargo formed under different physiochemical conditions present in different parts of the plumbing system, before being entrained into an ascending carrier melt. An origin through mush disaggregation for some of the plagioclase crystal cargo is supported by two arguments: (1) glomerocrysts with porous open structures and components at high angles to one another, which are interpreted as pieces of entrained disaggregated mush (Pan and Batiza, 2003); and (2) the high modal proportion of plagioclase in some basalts, which may be the result of melts interacting with plagioclase-rich crystal mushes and subsequent loss of olivine on ascent (Lange et al., 2013). We therefore conclude that: (1) mush disaggregation is an important process within the plumbing system of the Gakkel Ridge and (2) that crystal complexity attests to protracted growth histories of plagioclase within an open magmatic system.

Pan and Batiza, 2003. doi: 10.1029/2002GC000309
Lange et al., 2003. doi: 10.1002/ggge.20207

Fenitization as a Window into Processes at Ol Doinyo Lengai, Tanzania

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Fenitization is the in-situ metasomatism of country rock around intrusions of carbonatite and/or alkaline rocks. Ol Doinyo Lengai (ODL), Tanzania is the only know site of extrusive carbonatite volcanism. It is also a site where rare alkaline, natro-carbonatite lava is erupted.

During the 2007-8 eruption at ODL, an exotic block was erupted and this fenitized sample was taken for analysis. The results of this analysis build upon the work of Morogan and Martin, (1985) which analysed and characterised 9 fenitized samples from ODL. Their work provoked discussion about the links between fenitization and carbonatite genesis but was limited by the data available and type of analysis.

This current analysis involves a combination of both petrological and geochemical methods, including optical microscopy; scanning electron microscopy; and micro-Raman spectroscopy.

Preliminary results indicate that the sample has been completely recrystallized, obscuring the composition of the protolith. The mineralogy of the sample implies that high-temperature, high-salinity and highly-reactive fluids penetrated the sample. Complex veins cross-cut each other, and trace the outline of what were large crystals. There are many fluid inclusions notably: CO_2, carbonate, apatite and organic carbon.

The mineralogy and texture of the sample imply that it was in close proximity to the intrusion. Furthermore, the sample has undergone multiple phases of metasomatism and the fluids responsible were varied in composition: early fluids contained little water and carbon, whereas later fluids more water but fewer carbon compounds.

These preliminary results do not fit precisely within the classification of ODL fenites (Morogan and Martin, 1985) but together, the results are able to give insight into underlying processes at the natro-carbonatite volcano. The changing composition of metasomatic fluids imply that the source magma is variable in composition. This is in agreement with studies of the volcano's eruptive products.

Morogan & Martin, 1985. American Mineralogist 70: 1114-1126.

Evidence for largescale melt interaction in Rum Igneous Complex

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In mafic igneous systems, successive mantle-derived intrusions create layered complexes where existing cumulate and incoming crystal mush can react. Description and quantification of the resulting change in chemistry and texture are critical to understanding the internal dynamics of the chamber. We investigate these processes in the Rum Igneous Complex, where late-stage gabbro plugs cross-cut the mafic layered series (alternating troctolite and peridotite). These rocks typically contain plagioclase and clinopyroxene ± olivine. As we assume clinopyroxene grows in equilibrium with the melt, we can use compositional zonation to prove the reaction process.

What is the source of the gabbro? And does it interact with the layered series on its way up? In the field area, the gradual transition from marginal troctolite to the centre of the gabbro plug is clear and characterised by an increase in poikilitic texture, which we interpret as evidence for a reaction between the plug and the host layer. Arms of reactive material reaching into the plug centre also imply both phases were syn-magmatic. Chemical analysis confirms field evidence. Clinopyroxene chemical zoning patterns imply a complex growth evolution: i) clinopyroxene cores are assimilated from a troctolite lower in the series during partial melting induced by the intrusion of late-stage high temperature magma; ii) a clear mixing phase on a chemical level, results in a new hybrid mush; iii) the melt is depleted as Cr-spinel crystallises out of the melt.

A melt that was before described as inert is in fact highly reactive and shows clear evidence of mixing with the host layered intrusion.

This study show that magma chambers are dynamic bodies of melts that are in constant interaction with each other. Mush mobilisation is not an inert process but leads to mingling and mixing. The next step is REE data to better understand the melting processes and try to quantify the reactions.

Magmatic activity during subduction initiation along the Caribbean oceanic plateau

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The Panama arc is thought to have initiated on top of an oceanic plateau along the SW margin of the Caribbean plate in the Late Cretaceous Evidence for arc initiation along an oceanic plateau is preserved in uplifted segments of the forearc basement between southern Costa Rica and western Panama. This unique record provides a valuable opportunity to investigate magmatic and tectonic processes in a nascent subduction zone.

Previous work in Panama and Costa Rica has recognised a particular forearc stratigraphy considered to be related to subduction initiation. The forearc basement includes Upper Cretaceous (ca. 85 Ma) oceanic plateau sequences, which are crosscut and overlain by uppermost Cretaceous (75-73 Ma) 'proto-arc' dykes and lava flows. These dykes and lava flows have been interpreted as the earliest expression of volcanic arc magmatism during the establishment of an early volcanic front on top of the oceanic plateau. Our study aims at providing additional lithological, geochemical and temporal constraints on the formation of the proto-arc in Panama to give insight into the magmatic and tectonic activity occurring in the earliest stages of arc development, and test possible relations between plume and early supra-subduction processes.

New field work and sampling was undertaken to explore the extent of the proto-arc regionally, as well as to provide novel, detailed constraints in known proto-arc sequences. Preliminary field and geochemical results show that the proto-arc dykes are seen to be cross-cutting a depleted oceanic plateau. Results also confirm that the geochemistry of the proto-arc is transitional between plateau and arc signatures

Non-Hawaiian lithostratigraphy of Louisville seamounts and the formation of oceanic islands and guyots

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Guyots are large seamounts with a flat summit that is generally believed to form due to constructional biogenic and/or erosional processes during the formation of volcanic islands. However, despite large abundance of guyots in the oceans, there are very few direct constraints on the geology of their summit and how this relates to their formation. To address this problem we conducted a lithostratigraphic analysis of cores collected during IODP Expedition 330 from the summit of three Louisville guyots (South Pacific). Thirteen lithofacies of sedimentary and volcanic deposits were recognized, which include facies not previously documented on the top of guyots, and support complex interplay of erosional and constructional volcanic processes in the coastal environment of high-latitude volcanic islands.

The lithostratigraphy of Louisville seamounts preserves a very consistent record of the formation and drowning of islands, with from bottom to top: (i) volcaniclastic sequences with abundant lava-fed delta deposits, (ii) submarine to subaerial shield lava flows, (iii) erosional boundaries followed by post-volcanic shallow to deeper marine sedimentary rocks that lack thick reef deposits, (iv) post-erosional volcanic rocks emplaced during magmatic rejuvenation, and (v) pelagic sediments. High abundance of lava-fed deltas in the summit of Louisville guyots is dissimilar to the stratigraphy of Hawaiian-Emperor seamounts that is dominated by thick stacks of lava flows (ODP Leg 197). These lithostratigraphic observations and the alkaline character of volcanic rocks at Louisville suggest that slower magmatic growth occurred during the formation of Louisville islands; this possibly controlled formation of islands with a smaller shield volcano surrounded by extended lava-fed deltas. Hawaiian-type volcanoes and guyots are unusually large in the population of intraplate ocean volcanoes. Louisville-type guyots as defined in this study could therefore represent the most common mode of oceanic island formation in the Pacific Ocean and other similar fast-moving plate settings.

The deposition and remobilisation of distal Mazama ash (~7ka) in eastern Oregon and Washington

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The climactic eruption of Mount Mazama in Oregon, produced an extensive ash fall deposit across the conterminous USA and Canada. The Mazama tephra is widely used as a stratigraphic marker, therefore, dating of the eruption has been a priority. Using a combination of radiocarbon ages and Bayesian statistical modelling, the age of the eruption has been refined to between 7682–7584 cal. yr B.P. (Egan et al., 2015). What is less well known is the depositional pattern of the fall deposit. Numerous studies have constructed isopachs for the Mazama ash deposit, but few agree. The reason for the uncertainty may lie in the extensive remobilisation of ash after the eruption. This study compares existing Mazama isopach maps and critically evaluates their construction.

We focus on an area surrounding Walla Walla, Washington, ~400km from source, where we undertook fieldwork in August 2017. Existing isopach maps suggest Mazama ash thicknesses in the area could range between 5 and 30cm. We combine field observations with high-resolution digital elevation models and drainage networks to classify ash localities as primary or remobilised ash. For example, locally thick (up to 3m) sections of Mazama ash was classed as remobilised as it had been washed downstream and accumulated locally in canyons. However, we classify a ~30cm thick, relatively continuous Mazama ash deposit as primary, as it lies on a drainage divide, i.e. there is no upslope ash source. We are applying a variety of analytical techniques to distinguish primary ash from remobilised ash, which we will then use to construct isopachs from all data sources

We are also analysing both the location and extent of ash remobilisation in the Walla Walla region. Currently our understanding of remobilised ash is based on relatively small eruptions, such as Eyjafjallajökull and Chaitén. For large magnitude eruptions, the time and spatial scales of ash remobilisation, by gravity, water and wind, are much longer and pose greater risks.

Egan, J., Staff, R., Blackford, J., 2015. The Holocene 25, 1054–1067.

A tectonic control on the timing, chemistry and scale of voluminous pulsed intrusive magmatism: Evidence from the Lassiter Coast, Antarctic Peninsula

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Whilst magmatic flare-ups (and consequently Phanerozoic continental growth) commonly coincide with periods of tectonic deformation, their direct association is ambiguous. We present the evolution of a ~13,000 km^2 intrusive suite in Antarctica and show how its pulsed emplacement, chemistry and volume were controlled by syn-magmatic deformation, by combining magnetic anisotropy (AMS) data with field, structural, geochemical, and geochronological evidence.

The Lassiter Coast Intrusive Suite (LCIS) of the Antarctic Peninsula provides a unique opportunity to observe the evolution of a pulsed syn-tectonic intrusive suite. The LCIS is one of the largest magmatic events in West Antarctica, and its timing and scale during the Mid-Cretaceous period of global deformation and extensive trans-Pacific magmatism renders it of both regional and global significance.

New U-Pb zircon ages show that this voluminous intrusive suite was emplaced in three pulses (118, 113 and 110 Ma) followed by 15 Ma of waning plutonism. AMS, field and geobarometric data allow the syn-magmatic (rather than pre- or post- magmatic) deformation to be determined. This shows that the magmatic pulses are coincident with peaks in syn-magmatic deformation bracketed by post-compressional extension, whilst the waning magmatism is post-orogenic. Zircon oxygen and hafnium isotopic data reveal the effect of the variable deformation on the generation and evolution of magma, whilst also revealing new details on the nature of the Gondwanan margin's crustal structure.

This data highlights the causal link between voluminous pulsed magmatism and crustal deformation, with the pulsed timing of magmatic flare-ups deriving from pulses in tectonic compression; a result of deformation increasing melting and aiding ascent.

Recycled volatiles in supra-subduction zone melt channels from the Leka Ophiolite Complex, Norway

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Deep subduction of volatiles (water, halogens, noble gases) has major implications for the evolution and dynamics of Earth and potentially other planetary bodies. However, assessing the mass balance of volatile inputs to and outputs from subduction zones is complicated by a lack of samples from the deep oceanic lithosphere and by melt evolution and interaction during arc volcanism, respectively.

Ophiolites provide the only opportunity to study the deeper parts of oceanic lithosphere. Most ophiolites contain evidence of interaction with potentially large volumes of fluid(s) and/or melt(s) above subduction zones before their emplacement onto continental margins. Such supra-subduction zone (SSZ) ophiolites can provide more direct insights into the volatiles expelled from subducting slabs; unaffected by differentiation or assimilation in the arc crust. Alongside this, the surrounding partially serpentinised mantle harzburgites may help to understand the incorporation of volatiles into the lithosphere during seafloor alteration.

The mantle section of the ~497Ma Leka Ophiolite Complex, Norway, is cut by numerous dunite, pyroxenite and chromitite sheets, interpreted to result from melt-rock reaction with large volumes of hydrous melt above a subduction zone. Olivine, chromite and pyroxene separates from these sheets and their harzburgite host rock have been analysed for their noble gas abundances and isotopes by crushing in vacuo. There is clear heterogeneity in noble gas isotopes with SSZ dyke samples showing significantly more radiogenic Ar ($^{40}Ar/^{36}Ar$=335-608) than harzbugites ($^{40}Ar/^{36}Ar$=297-311) which are only slightly above the atmospheric ratio of 296. He isotopes also appear to show radiogenic signatures in the SSZ dykes ($^{3}He/^{4}He$=0.31-1.2 R_a).

Modelling of radiogenic ingrowth in the SSZ dykes indicates the signatures measured are unlikely to have developed in situ. In light of this, we interpret these signatures as representing a crustal fluid, most likely derived from the subducting plate at the time of emplacement. Conversely, the absence of this signature in the mantle harzburgites suggests they have been little affected by SSZ processes and may yield useful information about the seafloor or forearc hydration of the lithospheric mantle.

Explosive or effusive? What controls the eruptive style of volcanoes

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One of the challenges in understanding volcanoes is to explain why eruptive style changes from one eruption to the next, or even within the same eruptive period. Here we review the different ways of producing both explosive and effusive eruptions from silicic magmas. Eruptive style depends on a set of interrelated magmatic properties, such as viscosity, processes such as gas loss and external properties such as conduit geometry, which altogether initiate various feedbacks. Ultimately, these control the speed at which magmas ascend, decompress and the extent of outgassing on route to the surface, this determines the eruptive style and how it evolves.

The influence of temperature on permeability evolution in Volcán Chaitén rhyolite: An experimental approach

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The relationship between outgassing efficiency and overpressure development is often cited as one of the fundamental controls on eruptive behaviour. Therefore, the development of permeable pathways in volcanic material is a topic of great importance. Laboratory experimentation has been extensively used to provide insights into the mechanisms governing permeability evolution, however the majority of permeability studies of volcanic products have been conducted under ambient laboratory conditions. While these studies can provide insights into the mechanisms behind permeability development, results risk being unrepresentative of mechanisms occurring at magmatic temperatures in the conduit because volcanic materials often undergo modification by post-emplacement processes. By contrast, high temperature permeability experiments allow us to investigate in-situ fluid movement in a thermally dynamic environment.

This study reports the results of a systematic experimental investigation into the permeability of rhyolitic dome material from Volcán Chaitén at magmatic temperatures and shallow conduit pressures using the Rocchi Cell (a high temperature triaxial deformation apparatus at UCL) and the steady-state flow technique. The eruption of Volcán Chaitén in 2008-09 exhibited simultaneous explosive and effusive behaviour with both lava and ash columns being emitted from the same vent. The ability of gas to efficiently decouple from magma in the shallow conduit is believed to control such behaviour, and evolving modes of conduit outgassing and their respective efficiencies hold the key to understanding such hybrid activity. Experimental permeability results are applied to not only draw general conclusions regarding the permeability of volcanic material at high temperature, but also to enhance our understanding of the specific setting of Volcán Chaitén and the observed evolution of eruptive behaviour.

The Los Frailes Formation: deciphering shallow marine volcanism and its hazards

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The Los Frailes Formation (LFF) is part of the Miocene Cabo de Gata Volcanic Zone located in the Andalucía province in Southern Spain. The Cabo de Gata Volcanic Zone is part of the much wider Alboran Volcanic Provence caused by the collision of Africa and Europe. Volcanism in the Cabo de Gata has been constrained to 11.87 – 6.88 Ma (Duggen et al., 2004) During this time, the Cabo de Gata peninsula was an archipelago, with volcanism interpreted to have occurred in an emergent coastal environment. Each volcanic sequence in the LFF is separated by carbonate sediments, some of which contain marine fossils. Three of the four volcanic units in the LFF are andesitic/dacitic breccias breccias, variably interpreted as sub-aqueous domes/hyaloclastite and sub-aqueous debris avalanche deposits due to dome collapse, with the other a dacitic pumiceous lapilli-tuff interpreted as a sub-aqueous pyroclastic density current (PDC) deposit.

The complete stratigraphy of the LFF is recorded in cliff and coastal sections, which offers a unique opportunity to study shallow marine volcanism. This is important as although hazards associated with shallow marine eruptions are well known, such as loss of life via tsunamis and economic loss due to infrastructure damage (e.g. submarine communication network damaged in the 2015 eruption of Kick em' Jenny off the coast of Granada), the processes involved are less well understood due to difficulties in observation and sampling.

Building on field work by Soriano et al (2012, 2014, 2016) an updated geological map of the LFF has been produced. Here we provide a preliminary re-interpretation of the emplacement of the breccias, and the nature of the pumiceous lapilli-tuff. Further study will focus on chemical and textural analyses of the pumiceous lapilli-tuff to determine the behaviour of PDCs as they enter the water.

Duggen, S., et al (2004). EPSL, 218, 91–108.
Soriano, C., et al. (2012). JVGR, 231–232, 72–86.
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Soriano, C., et al (2016). Updates in Volcanology – From Volcano Modelling to Volcano Geology. InTech, Chapter

Are magmas at arc terminations anomalous to the adjacent arc?

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Subduction zones do not form continuous chains globally, but instead form individual arc segments that often have clearly defined terminations, associated with changes in plate geometry, triple junctions or slab dip (i.e. flat-slab subduction). Whilst traditional two-dimensional, slab-perpendicular representations of mantle convection and melt transport may be valid within an arc segment, such representations may not capture processes at arc terminations, where mantle flow around the edge of a subducting plate may influence wedge temperatures, melt fraction and transport, and arc magma compositions. Observations made at various end-arc volcanoes (e.g., Hudson (southern Andean SVZ), Shiveluch (northern Kamchatka), Zavodovski (northern South Sandwich)) display anomalous chemistries and unusually high productivity in the context of their particular arcs, but it is unclear if this is a consistent pattern across arc terminations, and if such changes are attributable to mantle flow associated with a slab edge. Investigating melting processes at arc terminations has the potential to improve our overall understanding of melt generation and transport within subduction zones.

By taking a global perspective and analysing the chemistry of 'typical' arc volcanoes in comparison to their adjacent end-arc volcanoes, we assess evidence for systematic chemical variations at arc terminations. Our approach builds upon the global arc magma analysis of Turner and Langmuir (2015), and adopts comparable methods to filter whole-rock geochemical data and define a primitive magma composition at individual volcanoes. A variety of approaches have been tested to derive data that can be objectively compared both globally and within individual arcs.

Sparse data coverage means that a large number of volcanoes fail our data filtration tests, leaving a relatively small number of data for several arcs. Globally, end-arc volcanoes span a more limited compositional range than their adjacent arcs, and show major element distributions that support a pattern of increased mantle melting. Ongoing investigations will compare different termination types, and test whether volcanic flux also supports a model of increased melting in these settings.

Turner & Langmuir., 2015. EPSL 42: 182-193.

Emplacement of an andesitic hyaloclastite-lava lobe complex and implications for paleoenvironment at pre-160 ka Ruapehu Volcano, NZ

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Intermediate composition glaciovolcanic deposits are dominated by coherent lava flows, emplaced from effusive eruptions and confined by glaciers, resulting in over-thickened morphologies and fine-scale cooling joints orientated perpendicular to flow margin. Less commonly, fragmental deposits are reported at such volcanoes; their rarity is attributed to the usual steepness of stratocones, giving rise to efficient meltwater drainage which inhibits primary fragmentation and enhances erosion of unconsolidated, volcaniclastic material.

We present new field data from a basaltic-andesite hyaloclastite breccia pile, exposed in a deep glacial valley, flanking the composite Ruapehu volcano, New Zealand. The pile is $\geq$ 150 m thick and at least 1 km^2 in area, intruded by numerous coherent lava lobes that have the same composition as the breccia. Jigsaw-fit fracturing of monolithologic clasts from coarse tuff to m-scale blocks indicate in-situ quench fragmentation of effusively erupting lava on contact with external meltwater. The tectonic setting and elevation of Ruapehu, combined with extensive glacial evidence suggests that ponded water was sourced from a capping glacier and we infer that the eruptive environment was predominantly subglacial. Age data from overlying subaerial lava flows and geochemical correlation with well-constrained chemical changes in the volcanic stratigraphy indicate an age for this hyaloclastite deposit of ~160 ka, within MIS 6.

This deposit is analogous to submarine hyaloclastite-lobe complexes or subglacial deposits formed beneath thick ice. Based on the thickness of this deposit and our interpretation for its subglacial formation, we estimate that the glacier was at least 300 m thick. Such results exemplify the way in which glaciovolcanic deposits can act as important indicators for paleoenvironment. They also prompt examination of the stability of thick ice on alpine volcanoes and the subglacial hydrology that allows thick hyaloclastite to form on such volcanoes. The composite morphology of Ruapehu may have been established early in the volcano's history allowing thick ice to accumulate on the edifice and fragmental deposits to be preserved.

Curved Seismic Sources for LP Events in Volcanic Environments: Model and Radiation Patterns

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Long period (LP) seismicity is direct evidence of magma movement in the plumbing system and, therefore, it has implications for volcanic hazard forecast such as dome collapse (Neuberg et al., 2000). Following classic seismology seismic sources are assumed to involve planar fault surfaces. However, in volcanic plumbing systems there is evidence of more complex geometries which we explore as possible seismic sources, where magma undergoes brittle failure in zones where strain rate is high, e.g. at the conduit wall (Neuberg et al., 2006).

LP events comprise a short period onset, which gives information about the source, and a long period coda, which contains information about the properties of the plumbing system (Neuberg et al., 2000). Here we test seismic sources for these events with geometries following the boundaries of dykes and conduits.

We approximate these complex sources by superimposing several double couple sources to create both, seismic radiation patterns and use the QSEIS software (Wang, 1999) to create synthetic seismograms. We find that the resulting waveforms represent the second derivative of the source time function which are used for each double couple, and the amplitude depends on the geometry of the complex source.

Classic interpretations by moment tensor inversion could lead to misinterpretations of the source time function since complex source geometries are not taken into account.

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Wang, R., 1999. Bull.Seis.Soc.America. 89(3): 733-741.

Plutonic xenoliths provide evidence for differentiation and storage in a volatile rich, polybaric mush beneath Statia, Lesser Antilles Volcanic Arc

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The Quill volcano, on the island of St. Eustatius (Statia), in the Lesser Antilles is predominantly andesitic, but whole-rock SiO_2 contents of volcanic rocks erupted from the Quill display one of the broadest ranges of any arc volcano (52-72 wt.%). In addition, the Quill has erupted an exceptional number of plutonic xenoliths. In general, the plutonic xenoliths are dominated by plagioclase and amphibole, but also contain variable proportions of olivine, clinopyroxene, orthopyroxene and oxides. This study focusses on the petrology and geochemistry of the plutonic xenoliths in order to determine the complexity of the magmatic plumbing system beneath the Quill.

The plutonic xenoliths can be divided into cumulates, with a subtractive assemblage, or non-cumulate gabbros with a plutonic origin, representing solidified aliquots of magma. These types are distinctive in texture, mineralogy, and mineral chemistry, and therefore likely represent different portions of the sub-volcanic plumbing system.

In order to explore the composition of the melts that were present in the plumbing system, we analysed xenolith hosted melt inclusions (MI's) and interstitial glass by SIMS. MI compositions span a large range (49-78 wt% SiO_2) and fall into two groups, with a compositional gap at 60-65 wt% SiO_2. Interstitial glass has a smaller range in SiO_2 (49-65 wt%) covering only the low SiO_2 group and likely represents remobilisation of cumulates by lesser evolved melts. The chemistry of MI's systematically varies with the host phase, with olivine hosting the least evolved melt, and orthopyroxene, hosting the most evolved melt. Trace element concentrations also display considerable variations. The large range in MI compositions reflects the diversity of volcanic rocks erupted from the Quill and indicates that the plutonic xenoliths are capturing all stages of differentiation.

The water contents of melt inclusions cover a large range (0-9 wt%), as do CO_2 contents (0-1350 ppm). These indicate saturation pressures of 0-310 MPa, suggesting crystallisation and/or storage over a large range of depths (0-11 km). H_2O and CO_2 are not correlated with incompatible trace elements and therefore MI's may provide evidence for fluxing by CO_2 rich vapours. This study suggests the plumbing system beneath Statia is a volatile-rich and vertically extensive mush zone, in which a large range of melts are generated and stored.

The Pulsatory Nature of Bagana Volcano, Papua New Guinea

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Bagana volcano, in Papua New Guinea, presents a rare opportunity to examine a very young (300-400 y.o.), polygenetic, andesitic volcano (Wadge et al., in review). It erupts near-continuously, having the third-highest SO_2 flux of persistently active volcanoes worldwide, at 1204 x 10^6 kg/y (McCormick et al., 2012) and a high rate of lava extrusion (1 m^3/s) measured over decades (Wadge et al., in review). Pulses of activity lasting many months is typical, with slow-moving channelized lava accompanied by minor ash and copious SO_2. Very occasional larger eruptions produce ash and pyroclastic density currents (Wadge et al., in review).

We are investigating the nature of this variable and pulsatory behaviour, on the remote volcano using space-borne remote sensing data. Specifically, the SO_2 flux from OMI (and TROPOMI), the ash distribution from geostationary satellites, heat flux from MODIS and ASTER, and the lava flux from InSAR.

We anticipate improved understanding of the underlying physical processes driving this unusual volcano. We will assess the hazard posed by the explosive eruptive phases to the increasingly populated southwestern slopes of the volcano (Wadge et al. 2012) and also the busy airspace between Oceania and Asia (McCormick et al., 2012).

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Tracing volatiles in Earth's mantle using He-C-N isotopes in garnet-bearing diamondites

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The origin of diamond-forming carbon in the Earth is unclear (Cartigny et al., 2014; Stachel & Harris, 2008; Mikhail et al., 2014); sources include subducted organic sediment and primordial mantle carbon. For example, some diamonds contain eclogitic silicate + sufide inclusions and have depleted δ13C (-10 to -30‰), enriched δ15N (+3 to +35‰) values, consistent with subducted crustal material (Stachel & Harris, 2008; Mikhail et al., 2014). However, some diamonds show mantle-like δ15N (<-5‰) and depleted δ13C values (-10 to -30‰) which have been cited as evidence of enstatite chondrite-like primordial C-N sources (Cartigny et al., 2014). The helium isotope composition of mantle rocks are powerful tracers,of Earth's volatile history because primordial 3He is not recycled back into the mantle. However, there are few He isotope studies of diamond fluids. The 3He/4He of garnet-bearing diamondites from the Orapa mine (Botswana) range from 0.1 to 3 Ra (Burgess et al., 1998; Gautheron et al., 2005), consistent with a recycled origin. However, our recent work has identified a suite of diamondites with 3He/4He = 0.06 to 8.2 Ra which correlates negatively with δ13C, suggesting that the subduction-related C is associated with mantle 3He/4He ratios.

To unravel this complexity we are combining He, C and N isotope analyses in polycrystalline diamond from garnet-bearing diamondites from the Orapa mine. These data will also be used to assess the extent to which carbon and nitrogen isotopes are decoupled during diamond-formation (Mikhail et al., 2014).

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Ascension Island: analysing ash fall hazard on a volcanic island with limited data

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Volcanic ash fall hazard analyses are typically based on past eruption magnitudes and frequency. However, where there is limited geological data through either poor exposure, poor preservation or a lack of resources to carry out the required fieldwork, ashfall hazard analyses must draw on other sources of information. Tephra dispersion models used to carry out ashfall simulations of chosen scenarios require a number of input parameters including eruption column height, erupted volume and grain size distributions. These parameters can be chosen through the use of well-studied analogue eruptions and the elicitation of a group of scientific experts.

Here we present a case study of an ash fall hazard analysis carried out for Ascension Island. Simulations were run for three scenarios developed with input from the Ascension Island Government:

1. A small magnitude short-lived eruption producing lava flows and depositing ash locally on island affecting operations and quality of life;
2. A moderate magnitude producing an eruption column up to 17 km high (tropospheric) dispersing ash and gases and impacting transport on/off and around Ascension; and
3. A large magnitude eruption producing pyroclastic density currents and an eruption column ~27 km high (stratospheric), dispersing ash and gases, and posing a threat to life.

Due to inherent uncertainties, parameters were chosen using the analogous Fogo Volcano, Sao Miguel Island, Azores and expert elicitation. Variation in wind conditions was evaluated using a ten-year NCEP-NOAA reanalysis wind dataset (NOAA, 2015).

Our results reveal that regardless of the wind direction, an explosive eruption producing an ash column of even just a few kilometres above sea level would result in at least 1 mm of ash fall on Ascension Island, with thicker ashfall in many places. Ash thicknesses of just a few millimetres can have significant impacts on transport and infrastructure, while thicker ash falls can have prolonged effects on health, infrastructure and the economy.

NOAA, 2015, NCEP-NOAA Reanalysis 2 wind data. http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis2.html.

Mineralogical control on thermal damage and the presence of a thermal Kaiser effect during temperature-cycling experiments

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Volcanic and geothermal systems are in part controlled by the mechanical and thermal stresses acting on them and so it is important to understand the thermo-mechanical responses of volcanic rocks. One of these responses is the Kaiser `stress-memory' effect which can be observed under cyclic mechanical loading. However, the similar 'Kaiser temperature-memory effect' is more elusive. This study explored the possibility of a Kaiser `temperature-memory' effect using three igneous rocks of different composition and grain size; Slaufrudalur Granophyre (SGP), Santorini Andesite (SA) and Seljadalur Basalt (SB). We present a series of thermal stressing experiments in which Acoustic Emissions (AE) were recorded contemporaneously with temperature. All of the materials were subjected to both a single heating and cooling cycle to a maximum temperature of 900 °C and multiple temperature cycles to peaks of 350°C, 500°C, 700°C and 900 °C all at a constant rate of 1°C/min on heating and a natural cooling rate of <1°C/min. Porosity, permeability and P-wave velocity measurements were made on all starting materials and thermally treated end member samples. We use the onset of AE's as a proxy for thermal cracking onset to show the presence of a Kaiser `temperature-memory' effect in SGP but not in SA and SB. We find that the vast majority of thermal crack damage is generated upon cooling in the finer grained materials, but substantial thermal cracking occurs upon heating in the coarser grained SGP. The total amount of thermal crack damage generated due to heating or cooling is dependent on the temperature the rock is exposed to as well as the rock type, mineral composition and most importantly the grain size and arrangement. Knowledge of thermal stressing and a Kaiser `temperature-memory' effect can be applied to magma chambers, where the cyclic nature of mechanical and thermal magma chamber inflation and deflation can accumulate damage, potentially leading to rupture.

Daoud,A.,Browning,J.,Meredith,P.G., Mitchell,T.M. In prep. Mineralogical controls on the dynamics of thermal cracking. Geophysical Research Letters.

Critical eruptive controls of an intraplate volcano: Ascension Island

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Located 90 km west of the Mid-Atlantic Ridge, Ascension Island is an intra-plate volcano with a wide compositional range of products, which span a broad range of eruptive behaviours (Chamberlain et al., 2016). Almost all compositions of magma are capable of erupting both passively and explosively and a fundamental element relevant to volcanic hazard assessment here is understanding whether there are indicators of whether future eruptions will be effusive or explosive.

Felsic activity (including >75 explosive eruptions) is confined to the central and the eastern parts of the island, where it dominates the stratigraphy (Preece et al., in prep.). Previous work has shown that this evolved material can be derived via simple fractional crystallisation of high Zr/Nb basalt (Chamberlain et al., in 2016; in revision).

It is interpreted by Chamberlain et al., (in 2016; in revision) that an array of plutonic bodies in the central and eastern regions cause mafic melts to stall at depth, allowing fractional crystallisation to occur and resulting in only evolved melts reaching the surface. The presence of a large mafic scoria cone on Green Mountain raises the question of how some mafic melts are able to 'punch through' this array where others are not. Targeted petrographic and geochemical analyses of effusive and explosive products from the central, eastern and Green Mountain regions that can be temporally and geochemically related will allow the reconstruction and comparison of magmatic conditions.

Through comparison of key parameters such as volatile content and eruptive dynamics between eruptions of similar composition but varying eruptive style, we hope to better understand the starting conditions that lead to the diverse range of behaviours observed on this enigmatic ocean island.

Chamberlain, et al., 2016. J. Volcanol Geotherm Res. 327: 349-360
Chamberlain et al., in 2016; in revision.
Preece et al., in prep.

Unravelling magmatic system dynamics through *in situ* isotopic micro-analyses: insights into the Campanian Ignimbrite activity (Campi Flegrei, Italy)

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Large compositional variations in ignimbrites reflect significant zoning in shallow magma reservoirs and represent an excellent source of information on magma storage conditions and volcanic evolutionary processes. Configuration of these magma chambers is still not clear, so its knowledge represents an important task to better understand how emptying dynamics work during large explosive eruptions.

The Campanian Ignimbrite (CI) eruption, from Campi Flegrei volcanic field, Italy, represents a typical example of such events, producing a voluminous pyroclastic sequence of trachytic to phonolitic magma around 39 ka ago. Great whole-rock geochemical variations are reported in literature and considerable isotopic dataset exists for products from medial CI outcrops, suggesting Sr-isotope disequilibria. Nevertheless, less is known about isotopic variations in stratigraphic sections of CI from proximal outcrops, despite its more detailed sequences in the field and the more remarkable heterogeneity of its components. In order to provide a complete picture of the compositional variability within the proximal CI sequences, we have performed geochemical and isotopic micro-analyses on matrix glasses of all juvenile components of the proximal CI. Samples were collected along six different proximal CI outcrops from all the six stratigraphic units recognised for the proximal CI sequence. Our major and trace element data on matrix glasses and Sr-Nd isotopes point out a much larger geochemical heterogeneity than that already displayed by whole-rock data.

Moreover, our detailed micro-analytical data show a compositional complexity even at the micro-scale, possibly revealing the presence of multiple magma components in the CI system interacting in a complex magmatic network. Recent hypotheses have suggested that the CI magma reservoir evolved by incremental addition of deeper recharge into a high-crystallinity region (i.e. crystal mush), from which crystal-poor melts were extracted. In this light, the present work also contributes to better understand crystal mush systems linked to highly explosive eruptions, through a detailed in situ isotopic micro-analytical study.

Dyke propagation paths in heterogeneous volcanoes

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Santorini is a stratovolcano located in the Aegean Sea, Greece. It is a part of the active Hellenic South Aegean Volcanic arc, formed by the subduction and rapid rollback of the African plate beneath the Aegean microplate. This study focuses on quantifying dyke propagation paths in Santorini. To do this we have mapped a dyke swarm exposed in the northern caldera wall. We measured the attitude and thickness of 91 dykes as well as features such as dyke segmentation, arrested fracture tips, associated faults and other discontinuities. The northern section of Santorini hosts a complex and highly mechanically heterogeneous host rock succession. In this study we seek to understand the role of mechanical heterogeneity in influencing dyke propagation pathways.

The FEM software COMSOL Multiphysics was used to model field measured dyke propagation paths in host rocks of different mechanical properties and subject to variable loading regimes. Using appropriate values of elastic moduli, density and Poissons ratio we were able to calculate the crustal stress distribution responsible for the arrangement of dykes observed in the field.

Results show correlations between field observations and regional tectonic loading conditions. We observe and model complex interplays between normal faults, of which there are several within the section studied, and dykes. Several dykes are found to partially intrude the fault segments for a distance along dip, but then change their course to move away from the fault. Other dykes became arrested at discontinuities and contacts between mechanically dissimilar layers. Overpressure, mechanical layering and stress distributions around faults appear to be important parameters controlling dyke propagation paths and arrest.

Observations of the 2011-2013 Kīlauea lava flows from Synthetic Aperture Radar intensity data

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Synthetic Aperture Radar (SAR) amplitudes can be used to understand changes to the Earth's surface caused by volcanic activity. We present preliminary SAR amplitude-derived observations of recently emplaced lava flows from Kīlauea, Hawai'i. Kīlauea is a particularly exciting target for this work due to high rates of effusion, the high density of past in situ and remote geophysical measurements and the availability of seven years of high resolution (COSMO-SkyMed) archive SAR images.

We use SAR as a tool to examine variations in lava flow patterns, which are important in understanding why lava flow bifurcate, overflow or breakout, identifying possible factors that affect the sinuosity of the flow and the interaction with the underlying topography. Changes in the scattering properties make it possible to identify variations in effusion rates allowing us, for example, to discriminate between steady-state or pulse dominated effusion.

The roughness, angle of slope (with respect to the satellite) and the dielectric properties of the ground surface are the primary controls on radar amplitude. Different stages of lava flow development produce distinct patterns in roughness and local gradient. For example, cooling and changes in viscosity can change the roughness of a lava flow as it progresses from the vent. Changes in lava flow level within a levee-bounded channel will also result in large differences in brightness. We will compare our observations with previous independent lava flow mapping at Kīlauea that used phase coherence and bistatic radar imagery. This will provide a test for the applicability of various SAR intensity-based methods for investigating lava flow development.

Magmatic sources and processes recorded by the volcanics from the Izu Bonin rear arc

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The Izu rear-arc volcanism was investigated by IODP EXP350 in spring 2014. A total stratigraphy of 1800 m was drilled, and contains volcaniclastic material within tuffaceous mudstone. This study will focus on the explosive volcanism that erupted a 44 m thick unit dominated by lapilli-tuff and lapillistone between 682 and 727 mbsf that was deposited at approximately 4.3 Ma. Mineral chemistry and 87Sr/86Sr isotope analyses has been conducted on plagioclase crystals with the objective of investigating the magmatic processes and magma sources recorded in the phenocrysts; themobarometric models were utilised to infer conditions of magma storage.

We present analyses of 93 individual plagioclase crystals from 10 stratigraphically constrained rock samples and provide 645 new mineral spot analyses. The plagioclase crystals exhibit a wide range of anorthite contents with a notably bimodal distribution. The dominant population has ~An 20 to 40 (n=318) and a smaller population, with a left skewed distribution, has a peak at ~An 70 to 90 (n=155). Compositional variations in the plagioclase population as well as normal and reverse zoning in individual phenocrysts reveals a complex mixing history. Stratigraphic relationships between the samples indicate episodic recharge of a felsic magma chamber by a more mafic magma.

There are 11 87Sr/86Sr analyses reported from 10 individual crystals returning values between 87Sr/86Sr = 0.703096 and 0.703380. These likely represent a low 87Sr/86Sr magma reflecting the ambient PSP mantle, and a magma which has experienced a higher degree of flux of subduction fluids resulting in an enriched 87Sr/86Sr signature.

Thermobarometric modelling suggests mixing between these magmas likely occurred both in the lithospheric mantle and in a shallow crustal region; modelled crystallisation temperatures range from 922 to 1175 (±36) °C and pressures range from 10 to 1590 (± 247) MPa.

Using volcanic ash advisories for understanding explosive volcanic activity

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Notifications describing an ongoing eruptive episode and its characteristics are crucial for communicating potential hazard to at risk communities. Reports are designed to provide tailored information according to different stakeholder needs. An example of one such report is volcanic ash advisories (VAAs). VAAs are provided every 6 hours in the event of an eruption, and are provided by the Volcanic Ash Advisory Centre (VAAC) responsible for the affected airspace. These reports are designed to communicate height and distribution of ash in the atmosphere, and forecasts for dispersion for the following 18 hours, predominantly to the aviation industry. In addition to this information, remarks regarding the style of eruption and observations (e.g. from the volcano observatory, pilots and satellite imagery) are also included. Given the frequency of distribution and content of these reports, analysis of the contained information can provide insight on not only on reporting, but also eruptive activity. Here, we show how analysis of available reports can be used to understand global rates of volcanic eruptive activity, and inform eruption source parameters crucial for application of ash dispersion models. Using information within past VAAs, we assess the utility of information contained within volcanic ash advisories (VAA's) to inform distributions of key input parameters, in particular plume height and duration, and investigate how these parameters change both during an eruption, but also over a number of different eruptive events. Our research demonstrates the value of analysing previous advisories for the purpose of understanding eruptive behaviour, but also allows some insight into reporting practises.

IFRiT: a new tool for measuring volcanic SO_2 flux from scattered solar UV light

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Measuring the flux of volcanic gases is crucial for volcano monitoring. Analysis of the gases emitted by a volcano can give insight into the underlying magmatic processes, while significant changes in gas flux can signal a change in volcanic activity - such as the onset of an eruption. Many gases and aerosols emitted by volcanos can have a significant impact on the local and global climate, affecting air quality and contributing to climate change. One of the simplest gases to measure is sulphur dioxide (SO_2), due to its low background atmospheric concentration.

At present, the primary method of measuring volcanic SO_2 flux is Differential Optical Absorption Spectroscopy (DOAS). Although DOAS is a powerful technique, the requirement for a clear-sky reference spectrum taken outside the plume can complicate the post-analysis. We have developed a new spectral analysis tool named IFRiT (Intensity Fitting in Real Time), to address this issue.

IFRiT utilises a high resolution solar spectrum in place of the clear-sky reference used in DOAS, allowing for straight forward, real-time analysis of the data. This also prevents the possibility of SO_2 contamination in the reference, which can lead to systematic errors in retrieved SO_2 column amounts.

IFRiT is controlled through a simple graphical user interface, allowing the user to acquire and accurately analyse spectra in real time with ease, even if they are non-experts. As a result, IFRiT provides high quality gas flux measurements with minimal post processing by the user.

We present results from field measurements made at Soufrière Hills Volcano, Montserrat, in May 2017. We compare our results to DOAS, as well as to past flux measurements from the volcano. Over 3 days, traverses of the plume performed by car and helicopter gave an average SO_2 flux of 305 (±100) tonnes per day, with a minimum and maximum of 240 and 350 tonnes per day respectively. This is in agreement with past flux measurements from the volcano. We will also discuss the planned future development of IFRiT, as well as possible, non-volcanic applications.

The Role of Accurate Earthquake Locations in the Mapping of a Volcanic Plumbing System

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Volcanic activity is usually accompanied by an increase in seismicity; therefore, the change in rate and location of earthquakes is a useful indicator of current and future activity. Consequently, volcanic seismicity is an important monitoring method used by the Montserrat Volcano Observatory (MVO) to study Soufrière Hills Volcano.

Soufrière Hills Volcano is located on the island of Montserrat, part of the Lesser Antilles Volcanic Island Arc. The current eruption has been ongoing since July 1995 with 5 main phases of dome growth, all of which were accompanied and preceded by increased seismicity. Seismicity at Soufrière Hills Volcano is linked to magma movement and ascent.

Currently earthquake locations at MVO are determined within SEISAN using the location program 'Hypocenter', which is a centred and scaled iterative least squares algorithm using a simple 1D velocity model; this method uses a combination of features from Hypo71 and Hypoinverse. One of the main problems with this method is the ability for the algorithm's solution to converge near a local solution, missing the true location (global solution). Further, the use of a 1D layered velocity model reduces accuracy in the calculated locations.

This study plans to compare several location algorithms including HypoDD, NonLinLoc, Bayesloc and a coalescence microseismic mapping technique to understand whether a more effective location method could be implemented by MVO. Addition of a 3D velocity model, topography and comparison of several parameters within each program will provide more accurate earthquake locations to relocate both the existing catalogue at MVO, and for future events.

Initial comparison of NonLinLoc and Hypocenter use a subset of the data containing 36 earthquakes from a VT string on the 27th July 2017. Results using a 1D velocity model and the Oct-Tree Importance Sampling algorithm in NonLinLoc show locations under the summit of Soufrière Hills Volcano, with some similarities to locations produced by Hypocenter. The NonLinLoc locations are more tightly clustered around a central point compared to the Hypocenter locations, but have several outliers.

Acid dissolution of volcanic rocks: the evolution of strength and permeability

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Subaerial volcanoes often host acid lake systems. Their existence and persistence requires an influx of water at a rate greater than the rate of its escape via evaporation or fluid flow through the edifice, in tandem with the transfer of magmatic heat and volatiles. One of the most common acid agents is sulphuric acid (H_2SO_4), derived from the disproportionation of volatile sulphur dioxide, or from the hydrolysis of elemental sulphur.

We examine the evolution of physical and mechanical properties of a volcanic rock when immersed in acid, analogous to the aggressive aqueous chemical environment encountered in acid lake-hosting volcanic systems.

Core samples of andesite were characterised in terms of their initial mass, porosity, and permeability. Half of the samples were set aside in order to measure their uniaxial compressive strength (UCS). The remaining samples were immersed in a 0.125 M solution of H_2SO_4 at 22.9 ± 0.7 °C (with a starting pH of 0.64: a typical value for volcanic acid lakes), with samples being removed at intervals to re-characterise their physical and mechanical properties.

Sample mass was observed to decrease consistently over time due to mineral dissolution. It was shown to be coincident with an increase in porosity and permeability, presumably due to ongoing volumetric change as new mineral faces are exposed to the acid over time. Although porosity increase was relatively small (~1 vol.% after immersion for 600 h), permeability increased by a factor of >2.5 over the same timeframe. Interestingly, compressive strength of these andesites was not adversely affected by prolonged acid immersion: UCS of acid-treated samples was within the range of the untreated suite.

These results underscore the importance of the chemical environment for fluid flow in hydrothermal and geothermal systems in volcanically active regions, as well as volcanic systems themselves.

Introducing Volcanica: a paradigm shift in academic publishing.

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As of 2015, the annual revenue of the academic publishing market was estimated to be $25.2 billion (Ware and Mabe, 2015). Access to research can be prohibitively expensive as a result of the for-profit business model of large publishing houses. The Research Information Network (2008) reports that around a third of the global research budget was dedicated to publishing research results that—significantly—99% of people have no access to.

Volcano-related research is no exception to this: where open access options exist, they typically incur substantial article processing charges (APCs). Otherwise, the research is paywalled, rendering it inaccessible without an institutional subscription or one-off per-article payments.

Unlike some science disciplines, volcanology has a more direct link between research output and observatory or governance practice. The current profit-driven paradigm of scholarly publishing exacerbates bias and inequality, and keeps information away from those who may need it most: globally, areas most at risk from volcanic hazard are often situated in less-economically developed regions.

Here, we propose an alternative publishing solution for volcano-related research. *Volcanica* is a diamond open access online journal, dedicated to publishing research on all aspects of volcanology and related disciplines. This includes field and experimental volcanology alongside the societal and climatic influence of volcanic phenomena throughout history.

By keeping working costs to a minimum and with financial backing from Presses universitaires de Strasbourg, we do away with expensive article processing charges or subscription costs. In short, a volcanology journal that is free for authors and readers alike. Find out more at **www.jvolcanica.org**.

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Interpreting volcanic eruptions using space-borne remote sensing instruments

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The regional-to-global nature of volcanic hazards makes satellite observations a valuable resource for investigating eruption plumes. In this work, we exploit the NASA Earth Observing System's Multi-angle Imaging SpectroRadiometer (MISR), MODerate Imaging Spectroradiometer (MODIS) and the Ozone Monitoring Instrument (OMI) to investigate and compare volcanic plumes generated in Kamchatka, Russia.

We use MISR multi-angle imaging to derive plume height, dispersion characteristics, and qualitatively characterize plume microphysical properties. Plumes were observed dispersing up to 400 km in length and were imaged at a spatial resolution of 1.1 km. Individual plume assessments display evidence of particle development, generated by both physical and chemical conversion processes. OMI SO_2 concentrations were compared with individual MISR plume retrievals where corresponding observations were available. Variations in eruptive style for individual volcanoes over time were also identified. Additionally, differences in plume properties and dispersion were established between volcanoes, providing clues about underlying regional geology. Daily MODIS surface thermal anomalies and OMI SO_2 concentrations were incorporated to infer details of eruption phases and ongoing eruption dynamics at each volcano.

The developed technique of investigating eruption dynamics can be implemented globally and is predominately limited by the observation frequency of the MISR satellite (observations every ~2-8 days depending on latitude). Satellite-based techniques are particularly valuable in remote locations where extensive monitoring is financially or logistically restricted.

Contrasting styles of volcanic activity along the Main Ethiopian Rift: Implications for contemporary volcanic hazards

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The Main Ethiopian Rift (MER) is the type example of a magma-assisted continental rift. We focus on the central MER (~7-9 °N), which includes regularly spaced silicic caldera complexes and central stratovolcanoes on the rift axis, as well as large fields of small eruptive centres, predominantly scoria cones of basaltic composition. The recent history of volcanism in the central MER is poorly known, and no eruptions have occurred in the living memory of the local population. The only way to assess contemporary volcanic hazards and associated risk is therefore in the first instance based on the volcanic geology. We present a compilation of new field observations and geochemical data on tephra deposits from the main centres of Late Quaternary volcanic activity in the central MER, as well as existing literature data, and discuss the most recent styles of activity at each, with implications for contemporary volcanic hazards.

Most central MER volcanoes host large calderas with associated widespread ignimbrite flow sheets of trachyte and peralkaline rhyolite composition. Several of these caldera-forming events are mid-Pleistocene in age. Our observations show that these systems have displayed highly contrasting eruptive behaviour in their most recent post-caldera stages, despite similar magma compositions and tectonic controls. Post-caldera activity is dominated at most centres by eruptions of peralkaline rhyolitic magmas, which have generated obsidian flows and domes, and pumice cones. The frequency and magnitude of explosive events however varies up to an order of magnitude between individual volcanoes. Some systems suggest a strong dominance of basaltic volcanism in their post-caldera stage, which may be controlled by the tectonic development of different rift segments.

This work indicates that (1) relatively low-cost reconnaissance of the volcanic geology of poorly known volcanoes can yield a wealth of crucial information about potential hazards; (2) seemingly similar volcanoes in a given tectonic context display highly contrasting behaviour, which raises concerns about the use of analogues to inform hazard and risk mitigation policies.

Automatically isolating and monitoring signals of volcanic unrest in InSAR time series.

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There are some 1500 subaerial volcanoes with the potential to erupt in the future, but most are not routinely monitored. However, the systematic acquisition strategy of the Sentinel-1 mission fulfils a key requirement for InSAR to progress from a retrospective analysis tool, to one used for global real-time monitoring.

We postulate that much of the signal contained in a time series of interferograms can be considered as a linear mixture of several latent sources, and present results of using principal component analysis (PCA), and spatial independent component analysis (sICA) to isolate these signals. We find that sICA performs well with synthetic data and proceed to apply the method to real data. For this, we use a Sentinel-1 time series of Wolf Volcano in the Galapagos Archipelago, where we are able to automatically isolate three signals that are broadly similar to those described in other studies.

This approach to isolating signals of geophysical interest allows us to implement a prototype automatic detection algorithm, which we demonstrate is able to detect the 2015 Wolf eruption.

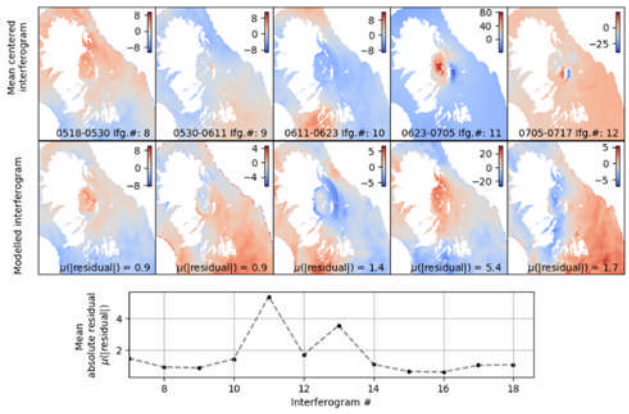

Fig. 1: The results of the automatic detection algorithm. The top row shows the time series of interferograms (note the large co-eruptive signal in interferogram 11), and the bottom a reconstruction of the corresponding interferogram made from components discovered by sICA. As the eruptive event introduces new ground movement that is not captured by the existing sICA components, the residual (row 3) jumps during the eruption.

Delivery of deep-sourced, volatile-rich plume material to the global ridge system

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Approximately one-third of the global mid-ocean ridge (MOR) system is affected by nearby mantle plumes, as reflected in enrichment of incompatible trace elements, isotope signatures and elevated ridge topography (excess melting). This enhanced ridge volcanism, together with that at the associated islands and seamounts, involves significant amounts of volatile (CO_2, H_2O) outgassing from the mantle. The "standard model" for plume-ridge interaction involves solid-state flow of deep-sourced material from the plume stem to an adjacent MOR. This model does not explain, however, certain enigmatic features, such as long-lived, linear, volcanic ridge-like structures radiating from active, hotspot-related oceanic islands to the nearby MOR. Examples include: Galápagos (the Wolf-Darwin lineament), La Réunion (Rodrigues Ridge), Discovery (Discovery Ridge), and numerous smaller ridge-like structures associated with the Azores and Easter-Salas y Gómez hot spots. A striking feature is that mid-ocean-ridge basalts (MORB) with exceptionally-high volatile contents correspond to the intersections of these plume-related volcanic ridges.

We use new joint models for rare-earth element inversion and volatile behaviour during mantle melting to show that the most H_2O-rich basalts on global ridges contain up to 15% of "deep", small-fraction melts forming in plume stems beneath associated oceanic islands. We propose that these melts are transported directly to nearby MOR segments via pressure-induced, highly-channelized flow in sub-lithospheric channels --- expressed at the surface as volcanic lineaments and ridges -- and that these constitute a primary delivery mechanism for deep hydrous melts from plume stems to nearby mid-ocean ridges. Delivery of the volatile-rich plume stem melt to the adjacent ridge accounts for the short wavelength variability (over 10's of km) in geochemistry and bathymetry that is superimposed on the much larger (many 100's of km) region of plume-influenced ridge. Since almost all mantle plumes are interacting with mid-ocean ridges these long-lived melt channels are important pathways for the transfer of deep-sourced volatiles to the global ridge system and mantle outgassing.

The Askja magma plumbing system (Iceland), an interesting puzzle

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Askja is an active volcano in the Northern Volcanic Zone of Iceland, lying within a spreading segment of the mid- Atlantic ridge. There have been at least 40 eruptions in the last 1100 years, including the 1875 VEI-5 caldera-forming Plinian event. However the current state of the complex magmatic system and the probability of an eruption in the near future are not well understood.

Steadily decaying subsidence within the main caldera has been recorded with a variety of geodetic measurements since at least 1983. It has been postulated that rifting extension and shallow magmatic processes, e.g. outflow and/or crystallisation, could be responsible for this subsidence. All models using surface deformation data agree that there is at least one shallow source at 2-2.5 km b.s.l. (3-3.5 km below the surface), shrinking at a rate of approximately -1.4 to -2.1×10^6 $km^3 yr^{-1}$. This depth is consistent with results from seismic tomography, which also reveal the presence of two melt storage regions at about 5-7 and 9-11 km b.s.l. The subsidence has been accompanied by a gravity decrease (mass loss) since at least 1988, except for a measured increase between 2007 and 2008. These gravity signals have been interpreted as the result of magma drainage and magma intrusion, respectively.

Here, we present new gravity results from 2015-2017, measured over an extended network within the caldera, together with new InSAR time series results. We use these data to model the location, depth, volume and mass changes beneath Askja from 2002-2017. Our results show a gravity decrease over a larger area than previously recognised, implying greater mass loss than previously thought. The InSAR results show a gradually decreasing rate of subsidence, consistent with earlier results from levelling and GPS, but the spatial pattern is more complicated than a simple spherical source would imply. Taken together the volume and mass decreases can be explained by magmatic drainage from shallow to deeper reservoirs due to pressure changes induced by plate spreading, and hydrothermal circulation.

Influence of crustal processing on the identification of mantle heterogeneity

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Low-K tholeiites erupted from volcanoes in eastern and north-eastern Galápagos are more isotopically depleted and have lower concentrations of strongly-incompatible trace elements than those from other parts of the archipelago. This is explained by the presence of thinner lithosphere in the eastern archipelago allowing greater adiabatic decompression melting of more refractory mantle material. However, olivine minor element analysis indicates that there is a significant contribution from a recycled, pyroxenitic component in the eastern archipelago (Vidito et al. 2013). These results appear at odds with the major- and trace-element systematics of eastern Galapagos basalts. Pyroxenite components influence the thermodynamic properties of upwelling mantle and the chemical and rheological characteristics of resulting melts. We therefore explore several alternate hypotheses that may have led to mis-identification of pyroxenite in the Galapagos mantle.

Our primary focus is to determine whether crustal processing of magmas can influence the results of olivine minor element investigations. Simple fractional crystallisation and magma mixing models, as well as hypothetical models of diffusive re-equilibration following mush entrainment/disaggregation, indicate these processes result in erroneously high estimates of the proportion of pyroxenite-derived melt.

In the samples available for study, we see petrological evidence for magma mixing in complex zonation patterns and dissolution textures in olivine phenocrysts. Additionally, the trend of olivine data in forsterite vs Ni space for Isla Santa Cruz is characteristic of diffusive re-equilibration of high forsterite phenocrysts rather than fractional crystallisation. These results indicate that crustal processing of magmas, significantly interfere with our ability to identify mantle heterogeneities.

Finally, we analysed olivine Ni, Ca and Mn contents of carefully selected olivine phenocrysts in key samples, least likely to be affected by the processes described above. Results indicate that a pyroxenitic lithology may be present in the Galapagos mantle, but likely correlates with isotopic enrichment, contrary to previous suggestions.

Vidito, C, et al., 2013. *Geochem. Geophys. Geosyst.* 14(10): 4214-4240.

Diffusion of trace elements during mixing of shoshonitic and rhyolitic magmas: an experimental study

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Diffusion is a major process in magmatic systems; particularly, it controls mass transfer during magma mixing events and represents a potential source of timescales in pre-eruptive magma mixing. We experimentally studied the diffusive mass exchange of 30 trace elements between melts of natural shoshonitic and rhyolitic composition sampled at Vulcano Island, Italy. A set of 13 diffusion couple experiments was run in an Internally Heated Pressure Vessel at temperature of 1200 °C, pressure ranging from 50 and 500 MPa, and both dry and hydrous (1 wt.% and 2 wt.% added H_2O) conditions. Concentration-distance profiles were measured by LA-ICP-MS and water contents were determined by FTIR. Concentration-dependent diffusion coefficients of elements following Fick's laws were determined by a modified Boltzmann-Matano method.

A group of 13 elements show Fickian diffusion profiles, and hence diffusion coefficients were calculated. We find that water content is the main conditioning factor of diffusion in our experimental setup, followed by bulk composition. The addition of 2 wt.% dissolved water results in a diffusivity increase between 1.0 and 1.4 orders of magnitude, with the highest values corresponding to LILE (Ba, Cs, Rb and Sr) and the lowest to transition elements (Ta, Cr). Diffusivities increase smoothly from rhyolitic to shoshonitic melts, with the exception of Ba and Sr, which are insensitive to melt composition. Evidence of coupling to SiO_2 diffusivity is observed. Pressure does not have a measurable effect in the studied range.

A second group of elements comprising Y, Zr, Nb, Pb and, most notably, REE (except Eu) display prominent uphill diffusion in the form of very deep minima in the rhyolitic side coupled to wide maxima in the shoshonitic side. This behaviour indicates that diffusion is strongly affected by activity gradients induced by the strong SiO_2 contrast, resulting in a transient melt-melt partitioning in favour of the less polymerized shoshonitic melt. These results highlight the complexity of the diffusion process in magma mixing events involving mafic and silicic melts.

The Palaeogene magmas of Arran: genesis, storage, and emplacement

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The island of Arran on the west coast of Scotland contains many well-exposed remnants of the British Palaeogene Igneous Province (BPIP). While the igneous rocks have been studied for well over a century, relatively little is known about the crustal architecture of the region. It is known that the island is bisected by the Highland Boundary Fault (HBF), which separates the Grampian Terrane to the north from the Midland Valley Terrane to the south, but the trace of this fault across the island is poorly constrained, and little is known about what form it takes at depth. It is also unclear what basement underlies the Dalradian Supergroup of the Grampian Terrane, and Palaeozoic sandstones of the Midland Valley Terrane in the region.

Sr-Nd-Pb-Hf isotopic analyses of various magmatic rocks from the North Arran Granite and the Central Arran Igneous Complex (CAIC) show varying degrees of contamination by a variety crustal sources. The majority of rocks in the CAIC show contamination of depleted mantle-derived melts by crustal units which are isotopically similar to a suite of lower crustal xenoliths from the Midland Valley. This suggests these magmas rose sub-vertically through the Midland Valley crust without interaction with the HBF or Grampian Terrane crust. The isotopic signature of the North Arran Granite is consistent with contamination by crustal material resembling the Dalradian Supergroup, again suggesting sub-vertical ascent. Some mafic intrusions from the CAIC, however, show contamination by a crustal source which most closely resembles the Proterozoic Rhinns Complex on Islay, 80 km to the N. This has been interpreted to represent the basement to the Dalradian Supergroup. The isotopic composition of these magmas therefore suggests the presence of Proterozoic basement at depth below Arran. If these magmas were contaminated by Rhinns-like material, it suggests that they may have ascended to the north of the HBF, and then crossed the fault laterally before emplacement in the Midland Valley Terrane.

Insights into subvolcanic architecture from magnetic techniques

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Iceland presents a unique opportunity to explore the frontiers of what magnetic techniques can tell us about magmatic processes. Presented here are new data from a suite of novel rock magnetic experiments, including out-of-phase AMS data, which are used to explore the origin, evolution and emplacement of Icelandic granitoids.

The plutonic rocks of Iceland are well-exposed, tectonically undeformed and geochemically well-characterised. The Austurhorn subvolcanic complex in SE Iceland is a prime example. The presented geological map, field evidence and field bulk susceptibility data of the basal section of the Austurhorn intrusion show that it is constructed from numerous small-volume intrusions of both mafic and felsic material, intruded contemporaneously resulting in widespread mixing and mingling. Sheet-like geometries defined by facies contacts and silicate fabrics are discernible in the field, but elsewhere magmatic architecture is harder to constrain using only field observations.

Anisotropy of magnetic susceptibility (AMS) allows subtle fabrics defined by magnetic crystals to be detected and quantified. Out-of-phase magnetic susceptibility measures the lagged response to an applied magnetic field, and its geological applications are little-explored. However since only certain ferromagnetic minerals give an out-of-phase response, measuring out-of-phase AMS make it possible to compare alignments in different minerals within the same rock. Here we use both in-phase and out-of-phase AMS to map the architecture of the Austurhorn basal complex and provide insight into the mechanisms of subvolcanic magma movement.

A Petrogenetic Study of East Siberian Intrusives and their Links with the Siberian Large Igneous Province

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Basaltic intrusive rocks represent a significant proportion of the Siberian Traps (ST) Large Igneous Province and are the only magmatic representations of the magmatic event in some parts of the province. Associated with some of these intrusions are significant ore deposits, with the Noril'sk area of the ST representing one of the largest Ni-Cu sulphide deposits in the world. Despite the significance of the intrusive history, research has focused on petrogenesis of the ST lavas. The aim of this study is, based on whole rock major and trace, and radiogenic isotope data, to establish potential correlative and petrogenetic links between well-studied intrusive and extrusive rocks at Noril'sk with intrusive rocks exposed along the south and east periphery of the province.

Preliminary findings on data collected from 22 intrusive samples from Yakutia and East Siberia indicate that sills and dykes in the southeast are overall compositionally similar to the Noril'sk low-Ti upper series of lavas. These samples share trace element abundances typical for intrusive rocks from Noril'sk Groups 3, 4 and 5A including low La/Sm (2.1–2.6) and Gd/Yb (1.5–1.9) ratios indicative of formation by large degrees of partial melting followed by limited crustal contamination. The link to group 5A intrusions is significant as these are related to ore-bearing formations. Intrusions located further from the periphery of the Siberian craton display a wider range in chemistry implying a stronger influence of crustal lithologies and/or craton thickness. The observed data range is tentatively interpreted to reflect processes including small degrees of partial melting, fractional crystallisation (Mg# 30–67), crystal accumulation and various degrees of contamination of primary magmas by crustal lithologies. However, intra-sill variation from top to centre in e.g. SiO_2 (53 to 49 wt.%), La/Sm (4.7 to 2.6) and $^{87}Sr/^{86}Sr_{initial}$ (0.709920 to 0.705286) observed in a single sill (~300 m thick) are interpreted to reflect magma interaction with host rock.

Further work will focus on establishing a refined petrogenetic model for the intrusive history of the ST, including use of radiogenic isotope ratios to determine the degree of crustal contamination, as well as establishing a refined correlation between intrusions in east Siberia and the ore-bearing intrusions in the Noril'sk area.

Is Volcán de Colima (Mexico) due for a very explosive and potentially devastating (Plinian) eruption?

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Volcán de Colima is the western most volcano in the Transmexican Volcanic Belt (TMVB) and the most active volcano in North America (Luhr et al. 2010). This stratovolcano is known for its cyclic activity which terminates in highly explosive (Plinian) eruptions, such as those in 1818 and 1913. This ~100-yr pattern has so far failed to repeat with the current cycle, which remains in a state of effusive venting and mildly explosive activity. This brings into question whether Volcán de Colima is still capable of producing a Plinian style eruption, that would cause great devastation to the regional population and industry.

Utilising historical datasets of mineralogical and petrological analyses at Colima (Savov et al. 2008), a chronology of changes during the different eruptive cycles were identified. In addition, primary samples were collected from deposits of known age (2013 & 2014) and were examined in comparable means to previous datasets. This included utilising microscope suites, ICP-MS and XRF.

Analysis revealed that percentages of Plagioclase, Hornblende and vesiculation in thin section show an increasing trend between 2013 & 2014, in contrast to previous observations reported by Savov et al. (2008), which showed a gradual decline. This was supported by decreases in Hornblende compatible elements, such as Y and Tb, whereas trends of Rb, a SiO_2 proxy, were seen to be following previous conclusions and declining. These contrasting patterns were observed throughout the study, suggesting that Volcán de Colima may have been experiencing increases in temperature, water and gas contents at depth, as per previous end cycle events, whilst simultaneously trending away from such an event in other areas.

This may explain why Colima has remained in its current eruptive state for so long, as the recipe of previous events has yet to replicate itself fully. It may still be possible for it to return to its previous Plinian behaviour, but current trends in the record leave the big question of when it will occur difficult to answer.

Savov, I.P. et al. 2008. J. Volcanology & Geothermal R., 174: 241-256.
Luhr, J.F. et al. 2010. Contributions to Mineralogy & Petrology, 71: 343-372.

Formation and Eruption of Silicic Magmas by Crustal Melting

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The processes involved in the formation and eruption of silicic magmas vary between settings and require some crustal processing of melts. Models for production of such magmas include extensive fractionation of mafic magma in the crust, incorporation of large quantities of crustal material into mafic magmas, and partial melting of continental crust. One of the suggested causes for the latter is intrusion of mafic bodies into the continental crust, causing melting in the surrounding crust and production of an overlying, less dense silicic body.

A numerical model has been developed using idealised fluid dynamic and heat transfer arguments. A near-liquidus basalt sill in injected into continental crust, causing crustal partial melting, and subsequent thermal and physical evolution is modelled. This model builds on previous work (Huppert and Sparks, 1988) by including the effect of partial crustal melting, crystal settling and the role of volatile exsolution. The resultant volume and eruptability of such bodies is assessed in relation to such variables as thickness of basalt injected, background crustal temperature, depth, and fall speed of crystals. The likelihood of mixing or mingling between the magmas is investigated in these different scenarios.

This model has been applied in the context of the El Hoyazo eruption in SE Spain. This was a dacitic eruption of approximately $1km^3$ which erupted 6.3Ma, as part of the Neocene Volcanic Province. It has been previously described as an 'erupted migmatite' (Zeck, 1968) and is the product of deep (25km) crustal partial melting. Here the dacite production is modelled as a crustal melting event, caused by the intrusion of a hot mafic body into the lower crust. Published geochemical data has been used to constrain the input parameters for the model. Results from the model will give information about the size of the basalt sill injected and the likely storage time of the dacite before eruption.

Future work will involve complementary analogue experiments to investigate processes such as mingling of the magmas and crystal and volatile exchange between magmas.

Huppert, H.E., Sparks, R.S.J., 1988. J Petrology 29, 599–624.
Zeck, H., 1968. Thesis, Amsterdam University.

Geochemical correlation of ancient pyroclastic sheets from the nested calderas of the Borrowdale Volcanic Group, N.W. England

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Well-exposed, exhumed caldera volcanoes provide a rare insight into the behaviour of super-volcanoes, allowing the reconstruction of major explosive events, and patterns of associated vent migration and subsidence. Several caldera volcanoes lie within the ~6 km-thick Ordovician Borrowdale Volcanic Group inlier, north-west England, which is a remnant of a Palaeozoic subaerial continental arc. Scafell caldera, >140 km^2, is best-known and intensively studied because it is a rare example worldwide, where exhumation and glacial erosion reveals the entire pre-caldera, caldera-fill and post-caldera lake succession along with the caldera floor faults, vents and domes.

Several calc-alkaline, high-K andesitic–silicic ignimbrites and fallout layers are associated with Scafell and nearby calderas, e.g. Langdale caldera. However, many outflow ignimbrites remain that have not yet been traced to their source areas.

Correlation of individual outflow sheets has been hampered by their large number, by caldera-related hydrothermal alteration, regional low-grade (prehnite-pumpellyite) metamorphism, cleavage and thrusting.

In order to correlate the outflow sheets with proximal equivalents inside Scafell, Langdale and other potential calderas, trace-element geochemical finger-printing is being used in combination with existing data on the calderas, local detailed stratigraphic mapping and textural work to resolve local pyroclastic successions. Initial results show that some outflow sheets can be traced to their sources, whereas others are 'exotic' and derived from as yet unidentified sources. The improved correlations are enhancing our understanding of ignimbrite volumes and eruption parameters, relative ages of the ignimbrite eruptions, caldera collapse events and intracaldera lacustrine sedimentation in the nested caldera complex. The aim is to correlate outflow sheets with caldera fills and ultimately to individual vents and exposed conduit-fills. Understanding ancient pyroclastic successions is of fundamental importance to our understanding of exhumed caldera volcanoes, and can be resolved successfully even where there has been limited alteration and tectonic deformation.

A discrete-element approach to modelling lava dome stability

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Lava dome collapse can result in a range of activity including rockfalls, debris avalanches, pyroclastic flows and explosive eruptions, all of which can present hazards to communities living on the volcano flanks. Many mechanisms have been observed to trigger collapse including: gravitational collapse due to oversteepening; internal gas overpressures; interaction of the dome with rainfall; a switch in extrusion direction and topography-controlled collapses (e.g. a dome exceeding the size of the crater in which it sits).

Despite the hazards associated with dome collapse, there remains limited understanding of the interaction between a dynamically evolving dome and factors influencing its stability. In order to interrogate such interactions, we establish and interrogate a global, historical database (Global Archive of Dome Instabilities, GLADIS). This allows the most common mechanisms attributed to dome collapse to be identified, and we use these as scenario models for a numerical analysis.

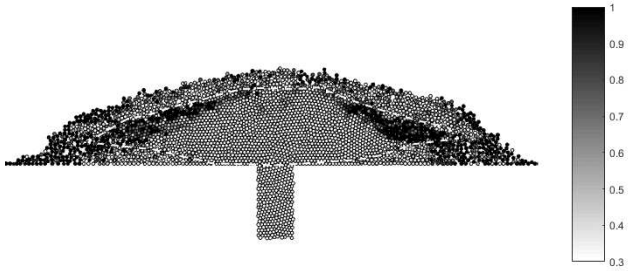

Fig. 1: An example dome model shown as a function of normalised finite shear strain, after a 1MPa of gas overpressure has been applied. The model shows development of a deep rotational shear failure that intersects the interior of the dome. Dotted line shows rheological boundary between core and talus material.

We create a 2D numerical model in Itasca's Particle Flow Code. We calibrate our dome emplacement model to realistic dome rock properties from Soufrière Hills Volcano, Montserrat and use this model as a starting condition for a suite of models that test the collapse trigger mechanisms outlined above. Here we present initial results of the numerical analysis simulating a switch in extrusion direction and the application of a gas overpressure, thus showing the subsequent development of two different failure mechanisms: (1) shallow, small-scale rockfalls, and (2) deep, rotational shear failure.

Comparison of satellite observations of atmospheric emissions from the April 2015 eruption of Calbuco volcano

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Calbuco volcano, Chile, erupted in three distinct phases in April, 2015. The first two phases, on 22nd and 23rd April, produced large ash and gas eruption columns, reaching ~ 12 and 15 km respectively. The third phase of the eruption, on 30th April, produced a weak ash column not exceeding 4.5 km. The plume was observed by numerous passive and active satellite instruments, including IASI, OMPS, OMI, MLS, CALIOP and CATS.

Direct observation of volcanic plume altitude is possible with active lidar instruments such as CALIOP and CATS. CATS was installed on the International Space Station (ISS) in January 2015 but the data have thus far been under-utilised. We will present comparisons between these lidar measurements and altitude retrievals from passive satellite instruments – IASI, MLS and OMPS (both the limb and nadir instruments). These comparisons provide as close to a 'true validation' of the altitude retrievals from the spectrometers as possible. The addition of data from CATS increases the frequency of lidar measurements, providing observations at different times of day due to the lower ISS orbital altitude.

Visible lidars are unable to directly observe SO_2 or H_2S plumes and so their retrievals of volcanic products are limited to sulphate aerosol and ash. This means that the comparison instrument has to be able to directly retrieve volcanic ash or aerosol, or an assumption has to be made that the ash and SO_2 plumes are co-located. Within the first several hours to days, this assumption should be reasonably reliable, however this is a likely source of error between the measurements and will increase with time.

The orbital tracks of all of the instruments following the Calbuco eruption produced measurements through, or very close to, the centre of the eruption plume. This allowed for comparison of the retrieved altitudes for the plume immediately following release, as well as facilitating tracking of the plume as it moved both vertically and longitudinally over time.

The volcanic plume was caught in a cyclonic system for several days off S. Africa, constraining it to an unusually small region. This meant the gas concentrations remained high for several weeks and allowed both the spectrometers & the lidars to track the in-plume conversion of SO_2 into sulphate.

The Influence of Viscoelastic Rheologies on Volcano Deformation: A Comparative Study

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Deformation of a volcano often, but not always, occurs prior to an eruption, with deformation patterns offering vital insights into the characteristics of the magmatic system. Modelling of volcanic ground deformation can provide inferences into the source parameters, including shape, size and location. However, volcano deformation modelling is inherently an inverse problem, requiring a wealth of geological, geodetic and geophysical observations in order to distinguish plausible models.

Recent geodetic modelling has begun to incorporate viscoelastic crustal rheologies to account for elevated crustal temperatures and thermal legacies, resulting from long magmatic and volcanic histories. These studies use a variety of different linear and power-law viscoelastic models without fully justifying their selected choice. Here, we investigate the influence of different linear crustal viscoelastic representations on surface deformation, resulting from a subsurface pressurised, or expanding, deformation source (representing a magmatic reservoir). This vital difference in source boundary condition is often overlooked, but causes vast differences in modelled spatial and temporal deformation patterns. We include the Maxwell, Kelvin-Voight and Standard Linear Solid viscoelastic representations in our assessment.

We will apply the results from this theoretical study to Lake Taupo, New Zealand, and explore the nature of the processes facilitating recent ground deformation. The last caldera-forming eruption at Taupo occurred 1800 years ago, and it is thought that a substantial amount of melt remains. Non-eruptive inflation and deflation episodes have recently been recorded at Taupo, and raise the fundamental question of whether they represent individual phases of an active magmatic system undergoing unrest or, instead, are driven by a combination of post-eruptive and tectonic processes. The results will feed directly into the interpretation of monitoring data at Taupo and, ultimately, improve New Zealand's resilience to large volcanic eruptions.

50 shades of ignimbrite: How hydrothermal alteration modifies permeability and strength

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Ignimbrites are among the most diverse rock types on the planet, with highly variable grainsize distribution and welding intensity. Subsequent hydrothermal alteration can increase or decrease porosity, permeability, and strength. These factors are important for volcano modelling, geothermal energy production, and epithermal Au-Ag mineralisation. Our goal here is to quantify the varied appearance of an ignimbrite—the Ohakuri ignimbrite (Taupō Volcanic Zone, New Zealand)—that hosts a palaeo-hydrothermal system. This deposit ranges from an unaltered, loose ash-lapilli mixture up to a hard and dense rock (Fig. 1). We provide laboratory data on the porosity, matrix permeability, fracture permeability, uniaxial compressive strength, stiffness, and failure modes (brittle versus ductile).

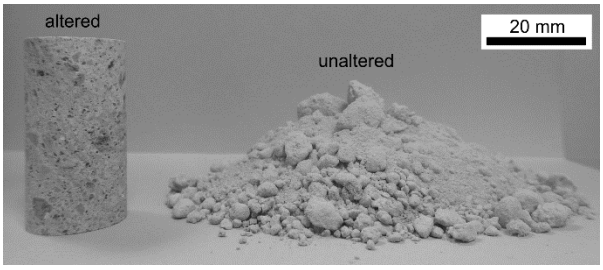

Fig. 1: Photograph of a core sample of the altered deposit at Ohakuri Dam (left) and a heap of unaltered deposit (right).

The unaltered deposit is cohesionless and characterised by high porosity (~0.5) and high permeability (~10^{-13} m^2). The most intensely altered rock contains a porosity as low as 0.24 and a permeability as low as (2×10^{-17} m^2). Hydrothermal alteration reduced permeability by about four orders of magnitude. Although it is intuitive that a reduction in matrix permeability will inhibit fluid flow, an increase in strength and, importantly, stiffness fosters brittle behaviour, creating high permeability pathways that are favourable for channelling hydrothermal fluids. Alteration also extends the depth at which we can expect brittle behaviour. Alteration can therefore change permeability behaviour from distributed to discretized fluid flow, thereby increasing the equivalent permeability of a rock mass.

Braided peridotite sills in the Rum Layered Suite, Scotland

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The Eastern Layered Intrusion (ELI) represents an archetypal open-system layered intrusion, constructed of sixteen macro-rhythmic units. Each unit consists of a peridotite base, followed by a troctolite (± olivine gabbro) top generally attributed to fractional crystallisation of a single magma batch. However, the classic paradigm of an aggrading cumulate sequence has been challenged in the ELI where the peridotite portions of the macro-rhythmic units have been shown to be intrusive. This has been demonstrated in Units 9[1], 10[2], and 14[3] where small volume sill emplacement has been proposed, particularly in localities where layers of skeletal olivine-bearing cumulate (harrisite) and Cr-spinel seams coexist.

To test whether other major peridotites within the ELI represent sills emplaced into feldspathic cumulate, we have carried out a new field, petrographic, textural and mineral chemical study of Units 7, 8, and 9. The peridotites in these units display local (~10 cm) and broad (1–5 m) amplitude cross-cutting relationships with the surrounding layered feldspathic cumulate, indicative of intrusive relationships. The peridotites exhibit spatial compositional variation (e.g., in plagioclase and clinopyroxene mode) along strike. Field evidence indicates that the peridotites locally exhibit a braided geometry where they coalesce and feldspathic cumulate is missing. As with Unit 10, the importance of incremental, small volume magma replenishment is supported by the abundance of harrisitic peridotite (and Cr-spinel seams) throughout Units 7, 8 and 9. Clinopyroxene-rich chromitites within Unit 8 point to lateral reactive partial melting of pre-existing cumulate during the emplacement of thin peridotite sills along amenable lithological boundaries. The structural and lithological complexity of peridotites in the ELI also allow for a basic chronology of intrusive events during crystal mush construction, suggesting comparatively late-stage intrusion of picritic magma into the Rum Layered Suite.

The new data from the ELI cannot be reconciled with a classic magma chamber paradigm, and are better explained by the emplacement of peridotite sills into pre-existing feldspathic cumulate. These data are combined with recent observations from other parts of the Rum Layered Suite[4], and a new conceptual model is presented for the construction of the layered complex as a whole.

[1]Bedard et al (1988). J Geol Soc London **145**, 207–224
[2]Hepworth et al (2017). J Petrol. **58** 137–166
[3]Renner & Palacz (1987) J Geol Soc London **144**, 961–970
[4]Hepworth et al (*in revision*) J Petrol.

Evolution of the Kameni Islands volcanic centre (Greece) from chemical and textural studies.

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During the last 2000 years there have been 8 subaerial and at least 5 underwater largely effusive eruptions of dacites from the Kameni Islands volcanic centre, situated within the Thera (Santorini) Caldera. The lavas have a limited range in chemical composition (SiO_2 = 64-68.5%) which contrasts with their wide range in textures (plagioclase = 3-22%). The dacites are commonly glassy with abundant macrocrysts of plagioclase and minor pyroxenes and magnetite. Some macrocrysts occur in loose clusters with relatively fine-grained cores. Most plagioclase crystals have simple zoning and belong to the same population. Enclaves are present but do not appear to have contributed significantly to magmatic diversity.

Starting with the 46CE eruption SiO_2 initially rose until the explosive 726CE eruption and then descended until 1950CE. Plagioclase abundances mirror this variation and are broadly correlated with SiO_2 and Eu/Eu*. Mass balance calculations show that most of the compositional diversity can be accommodated by addition of plagioclase macrocrysts to a slightly heterogeneous dacite liquid.

Crystal size distributions (CSD) are curved and have been modelled by adding two straight CSDs reflecting deep and shallow processes. Large crystal CSD components show relatively little temporal variation, except for 4 early, low-plagioclase samples that have more large crystals. Small crystal CSDs become steeper with time and plagioclase content, suggesting progressively more rapid transport.

We propose that the compositional diversity was produced by dynamic processes, rather than the sampling of a static stratified magma chamber. Injection of hot mafic magma into the base of the chamber provoked degassing, followed by bubble formation on the silicate crystals. The buoyant crystals then rose to the top of the chamber. If eruption occurred shortly after the injection event then the magmas would be crystal rich, otherwise the magma chamber would become rehomogenised by convection and the crystal content of the magmas would be lower.

Facies analysis and physical volcanology of the Þórólfsfell tuya, South Iceland

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Þórólfsfell is an enigmatic tuya located between the stratovolcanoes Tindfjallajökull and Eyjafjallajökull, South Iceland. The edifice is unusually asymmetrical, with a vent to the north and a southern depocentre, a result of its construction on the sloping southern flank (~12°) of Tindfjallajökull. Here we present the first descriptions and volcanological interpretations of the stratigraphic succession at Þórólfsfell, suggesting an additional model for the subglacial emplacement of tuyas.

Architecturally, Þórólfsfell lacks the pillow lava base, passage zone, and the abundant hyaloclastites that typify descriptions of mafic-intermediate tuyas. Instead, the tuya is lava-dominated and is primarily composed of a pahoehoe-fed lava pile, up to 420 m thick, which preserves a 'drying up' sequence reflected by changes in fracture density populations and the concentration of magmatic H_2O volatile species within glass samples, analysed using Thermogravimetric Analysis (TGA) techniques. Minor volumes of phreatomagmatic tephra sandwiched between lavas indicate that explosive activity occurred simultaneously with lava effusion, either from the same or different vent(s) along a volcanic fissure. Ash particle morphologies, in conjunction with field evidence, also imply a 'drying-up' succession within the tephra, with a corresponding decrease in coolant supply with time. The upper section of the tuya is a lava cap. Colonnades are large, reaching widths of 58 cm. Despite this, there is little evidence to suggest significant shoaling above the ice surface, with few ropes observed and a continuous distinct lack of a passage zone and tuff cones throughout the tuya.

A waning effusion rate throughout the monogentic eruption is assumed, potentially diminishing from a maximum of ~5 m^3s^{-1}. Lava lobes increase in size with elevation due to reducing coolant availability and increased accommodation space thus permitting inflation. Excellent preservation, and a lack of alteration, suggests the eruption occurred during the Weichselian glacial period.

Global monitoring of volcano deformation with Sentinel-1

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The Sentinel-1 constellation represents a major advance in our ability to monitor our planet's volcanic zones. Here we present the latest progress from COMET, where we are providing volcano deformation results to the community. We process interferograms systematically using our dedicated LiCSAR chain, making interferometric products available for the majority of subaerial volcanoes. We currently serve displacement and coherence grids, but plan to provide average deformation rates and time series. Results are available through our dedicated InSAR portal: http://comet.nerc.ac.uk/COMET-LiCS-portal and the COMET Volcano Deformation Database: https://volcanodeformation.blogs.ilrt.org/

We show here examples of our latest results. We also discuss how these can be used to build value-added products including volcano deformation alerts, which use blind source separation algorithms to automatically detect new deformation sources and changes in deformation rate.

Petrological and geochemical evolution of Arthur's Seat Volcano

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Arthur's Seat, located in central Edinburgh, is an intraplate volcano that erupted 341.2 Ma ago, generating a succession of alkaline to tholeiitic basaltic lavas (Moreland, 2012; Monaghan et al, 2014). The volcanic activity is thought to be related to strike-slip tectonics and back-arc extension in the Midland Valley, which is associated with the Variscan Orogeny (Upton et al, 2004). Although some preliminary geochemical studies have been published on Arthur's seat (Clark, 1956; Black, 1966), the overall temporal evolution of the mineral chemistry, and textures of its products have yet to be studied in detail.

Stratigraphically-well-constrained volcanic rocks have been collected from the Whinny Hill area of Arthur's Seat. Ongoing work aims to characterize these volcanic rocks to provide insight into the nature and evolution of the source of these eruptions. This study will focus on any temporal variations in whole-rock and mineral chemistry, and crystal size distribution of the main mineralogical phases in the Whinny Hill sequence.

Here, we will present ongoing petrological work from lava flows across the Whinny Hill region. Ultimately, our results will improve not only current understanding of the Arthur's Seat Volcano, but also the overall evolution of the Scottish Dinantian magmatism, allowing improved evaluation of regional tectono-magmatism process.

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Measuring Fe oxidation state of silicate glasses using EPMA: Time-Dependent Ratio Flank Method

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The Fe oxidation state of silicate melts provides a proxy for oxygen fugacity, which controls the chemical and physical properties of volcanic and magmatic systems. The glasses quenched from these melts tends to be small (e.g., melt inclusions, interstitial glass or experimental run products), therefore high resolution, in situ techniques are required.

Currently, μXANES is the preferred technique due to its high precision and spatial resolution (e.g., Cottrell et al., 2009), but it requires access to synchrotron facilities and difficult sample preparation. It is possible to use the electron probe, which is common at many institutions and requires simple sample preparation, to measure the Fe oxidation state using the Fe L lines. Unfortunately, the analytical conditions required can cause changes in the redox state of the glass during analysis, which have previously prevented analyses at high spatial resolution.

We present an adaptation to the Flank method (Hofer & Brey, 2007), which is currently used on minerals, allowing high precision and spatial resolution analyses of silicate glasses. Time-Dependent Ratio measurements are made, which record the redox changes in the glass during analysis, and can be extrapolated to time zero to calculate the initial Fe oxidation state.

We have explored the compositional space of silicate glasses (SiO_2, Fe^{2+}/Fe_T, total alkalis and H_2O) to understand the controls on redox changes during electron beam irradiation. Sub-surface charging during analysis causes the redox changes in the glass (Fialin & Wagner, 2012). Anhydrous basaltic glasses reduce due to electrons hopping between O and Fe^{3+}, away from the negative charge at depth. Hydrous basaltic glasses oxidise because H^+ migrates towards the negative charge at depth, leaving behind O^{2-} which oxidises FeO. Interestingly, hydrous dacitic glasses do not change oxidation state during analysis.

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The structure and eruptive dynamics of three peralkaline rift volcanoes using high-resolution digital elevation models

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The peralkaline rift volcanoes of Ethiopia are among the least studied in the world, yet are located in an area of dense rural population and are the subject of recent geothermal investigations. Their eruptive histories are largely unknown, and the effects of their unusual chemistry on eruptive dynamics have not been documented.

We present three high-resolution digital elevation models which enable the update of geological maps of each centre. This is combined with ground truthing of Fentale volcano, the northernmost centre within the Main Ethiopian Rift. We have found evidence for significantly more post-caldera activity at Fentale than has been reported. Eruptive vents align along rift-related structures and cross-rift faults, indicating the interplay between pre-existing weaknesses and the stress field at time of eruption. The morphology of obsidian lava flows on Fentale varies greatly, including abundant levees and rarer ogives. These features and their volumes provide clues as to the dynamics involved in emplacement, which is the focus of further work.

The structure of the calderas along the rift also varies, from Fentale's deep, regular crater to the wide and low-relief caldera of the Corbetti complex. The irregularity of the Corbetti and Gedemsa calderas suggest a different formation mechanism compared to Fentale. The alignment and ellipticity of post-caldera craters at Corbetti, and the locations of limited post-caldera activity at Gedemsa, further emphasise the influence of cross-cutting structures in rift volcanism.

This work provides insights into the styles, locations and magnitudes of previous eruptions at Fentale, Corbetti and Gedemsa. Though Gedemsa is thought to be inactive, Fentale and Corbetti have active geothermal systems and display recent deformation. Satellite imagery, as used in this study, offers a convenient method for investigating large areas in order to constrain potential risk associated with future volcanic activity.

Amphibole reveals the hidden complexity of lower crustal magma plumbing systems at arcs

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Subduction zone volcanoes overlie complex plumbing systems in which magmatic components interact during magma storage at a range of pressures. This shallow magma assembly obscures information about deeper crustal processes, and bulk rock compositions therefore hide complexity that can inform us about the structure and composition of the continental crust. Melt inclusions provide an effective window onto the uppermost 10-15 km of sub-volcanic plumbing systems but it remains challenging to understand processes operating in the lower crust, as identified by geophysical anomalies.

We present a new multiple regression analysis of trace element partitioning in amphibole, which allows us to invert the measured trace element compositions of amphibole crystals to find the compositions of their parent melts, here applied to Mount St Helens volcano, USA. Evolved melts crystallised Mg-hornblende and are in equilibrium with the least evolved, plagioclase-hosted melt inclusions. Melts that crystallised Mg-hastingsite reflect an earlier stage of amphibole-dominated fractionation at high pressures (>300 MPa).

A wide variability of Nb, Zr and REE concentrations in the calculated amphibole equilibrium melts indicates assimilation of partially-remelted, older intrusive material containing biotite + zircon + apatite at mid-crustal levels. This emphasises the importance of repeated episodes of intrusion and remobilisation during the formation of arc magmas, and demonstrates how efficiently the different magmatic components are homogenised during shallow-pressure magma assembly.

This new method is an effective probe for deep crustal magmatism which can be applied to magmatic systems worldwide, and offers a new tool to explore the nature of deep crustal melt evolution in hydrous magma systems.

The Role of the Mantle and Crust in High-Volume Silicic Volcanism

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Silicic volcanic rocks (lavas and ignimbrites) associated with the Variscan orogeny are widespread in Europe and North America. This collisional event caused the juxtaposition of lithologically distinct zones (e.g. Moldanubian and Saxothuringian) and was followed by an extensive phase of rhyolitic Carboniferous-Permian magmatism throughout Western and Central Europe. It seems relatively well established that early Permian A-type felsic rocks in western and central Europe (e.g. Cornwall and Black Forest) were formed after, and independent of, granitic emplacement. Yet, very little is known about the conditions of formation, the source region and the role of the mantle for the post-Variscan effusive stage of volcanism.

This study focuses on 40 A-type rhyolite samples from the Black Forest, Vosges, and the Odenwald regions. Whole rock XRF and ICP-MS major and trace element data, supplemented by radiogenic isotope data define two distinct chemical volcanic domains. A northern domain can be distinguished by high SiO_2 (≥75 wt.%), Nb/Zr ratios (>0.3) and Rb (>300 ppm) with low TiO_2 (<0.2 wt.%), compared to samples in the south. This is also reflected in radiogenic Hf isotope ratios above 0.2826 for samples from the north. Furthermore, the range in Sr-isotope data ($^{87}Sr/^{86}Sr$ = 0.351 to 0.712) imply a strong hydrothermal overprint in the whole of the region. We tentatively interpret the observed range in data to reflect distinct crustal sources which coincide with the large-scale lithological domains. With the exception of samples from the northernmost Black Forest, the initial findings suggest that Black Forest and Vosges volcanism can be linked to a syn-collision formation; whereas, Odenwald and the northernmost Black Forest volcanism was caused by processes similar to volcanic-arc settings. If true, this may suggest a revision of Variscan tectonics in this area is required.

New geophysical and geochemical constraints on the plumbing of Ethiopia's restless rift volcanoes

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Restless silicic calderas present major geological hazards, and yet many also host significant untapped geothermal resources. In East Africa this poses a major challenge, although the calderas are largely unmonitored their geothermal resources could provide substantial economic benefits to the region. Understanding what causes unrest at these volcanoes is vital for weighing up the opportunities against the potential risks. Here we bring together new field and remote sensing observations to evaluate causes of ground deformation at Aluto, a restless silicic volcano located in the Main Ethiopian Rift. Interferometric Synthetic Aperture Radar (InSAR) data reveal the temporal and spatial characteristics of a ground deformation episode that took place between 2008 and 2010. Deformation time-series reveal an accelerating uplift pulse, and analytical models support inflation source depths of ~5 km. Gases escaping along the major fault zone of Aluto show high CO_2 flux, and a clear magmatic carbon signature (CO_2–$\delta^{13}C$ of –4.2 to –4.5 ‰). This provides compelling evidence that the magmatic and hydrothermal reservoirs of the complex are physically connected. We suggest that a coupled magmatic-hydrothermal system can explain the uplift-subsidence signals. We hypothesize that magmatic fluid injection and/or intrusion in the cap of the magmatic reservoir drives edifice wide inflation while subsequent deflation is related to magmatic degassing and depressurization of the hydrothermal system. These new constraints on the plumbing of Aluto yield important insights into the behaviour of a restless rift volcano and may be crucial for interpreting future patterns of unrest at other caldera systems in East Africa.

Missing Melts: Examining Across Rift Variations in Magma Storage at Aluto and Butajira, Main Ethiopian Rift

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The Main Ethiopian Rift has been volcanically active throughout the Quarternary. The rift axis is punctuated by numerous peralkaline caldera systems. Aluto volcano in the central MER has a 42 km^2 collapse structure formed after large-volume ignimbrite eruptions ~300 ka. Post-caldera volcanism initiated ~60 ka and widespread tephra deposits suggest that explosive Sub-Plinian eruptions have occurred. Towards the Western flank, off-axis activity is dominated by scoria cones, in areas such as the Butajira volcanic field.

Studies of Aluto's eruptive products suggest a seemingly simple evolution dominated by fractional crystallisation at shallow depths. However, geophysical investigations have produced complex and contrasting results. There is aseismicity at ~9km depth beneath the caldera, which could be consistent with magma elevating local temperatures. In contrast, magnetotelluric surveys have not imaged any increased conductivity in the crust beneath Aluto that would suggest the presence of an interconnected magma body, despite revealing a large conductor directly to the West beneath Butajira.

This study utilises petrological and geochemical observations to interpret the geophysical results and infer differences between caldera systems, and the off-axis volcanic fields. The off-axis melts are thought to be supplied by a more complex trans-crustal system; phase equilibria also indicates these melts may be more water-rich. Observation of a low conductivity zone may be caused by low melt water content, or poor melt interconnectivity. Volatile contents of mineral-hosted melt inclusions yield H_2O contents of up to 7 wt% for the Aluto erupted compositions, which suggests vapour-saturated, pre-eruptive magma storage at a depth of >10 km. The magma reservoir system beneath Aluto is likely mush-dominated with small, segregated, residual melt lenses, that cannot be resolved by MT, feeding post caldera eruptive phases.

Living with Volcanic Gases: Masaya Volcano

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We present here a case study of Masaya volcano in Nicaragua, one of the biggest volcanic polluters in the world, which has been causing severe air pollution in populated areas for many centuries.

Our project has explored how local residents have developed different kinds of informal knowledge and practices meant to deal with permanent volcanic emissions of Masaya.

We present here outreach material that we have developed based on our work, and which we have used to deliver the scientific findings of our project to the communities.

https://unresp.wordpress.com/
https://twitter.com/UNRESPproject

Unseen but not unfelt: resilience to persistent volcanic emissions (UNRESP). Case study from Masaya volcano, Nicaragua

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The last decade has been inundated with reports of environmental disasters impacting the lives of billions of people around the world. While news coverage of floods, hurricanes, earthquakes or wild fires are always accompanied with spectacular images of destruction that emphasise the speed at which they strike, a myriad of slow and latent hazards have been left in the shadow of the public attention. One of those overshadowed and underestimated hazards is environmental pollution caused by persistent volcanic emissions (PVE). UNRESP project seeks to develop early-warning procedures for PVE events during which air pollution reaches hazardous levels, using an approach that bridges volcanology, environmental sciences, history, human geography and sociology.

We present here a case study of Masaya volcano in Nicaragua, one of the biggest volcanic polluters in the world, which has been causing severe air pollution in populated areas for many centuries. Within our project we seek to reduce the impact of Masaya's PVE on the local populations by introducing early warning and mitigation procedures for episodes when volcanic air pollution reaches hazardous levels. It is important that the early-warning procedures are highly applicable and easily accessible to the populations at risk. We seek to apply a stakeholder-first approach, which enables and encourages the local communities to be involved in the building of the resilience strategies.

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Double Trouble: A crystal's-eye view of Torfajökull-Veiðivötn twinned eruptions

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Torfajökull is the largest silicic centre in Iceland. Situated in the south east, it intersects the southern tip of the Veiðivötn fissure swarm. The last two historical rhyolite eruptions of Torfajökull, 871 AD and 1477, were erupted simultaneously with basaltic material from Veiðivötn. Whole rock chemistry and macrotextures show evidence for mixing between rhyolitic and basaltic material. If these interactions represent movement of rift magmas towards the central volcano, it would have major implications for eruption triggering mechanisms at Torfajökull. Nevertheless the depth, extent and timescales of these interactions remains unclear.

Plagioclase populations hosted in both basalts and rhyolites exhibit kinked CSD profiles indicating the presence of multiple populations. In addition crystals show large ranges in An within crystals from a single lava (30-80 An%) and P-T calculations for core and rim analyses show evidence for two levels of magma storage. Most high An cores suggest crystallisation at pressures of ~4 bars. The crystals then show abrupt zoning and a rim of lower An crystallised at a pressure of ~1-2 kbars suggesting shallow crust melt interactions.

Mafic blobs and filaments hosted in rhyolites are visible at a macro scale suggesting large viscosity contrasts between basaltic and rhyolitic melts. Macrotextural filaments indicate failed hybridisation and concentration variance decay timescales calculations show very fast mixing to eruption times. Consistent with diffusion timescales calculated from SIMS data of ~4 days, with magma ascent rates of ~ 0.12km/h.

Peralkaline magmatism of the Atlantic islands

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The intraplate oceanic-island magmatic systems of the Atlantic Ocean exhibit significant diversity in their respective sizes, ages, and the compositional ranges of the magmas they have produced. Despite this, almost all of the major Atlantic islands and island groups have produced variably peralkaline (mol. $(Na_2O + K_2O)/Al_2O_3 > 1$) felsic magmas during their lifespans, including both silica-oversaturated and silica-undersaturated varieties. This implies that similar petrogenetic regimes may be operating at various centres throughout the Atlantic Ocean. The origins of peralkaline magmas are complex, but are frequently interpreted to be linked to low-degree partial melting of enriched mantle, followed by protracted differentiation in the shallow crust, despite the common occurrence of compositional bimodality (the Daly gap). Nevertheless, additional petrogenetic processes such as crustal melting and contamination, and magma mixing have been identified at numerous peralkaline centres. The onset of peralkalinity leads to magma viscosities that may be in excess of one order of magnitude lower than those typical for metaluminous rhyolites and trachytes, which may be intensified by high H_2O_{melt} values. This has profound implications for processes that contribute to magmatic differentiation (e.g. crystal settling), as well as eruptive behaviour, which may be notably reduced in explosivity due to enhanced degassing rates.

In this study, we evaluate the following key topics: (1) are the peralkaline magmas of the Atlantic Ocean generated via the same framework of petrogenetic processes?, (2) is peralkaline magmatism an inevitable stage in the life cycle of ocean-island volcanoes?, (3) if so, can the development of peralkaline magmas be predicted based upon pre-existing models for the temporal evolution of ocean-island volcanic centres?, or, if not, (4) what factors are required to promote the establishment and subsequent maintenance of peralkaline magma systems?, and (5) is there a predictable effect of peralkalinity upon eruptive behaviour? We utilise examples from a variety of volcanic centres throughout the Atlantic Ocean, aiming to evaluate the key factors that generate Atlantic peralkaline magmas.

Constraining P-T-X-t paths of magma in the Icelandic crust

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Tracking the crustal storage and transfer of magmas on their way to eruption is an important goal in volcanology. Most information about magma migration within volcanic plumbing systems is typically obtained with geodetic and seismic methods. However, as magma ascends towards the surface, its physico-chemical properties change to the extent it may affect the style, intensity and duration of future eruptions. Tracking how, where and over what timescales magma chemistry changes as the magma moves underground is essential for the long-term goal of better anticipating future volcanic hazards and risks. To this end, we apply an integrated method, linking Systems Analysis, a time-integrated study of zoned olivine populations [1-4], melt inclusion geochemistry and thermobarometry. This enables us to constrain the pressure-temperature-composition-time (P-T-X-t) paths for magma evolution and migration within different volcanic systems in Iceland. Here, we present first results of samples from the Northern Volcanic Zone (NVZ) and the Snæfellsnes volcanic belt (SVB) in W-Iceland. We investigated 127 olivine macrocrysts in lava samples from SVB (Búðahraun, *Búð*, and Berserkjahraun, *Bers*) and the NVZ (Bóndhólshraun, *Bón*). Macrocrysts from SVB are characterized by simple *normal* and complex, multi-step *reverse* zoning patterns, whereas olivine from the NVZ is predominantly *normally* zoned. Besides differences in zonation patterns, the olivine macrocrysts from SVB and from the NVZ also differ in terms of their specific core (*Búð* and *Bers*: Fo_{73-91}; *Bón*: Fo_{86-90}) and rim (*Búð* and *Bers*: Fo_{71-80}; *Bón*: Fo_{80-81}) compositions. Detailed systemization of the information stored in the sequential zoning record of the olivines enables us to identify and distinguish six different olivine populations (>Fo_{90}, Fo_{87-89}, Fo_{85-87}, Fo_{80-82}, Fo_{75-78}, and Fo_{72-74}), which are the result of sub-surface magma transport and olivine evolution in different magmatic environments prior to eruption.

[1] Kahl, M. et al., 2011. EPSL. 308: 11-22
[2] Kahl, M. et al., 2013. Bull Volc. 75:692
[3] Kahl, M. et al., 2015. JPet. 56: 2025-2068
[4] Kahl, M. et al., 2017. JPet. 58: 443-472

Pre-eruptive inflation caused by gas accumulation: Insight from detailed gas flux variation at Sakurajima volcano, Japan

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Volcanic gas measurements provide crucial insights for the condition of conduit system at a volcano. Sulfur dioxide (SO_2) emission rate observations were made at Sakurajima volcano, Japan, to quantify the relationship between the SO_2 emission rate and inflation prior to Vulcanian explosions. The explosions associated with precursory inflation events were preceded by decreases in SO_2 emission rates by 10–60 min (Fig. 1). The amounts of accumulated gas were calculated using time series of SO_2 emission rate. The amounts of accumulated SO_2 and increases in strain records before the explosions showed a positive relationship. The volume increase of a deformation source calculated using the strain records was of the comparable order of magnitude as the volume of the accumulated volcanic gas. The results suggest that the inflations before the explosions were caused by the gas accumulation.

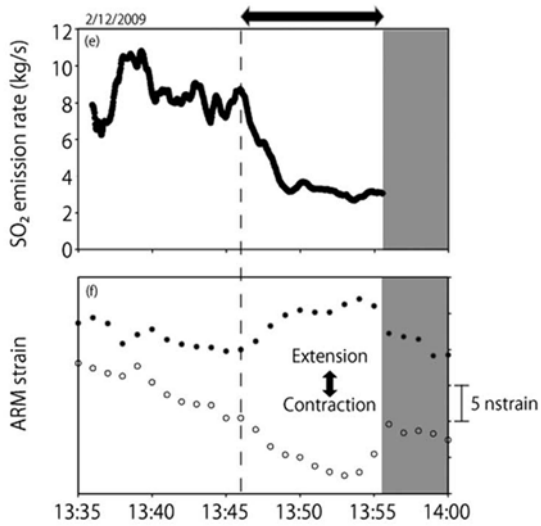

Fig. 1: An example of comparison between SO_2 emission rate and ground deformation data.

Linking precious metal enrichment and halogen cycling in the Rum Layered Suite, NW Scotland

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Layered intrusions host the world's largest concentrations of the platinum-group elements (PGE), primarily enriched within laterally extensive layers known as 'reefs'. Importance has been placed on the role of halogen-rich fluids in precious metal enrichment; however, the timing of mineralisation (i.e. magmatic or later metasomatism), the extent of halogen cycling, and the source of such fluids is actively debated.

We present halogen concentration and ratio data for a suite of samples from the Palaeogene Rum Layered Suite, NW Scotland, to elucidate the importance of halogens in PGE-reef mineralisation and the extent of halogen cycling in mafic magmatic systems more generally. Samples include PGE-enriched chromite seams, various cumulates (e.g. peridotites), picrites (approximating the Rum parental magma), and pegmatites representing volatile-rich melts that circulated the intrusion at a late-stage in its solidification history.

The new data reveal that chromite seams display unusually high I/Cl ratios (<0.07 wt.), attributed to both an enrichment of I (<121 ppb) and relative depletion of Cl (<3 ppm). Picrite samples, plus olivine separates, have compositions close to subcontinental lithospheric mantle of 0.004 wt. Br/Cl and 0.0001 wt. I/Cl (Burgess *et al.* 2002), consistent with the Rum magma source region (O'Driscoll *et al.* 2009). Pegmatite samples and mineral separates also appear enriched in I (<599 ppb), but mildly depleted in Br relative to Cl (>0.0008 wt.), indicating that the cycling of fluids with this distinctive composition operated for a protracted period of time. The preferential enrichment of I with respect to Cl in Rum chromite seams and pegmatites may indicate assimilation of an organic-rich sediment. Modelling indicates ~10% contamination with marine shale may produce the observed signatures within chromitite seams, perhaps pointing to a key trigger for PGE-mineralisation in layered intrusions.

O'Driscoll, B., *et al.*, 2009. Earth Planet. Sci. Lett. 286(1-2): 41-51.

Burgess, R., *et al.*, 2002. Earth Planet. Sci. Lett. 197: 193-203.

Statistical analysis of volcano monitoring time-series

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Despite recent advances, challenges remain in interpreting and forecasting volcanic activity from near-real-time analysis of time-series from volcano monitoring. Statistical methods have the potential to characterise the underlying structure and facilitate intercomparison of these time-series, and so identify and inform interpretation of changes in activity. We demonstrate the utility of two statistical techniques, Shannon entropy and detrended fluctuation analysis (DFA), which respectively quantify uncertainty and long-range correlations in data. Both could be widely applicable to monitoring time-series; we apply them to various data (principally seismic) from periods of temporally varying activity at diverse volcanoes.

We find the entropy of real-time seismic measurements and some volcano-seismic event counts at Soufrière Hills (Montserrat) and Volcán de Colima (Mexico) to be temporally variable. Generally, these data have higher entropy during periods of lava effusion and/or large Vulcanian eruptions, with the entropy sometimes changing prior to or coincident with transitions in seismic/eruptive activity. Comparative analysis shows that the entropy variability is distinct from that of conventional measures of data distribution. DFA of the same seismic time-series revealed changes in extent of correlation in these data, also associated with transitions in activity in some cases (Lachowycz et al., 2013). We analyse (by DFA) the correlation dynamics of time-series during other styles of activity, for example volcano-seismic event counts at Telica (Nicaragua), a persistently restless volcano with highly variable seismicity rates. Here shifts in the correlation extent of high- and low-frequency seismic events are found to often coincide, and some shifts are associated with transitions in seismic/eruptive activity.

In summary, both methods reveal temporal variations in the structure of some of the time-series analysed that were not apparent from conventional analysis. We suggest that such statistical analysis could inform near-real-time monitoring and interpretation of changes in volcanic activity.

Lachowycz, S.M. et al., 2013. JVGR 264: 197-209.

Experimental and isotopic constraints on the deep magmatic plumbing system of the Taupo Volcanic Zone, New Zealand

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Of all eruptive styles, rhyolitic caldera forming events are arguably the most hazardous on Earth. These are a common feature in continental arcs, where ignimbrites often blanket the underlying landscape, covering evidence of precursor eruptive periods. However, there is still much to learn about the processes governing formation of such large bodies of eruptible magma.

To produce high volumes of eruptible silicic magmas, large volumes of parental basaltic material are essential. This could be either as a heat source for crustal anatexis, or as a parental magma from which to fractionate. Unravelling the magmatic processes that occur deep within the magmatic plumbing system is fundamental if we are to understand genesis of arc magmas.

Nowhere in the world is the generation of silicic arc magma more apparent than the Taupo Volcanic Zone (TVZ). In the last 2 Myrs, ~15000 km^3 of silicic material has been erupted, accounting for > 98% of the total erupted material. Small eruptions of basalt occur on active faults or caldera rims, suggesting a primary structural control on the eruption of mafic material. In addition, many ignimbrites are known to contain mafic enclaves, suggesting the intrusion of mafic magmas into these reservoirs may trigger eruption. Overall, this evidence suggests that basalt generation may be intrinsically linked to the rhyolite, by differentiation and assimilation processes. However, each erupted basalt shows mineral assemblages that are unique from one another, indicative of crystallisation for different periods of time in different portions of the crust.

Combining piston-cylinder experiments with isotopic analysis of crystals from natural samples is revealing the polybaric nature of the basaltic plumbing system in the TVZ. $\delta^{18}O$ ranges from MORB (+5‰), to + 7‰, indicative of crustal assimilation early in the evolutionary history, whilst experiments constrain the P-T conditions of crystallisation. This, combined with mineral chemistry will reveal the influence of basaltic magmatism on rhyolitic volcanism at the surface.

Late Cretaceous magmatism in central Tibet: evidence for orogenic delamination and crustal thickening prior to India-Asia collision?

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Structural geology and sedimentology studies suggest that central Tibet had experienced major shortening and had been partly above sea level by the Late Cretaceous (Zhang et al., 2012 and references therein). This implies substantial crustal thickening and perhaps plateau formation in central Tibet prior to the Indo-Asian collision. However, its magnitude is still poorly known (Kapp et al., 2005). Small-volume but widespread Late Cretaceous magmatic rocks in central Tibet contain important continental evolution information during that period.

Here we compile geochemical data of those rocks, and use the Sr/Y and La/Yb ratios of intermediate magmatic rocks to quantify the crustal thickness of Lhasa-Qiangtang continental collision belt with the equations newly constructed by Hu et al. (2017). Then we choose the volcanic sequence near Anduo county for petrological and geochemical studies to interpret its petrogenesis, and further explore the mechanism by which the central Tibet accumulated such crustal thickness and produced widespread magmatism in Late Cretaceous.

Hu, F.Y. et al., 2017. Sci. Rep. 7: 7058.
Kapp, P. et al., 2005. Geol. Soc. Am. Bull. 117: 865–878.
Zhang, K.J. et al., 2012. Earth-Sci. Rev. 114: 236–249.

Rapid Cooling and Protracted Storage in Thin Lower Crustal Sills

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Petrological observations indicate that some recent lava flows in Iceland were directly fed from near-Moho magma chambers. One such flow, Borgarhraun, carries a record of its evolution in a cargo of macrocrysts including olivine (Fo_{86-92}), clinopyroxene (Mg# 85-92), plagioclase (An_{83-91}) and chromian spinel. These phases all host abundant melt inclusions. Furthermore, small ultramafic and gabbroic nodules are found in Borgarhraun. Fresh, microlite-free glass is also present in the tephra, indicating that the carrier liquid had a MgO content of close to 9 wt%.

The lowest Mg# macrocrysts are in equilibrium with the carrier liquid. The full range of macrocryst compositions can be generated by cooling from ~1350°C to ~1230°C, a cooling interval that corresponds with ~25% crystallisation of mantle melts.

The relationship between the trace element diversity of melt inclusions and the Fo content of their olivine hosts indicates that the timescales of cooling and compositional homogenisation of mantle melts are similar. Models of convection in sills can match this feature of the observations if the sill thickness is less than about 10m, with a timescale of cooling of a month or less.

The distribution of olivine core compositions shows a distinctive unimodal peak, offset by 2-3 mol% Fo from the expected olivine in equilibrium with the carrier liquid. This distribution can be generated by diffusive exchange of through liquid trapped in an olivine-rich mush pile at the base of the chamber. A 4m thick mush pile generated by fractional crystallisation can be modified to match the observations by ~800 years storage. This timescale can also account for patterns of Cr# zonation observed in spinel inclusions in pyroxenes from Borgarhraun.

These observations can be understood in an overarching model where primitive melts are injected into a <10m thick sill and undergo rapid cooling, crystallisation and mixing, followed by hundreds of years of storage prior to eruption. This scenario can be achieved if the lower crust under Borgarhraun was hot, similar to the adiabat-corrected eruption temperature, but subsolidus because the country rock is composed of primitive cumulates.

Magma – crust interaction at Gunung Guntur, west Java, Indonesia

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Magma generated by volcanic arcs inherits its primary composition during melting of the mantle wedge. This composition will change as crystallisation occurs and magma interacts with arc lithosphere en route to emplacement or eruption. Therefore, arc magmas contain a geochemical record of the composition of arc lithosphere that can be used to understand the mechanisms of crustal growth and evolution.

West Java is particularly well suited to examining variations in magma - crust interaction because of the high density of volcanic centres that extend along and across the arc. Crust beneath the Sunda Arc has previously been termed "transitional" from continental in the west to (possibly thickened) oceanic in the east. However, recent studies of the structures, sediments and volcanic rocks in Java indicate that the basement has experienced intra-arc thrusting and incorporation of ancient material, probably derived from Gondwana during the early- or mid-Cretaceous.

This study uses the composition of two series of volcanic rocks from Gunung Guntur, west Java, as a geochemical probe to explore how magma interacts with crust in west Java. An Old Series differentiated in a stable, deep plumbing system that supplied relatively homogeneous tholeiitic basaltic andesite to the shallower crust, where it was contaminated by crust which had been derived from Gondwana. A Young Series indicates that similar basaltic andesite parent magma interacted with more mafic components, most probably oceanic crustal fragments trapped between blocks of Gondwana crust. In many respects the Old and Young series resemble classical "calc-alkaline" and "tholeiitic" rocks, respectively. Trace element and isotopic variations show that both are derived from similar parent melt and differ because but each interacted with separate crust, suggesting significant reconfiguration of magma transport and storage during the development of Guntur.

The evolution of Krakatau's 1883 magma: Insights from modelling and crystal zoning

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Krakatau produced one of the most explosive eruptions in the last 200 years in 1883, killing c. 36,000 people. The aim of this study is to determine processes and conditions in the magma reservoir prior to the eruption n order to explain why it was so explosive.

The stratigraphy of the 1883 eruption was determined during fieldwork. It comprises fall deposits at the base, interbedded with pyroclastic density currents (PDC) and dilute-PDC deposits (2-4m), overlain by a lithic lag breccia (0.25m), and then PDCs and dilute-PDCs (5-14m). Above this is a thin phreatomagmatic layer (0.1m) followed by PDCs which become more lithic-rich up the sequence (34m), with another lithic lag breccia at the top (0.2m).

Samples of ash collected on board ships during the 1883 eruption were borrowed from the British Geological Survey for analysis. Backscattered Electron images of pyroxene and plagioclase phenocrysts picked from these samples were obtained to assess crystal zoning patterns. Matrix glass compositions, measured by Electron Microprobe, and glass compositions from recent mafic lavas from Anak Krakatau were modelled with Rhyolite-MELTS to determine the intensive (magmatic) parameters during fractional crystallisation. The parameters were modelled both isobarically and isothermally at 1-3.5 wt% H_2O, 50-300 MPa and 1200-700 ºC.

Approximately 75% of the plagioclase crystals and 80% of pyroxenes that exhibit visible chemical zoning are normally zoned. MELTS modelling shows that - for major elements - the 1883 glass chemistry can largely be produced by fractional crystallisation of the most primitive Anak Krakatau sample under similar conditions as those determined by Darhen et al. (2011). The MELTS modelling and the normal zoning of the phenocrysts suggest that fractional crystallisation was the dominant process that occurred within the magma reservoir prior to the 1883 eruption of Krakatau.

Future work will focus on obtaining more quantitative chemical data on the phenocryst zoning profiles, and using petrological experiments to replicate magma storage conditions.

Dahren et al. 2011. Contributions to Mineralogy and Petrology, 163: 631-651.

Structure and dynamics of surface uplift induced by incremental sill emplacement

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Ground deformation commonly heralds eruptions at active volcanoes, providing insight into the location and geometry of subsurface intrusions that are critical to volcanic hazard assessment. To constrain the evolution of ground deformation beyond dynamic events captured by geodetic data, we examine the structural and extrusive history of the Alu dome, Ethiopia. Surface uplift and subsidence in 2008, recorded by InSAR during a nearby eruption, demonstrates that Alu is actively deforming; ground deformation patterns were attributed to deformation of a shield volcano above a tabular sill. We contend that Alu is a forced fold developed above an incrementally emplaced saucer-shaped sill because: (1) there is no central vent or evidence of construction from lava flow build-up; (2) surrounding lava flows deflect around Alu, indicating it had a topographic expression prior to extrusion; (3) the boundary of Alu directly overlies the lateral tips of a sill modelled from InSAR data; (4) normal faults across Alu are compatible with outer-arc extension during doming; (5) the disposition of lava flows radiating from Alu and emanating from vents and/or spatter cones distributed around the periphery of the dome is consistent with their being fed by a saucer-shaped sill; and (6) the scale and timespan of ground deformation during the 2008 eruption suggests that Alu formed through the incremental injection of distinct magma pulses. Whilst the size and shape of Alu resembles that of a laccolith, we show that forced folds above sills and laccoliths are commonly indistinguishable. Intrusion geometries interpreted from the topographic expression of long-lived magma bodies, like those modelled from geodetic data, are therefore non-unique.

Recharge, recycle, repeat: The steady-state plumbing system of Popocatépetl volcano, Mexico

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Popocatépetl (Popo) is a quaternary stratovolcano located about 70 km SE of Mexico City. Continuously active since 1994, the present-day edifice is shaped by voluminous lava flows punctuated by at least six Plinian eruptions in the last 23 ka, the largest one being the VEI 6 Pumice with Andesite Plinian eruption ~14 ka BP.

We present a detailed textural and compositional study of phenocryst assemblages and populations in effusive and explosive products of the last 14 ka. Both pumices and lavas are hybridised products of 1) a mafic magma with a phenocryst assemblage of Cr-spl + ol (≤Fo88) + opx (Mg# 79–90) + cpx (Mg# 84–93) ± pl at T=1040–1070°C, and 2) an evolved magma with T<960°C and pl (An32-50) + opx (Mg# 53–71) + cpx (Mg# 67–77) + ap + ox. Compositionally zoned px and pl and varying degrees of diffusive overprints imply frequent mafic injections into the evolved magma. Fe-Mg diffusion modelling in opx reveals pre-eruptive crystal residence times in the evolved melt from >1000 years to <7 days. This suggests that the evolved reservoir comprises multiple generations of antecrysts, and that mafic recharge can rapidly trigger both explosive and effusive eruptions by remobilising and recycling this reservoir. Pumices and lavas of the last 14 ka show consistent crystal populations only varying in modal abundances, and homogeneous whole-rock compositions. We therefore argue that Popo is buffered by an integrative, compositionally stable, steady-state plumbing system since at least the Pumice with Andesite Plinian eruption 14 ka BP.

The dispersion pattern of sulphate, fluoride and chloride released by the degassing of Masaya Volcano, Nicaragua and the impact on soil, water and rain composition

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Masaya volcano, Nicaragua, although not often actively erupting is almost constantly degassing. Volcanic degassing can be harmful when it contaminates water & soil, particularly when concentrations reach guideline health values. Symptoms of dental fluorosis have been observed in populations living beside Masaya, particularly in children, suggesting concentrations of fluoride could be significant and potentially contaminating drinking water. The aim of this project is to investigate fluoride, sulphate and chloride concentrations and their relative dispersion patterns at Masaya volcano. Samples of soil, water and aerosol were collected in March & July 2017 as part of the UNRESP project at Masaya volcano. Ion Chromatography and pH analysis has been carried out, including both H_2O and acid extractions of soil, to mimic dissolution by rain, acid rain, and ingestion. Results show definitive concentration peaks at the crater rim with decreasing concentrations South West (downwind). Patterns of dispersion vary between Cl^-, F^- and SO_4^{2-} both due to topography and other physical factors, in addition to geochemical reactions between ions, the atmosphere and rain (dissolution). The concentrations, particularly of fluoride, are significantly over world health guidelines in a number sites. When examining the rate of increase in fluoride concentrations when tap water is left uncovered (open to atmosphere interaction), it is proven that this is significant enough that it will be key to make the public aware of the risks of drinking this water.

Aftermath of the 2015 Calbuco eruption, southern Chile: complex morpho-sedimentary responses to explosive volcanism

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Landscapes impacted by explosive volcanism exhibit some of the highest sediment yields on Earth, where ambient drainage and sedimentary systems are overwhelmed by huge volumes of particulate material. Although we have a broad understanding of morpho-sedimentary responses in terms of patterns and chronologies of erosion, resedimentation, and aggradation, more recent studies have focussed on untangling the system- and catchment-specific controls that govern the style, severity and duration of the post-eruptive impact.

The c. 0.31 km^3 April 2015 eruption of Calbuco Volcano in southern Chile generated sub-Plinian eruption columns, multiple topographically confined pyroclastic density currents, and both hot and cold primary eruption-triggered lahars in multiple drainages. Fieldwork and remote-sensing analyses, focussed on 3 major catchments with differing physiography and hydrological regimes that each received differing proportions and volumes of tephra and pyroclastic flow material, highlight local nuances in the morpho-sedimentary response

Overall, except for where an internal impermeable crust developed, the majority of the coarse tephra deposited by the 2015 eruption appears to have low remobilisation potential, suggesting that Calbuco lies close to the other end of the spectrum of post-volcanic landscape sensitivity to that shown by the 2008 Chaitén eruption. In the Rio Blanco Este, the most heavily impacted catchment that lay under the tephra dispersal axis and received extensive pyroclastic flows, major rain-triggered lahar activity was delayed until the first significant post-eruptive rainfall event in mid-May 2015. Subsequently, up to 12 m of aggradation has occurred as remobilised material translates downstream as a kinematic wave. However, identification of a large reservoir of as yet untapped pyroclastic material high on the mountain, has important potential implications for the duration and severity of the response in the catchment. Other catchments have responded differently as a function of basin physiography, hydrology and the volumes and spatial distributions of pyroclastic material.

Causes and relievers of stress: Coupled flow and deformation modelling to explain observed deformation at silicic volcanoes

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As magma ascends through a volcanic conduit, it exerts shear stress at the conduit walls that pulls up the surrounding edifice. During the 2013-4 eruptive activity at Tungurahua volcano, Ecuador, Vulcanian explosions were often associated with a significant decrease in tilt of up to 500 μrad and an increase in low-frequency seismicity. Studies have shown that a shear stress of around 20 MPa is sufficient to explain the tilt variations observed. However, whether such shear stresses are achieved in nature is so far unclear. Here, we perform flow modelling using COMSOL Multiphysics to assess the role of such processes as shear thinning, shear heating, and the development of a thermal boundary layer on the shear stress in the conduit. From this it can be determined whether sufficient shear stress to explain the deformation observed at silicic volcanoes can be achieved through realistic ascent of magma. Additionally, this will provide information on where in the conduit the critical shear stress required for brittle failure of magma is reached, thereby linking the low frequency seismicity to the tilt.

Eruptive dynamics and hazards associated with obsidian bearing volcaniclastics of the Geghama volcanic highland: a textural insight

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The Geghama volcanic highland in central Armenia is an ideal setting to study the young Quaternary volcanism that characterises the Lesser Caucasus region. Volcanism in the Geghama region is bi-modal in composition with older silicic volcanism in the west, and younger less evolved volcanism in the east. This work focuses on the silicic volcanism of Gutanasar, a polygenetic dome volcano.

During its eruptive history (~500-200ka) Gutanasar has produced basaltic scoria and obsidian bearing rhyolitic flows and domes, as well as extensive obsidian bearing volcaniclastic deposits (Lebedev et al, 2013). Little attention has been paid to these volcaniclastics, yet the obsidian textures within them attest to a complex petrogenetic history. Deciphering these obsidian textures will improve understanding of this volcanic system and better constrain eruptive dynamics.

This study uses quantitative textural analysis to determine the petrogenetic history of this obsidian and to better understand the eruptive dynamics of Gutanasar. Microlite crystals are ubiquitous in these obsidians, and z-stack microscopy is utilised to obtain 3D crystal measurements from thin section. Combined with semi quantitative outcrop and hand specimen measurements, textural evidence suggests that dome collapse and subsequent post-depositional welding are the main processes that have governed the formation of this deposit. These interpretations are important for the assessment of the potential impact of palaeovolcanic hazards on the movement of early humans in the Caucasus region.

Lebedev, V. A. et al (2013). *JVS*, **7**, 204-229

Satellite observations of lava and gas fluxes from Bagana volcano

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Long-lived eruptions from silicic volcanoes are a common, hazardous mode of volcanism worldwide. Two hundred volcanoes exhibit cycles of lava dome building and destruction and have caused two thirds of the total volcanic fatalities since 1600. The key characteristics of this style of volcanism are: the emplacement of lava flows and domes composed of crystal-rich, high viscosity lava; strongly cyclic behaviour with alternating extrusive and explosive episodes; and relatively slow extrusion rates that may persist for months or years. Many persistent silicic volcanoes are also major sources of gas, with high outgassing fluxes even during inter-eruptive pauses.

Few volcanoes are so persistently active as Bagana, Papua New Guinea, which has exhibited near-continuous extrusion of lava since it was first observed by scientists in the 1840s. Based on recent estimates, the entire edifice may have been constructed in only 300-500 years. Bagana is also a remarkable emitter of gas: over the past decade only Ambrym and Kilauea have vented more SO2. Bagana's remote location limits in-situ monitoring, and satellite remote sensing is a critical tool for studying the volcano.

In this contribution we present new observations of lava extrusion and SO2 emissions at Bagana. We show that there is a first-order coupling between lava and SO2 fluxes, but that substantial passive degassing continues during inter-eruptive pauses. By comparing lava volumes to gas mass flux, we find evidence for a significant exsolved volatile phase in the shallow plumbing system at Bagana that makes a major contribution to the remarkable SO2 outgassing. This volatile-rich phase, presumably sourced from a more primitive, unerupted magma, is likely to exert a strong influence on eruptive style and the chemical composition of the emitted gases.

Using trace element chemistry to correlate distal ignimbrite outflow sheets from Langdale Caldera, English Lake District.

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The Borrowdale Volcanic Group of N.W. England preserves several silicic caldera volcanoes from an Ordovician subaerial continental arc. The calderas are important because exhumation and deep glacial dissection have beautifully exposed entire intracaldera and extracaldera successions along with caldera floors, caldera faults, vents and domes.

The main focus of research has been Scafell caldera due to its world-renowned exposure. But there are also several large pyroclastic sheets that do not relate to Scafell, and which have not yet been traced back to any source volcano. This has led the focus of research to shift towards less intensely studied parts of the succession.

The recently discovered Langdale caldera, 10 km SE of Scafell, has a thick (≥300 m) massive zoned intracaldera ignimbrite that can be traced across its faulted caldera margin into a chemically zoned proximal outflow sheet. However, the distinctive outflow sheet has not been traced beyond ~3 km from the caldera, largely due the number of candidate ignimbrites in the succession coupled with an abundance of post-volcanic (Acadian) faults and a lack of detailed fieldwork.

Whole-rock geochemistry will be used alongside previous work to characterise different ignimbrite outflow sheets in SW Lake District with the aim of correlating one of them with the proximal ignimbrites of Langdale caldera.

The outflow sheets have experienced various degrees of alteration during hydrothermal activity and regional low-grade metamorphism. Plotting loss- on-ignition against major element abundances has identified several elements that have been mobilised, and so our interpretations focus on less mobile trace elements (i.e. HFSE). Results to-date have allowed us to robustly characterise and distinguish between individual distal ignimbrites: one of these is a good candidate to be sourced from Langdale caldera.

As successful correlations are made, we should be able to refine the stratigraphy of the Borrowdale Group and develop a more thorough understanding of each volcano, as well as the scales of the individual large explosive eruptions.

Diamondite-formation reveals subduction-related carbonaceous melt metasomatism in the sub-continental mantle beneath Orapa, Botswana

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Diamondites are comprised of fine- to medium-grained polycrystalline diamond intergrown with garnet, and minor clinopyroxene, rutile, Mg-chromite, and sulfide. They show petrological and geochemical features that distinguish them from cubic (coated) and inclusion-bearing monocrystalline diamonds. These features include a dominance of websteritic garnet over peridotitic or eclogitic garnet, a total absence of olivine, and ^{13}C-depletion and ^{15}N-enrichment for all paragenetic types. A suite of polycrystalline diamonds from the Orapa kimberlite, Botswana intergrown with oxides and silicates yielded a total of 15 garnets, 2 clinopyroxenes, 2 rutiles, 1 ilmenite, and 1 Mg-chromite for study. C-isotope compositions of all 22 diamonds, O-isotope compositions of 7 garnets, the major element abundances of all intergrowths, and the trace element abundances of all of the garnets require that mantle (peridotitic) react with (eclogitic) carbon and silicate to form diamondite. The abundance of peridotitic clinopyroxenes and the co-existence of both websteritic and peridotitic garnets (ORF53) require the peridotitic component. The abundance of websteritic and eclogitic garnets and progressive $LREE_N$-$HREE_N$ enrichment patterns observed in the garnets require an eclogitic component. The coupling of ^{18}O-enrichment ($\delta^{18}O > +6‰$) in the garnet with ^{13}C- depletion ($\delta^{13}C < -8‰$) in the diamond could only occur at temperatures <lithospheric mantle. Orapa diamondites can form by melt metasomatism of peridotitic rocks by C-rich fluid bearing eclogitic melts derived from hydrothermally altered oceanic lithosphere via subduction of crustal volatiles. Fluid-rich melts metasomatize mantle peridotite and create spontaneous, C-oversaturated diamondite-formation. The formation of polycrystalline versus monocrystalline diamond is the result of a greater abundance of carbon in the fluid. The timing of fluid subduction has not been directly determined geochronologically, but based on the relative degree of nitrogen aggregation for the coated diamonds, monocrystalline diamonds, and diamondites (at Orapa) we suggest the diamondites to be older than the coats of the coated diamond, but younger than the monocrystalline diamonds.

InSAR Observations of the On-going 2017 Eruption of Erta 'Ale Volcano, Afar.

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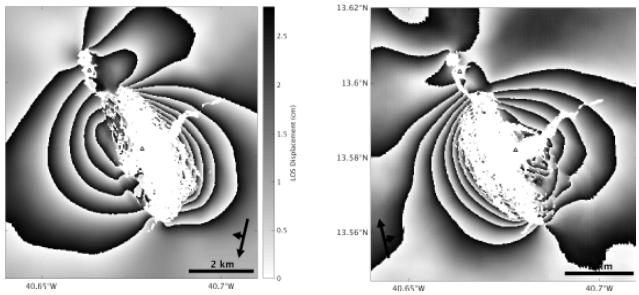
Late-stage continental rifting in Afar, Ethiopia, provides the opportunity to observe magmatic spreading centres analogous to slow-spreading ridge systems. Erta 'Ale volcano, in northern Afar, has been the site of a sustained lava lake for over 90 years. On January 21st 2017, a fissure eruption opened on the south flank of Erta 'Ale, ~ 7 km SE of the summit caldera and lava lake. From the eruption date to present, the fissure eruption site remains active, producing large sustained lava flows that have extended up to 15 km from the vent, whilst retaining 'normal' activity at the summit lava lake.

We use Sentinel-1A/B and COSMO-SkyMed interferometric synthetic aperture radar (InSAR) to observe ground deformation during the 2017 Erta 'Ale eruption. We employ elastic halfspace models, to assess the magnitude and geometry of the deformation sources occurring during, before and following the eruption. Initial results are consistent with a dyke intrusion between the 11th and 28th of January aligned with the ridge axis, extending from the summit caldera to the south flank eruption site, producing ridge-perpendicular extension of up to 45 cm. Ridge-perpendicular compression of up to 10 cm is also detected about the summit caldera, consistent with conduit or chamber contraction. Within 3 months previous to the eruption, an extensional signal of up to 6 cm is observed about the lava lake, indicating the influx of new melt at depth prior to the eruption. The deformation of Erta 'Ale during this eruption is significantly different to the behaviour during any previous overflow of the lava lake that has been observed with InSAR. We discuss the influence of the event on the plumbing system of Erta 'Ale, and the wider implications for spreading centre behaviour.

Fig. 1: Ascending and descending Sentinel-1 interferograms



Characterising the explosive episodes of flood lava eruptions: 10th century Eldgjá, Iceland

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Volcanic eruptions were included on the UK National Risk Register for the first time in 2012 in reaction to the 2010 eruption of Eyjafjallajökull. Whilst both explosive and effusive eruption scenarios are included, a relatively short duration is ascribed to the former and the latter focuses entirely upon the risks arising from associated volcanic gases. There is growing evidence that explosive eruptions can occur during long duration flood lava eruptions, combining and exacerbating the hazards described above.

One such example is the 10th century Eldgjá basaltic fissure eruption in southern Iceland which produced at least sixteen explosive phases and deposited a total of 1.3 km^3 (dense rock equivalent, DRE) of tephra in addition to 19.7 km^3 of lava. The explosive aspect of Eldgjá is often attributed to the subglacial nature of a portion of the vent system. However, explosive phases took place at both subglacial and subaerial segments of the 70-km-long system with activity starting beneath the glacier Mýrdalsjökull. The internal stratigraphy of Eldgjá tephra is composed of both magmatic and phreatomagmatic tephra units which, together with dispersal patterns, indicates activity switched between subaerial and subglacial vents several times.

In order to compare the two styles of activity, units 7 and 8 of the Eldgjá tephra deposit were mapped in detail and sampled. Unit 7 is a magmatic deposit originating from a subaerial fissure segment. It has a positively-skewed, unimodal total deposit grain-size distribution (TGSD) and a mode of -2.2 Φ. Unit 8 originates from beneath the glacier and is phreatomagmatic with a bimodal TGSD with modes at 0.0 and 5.0 Φ. The height of the plumes during these phases is estimated to have been between 11 and 18 km, higher than the tropopause above Iceland.

Despite this difference in TGSD, the magmatic and phreatomagmatic tephra of Eldgjá have identical vesicle-size distributions indicating that explosivity was not driven by interaction with external water.

What happens before a no-warning explosive eruption? The 2015 Calbuco Volcano eruption, Southern Chile

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During 22nd-23rd April, 2015 a no-warning explosive eruption consisting of two pulses occurred at Calbuco Volcano, Southern Chile. A seismic swarm started 3 hours before (SERNAGEOMIN, 2015) and no deformation was noted via InSAR as close as one day before the eruption (Delgado et al., 2017). Eight samples (4 lapilli fall deposits and 4 bombs) were collected from 7 locations to study the petrology and the magmatic intensive conditions of the eruption.

The mineralogy comprises plagioclase, clinopyroxene, orthopyroxene, amphibole, olivine, titanomagnetite, ilmenite, apatite, and pyrite. Several thermometers, barometers and oxybarometers were used across these phases and an average magmatic temperature of 978-986 ºC was obtained. The following mineralogical and petrological features suggest the presence of a mush zone in the magma reservoir beneath the volcano: high-crystallinity products (average 42%), presence of crystal clots with interstitial melt, lack of evident mixing, and textural mineral complexity (reverse and oscillatory zonation) in pyroxene and plagioclase crystals.

Via traverses crossing from cores to rims and across boundaries of titanomagnetite-ilmenite crystal pairs, temperature and oxygen fugacity conditions were determined. Rim temperatures are higher than cores, evidencing heating before the eruption together with a decrease in oxygen fugacity. The Fe-Ti exchange related to the heating formed diffusion profiles in the crystal rims, allowing us to constrain the time between the heating and the eruption via diffusion chronometry to be a maximum of 6 days before the eruption.

SERNAGEOMIN 2015a, REAV - Región de los Lagos, 2015, abril 22 – 18:00.
Delgado, F. et al., 2017. J. Volcanol. Geoth. Res. 344: 270-288.

Olivine timescales: origins and meanings

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Diffusion timescales in olivine, derived from Fe-Mg interdiffusion are becoming more routinely examined and recorded in studies of basaltic magmatism and volcanism. As the techniques improve and we can gather data from increased numbers of crystals such that we start to tap population-scale information, it is worth stopping to re-evaluate what timescales mean and how they originate. Even relatively simple observations such as the type of boundary conditions that seem to be prevalent during olivine diffusion are informative of the magma system. This poster will look at a selection of results across some projects undertaken at Leeds to understand how the diffusion process that yield timescales arise within the magma system, and how that might influence our interpretations of how crystals and magmas reside and are stored before eruption.

Rapid magma transport from the lower Icelandic crust

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The rate of magma transfer throughout the crust, particularly transport from the lower crust and upper mantle beneath spreading ridges, is largely unknown. Diffusion chronometry has proven to be a powerful method for extracting quantitative timescales of magmatic processes. However this method is fraught with challenges, particularly linking timescale estimates to petrological constraints and effectively quantifying uncertainties. Here we address the aforementioned issues by applying newly parameterised multi-element diffusion models to the well-understood Borgarhraun picrite of the Theistareykir Volcanic System, Northern Iceland. The compositionally zoned crystal-cargo of olivine (Fo_{86-90}), plagioclase (An_{84-90}), clinopyroxene, spinel and rare wehrlitic nodules contain valuable information on the P-T-t history of the underlying magmatic system. Crystallisation took place in deep sub-Moho magma chambers (~24 km) from a diverse suite of geochemically distinct mantle melts that were CO_2 undersaturated. The results of finite-element diffusion models applied to wehrlitic olivines suggest that the timescale of final ascent was typically shorter than 1 year; the first timescale estimate of sub-Moho magma supply at a spreading centre. These rapid ascent timescales have important implications for the physical modelling of primitive magmas as well as for understanding the architecture of magma-plumbing systems in the temporal domain.

Evaluating oxygen fugacity proxies in basalts from the Reykjanes Ridge, Iceland

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Mantle oxygen fugacity (fO_2) is a thermodynamic variable regulating the speciation of fluids, volcanic gasses and the stability of mineral phases in the Earth's interior. As such, knowledge of mantle fO_2 is paramount in order to understand the chemical evolution of the Earth and the formation of the atmosphere.

Mantle fO_2 is potentially constrained by the ferric iron content (Fe^{3+}/Fe^{tot}) or trace element ratios (V/Sc) of primitive, deeply sourced basaltic lavas [e.g. 1,2]. Unfortunately, data from different fO_2 proxies can differ by more than 1 log unit in reference to the QFM (quartz-fayalite-magnetite) buffer. These discrepancies may be related to inaccurate assumptions associated with individual proxies when converting melt compositions into mantle fO_2.

In this study we report geochemical compositions of a set of well characterized basaltic glasses from a ~1000 km transect of the Reykjanes Ridge with the aim to compare and contrast proposed fO_2 proxies and ultimately better constrain mantle fO_2. We present new laser ablation trace element data of 64 specimens displaying systematic changes in trace element, radiogenic isotopes and (Fe^{3+}/Fe^{tot}) with distance from Iceland [3,4]. Additionally, we present vanadium stable isotope data on the same samples as transition metal isotopes have the potential to reflect fO_2 [5]. We discuss the strengths and weaknesses of potential redox proxies as applied to mantle lavas and present thermodynamic models simulating melting processes and their predicted relationship with mantle fO_2.

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Hydrothermal fluid pathways beneath Aluto volcano, Main Ethiopian Rift, from seismic anisotropy

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The silicic peralkaline Aluto volcano in central Main Ethiopian Rift is the site of a producing geothermal power plant, and last erupted ~400 years ago. It has also experienced surface uplift and subsidence of tens of cm over periods of months since at least 2004 (Hutchison *et al*., 2016), which has been attributed to thermal shrinking within the geothermal reservoir (at ~4 km depth), and changes in magmatic and hydrothermal overpressure deeper (~5.5 km).

We use S-waves from volcano-tectonic earthquakes (down to 20 km) beneath Aluto (Wilks *et al.*, 2017) to retrieve shear wave splitting parameters at 12 stations, and thereby the shear wave anisotropy present, *A*. Anisotropy is very large ($5\% \leq A \leq 15\%$) within the inferred caldera ring fault, and small elsewhere ($A \leq 2\%$), and is restricted to the top 4 km. The polarisation of the fast shear wave is parallel to the local fault trend and maximum horizontal compressive stress outside the caldera, but oblique within. In both cases, anisotropy probably derives from aligned crustal fluid-filled microcracks.

Coupled with other geophysical and geological data, our results suggest that the geothermal reservoir is restricted to the caldera and is multiply fractured, these fracture sets possibly being formed when the caldera floor collapsed. Local earthquake tomography shows that V_P/V_S in the reservoir is very low (~1.4; Wilks *et al*., submitted to Geology), suggesting that gas is a large contributor to the overpressure in the reservoir, which is fed with fluids and heat by a deeper magma source. Fluids later escape to the surface via a fault system which cross-cuts the caldera.

Our study suggest a causative mechanism for geothermal reservoirs beneath caldera systems, namely that the subsided centre has elevated permeability created during caldera formation.

Hutchison *et al*., 2016. Geochem. Geophys. Geosys. 17, 3008–3030. doi:10.1002/2016GC006395
Wilks *et al.*, 2017. J. Volcanol. Geoth. Res. 640, 52–67. doi:10.1016/j.jvolgeores.2017.04.003

InSAR investigation into the 2014 eruption of Kelud volcano

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We use Interferometric Synthetic Aperture Radar (InSAR) to measure deformation at Kelud volcano in Indonesia, before, during and after the explosive eruption on 13th February 2014. Our aim is to model any co-eruptive displacements and estimate the depth of magma storage zones. We will compare our findings with petrological studies of Kelud's magma plumbing system. The relatively sudden change in style between the 2007-08 effusive eruption and the 2014 explosive eruption makes the pre-eruptive conditions particularly interesting.

Kelud is a highly hazardous basaltic andesite stratovolcano. Its eruptive history has been dominated by plinian and phreatomagmatic eruption styles and it has the capacity to create destructive. In 2007-08 Kelud erupted in an effusive manner, but this was followed by an explosive eruption in 2014, which lasted only a few hours but had an intensity greater than Mt St. Helens in 1980.

We are analysing a set of 29 interferograms that span from December 2013 to May 2014 from the COSMO-SkyMed satellite system which uses high-resolution synthetic aperture radar (SAR) operating in the X-band frequency range. Due to the coverage of vegetation around Kelud, traditional InSAR techniques are challenging because of rapid temporal decorrelation. We therefore take a persistent scatter approach.

Preliminary analysis of the data suggest that there is unlikely to be deformation preceding this eruption, but that some coseismic subsidence may have taken place. Geodetic Bayesian Inversion Software (GBIS) will be used to model depths to magma storage zones.

Gutanasar Volcanic Complex, Armenia: Evolution, Eruption and Hazards

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Within Armenia, Late-Neogene volcanism occurred in the Lesser Caucasus as a product of Neogene-Quaternary, regional-scale magmatism, resulting from collision of Eurasian and Arabian plates (Arutyunyan et al., 2007). Products of extensive rhyolitic volcanism are observed throughout Armenia, the dates of which coincide with the occupation of the area by Lower Palaeolithic hominin communities (Adler et al., 2014; Frahm et al., 2016).

Whilst volcanic deposits have been well used as tools for dating archaeological sites, little work has been done to better understand the eruptive dynamics and hazards associated with the rhyolitic volcanism in Armenia. This study aims to utilise whole rock and mineral geochemistry to assess the relationship between the multiple silicic volcanic centres in the Geghama volcanic region and to assess the pre-eruptive storage conditions of the source magma. In addition textural and field data will be used to assess the emplacement mechanisms of different units. Combined, this data will aid our understanding of the environment local hominin populous were exposed to and highlight if, and how, volcanic activity controlled movement of man in the area.

Preliminary geochemical data show limited ranges in trace element and isotope ratios observed in samples from Gutanasar, Hatis and Alapars. This could potentially suggest a single source for the entire area. It is hoped that P-T conditions from mineral chemistry will shed more light on the arrangement of this source relative to the vents.

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Evaluating alternative scenarios for the 1973 Heimaey Eruption

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Heimaey, largest and only inhabited island of 17 that comprise the Vestmannaeyjar archipelago, lies 10 km off the south coast of Iceland. The notable eruption of 1973 lasted 5-6 months[1]: Beginning in January 1973, a fissure 1.5 km in length ruptured with c. 20 minor vents delivering lava fountains of 50 to 150 metres high. During the first 24 hours, these vents reorganised into a single volcanic edifice forming a 200 m high scoria/spatter cone - Eldfell[2]. The SE-prevailing winds caused tephra from Eldfell to fall over the town of Vestmannaeyjar[3] destroying 417 houses, and resulting in an evacuation of ~5300 residents[4]. Simultaneously, basaltic (pahoehoe) lava advanced towards the island's only harbour entrance thus threatening one of Iceland's largest fishing ports, and the main income source of Heimaey. Famously, seawater pumping system was used to slow the advance of the lava flow, thus protecting the harbour, the town and electric power lines, and creating natural lava levees where lava built up to as high as forty metres in places[5]. An estimated 240 million cubic metres of new volcanic material was created in the eruption - extending the island area by 20%.

Our study simply considers '*what if..*', in other words the potential scenarios resulting from changing a single factor during the 1973 eruption. For instance, we use DEM and satellite imagery of Heimaey to explore alternative directions of lava flow, and their subsequent effects. We then deliver hazard maps showing how Heimaey might look today if these different scenarios had occurred – such as no cooling through water pumping/cooling. These predictions and maps are entirely theoretical, yet can provide a useful basis for scenario planning on Heimaey, and similar eruptive situations.

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The younger volcanic units of the Central Atlantic Magmatic Province: implications for reconstructing distal effects of Large Igneous Provinces

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The end-Triassic extinction (201.564±0.015 Ma) is strongly associated with volcanic episodes of the voluminous Central Atlantic Magmatic Province (CAMP). However, widespread CAMP volcanic activity was still occurring up to 700 kyr after the extinction and onset of volcanism, and has also been inferred to have had a profound impact on the global environment. CAMP volcanism is poorly preserved, but is largely recorded as flood basalt flows. A cm-thick tuff (the Pompton Ash) is known from multiple sedimentary records across two North American basins, but its relation to CAMP has been unknown.

In this study, we investigate the youngest known CAMP flood basalt from North America and Morocco (dated to 200.916±0.064 Ma) and the Pompton Ash, thought to have erupted about 120 kyr earlier. The volatile emissions and potential environmental impact of these two volcanic units are investigated through analysis of the mercury (Hg) content of sediments above and below them. Sedimentary Hg enrichments are increasingly being employed as a marker of volcanic volatiles, and have already been used to document early CAMP volcanism in distal sediments.

Additionally, the trace-element geochemistry of Pompton Ash is compared to that of CAMP basalts, confirming that the Pompton was likely derived from CAMP volcanism. However, it is not yet clear whether this tuff was produced from a specifically placed small eruption, or a more distal linear fissure-eruption. Establishing the style of eruption may give important insights into the possible role played by more explosive eruptions in the emplacement of this and other Large Igneous Provinces.

PAGES: Pleistocene Archaeology, Geochronology and Environment of the Southern Caucasus

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The nature and timing of the dispersal of *Homo* sp. is fundamental to our understanding of human evolution during the Pleistocene, yet current knowledge is largely based on the Early Palaeolithic records of East and Southern Africa. As a result, it is presently unclear what mechanisms drove human dispersal to other geographic regions, and how technological innovations (i.e. stone tools) and ecological adaptations developed along the way.

The Southern Caucasus forms part of a land bridge between Africa and Eurasia and is the location of archaeological sites e.g. Dmanisi (Georgia) and Nor Geghi 1 (Armenia), where the earliest human fossils outside Africa [Ferring et al. 2011; Lordkipanidze et al., 2013] and the earliest evidence for advanced human behaviour [Adler et al., 2014] have been found, transforming our understanding of the relationship between the European and African Palaeolithic. The archaeology is often associated with volcanic deposits, including lava flows, pyroclastic deposits and cryptotephra.

The interdisciplinary PAGES project aims to build a geochronological framework of the Southern Caucasus, specifically focussed on the Hrazdan and Debed gorges in Armenia, which are formed of volcanic deposits and intercalated alluvial and lacustrine sediments. Detailed geological mapping, $^{40}Ar/^{39}Ar$ geochronology, tephrochronology and geochemical/petrological characterization of the volcanic deposits, will provide a stratigraphic link between archaeological sites in the region. The data will be used in conjunction with palaeoenvironmental and climate records from sediments in order to enhance understanding of human habitation and dispersal in the region and to contribute to a high-resolution model of early human evolution.

Ferring, R. et al., 2011. PNAS. 108:10432-10436
Lordkipanidze et al., 2013. Science. 342: 326-331
Adler, D.S. et al., 2014. Science. 345: 1609-1613

The three dimensional architecture of the Mull Lava Pile, Isle of Mull, Scotland

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Understanding the 3D architecture of exposed portions of lava piles is critical to our understanding of the expected expression of subsurface lava fields, which generally rely on interpretation of low-resolution geophysical surveys. The subsurface record typically provides an oversimplified view of lava field architecture generally resulting in a 'layer-cake' interpretation of the 3D structure that is often aided by geochemical correlations.

Recent 3D drone derived virtual outcrops have been acquired from part of the Palaeocene Mull Lava Pile, which provide new insight into the 3D architecture of the sequence, previously not possible through geochemistry alone.

The Mull Lava Pile consists of 840km^2 of basaltic lava flows and reaching an exposed maximum thickness of 1000m.

Using data collected from the north-western extremities and lower stratigraphical levels of the lava pile, a 3D model has been generated in this new study by combining drone imagery, along with detailed field mapping and logging over a 3.8km section of coastline. The model was analysed to identify the lava flow tops, bases and crusts, as well as sedimentary interbeds, dykes and faults. Preliminary results have elucidated a highly heterogeneous model, emphasising the complexity of the lava pile. In addition this study highlights the underrepresentation of normal faulting in such extensional regimes.

Further fieldwork including additional acquisition of high-resolution imagery will be synthesised and calibrated with existing and new geochemical data in order to produce a generic 3-D model of lava fields, on a larger scale than previous studies, which may be used as an analogue for other areas.

What is the magma composition?

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A critical question for volcanological studies is "what was or is the melt composition?" In the past, whole rock analysis was employed to answer this question, and still today, whole rock analyses considered a fair representation of the magma composition in the final reservoir before eruption. However, many natural magmas contain crystals and lithics that are unrelated to, and are not in equilibrium with, their host melt. In whole rock analysis, these foreign and host materials become homogenized into the bulk, leading to results that do not represent the melt composition at the time of eruption.

We present a better method for ascertaining the host melt major element composition of an accumulative igneous rock using whole rock analysis, modal analysis of foreign and allochthonous materials and mineral phases as well as compositional analyses of the constituent crystals. The application of this method will be demonstrated on a suite of rocks from Ritter Island Volcano, Papua New Guinea.

By including modal analyses of xenocrystic and phenocrystic crystals this method is able to reflect the amount of accumulation in a rock. By utilizing mineral composition data and the relative percentages of mineral phases, the amount of each oxide present in xenocrystic material can be estimated and removed from the final result. Thus, applying a simple algorithm, the chemical composition of the host magma is calculated. While this remains an approximation of the actual magma composition, we believe the result of this method is an improvement on current practices.

A new view of Ritter Island Volcano, Papua New Guinea

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Ritter Island volcano is a small subduction-related arc volcano in the Bismarck Sea, Papua New Guinea, which experienced a tsunamigenic lateral collapse in 1888. This event is one of two historical volcano collapse events in island volcanoes for which we have eyewitness accounts and as such a valuable source of information on this phenomenon.

In November 2016, an international team of scientists investigated the submarine scar, as well as the new post-collapse cone which is growing inside it. 2D and 3D seismic surveys, improved bathymetric data, and video and photo material from dives with remotely operated vehicles yielded information on the submarine surface of the scar in the old edifice, the 1888 landslide deposit and its internal structure, and the constraining ocean floor morphology. High quality video of the subaerial edifice was captured during two drone surveys. We present some of this visual data as preliminary results from this cruise and our initial analysis and conclusions from it.

The drone imagery of the remnant island provides the basis for a structure-from-motion digital elevation map of the island, and will be used to map the distributions and orientations of sheet intrusions and alteration zones exposed in the collapse scar headwall. Submarine data cover the full extent of the submarine landslide deposit from the 1888 collapse event. We confirm that a new cone is forming within the collapse scar. Bathymetric data also suggest that submarine thin-skinned landslides have already occurred on the new cone. This is consistent with reports of small tsunamis during eruptions in 1972, 1974 and 2007.

ROV dives on the flanks and into the open summit region of the new cone show that it comprises heavily intruded scoria layers. It has a cover of soft yellowish material that is carried away from the summit region in submarine currents, indicating ongoing emissions.

Geothermal activity at Bárdarbunga, Iceland, following the 2014–15 caldera collapse, investigated using geothermal system modelling

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The gradual collapse of the subglacial Bárdarbunga caldera in 2014–2015, provided an opportunity to explore the geothermal signals produced by such large-scale subsidence. A few weeks after the start of the collapse, rapid growth occurred in three cauldrons on the caldera rims, with four smaller cauldrons forming in 2015–2017. The shortest-lived cauldron on the caldera rim was active for 7 months, and several continue to increase in volume after 3 years. The cauldrons have reached volumes in the range of 1.0±0.2 to 17±2 million m^3. HYDROTHERM numerical simulations of fluid flow and heat transport in the uppermost 1 km of the crust were performed to assess the role of shallow magmatic intrusions, for a range of likely permeability values and initial bedrock and groundwater temperatures. The heat transfer required to create the more rapidly formed non-eruption cauldrons, at or near the caldera rims, can be reproduced with shallow intrusions and high permeability pathways, which were found to greatly enhance the surface thermal signal. The delay in onset time for some of the cauldrons suggests, however, that such pathways are not always present. The pre-intrusion temperature of the surrounding bedrock has a major effect on heat transfer to the surface, with cold bedrock causing a buffering effect, whereas temperature conditions close to the boiling point of water produce far more efficient heat transfer due to the formation of steam plumes. Not all behavior observed is reproduced our models, suggesting that changes to geothermal reservoirs below 1 km depth may play a significant role in the observed thermal anomalies.

The heterogeneity of the Miocene Iceland mantle plume

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The oldest basalts (15-16 Ma) on Iceland are preserved in several ~1 km thick sequences in Vestfirdir in NW Iceland. Each sequence contains a marked hiatus in volcanism, marked by a laterite-lignite horizon, that is likely the result of the relocation of a spreading axis (Hardarson et al., 1997). The basalt geochemistry provides an insight into the heterogeneity of the Iceland mantle plume in the mid-Miocene. A suite of 605 basalt samples have been collected from 21 profiles. A preliminary study demonstrated that the sequence contains an enriched mantle component and a depleted mantle component that is present only in the basalts from below the volcanic hiatus (Hardarson et al, 1997). They are characterised by high $^{3}He/^{4}He$ (37 R_a) requiring the involvement of deep mantle (Ellam and Stuart, 2004).

Incompatible trace element and $^{143}Nd/^{144}Nd$ data indicate that there are two enriched mantle components within the Miocene mantle (we term NWE1 and NWE2). Both have low $^{143}Nd/^{144}Nd$ (0.513298) that are comparable with the most enriched modern Iceland basalts. The two components are differentiated by the relative enrichment in the more incompatible trace elements. Component NWE1 is characterised by low Nb/Zr (~0.10) and La/Sm (~1.15) ratios. This is similar to the enriched plume derived component in the neo-volcanic rift zone basalts. The higher Nb/Zr and La/Sm of the NWE2 component is more comparable to modern off-axis magmatism. The depleted component (NWD1) identified in the Vestfirdir basalts ($^{143}Nd/^{144}Nd$ = 0.51320) is distinct from modern North Atlantic NMORB and the depleted component in the neovolcanic rift zones by, for instance, higher Nb/Zr and La/Sm and incompatible trace element concentrations.

Ellam, R.M. & Stuart, F.M., 2004. Earth Planet. Sci. Lett. 228:511-523.
Hardarson, B.S. et al., 1997. Earth Planet. Sci. Lett. 153: 181-196.

Spectral Emissivity of eruptive products using laboratory based FTIR and Thermal Remote Sensing analysis of same area targets

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As less than 10% of the ~1500 active subaerial volcanoes around the world are monitored with appropriate quality, frequency and timeliness, a combination of passive and active remote sensing (RS) are accepted to be a technological solution for bridging critical gaps in volcanic hazard assessment and risk mitigation. We note that the exceptionally large literature available on optical remote sensing of very-high temperature volcanic features lacks detailed spectral emissivity information. Spectral emissivity - defined as the efficiency with which a surface radiates its thermal energy - is seldom measured and mostly assumed or estimated but it's an extremely important variable because of its close relationship with Land Surface Temperature (LST) values.

To fill this gap in knowledge, we designed a multi-stage experiment to measure spectral emissivity of rock samples collected in a grid, scaled to the spatial resolution of High-Resolution multispectral payloads – in particular, Landsat 8's TIRS and OLI – from which spectral emissivity can be derived using their thermal channels.

The experiment is aimed at clarifying the lateral spatial heterogeneity of the spectral emissivity of volcanic targets at the scale of a satellite image/pixel and the capacity for reproducing it from spaceborne observations. After a preparatory step to validate the method, >50 samples were collected according to the above criteria on Mount Etna, Italy in 2017. The suite of lava flow samples (1999 to 2017) were investigated using laboratory based Fourier Transform Infra-Red (FTIR) spectroscopy at 8 to 14.5 µm wavelength range and low-to-moderate temperatures (50-80˚C).

To develop a general method of spectral emissivity valuation, the initial investigation presented here assesses the correlation of laboratory measured data with (i) petrological composition and sample properties and (ii) high resolution RS data of the same target.

Bulk-rock chemistry of post-collapse lavas on Fogo, Cape Verdes

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The island of Fogo is the most volcanically active island in the Cape Verde archipelago. It is dominated by the Monte Amarelo lateral collapse structure that is 10 km (N-S) by 7 km (E-W) in diameter, open to the sea on the eastern side and bounded to the west by the Bordeira cliff. This cliff is still up to 1 km high despite infilling of the collapse scar by abundant post-collapse volcanism. Previous work (Foeken et al. 2009) indicates that the age of the collapse is between 123±5.2 and 62.4±1 ka. Thin sequences of post-collapse lavas outside the collapse scar provide the best way to sample post-collapse magmatism for analysis by XRF. Most of these lavas are tephrites and basanites with a few foidites. The La/Nb vs Zr/Nb plot shows that they are typical Ocean Island Basalts (OIB). Major element variation diagrams indicate fractionation of clinopyroxene (Ca and Ti), olivine (Mg), and titanium-rich magnetite (Fe, Ti and V). The absence of plagioclase phenocrysts is consistent with the increase of Al with fractionation. Trace element variation diagrams also indicate olivine (Ni), chromium spinel (Cr) and magnetite (V) fractionation. All high-field strength elements, S and Cl show strong incompatibility during fractionation. The Zr/Nb vs Nb/Y plot indicates that melting occurred in both the spinel-garnet and the garnet-peridotite zones.

Foeken, J. P., Day, S., & Stuart, F. M. (2009). *Quat. Geochronol.*, *4(1)*, 37-49.

Do Sea Level Changes Influence Eruptive Activity on Island Volcanoes?

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As the sea level rises and falls due to the contraction and growth of the Earth's polar ice sheets, the load on the oceanic crust increases and decreases. What effect, if any, does this have on volcanic activity? Possible links between eruptive activity on island volcanoes and sea level changes were discussed by McGuire et al. (1997), however, a lack of precisely dated volcanoes and local sea level records has so far prevented a rigorous comparison of the two. In this presentation, a synthesis of literature derived data combined with a geophysical model (Browning et al. 2015) presents tentative evidence of sea level changes influencing both the style and frequency of volcanic activity for an island volcano; the Aegean island of Santorini. These preliminary results, spanning the island's second eruptive cycle, imply that Santorini's eruption frequency is sensitive to the crustal unloading and loading associated with Quaternary sea level changes. They also imply that that lava eruptions during the second cycle only occurred when the sea level was -60m below present and phreatomagmatic eruptions are associated with sea levels higher than those of today (i.e. during the Eemian). A new programme of argon dating is planned, with support from the NERC, to further test the hypothesis that sea level is a primary control on both the style and frequency of eruptive activity on island volcanoes like Santorini. If emissions of greenhouse gases from island volcanoes around the world also respond to glacial-interglacial sea level changes, this would manifest a currently unquantified feedback in the climate system.

Browning et al. (2015) Forecasting magma-chamber rupture at Santorini volcano, Greece. Nature Scientific Reports DOI: 10.1038/srep15785
McGuire et al. (1997) Correlation between rate of sea-level change and frequency of explosive volcanism in the Mediterranean Nature 389 pp 473-476.

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Textural Analysis of Basalts in the Taupo Volcanic Zone, New Zealand

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Basalts are rarely observed on the surface in the Taupo Volcanic Zone (TVZ), representing less than 0.1 % of outcrop by volume. As such only limited information is known about basalt genesis and their potential significance to the region. In comparison, rhyolite volcanism is dominant within the TVZ, although the genesis of these felsic magmas is equivocal with competing end-member models of fractional crystallisation from parental basalt magmas and crustal anatexis proposed, plus a variety of hybrid models put forward. What is clear is that basaltic volcanism is likely to play a role in the silicic magmatism whether as an original parental magma and/or a heat source for crustal anatexis.

Crystals hosted in volcanic rocks have the potential to document the magmatic evolution and their passage through the sub-volcanic system. Each magmatic process has the potential to deposit a chemical or textural marker within a crystal producing zoned crystals.

Olivine, plagioclase and pyroxene crystals within Rotokawau, Kakuki, K-Trig, Waimarino and Ohakune basalts have been characterised for their textural appearance and major, minor and trace element concentrations.

Crystals hosted within crystalline groundmass are often zoned with reaction rims present on olivine crystals and sieved core/zones within plagioclase crystals. Combined with the geochemical data, we have identified multiple crystal populations within TVZ basalts and suggest many of these magmas have experienced (cryptic) mixing and/or assimilation of ultra-mafic cumulates prior to eruption.

Identification of Primary Tephra Layers on the SW Icelandic Shelf

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Marine sedimentary deposits off Iceland often provide the sole witness for explosive Icelandic volcanic eruptions, in cases where glaciation and erosion hampered the formation/preservation of deposits on land. However, interpretation of the marine record is not straightforward: The depositional environment of Iceland can produce reworked tephra layers which may not be easily distinguished from primary ones. Furthermore, a considerable time delay up to centuries may be involved between deposition of primary and reworked tephra from the same eruption in the same stratigraphic succession.

Here, we present results of a case study on sections taken from three marine gravity cores collected from the southwestern Icelandic shelf during the P457 cruise of R/V Poseidon, to better resolve the eruptive record and to evaluate methods for the identification of primary tephra layers in this complex environment. We employed visual macroscopic and microscopic inspection, and major element compositions and 2D shape parameter analysis of tephra shards, derived from electron microprobe analysis and images. We correlated layers in the core sections to two events of the volcanic systems Katla and Veidivötn-Bárdarbunga, respectively, and constrained their depositional histories. Major element signatures and characteristic bimodality of rhyolite and basalt identify the Katla layers as the ~ 12.1ka BP Vedde Ash, the Veidivötn-Bárdarbunga layers having formed ~ 300 years later. The depositional modes involve primary fallout, rafting of tephra by sea ice and/or icebergs, and background sedimentation of remobilised shards both from the layer-forming eruption and from earlier events. Our results demonstrate the power of a combined-method approach for the identification of primary tephra, in particular when reconstructing complex depositional histories such as those of the late Quaternary Icelandic shelf.

The analysis and interpretation of very-long-period seismic signals on volcanoes

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The study of very long period (VLP) seismic signals became possible with the widespread use of broadband instruments. With periods ranging from several seconds to several minutes, VLP signals close the gap between geodesy and short period seismology. On the example of a VLP signal recorded on 23 March 2012 at Soufriere Hills volcano, Montserrat, by instruments with different natural periods, we show the processing steps required to obtain displacement information out of velocity seismogram in this frequency range through restitution and forward modelling. When ground displacements can not be retrieved through restitution process due to inability to restitute band-pass limited seismograms we show how with modelling ground displacements and accounting for the seismometer response, we can compare the synthetic and observed waveforms in the velocity domain and determine the best model. This unique dataset gave us the opportunity to see the small changes in ground displacement and to use them in forward modelling to reveal much more details of the source process.

Pyroclastic Density Currents: the influence of variable aeration on deposit formation

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Pyroclastic Density Currents (PDCs) are hot, density driven mixtures of gas and volcanic particles formed during explosive volcanic eruptions. They are capable of depositing large ignimbrite sheets, which can exhibit a variety of sedimentary structures.

Due to their inherent nature, the direct observation of the deposition of ignimbrites by PDCs is incredibly challenging, and our knowledge of the internal processes of PDCs comes largely from physical and numerical modelling. PDCs are known to have high gas pore pressures due to various possible mechanisms of aeration, and this is thought to explain their greater than expected runout distances.

This series of experiments further examines the effect of aeration on analogue currents. Previous work has shown how sustained, aerated currents not only aggrade deposits thicker than the current itself but have much longer runout distances than non-aerated currents. Here, we use a novel flume apparatus that not only allows the simulation of high pore pressures by aerating the current through a basal gas flux, but which can provide different fluxes to three different divisions of the flume channel. This allows the modelling of different degrees of aeration within the same current, which is significant as PDCs are intrinsically heterogeneous in time and space.

The results of these variable aeration experiments will be discussed, and a sensitivity analysis of how slope angle as well as aeration states affect current dynamics and depositional behaviour will be presented. This work will inform future experiments in the same flume, examining the effects of complex topography and variable grain size on bedform formation.

Assessment of suitable Particle Size Distributions (PSDs) for modelling ash dispersal of magmatic and phreatomagmatic Icelandic eruptions

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It is the responsibility of the London Volcanic Ash Advisory Centre (VAAC) to produce real time dispersion forecasts to help mitigate the hazard from volcanic ash to western Europe. This is achieved using the lagrangian atmospheric dispersion model NAME. Multiple source parameters are required to initialize the model including the particle size distribution (PSD). However, information on the PSD of the ash is difficult to obtain in near-real time. Instead the London VAAC use a default PSD to initialize the operational use of NAME for volcanic ash dispersal. This PSD is based on airborne measurements of the PSDs within the distal ash clouds. However, the PSD depends on the degree of fragmentation and distance from the source. Therefore, it is important to use a PSD which reflects these processes and accurately represents the grain size distribution (GSD) at the source location. This project addresses the need for a better approach to assigning PSDs in operational dispersion models for forecasting volcanic ash cloud transport.

PSDs were derived from Icelandic and global Total Grain Size Distribution (TGSD) and used to initialize model runs for two hypothetical volcanic eruptions representative of common types of Icelandic eruptions. The two considered scenarios are a small basaltic magmatic eruption and a basaltic phreatomagmatic eruption based on the second stage of the Eyjafjallajökull 2010 and the 2011 Grimsvötn eruptions respectively.

Statistical analysis of the modelled total column mass loadings in the distal ash cloud displayed a large variation (up to 30% Fractional Bias) between runs initialized with PSDs derived from the phreatomagmatic TGSD and runs for the same scenario but initialized with the default PSD. The NAME output initialised with phreatomagmatic PSDs shows more disparity than magmatic PSD simulations in comparisons with the results with the VAAC default PSD. Creating a new standard PSD which better represents phreatomagmatic eruptions should be the starting point for the London VAAC for improving their current PSD

Alkaline magmas in collision zone settings: Age and petrogenesis of the Tezhsar Alkaline Complex, Armenia

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The occurrence of alkaline igneous rocks in collision zones is of interest with respect to their petrogenesis and rare earth element (REE) prospectivity in ore exploration. Despite that, alkaline complexes within collisional environments are rarely studied. Through this work we aim to bridge this gap, and we present petrological and geochemical data to infer petrogenetic processes acting in the Tezhsar Alkaline Complex (TAC) in Armenia. We also present a new date for the complex of 41.0 ± 0.5 Ma obtained by $^{40}Ar/^{39}Ar$ geochronology to integrate the study into a wider context of alkaline magma genesis amid regional Eurasian-Arabian continental convergence along the major Sevan-Akera suture.

The TAC is subdivided into three major units: An outer volcanic unit (OVU), an inner plutonic unit (SYU) and a central volcanic unit (CVU), subsequently juxtaposed by ring faulting. Trachytic/phonolitic rocks dominate the volcanic units with rare pseudoleucite phonolite, while the pluton comprises syenites and nepheline syenites with subordinate melanite garnet-bearing pegmatites. Occurrence of the ~10km wide complex suggests the presence of a large, ancient stratovolcano close to the suture zone.

Whole-rock data show a highly fractionated, metaluminous, alkalic and silica-undersaturated composition of the TAC. General trace element enrichment, strong fractionation of REEs (La_N/Yb_N ~70>), mantle-like initial $^{87}Sr/^{86}Sr$ ratios (0.704-0.705) and positive εNd values (+3 to +5) suggest low degrees of partial melting from an isotopically depleted mantle source with no crustal influence. Negative Nb-Ta signatures are likely inherited from ancient subduction of the Neotethyan Ocean underneath the Eurasian plate. Other trace element indices also point to variable effects of subduction-related metasomatism.

Primordial and recycled geochemical signatures in the Icelandic mantle: A noble gas perspective

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The Icelandic mantle source is known to be chemically and lithologically heterogeneous on both long and short length scales. Previous determinations of noble gas isotopic compositions from Midfell (SW Iceland), particularly $^{4}He/^{3}He$, $^{20}Ne/^{22}Ne$, $^{40}Ar/^{36}Ar$ and $^{129}Xe/^{130}Xe$, suggest that primitive Icelandic basalts sample a relatively undegassed mantle source that has undergone very little modification since the first c.100 Ma of Earth's history (Mukhopadhyay, 2012). Quantification of lithological variability based on major and trace elements and lithophile isotopes in Icelandic erupted basalts, however, indicates that the Icelandic mantle must contain at least 4-10%, and possibly as much as 40%, of an enriched component derived from ancient recycled oceanic crust (Shorttle et al., 2014). Therefore, an unresolved dichotomy between interpretations exists of different geochemical proxies: why do primordial and recycled geochemical signatures coexist in the same samples? In this study, we utilise a suite of >100 subglacial basalts collected from Iceland's active neovolcanic zones. Our samples map a high-resolution transect across the Iceland mantle plume, and are thus expected to preserve geochemical signatures of melts from both ancient sources and the convecting mantle. We aim to measure both inert noble gases, which provide tracers of primordial, unmodified mantle domains, and fluid-mobile halogens, which are tracers of recycled subducted material. By combining these new measurements with existing major, trace and lithophile isotope data from the same samples, we aim to explore the spatial and temporal relationships between Iceland's primordial and recycled mantle components. Here we present the first analyses of noble gases from our sample suite, obtained using the HELIX mass spectrometer at the University of Manchester. We discuss some of the successes and challenges in measuring heavy noble gases (Kr, Xe) in subglacial basalt samples. Preliminary results indicate that high precision analyses are possible and the technique is capable of resolving noble gas variability.

Mukhopadhyay, S. 2012. Nature.
Shorttle O. et al., 2014. AGU Fall Meeting Abstract

Volcanism in continental collision zones can sample ambient mantle heterogeneity

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Variations in the composition of the ambient mantle, prior to any additions from subducting slabs or delaminated crust have long been recognised in intraplate ocean island settings. More recently, it has been suggested that some variations in the composition of the mantle wedge can play as important a role as the slab in defining the composition of arc front volcanoes (Turner *et al*., 2017). Meanwhile, previous models to explain the enriched composition of often voluminous volcanism in continental collision zones have largely focussed on contributions from subducting slabs, delamination, and crustal contamination, largely ignoring the potential contribution of mantle heterogeneity.

The geochemistry of a series of volcanic fields in the Lesser Caucasus sector of the Arabia-Eurasia collision zone, where the fields strike roughly parallel to the collision zone from NW to SE (and so the tectonic setting of volcanism remains consistent), are compared.

All samples show similar arc-like signatures, in MORB normalised trace element diagrams. Amongst the most primitive samples (with whole rock #Mg of up to 62), those rocks from the SE have more alkaline compositions, show enrichment in the most incompatible trace elements (particularly the LREE, Sr and P); have higher $^{87}Sr/^{86}Sr$ (0.7043-0.7047 vs 0.7042-0.7044) and lower εNd (2.2-4.2 vs 3.1-5.2). Variation in the radiogenic isotope compositions require that either the extent of crustal contamination or the composition of the melt source is varying along the transect.

We show that crustal contamination, slab additions or lower crust delamination are unable to explain the observed elemental and isotope enrichment in the samples from the SE. Instead we favour a model of mixing between a subduction modified convecting mantle, and delaminated NW Iranian mantle lithosphere. This mixing could be induced by slab roll-back and round-slab flow mixing in Iranian mantle lithosphere from the south. This explains the enriched signature in the SE with the addition of mantle material alone.

Turner, S. et al., 2017. EPSL. 472: 216-228.

Characterising and spatialising the interactions between people, animals, volcanic hazards, and local perceptions and responses to Popocatépetl volcano, Mexico

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Popocatépetl volcano in Mexico is one of the most active volcanoes in the world, and it is a source of multiple physical volcanic hazards. More than 20 million people are estimated to live within 70km of the crater. Those populations situated closer to its slopes have already been regularly affected by ash emissions and lahar formation since volcanic activity recommenced in 1994, and there is furthermore the potential for another Plinian-scale eruption.

Despite this, local drills and evacuation events have proven challenging, particularly those involving rural populations, where communities or individuals have either refused to leave or returned prematurely. In many cases, the need to feed and manage livestock is cited as a cause of this behaviour.

Beyond direct threats to life from hazards or as a result of starvation, the health and welfare implications of ongoing volcanic emissions exposure to pets and livestock, that these communities may also be responding to when making their hazard decisions, are poorly understood.

This interdisciplinary project builds upon three research approaches: i) participatory social volcanology; ii) the growing recognition of all species of managed animals not only as 'economic units', but as wider effectors upon people's risk perceptions and responses to disaster; iii) animal geography.

We are presenting mapped volcanic hazard modelling data for Popocatépetl volcano, alongside plans for i.) qualitative interviews, ii.) participatory hazard mapping, iii.) a quantitative survey, iv.) citizen science volcanic ash sampling, and v) multivariate and spatial analysis of gained data.

These data will enable us to qualitatively, quantitatively and spatially characterize the interactions between people, animals, volcanic hazards and risk perceptions, and to subsequently consider whether risk management policy and activities could be spatially tailored and targeted for improved outcomes.

Protracted near-solidus storage and pre-eruptive rejuvenation of large magma reservoirs

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Building super-eruptive magma reservoirs in the cold, upper parts of Earth's crust requires a significant influx of magma over an extended period, sufficient to allow the magma to accumulate, differentiate and periodically erupt. Some models favour magma storage in a cold non-eruptible state, requiring extensive reactivation of the reservoirs before eruption, whereas others suggest storage at higher temperature and lower crystallinity, implying that magma in such reservoirs is readily eruptible. Consequently, constraining volcanic hazards requires observations directly linking magma residence timescales to the thermal state and crystallinity of storage. Here we simultaneously determine crystallisation temperatures and ages of magmatic crystals of zircon and titanite in the 900 km^3 Kneeling Nun Tuff (New Mexico, USA), which allows us to place tight constraints on the long-term thermal evolution of the magma reservoir. We show that zircon and titanite crystals record more than 600,000 years of magma assembly and constrain the dominant storage conditions to low temperatures, set between the granitic solidus (680 to 700°C) and the temperature of the onset of titanite crystallisation (about 720 to 730°C). We apply the zircon–titanite systematics to a suite of other super-eruptions and suggest that protracted low-temperature storage culminating in late-stage reheating is a widespread feature of large crystal-rich eruptions.

Determining the altitude of volcanic ash clouds using the CO_2 slicing method

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Volcanic ash clouds are one of the many hazards associated with volcanic eruptions. The 2010 eruption of Eyjafjallajökull, Iceland, demonstrated the importance of monitoring the emission and dispersion of volcanic ash in the atmosphere and the value of satellite imagery. To avoid this hazard and minimise disruption from delayed or cancelled flights, it is vital to know the position of an ash cloud in three dimensions. This is also an essential input for models of ash cloud propagation. CO_2 slicing is an established method for retrieving the altitude of meteorological clouds and has previously been applied to volcanic ash using the Moderate Resolution Imaging Spectroradiometer (MODIS). In this study, we adapt this technique to exploit the high spectral resolution of the Infrared Atmospheric Sounding Interferometer (IASI). To test the applicability of this technique for ash, it was first applied to data simulated with the fast-radiative transfer model RTTOV. The results demonstrated that there was a close match between the simulated and retrieved heights. Following this, the technique was applied to plumes from eruptions at Eyjafjallajökull and Grímsvötn. To validate the results, they were compared to those from the CALIPSO LiDAR. This comparison showed that the CO_2 slicing method is able to produce altitudes similar to those obtained with the satellite-borne LiDAR suggesting that this method can be used to determine the altitude of volcanic ash clouds in the troposphere.

Characterizing of a dike intrusion and its interaction with a volcano centre in Main Ethiopian Rift

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In continental rift zones extension is accommodated by dike intrusions, border faults and rift floor fault systems. The Main Ethiopian Rift (MER) is an ideal rift system to observe the interactions between fault systems, dike intrusion and volcanic centres in an extensional setting.

We focus here on a period of seismicity that occurred near Fentale volcano in 2015. We use Interferometric Synthetic Aperture Radar (InSAR) from the Sentinel-1 and Cosmo-SkyMed satellites to study surface deformation in the area. Interferograms show a three-lobed pattern of deformation characteristic of a dyke intrusion, ~8 km long and 1 m wide. Preliminary analysis suggests the dyke intrusion episode is unusually slow, with deformation continuing for at least 8 months. There is evidence of deformation at the volcanic centre several months following the initial intrusion. The line-of-site (LOS), and two-dimensional rates of displacement and time-series are calculated using Poly Interferometric Rate And Time-series Estimation (PI-RATE) method. We use a Markov Chain Monte Carlo Inversion (MCMC) to find the best fitting source and compare this to locations of seismicity.

Investigating characteristics of a slow dike intrusion and its interaction with the volcano centre will give us better understand the process that govern present rifting. Fentale volcanic centre seems to behave differently to other caldera systems in the MER (e.g. Aluto, Corbetti and the Tulu Moye volcanic field) which show long-lived cycles of inflation and deflation. Our works provides new constraints on the temporal and spatial variations of magmatism in MER, and will contribute significantly to hazard assessments in the region.

Predicting magma emplacement mechanisms and intrusion architecture: insights from sub-volcanic systems in Iceland

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The process of magma intrusion into the shallow crust remains a subject of debate amongst the VMSG community. Whilst quantitative models have been employed to assess the feasibility of schematic interpretations from some real systems obvious limitations arise because realistic geological complexities cannot be taken into account.

This PhD study investigates the structural and temporal parameters associated with the construction of a suite of granitoid laccoliths in SE Iceland with a view to creating a realistic quantitative model that is grounded in field, structural and geochronological data. Iceland provides an ideal setting for this study owing to its short and relatively simple tectonic history and excellent three-dimensional exposure of laccoliths and their associated host rock contacts.

We present new data from fieldwork, and anisotropy of magnetic susceptibility (AMS) analysis on the Reydara Pluton in SE Iceland. The 10km^2, ~700m thick, medium grained granite laccolith is well exposed in incised valleys with excellent exposure of the roof and interpreted floor zones. The intrusion is largely concordant to the flat-lying basaltic flows that form the roof of the intrusion. Broken bridge structures defined by xenolithic blocks >20 m long show that this laccolith was constructed through the coalescence of at least 2-3 discrete magma bodies. AMS transects of these flow structures are presented here. U-Pb zircon ID CA TIMS samples from each mapped flow structure will be processed later this year to elucidate the timescales involved in pluton construction.

Data from the Reydara Pluton will feed into a broader dataset that provides tight constrains on the timescale and structural controls upon the incremental construction of laccoliths in the shallow crust. Together these data will inform a dynamic quantitative model that will assess the impact of variables such as gravity, lithostatic load and host rock rheology to upon networks in different tectonic regimes.

SO_2 fluxes from Telica, Nicaragua, using UV cameras

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Telica volcano, Nicaragua, has been active for many years. It displays significant seismic and fumarolic activity interspersed with larger ash explosions reaching up to VEI 3, especially in more recent years. Such activity poses a danger to summit visitors as well as residents living on the flanks of the volcano.

Sulphur dioxide is the third most abundant volcanic gas after water and carbon dioxide, but is significantly easier to monitor due to its low atmospheric concentration and prominent absorption features, especially in the ultraviolet. Past measurements of the SO_2 flux at Telica using a traditional UV spectrometer have shown up to an order of magnitude variation, from 50-500 tonnes per day (GVN Bulletin, 2000).

Some of this apparent variation may be caused by the low temporal resolution of the traditional methods, since high frequency changes in flux are occasionally captured in a traverse or transect, leading to an unrepresentative measurement. An SO_2 camera, consisting of two UV cameras, is capable of a temporal resolution of greater than 1Hz, a significant improvement over other methods.

Here we present 0.1Hz SO_2 camera flux measurements from Telica volcano captured on both the 9th and 15th May 2013, showing average fluxes between 81 and 157 tonnes per day, with a maximum flux of 220 and minimum of 51 tonnes per day. These measurements are consistent with the previous values, whilst also revealing a new short term pulsing behaviour in SO_2 gas at Telica.

GVN Bulletin, 2000. Telica, vol. 25(2), Smithsonian Institution, Washington DC

Identifying molybdenum isotope variations in slab-derived fluids at the Izu arc, Japan

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The application of molybdenum stable isotopes to study geological processes in high temperature environments has gained considerable momentum over the last few years. In particular, their potential as tracers for deeply-recycled crustal material into the mantle is promising, although further constraints on the fractionation of Mo isotopes during subduction and the Mo signature of the residual slab that sinks into the mantle are required.

In this study, we analyse basaltic and sedimentary samples from the Izu volcanic arc (Japan) in order to characterise the mass-dependant fractionation of Mo isotopes during fluid release and transport from the subducted slab. Our samples come from five islands (Oshima, Miyakejima, Hachijojima, Torishima, Niijima) and also include volcaniclastic sediments from ODP site 1149, accounting for the output and input material to the arc system, respectively. Mo isotope data are obtained using a double-spike MC-ICP-MS technique (Willbold et al., 2016) and reported as permil deviations from the NIST SRM 3134 Mo standard ($\delta^{98/95}Mo_{NIST}$). The lavas from the Izu arc are a prime target for a detailed Mo isotope study as they show independent chemical and isotopic evidence for a variable contribution from fluids derived from the subducting oceanic crust without major input from sediment partial melts (Taylor and Nesbitt, 1998). This allows us to identify the effects of slab dehydration and fluid transport through the subducted crust and overlying mantle wedge on the mass-dependant fractionation of Mo. Our new data, supported by other geochemical proxies (e.g. Freymuth et al., 2015; Freymuth et al., 2016), will enable us to better characterise subduction zone fluxes and ultimately refine the Mo isotope signature of crustal material being recycled into the mantle.

Freymuth, H. et al., 2015. EPSL. 432: 176-186.
Freymuth, H. et al., 2016. GCA. 186: 49-70
Taylor, R. & Nesbitt, R., 1998. EPSL. 164(1-2): 79-98.
Willbold et al., 2016. Geostd. G. Res. 40(3): 389-403.

Characterisation of volcanic phases in the Panama Canal area during the emergence of the Isthmus of Panama

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The Isthmus of Panama forms the southern part of the intra-oceanic Central American volcanic arc that links North and South America. The emergence of the Isthmus of Panama during the Neogene was a significant geological event that disconnected the Pacific and Atlantic Oceans, and likely triggered a new regime of global oceanographic circulation associated with the establishment of the modern climate system. The emergence is usually considered to be the result of the collision between the Central American arc and South American continent, but the exact timing of this collision is controversial. In addition, it remains unconstrained whether constructional volcanic processes could have played a significant role in the emergence of the Isthmus. To help address these problems, we are conducting a field-based volcanological and geochemical study on igneous sequences exposed in the Panama Canal area and Central Panama, which is generally considered to have hosted one of the last straits connecting the Pacific and Atlantic Oceans before completion of the Isthmus.

New field observations, geochemical data and geochronological constraints in the Canal area complement previous regional studies and outline three main magmatic phases during the Oligocene and Miocene. The first (Oligocene) phase is characterised by amphibole-bearing hydrous, intermediate melts associated in the field with small volcanic centres dominated by breccia deposits. The second (early Miocene) phase is characterised by variously phyric, probably hydrous felsic melts, with abundant ignimbrite and tuff, and rarer lava flows and domes with block-and-ash flow deposits. The third (middle Miocene) phase is characterised by hydrous to anhydrous, predominantly mafic melts, associated in the field with monogenetic volcanoes with abundant phreatomagmatic deposits and subvolcanic peperitic intrusions. On-going work will reflect possible changes in tectonic and/or environmental conditions during the emergence of central Panama.

A bug's death: PDC-water interactions indicated by diatom-bearing ash aggregates in the Columbia River Flood Basalt Province

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The Ellensburg Formation encompasses all of the background non-lava stratigraphy of the Miocene Columbia River Flood Basalt Province (CRFBP; Smith 1988). It comprises a wide variety of siliciclastic, volcaniclastic and pyroclastic materials, including poorly documented silicic tuffs (Smith 1988), most likely derived from the contemporaneous Cascade Volcanic Arc. Ash aggregates, including accretionary lapilli and coated ash pellets (Brown et al. 2010), are present in these deposits (Schmincke 1967), between the Umatilla (14.5 Ma) and Elephant Mountain (10.5 Ma) Basalts (Barry et al. 2013).

SEM analysis shows that centric, non-motile, fresh-water diatoms are a consistent component in the fine-ash rim of the ash aggregates, indicating interaction with water during eruption.

The unexpected presence of diatoms within pyroclastic deposits can aid the identification of eruption dynamics, environmental conditions and the possible location of source vent(s). In this example, eruption of pyroclastic material through a lake is one possibility (e.g. Van Eaton et al. 2013), however, we argue that the interaction of a pyroclastic density current (PDC) with a fluvio-lacustrine system can also produce these peculiar diatom-bearing ash aggregates. This model is consistent with a relatively distal (> 100 km) location for the source vent(s) in the contemporaneous Cascade Volcanic Arc, involving PDCs with a large run-out distance.

Barry, T.L. et al. 2013. GSA Special Paper. 497: 45-66.
Brown, R.J. et al. 2010. GSA Bulletin. 122: 305-320.
Schmincke, H-U. 1967. GSA Bulletin. 78: 319-330.
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Van Eaton, A.R. et al. 2013. Geology. 41: 1187-1190.

Halogen heterogeneity in the Icelandic mantle source

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The transport of halogens between the solid Earth, oceans and atmosphere has influenced the evolution of our planet. Little is known about the long-term transport of halogens into and within the deep mantle, which requires further investigation. Fluid-mobile halogens (F, Cl, Br, I) are able to trace recycled subducted material through the mantle. These halogens are concentrated in seawater, sediment reservoirs and altered oceanic crust. During subduction, the breakdown of hydrous minerals releases halogens into the mantle (Kendrick et al., 2011).

Iceland's hybrid geological setting, a mid-ocean ridge above a mantle plume, provides the opportunity to study both MORB-like (shallow) and OIB-like (deep) mantle sources and their interaction with each other. However, the chemical and lithological heterogeneity in the Icelandic mantle is complex and not a simple mix between MORB and OIB components, but must include second-order effects involving a recycled subducted component (Shorttle et al., 2013, 2014).

In this study we aim to determine the halogen contents of Iceland's mantle sources and to test and refine mantle heterogeneity models. We have selected subglacially erupted pillow basalts from two sample locations: Miðfell in the Western Volcanic Zone, which has a high contribution from the mantle plume, and Snaefellsjökull, an off-rift zone located far from the plume centre. Olivine- and plagioclase-hosted melt inclusions from each sample will be analysed using microbeam techniques to measure concentrations of halogens, selected light elements, REEs and trace elements. We aim to use these data to characterise the halogen content of Iceland's primordial and recycled mantle domains, and quantify the contribution of recycled material to Iceland's mantle.

Kendrick et al., 2011. Geochim Cosmochim Acta 81:82-93
Shorttle et al., 2013. Geochim Cosmochim Acta 122:363-397
Shorttle et al., 2014. Earth Planet Sci Lett 395:24-40

Evolution of Vesuvius' Magma

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During the 18th and 19th centuries Vesuvius was highly active, alternating between effusive lava flows, fire fountaining events and short-lived paroxysms. Our work sets out to explore the causes of this short-timescale variability. Despite the high profile of the volcano, there have been no studies that have looked systematically at how the compositions of eruptive products changed through time, on short timescales. Using a previously unanalysed suite of 19th Century lava samples from the John Phillip's archive in the Oxford University Museum of Natural History, we investigated the petrological and chemical variations that occur between eruptions.

Analysis of both major and trace element traverses across over 100 zoned pyroxenes from 12 eruptions provides new insights into the precursors to these eruptions, and the evolution of the magmatic system beneath the volcano.

Vesicularity of vitric lapilli formed of impact-melt, Ries impact crater, Germany.

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Nördlingen Ries impact crater, Germany, is one of the best-preserved impact craters on Earth (Osinski, 2003). Ejecta deposits in and around the crater provide a valuable source of information about the physical processes that occurred when an asteroid hit Earth.

Ries '*suevite*' deposits closely resemble massive lapilli-tuffs, with abundant (accidental) lithic clasts, glassy lapilli (of dacitic composition) and shocked crystals, supported in a fine ash matrix. Within the crater the suevite can reach up to 400 m in thickness, and the outflow varies from 90-2 m thick. Despite years of study, there is surprisingly little international consensus about the origin of suevite: it has been interpreted variously as an ejecta curtain deposit, a fallout deposit from an atmospheric plume, or the deposit of a current, similar to a pyroclastic density current (Siegart et al., 2017).

We are testing two hypotheses: (1) methods to characterise pyroclast vesicularity at volcanoes can be used to characterise impact melt vesicularity; and (2) impact-melt vesiculates in a process analogous to magma/pyroclast vesiculation in explosive eruptions.

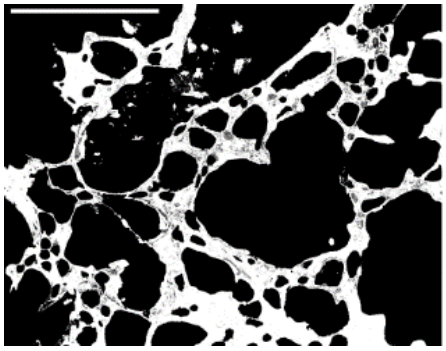

Fig 1: SEM image of part of a highly vesicular vitric clast (white) from the Ries suevite. Scale bar 1mm.

Preliminary results reveal a range of vesicularities from scoriaceous to pumiceous, with the most vesicular clasts occurring towards the top of the deposit. Further work will test this and provide a quantitative comparison of the vesicularities with pyroclasts from different styles of volcanic eruptions.

Osinski(2003) Meteoritics and Planetary Sci 38:1641-1667
Siegart, Branney, Hecht (2017) Geology. 45: 855-858

Plutonic Xenoliths from Santorini Volcano, Aegean Arc, Greece

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Plutonic xenoliths provide a means to explore the plumbing systems of volcanoes, representing snapshots of processes not clearly resolvable in the lava and pyroclastic rock record. Santorini volcano, in the South Aegean volcanic arc, has produced 12 major explosive eruptions within the last 360 ky, including the most recent ~1600 B.C. eruption that is amongst the most powerful in recent recorded history. Abundant plutonic xenoliths within eruption deposits provide an opportunity to gain a detailed insight into magma genesis and the plumbing system of Santorini. We use geothermobarometry and in-situ Laser ICP-MS trace element data to decipher storage depths and fractionation trends.

Xenolith lithologies range from troctolite, through olivine gabbros and gabbro, to gabbro-norites. Texturally, many can be described as 'cumulate', exhibiting a network of interlocking crystals with an intercumulus assemblage comprising quartz, alkali feldspar and glass. Mineral core and rim compositions vary between the xenoliths: plagioclase An_{92-86} in troctolite to An_{80-1} in gabbro-norites, olivine Fo_{84-77} in troctolite to Fo_{69-47} in gabbronorites, and clinopyroxene $Mg\#_{85-64}$ in olivine gabbros to $Mg\#_{79-54}$ in gabbro-norites. Intercumulus alkali feldspars reach Or_{87}. Interstitial glass and melt inclusion compositions range from basaltic to rhyolitic, spanning the full range of published Santorini melt compositions, with interstitial glasses generally being more SiO_2-rich than melt inclusions.

Mineral-melt thermometry estimates span a wide temperature range from 1150°C in the olivine-gabbro olivines to 800°C for plagioclase crystal rims and intercumulus crystals in the gabbro-norites. Pressure estimates from mineral-melt equilibria and experimental comparisons suggest mafic to silicic magma differentiation at $\leq 3 \pm 1$ kbar, which generally concurs with current models of magma storage and genesis. Unlike many arc volcanoes, including those within the Aegean arc, Santorini volcanic whole-rock trace element data and equilibrium melt compositions calculated from cumulate clinopyroxenes point towards only a modest role of amphibole fractionation, which is most prominent at late stages of evolution. This is corroborated by the presence of amphibole restricted to the cumulate late evolutionary stages.

Tracking and measuring volcanic plumes using drones

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Volcanic plumes are comprised of a complex mixture of volcanic and atmospheric gases, small aerosol particles and ash (Oppenheimer et al, 2004). Measuring the quantity and ratio of relative components is essential for assessing likely human, environmental and climatic impacts of the volcanic emission (Schmidt et al, 2011). Quiescently degassing volcanoes account for ~40% of global volcanic emissions; their plumes are often difficult to detect via satellite and so are usually monitored by ground-based instruments (Roberts et al, 2017).

The aim of this project is to develop a cross-section 'map' of aerosol and gas concentrations, which is not possible using ground-based or balloon instrumentation. When combined with wind speed, these measurements will be used to estimate the volcanic aerosol flux, a key parameter in dispersion modelling. Measurements in the plume from near-vent to distal locations will also be undertaken in order to determine how the gas and aerosol compositions change with time and investigate the conversion process of SO_2 gas to sulphate particles.

Here we develop and test an Unmanned Aerial Vehicle (UAV) platform for monitoring inside the plume of quiescently degassing volcanoes. We aim to fit the drone platform with an Alphasense OPC-N2 (Optical Particle Counter) for the detection of aerosols in the plume. Alphasense electrochemical SO_2 and H_2S gas sensors and a SenseAir Non-Dispersive Infrared (NDIR) CO_2 sensor will also be used. Initial testing of the UAV platform and instrument packages are planned to take place at geothermal power plants in Iceland.

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Roberts, T. et al, 2017. Bull Volcanol. 79: (5).
Schmidt, A., 2011. Proc. Natl. Acad. Sci. U.S.A. 108: (38) 15710-15715.

Isotopic and field evidence for the crustal interaction of alkaline rift magmatism in the Gardar Province, South Greenland

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Alkaline magma bodies host some of the world's most significant rare earth element (REE) deposits. These deposits tend to form in reduced magmatic systems where extensive autometasomatism concentrates REE in the final phases of magmatic fluid evolution. This model demands minimal interaction of the magma with oxidising crustal rocks or fluids. Sulphur, carbon and oxygen isotope systematics can be used to evaluate these processes. Sulphide minerals are relatively abundant in alkaline magmatic systems and sulphur isotope fractionation is sensitive to variations in temperature and redox. Carbon and oxygen isotopes are both fractionated by surface processes and are a further tool to study alkaline hydrothermal processes. Carbonate material is commonly associated with alkaline magmatism as carbonatite melt or localised mineralisation, and its isotopic signatures can be used to fingerprint the material's source.

Here we bring together new field observations and isotopic constraints from the metasomatic envelope of three alkaline igneous centres (Ilímaussaq, Motzfeldt and Ivigtût) located in the Gardar Province, South Greenland. The province was active from 1350 to 1140 Ma and these well-exposed, central-type intrusive complexes all host significant REE deposits.

We present new data which demonstrates that most $\delta^{34}S$ variation takes place in the roof zones of alkaline intrusions during late-magmatic and hydrothermal stages, and we identify clear differences between the complexes. At Ilímaussaq, where the magmatic series is exceptionally reduced (below QFM buffer), roof zone $\delta^{34}S$ remains narrow (0–3 ‰). At Motzfeldt, which has a more open oxidizing roof zone (MH buffer), $\delta^{34}S$ ranges from –12 ‰ in late-stage fluorite veins to +12 ‰ where local crust has been assimilated. Ivigtût is intermediate between these end-members, varying between –5 to +5 ‰. $\delta^{34}S$ variations primarily relate to temperature and redox variations between the systems and highlight important contrasts in roof zone sealing. These results provide new constraints on alkaline hydrothermal processes and are applicable to genetic and targeting models of alkaline REE deposits.

Review of petroleum prospectivity of west Indian volcanic rifted margin

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India's western margin is a classic example of a volcanic rifted margin: it contains major hydrocarbon discoveries both on and offshore[1]. Petroleum exploration and exploitation of India dates from the late 1800's, but recently hydrocarbon exploration has increased dramatically.

The tectonic configuration of India arose due to a series of complex multi-phase rifting events. Emplacement of the Deccan lava successions are contemporaneous with the last phase of extension affecting the margin. In the Late Cretaceous-early Paleogene India propagated northward, travelling over the proto-Reunion hotspot resulting in emplacement of the Deccan continental flood basalt succession. Toward the end of this eruptive episode, thinning of the continental margin occurred, followed by rifting of the Seychelles microcontinent and onset of sea floor spreading at chron 27N–28R[2,3,4]. Consequently, offshore basins were developed providing abundant accommodation space for Maastrictian – Danian (terrestrial?–marine) sediments. Rapid thermal subsidence during the Palaeocene to Eocene was accompanied by deposition of fluvial sandstones and associated organic-rich shales extending from the Gulf of Cambay to offshore Bombay (i.e., Surat - Panna depression). Of these shales the Palaeocene – Eocene Panna Fm, form a regionally significant source rock[5] contributing to oil and gas in the Mumbai offshore basin. Along the margin post Deccan extensional faulting has led to the juxtaposition of source rocks with volcanic reservoirs leading to volcanic basement plays which form exploration targets in addition to conventional clastic reservoirs. Here we explore the influence of Deccan volcanism and volcanic rifted margin development on the occurrence of hydrocarbon deposits offshore Western India.

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Crystal Cargoes of the Mauna Ulu Eruption (1969-74), Kilauea Volcano

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The Mauna Ulu eruption (May 1969-July 1974) was the most voluminous and long-lasting flank eruption on Kilauea in the preceding 2200 years. Due to the wide geographical spacing of eruption sites across the Kilauea edifice, study of this five year period provides a unique insight into the transport and storage of magma between the summit caldera, and the two prominent rift zones.

Activity focused at a site on the East Rift Zone (ERZ), now marked by the Mauna Ulu shield. However, at two separate intervals, the locus of activity shifted to the summit caldera, with associated eruptions in the northern and south strand of the South West Rift Zone (NSWRZ; SSWRZ). Two breakouts also occurred uprift of Mauna Ulu.

By investigating the chemical and textural affinities of crystal populations and their host liquid (EPMA for chemistry, SE imaging for shape), models of magma transport can be tested. We investigate:
1)-Two episodes of fountaining at Mauna Ulu, 1969.
2)-Summit eruptions of August-September, 1971, and associated NSWRZ eruptions.
3)-An uprift breakout at Pauahi, November 1973.
4)-Summit eruptions of July/September 1974, and accompanying SSWRZ eruption of December, 1974.

It has been suggested, based on seismic evidence, that magma was supplied to Mauna Ulu along two routes; one via the summit reservoir, and the second by vertical transport from an ERZ conduit (c.f. Ryan, 1988). The presence of large deformed antecrysts in Mauna Ulu lavas, inferred to originate from large olivine cumulate bodies beneath the ERZ, has been suggested to support this model (Vinet & Higgins, 2010).

Our preliminary results show that large antecrystic olivines are absent in summit and NSWRZ lavas, but present in ERZ and SSWRZ lavas. This implies vertical transport (bypassing the summit reservoir) of these olivines from cumulate bodies within the ERZ *and* the SSWRZ. As olivine cumulates are associated with edifice instability on Kilauea, insight into their distribution has important hazard implications.

Ryan, M.P, 1988, J Geophys Res. 93 (B5): 4213-4248
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Transitions between explosive and effusive activity at the Fossa cone, Vulcano, Aeolian Islands

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The Fossa cone, Vulcano (Aeolian Islands), formed over 5.5 kyr and last erupted in 1888-90. It is dominated by alternating explosive and effusive activity, comprising 7 major eruptions: Punte Nere, Grotta dei Palizzi 1, 2 and 3, Caruggi, Pietre Cotte and Gran Cratere. Volcanic eruptions from the Fossa cone generally commence with pyroclastic successions of dilute pyroclastic density currents (PDCs) and fallout layers, which are often capped by lava flows.

In this study, we focus upon the explosive to effusive transitions recorded in the silica-rich, predominantly rhyolitic Grotta dei Palizzi 2 (2.2 ka) and Pietre Cotte (AD 1739) formations (De Astis *et al*. 2013 and references therein), which share similar field and petrological characteristics. Both successions consist of alternating massive to planar and cross-stratified lapilli-tuffs from pyroclastic density currents (PDCs) and pumiceous fallout layers, terminating with obsidian lavas with abundant mafic enclaves. Petrographical analyses of both formations show abundant disequilibrium textures (e.g. resorbed mineral phases), as well as occurrence of crustal xenoliths and magmatic mafic enclaves in the lava flows, highlighting the importance of magma mingling processes and the role of crustal contamination in the magmatic system.

Here, we present detailed field logs together with quantitative textural analyses of pumice, scoria, lavas and magmatic enclaves, and mineral and glass geochemical data to shed light on the magma storage conditions, and factors controlling the transitions between explosive and effusive volcanic activity recorded in the Grotta dei Palizzi 2 and Pietre Cotte formations. Understanding these processes has large implications for the evaluation of volcanic hazards associated with the active Fossa cone on Vulcano.

De Astis *et al.* 2013. Geol. Soc. London Memoirs. 37. 281-349.

An Ash Shape and Componentry Study of the 2015 – 2016 Eruption of Momotombo, Nicaragua

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Momotombo volcano, a basaltic-andesite stratovolcano in Nicaragua, has experienced 19 confirmed explosive eruptions during the Holocene. Following 110 years of quiescence, it entered an eruptive phase from December 1st 2015 to April 7th 2016. Currently, little is known about its magmatic system and eruptive products. A better understanding would help predict future eruptive patterns and improve hazard planning efforts in the region.

In order to gain insight into the dynamics of Momotombo's eruptions one lava sample and five ash samples, collected at various times, were imaged using the optical and electron microscope respectively. They were then analysed using particle componentry and shape parameters.

The eruption began when basaltic-andesite magma erupted through part of a conduit plug on December 1st. When comparing samples collected at 5AM, 6AM and 3PM on December 2nd, ash from 6AM was found to contain more crystal-based and mafic grains. This suggests that the sample had a deeper magma source. Furthermore the large number of crystals in the magma made it harder for bubbles to grow and coalesce, leading to more fragmentation and a more explosive eruption. The abundance of broken crystals and non-vesicular grains as well as the smaller modal grain size of the 6AM sample reflect this higher fragmentation efficiency. Non-vesicular grains may also represent parts of a degassed conduit plug. The plug was cyclically (partially) reformed and destroyed, reflected in the increased explosion frequency throughout the eruptive period. This process continued until the magma supply rate was low enough to end the eruptive period on April 7th. Overall the shape and componentry analysis of the ash grains revealed a series of Strombolian – Vulcanian style eruptions, whose fragmentation efficiency varied as the eruptive period progressed. Our results also support previous studies in recognising the control of bubbles and phenocryst size distributions on ash morphology (Liu et al., 2015) and componentry (Jones et al., 2016).

Liu, E.J. et al., 2015. Geology 45: 239-242.
Jones, T.J. et al., 2016. J Volcanol Geotherm Res 327: 70-83.

Experimental insights into degassing of open-vent basaltic volcanoeS

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Open vent basaltic volcanism is characterised by the continuous release of gas, which may manifest itself through the intermittent release of gas slugs or more quiescent high frequency degassing of small bubbles. Prior efforts to understand the controls on the phenomena have focussed on two-phase (liquid-gas) flows, in which the stability of a foam in a magma chamber has a key role on the form of gas venting at the surface. However, it has become clear that in many cases the magma may be highly crystalline, leading to important differences in the rheology of the melt-crystal mixture, and in turn this may also influence the style of degassing. Here we report a series of novel three-phase (liquid-solid-gas) analogue experiments aimed at probing how the dynamics of gas flow through a particle suspension varies with the particle load as an analogue for the effect of different crystal content on open vent degassing. The small-scale experimental setup consists of a long vertical Perspex tube filled with mixtures of glycerol and water of varying viscosity together with cellulose acetate particles to represent crystals. Gas is introduced via a pump at the base of the cylinder and the nature of the flow has been investigated for various gas flow rates, particle loading and liquid viscosity.

Long-period seismicity reveals magma pathways above a propagating dyke during the 2014-15 Bárdarbunga rifting episode, Iceland

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The 2014-15 Bárdarbunga-Holuhraun rifting episode comprised the best-monitored dyke intrusion in the world to date and the largest eruption in Iceland in 250 years. A huge variety of seismicity was produced, including over 30,000 volcano-tectonic earthquakes (VTs) associated with the dyke propagation, seismic tremor, and high-magnitude earthquakes accompanying the caldera collapse. We here report a study of the long-period seismicity, both long-period events (LPs) and tremor, associated with the rifting episode.

We systematically detect and locate LPs and tremor during the dyke propagation phase and the first week of the eruption. We identify clusters of highly similar, repetitive LPs. The LPs have a peak frequency of ~1 Hz, clear P but often emergent S arrivals, and a long-duration, low frequency resonance or surface wave phase. Three ice cauldrons were observed on the surface of Vatnajökull glacier above the path of the dyke. Most of the LP clusters occur in the vicinity of the northermost ice cauldron, at shallower depth than the VTs associated with dyke propagation. Tremor was also located in this area. Additional clusters of LPs were observed further south at similar depths to the VT earthquakes, near the other two ice cauldrons. Tremor was also observed in the region of the central ice cauldron. We suggest that the long-period seismicity results from excitation of cavities filled with magmatic fluids. This seismicity therefore represents magma pathways between the depth of the dyke-VT earthquakes and the surface. Notably, we do not detect tremor associated with the southerly, largest cauldron, despite melt reaching the base of the overlying ice cap, which is a concern for hazard forecasting.

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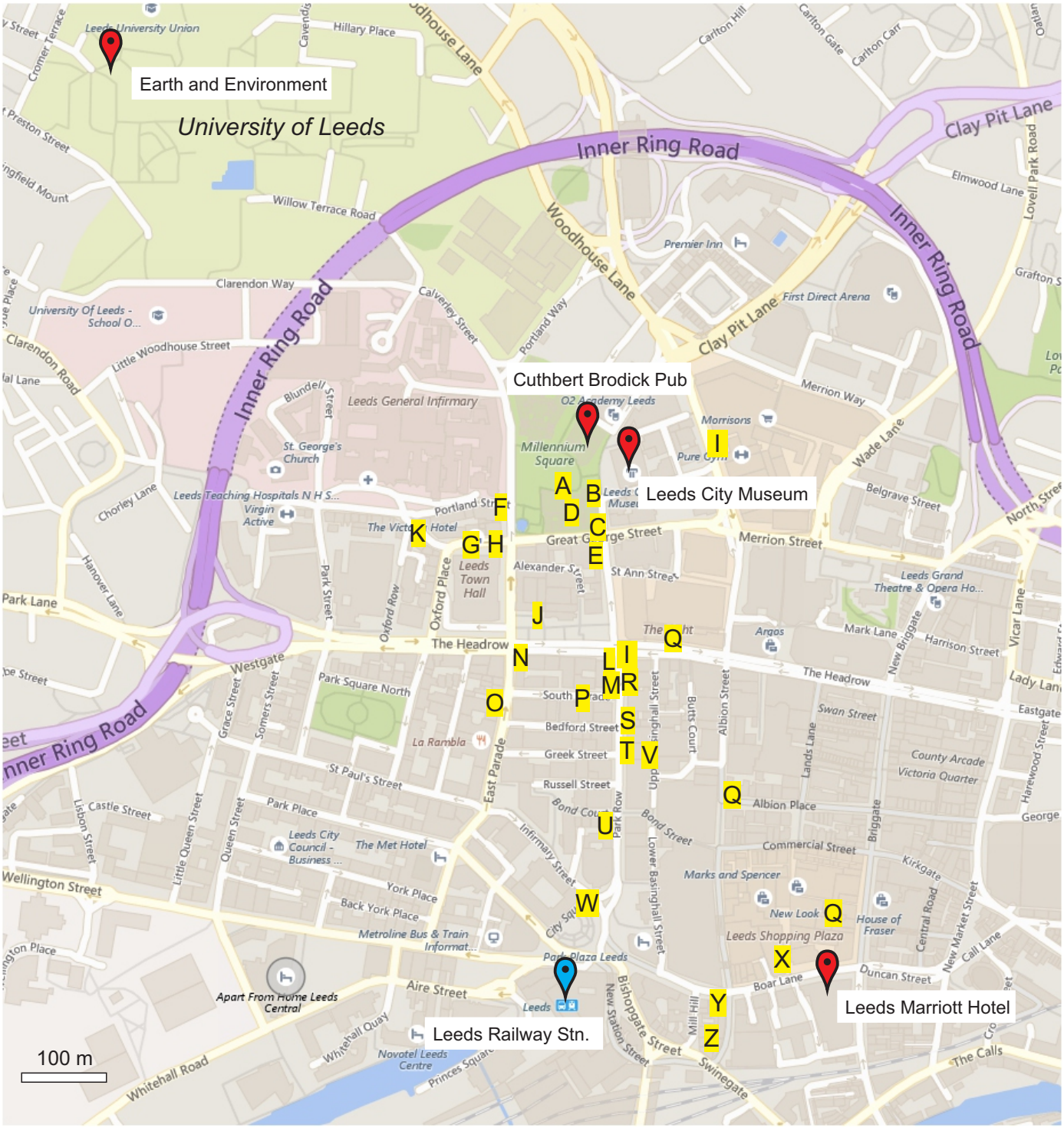

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