Rift Volcanism: Past, Present and Future



What controls volcanism in a continental rift?



 How does rifting influence magma generation, storage, migration and eruption?
What drives unrest at volcanoes?

3. What are the potential volcanic threats?

What controls volcanism in a continental rift?



- 1) First dated catalogue of eruptions and deposits at a continental rift
- 2) Integrated models of the ascent and storage of melts through a rift
- 3) Characterisation of the source(s) of volcanic unrest
- 4) Novel probabilistic analysis of volcanic hazards
- 5) Improved local & global resilience over NERC's 3 key impact areas

Why Ethiopia (1): THE classic mature continental rift



Specific Objectives

O1: Constrain the timing and magnitude of Holocene to Recent volcanism.

O2: Understand magmatic controls on eruption style at the central volcanoes.

O3: Determine the links between eruption style and climate/hydrology.

O4: Define the role active rifting plays on magmatic plumbing systems and volcanism.

O5: Characterise the spatial and temporal variations in stress and strain associated with magmatic, hydrothermal and fault-related processes at the silicic volcanic centres.

O6: Quantify the state of unrest from geophysical data.

O7: Develop probabilistic assessment methods to fully characterise key volcanic hazards at a high risk central volcano.

O8: Develop a regional analysis of ash fall hazard and assess the long-term volcanic threat, incorporating the inherent uncertainty.

Century PAST: What has driven eruptions over geological timescales?

Year





100 kyr



FUTURE: What are the potential threats from future volcanic activity?

Year Decade **Objectives:** Century Alert criteria Probabilistic tools for sparse datasets 1 kyr Regional/long-term volcanic threat 10 kyr

100 kyr

RiftVolc Team

Bristol, Cambridge, Edinburgh, Leeds, Oxford, Southampton, BGS

Bristol Juliet Biggs; Jon Blundy;, Kathy Cashman; Jo Gottsmann; Michael Kendall; Alison Rust; Fiona Whittaker Addis Ababa University Atalay Ayele; Elias Lewi; Getnet Mewa, Shimeles Wodemichael, Gezahegn Yirgu

Cambridge Marie Edmonds

Edinburgh Kathy Whaler; Andrew Bell; Eliza Calder; Ian Main

Leeds Andy Hooper; Graham Stuart; Tim Wright British Geological Survey Brian Baptie; Julia Crummy; Murray Lark; Sue Loughlin; Richard Luckett; Kay Smith; Charlotte Vye-Brown

Oxford Tamsin Mather; David Pyle; Victoria Smith

> Southampton Derek Keir

+ PDRAs and PhD students (see later)





Progress (1): Science Highlights

- WP1 field season (Fontijn et al)
- ~25 ash layers from the Holocene deposited in lake cores near Aluto (McNamara)
- WP2 field season: 36 seismic stations deployed (Keir et al) & crossrift MT profile measured (Hübert, Whaler & Fisseha)
- Processed 3-year GPS & InSAR archive ~7 cm/yr uplift at Corbetti, ~2cm/yr subsidence at Aluto (Birhanu & Lloyd)
- Repeat dynamic gravity survey show magma input at Corbetti (Birhanu & Gottsmann)
- World-bank funded expert elicitation on the characteristics and frequencies of explosive eruptions in Ethiopia and Kenya (Vye-Brown et al)

Progress (1): Science Highlights

- Most seismic stations serviced (Birhanu)
- 2-D model of MT profile (Hübert, Whaler & Fisseha)
- Data from January 2016 Hawassa earthquake analysed and published (Wilks et al)
- Field campaigns suspended when state of emergency imposed
 - action supported by AAU colleagues and Advisory Board
 - situation seems easier now, and AAU advice is we can consider resuming
 - FCO travel advisory to our region lifted, but other alerting services still recommending against travel

Progress (2): Personnel

Project Administrator: Anne Galbraith

Postdoctoral Researchers:

- PDRA1 (Oxf) Karen Fontijn
- PDRA2 (Sot) Tim Greenfield
- PDRA3 (Bristol) Yelebe Birhanu
- PDRA4 (Edin) Juliane Hübert
- PDRA5 (BGS) ad out soon
- PDRA6 (Data) TBA

Tied Studentships:

- PhD1 (Bristol) Keri McNamara
- PhD2 (Edin) Rachel Wilcock
- PhD3 (Leeds) Chris Moore
- PhD4 (Cambridge) Fiona Iddon

Associated Studentships:

- Ryan Lloyd (Bristol)
- Jon Hunt (Oxford)
- Ben Clarke (Edinburgh)
- Melanie, Aude & Finn (Southampton)
- Emma Chambers (Sot)
- Tesfaye Temtime (Bristol)

Exchange visits with AAU:

- Elias Lewi (Bristol, 2015);
- Amde Zafu (Oxford, 2016)

Progress (3): Publications

Peer-reviewed publications:

- Goitom, B., Oppenheimer, C., Hammond, J.O.S., Grandin, R., Barnie, T., Donovan, A., Ogubazghi, G., Yohannes, E., Kibrom, G., Kendall, J-M., Carn, S.A., Fee, D., Sealing, C., Keir, D., Ayele, A., Blundy, J., Hamlyn, J., Wright, T. and Berhe, S. (2015) First recorded eruption of Nabro volcano, Eritrea, 2011. Bulletin of Volcanology, 77, (10), Art.85. (doi:10.1007/s00445-015-0966-3).
- Civiero, C., Hammond, J.O.S., Goes, S., Fishwick, S., Ahmed, A., Ayele, A., Doubre, C., Goitom, B., Keir, D., Michael, J., Leroy, S., Ogubazghi, G., Rumpker, G. and Stuart, G.W. (2015) Multiple mantle upwellings in the transition zone beneath the northern East-African Rift system from relative P-wave traveltime tomography. Geochemistry Geophysics Geosystems, Early View (doi:10.1002/2015GC005948).
- wauthier, C., Smets, B. and Keir, D. (2015) Diking-induced moderate-magnitude earthquakes on a youthful NIt: The 2002 Nyiragongo-• Kalehe sequence, D.R. Congo. Geochemistry Geophysics Geosystems, Early View (doi:10.1002/2015GCP
- ease keep us updated Lewi, E., Keir, D., Birhanu, Y., Blundy, J., Stuart, G., Wright, T. and Calais, E., Wright, T.J., Ayele, A. (2015) Use of a high-precision gravity survey to understand the formation of oceanic crust approach Ethiopia. Geological Society London Special Publications, 420 (doi:10.1144/SP420.13).
- Thompson, D.A., Hammond, J.O.S., Kendall, J-M., Stuart, G.W., Helffrich, G.R., Kejzmantle transition zone beneath the Afar Triple Junction. Geochemistry Geophy
- Vye-Brown, C., Sparks, R.S.J., Lewi, E., Mewa, G., Asrat, A., Loughlin, S.C. through the application of research on active volcanic systems: A p Publication, 420
- Biggs, J., Robertson, E., Cashman, K.V., 2016. The lateral ٠
- Robertson, E. A. M., Biggs, J., Cashman, K. V., Floyd formation of elliptical calderas in the Kenyan منه
- Wilks, M et al. (2016). The 24th January *2*^e 125
- Ahmed, A., et al. (2016) Algana by regional seismic netwo
 - Biggs, J., Robertson doi:10.1038/nge
 - Gallacher, R., et al. doi:10.1038/ncomm

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ern Red Sea rift in Afar,

015) Hydrous upwelling across the

x46. (doi:10.1002/2014GC005648).

Supporting long-term disaster risk planning

ar, Ethiopia. Geological Society of London, Special

event in western Gulf of Aden during the November 2010 - March 2011 period captured and interactions with a nascent transform zone. *Geophys. J. Int.,* 205, doi: 10.1093/gji/ggw068 fateral extent of volcanic interactions during unrest and eruption. *Nature Geoscience*

segmented buoyancy-driven melting during continental breakup. Nature Communications 7,

- Hutchison, W., Fusillo, ۲., Mather, T., Blundy, J., Biggs, J., Yirgu, G., Cohen, B., Brooker, R., Barfod, D. and Calvert, A. (2016) A pulse of mid-Pleistocene rift volcanis n Ethiopia at the dawn of modern humans, Nature Communications 7, doi:10.1038/ncomms13192
- Hutchison, W. et al.. (2016) Causes of unrest at silicic calderas in the East African Rift: New constraints from InSAR and soil-gas chemistry at Aluto volcano, Ethiopia, Geochemistry, Geophysics, Geosystems, June 2016, doi: 10.1002/2016GC006395
- Poppe, S. et al.. (2016) Holocene phreatomagmatic eruptions alongside the densely populated northern shoreline of Lake Kivu, East African Rift: timing and hazard implications. Bulletin of Vulcanology November 2016, 78-82, doi: 10.1007/s00445-016-1074-8
- Vye-Brown, C. et al. (2016) In: Wright, T. J., Ayele, A., Ferguson, D. J., Kidane, T. & Vye-Brown, C. (eds) Magmatic Rifting and Active Volcanism. Ethiopian volcanic hazards: a changing research landscape. Geological Society, London, Special Publications, 420, pp.SP420-16.

Plus plenty of conference presentations, including at the meeting following this

Next Science Meeting

Dovedale House, Ilam, South Peaks <u>www.dovedalehouse.org</u>

July 2017



Breakout questions

These are the Project Outputs:

1) the first integrated eruption catalogue for a continental rift, detailing dates, magnitudes, mechanism and chemical characterization of major eruptions and associated flows and cones;

2) combined geophysical and geochemical models of the ascent and storage of melts through an active rift and the influence of along-rift variations in magma supply and tectonic setting;

 3) characterisation and statistical analysis of the evolving stress, strain and fluid flow fields around actively-deforming volcanic systems, and comparison with quiescent volcanoes;
4) novel probabilistic analysis of the hazards associated with rift volcanism at both volcano-specific and regional scales, and new statistical methods to assess regional volcanic threat

Breakout questions

- What is required to produce an *integrated* eruption catalogue?
- What dating is required? Is it going to be a limitation?
- How is the chemical characterization proceeding?
- What geophysical and geochemical data will we have and how will they be combined to model magma ascent and storage?
- What along-rift variations in magma supply and tectonic setting have been documented to date?
- What about across-rift variations e.g. Silte-Debra Zeit Fault Zone versus Wonji Fault Belt?
- Characterization of some actively-deforming volcanic centres is proceeding well, but what about the evolving stress, strain and fluid flow fields around volcanic systems? And statistical analysis?
- How will we undertake comparison with quiescent volcanoes?
- What information is required to undertake novel probabilistic analysis of the hazards associated with rift volcanism at both volcano-specific and regional scales, and new statistical methods to assess regional volcanic threat?