Integrating remote sensing, field studies and CO$_2$ surveys to unravel structural controls on fluid pathways at a young rift volcano

- How do regional tectonics influence volcanism?
- What processes control fluid flow in an active rift zone?

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Rifting and volcanism in Ethiopia

- **Main Ethiopian Rift** - zone of active magmatic-tectonic extension

- Young (< 500 ka) caldera-forming volcanoes developed within active fault system

- **Goal** - understand how pre-existing structures control fluid flow to the surface, implications for:
  - geothermal exploration
  - mineralisation
  - volcanic hazard
Mapping techniques

Magma
• Airborne LiDAR to construct 2m$^2$ DEM
• Map the location and shapes of volcanic vents

Hydrothermal fluid
• Aerial photographs orthorectified using DEM
• Zones of fluid alteration and mineralisation mapped using imagery

Gas
• CO$_2$ flux determined directly using accumulation chamber
• Degassing patterns analysed by gridding discreet point measurements
Structural setting and geological overview

- Deep well data reveals that the complex is dissected by rift aligned faults
- Faulting likely preceded formation of silicic volcanic complex
Vent alignment to tectonic faults

- Several linear trends in vents aligned with rift faulting
- Alignment along underlying tectonic structures explains ~30% of vent distribution
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- Several linear trends in vents aligned with rift faulting
- Alignment along underlying tectonic structures explains ~30% of vent distribution
• Ellipse fit explains ~40% of total vent distribution (at ±500 m uncertainty)
• E-W elongated calderas are common in Ethiopian rift (Acocella et al. 2003), possibly explained by elongation of underlying magma chamber
Degassing and alteration

- CO₂ flux peaks along mapped volcanic and tectonic structures
- Significant local variability in CO₂ flux suggesting other small scale controls
Near surface controls on degassing

**Mapping**
- **CO₂ transects**
  - **X – X’ Structural controls**
  - **Y – Y’ Lithological controls**
  - **Z – Z’ Topographic controls**

**Gridded CO₂ flux**
- **Shaded relief DEM**
- **Surface geology**
- **log CO₂ flux (g m⁻² d⁻¹)**
Conceptual model – How are fluids released?

1) Pre-existing regional faults – dissect complex, provide key pathways for fluid flow to surface

2) Volcanic structure – volcanic eruptions build up Aluto complex, ring fracture system develops

3) Post-caldera volcanism – recent eruptions, geothermal fluids and gas exploit the existing fracture network

Implications

- Geothermal field – understanding of fluid flow along these structures is critical to maximise productivity of the field
- Volcanic hazard – accurate subsurface picture of these faults would allow evaluation of future eruption scenarios at Aluto
• Using remote sensing and direct observations we have mapped fluid release at a young rift volcano.

• Tectonic faulting precedes formation of volcano and provides key pathways for magma, gas and geothermal fluids to upwell.

• An elliptical structure (caldera and ring fractures) also deflects these fluids to the surface.

• Fluids are exploiting these volcanic and tectonic structures but subtle near-surface controls (e.g. topography & lithology) play an important role in the final ascent of gas and geothermal fluids.

LiDAR DEM freely available ...

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