

# Volcanic Activity and Hazard in the East African Rift Zone

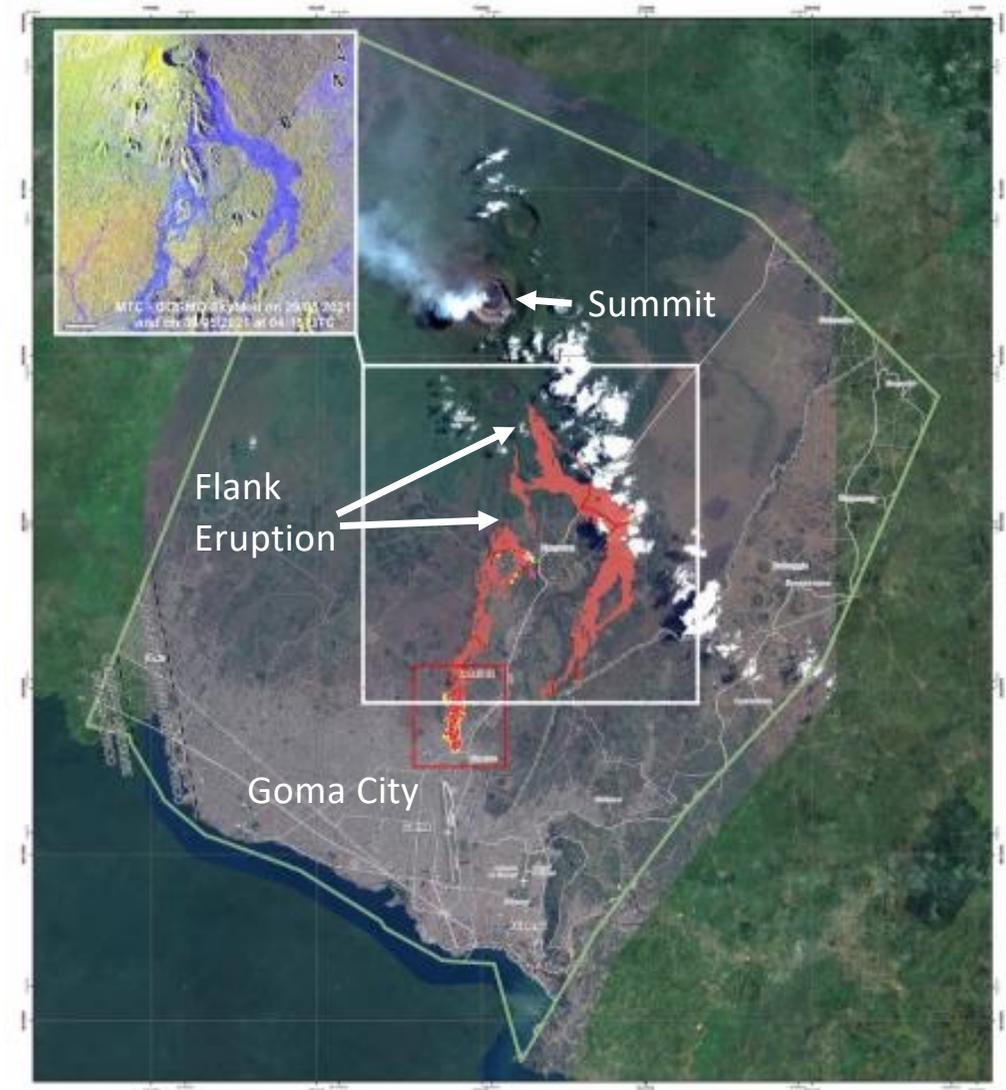


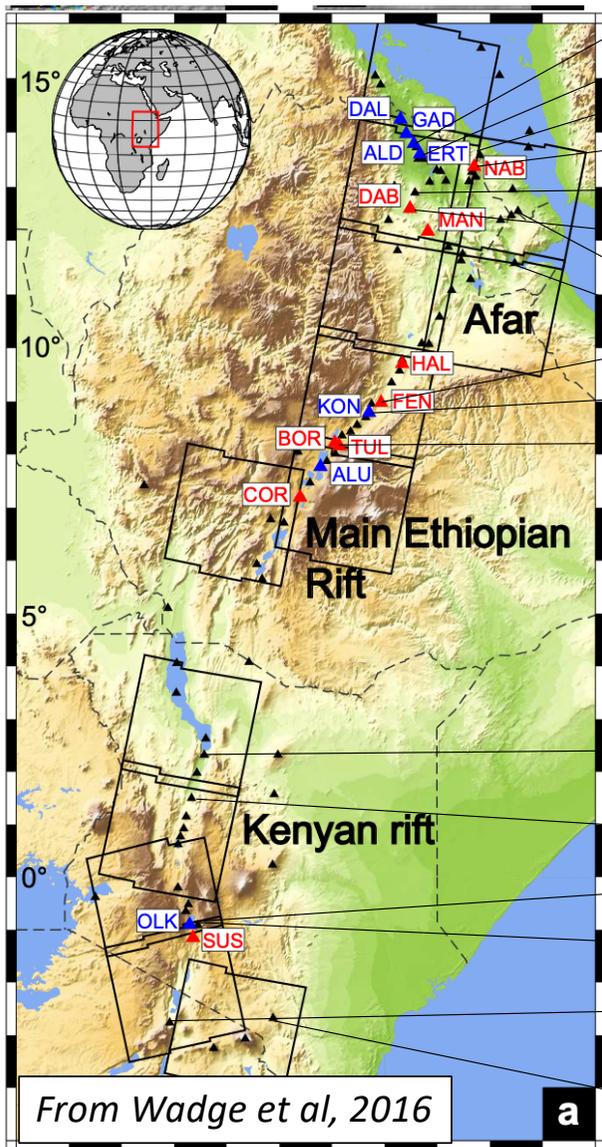
Juliet Biggs  
East Africa Seismic Risk Partnership  
Webinar March 2022



# Nyiragongo, DRC

- 30 major eruptions in the last 100 years alone
- Deadly eruptions in 2002 & 2021
- Lava flows enter Goma – 2 million residents.
- Crisis management complicated by 'armed conflicts, poverty, malnutrition, COVID-19' (Zehraoui and Provodnikova, 2021)





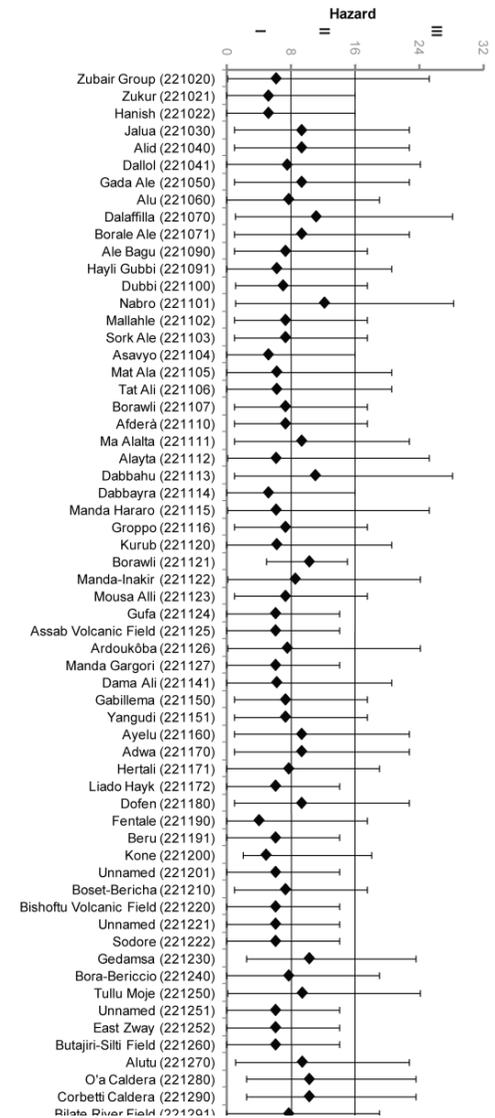
- Alu-Dalafilla, 2008
- Erte Ale, 2017
- Dubbi, 1861
- Nabro, 2011
- Alayta, 1906-1907
- Dabbahu, 2005-2010
- Kammourta, 1928
- Ardoukoba, 1978
- Fentale, 1810
- Kone, 1820
- Tullu Moje, ~1900
- The Barrier, 1895
- Emurangogolak, 1910
- Olkaria, ~1800
- Longonot, 1863
- Oldoinyo Lengai, 2007-2008
- Chyulu Hills, 1865-1866

# Historical Eruptions

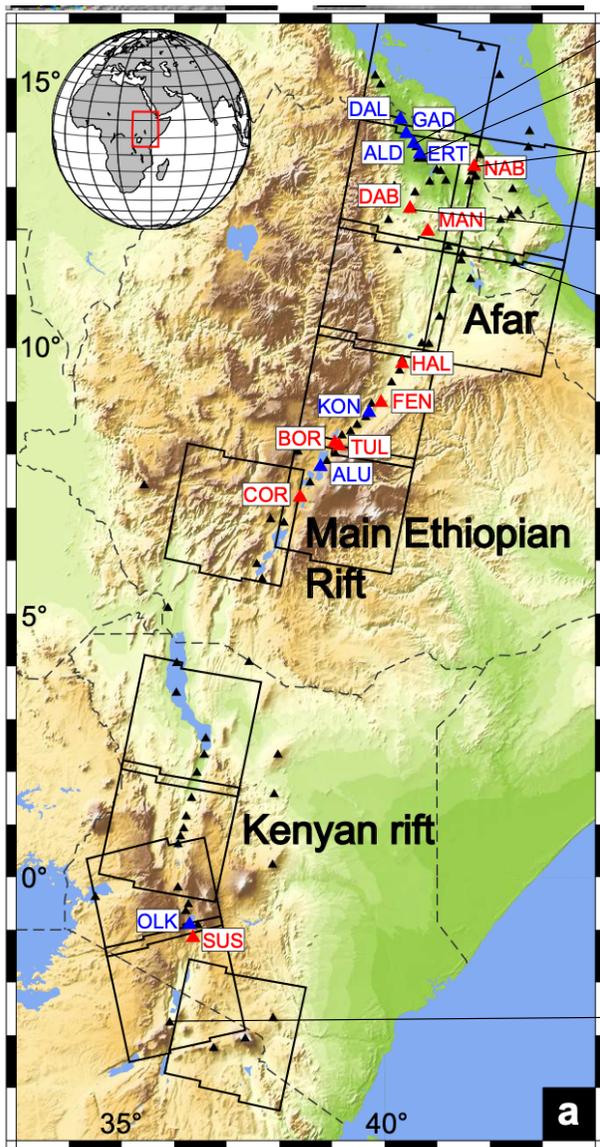
- 21 volcanoes have erupted historically (since ~1800)
- Largest eruption = VEI 4 eruption of Dubbi in 1861
- >4 million people within 10 km of a volcano.
- >120 million people within 100 km



Erte Ale, Ethiopia



UN Global Assessment of Risk



Alu-Dalafilla, 2008  
Erte Ale, 2017

Nabro, 2011

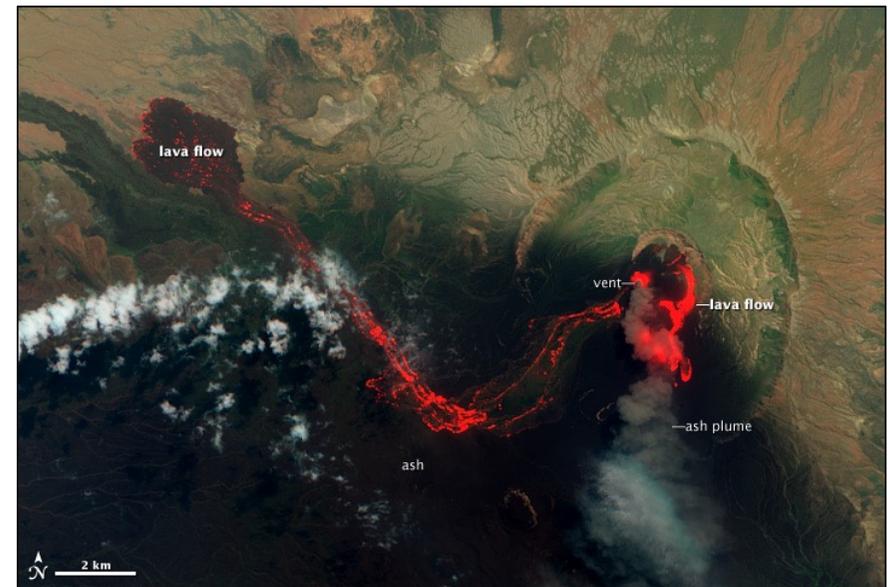
Dabbahu, 2005-2010

Ardoukoba, 1978

Oldoinyo Lengai, 2007-2008

## Recent Volcanic Activity

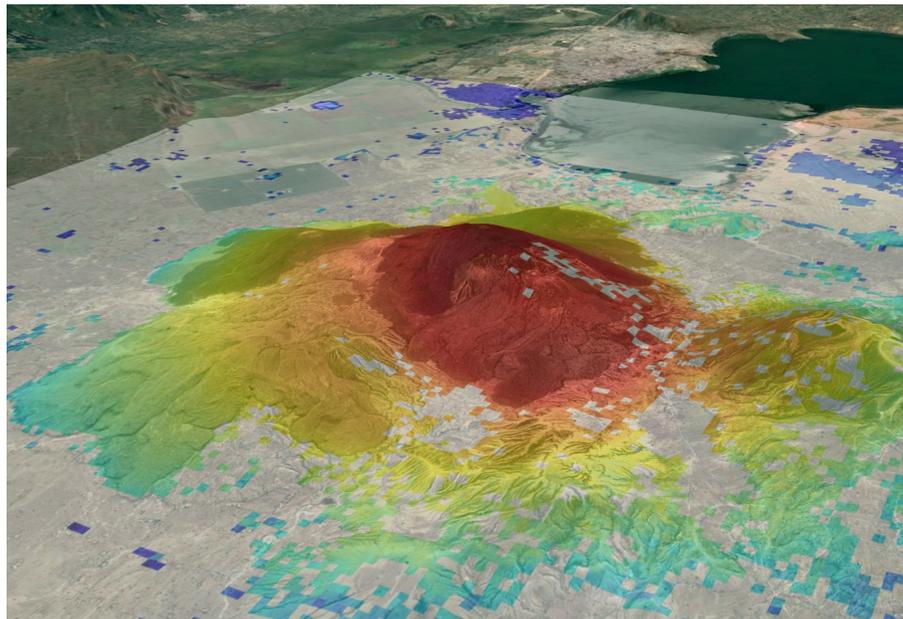
- Most recent eruptions in sparsely populated Afar.
- 2011 Nabro eruption caused:
  - two villages completely destroyed
  - economic losses estimated at \$3 million
  - ~12,000 residents self-evacuated,
  - >7 fatalities recorded,



# Current Activity: Deformation

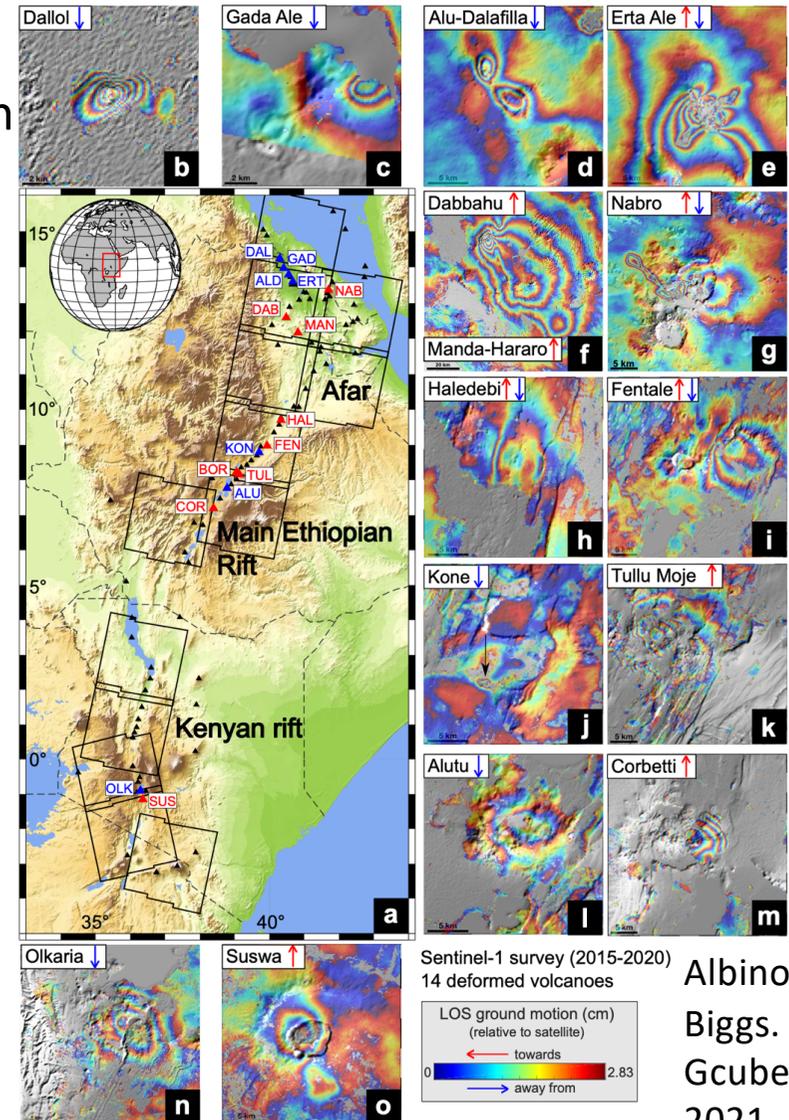
Since 2003, satellite technique (InSAR) survey deformation

- 17 volcanoes deforming
- Lots of different magmatic processes



e.g. Corbetti – 6 cm/yr since 2009 = 0.19-0.23 km<sup>3</sup>  
 => fill Wembley stadium 200 times

## Sentinel-1 Survey 2014-2020

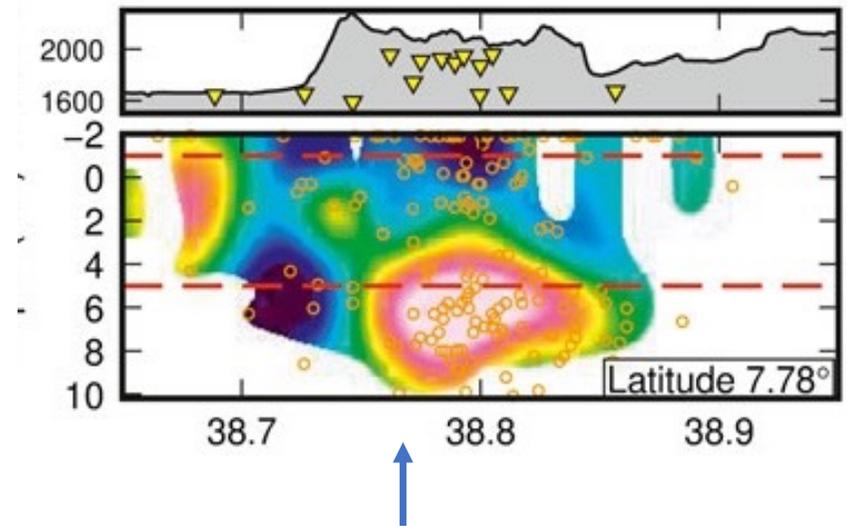
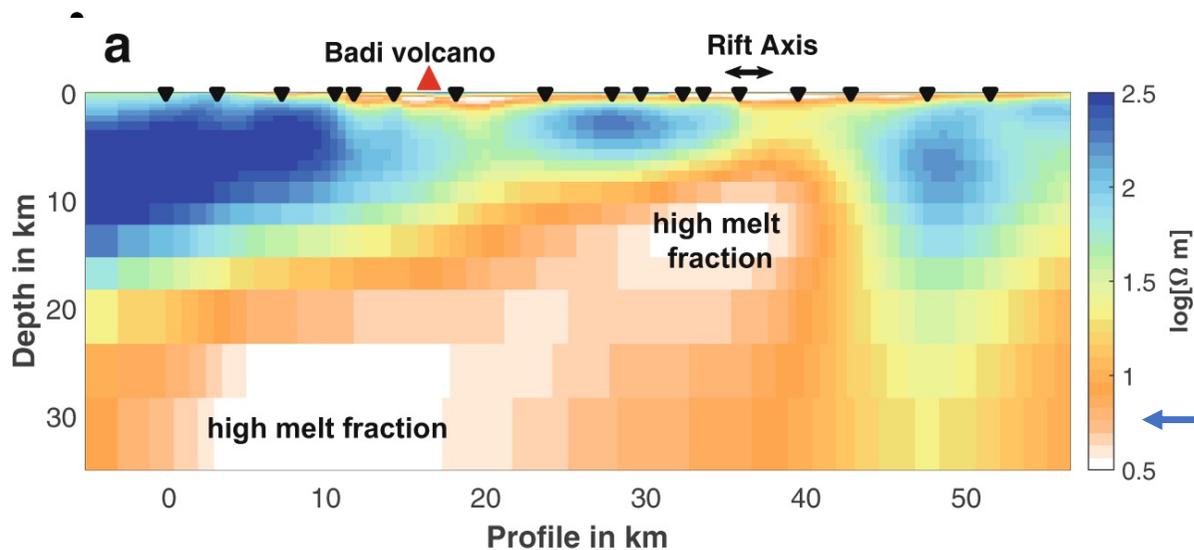


Albino &  
 Biggs.  
 Gcubed,  
 2021

# Transcrustal Magma Systems

Use geophysical and geochemical methods to image the distribution of fluids within the crust

- Fed by partial melt throughout the crust, often offset from volcanic centre
- Magmatic and hydrothermal systems in upper 10 km.

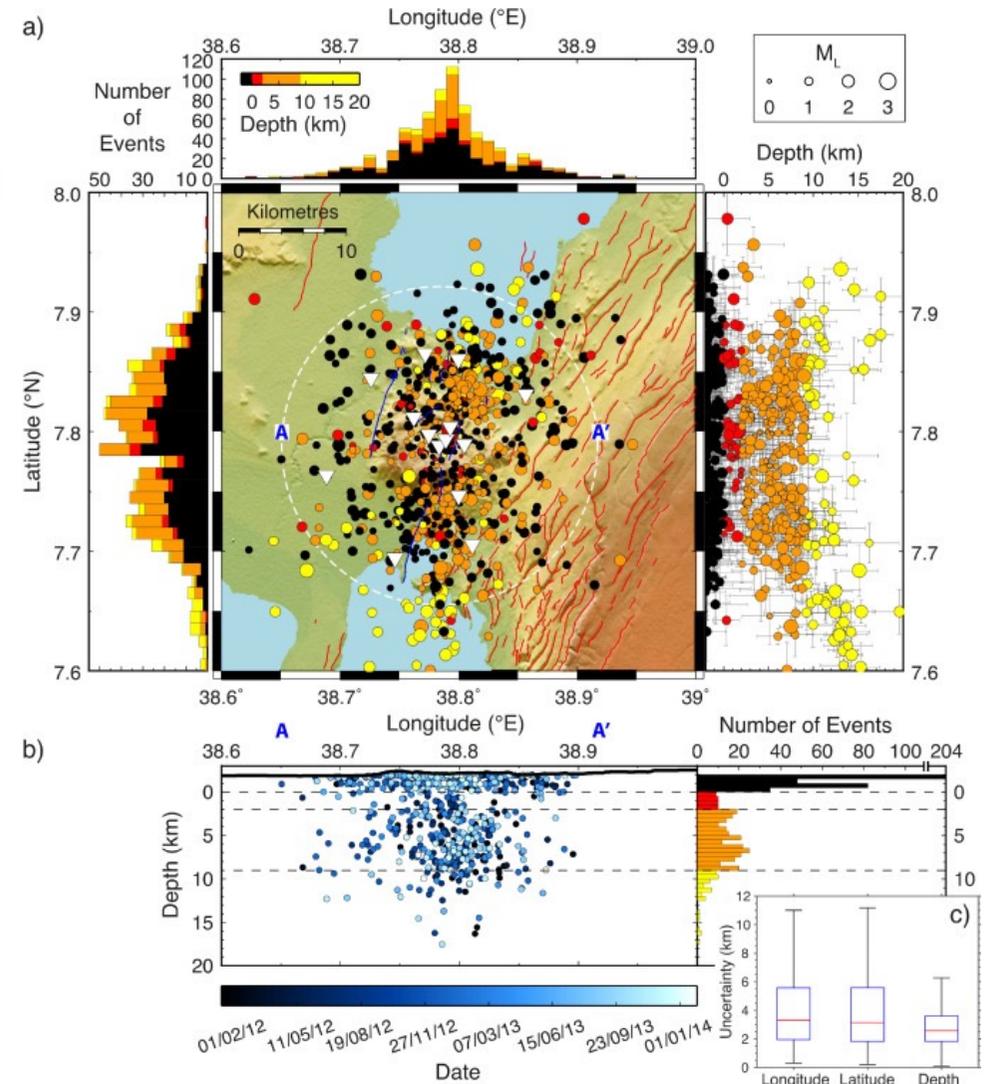


Seismic tomography image of the coupled magmatic and hydrothermal systems beneath Aluto volcano (Wilks et al, 2020)

Magnetotelluric image of transcrustal magma system in Afar ( Biggs et al, 2021)

# Current Activity: Seismicity

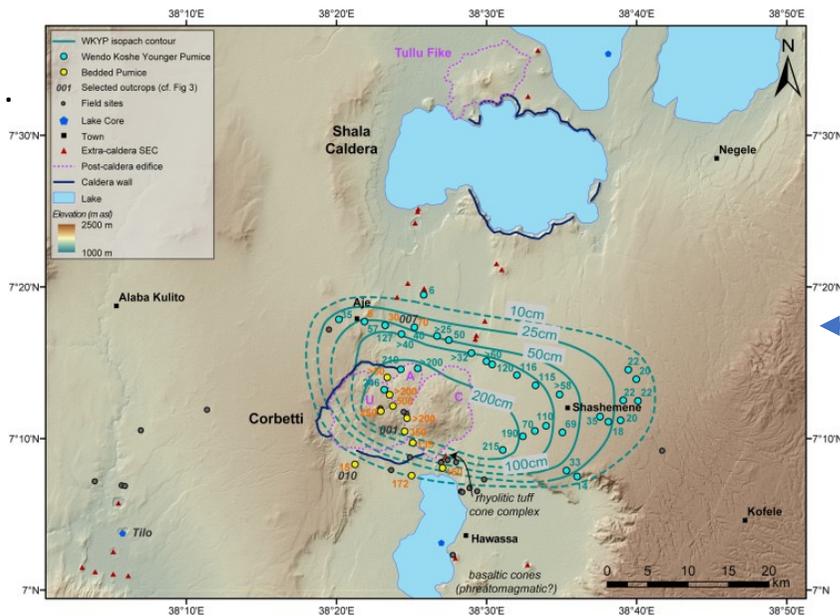
- Sparse national network has detection threshold of M3.5.
- Short-term, local seismic deployments recorded:
  - thousands of small magnitude ( $M < 3$ ) volcano-tectonic earthquakes
  - low-frequency events and swarms characteristic of fluid movement
- **But:** no long-term monitoring



Aluto 2012-2014 (Wilks et al, 2016)

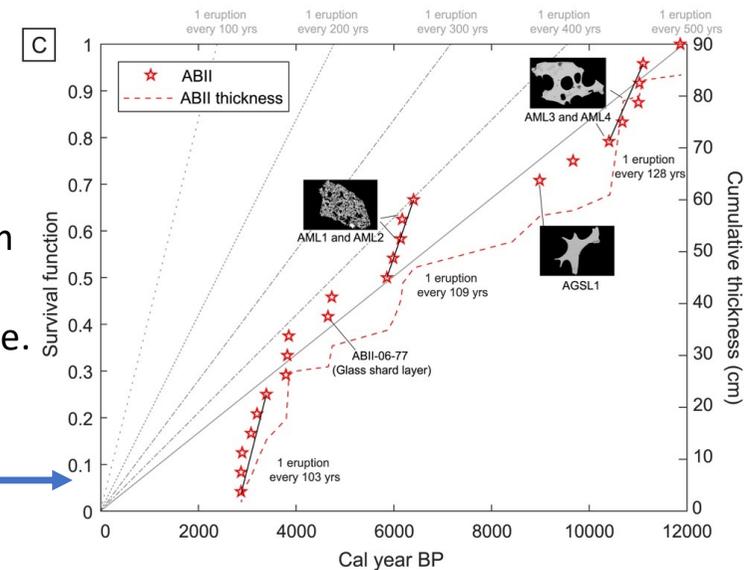
# Past Eruptions: Geology

- Detailed field studies needed to map and date ash layers from past eruptions.
- Example: Aluto Volcano, Ethiopia
  - 1–3 events per 1000 yrs.
  - Magnitude: VEI 3-4
  - Clusters of events, most recently at ~3.5 ka.



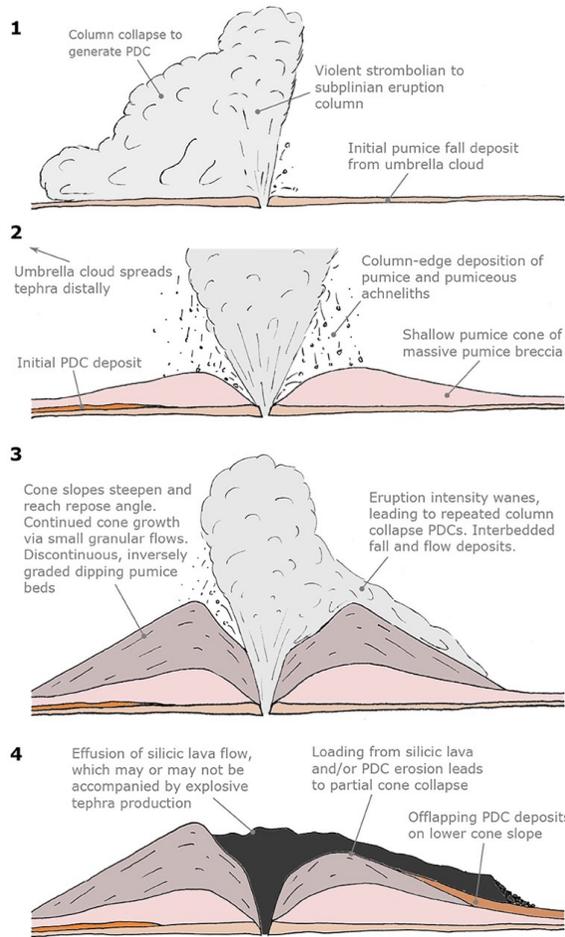
Ash Thickness Map from Fontijn et al, 2018 used to estimate eruption size.

Lake Core record for McNamara et al, 2018 showing event clusters



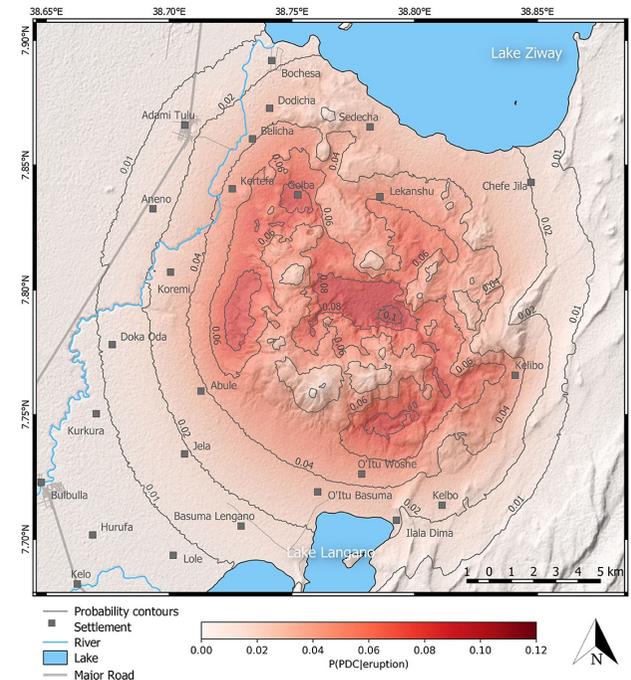
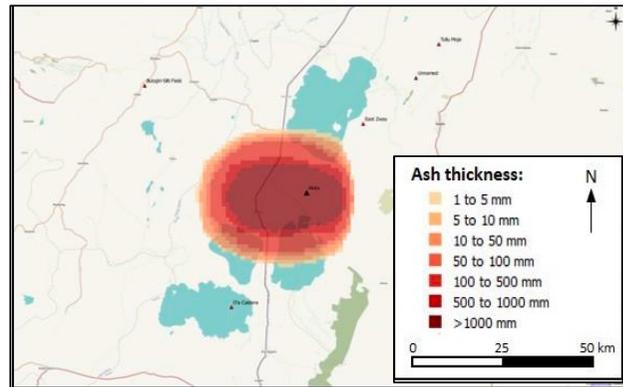
# Eruptions Hazards

Eruptions may last several years and are inherently multihazard.



## Formation of Pumice Cones

- Violent eruption -> pumice fall deposit
- Repeated column collapse -> generates pyroclastic flows
- End of eruption -> silicic lava flows
- Rainy season -> ash forms lahars (mudflows).



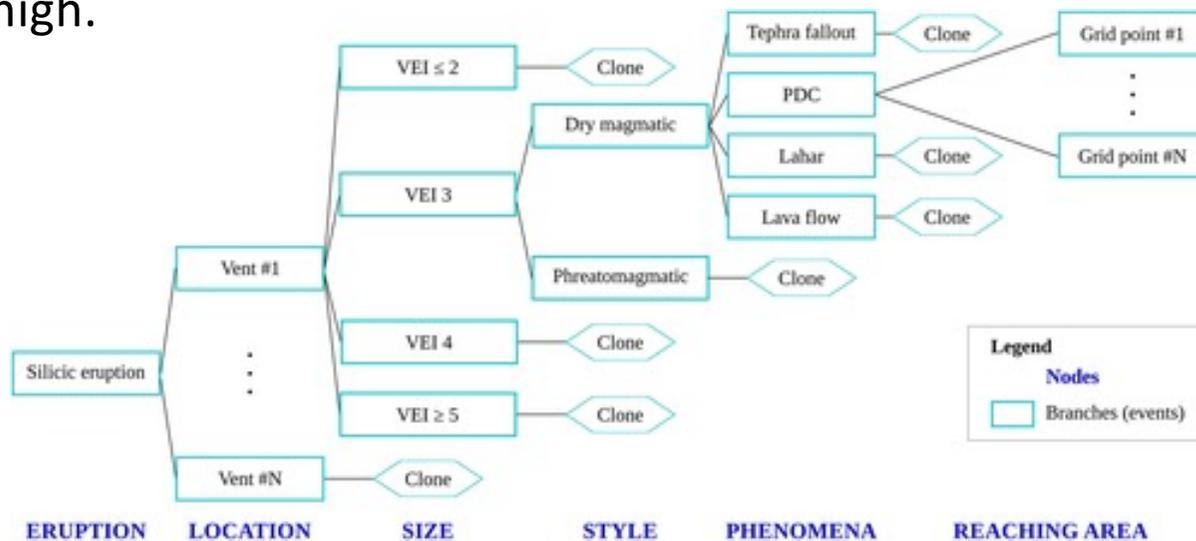
Pyroclastic Flow Inundation Map, Clarke et al, 2020

Tierz et al, 2020

Ashfall hazard (1000 year return), Jenkins et al, 2015

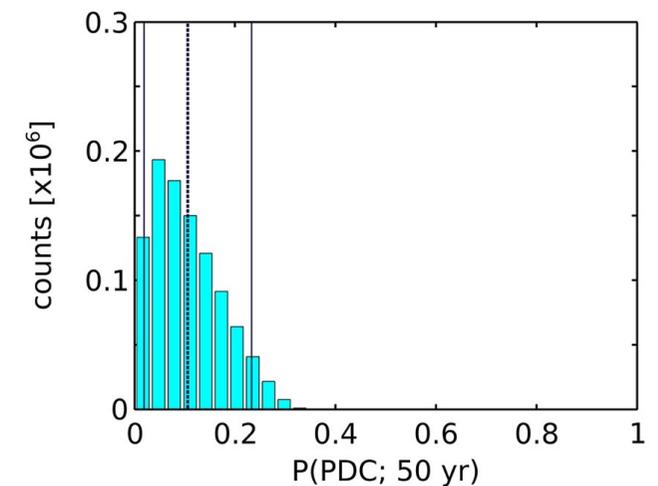
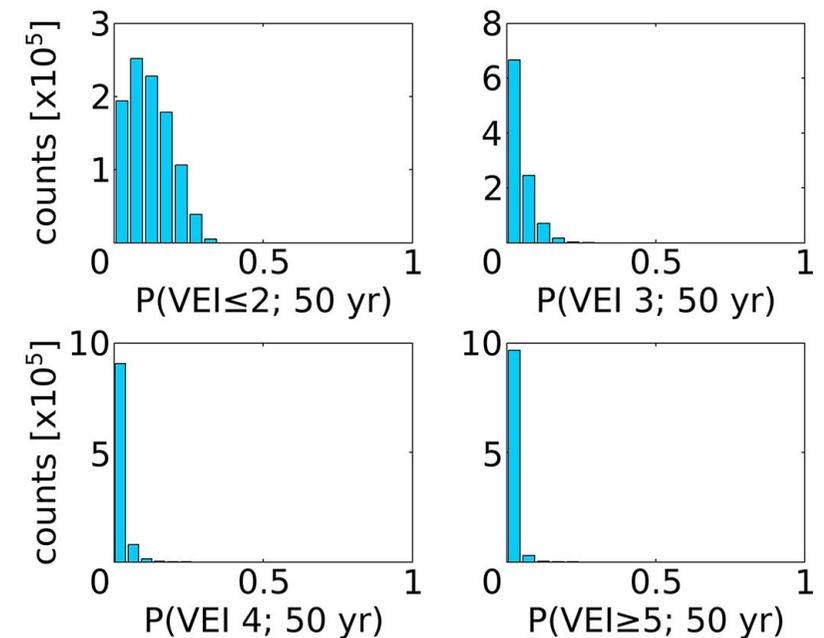
# Volcanic Hazard: Event Trees

In practice, volcanic hazard assessment is mostly done using event trees but in Africa, epistemic uncertainty is high.



For example: at Aluto, in the next 50 years

- probability of a silicic eruption is 2-35%
- probability of pyroclastic flow is 2–23%.



Event tree for Aluto, volcano (Tierz et al, 2020)

# Conclusions



- Multidisciplinary studies have unearthed a rich history of volcanic activity and unrest in the densely-populated East African Rift System.
  - characteristics of the volcanic plumbing systems
  - foundation for hazard assessments.
- Raised awareness is driving a shift from crisis response to reducing disaster risk
- But, lack of institutional and human capacity means baseline data are sparse and uncertainties high.
- Mitigating volcanic hazards remains challenging.

More Info: Open Access Review Article

The screenshot shows the top portion of a research article page from Nature Communications. At the top left is the Nature Communications logo, which includes a stylized wave graphic. Below the logo, the text 'nature COMMUNICATIONS' is displayed. The main heading of the article is 'REVIEW ARTICLE' in a bold, sans-serif font. To the right of this heading is a small button that says 'Check for updates'. Below the heading is a DOI link: 'https://doi.org/10.1038/s41467-021-27166-y' followed by the word 'OPEN' in orange. The title of the article is 'Volcanic activity and hazard in the East African Rift Zone'. Below the title, the authors are listed: 'Juliet Biggs<sup>1</sup>, Atalay Ayele<sup>2</sup>, Tobias P. Fischer<sup>3</sup>, Karen Fontijn<sup>4</sup>, William Hutchison<sup>5</sup>, Emmanuel Kazimoto<sup>6</sup>, Kathy Whaler<sup>7</sup> & Tim J. Wright<sup>8</sup>'. Each author name is followed by a small circular icon containing a number, likely representing a citation or ORCID ID.

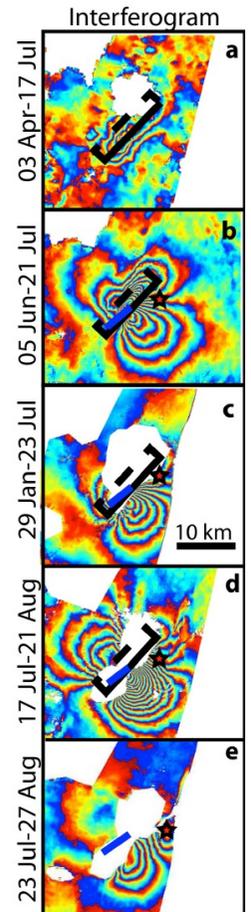
# Multi-hazard

Eruptions may last several years and are inherently multihazard.

## Example 2: 2007-8 Rifting Episode, Tanzania

- Lake Natron– July-Aug 2007.
  - M5.9 earthquake + 7 km long dyke
- Oldoinyo Lengai – Sept 2007 - April 2008
  - Change in eruption style from effusive carbonitite to explosive silicate.

Biggs et al, 2009,2013



# Conceptual models

## Early-stage rifting (Kenya/Tanzania)

- unusual magmas and extreme volatile emissions

## Mature Continental Rift (MER)

- pervasive melt in the upper mantle and lower crust
- large (5–15 km diameter) silicic caldera systems
- distributed fields of mafic cones and lava flows

## Incipient Sea-Floor Spreading (Afar)

- extensive faulting, lithospheric stretching and dyke intrusions
- thought to represent the final stages of continental break-up or the onset of sea-floor spreading

