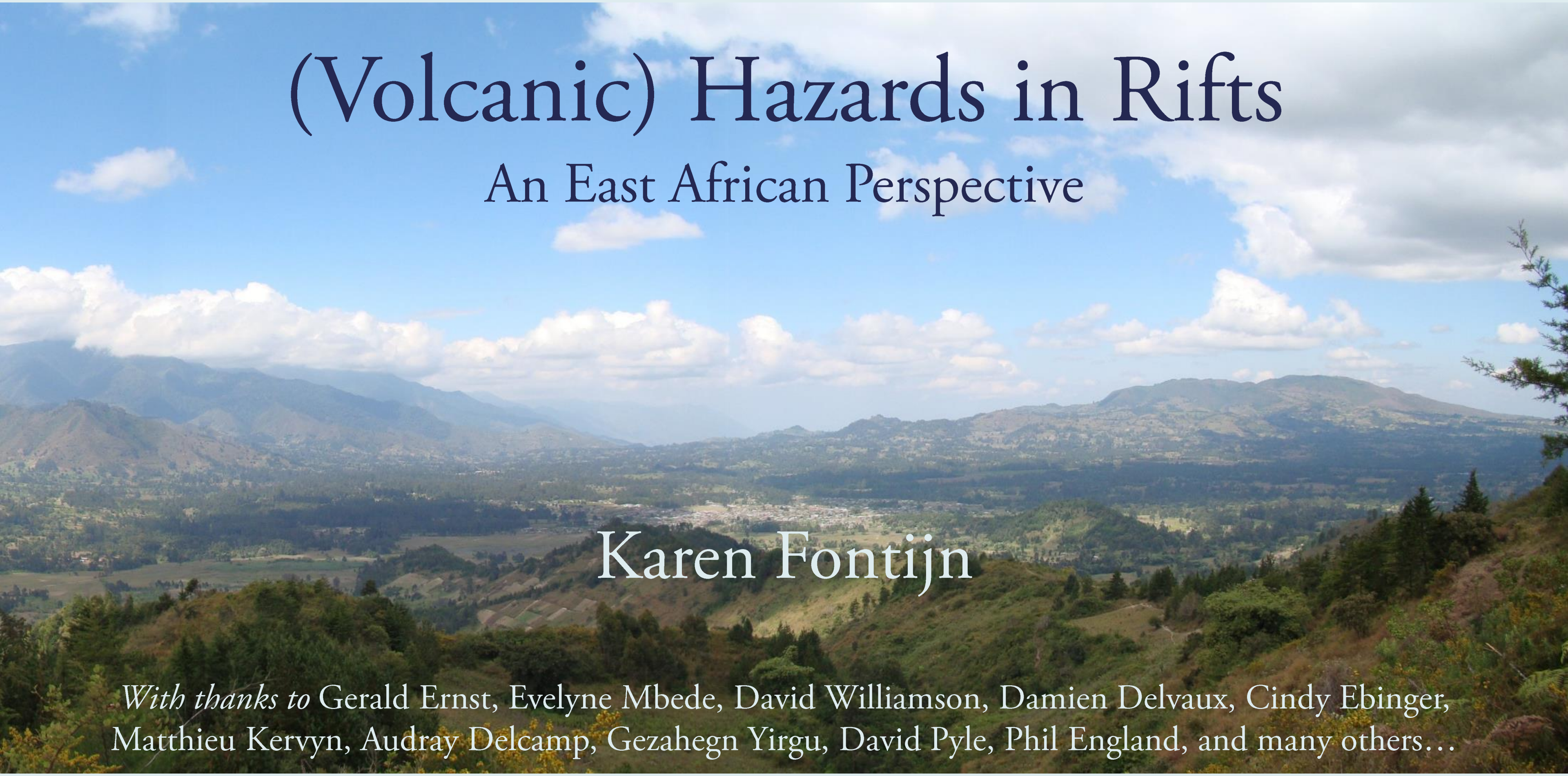

(Volcanic) Hazards in Rifts

An East African Perspective

Karen Fontijn

With thanks to Gerald Ernst, Evelyne Mbede, David Williamson, Damien Delvaux, Cindy Ebinger, Matthieu Kervyn, Audray Delcamp, Gezahegn Yirgu, David Pyle, Phil England, and many others…

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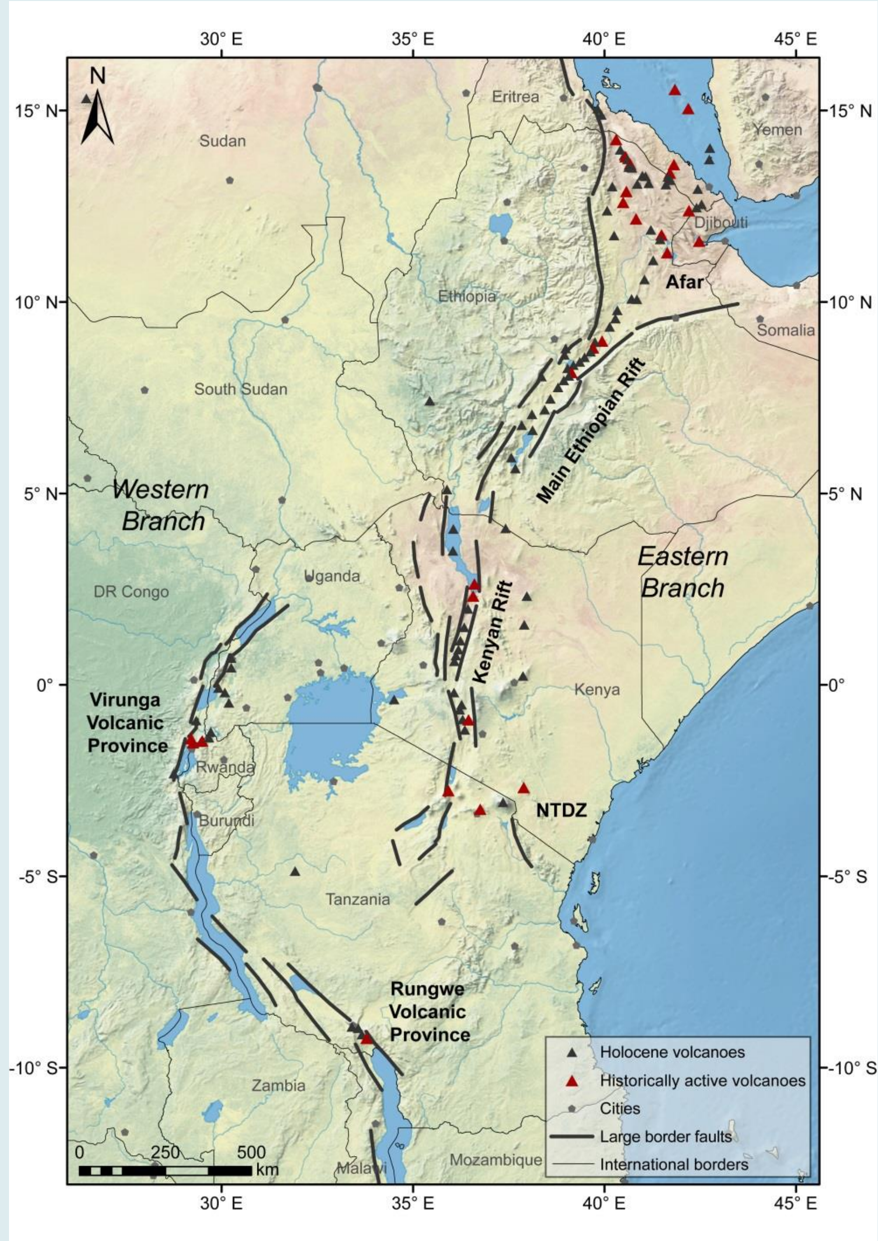
RIFT VOLC

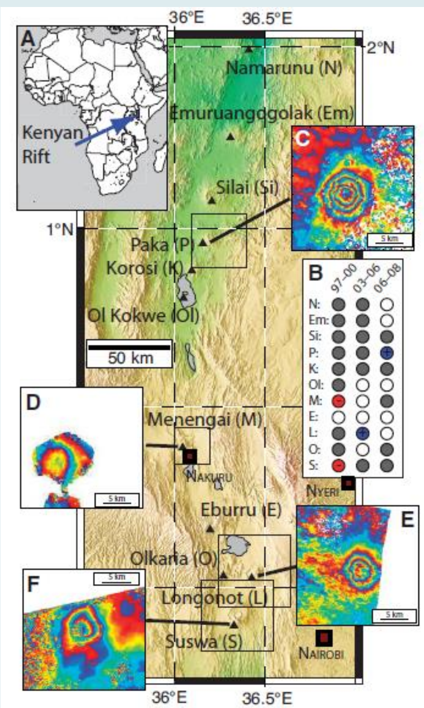
Introduction

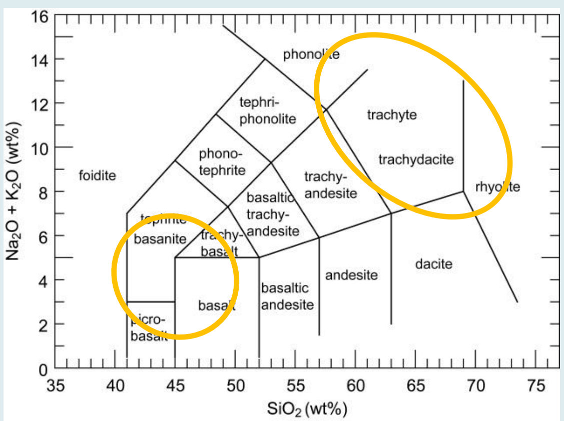
- Rift segments in different stages of development
- Favourable climate, lakes, fertile soils …
  - High population exposure
- Primary geophysical hazards
  - Earthquakes & **Volcanoes**
  - *Landslides*
- Geologically recent history serves as proxy for contemporary hazards



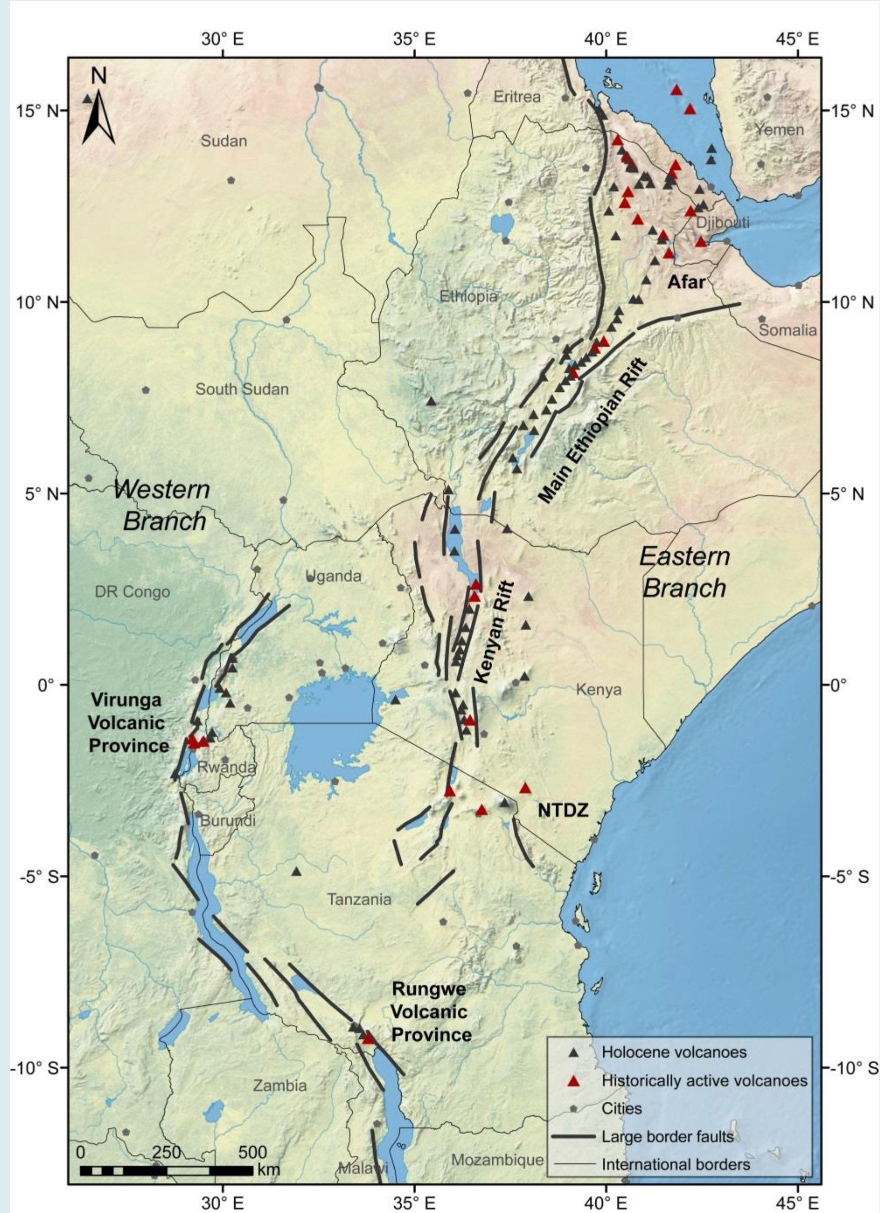
Introduction

- >100 EARS + Red Sea volcanoes
  - >25 with historical eruptions
  - ca. 25 M people within 30 km
  - Recent ground deformation
  - Geothermal energy development
- Composition: bimodal, alkaline

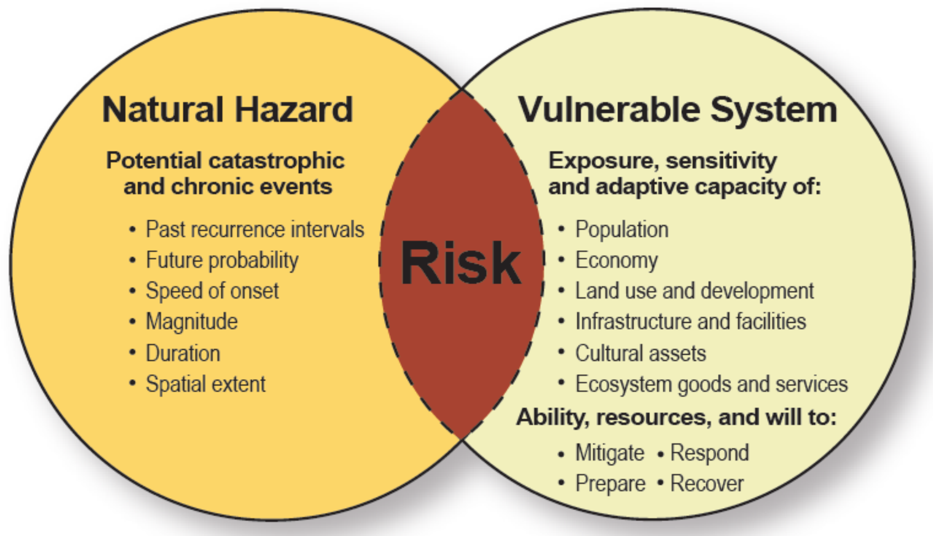




Biggs et al. (2009)



Hazard *vs.* Risk

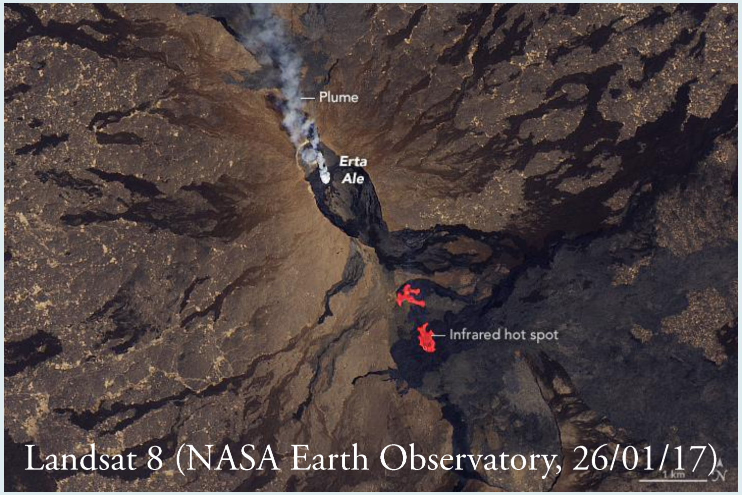


Wood (2011) – USGS Hazard-Risk Factsheet

- Risk = **Hazard** x Exposure x (Vulnerability – Resilience)
- Hazard/Risk index = *recurrence* + *magnitude / style* + *population exposure*

Mafic volcanoes

- Mainly in Virunga and Afar
  - Tourist attractions
- Eruptive style
  - Lava lakes, occasional overflow
  - Fissure-fed flank eruptions feeding lava flows
  - Calderas formed by drainage
- Notable events
  - Erta Ale Jan 2017
  - Nyiragongo 2002: ca. 150 fatalities, ca. 400k displaced



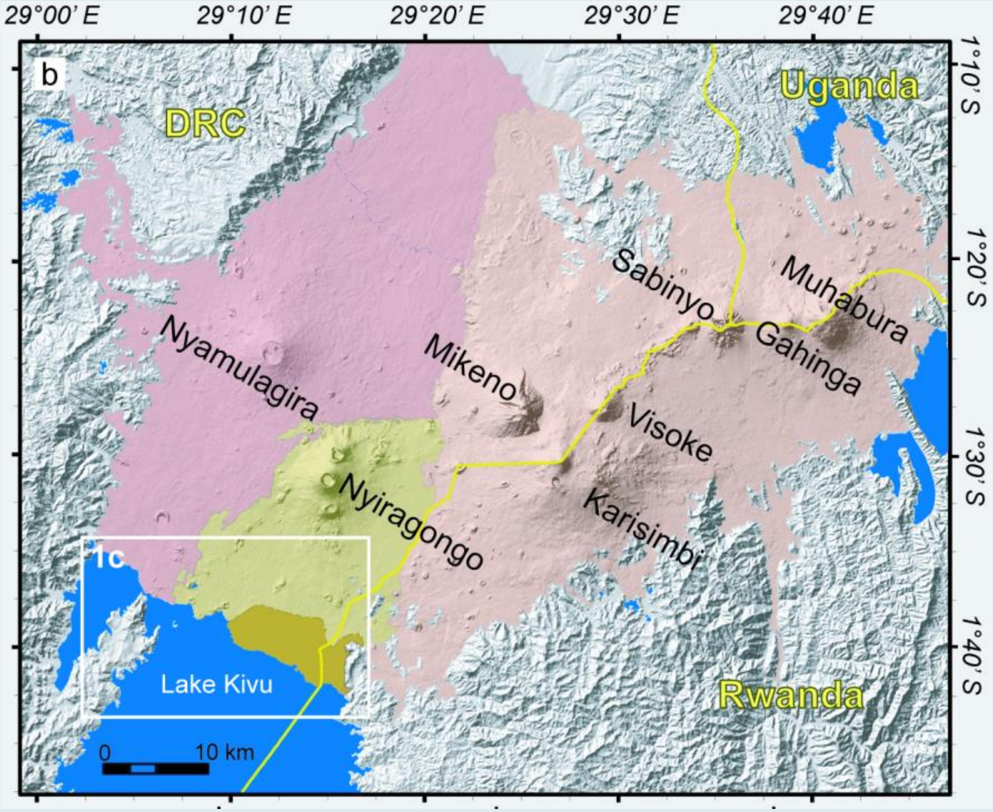
Landsat 8 (NASA Earth Observatory, 26/01/17)


Erta Ale, 29/12/16 (© J-W Erben)


Nyamulagira 2012 flank eruption feeding distant lava flows (VolcanoDiscovery)

Virunga volcanoes

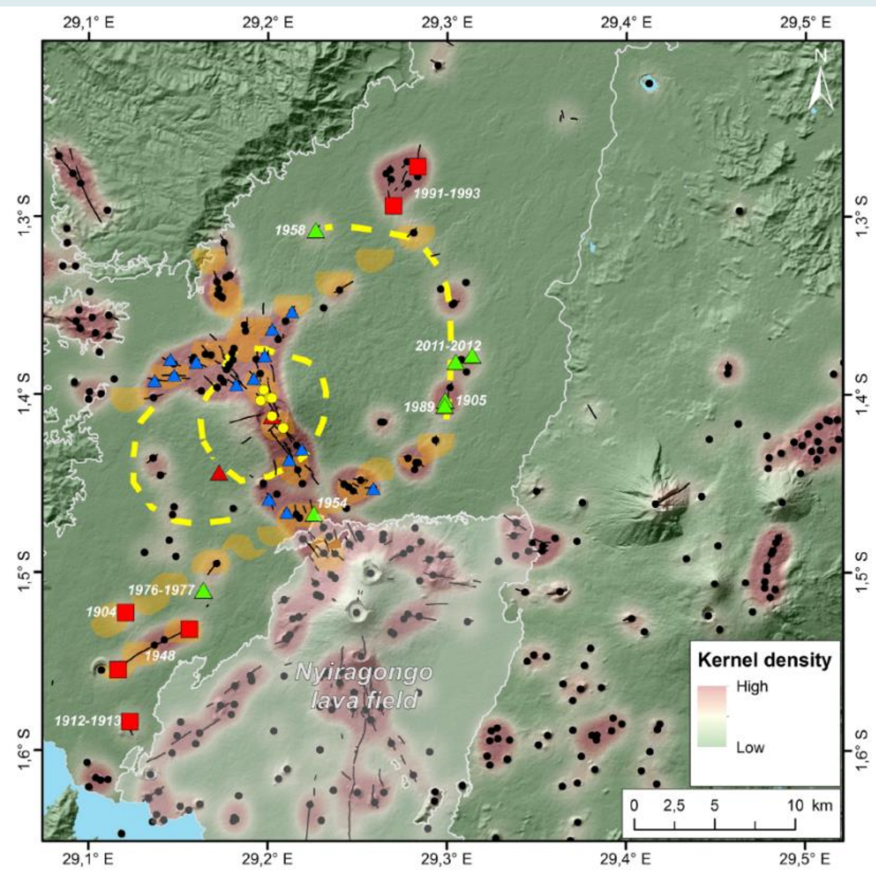
- Nyamulagira, Nyiragongo: most frequently active volcanoes in Africa



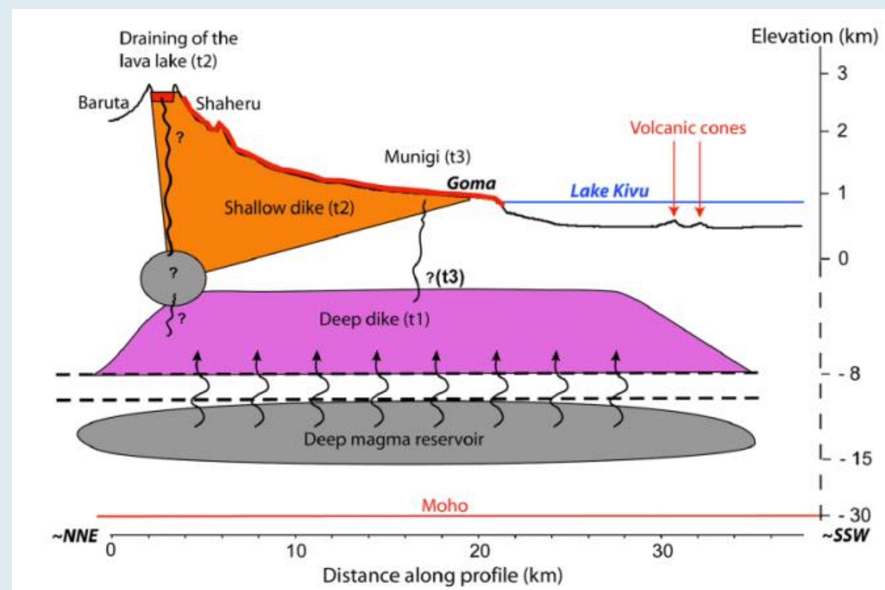
Poppe et al. (2016)

Virunga volcanoes

- Nyamulagira, Nyiragongo: most frequently active volcanoes in Africa
- Plumbing systems: deep (20-25km) reservoirs feeding smaller and shallow (3-5 km) reservoir as well as direct lower flank eruptions



Smets et al. (2015)



Wauthier et al. (2012)

Virunga volcanoes

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  - Low viscosity makes the lava flows travel fast (10s km/hr) and far (>10-15 km)

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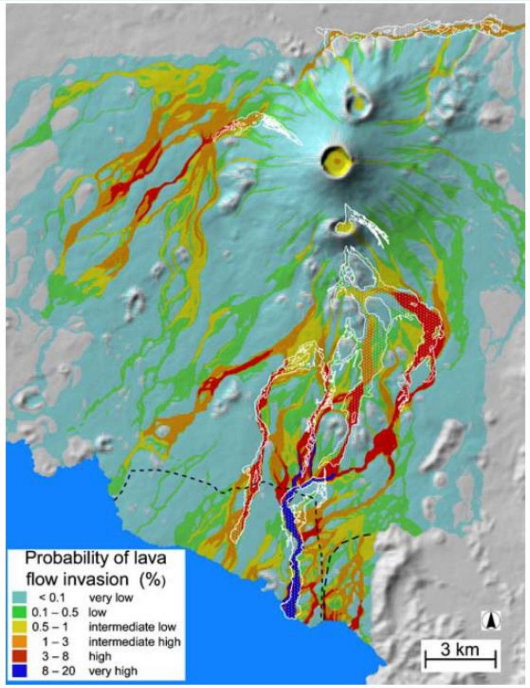

Favalli et al. (2009)

Virunga volcanoes

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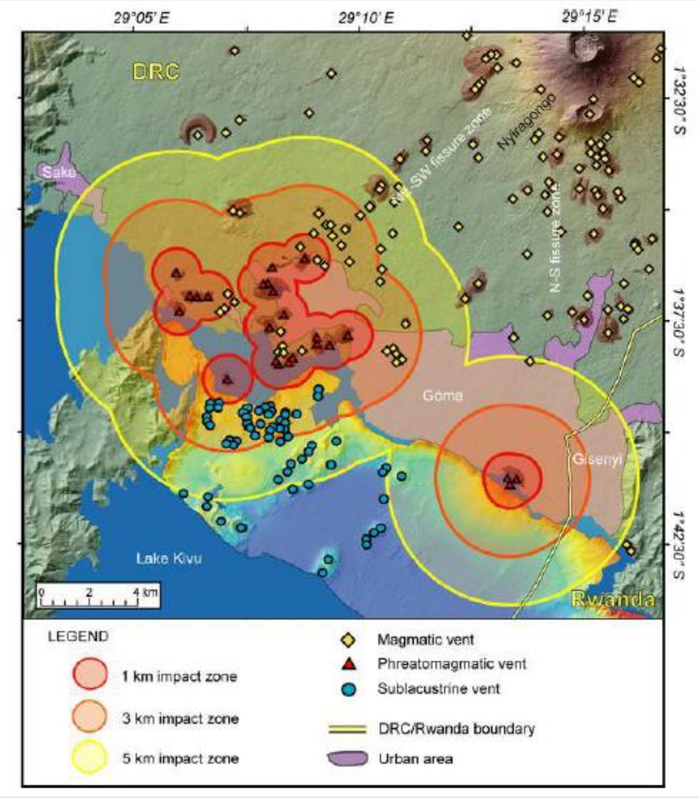
    - Phreatomagmatic eruptions
    - Potential for CO_2/CH_4 outbursts



Poppe et al. (2016)

Virunga volcanoes

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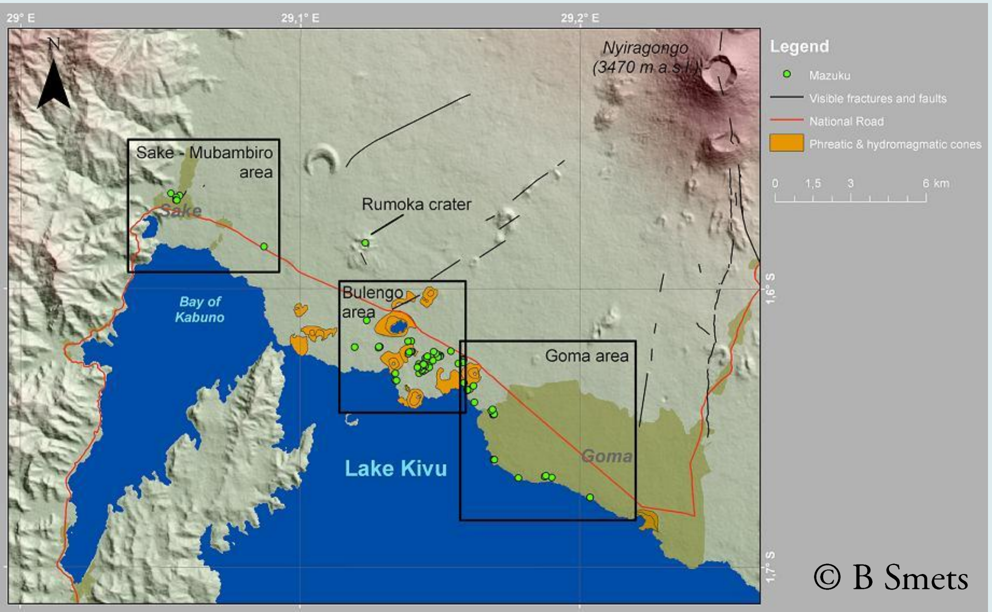
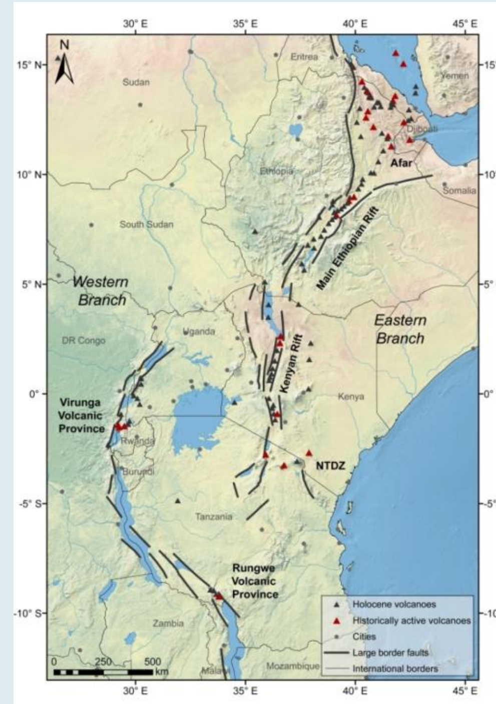
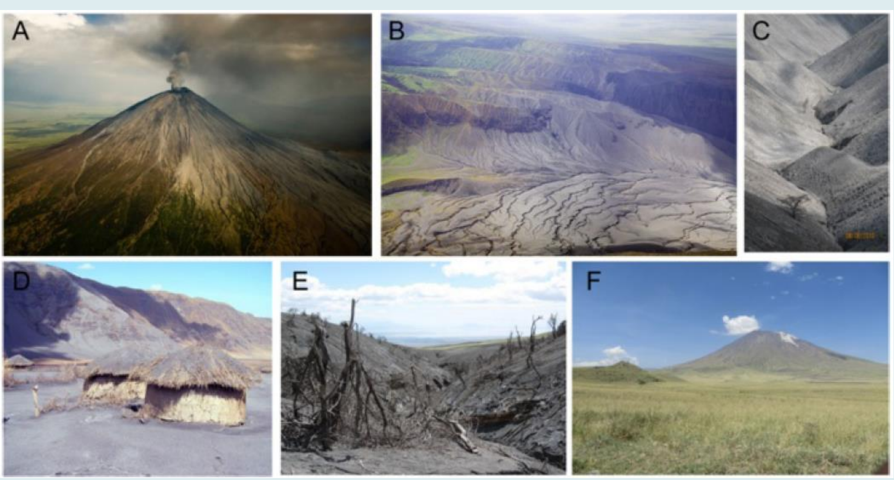
    - Potential for CO_2/CH_4 outbursts
  - Persistent dry and cold CO_2 vents (*mazuku*)



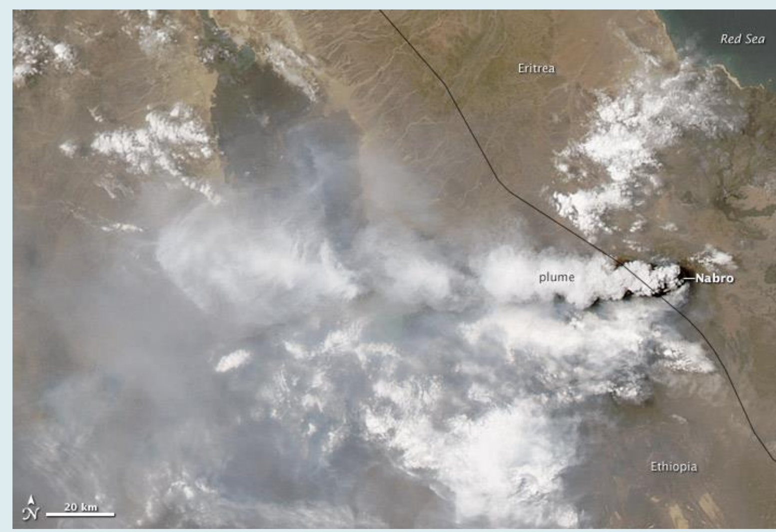
Silicic volcanoes

- RVP & Eastern Branch / Afar
- Trachyte/phonolite – peralkaline rhyolite
  - Typically crystal-poor
  - Rel. low viscosity
- Notable historical events
  - Dubbi 1861: trachyte explosion followed by basaltic fissure eruption
  - Nabro 2011: infrastructure damage (eqs), 12,000 evacuated, atmospheric perturbation by SO_2-rich plume
  - Ol Doinyo Lengai 2007: thin ash fall causing (ground)water contamination, impact on vegetation and cattle, respiratory problems; estimated 65,000 people affected



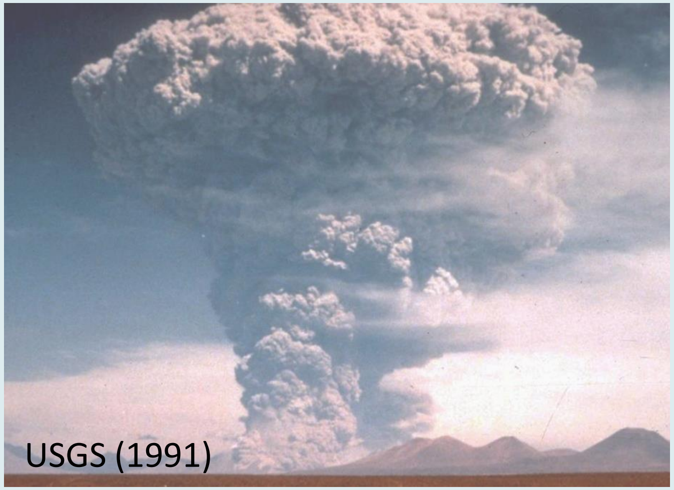


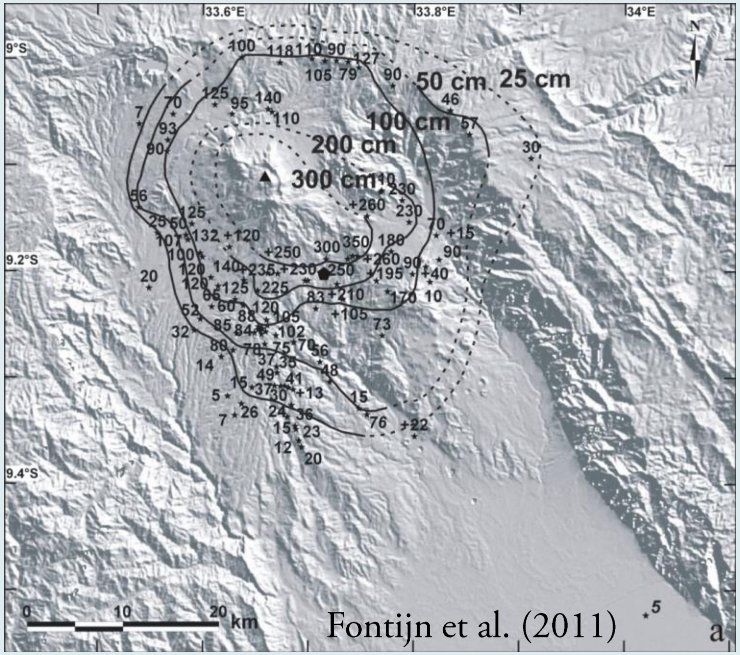
De Schutter et al. (2015)



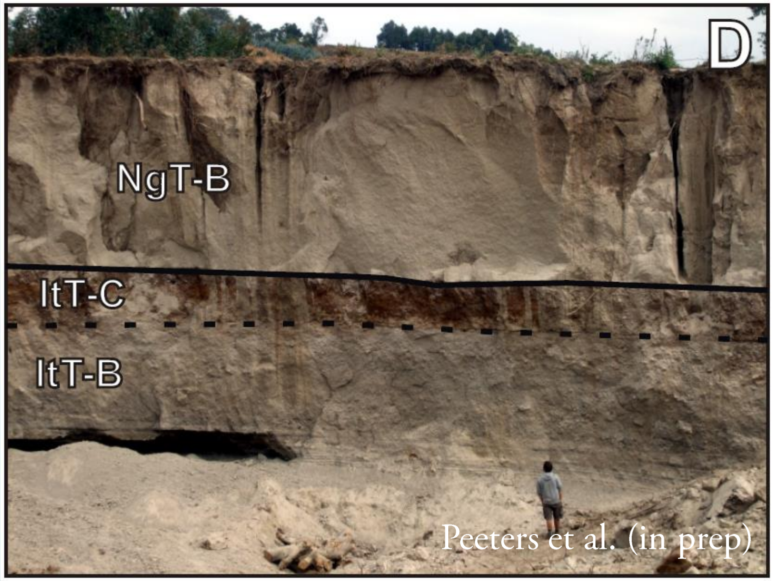
MODIS – 15/06/11; NASA Earth Observatory

Silicic volcanoes


USGS (1991)



Fontijn et al. (2011)

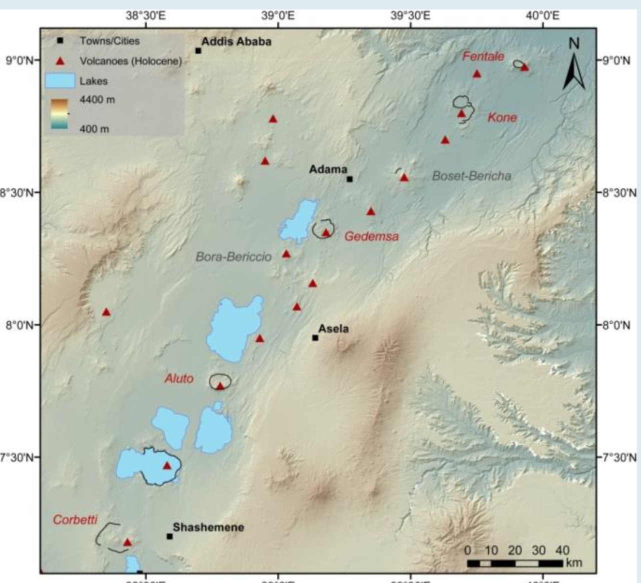


Peeters et al. (in prep)

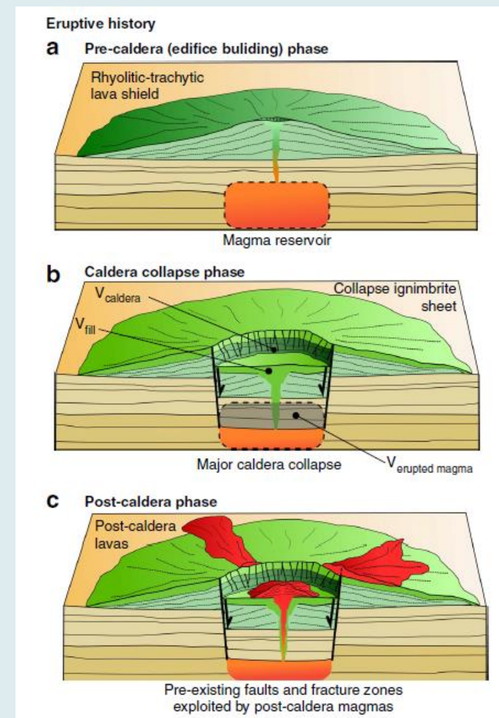
- Eruption style
  - Explosive eruptions
    - Ash eruptions
    - Plinian-style eruptions: tephra fallout and/or PDCs
      - Rungwe / Ngozi: 1-2 eruptions per 1000 years
        ~ 0.5 – 1 km³/ky
    - Caldera-forming, ignimbrites
  - Lava flows

MER volcanoes

- Large calderas with widespread ignimbrite deposits (mid-Pleistocene)
- Post-caldera stage highly variable eruption rates and styles
  - Some limited to no post-caldera silicic activity
  - Some predominantly silicic effusive eruptions
  - Most active ones ca. 1-2 explosive eruptions per millennium
    - Peralkaline rhyolite pumice cones with tephra fallout, small-scale PDCs and obsidian flows



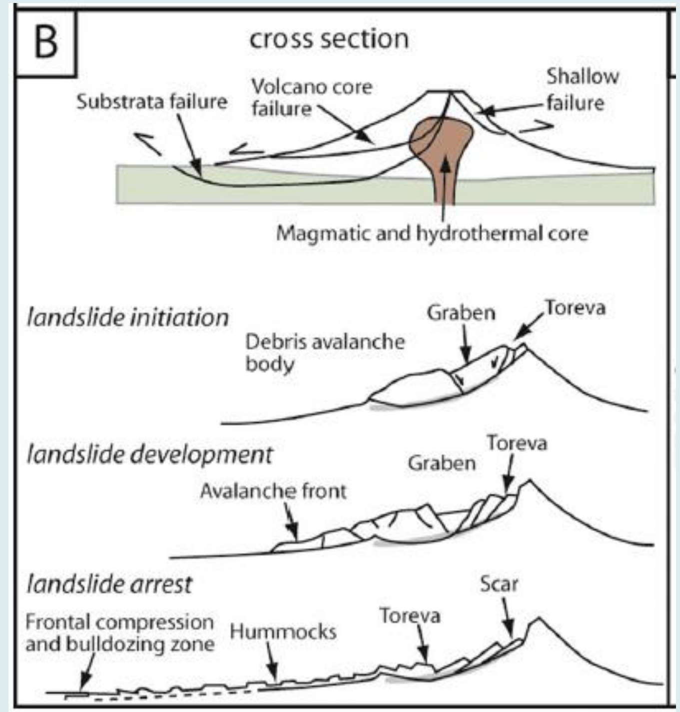
Fontijn et al. (in prep)

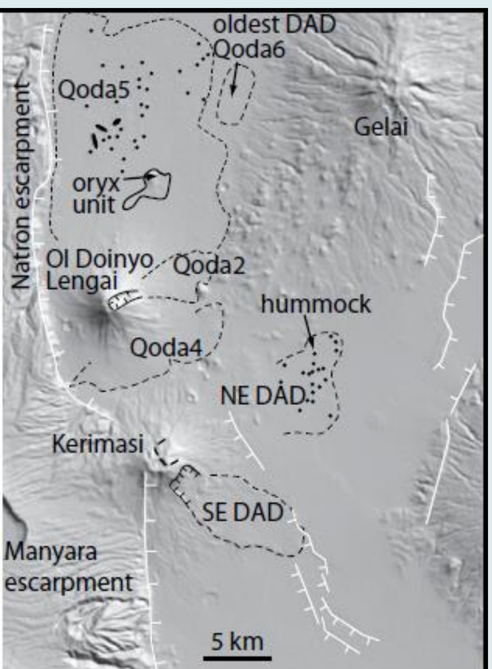


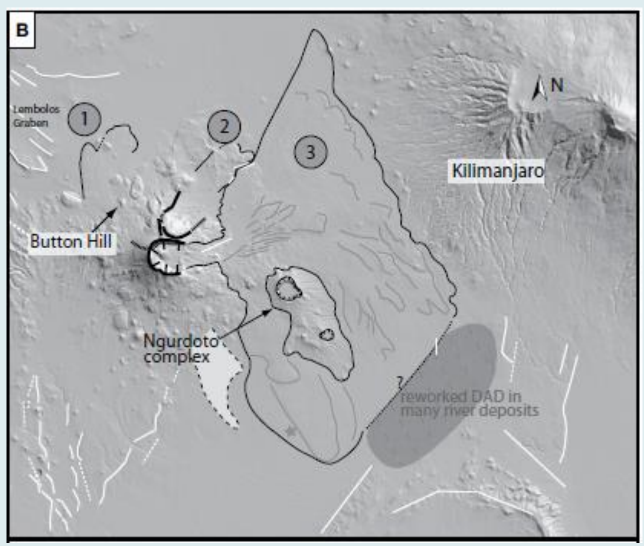
Hutchison et al. (2016)

Other hazards: debris avalanches

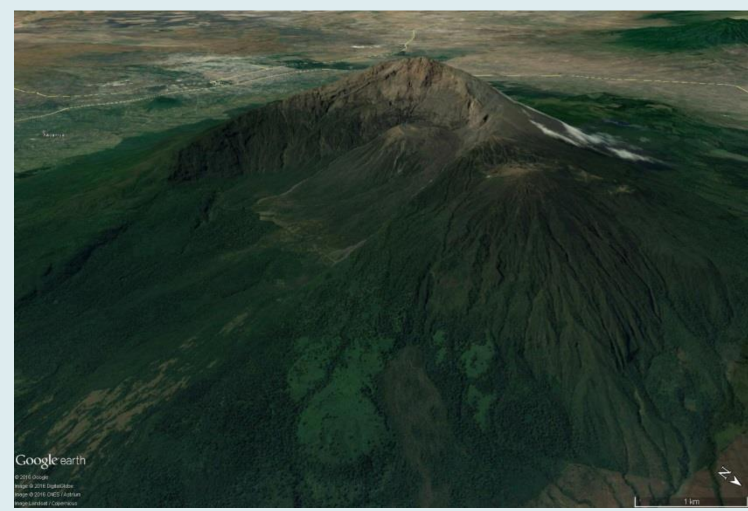
- Confirmed in NTDZ and RVP
  - Both at active and extinct volcanoes
  - Poorly constrained ages
  - Meru Momella DAD ca. 20 km^3; ca. 9 ka (?)
- Complex volcano-tectonic interactions
  - Some associated with volcanic eruption
  - Collapse orientation related to stress regime







Delcamp et al. (2015, 2016)



Hazard complexity in the EARS

- Strongly interrelated volcano-tectonic processes
  - Structural control on volcanic behaviour
  - Seemingly similar volcanoes displaying highly contrasting behaviour
  - Complex multi-hazards acting on multiple time scales (e.g. CO_2 degassing)
- Generally low recurrence rates
  - No living memory, poorly prepared population and authorities
  - Highly active silicic volcanoes: 1-2 eruptions per millennium
  - Poor understanding of onset, duration, evolution of events

→ *What are the mid/long-term magma production/eruption rates?*
→ *How do the plumbing systems work; what are the eruptible volumes?*
→ *What are the secondary controls (e.g. tectonic, climatic) on eruption rates and styles?*
→ *How are eruptions triggered (magma mixing; tectonic triggers; passive degassing; …)?*
→ *What is the importance of volatiles (other that water) in controlling explosive volcanism?*
→ *What are the most likely scenarios; and what are the less likely but worst case scenarios?*
→ …

Job done! …?

The RVP region is subject to potential hazards related to both earthquakes and volcanic eruptions. An *M* 7.4 tectonic earthquake

The RP is the very first Quaternary Plinian-style deposit to be closely documented on the African continent. Rungwe is a dormant volcano; the local population has no recollection of historical eruptive activity. Rungwe has, however, been regularly active throughout the late Holocene. All existing evidence points to a very active volcano with typical repose times of a few hundreds to a thousand years, separating violent strombolian to Plinian-style explosive eruptions (Fontijn et al. 2010b). Apart from the risk associated with pyroclastic density currents, Rungwe, the foothills of which are densely populated and which is not monitored, poses a similar threat from extensive tephra fallout, as was the case at Mt. Pinatubo before it erupted in

4.4. Geohazard risk mitigation and resource benefits

To assess volcanic hazards further towards geohazard risk mitigation, it is essential to share scientific findings and their implications with local scientists, authorities and communities. In less industrialized countries affected by extensive income poverty, such as Tanzania, local authorities struggle mostly with socio-economic, poverty-related issues. Hence assigning resources to the study and mitigation of tectonic or volcanic hazards is not considered a priority. In Tanzania today, there is currently an expertise shortage in technical and specialized volcanology, and yet the country has historically active and hazardous volcanoes, e.g. Ol Doinyo Lengai and Meru, as well as several Late Quaternary volcanic centres that are likely to erupt again in the future, e.g. the RVP volcanoes and Kilimanjaro.

The RVP volcanoes exhibit unique features that are of profound scientific interest to advance our understanding of how volcanic systems and eruptions work (e.g. the striking absence of PDCs in Rungwe's recent deposit record; the significant explosive nature of low-to-moderate-viscosity magmas with implications for volatile budgets and magma ascent rates; the strikingly contrasting explosive behaviour at Ngozi vs. Rungwe vs. Kyejo). More detailed fundamental studies of the RVP tectono-magmatic system, and indeed of many volcanic regions in Africa (e.g. eruption frequency–magnitude relationships, magma chamber recharge rates, earthquake recurrence intervals, etc.), are not only critical to assess and mitigate potential geohazards, but will ultimately contribute to sustained geohazard mitigation strategies (ITCP, 2009).

towards the Malawi border, is located W of Rungwe. It is clear that a new explosive eruption of Rungwe or Ngozi dispersing pumice and ash over an area of even only a few hundred km^2 would have a major impact on a local population that is unaware of potential hazards.

Fontijn et al (2010a, 2010b, 2011, 2012)

Take home messages

- Models developed from studies in other tectonic settings are <u>not easily applicable to continental rifts</u>

- A big contributor to risk from volcanoes and earthquakes in continental rift settings are the <u>low recurrence rates</u> and <u>complex multi-hazard</u> scenarios in densely populated areas

- To improve our understanding of geophysical hazards in rift settings, we need to <u>prioritise a multidisciplinary approach to understand the fundamental surface and deeper processes that lead to these specific hazards</u> in high-risk areas
  - *Significantly more work is needed on time series of volcanic and seismic activity, to allow the development of probabilistic hazard models*

- We need to <u>actively work with a range of stakeholders</u> to ensure that our research results are being used and interpreted correctly, so that resources for risk mitigation can be allocated in the most appropriate ways