

# Volcanic hazard in East Africa

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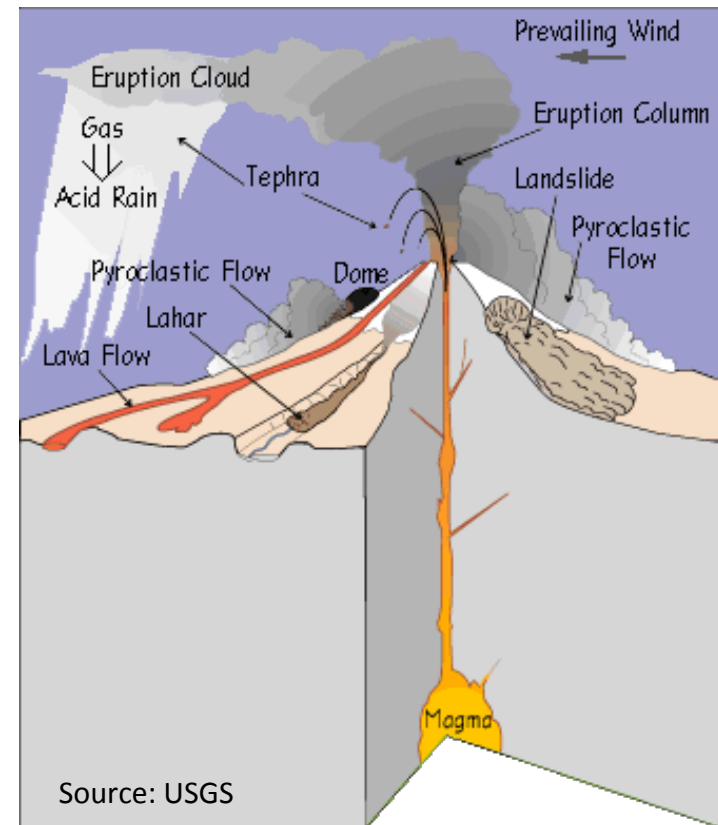
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# Type of volcanic hazards

- Gas (during eruptions, fumaroles, hydrothermal systems...) => explosions, acid rain,...
- Lava flows (note: 2 world records are in EAR: Lengai and Nyiragongo !)
- Earthquakes
- Landslides, rock avalanches
- Tephra
- Lahars, mudflows
- Pyroclastic flows

+ Limnic eruptions

+ Tsunami



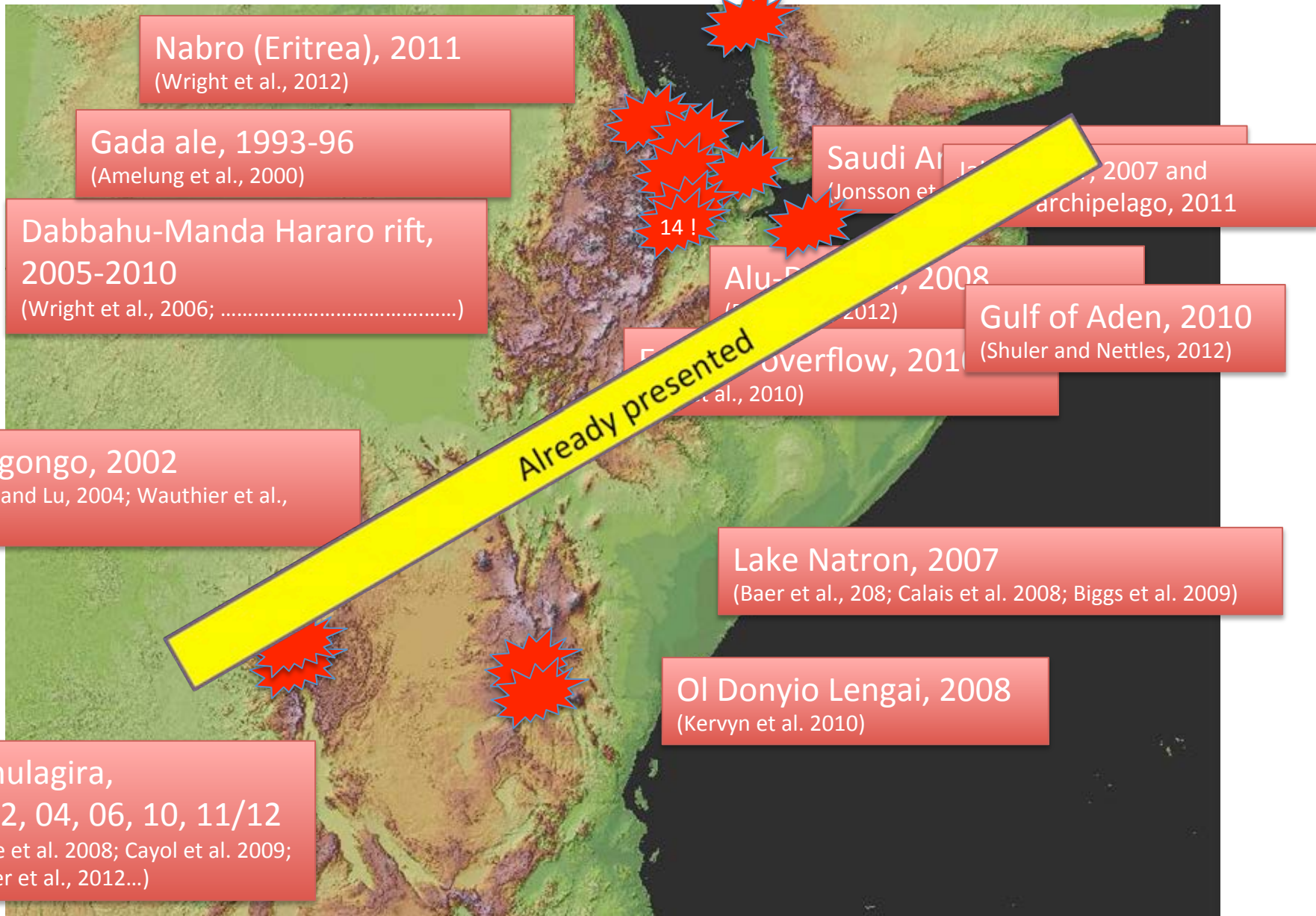
# Preliminary comments

- Effects at various distances/altitudes from volcano
- *Some hazards, such as lahars and landslides, can occur even when a volcano is not erupting*
- *Hazard depends on*
  - *Type of volcanoes*
  - *Time since last eruption*
  - *Geographical location*
  - *Local climate*
  - *Time of the year*
  - ...
- Hazard is not risk.

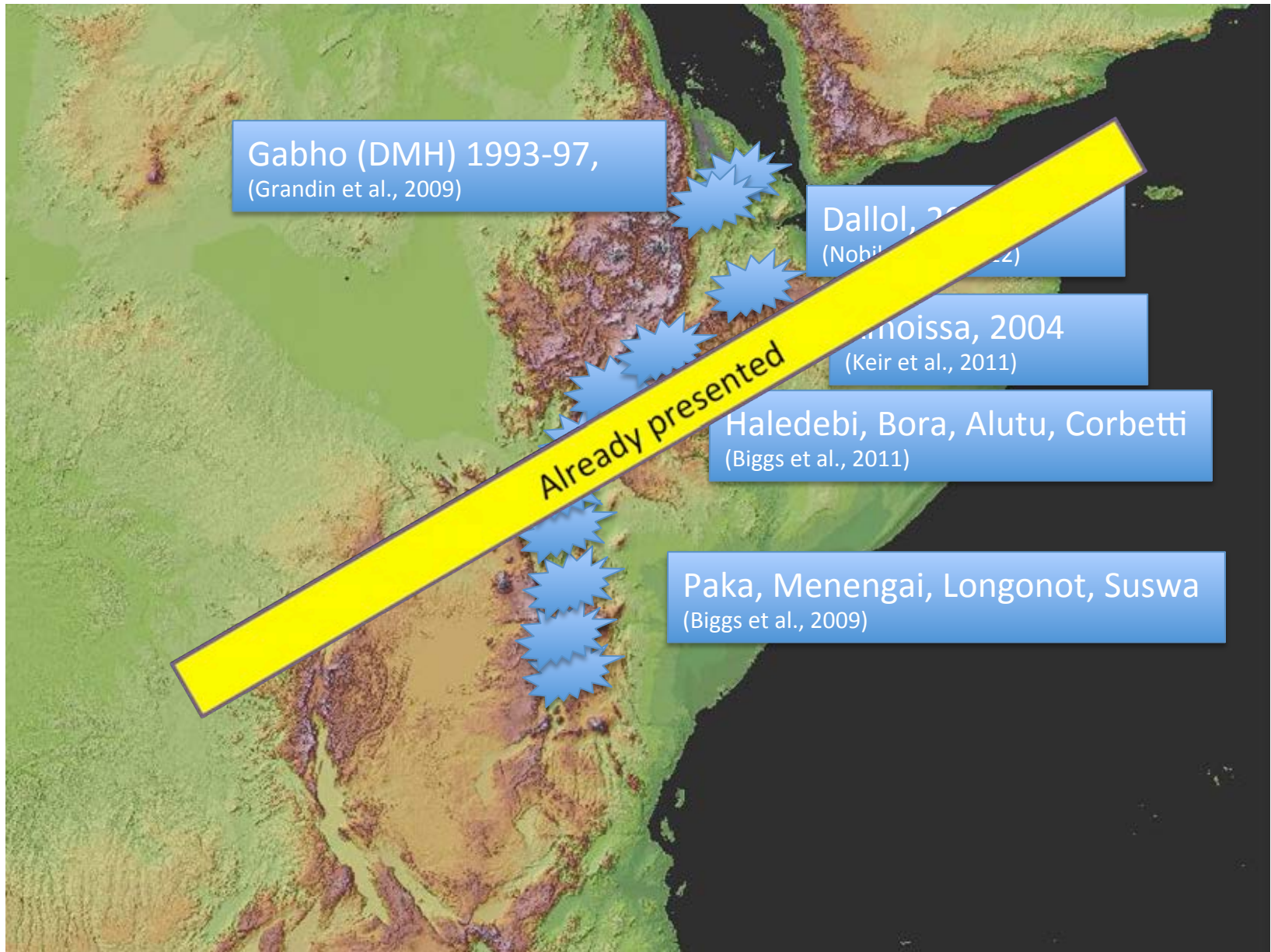
Definitions and numbers  
(Smithsonian Global Volcanism Program)

- **Active volcano:** if it has erupted in the last 10,000 years (i.e. Holocene time)
- There are about 1.500 active volcanoes in the world, among which about 100 in EAR.
- **Dormant or extinct:** ?

# We know about volcanic/dyking events e.g. from recent seismicity and InSAR

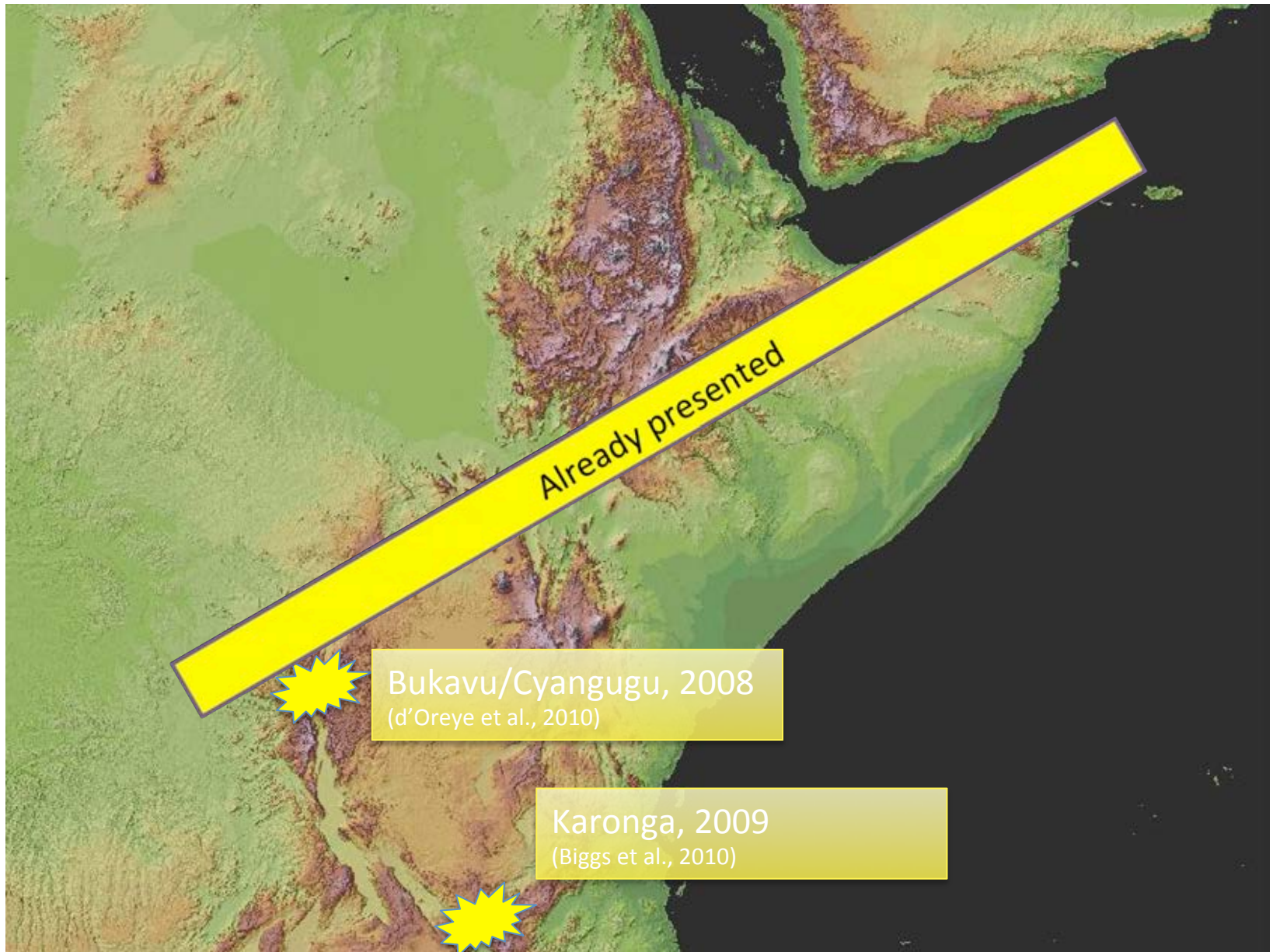


# More activity is revealed by InSAR/seismicity: recent and on-going.

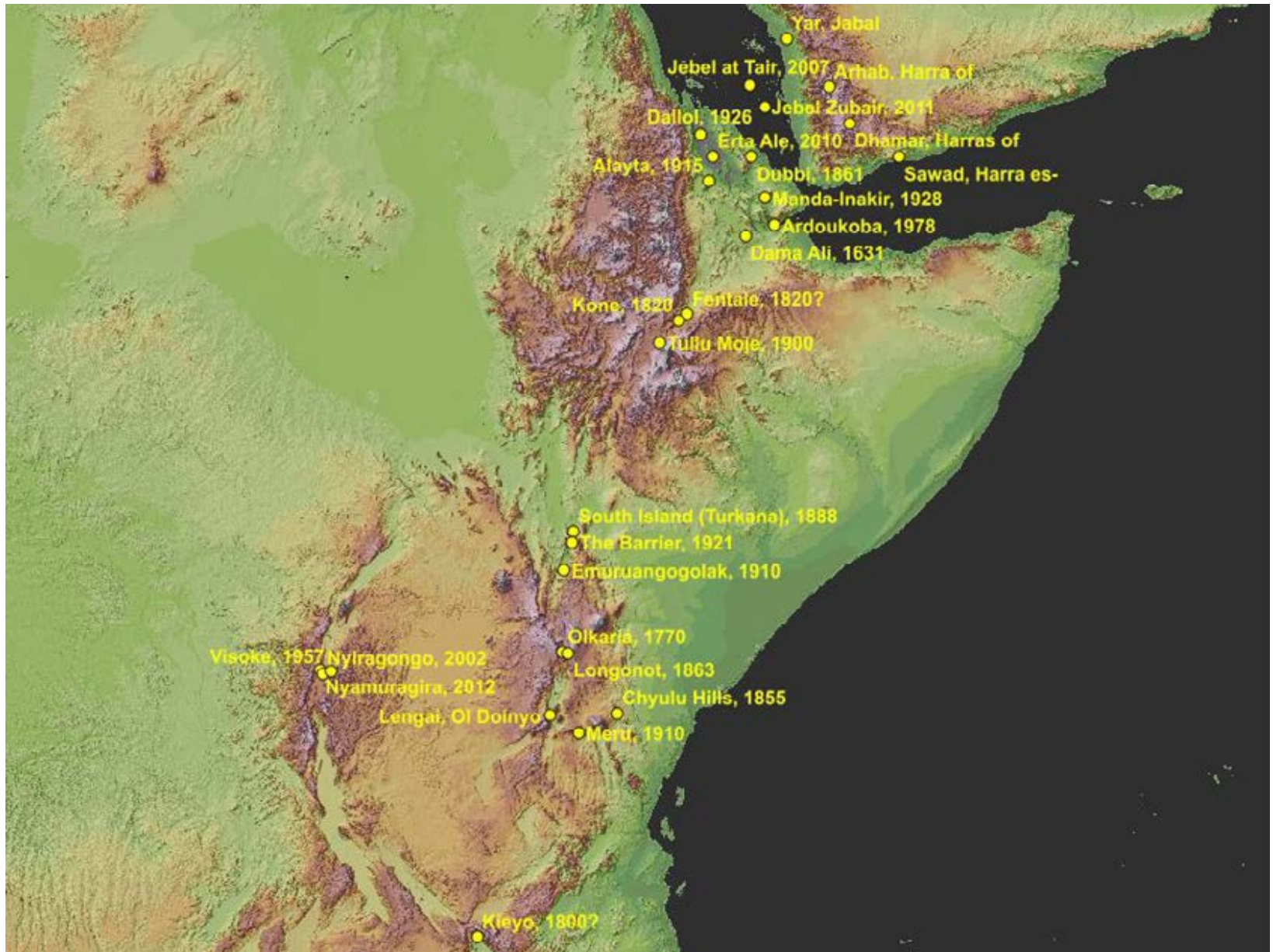




We know about **non-volcanic/dyking** events despite possible similarities with e.g. Natron or Dabahu:



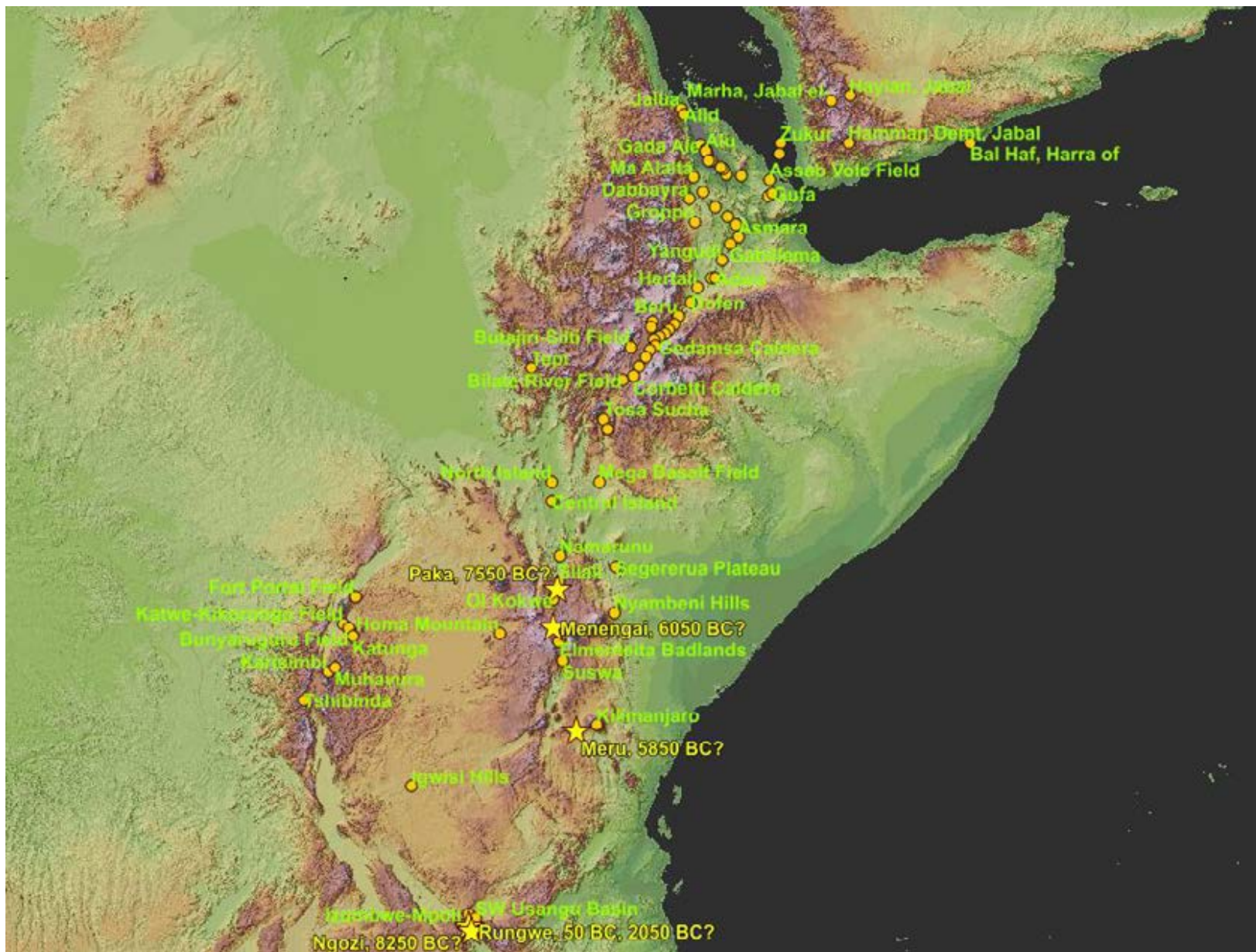
# What do we know about historical activity? (at least 22 + 6 volcanoes)





# What do we know about 100<sup>s</sup> Holocene activity ?

Stars: Large-volume Holocene explosive eruptions with VEI  $\geq 4$

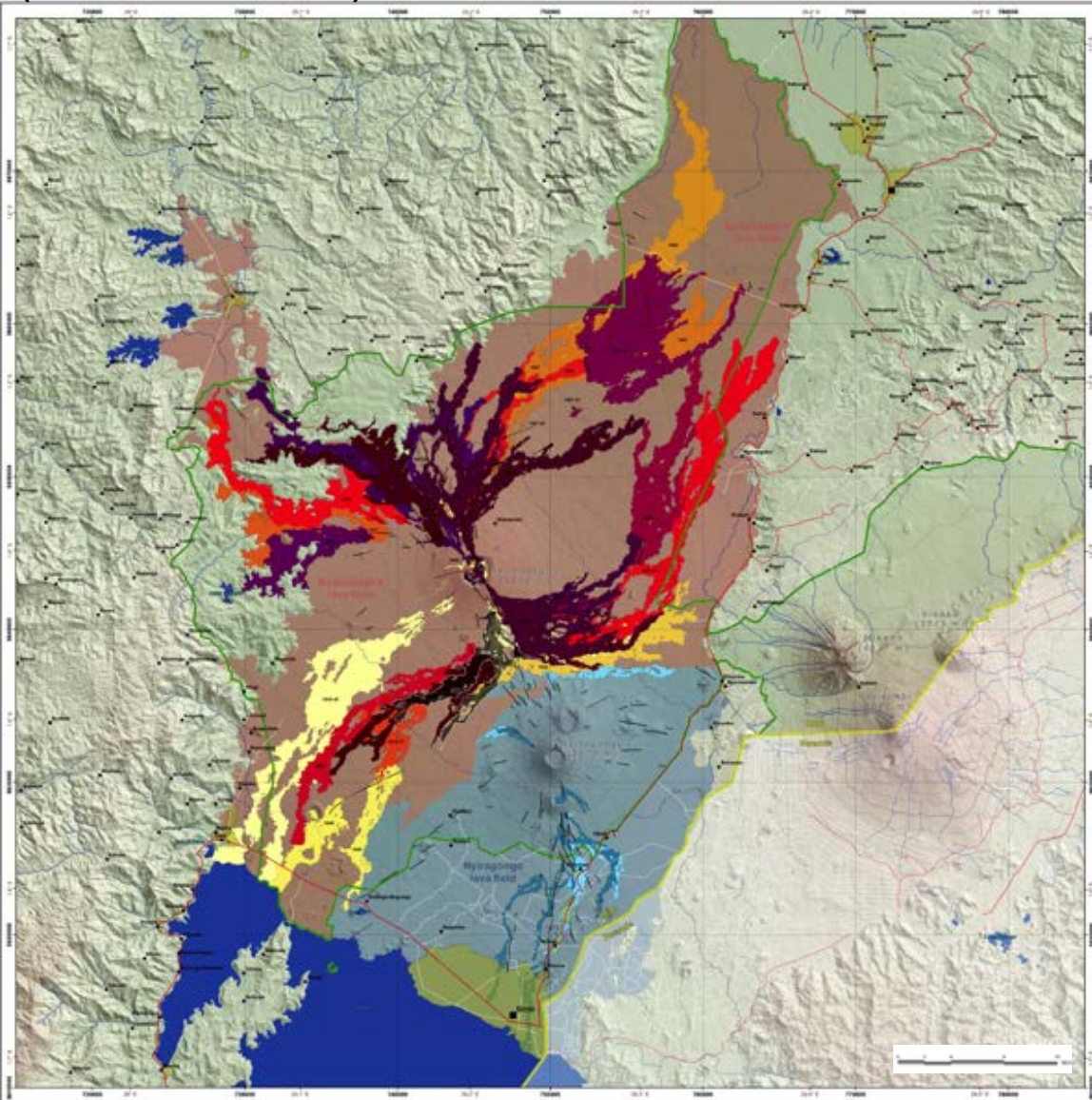


# North: MER, Afar, Red Sea

- Highly active (about 60 Holocene volcanoes in MER + Afar), including Dubbi, 1861: “the largest historical eruption in Africa” (Wuart and Oppenheimer, 2000)
- Probably the most studied region of EAR: See other contributions in the present meeting and extended literature.
- Though... still a lot of unsolved questions (GEOPRISMS science plan)!

# West: Virunga Volcanic Province

(Smets et al. 2010)



A unique case in EAR/world:

**Nyiragongo + Nyamulagira = 2/5 of historical eruptions in Africa** (*Simpkin and Siebert, 1994*)

**But not only...**



Nyamulagira: 3000m

Nyiragongo: 3500m

Goma



# The cities of Goma (DRC) and Gyseni (R)



Goma : 1972



2012 (Google Earth)





Imagery Date: 9/16/2010

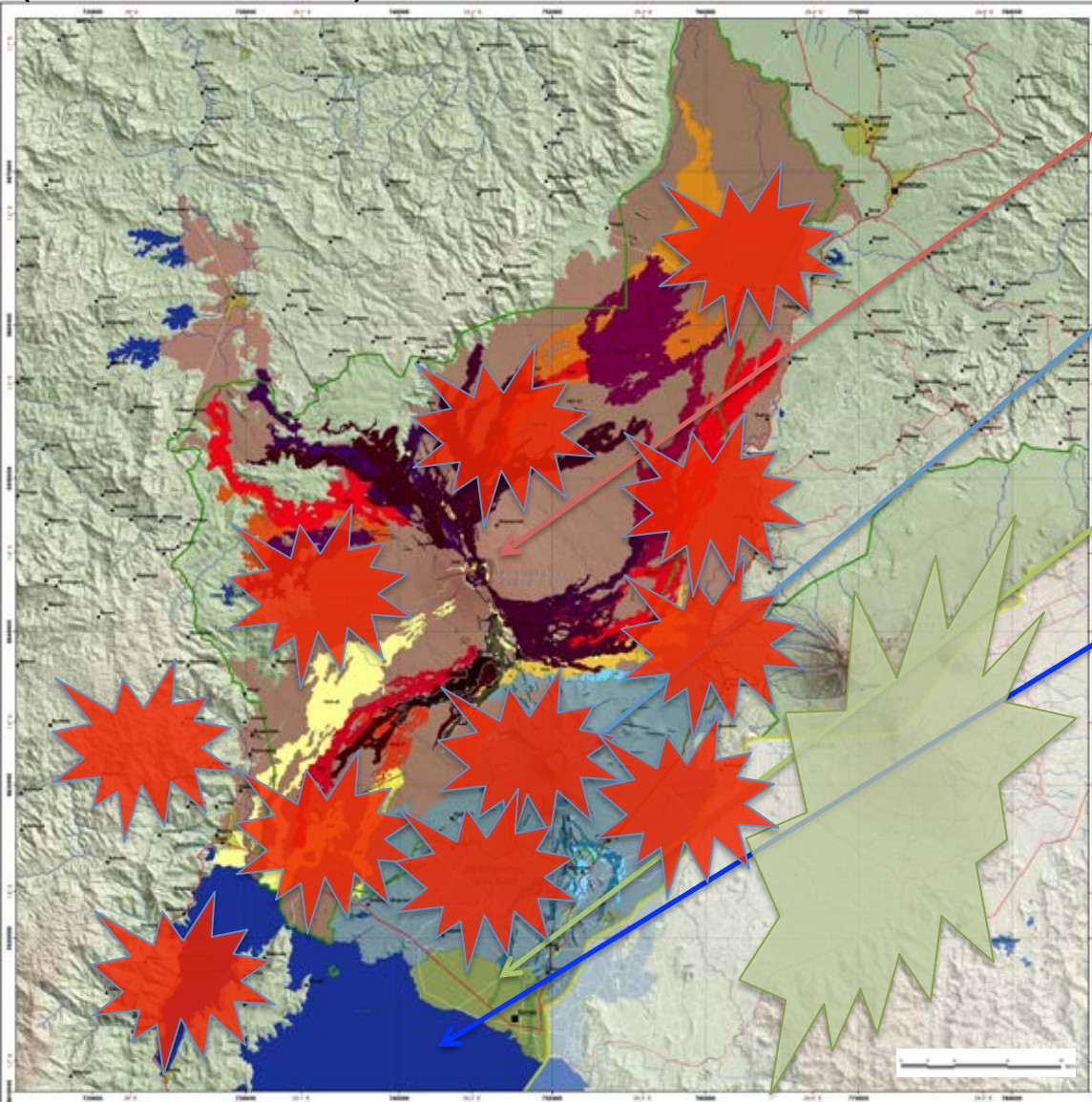
lat -1.661932 lon 29.223449 elev 1534 m

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# West: Virunga Volcanic Province

(Smets et al. 2010)



Nyamulagira: most active in African; ~2 years

≠

Nyiragongo: 1977 & 2002.  
Most fluid lavas ; largest lava lake

+ Volcanic plume, Pele's hair & mazuku

Goma: 1 Mo inhabitants (+2,000% since 1977)

Lake Kivu: CO<sub>2</sub> + CH<sub>4</sub>

Civil war: field not accessible

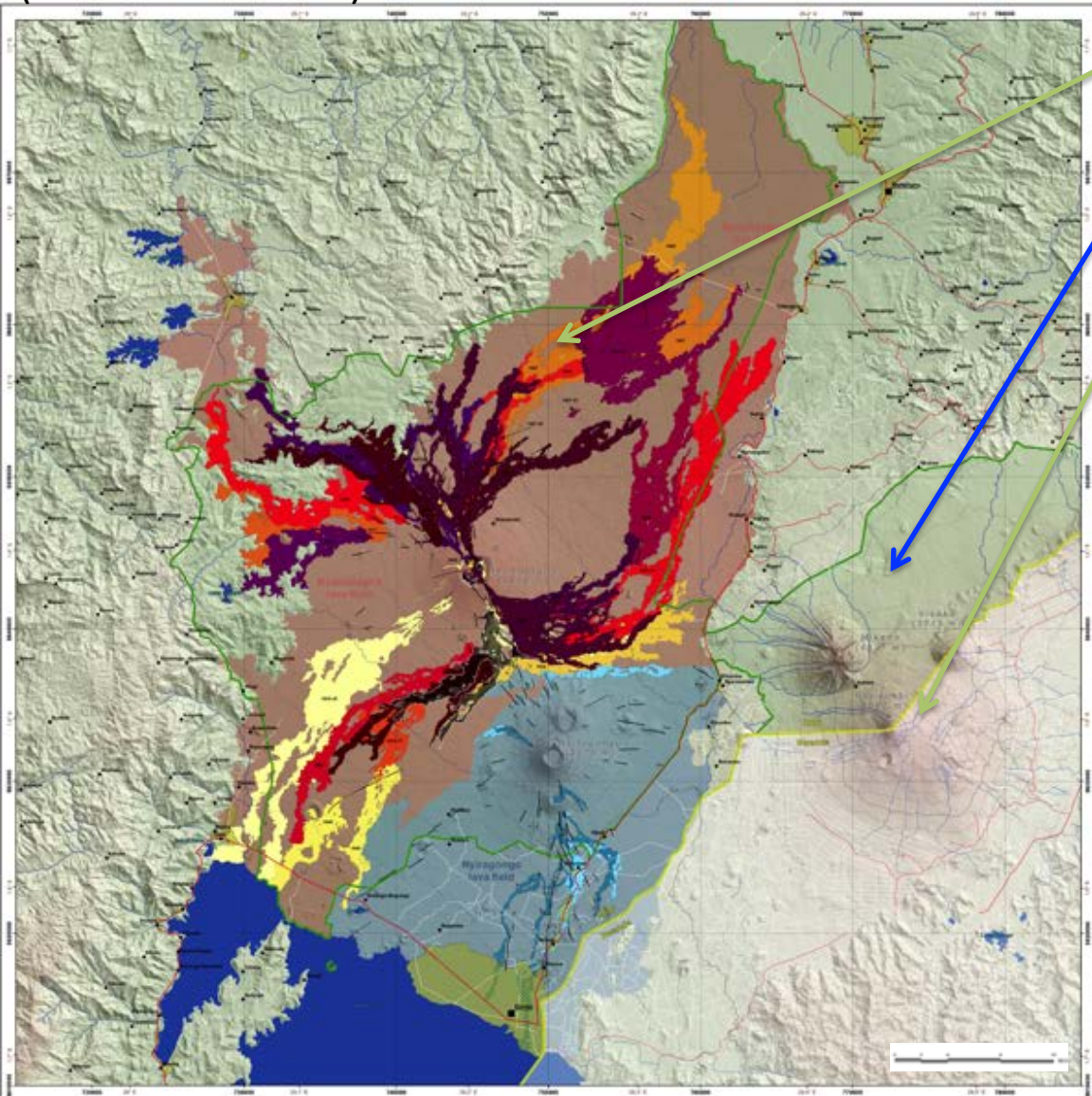
Political context: neighbors

Difficult conditions: see also poster d'Oreye et al. (this meeting)



# West: Virunga Volcanic Province

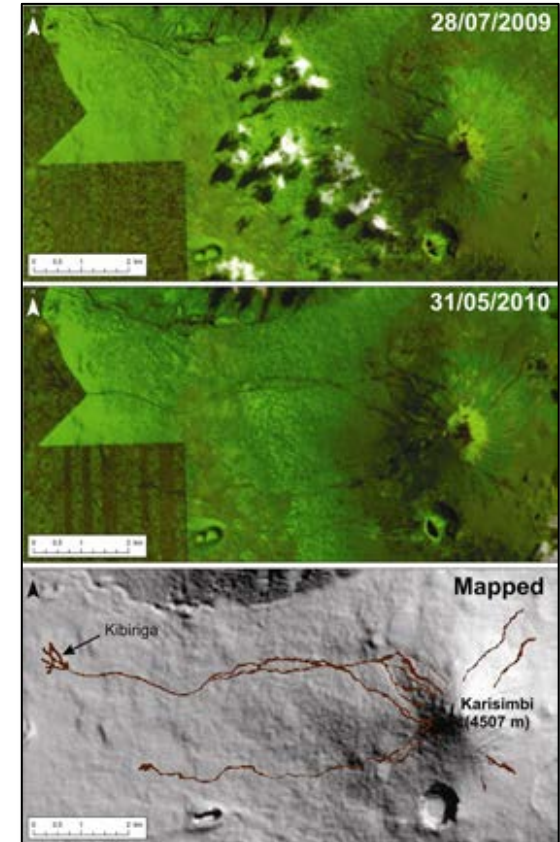
(Smets et al. 2010)



High impact on forest and fauna

Visoke, 1957

Mud flows (e.g. 2010)





# Nyiragongo lava lake:

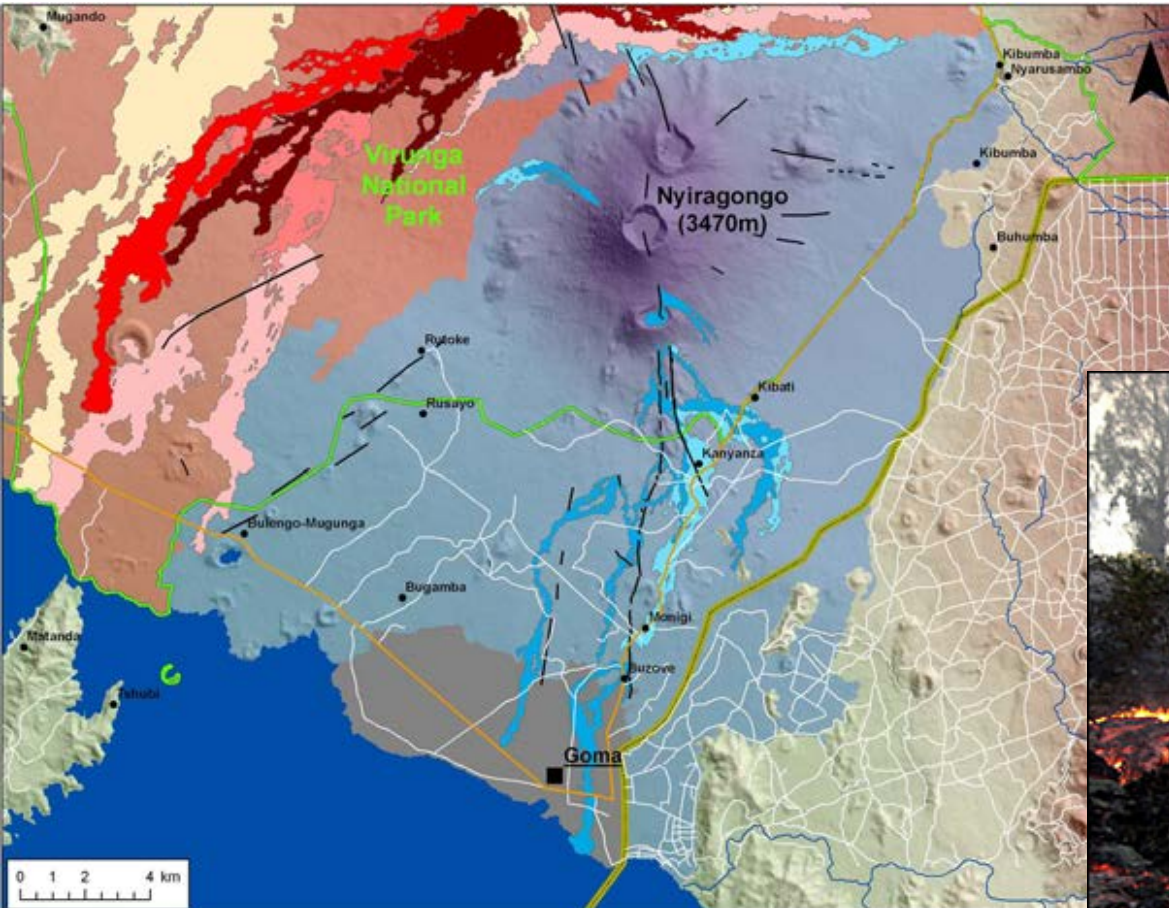
Largest active lava lake:  
Diameter = 200m



Level rise: + 200m in 5 years (=10 cm/day or 22.000 m<sup>3</sup>/day), that is about 40 millions m<sup>3</sup> (>11 x volume of St Pieter in Rome or 15 x volume of Cheops pyramid).

# Nyiragongo lava lake:

Drained in a few minutes/hours during eruptions like in 1977 and 2002:



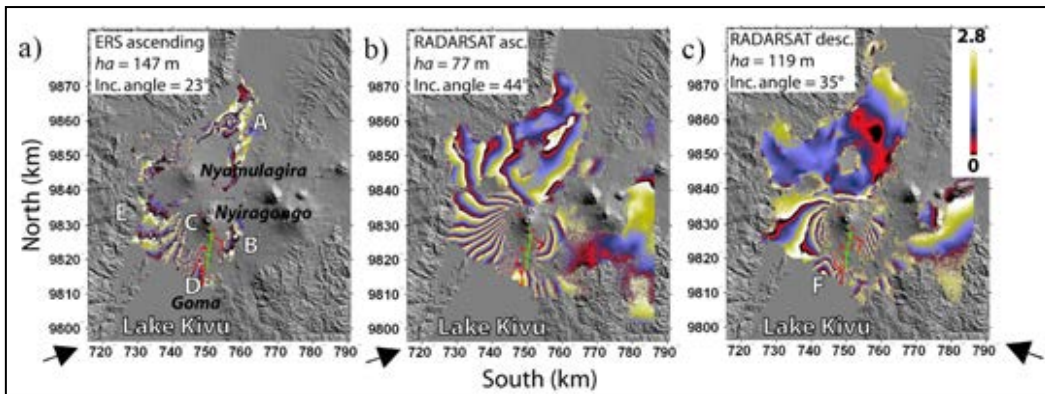




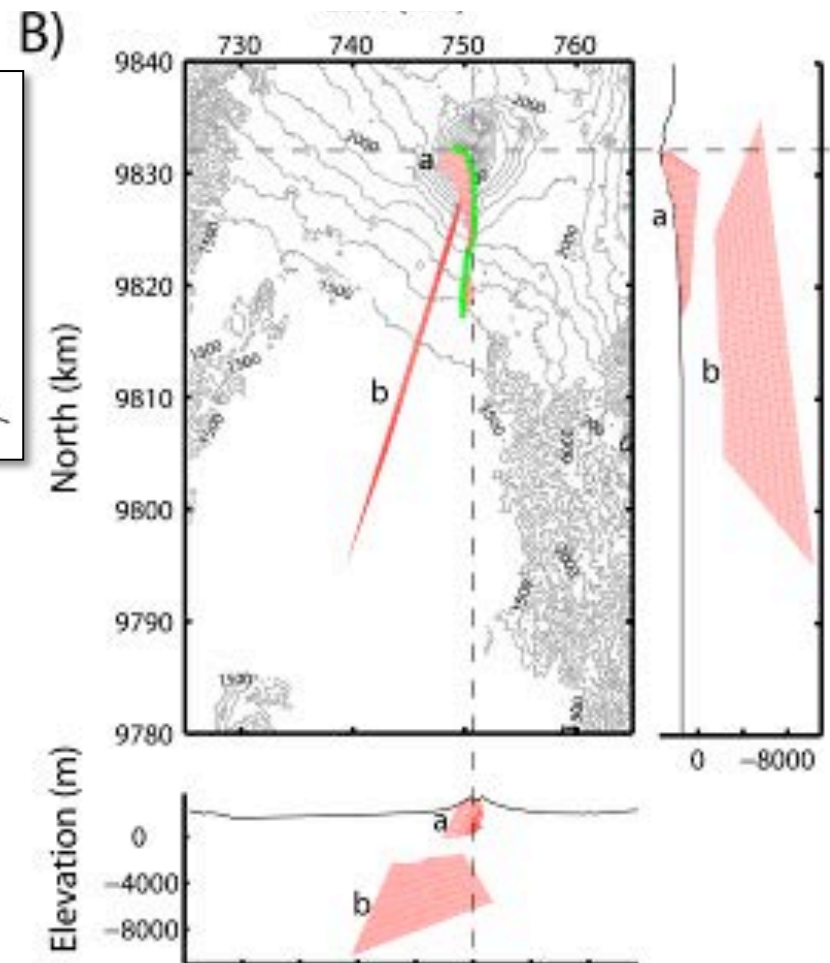


# Nyiragongo 2002 eruption

See poster Wauthier et al. (this meeting)



(from left to right): ERS-2: 6 September 00 – 3 July 02; RADARSAT-1, ST6 mode: 31 December 01 – 17 February 02; RADARSAT-1, ST4 mode: 21 December 01 – 03 March 02. One color circle represents a 2.8cm satellite-ground range change with positive fringe (red-blue-yellow) corresponding to positive range. Black arrows show Line Of Sight (LOS) vector direction. The 2002 lava flow are shown in red and eruptive fissures are drawn in green.

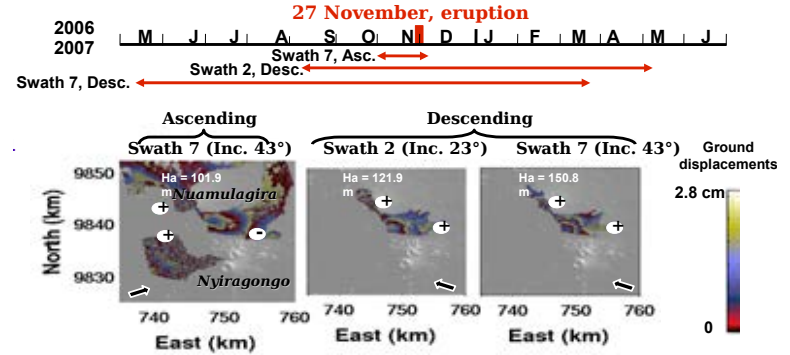


(C. Wauthier et al., 2012)

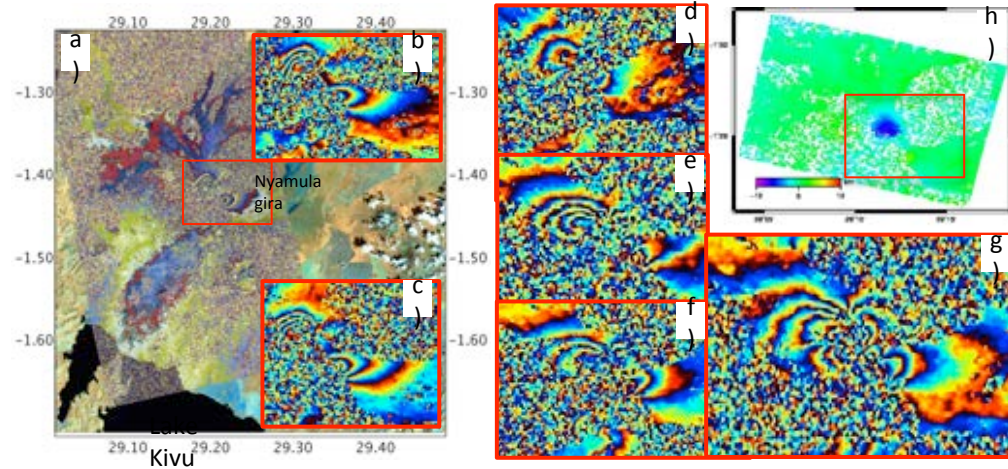


For detailed about some recent events : visit poster d'Oreye et al. (this meeting).

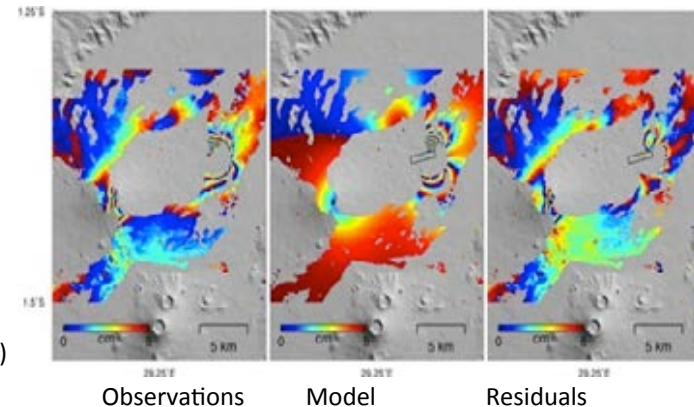
Nyamulagira 2006 eruption (Wauthier et al. in press, Cayol et al. in prep.) :



Nyamulagira 2010 eruption: (Smets et al., in prep)



Nyamulagira 2011/2012 eruption monitored by InSAR and GPS (in prep.):



(Courtesy: P. Gonzalez)

# West: Virunga

- Still many unknowns (why so close and so different ?; why there ?; what plumbing system ?; driving mechanisms ?... )
- A lot is still to be done

# West: Toro-Ankole, South Kivu

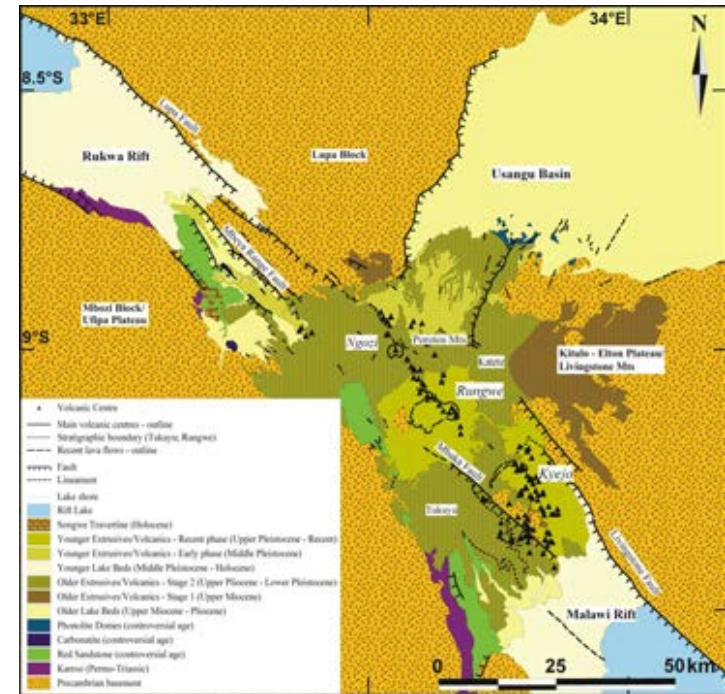
- Katwe-Kikorongo (T-A): tuff cones and maars. Historical time ?
- South Kivu: considered as extinct. Bukavu/Cyangugu EQ sequence confirms (d'Oreye et al. 2011). However, Tshibinda (Kahuzi-Biega) cinder cones may have been active in the past 2000 years ?
- A lot is still to be done



Lake-filled crater in the Katwe-Kikorongo volcanic field (Uganda). *Photo by Nelson Eby (Univ. of Massachusetts)*

# West: Rungwe triple junction

- Considered as dormant, though 3/6 of Holocene eruptions with VEI  $\geq 4$
- Rungwe Volcano:
  - ✓  $\geq 7$  explosive eruptions in last  $\sim 4$  ky
  - ✓ 1 Plinian event  $\sim 4$ ka (Fontijn et al., 2011)
  - ✓ 1 subplinian event  $\sim 2$ ka
  - ✓  $\geq 5$  Vulcanian-scale eruptions at few 100s years intervals
  - ✓ Imprecise dating
- Ngozi Caldera:
  - ✓ 2 plinian-scale eruptions in  $\sim 10$  ka
  - ✓ Possible hazard:
    - instability of caldera walls/lake breaching**  
(Fontijn et al., 2012)
  - ✓ Limited dataset
- Kyejo volcano: effusive eruptions ca. 200 years ago (Harkin, 1960)



(Fontijn et al., 2012)

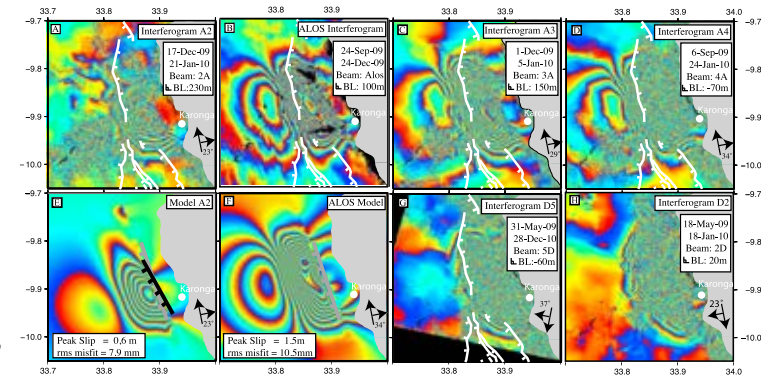


Figure 2. Envisat Interferograms for the 2009 Karonga earthquakes, Malawi. Interferogram (a) A2 covers only the December 19th event; interferograms (b) Alos, (c) A3, (d) A4, (g) D5, and (h) D2 cover the entire sequence. Distributed slip models shown for (e) A2 and (f) Alos. The grey line is the surface projection of the best fitting uniform slip model for all events and the black line for the 19 December event. White lines are mapped faults.

Karonga Seismic sequence in December 2009: unlike Dabbahu, Natron, Saudi Arabia: no magma involved here (Biggs et al., 2010)



# Eastern branch

- 3/6 of Holocene eruptions with VEI  $\geq$  4: Meru, Menengai, Paka
- Most active: Lengai:
  - Alternating low hazard effusive natrocarbonatite eruptions during few decades and explosive episodes (e.g. 1917, 1940–1941, and 1966–1967, 2007) : 2–15 km high eruption columns dispersing ash up to 100 km distance). ([Kervyn et al., 2010](#)). In 1967 it affected Nairobi and Arusha, 180 and 110 km. Ashes cause respiratory problems, may affect airplanes, cause lahars...
  - Sector collapses : at least 3 debris avalanche deposits (up to 5km<sup>3</sup>) occurred in the last 10 ky ([Klaudius and Keller 2004](#); [Kervyn et al. 2008b](#)).
  - The fresh meter- thick ash layers : lahar hazard during heavy rainfall events. ([Kervyn et al., 2010](#))
  - Almost no ground-based monitoring and no geophysical study have yet taken place at OL, little is known about the volcano's internal structure
  - Dyke intrusion in July 2007 ([Baer et al. 2008](#), [Calais et al. 2008](#), [Biggs et al. 2009](#))
- Meru: last eruption in 1901. Presence of massive debris avalanches and lahars that travelled 40km up to Kilimanjaro volcano. Proximity of Arusha city.
- Kilimanjaro: Pleistocene, but a group of youthful-looking nested summit craters are of apparent Holocene age, and fumarolic activity continue. Proximity of Moshi city.
- Paka: The three youngest post-caldera pyroclastic cones on the NE flank may be only a few hundred years old.
- But also deforming volcanoes in Kenya: Paka, Menengai, Longonot, Suswa ([Biggs et al., 2009](#))

# conclusions

- *Africa has the highest percentage of volcanoes that are undated but known to be Holocene (Simpkin and Siebert, 1994)*
- No time in this talk to list the wide range of volcanic activity in EAR but EAR is affected by (almost) all type of volcanism and associated hazards
- Need to know where, when, how often, which type of volcanism : useful for both science and risk assessment. Also useful for resources, climate, etc...
- In particular, need :
  - instrumental and quantitative measurements for monitoring and studying current activity + understanding active systems
  - geochemical, geomorphological, structural... studies for past history assessment



Thank you for your attention



Nyamulagira 2010 eruption