Volcanic hazards of rift environments

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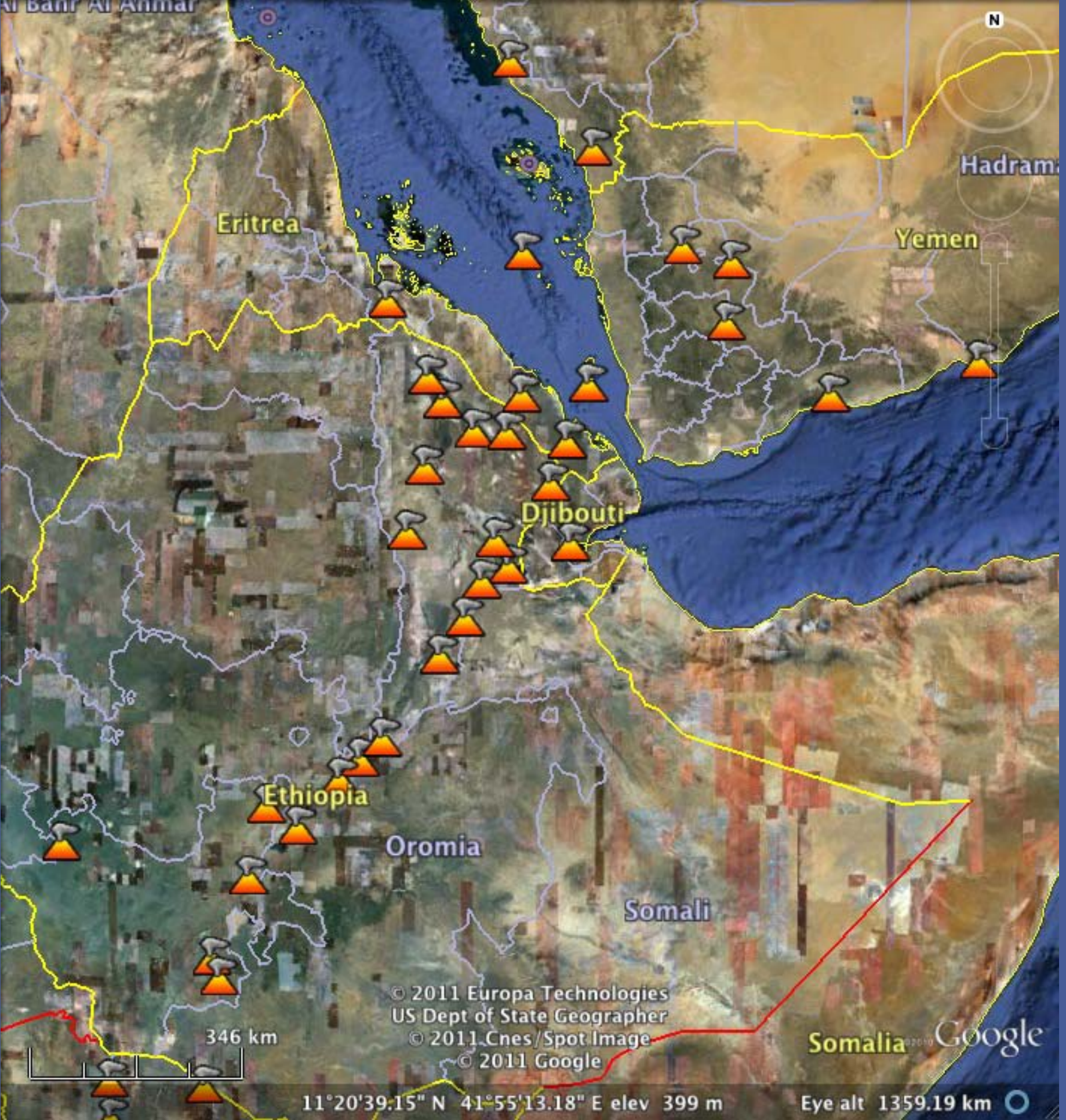
Volcanic hazards - challenges

- To assess hazards quantitatively, we need to know volcanic history in space and time
  - Vent locations [where?]
  - Frequency [how often?]
  - Eruption styles [what are the impacts?]

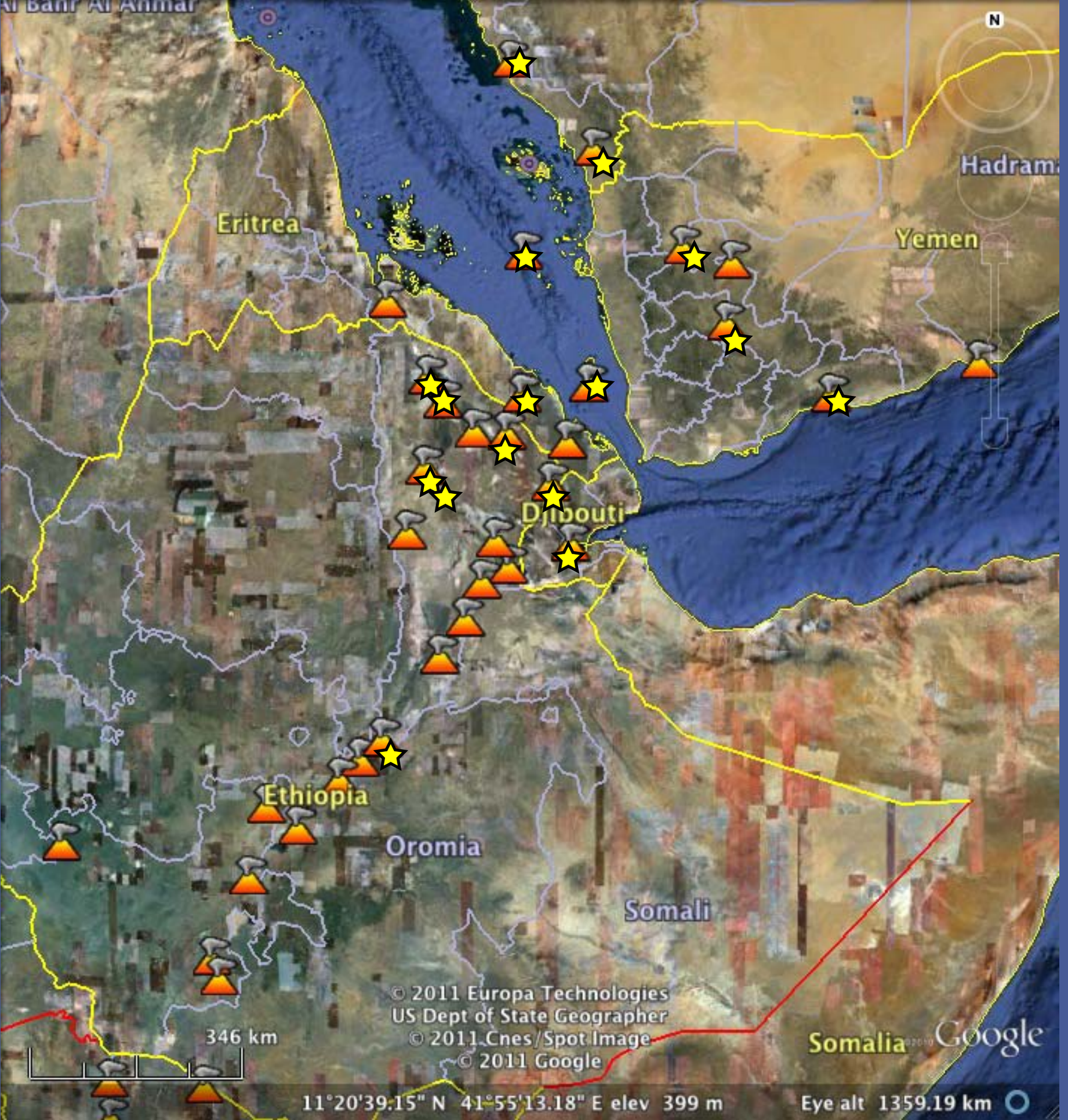
- To mitigate hazards we need to worry about both planning for future activity and response to eruptive crises

- To make predictive models, we need to understand complex magmatic systems, that is, the fundamental processes that drive magma storage, ascent and eruption

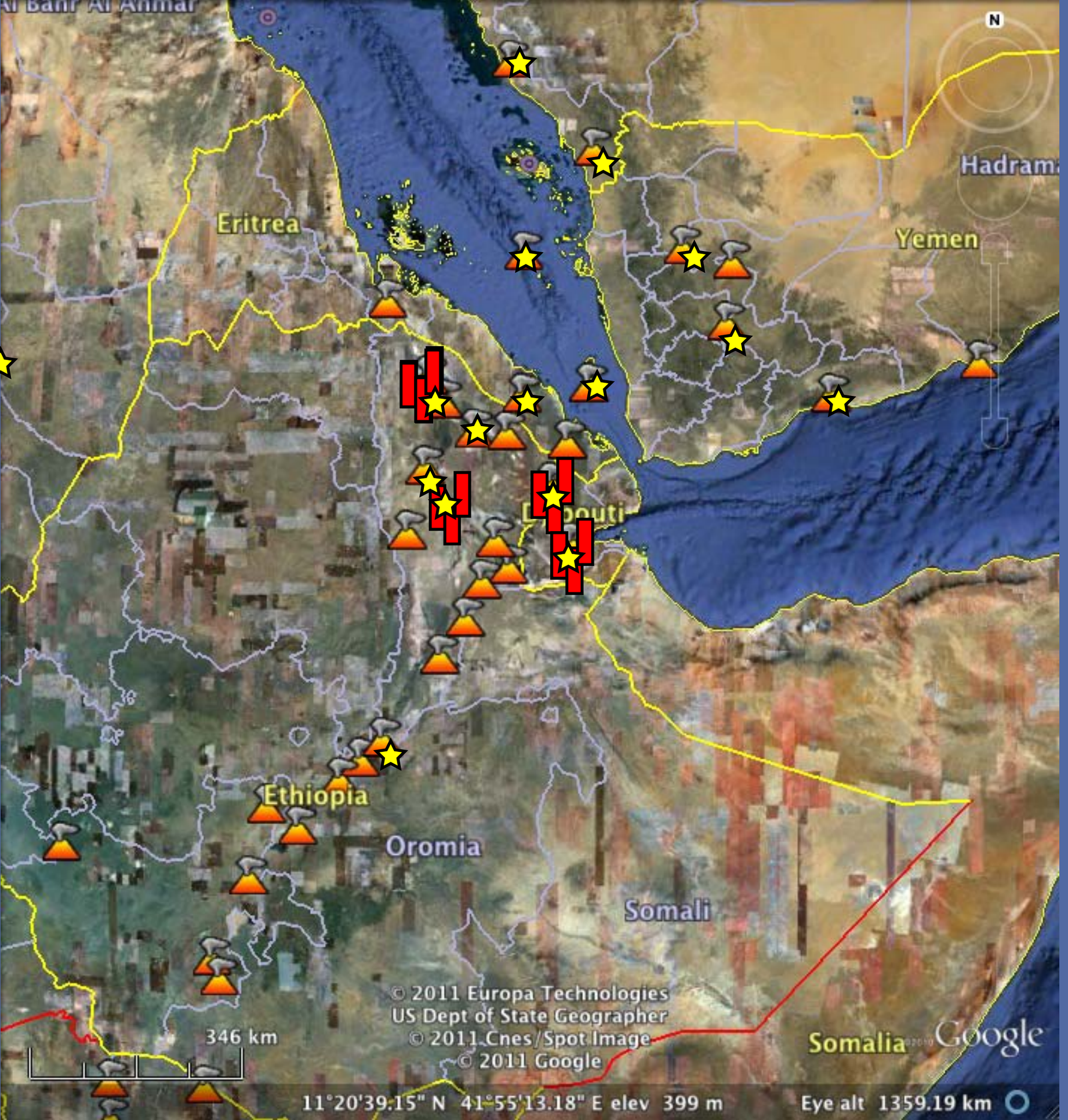
Rift volcanoes in space and time... an overview



Holocene volcanism



★ Historic eruptions



Historic eruptions

Fissure vents

Fissure eruptions

Krafla, Iceland

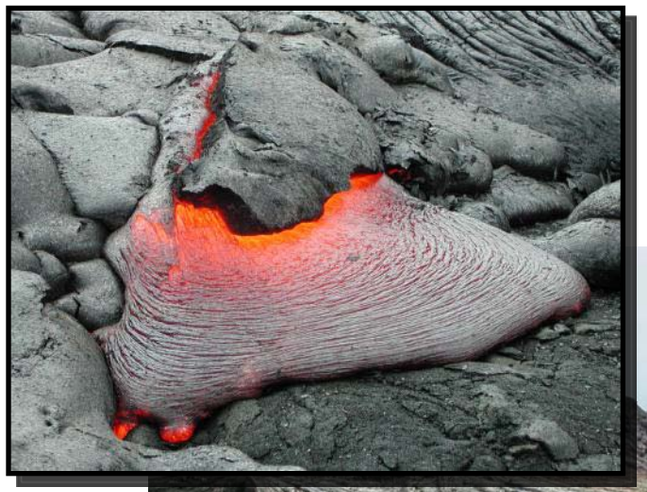
Kilauea, Hawaii

- Lava flows
- Fed from central volcano
- Individual eruptions of short duration
- Can’t be distinguished from dyking events

Image by M Patrick and S Carn

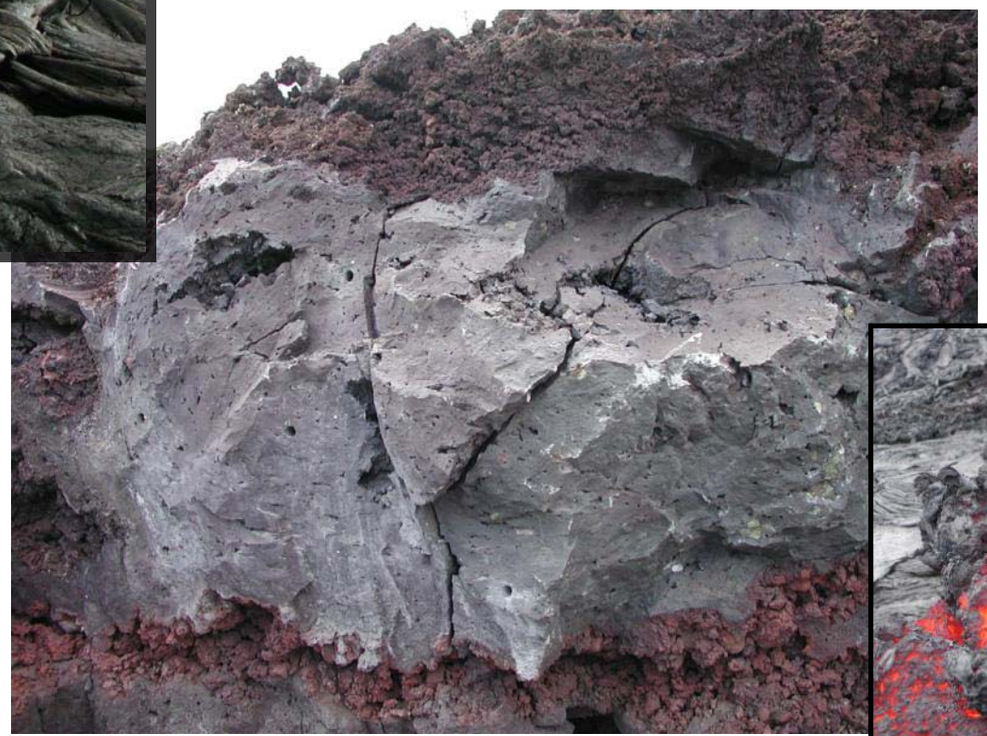
Alu-Dalafilla
Nov 2008

Lava flow basics



Pahoehoe

Blocky



Aa

Morphology determined by emplacement conditions

Surface morphology determined by crystal content and shear rate

< ~ 15-20% crystals

> 30-35% crystals

Crystal content is a function of original crystallinity and extent of cooling during flow

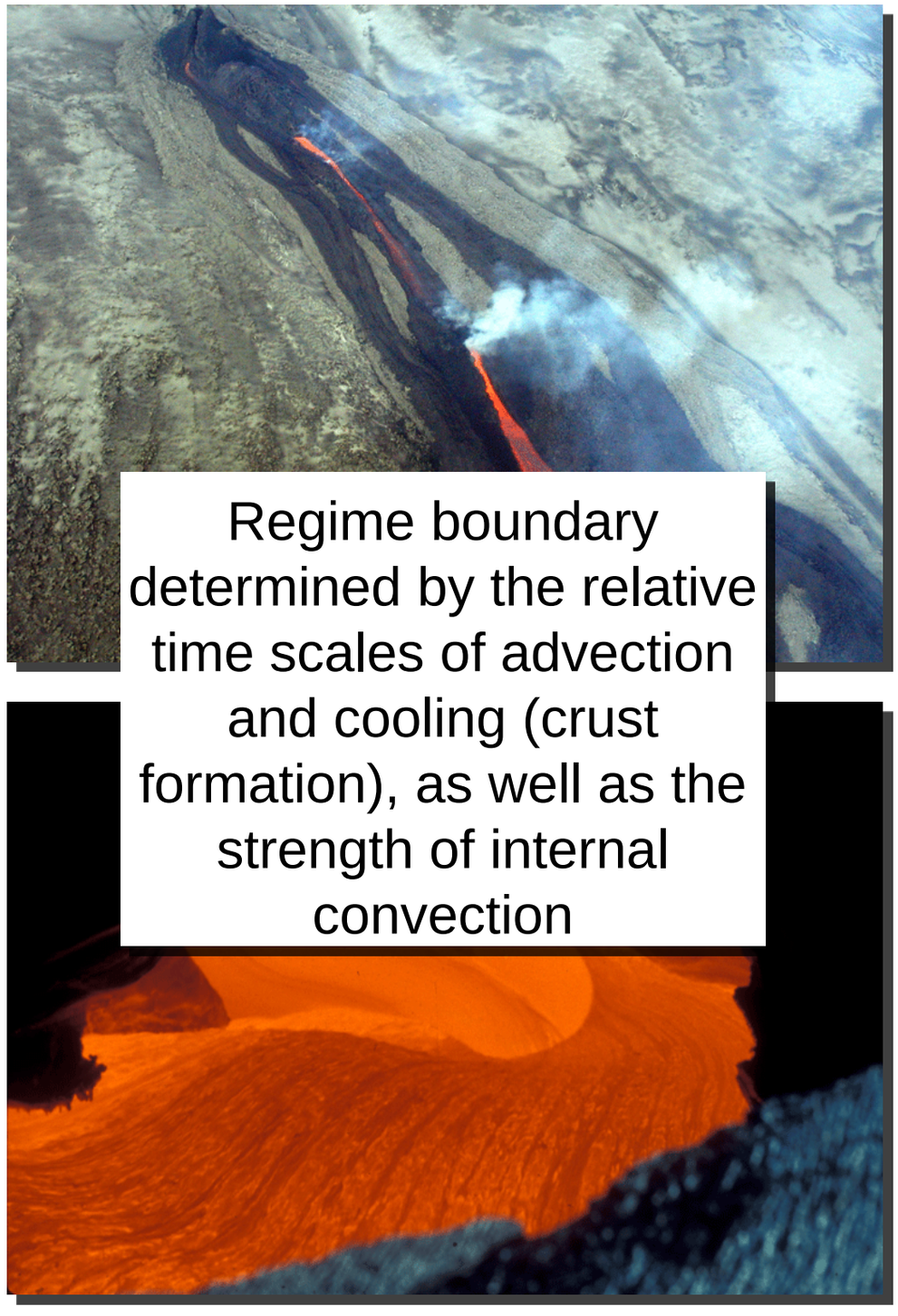
Channelized flow - Two regimes

1. Open channel
   - steady, mobile central crust
   - fragmented solid in shear regions

HIGH EFFUSION RATES; STEEP SLOPES

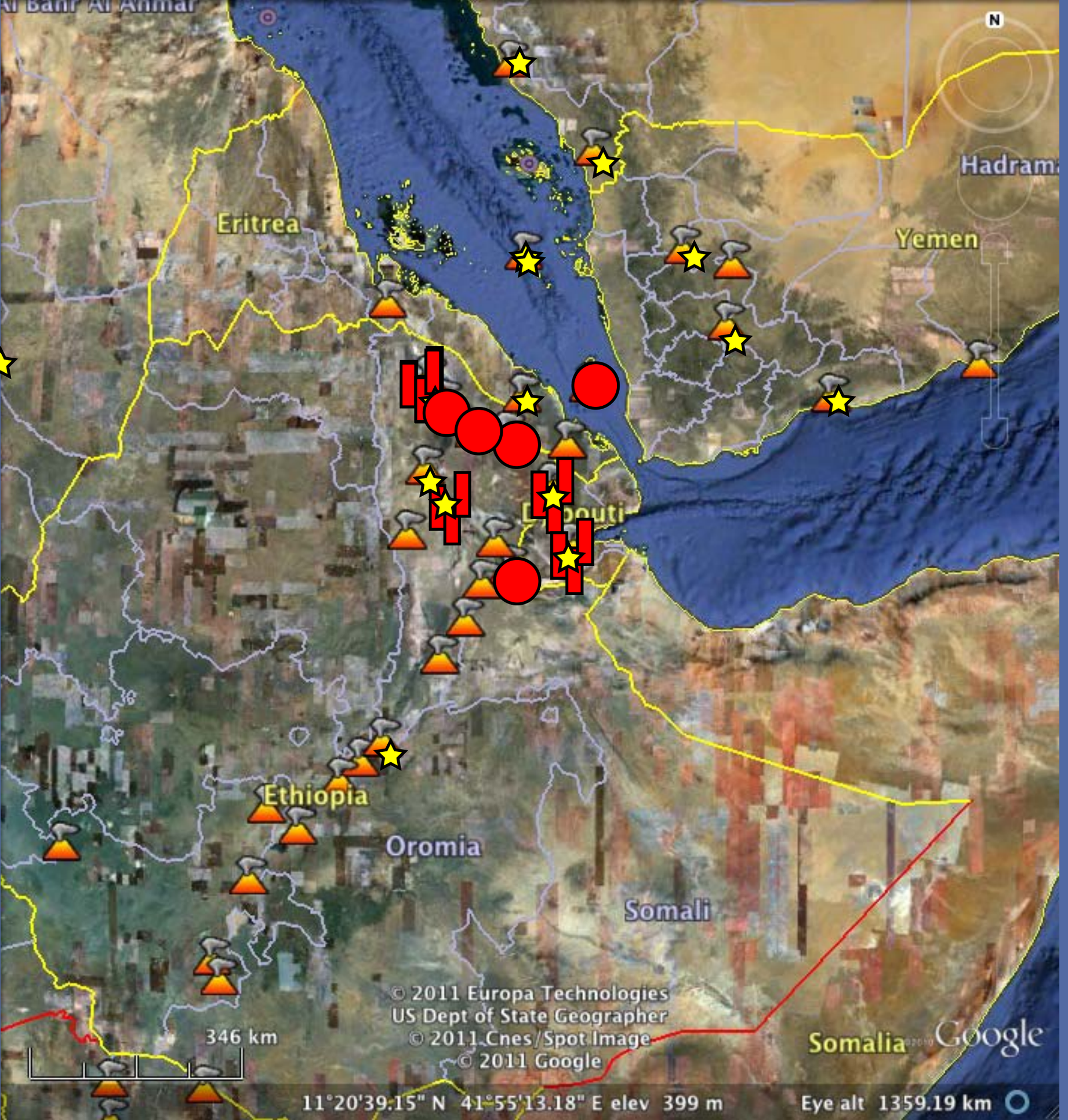
2. Insulating tube
   - continuous solidified roof
   - efficient delivery of fluid lava

LOW EFFUSION RATES; LOW SLOPES



Regime boundary determined by the relative time scales of advection and cooling (crust formation), as well as the strength of internal convection

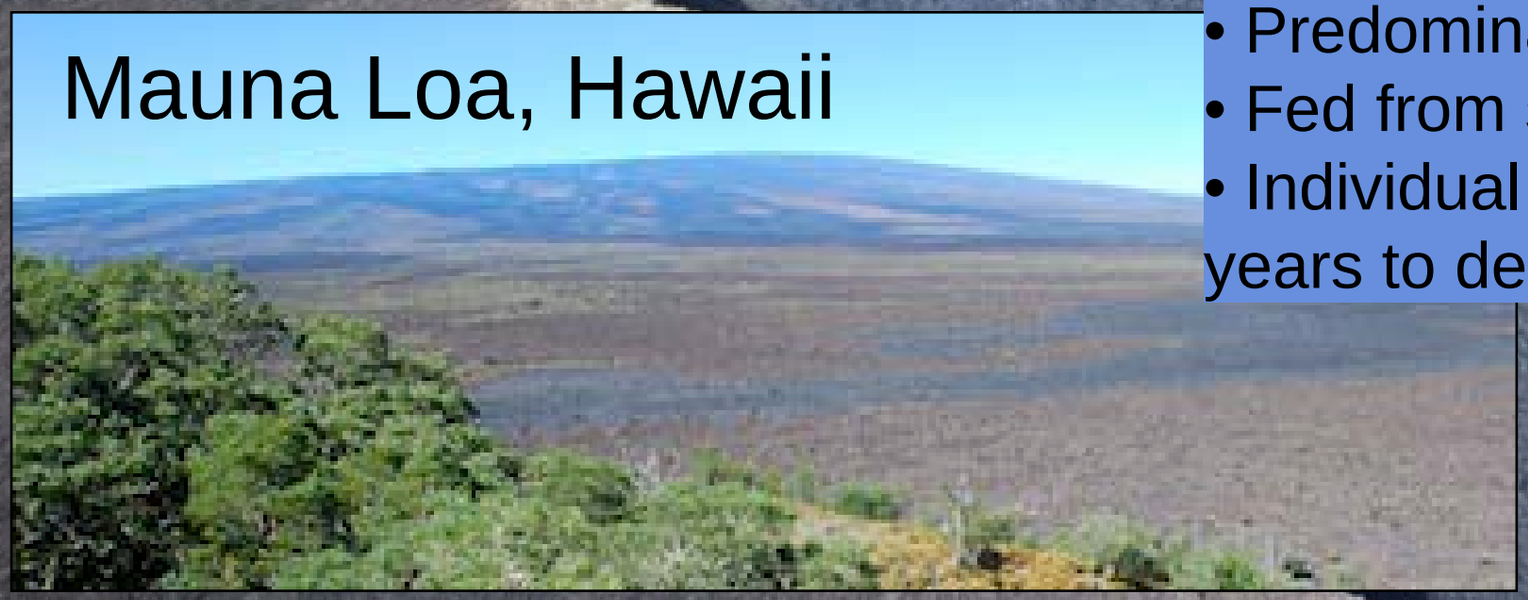
Griffiths et al. (2003); Cashman et al. (2006)



Historic eruptions

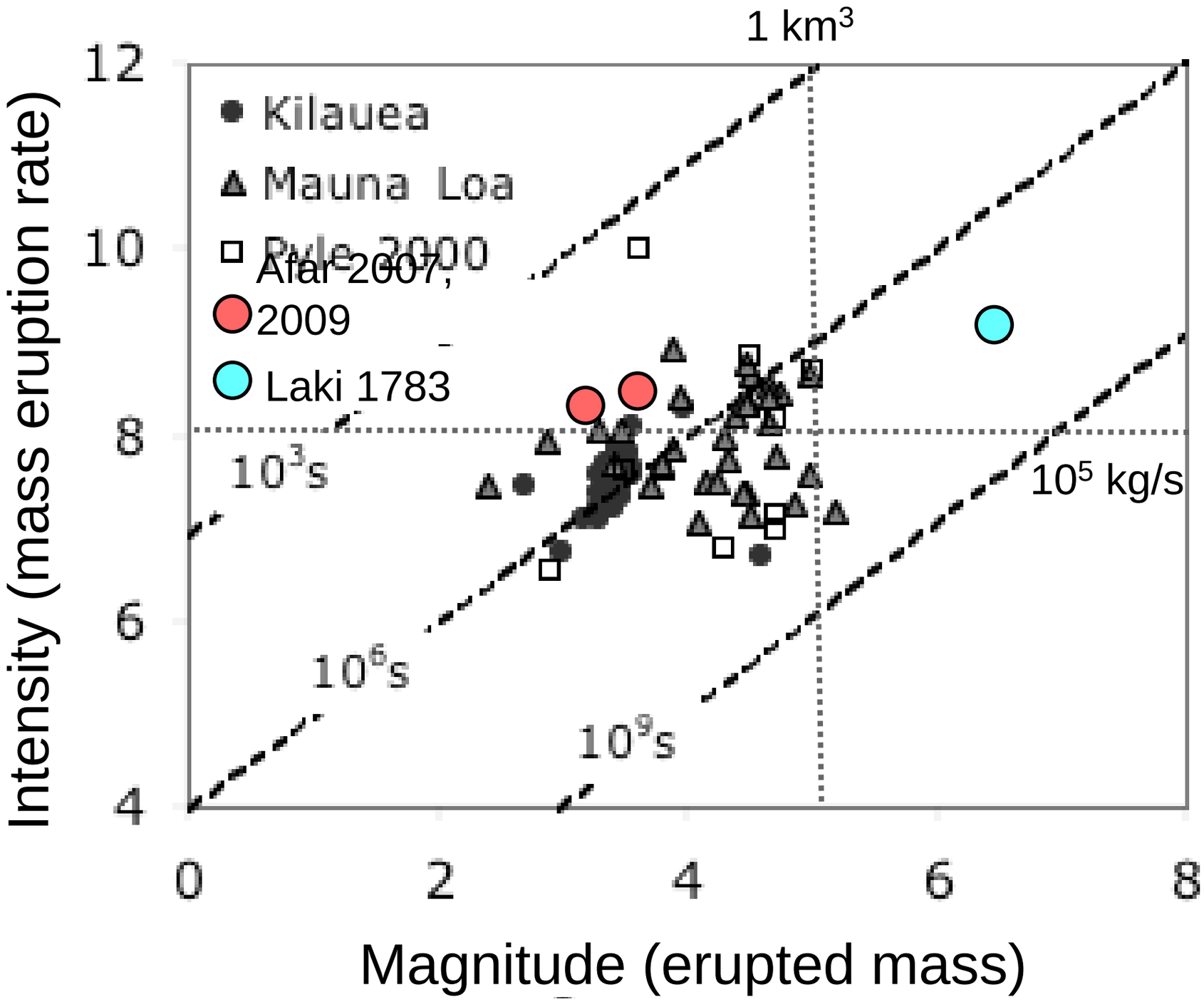
Fissure vents

Mafic shield

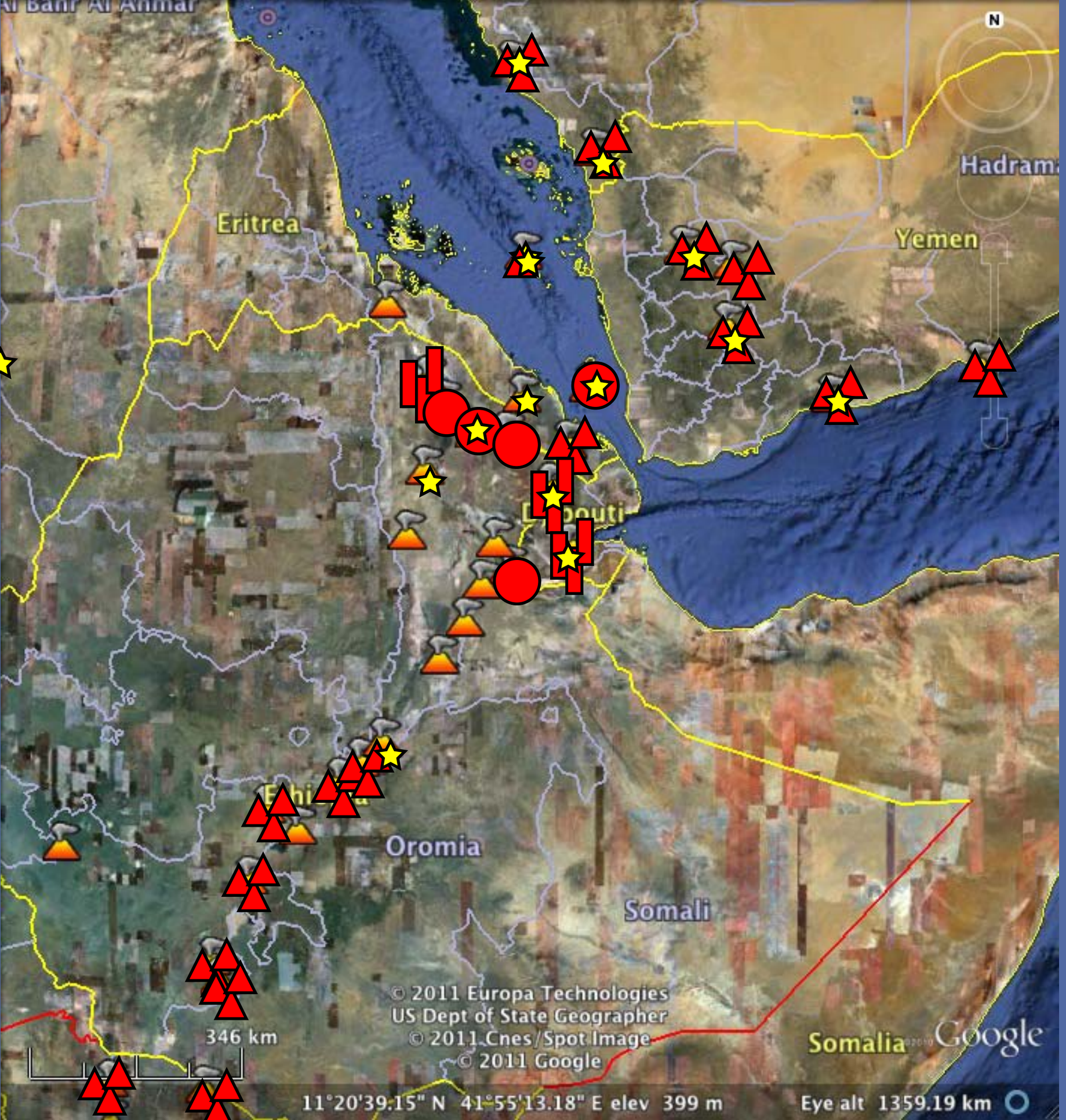


- Predominantly lava flows
- Fed from shallow magma storage regions
- Individual eruptions can last for months to years to decades

Mafic effusive eruptions



Both shield and fissure eruptions can produce flows with a large variation in magnitude; it appears that events of long duration may require large volumes of shallow-stored magma?



Historic eruptions

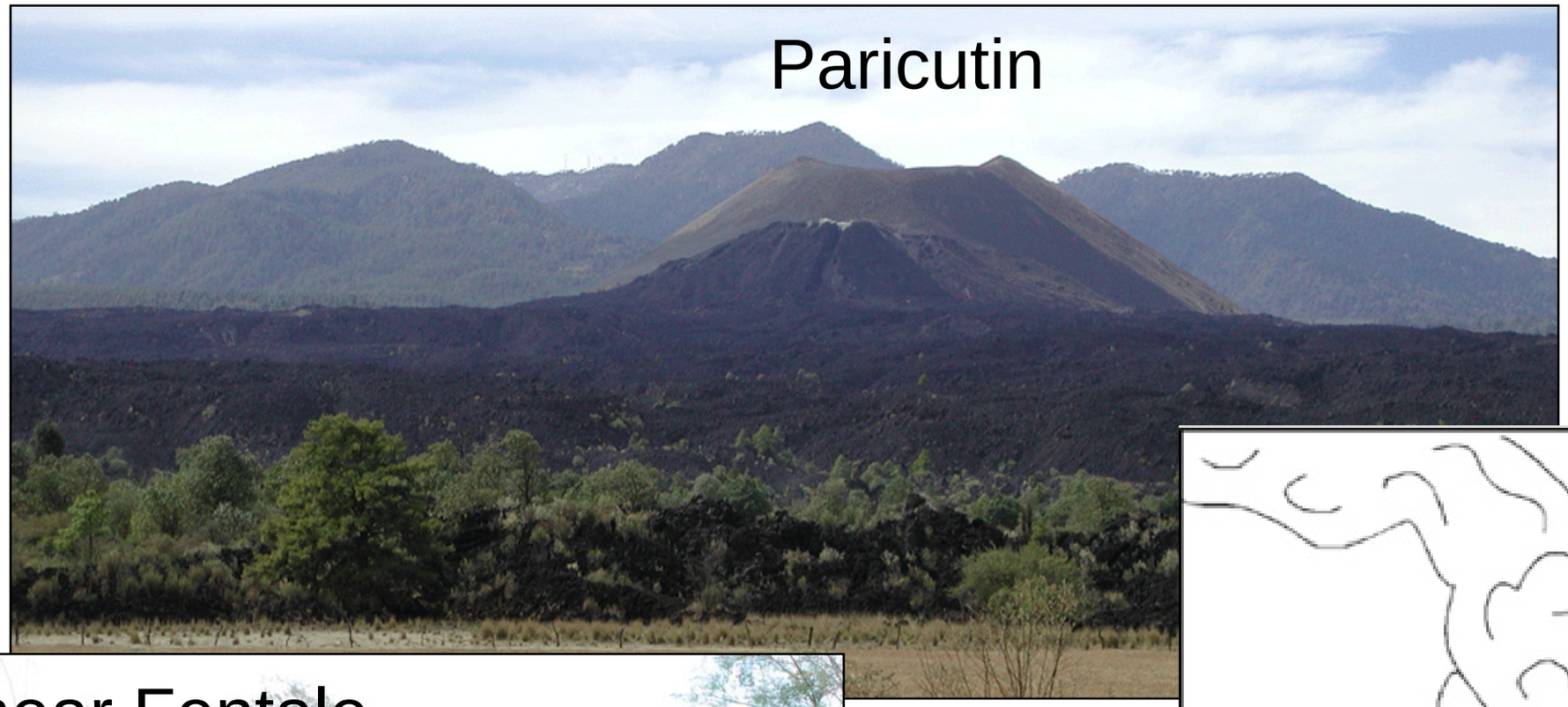
Fissure vents

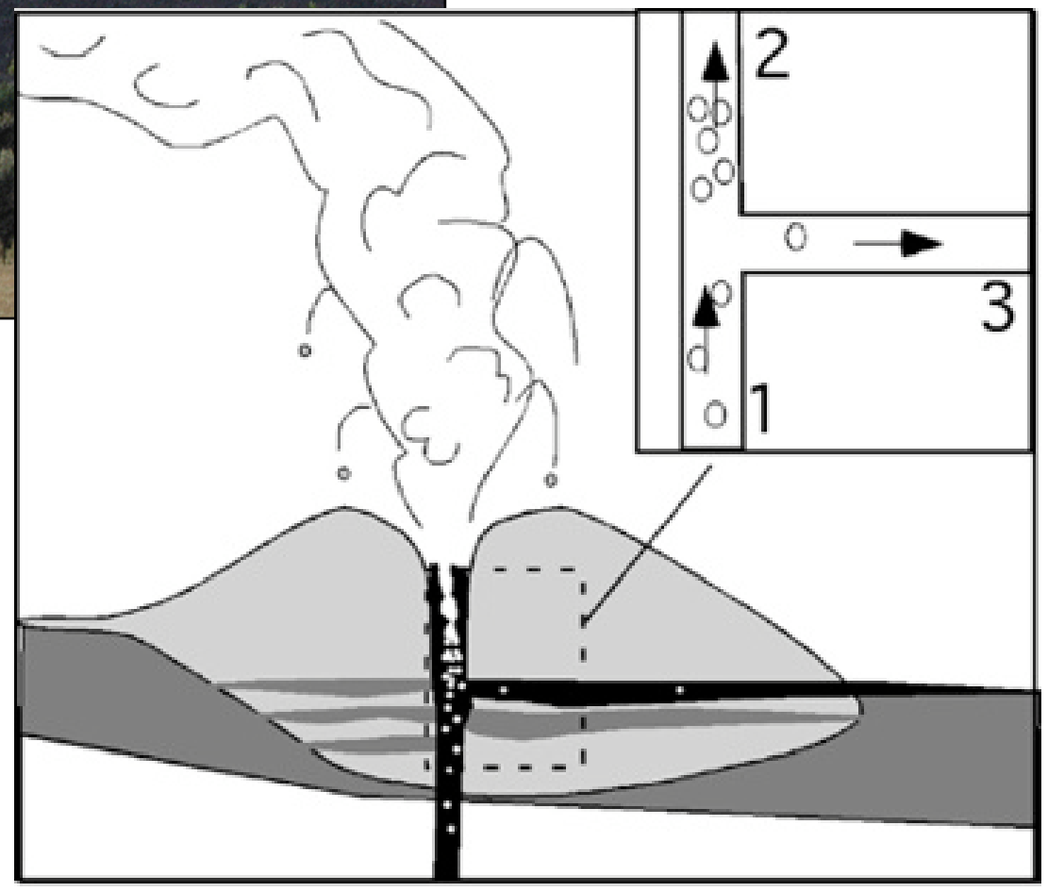
Mafic shield

Volcanic fields

Cinder cone fields

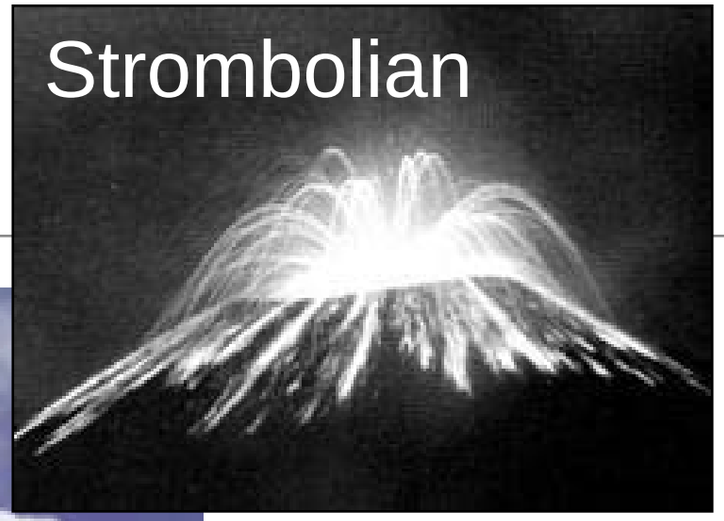
Cinder cones - effusive



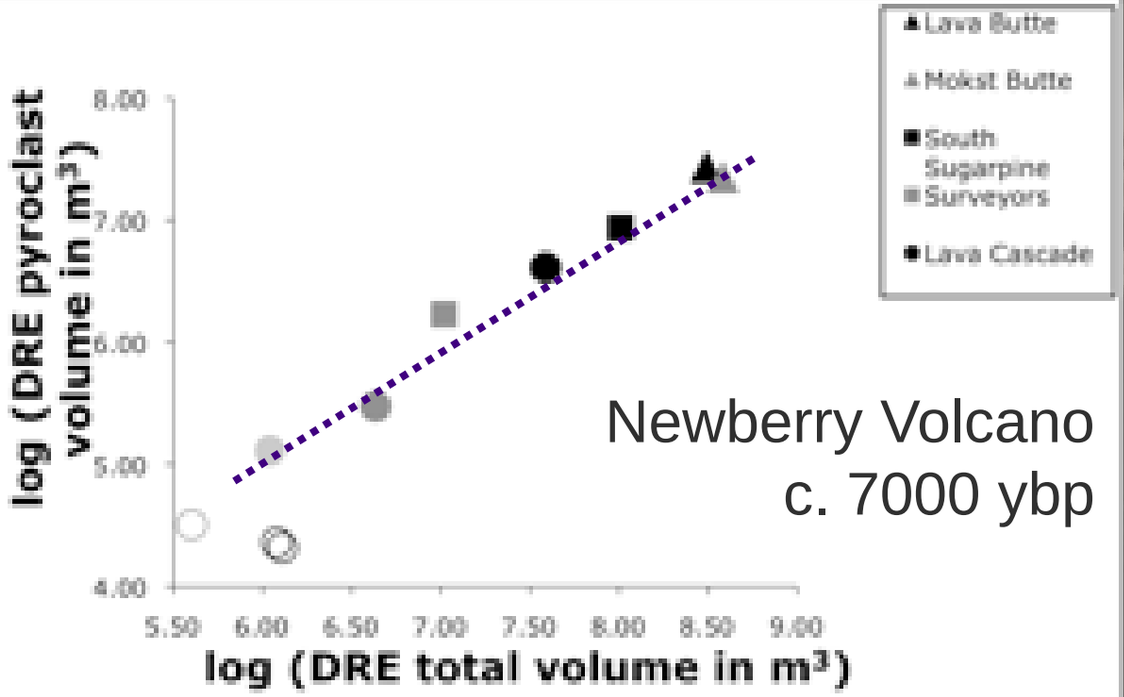


Pioli et al. (2009)

Cinder cones - explosive



young cone south of Fentale

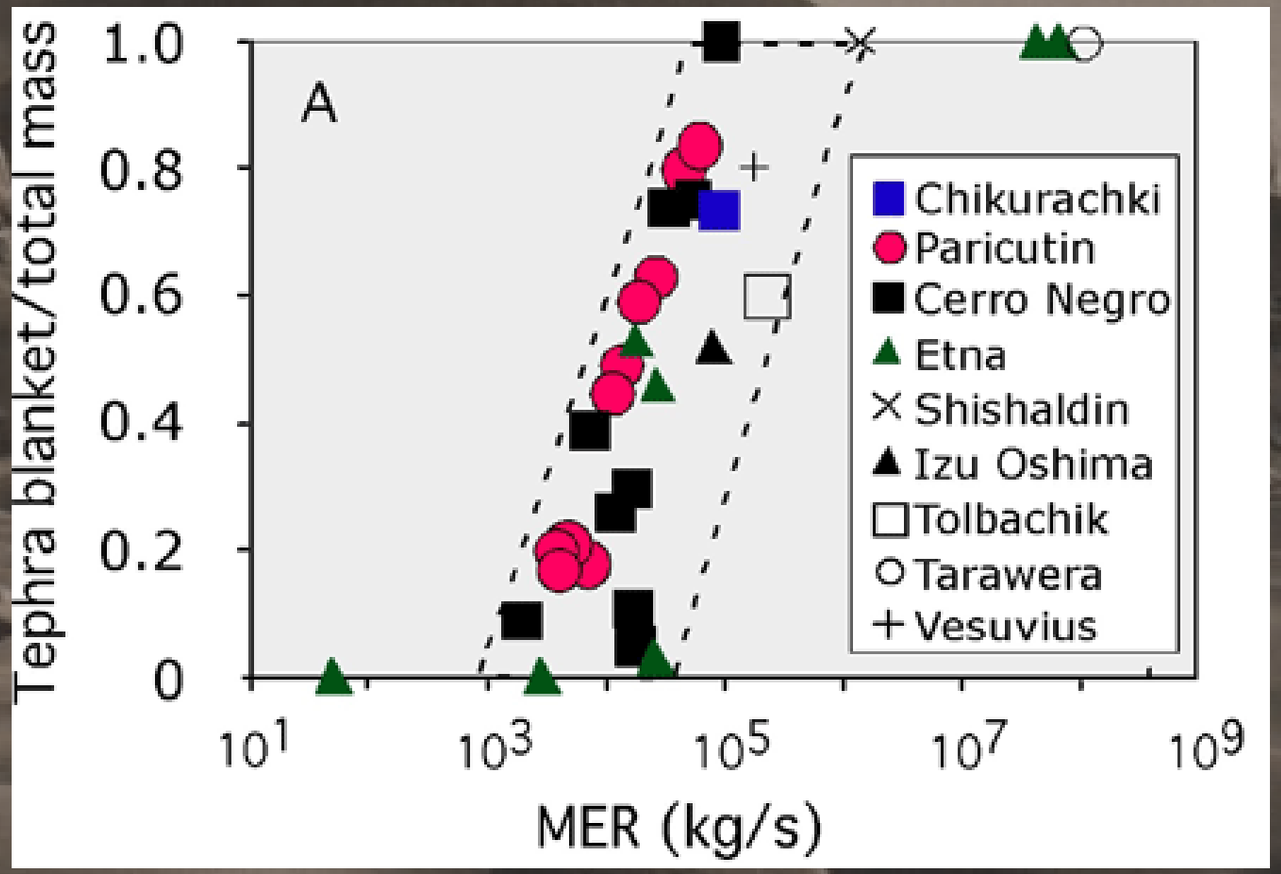


Newberry Volcano
c. 7000 ybp

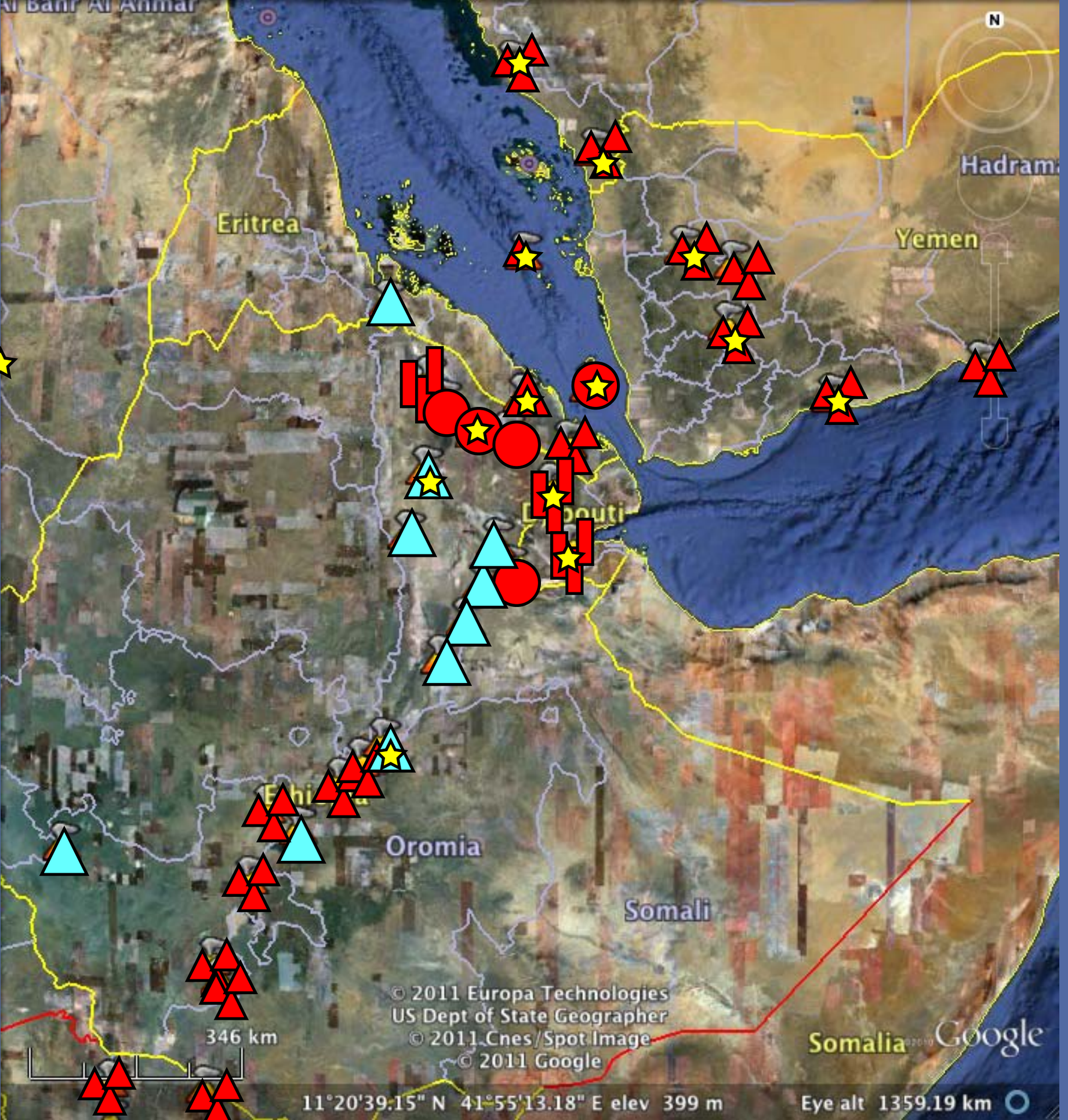
In many tectonic settings, effusive volume ~ 10 x explosive volume

McKay et al. (in prep)

Proportion of tephra increases with MER



Pioli et al. (2009)



Historic eruptions

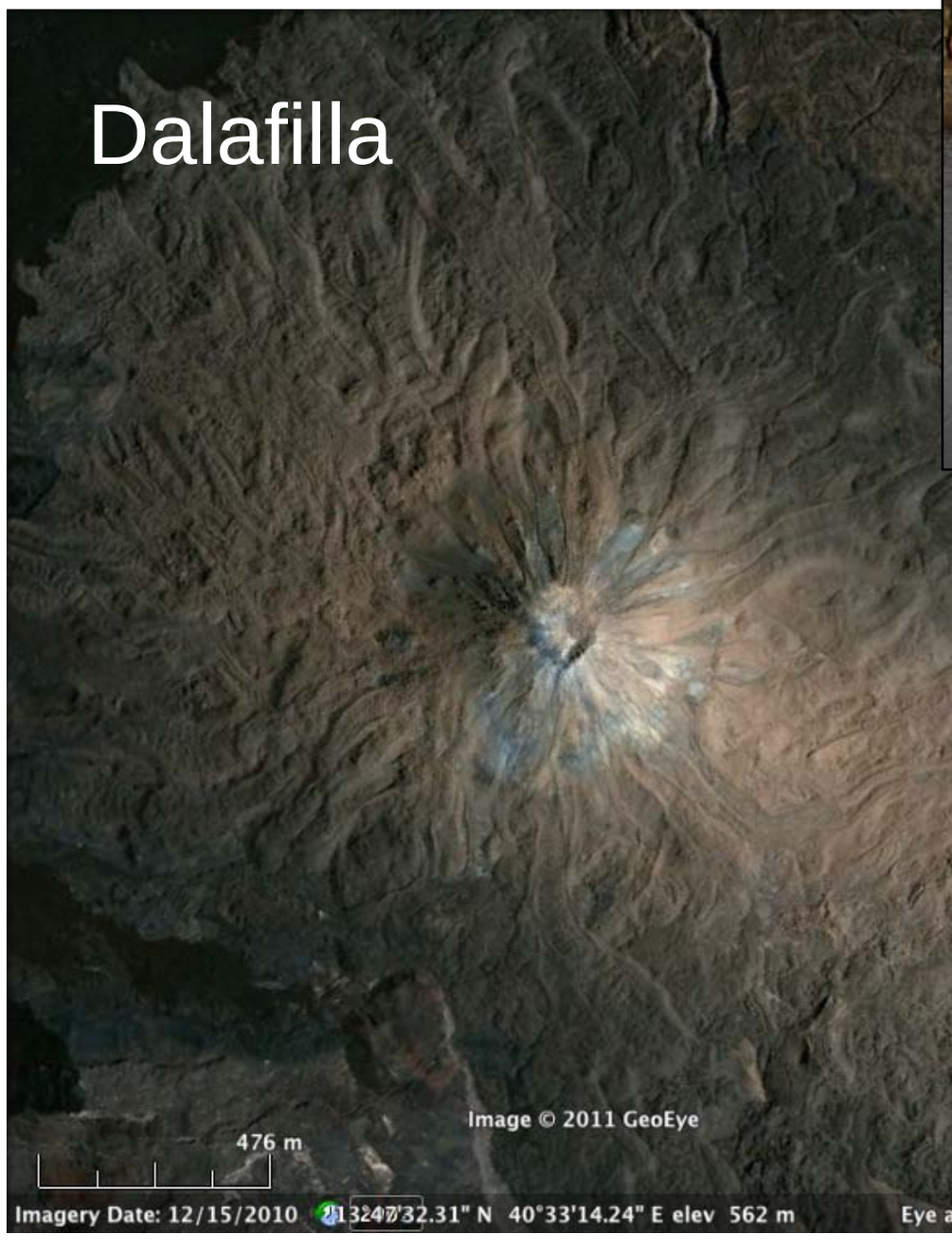
Fissure vents

Volcanic fields

Mafic shield

Silicic centers

Stratovolcanoes

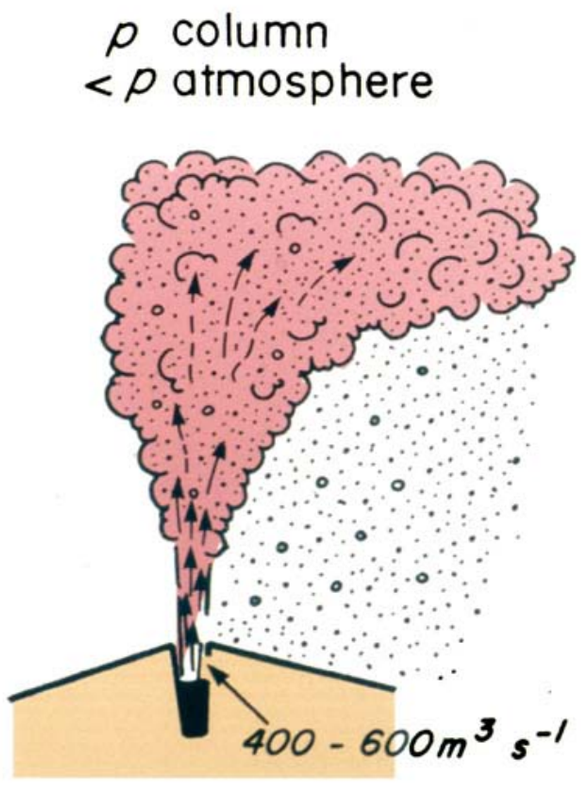


- Both explosive and effusive activity
- Develop shallow magma storage regions
- Erupt a range of compositions

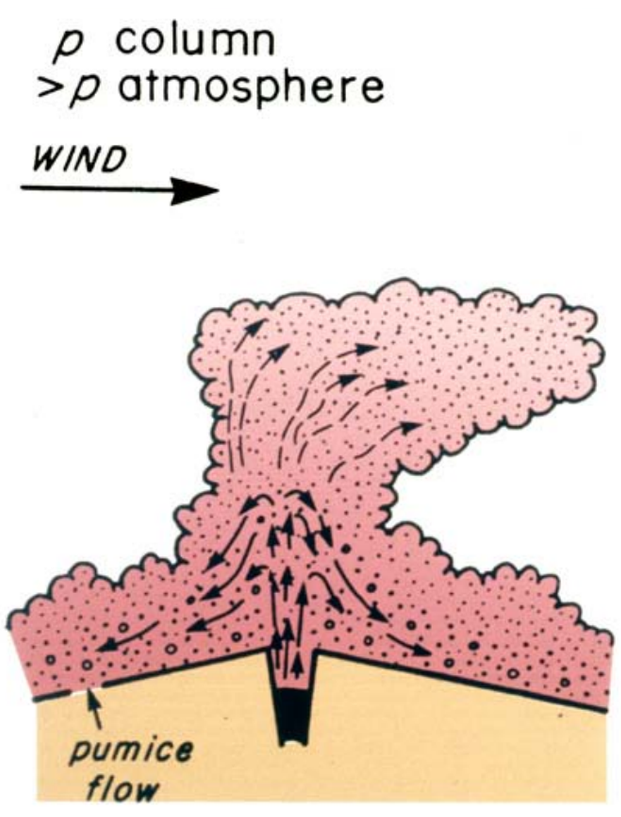
Stratovolcanoes - explosive eruptions

Most common hazards from subplinian to plinian eruptions are deposition of fragmented material from high columns and rapid transport of material via pyroclastic density currents

Pyroclastic fall

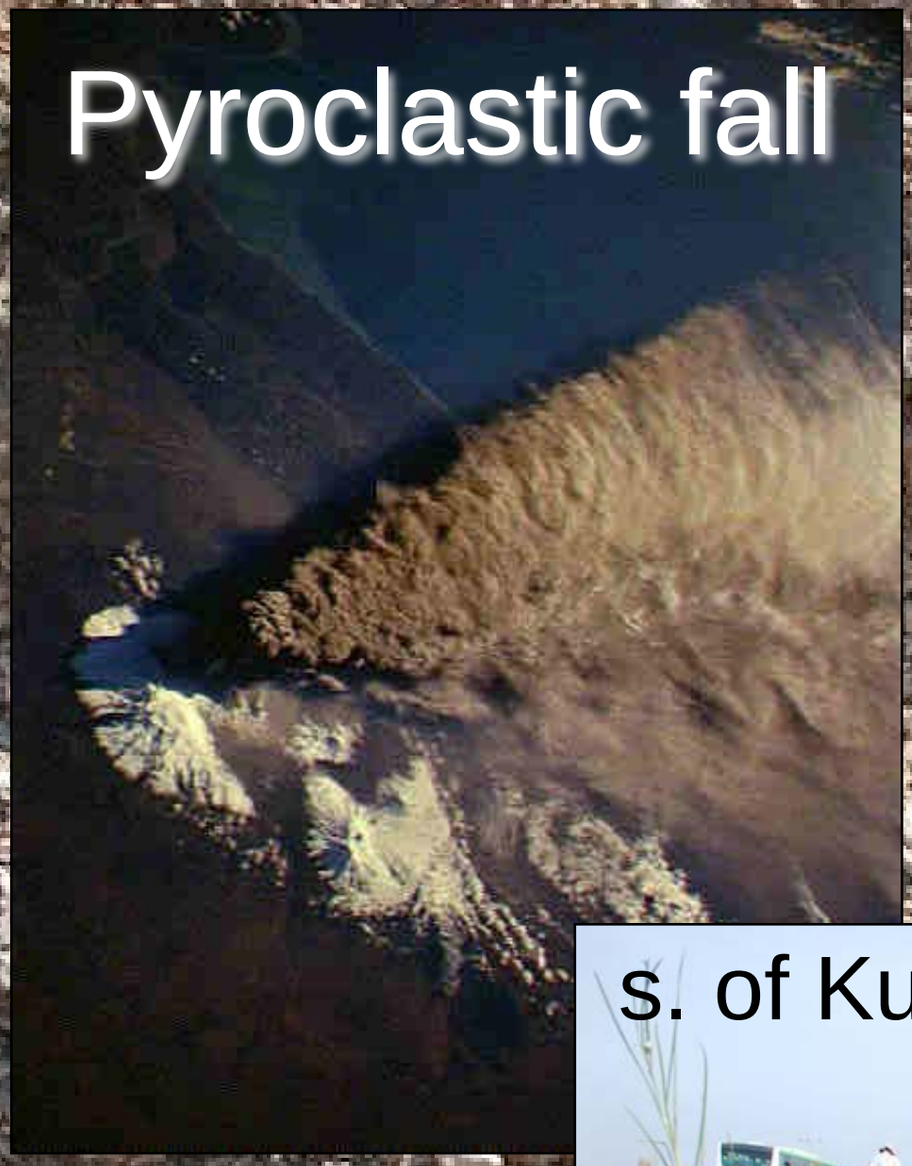


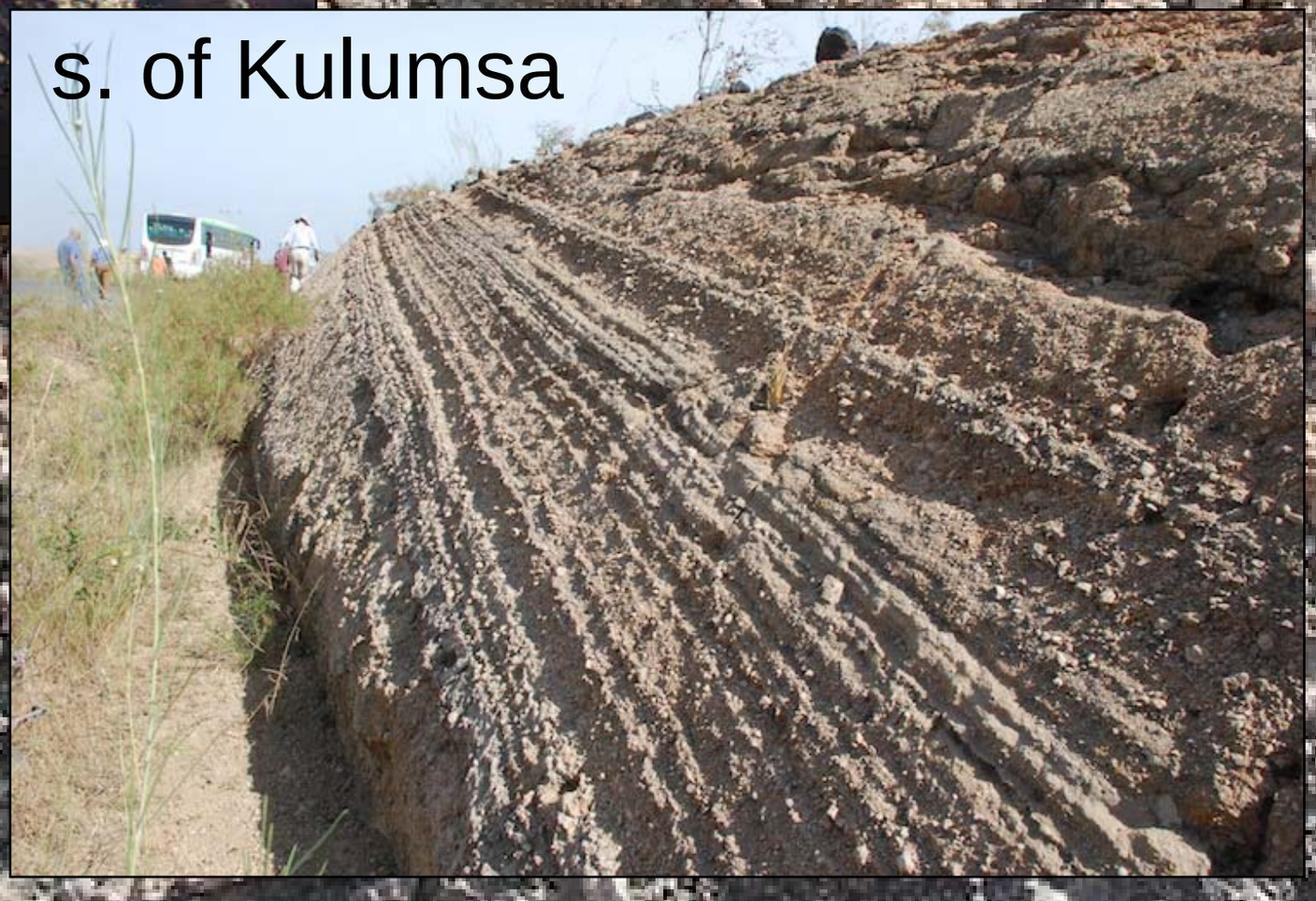
Pyroclastic flow



Pyroclastic flows

Pyroclastic fall

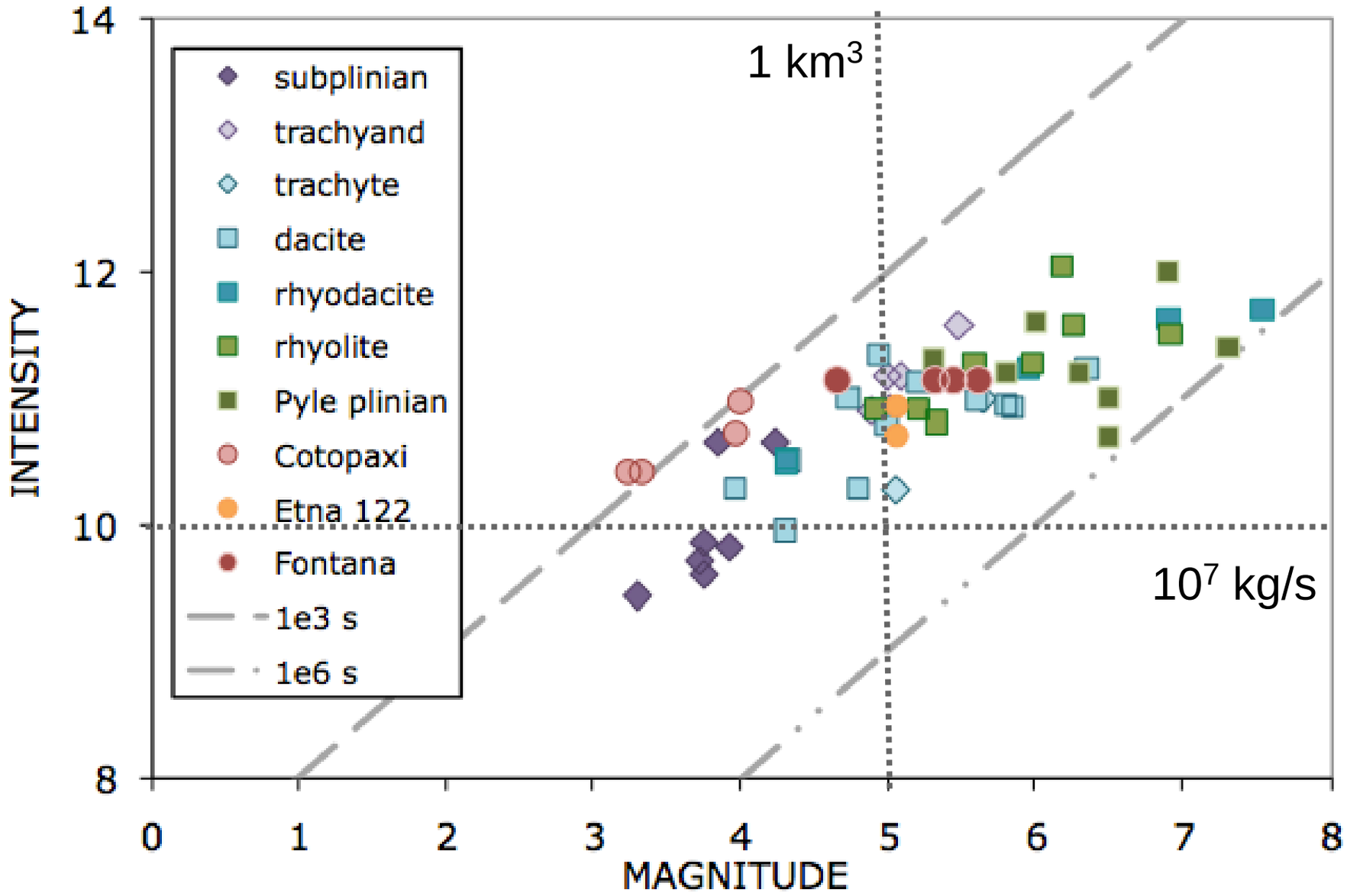




Distal hazards

Recent eruptions have highlighted the impact of distal ash on aircraft... could also adversely affect shipping

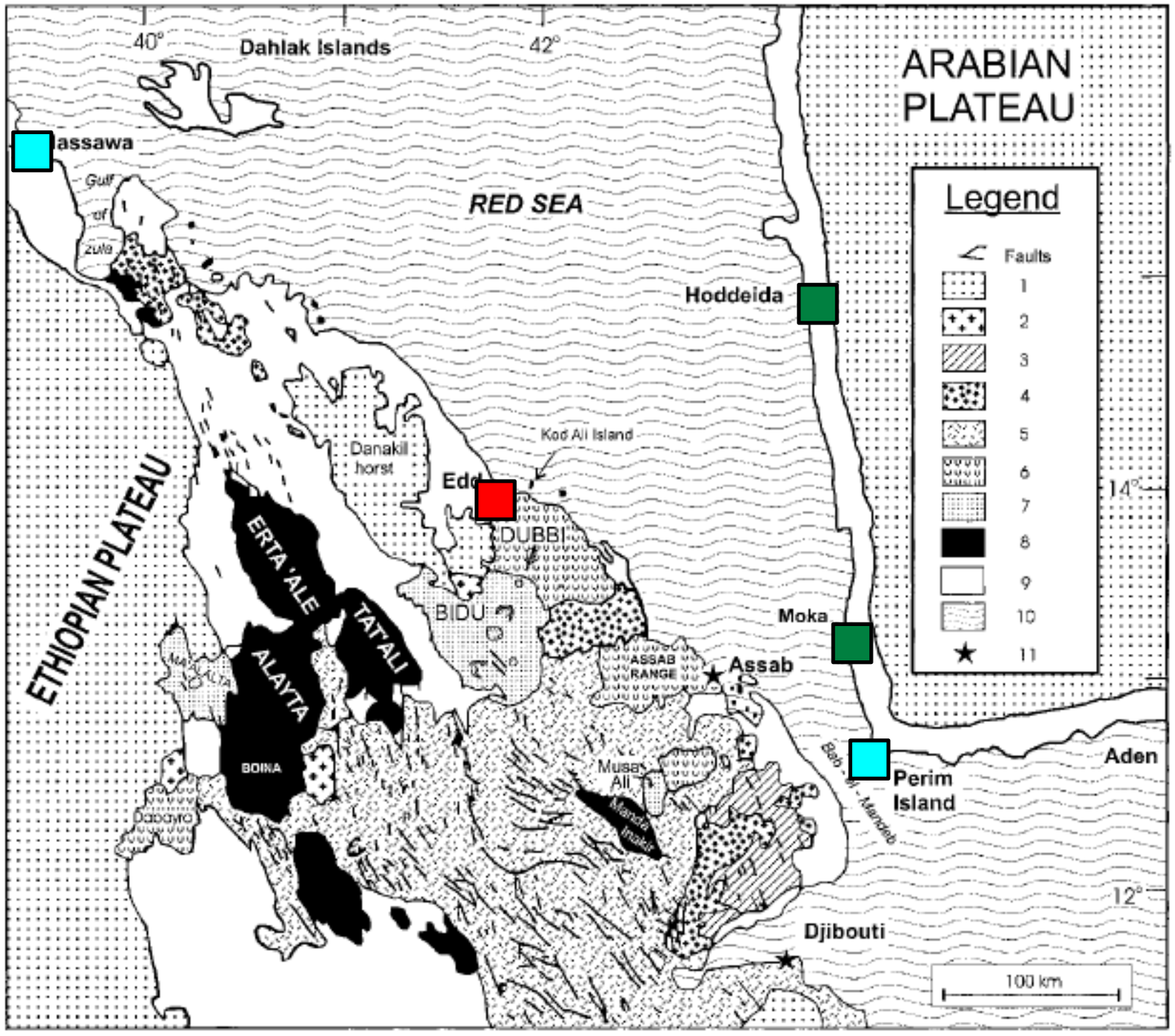
Explosive eruptions



- Magnitude and intensity are not directly related (duration also important)
- Making accurate measurements of volume (and intensity) difficult
- Often assessed only for fall deposits

data from Carey & Sigurdsson (1989), Carey et al. (2007); Costantini et al. (2009), Houghton et al. (2004), Pistolesi et al. (2011), Pyle (2000); Wong & Larsen (2009)

May 1861 eruption of Dubbi



Ash fall

Felt earthquakes

Explosion heard

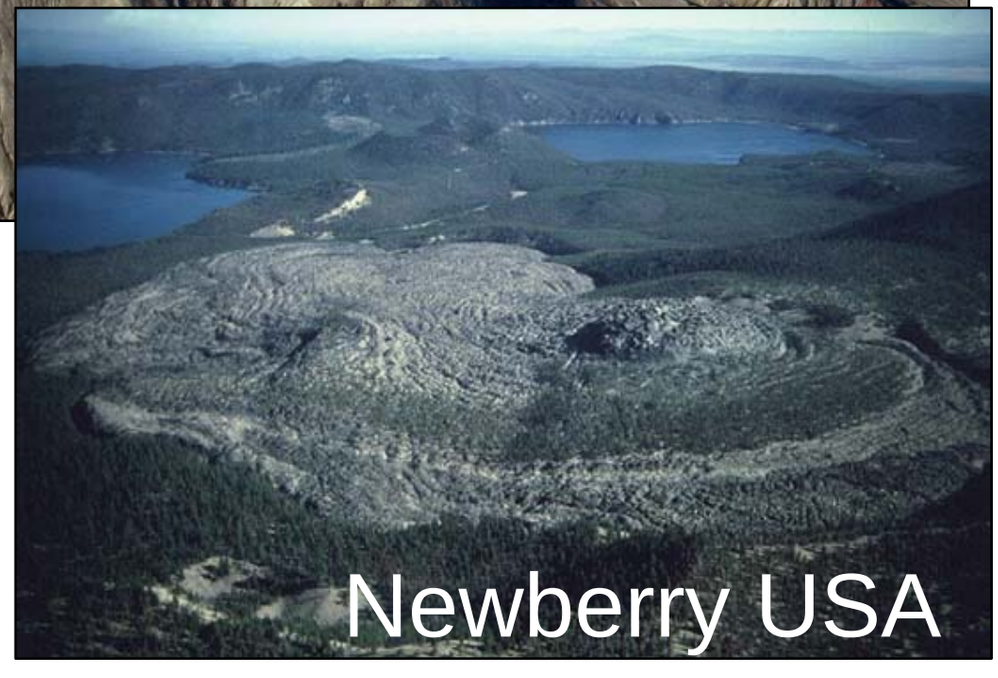
440 km^2 pumice
2.6 km^3 mafic lava

2 villages destroyed
> 100 fatalities

Wiart et al. (2000)


N
11.1 km
© 2011 Cnes/Spot Image
Image © 2011 DigitalGlobe
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
©2010 Google
Imagery Date: 4/25/2007
13°43'06.22" N 41°50'21.98" E elev 236 m
Eye alt 49.27 km

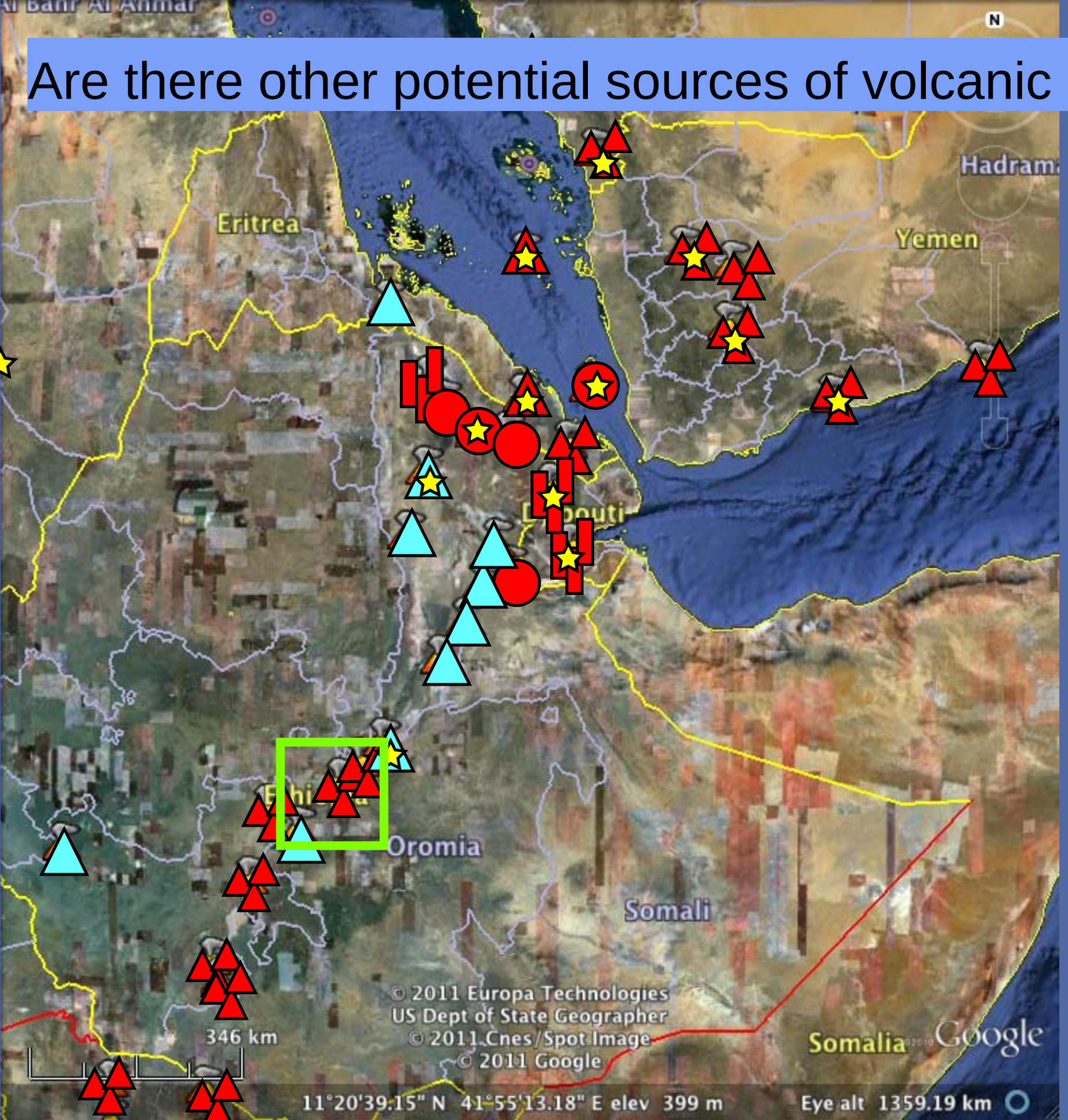
Stratovolcanoes - effusive eruptions



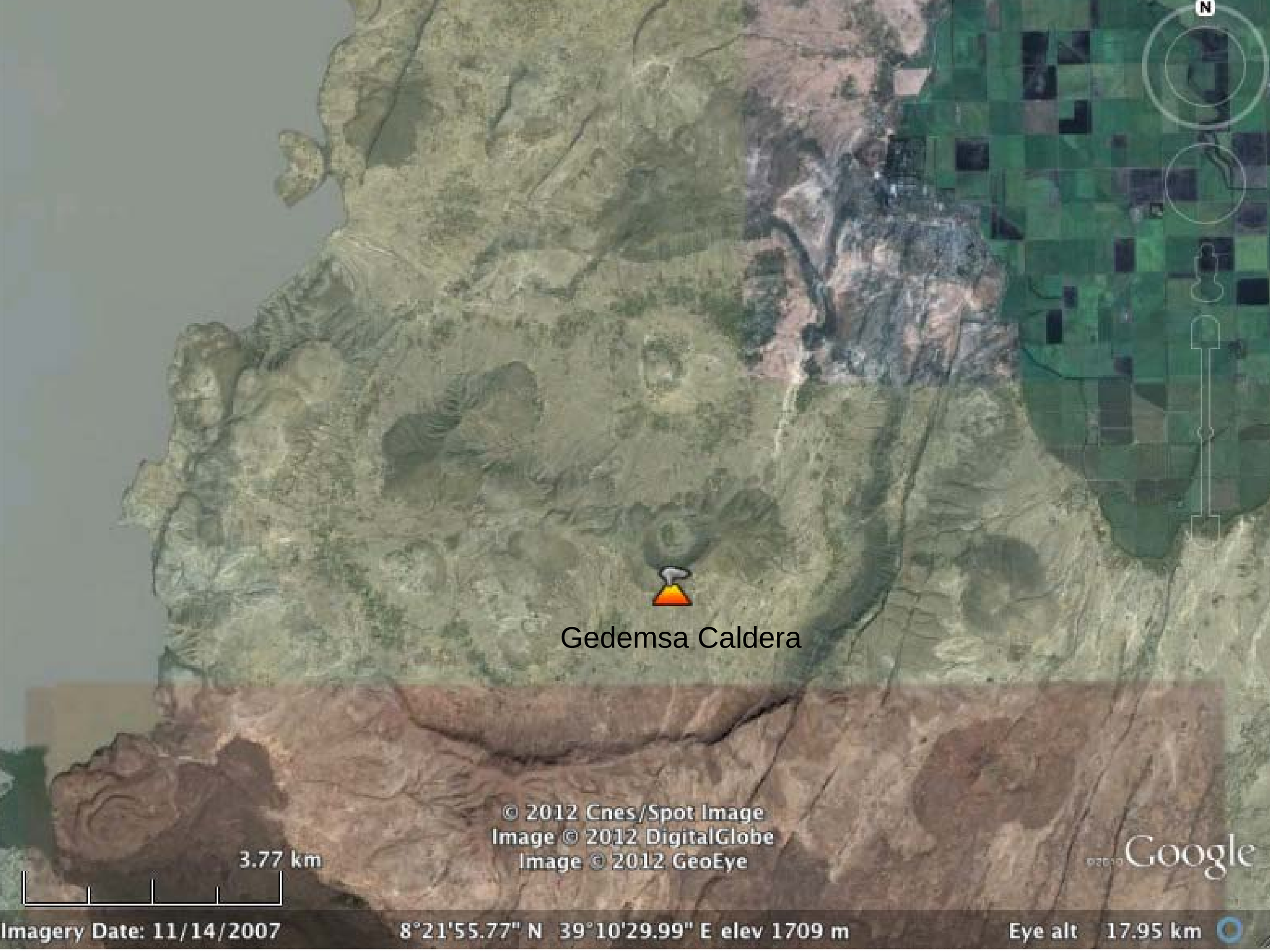
Hazards of effusive eruptions

Obsidian flows may be preceded by violent explosive eruptions

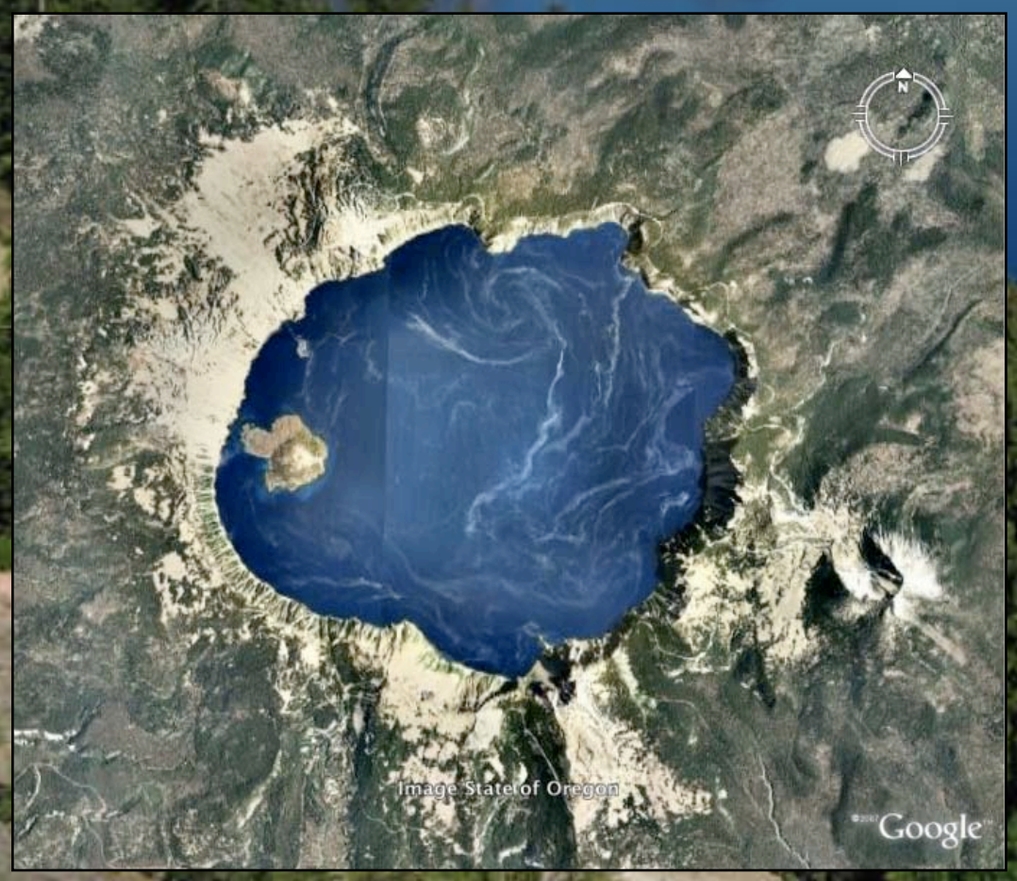
Are there other potential sources of volcanic hazard?



- Historic eruptions
- Fissure vents
- Volcanic fields
- Mafic shield
- Silicic centers

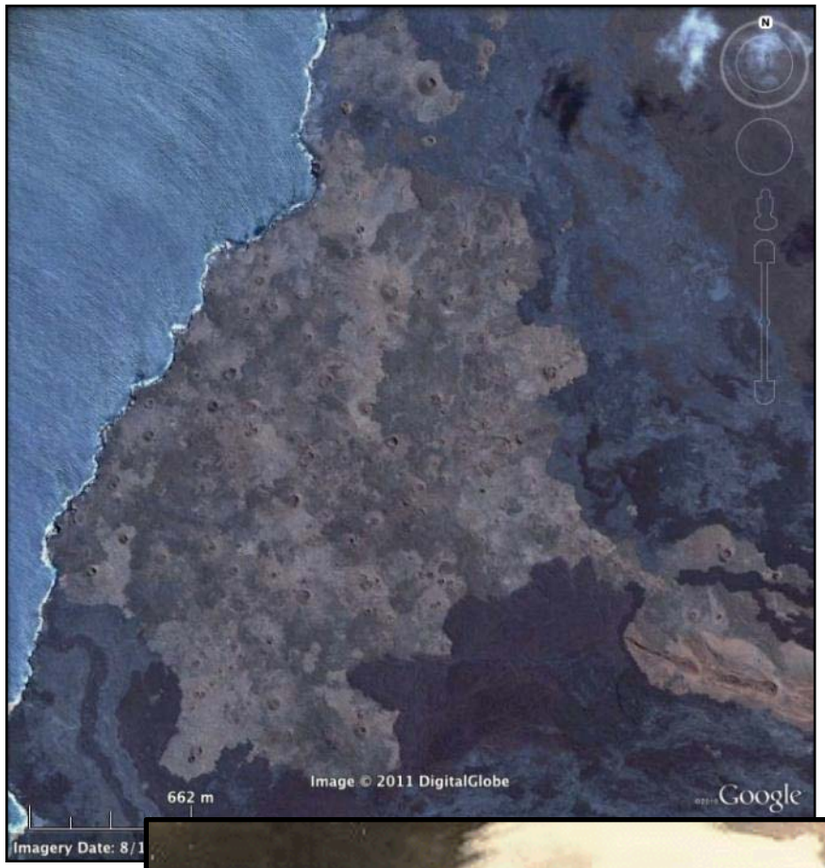

N
Gedemsa Caldera
© 2012 Cnes/Spot Image
Image © 2012 DigitalGlobe
Image © 2012 GeoEye
3.77 km
Google
Imagery Date: 11/14/2007
8°21'55.77" N 39°10'29.99" E elev 1709 m
Eye alt 17.95 km

Crater Lake, OR c. 7700 ybp ~50 km^3 DRE



Return to the question of the large MT anomaly beneath Dabbahu... what is required to generate a caldera-forming eruption?

Hydrovolcanic eruptions



- Lava flows that enter water

- Eruptions through standing water

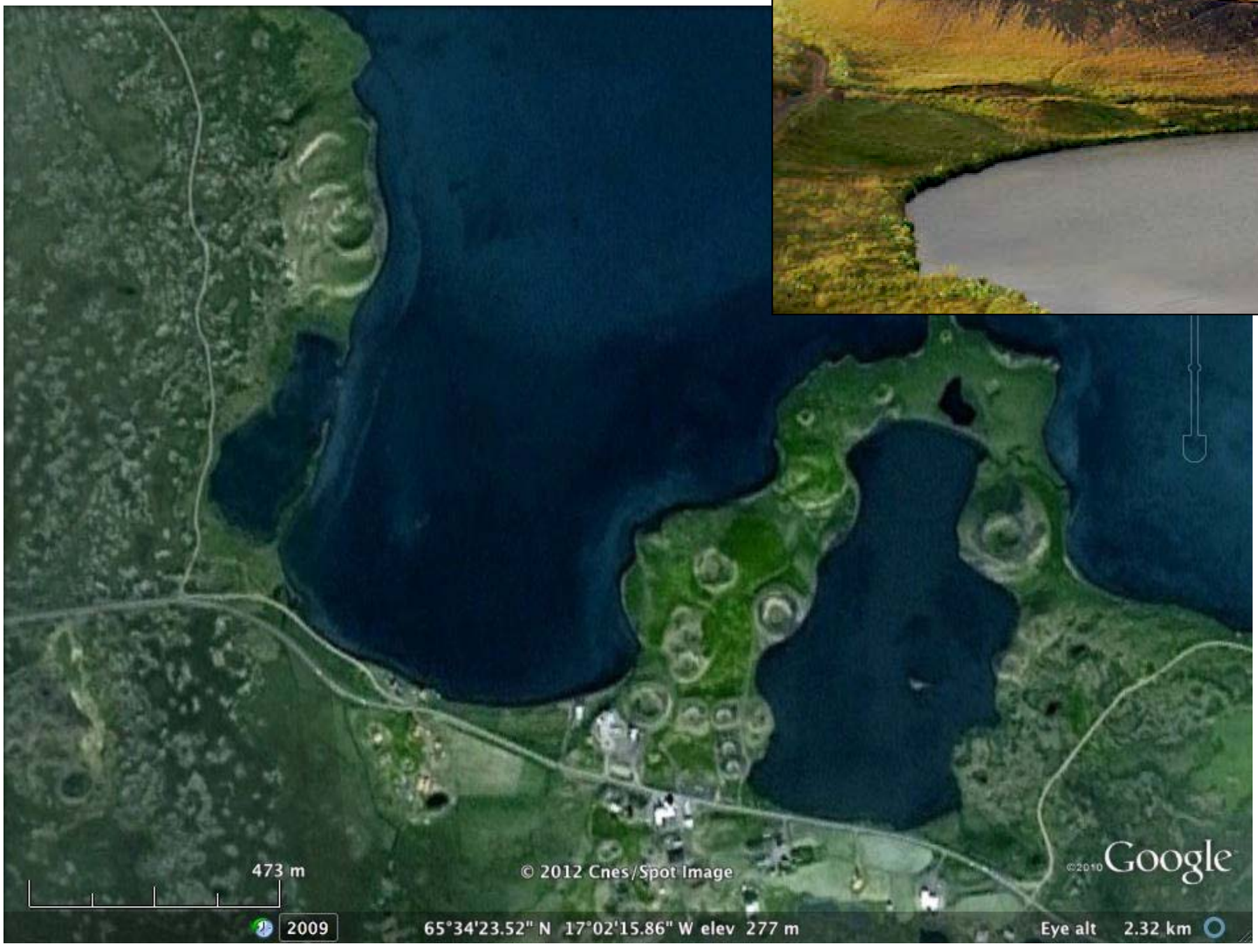
- Phreatic eruptions

Maars and tuff cones

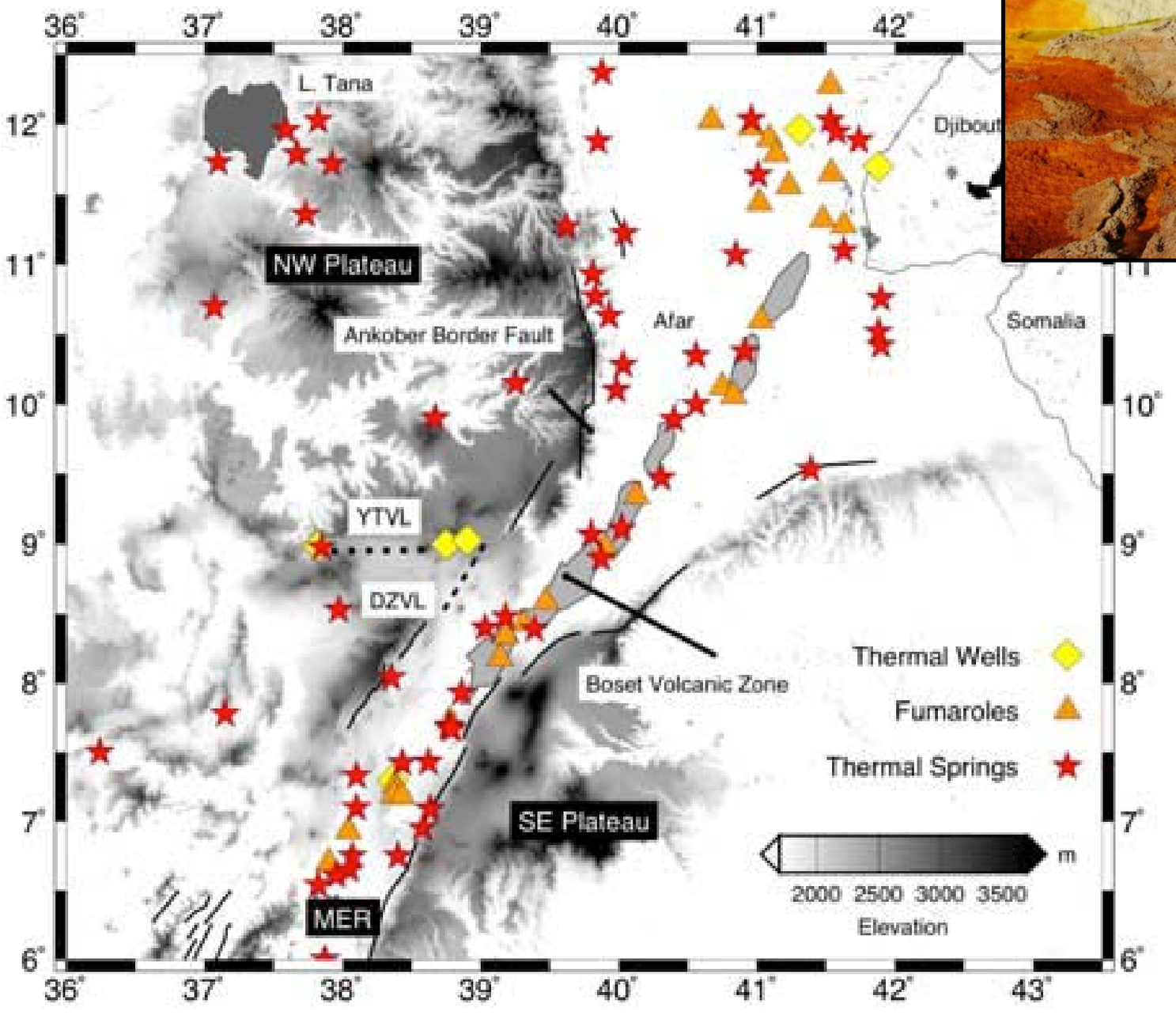
Hawassa

Hydrovolcanism in Afar/Red Sea

Lake Myvatn, Iceland



Phreatic eruptions



Keir et al. (2009)

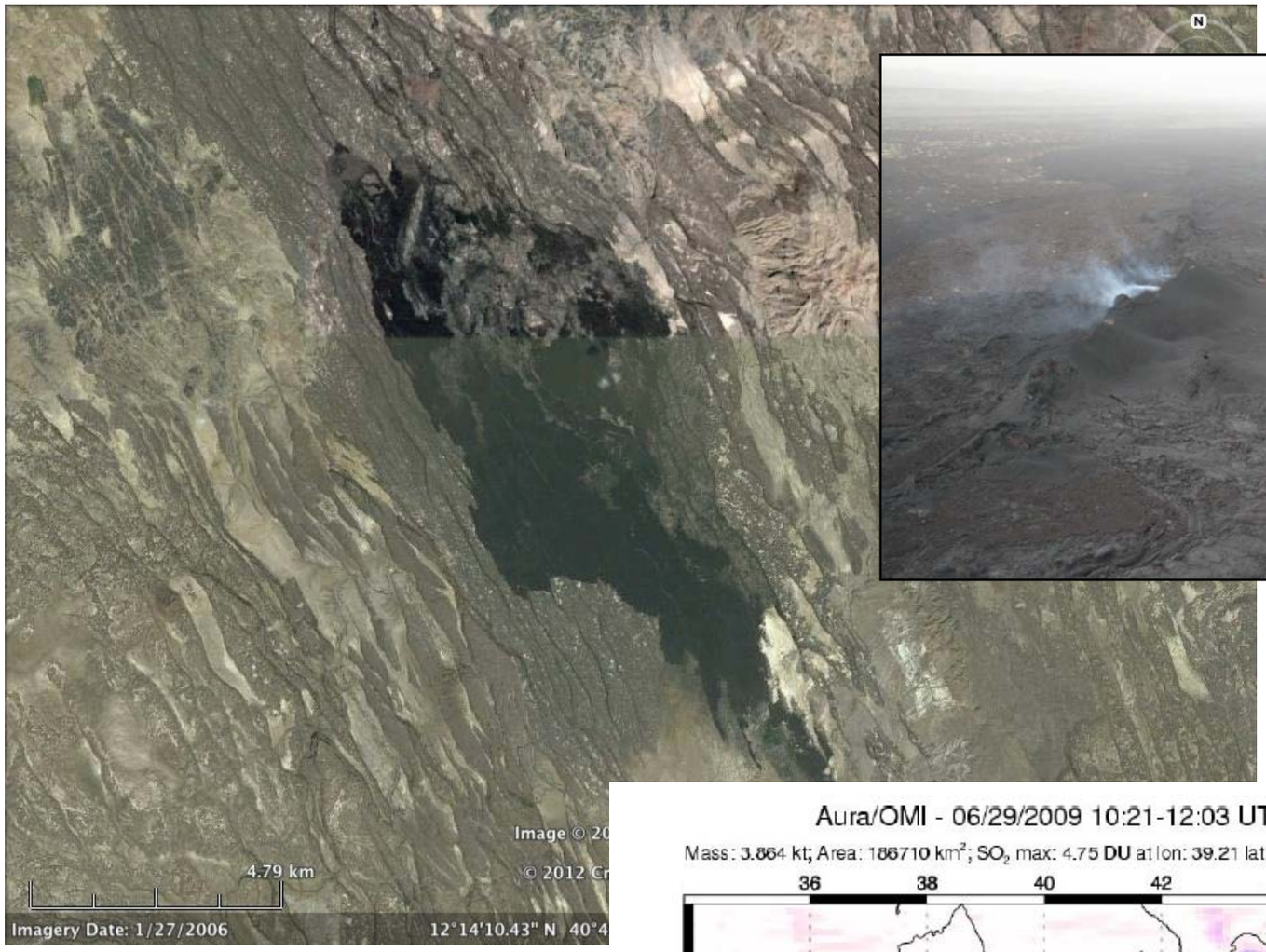
http://www.phenomenica.com/2009/04/dallol-hell-on-earth.html

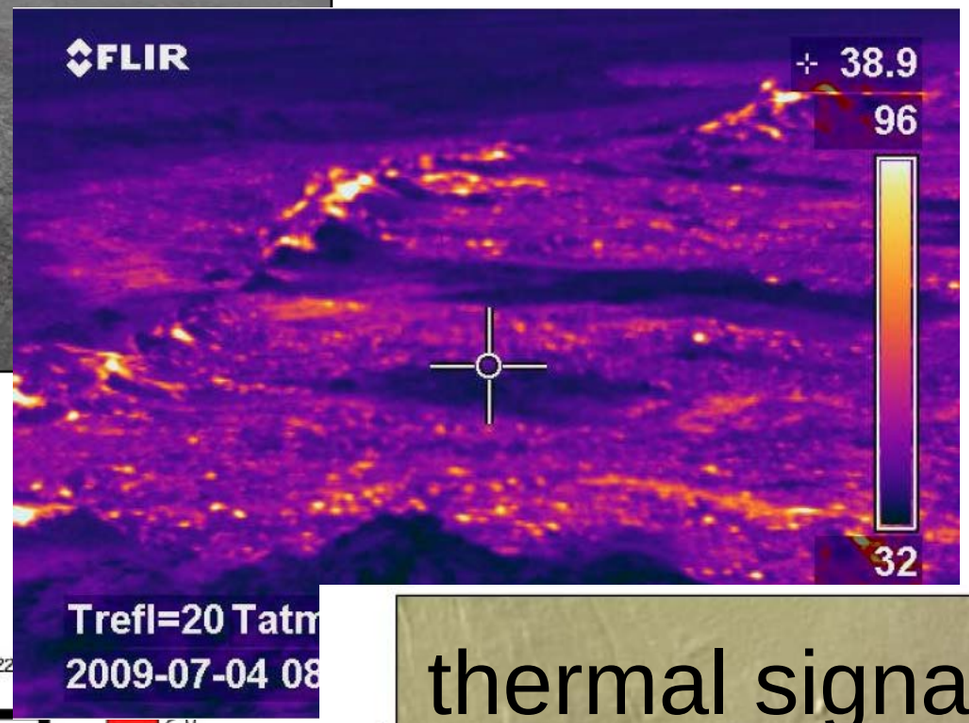
Dallol is an Afari term that means dissolution or disintegration

To Summarize

- Rifting environments in general, and Ethiopia specifically, exhibit a wide range of volcanic activity
- Although there is no simple spatio-temporal relationship to eruptive activity, we can see that areas of active rifting tend to be dominated by fissures fed by axial volcanoes
- More evolved magma where magma supply rates are lower
- Question of caldera-forming eruptions
- Concern about hydrovolcanic activity

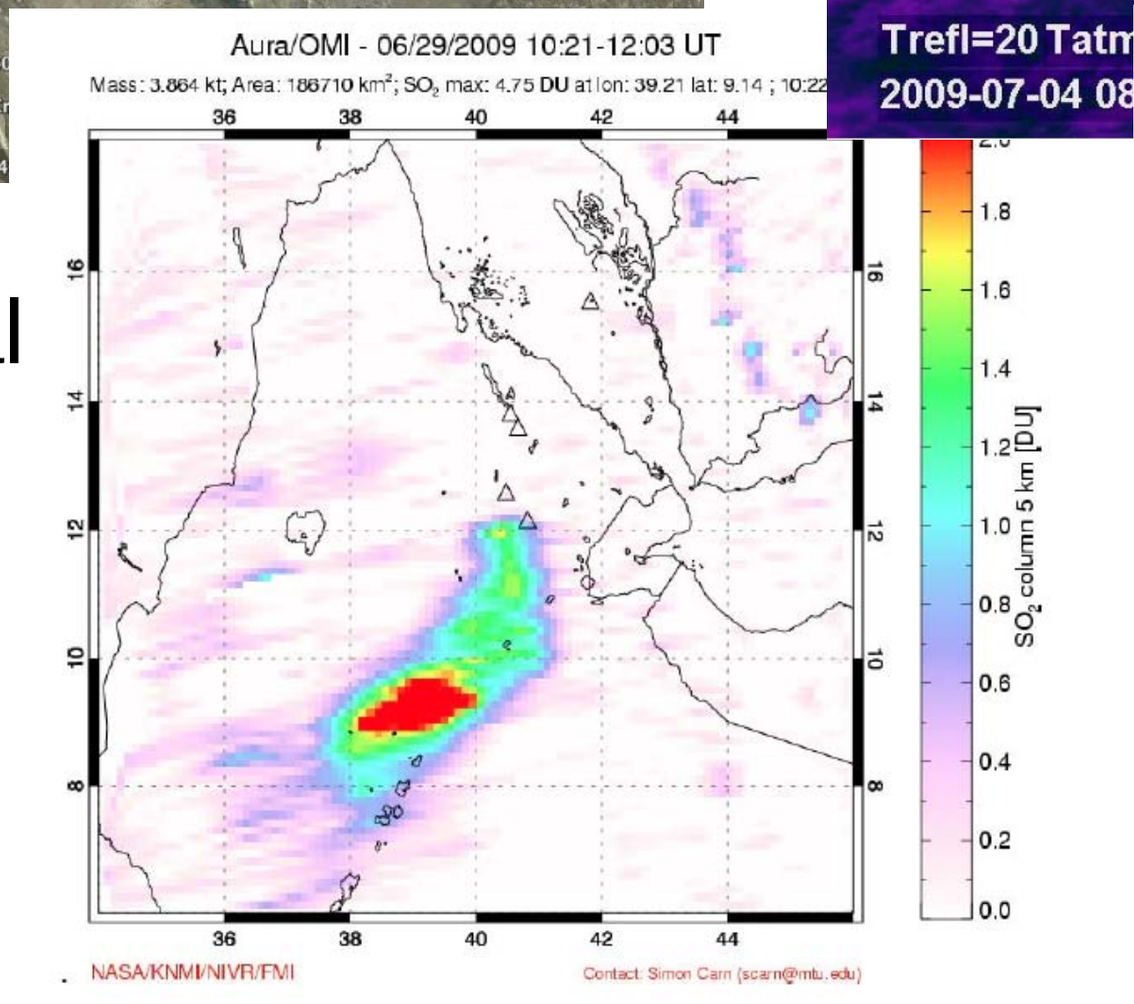
2009 Karbahi II eruption

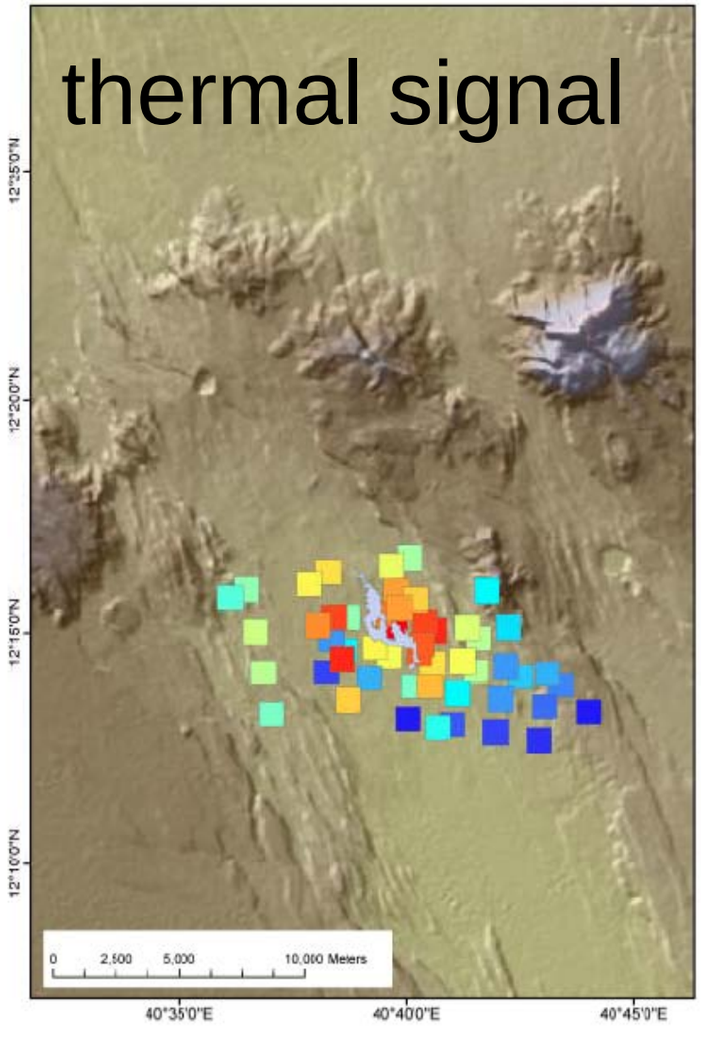




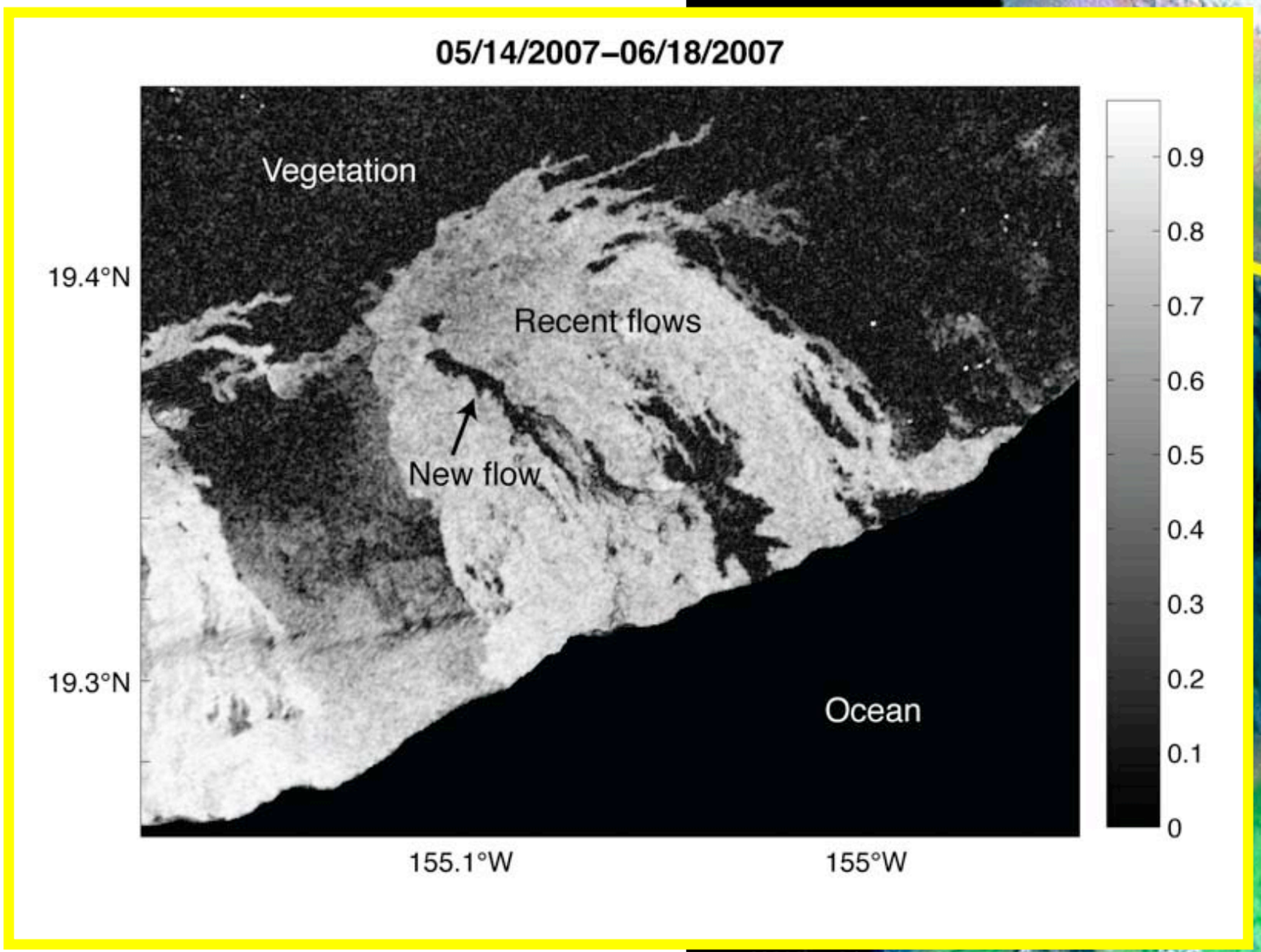
SO_2 signal

from Yirgu et al. preliminary report 2009



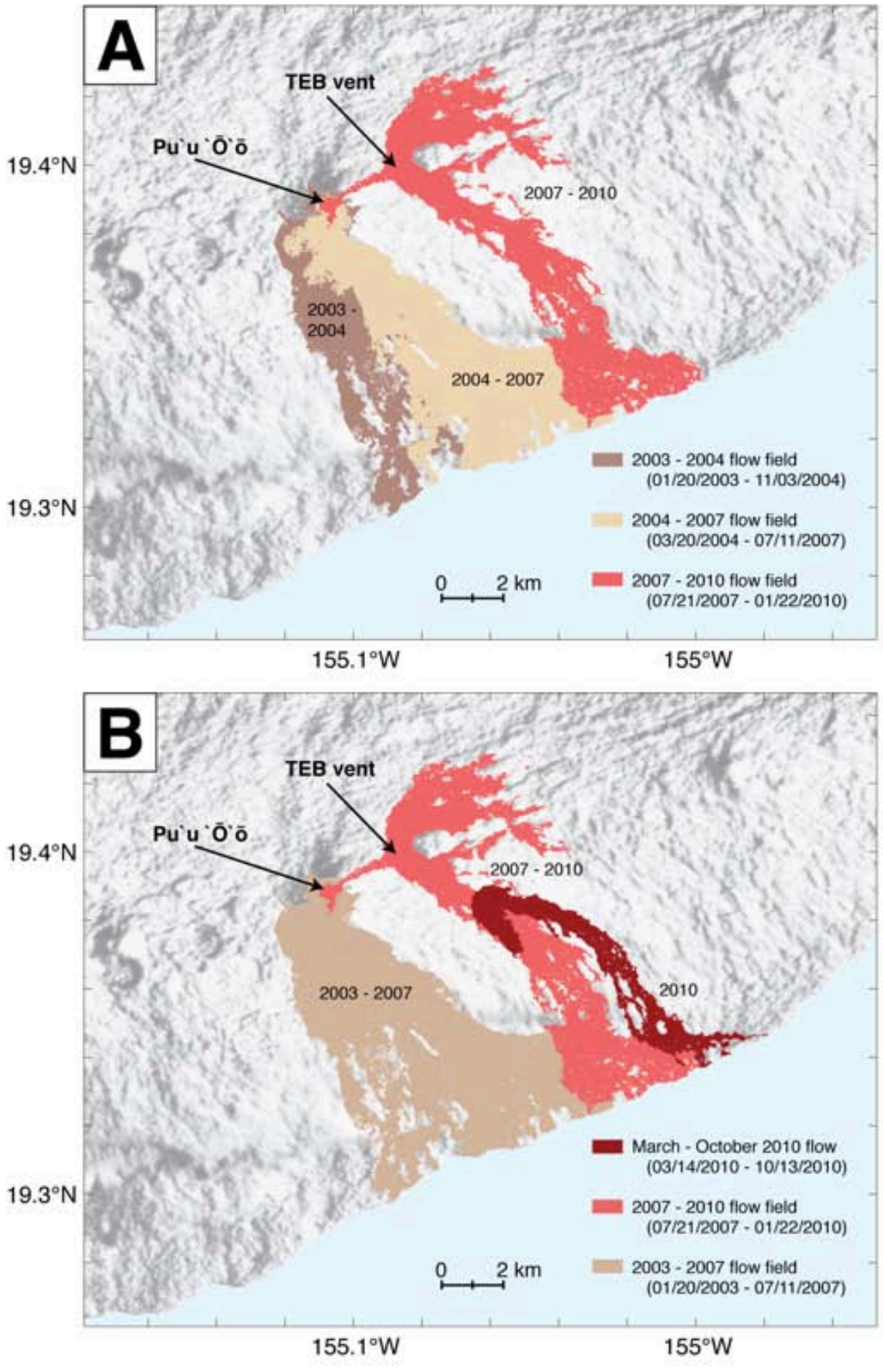


Real-time mapping of active flows

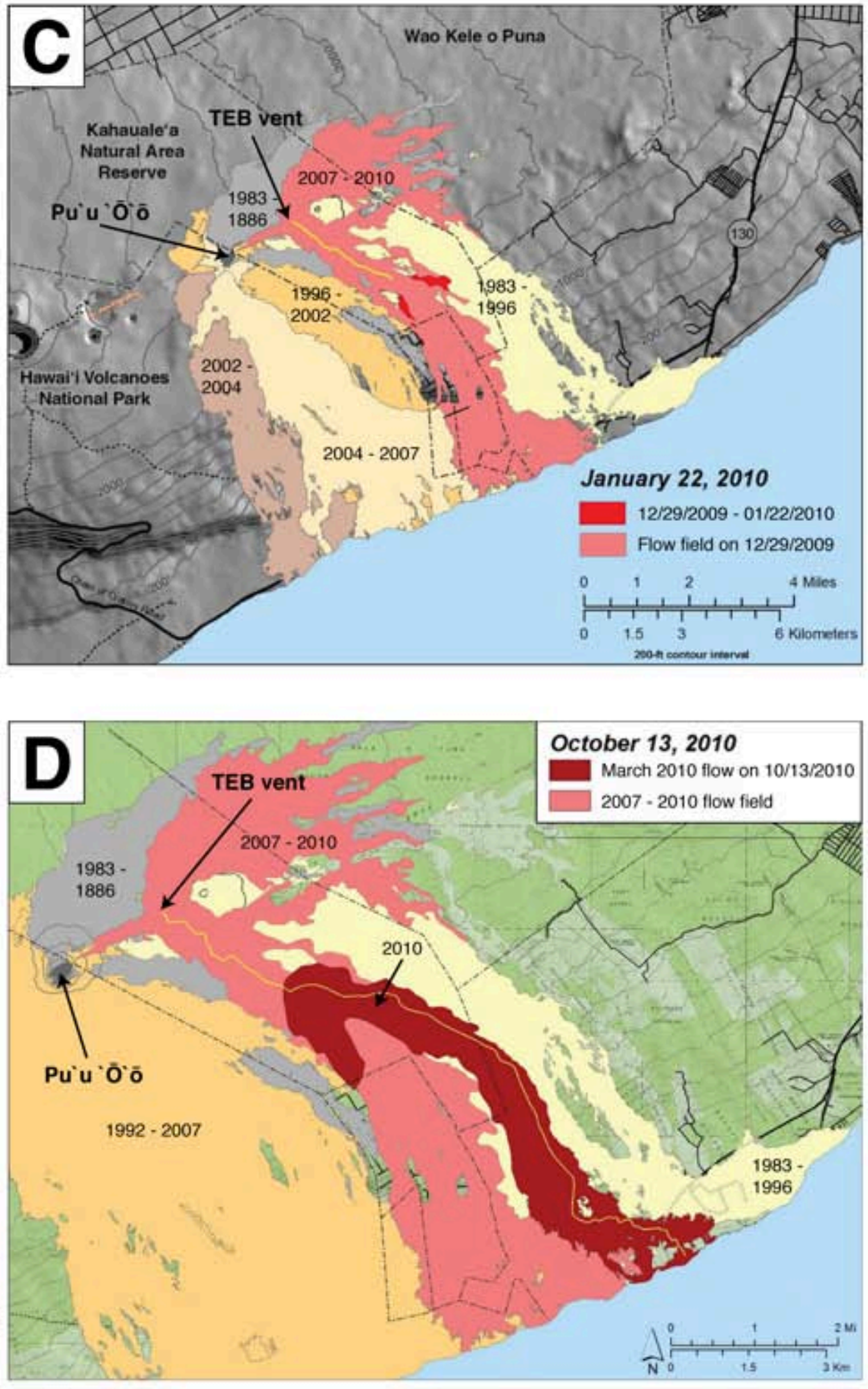


SAR decorrelation mapping Kilauea 2003-2010

SAR-derived flow maps



USGS flow maps



Dietterich et al. (in review)

Effusive eruptions - what are the hazards?

Hazards mostly related to property...

persistent activity may adversely affect air and water quality

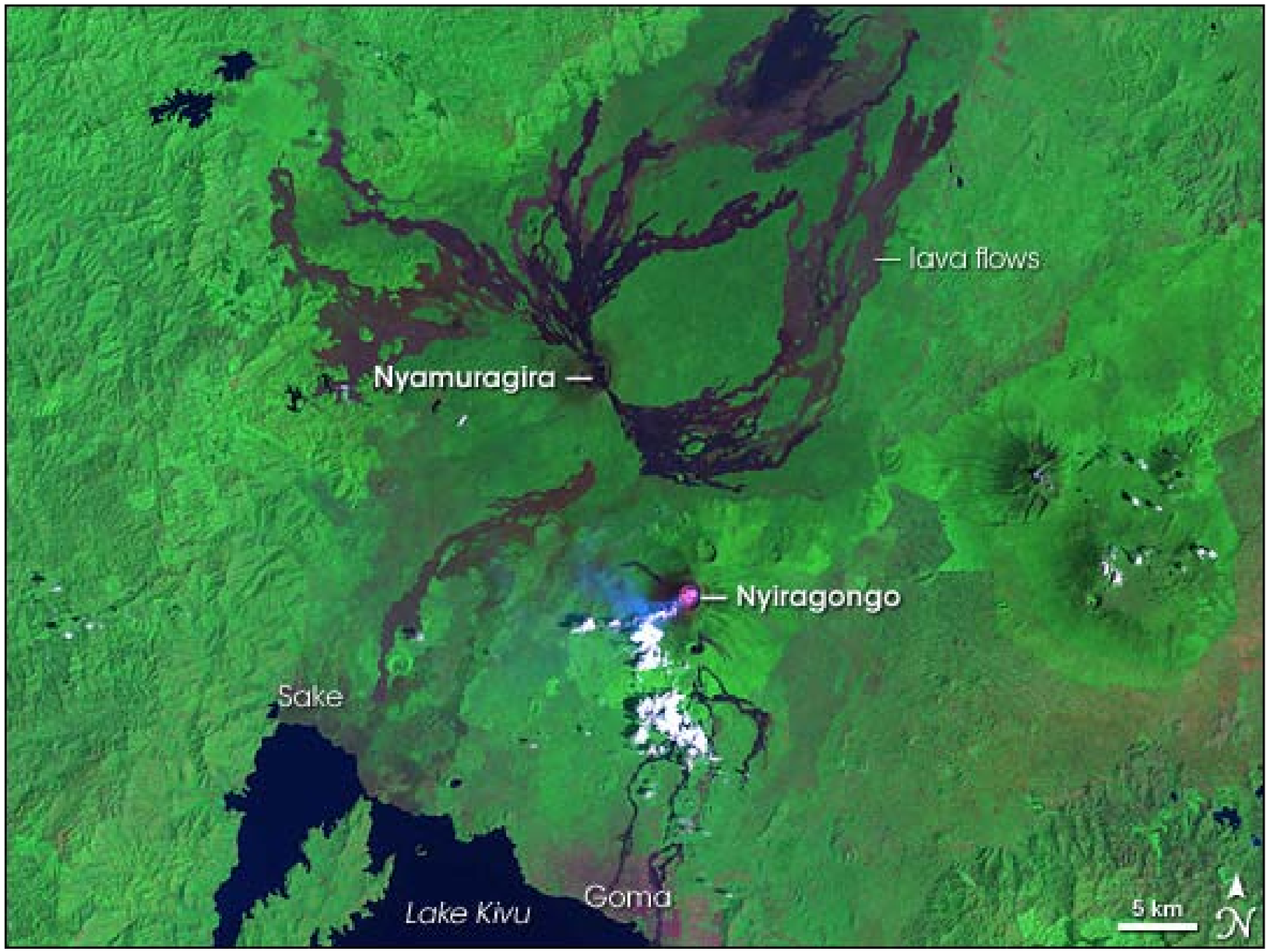
What determines the hazards?

Where?

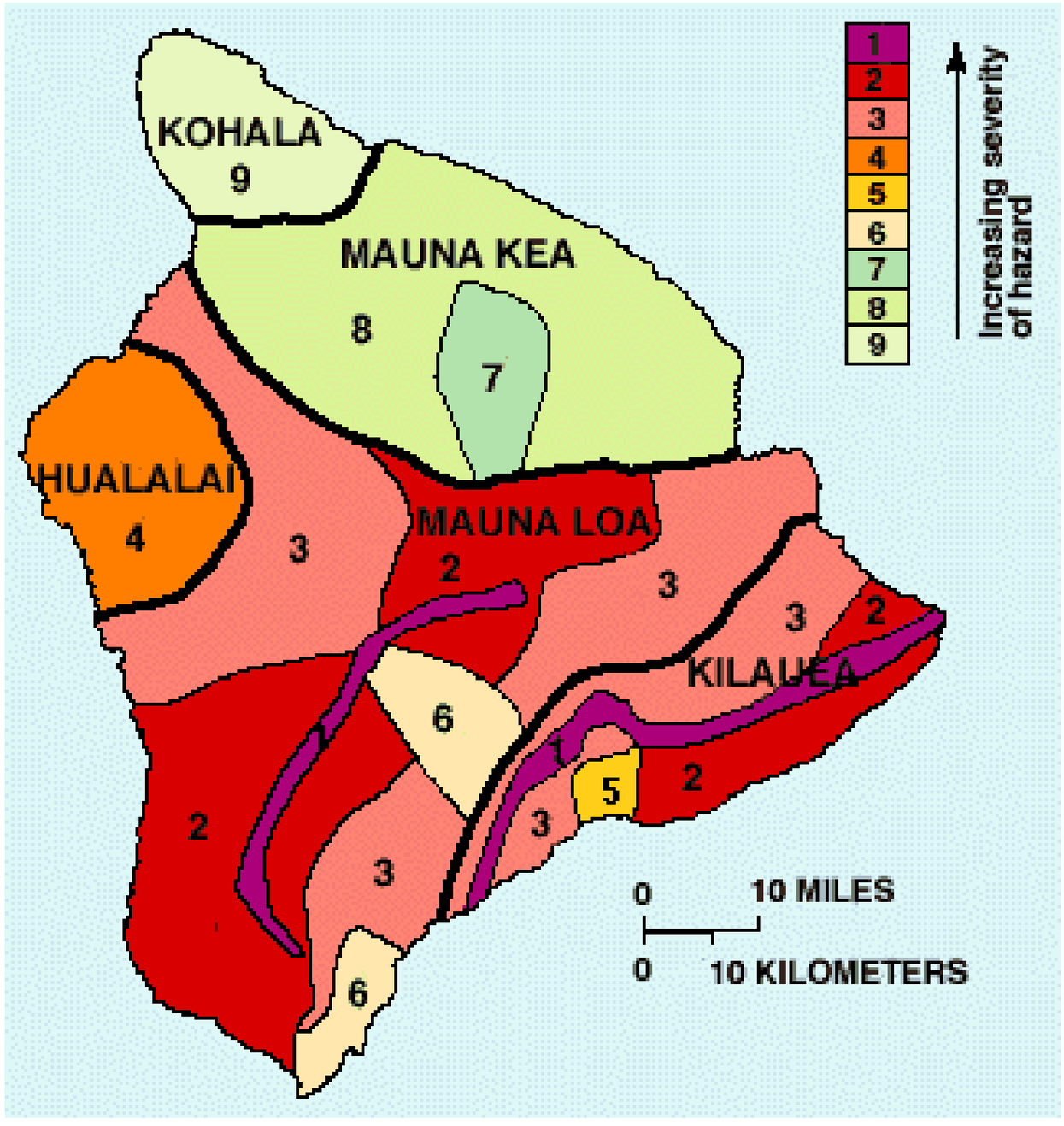
How often?

Flow velocity
[how fast?]

Areal coverage
[how far?]



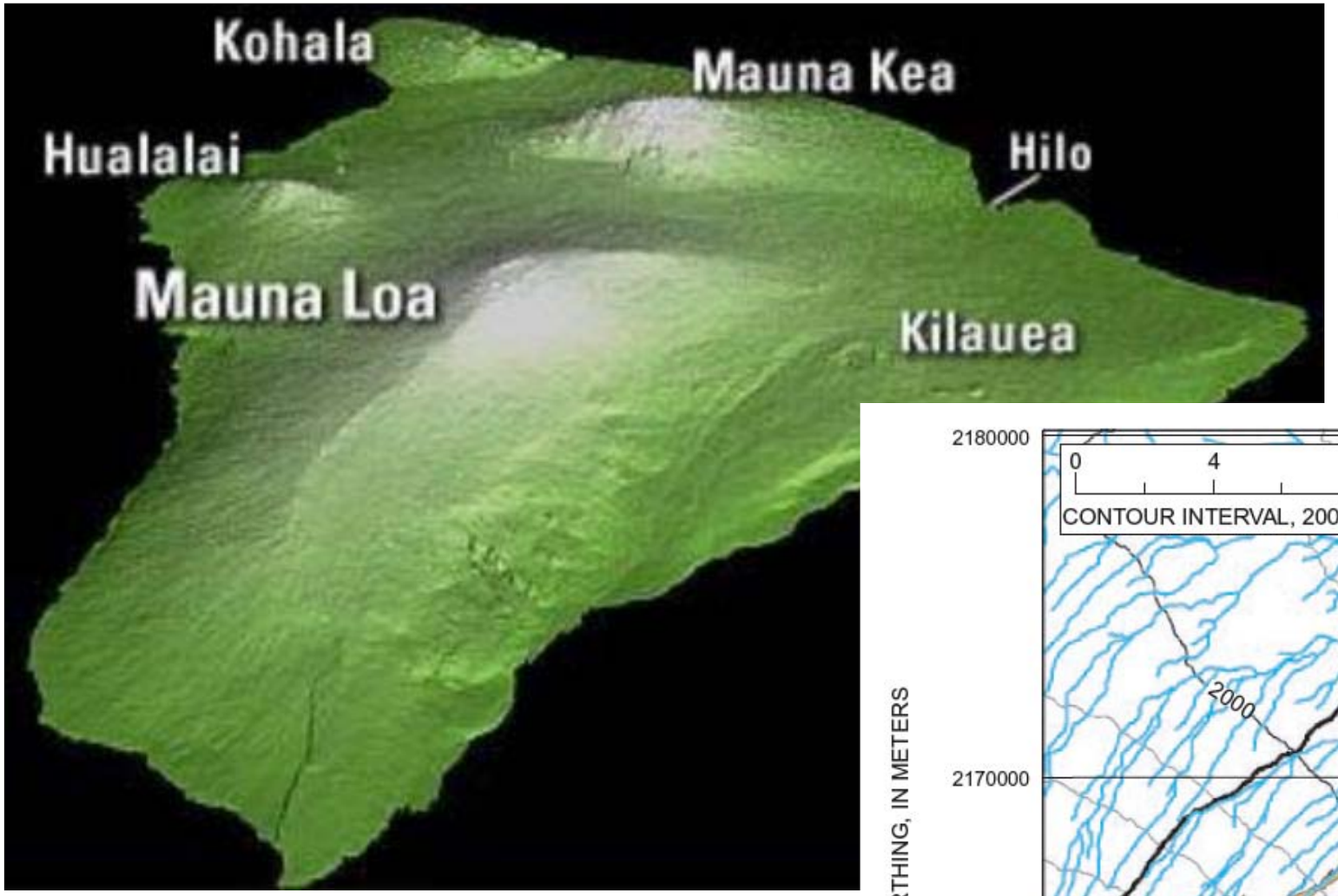
Hazard mapping



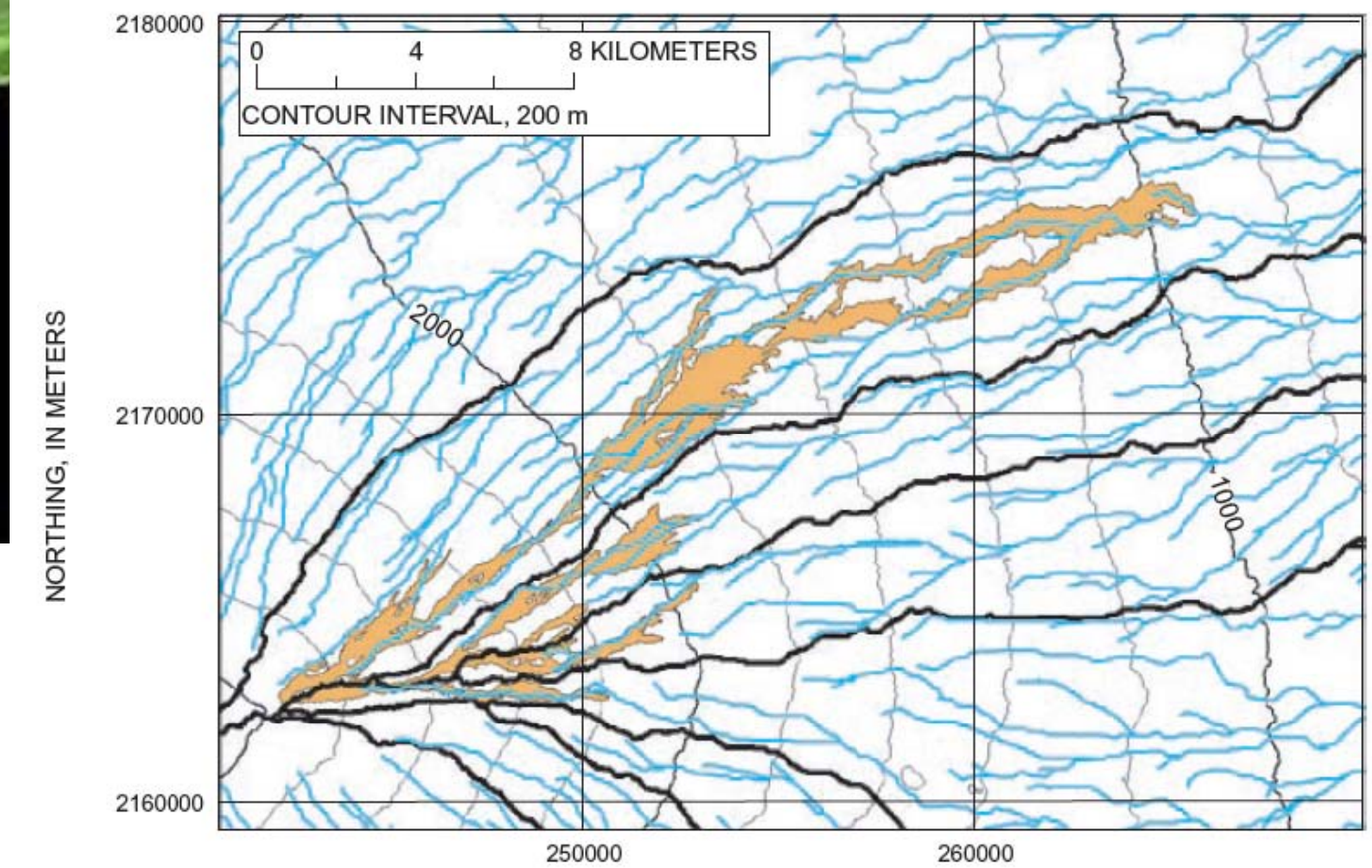
Lava flow hazards maps in Hawaii (or Etna, IT) are based on past activity (%area covered over time)...

It is not clear that this is the best approach for an environment like the Afar, where volcanism is distributed in space and may vary widely in composition

Where?

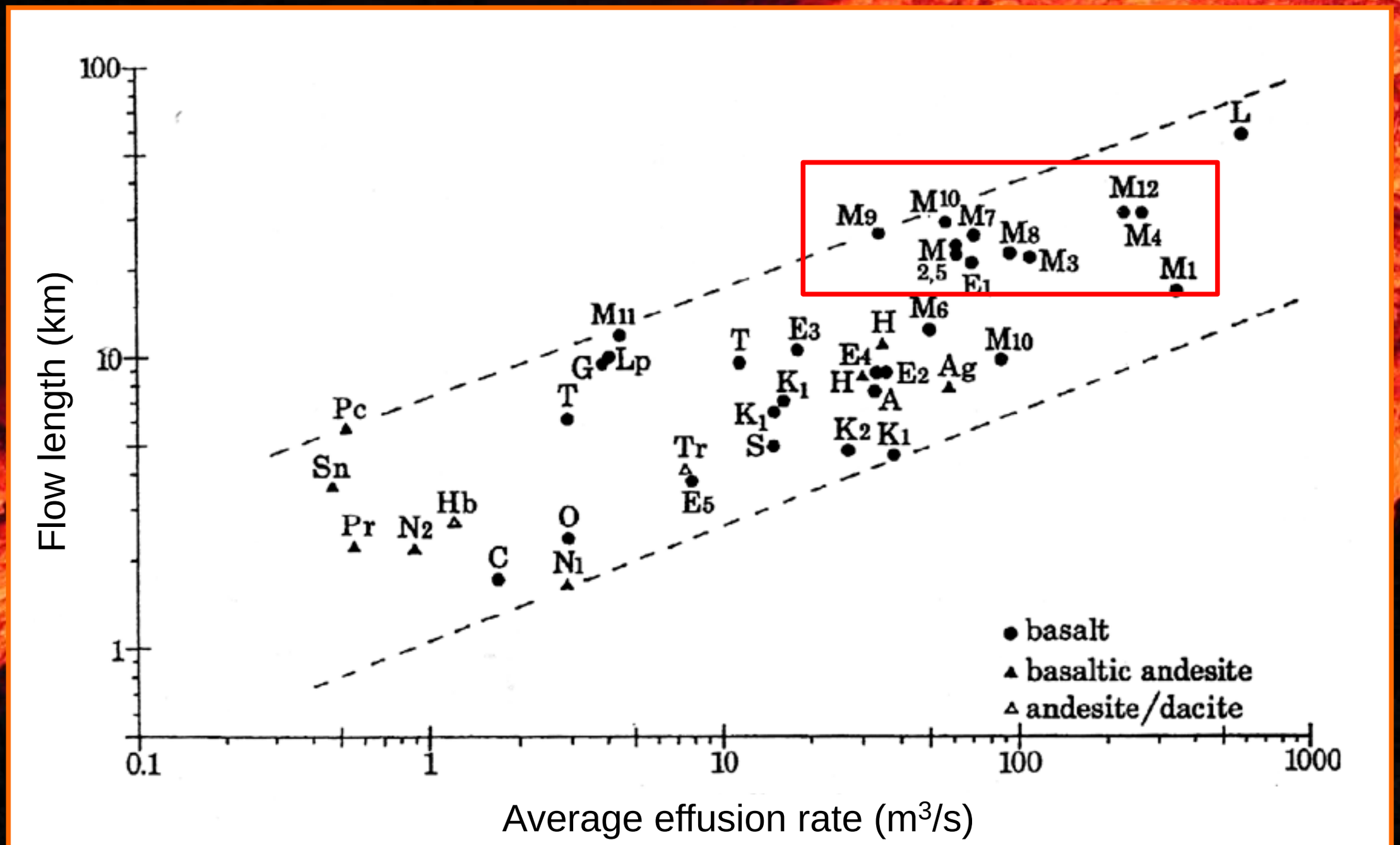


Once the vent is established, possible flow paths can be predicted using “lava sheds”



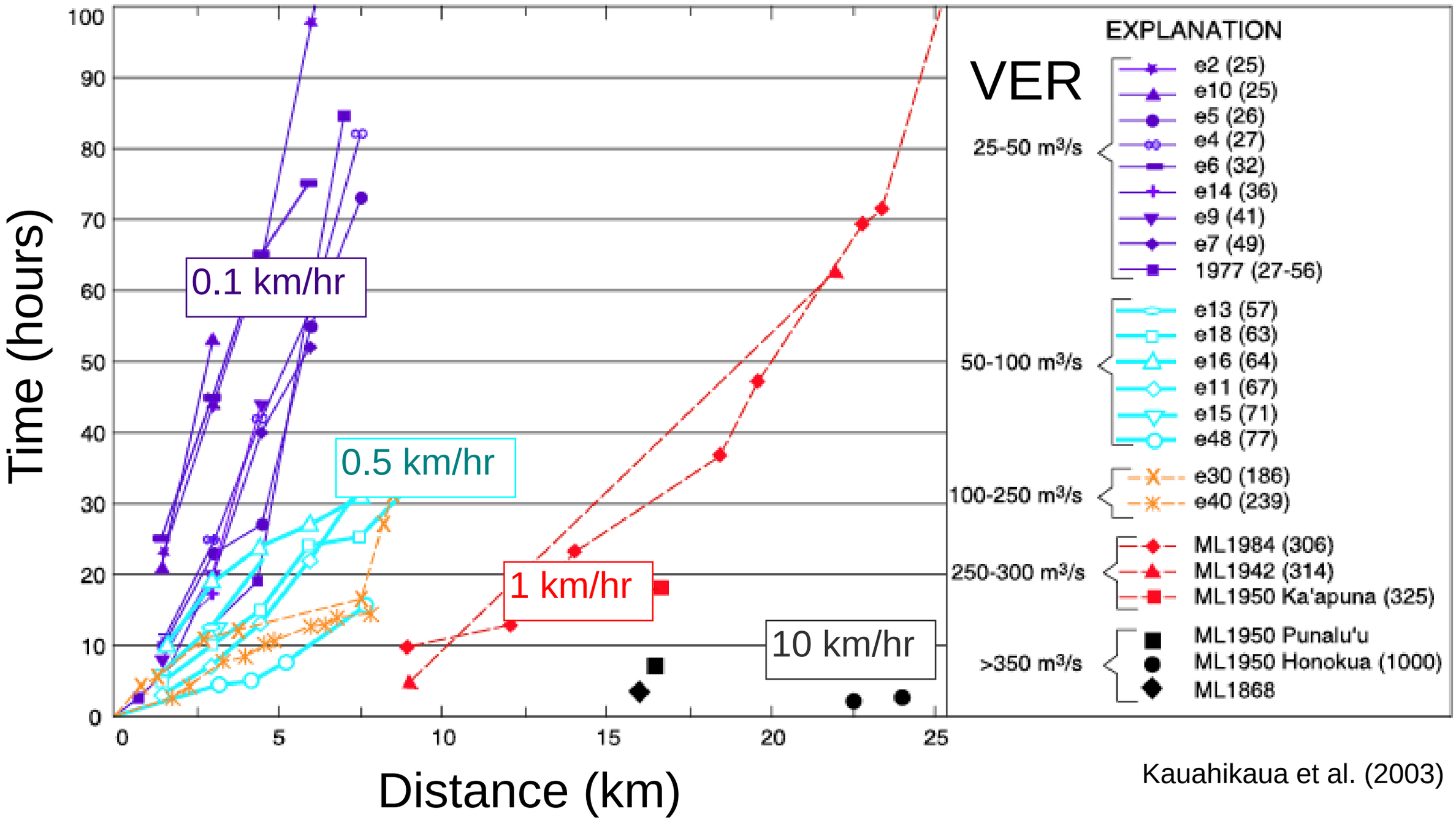
Kauahikaua et al. (2003)

How far?



Walker (1973)

Flow advance rates (how fast?)

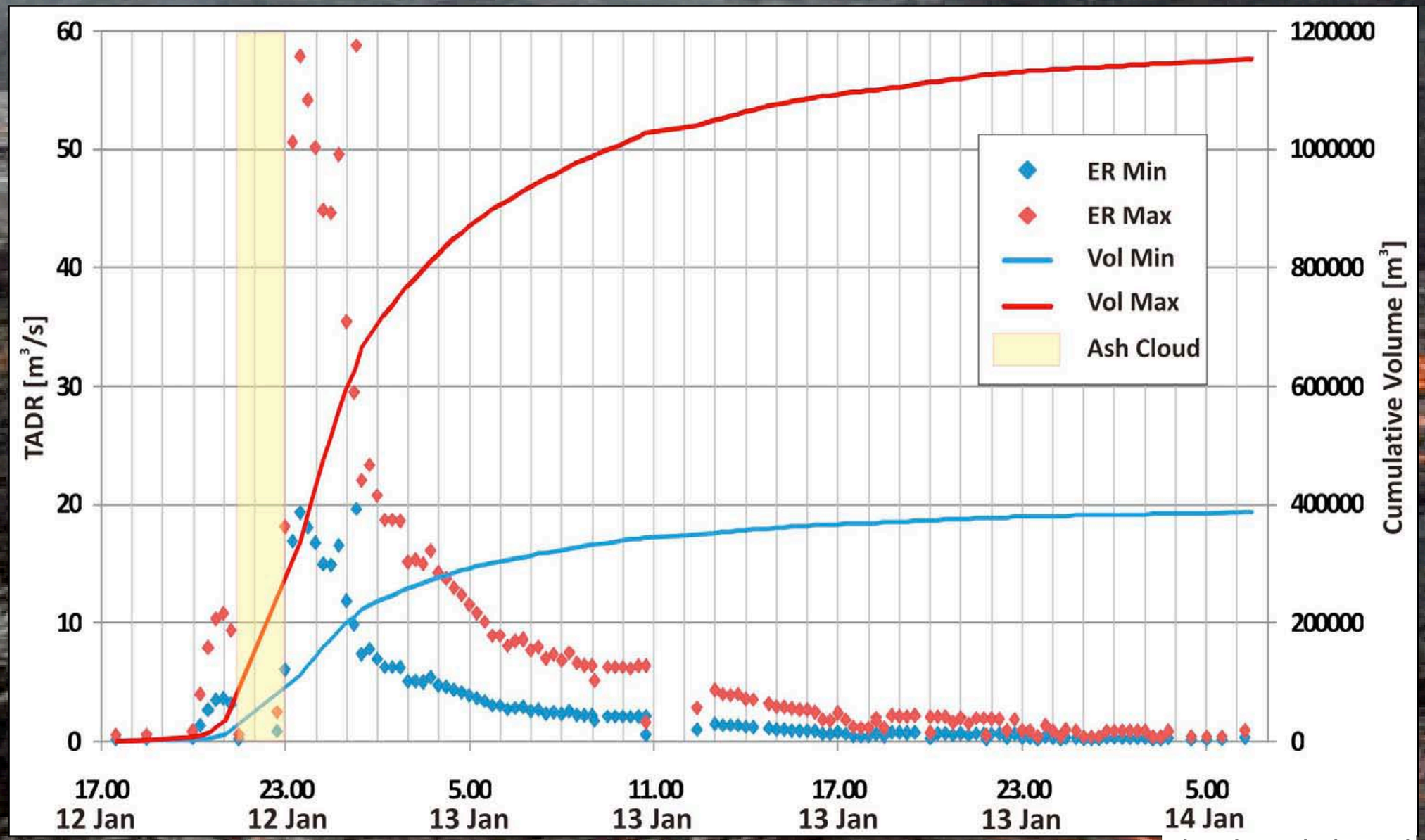


Kauahikaua et al. (2003)

How to measure MER?

Making direct measurements on active flows is challenging...

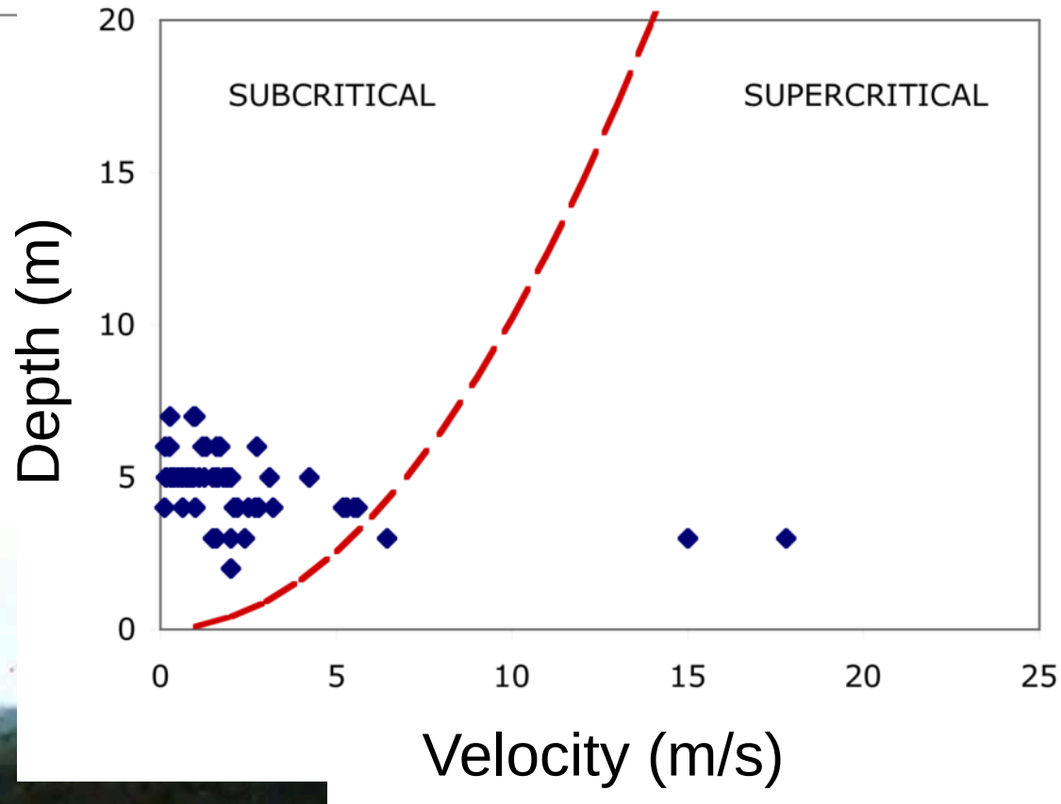
Thermal Imaging (time-averaged discharge rate)



Vicari et al. (2011)

Using observed flow features?

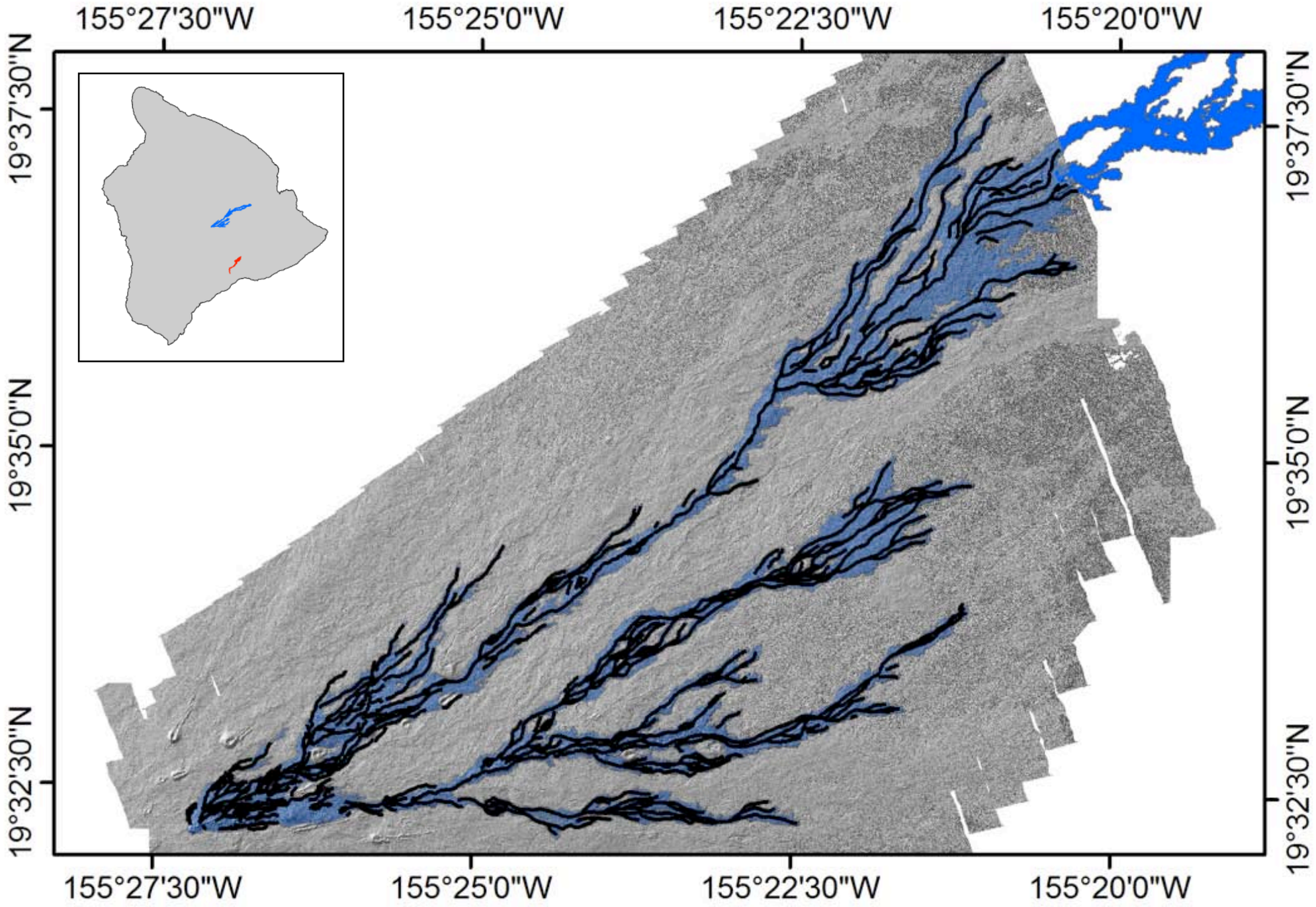
Standing waves in lava channel, east rift zone of Kilauea Volcano. The height of the wave is approximately 2–3 m (November 6, 1983, C.A. Neal).



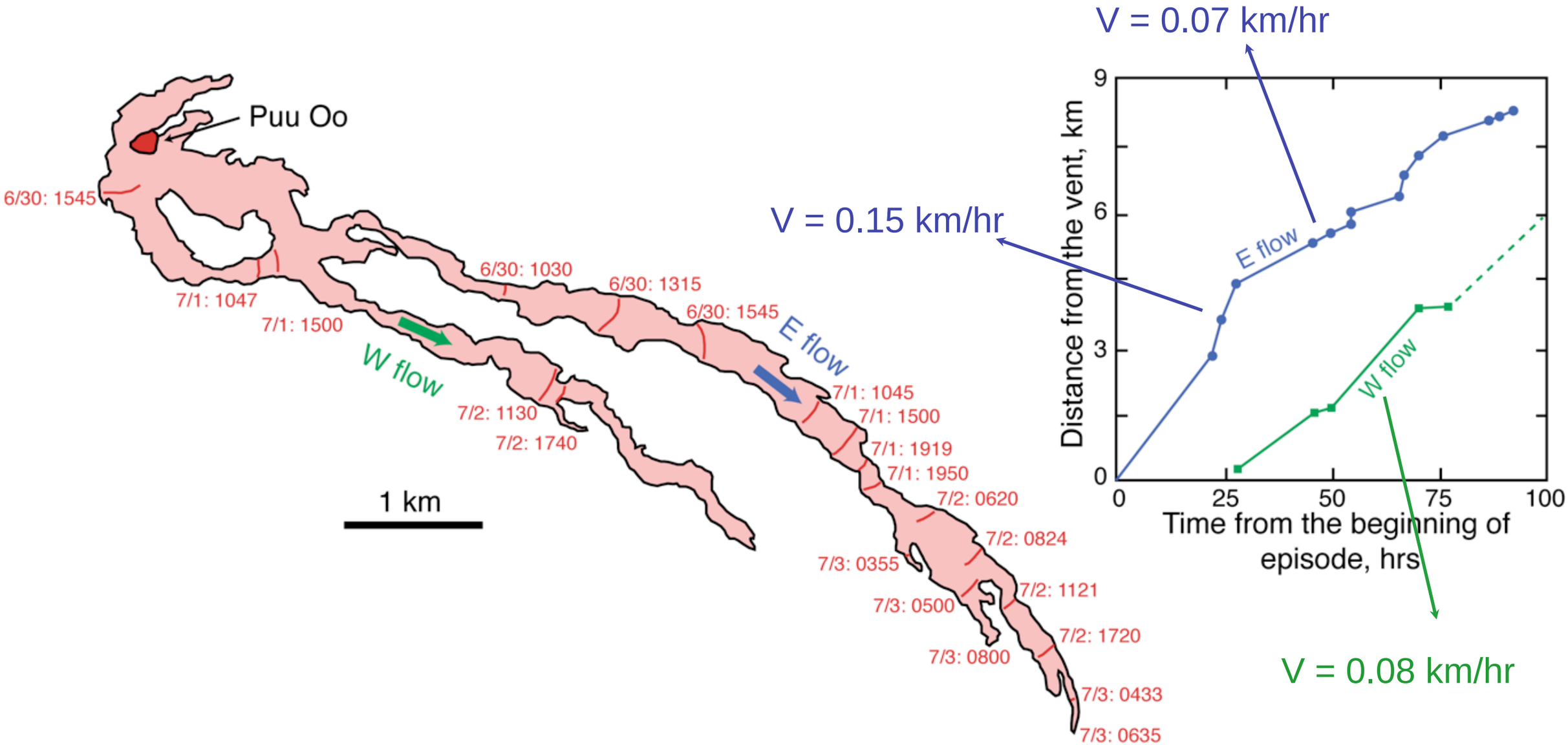
$Fr = 1$

$V = \sqrt{gd}$

Flow branching



Flow branching also affects flow advance rate



Episode 5

data from Wolff et al. (1988)

155°20'0"W

155°17'30"W

19°22'30"N

19°20'0"N

19°17'30"N

Fissure vent

Koae fault zone

Topographic confinement
can increase flow length

Manda Hararo

Summary - Lava flow hazards

Hazards relate primarily to property damage... associated hazards include fires, volcanic gas, and ‘rootless’ explosions

Hazard impacts depend on magnitude and intensity (control area covered and rates of flow advance)

Remote sensing techniques for monitoring are improving rapidly