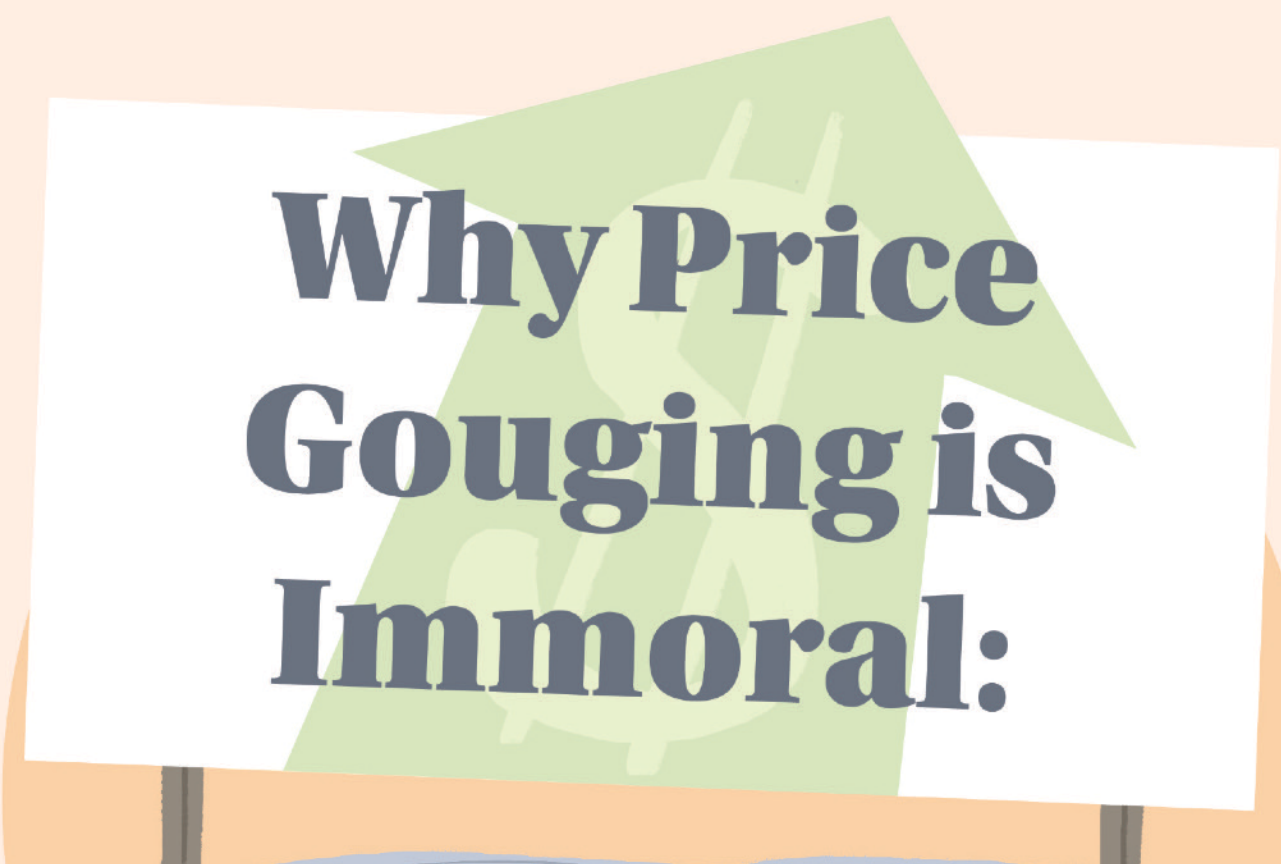


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**Why Price  
Gouging is  
Immoral:**

**Recovering  
from Disasters**

IEPA Guest Speaker:

**Dr. Elizabeth Brake**

5:30 PM

**Wednesday, October 17, 2018**

Batten Arts and Letters Building  
RM 1012

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# Natural Hazards and Disaster

Continued from:

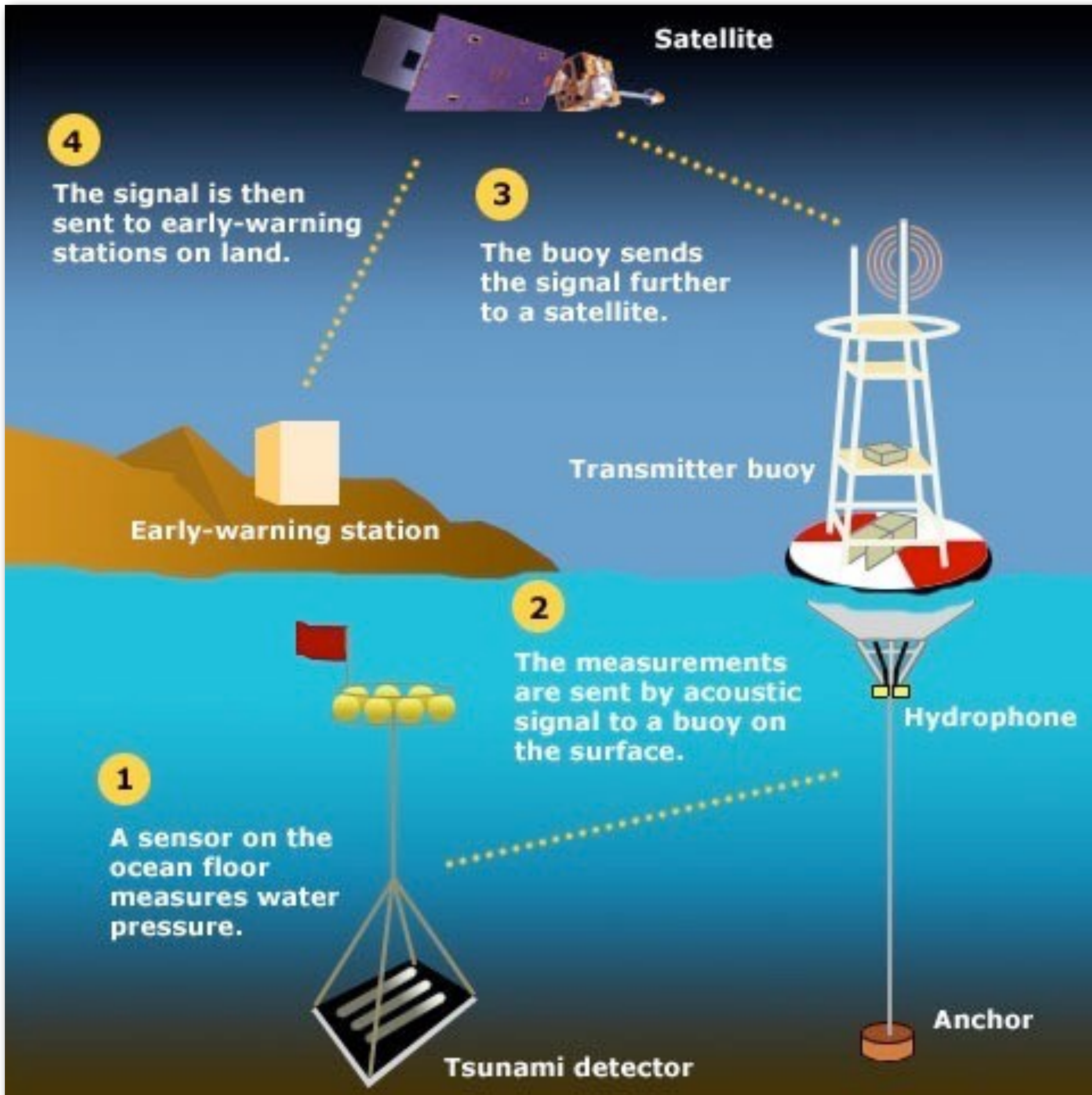
## Class 5: Disasters Triggered by Earthquakes and Tsunamis

- Waves
- Tsunamis
- Earthquake Tsunamis
- Landslide Tsunamis
- Tsunami Detection, Prediction and Awareness

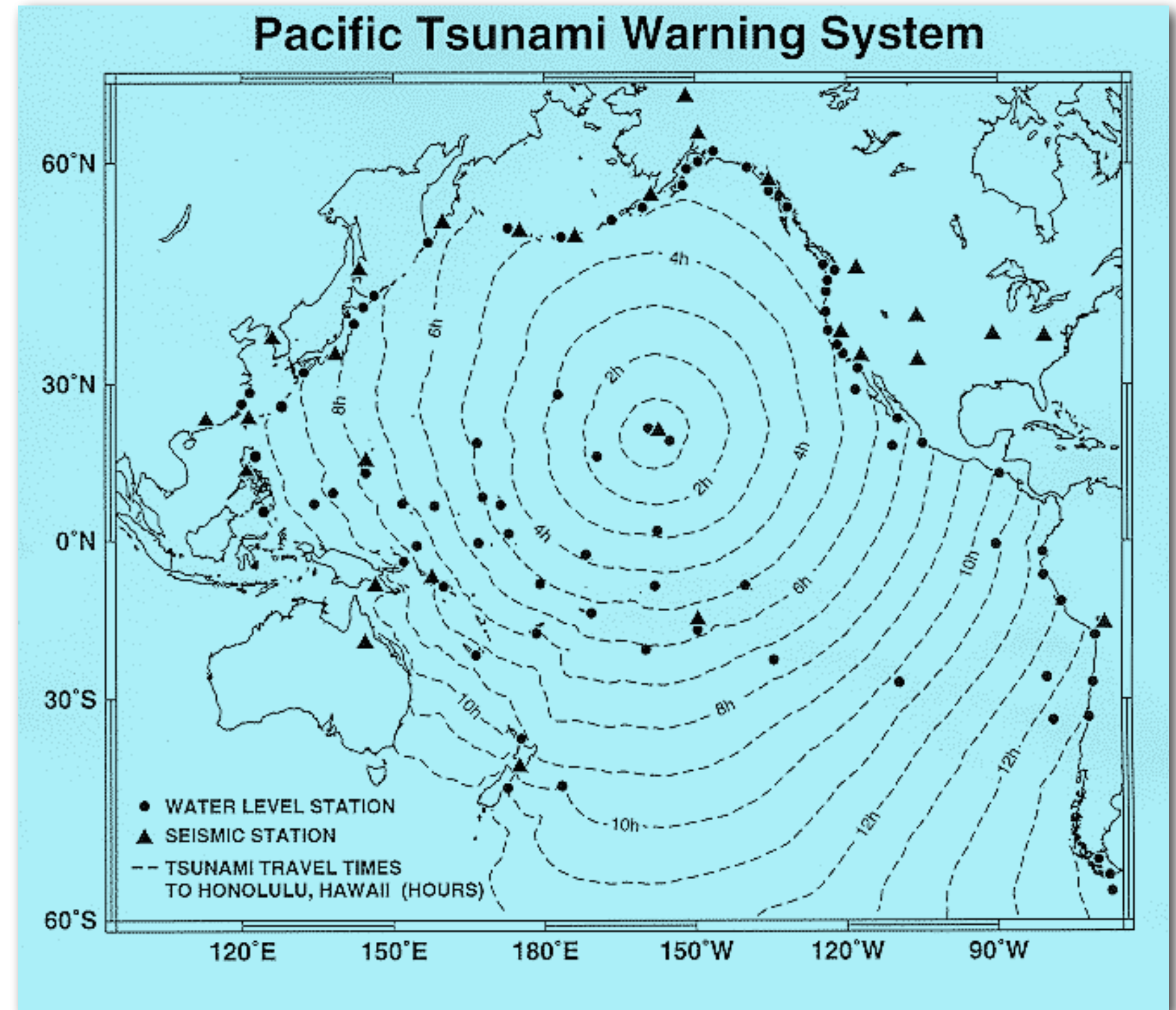
“Harbor Wave”



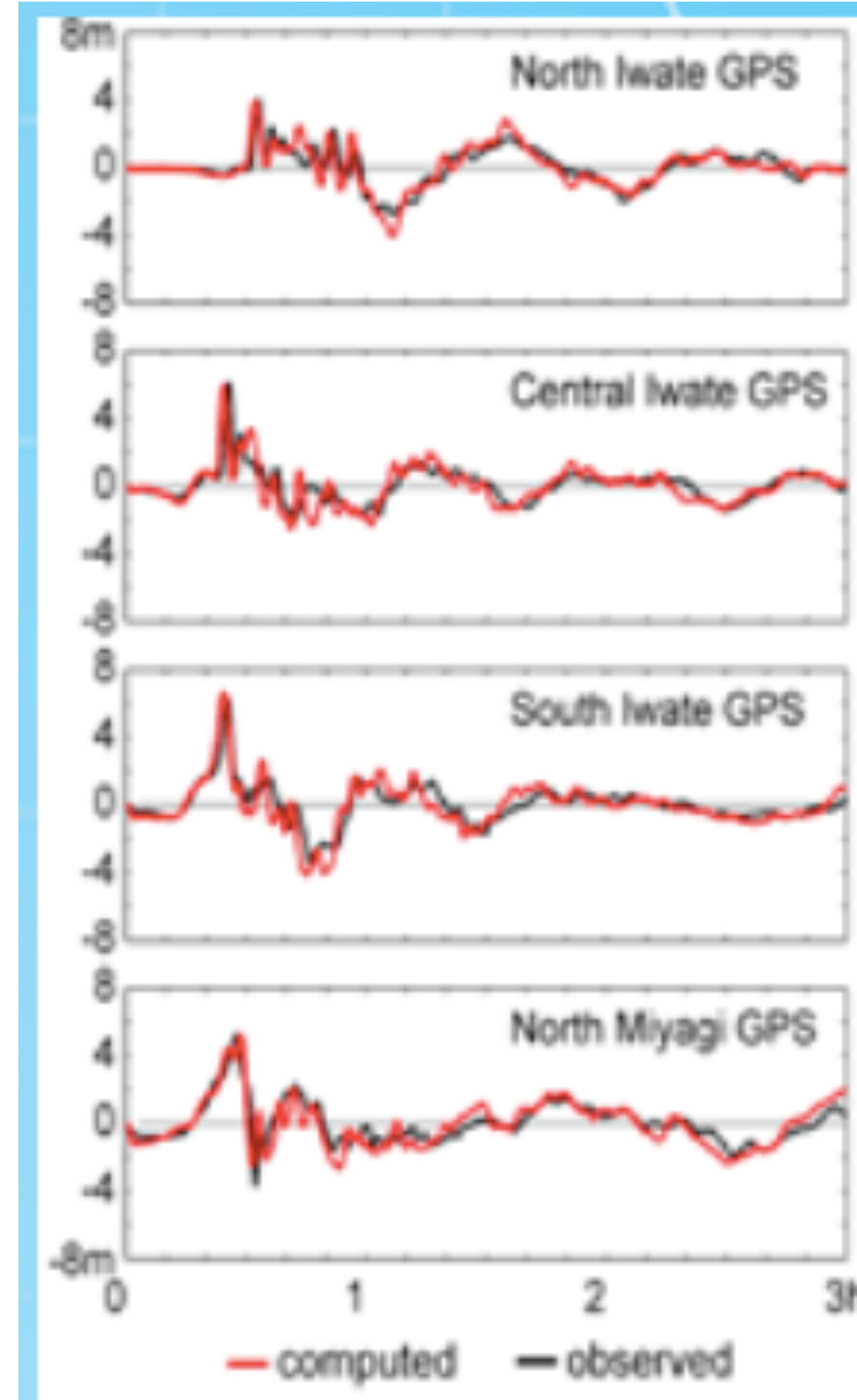
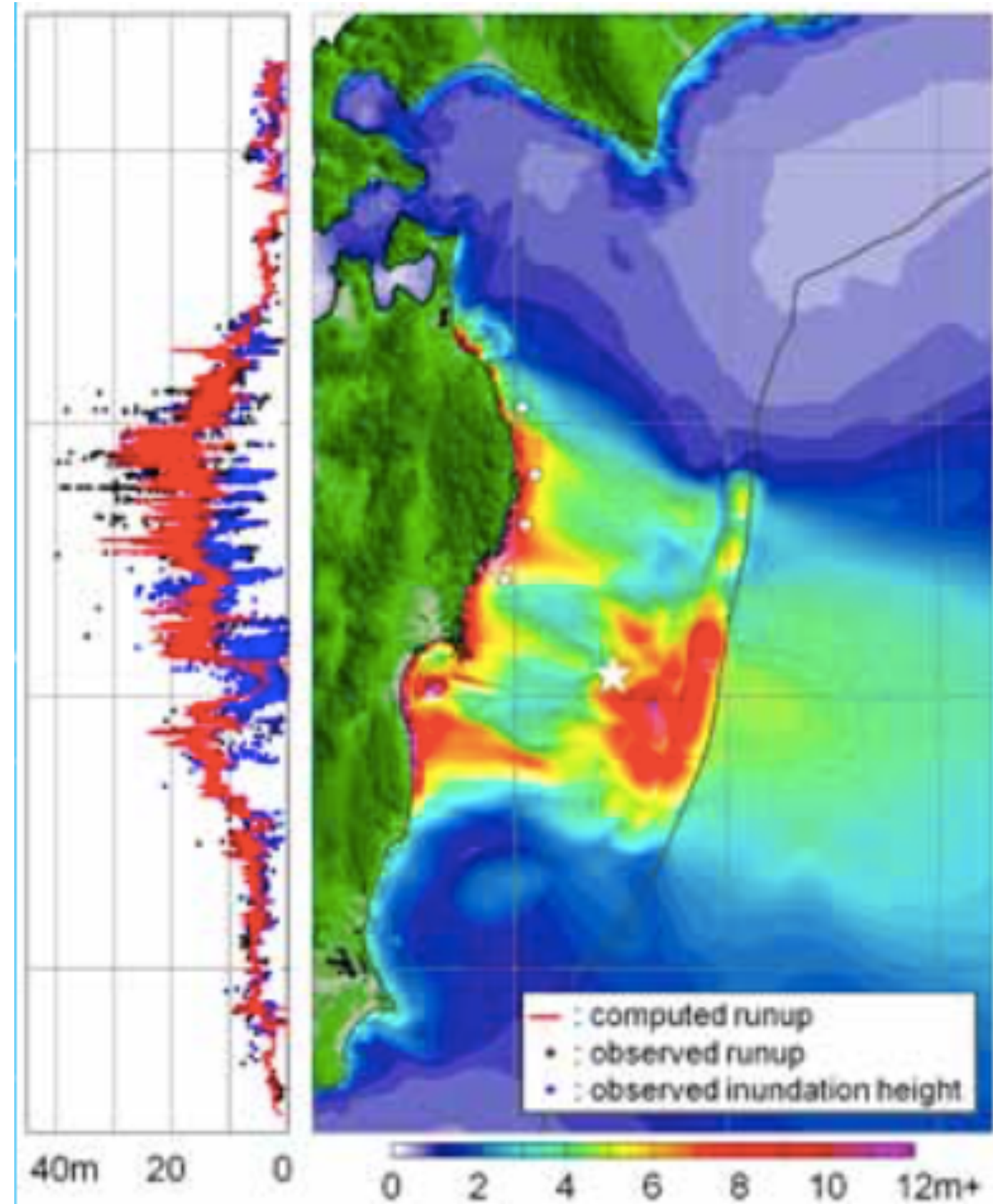
津波



## DART - Deep-ocean Assessment and Reporting of Tsunamis



<http://www.tulane.edu/~sanelson/geol204/tsunami.htm>

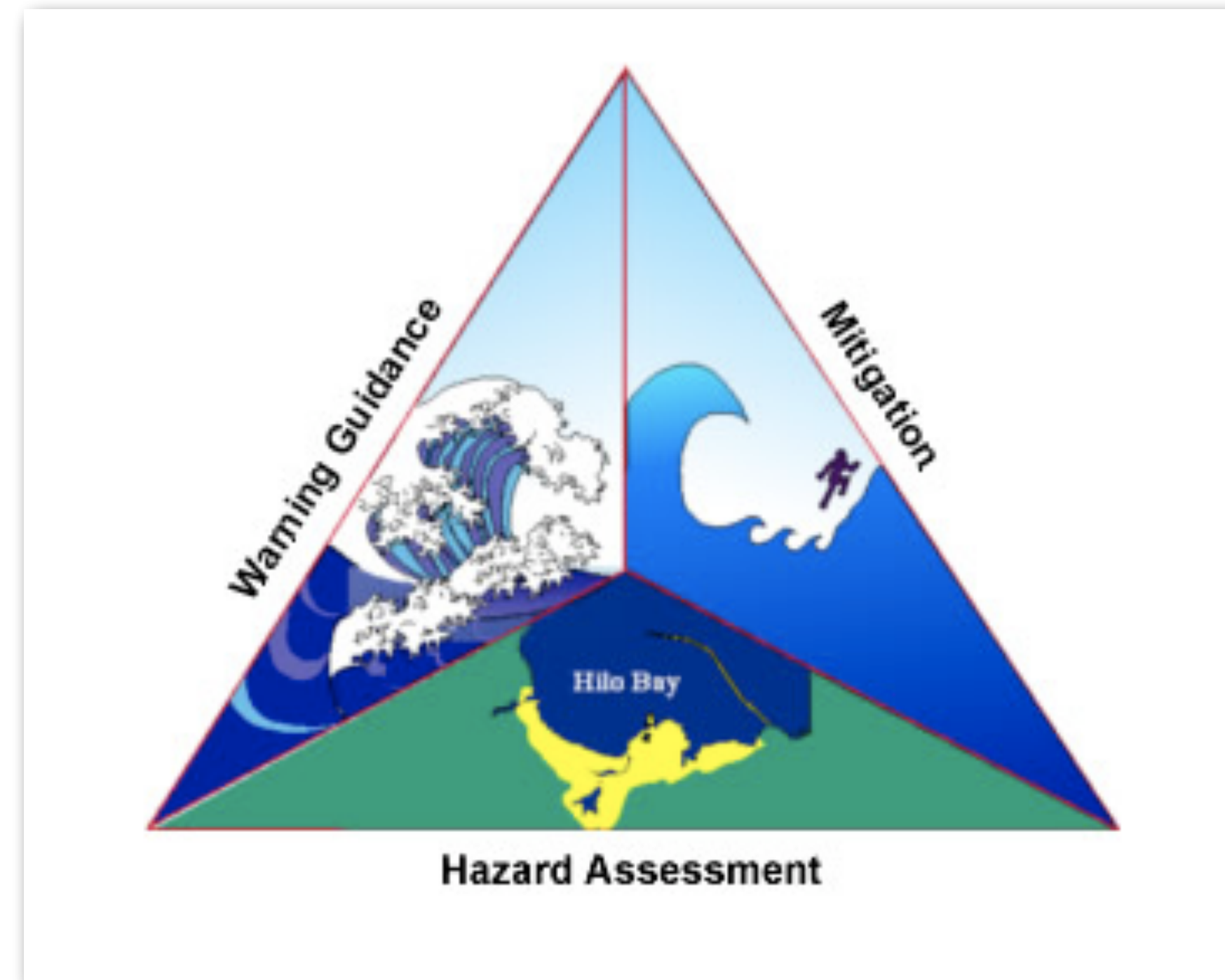


**Computed sea surface elevations show excellent agreement with the observed GPS buoy data (Y. Yamazaki and K.F. Cheung, Univ. of Hawaii).**

**11 March 2011 Japan Tsunami. Left: Computed model (red line) compares well with observed runup (black) and inundation height (blue). Right: Maximum wave amplitude along the northern Tohoku coast. At sea, the model shows up to 11-m amplitudes around the epicenter (star), and up to 7-m at nearshore GPS buoys (white circle). At the coast, local maximum runup heights 15-40 m were measured in many places.**



[http://www.new-zealand-pictures.co.nz/data/media/20/tsunami-warning-sign\\_1549.jpg](http://www.new-zealand-pictures.co.nz/data/media/20/tsunami-warning-sign_1549.jpg)

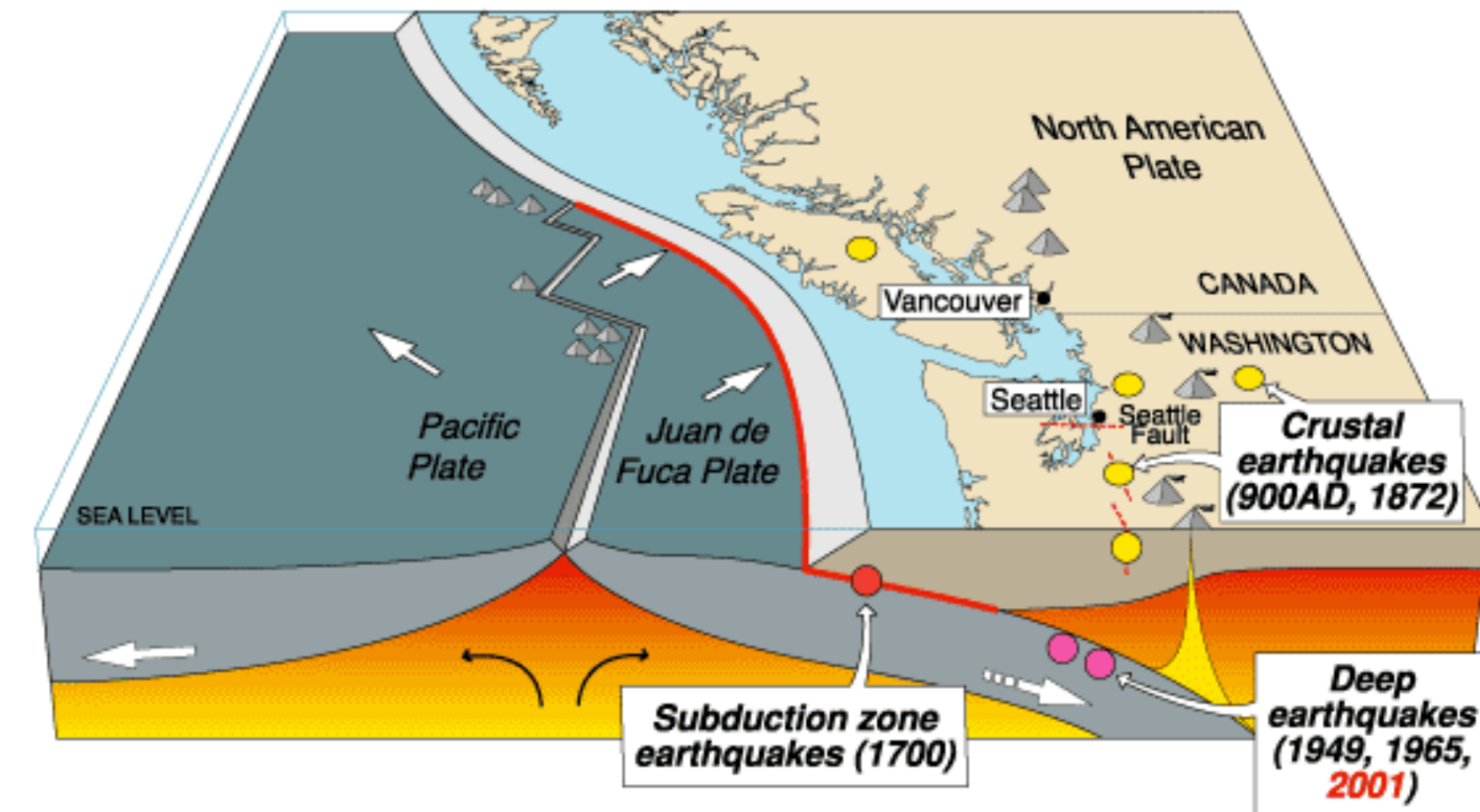


<http://www.tsunami.noaa.gov/>

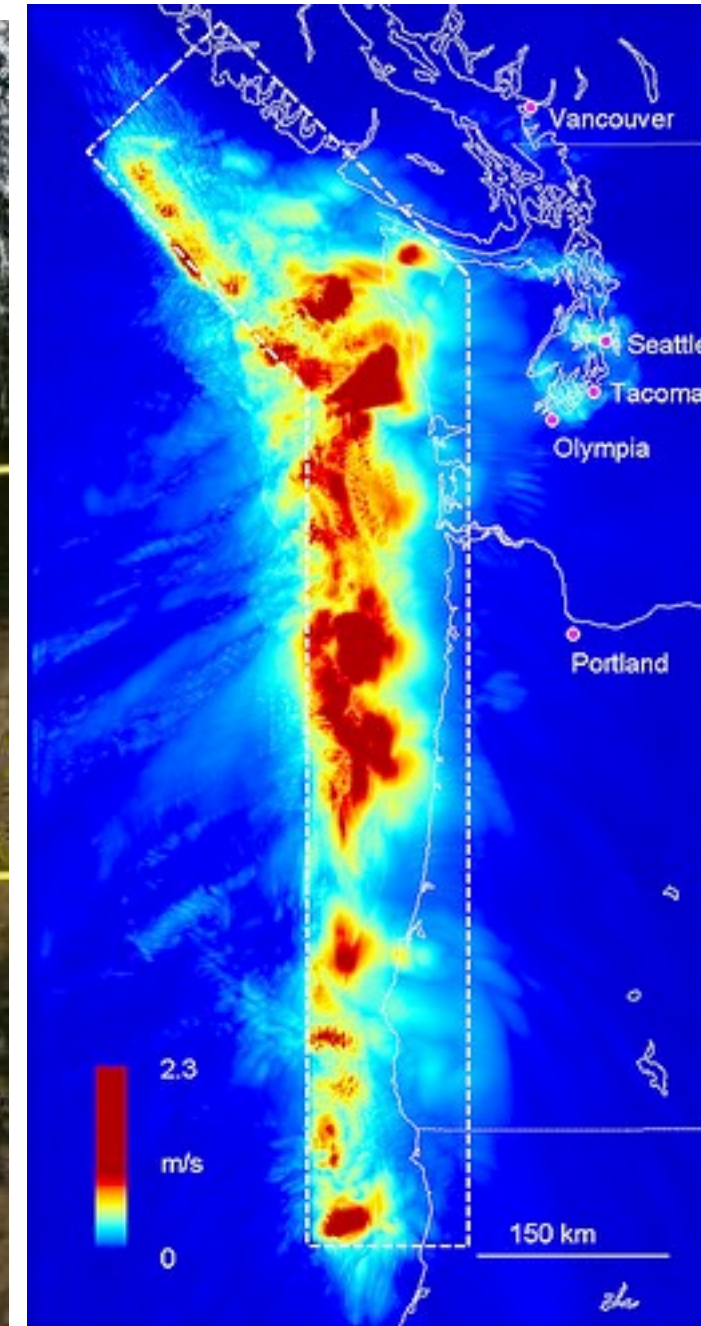


<http://www.hobotraveler.com/208-asia/207-039-tsunami-warning-route-thailand.jpg>

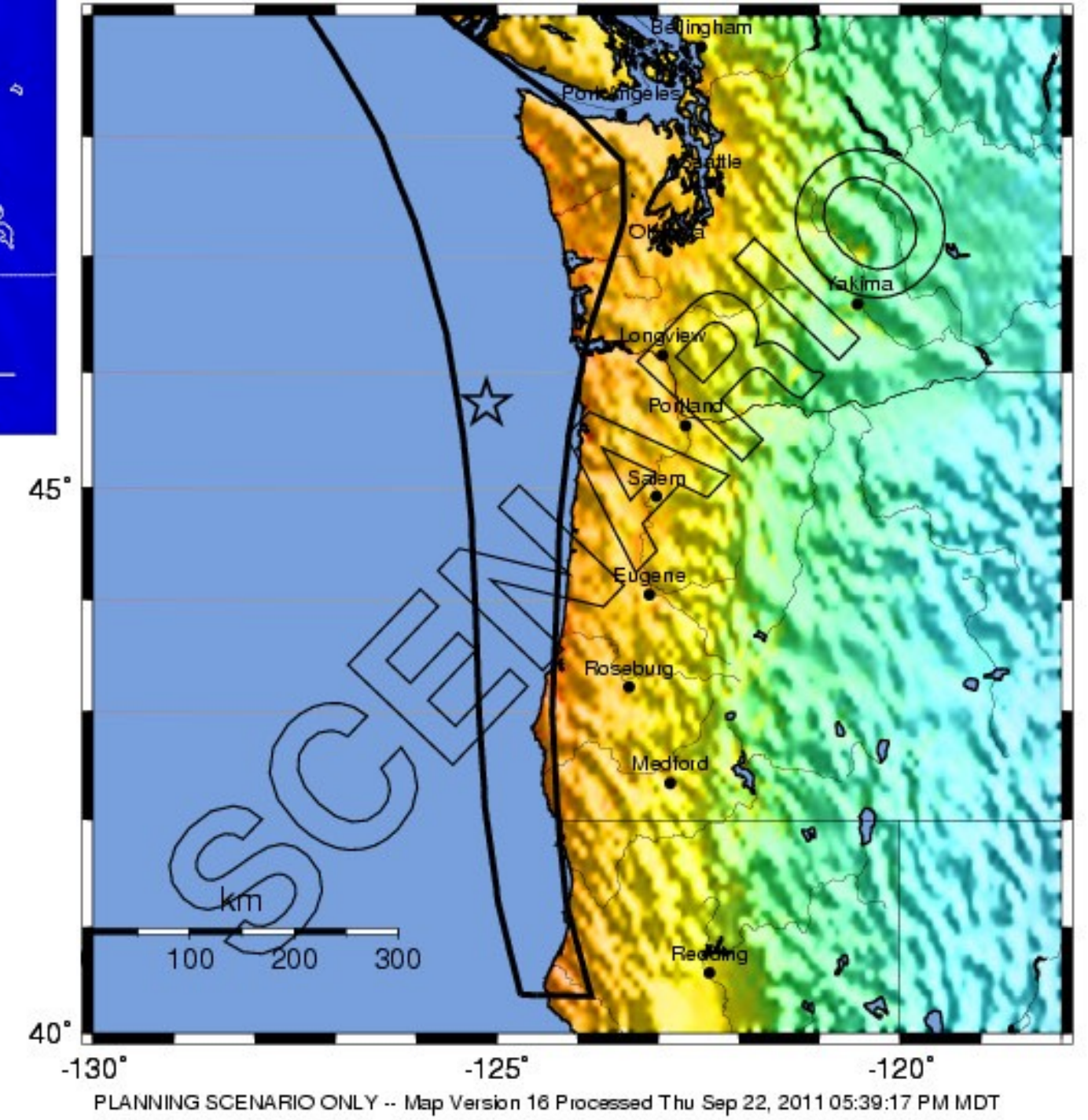
## Cascadia earthquake sources



Source	Affected area	Max. Size	Recurrence
● Subduction Zone	W.WA, OR, CA	M 9	500-600 yr
● Deep Juan de Fuca plate	W.WA, OR,	M 7+	30-50 yr
● Crustal faults	WA, OR, CA	M 7+	Hundreds of yr?



-- Earthquake Planning Scenario --  
ShakeMap for Casc9.0 Scenario  
Scenario Date: Wed Sep 7, 2011 12:00:00 GMT M 9.0 N45.73 W125.12 Depth: 0.0km



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC (%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL (cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

# Tsunami Awareness

<http://nvs.nanoos.org/TsunamiEvac>

[http://www.oregongeology.org/pubs/tsubrochures/WarrentonEvacBrochure-5-29-13\\_onscreen.pdf](http://www.oregongeology.org/pubs/tsubrochures/WarrentonEvacBrochure-5-29-13_onscreen.pdf)

<https://www.portlandoregon.gov/pbem/article/504516>

# Natural Hazards and Disaster

## Class 6: Volcanoes

- News
- Size of Volcanic Eruptions
- Location
- Types
- Volcanic Gases
- Volcanic Eruptions - Examples
- Large Eruptions
- Impacts of Eruptions
- Comparison to other Hazards



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### Our New Book



**Volcano Discoveries:** "One of the most eye-catching guides to the world's volcanoes ever published."

### Volcano Travel

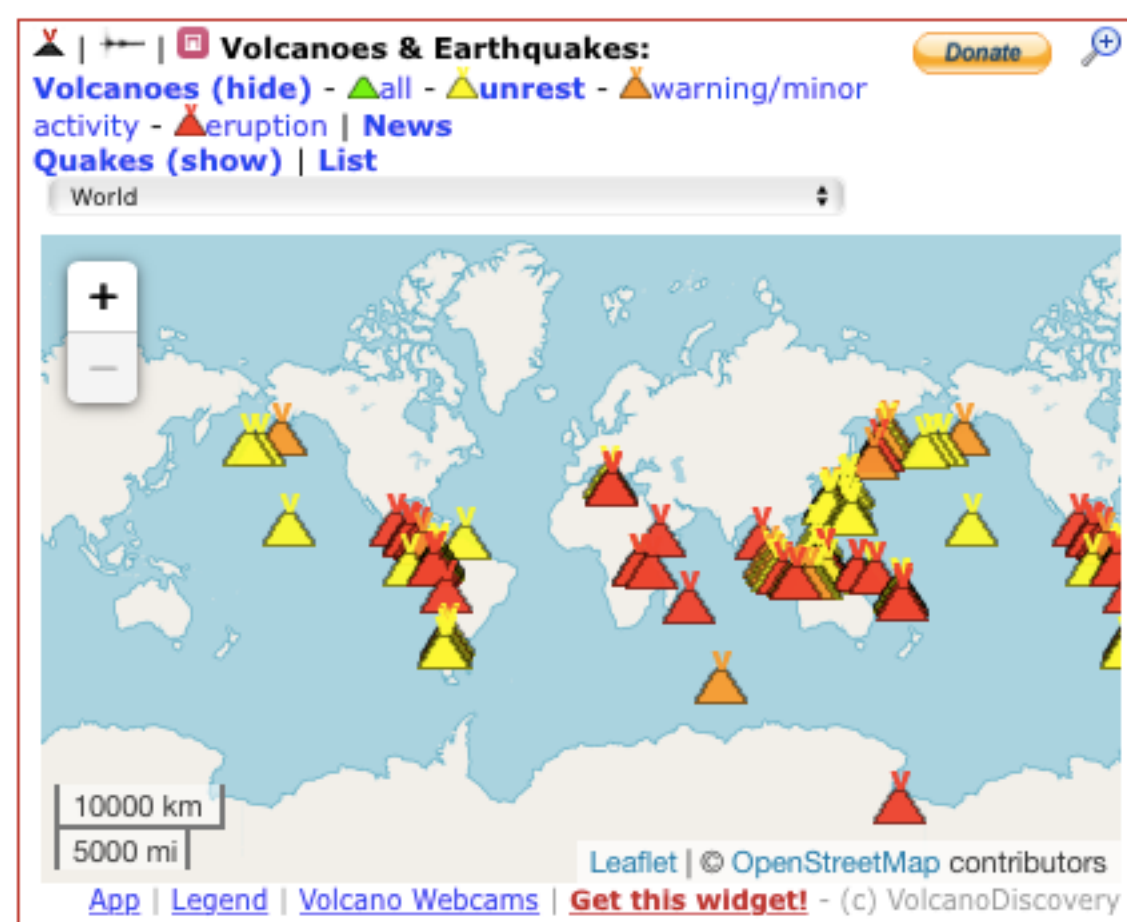


**VolcanoAdventures:** Our professional team of volcanologists and photographers offers unique travel opportunities: volcano expeditions, photo tours, and relaxed walking & study tours.

### Volcano Adventure Guide

## What's erupting? List & map of currently active volcanoes

[hide map] [enlarge map]



- Europe and Atlantic Ocean:**
  - Stromboli (Eolian Islands, Italy)
  - Etna (Sicily, Italy)
  - Campi Flegrei (Phlegrean Fields) (Italy)
- Iceland:**
- Africa and Indian Ocean:**
  - Piton de la Fournaise (La Réunion)
  - Oi Doinyo Lengai (Tanzania)
  - Erta Ale (Danakil depression, Ethiopia)
  - Barren Island (Indian Ocean)
  - Nyiragongo (DR Congo)
  - Heard (Australia, Southern Indian Ocean)
  - Nyamuragira (DR Congo)
- Aleutians, Alaska and North America:**
  - Veniaminof (Alaska Peninsula, USA)
  - Cleveland (Aleutian Islands, Alaska)
  - Great Sitkin (United States, Aleutian Islands)
  - Semisopochnoi (United States, Aleutian Islands)
- Mexico, Central America and Caribbean:**
  - Popocatepetl (Central Mexico)
  - Santiago (Guatemala)
  - Fuego (Guatemala)
  - Pacaya (Guatemala)
  - Masaya (Nicaragua)
  - Turrialba (Costa Rica)
  - Kick 'em Jenny (West Indies, Grenada)
- Pacific Ocean:**
  - Bagana (Bougainville Island, Papua New Guinea)
  - Manam (Papua New Guinea)
  - Kadovar (Northeast of New Guinea, Papua New Guinea)
  - Yasur (Tanna Island, Vanuatu)
  - Ambrym (Vanuatu)
  - Kilauea (Hawaii)
  - Ulawun (New Britain, Papua New Guinea)
  - Lopevi (Vanuatu)
  - Aoba (Vanuatu)
  - Gaua (Vanuatu)
  - Suretamatani (Banks Islands, Vanuatu)
  - Sierra Negra (Isabela Island, Galapagos)
- Ring of Fire (Kurile Islands to Philippines):**

### Latest volcano news:

Volcanoes Today, 15 Oct 2018: Fuego volcano, Krakatau, Ibu, Kerinci, Reventador, Turrialba, Sangeang Api, Sabancaya

Monday, Oct 15, 2018 [more]

**Fuego volcano Volcanic Ash Advisory: VA EM OBSD**  
Monday, Oct 15, 2018  
Volcanic Ash Advisory Center Washington (VAAC) issued the following report: ... [more]

**Kerinci volcano Volcanic Ash Advisory: VA TO FL140 EXT W LAST OBS AT 15/0101Z.**  
Monday, Oct 15, 2018  
Volcanic Ash Advisory Center Darwin (VAAC) issued the following report: ... [more]

**Sangeang Api volcano (Indonesia) activity update: New small ash emissions**  
Monday, Oct 15, 2018  
A new episode of small, regular ash emissions is occurring, with ash plumes to 2.2km (7,000ft). The level of seismicity has remained high following the minor eruption last year. The Alert Level remains at 2. [more]

**Volcanic activity worldwide 14 Oct 2018: Pacaya volcano, Fuego, Krakatau, Sopotan, Dukono, Kerinci, ...**  
Sunday, Oct 14, 2018  
**Ebeko (Paramushir Island):** Volcanic Ash Advisory Center Tokyo (VAAC) issued the following report: POSS ERUPTION OBS AT 20181014/1320Z FL120 EXTD SE OBS VA DTG:14/1420Z ... [more]

**Sopotan volcano (North Sulawesi, Indonesia) activity update: Continuing decreasing trend of activity**  
Sunday, Oct 14, 2018  
The level of activity is continuing to decline. Seismicity appears to have returned to pre-eruption pattern of low rates. A renewal of high activity remains possible at this highly



**The Volcano Adventure Guide:** Excellent information and background for anyone wishing to visit active volcanoes safely and enjoyably. The book presents guidelines to visiting 42 different volcanoes around the world.

### Guaranteed tours:

- 13-29 Nov 2018: **Volcano Special: Ibu - Dukono - Lokon** - Halmahera (Indonesia)
- 17-30 Nov 2018: **Desert, salt and volcanoes** - Danakil desert (Ethiopia)
- 8-21 Dec 2018: **Desert, salt and volcanoes** - Danakil desert (Ethiopia)
- 27 Dec 18 - 2 Jan 2019: **Kilauea Volcano Special** - Big Island, Hawai'i
- 6-13 Apr 2019: **Pearl of the Aegean - Santorini** - Santorini Island, Greece
- 22-27 Apr 2019: **Aegean's Hidden Gem: Isle of Milos** - Milos Island (Greece)
- 2-17 May 2019: **From Krakatau to Bali** - Java (Indonesia)
- 4-11(12) May 2019: **Essential Volcano**

### Indonesia:

- Dukono (Halmahera, Indonesia)
- Ibu (Halmahera, Indonesia)
- Semeru (East Java, Indonesia)
- Krakatau (Sunda Strait, Indonesia)
- Sinabung (Sumatra, Indonesia)
- Agung (Bali, Indonesia)
- Sangeang Api (Indonesia)
- Merapi (Central Java, Indonesia)
- Kerinci (Sumatra, Indonesia)
- Karangetang (Siau Island, Sangihe Islands, Indonesia)
- Gamkonora (Halmahera, Indonesia)
- Lokon-Empung (North Sulawesi, Indonesia)
- Sopotan (North Sulawesi, Indonesia)
- Gamalama (Halmahera, Indonesia)
- Rinjani (Lombok, Indonesia)
- Paluweh (off Flores Island, Indonesia)
- Lewotolo (Lesser Sunda Islands, Indonesia)
- Bromo (East Java, Indonesia)
- Banda Api (Banda Sea, Indonesia)
- Dempo (Sumatra, Indonesia)
- Marapi (Western Sumatra, Indonesia)

### South America:

- Sangay (Ecuador)
- Sabancaya (Peru)
- Reventador (Ecuador)
- Nevados de Chillán (Central Chile)
- Nevado del Ruiz (Colombia)
- Machin (Colombia)
- Nevado del Huila (Colombia)
- Sotará (Colombia)
- Galeras (Colombia)
- Cumbal (Colombia)
- Cerro Negro de Mayasquer (Colombia)
- Osorno (Southern Chile and Argentina, South America)
- Puyehue-Cordón Caulle (Central Chile and Argentina, South America)
- Copahue (Chile/Argentina)
- Planchón-Peteroa (Central Chile and Argentina, South America)

### Other regions:

- Erebus (Antarctica)

■=major eruption ■=erupting ■=minor activity / eruption warning ■=unrest

active volcano, though m likely than last week. [m


**Kerinci volcano (Sumatra, In**  
Activity appears to have decl  
Sunday, Oct 14, 2018  
No reports of continuing week. It would appear th decreased to low levels. restless and renewed mi occur at any time. [more]

**Volcanic activity worldwide 14 Oct 2018: Pacaya volcano, Fuego, Popocatepetl, ...**  
Saturday, Oct 13, 2018  
**Ebeko (Paramushir Island, Kuril Islands)** (12 Oct) Volcanic Ash Advisory Center Tokyo issued the following report: ERUPTION OBS AT 20181012/2224Z FL140 DTG:12/2220Z ... [more]

**Semisopochnoi volcano (United States, Aleutian Islands) activity update: Eruption stopped. Elevated seismicity**  
Friday, Oct 12, 2018  
AVO has lowered the Aviation Alert Level to YELLOW/Alert Level 2 based on satellite observations and data recently indicating that eruption stopped. Elevated seismicity remains. [more]

**Volcanic activity worldwide 14 Oct 2018: Pacaya volcano, Fuego, Popocatepetl, Krakatau, ...**  
Friday, Oct 12, 2018  
**Ebeko (Paramushir Island, Kuril Islands)** (11 Oct) Volcanic Ash Advisory Center Tokyo issued the following report: ERUPTION OBS AT 20181011/1320Z FL120 EXTD SE OBS VA DTG:11/1320Z ... [more]

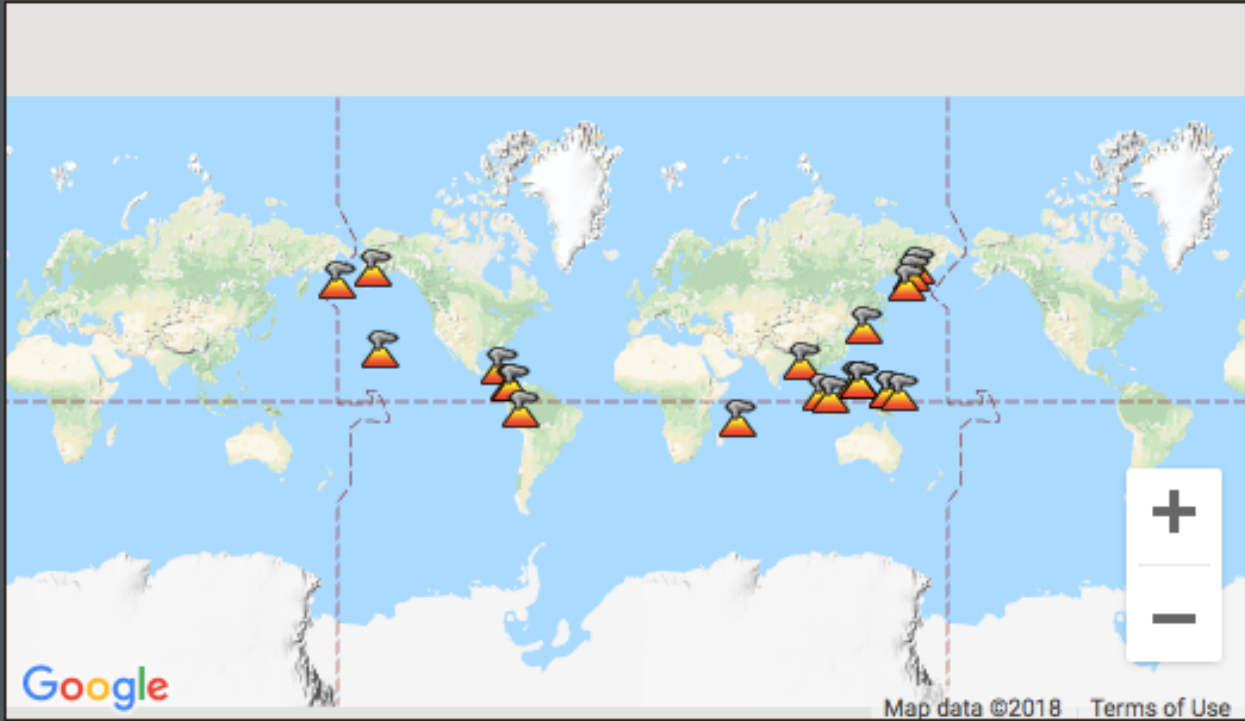
[http://volcano.si.edu/reports\\_weekly.cfm](http://volcano.si.edu/reports_weekly.cfm)



Smithsonian Institution  
National Museum of Natural History  
Global Volcanism Program



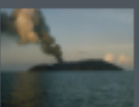
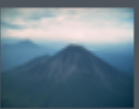

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### Smithsonian / USGS Weekly Volcanic Activity Report



Map data ©2018 Terms of Use

**New Activity / Highlights**

-  [Gamalama](#)
-  [Soputan](#)
-  [Barren Island](#)
-  [Ulawun](#)
-  [Kilauea](#)

[Download Google Earth Network Link](#) [USGS Photo Glossary](#)

Weekly Report Archive Feeds Criteria & Disclaimers Acronyms & Abbreviations

Activity for the week of 3 October-9 October 2018

Weekly Report Archive Feeds Criteria & Disclaimers Acronyms & Abbreviations

**Activity for the week of 3 October-9 October 2018**

The Weekly Volcanic Activity Report is a cooperative project between the Smithsonian's Global Volcanism Program and the US Geological Survey's Volcano Hazards Program. Updated by 2300 UTC every Wednesday, notices of volcanic activity posted on these pages are preliminary and subject to change as events are studied in more detail. This is not a comprehensive list of all of Earth's volcanoes erupting during the week, but rather a summary of activity at volcanoes that meet criteria discussed in detail in the "Criteria and Disclaimers" section. Carefully reviewed, detailed reports on various volcanoes are published monthly in the Bulletin of the Global Volcanism Network.

Name	Location	Activity
<a href="#">Barren Island</a>	Andaman Islands (India)	New
<a href="#">Cuicocha</a>	Ecuador	New
<a href="#">Gamalama</a>	Halmahera (Indonesia)	New
<a href="#">Kilauea</a>	Hawaiian Islands (USA)	New
<a href="#">Piton de la Fournaise</a>	Reunion Island (France)	New
<a href="#">Semisopochnoi</a>	United States	New
<a href="#">Soputan</a>	Sulawesi (Indonesia)	New
<a href="#">Ulawun</a>	New Britain (Papua New Guinea)	New
<hr/>		
<a href="#">Aira</a>	Kyushu (Japan)	Ongoing
<a href="#">Dukono</a>	Halmahera (Indonesia)	Ongoing
<a href="#">Ebeko</a>	Paramushir Island (Russia)	Ongoing
<a href="#">Ibu</a>	Halmahera (Indonesia)	Ongoing

# Latest Mount Mayon Volcano Eruption Update: Ash And Lava Choke The Philippines



**Trevor Nace** Contributor ⓘ  
Science

f  
t  
in



Farmers view pyroclastic clouds coming from Mayon volcano on January 17, 2018, in Camalig, Albay, Philippines. Thousands evacuate as Philippines' Mayon volcano erupts.

January 17, 2018



Eruptions at Mexico's Popocatepetl volcano erupting on September 30 ,2017

NATURAL DISASTERS · 3 days ago

## Vanuatu volcano erupts; 11,000 prepare to evacuate

Fox News



World

## Mount Agung eruption: Bali declares state of emergency as volcano threatens to blow

More than 140,000 people have fled the region in recent weeks.



By Isabelle Gerretsen

October 3, 2017 11:01 BST



Indonesian officials map potential damage of Agung volcano

IBT

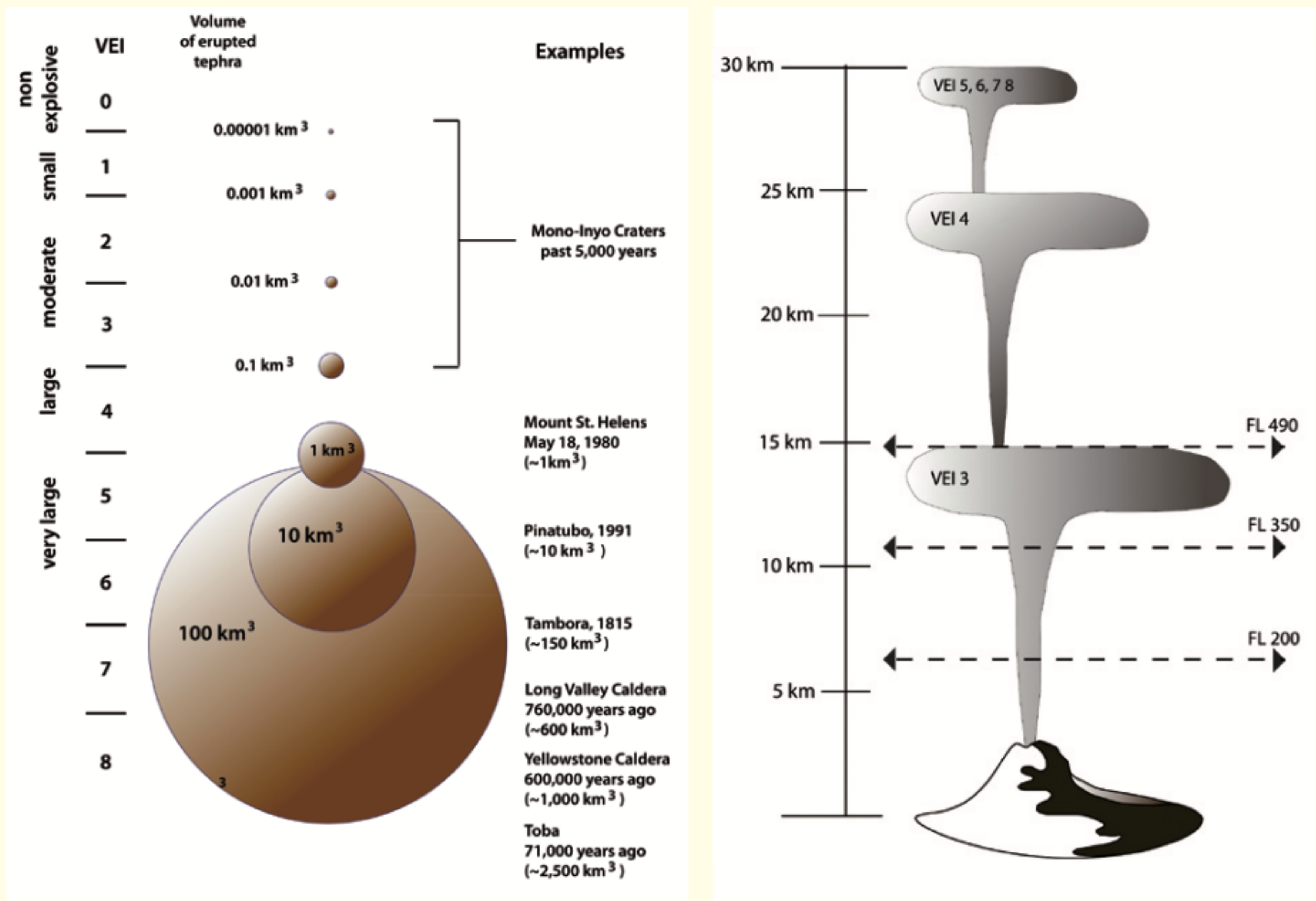


# Natural Hazards and Disaster

## Class 6: Volcanoes

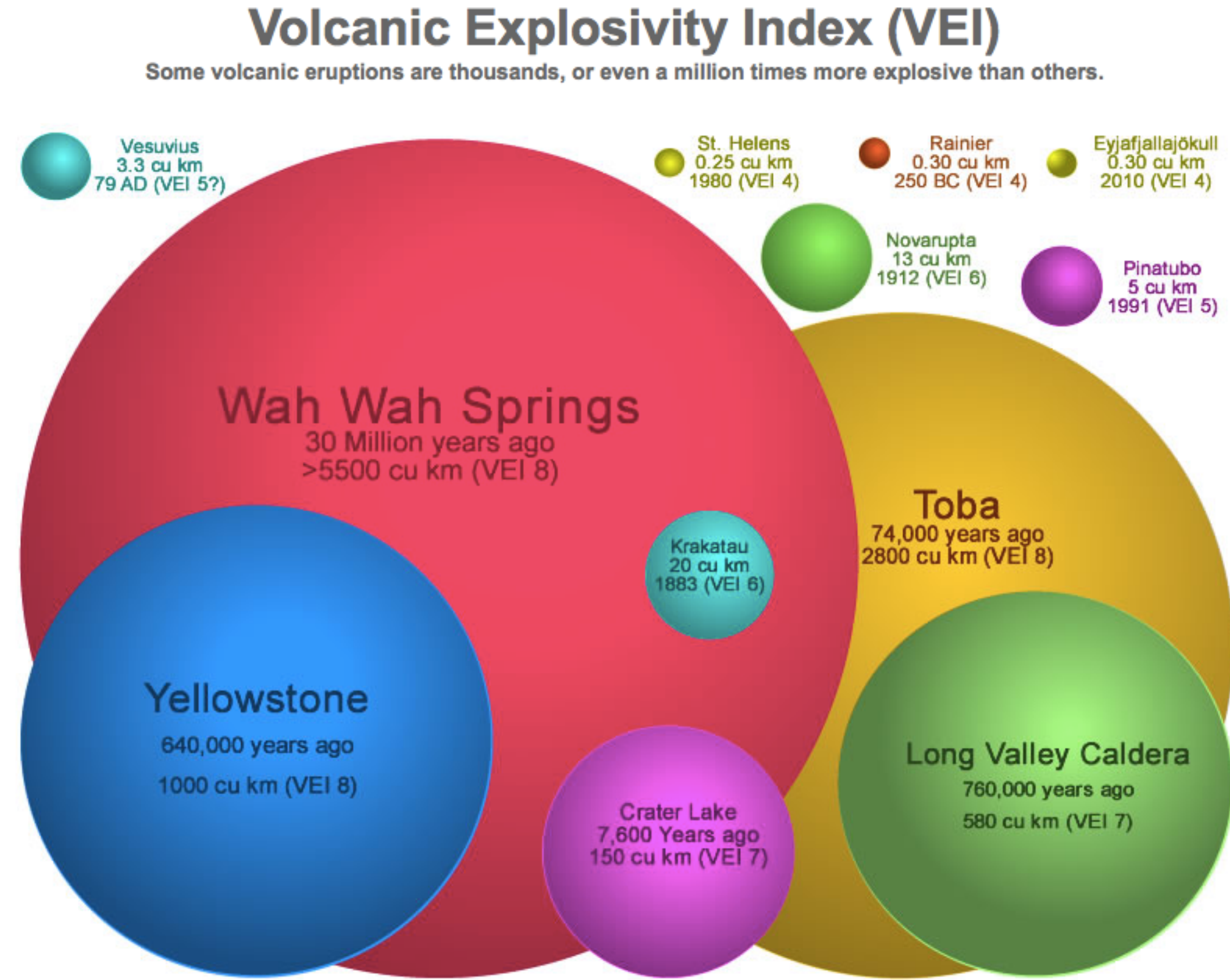
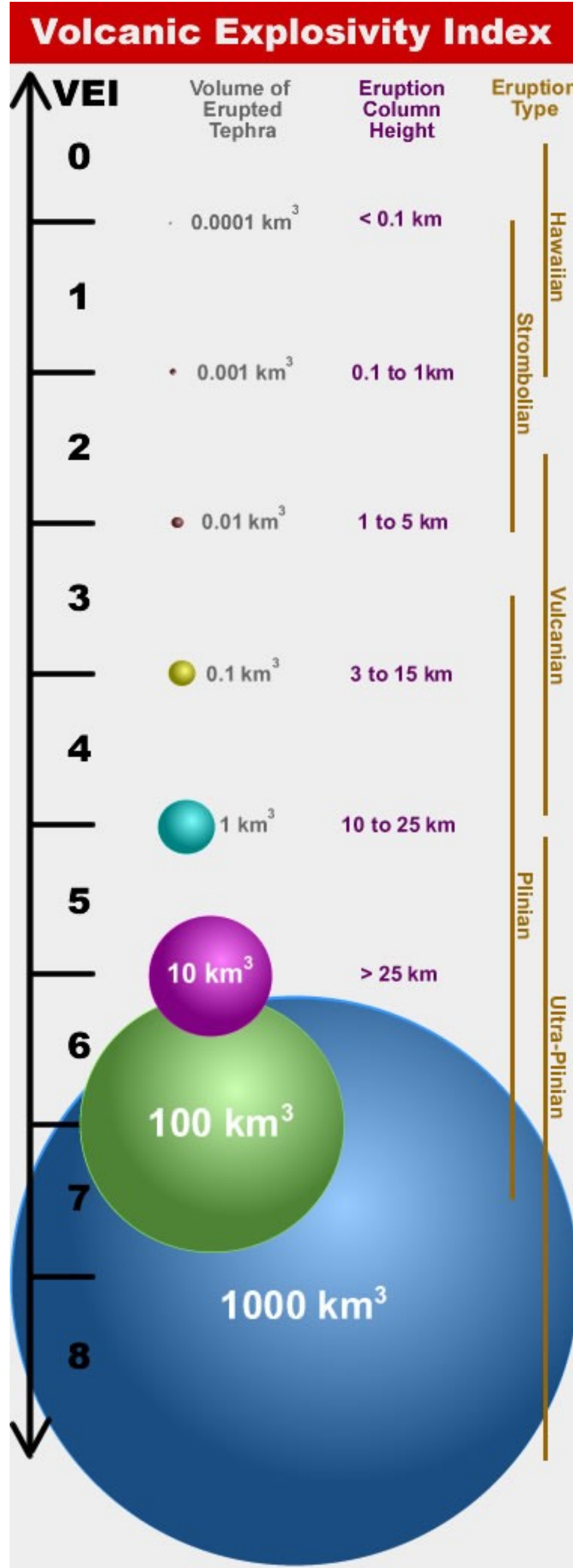
- News
- Size of Volcanic Eruptions
- Location
- Types
- Volcanic Gases
- Volcanic Eruptions - Examples
- Large Eruptions
- Impacts of Eruptions
- Comparison to other Hazards

# Size of Volcanic Eruptions

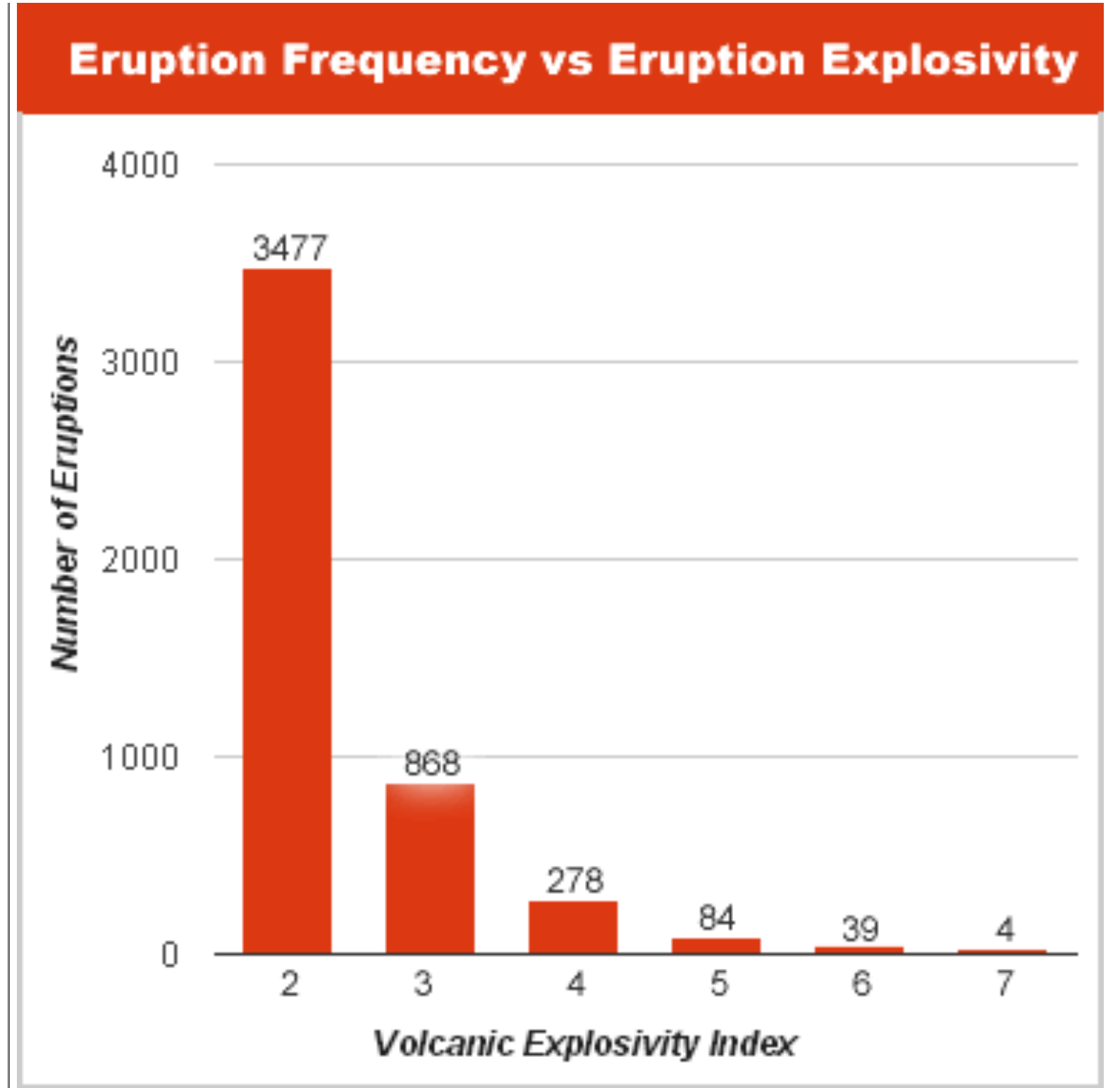


**Figure 11.** Measures for the magnitude of volcanic eruptions. Several indicators have been proposed to measure the severity of volcanic eruptions. The Volcanic Explosivity Index (VEI) introduced by Newhall & Self (1982) is a semi-logarithmic scale that uses a combination of the volume of the erupted tephra (left) and the eruption plume height (right) to measure the eruption size. Note that most commercial aircraft travel at height between Flight Levels FL 200 and FL 350.

# Size of Volcanic Eruptions



**Volcanic explosivity index:** The spheres in the illustration above represent the volume of erupted tephra for some of the most widely-known explosive volcanic eruptions. Although most people believe that Vesuvius (79 AD - the Pompeii eruption), Mount St. Helens (1980), and Mount Pinatubo (1991) were enormous, they are very small compared to ancient eruptions such as Wah Wah Springs, Toba, Yellowstone, or Long Valley Caldera.



**VEI vs. eruption frequency:** This chart shows how small, less explosive eruptions are much more frequent than large eruptions. The data used to prepare the chart is from the Global Volcanism Program database of the Smithsonian Institution. This database includes recorded and historic eruptions that occurred between about 10,000 years ago and 1994.

# Size of Volcanic Eruptions

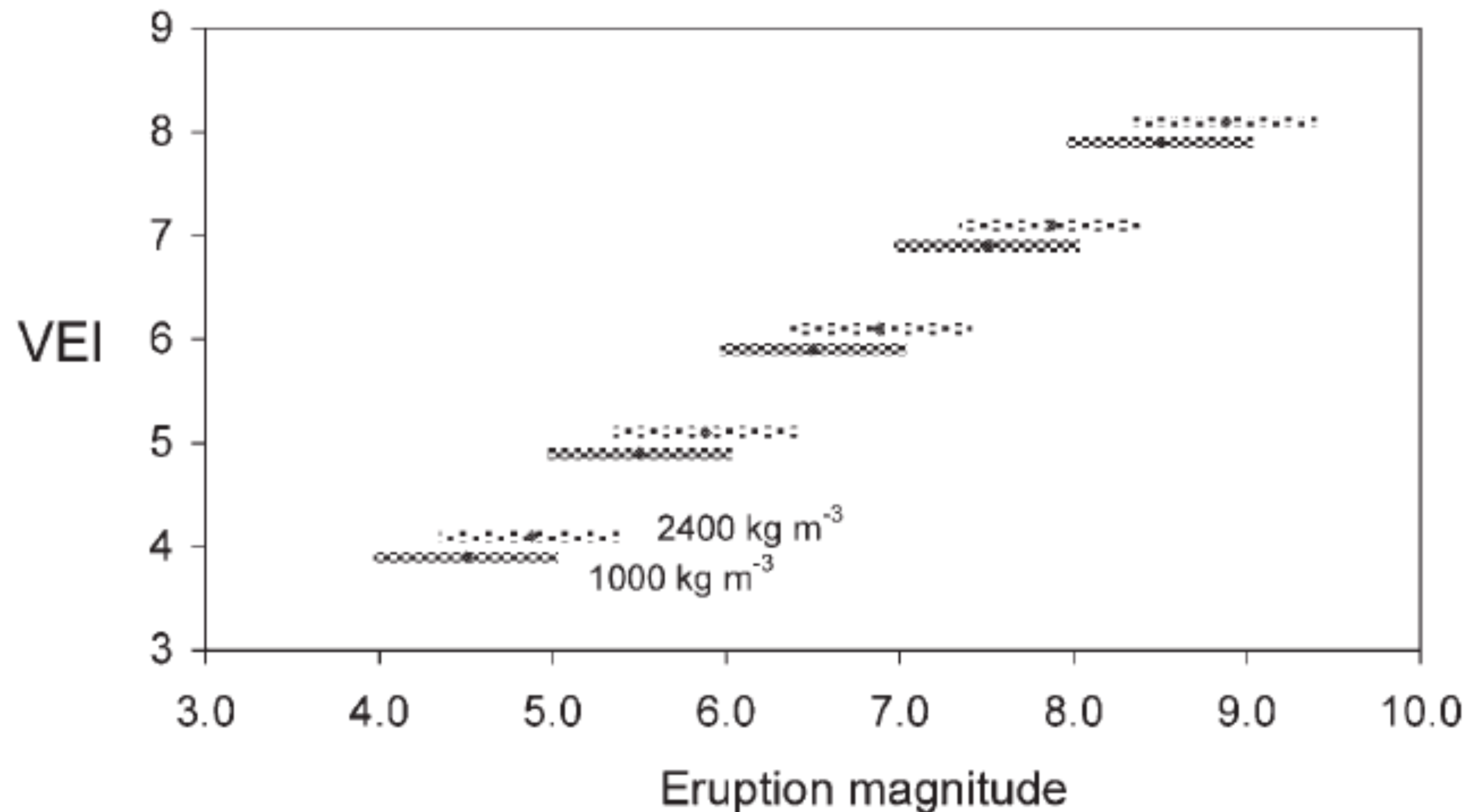


**Redoubt eruption:** Eruption cloud from Redoubt Volcano as viewed from the Kenai Peninsula. This eruption lasted from December 14, 1989 until June 20, 1990. It was only a VEI 3. Photograph by R. Clucas, April 21, 1990. USGS image.

**Mount St. Helens eruption:** The May 18, 1980 eruption at Mount St. Helens was considered by most people to be an enormous eruption. The blast removed the top 400 meters of the mountain, produced a debris avalanche that covered 62 square kilometers, and knocked down trees over an area of about 600 square kilometers. This eruption was a VEI 4. Toba, at a VEI 8, was approximately 10,000 times as explosive. Image by USGS.







$$M = \log_{10}(m) - 7.0$$

$M$ : magnitude  
 $m$ : mass

**Fig. 1** The relationship between eruption magnitude,  $M$ , and Volcanic Explosivity Index, VEI, for deposits of bulk density 1,000 and 2,400 kg m<sup>-3</sup>

# Size of Volcanic Eruptions

**Table 5.** Classification of volcanic eruptions. V: ejecta volume; EC: eruption classification; D: description; PH: plume height; FE: frequency of eruption; O: known/estimated occurrences in the Holocene.

<b>VEI</b>	<b>V</b>	<b>EC</b>	<b>D</b>	<b>PH</b>	<b>FE</b>	<b>O</b>
0	< 10,000 m <sup>3</sup>	Hawaiian	Effusive	< 100 m	Persistent	Many
1	> 10,000 m <sup>3</sup>	Hawaiian/Strombolian	Gentle	100–1,000 m	Daily	Many
2	> 1,000,000 m <sup>3</sup>	Strombolian/Vulcanian	Explosive	1–5 km	Weekly	3,477
3	> 10,000,000 m <sup>3</sup>	Vulcanian/Pelean	Severe	315 km	Few months	868
4	> 0.1 km <sup>3</sup>	Pelean/Plinian	Cataclysmic	1,025 km	≥1 yr	421
5	> 1 km <sup>3</sup>	Plinian	Paroxysmal	2,035 km	≥10 yrs	166
6	> 10 km <sup>3</sup>	Plinian/Ultra-Plinian	Colossal	> 30 km	≥ 100 yrs	51
7	> 100 km <sup>3</sup>	Ultra-Plinian	Super-colossal	> 40 km	≥ 1,000 yrs	5*
8	> 1,000 km <sup>3</sup>	Supervolcanic	Mega-colossal	> 50 km	≥10,000 yrs	0

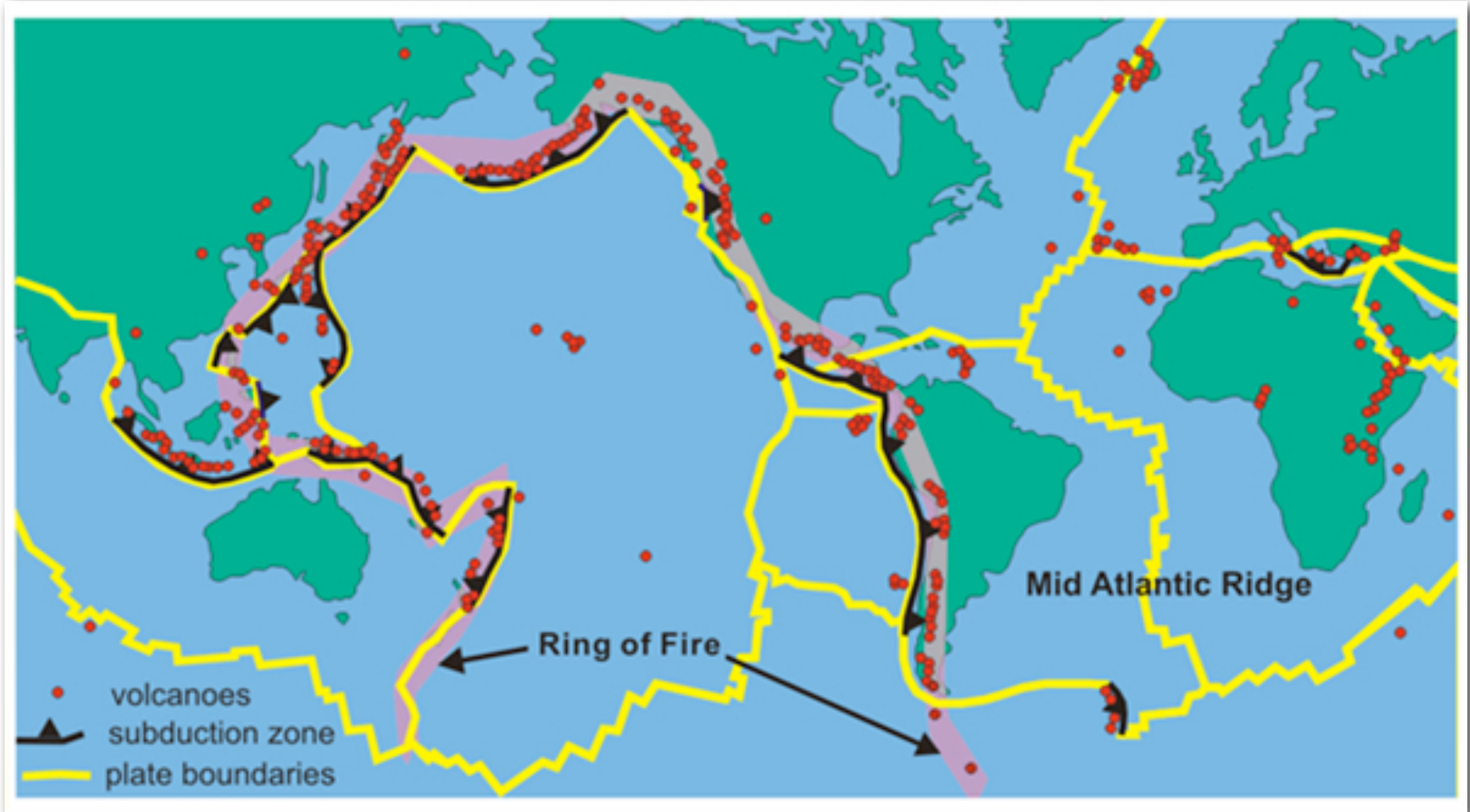
\* plus two suspected.

# Natural Hazards and Disaster

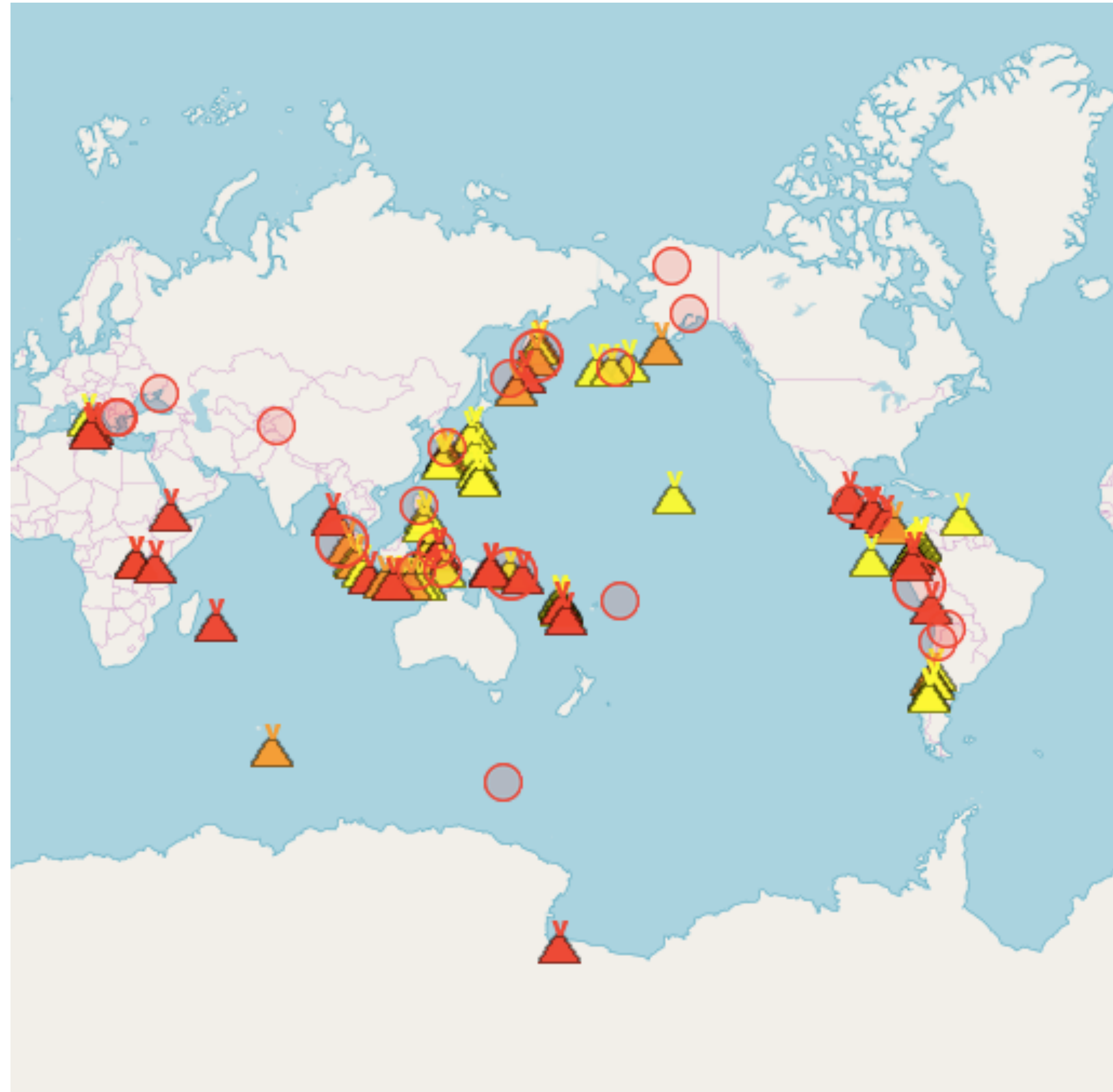
## Class 6: Volcanoes

- News
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Most volcanoes (not all) are on plate boundaries



Most volcanoes (not all) are on plate boundaries



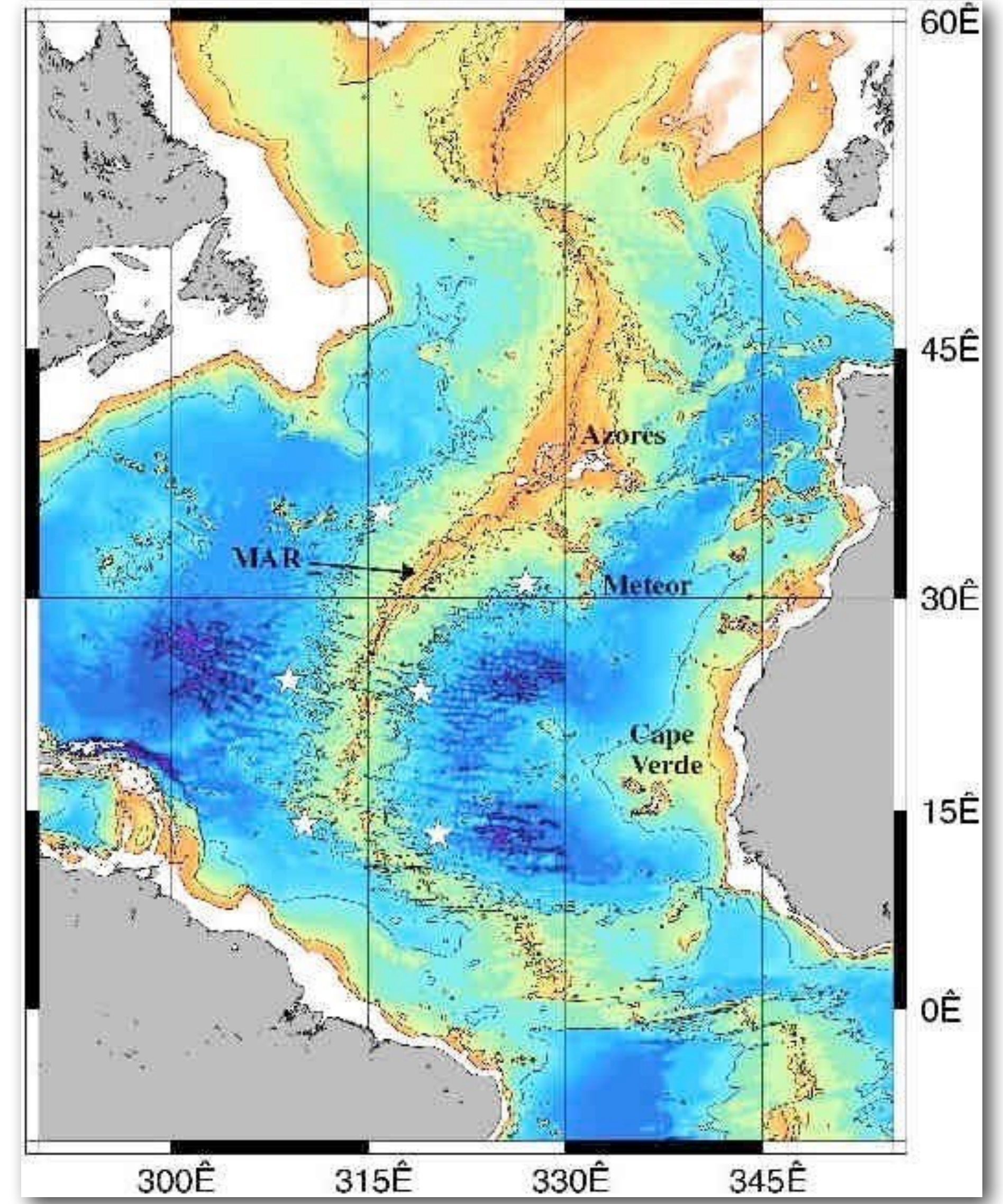
# Location

## Undersea volcanoes

- Mid Ocean Ridges

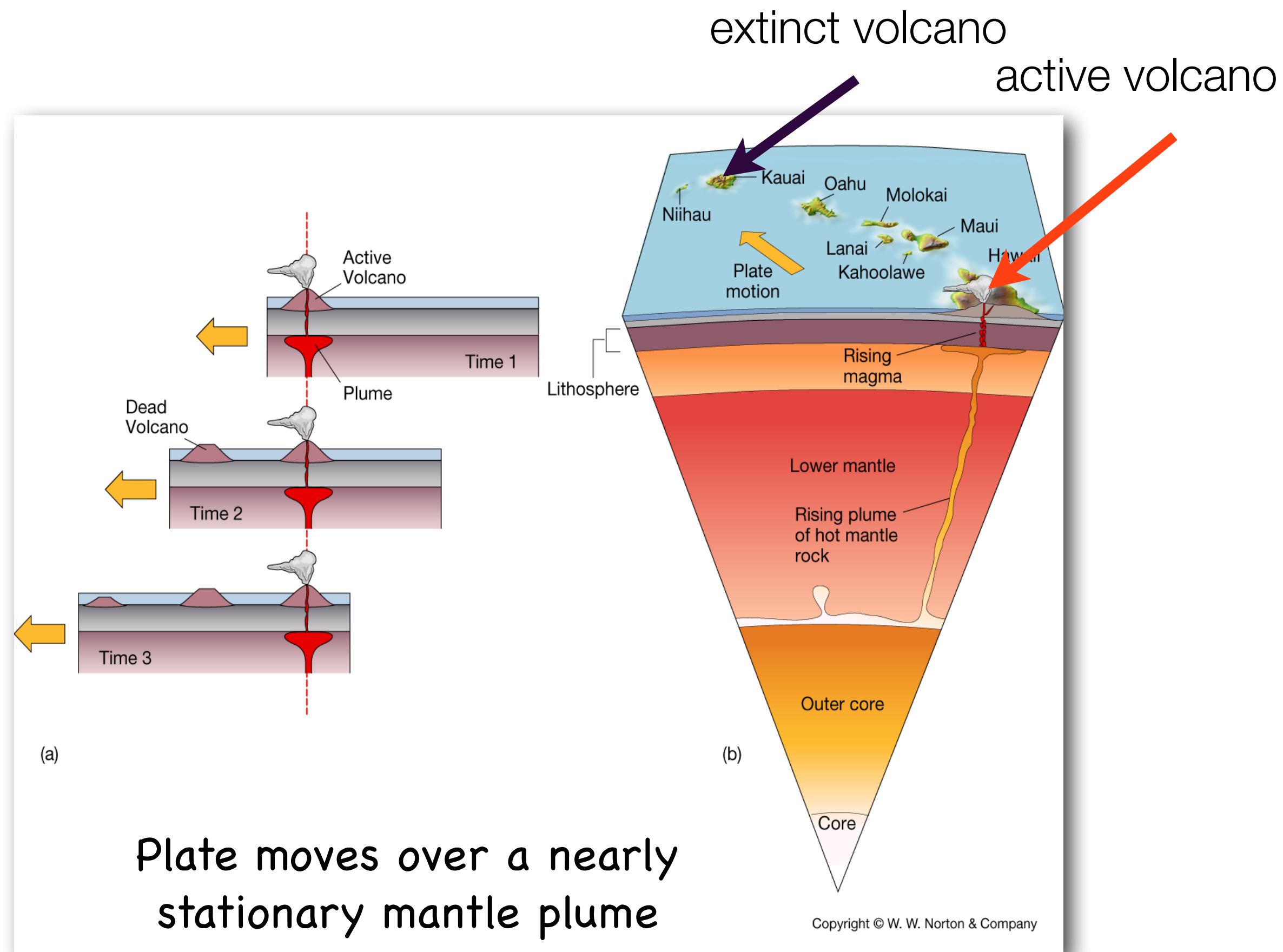


- Quiet - low risk
- Not much to see on the surface!



[http://www.pmel.noaa.gov/vents/acoustics/images/haru\\_atl\\_locs-big.jpg](http://www.pmel.noaa.gov/vents/acoustics/images/haru_atl_locs-big.jpg)

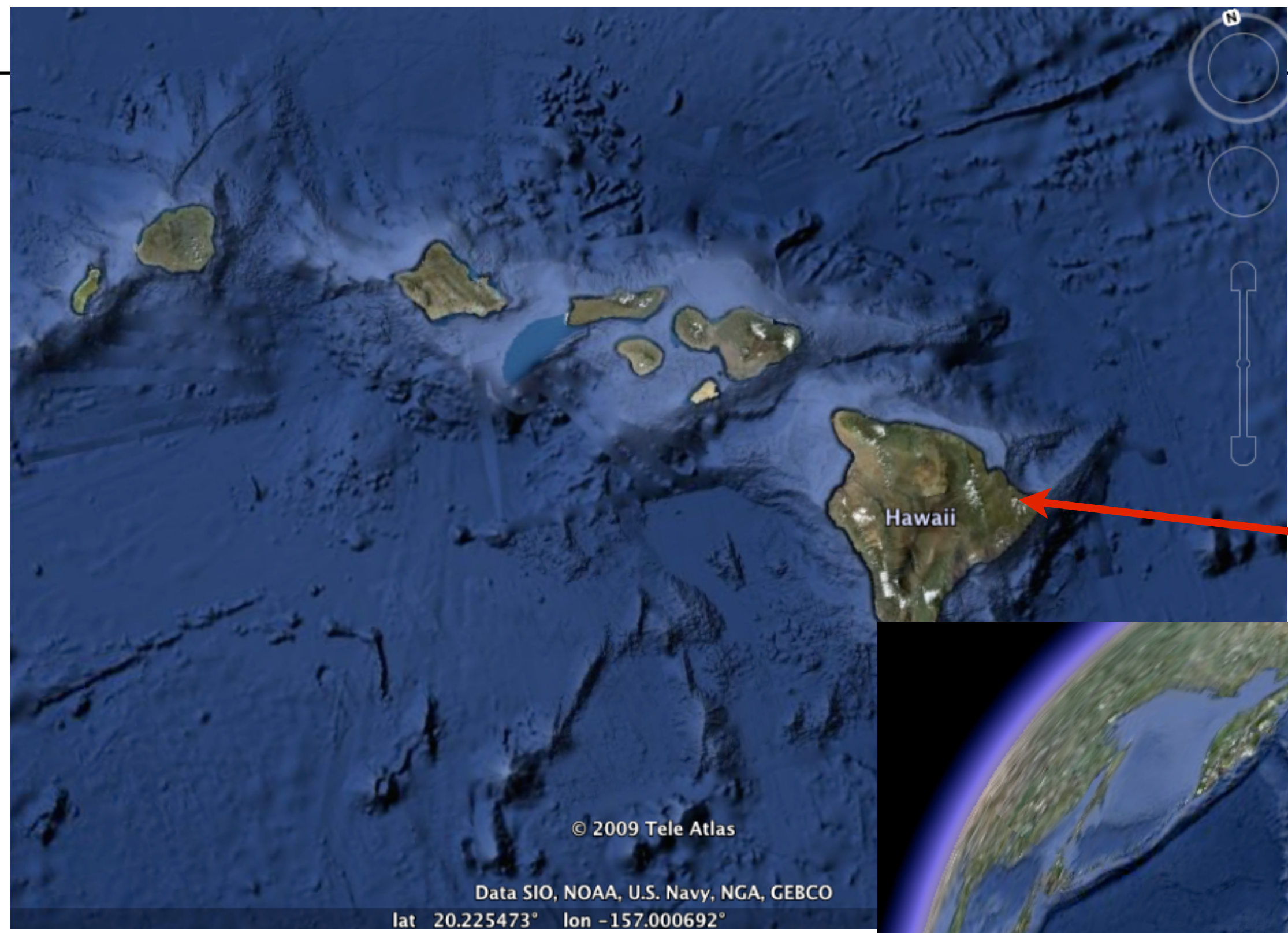
Oceanic Volcanoes do reach surface sometimes  
e.g., Hawaiian 'hot spot'



[http://webpages.csus.edu/~cjf28/hawaii\\_volcano.jpg](http://webpages.csus.edu/~cjf28/hawaii_volcano.jpg)

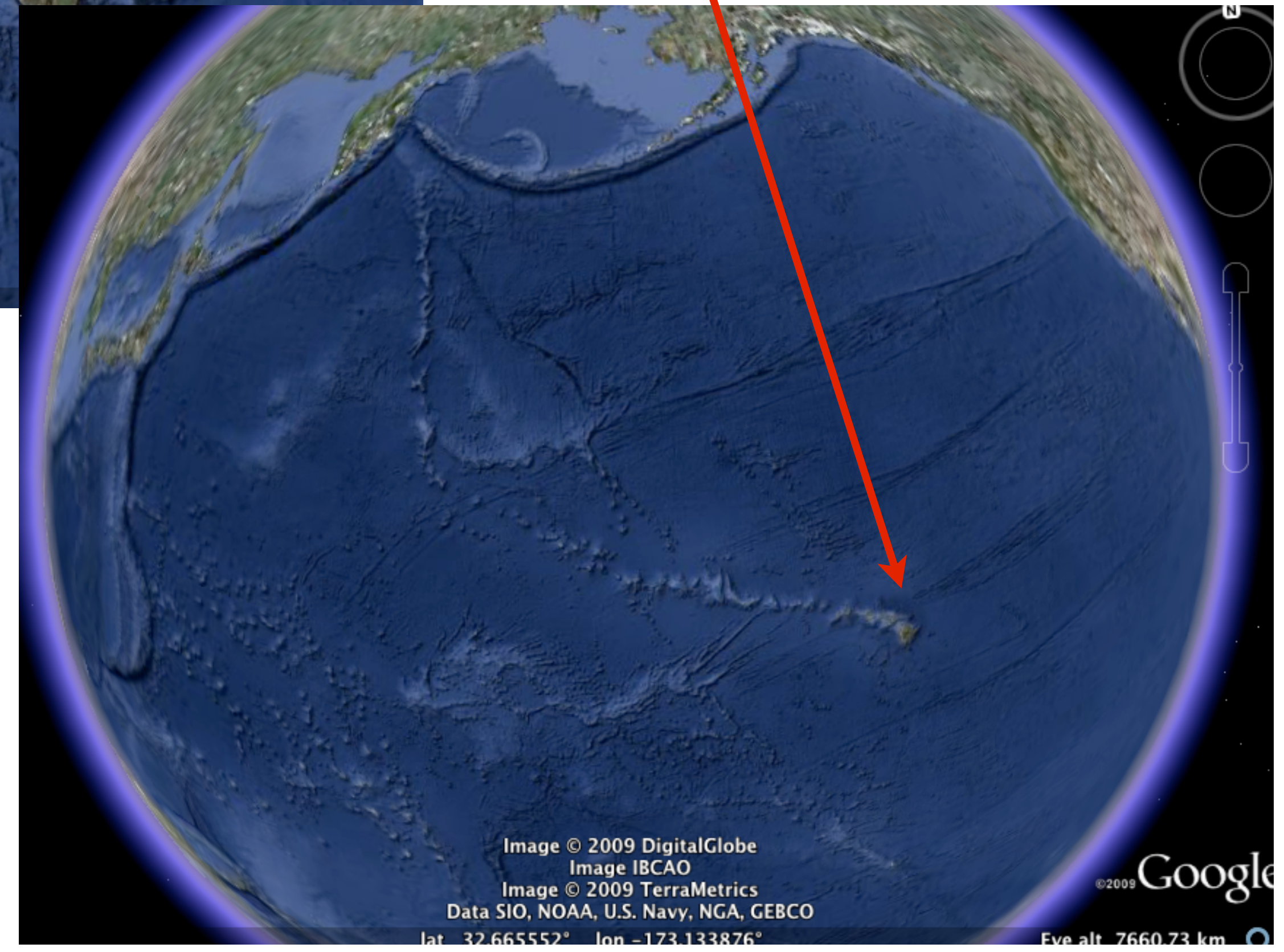
low viscosity -  
lava 'fountains' and lava 'rivers'

# Location



Hawaiian Hot Spot track

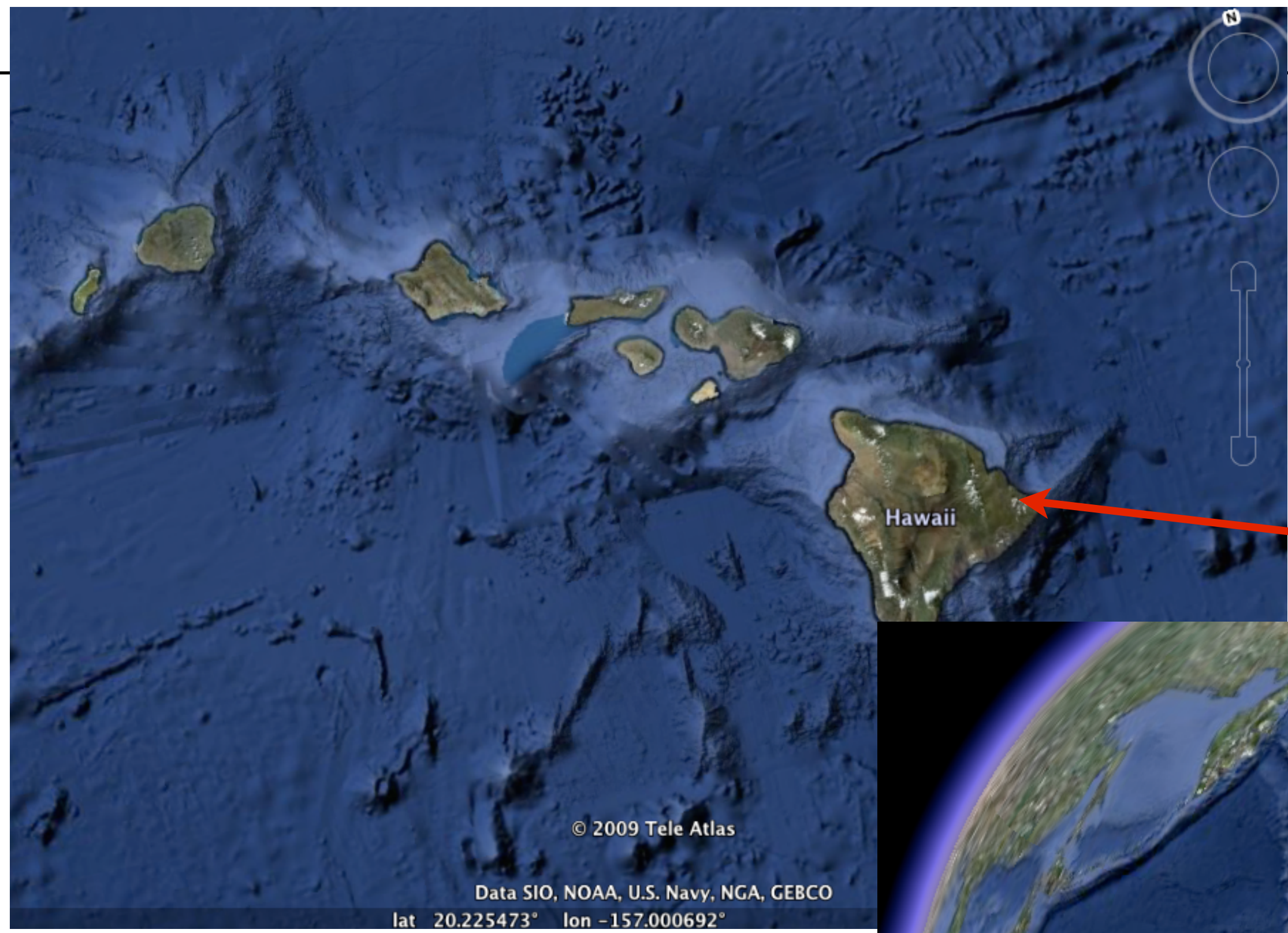
**active**



NOT a mid-ocean ridge spreading system

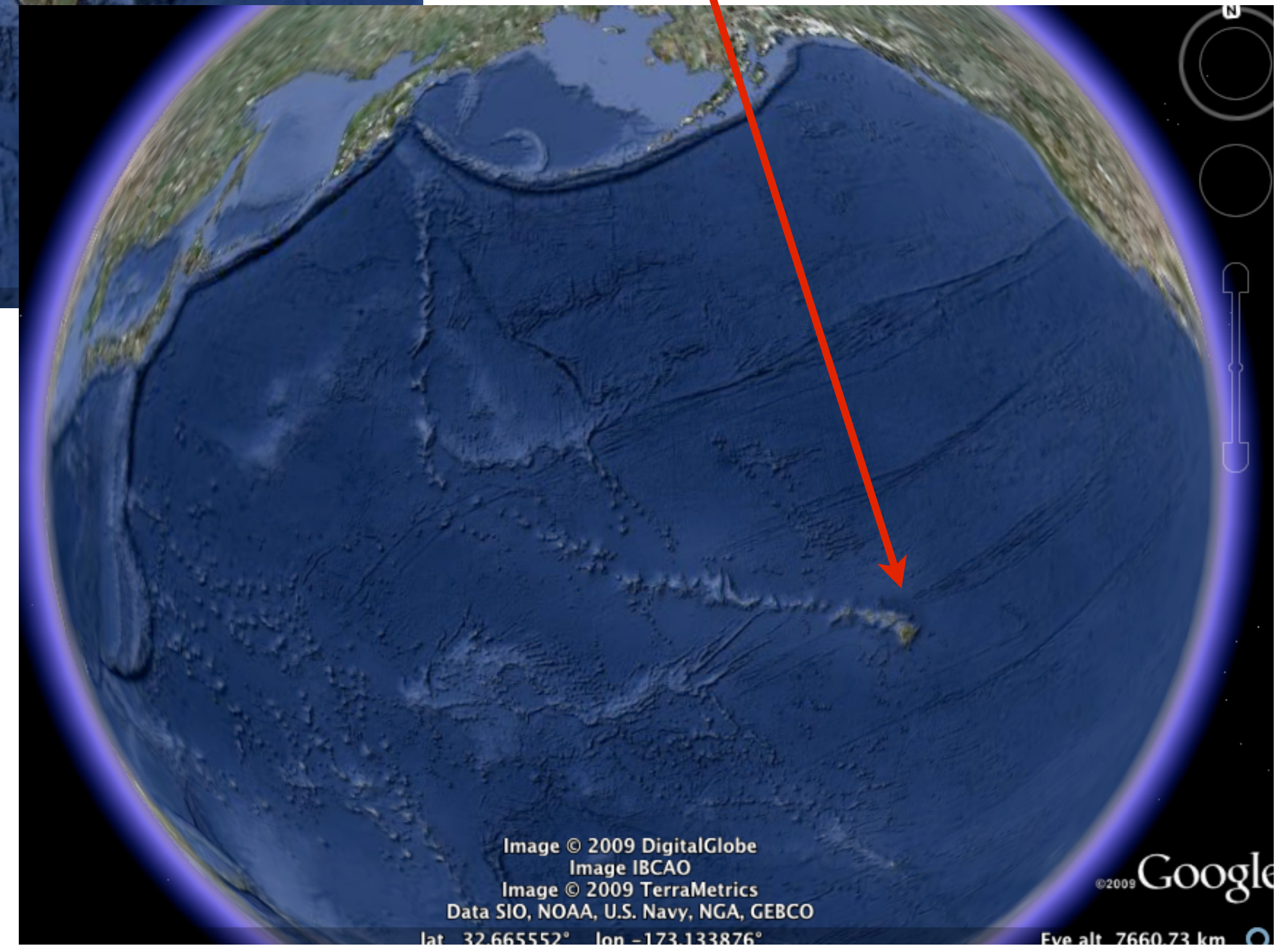


# Location



Hawaiian Hot Spot track

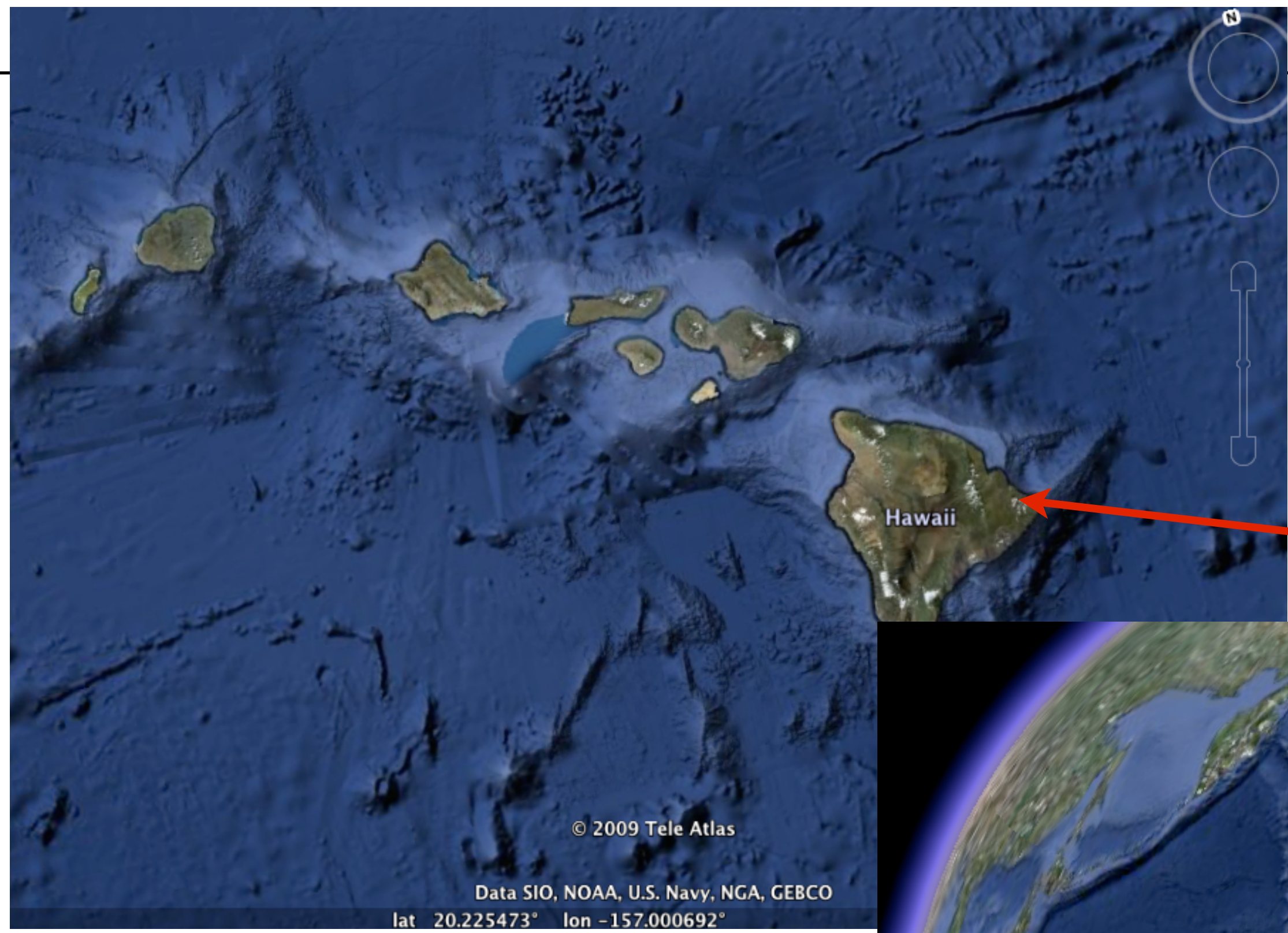
**active**



NOT a mid-ocean ridge spreading system

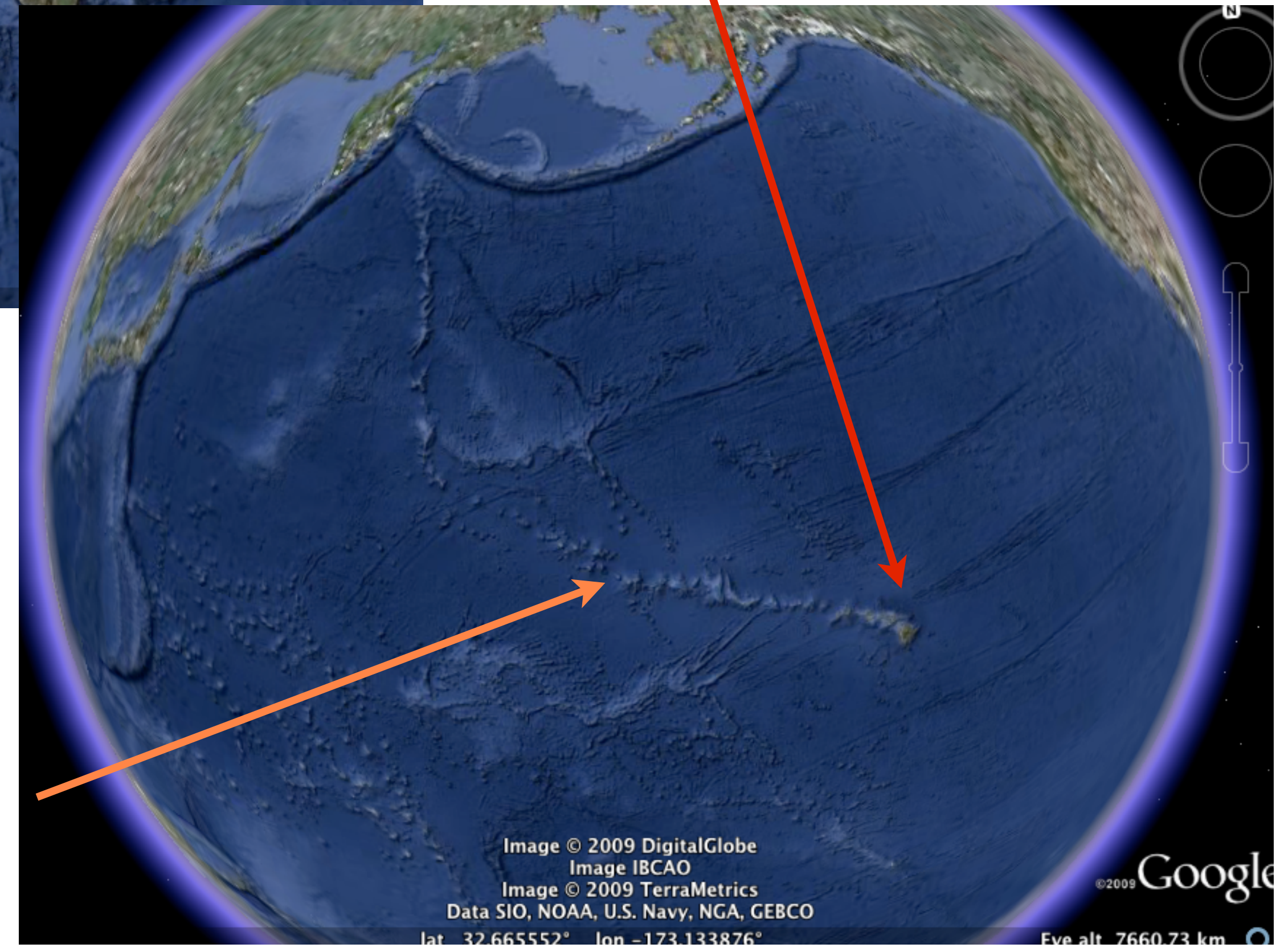
How do we know?

# Location



Hawaiian Hot Spot track

**active**



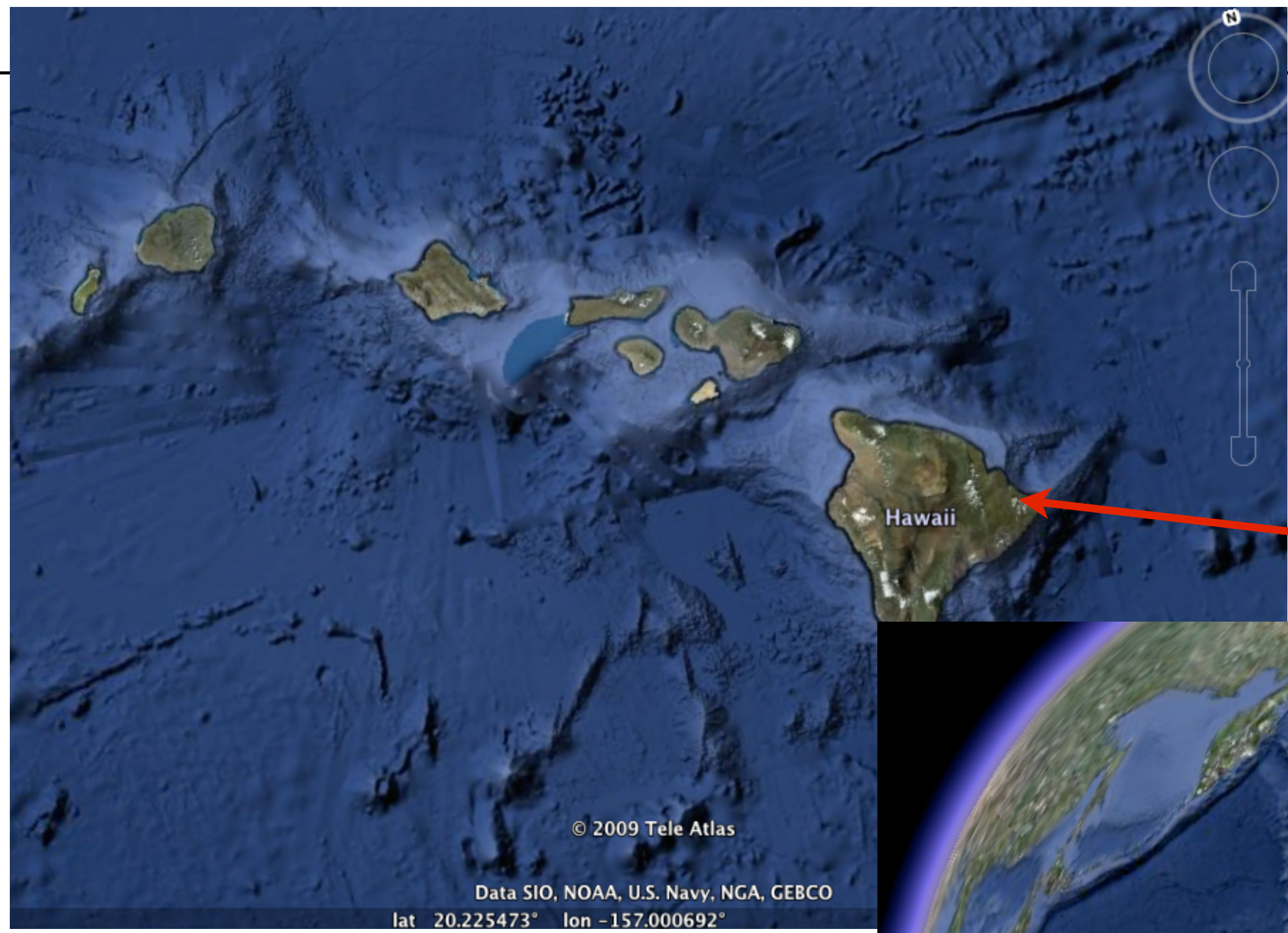
NOT a mid-ocean ridge spreading system

**30 million years ago**

© 2009 Tele Atlas  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
lat 20.225473° lon -157.000692°

Image © 2009 DigitalGlobe  
Image IBCAO  
Image © 2009 TerraMetrics  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
lat 32.665552° lon -173.133876°  
©2009 Google  
Eye alt 7660.73 km

# Location



Hawaiian Hot Spot track

**active**

NOT a mid-ocean ridge spreading system

**47 million years ago**

**30 million years ago**

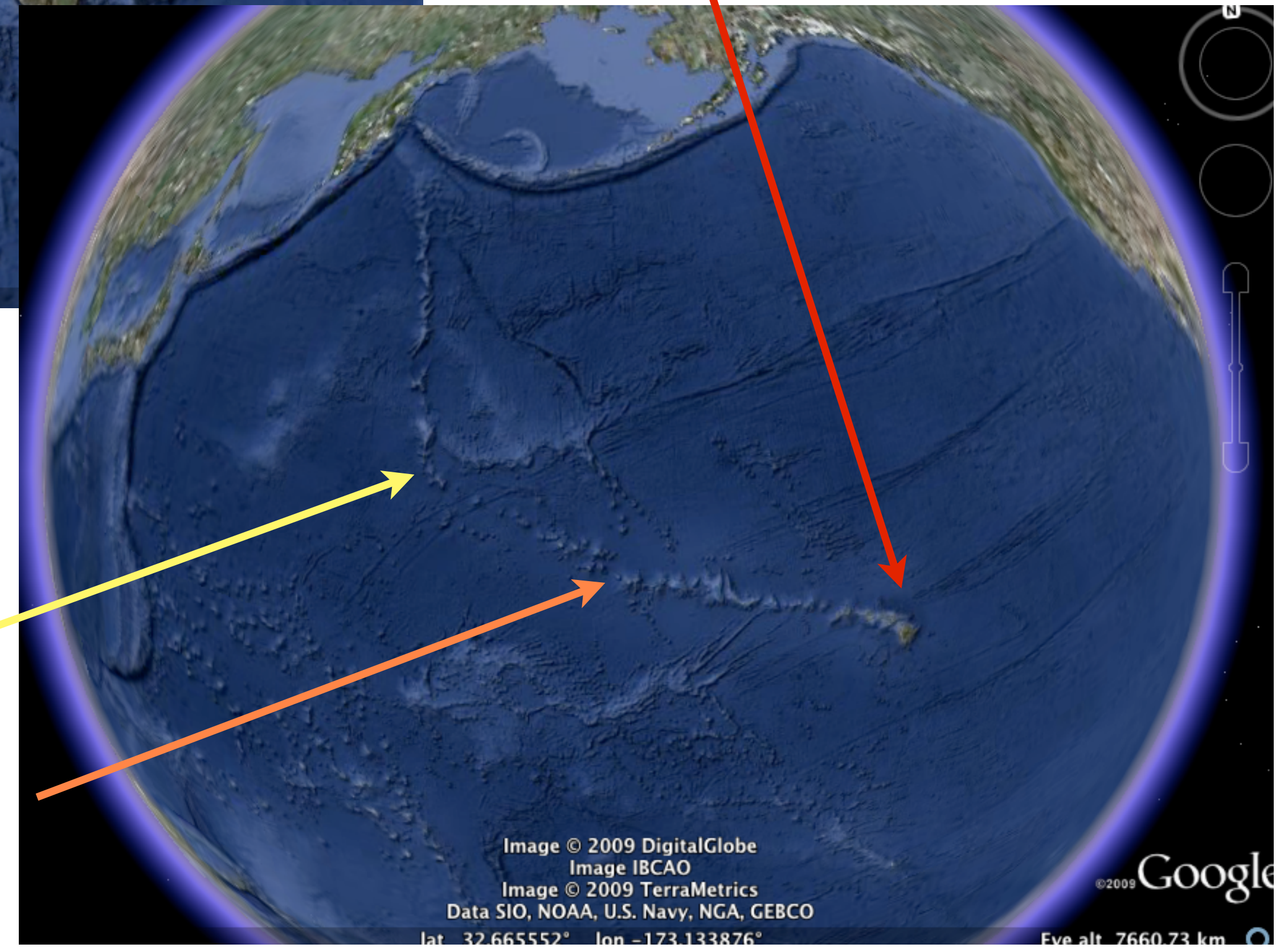
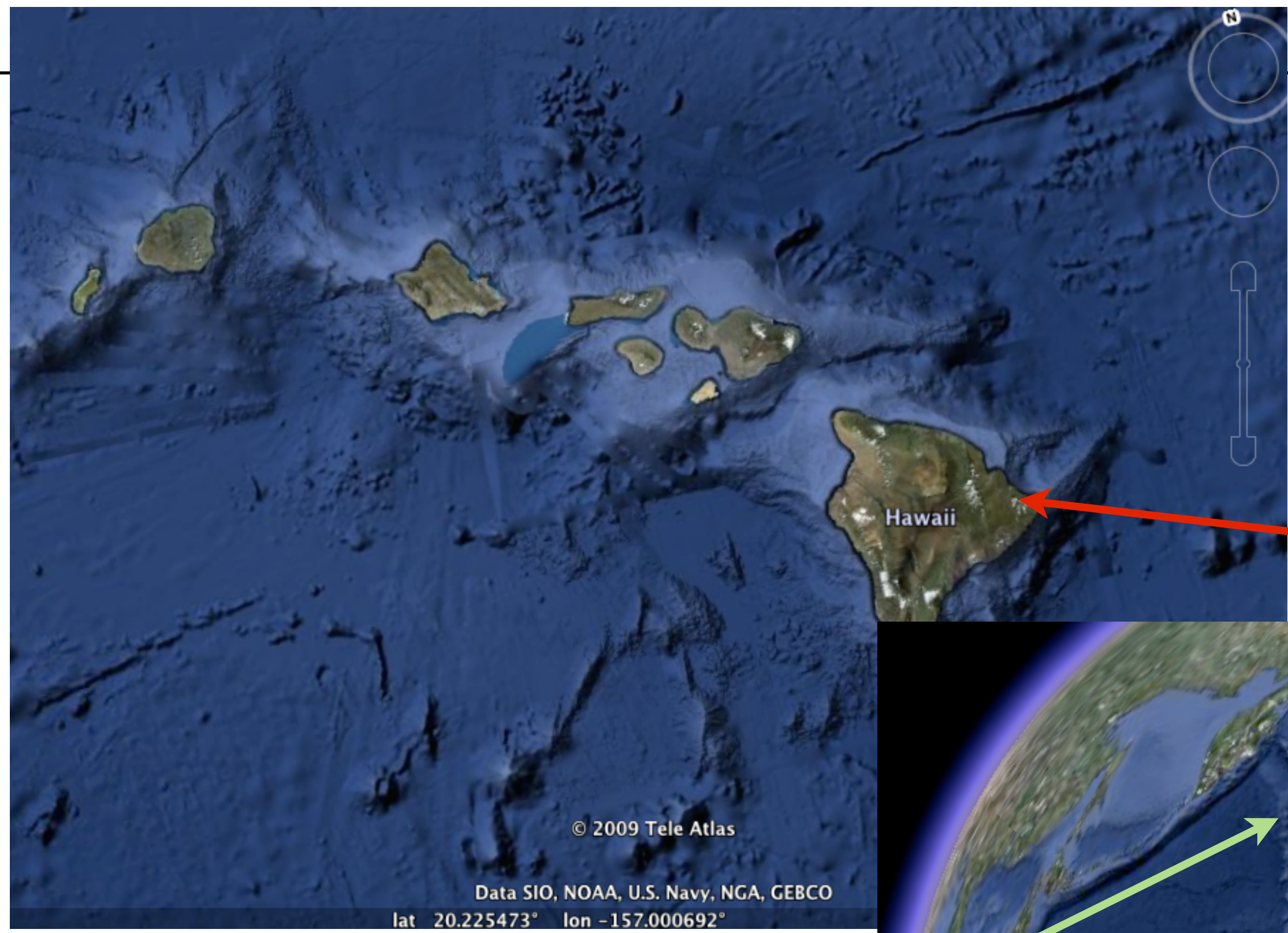


Image © 2009 DigitalGlobe  
Image IBCAO  
Image © 2009 TerraMetrics  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
lat 32.665552° lon -173.133876°

©2009 Google

Eye alt 7660.73 km

# Location



Hawaiian Hot Spot track

**active**

NOT a mid-ocean ridge spreading system **82 million years ago**

**47 million years ago**

**30 million years ago**

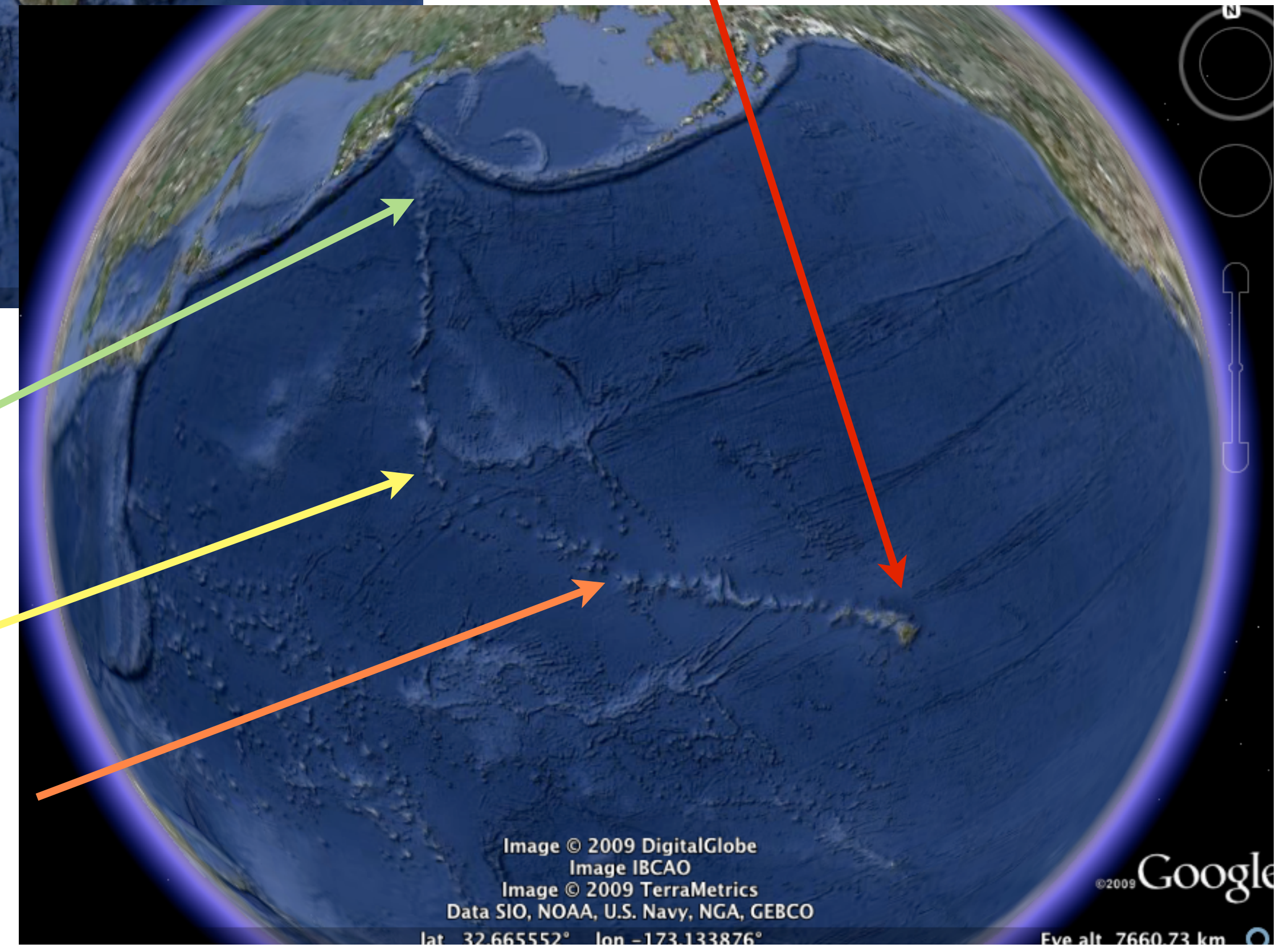
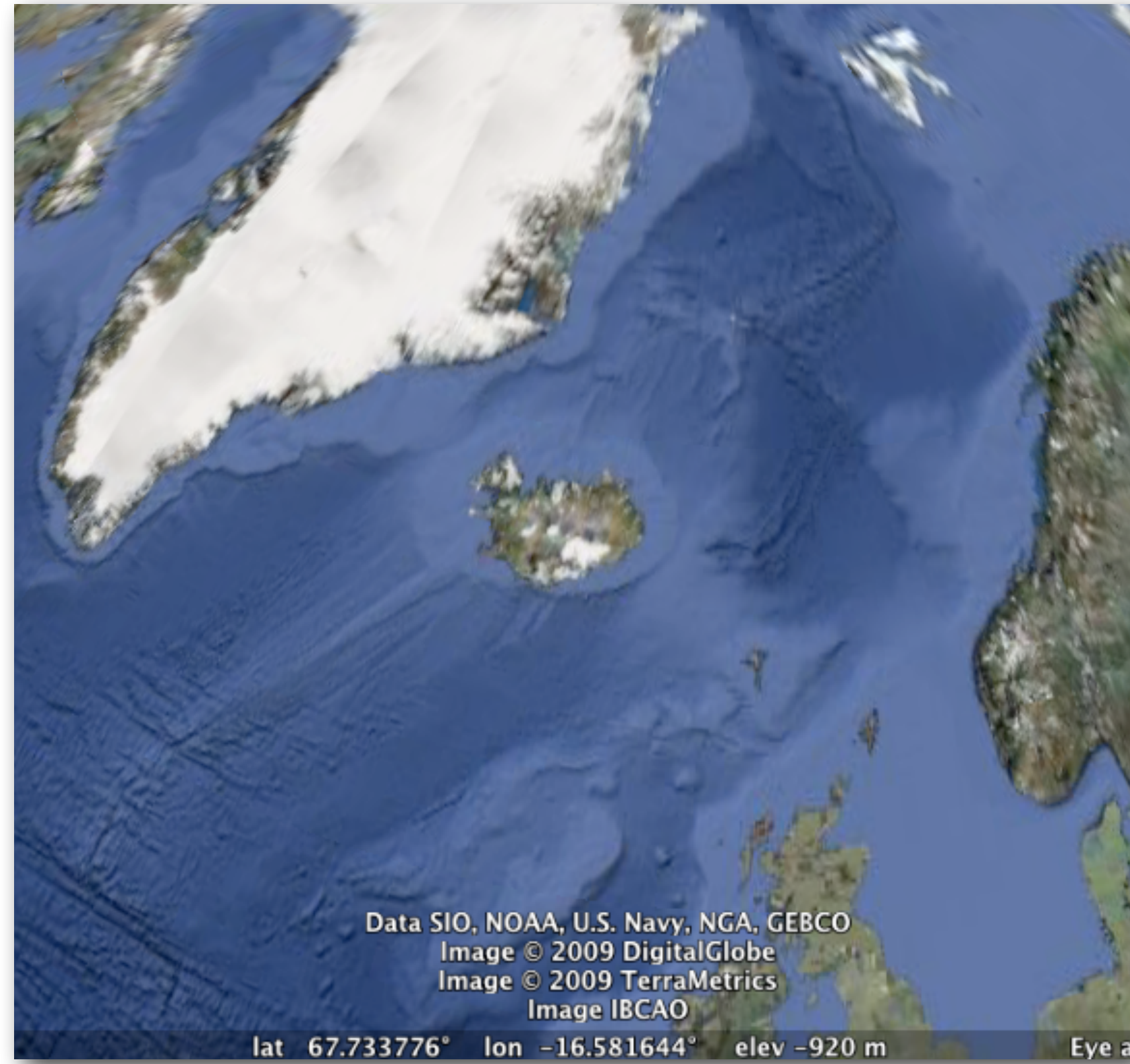


Image © 2009 DigitalGlobe  
Image IBCAO  
Image © 2009 TerraMetrics  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO  
lat 32.665552° lon -173.133876°

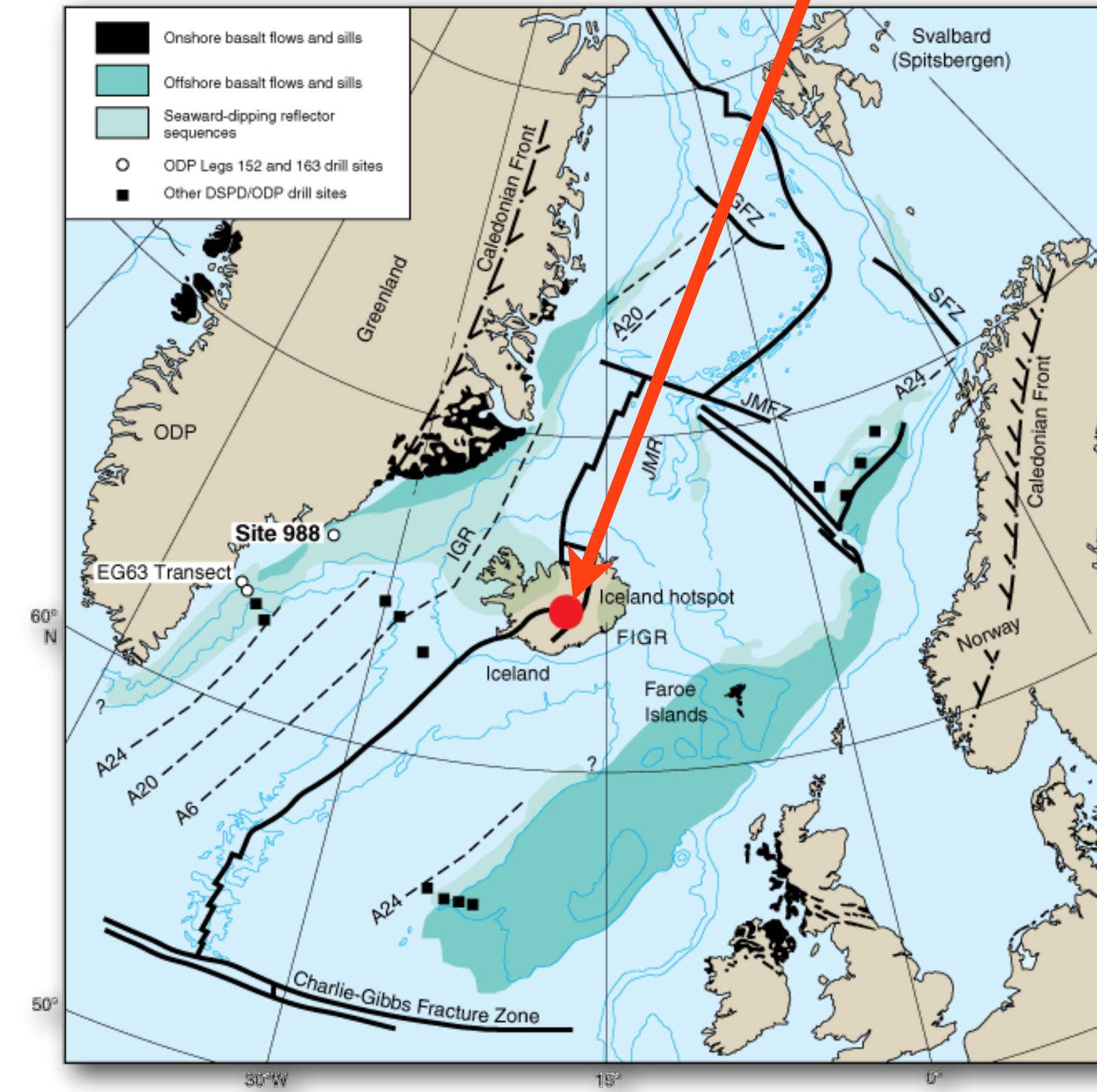
©2009 Google

Eye alt 7660.73 km

## Iceland



## Mid-ocean Ridge + Hot Spot



[http://www-odp.tamu.edu/publications/163X\\_IR/101/images/01\\_f01.gif](http://www-odp.tamu.edu/publications/163X_IR/101/images/01_f01.gif)

Mid-Atlantic Ridge is coincidentally above a mantle plume in this location

# Location

## Surtsey, Iceland



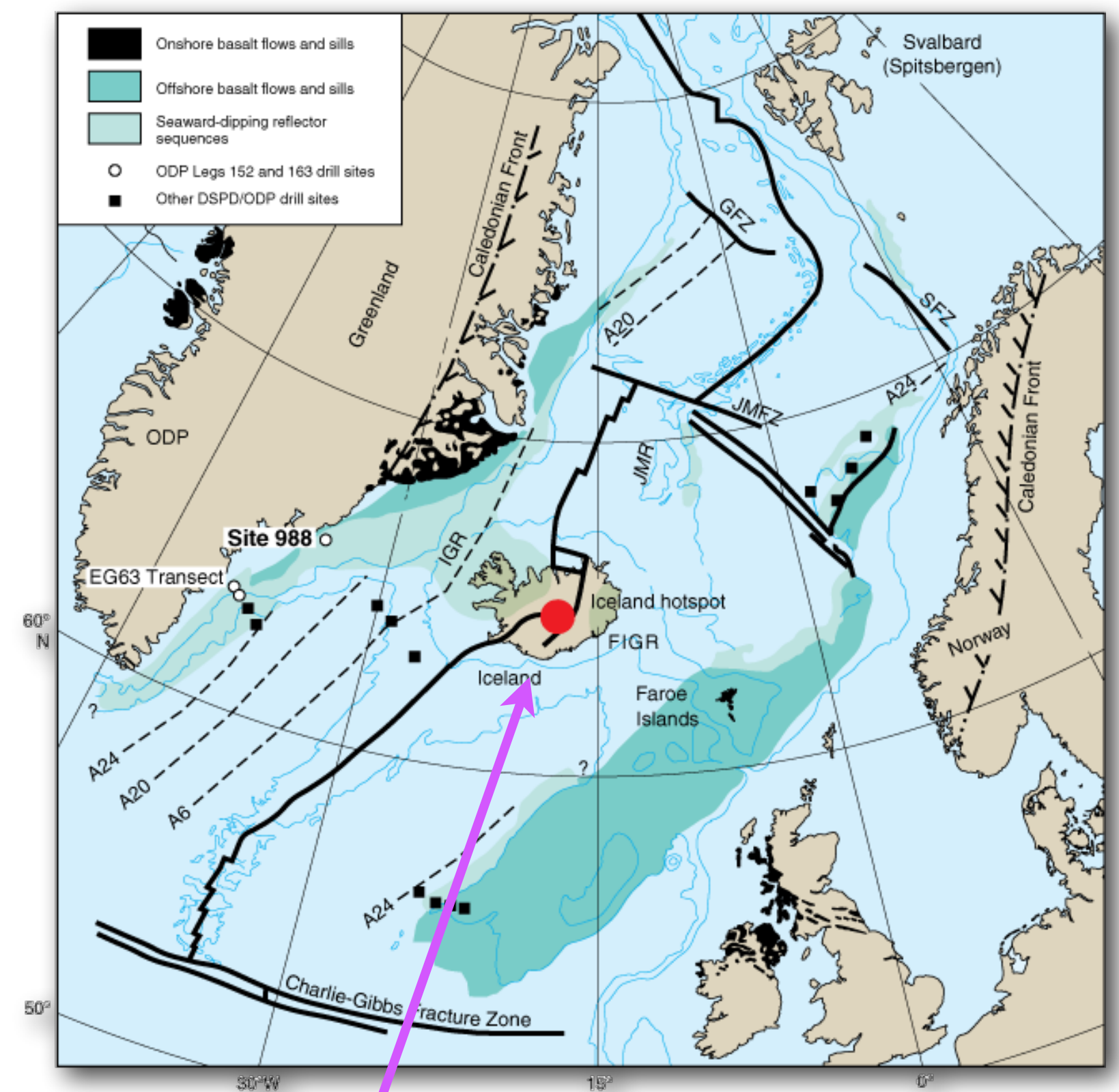
Birth of a new island, 1963

<http://www.allseasonhotels.is/FileLib/Myndir/sidur/Natturan/Surtsey/Iceland2.jpg>



image from GoogleEarth

## Mid-ocean Ridge + Hot Spot



[http://www-odp.tamu.edu/publications/163X\\_IR/101/images/01\\_f01.gif](http://www-odp.tamu.edu/publications/163X_IR/101/images/01_f01.gif)

Surtsey

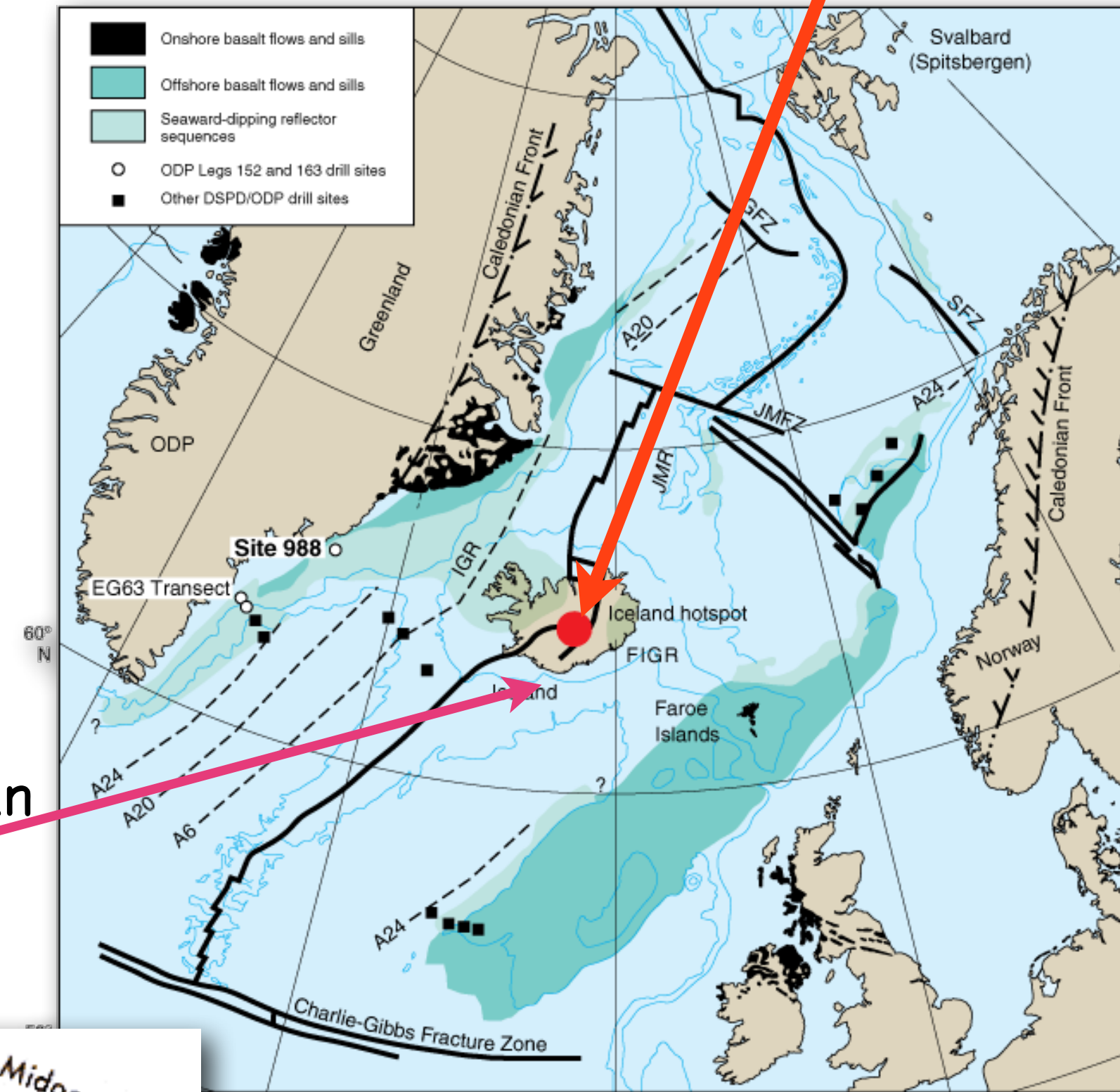
Surtsey, Iceland



one year later

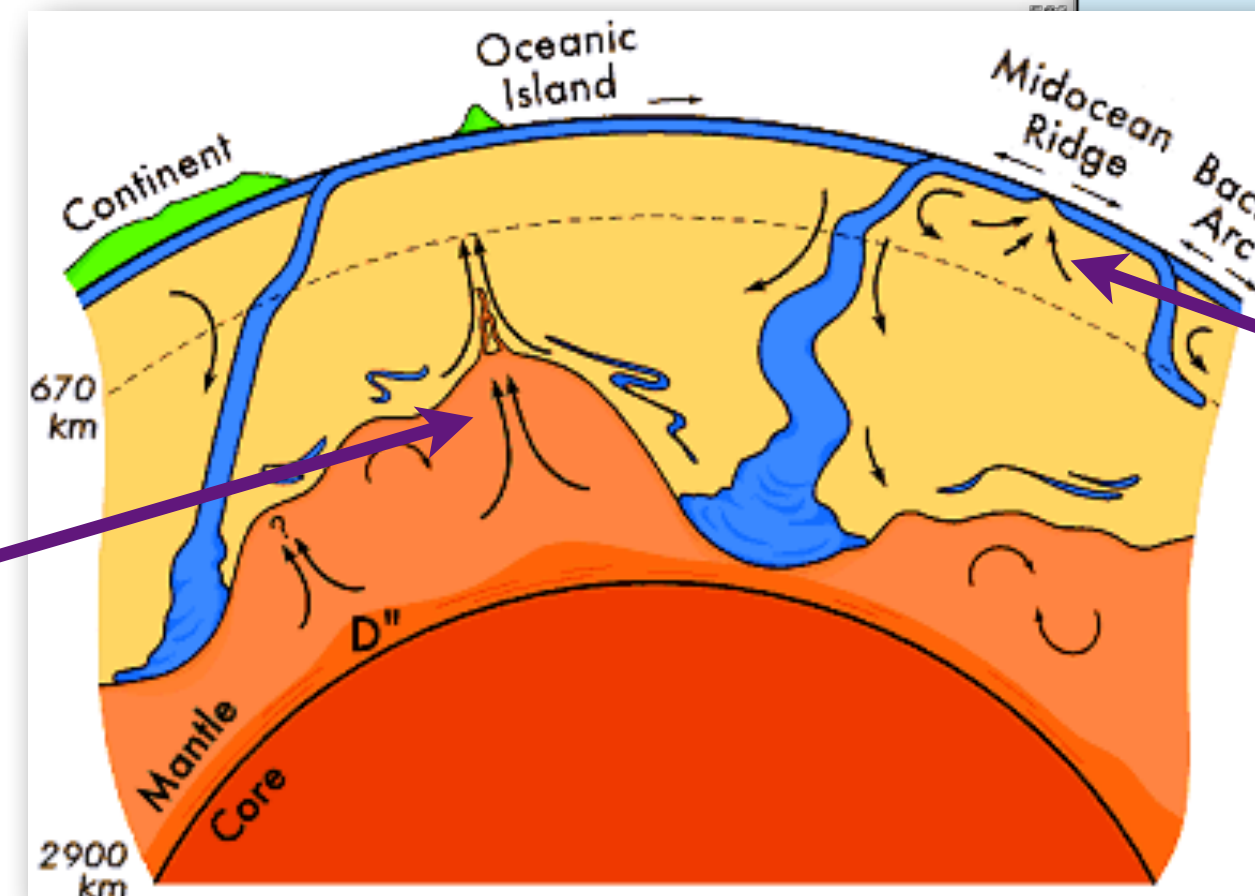
the new island is NOT exactly on mid ocean ridge, but to one side

## Mid-ocean Ridge + Hot Spot



[www-odp.tamu.edu/publications/163X\\_IR/101/images/01\\_f01.gif](http://www-odp.tamu.edu/publications/163X_IR/101/images/01_f01.gif)

Hot Spot above deep Mantle plume



Spreading ridge above Upper Mantle convection

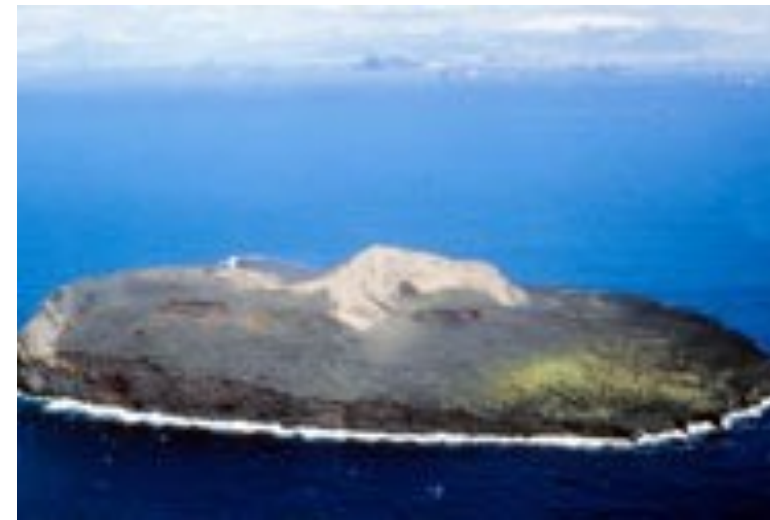
# Location

## Surtsey, Iceland

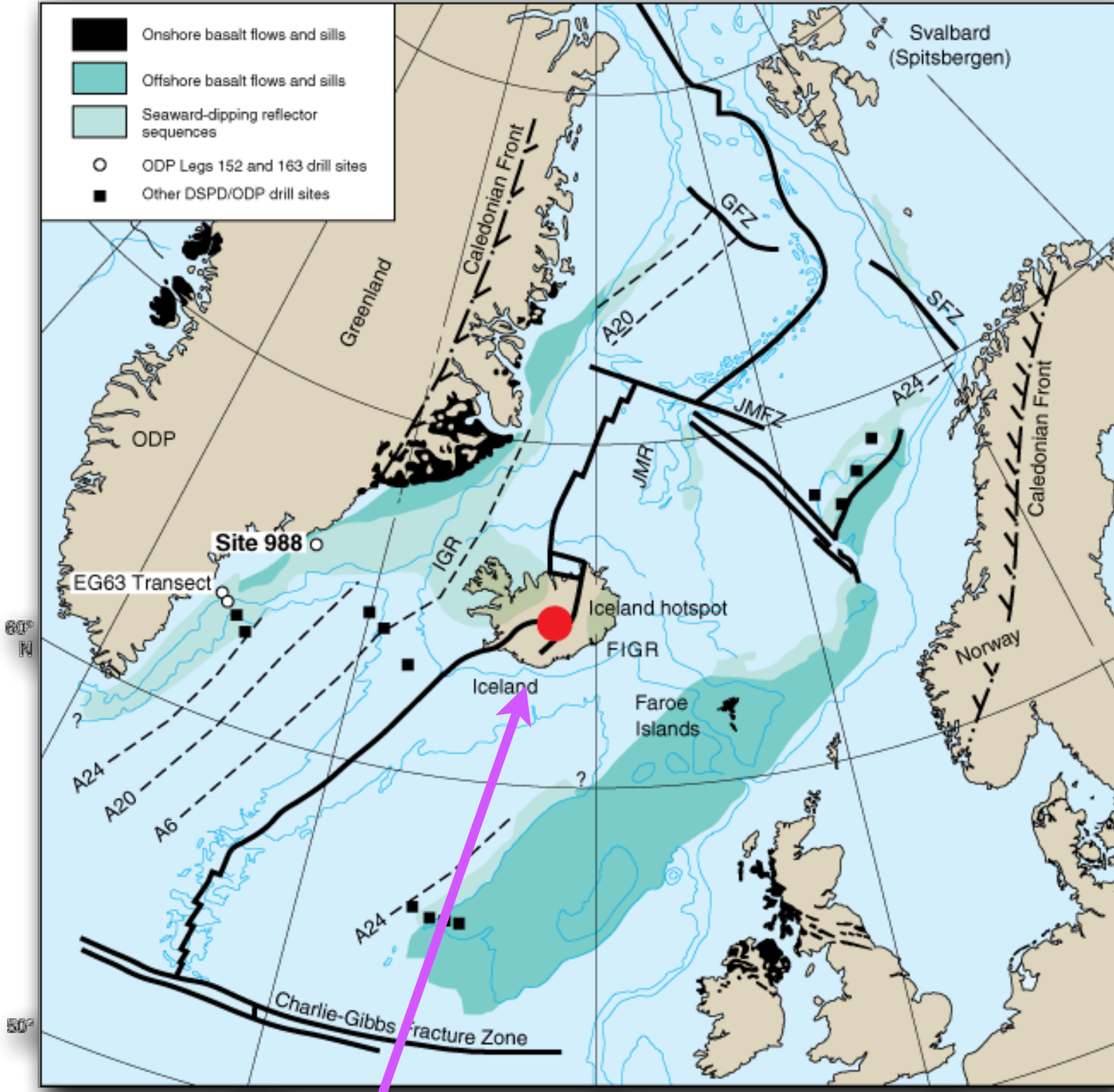
## Mid-ocean Ridge + Hot Spot



2008



<http://whc.unesco.org/en/list/1267>



[http://www-odp.tamu.edu/publications/163X\\_IR/101/images/01\\_f01.gif](http://www-odp.tamu.edu/publications/163X_IR/101/images/01_f01.gif)

<http://www.allseasonhotels.is/FileLib/Myndir/sidur/Natturan/Surtsey/Iceland2.jpg>



image from GoogleEarth

Surtsey



# Natural Hazards and Disaster

## Class 6: Volcanoes

- News
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- Comparison to other Hazards

## Basalt

- ⊗ A relatively low viscosity magma - extrudes onto the surface
- ⊗ low in Silica content ( $\text{SiO}_2$ )
- ⊗ dark color - contains lots of iron oxide ( $\text{FeO}$ ,  $\text{Fe}_2\text{O}_3$ ) and magnesium oxide ( $\text{MgO}$ )
- ⊗ high density  $\rho = m/v$
- ⊗ may contain distinctive green olivine crystals

Hawaii and Iceland are both made of Basalt



[http://z.about.com/d/geology/1/0/H/W/basalt\\_hawaii2.jpg](http://z.about.com/d/geology/1/0/H/W/basalt_hawaii2.jpg)



<http://www.grossmont.edu/judd.curran/images/EldfellEruptionIceland.jpg>



[http://www.geology.wisc.edu/~g111/Volcanoes/Heimaey/usg0403\\_Fx\\_Web.jpg](http://www.geology.wisc.edu/~g111/Volcanoes/Heimaey/usg0403_Fx_Web.jpg)



<http://www.earth.northwestern.edu/people/seth/107/Ridges/Image24.jpg>

dangerous and damaging,  
but localized

# Rhyolite

High viscosity, 'sticky' lava

extrusive equivalent of granite

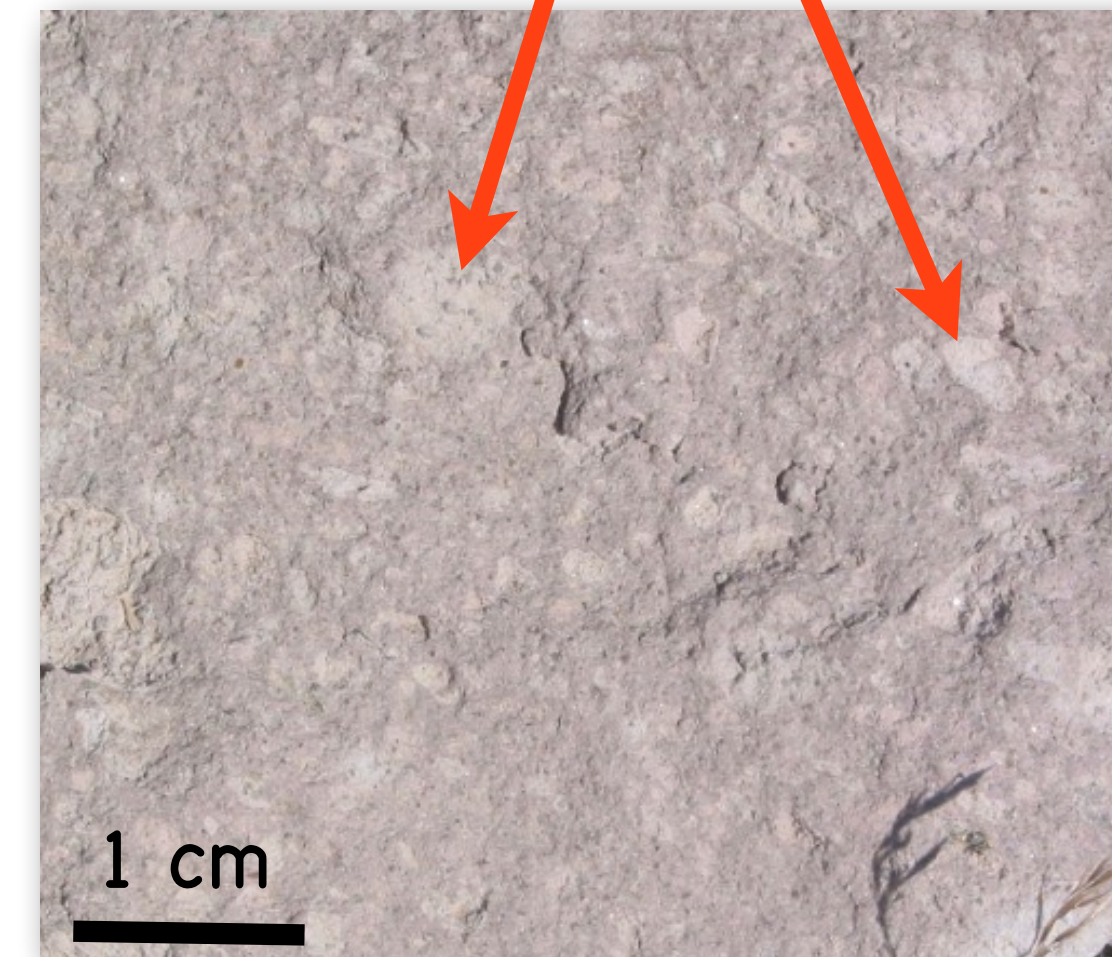
pale in color, low density

high silica content (SiO)

main minerals: quartz (SiO<sub>2</sub>), feldspar (Al-Si-oxide)

**rich in volatiles** (gases) that can make 'foam' → pumice

feldspar crystals



rhyolite (above) and pumice (below) from Long Valley, CA



## Rhyolite forms steep-sided, explosive volcanoes



e.g. Mt. St Helens,  
Washington  
May 1980



<http://pubs.usgs.gov/pinatubo/>

e.g. Mt. Pinatubo,  
Phillipines  
June 1991

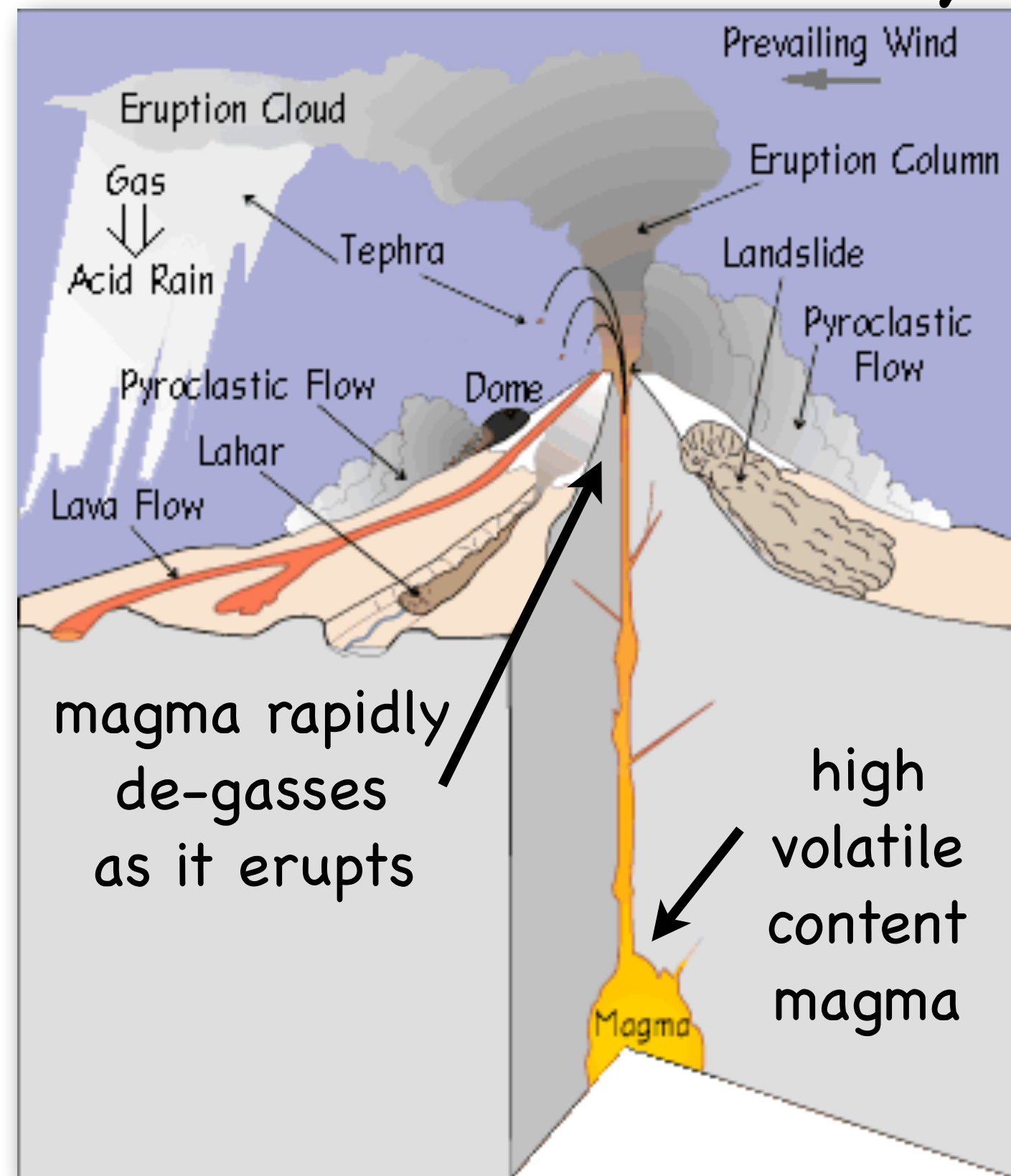


<http://geology.com/usgs/redoubt-volcano-photos/>

e.g. Mt. Redoubt, Alaska  
March 2009

can you find  
others?

# Pyroclastic Flows/Ash Flows



pyroclastic flows - highly dangerous!

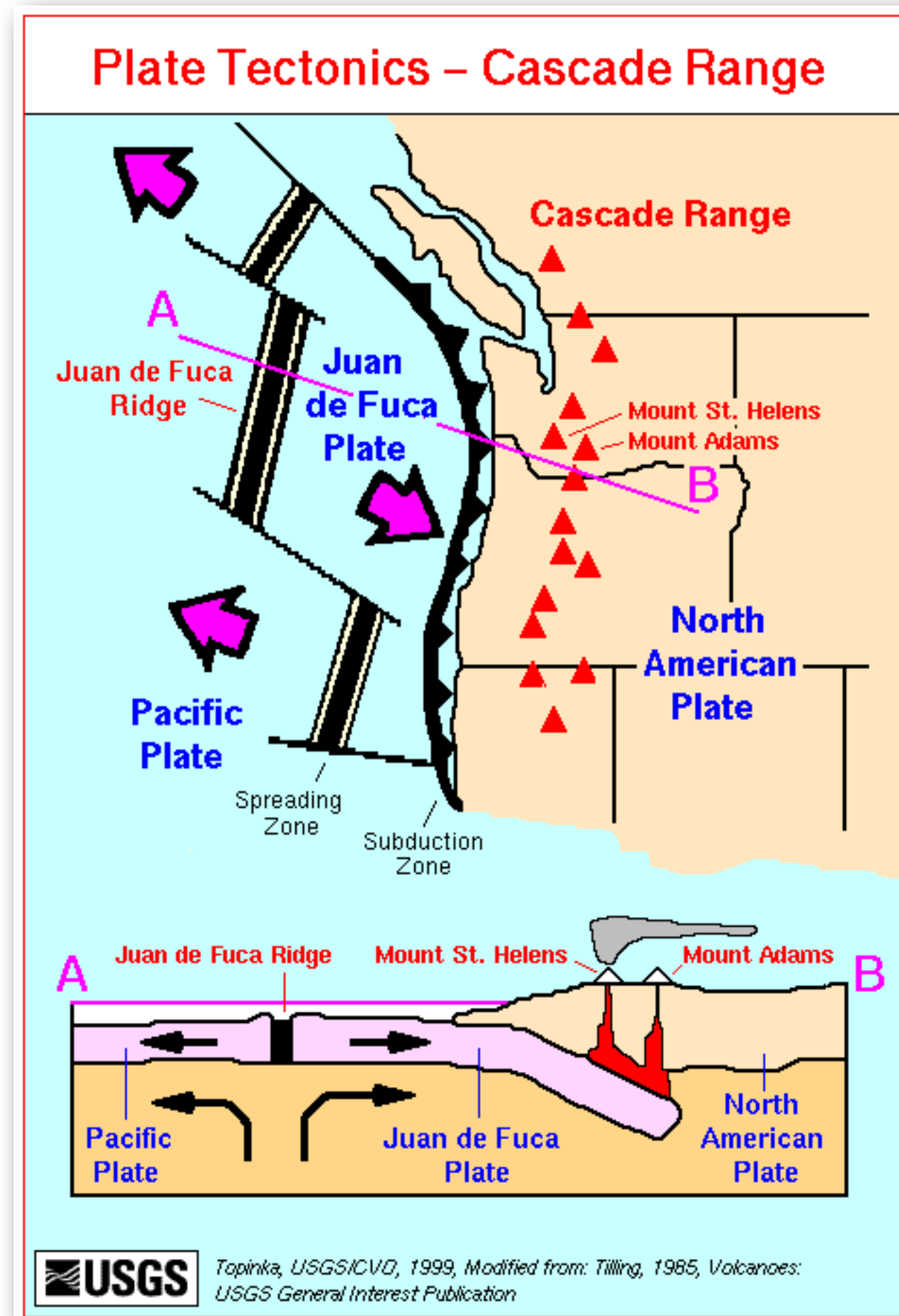


Mayon, Philippines 1984

[http://volcanoes.usgs.gov/Images/Jpg/Mayon/32923351-020\\_caption.html](http://volcanoes.usgs.gov/Images/Jpg/Mayon/32923351-020_caption.html)

very hot gas (up to 800°C) + ash + lava + rock  
moves extremely fast >150 km/h

# Explosive volcanoes are usually subduction-related

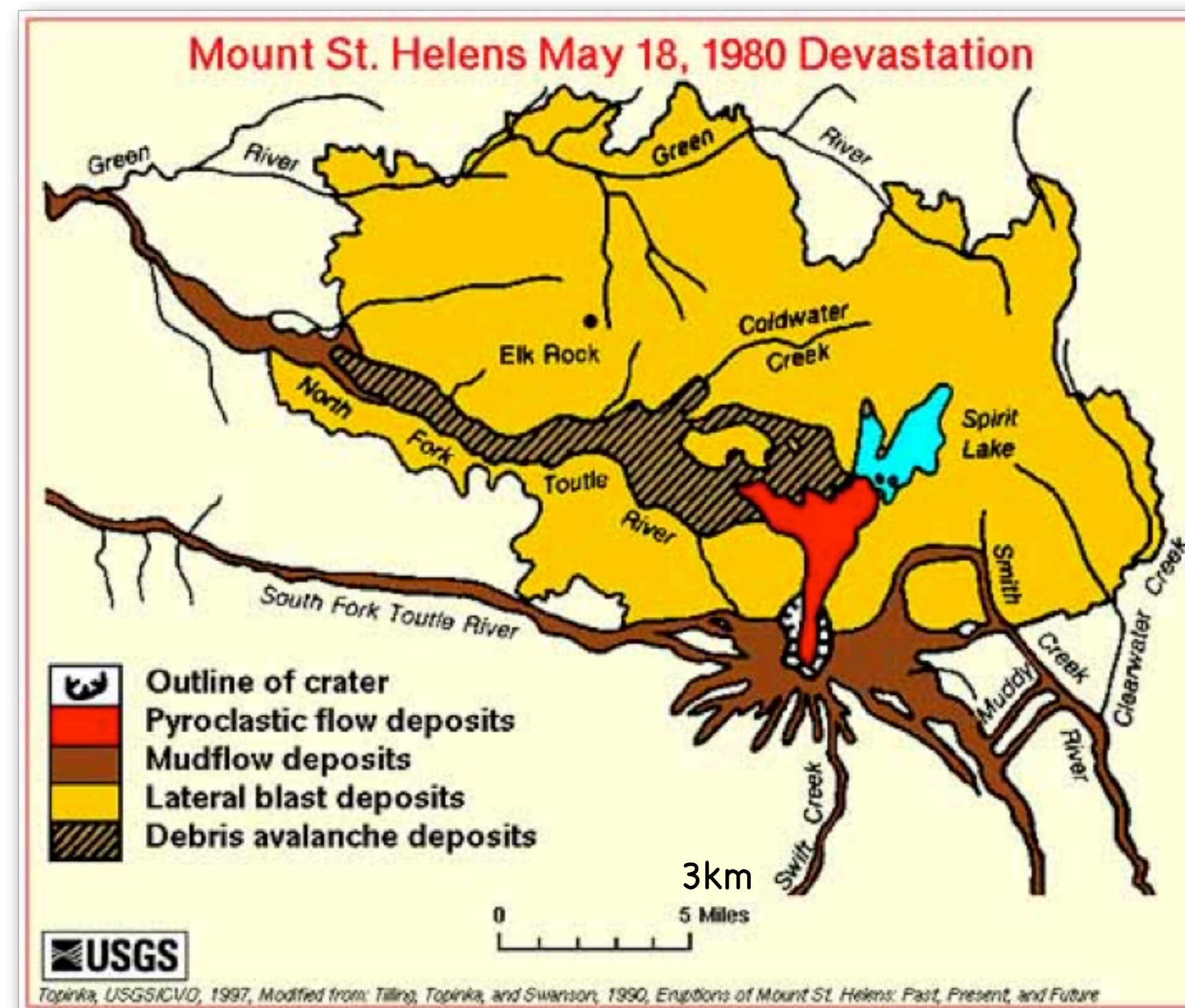


[http://www.skimountaineer.com/CascadeSki/ThreeSisters/  
NorthMiddleSisters.jpg](http://www.skimountaineer.com/CascadeSki/ThreeSisters/NorthMiddleSisters.jpg)

At collisional plate boundaries



## Mt. St. Helens

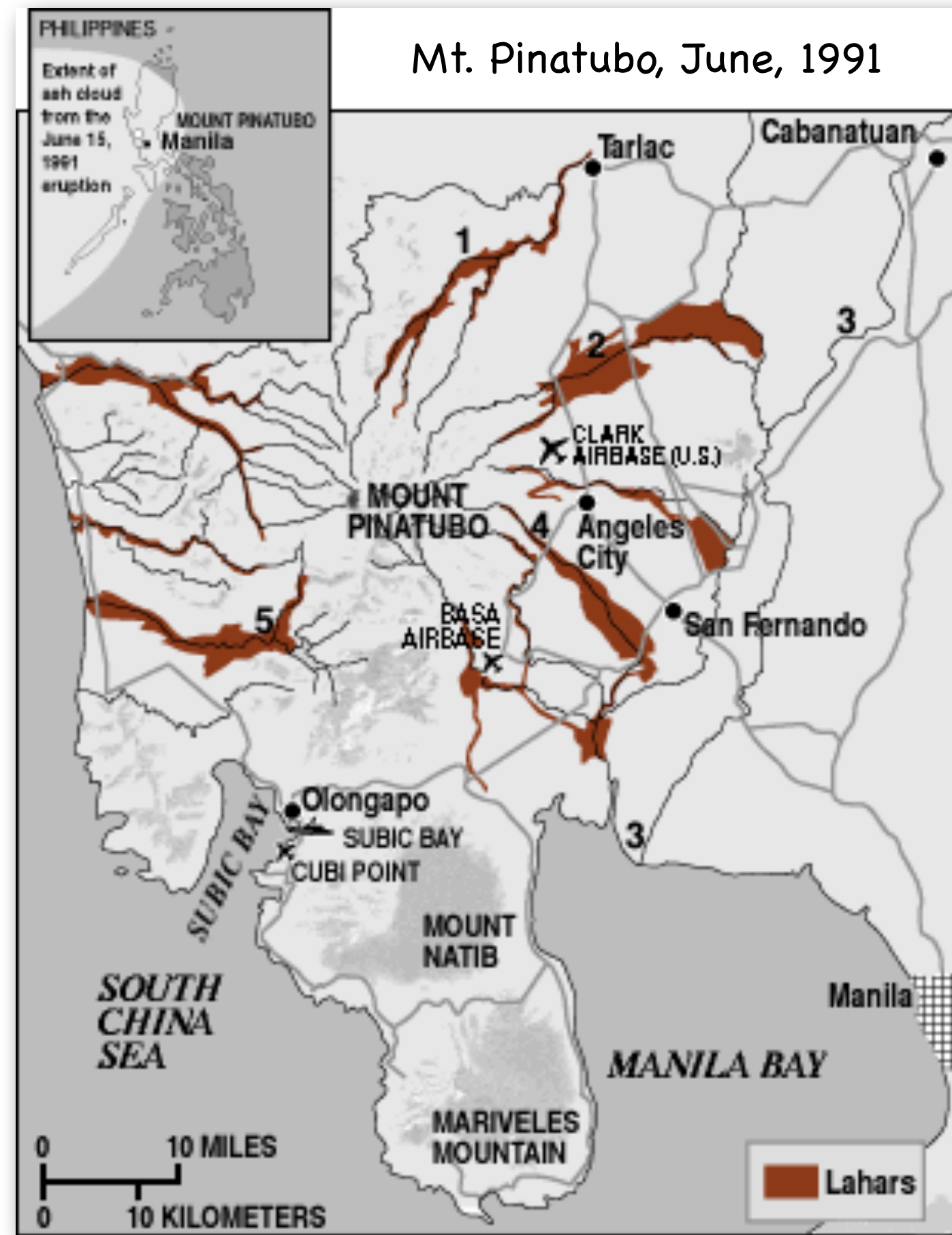


1 cubic km of magma erupted  
main damage was from the lateral blast



Lahars: Mudflows resulting from volcanic activity

slurry of water + lava rocks  
at speeds up to 30 mph



<http://pubs.usgs.gov/fs/1997/fs114-97/resources/LaharMap1.gif>



<http://pubs.usgs.gov/fs/1997/fs113-97/resources/eruption1.jpg>

little or no warning!

>400 square km buried - note location of lahar flows

- ☉ Lahars can be more deadly than the eruption itself!



[http://volcanoes.usgs.gov/Images/Jpg/Ruiz/30410135\\_070\\_large.jpg](http://volcanoes.usgs.gov/Images/Jpg/Ruiz/30410135_070_large.jpg)



[http://volcanoes.usgs.gov/Images/Jpg/Ruiz/30410135\\_069\\_large.jpg](http://volcanoes.usgs.gov/Images/Jpg/Ruiz/30410135_069_large.jpg)

former location of Armero, Columbia after 1985 eruption of Nevado del Ruiz, some 50 km away

over 20,000 killed overnight

Lahars are caused by:

- ☉ Heavy rain during eruption
- ☉ Release of a crater lake
- ☉ Eruption beneath snow or ice

# Natural Hazards and Disaster

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- Volcanic Gases
- Volcanic Eruptions - Examples
- Large Eruptions
- Impacts of Eruptions
- Comparison to other Hazards

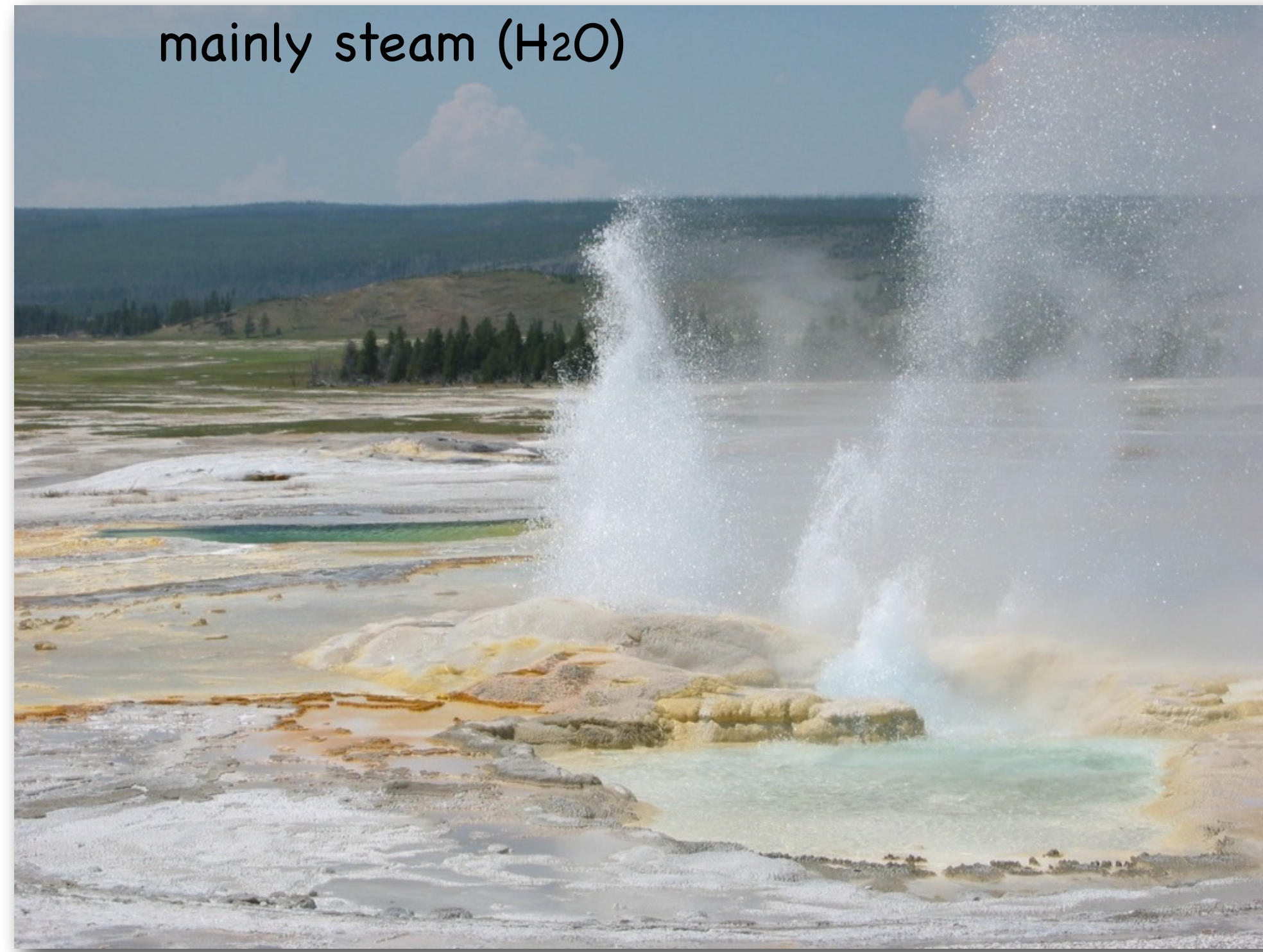
# Natural Hazards and Disaster

## Class 6: Volcanoes

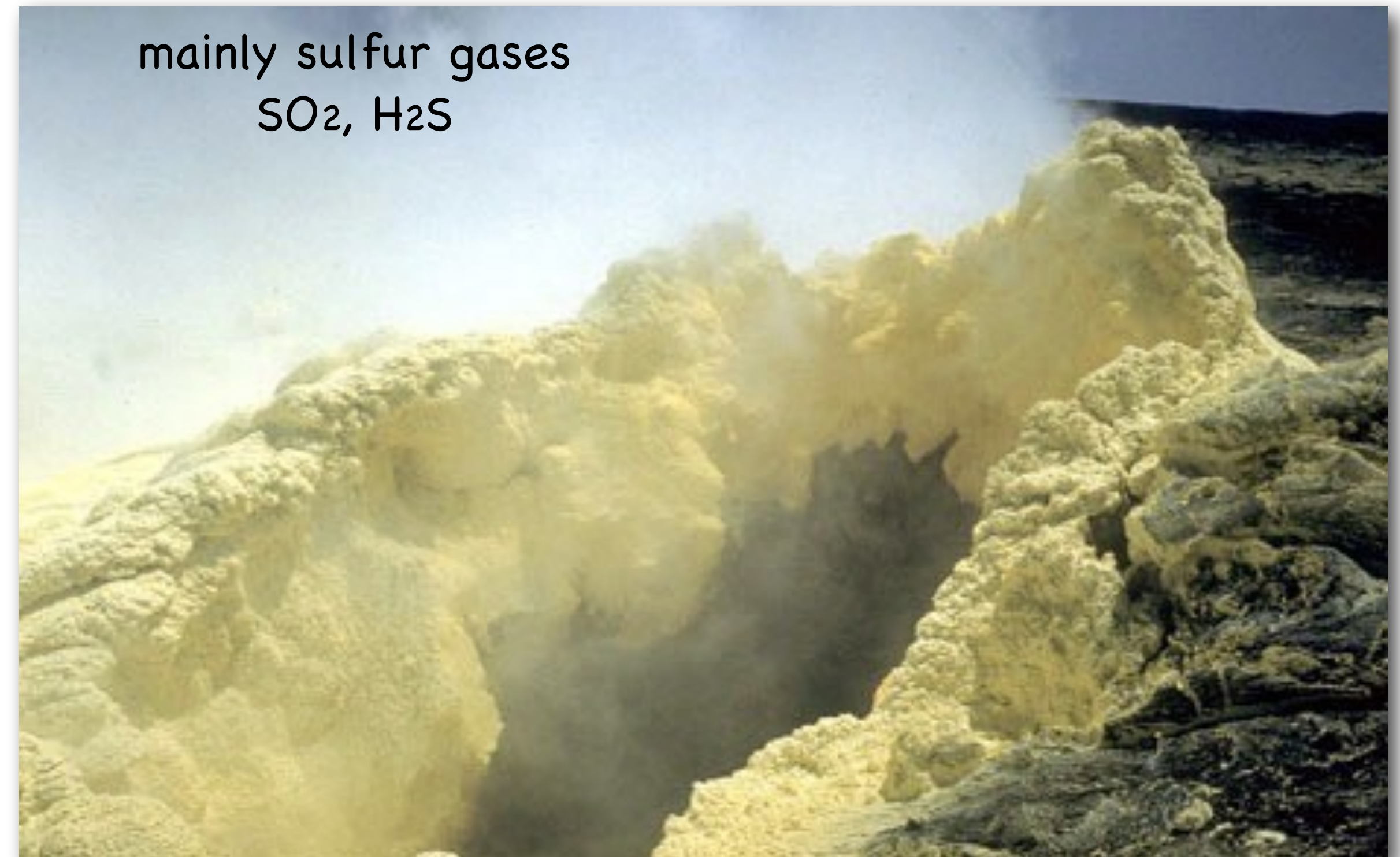
- News
- Size of Volcanic Eruptions
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Volcanoes are sources of dissolved gases  
 $\text{H}_2\text{O}$ ,  $\text{SO}_2$ ,  $\text{CO}_2$ ,  $\text{HCl}$ ....



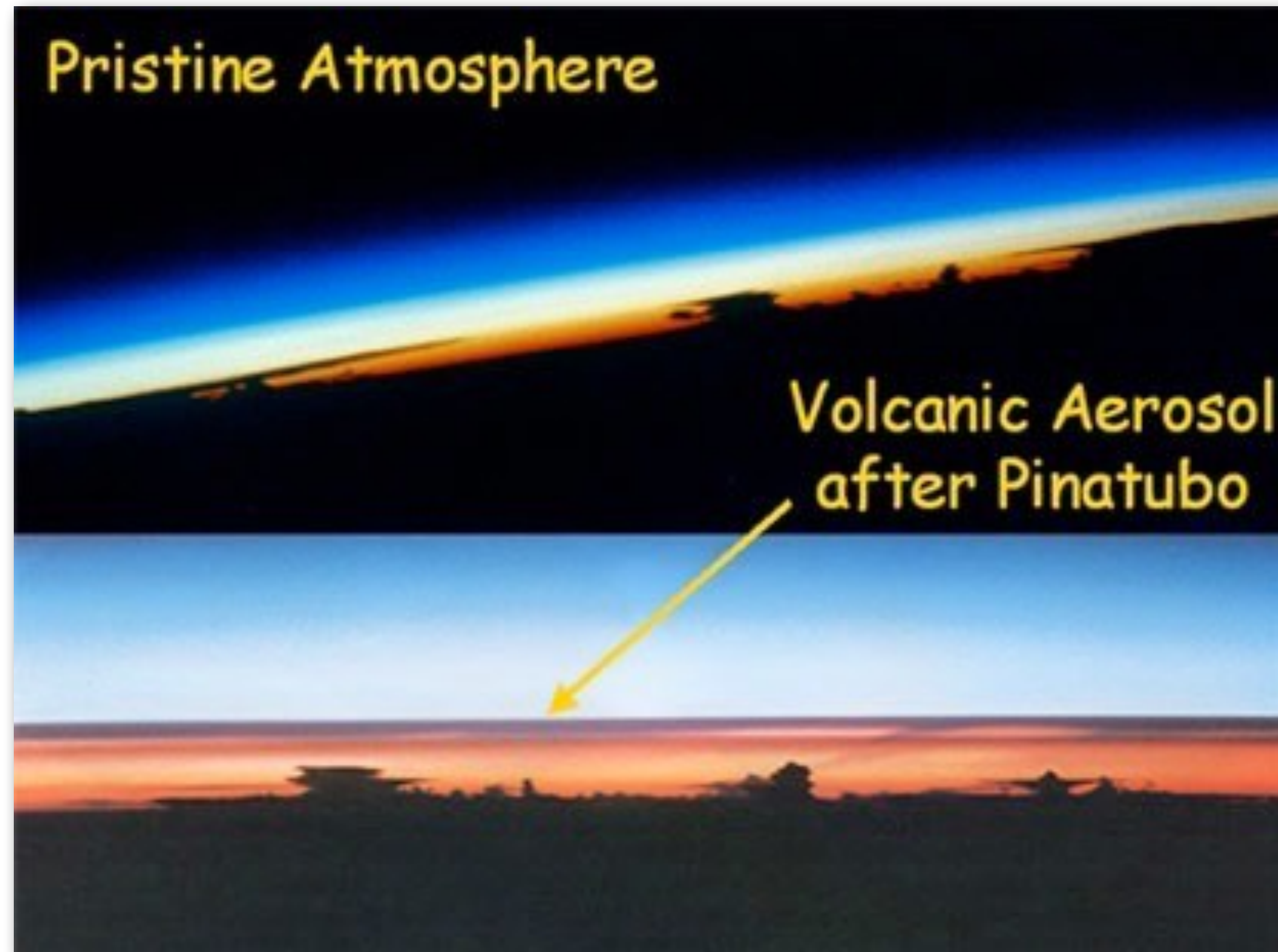
<http://emp.byui.edu/JordanB/Images/Yellowstone/Geyser.jpg>



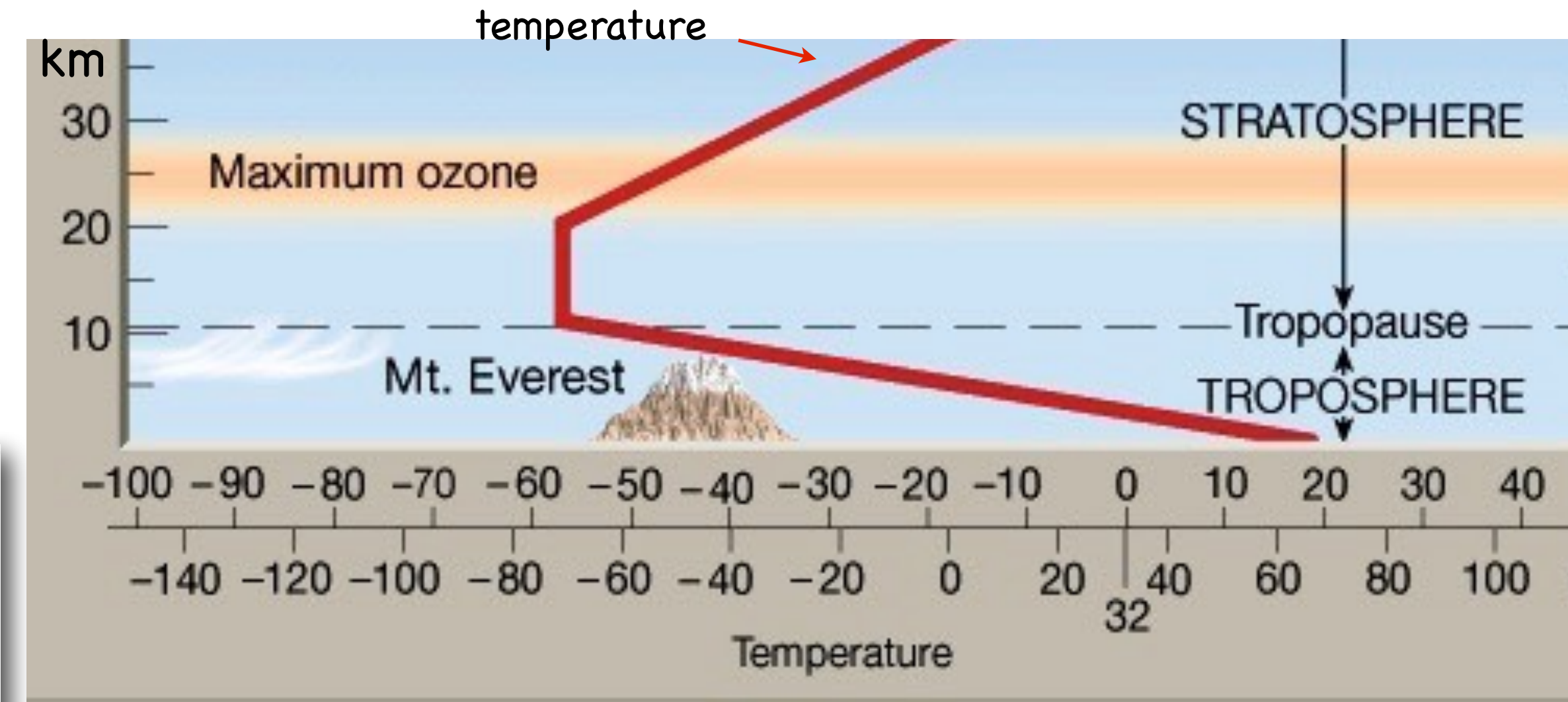
[http://www.geology.sdsu.edu/how\\_volcanoes\\_work/Images/Vent\\_types/fumarole\\_med.jpg](http://www.geology.sdsu.edu/how_volcanoes_work/Images/Vent_types/fumarole_med.jpg)

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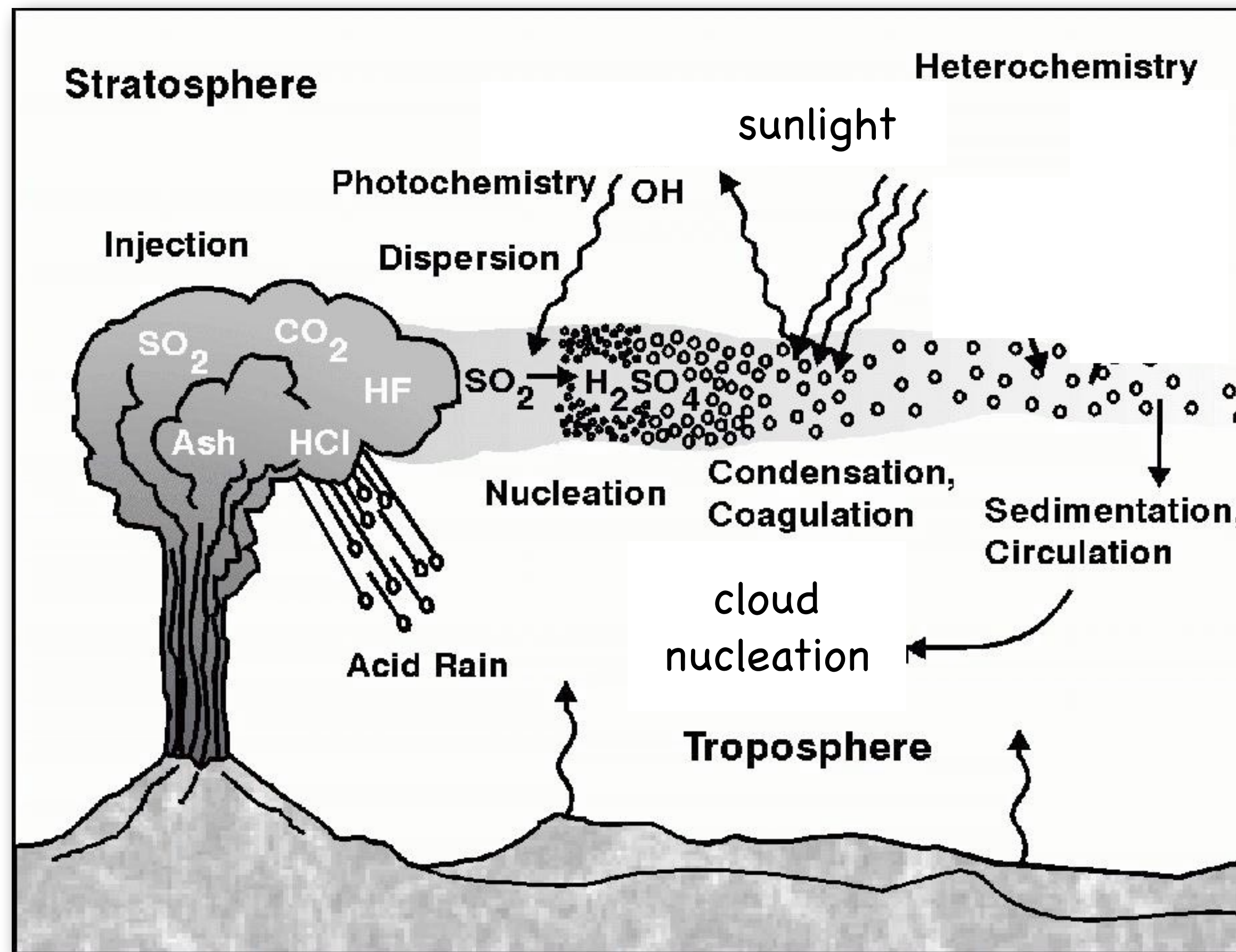
When these get into stratosphere, they can cause temporary global cooling



## Gases in the stratosphere



[http://www.ux1.eiu.edu/~cfjps/1400/FIG01\\_019.JPG](http://www.ux1.eiu.edu/~cfjps/1400/FIG01_019.JPG)



[http://vulcan.wr.usgs.gov/Imgs/Jpg/Projects/Emissions/fsheet\\_fig1.jpg](http://vulcan.wr.usgs.gov/Imgs/Jpg/Projects/Emissions/fsheet_fig1.jpg)

1. Block sunlight
2. Nucleate stratospheric clouds
3. Cause acid rain

Volcanoes are sources of dissolved gases

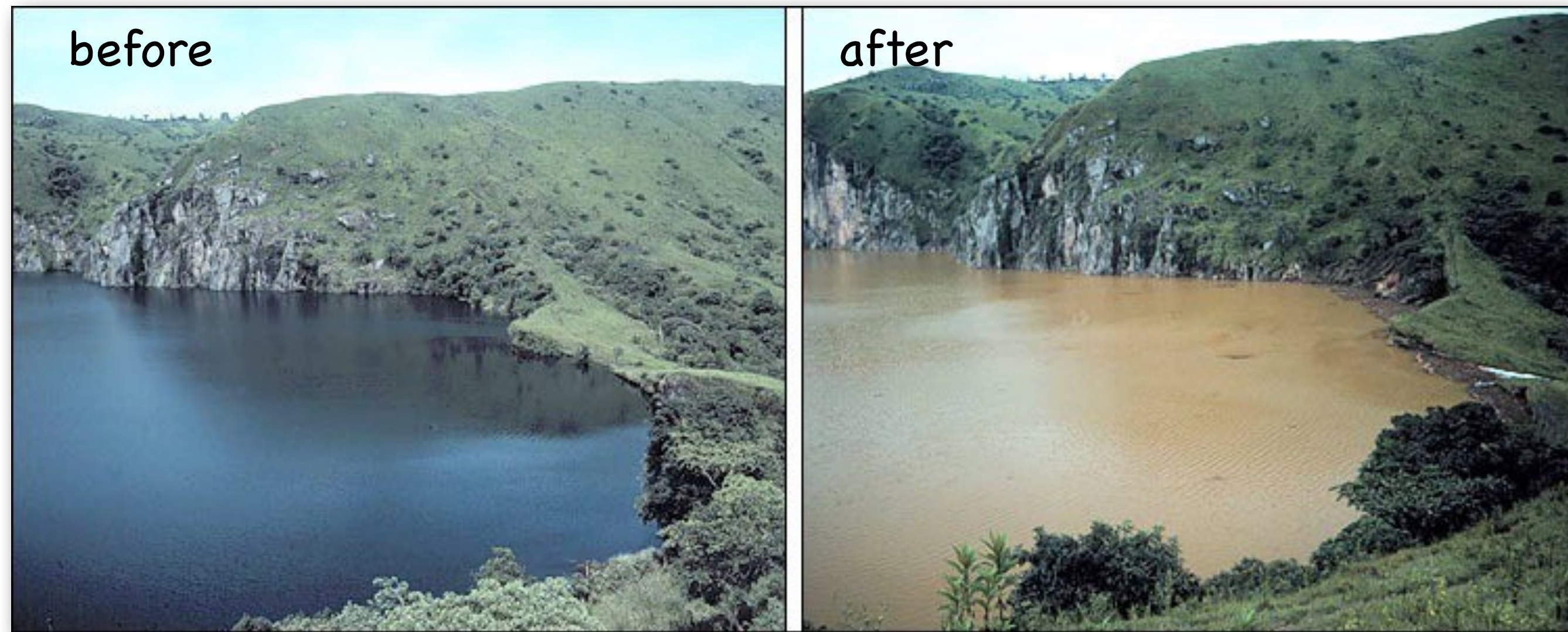
$\text{H}_2\text{O}$ ,  $\text{SO}_2$ ,  $\text{CO}_2$ ,  $\text{HCl}$ ....

When these get into stratosphere, they can cause temporary global cooling

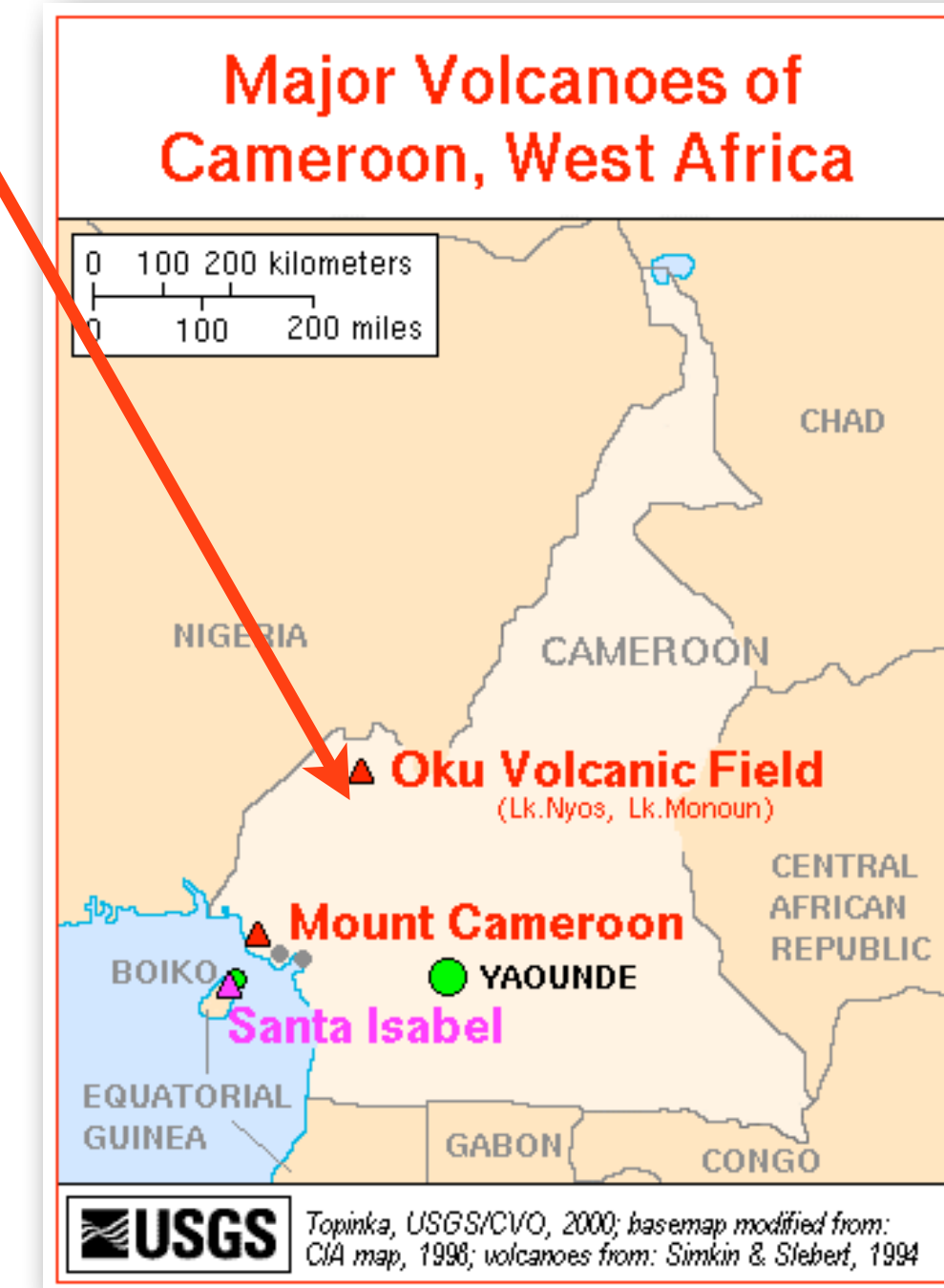
When they collect at the bottom of lakes, this can become disastrous!



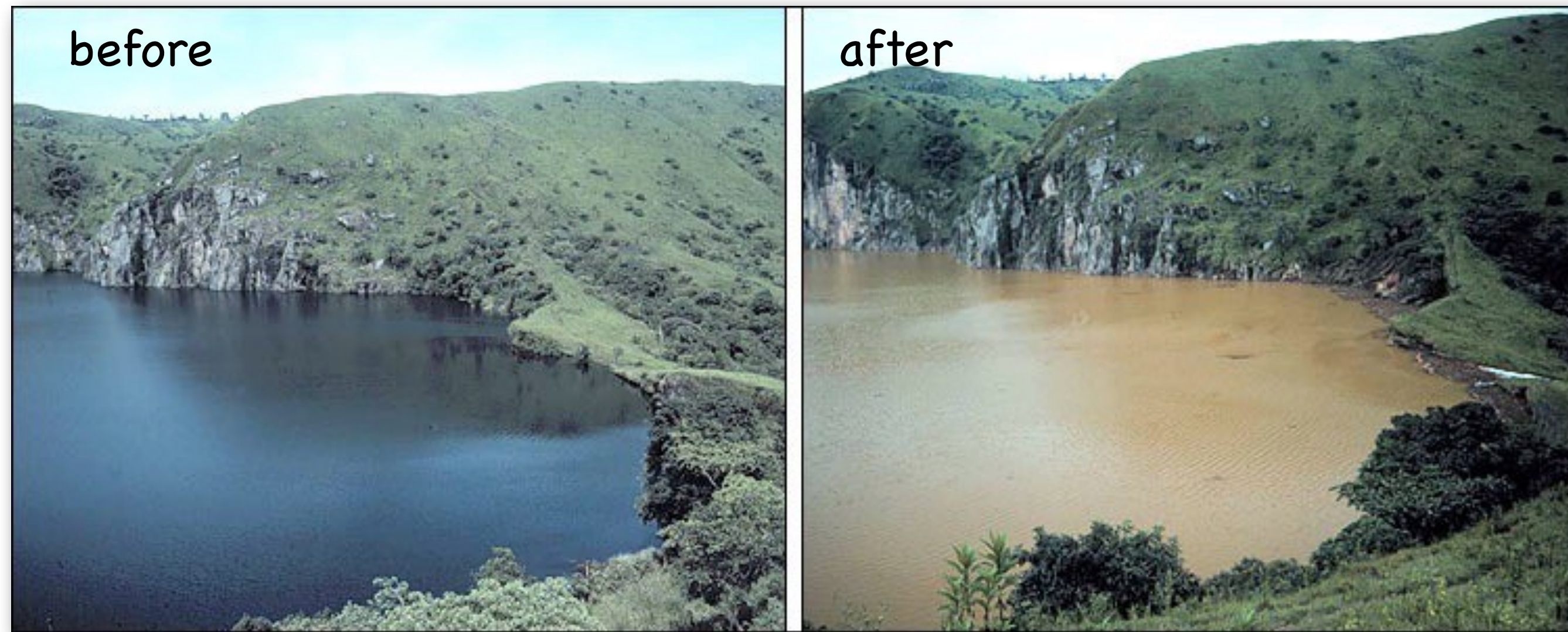
## August 21, 1986 Lake Nyos, Cameroon



[http://news.bbc.co.uk/nol/shared/spl/hi/pop\\_ups/05/sci\\_nat\\_enl\\_1127817614/img/1.jpg](http://news.bbc.co.uk/nol/shared/spl/hi/pop_ups/05/sci_nat_enl_1127817614/img/1.jpg)

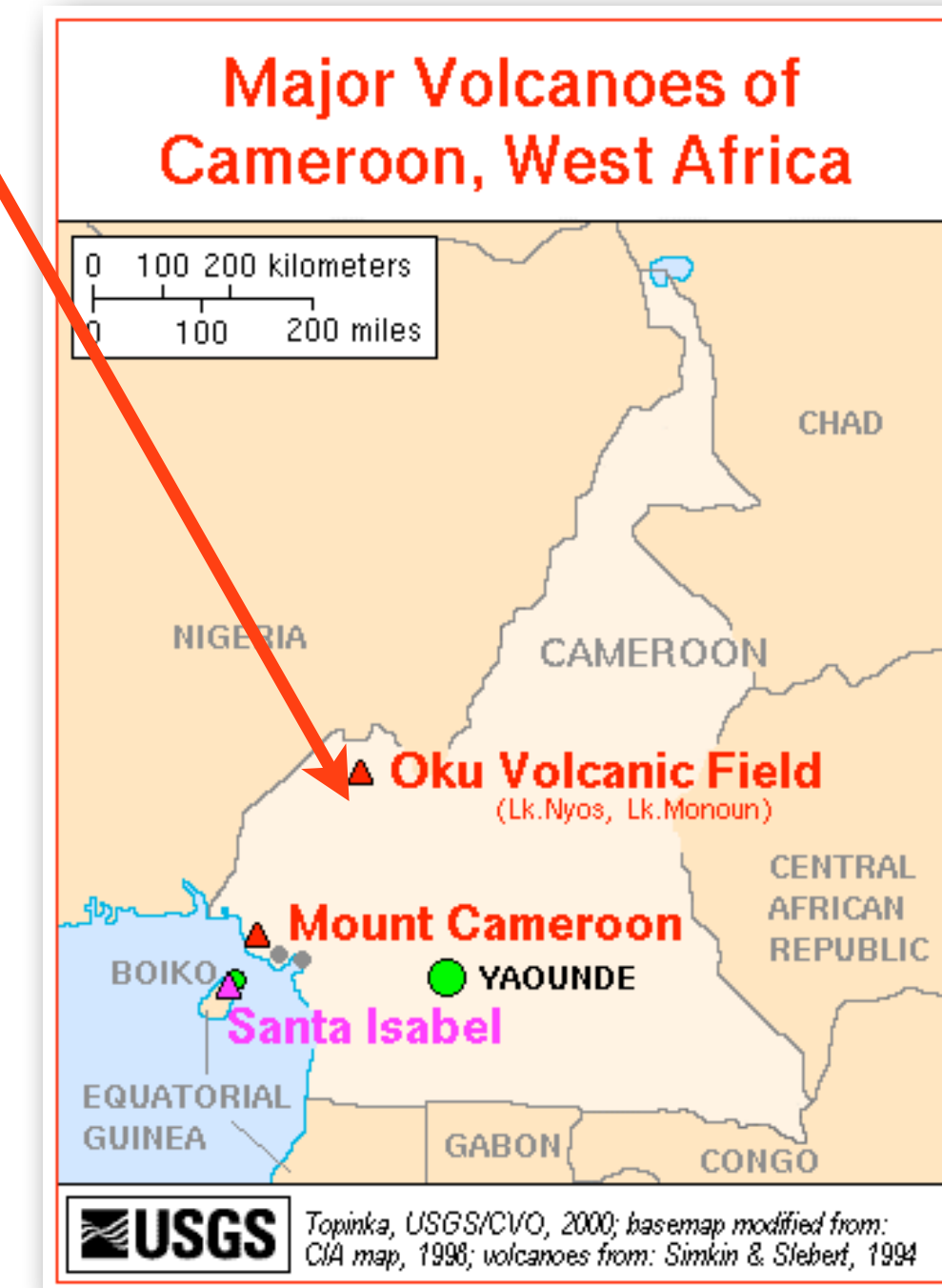


## August 21, 1986 Lake Nyos, Cameroon

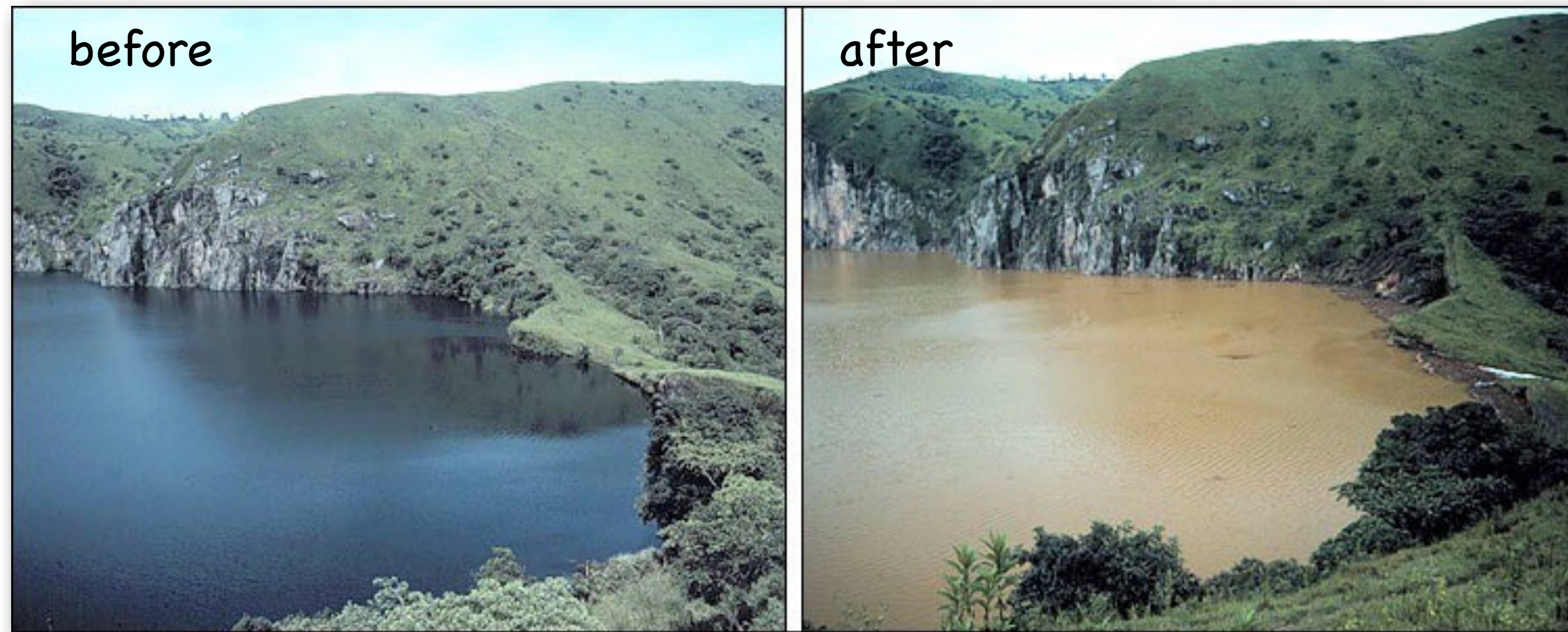


[http://news.bbc.co.uk/nol/shared/spl/hi/pop\\_ups/05/sci\\_nat\\_enl\\_1127817614/img/1.jpg](http://news.bbc.co.uk/nol/shared/spl/hi/pop_ups/05/sci_nat_enl_1127817614/img/1.jpg)

Over 1,800 people and thousands of animals found asphyxiated



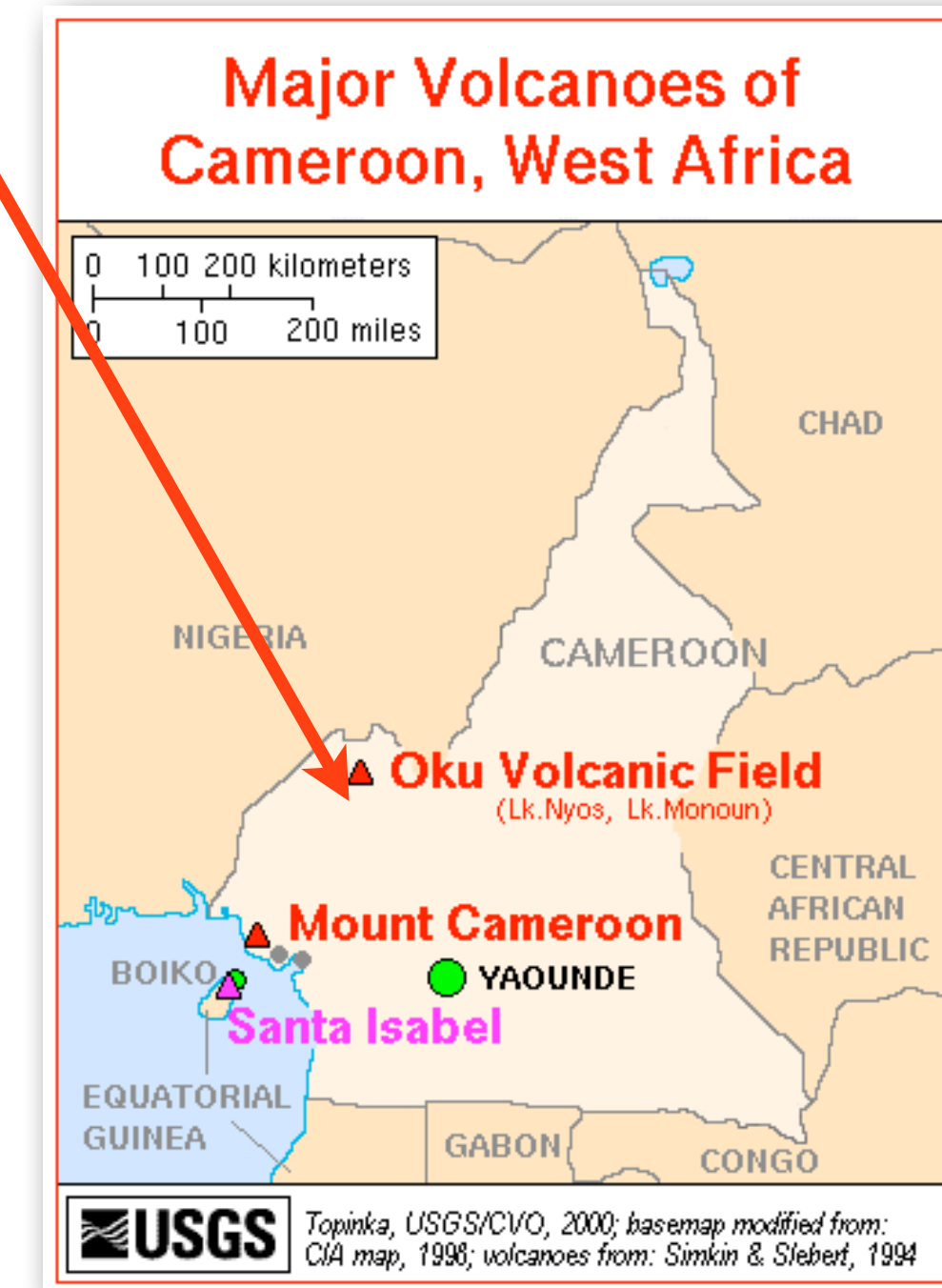
## August 21, 1986 Lake Nyos, Cameroon



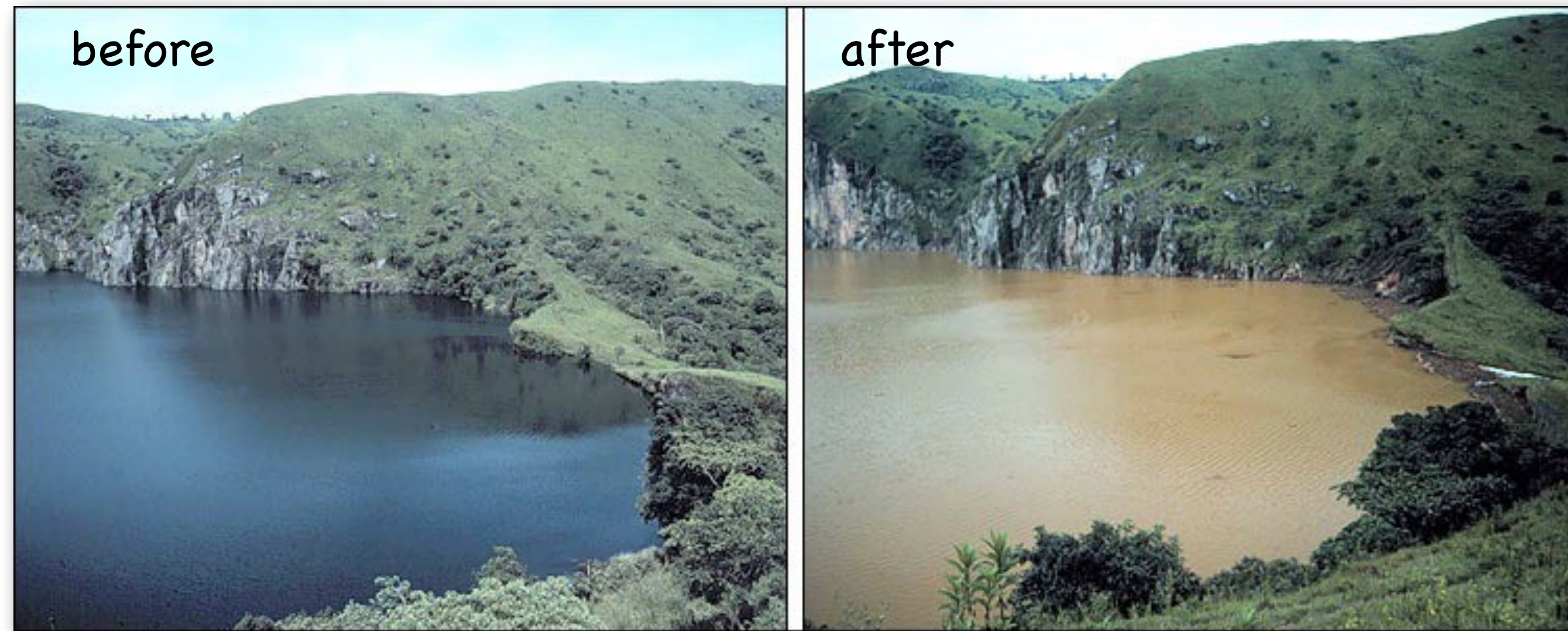
[http://news.bbc.co.uk/nol/shared/spl/hi/pop\\_ups/05/sci\\_nat\\_enl\\_1127817614/img/1.jpg](http://news.bbc.co.uk/nol/shared/spl/hi/pop_ups/05/sci_nat_enl_1127817614/img/1.jpg)

Over 1,800 people and thousands of animals found asphyxiated

No property or vegetation damage



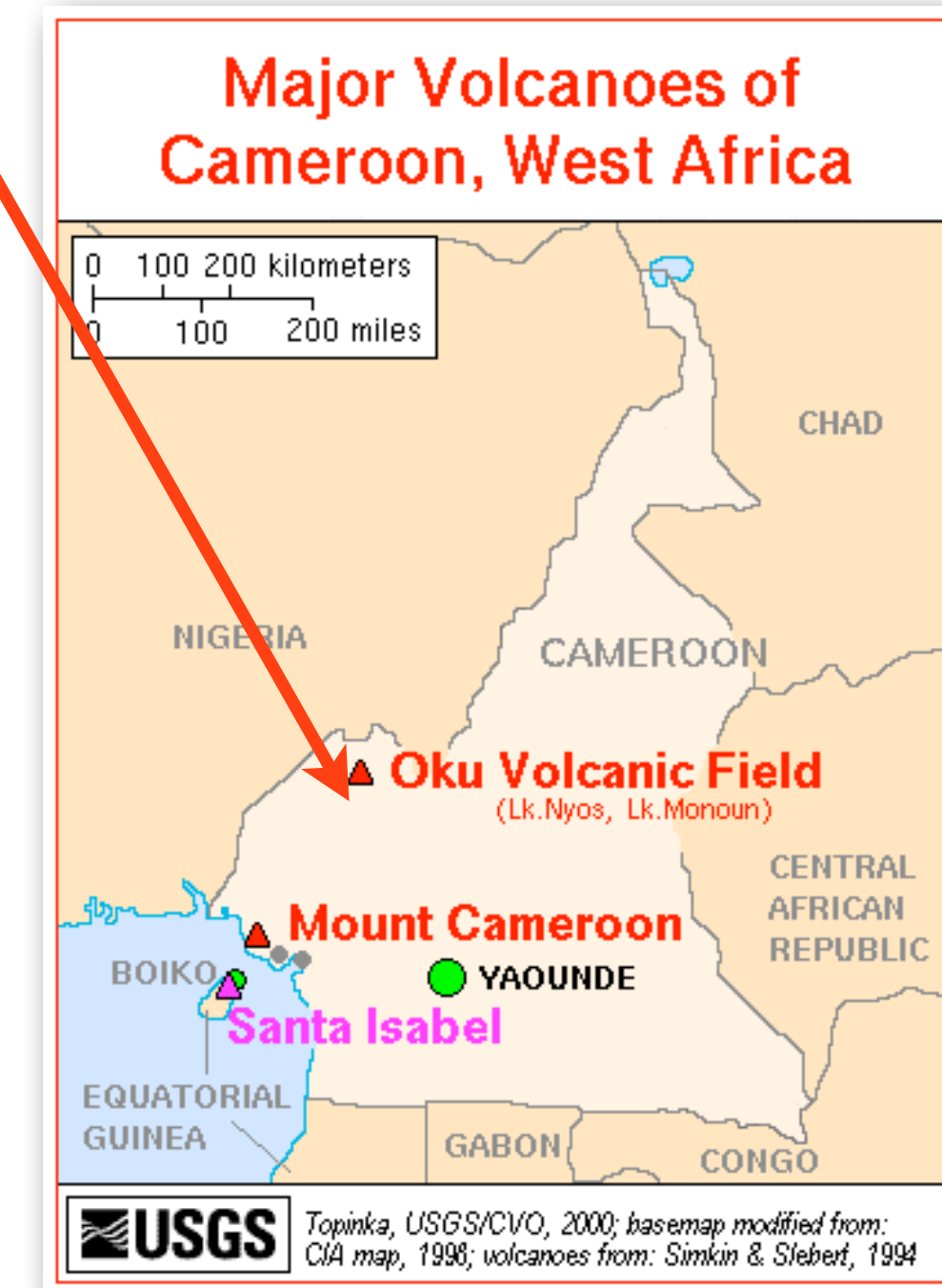
## August 21, 1986 Lake Nyos, Cameroon



[http://news.bbc.co.uk/nol/shared/spl/hi/pop\\_ups/05/sci\\_nat\\_enl\\_1127817614/img/1.jpg](http://news.bbc.co.uk/nol/shared/spl/hi/pop_ups/05/sci_nat_enl_1127817614/img/1.jpg)

Over 1,800 people and thousands of animals found asphyxiated

No property or vegetation damage



## What happened?



[http://i.ehow.com/images/GlobalPhoto/Articles/5259929/300px-DietCokeMentos-main\\_Full.jpg](http://i.ehow.com/images/GlobalPhoto/Articles/5259929/300px-DietCokeMentos-main_Full.jpg)

dissolved  $\text{CO}_2$  under pressure  
is perfectly safe....



[http://img.youtube.com/vi/uFzz5c\\_VvIk/0.jpg](http://img.youtube.com/vi/uFzz5c_VvIk/0.jpg)



[http://i.ehow.com/images/GlobalPhoto/Articles/5259929/300px-DietCokeMentos-main\\_Full.jpg](http://i.ehow.com/images/GlobalPhoto/Articles/5259929/300px-DietCokeMentos-main_Full.jpg)

dissolved  $\text{CO}_2$  under pressure  
is perfectly safe....



[http://img.youtube.com/vi/uFzz5c\\_VvIk/0.jpg](http://img.youtube.com/vi/uFzz5c_VvIk/0.jpg)

...but if too much  $\text{CO}_2$  or if something disturbs the equilibrium,  
get a sudden burst of gas release



Lake Nyos, August 22 1986

[http://www.hprcc.unl.edu/nebraska/Lake\\_Nyos.jpg](http://www.hprcc.unl.edu/nebraska/Lake_Nyos.jpg)



Sudden burst of dissolved CO<sub>2</sub> from the bottom of Lake Nyos blanketed the area in deadly, odorless gas



[http://www.hprcc.unl.edu/nebraska/Lake\\_Nyos.jpg](http://www.hprcc.unl.edu/nebraska/Lake_Nyos.jpg)

Sudden burst of dissolved  $\text{CO}_2$  from the bottom of Lake Nyos blanketed the area in deadly, odorless gas



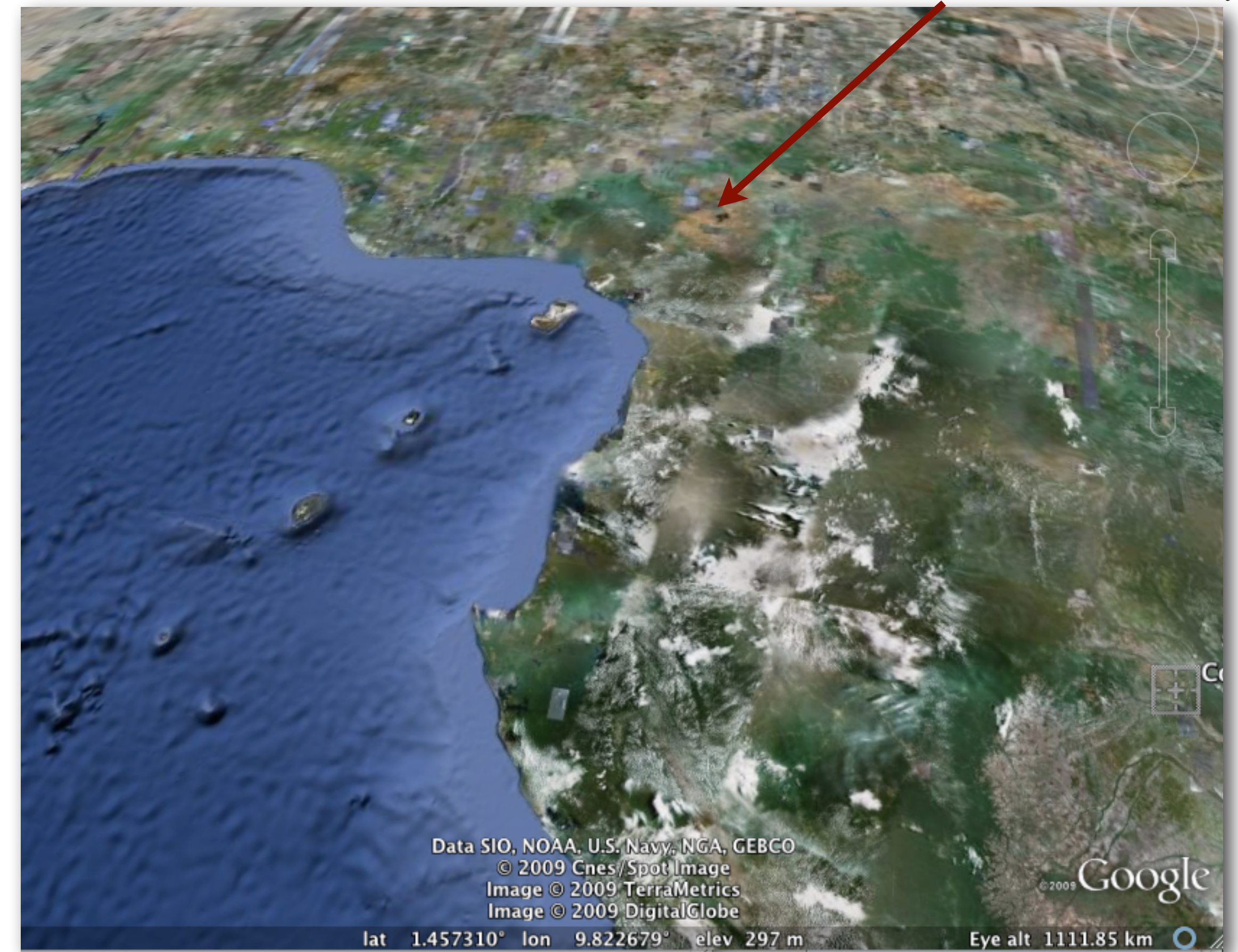
**Why here?**





Is Cameroon on a plate boundary?

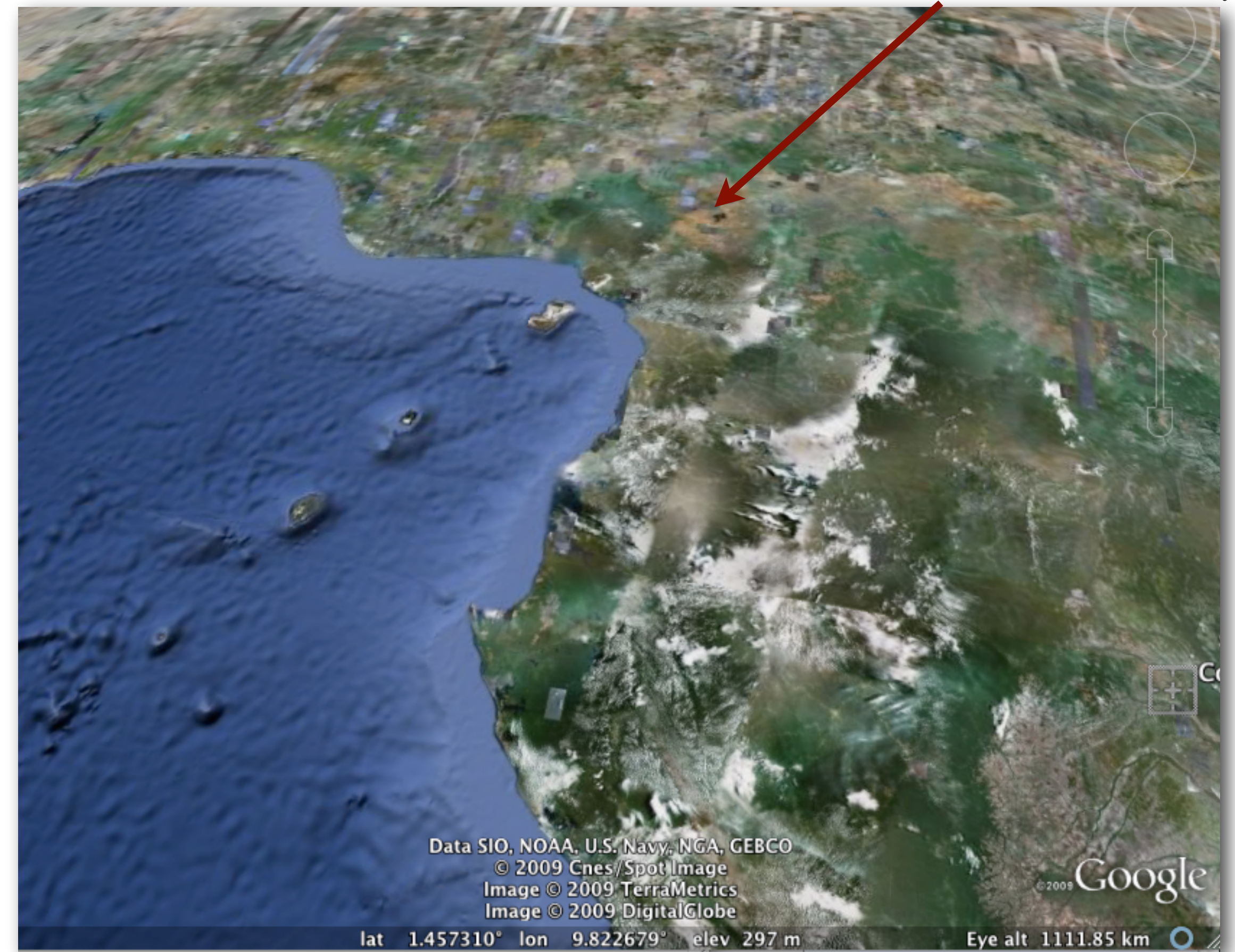
Lake Nyos

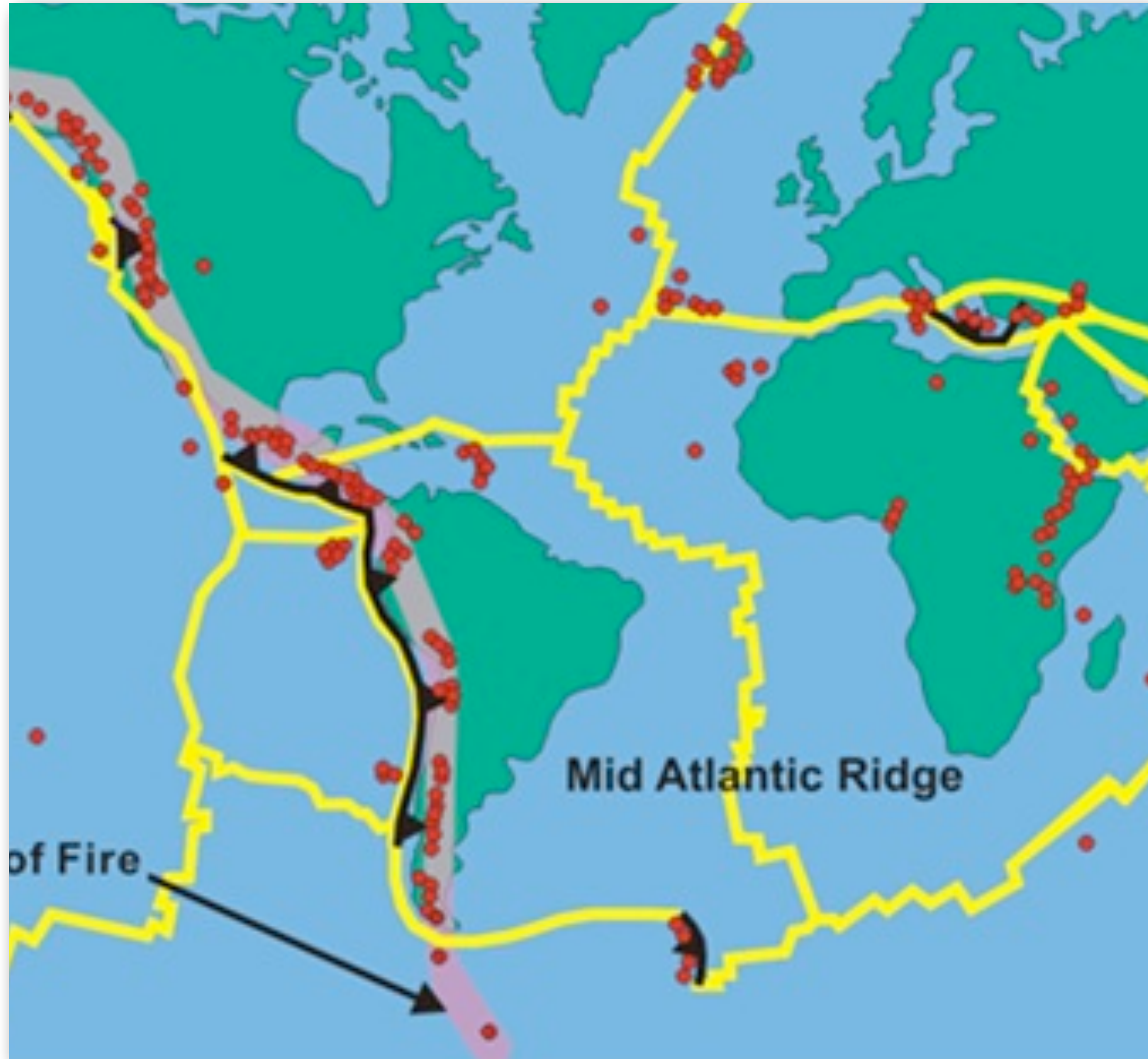


Is Cameroon on a plate boundary?



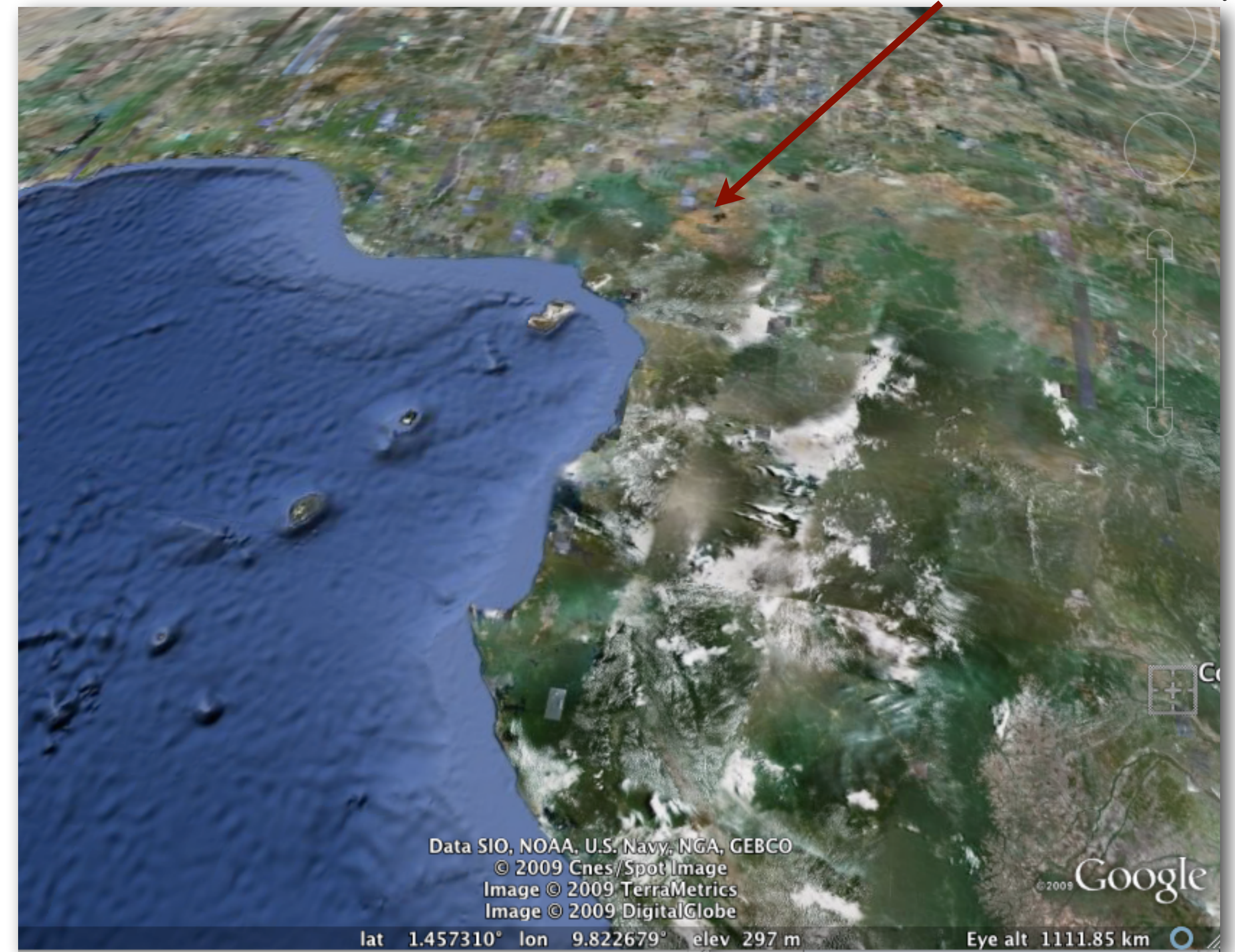
Lake Nyos

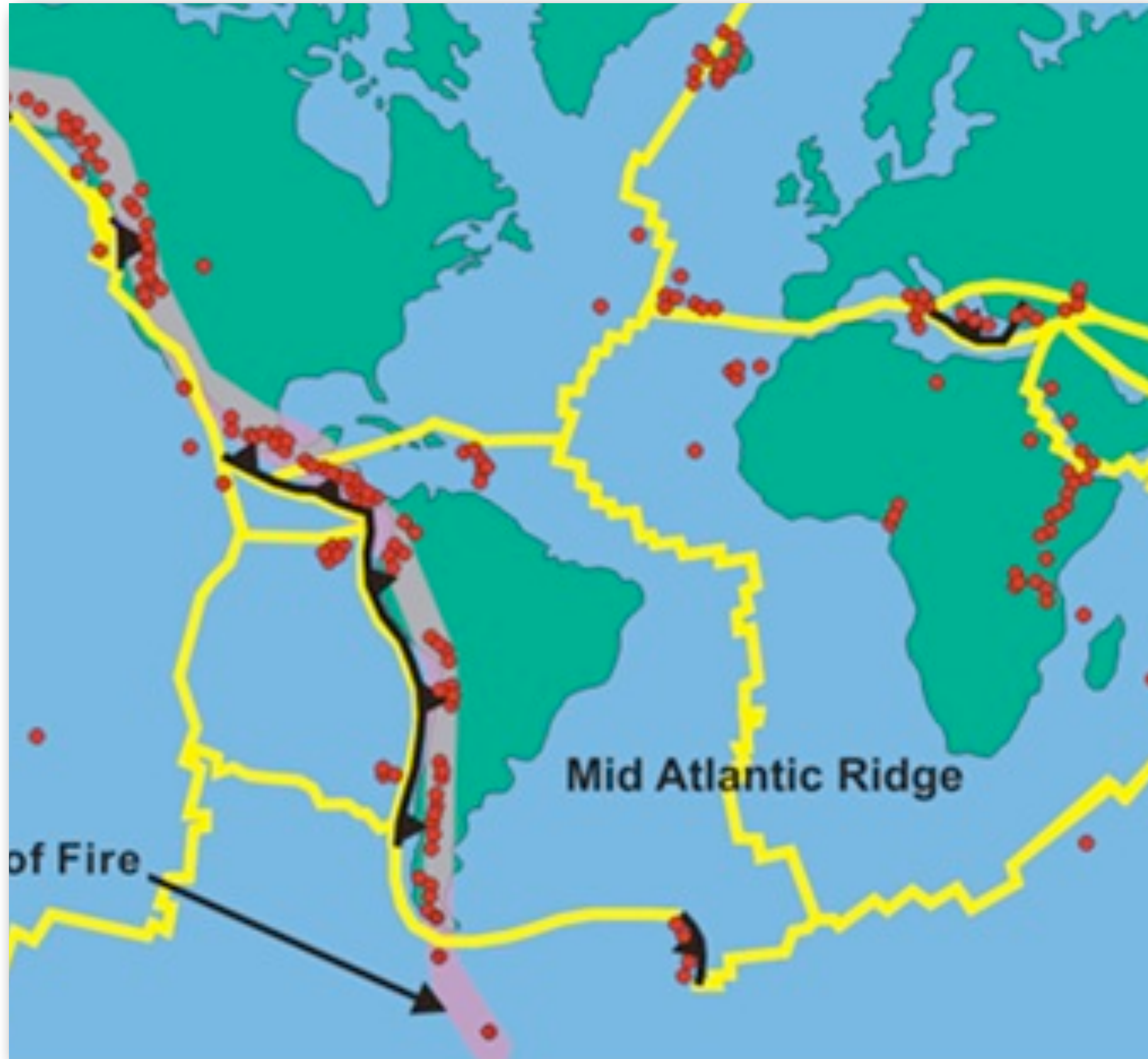




Is Cameroon on a plate boundary?

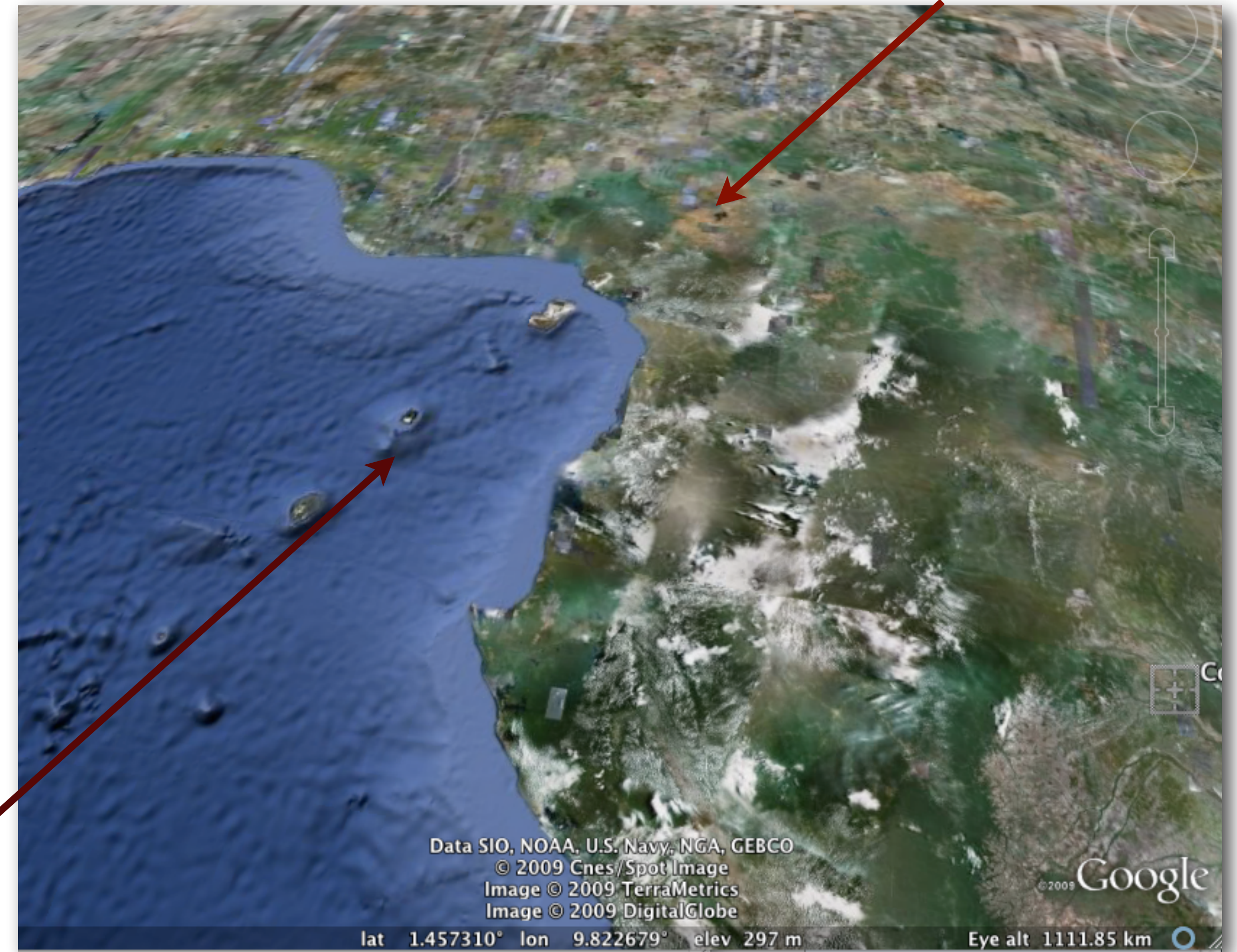
Lake Nyos





Is Cameroon on a plate boundary?

Lake Nyos

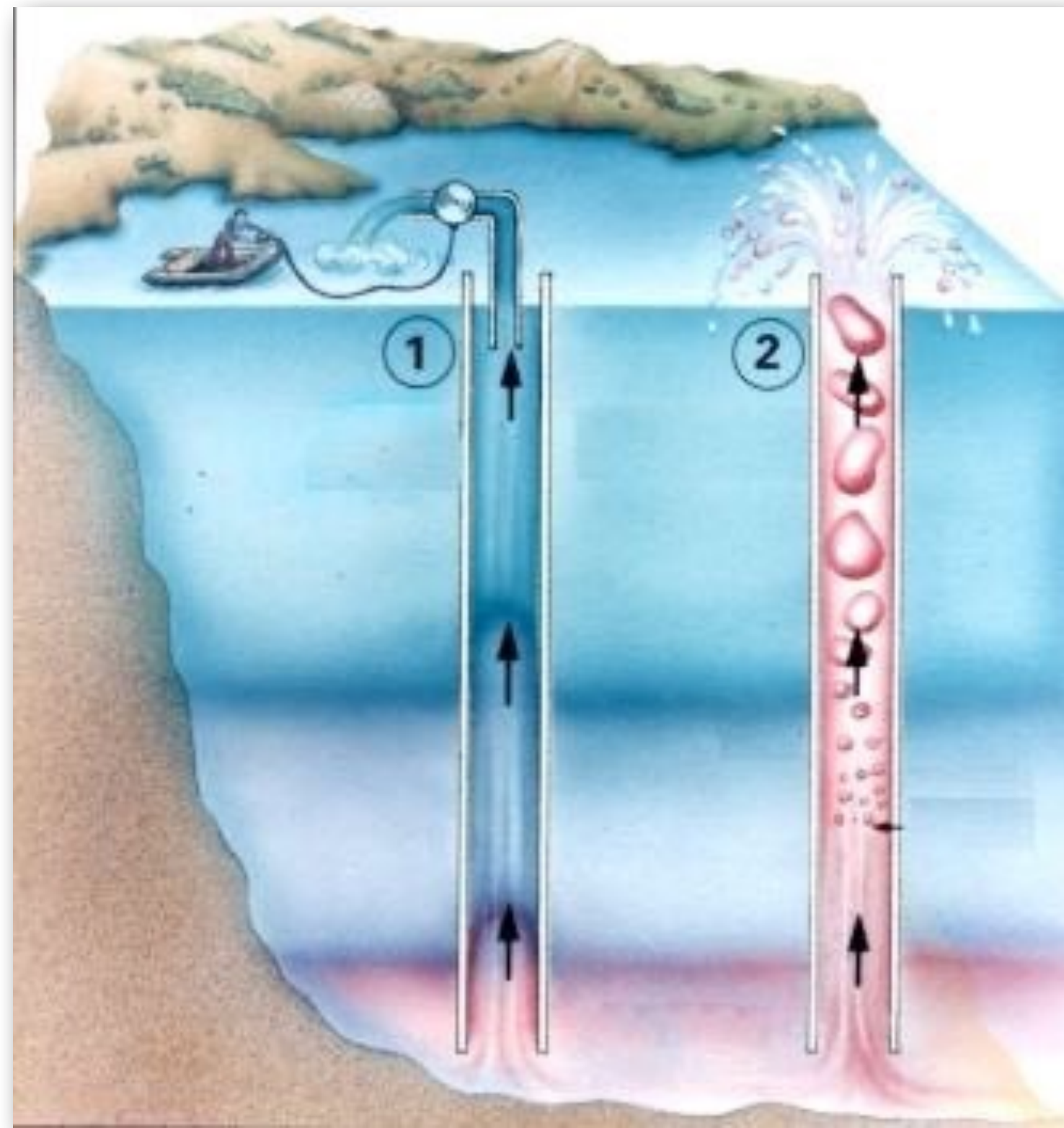


What does this string of volcanic islands remind you of?

# Mitigating future volcanic gas eruptions

## Mitigating future volcanic gas eruptions

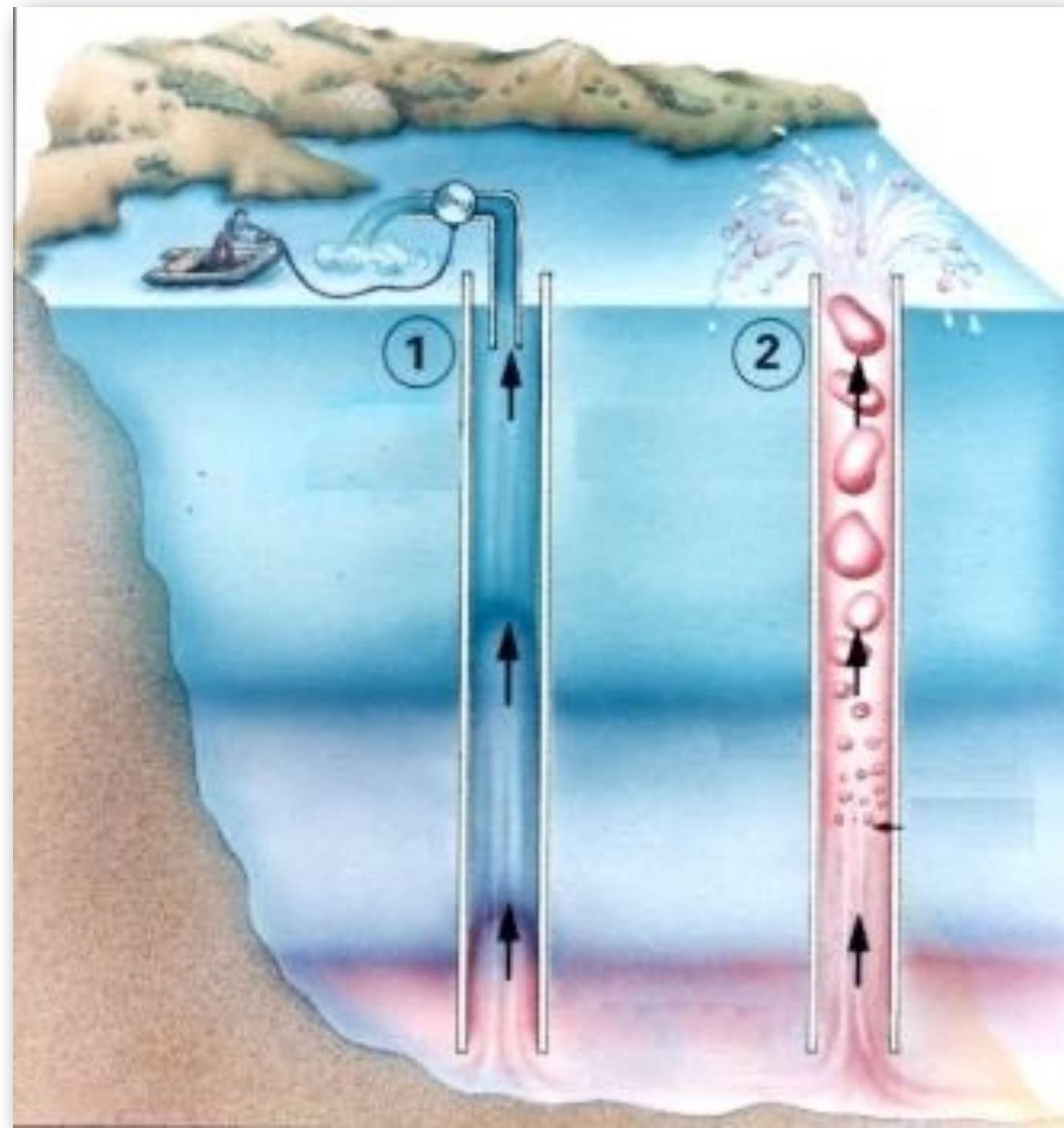
... by controlled gas release



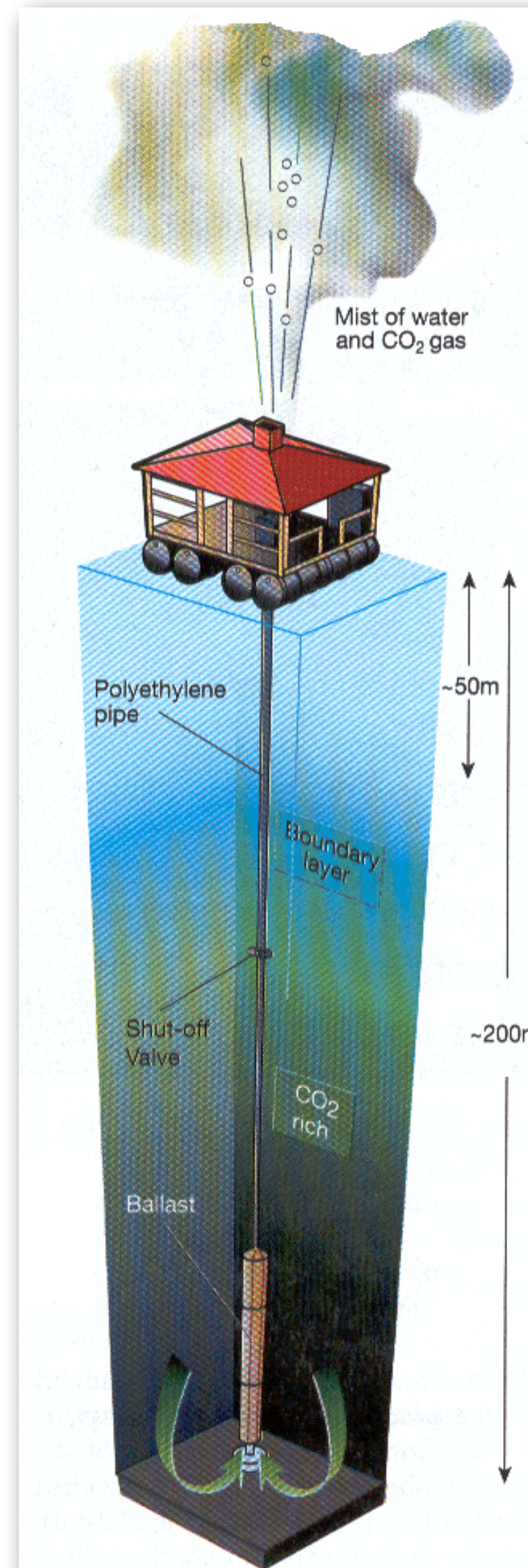
[http://www.geo.arizona.edu/geo5xx/geos577/projects/kayzar/assets/images/degassing\\_lake\\_nyos.jpg](http://www.geo.arizona.edu/geo5xx/geos577/projects/kayzar/assets/images/degassing_lake_nyos.jpg)

## Mitigating future volcanic gas eruptions

... by controlled gas release



[http://www.geo.arizona.edu/geo5xx/geos577/projects/kayzar/assets/images/degassing\\_lake\\_nyos.jpg](http://www.geo.arizona.edu/geo5xx/geos577/projects/kayzar/assets/images/degassing_lake_nyos.jpg)



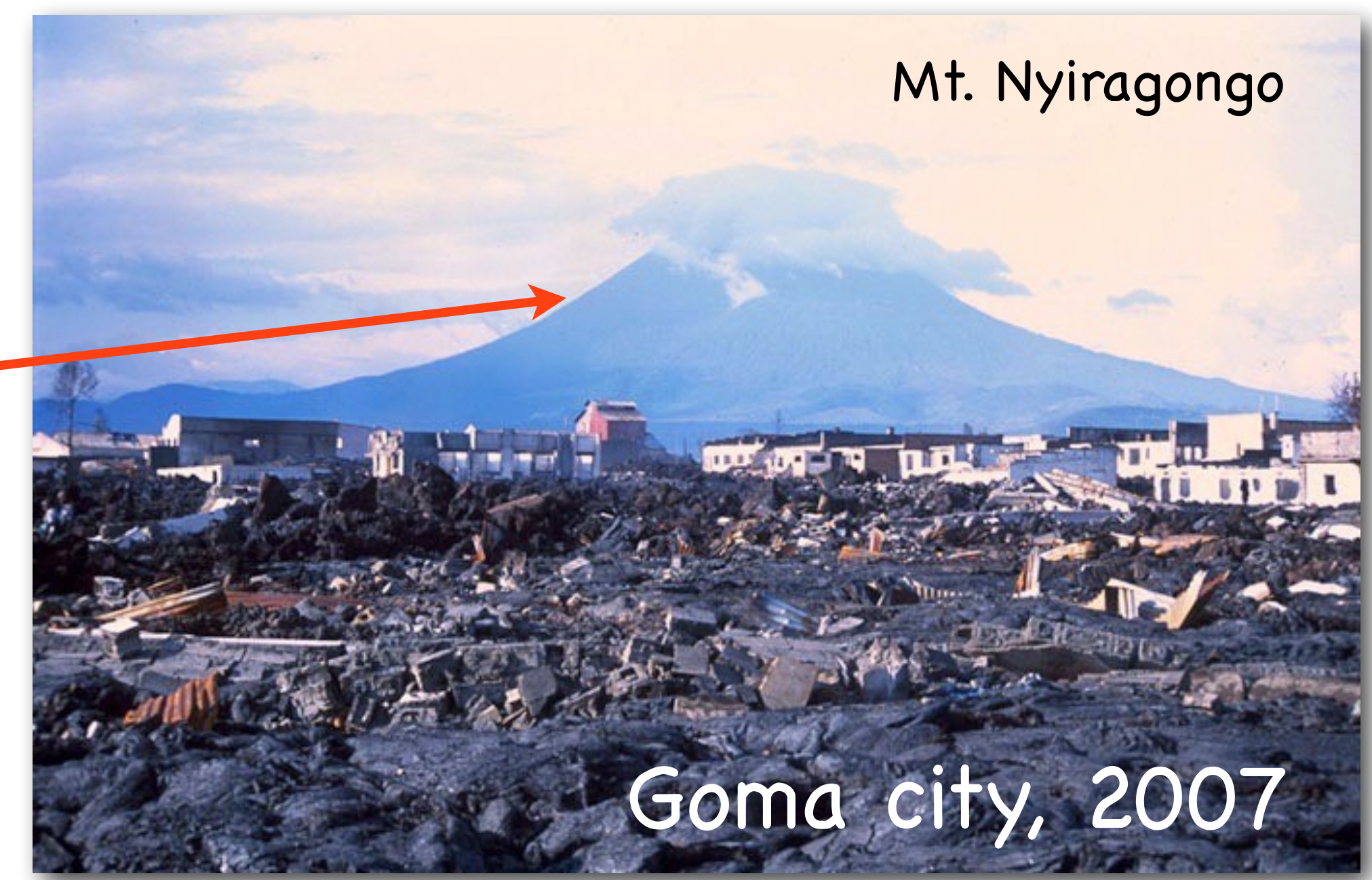
<http://records.viu.ca/~earles/nyos-degasser.gif>



[http://www.ulb.ac.be/sciences/cvl/Big%20jet%20from%20boat\\_2.jpg](http://www.ulb.ac.be/sciences/cvl/Big%20jet%20from%20boat_2.jpg)

# Volcanic Gases

Lake Nyos is not the only one...



<http://dodoincoma.files.wordpress.com/2007/10/058-destruction-of-goma-town-by-nyiragongo-volcano2-kopie.jpg>

Goma city, on Lake Kivu, East Africa also has a volcanic gas problem, and “ordinary” lava eruptions too

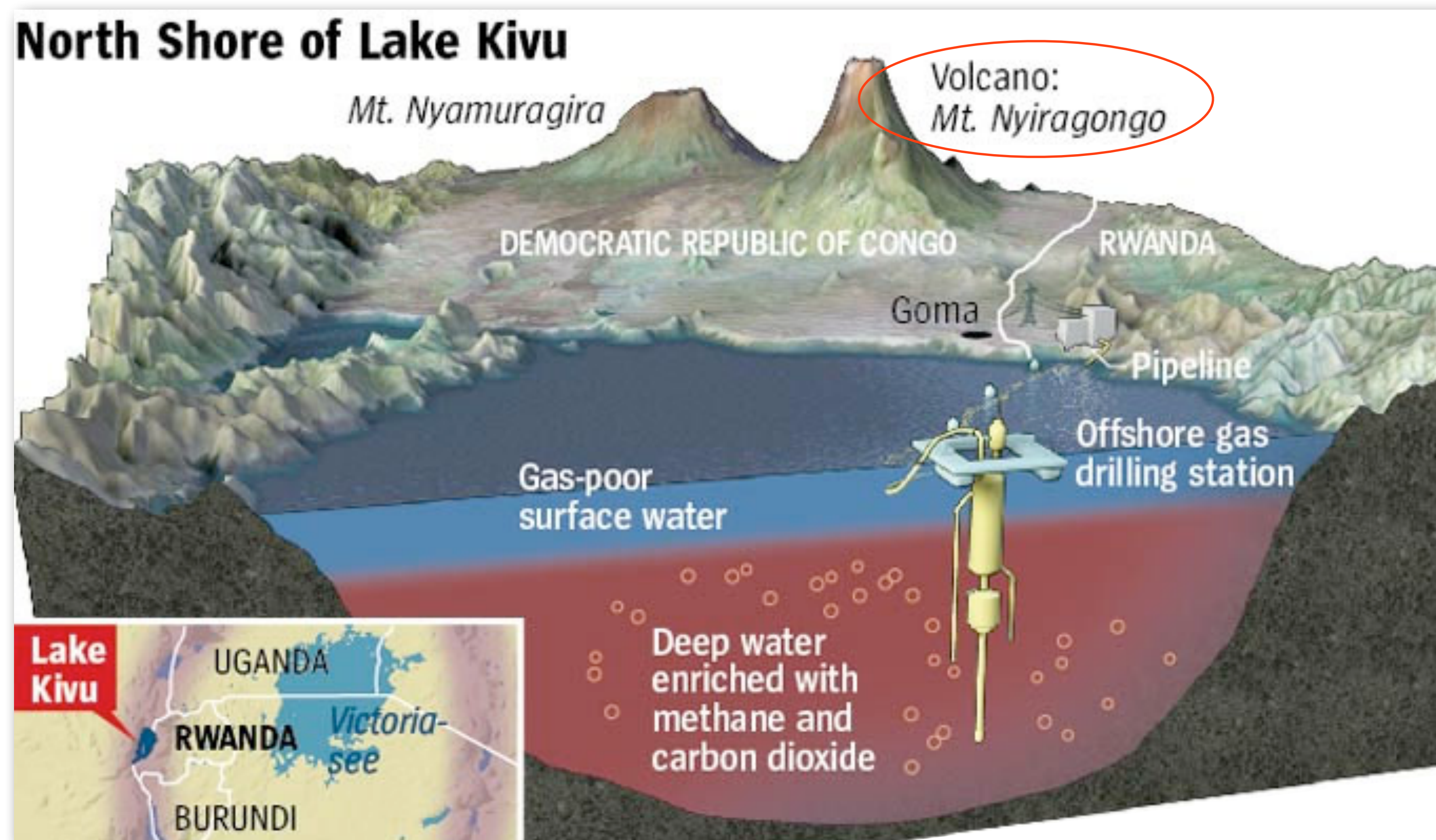


# Volcanic Gases

## Mitigating the gas problem at Lake Kivu

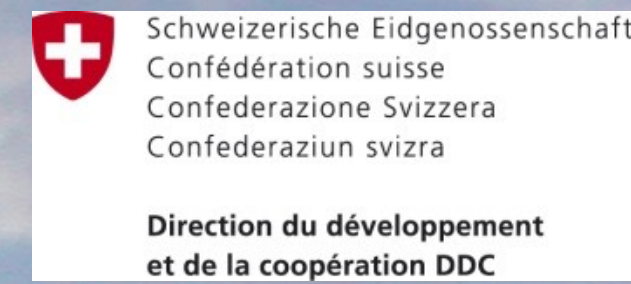


<http://www.volcanolive.com/goma.jpg>



<http://www.geo.arizona.edu/geo5xx/geos577/projects/kayzar/index.html>

Allows steady, harmless gas release  
Also monitoring the volcano



# Natural Disasters in Lake Kivu area: a UNOPS pilot project ... a best practice ?



**UNOPS/E.U./Swiss Coop. (DDC)**

**Dept. Environmental Sciences, University of Naples2 (Italy)**

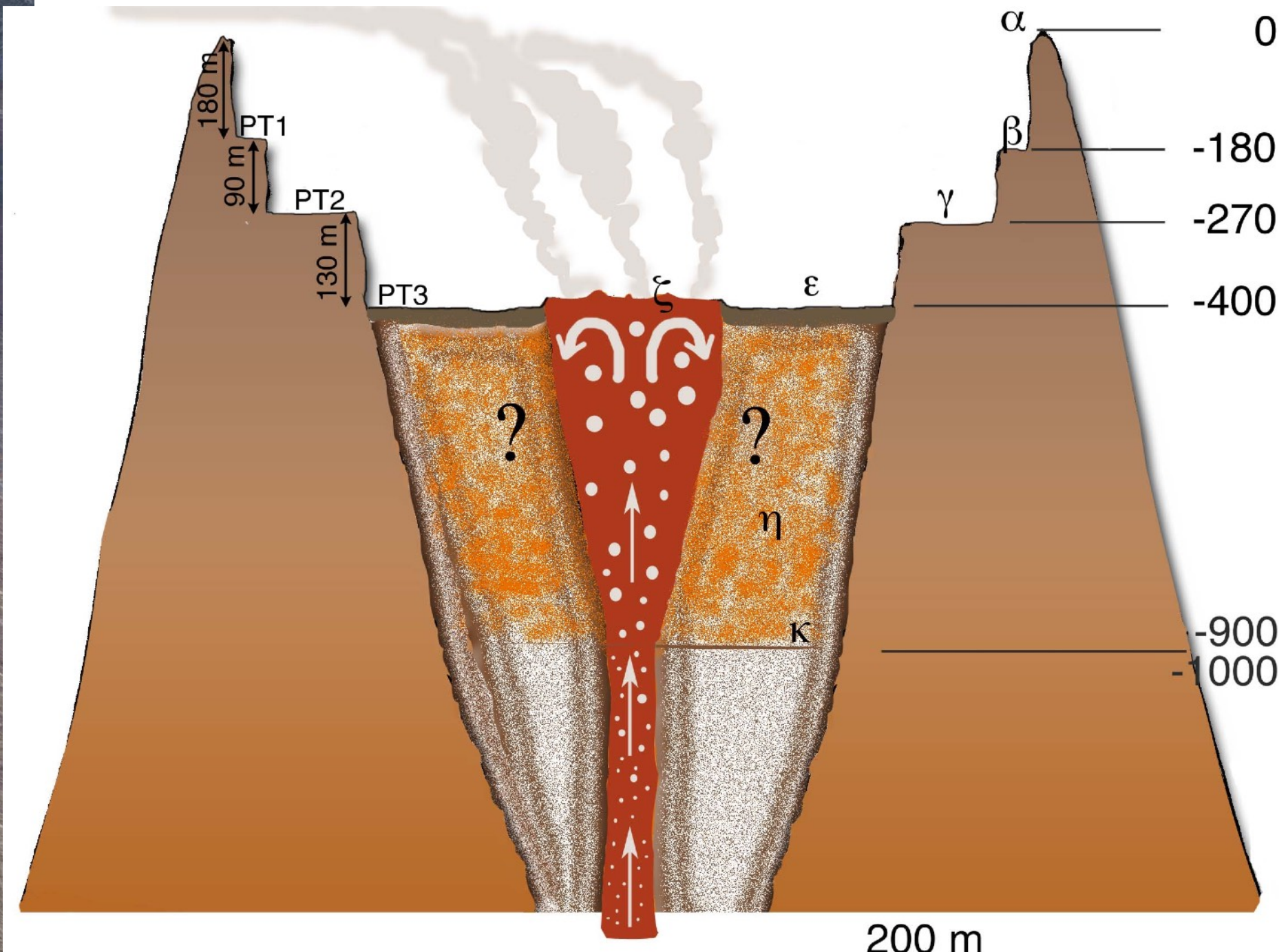
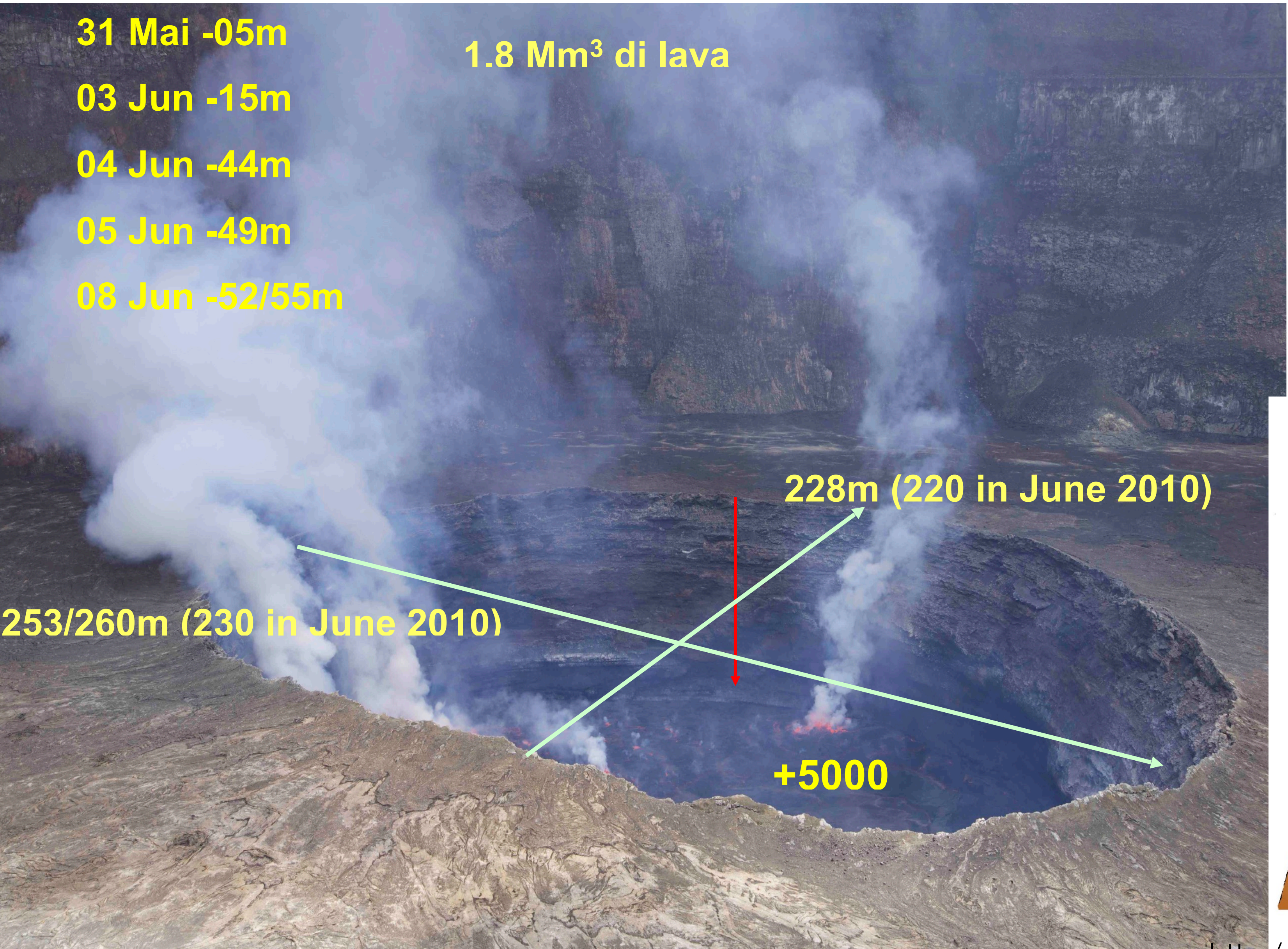
**Goma Volcano Observatory (DRC)**

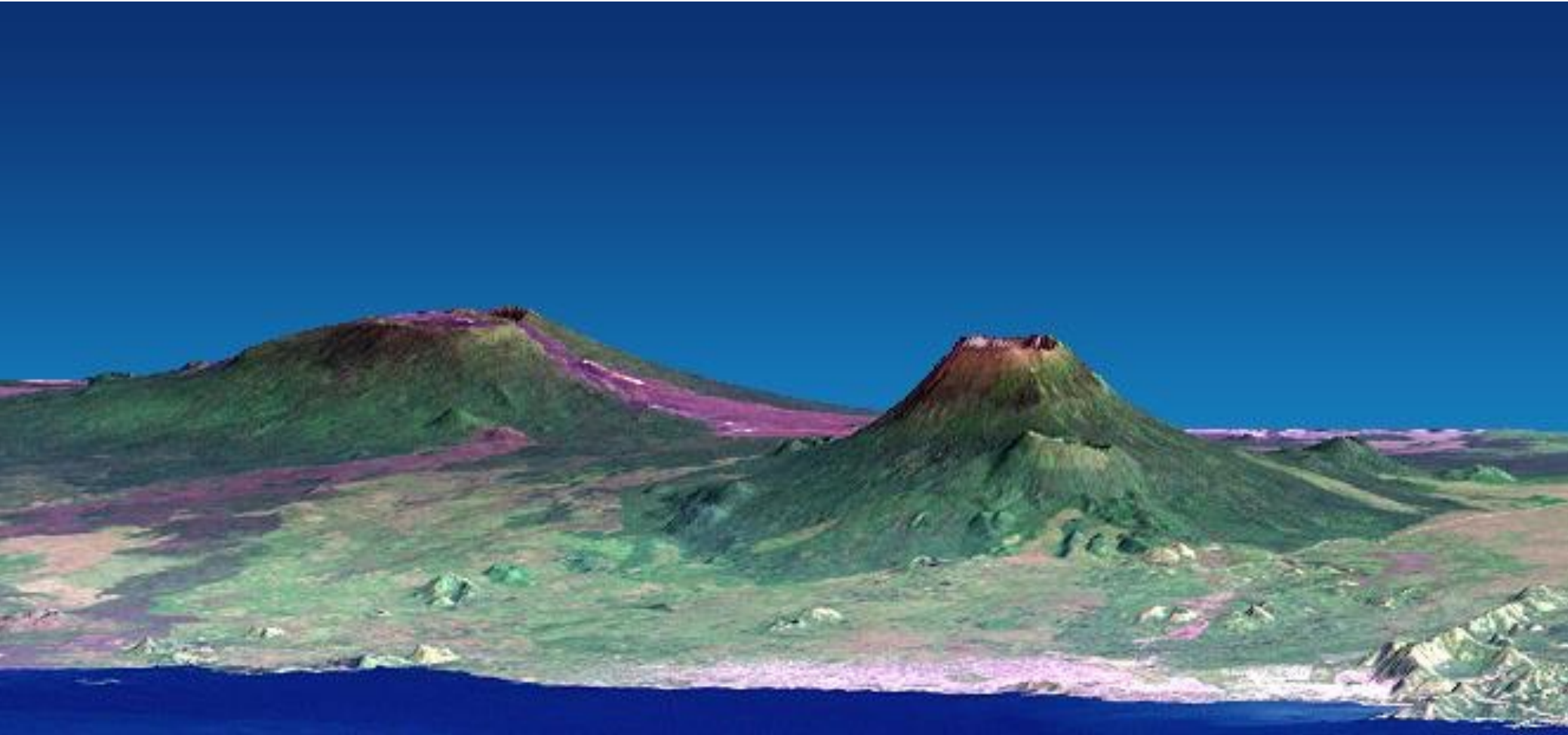
Dario Tedesco

[http://www.geohazcop.org/workshops/Sant\\_Feliu\\_2011/](http://www.geohazcop.org/workshops/Sant_Feliu_2011/)



Several recent eruptions have cause a lot of damage in Goma





Nyamuragira (left) and Nyiragongo (right)

Located in Democratic Republic of Congo

Many eruptions. For example, 2002:

- at least 147 death due to toxic gasses;
- 400,000 evacuated.

Population nevertheless grows.

Often death due to local carbon dioxide accumulation in lower parts of Goma.

New vent discovered in 2016.

Mt. Nyiragongo is unique with the largest lava lake on Earth.

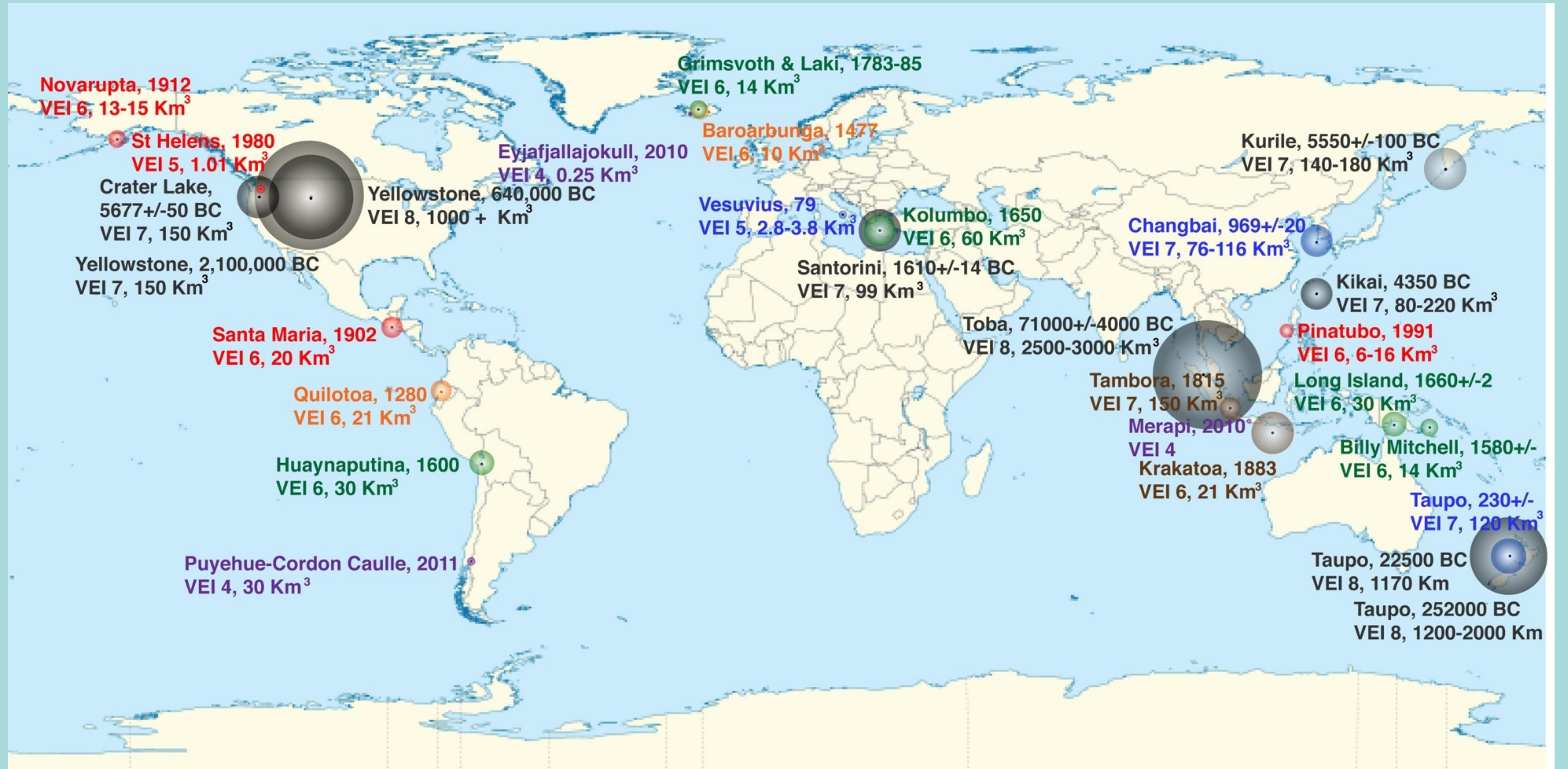


# Natural Hazards and Disaster

## Class 6: Volcanoes

- News
- Size of Volcanic Eruptions
- Location
- Types
- Volcanic Gases
- Volcanic Eruptions - Examples
- Large Eruptions
- Impacts of Eruptions
- Comparison to other Hazards

# Volcanic Eruptions



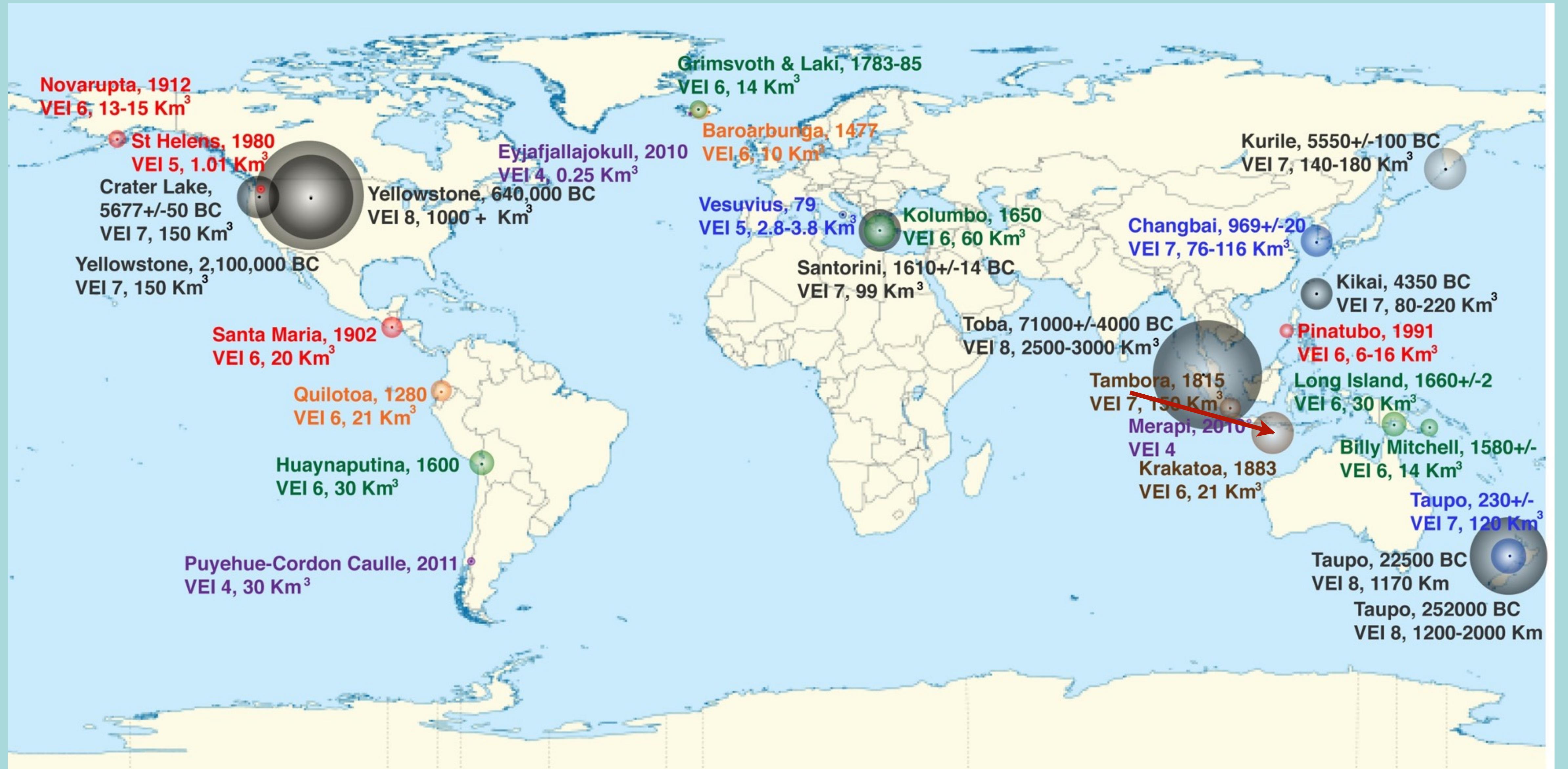
# Volcanic Eruptions



● 2000 AD +   
 ● 1900-1999   
 ● 1800-1899   
 ● 1500-1799   
 ● 1000-1499   
 ● 1-999 AD   
 ● BC



# Volcanic Eruptions

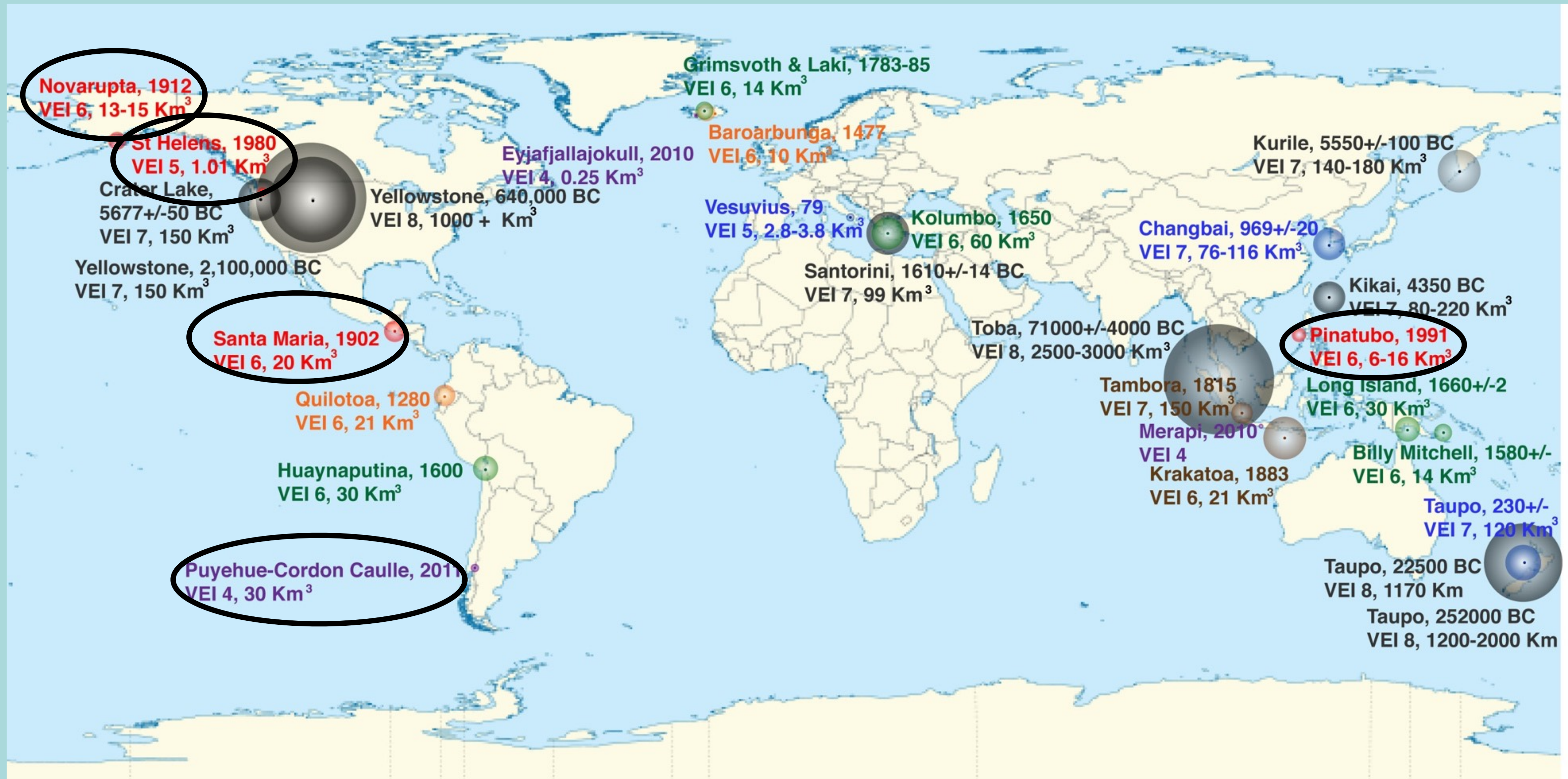


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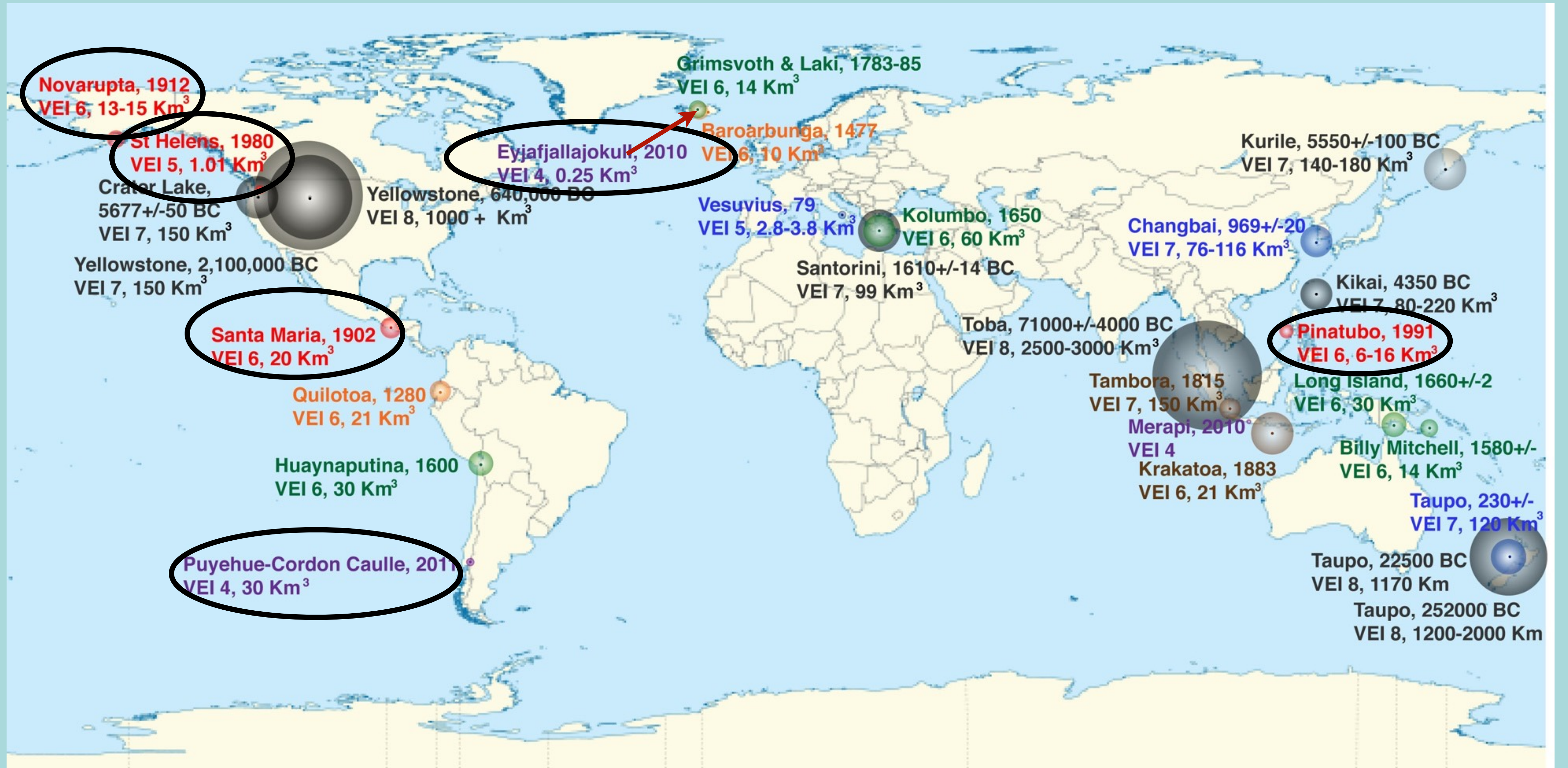


# Volcanic Eruptions



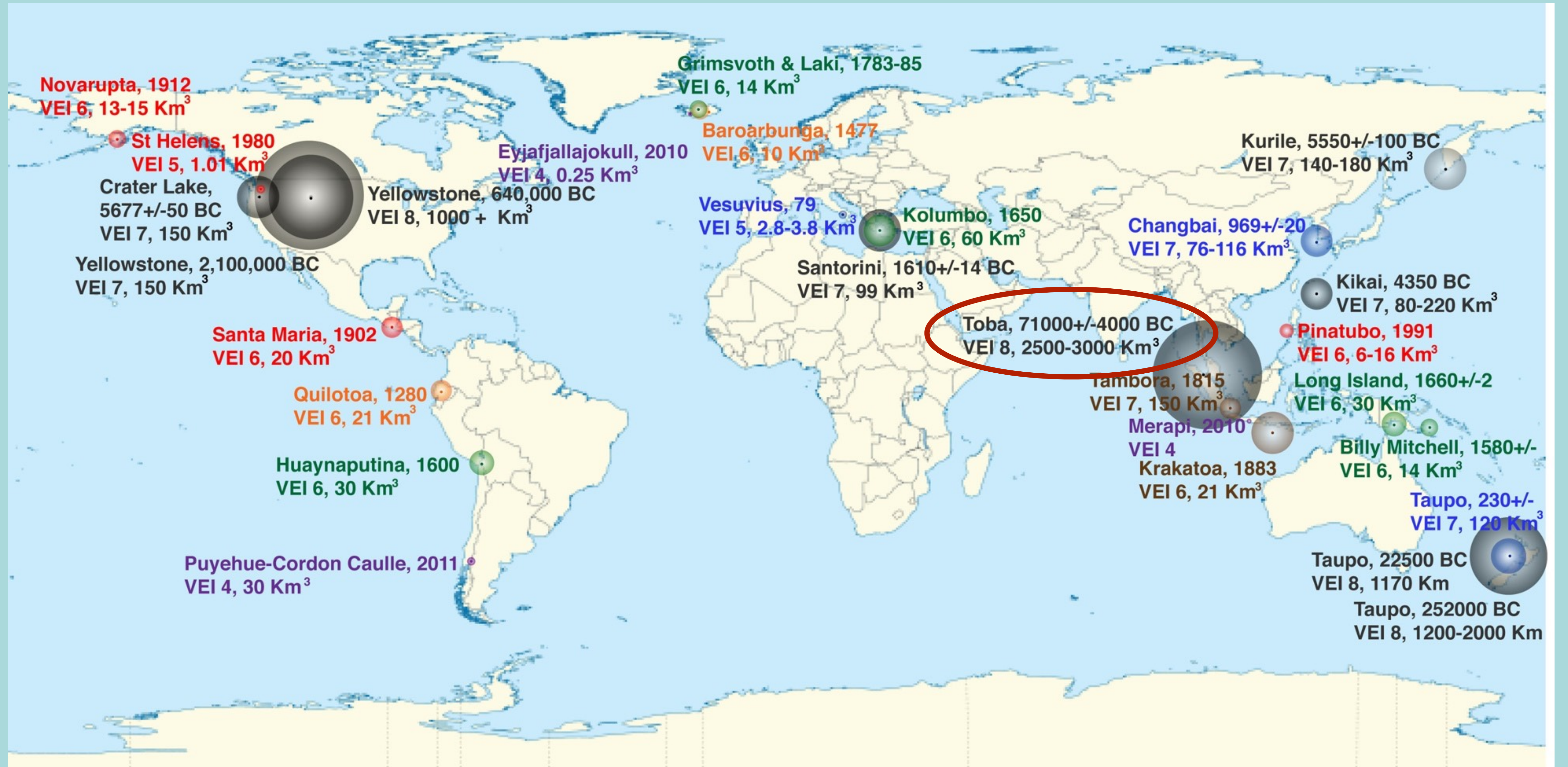
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# Volcanic Eruptions

Deaths	Volcano	Year	Cause
100,000	Tambora, Indonesia <sup>2)</sup>	1815	Starvation
40,000	Krakatau, Indonesia <sup>1) 2)</sup>	1883	Tsunami
30,000	Mt. Pelee, Martinique	1902	Ash flows
25,000	Ruiz, Colombia	1985	Mudflows
15,000	Unzen, Japan	1792	Tsunami
10,000	Laki, Iceland <sup>2)</sup>	1783	Starvation
5,000	Kelut, Indonesia	1919	Mudflows
4,000	Galunggung, Indonesia	1882	Mudflows
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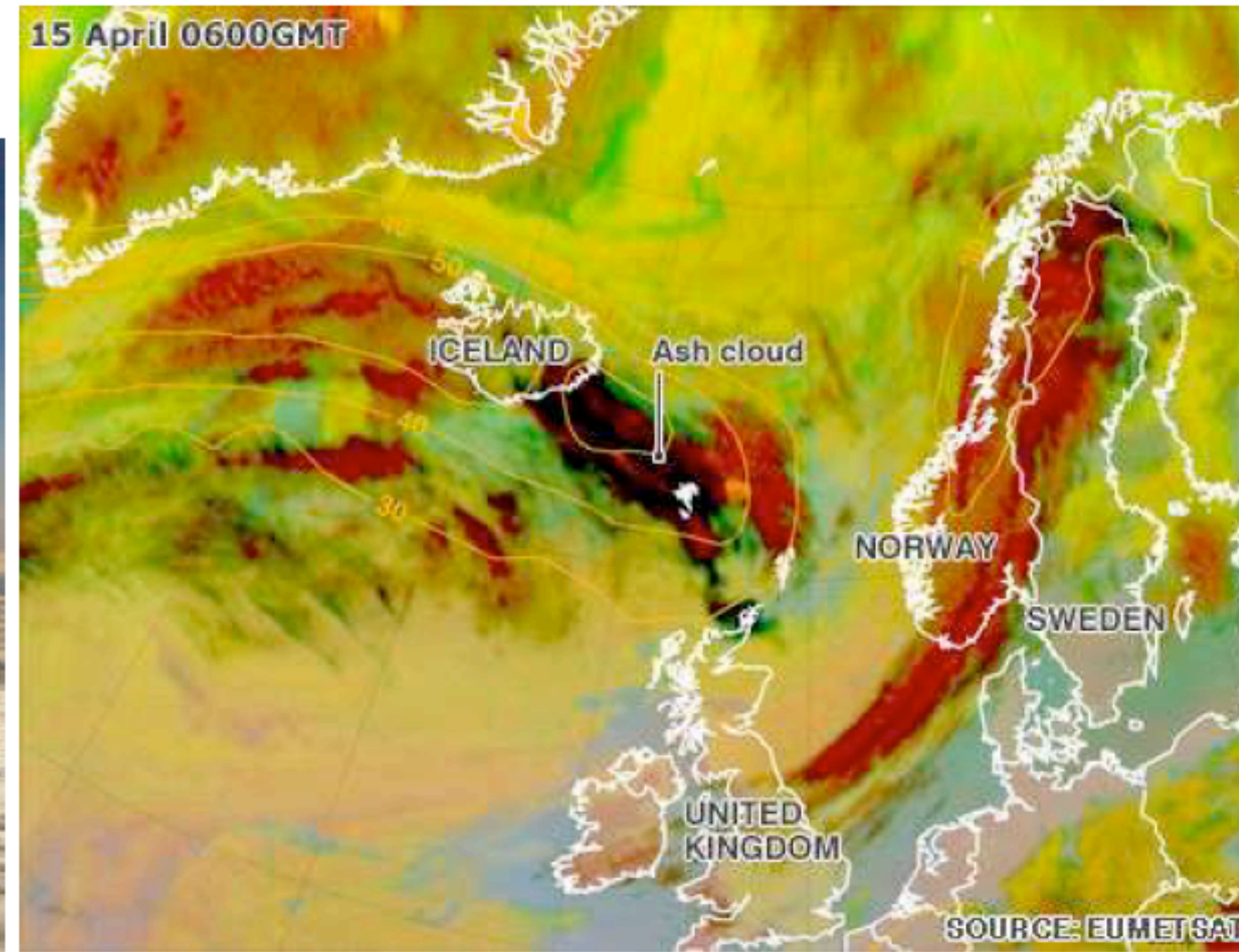
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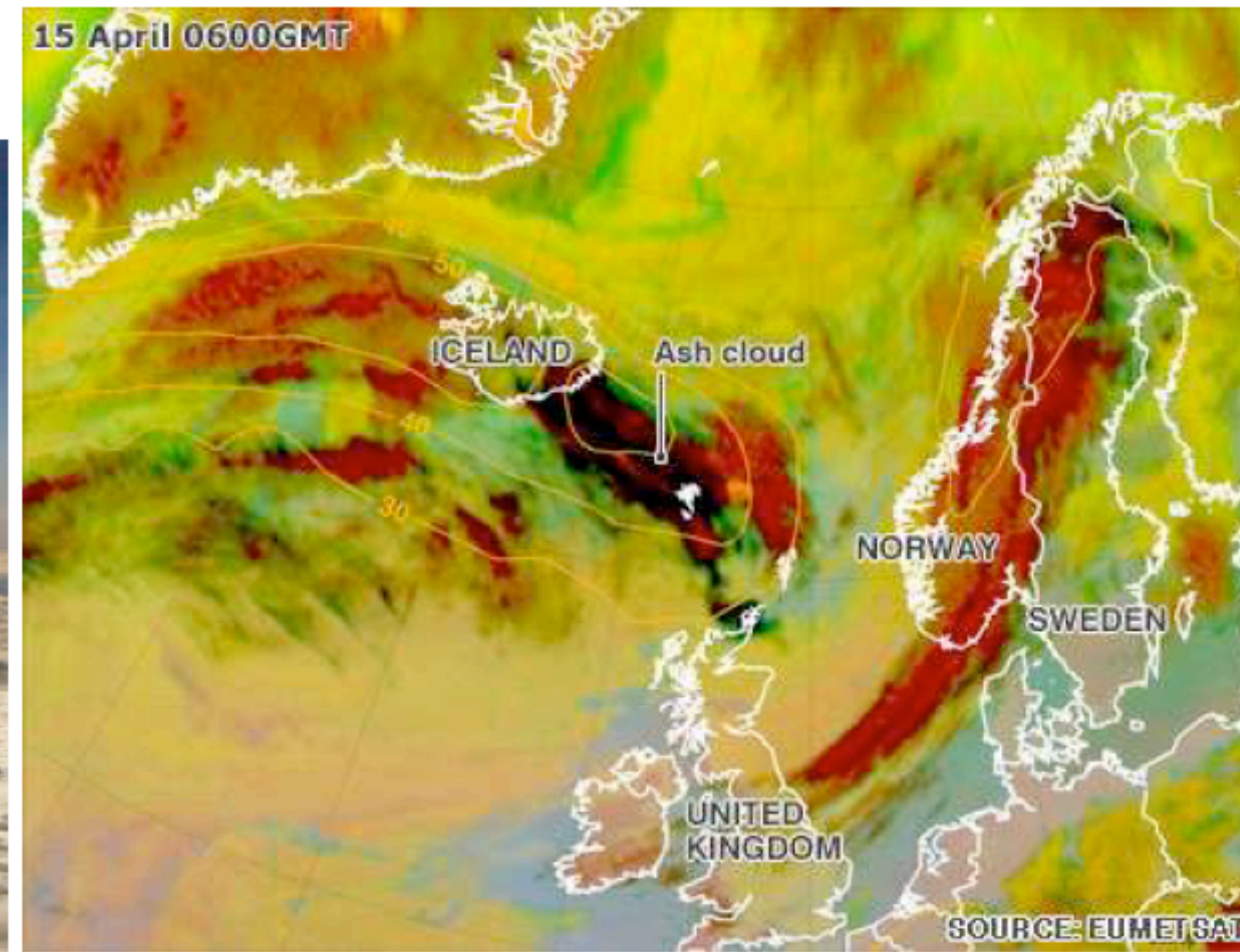
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# Volcanic Eruptions



Eyafjallajokull, 2010: VEI 4, 0.25 km<sup>3</sup>  
Laki 1783-85: VEI 6, 14 km<sup>3</sup>



Eyafjallajokull, 2010: VEI 4, 0.25 km<sup>3</sup>  
Laki 1783-85: VEI 6, 14 km<sup>3</sup>

Several eruptions that happened during the last 2,000 years would be devastating under today's conditions

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- VEI 8 / M 8:
- 1.4 events/Ma to 22 events/Ma
  - largest, high-intensity terrestrial phenomena



## VEI 8 / M 8:

- 1.4 events/Ma to 22 events/Ma
- largest, high-intensity terrestrial phenomena

## VEI 7 / M 7:

- on timescales of ~100 ka, M7-M8 eruptions have release more energy than the largest expected impactors
- M7 are relatively frequent ...



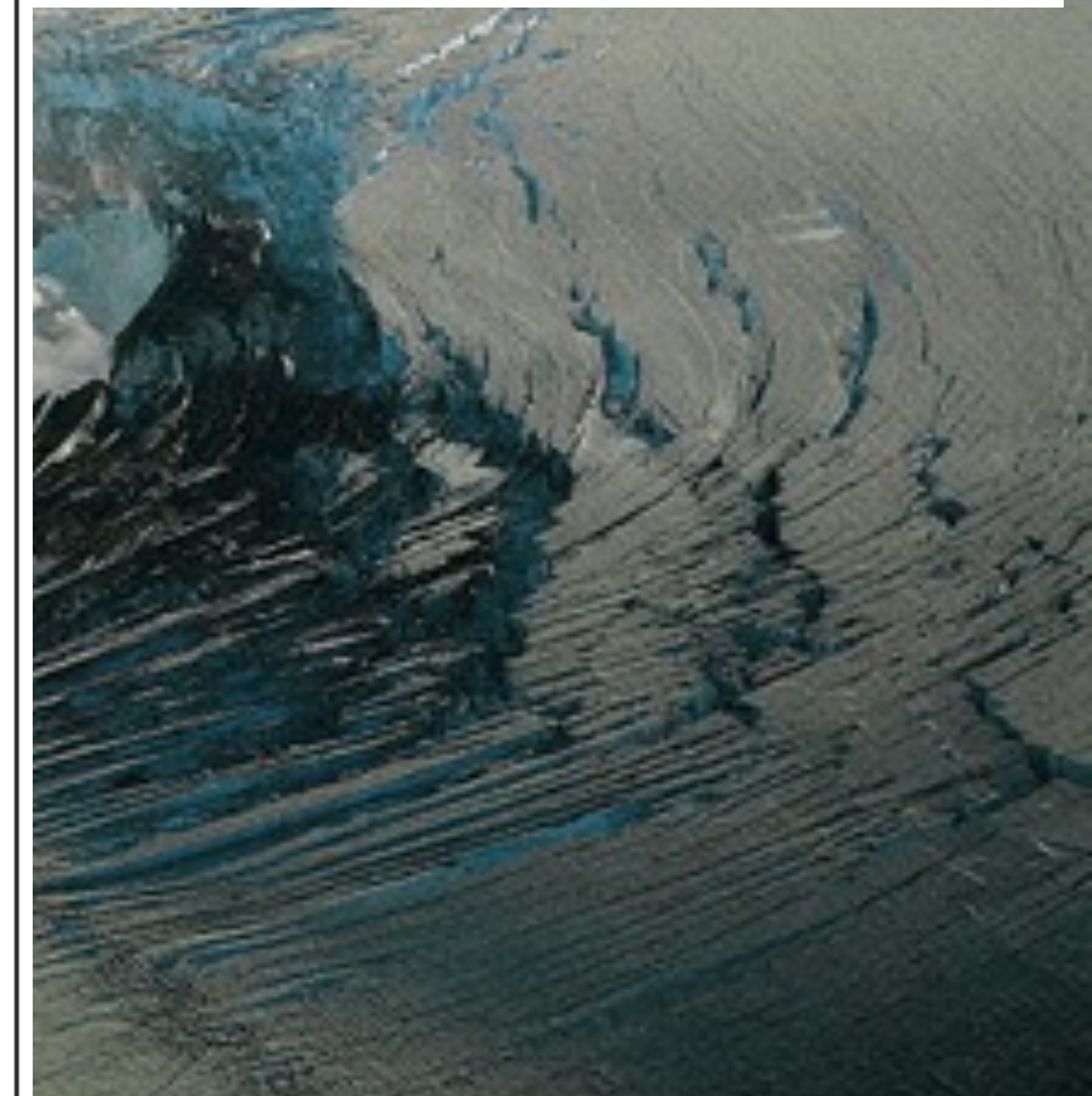


# Large Eruptions

Year	Location	VEI	km <sup>3</sup>	Deaths	Comment
2011	Puyehue-Cordon Caulle, Chile	4	30		
2010	Merapi, Indonesia	4		353	MCD: pyroclastic flows
2010	Eyjafjallajökull, Iceland	4	0.25	0	Caused severe traffic distortions
1991	Pinatubo	6	6-16	847	MCD: failing roofs
1985	Nevado de la Ruiz, Colombia	3	0.03	25,000	MCD: Lahar
1980	St Helens	5	1	57	
1919	Kelut, Indonesia			5,100	MCD: mudflows
1912	Novarupta, Alaska	6	15-30	unknown	
1902	Mount Pelee, Martinique	4	>0.1	29,000	MCD: pyroclastic flow
1902	Santa Maria, Guatemala	6	20	>5,000	
1883	Krakatau, Indonesia	6	21	36,000	MCD: tsunami
1882	Galunggung, Indonesia	5		4,000	MCD: mudflows
1815	Tambora, Indonesia	7	150	92,000	MCD: starvation
1783-85	Laki and Grimsvoth, Iceland	6	14	9,400	MCD: famine and fluorine poisoning; deaths are for Iceland only
1660	Long Island	6	30		
1650	Kolombo	6	60		
1631	Vesuvius, Italy			3,500	MCD: mud and lava flows
1600	Huaynaputina	6	30		
1580	Billy Mitchell	6	14		
1477	Baroarbunga, Iceland	6	10		
1280	Quilotoa	6	21		
969 ± 20	Changbai, China	7	76-116		
230	Taupo	7	120		
79	Vesuvius, Italy	5	2.8-3.8	3,400	MCD: Ash flows
1610 ± 14 BC	Santorini	7	99		
4350 BP	Kikai	7	80-220		
5550 ± 100 BC	Kurile	7	140-150		
5677 ± 50 BC	Crater Lake	7	150		
26500 BC	Oruanui, New Zealand	8			
73000 ± 4000 BP	Toba, Indonesia	8	2500-3000		Killed up to 60% of the global population; MCD: starvation
640000 BP	Yellowstone	8	1000		

nenana

an the largest expected impactors



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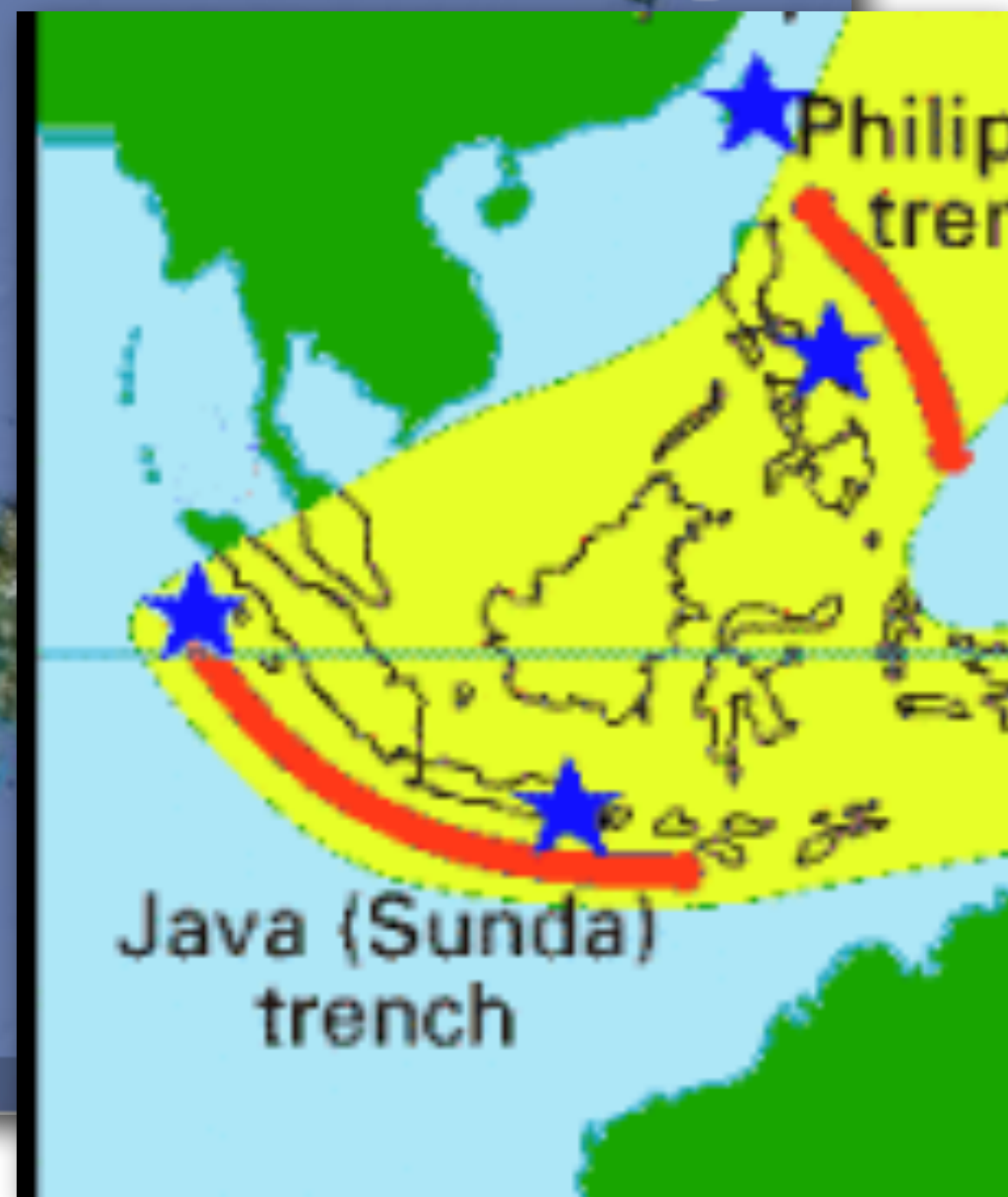
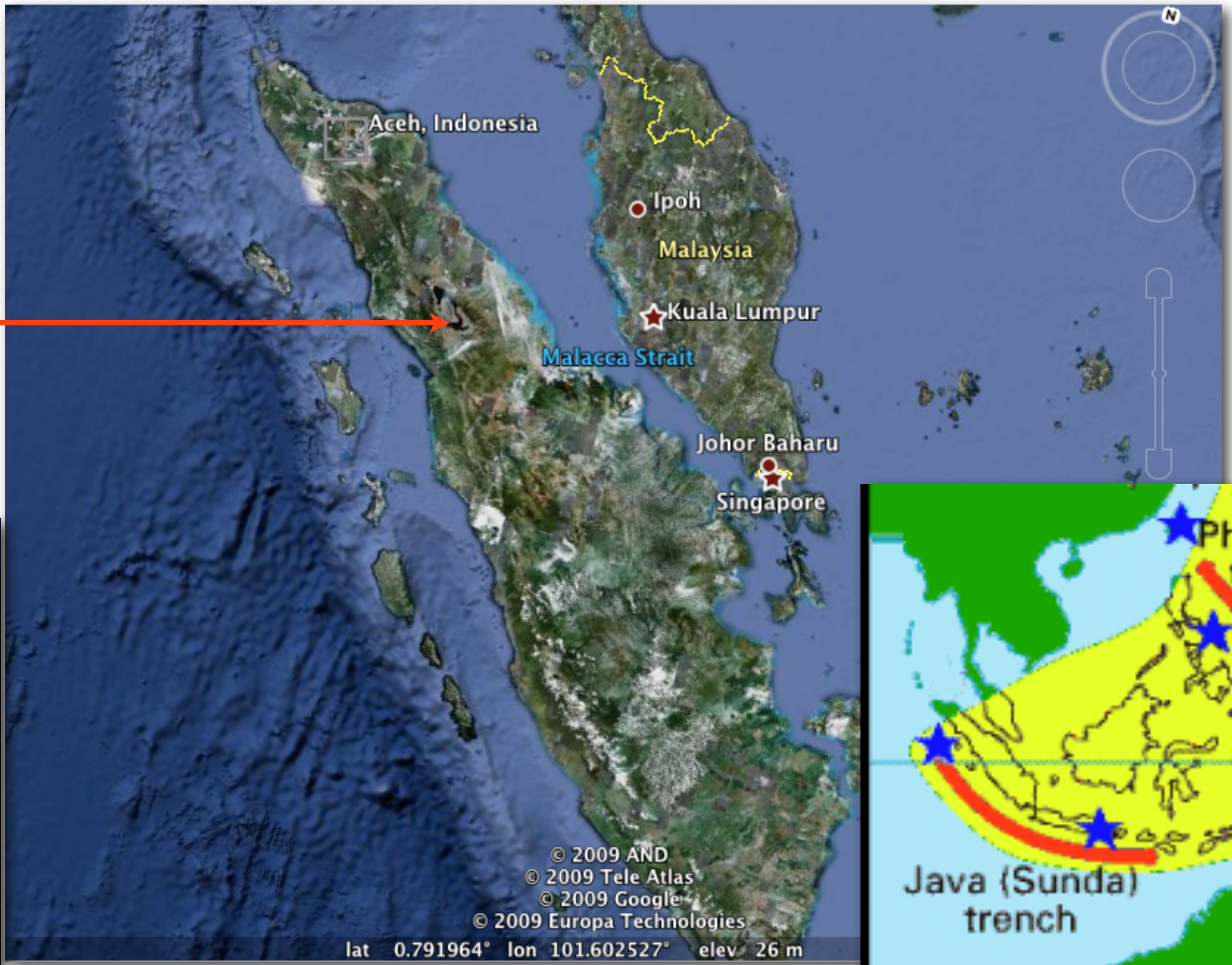
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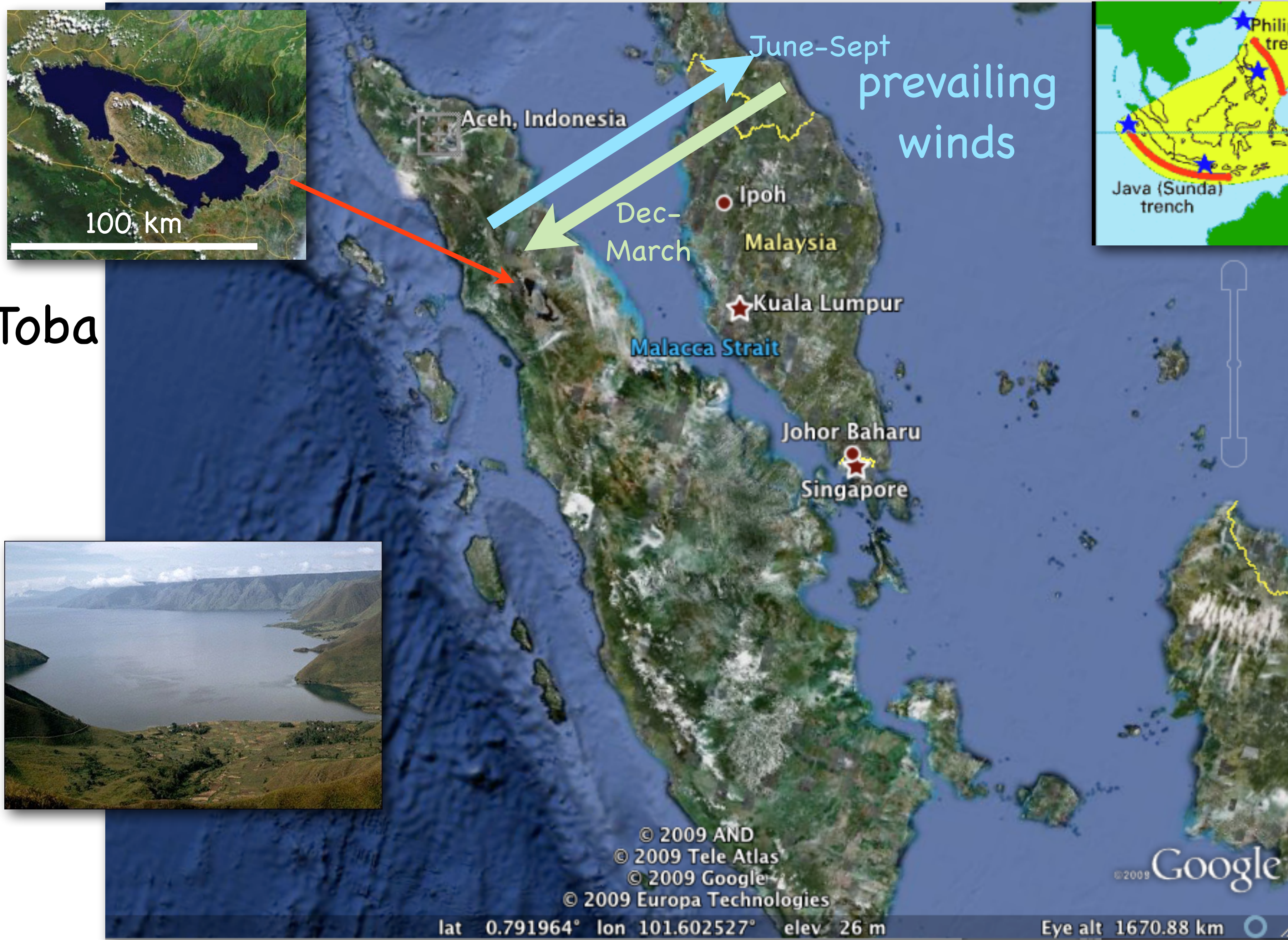
an the largest expected impactors

**VEI 7 / M 7:**

- at least seven events in the Holocene
- ~5% - 10% chance that this will happen in the 21st century
- Will have very different impact than previously

# Large Eruptions





## Lake Toba



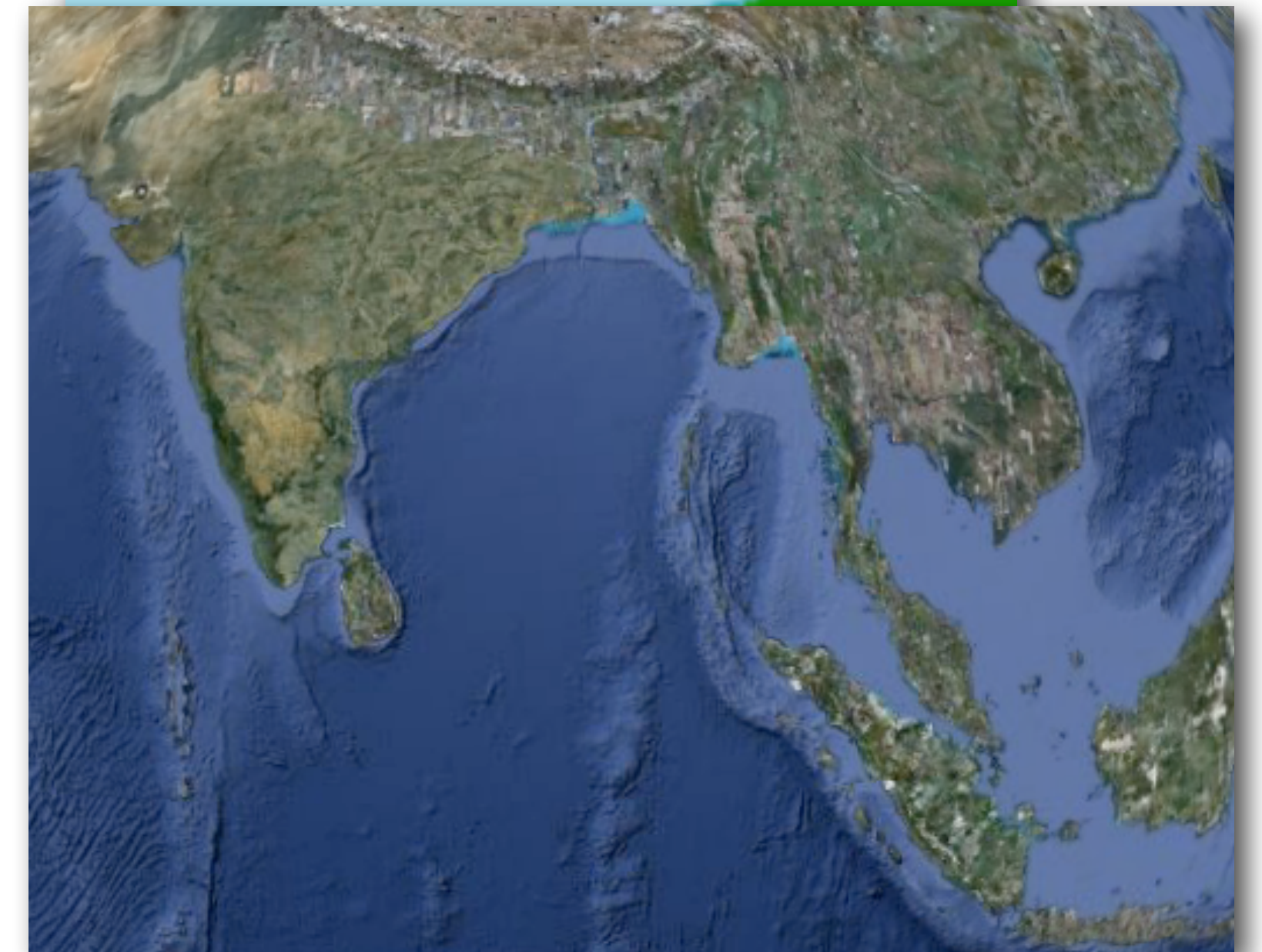
© 2009 AND  
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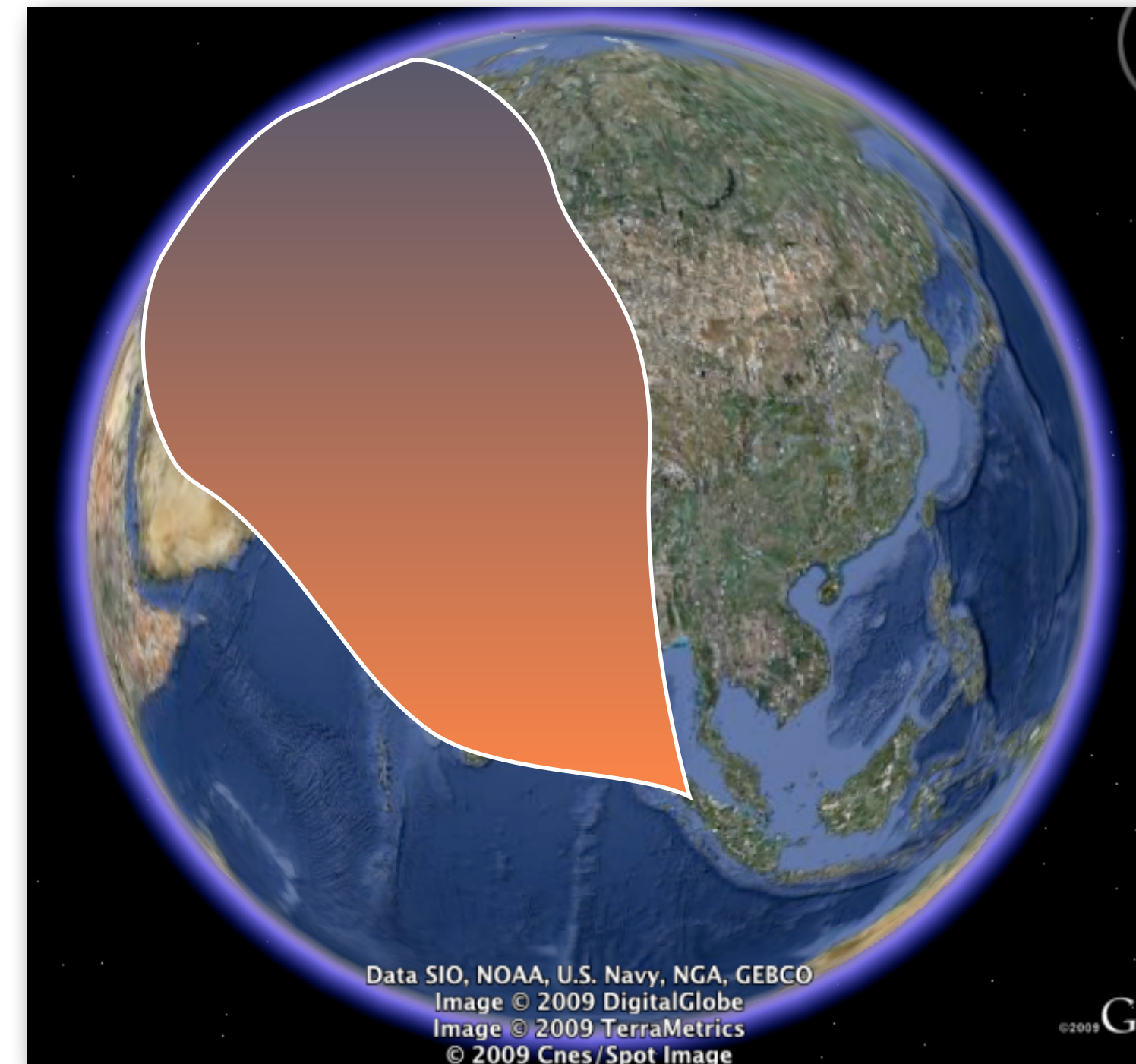
lat 0.791964° lon 101.602527° elev 26 m Eye alt 1670.88 km

## Lake Toba

- 4 overlapping volcanoes on 400,000 year cycle
- Last cataclysmic eruption ca.74,000 years ago
- Over 700 million tons of ash & pyroclastic deposits
- Ash layer 15 cm thick over all of India
- Ash also present in Greenland Ice Cores

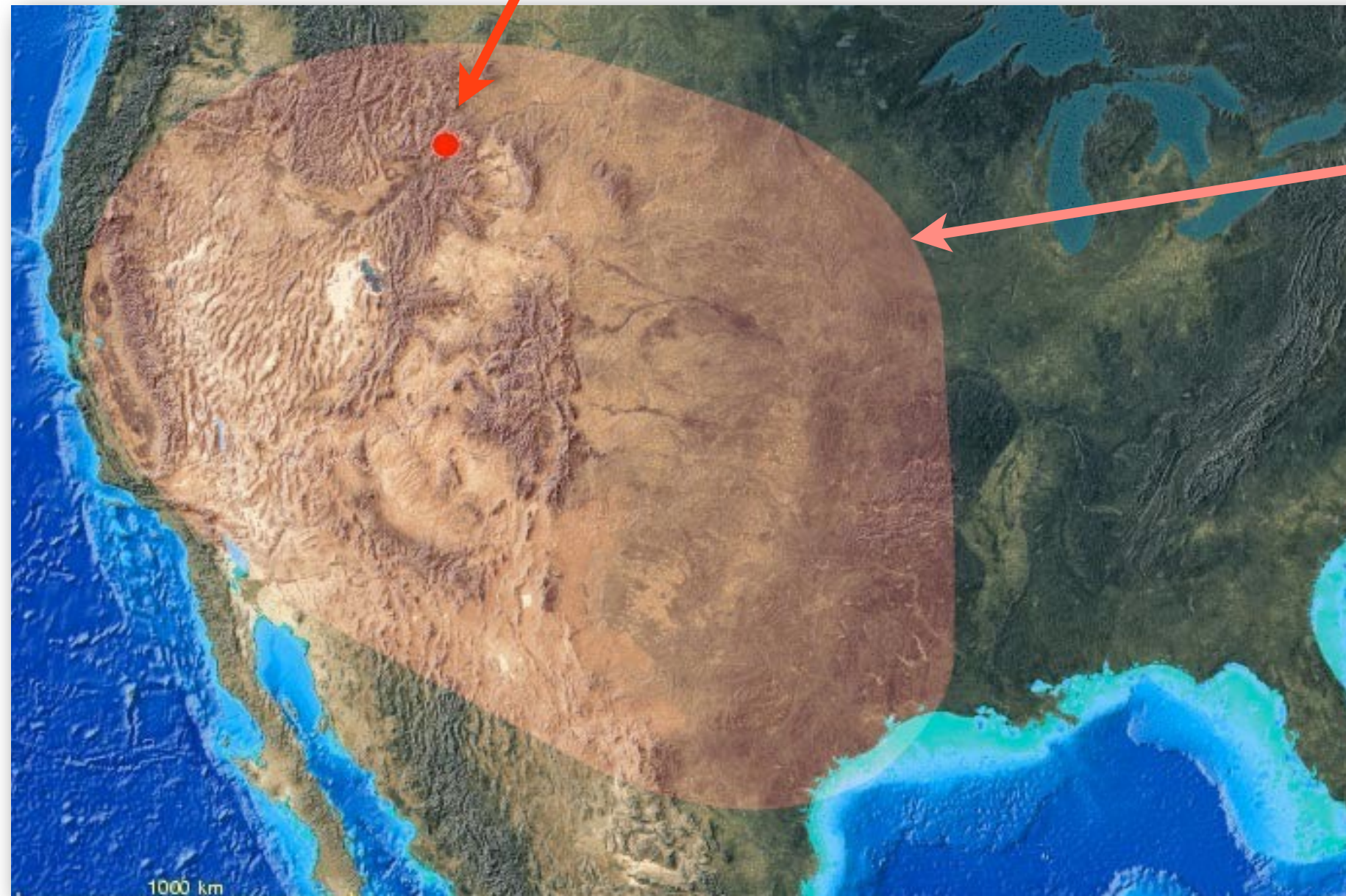


- At least 3°C (with extreme estimates of -15°C) drop in global average temperature
- Snow for most of year in temperate climates
- Evidence from mitochondrial DNA suggests catastrophic number of humans killed, thus reducing genetic diversity, but this is controversial.
- Evidence from artifacts below and above ash layer suggests at least some humans survived in the region



**Ash plume  
spread to NW**

Yellowstone

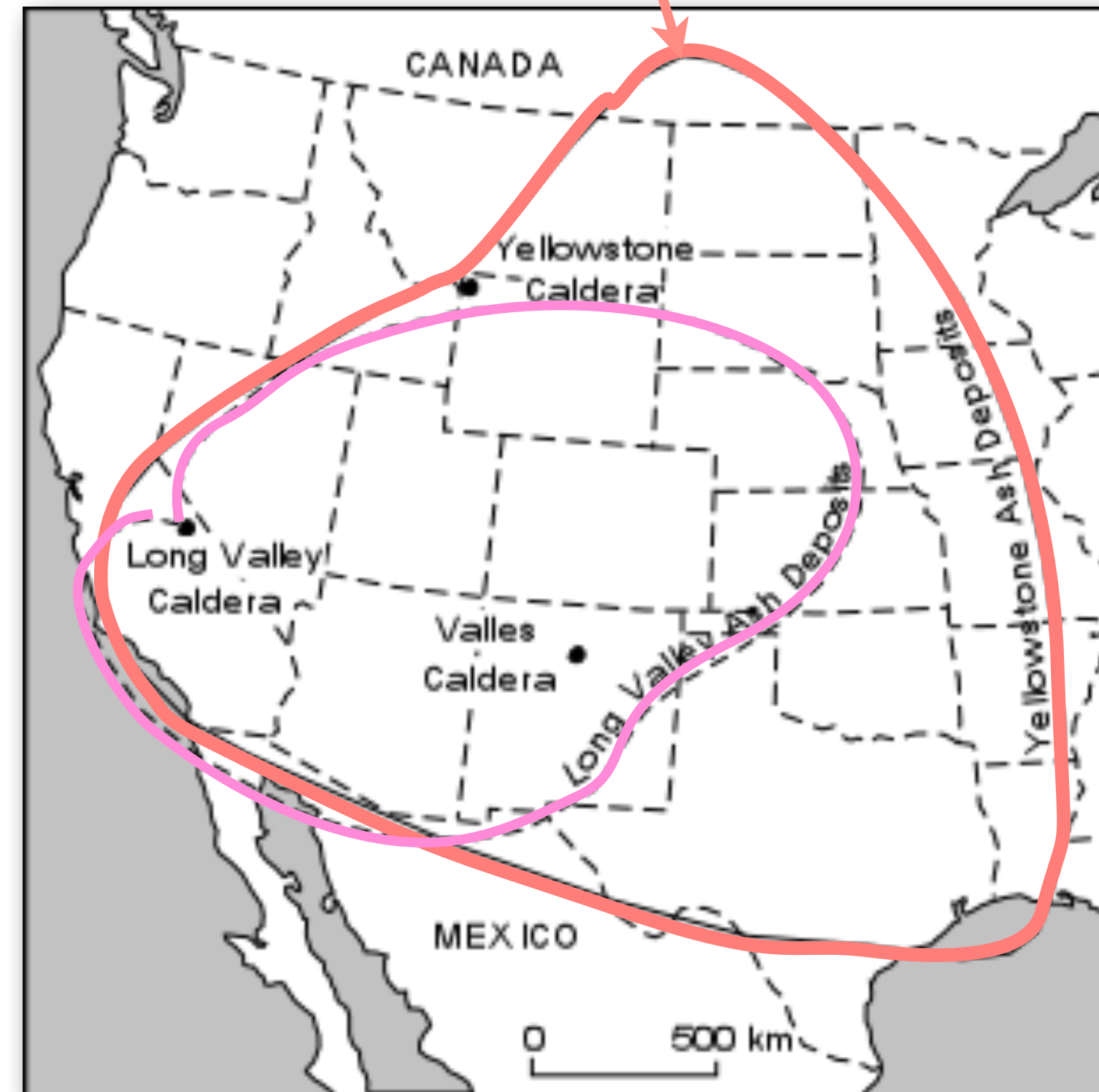


<http://www.swisseduc.ch/stromboli/perm/yellowstone/icons/ashfall.jpg>

Supervolcano - an eruption that ejects  $>1000 \text{ km}^3$  ( $>240 \text{ miles}^3$ ) of ash and pumice in a single event

## Yellowstone, MT

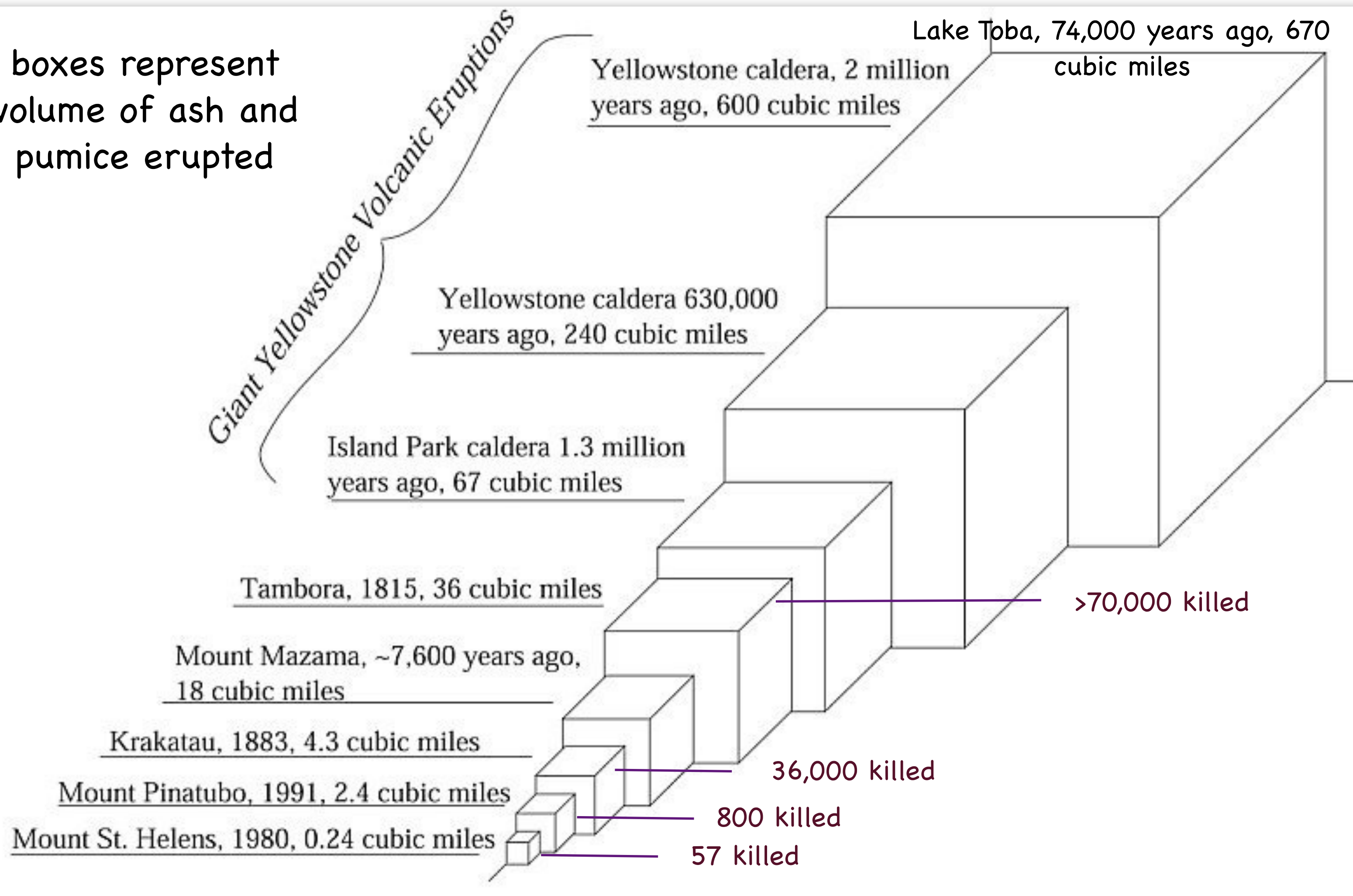
Limit of Yellowstone caldera ash deposits



<http://www.tulane.edu/~sanelson/images/yellowstoneash.gif>

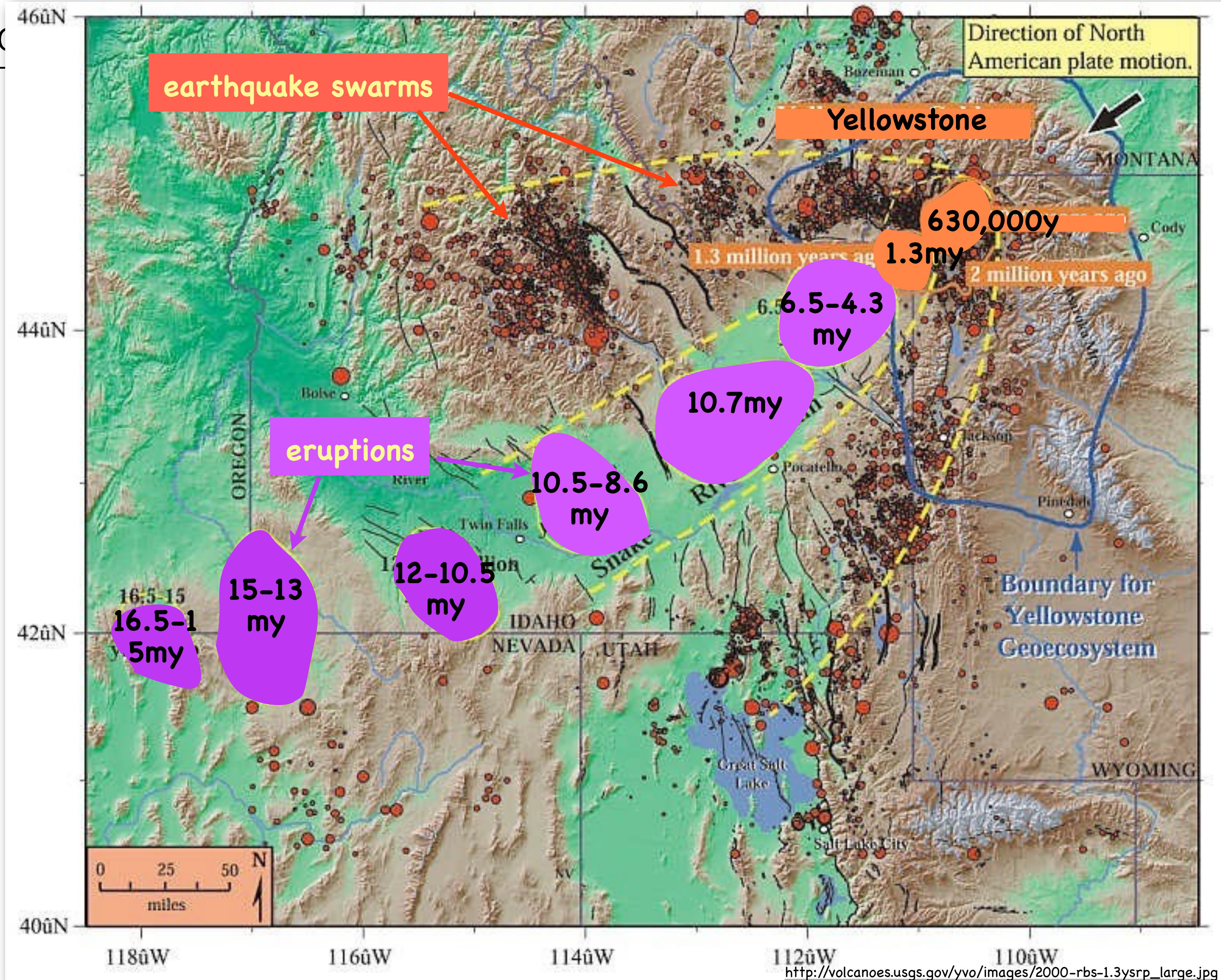
## Eruption size vs. casualties

boxes represent  
volume of ash and  
pumice erupted

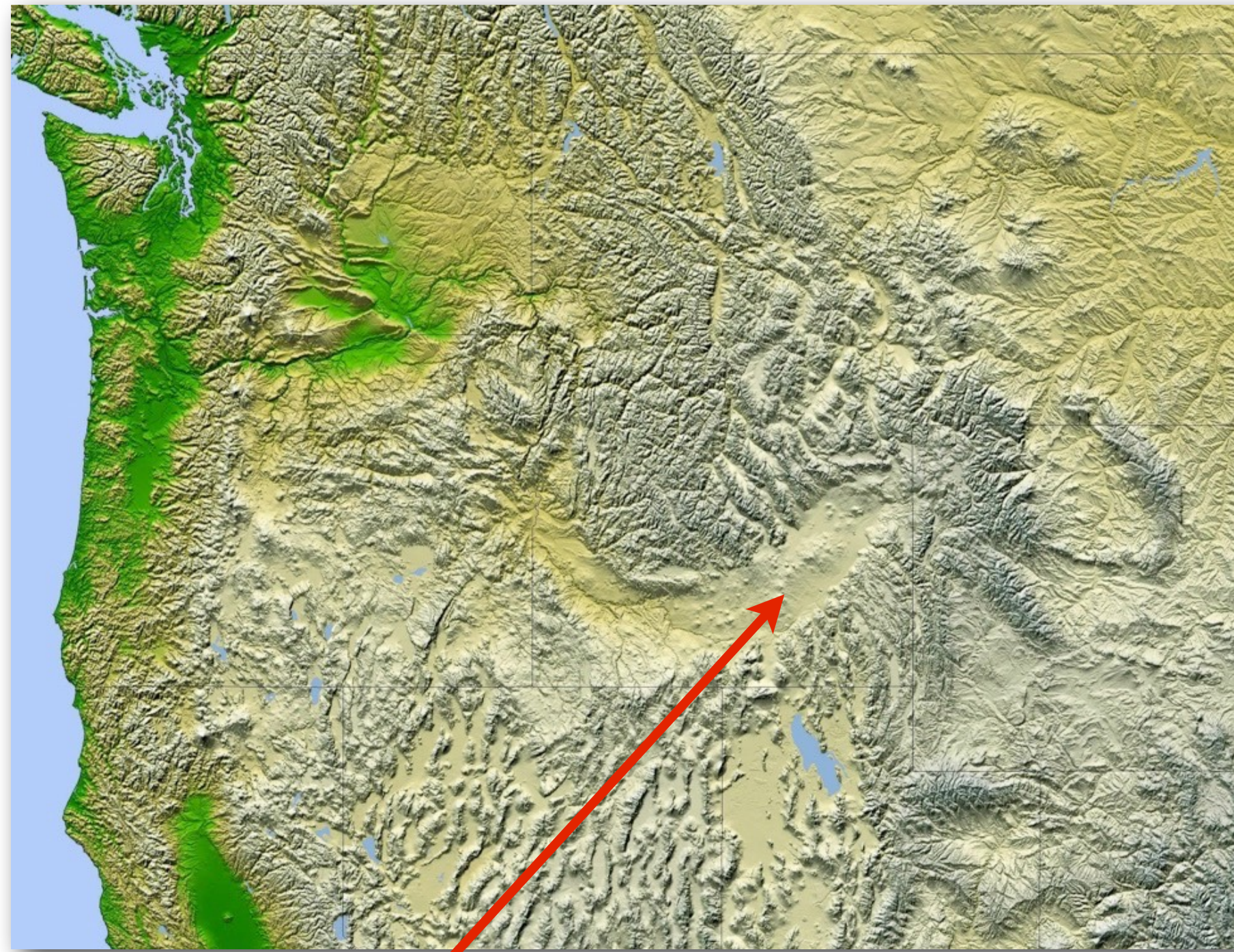




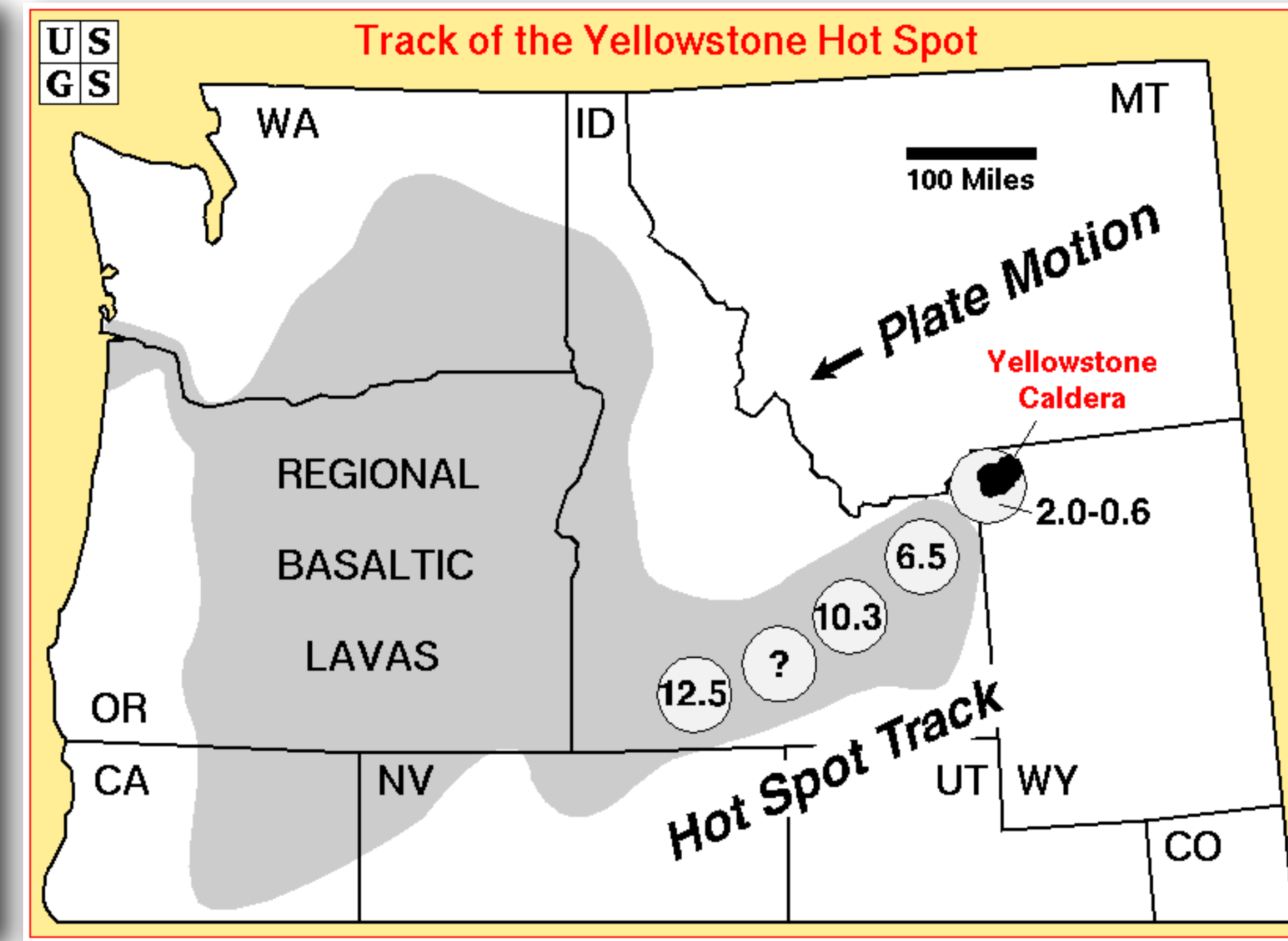
# Large Eruptive



# Large Eruptions

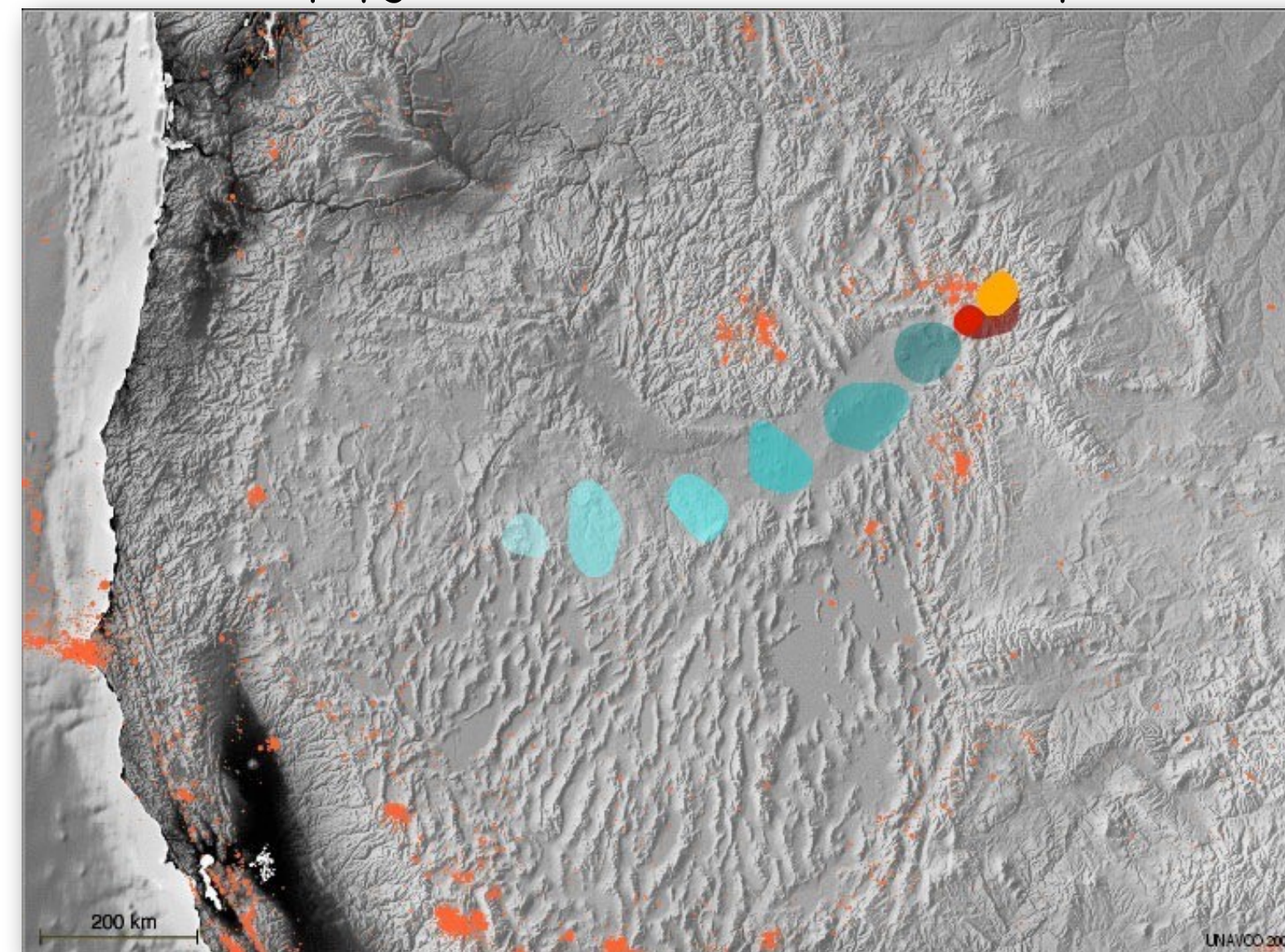


<http://geology.com/shaded-relief/northwest-shaded-relief-map.jpg>



<http://vulcan.wr.usgs.gov/Imgs/Gif/Yellowstone/OFR95-59/figure1.gif>

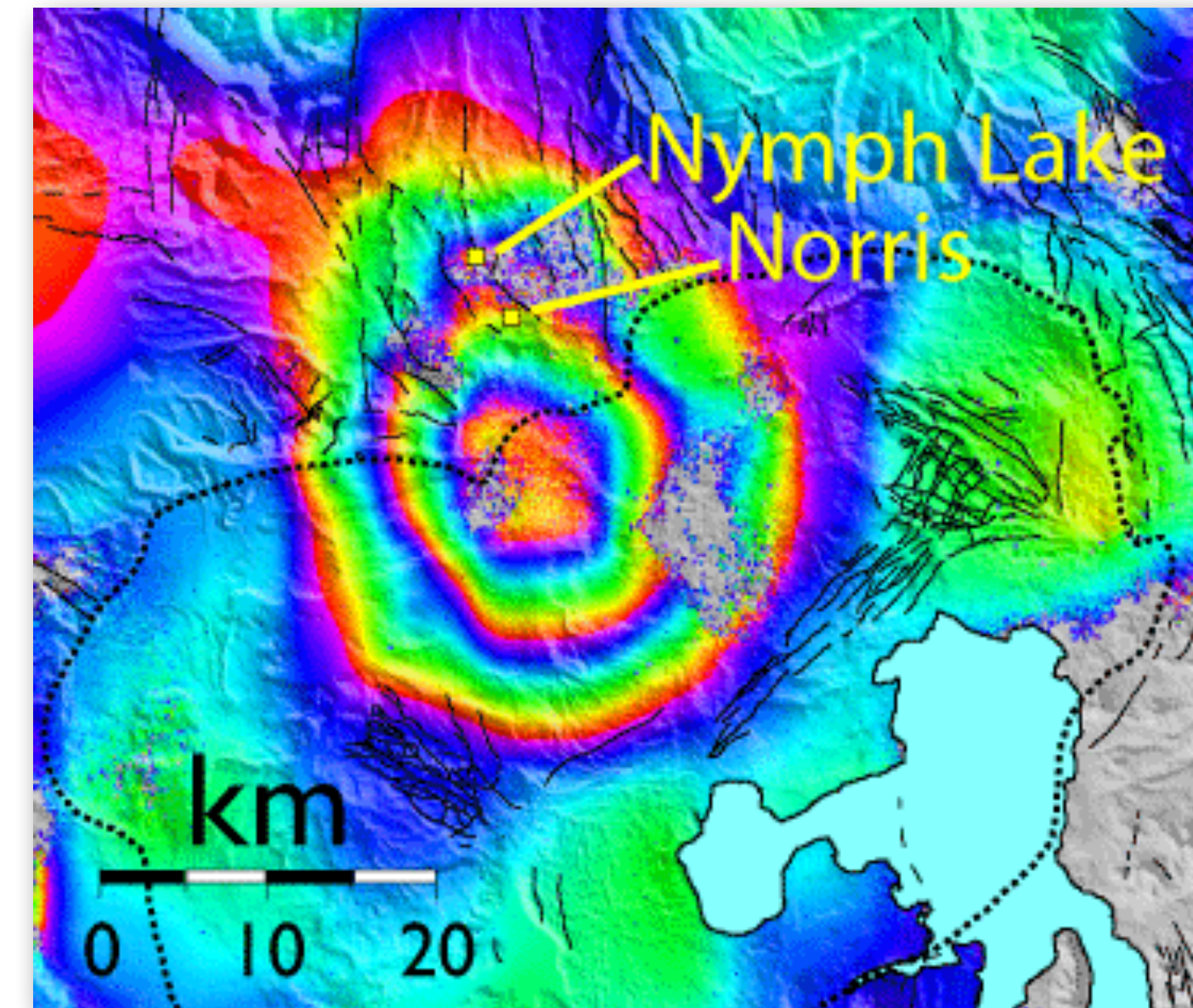
hot spot track is evident in topography



<http://www.swisseduc.ch/stromboli/perm/yellowstone/icons/migration.jpg>



2004-2006 interferogram  
(ground deformation pattern)



[http://volcanoes.usgs.gov/yvo/images/96\\_00norris.gif](http://volcanoes.usgs.gov/yvo/images/96_00norris.gif)

shows relative changes in  
ground surface uplift

a sleeping giant, or going out  
with a fizz....?

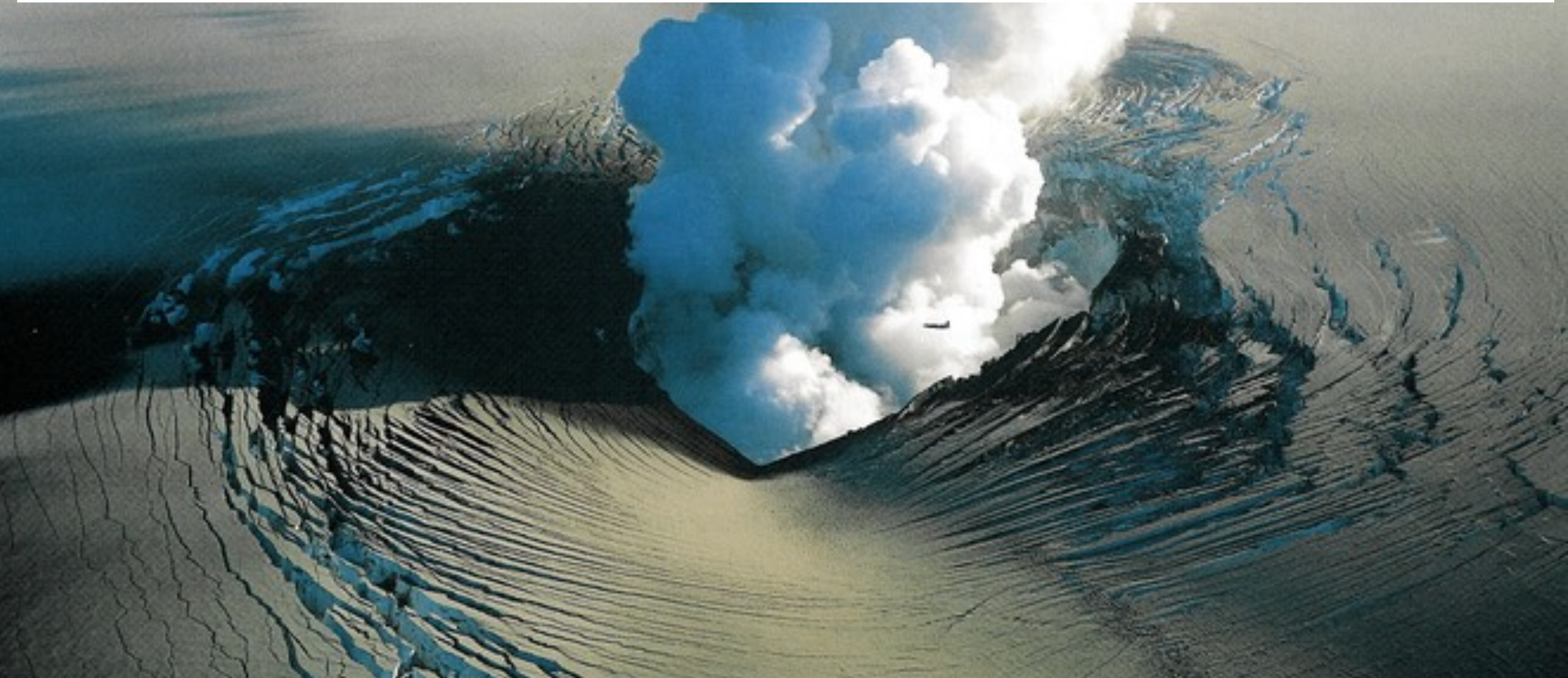


# Large Eruptions



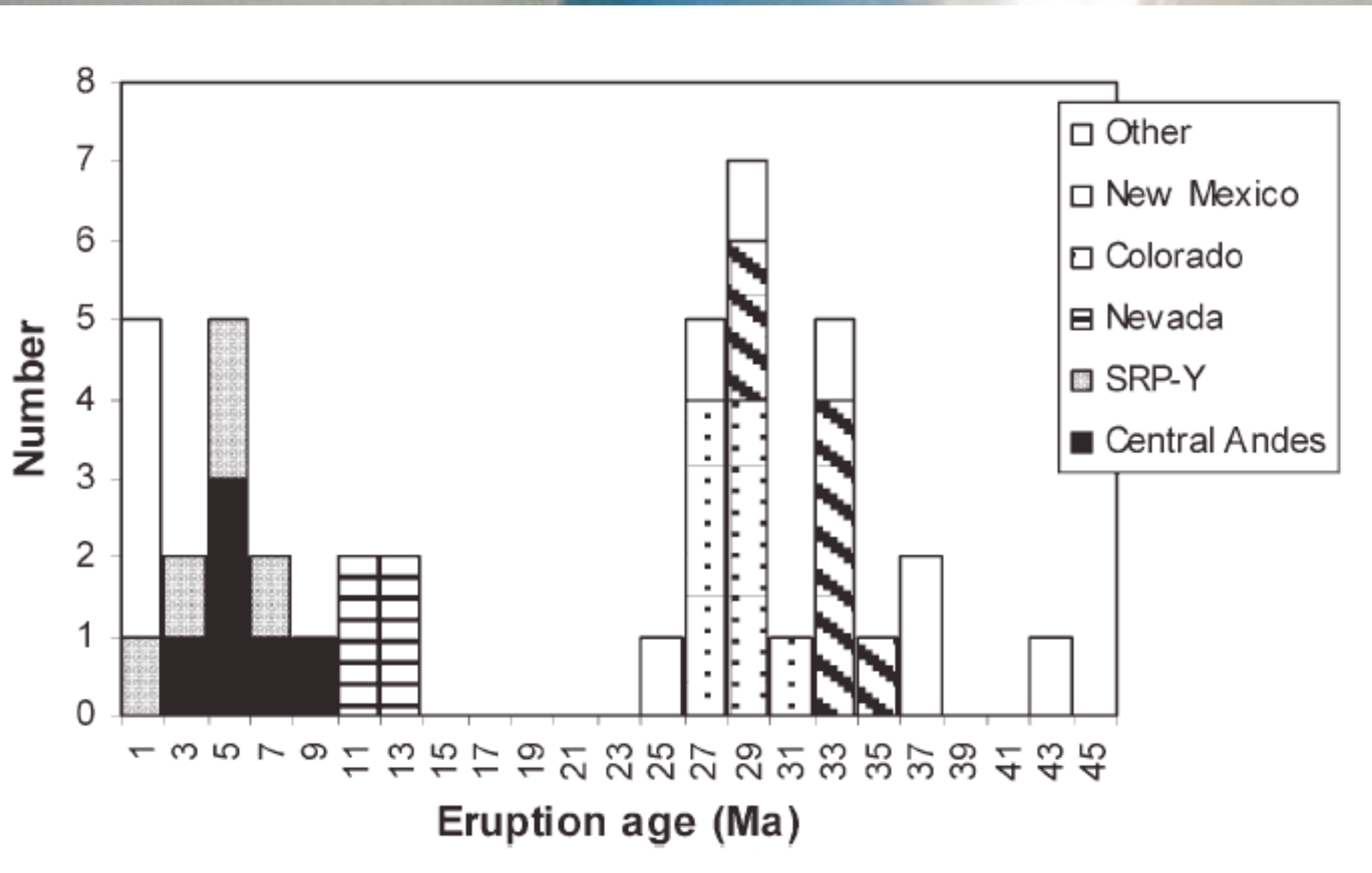
VEI 8 / M 8: 45 events identified in the last 36 Ma (Mason et al., 2004), not equally distributed in time

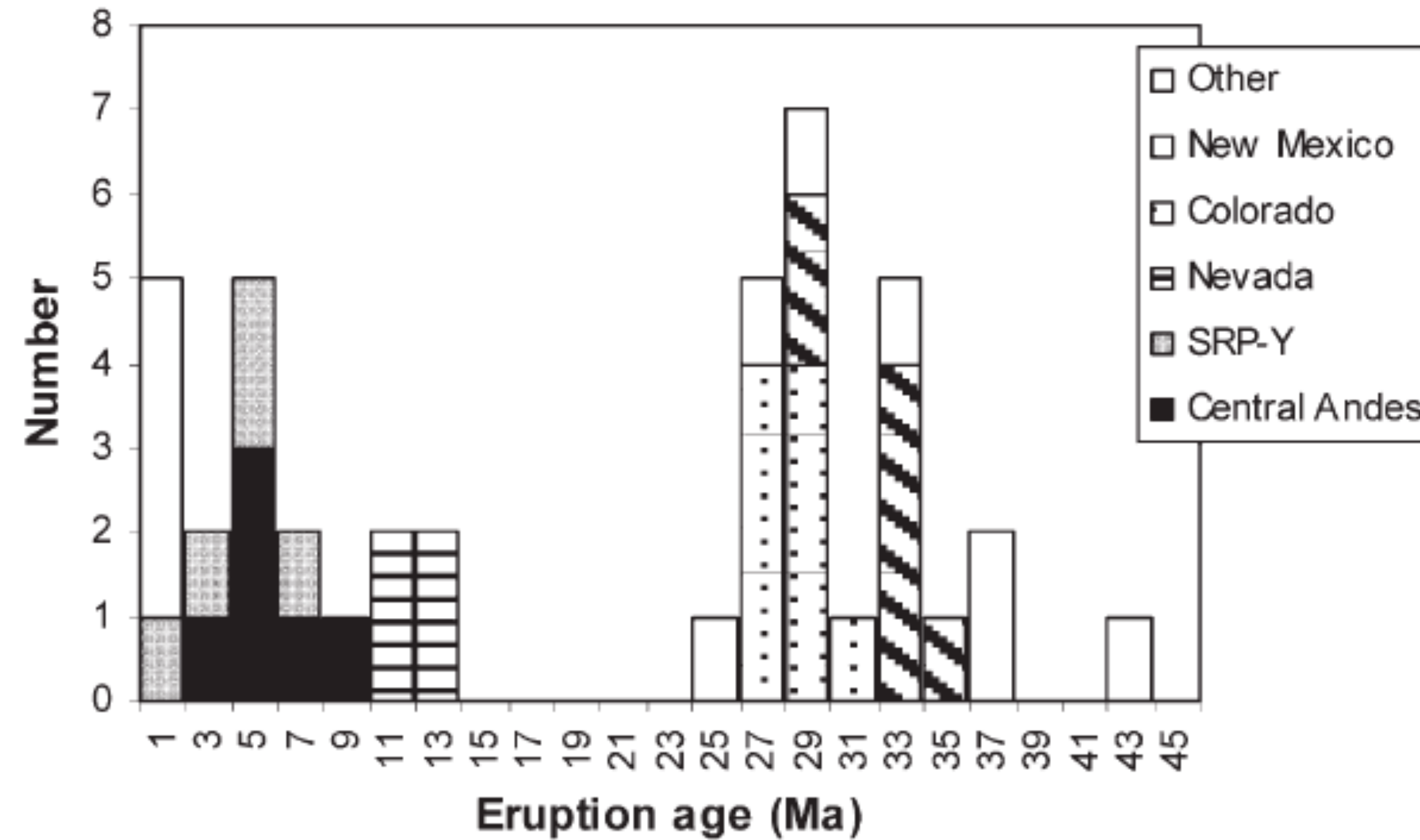
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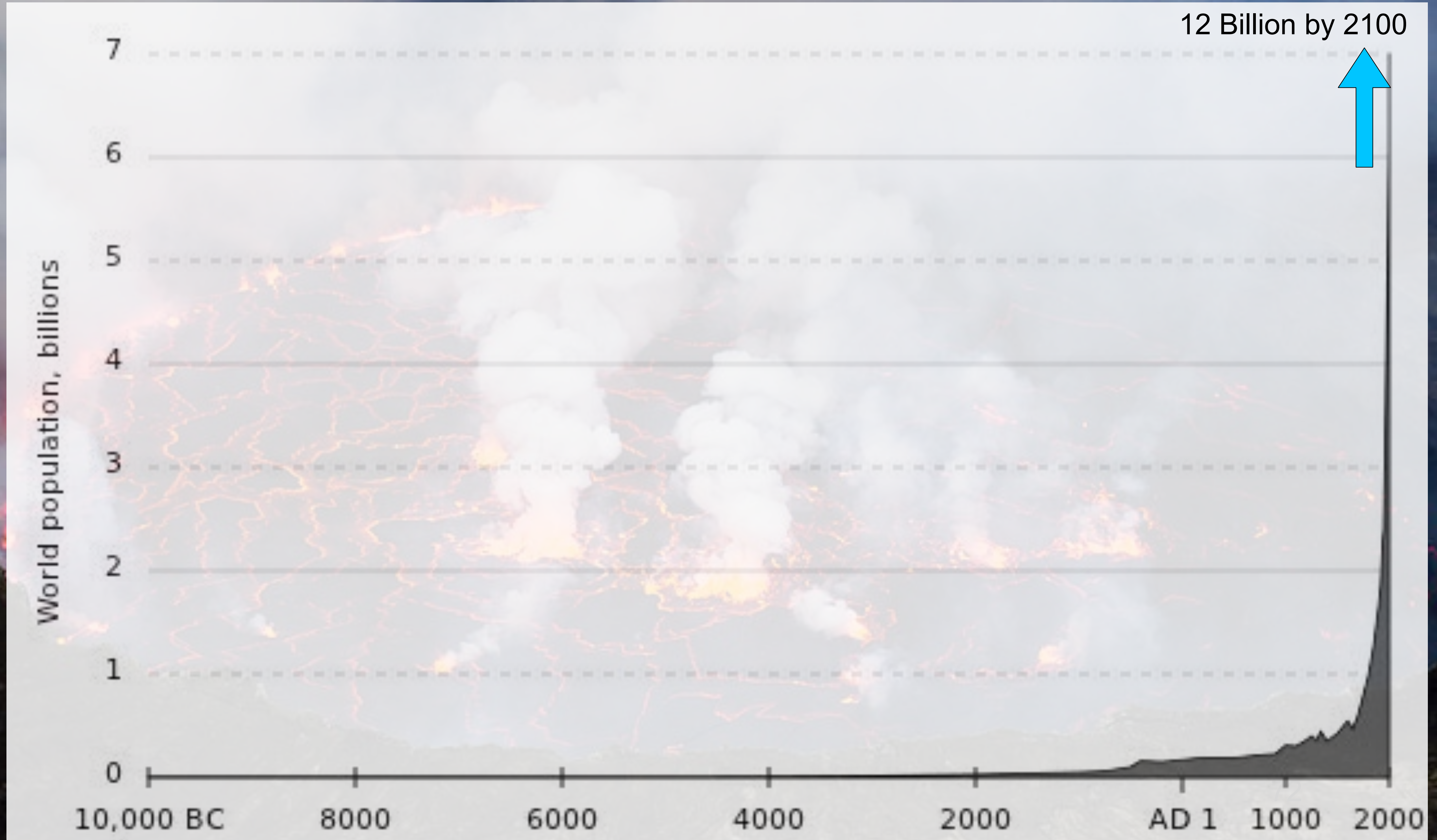


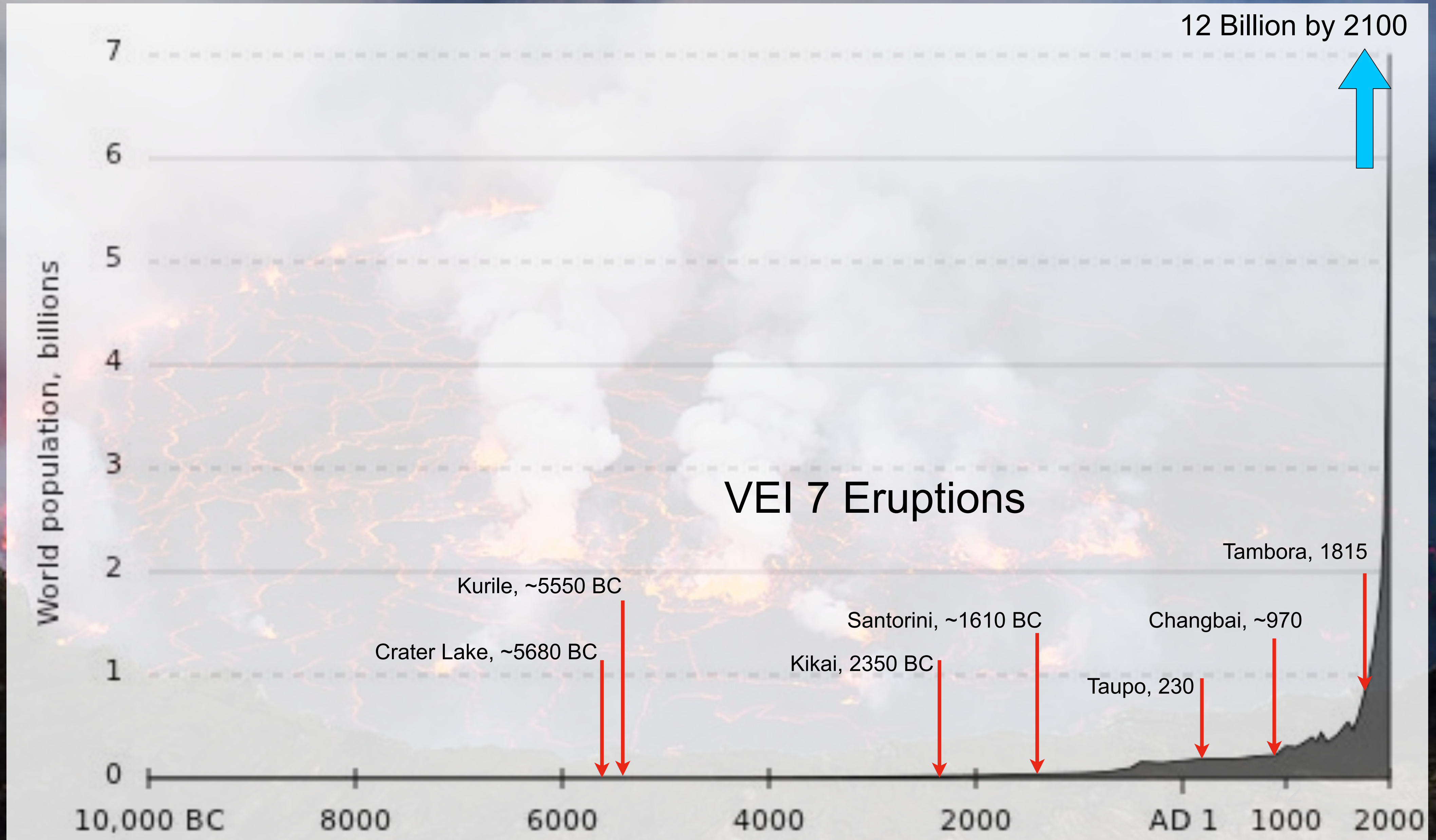
**Fig. 5** Histogram (at 2 Ma intervals, with age of the midpoint given on the x axis) showing the time distribution of the 42 known eruptions of M8 and larger over the past 46 Ma. Key geographical areas are highlighted (New Mexico, Colorado, Nevada are in the south-western USA; SRP is the Snake River Plain-Yellowstone province of western USA). Although the record is incomplete, the bimodal pattern of known eruptions may be real, and probably reflects the control of global tectonics on rates of occurrence of large eruptions. Known events from the past 13.5 Ma are dominated by eruptions in the Central Andes and the Snake River Plain-Yellowstone province, while events between 25 and 38 Ma are dominated by eruptions in Colorado and New Mexico, south-western USA. No large silicic provinces are known from the period 17–25 Ma



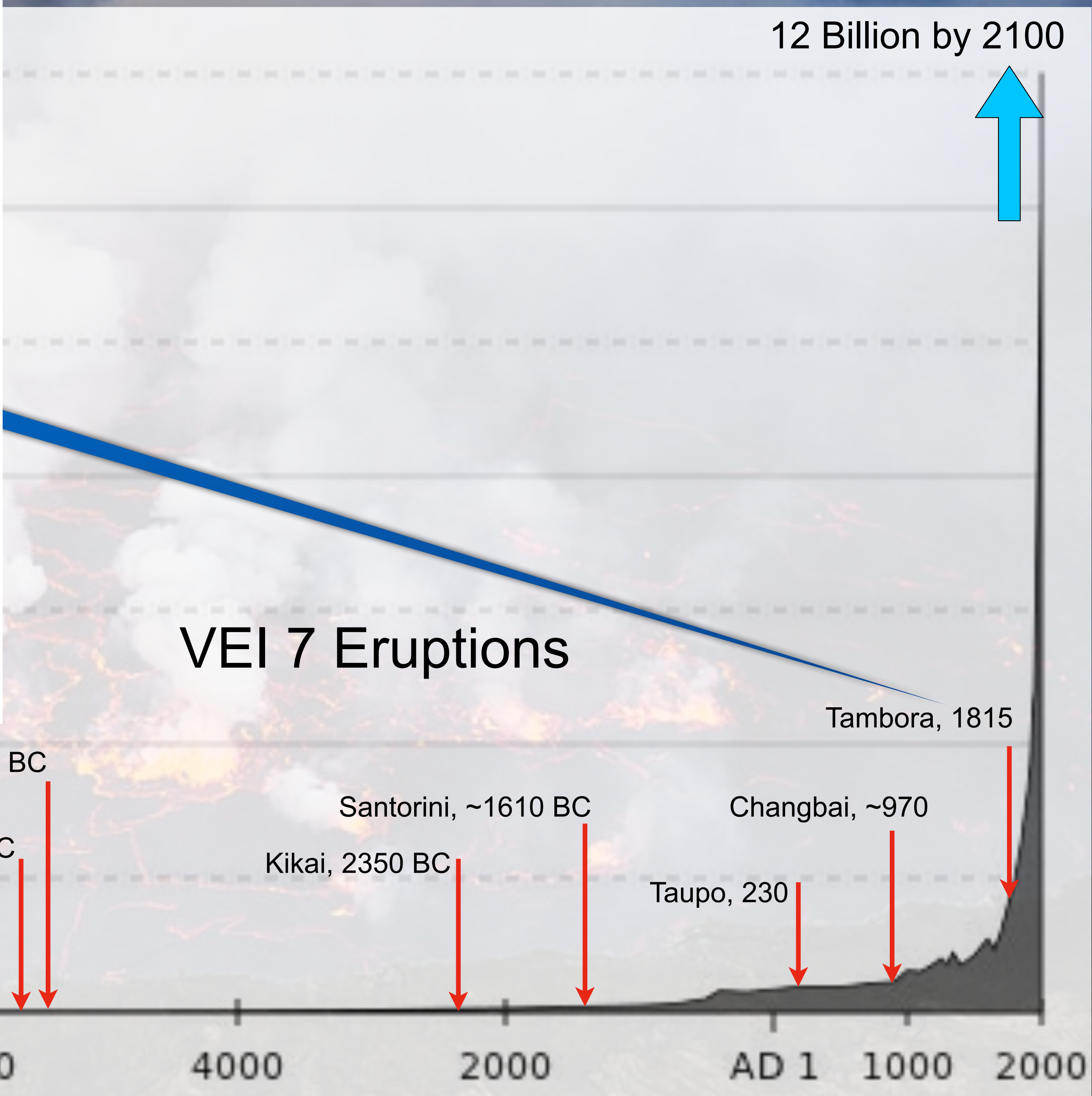


# Large Eruptions





# Large Eruptions

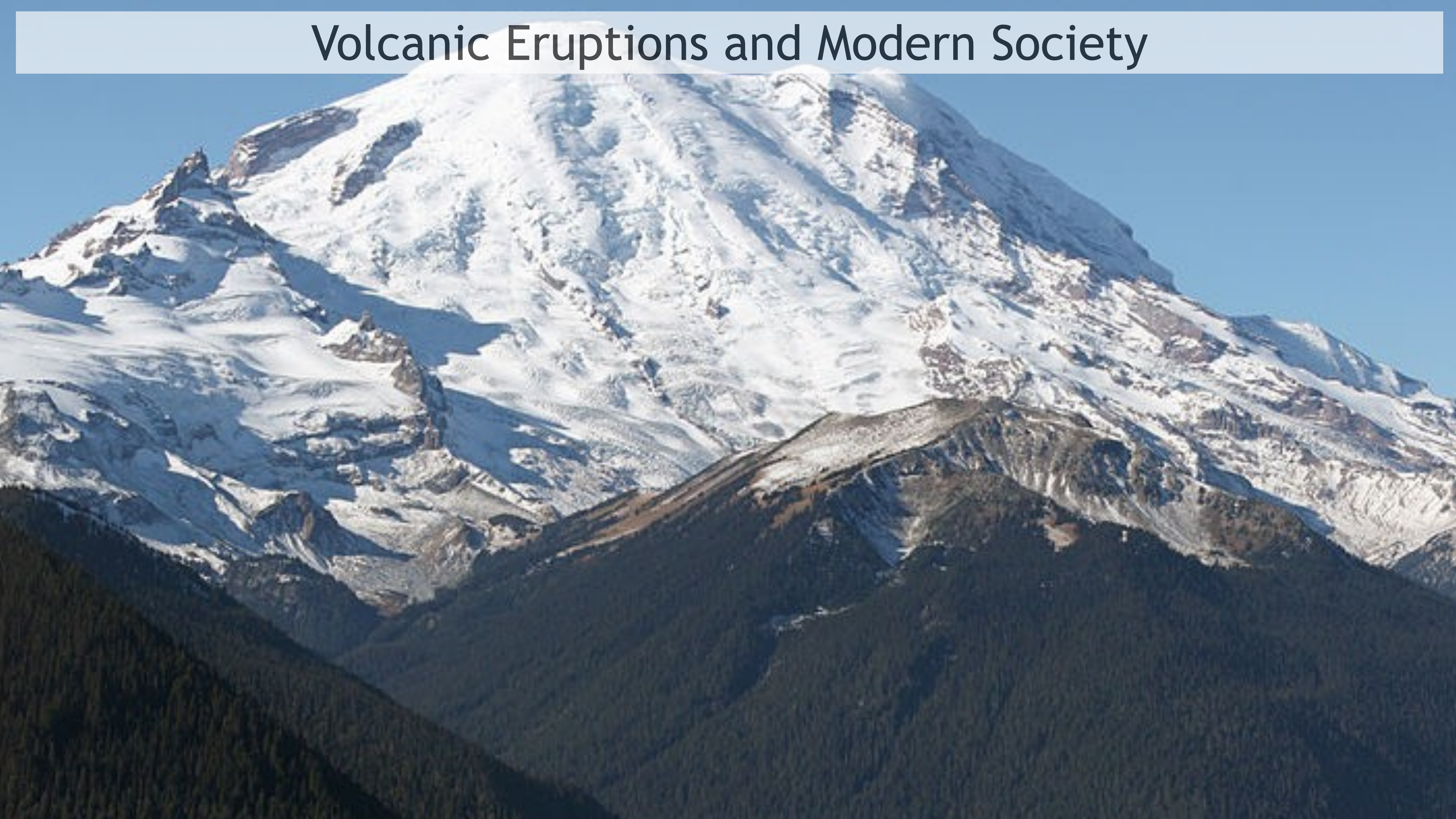


# Natural Hazards and Disaster

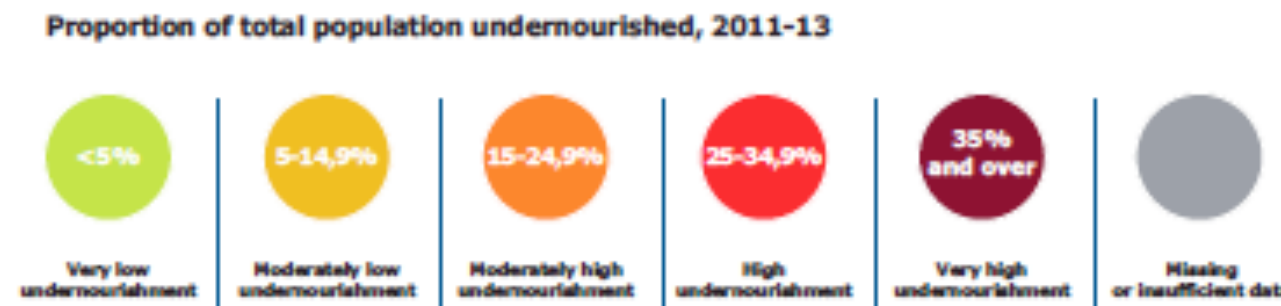
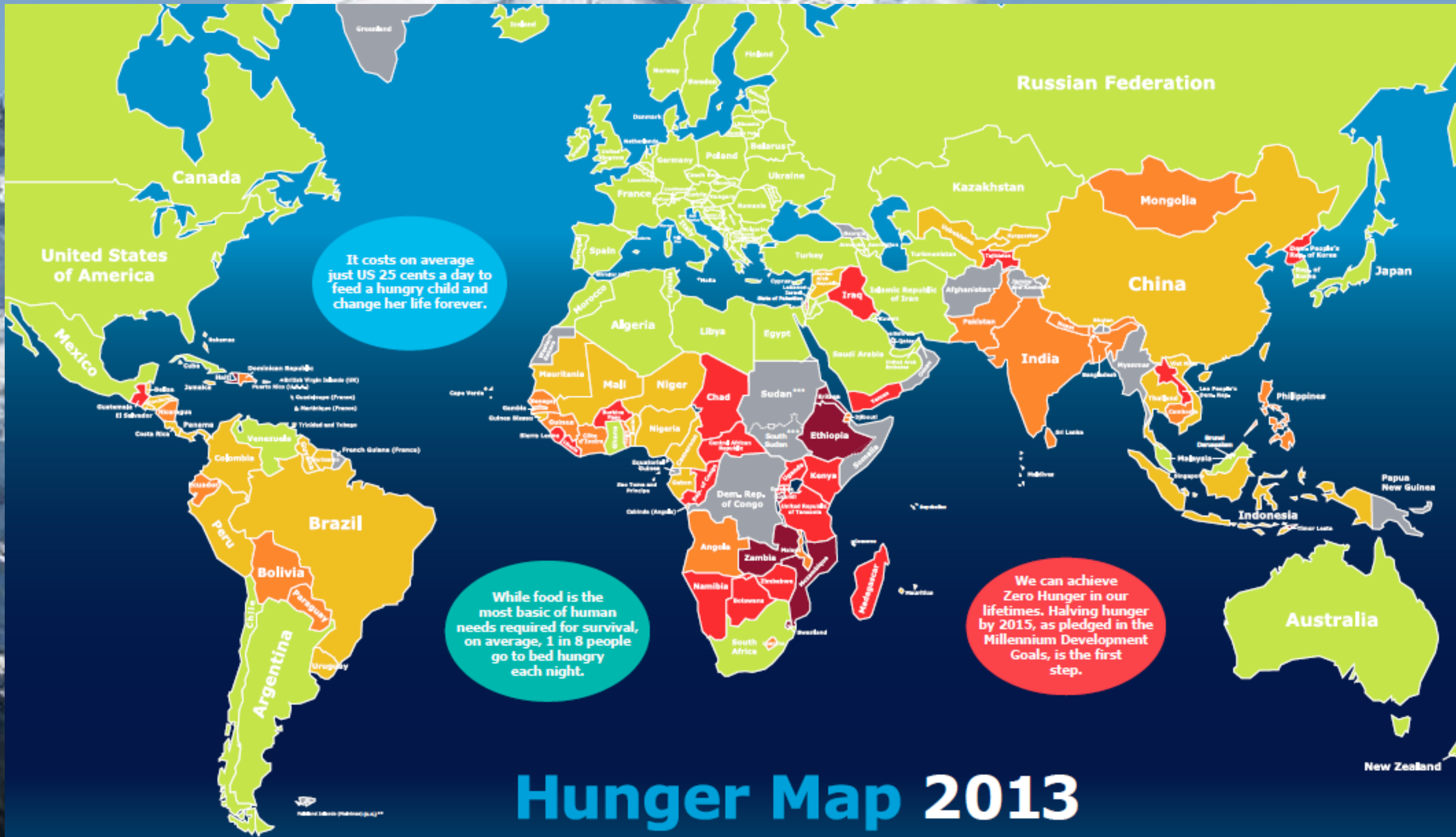
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# Volcanic Eruptions and Modern Society



# Volcanic Eruptions and Modern Society



This map shows the proportion of undernourishment in the total population of developing countries as of 2011-13. The indicator is an estimate of the percentage of the population at risk of chronic undernourishment. Further information is available at [www.fao.org/publications/sofi/en/](http://www.fao.org/publications/sofi/en/)

Source: FAO, IFAD and WFP 2013, The State of Food Insecurity in the World 2013. The multiple dimensions of food security. Rome, IAO. Data source: [fao.org/economic/sofi](http://fao.org/economic/sofi)

© 2013 World Food Programme

The boundaries and the nomenclature of material in this map do not imply the expression of any opinion whatsoever on the part of WFP regarding the legal or constitutional status of any country, territory or sea area, or concerning the delimitation of frontiers.

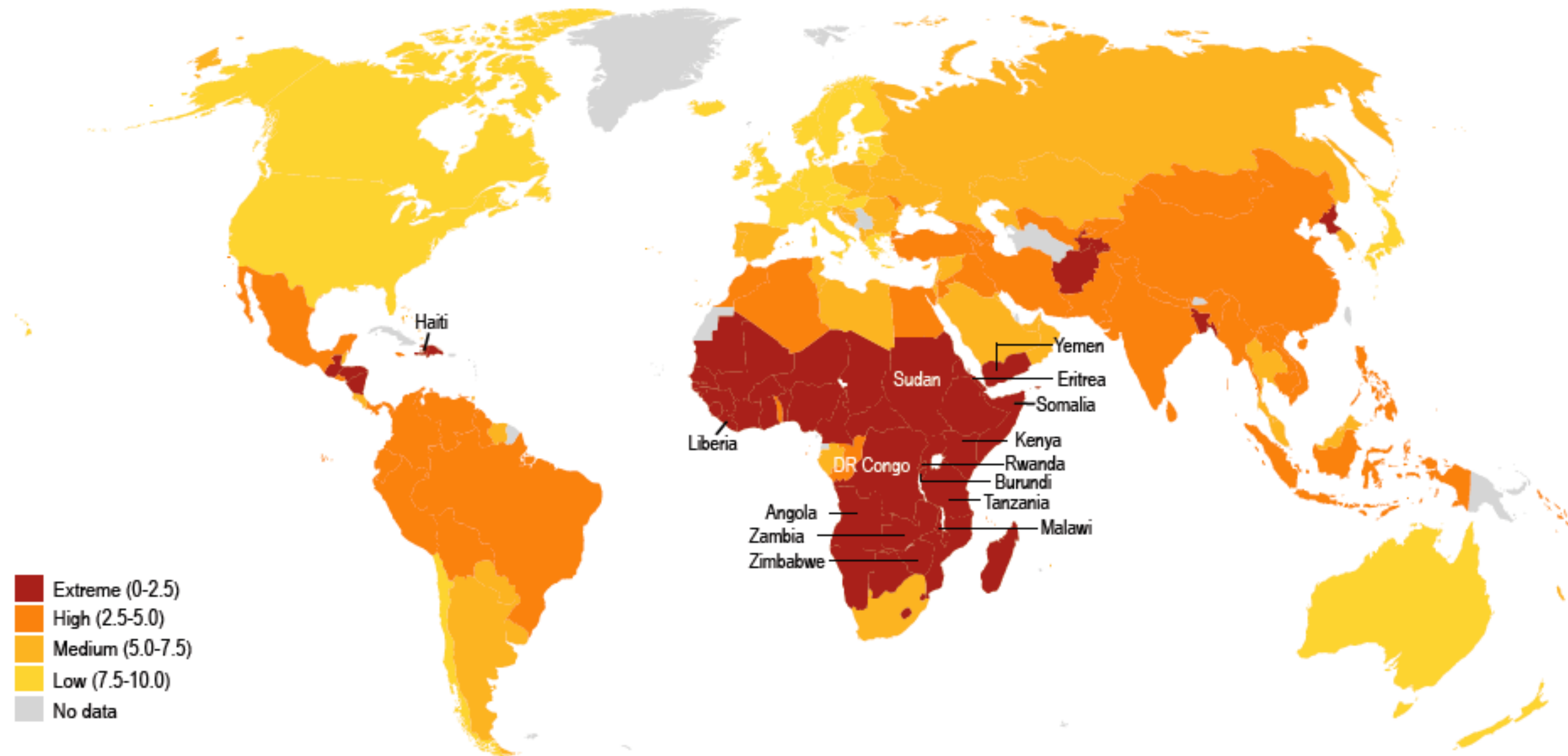
\*\* United Nations Economic and Social Commission for Western Asia (ESCWA) and United Nations Economic and Social Commission for Western Asia (ESCWA) have not yet been updated by the UN.

\*\*\* A dispute exists between the governments of Argentina and the United Kingdom of Great Britain and Northern Ireland concerning sovereignty over the Falkland Islands (Malvinas).

\*\*\*\* Final boundaries between the Republic of Sudan and the Republic of South Sudan have not yet been determined. South Sudan declared its independence on 9 July 2011. Data for Sudan (year 2011) and South Sudan are not yet available.

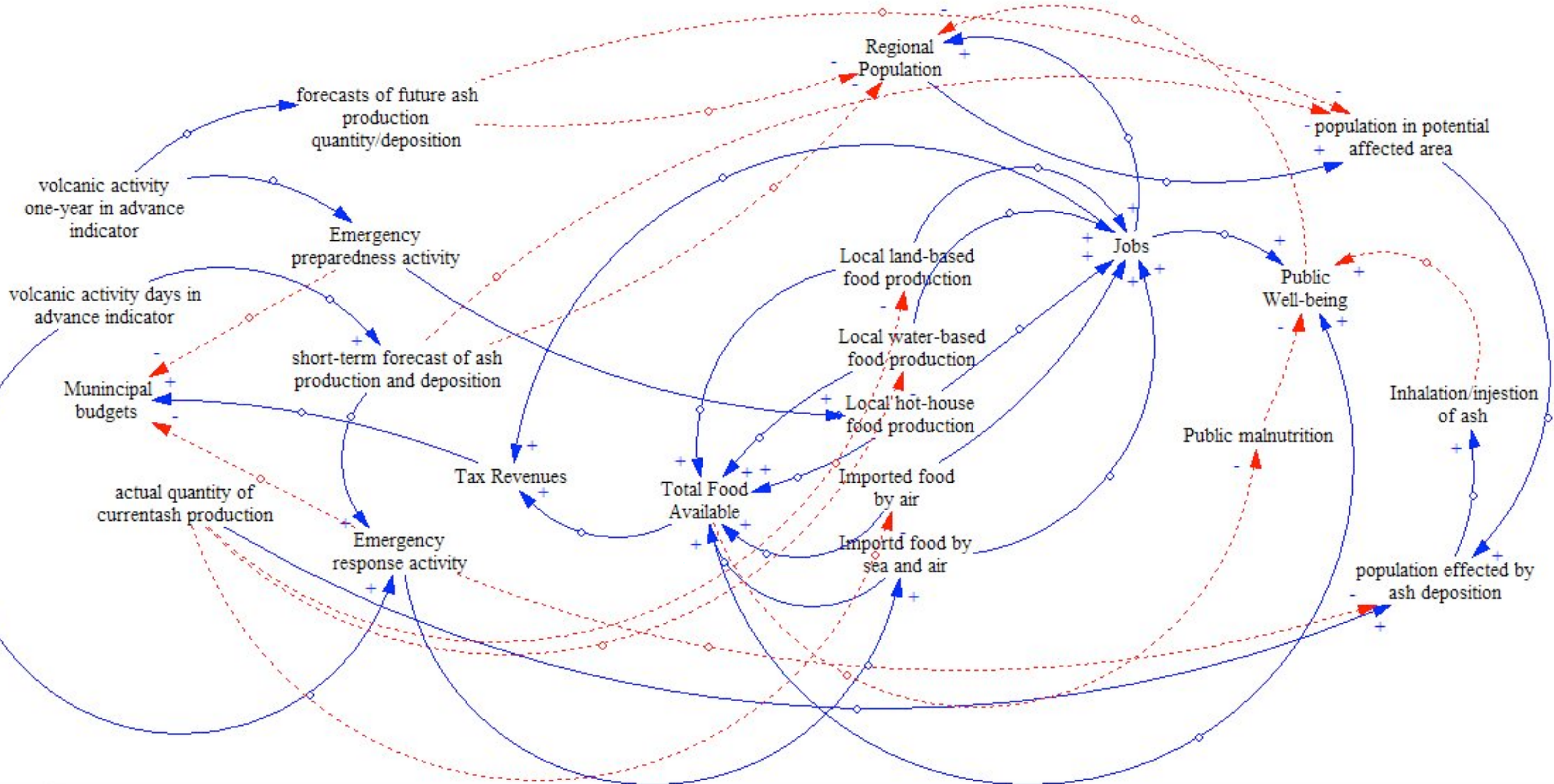
# Volcanic Eruptions and Modern Society

## Maplecroft's global map of food security



**Food Security Index:** This map is the visual representation of the Maplecroft Food Security Index (FSI). The FSI evaluates the risk of food insecurity in 162 countries across the globe. It provides a quantitative assessment of the availability, stability and access to food supplies, as well as the nutritional outcomes that result from food insecurity. Each country is assigned an index score based on its performance across 18 key indicators, classified into four sub-indices. Four categories of risk have been identified based on the FSI value for each country – extreme risk (0.0-2.5), high risk (2.5-5.0), medium risk (5.0-7.5) and low risk (7.5-10.0).

# Volcanic Eruptions and Modern Society





# Natural Hazards and Disaster

## Class 6: Volcanoes

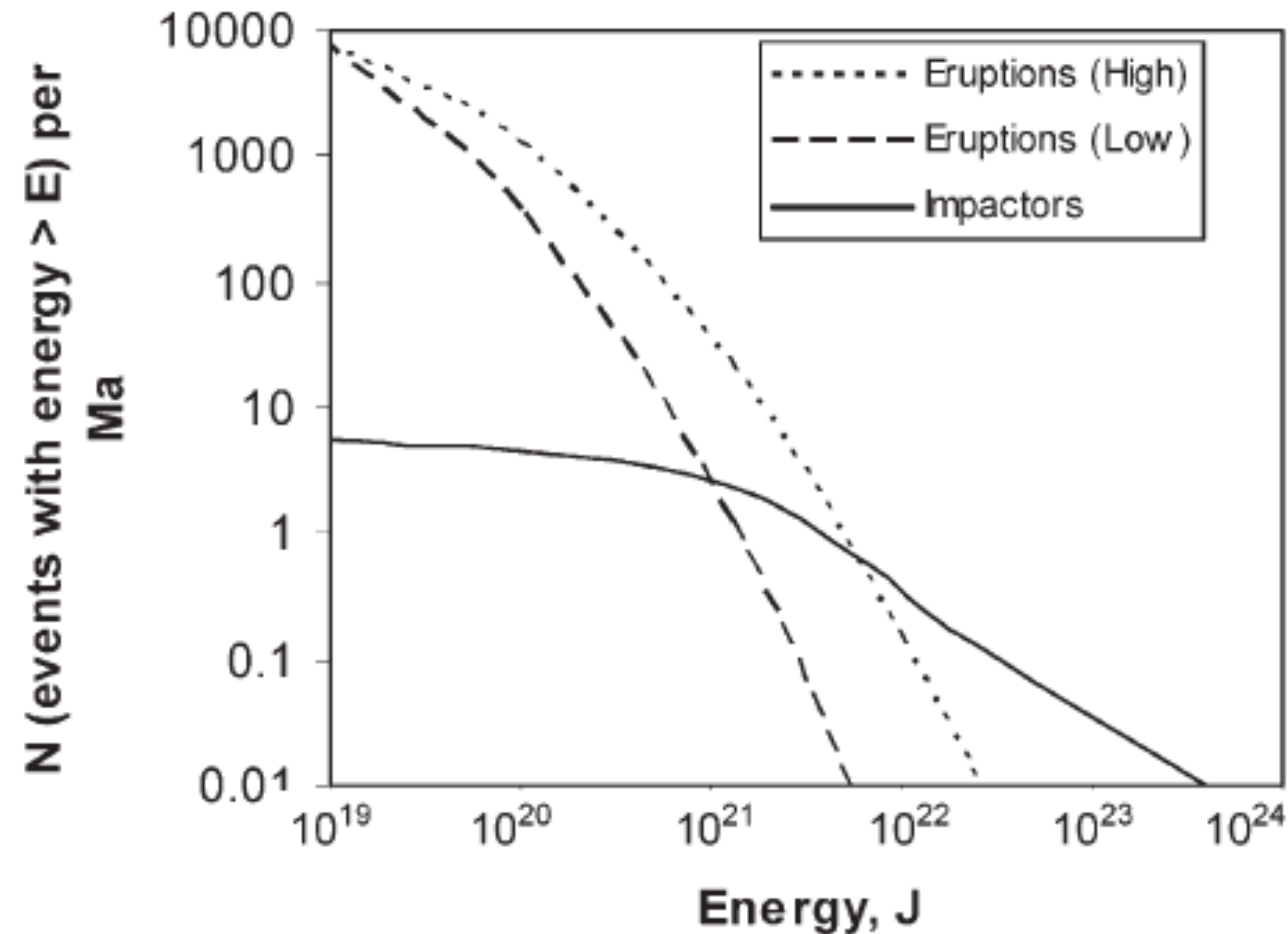
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# Comparison

Hazard	Events	Fatalities	Per year	Affected	Per year	Damage	Per year	<i>R</i>
Drought	410	558,565	19,261	1,551,455,122	53,498,452	76,949	2,653	0.036
Cyclone	1,211	402,911	13,893	496,560,639	17,122,781	533,371	18,392	0.081
Earthquake	706	385,630	13,298	136,333,515	4,701,156	351,079	12,106	0.283
Tsunami	18	229,551	7,916	2,481,879	85,582	10,046	0.346	9.249
Flood	2,887	195,843	6,753	2,809,481,489	96,878,672	397,334	13,701	0.007
Heatwave	126	89,889	3,100	4,614,411	159,118	21,990	758	1.948
Volcano	140	25,197	869	4,080,791	140,717	2,871	99	0.617
Landslide	366	20,008	690	7,031,523	242,466	6,060	209	0.285
Cold wave	156	11,595	400	6,875,103	237,073	5,902	204	0.169
Tornado	182	4,780	165	12,710,204	438,283	31,511	1,087	0.038
Avalanche	73	3,532	122	69,637	2,401	807	28	5.072
Wild fire	294	1,666	57	5,766,092	198,831	42,807	1,476	0.029

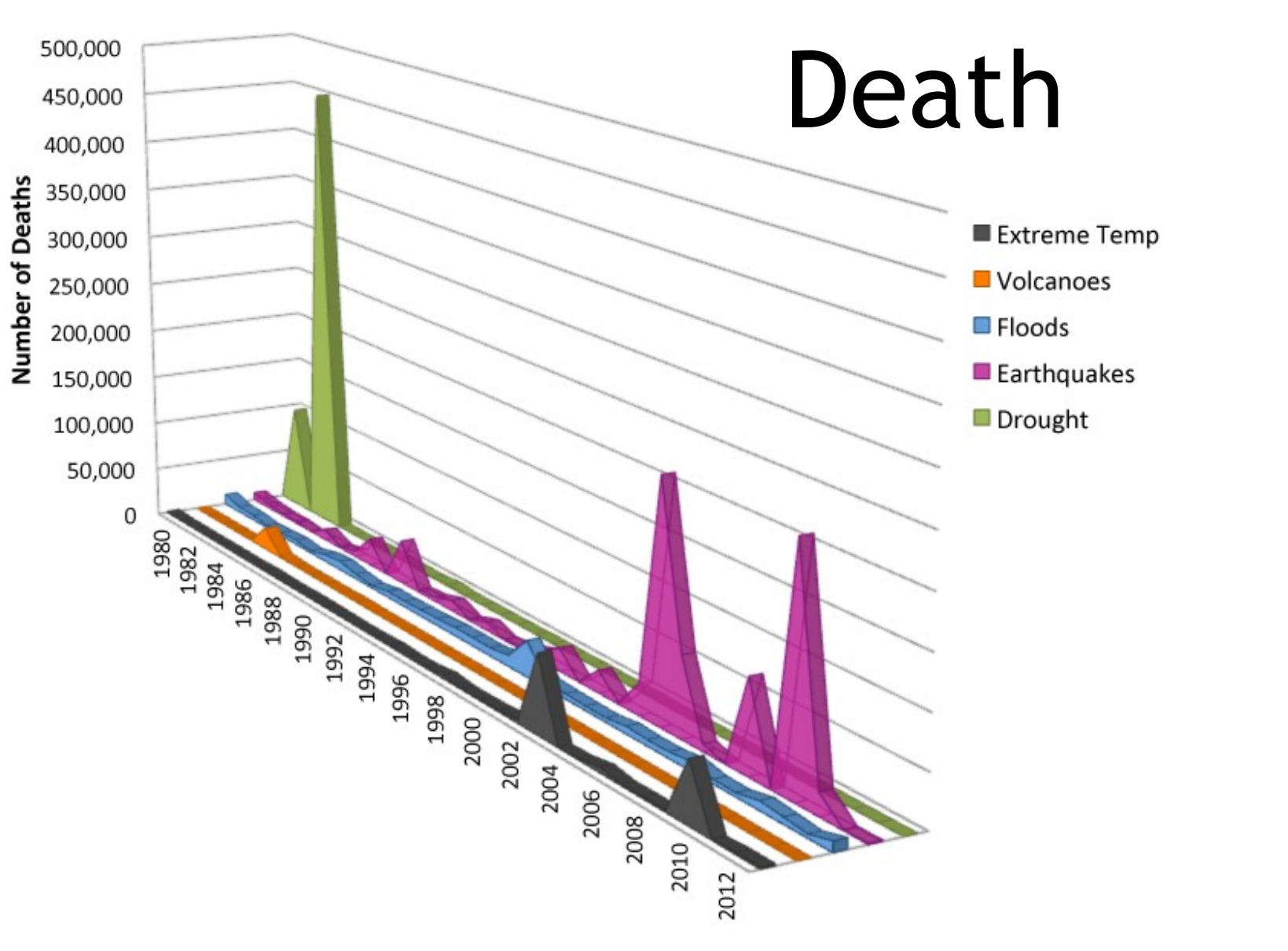
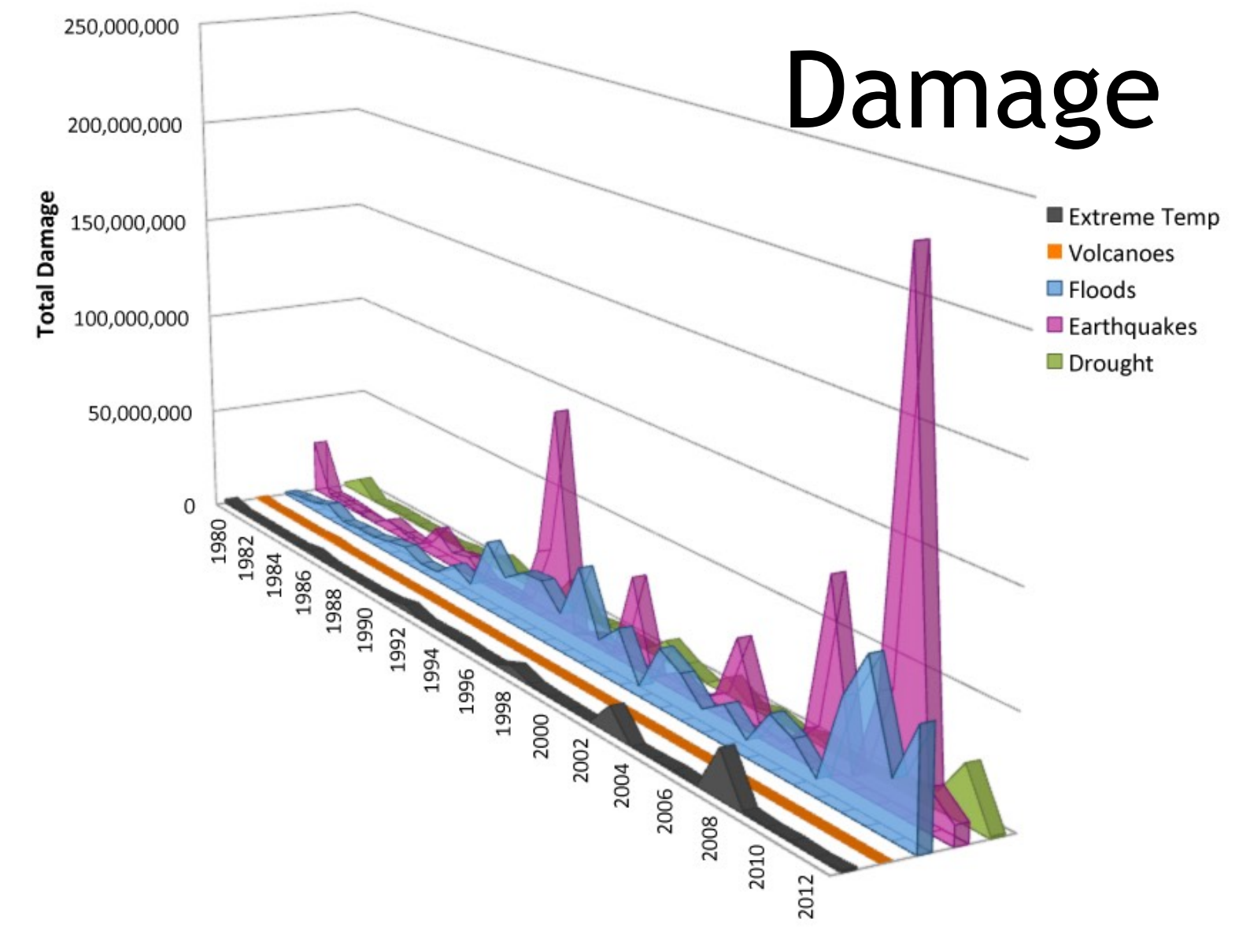
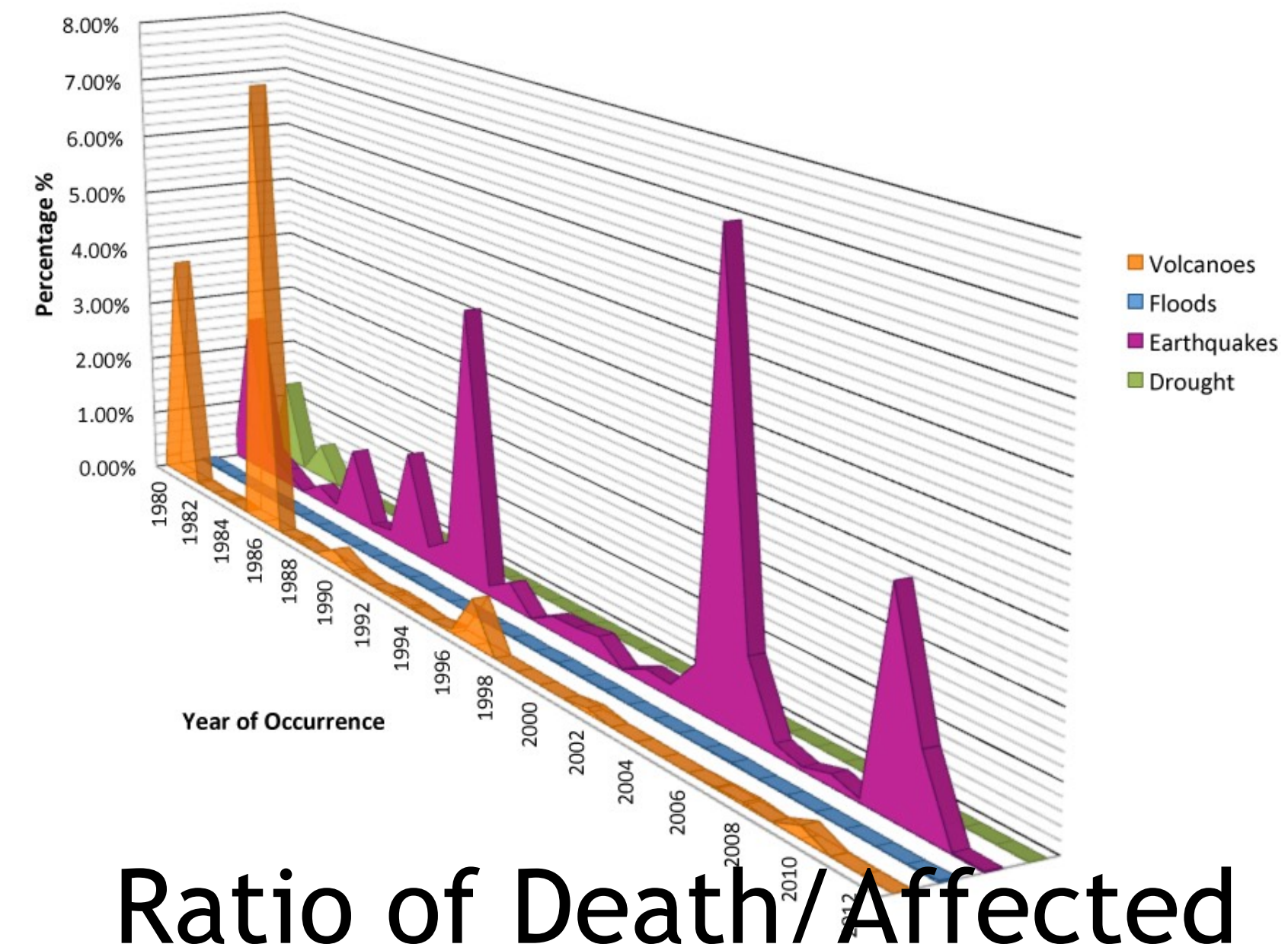
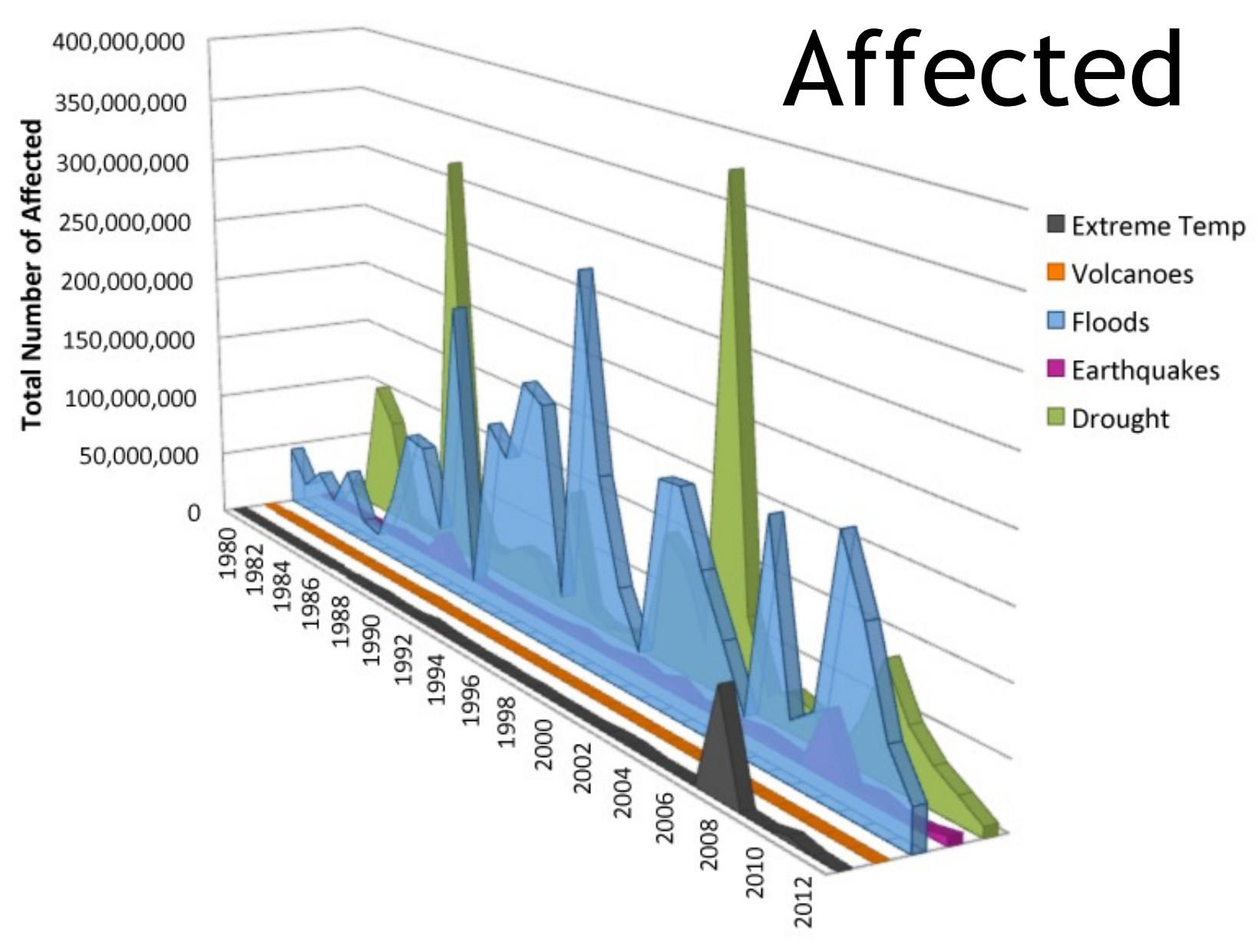
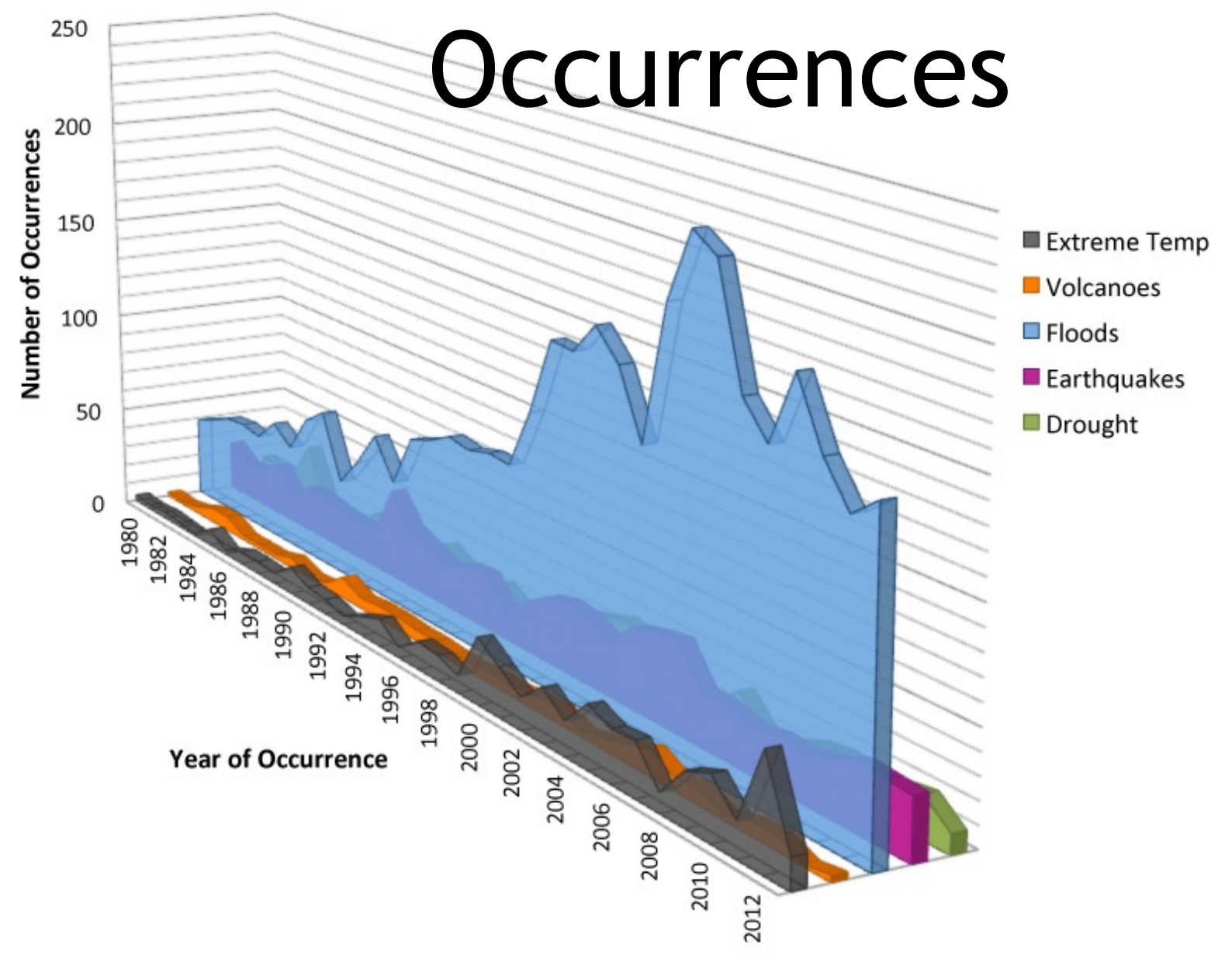
Plag et al., 2015

**Table 4.** Detailed disaster statistics for the period 1980 to 2008. Data from <http://www.preventionweb.net/english/professional/statistics/>. The database is the OFDA/CRED International Disaster Database, maintained by University Catholique de Louvain, Brussels, Belgium. Data version: v11.08. Damage is in million US \$. Hazards are ordered according to fatalities. *R* is the ratio of fatalities to the affected population in percent. See Table 3 for a caveat on the accuracy of the numbers.



**Fig. 9** Comparison of the energy and frequency of large volcanic eruptions and impacting asteroids. The impactor curve is based on estimates of the rate of cratering of Earth's surface over the recent past (Hughes 2000). The volcanic eruption curves are based on the upper and lower estimates of eruption frequencies of 22 events/Ma (high) and 1.4 events/Ma (low). For event energies of up to about  $10^{21}$ – $10^{22}$  J (a frequency of  $\sim 10$  events/Ma) volcanic eruptions are more frequent than asteroid collisions of equivalent energy

# Comparison



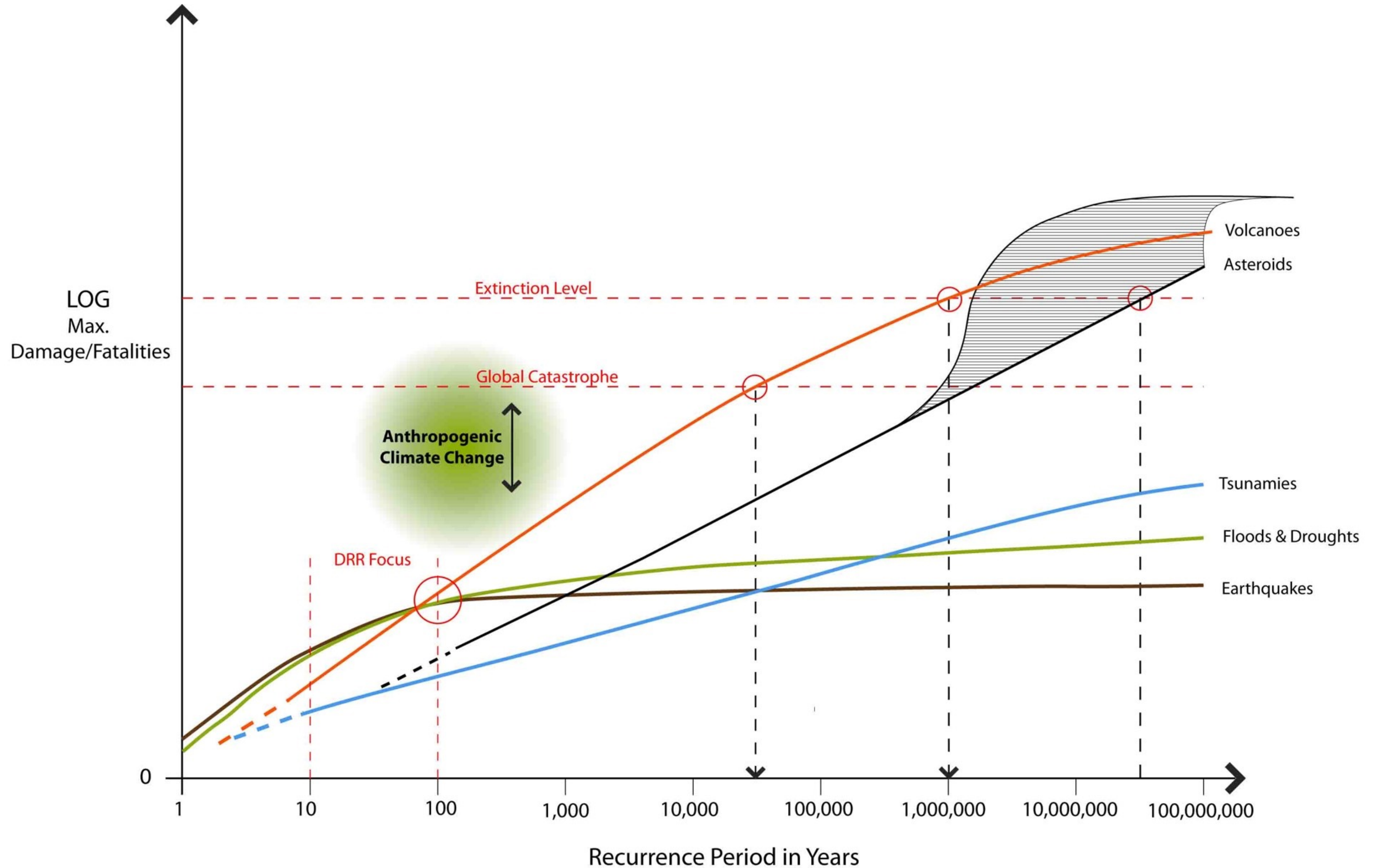
# Ratio of Death/Affected

# International Disaster Database

<http://www.emdat.be/advanced search/>

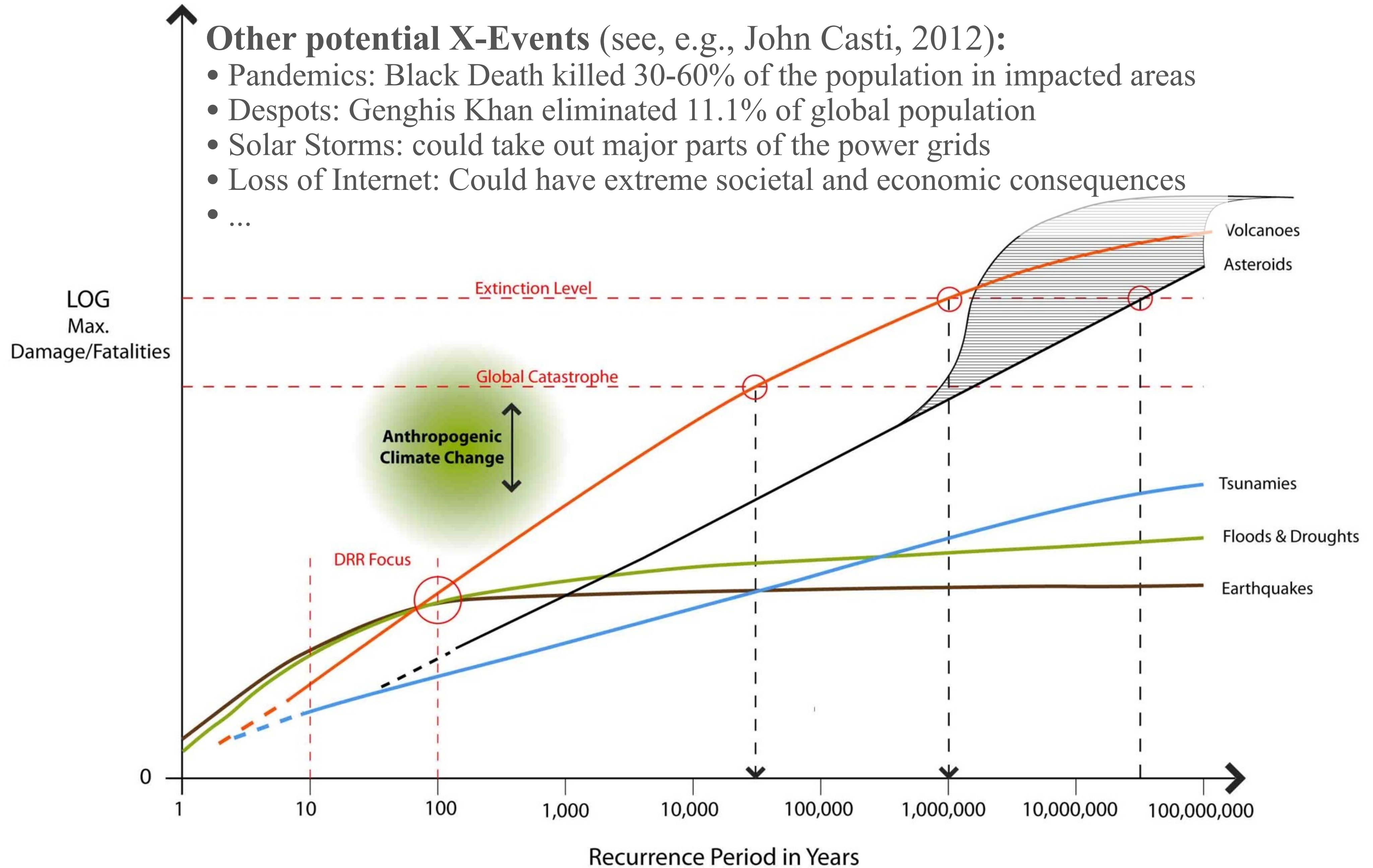


# Comparison



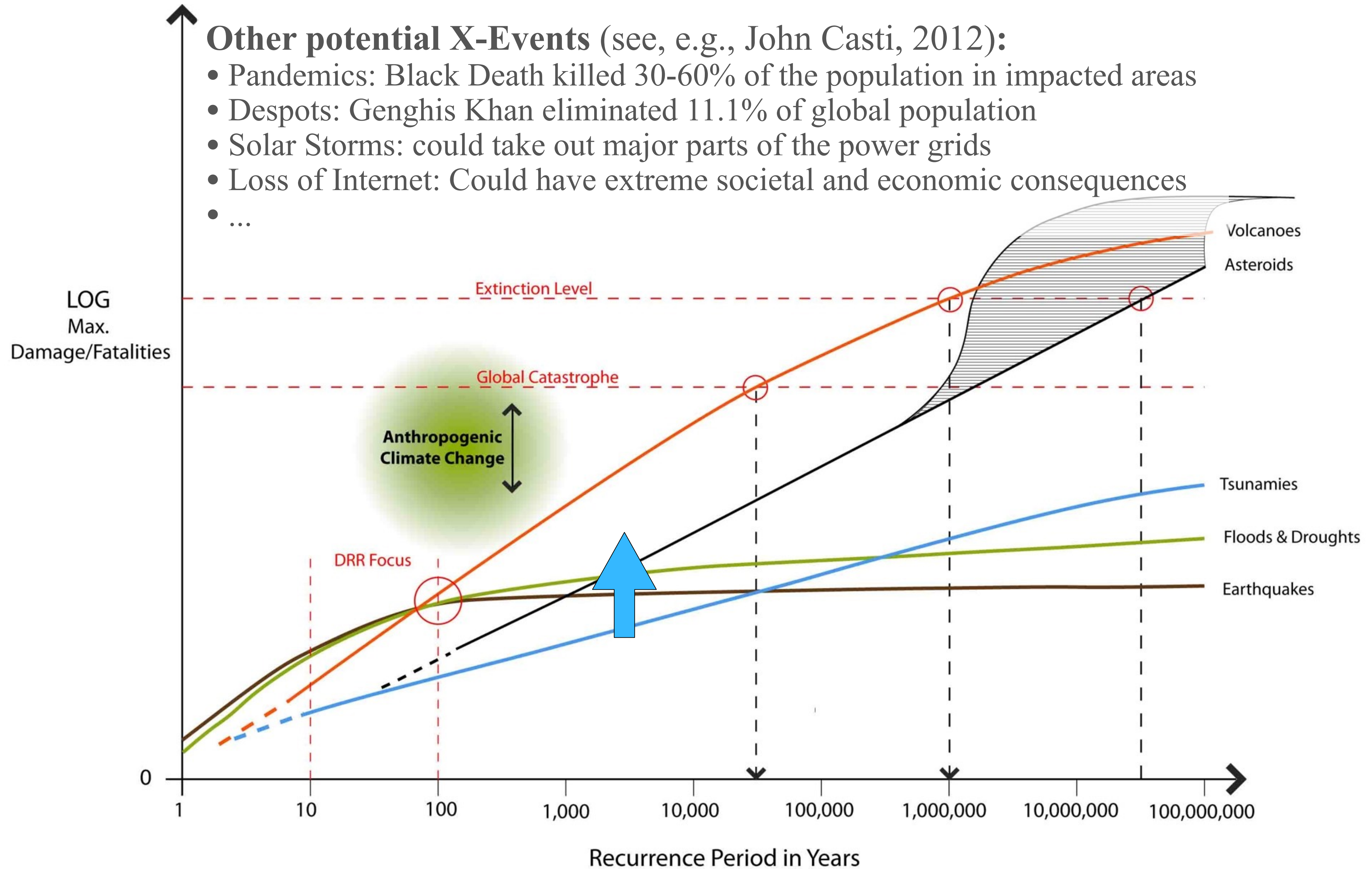
## Other potential X-Events (see, e.g., John Casti, 2012):

- Pandemics: Black Death killed 30-60% of the population in impacted areas
- Despots: Genghis Khan eliminated 11.1% of global population
- Solar Storms: could take out major parts of the power grids
- Loss of Internet: Could have extreme societal and economic consequences
- ...



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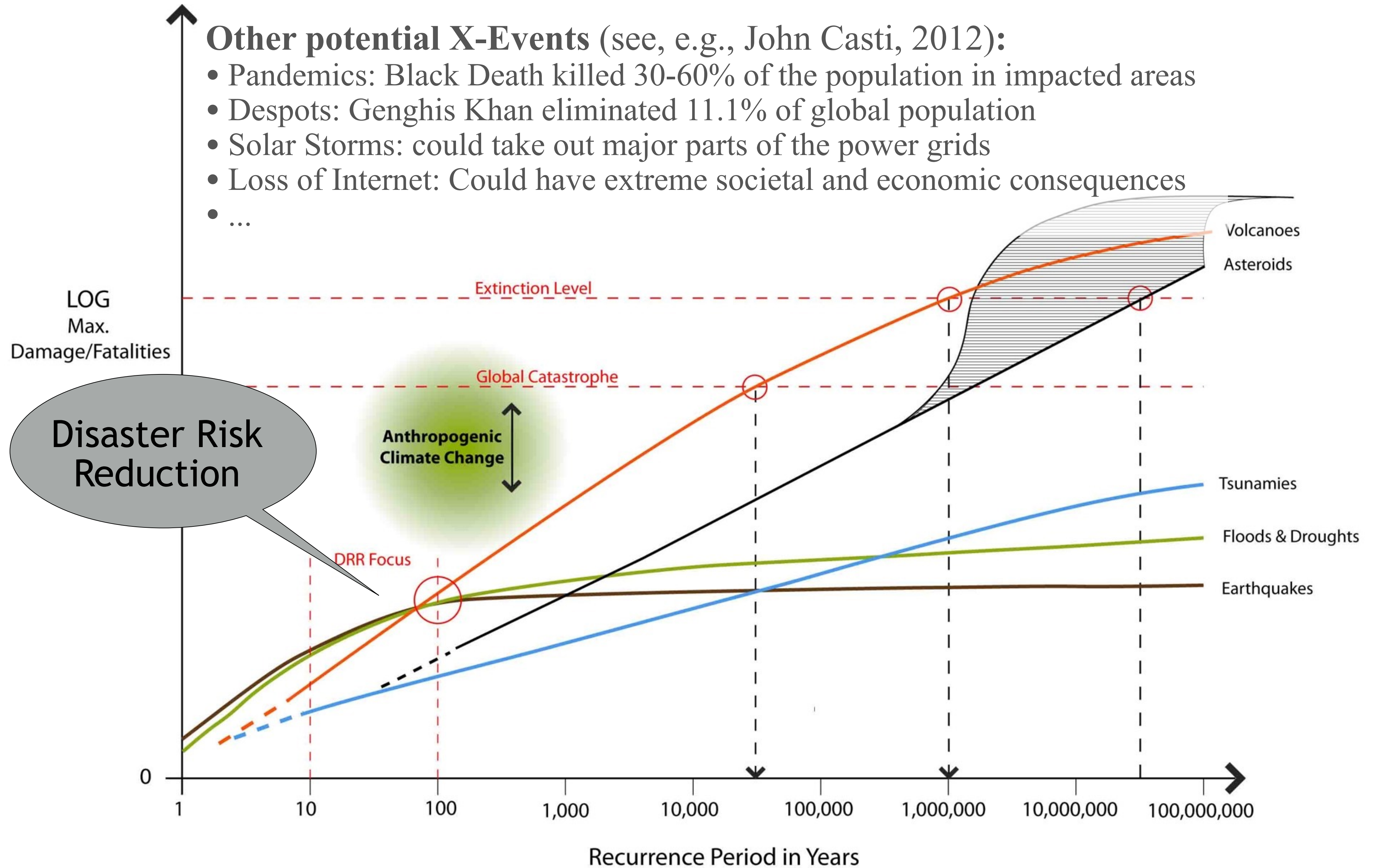
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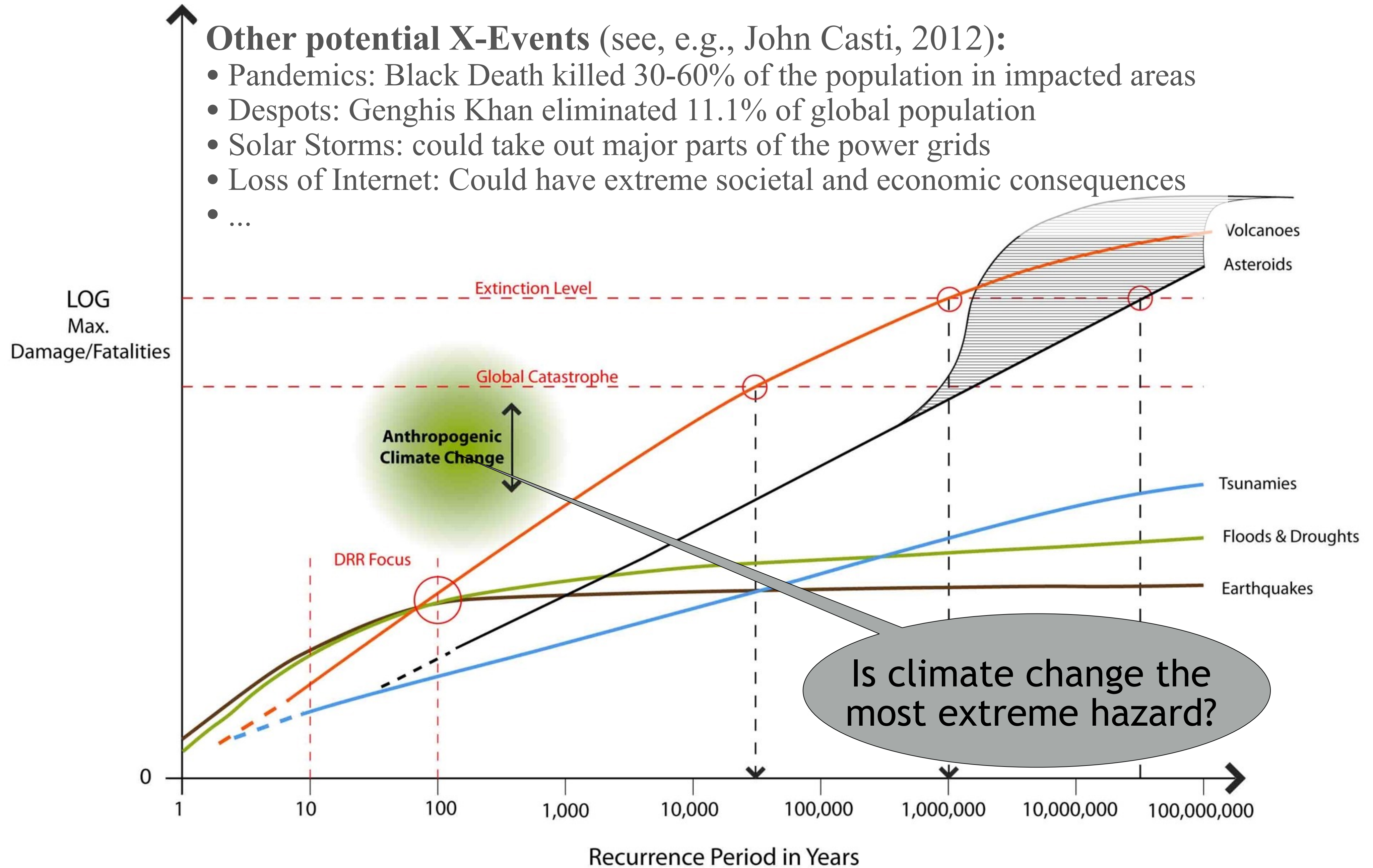
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Disaster Risk Reduction

## Other potential X-Events (see, e.g., John Casti, 2012):

- Pandemics: Black Death killed 30-60% of the population in impacted areas
- Despots: Genghis Khan eliminated 11.1% of global population
- Solar Storms: could take out major parts of the power grids
- Loss of Internet: Could have extreme societal and economic consequences
- ...



# Natural Hazards and Disaster

## Class 6: Volcanoes

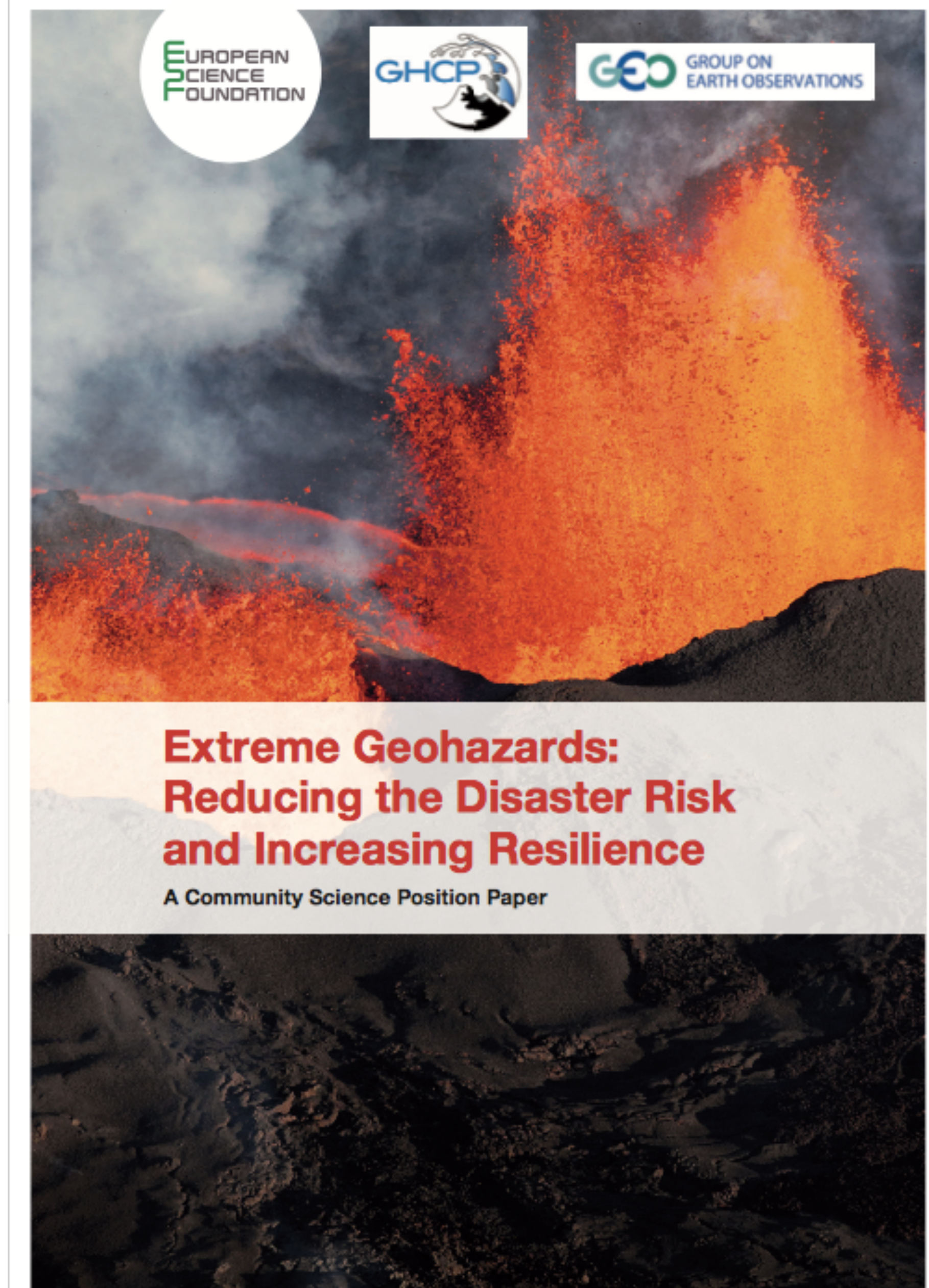
- News
- Size of Volcanic Eruptions
- Location
- Types
- Volcanic Gases
- Volcanic Eruptions - Examples
- Large Eruptions
- Impacts of Eruptions
- Comparison to other Hazards
- Mitigation and Preparedness

# Mitigation and Preparedness

Mitigation - the effort to reduce the consequences of disasters

- Structural (e.g. levees to hold back lahars)
- Management (e.g. evacuation)
- Reducing vulnerabilities and increasing preparedness

What information do we need for risk management?



Recurrence interval,  $T_R$  - avg. time between eruptions

- can be on geological time frame
- or on human time frame

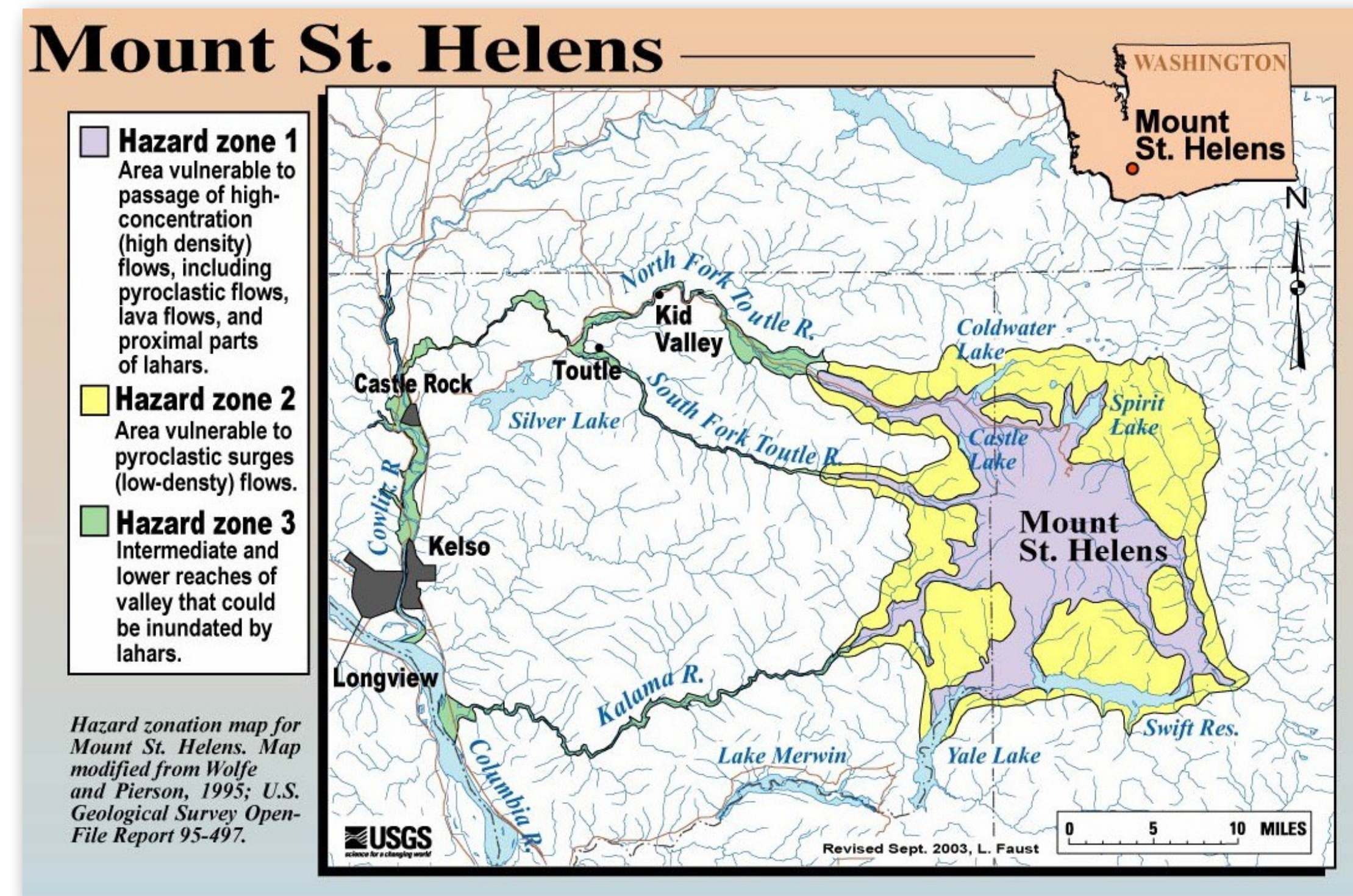
$$T_R = N/n$$

units of  $T_R$  can be in years,  
thousands of years, millions  
of years

$N$  is number of years (or  
thousands, or millions of  
years) in the record

$n$  is number of events

Hazard map - past distribution of ash, lava, pumice, lahars, etc.



- important to study prevailing winds (for ash flows) and topography (for lahars)

## Population density in region of hazard



## Cost

### preparedness:

- risk assessment
- construction of barriers (local)
- food security (regional and global)
- relocation (local to regional)

### before and during eruption:

- early warning
- evacuation
- rescue
- damage assessments

### After eruption:

- clean-up
- restoring
- relocation
- risk assessment





## Risk assessment

What information do we need?

1. Probability,  $P$ , of recurrence

$$P = 1/T_R$$

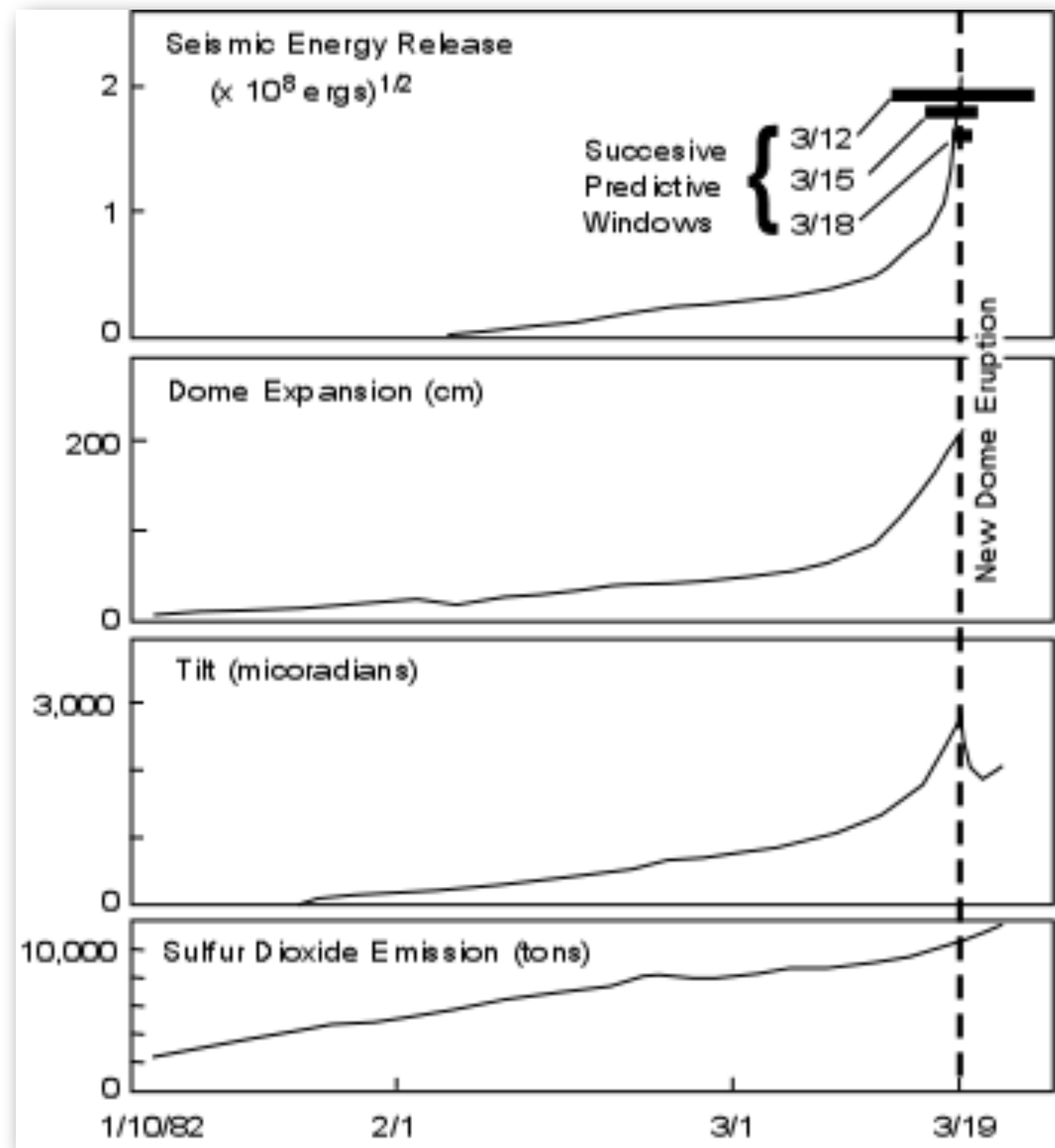
units of  $P$ , like  $T_R$ , can be in  
years, thousands of years,  
millions of years

$T_R$  = Recurrence interval (volcanic  
eruption frequency)

2. Hazard Map

3. Predictors - Early warning signals

## Early warning signals include:



Increase in local earthquake activity

Change of shape of volcano

Increase in gas emission and/or change in composition of gases

<http://www.tulane.edu/~sanelson/images/rruptprecurs.gif>

data from 1982 Mt St Helens eruption