Co-sponsored by
The Department of Ocean, Earth & Atmospheric Sciences
Mitigation and Adaptation Research Institute

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

Free & Open to the Public

IEPA INSTITUTE FOR ETHICS AND PUBLIC AFFAIRS

OLD DOMINION UNIVERSITY

philosophy@odu.edu

Natural Hazards and Disaster

Continued from:

Class 5: Disasters Triggered by Earthquakes and Tsunamis

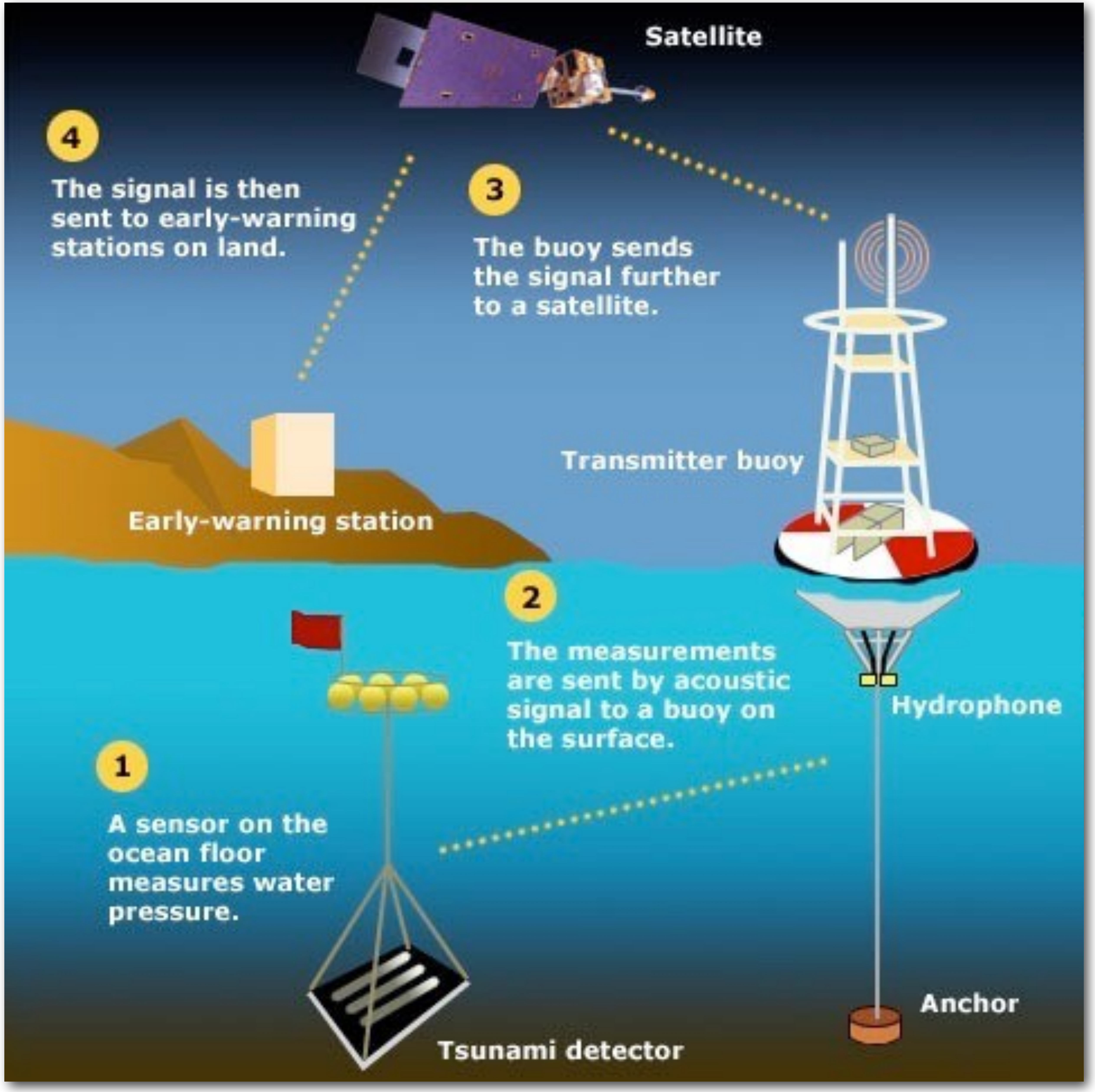
- Waves
- Tsunamis
- Earthquake Tsunamis
- Landslide Tsunamis
- Tsunami Detection, Prediction and Awareness

“Harbor Wave”

津波

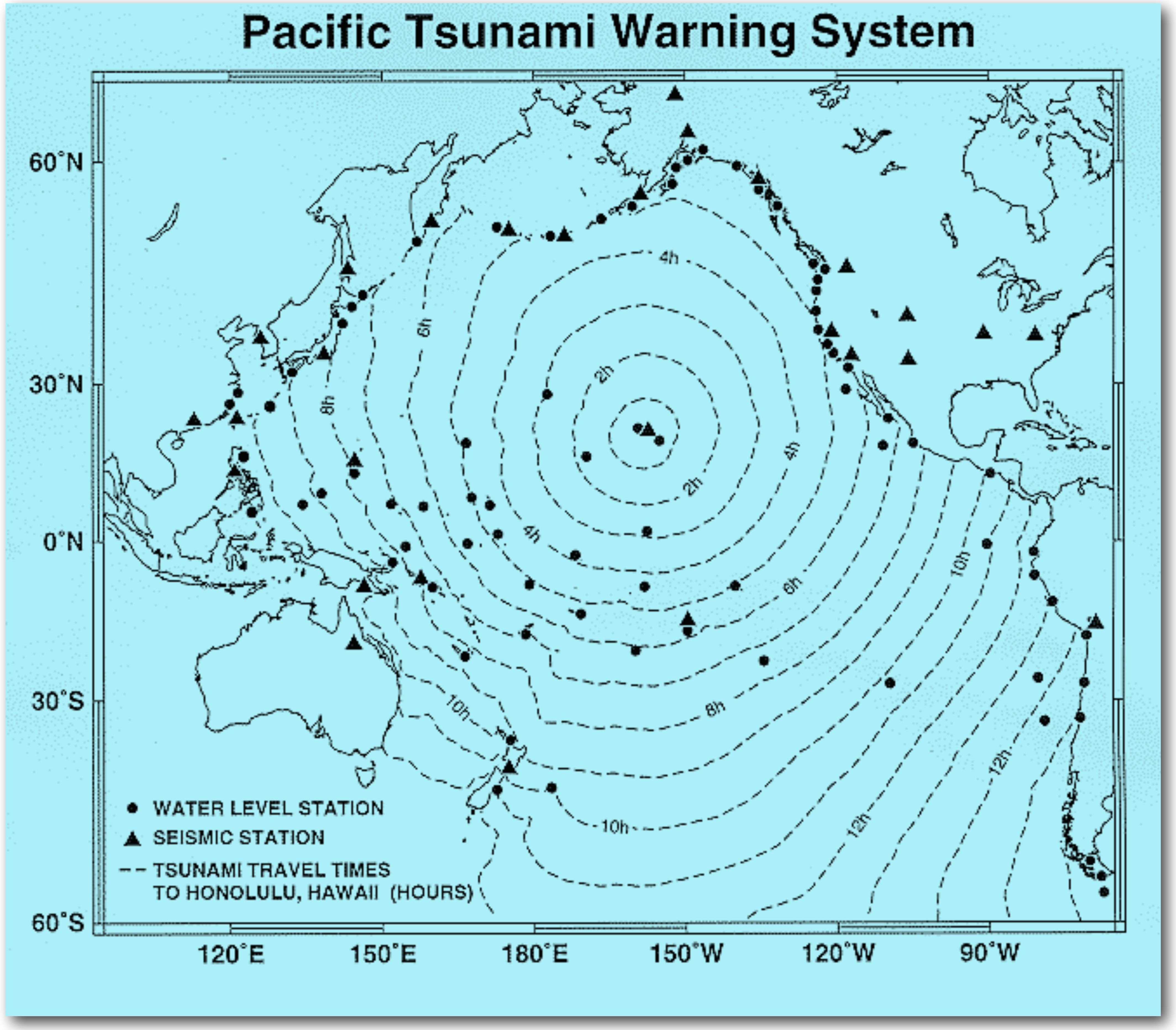
Katsushika Hokusai (1760–1849)

Tsunami Detection



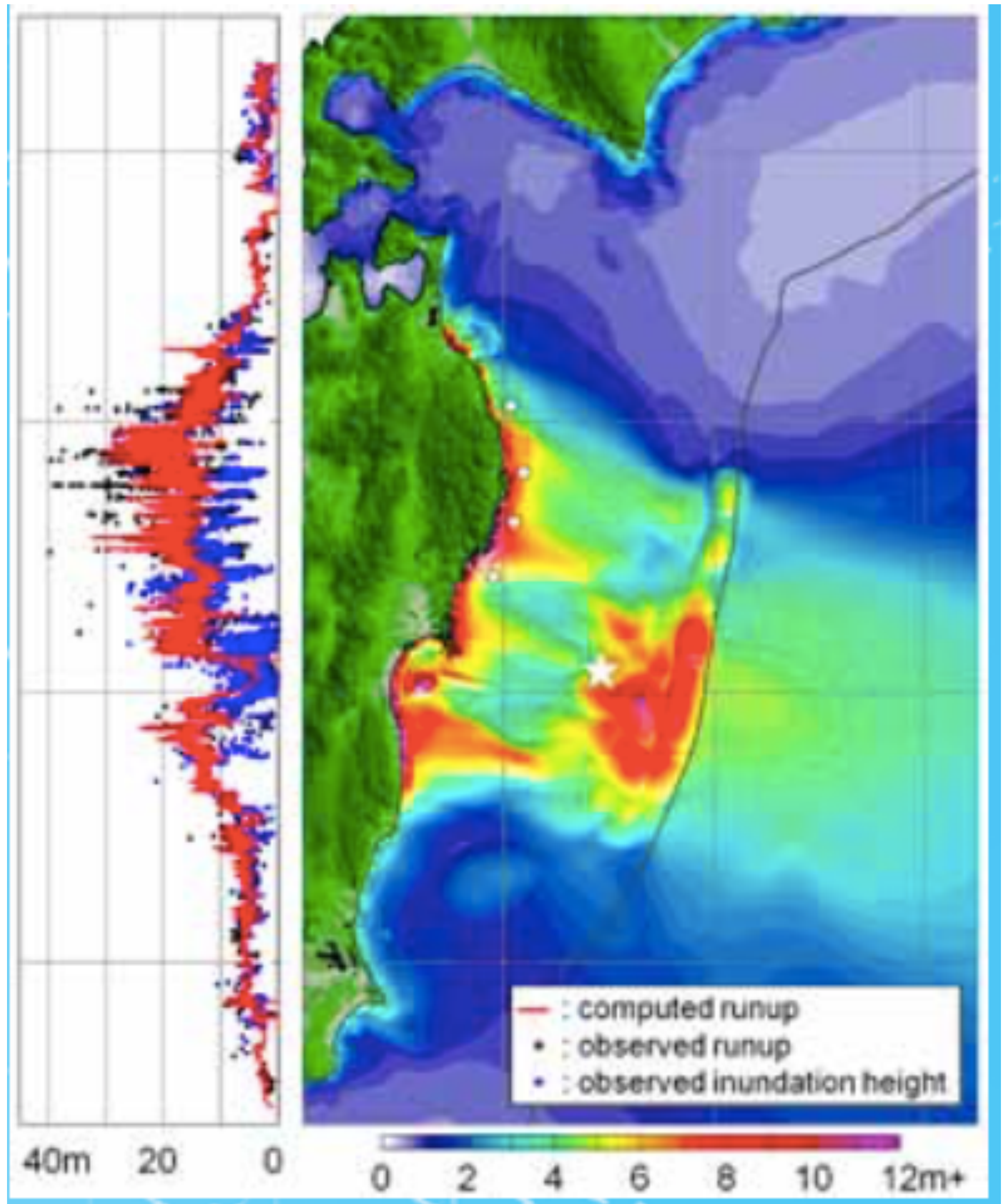
http://www.civildefence.govt.nz/memwebsite07.nsf/Files/Photo_library_tsunami/$file/tsunami-warning-system.jpg

DART - Deep-ocean Assessment and Reporting of Tsunamis

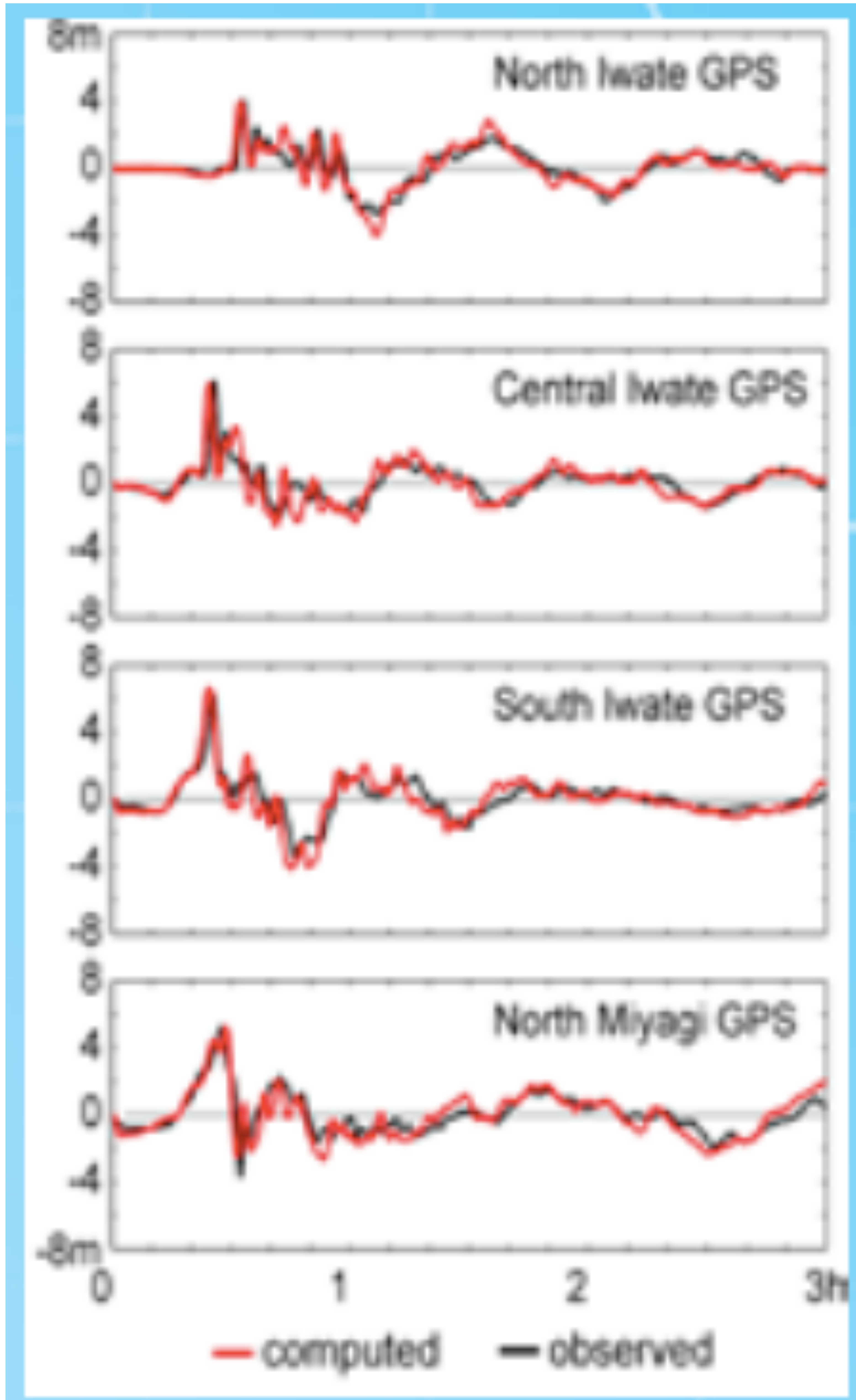


http://www.tulane.edu/~sanelson/geol204/tsunami.htm

Tsunamis Prediction



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.



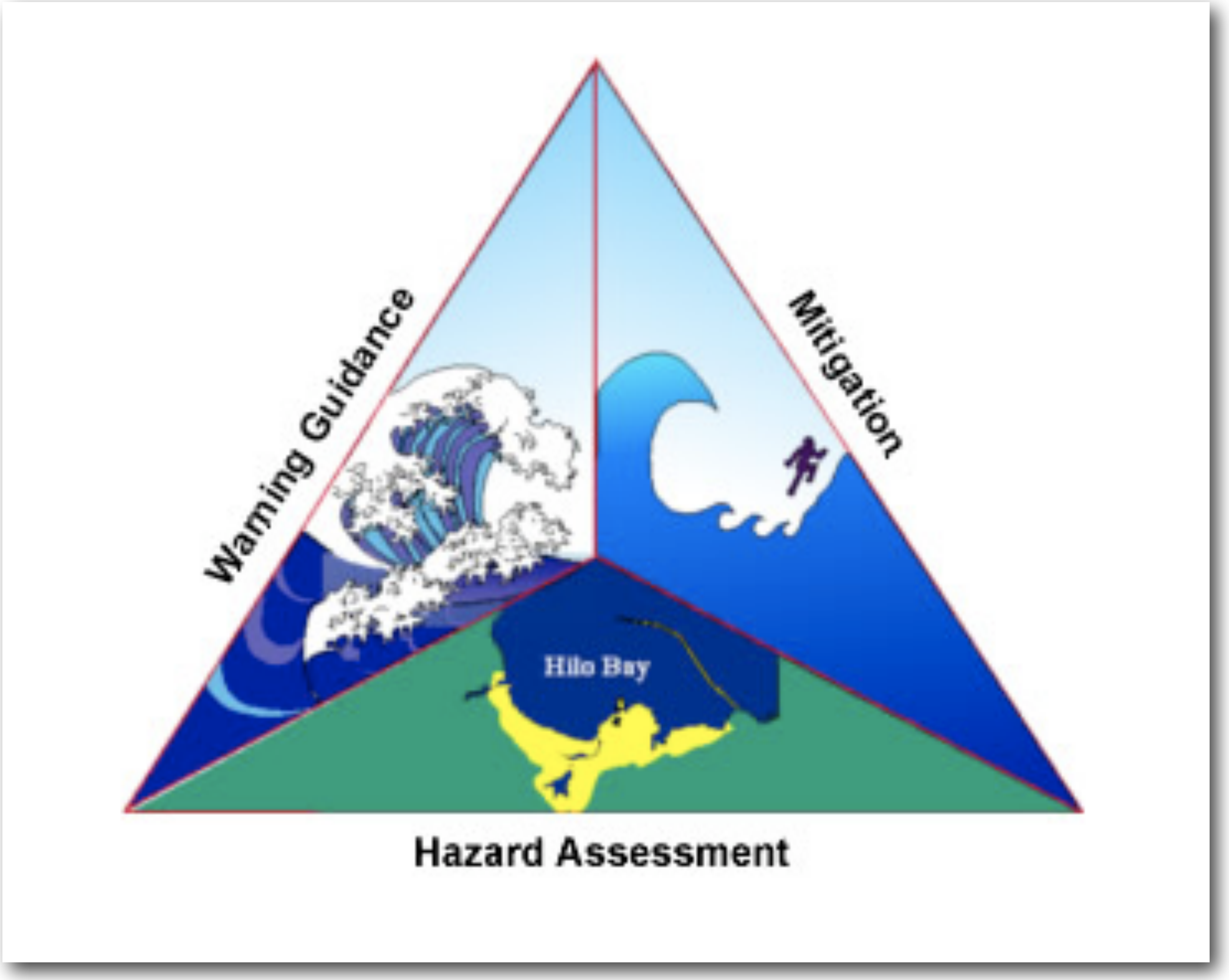
Computed sea surface elevations show excellent agreement with the observed GPS buoy data (Y. Yamazaki and K.F. Cheung, Univ. of Hawaii).

http://unesdoc.unesco.org/images/0014/001486/148609e.pdf

Tsunami Awareness

http://www.new-zealand-pictures.co.nz/data/media/20/tsunami-warning-sign_1549.jpg

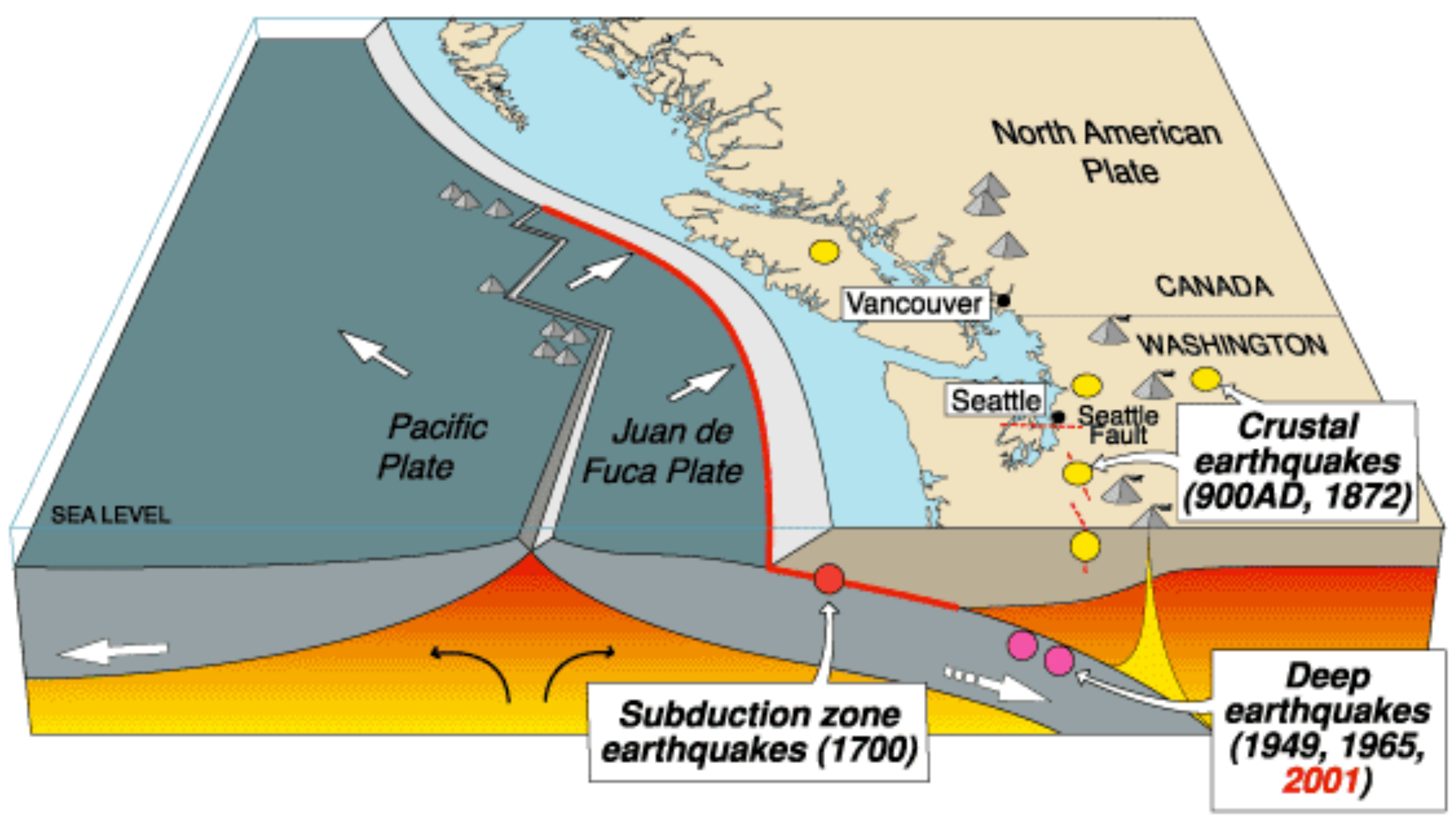
http://www.hobotraveler.com/208-asia/207-039-tsunami-warning-route-thailand.jpg



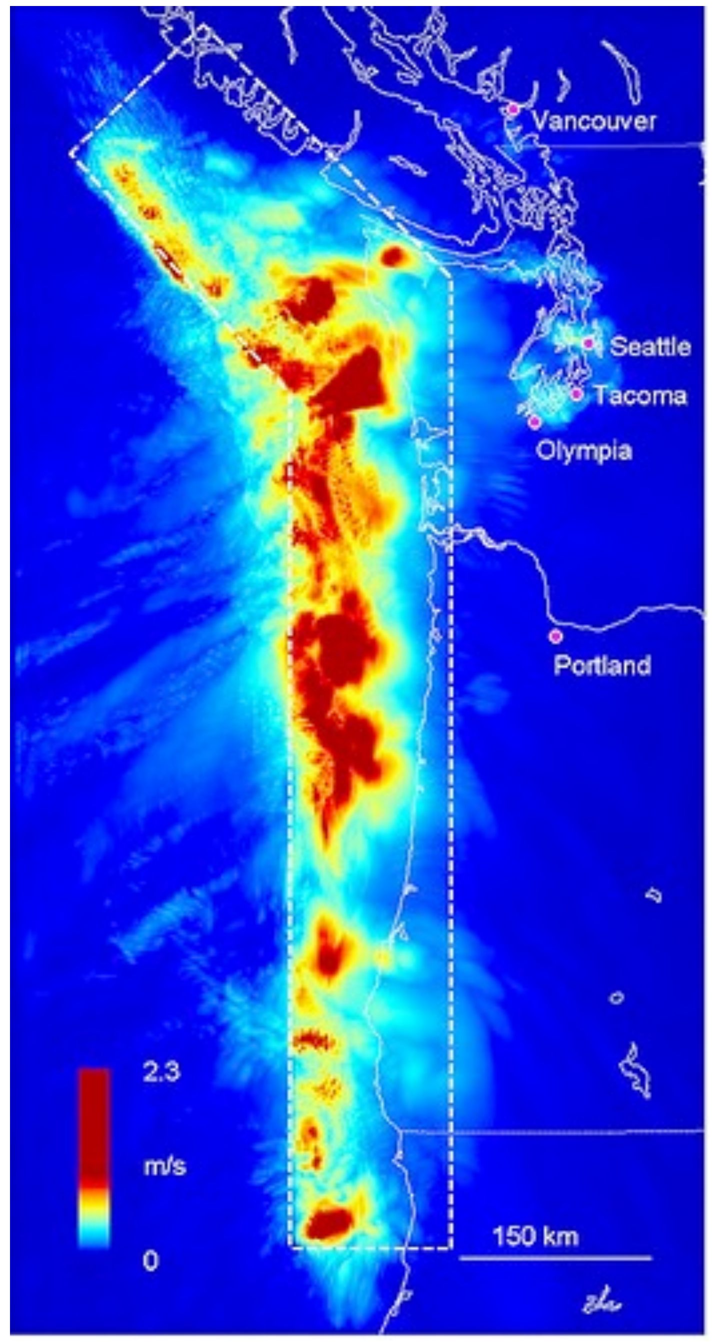
http://www.tsunami.noaa.gov/

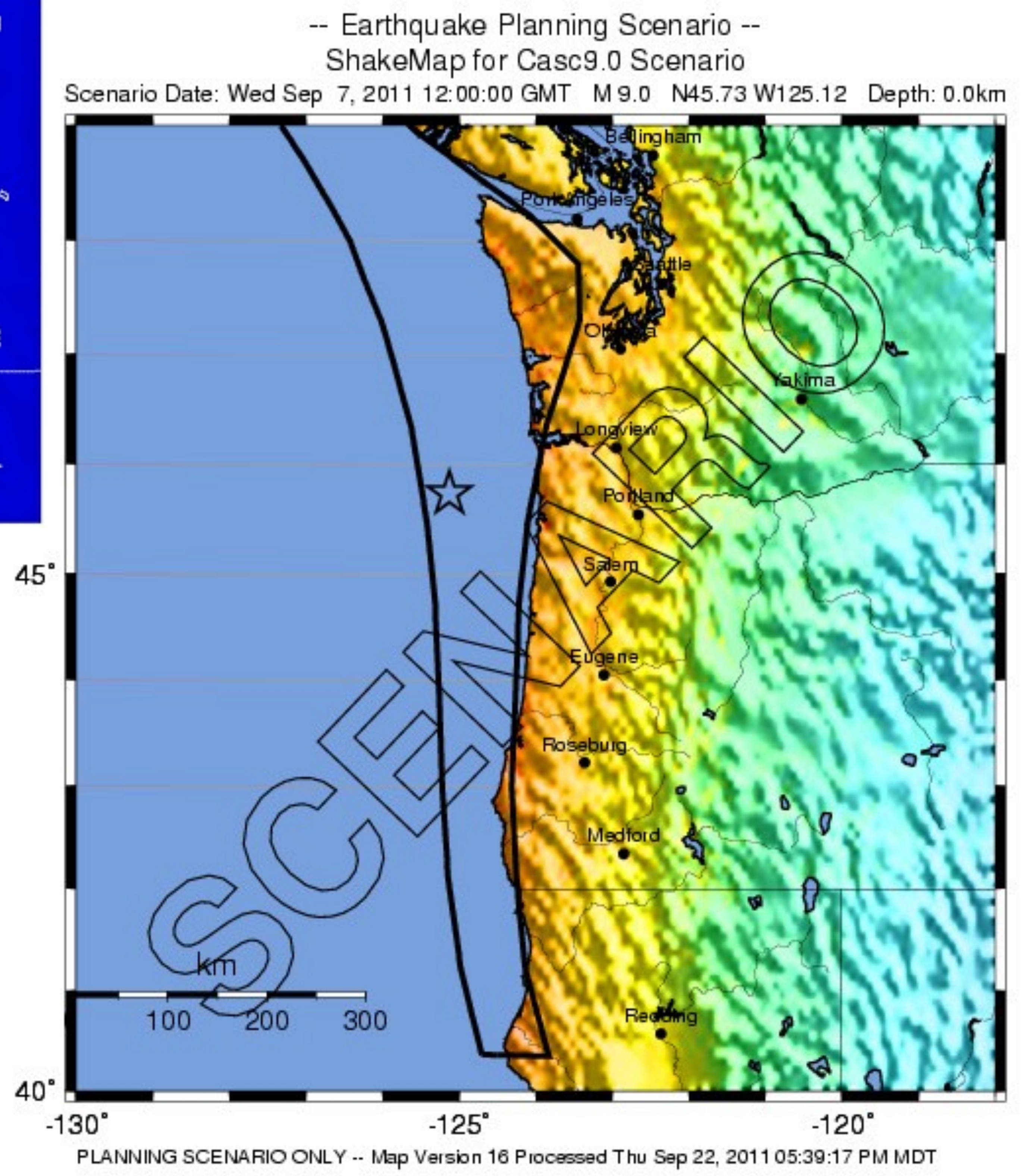
Tsunami Awareness

Cascadia earthquake sources



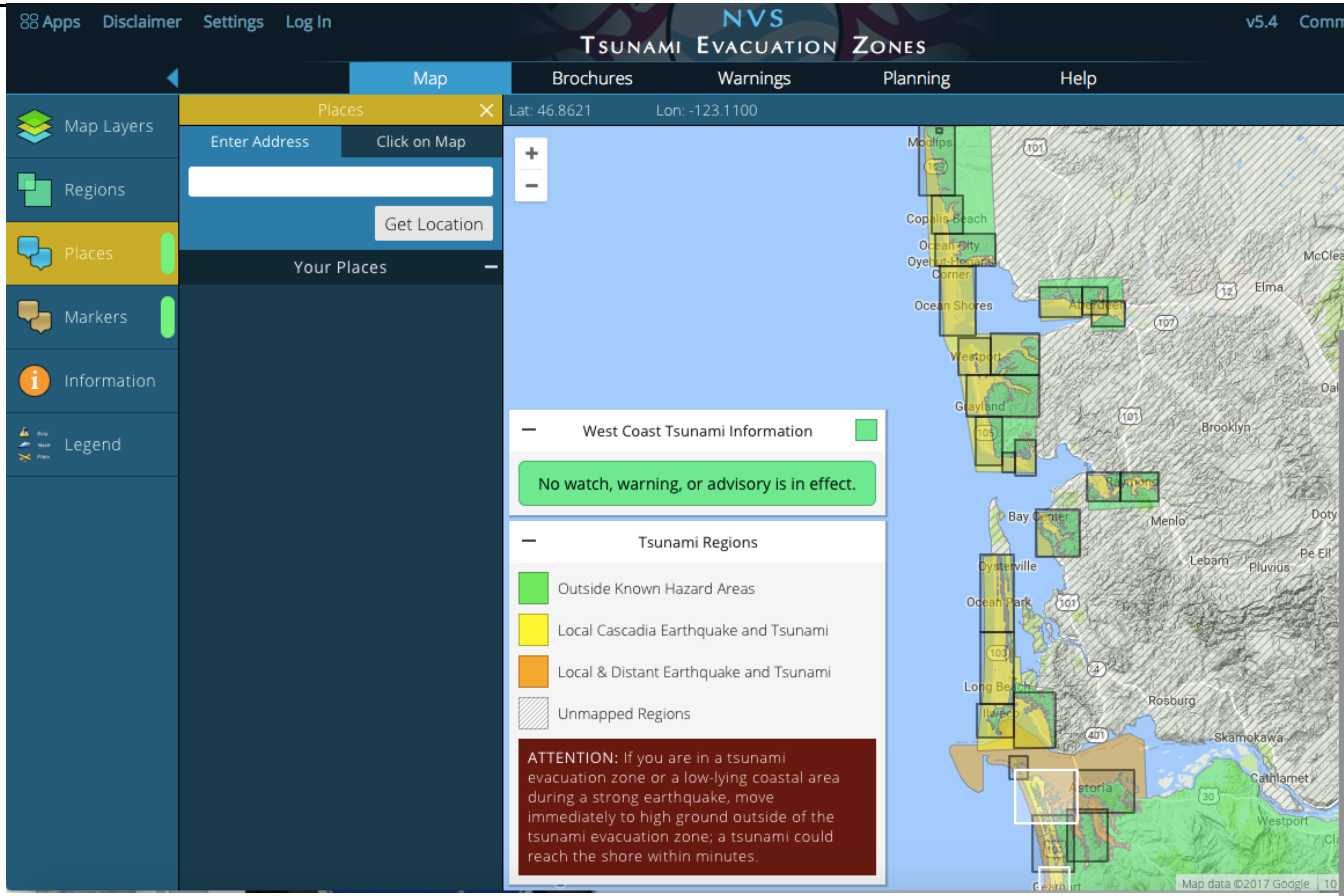
Source	Affected area	Max. Size	Recurrence
Subduction Zone	W.WA, OR, CA	M 9	500-600 yr
Deep Juan de Fuca plate	W.WA, OR,	M 7+	30-50 yr
Crustal faults	WA, OR, CA	M 7+	Hundreds of yr?



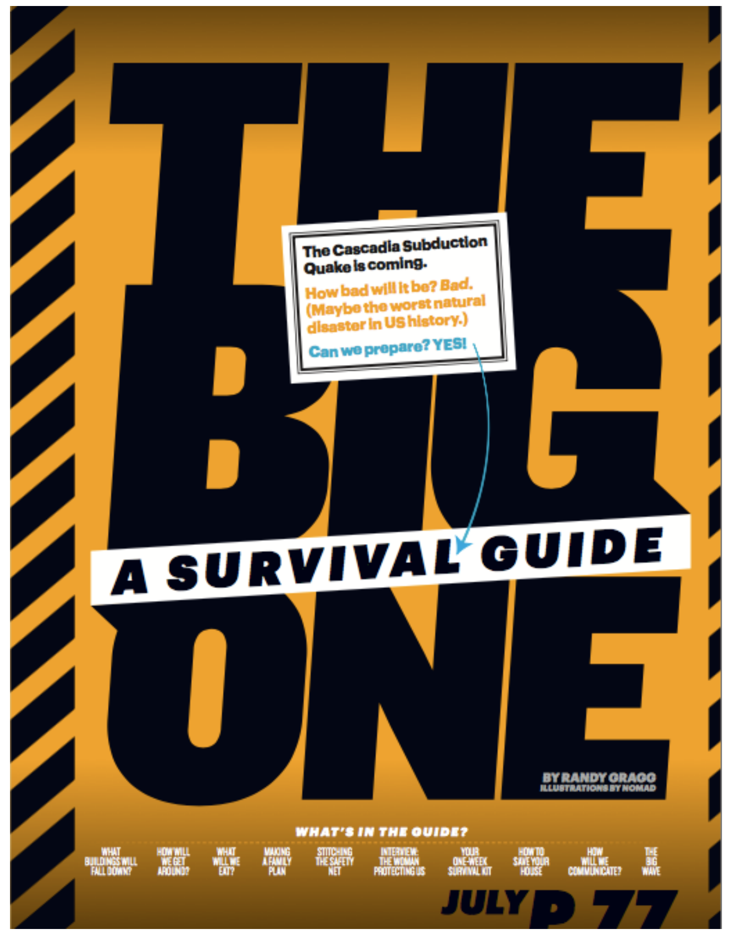


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16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

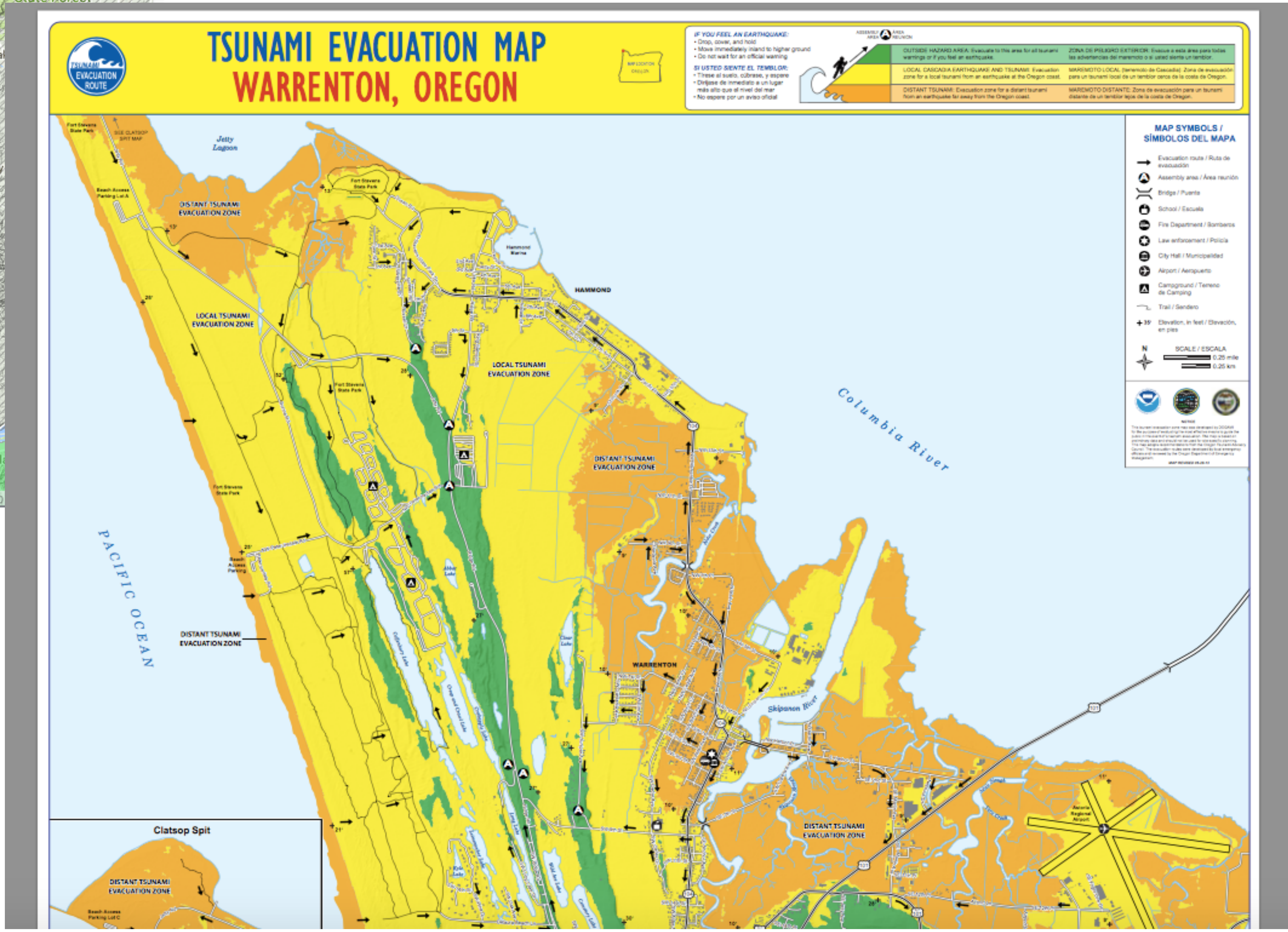
Tsunami Awareness



http://nvs.nanoos.org/TsunamiEvac



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



http://www.oregongeology.org/pubs/tsubrochures/WarrentonEvacBrochure-5-29-13_onscreen.pdf

Natural Hazards and Disaster

Class 6: Volcanoes

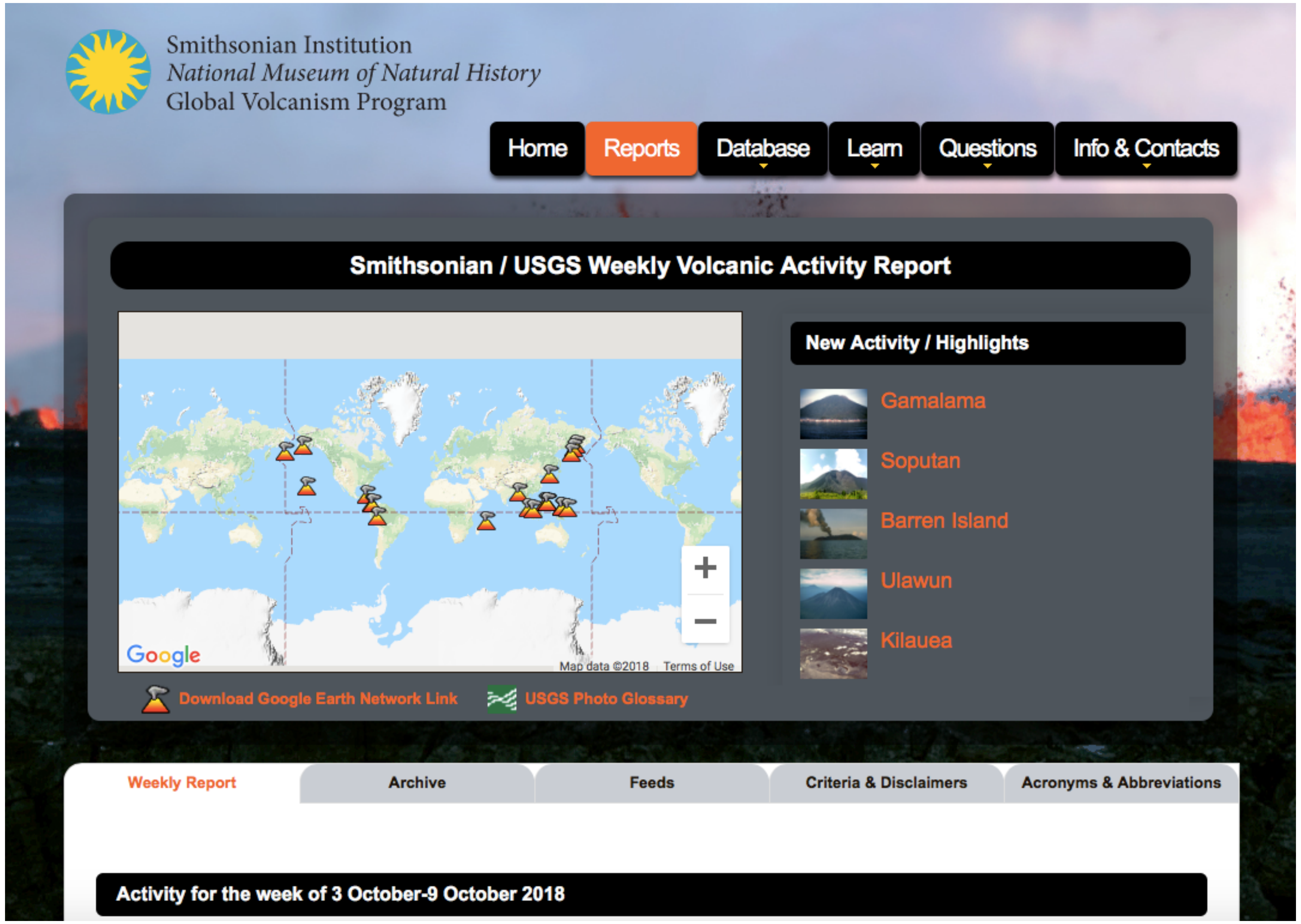
- News
- Size of Volcanic Eruptions
- Location
- Types
- Volcanic Gases
- Volcanic Eruptions - Examples
- Large Eruptions
- Impacts of Eruptions
- Comparison to other Hazards

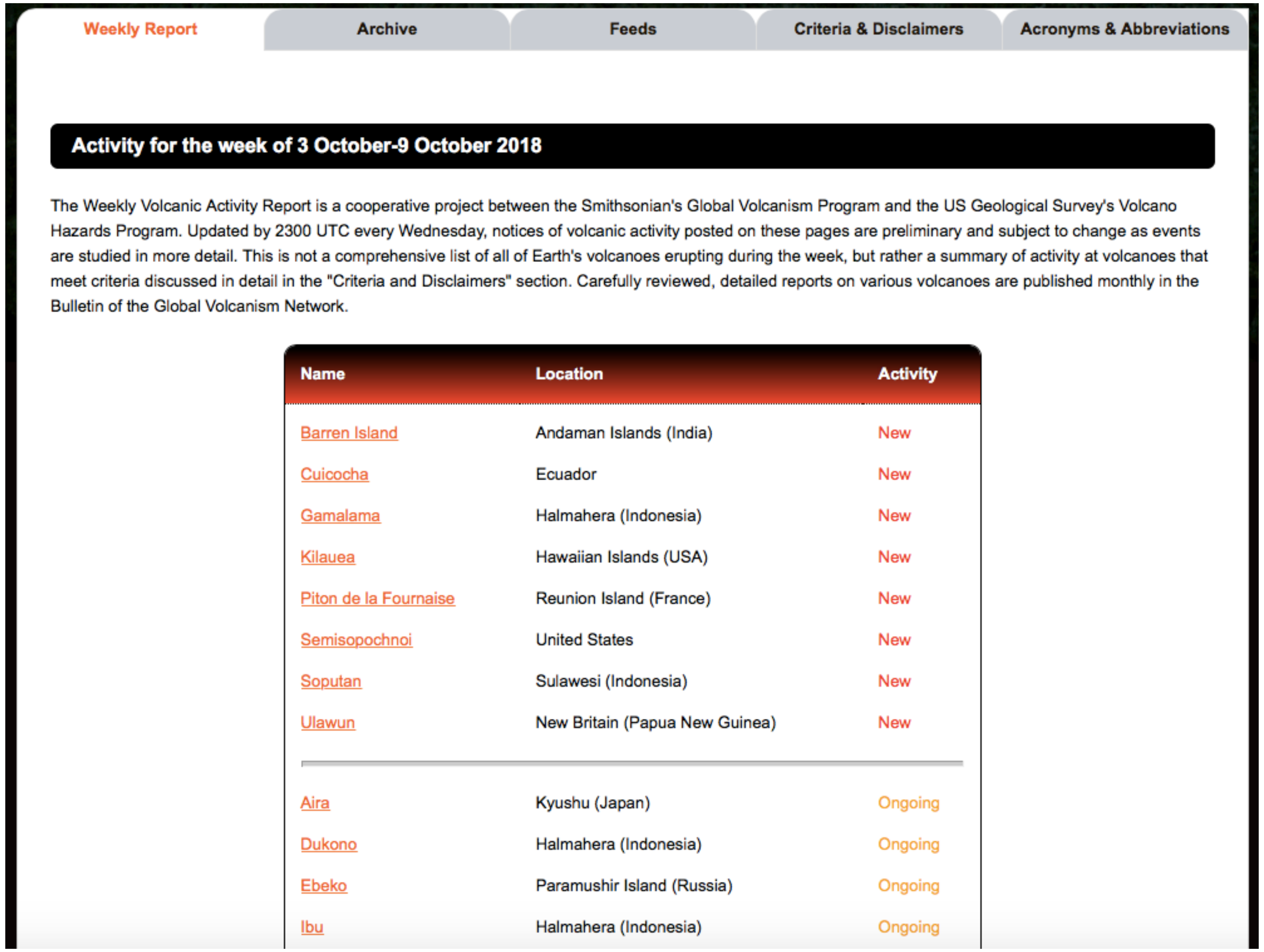
News

https://www.volcanodiscovery.com/erupting_volcanoes.html

News

http://volcano.si.edu/reports_weekly.cfm





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
Barren Island	Andaman Islands (India)	New
Cuicocha	Ecuador	New
Gamalama	Halmahera (Indonesia)	New
Kilauea	Hawaiian Islands (USA)	New
Piton de la Fournaise	Reunion Island (France)	New
Semisopochnoi	United States	New
Soputan	Sulawesi (Indonesia)	New
Ulawun	New Britain (Papua New Guinea)	New
Aira	Kyushu (Japan)	Ongoing
Dukono	Halmahera (Indonesia)	Ongoing
Ebeko	Paramushir Island (Russia)	Ongoing
Ibu	Halmahera (Indonesia)	Ongoing

News

Forbes Billionaires Innovation Leadership Money Consumer Industry Lifestyle Featur

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

Trevor Nace Contributor
Science

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

January 17, 2018

https://www.forbes.com/sites/trevornace/2018/01/22/mount-mayon-volcano-eruption-update-philippines/

News

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

Class 6: Volcanoes

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Size of Volcanic Eruptions

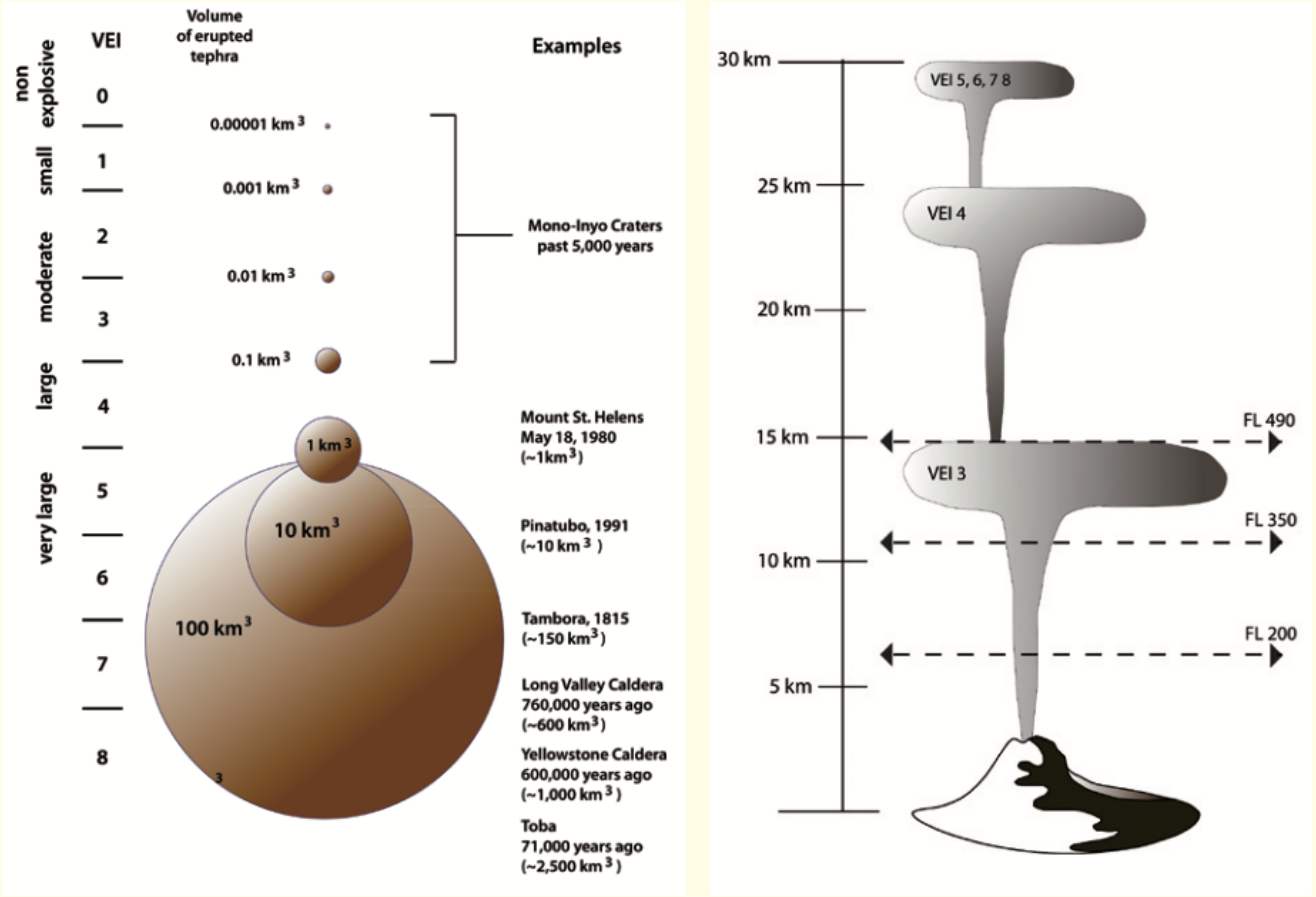
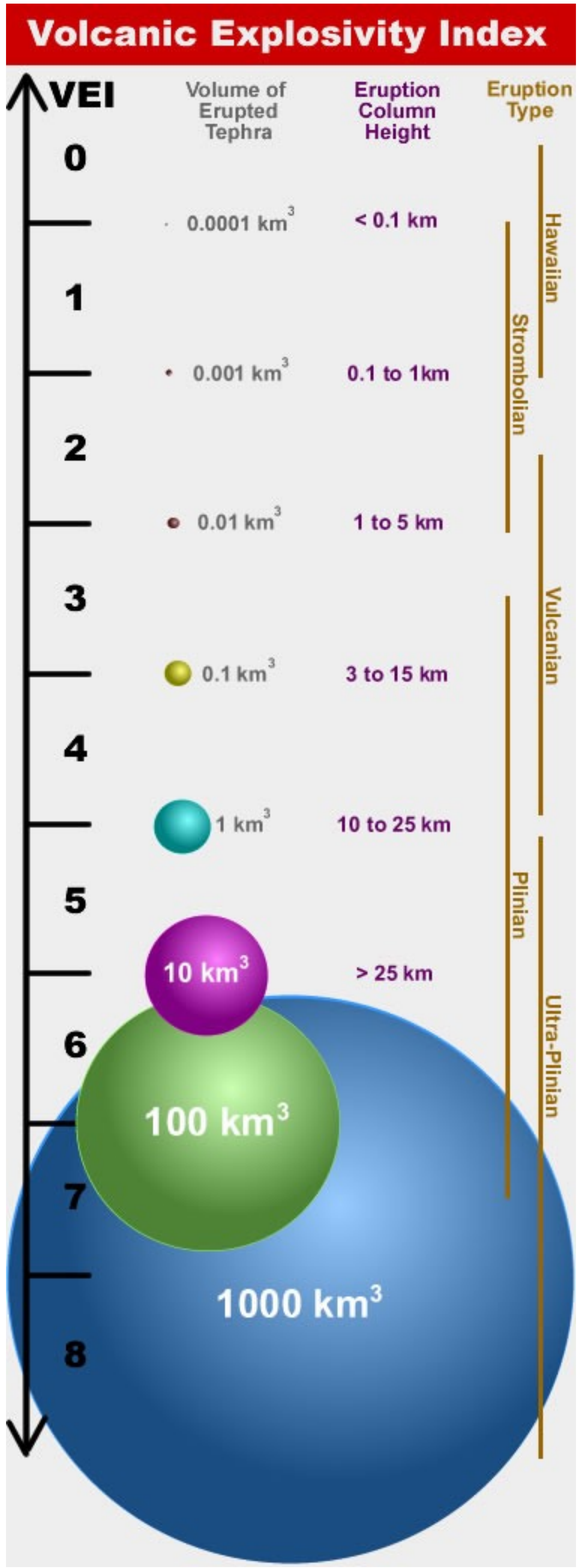
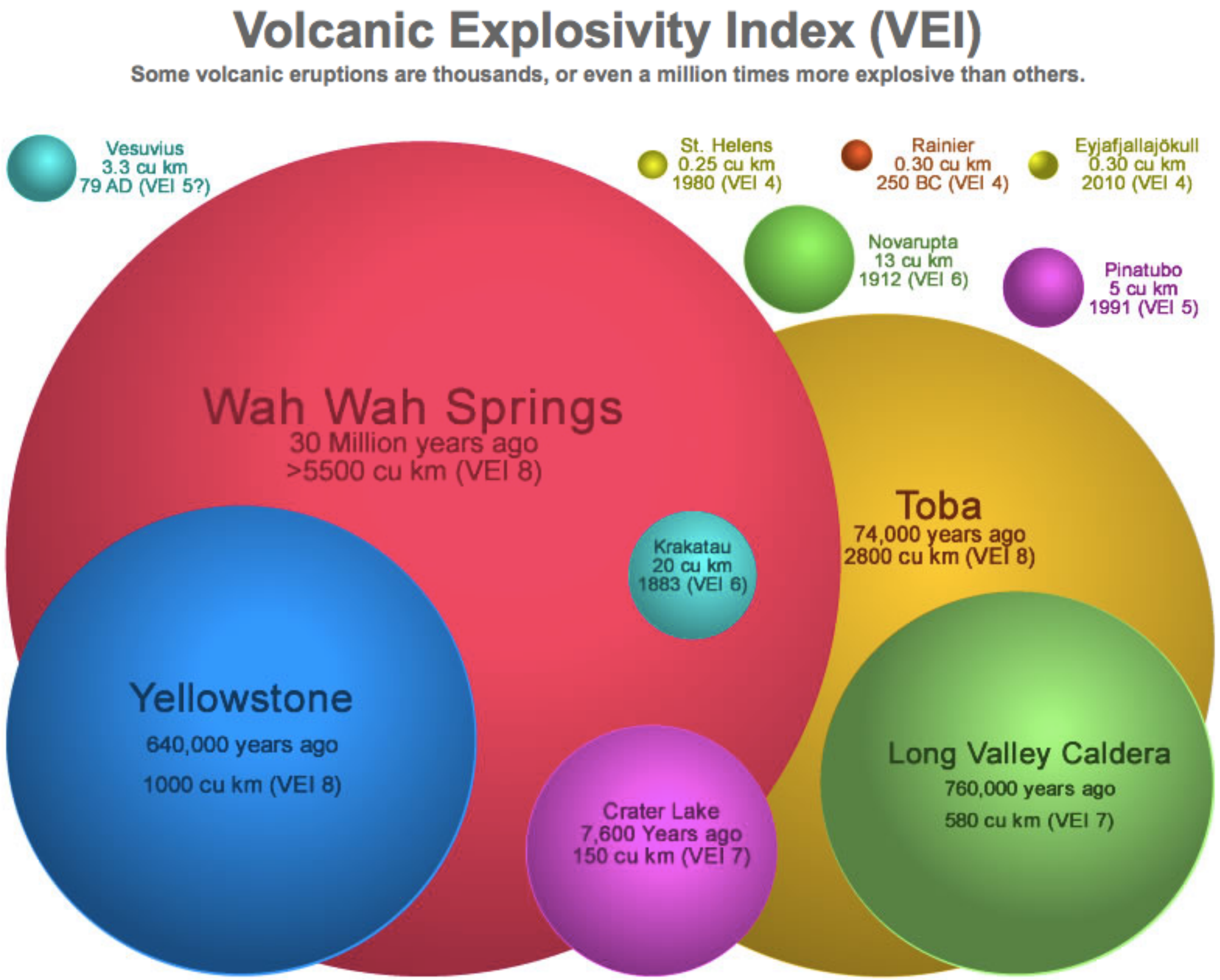


Figure 11. Measures for the magnitude of volcanic eruptions. Several indicators have been proposed to measure the severity of volcanic eruptions. The Volcanic Explosivity Index (VEI) introduced by Newhall & Self (1982) is a semi-logarithmic scale that uses a combination of the volume of the erupted tephra (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.

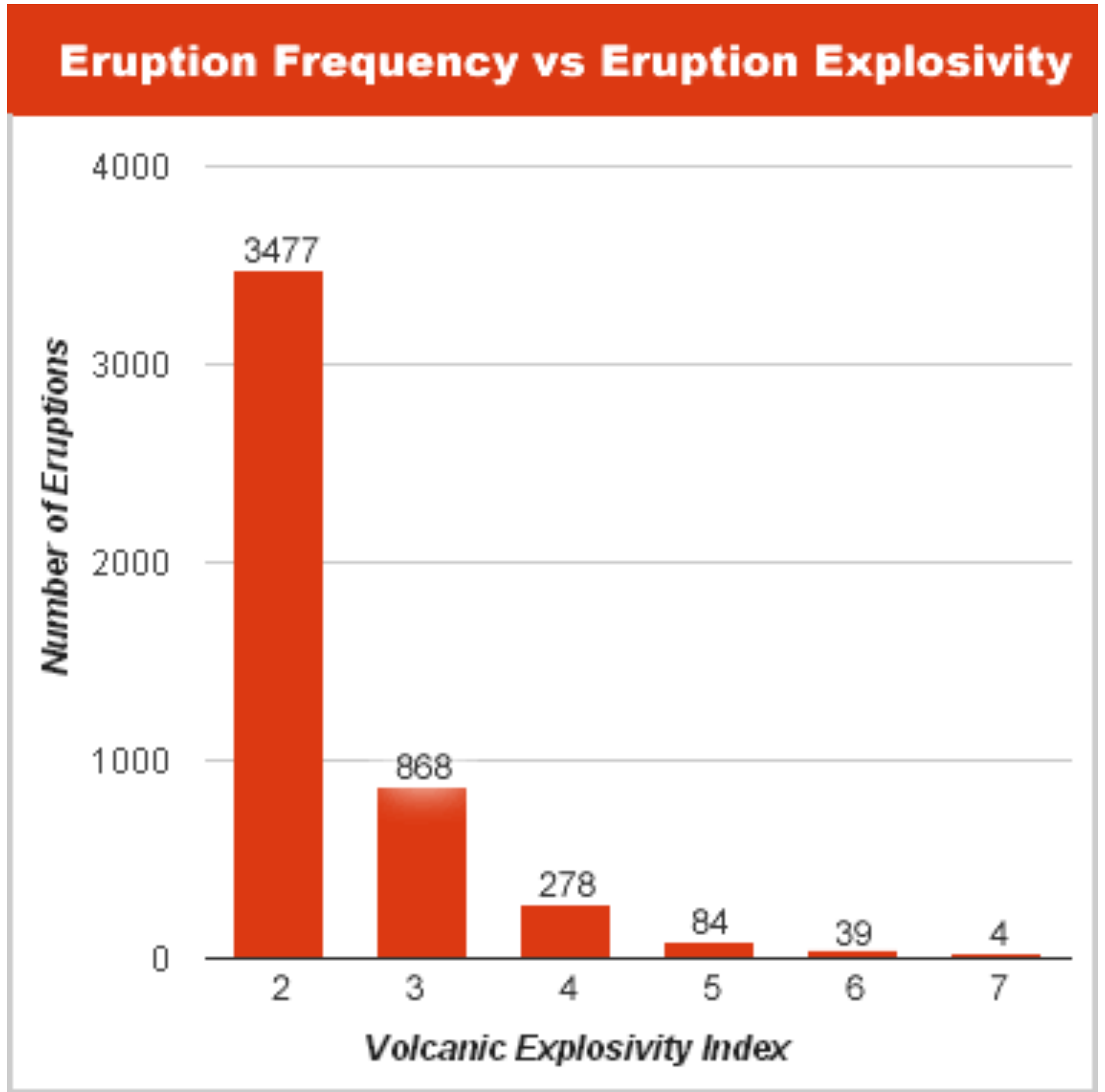
Plag et al., 2015

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.

http://geology.com/stories/13/volcanic-explosivity-index/

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.

http://geology.com/stories/13/volcanic-explosivity-index/

Size of Volcanic Eruptions

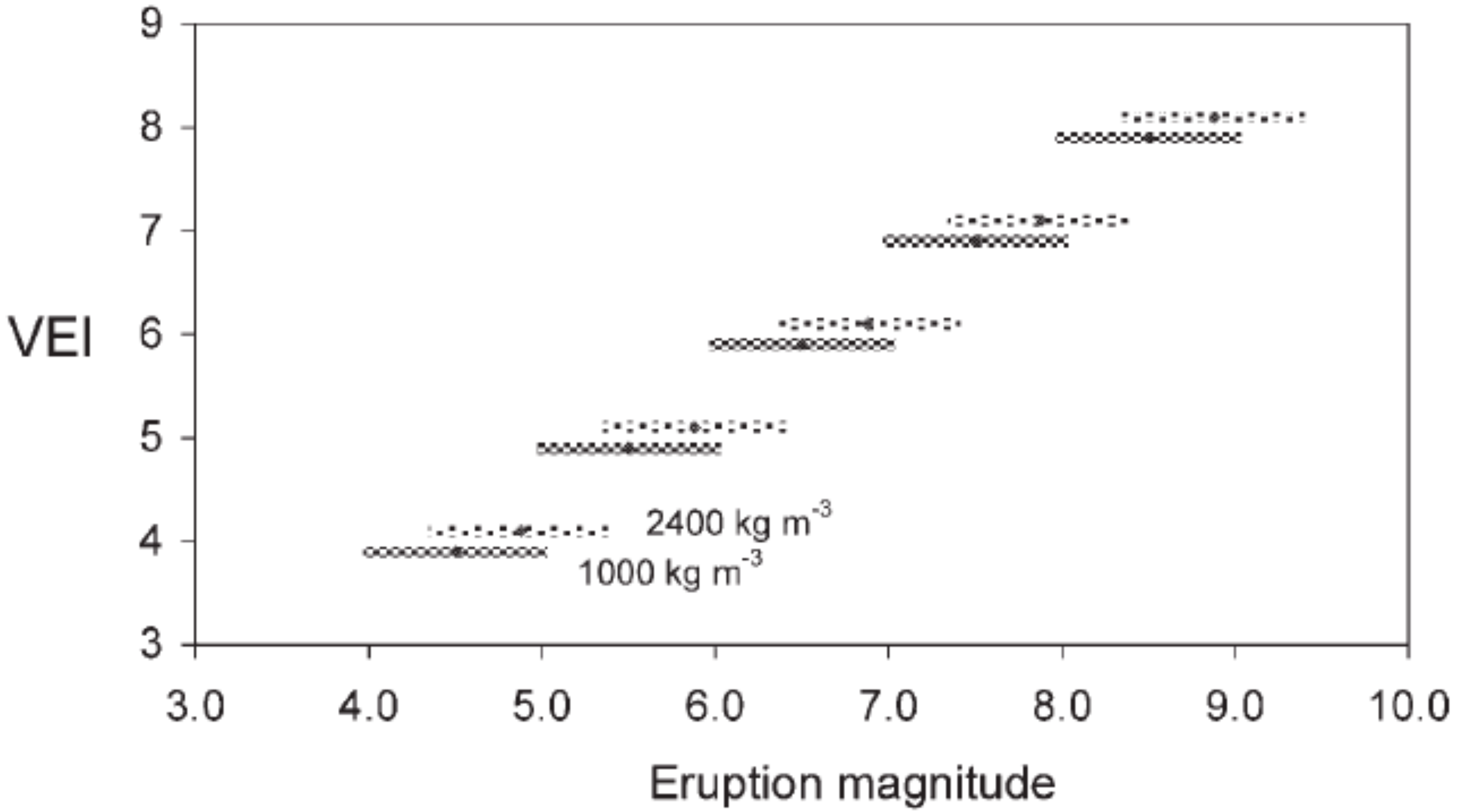


Fig. 1 The relationship between eruption magnitude, *M*, and Volcanic Explosivity Index, VEI, for deposits of bulk density 1,000 and 2,400 kg m^{-3}

$M = \log10(m) - 7.0$

M: magnitude
m: mass

Mason et al., 2004

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.

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

* plus two suspected.

Plag et al., 2015

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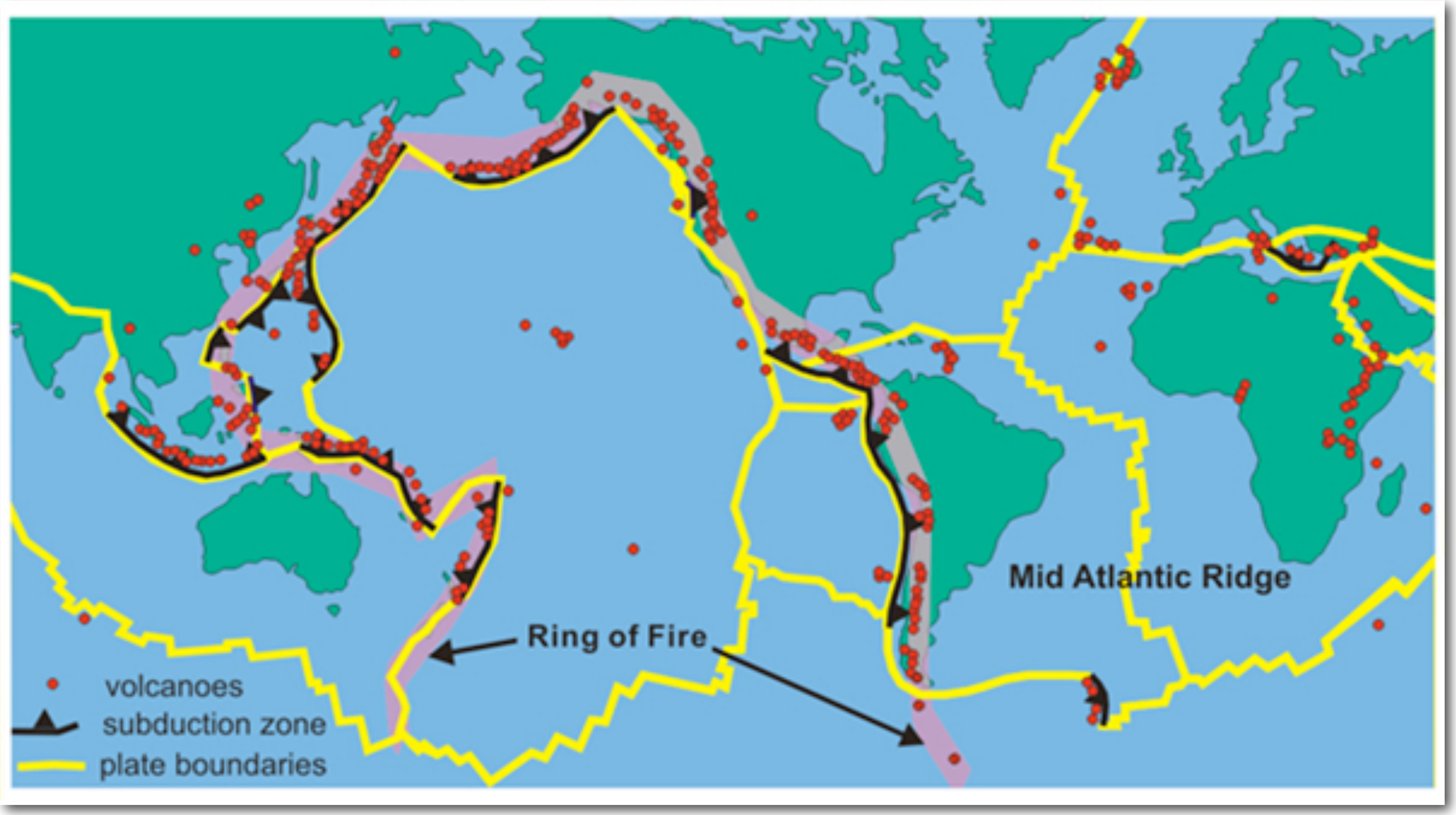
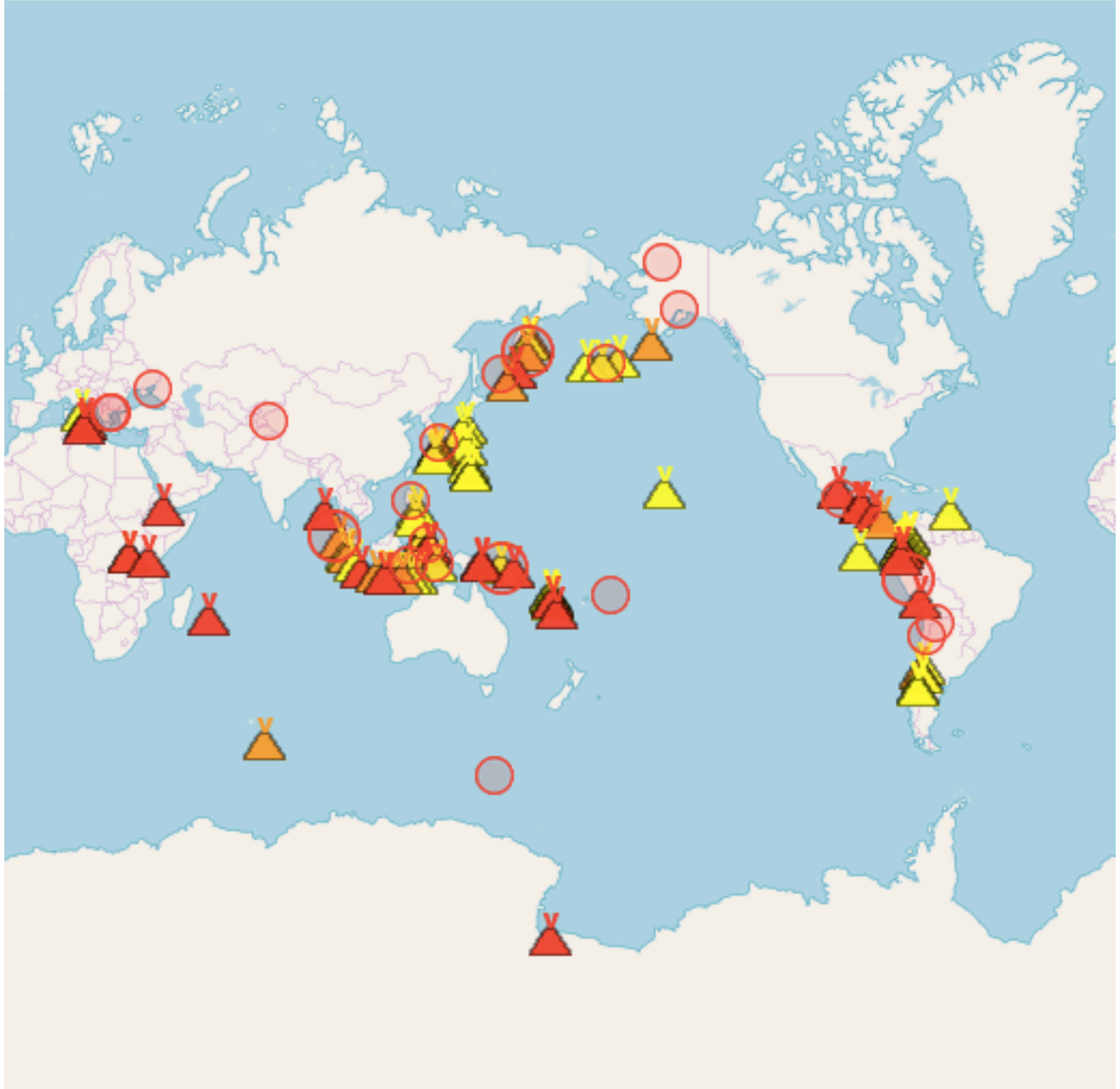
Location

Most volcanoes (not all) are on plate boundaries



Location

Most volcanoes (not all) are on plate boundaries



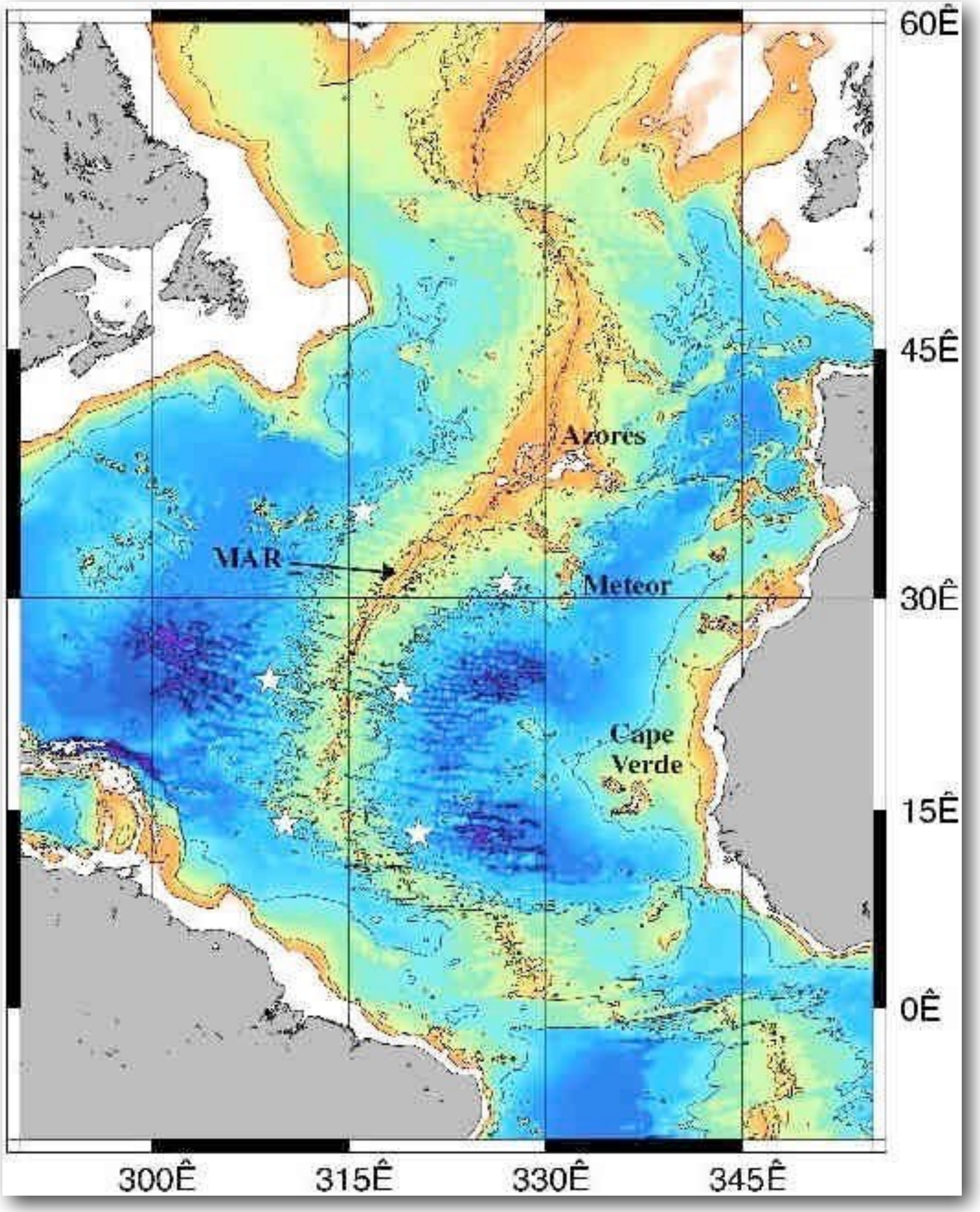
Location

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

Location

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

extinct volcano

active volcano

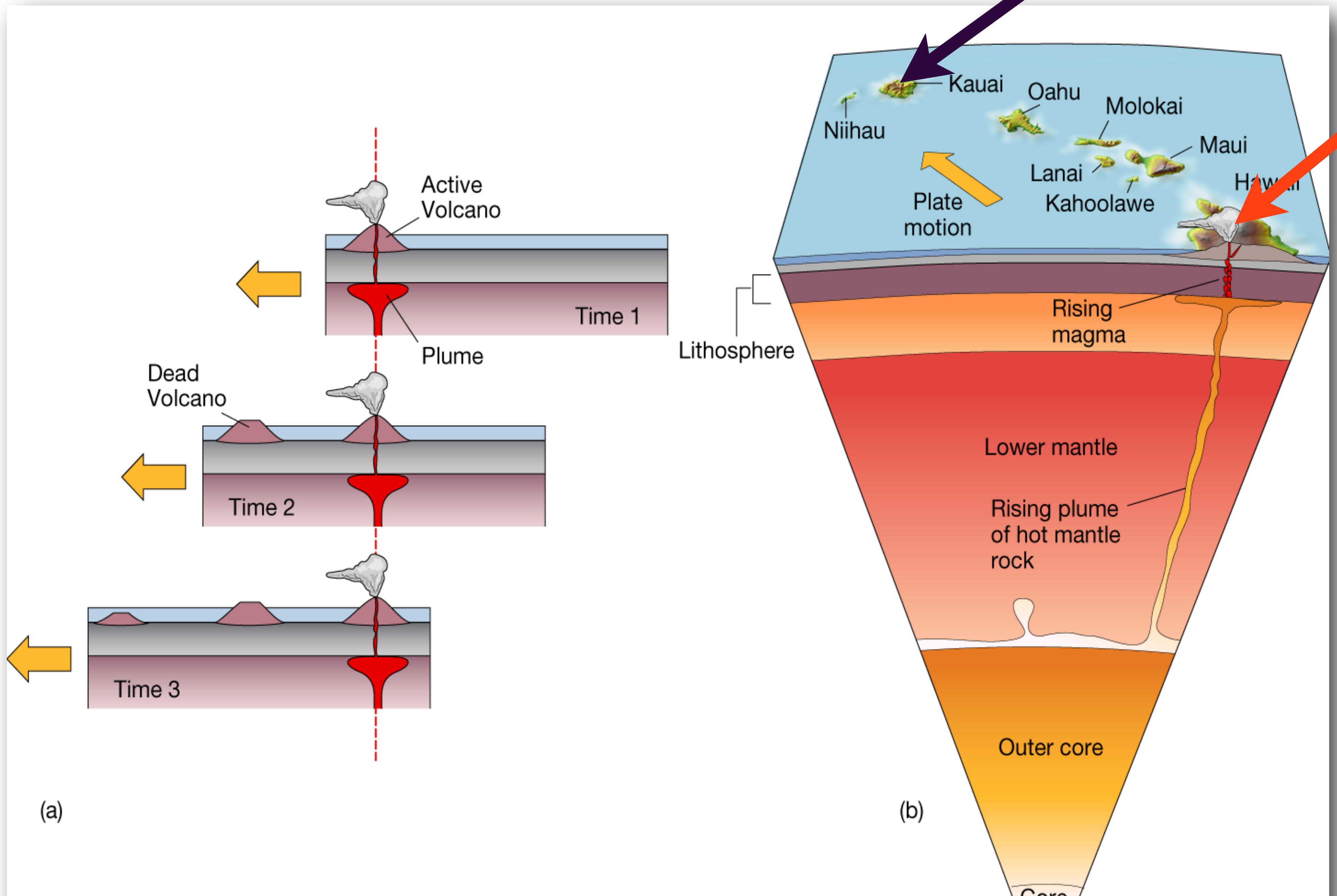
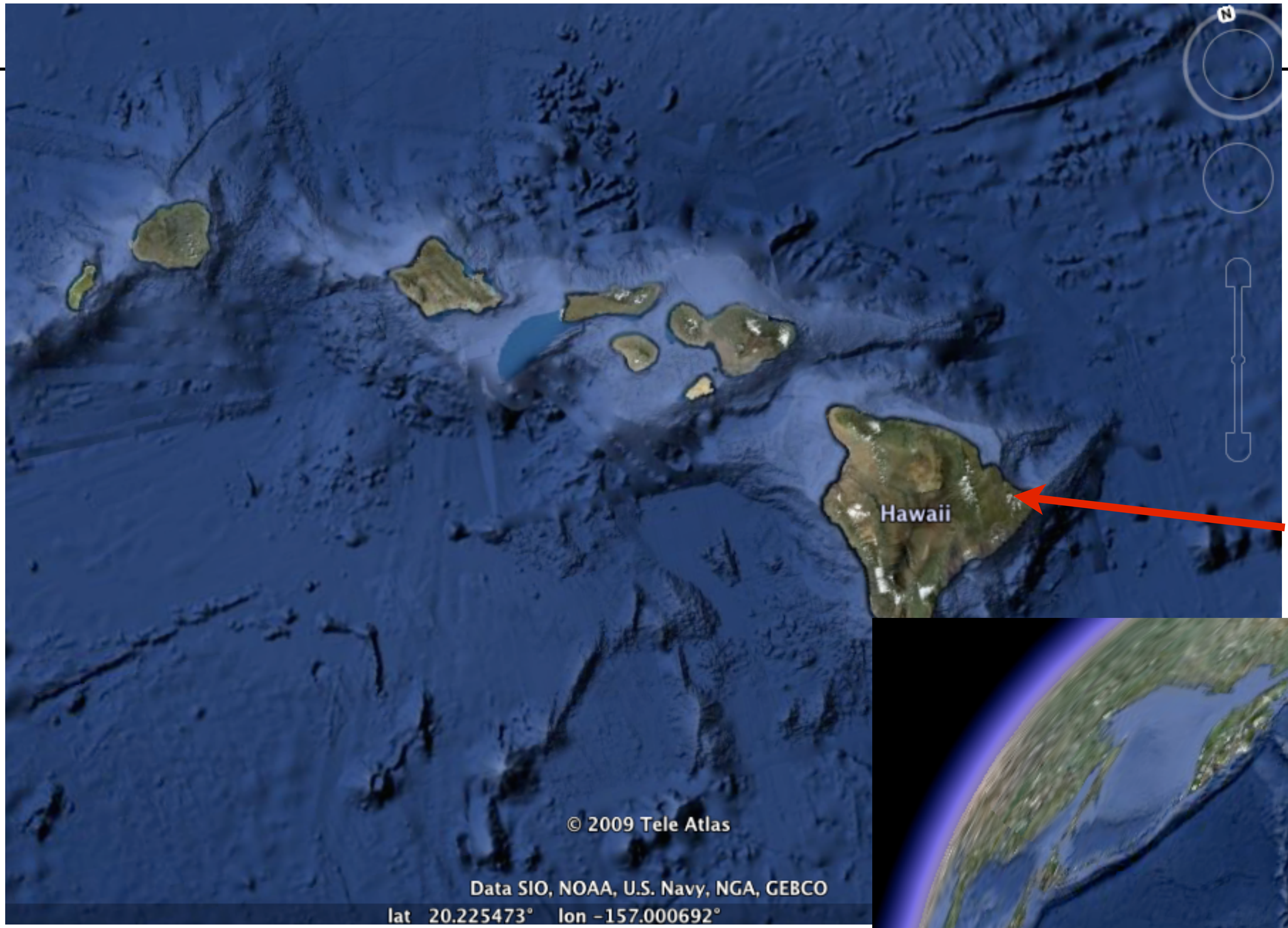


Plate moves over a nearly
stationary mantle plume

http://webpages.csus.edu/~cjf28/hawaii_volcano.jpg

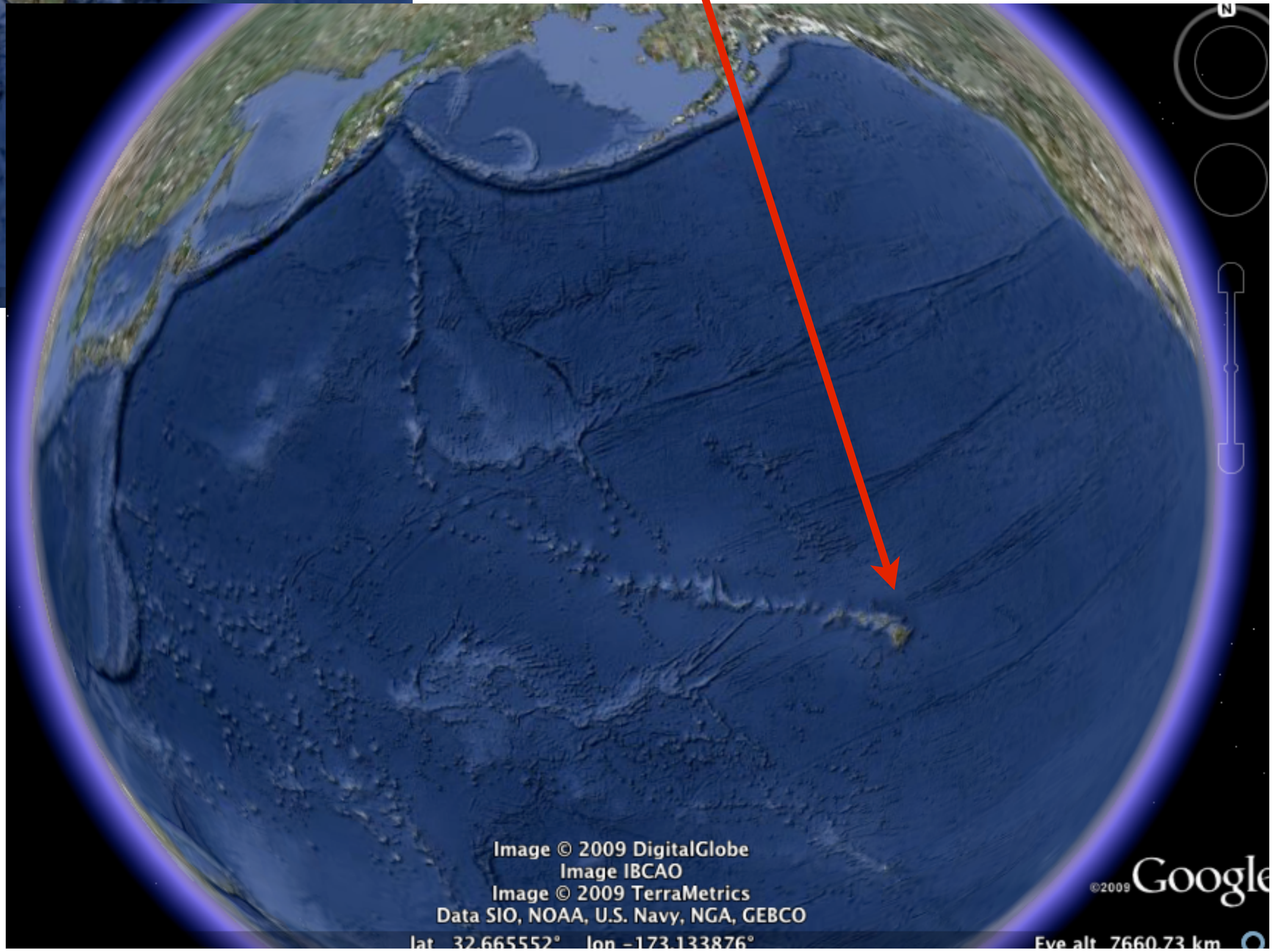
low viscosity -
lava ‘fountains’ and lava ‘rivers’

Location



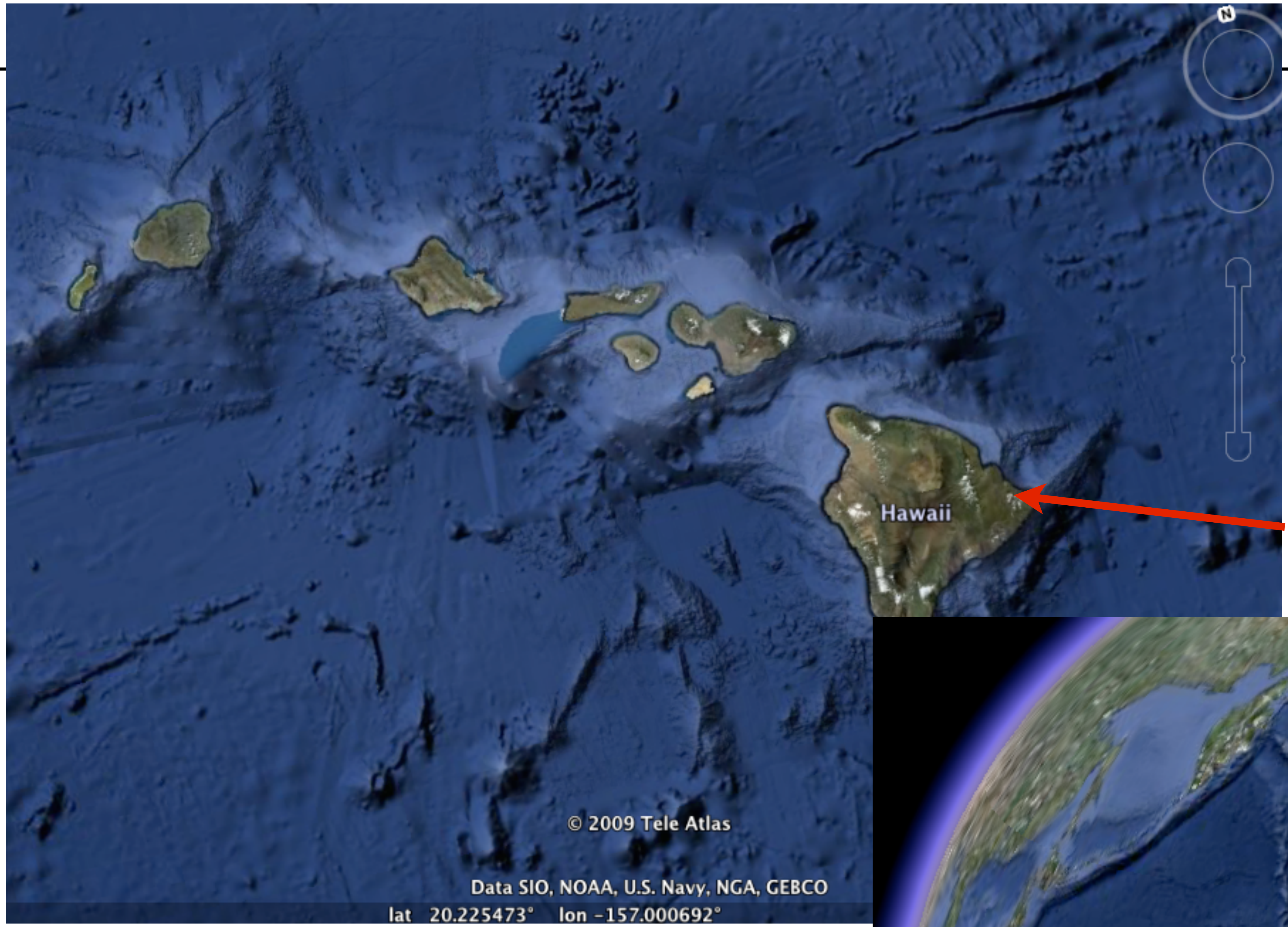
Hawaiian Hot Spot track

active



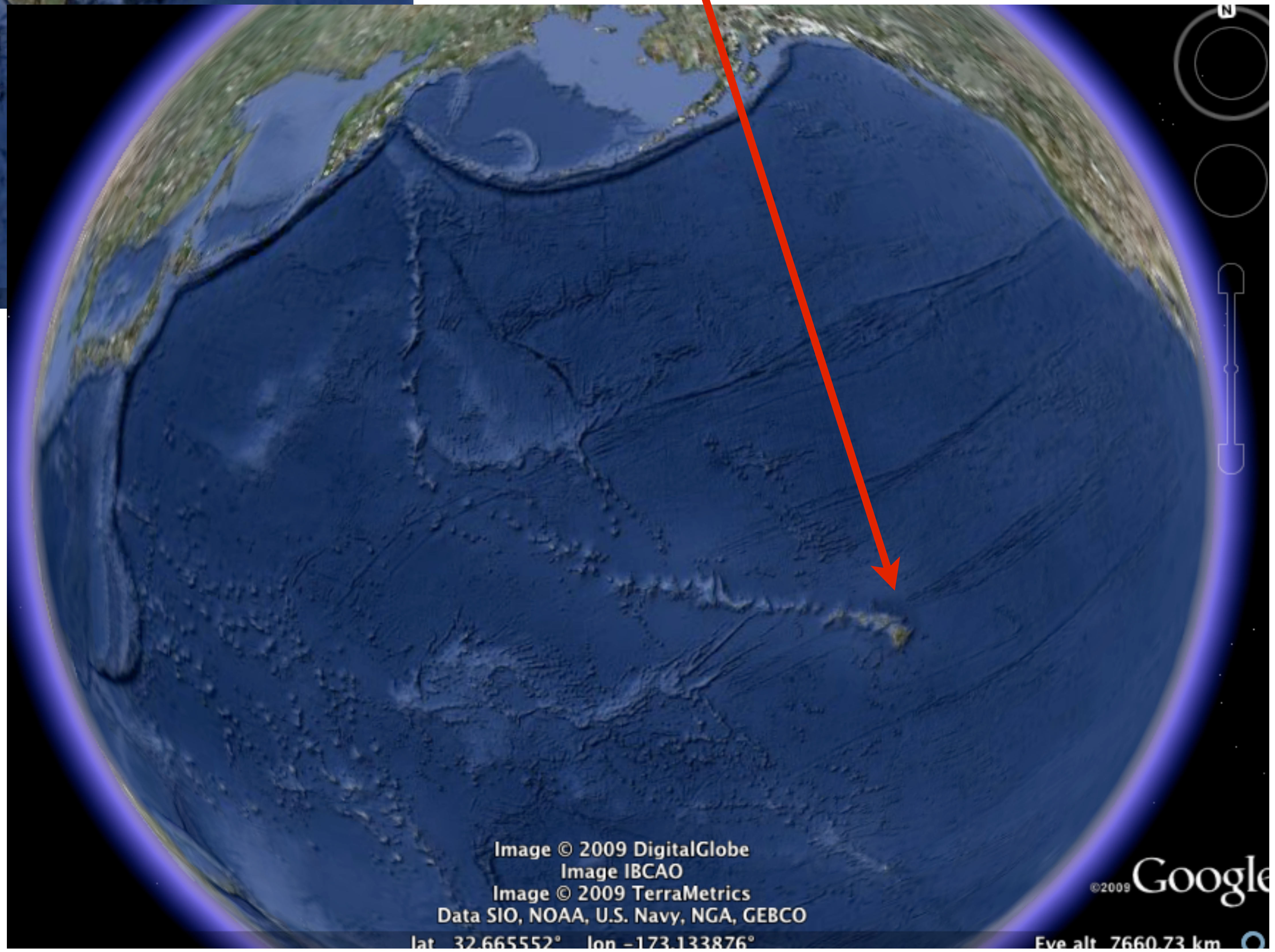
NOT a mid-ocean ridge spreading system

Location



Hawaiian Hot Spot track

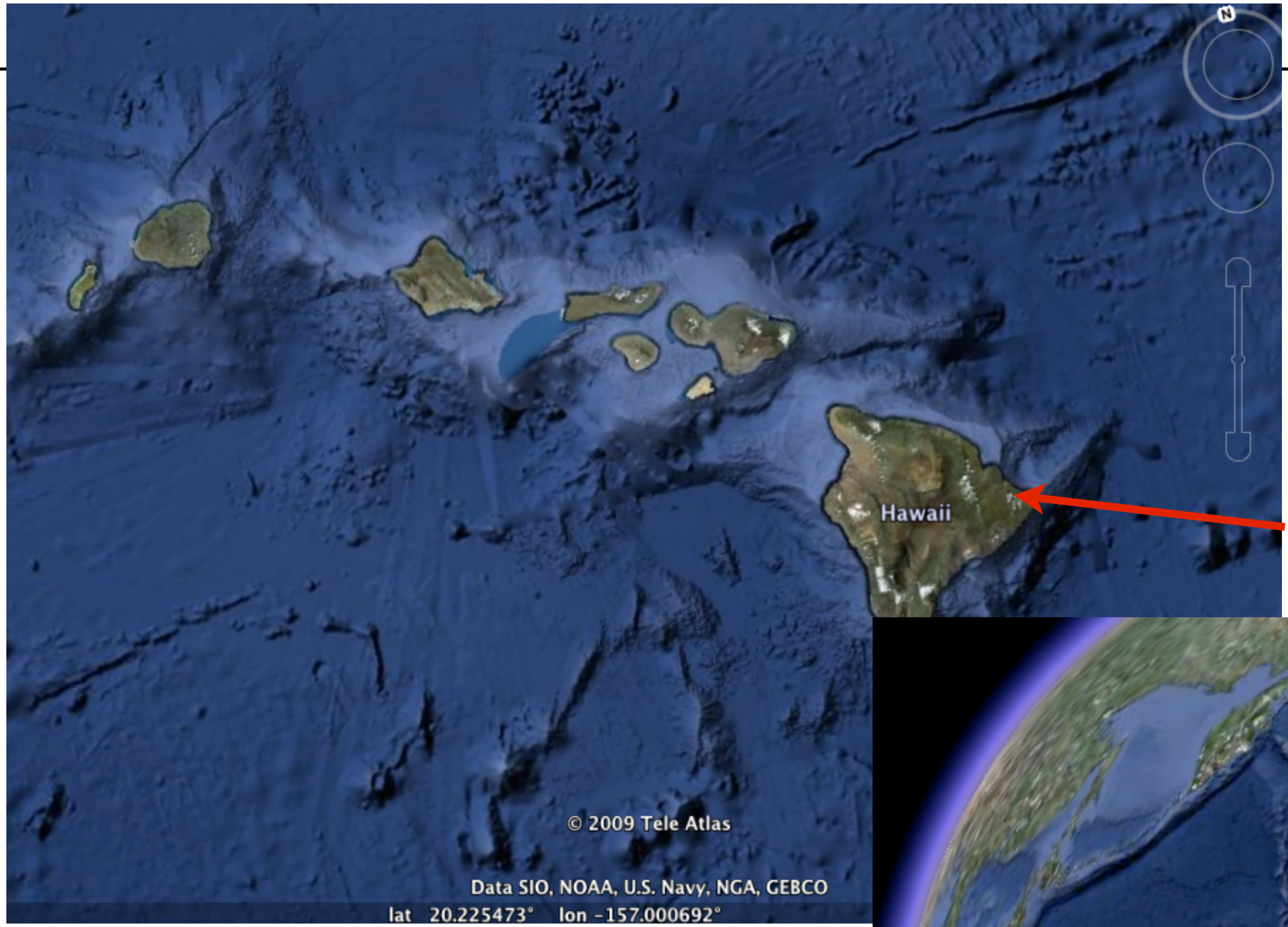
active



NOT a mid-ocean ridge spreading system

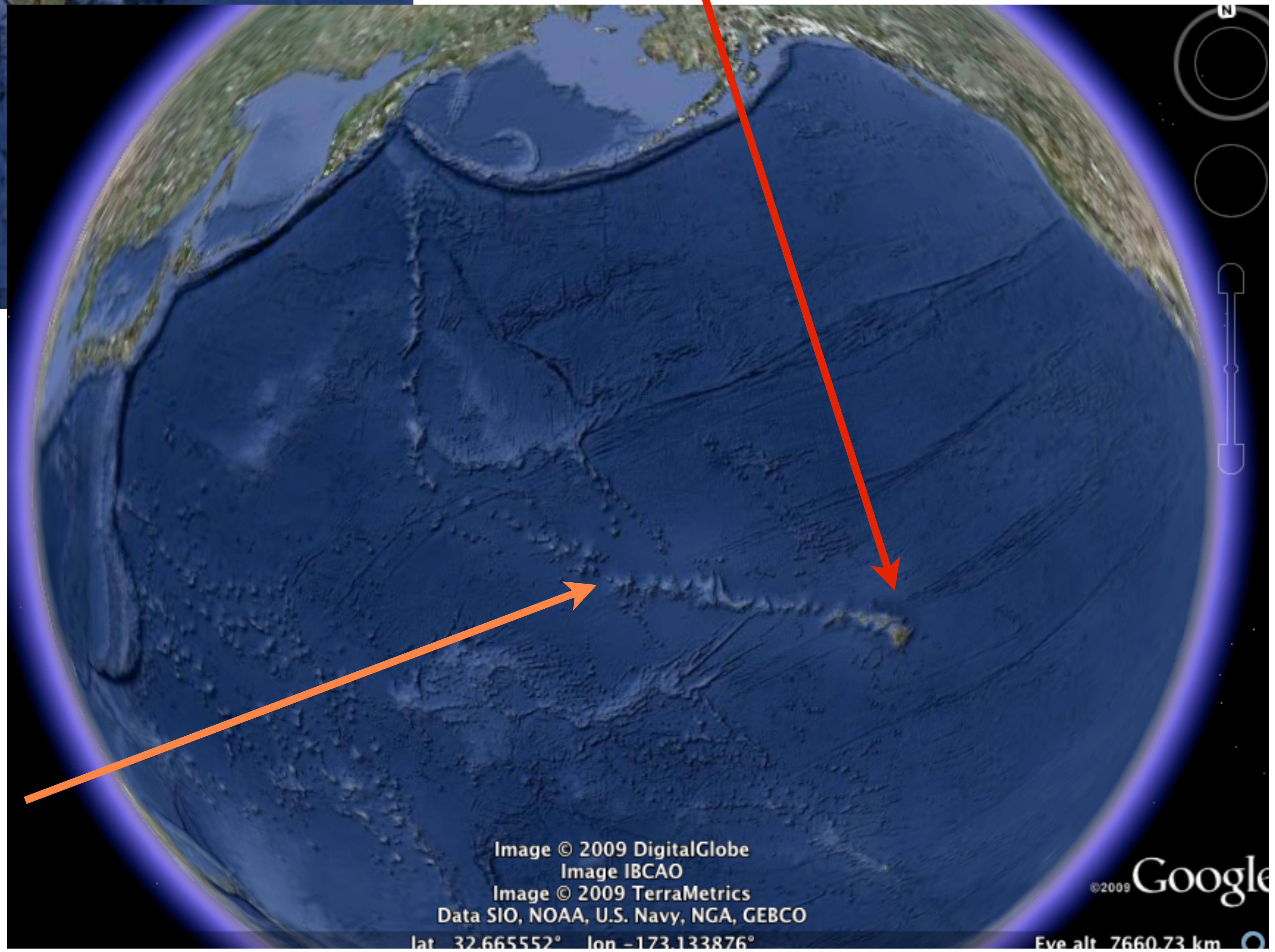
How do we know?

Location



Hawaiian Hot Spot track

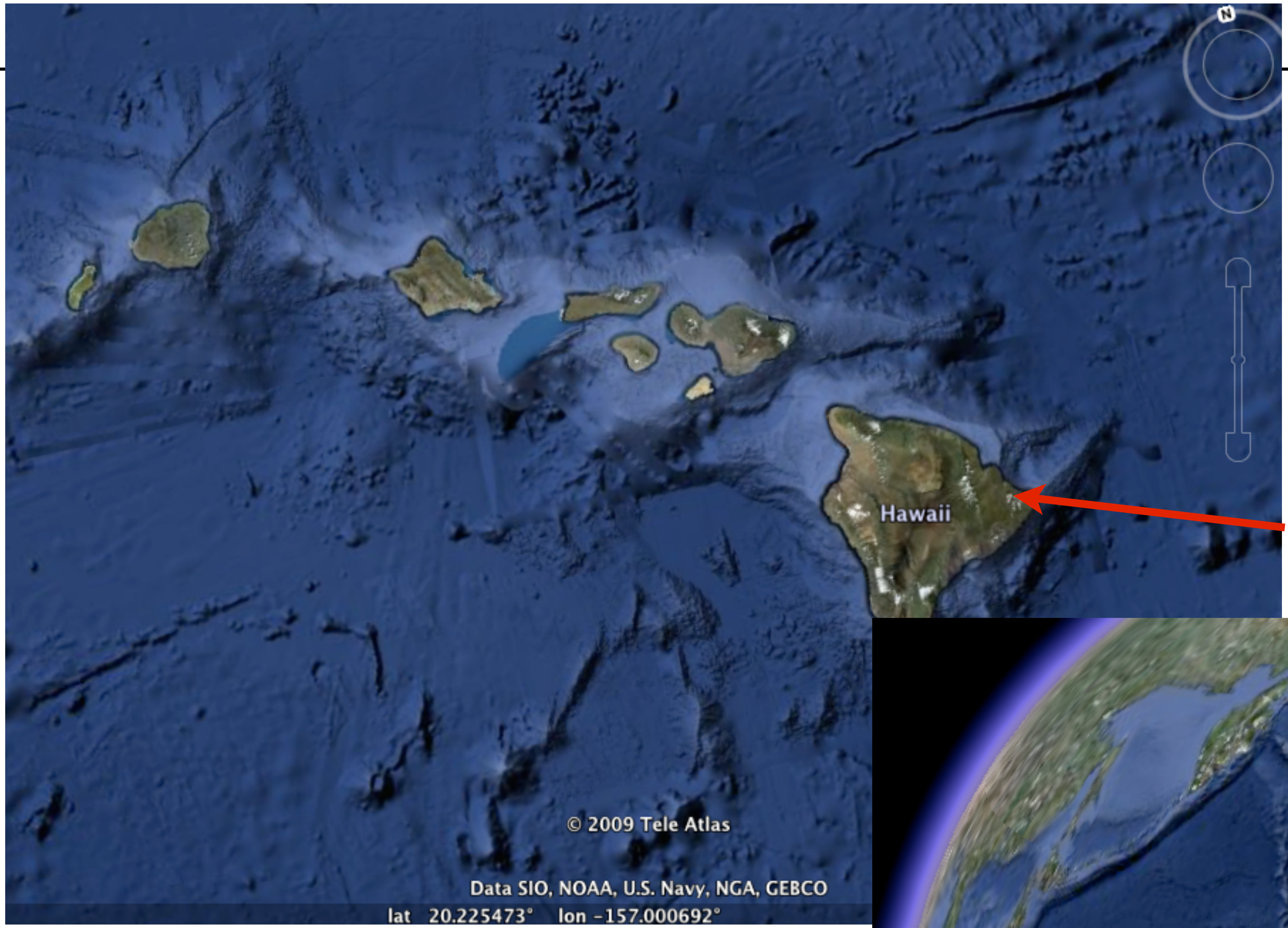
active



NOT a mid-ocean ridge spreading system

30 million years ago

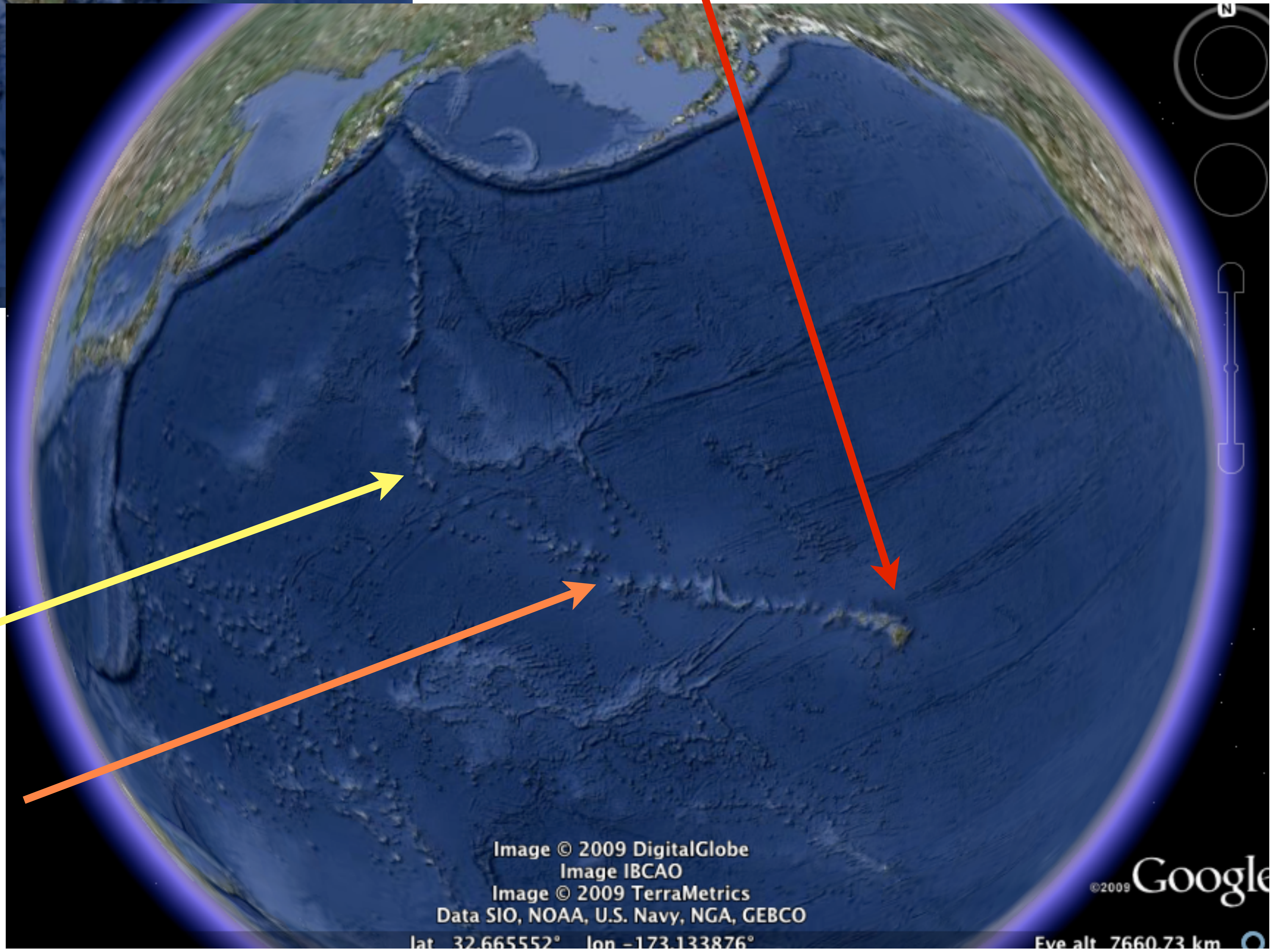
Location



Hawaiian Hot Spot track

active

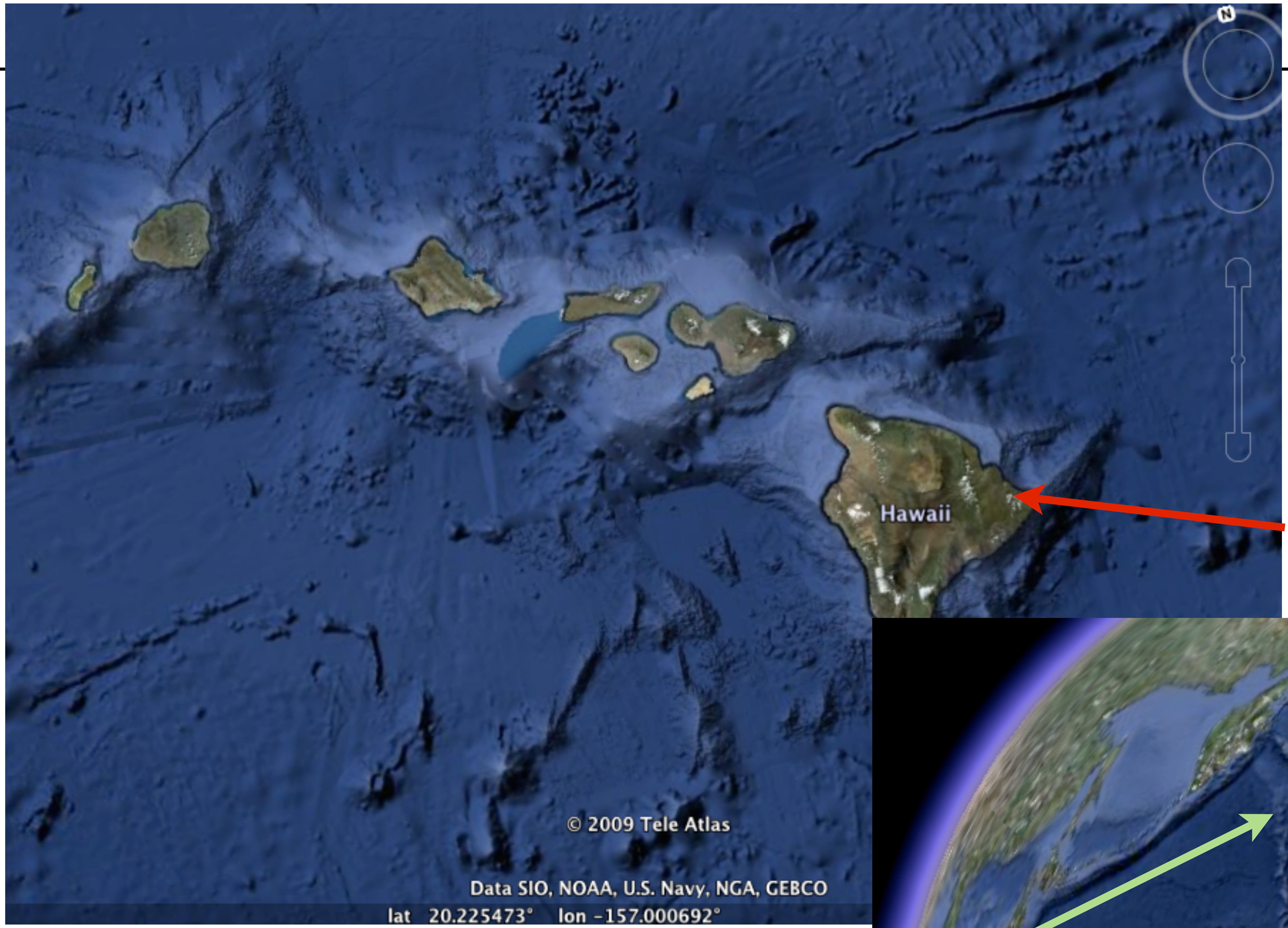
NOT a mid-ocean ridge spreading system



47 million years ago

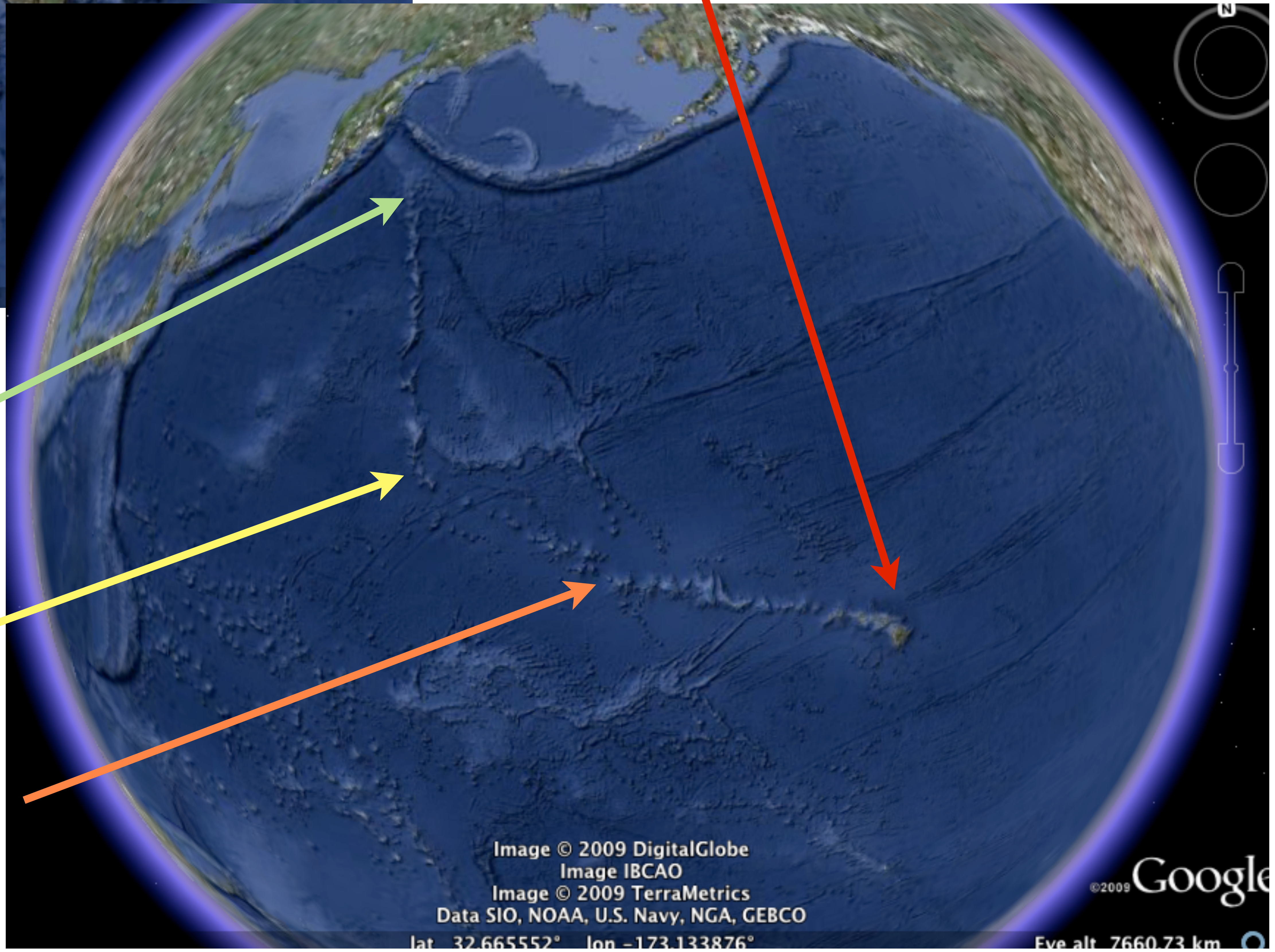
30 million years ago

Location



Hawaiian Hot Spot track

active



NOT a mid-ocean ridge spreading system

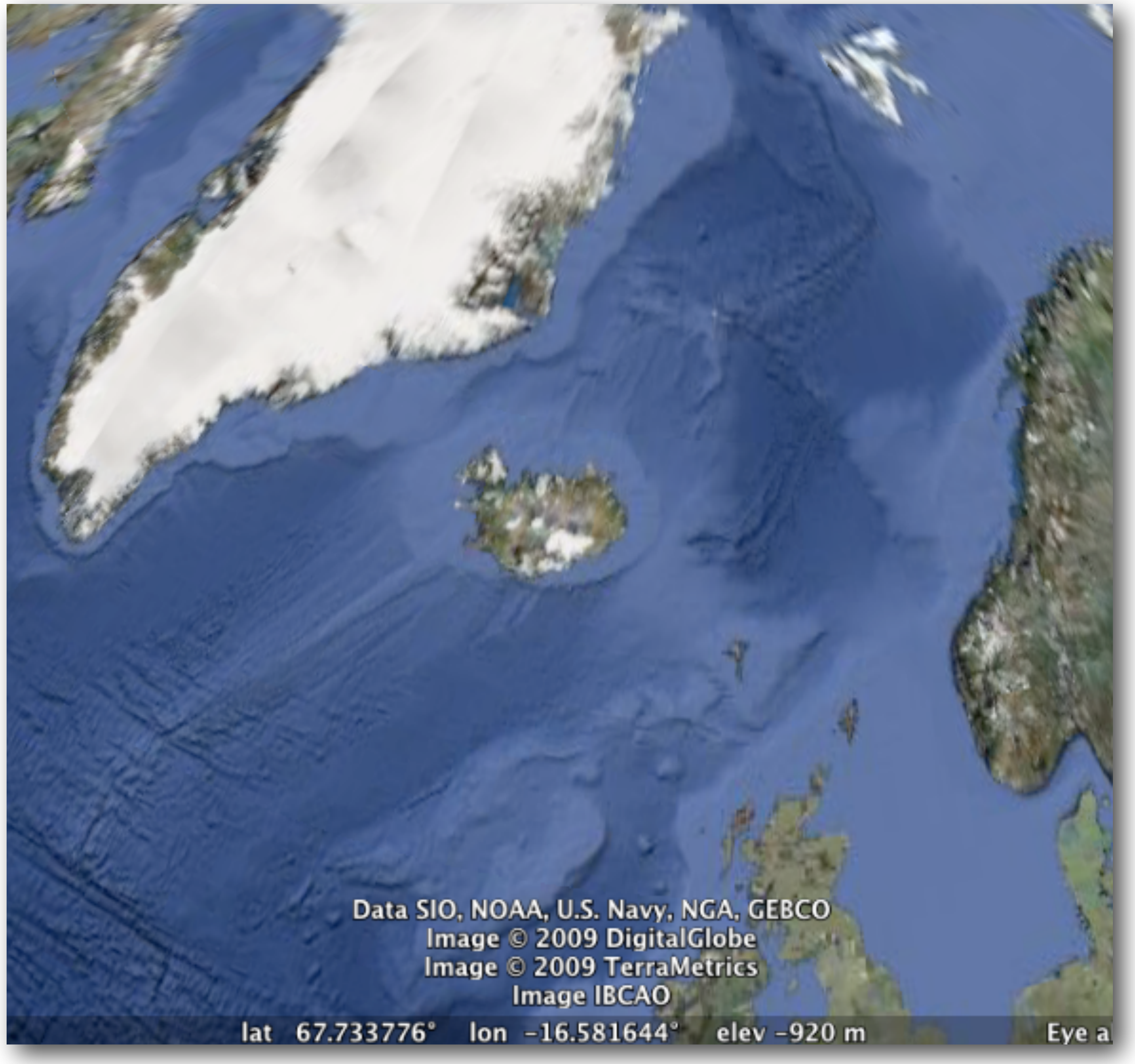
82 million years ago

47 million years ago

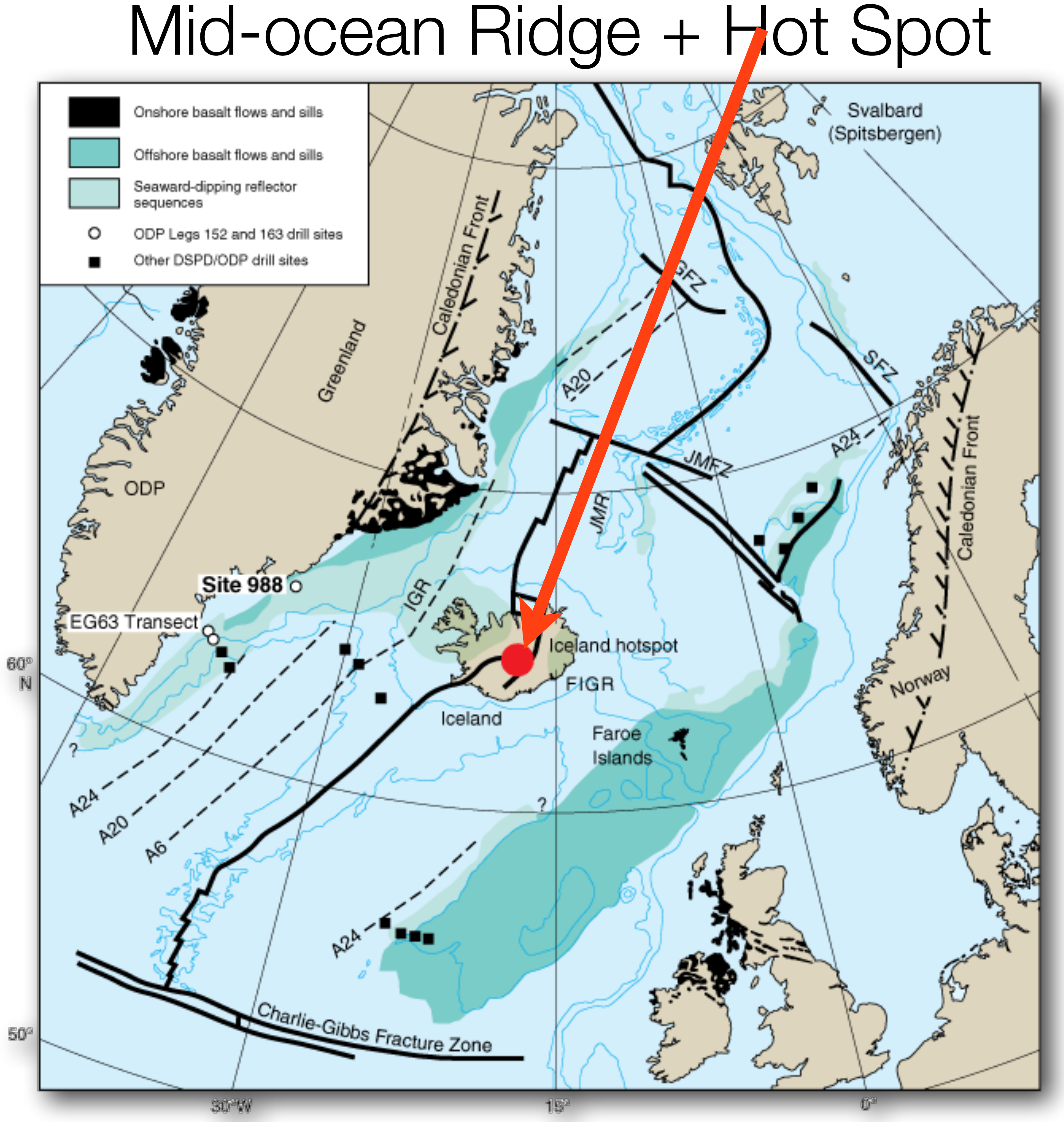
30 million years ago

Location

Iceland



Mid-ocean Ridge + Hot Spot



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

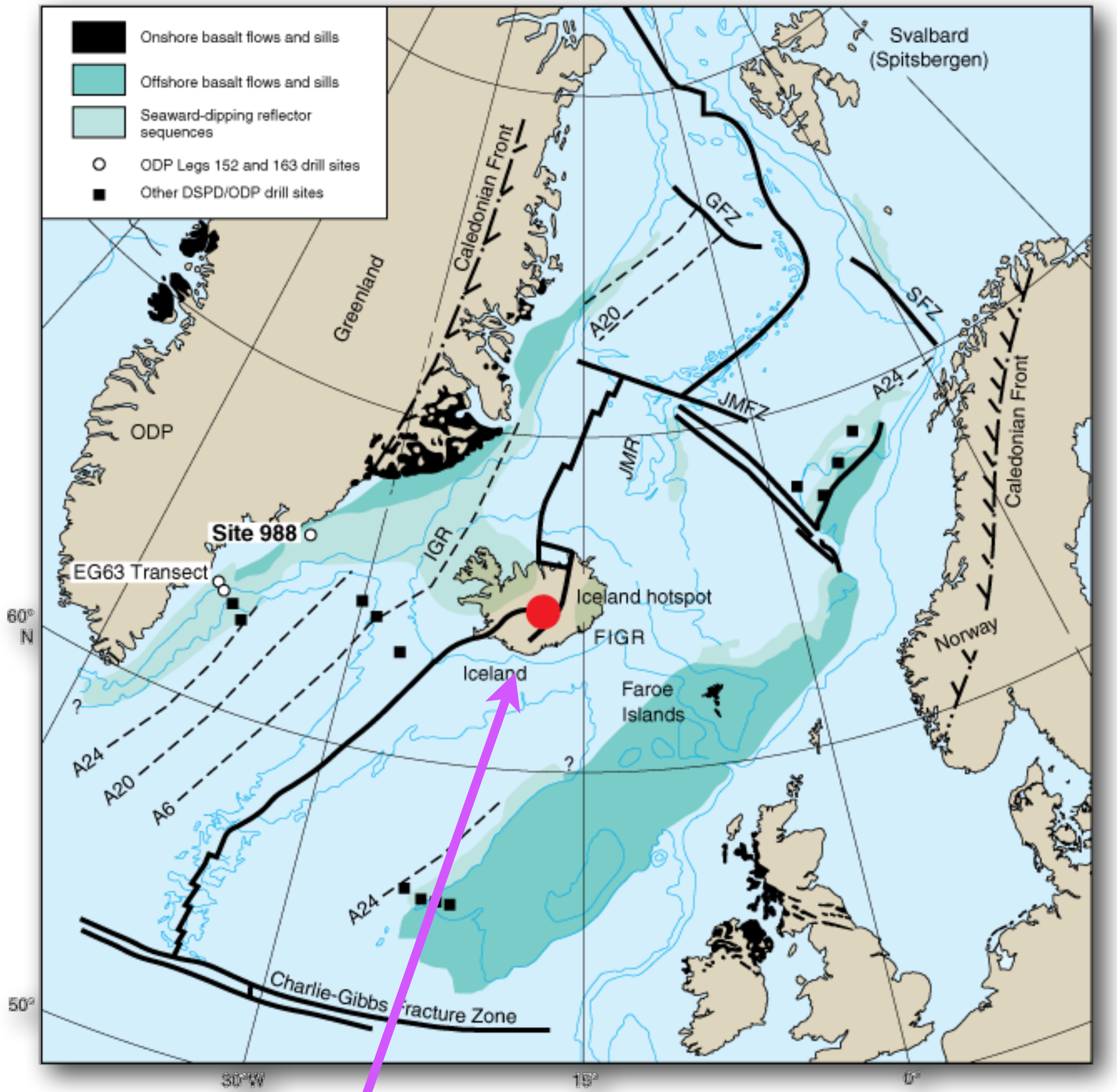
Surtsey, Iceland

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

Birth of a new island, 1963

image from GoogleEarth

Mid-ocean Ridge + Hot Spot



http://www-odp.tamu.edu/publications/163X_IR/101/images/01_f01.gif

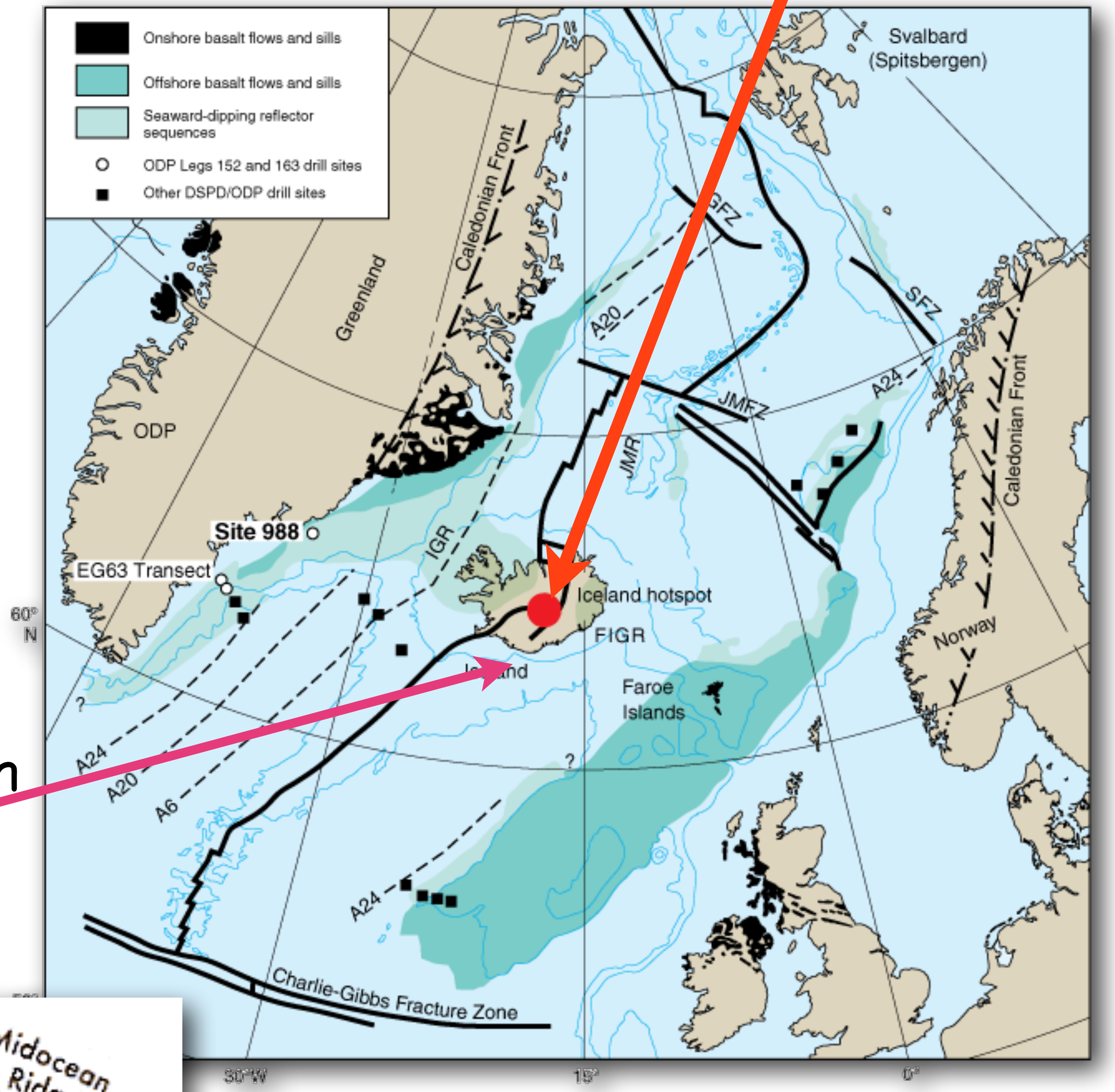
Surtsey

Location

Surtsey, Iceland

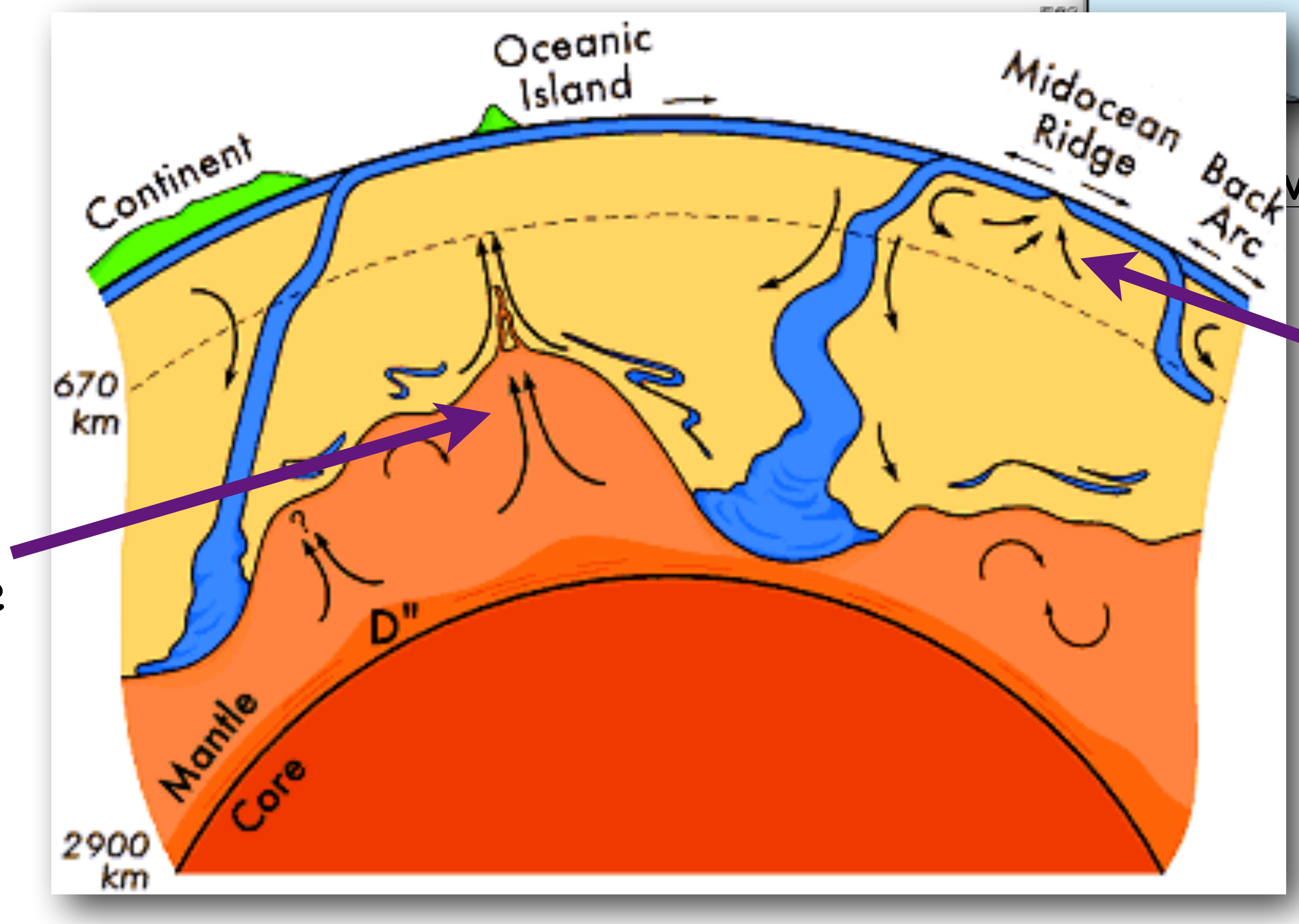
one year later

Mid-ocean Ridge + Hot Spot



www-odp.tamu.edu/publications/163X_IR/101/images/01_f01.gif

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



Hot Spot above deep Mantle plume

Spreading ridge above Upper Mantle convection

Location

Surtsey, Iceland

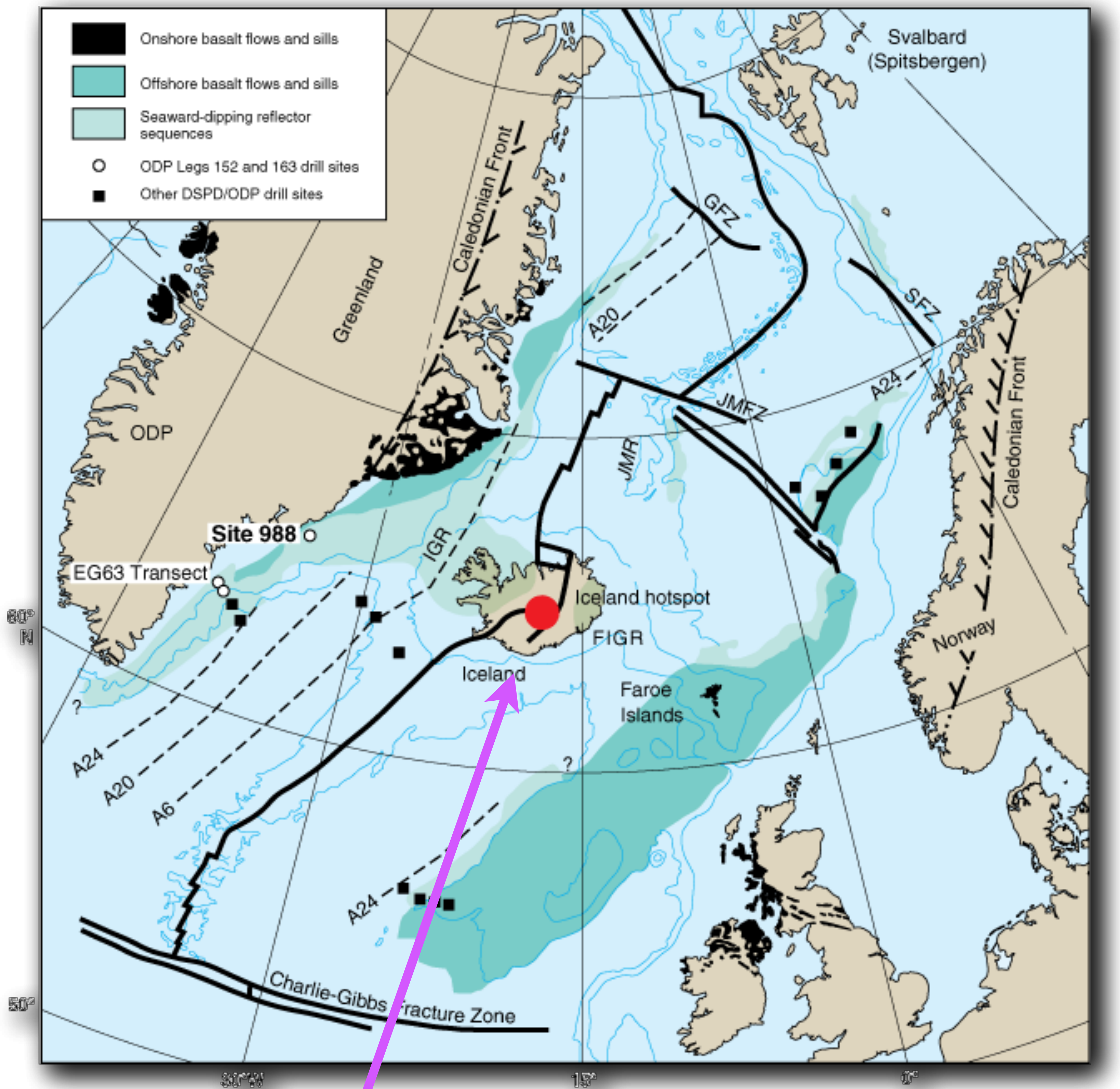
http://www.allseasonhotels.is/FileLib/Myndir/sidur/Natturan/Surtsey/Iceland2.jpg

2008

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

image from GoogleEarth

Mid-ocean Ridge + Hot Spot



http://www-odp.tamu.edu/publications/163X_IR/101/images/01_f01.gif

Surtsey

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Basalt

- A relatively low viscosity magma - extrudes onto the surface
- low in Silica content (SiO_2)
- dark color - contains lots of iron oxide (FeO, Fe_2O_3)and magnesium oxide (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

Types

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

http://www.geology.wisc.edu/~g111/Volcanoes/Heimaey/usg0403_Fx_Web.jpg

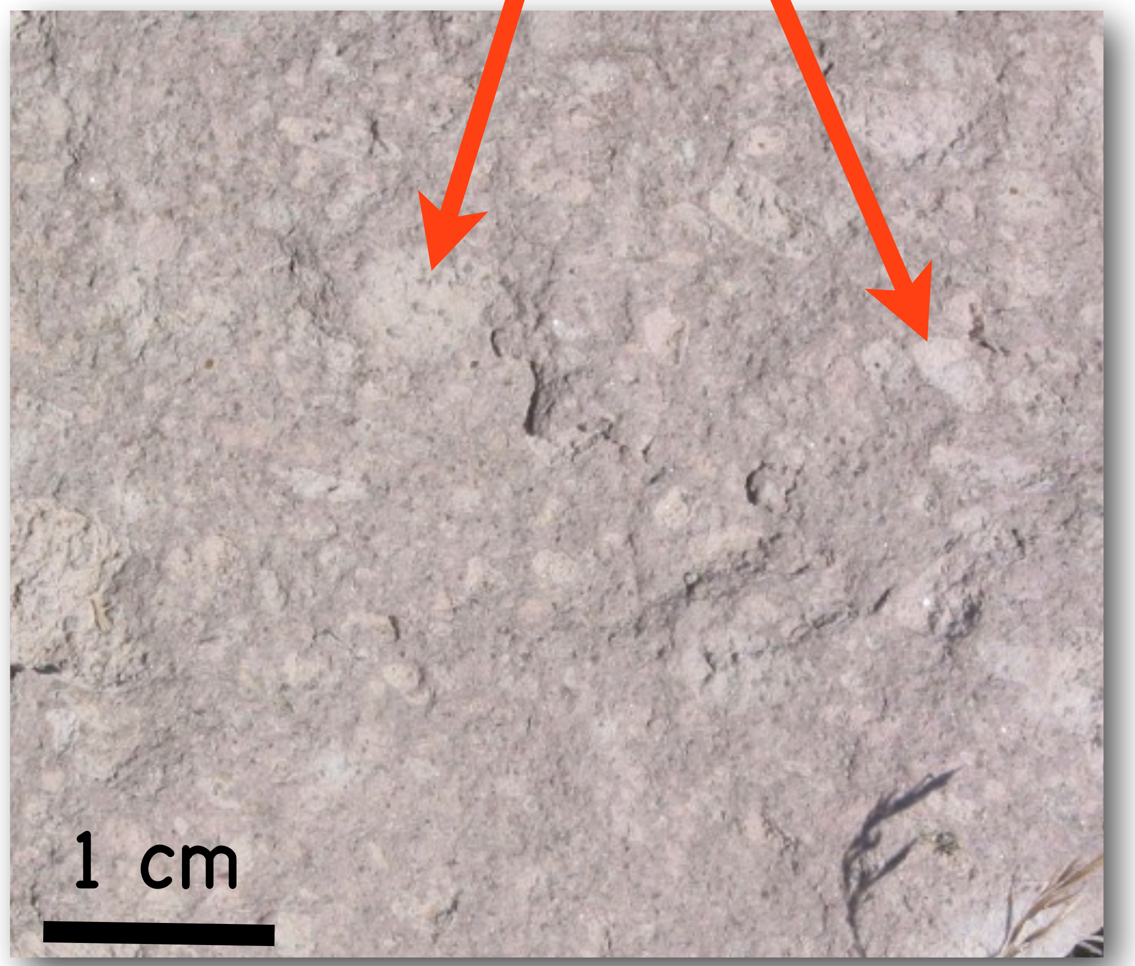
http://www.earth.northwestern.edu/people/seth/107/Ridges/Image24.jpg

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_2), feldspar (Al-Si-oxide)
- **rich in volatiles** (gases) that can make 'foam' ➔ pumice

feldspar crystals



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

Types

Rhyolite forms steep-sided, explosive volcanoes

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

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

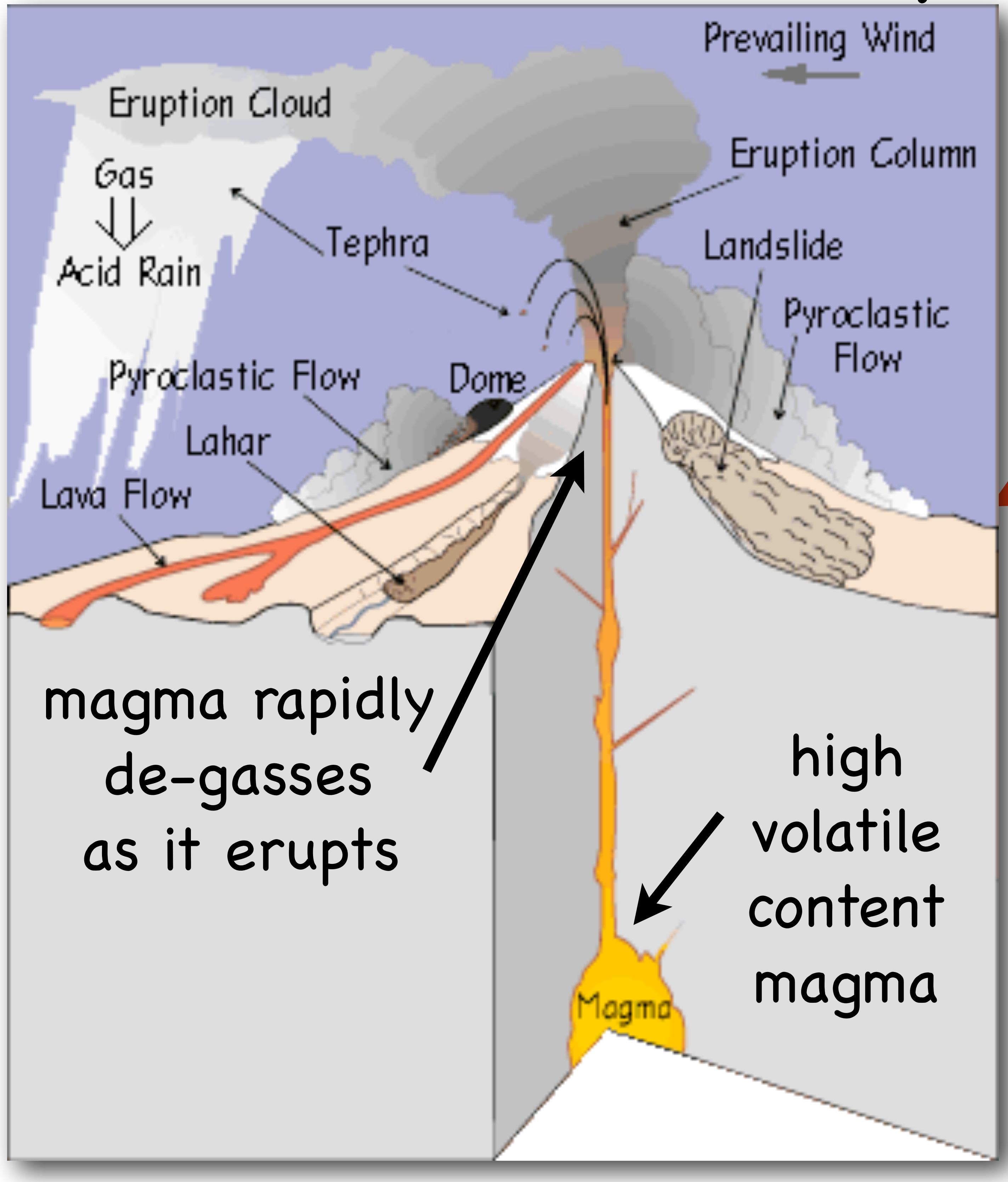
e.g. Mt. Pinatubo,
Phillipines
June 1991

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!

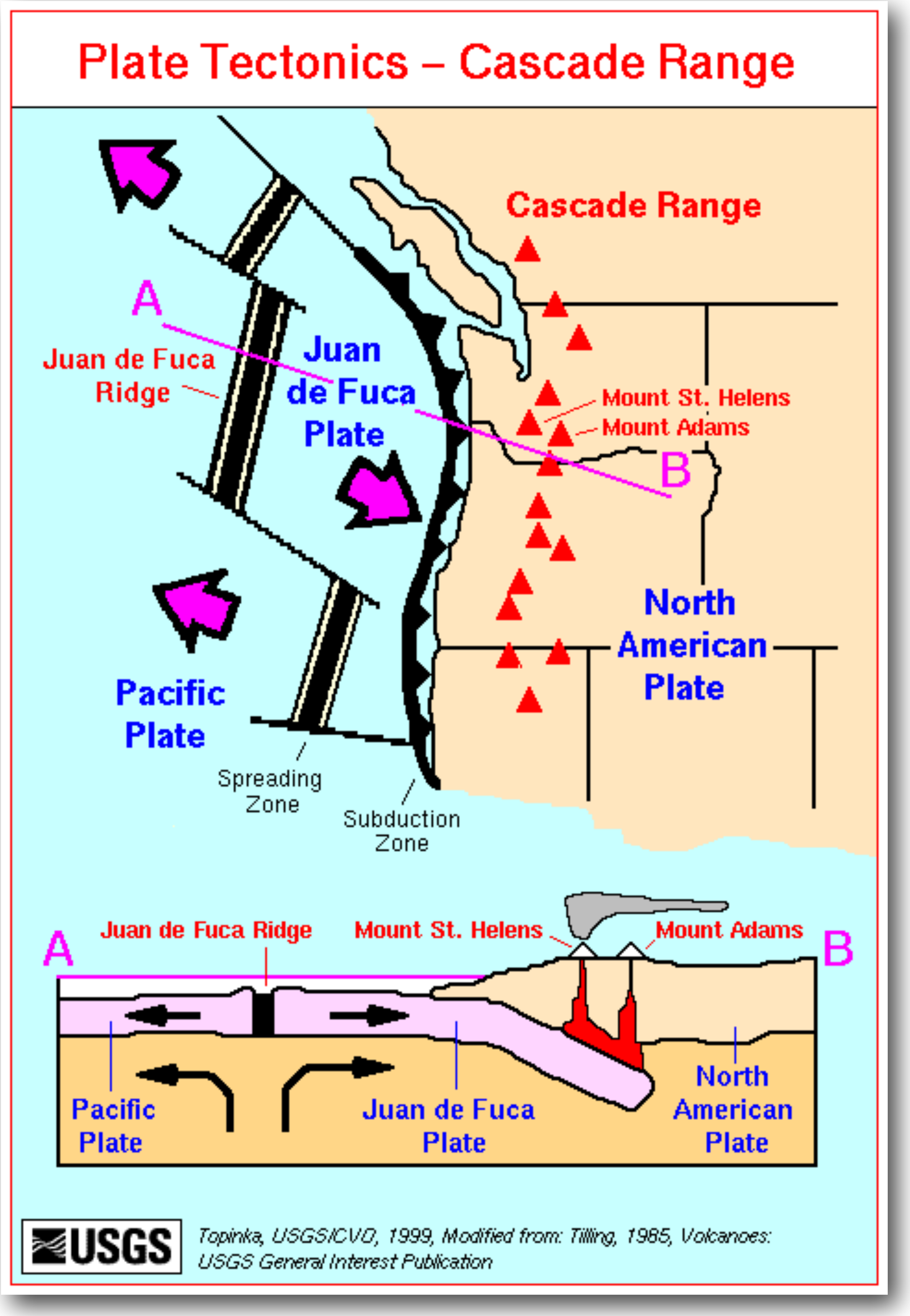
Mayon, Philippines 1984

http://volcanoes.usgs.gov/Imgs/Jpg/Mayon/32923351-020_caption.html

very hot gas (up to 800°C) + ash + lava + rock

moves extremely fast >150 km/h

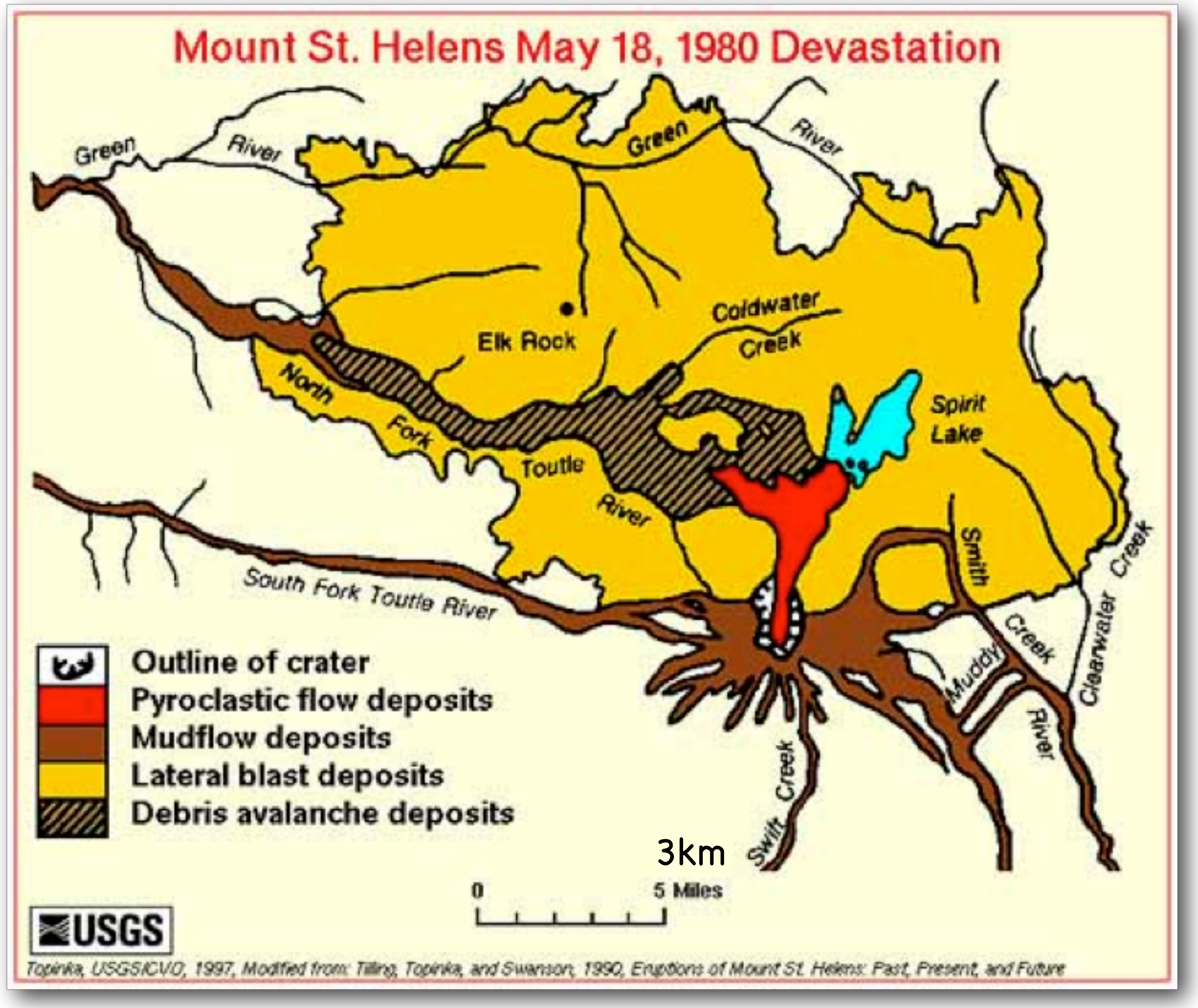
Explosive volcanoes are usually subduction-related



http://www.skimountaineer.com/CascadeSki/ThreeSisters/NorthMiddleSisters.jpg

At collisional plate boundaries

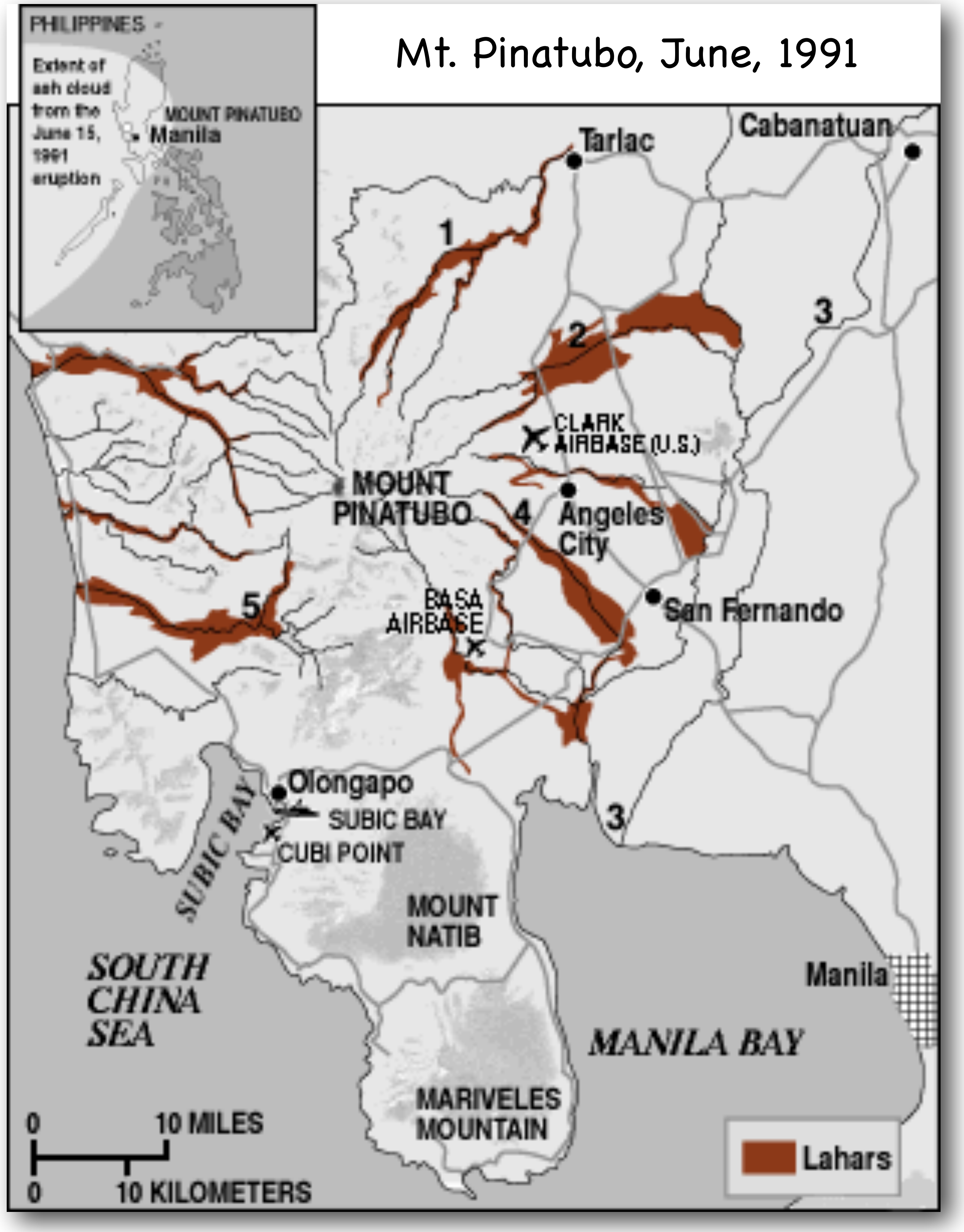
Mt. St. Helens



1 cubic km of magma erupted

main damage was from the lateral blast

Lahars: Mudflows resulting from volcanic activity



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

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

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/Imgs/Jpg/Ruiz/30410135_070_large.jpg

http://volcanoes.usgs.gov/Imgs/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

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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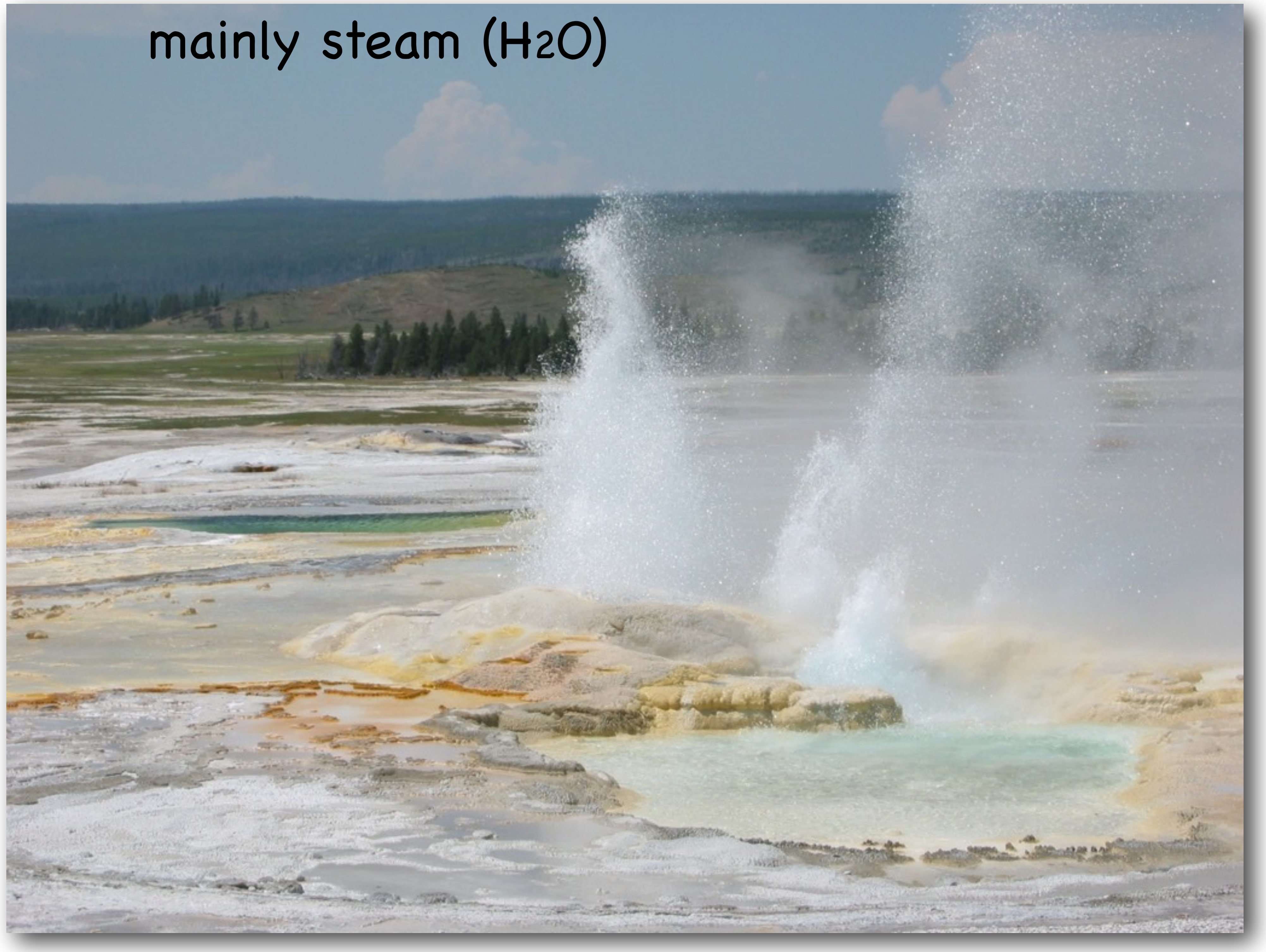
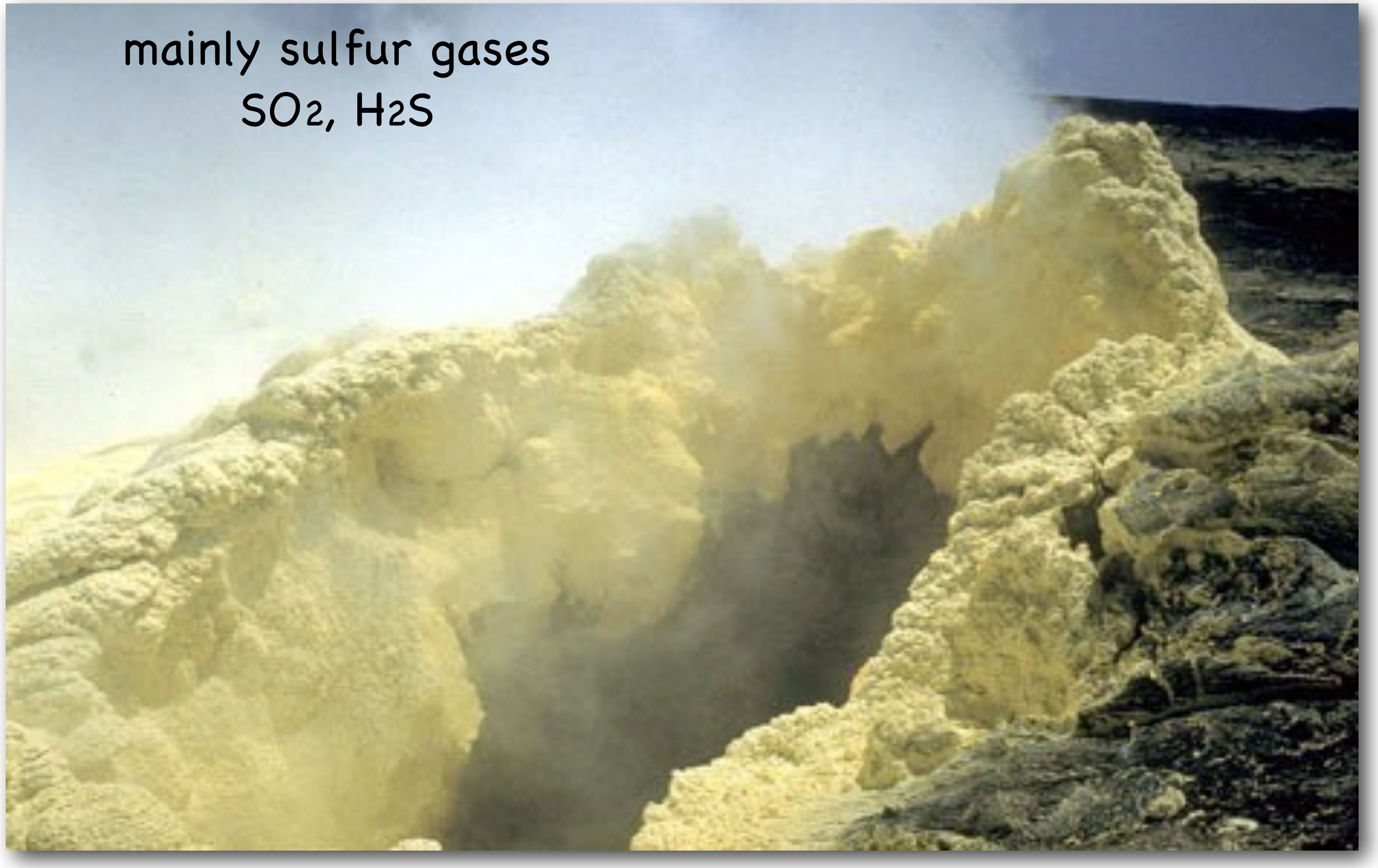
Volcanic Gases

Volcanoes are sources of dissolved gases
H_2O, SO_2, CO_2, HCl….



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



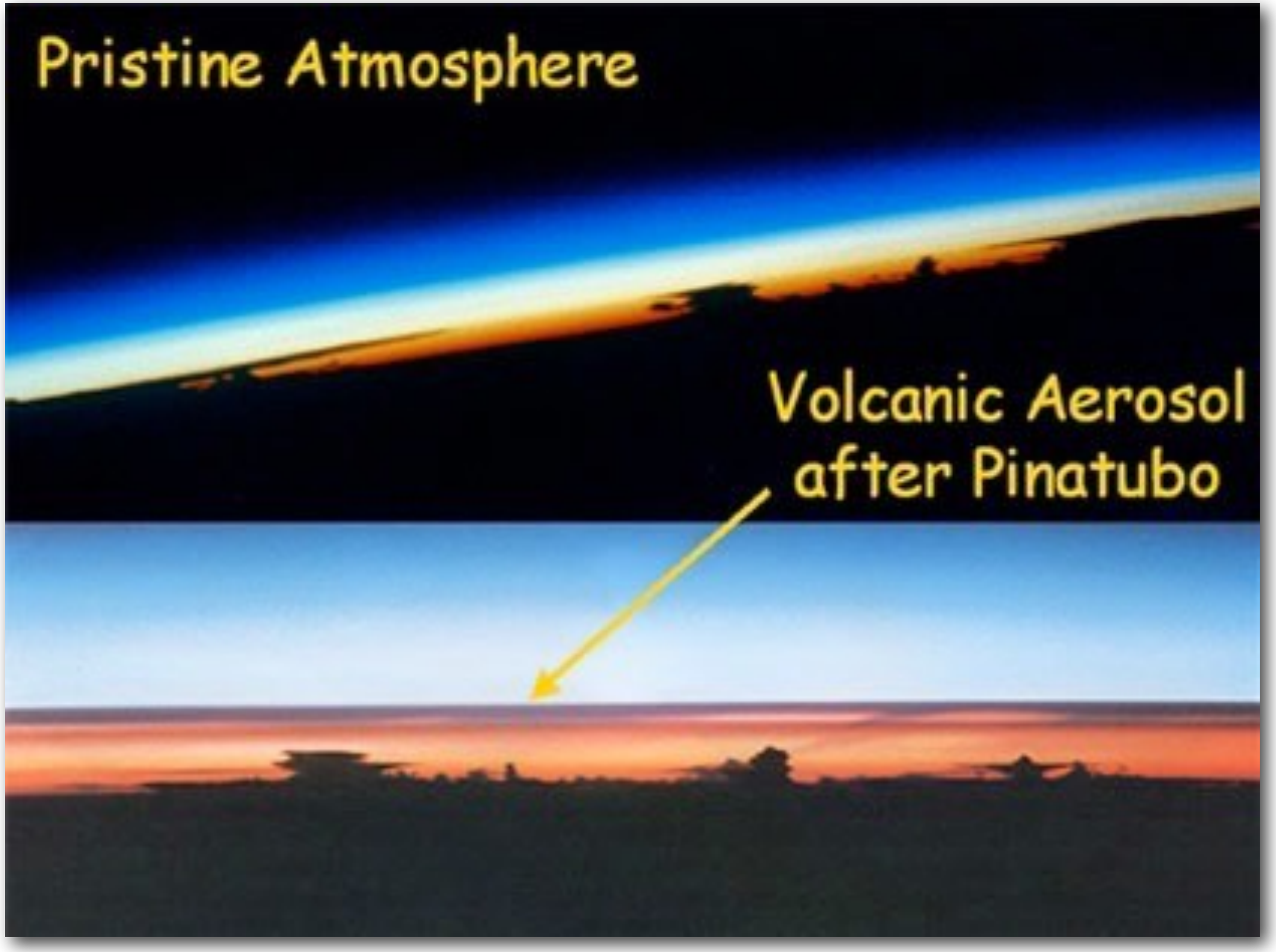
http://www.geology.sdsu.edu/how_volcanoes_work/Images/Vent_types/fumarole_med.jpg

Volcanic Gases

Volcanoes are sources of dissolved gases

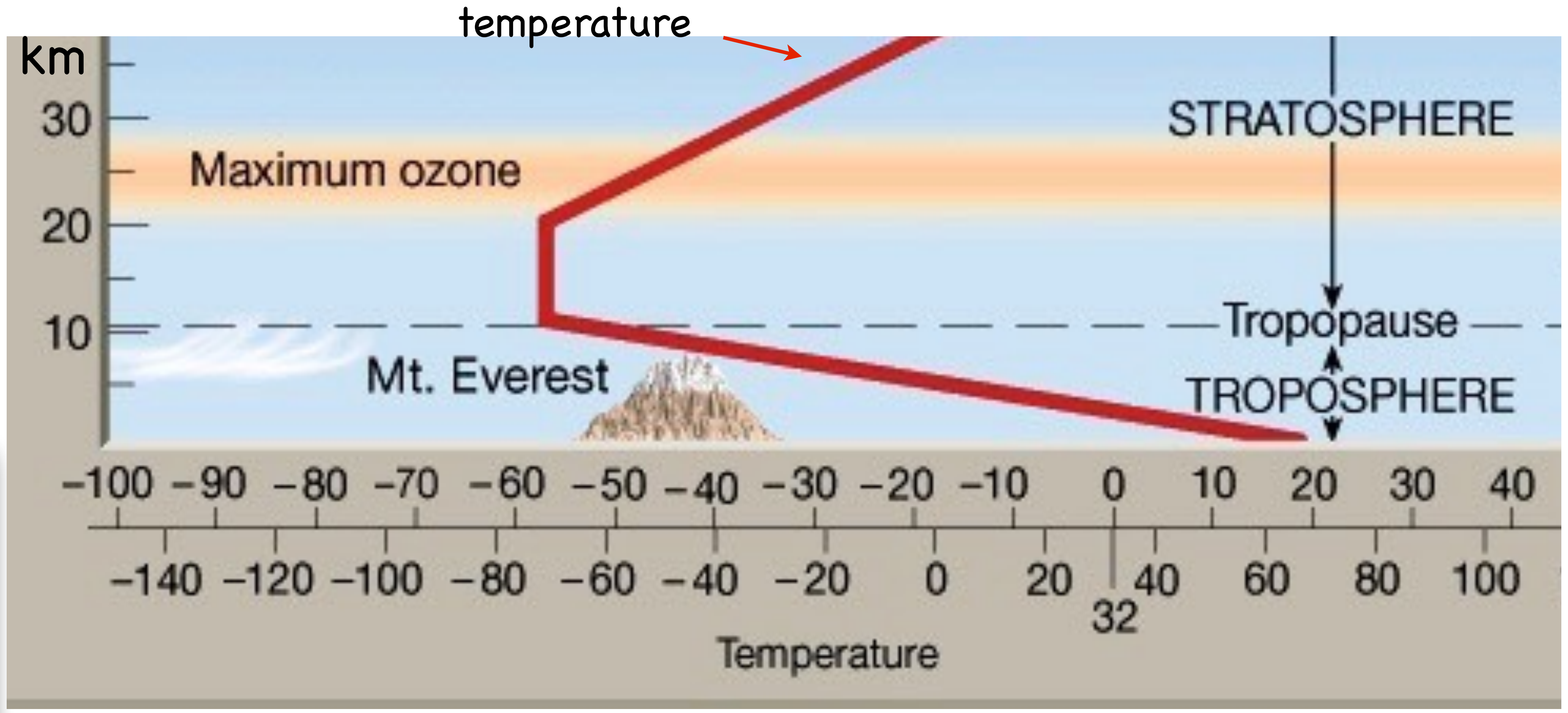
H_2O, SO_2, CO_2, HCl….

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

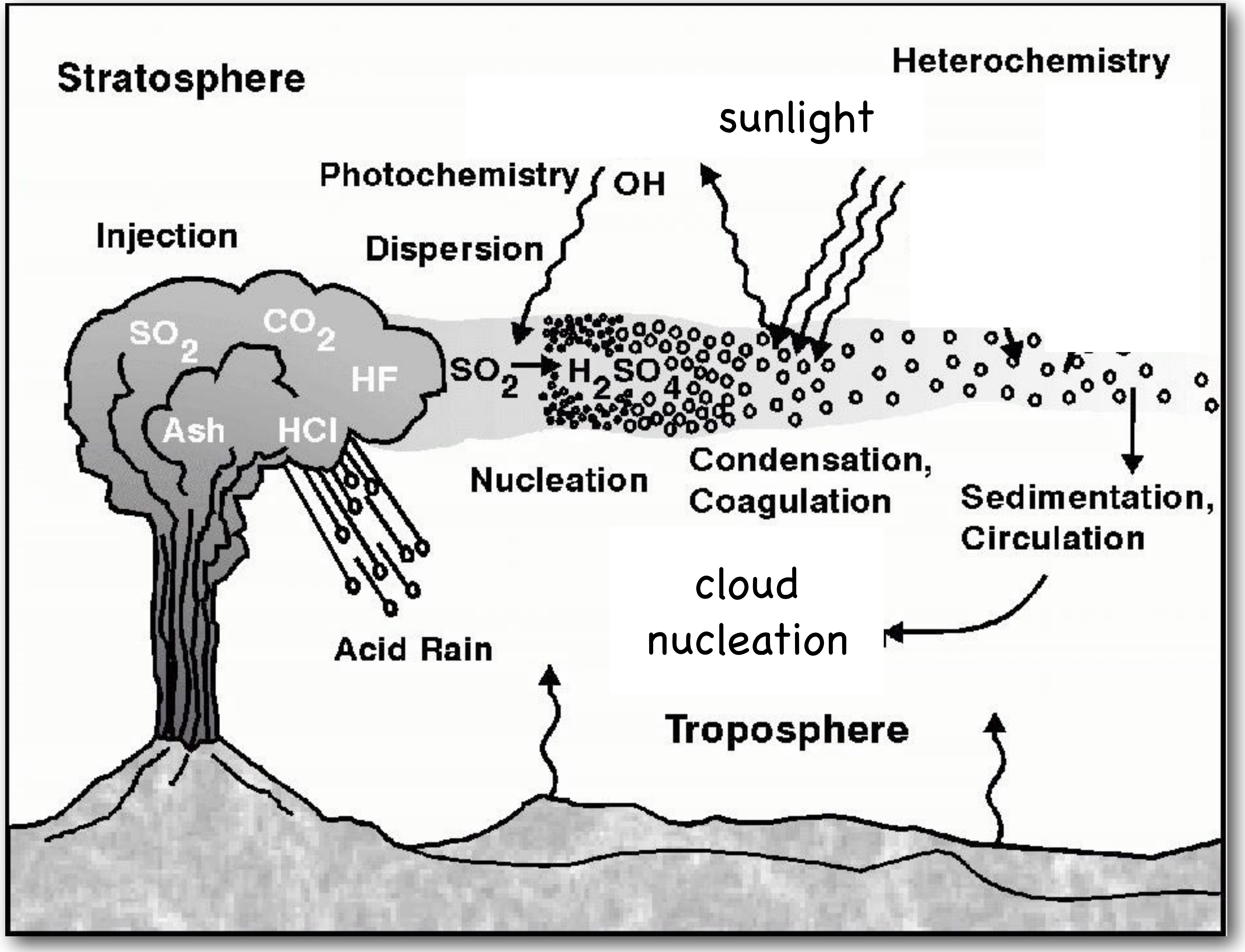


http://www.windows.ucar.edu/earth/climate/images/2atmospheres.jpg

Gases in the stratosphere



http://www.ux1.eiu.edu/~cfjps/1400/FIG01_019.JPG



http://vulcan.wr.usgs.gov/Imgs/Jpg/Projects/Emissions/fsheet_fig1.jpg

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

Volcanic Gases

Volcanoes are sources of dissolved gases

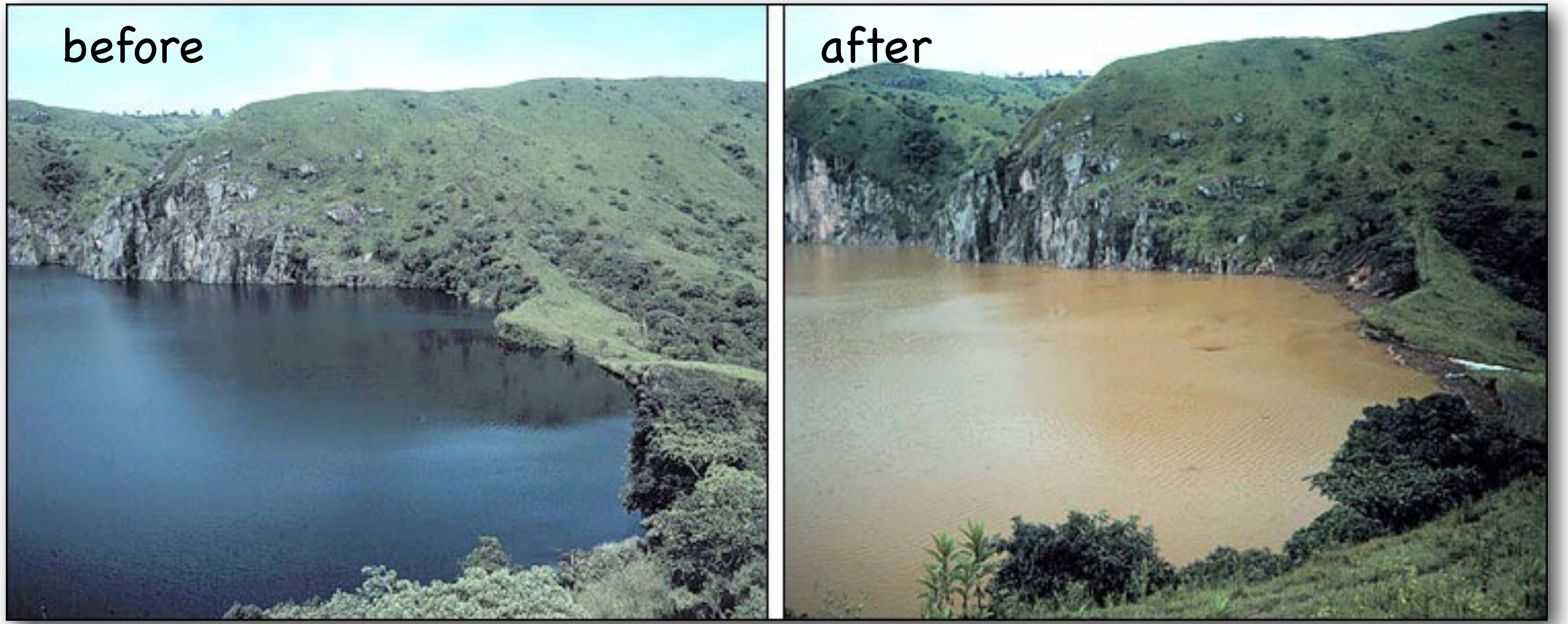
H_2O, SO_2, CO_2, HCl….

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

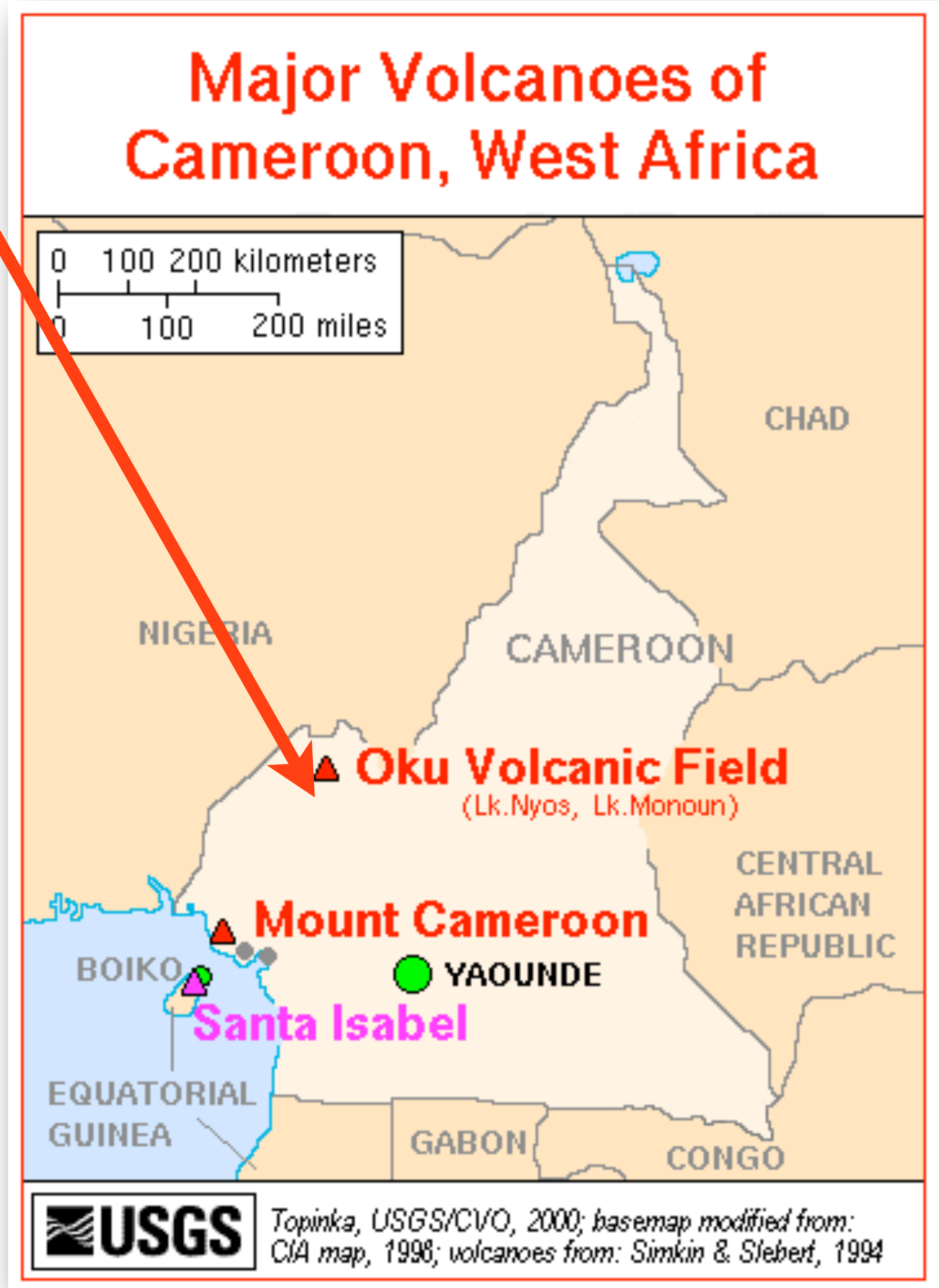
When they collect at the bottom of lakes, this can become disastrous!

Volcanic Gases

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



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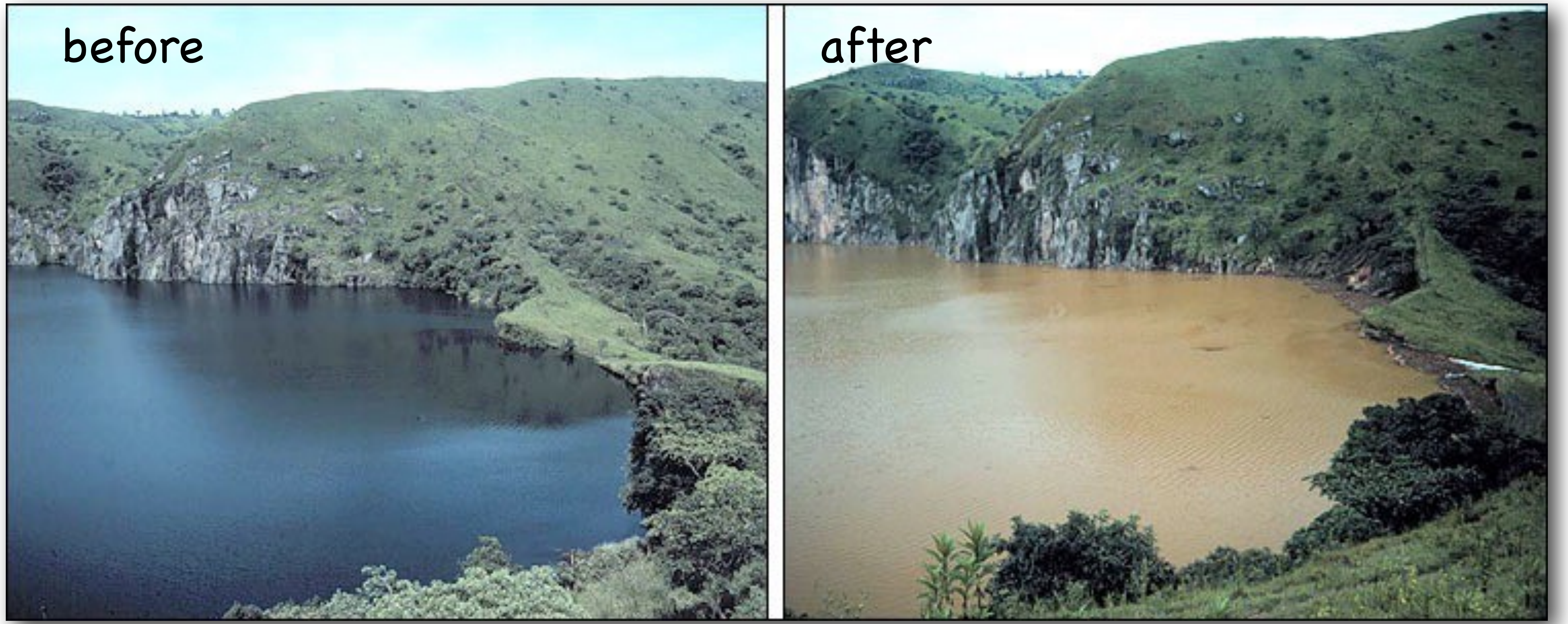

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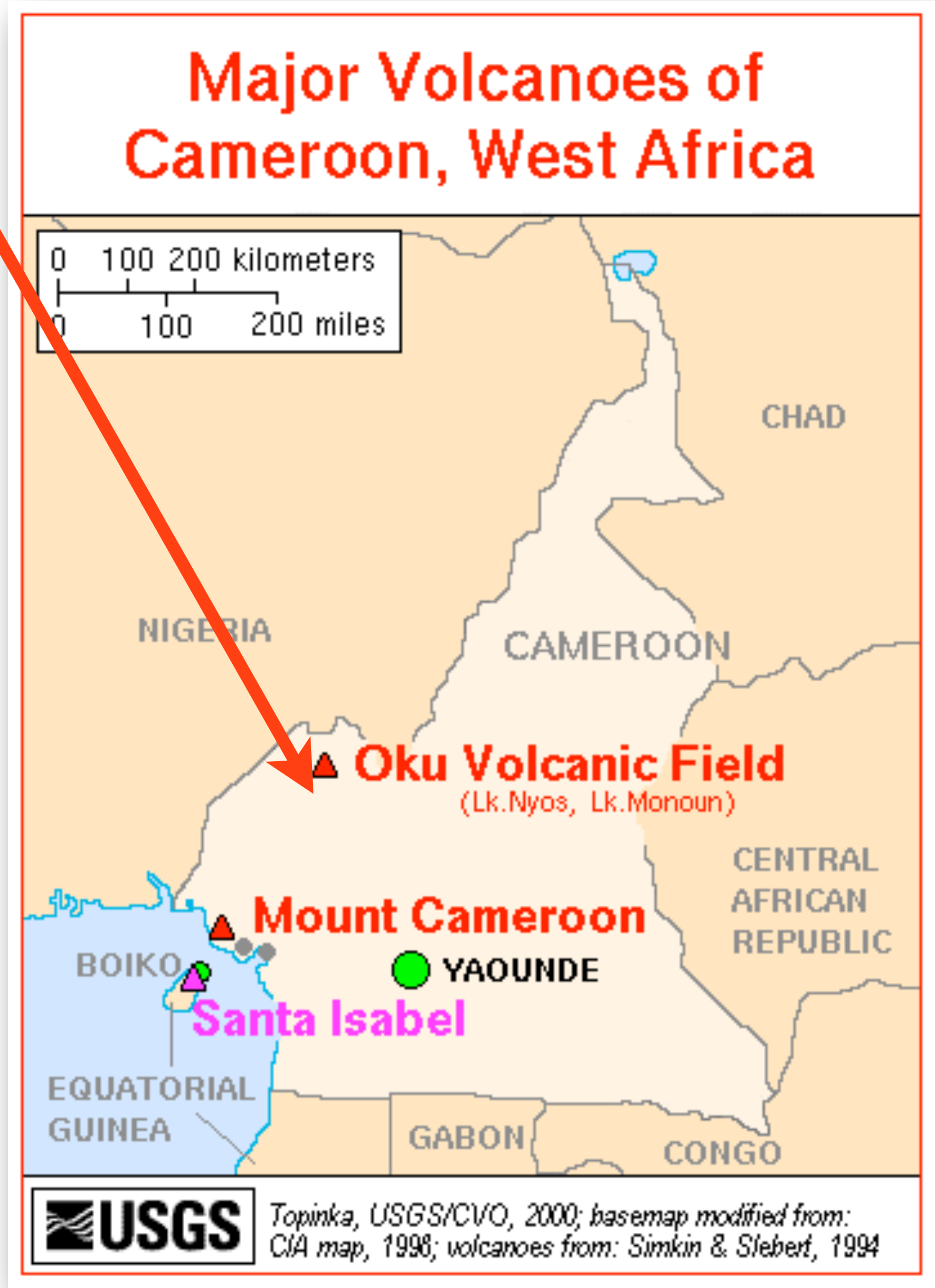
Over 1,800 people and thousands of animals found asphyxiated



Volcanic Gases

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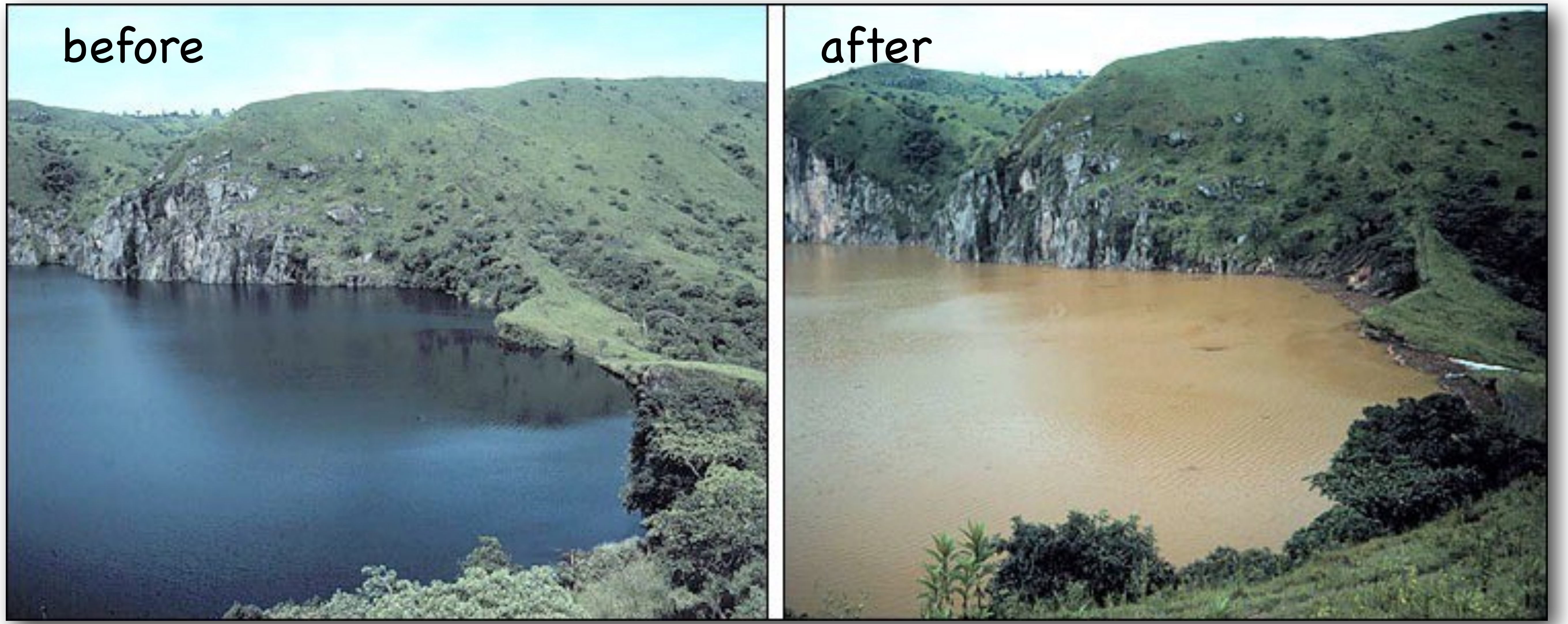

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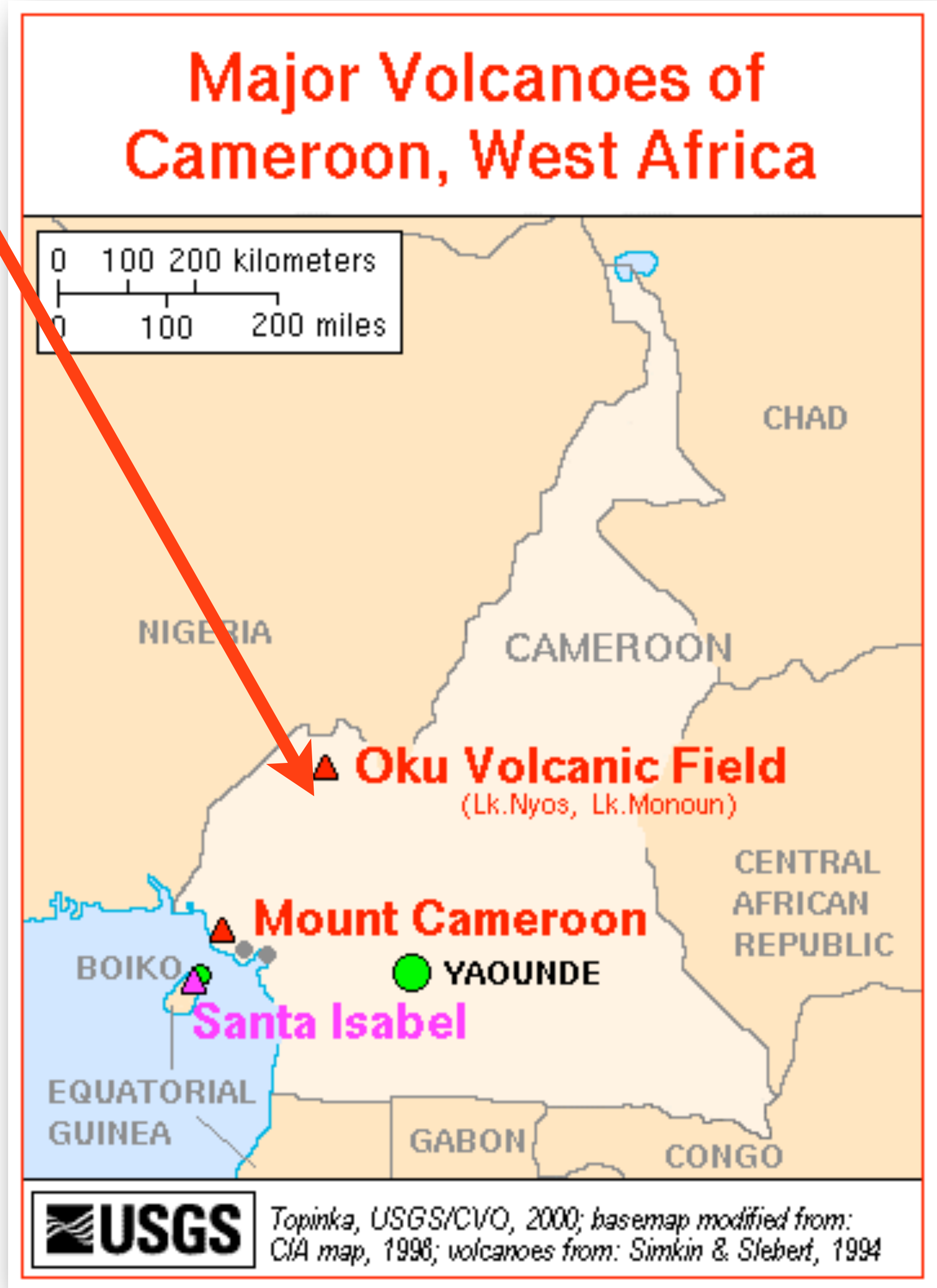

Over 1,800 people and thousands of animals found asphyxiated

No property or vegetation damage

Volcanic Gases

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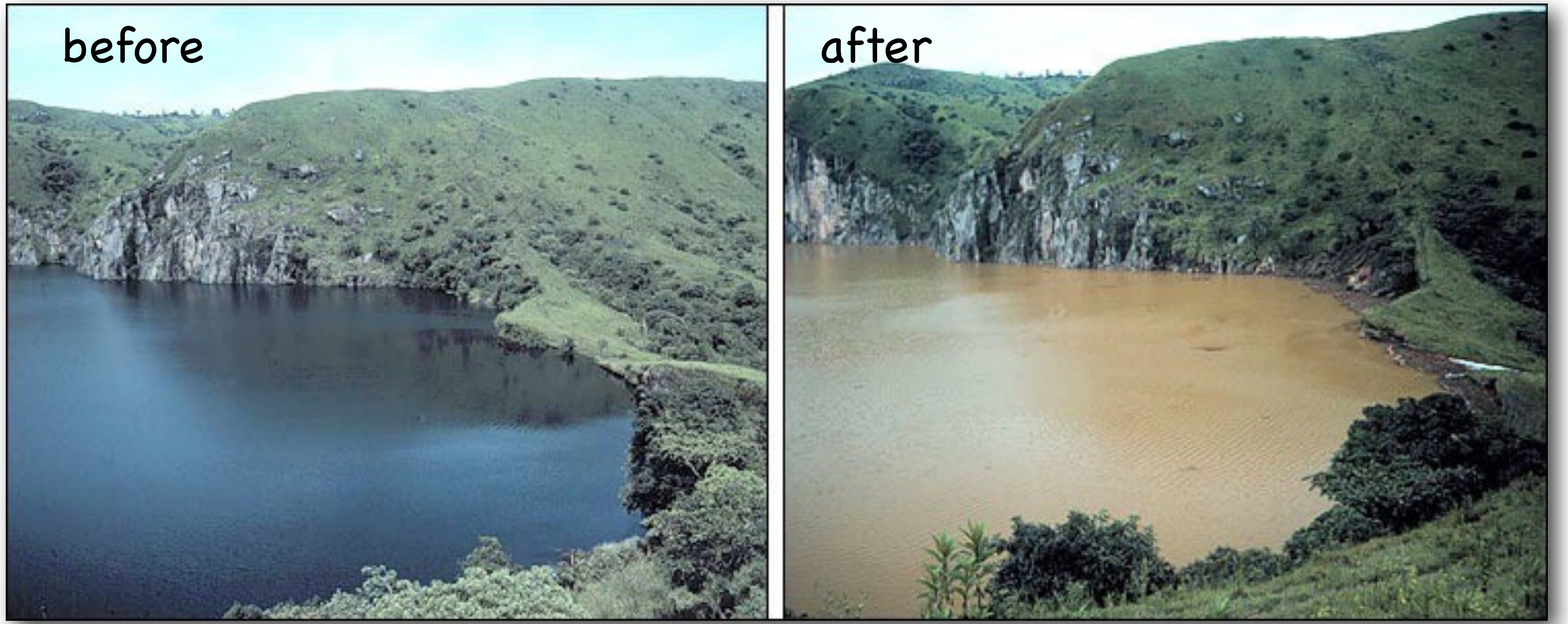

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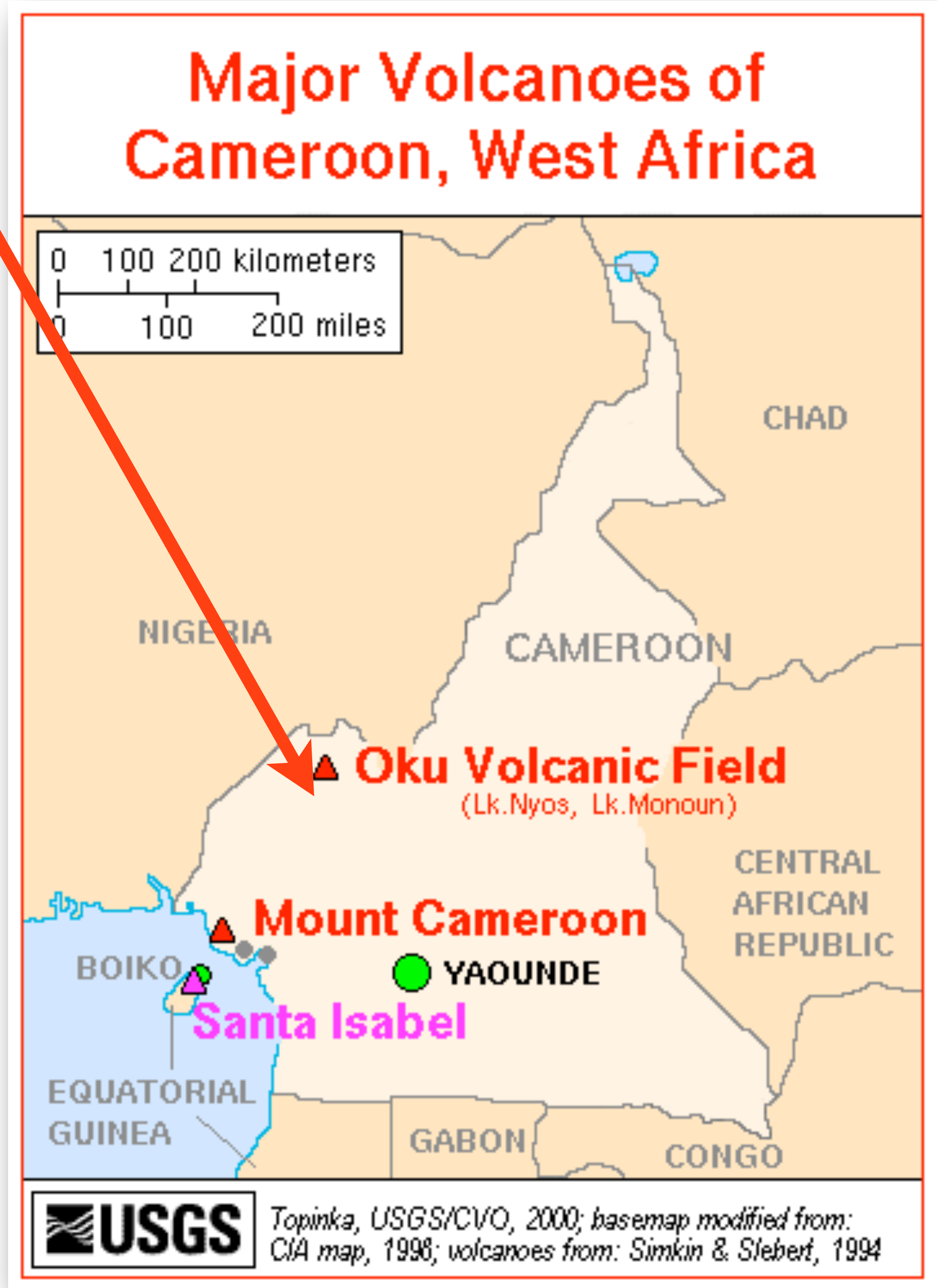

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No property or vegetation damage

What happened?

Volcanic Gases

http://i.ehow.com/images/GlobalPhoto/Articles/5259929/300px-DietCokeMentos-main_Full.jpg

dissolved CO_2 under pressure
is perfectly safe....

http://img.youtube.com/vi/uFzz5c_VvIk/0.jpg

Volcanic Gases

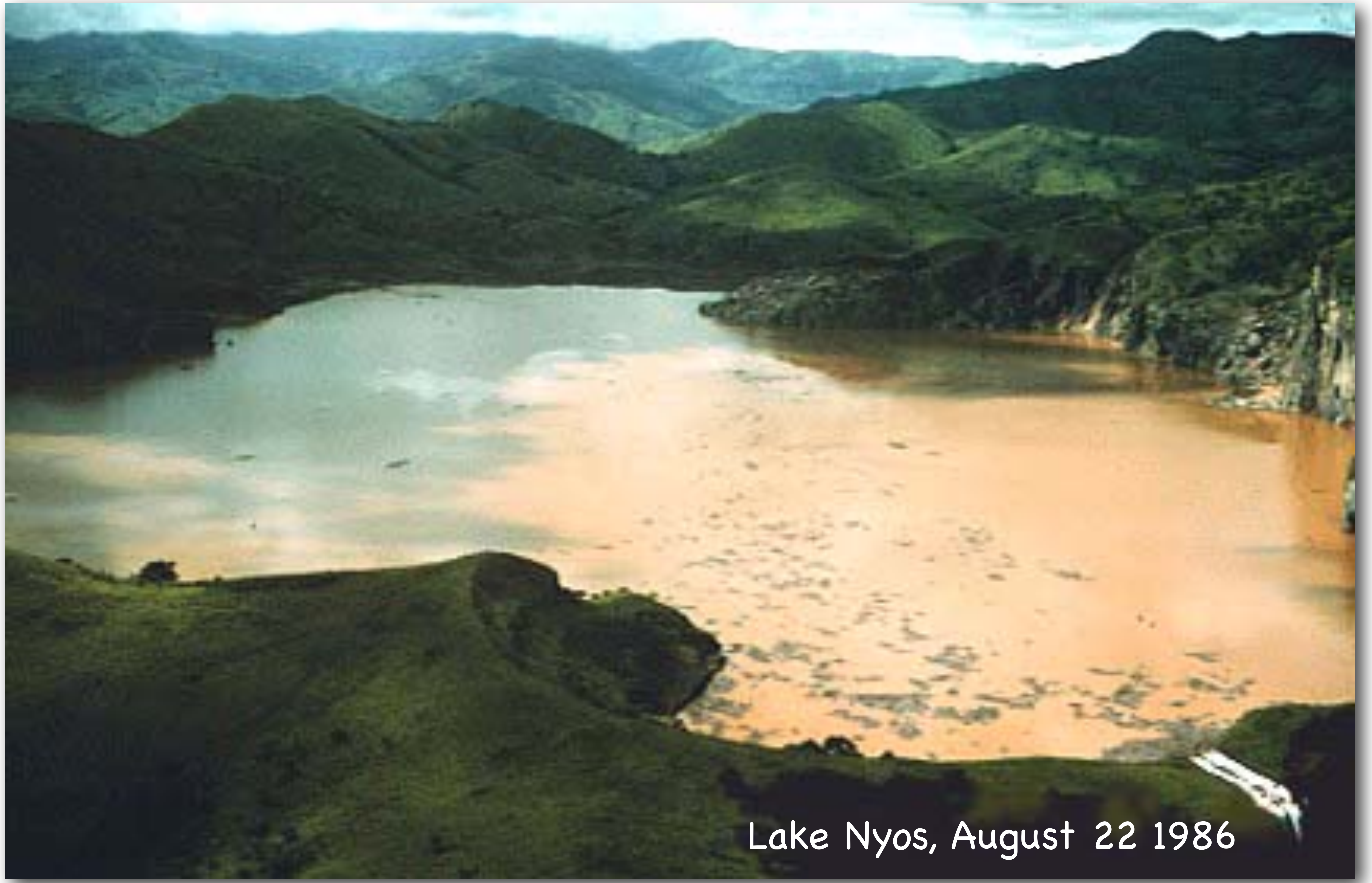
http://i.ehow.com/images/GlobalPhoto/Articles/5259929/300px-DietCokeMentos-main_Full.jpg

dissolved CO_2 under pressure
is perfectly safe....

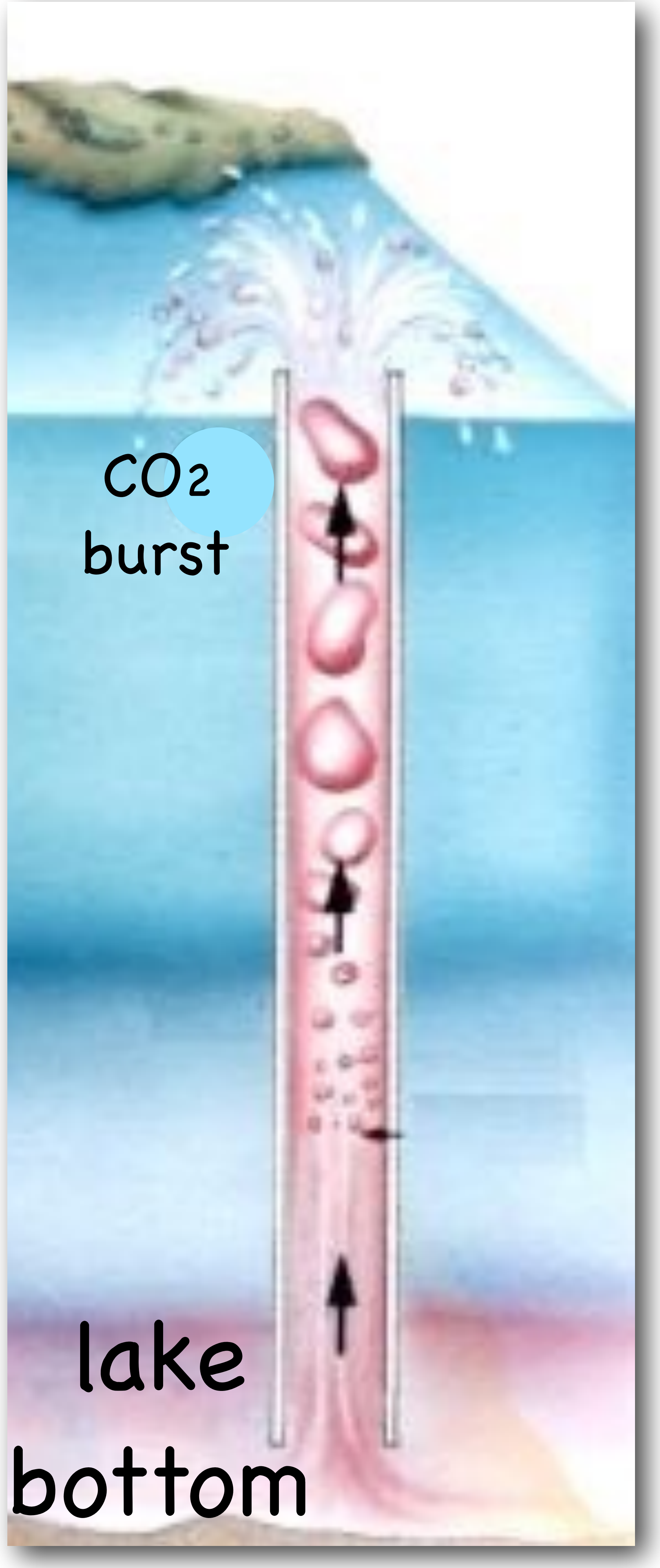
http://img.youtube.com/vi/uFzz5c_VvIk/0.jpg

...but if too much CO_2 or if something disturbs the equilibrium,
get a sudden burst of gas release

Volcanic Gases

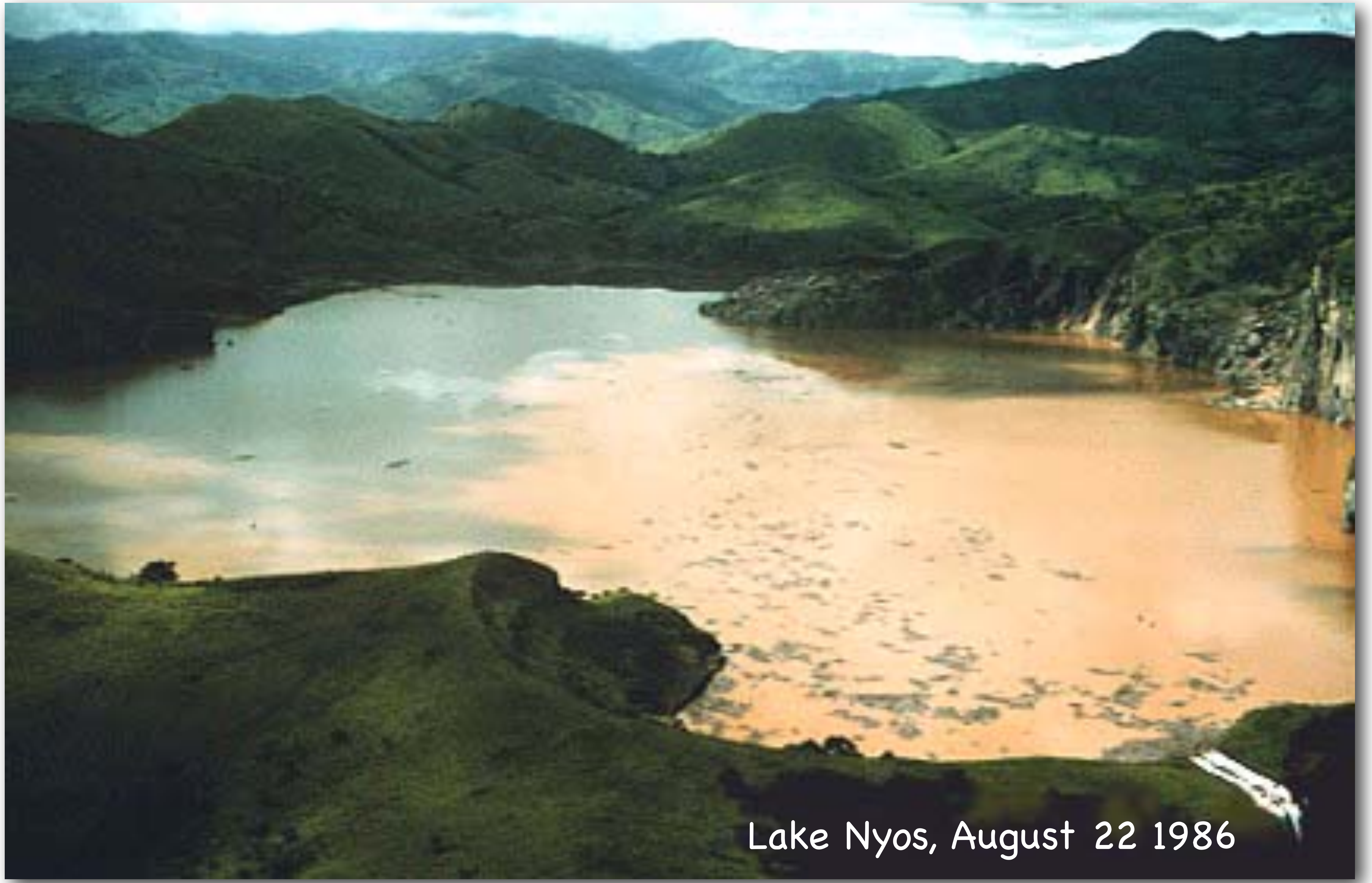


http://www.hprcc.unl.edu/nebraska/Lake_Nyos.jpg



Sudden burst of dissolved CO_2 from the bottom of Lake Nyos blanketed the area in deadly, odorless gas

Volcanic Gases



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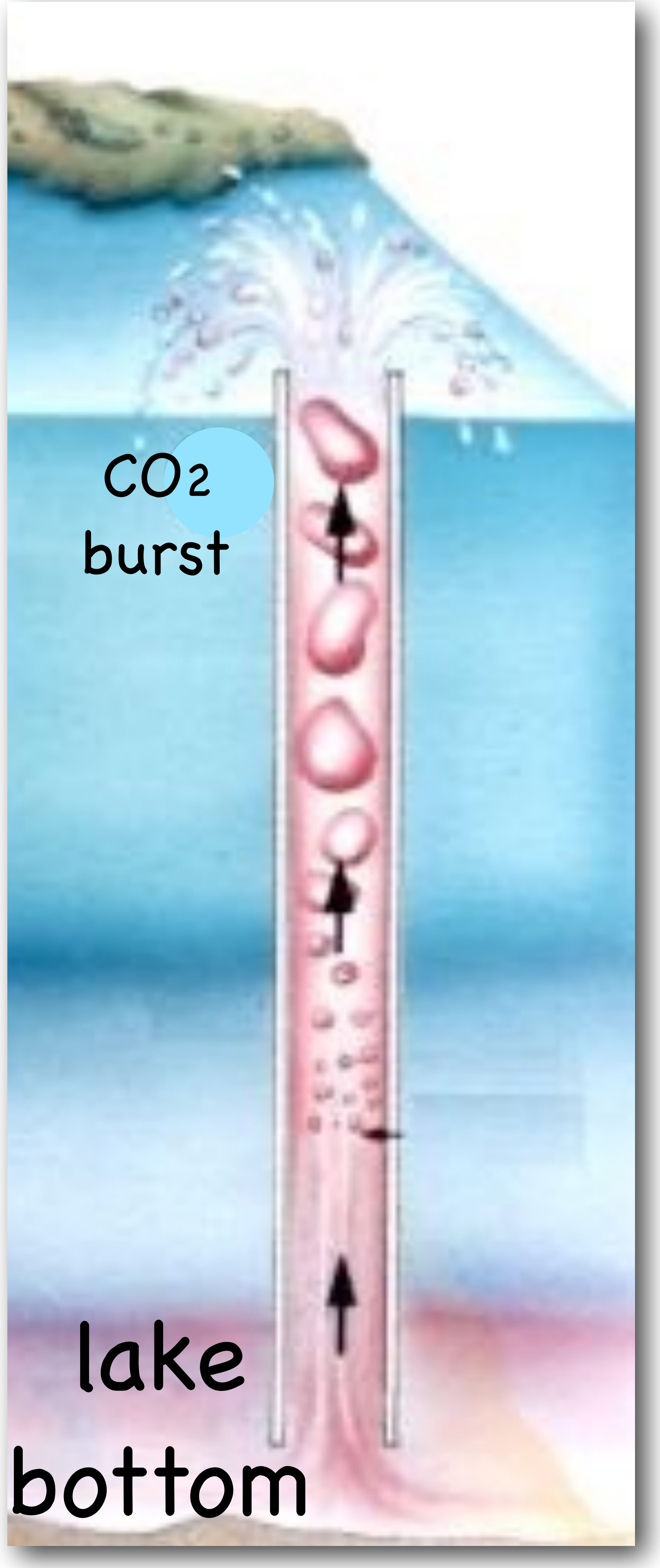
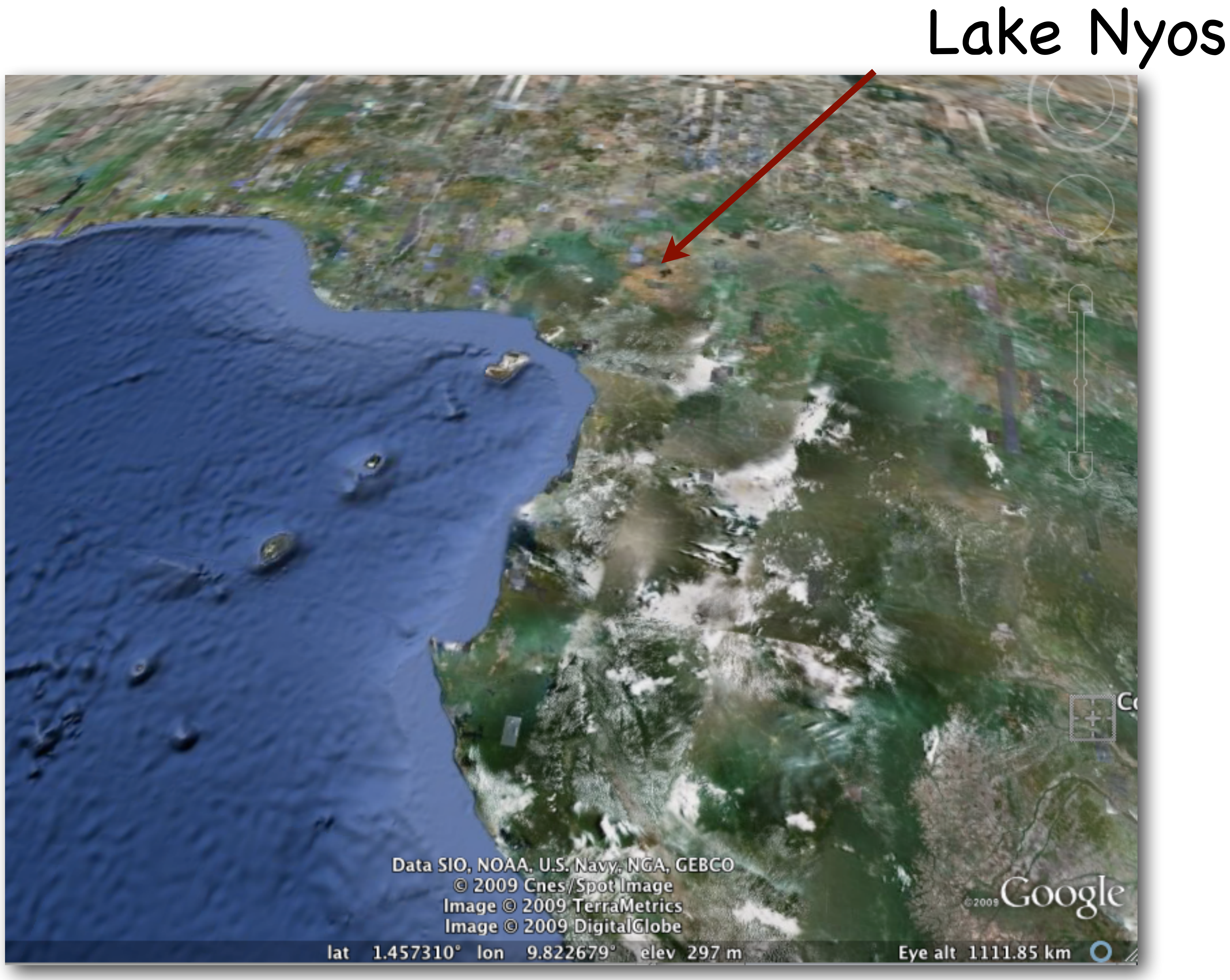


Sudden burst of dissolved CO_2 from the bottom of Lake Nyos blanketed the area in deadly, odorless gas

Why here?

Volcanic Gases

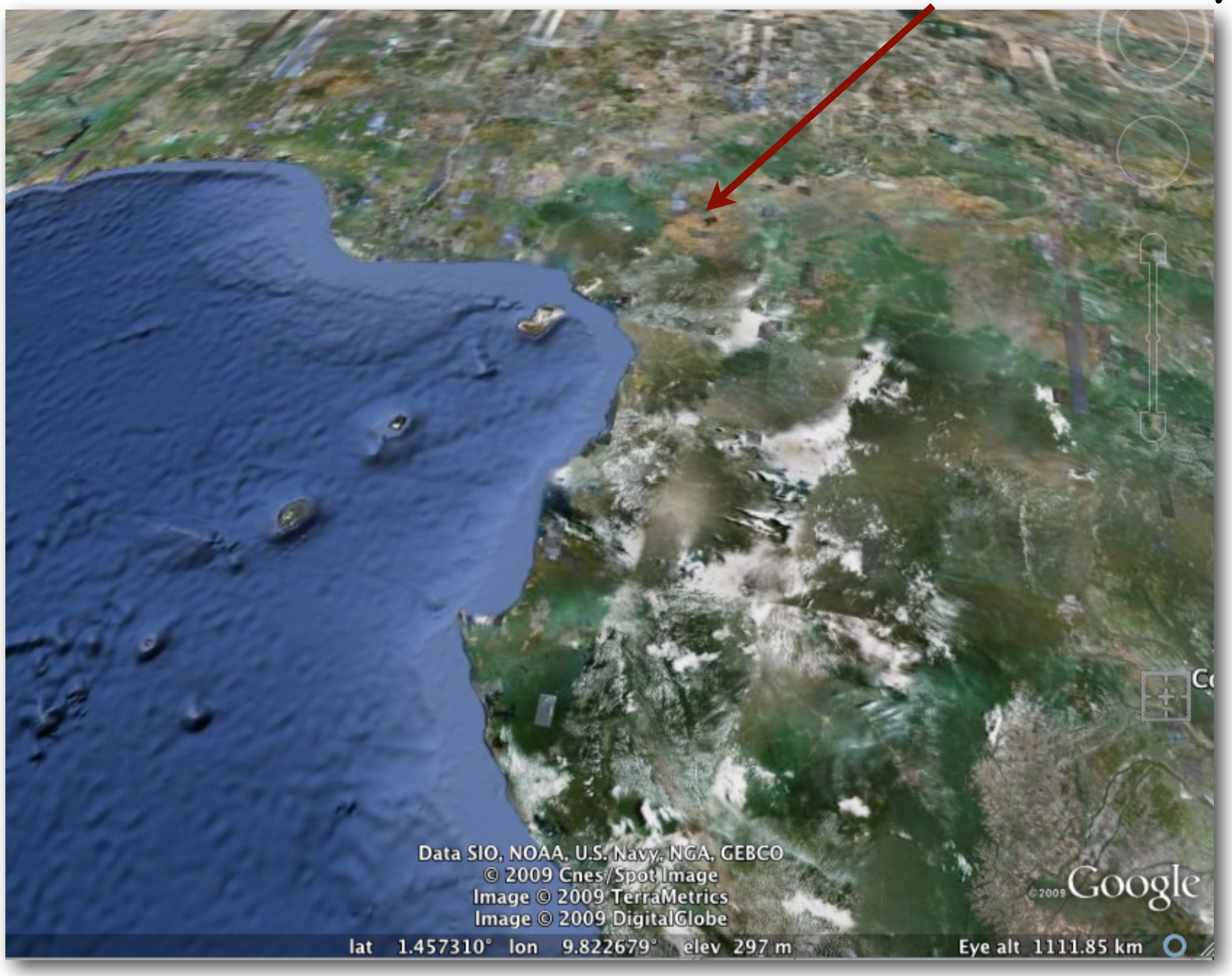
Is Cameroon on a plate boundary?



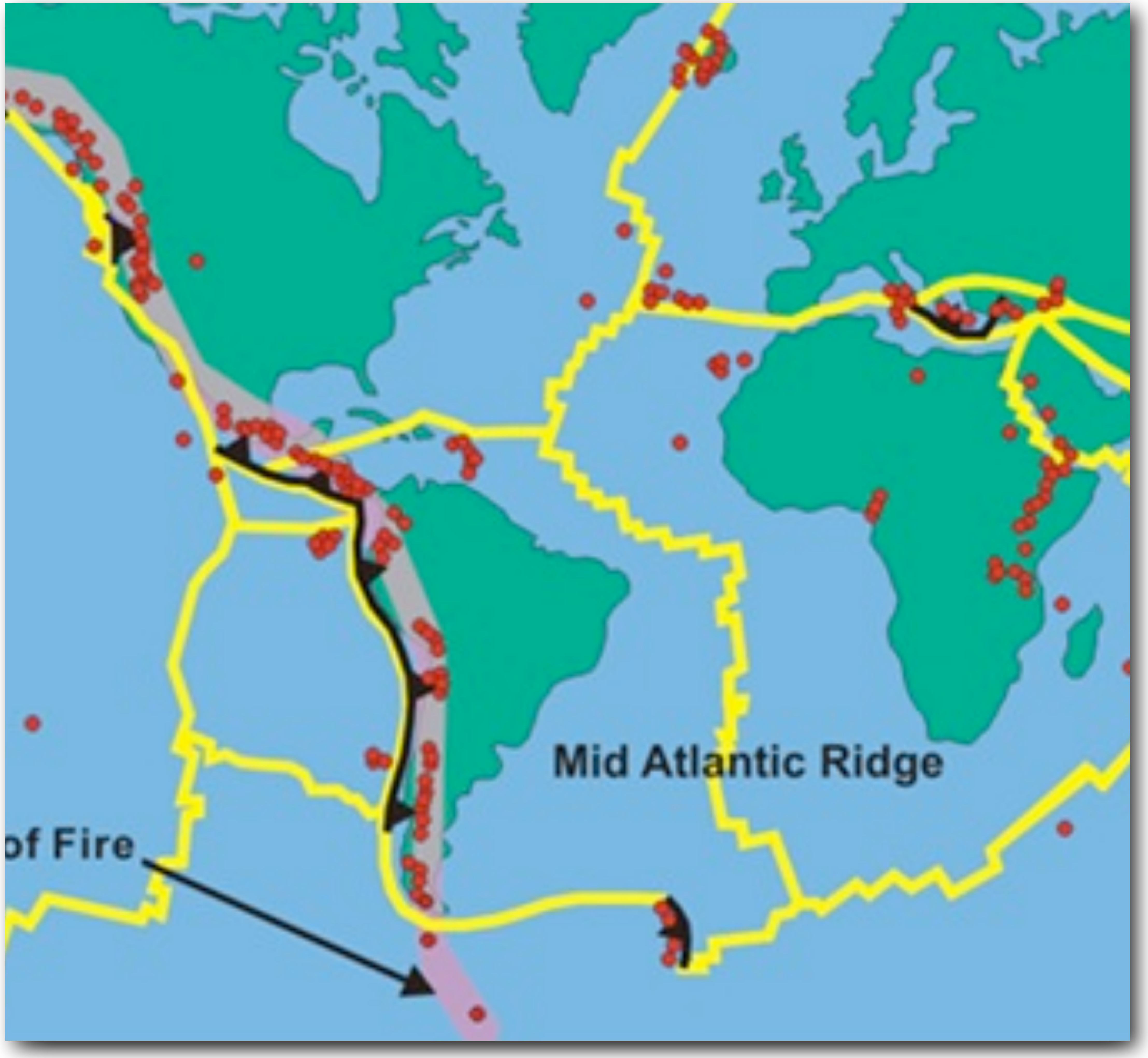
Volcanic Gases

Is Cameroon on a plate boundary?

Lake Nyos

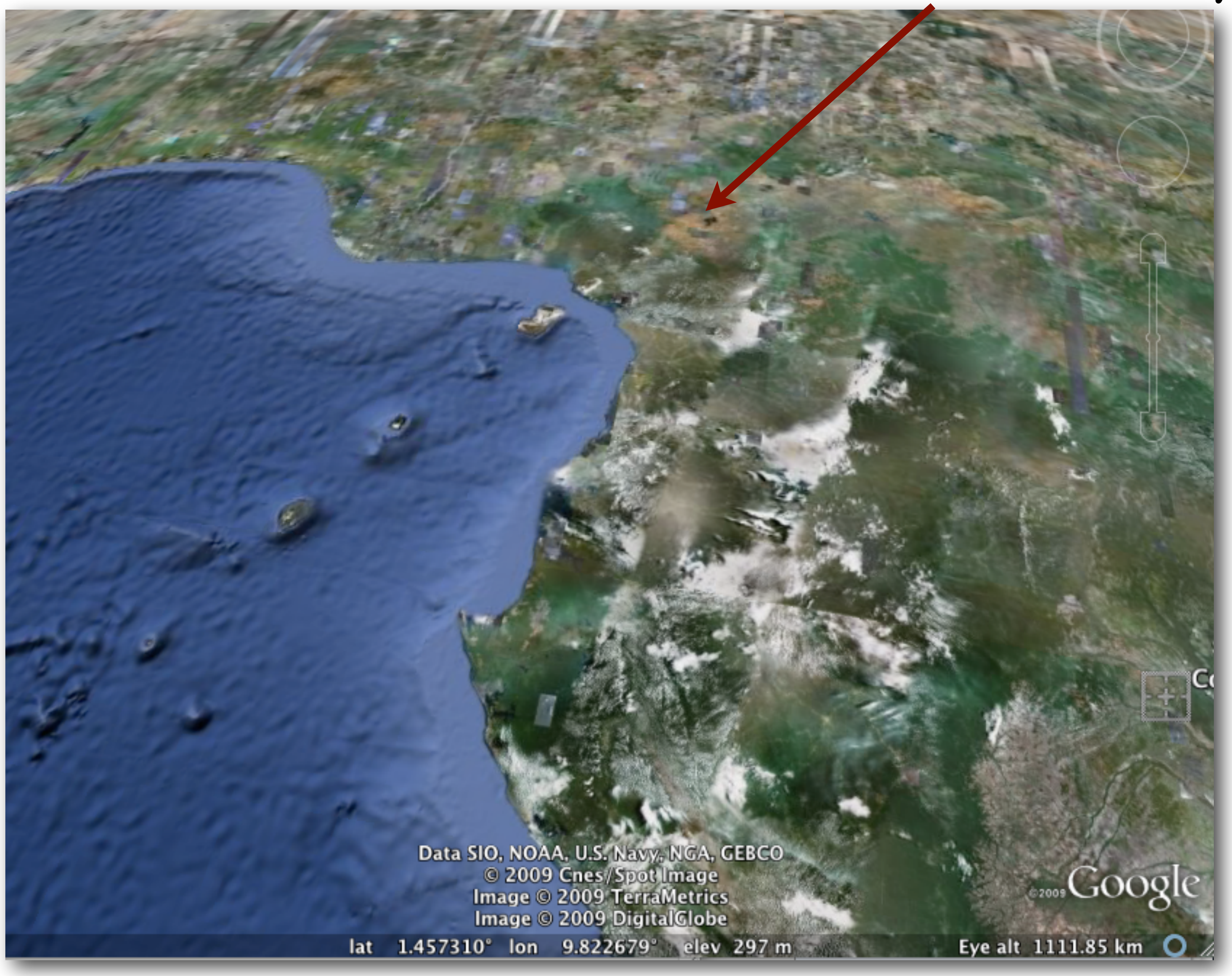


Volcanic Gases

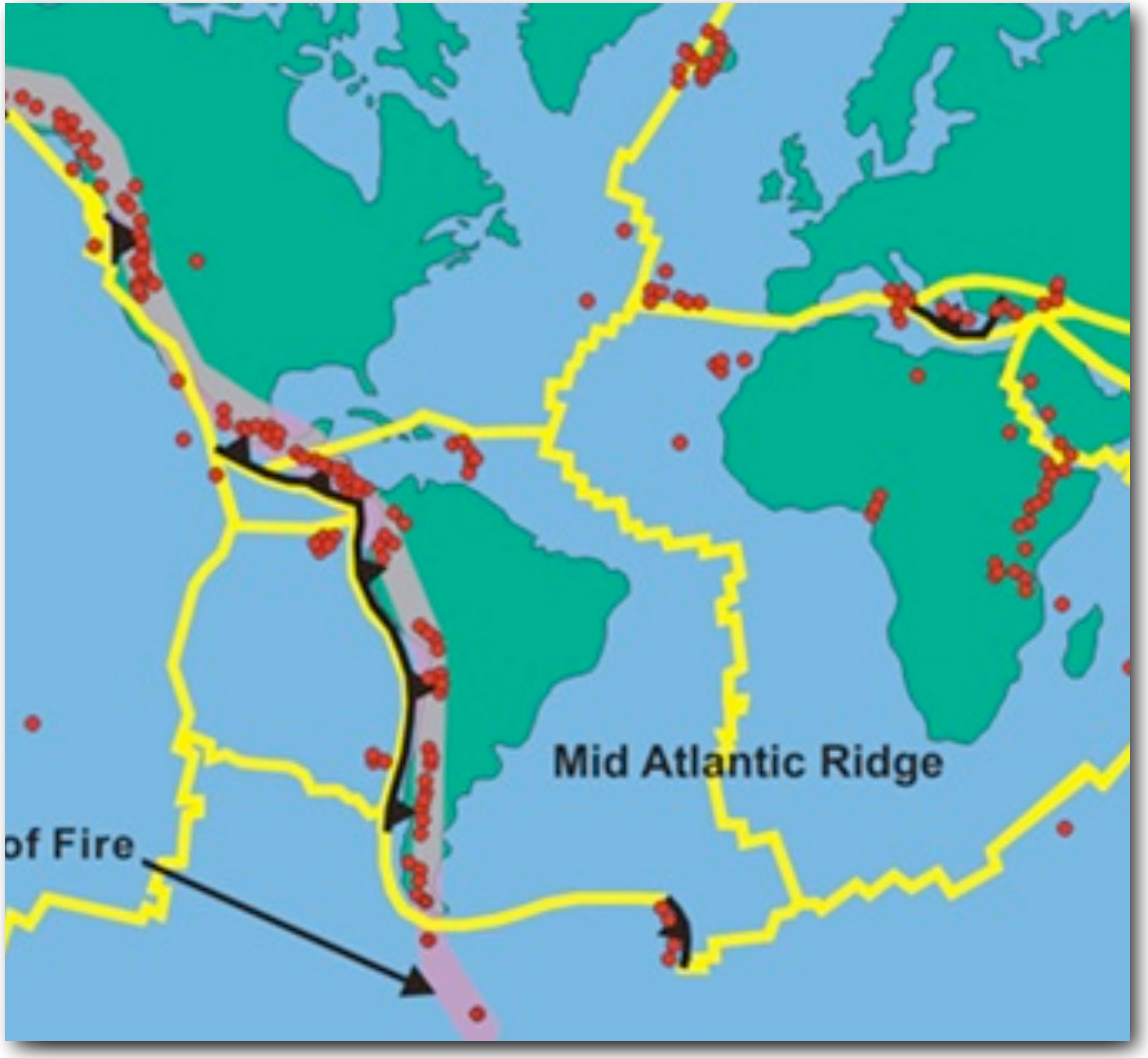


Is Cameroon on a plate boundary?

Lake Nyos



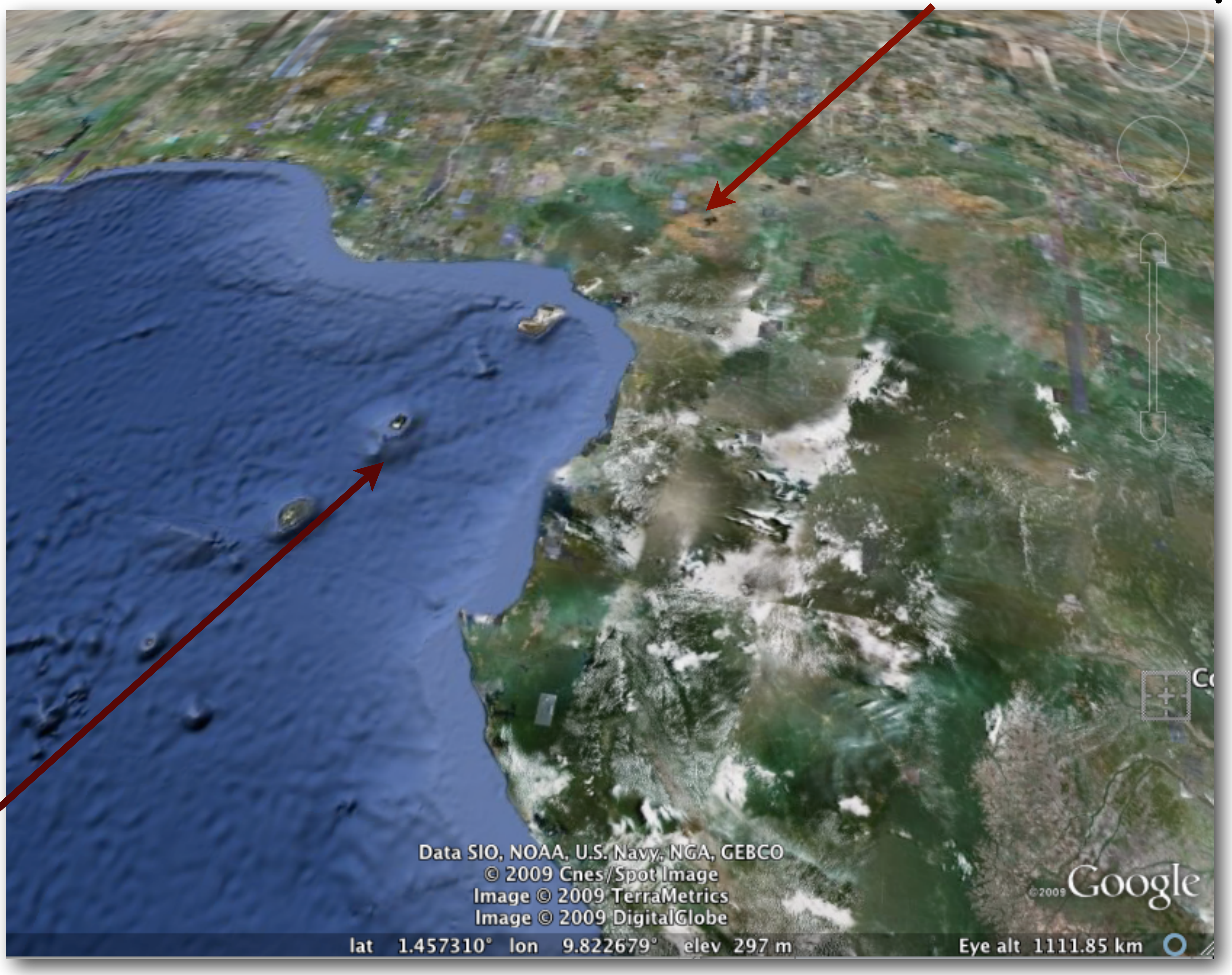
Volcanic Gases



What does this string of volcanic islands remind you of?

Is Cameroon on a plate boundary?

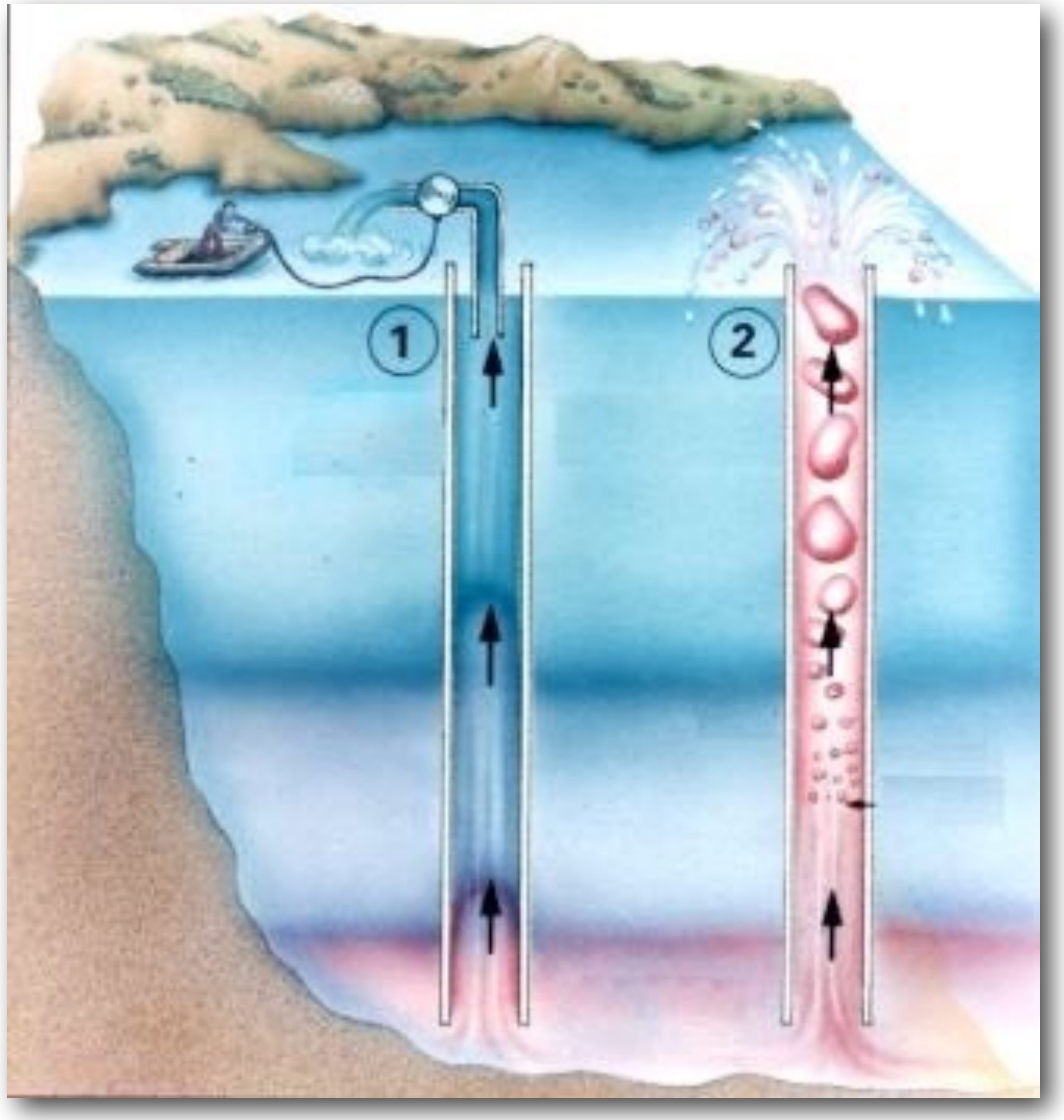
Lake Nyos



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

Mitigating future volcanic gas eruptions

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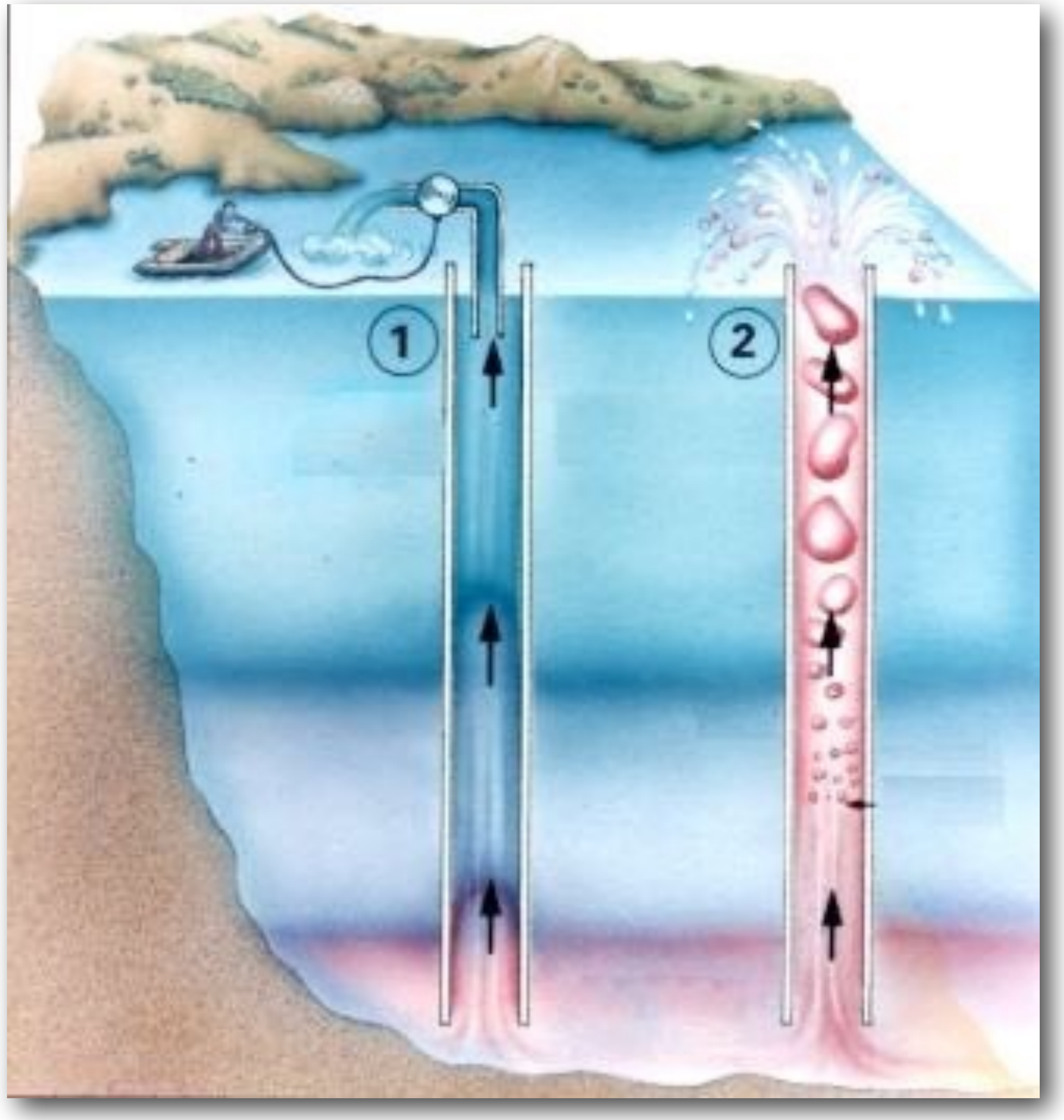

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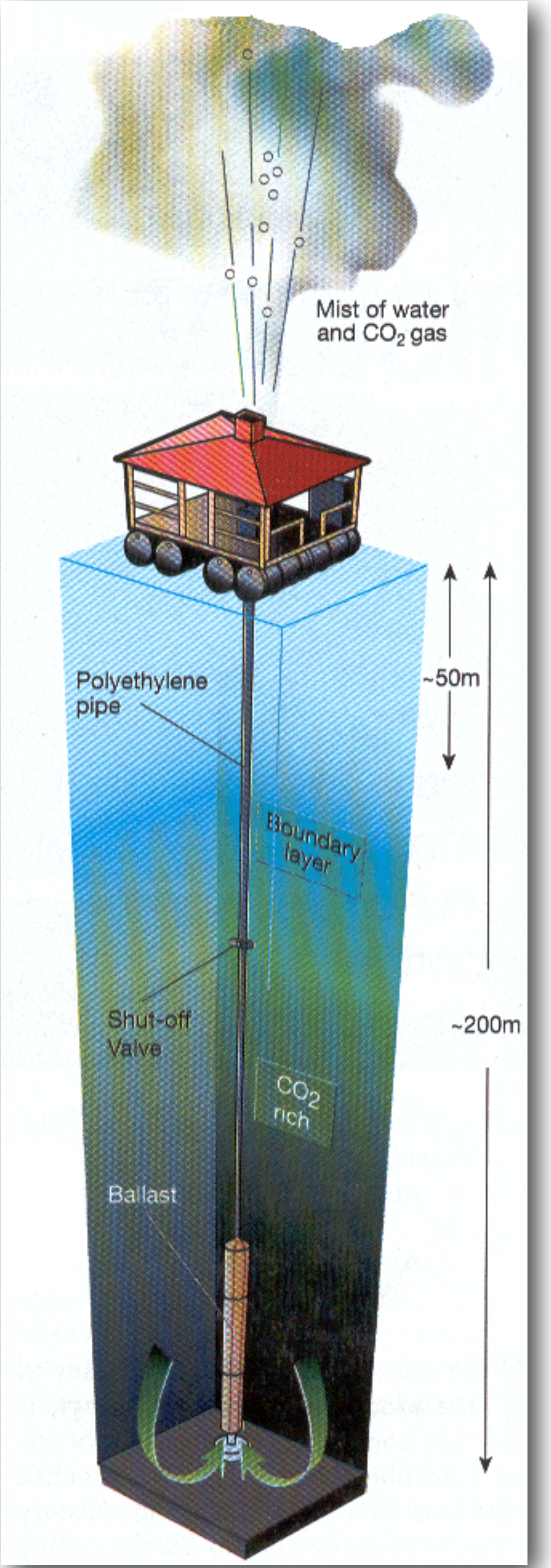
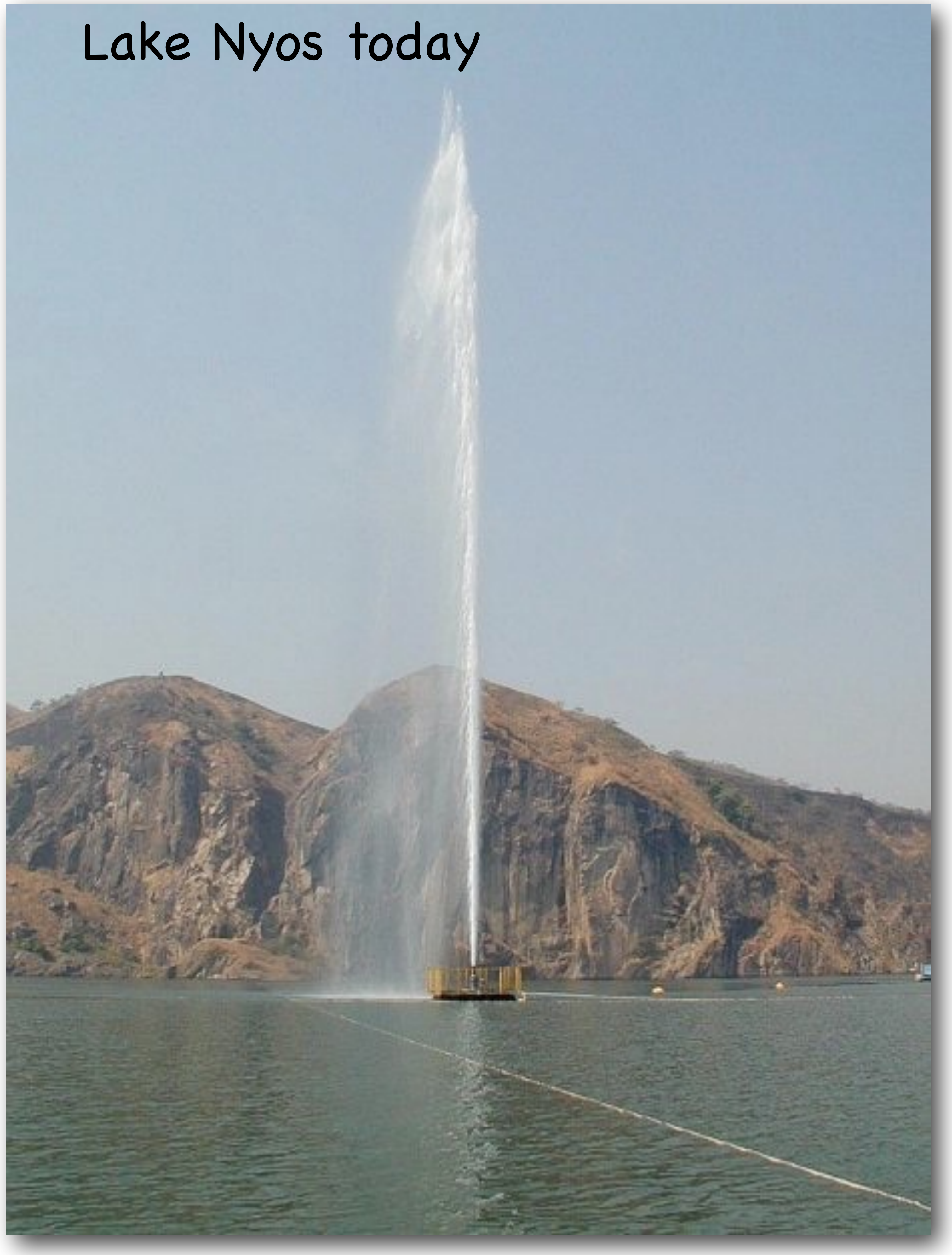


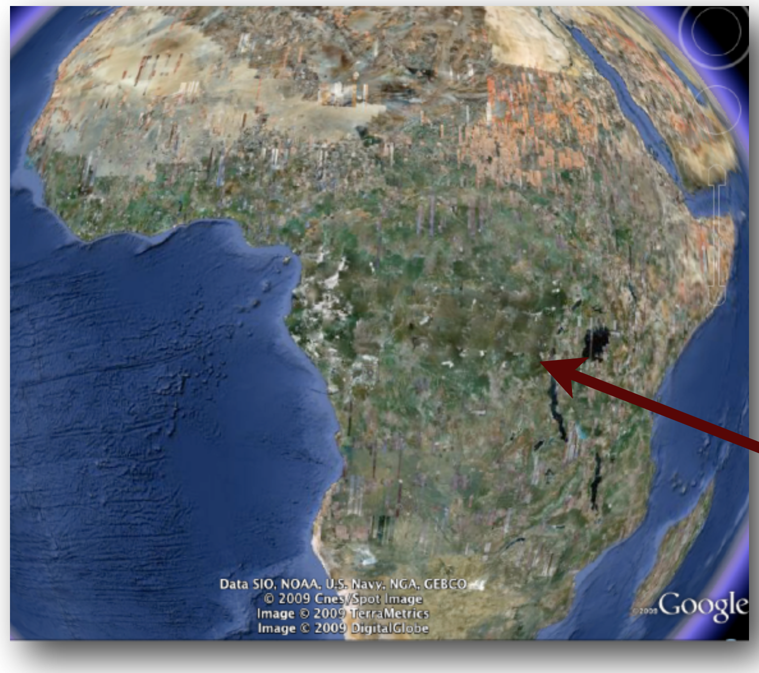
http://records.viu.ca/~earles/nyos-degasser.gif



http://www.ulb.ac.be/sciences/cvl/Big%20jet%20from%20boat_2.jpg

Volcanic Gases

Lake Nyos is not the only one...

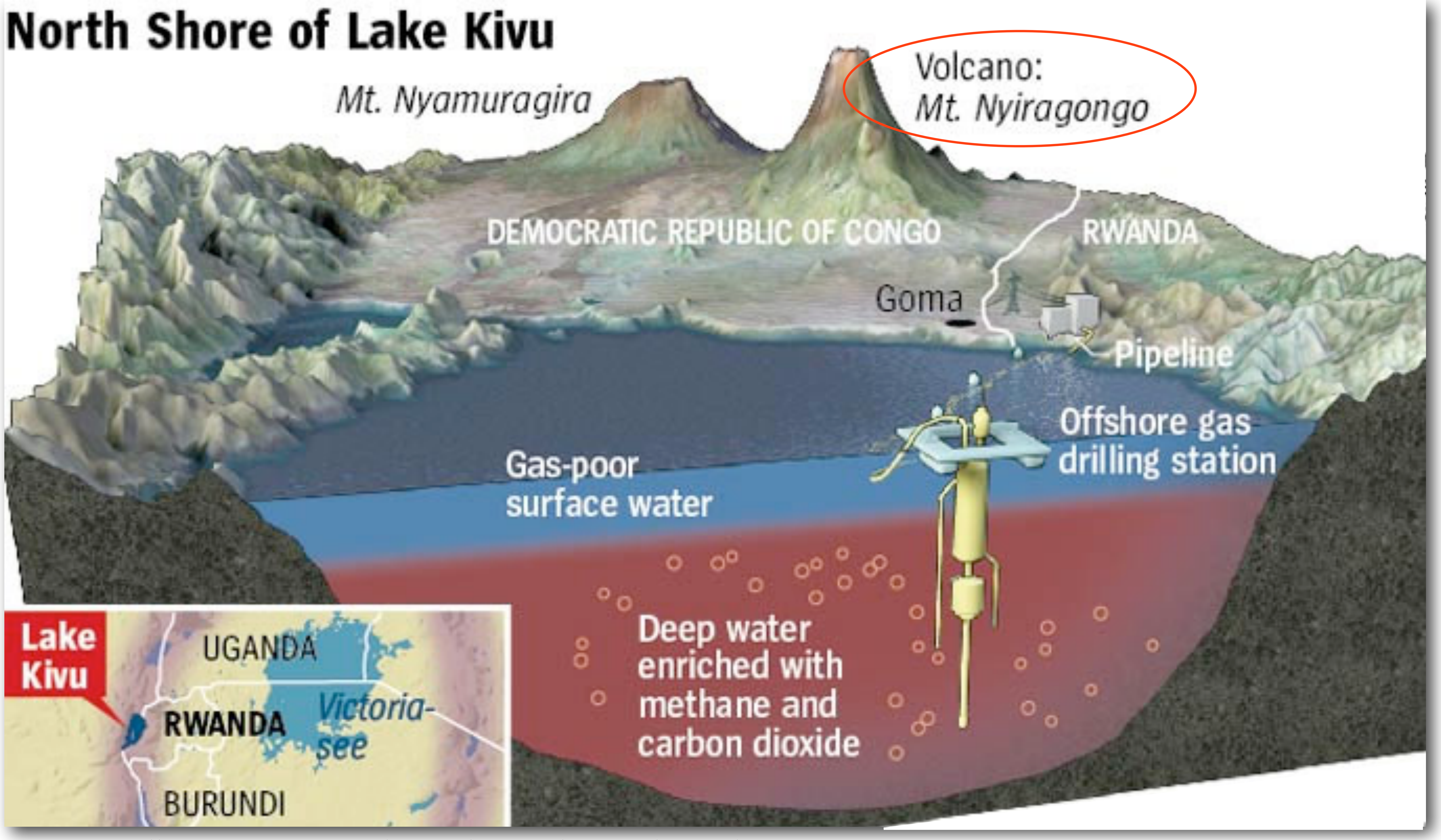


http://dodoingoma.files.wordpress.com/2007/10/058-destruction-of-goma-town-by-nyiragongo-volcano2-kopie.jpg

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

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)

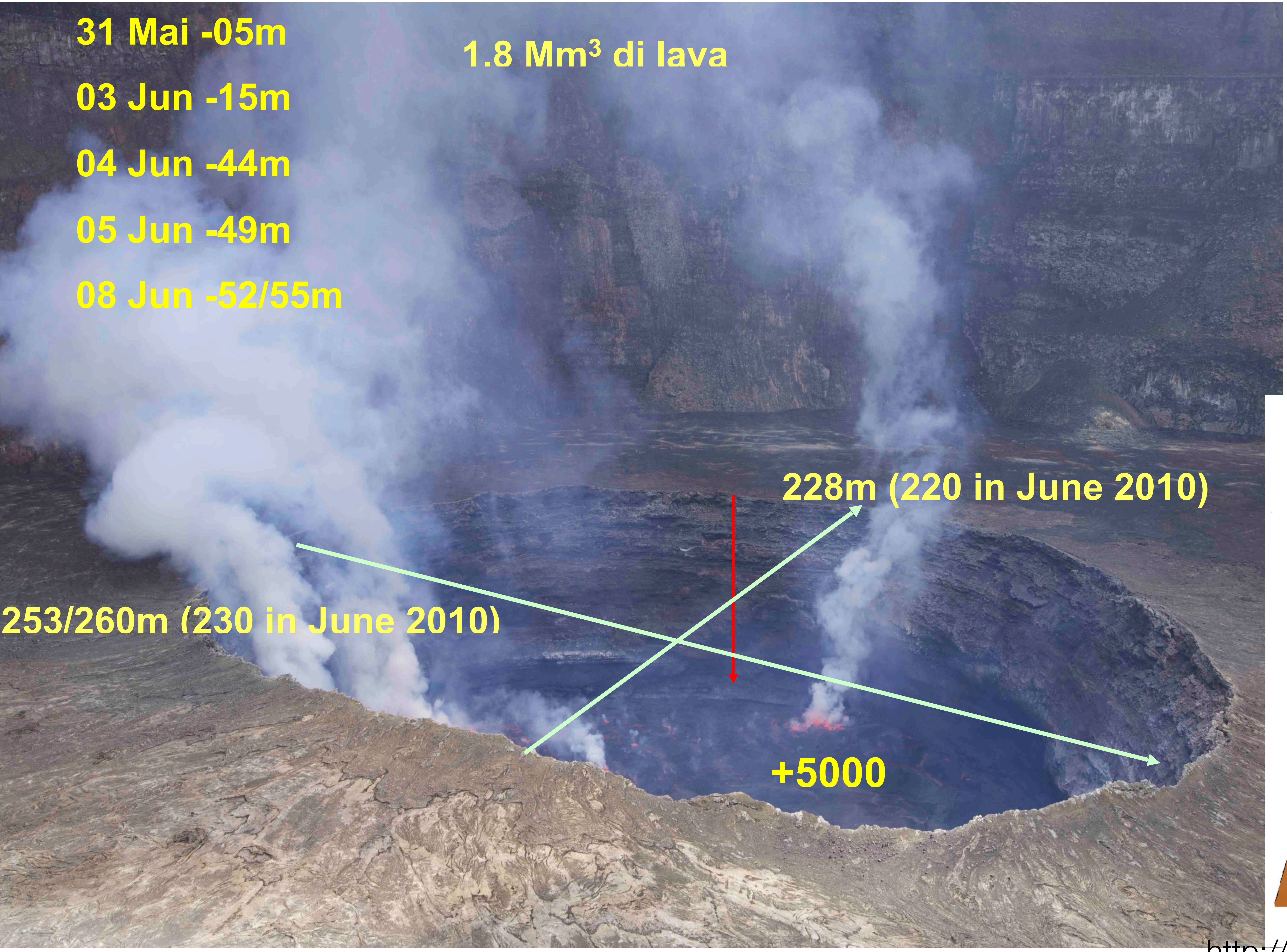
Goma Volcano Observatory (DRC)

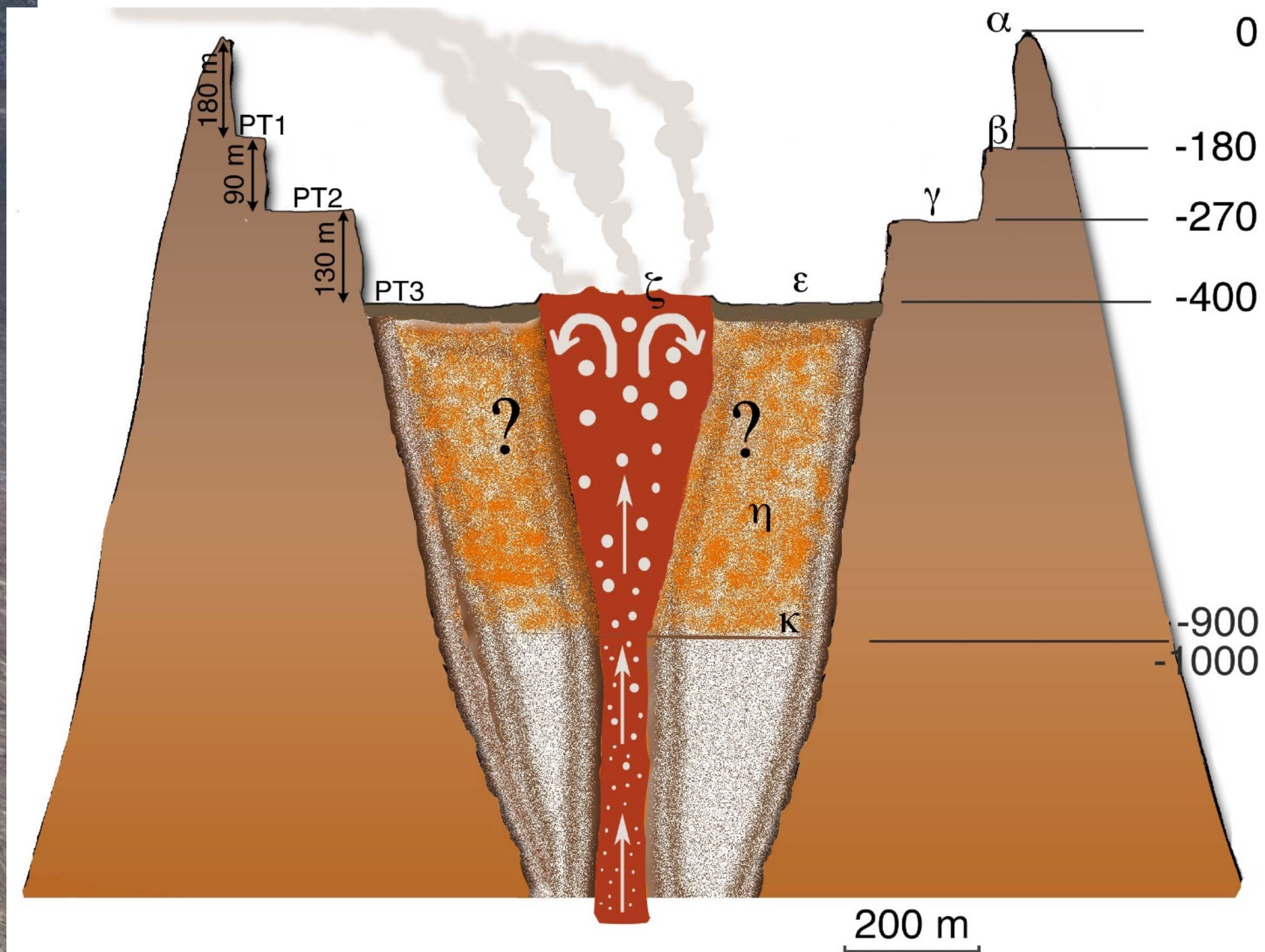
Dario Tedesco

http://www.geohazcop.org/workshops/Sant_Feliu_2011/

Several recent eruptions have cause a lot of damage in Goma

http://www.geohazcop.org/workshops/Sant_Feliu_2011/





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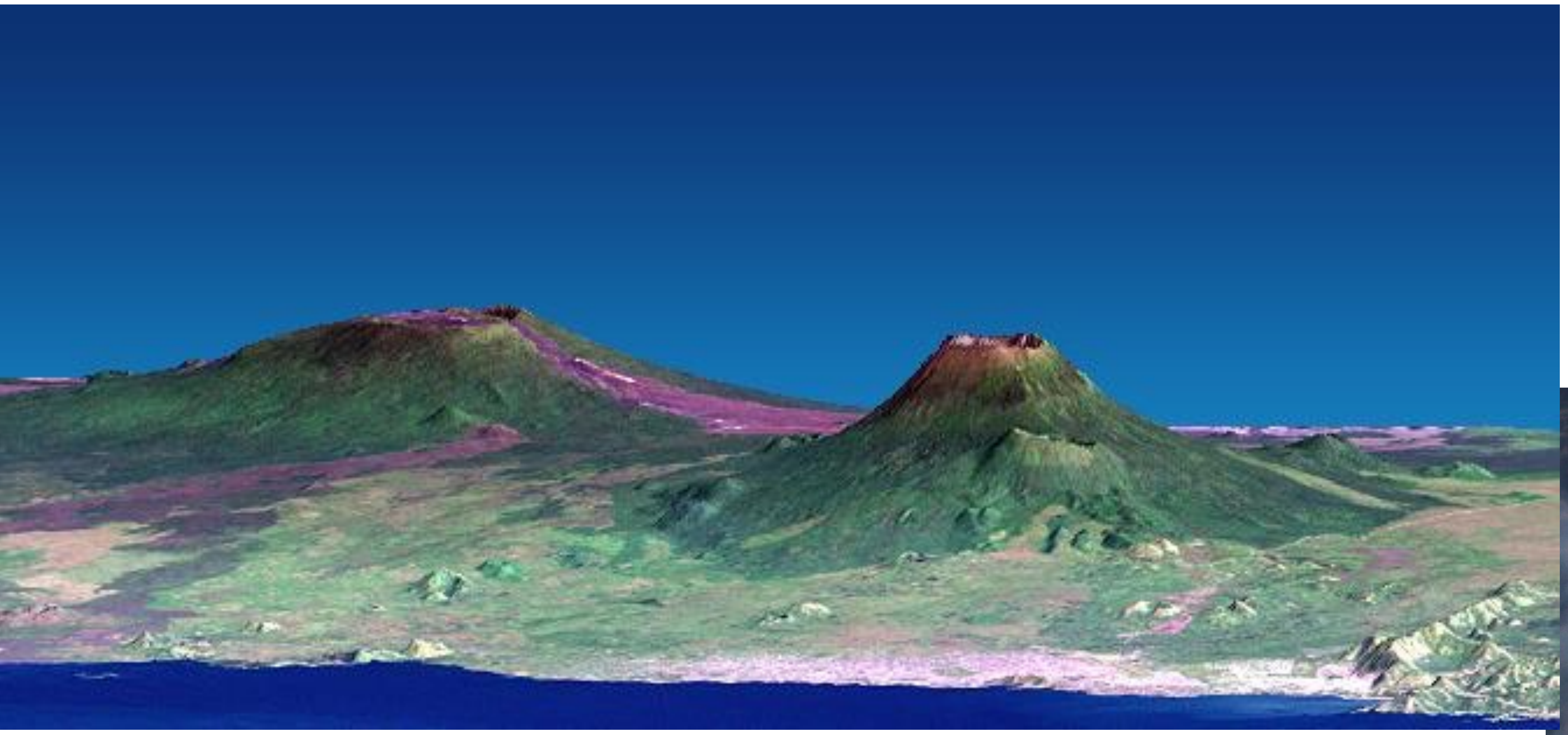
Volcanic Gases



Nyamuragira (left) and Nyiragongo (right)

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

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.

Natural Hazards and Disaster

MITIGATION & ADAPTATION RESEARCH INSTITUTE
MARI
OLD DOMINION UNIVERSITY

Class 6: Volcanoes

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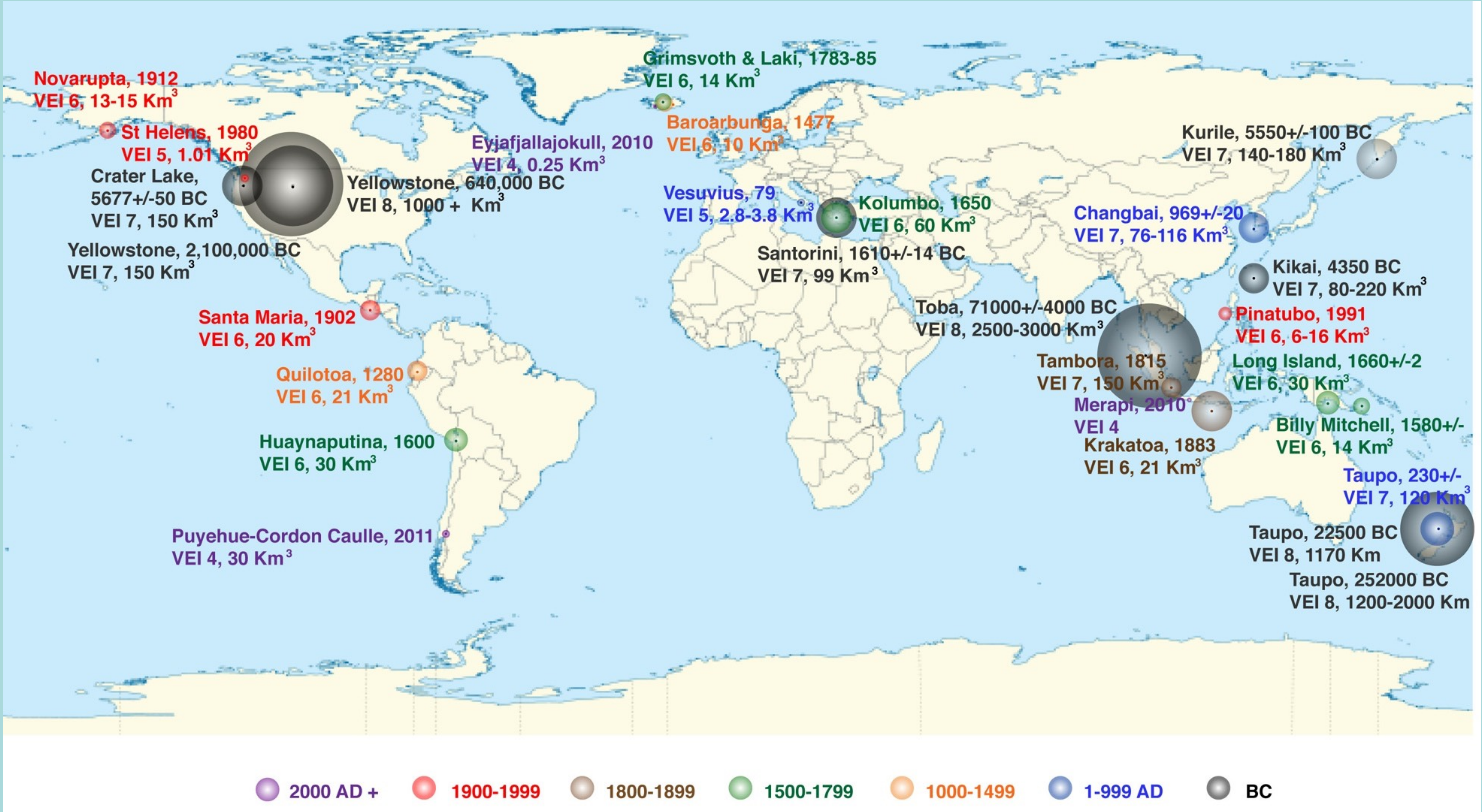
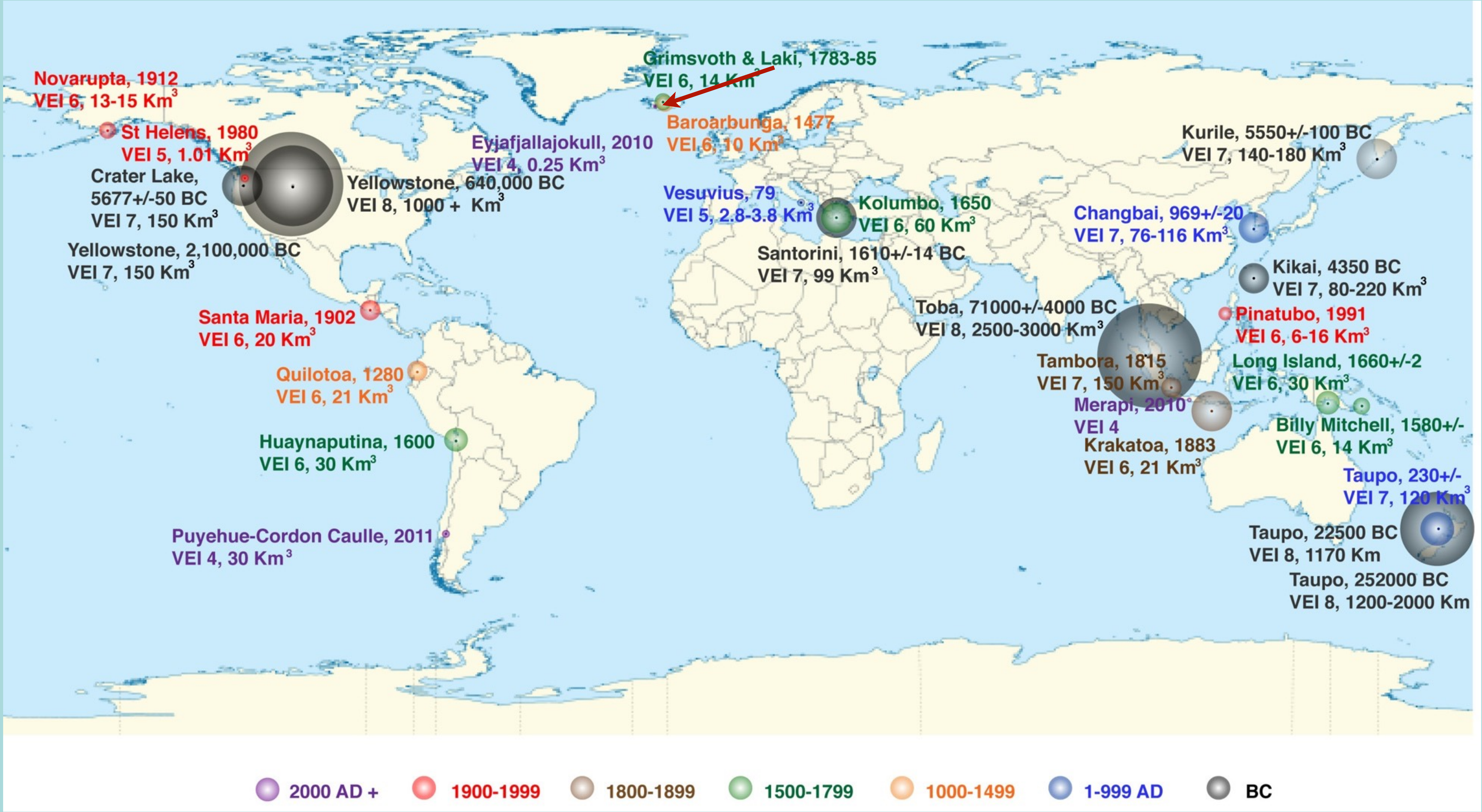
Volcanic Eruptions



Volcanic Eruptions



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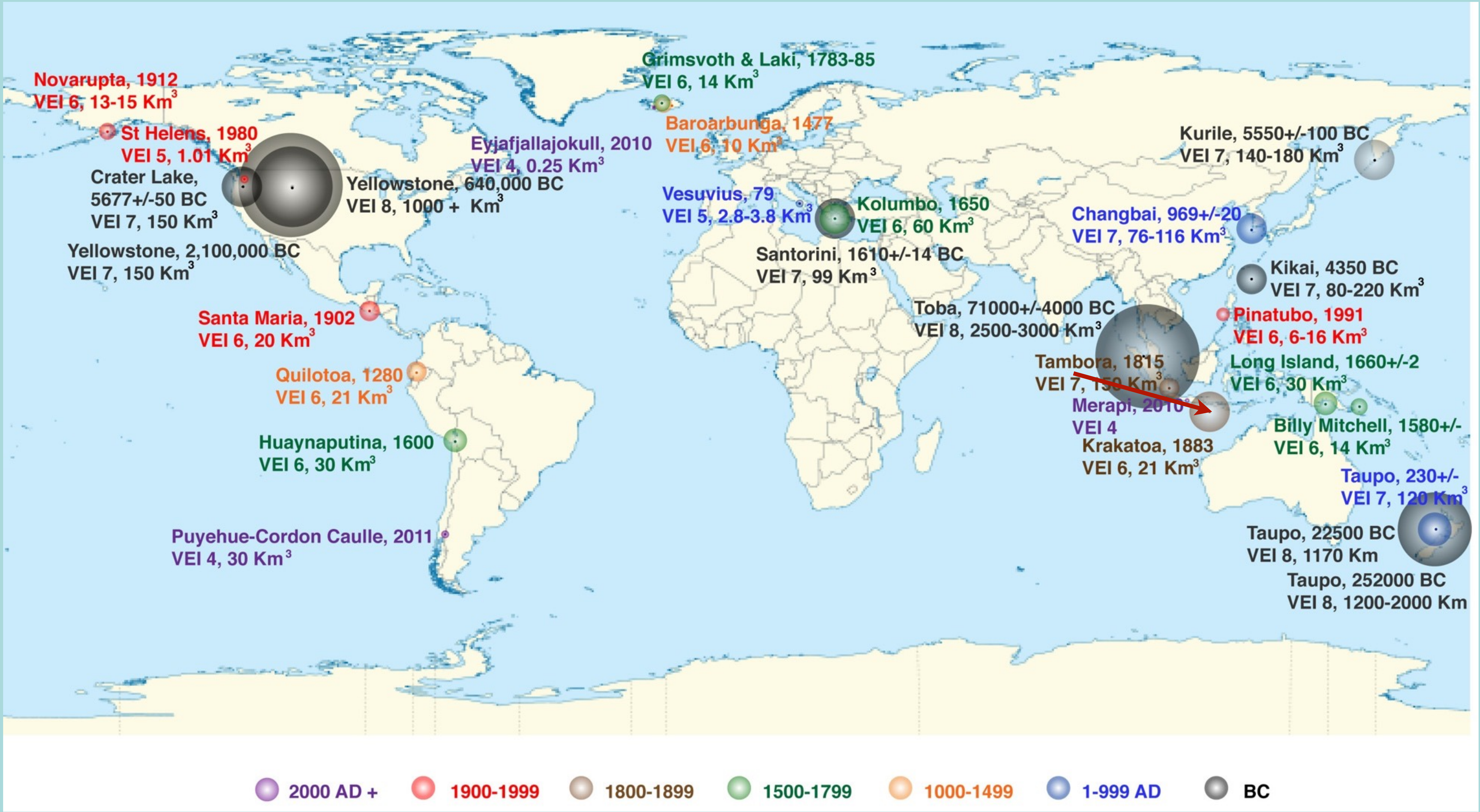

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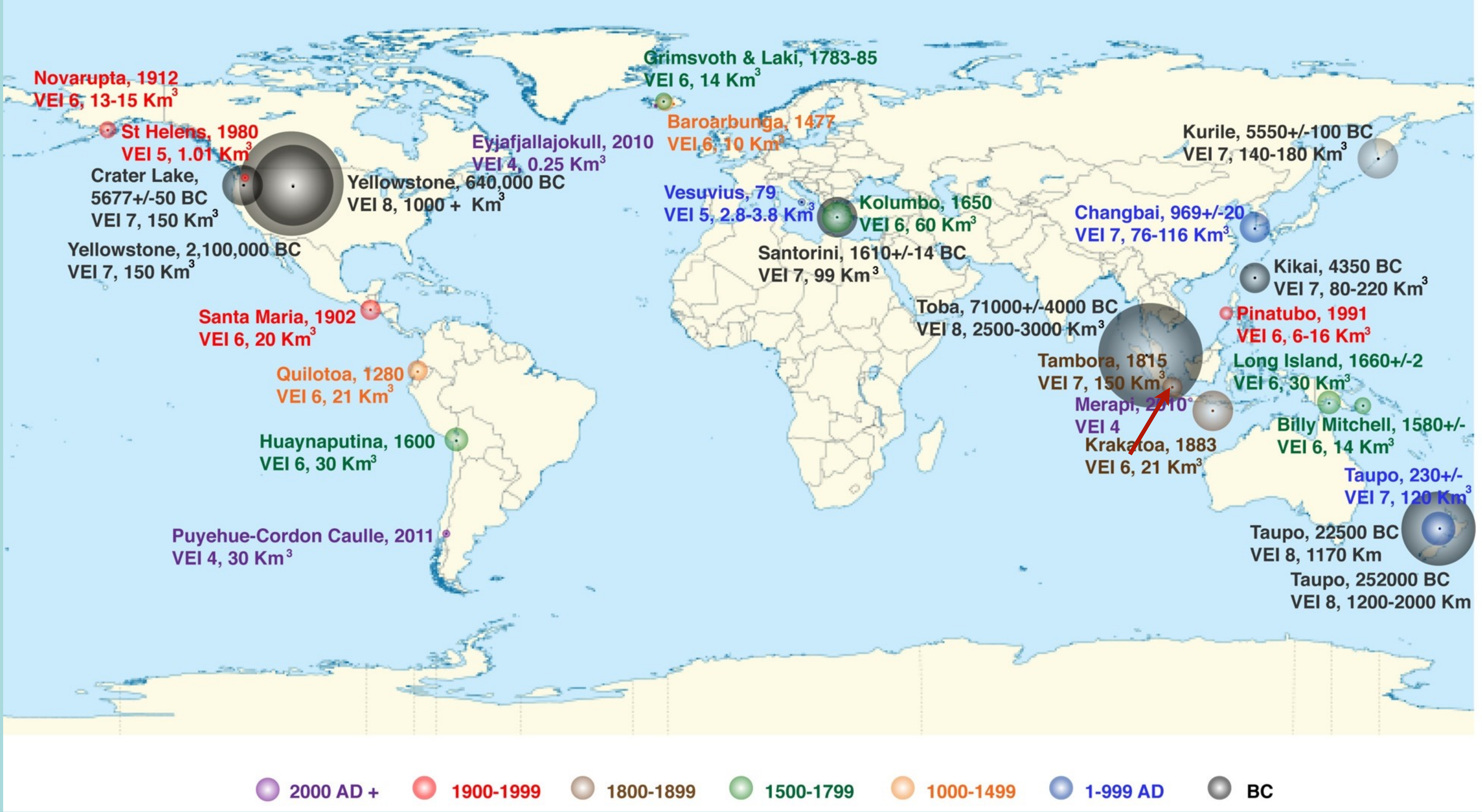

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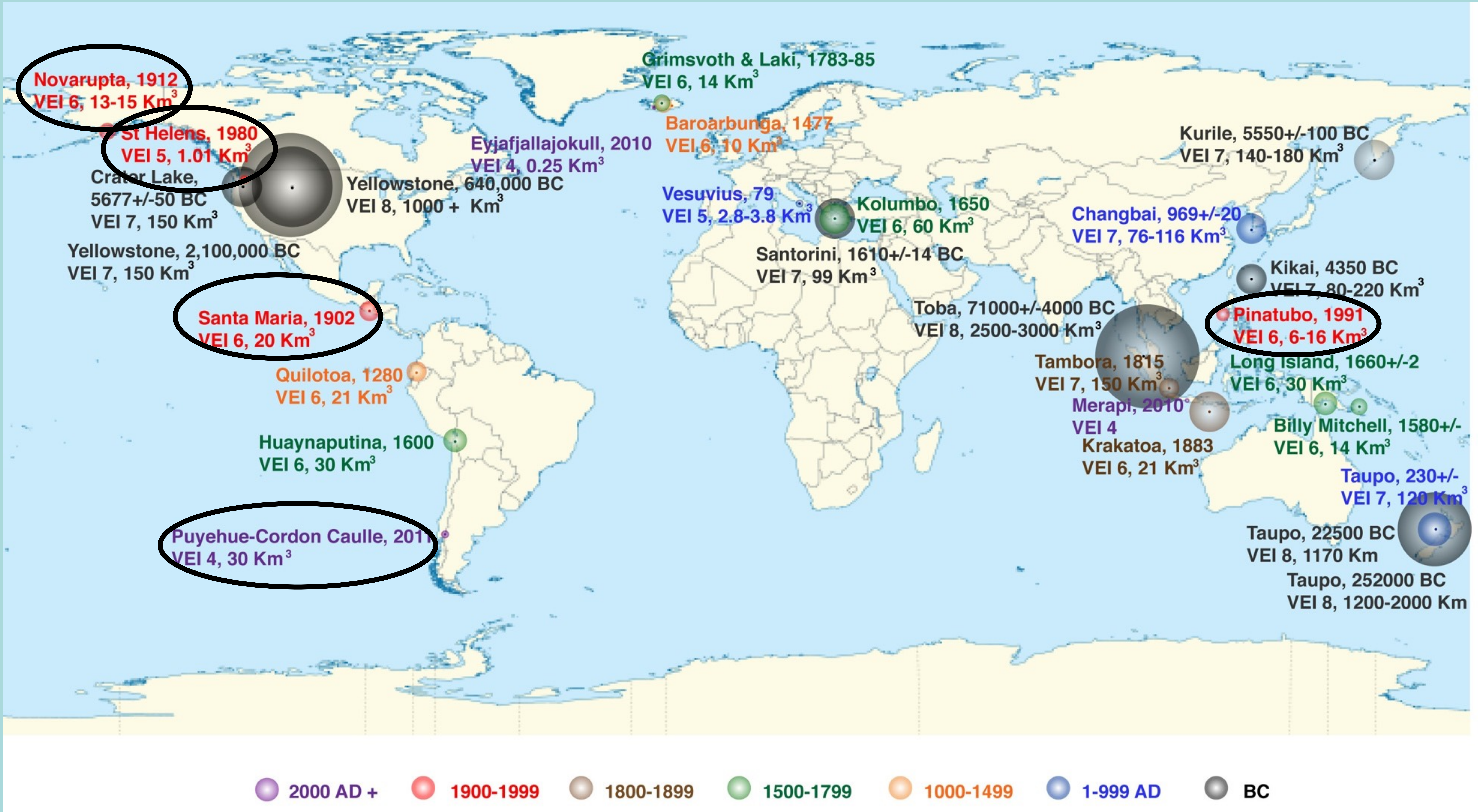

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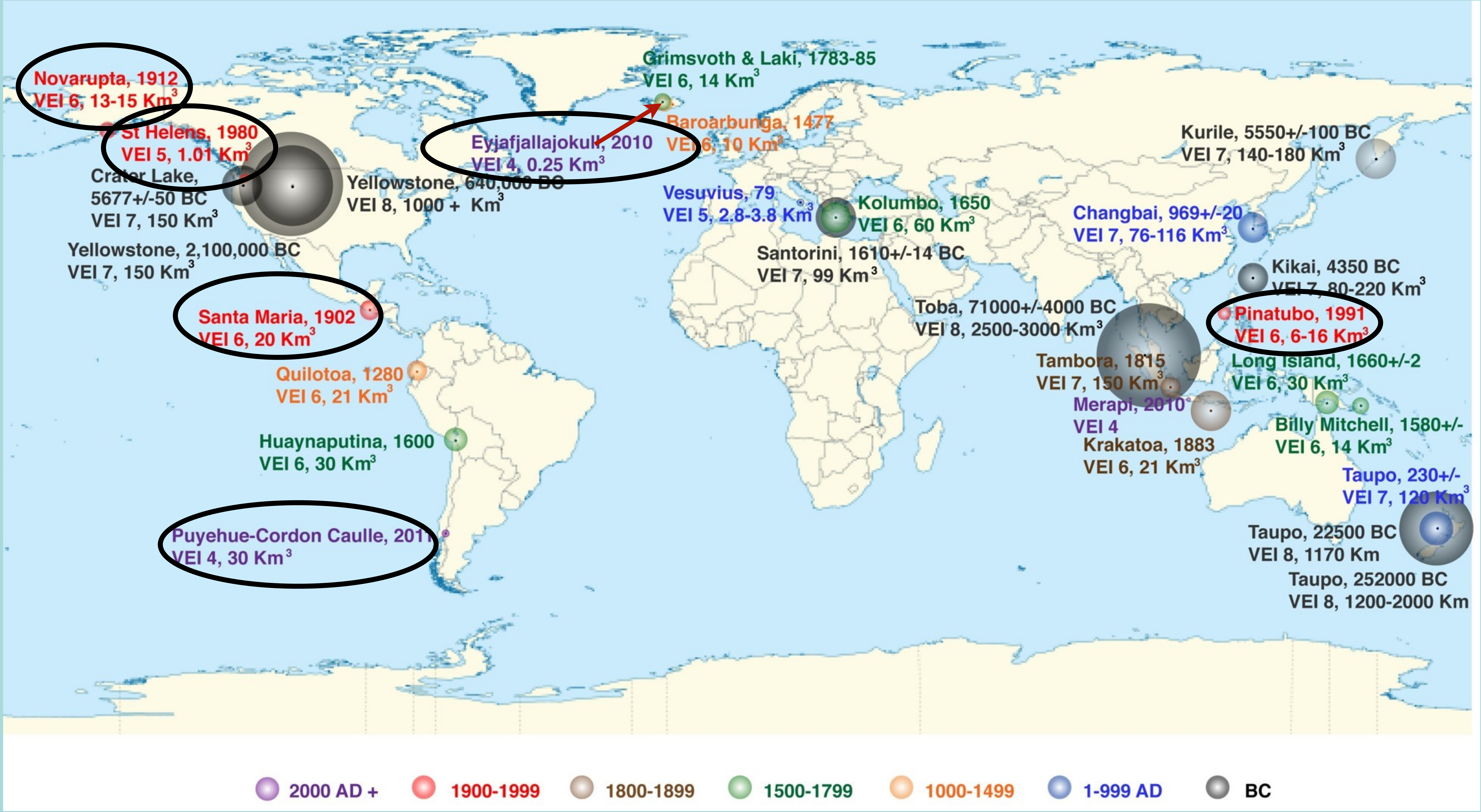

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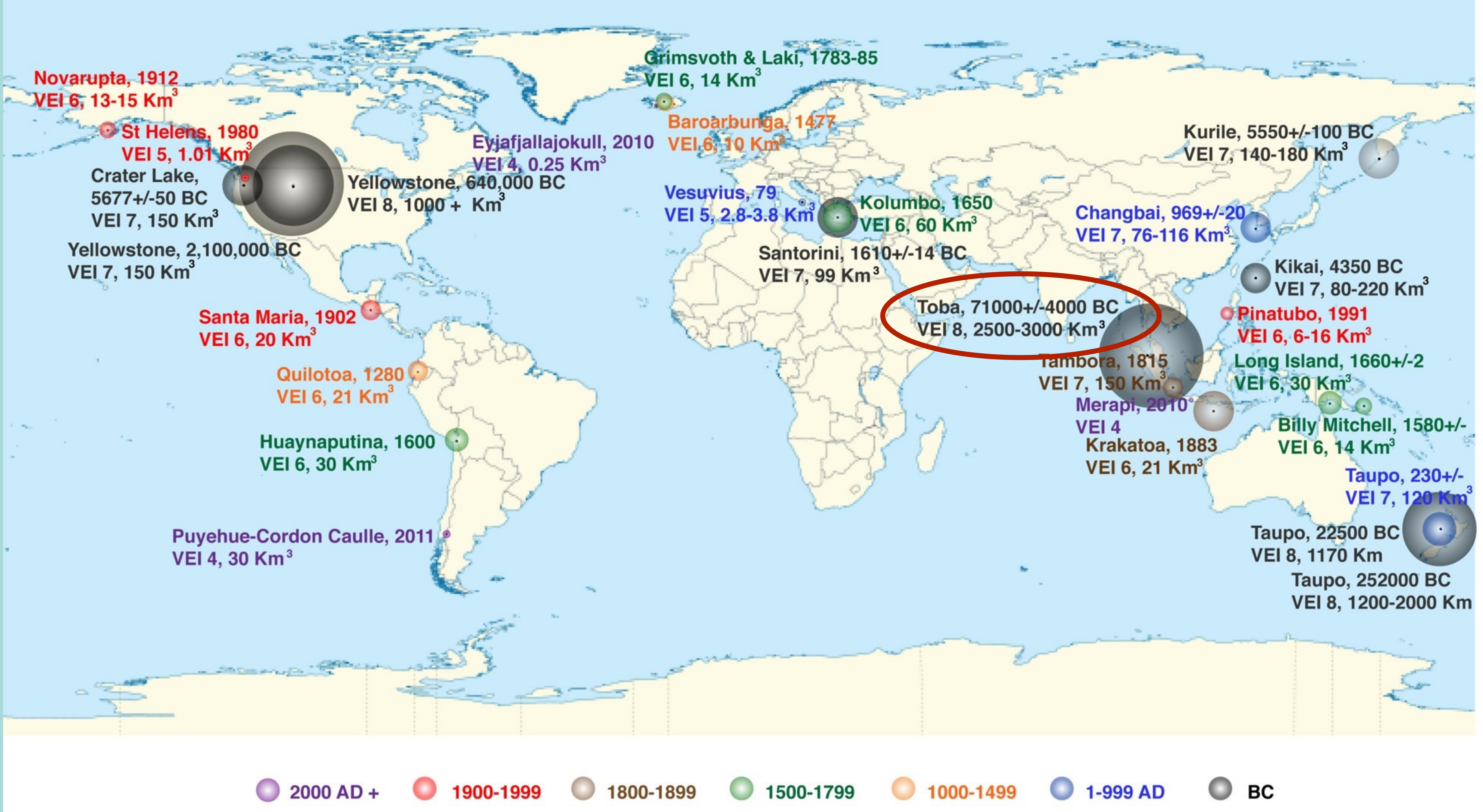

Volcanic Eruptions

Volcanic Eruptions

Deaths	Volcano	Year	Cause
100,000	Tambora, Indonesia [2)]	1815	Starvation
40,000	Krakatau, Indonesia [1)] [2)]	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 [2)]	1783	Starvation
5,000	Kelut, Indonesia	1919	Mudflows
4,000	Galunggung, Indonesia	1882	Mudflows
3,500	Vesuvius, Italy	1631	Mud and lava flows
3,400	Vesuvius, Italy	79	Ash flows

1) Krakatau was similar to Santorini eruption, 1600 BC, although 4 times smaller

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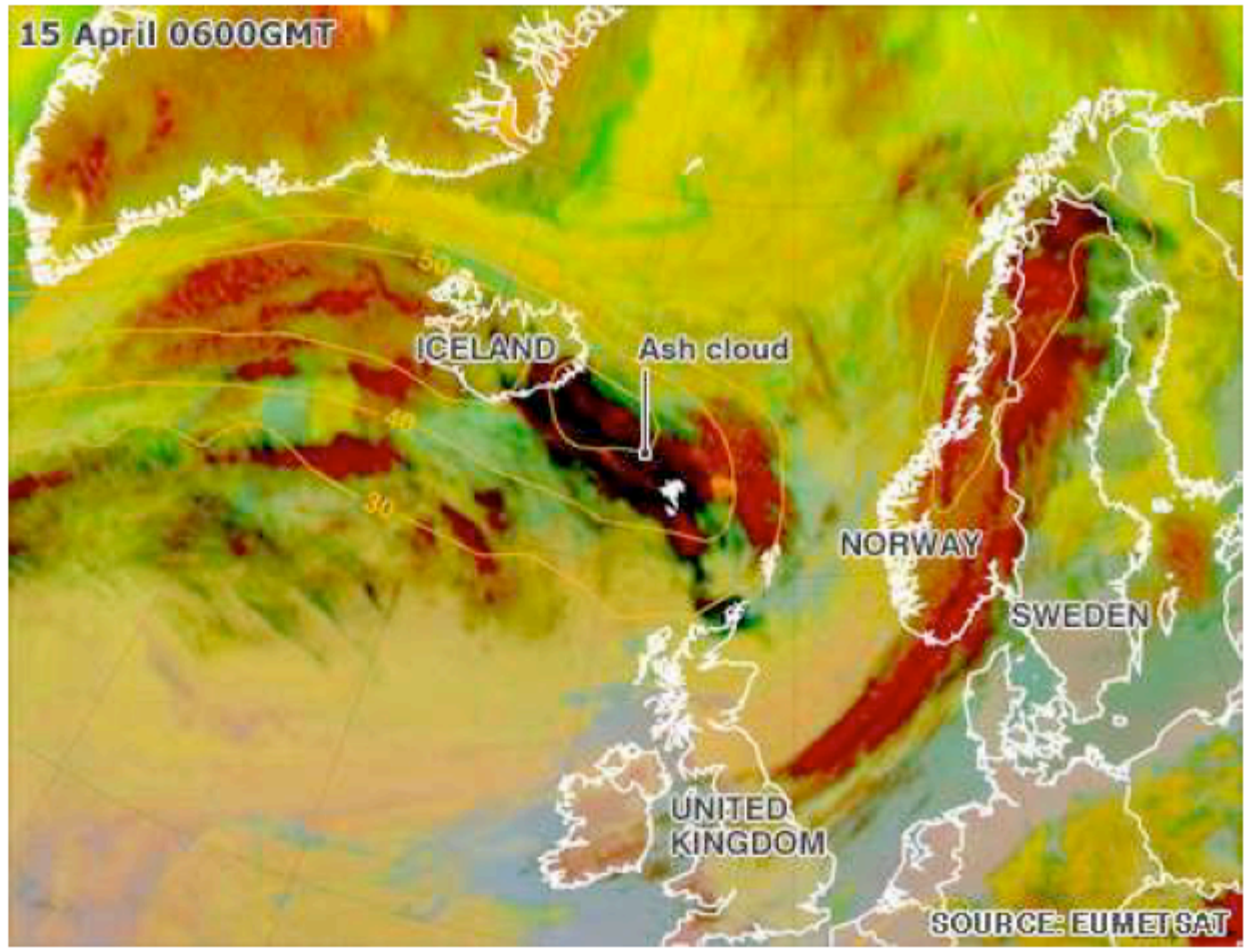
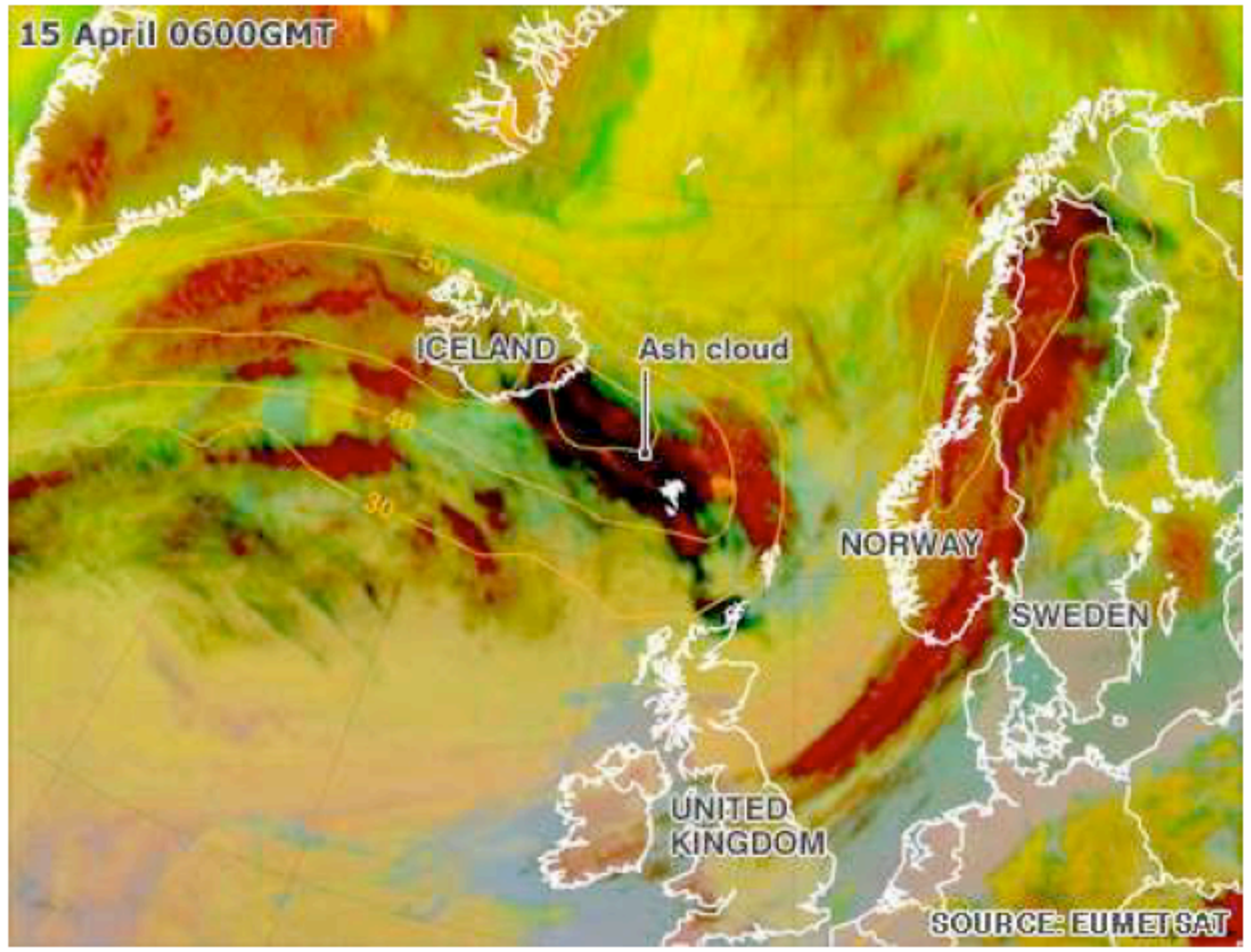
Volcanic Eruptions



Eyafjallajokull, 2010: VEI 4, 0.25 km^3
Laki 1783-85: VEI 6, 14 km^3

Volcanic Eruptions



Eyafjallajokull, 2010: VEI 4, 0.25 km^3
Laki 1783-85: VEI 6, 14 km^3

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

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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Large Eruptions

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

Large Eruptions

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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^3	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		

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an the largest expected impactors

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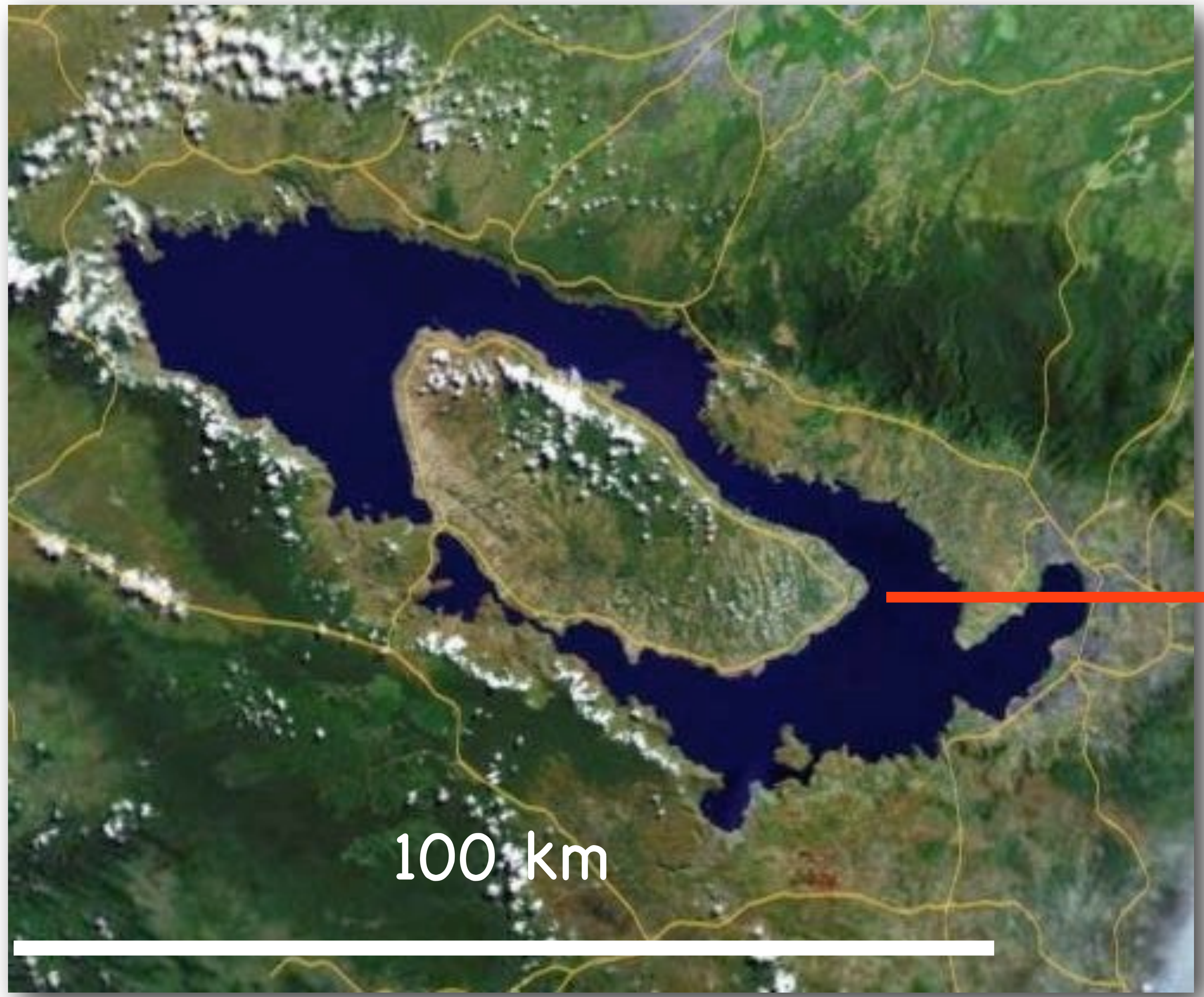
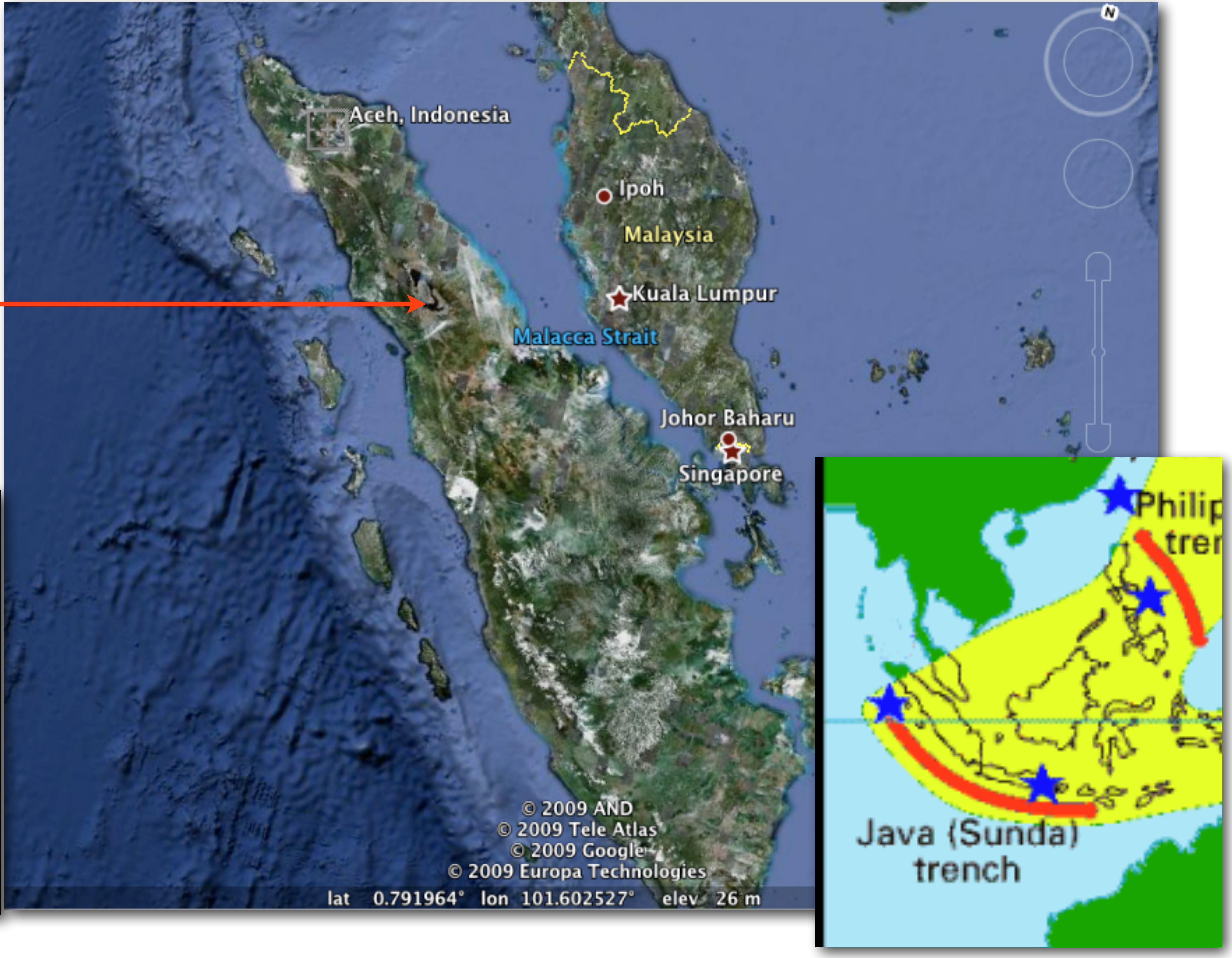
an the largest expected impactors

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



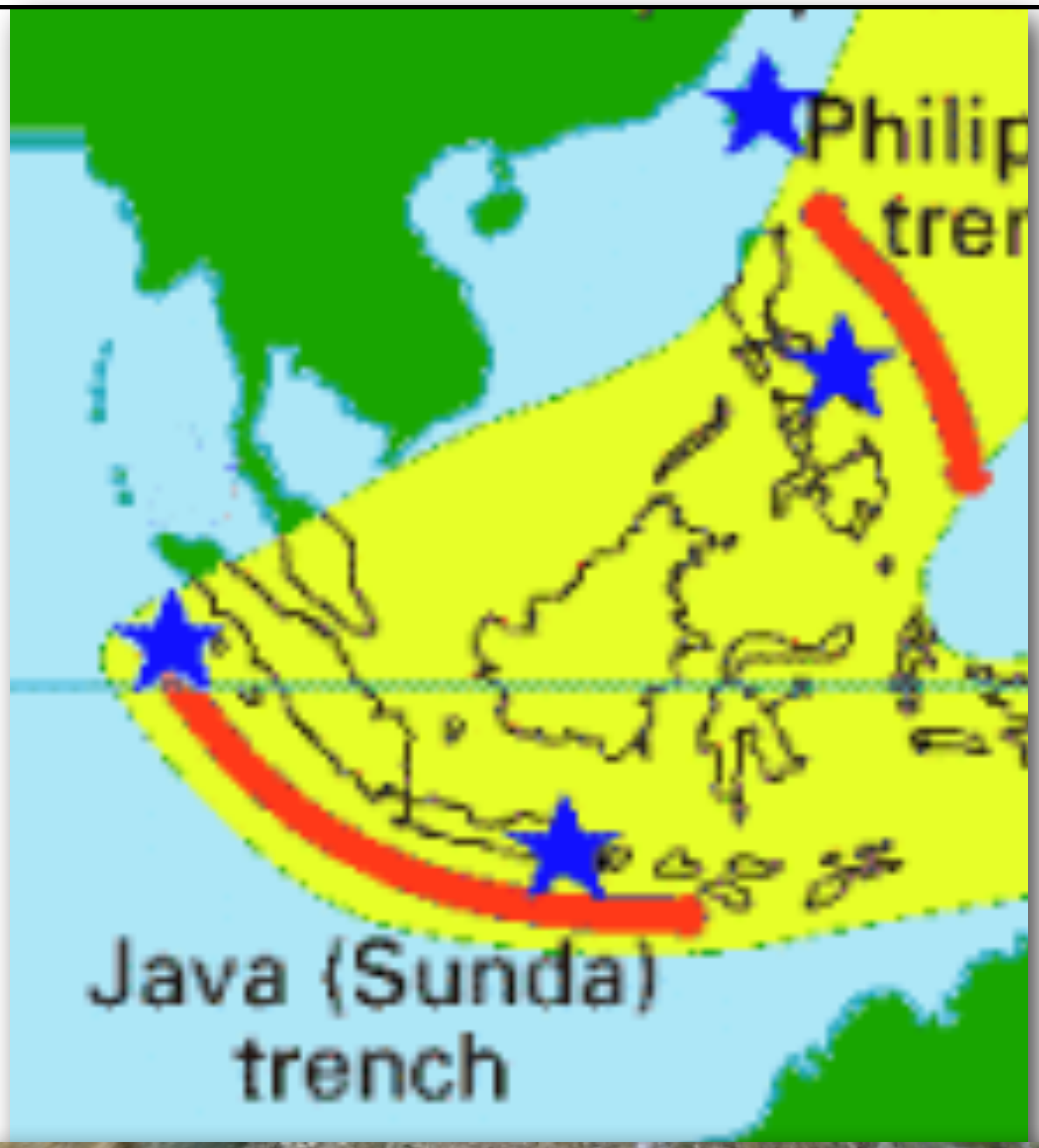


Large Eruptions

Lake Toba

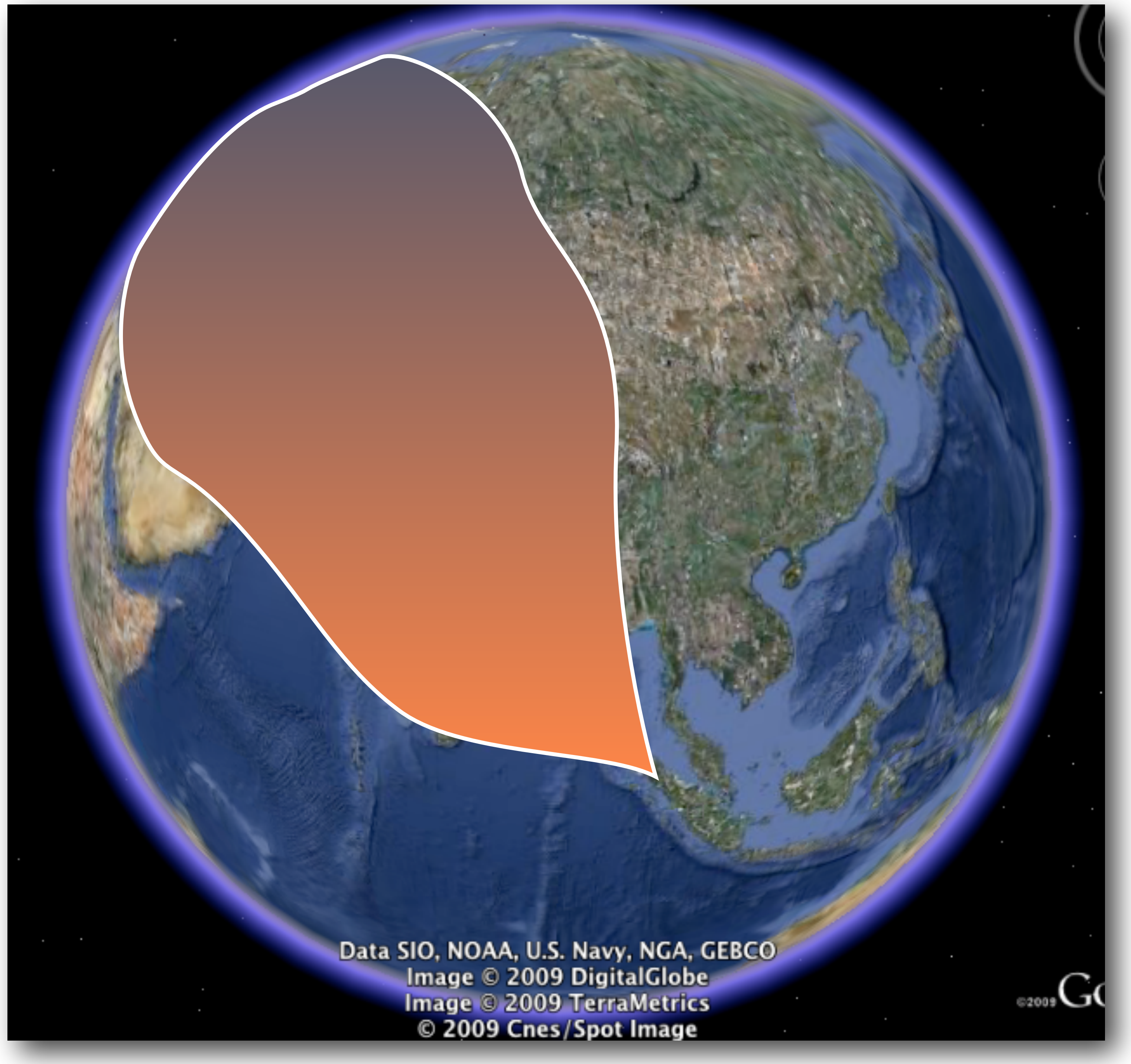
Lake Toba

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



Large Eruptions

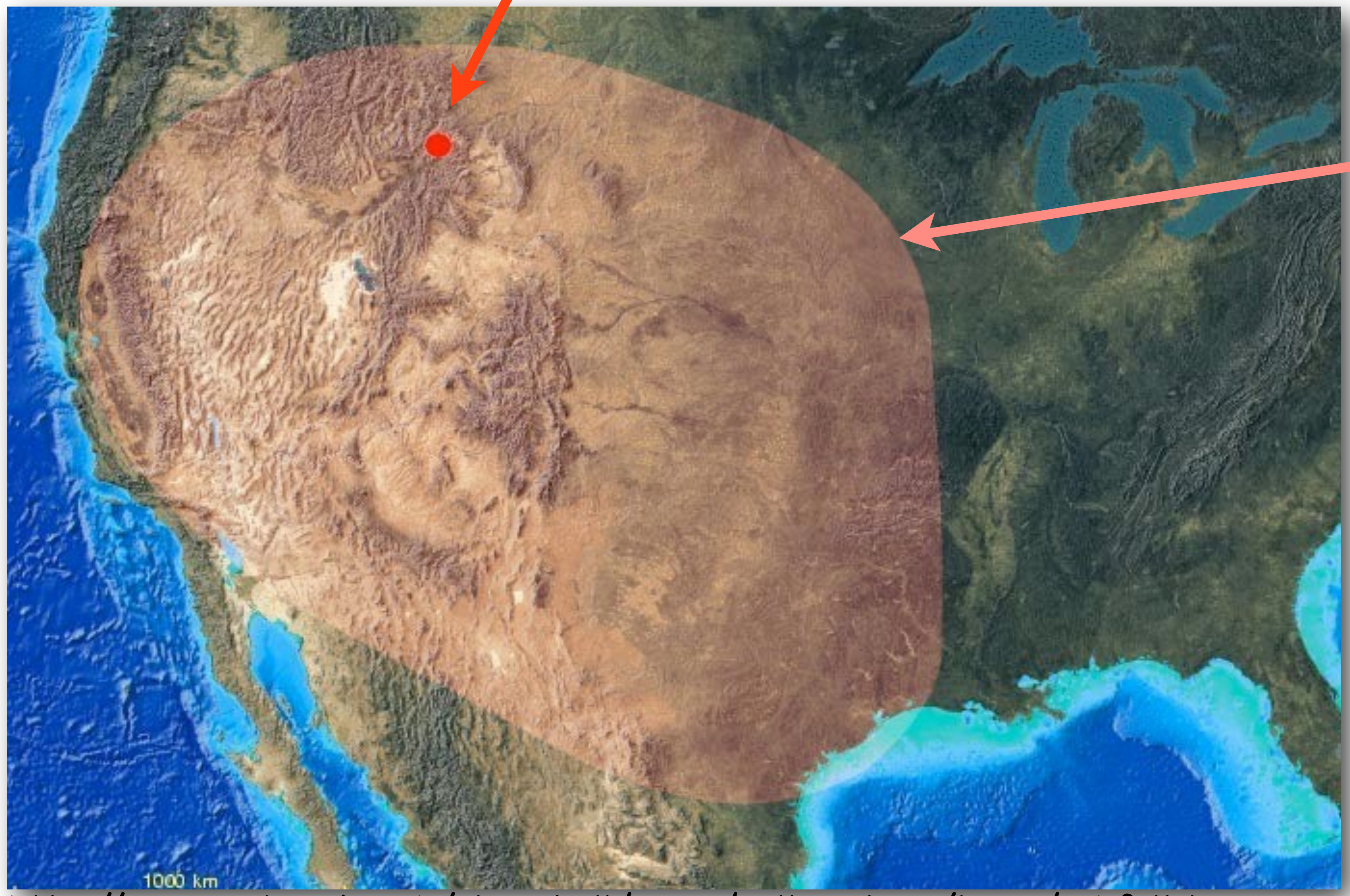
- At least 3°C (with extreme estimates of -15°C) drop in global average temperature
- Snow for most of year in temperate climates
- Evidence from mitochondrial DNA suggests catastrophic number of humans killed, thus reducing genetic diversity, but this is controversial.
- Evidence from artifacts below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



Ash plume spread to NW

Large Eruptions

Yellowstone



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

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

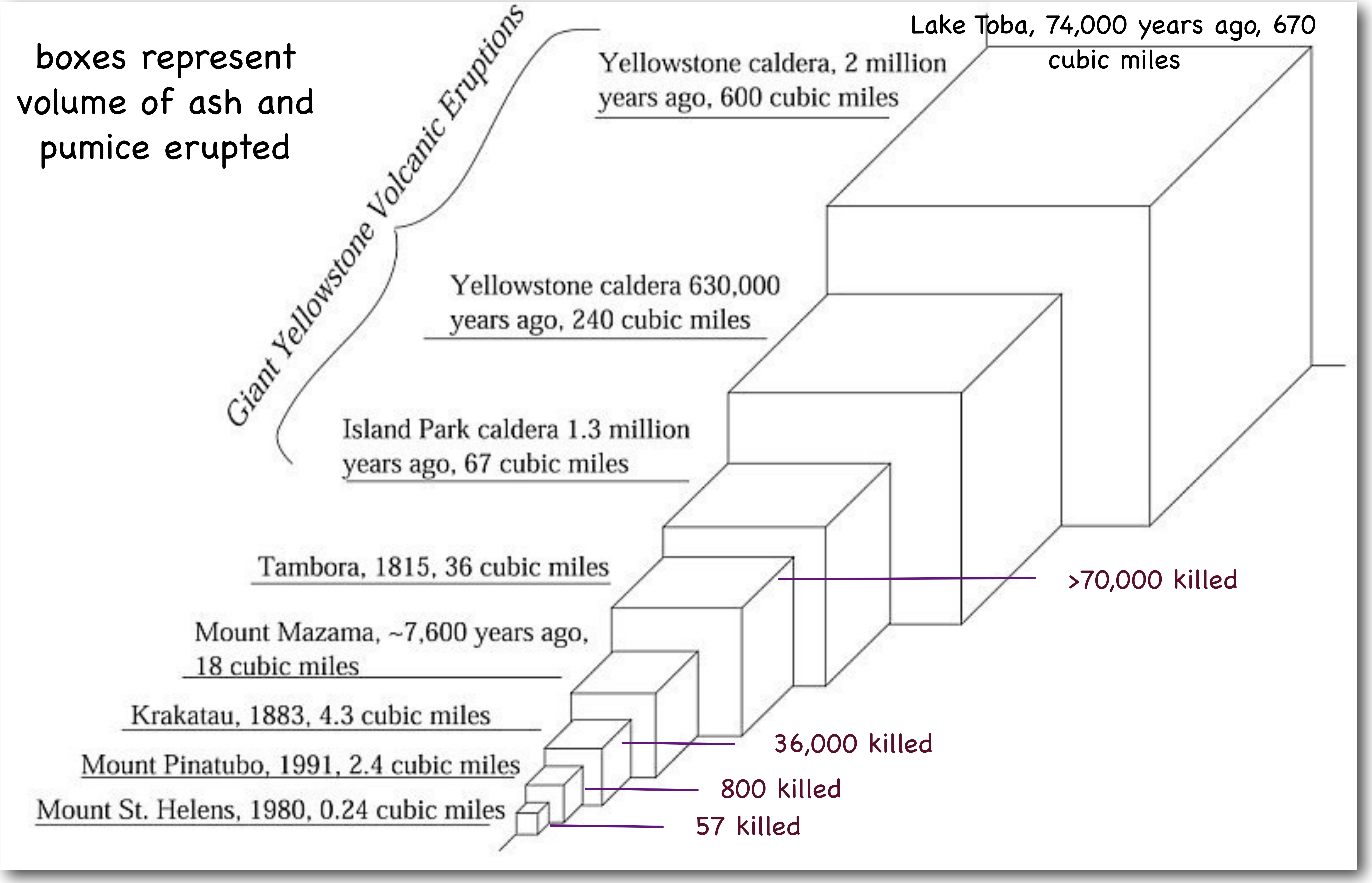
Yellowstone, MT

Limit of Yellowstone caldera ash deposits

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

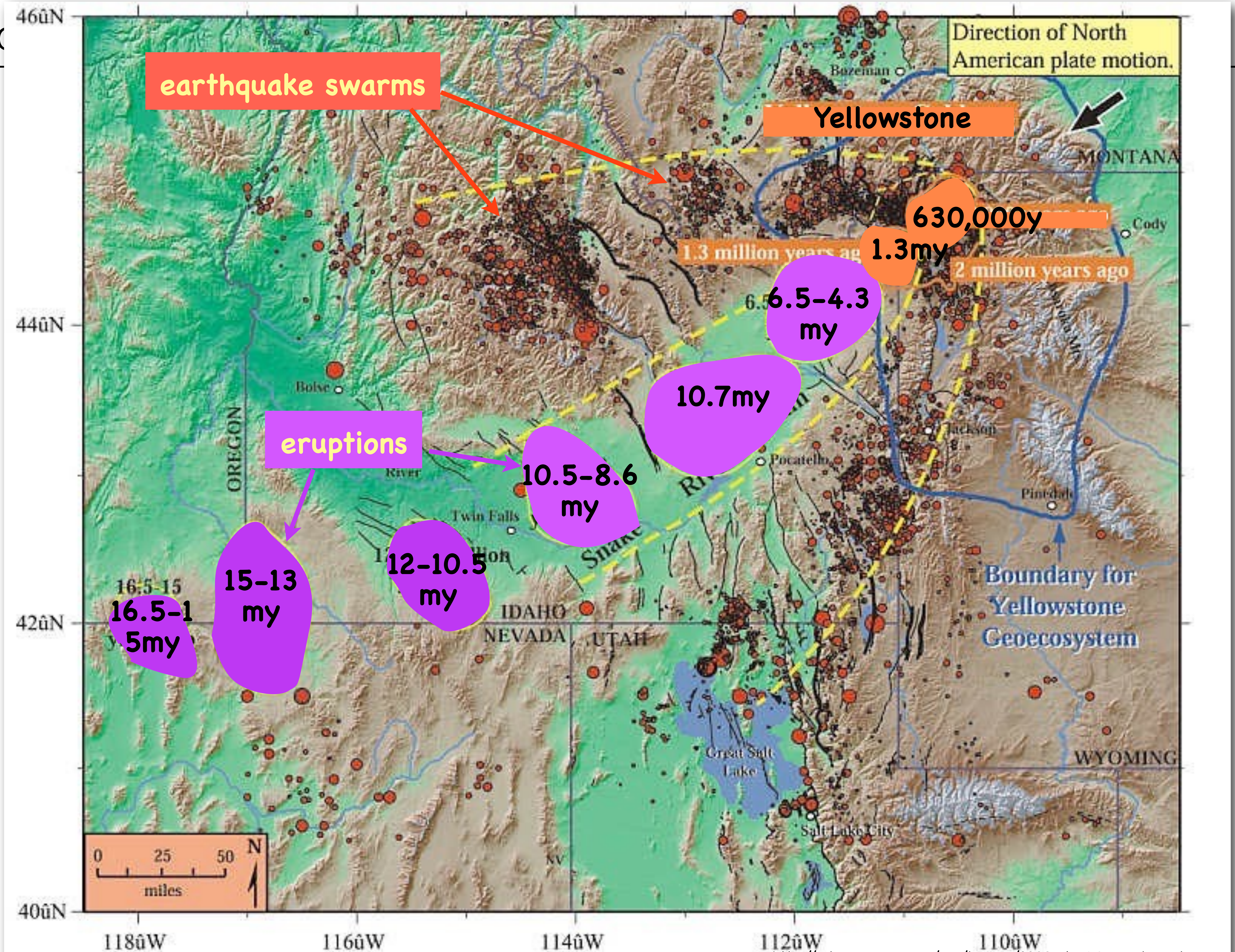
Large Eruptions

Eruption size vs. casualties



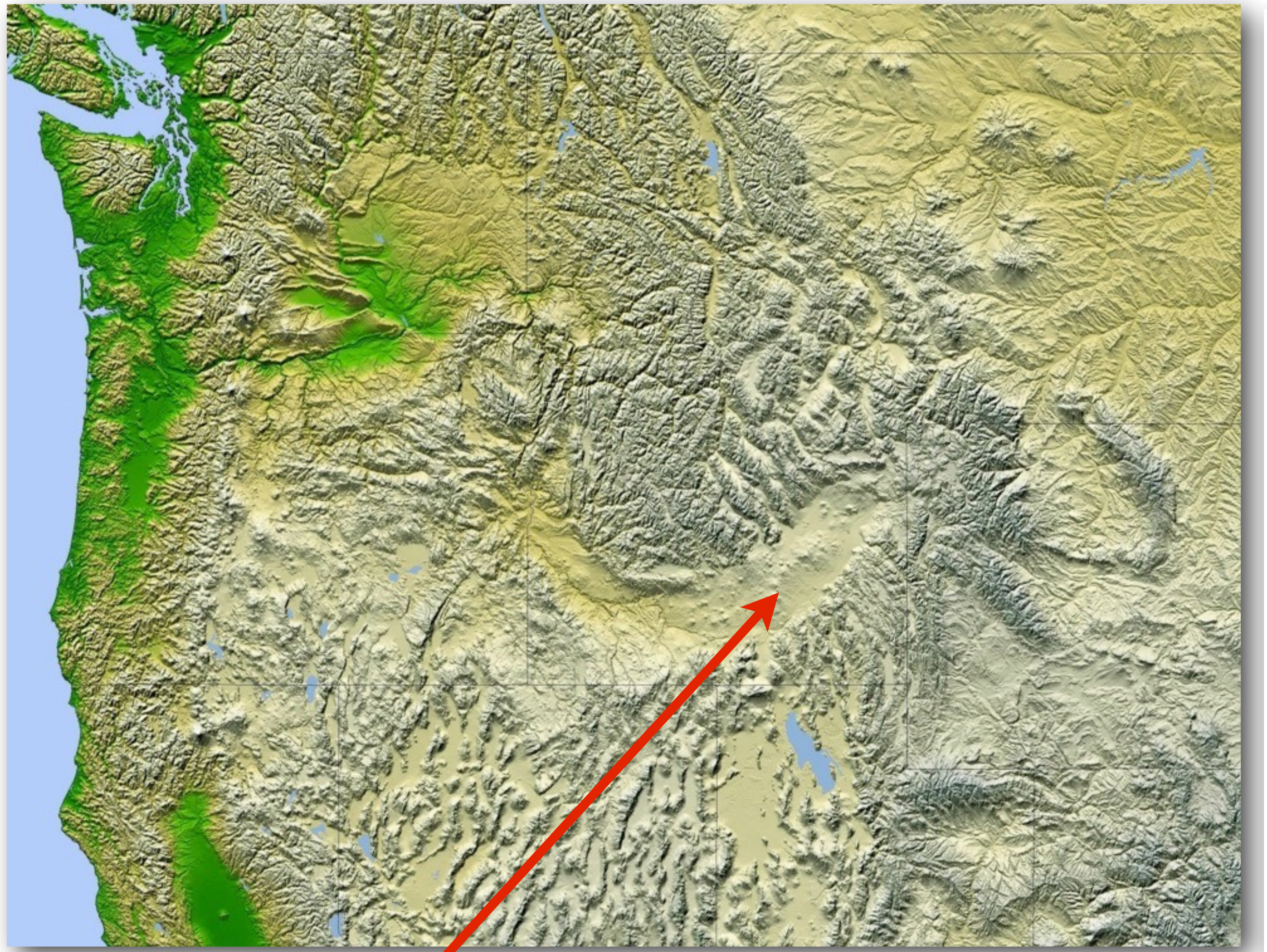
http://tetonwyo.org/em/docs/images/yellowstone_caldera_volumes_large.jpg

Large Eruptic

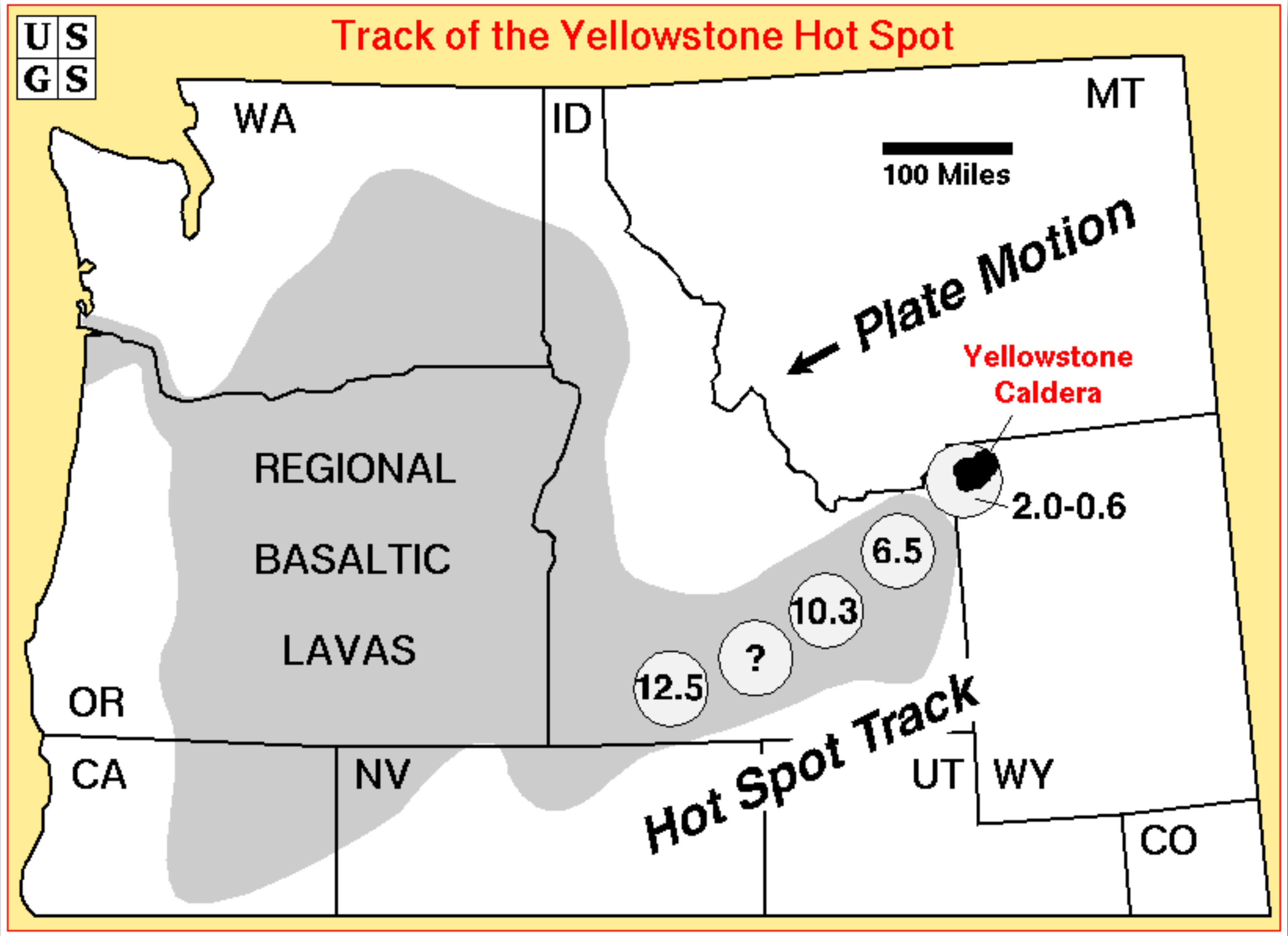


http://volcanoes.usgs.gov/yvo/images/2000-rbs-1.3ysrp_large.jpg

Large Eruptions

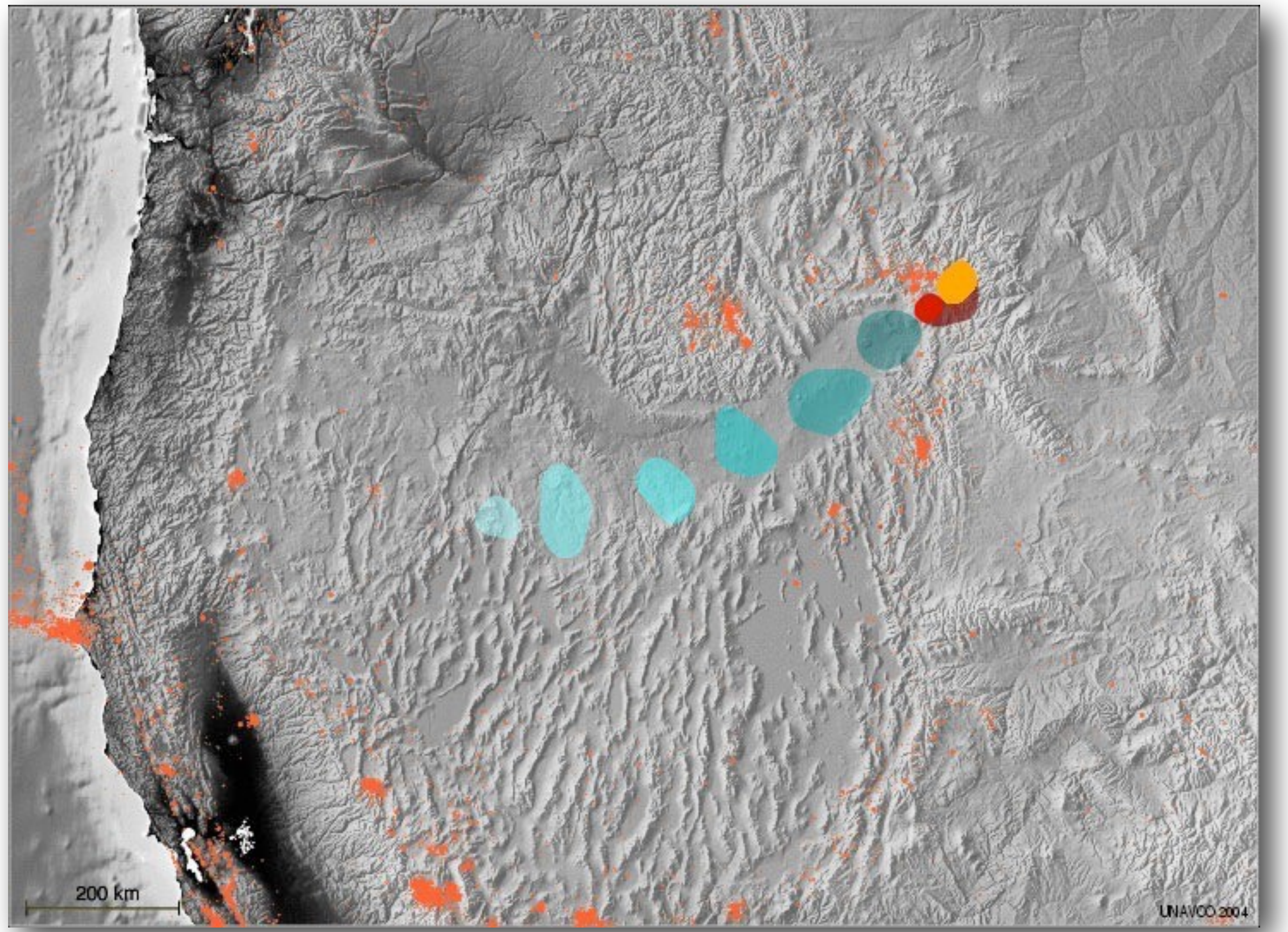


http://geology.com/shaded-relief/northwest-shaded-relief-map.jpg



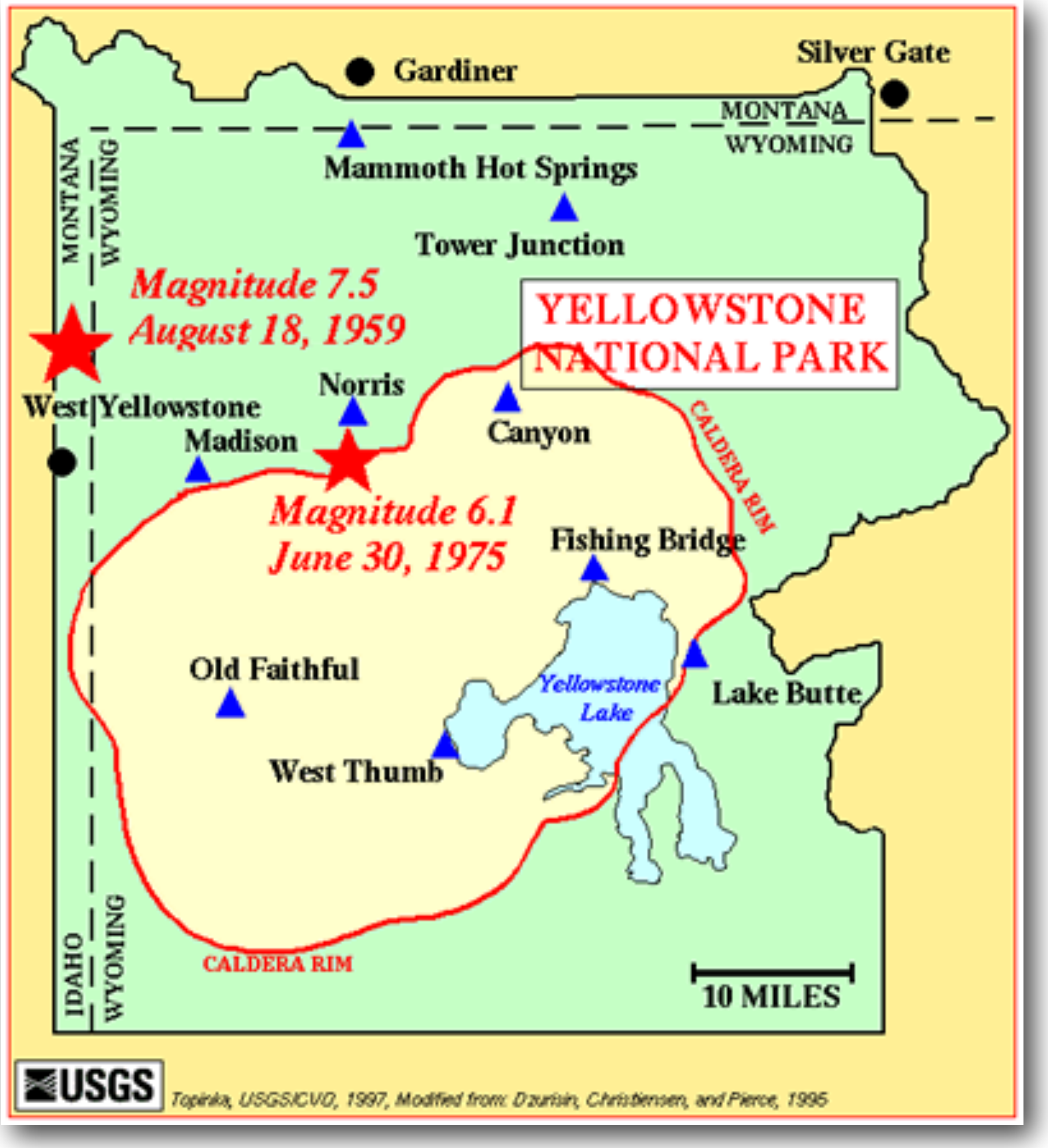
http://vulcan.wr.usgs.gov/Imgs/Gif/Yellowstone/OFR95-59/figure1.gif

hot spot track is evident in topography

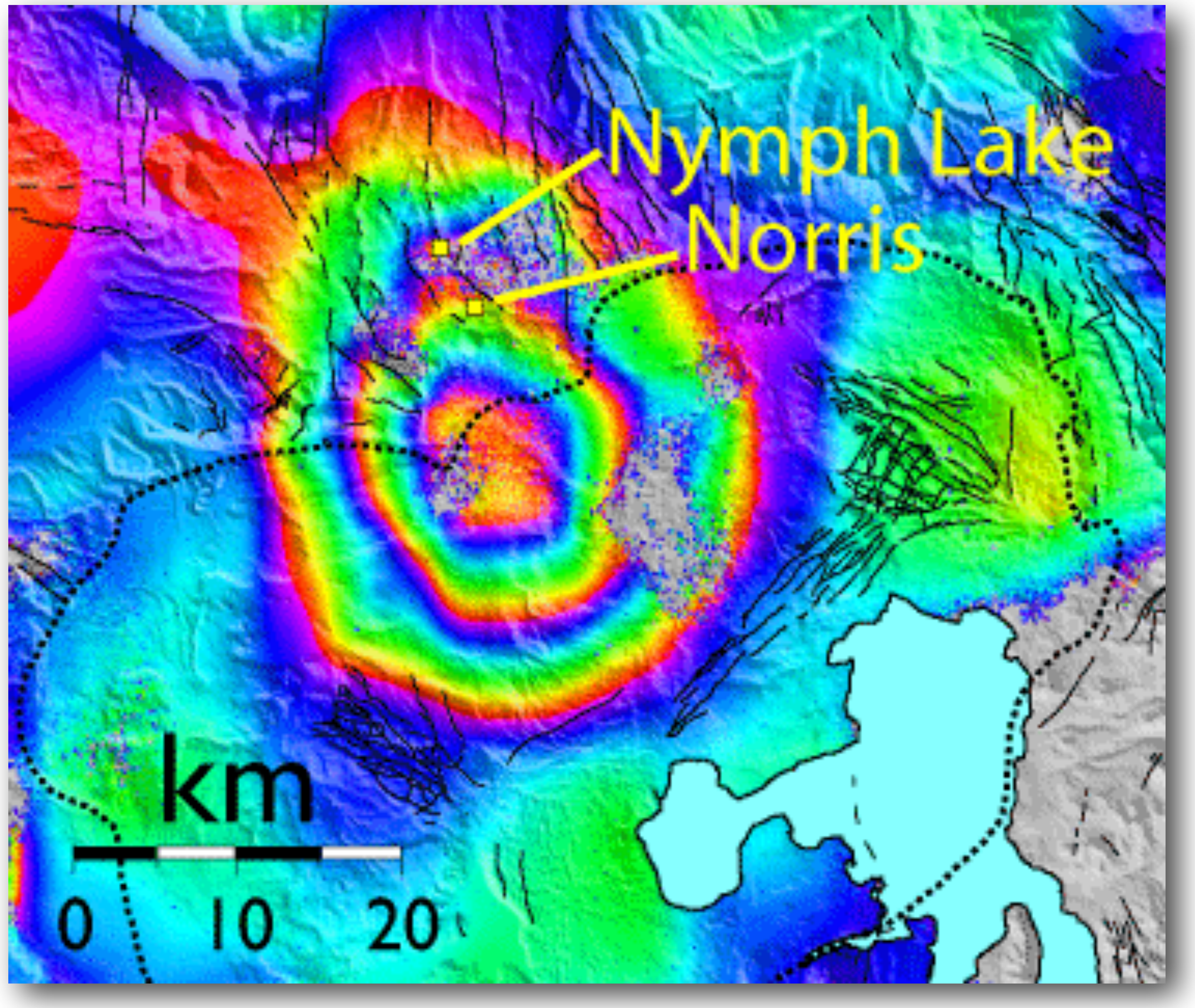


http://www.swisseduc.ch/stromboli/perm/yellowstone/icons/migration.jpg

Large Eruptions



2004-2006 interferogram
(ground deformation pattern)



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

Large Eruptions

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

- 1.4 events/Ma to 22 events/Ma
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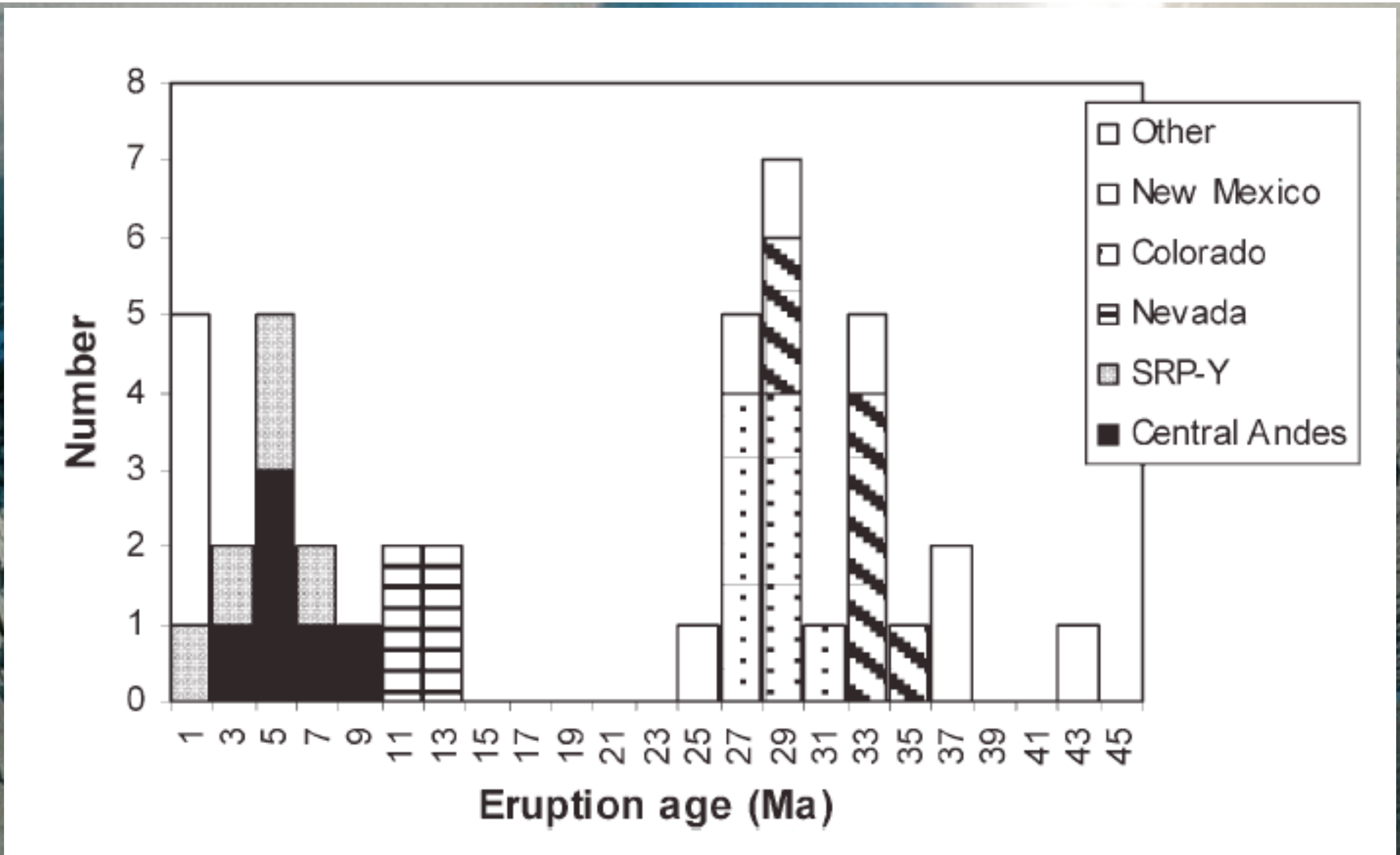

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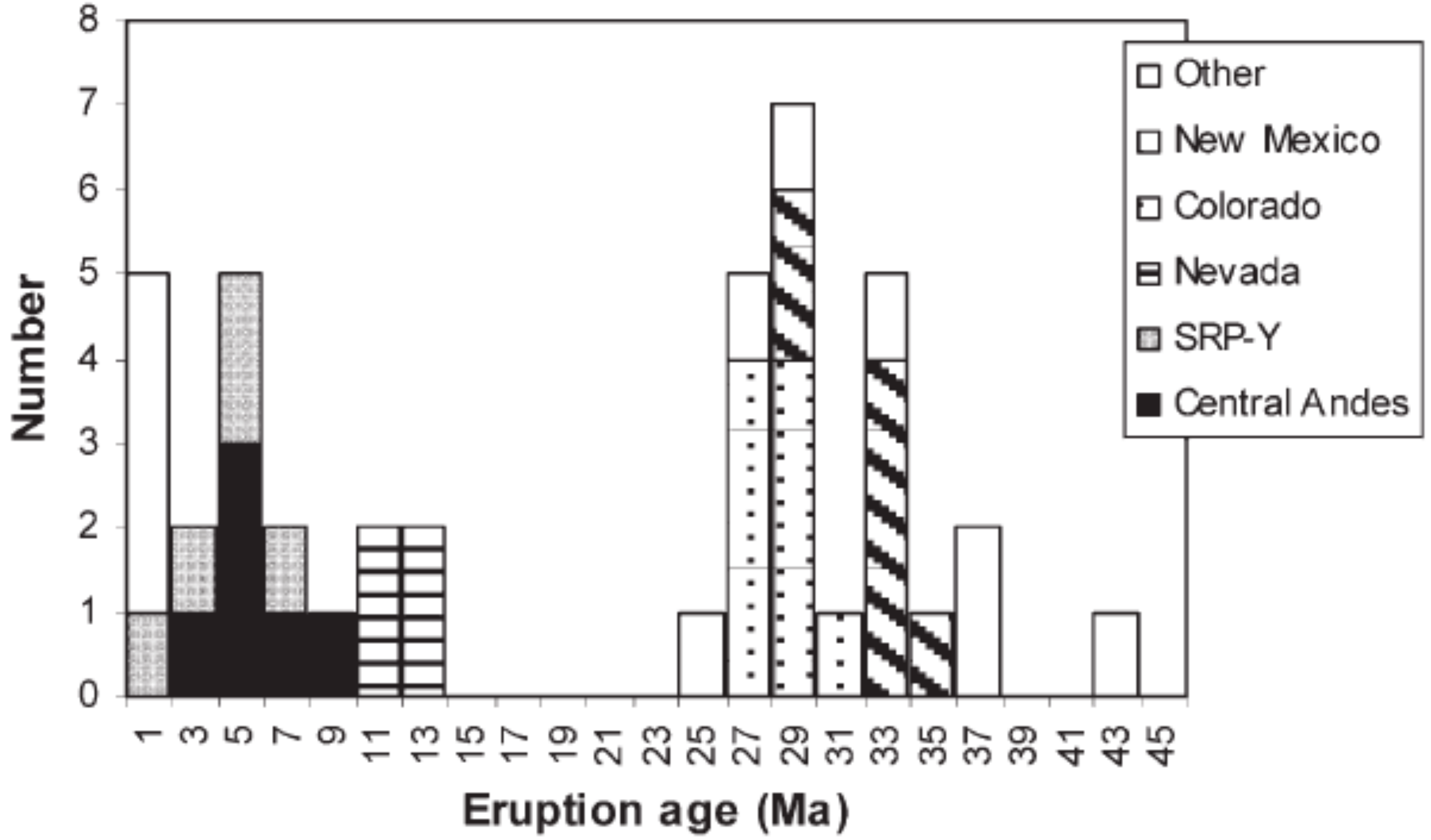
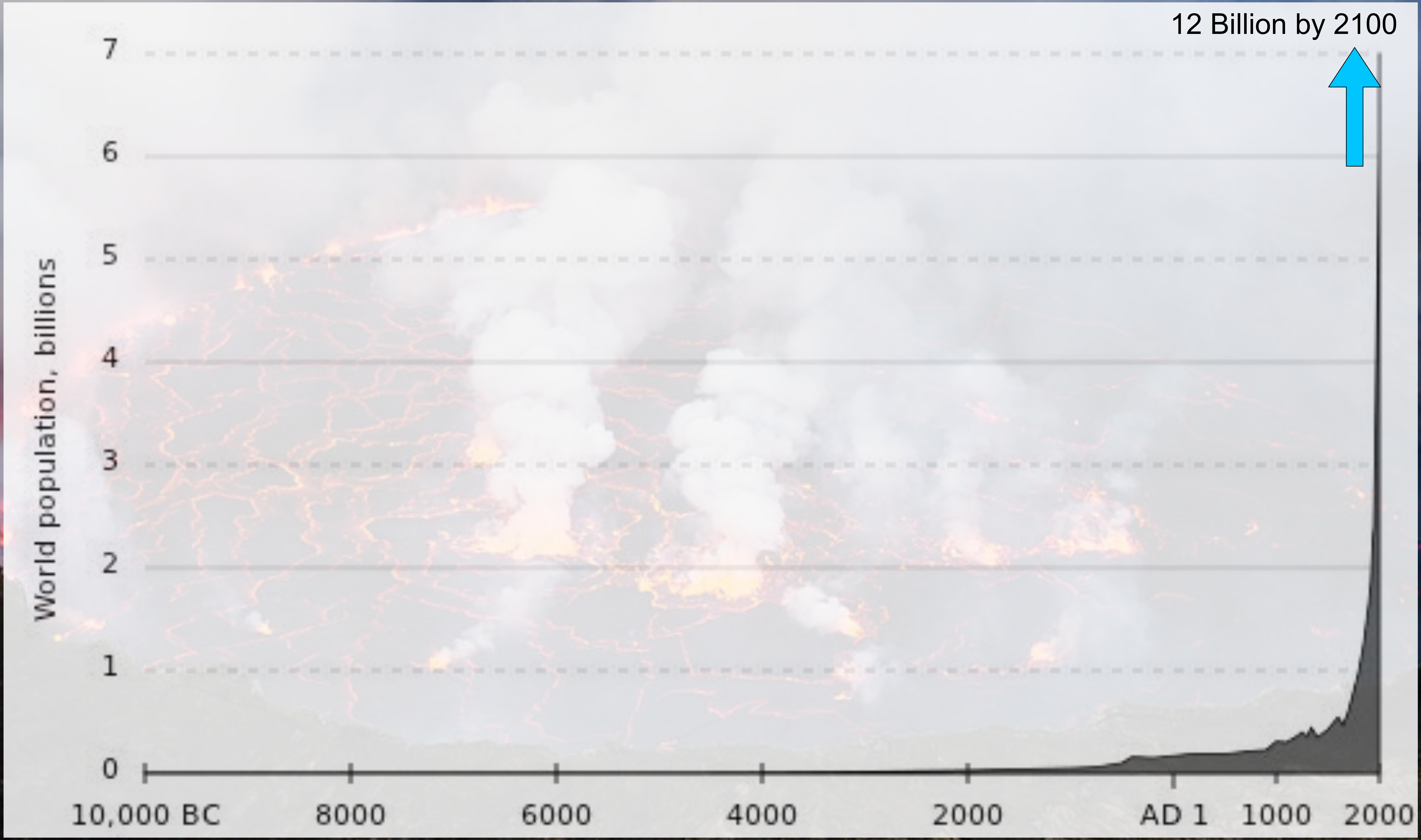


Fig. 5 Histogram (at 2 Ma intervals, with age of the midpoint given on the x axis) showing the time distribution of the 42 known eruptions of M8 and larger over the past 46 Ma. Key geographical areas are highlighted (New Mexico, Colorado, Nevada are in the south-western USA; SRP is the Snake River Plain-Yellowstone 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

Mason et al., 2004

Large Eruptions

Large Eruptions



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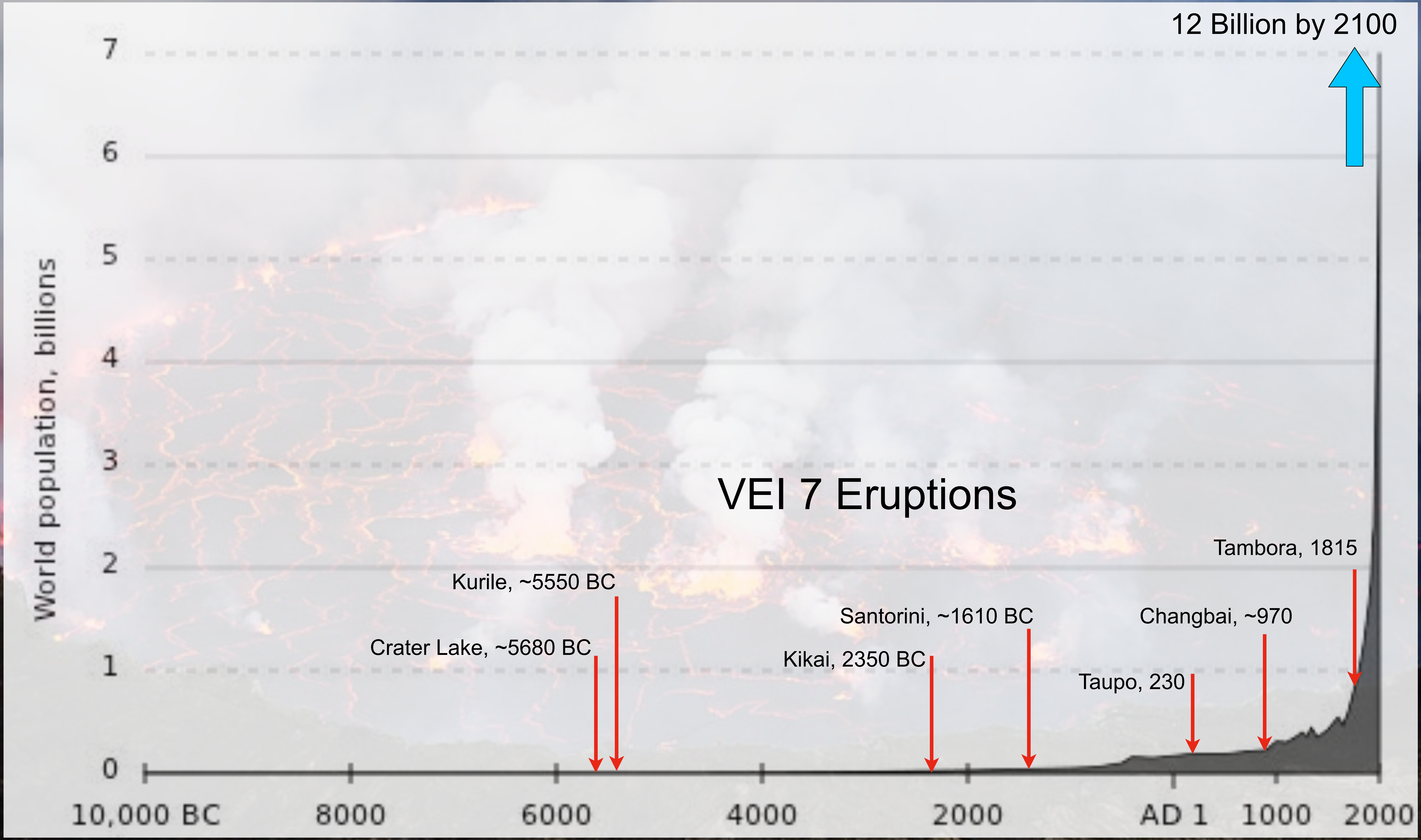
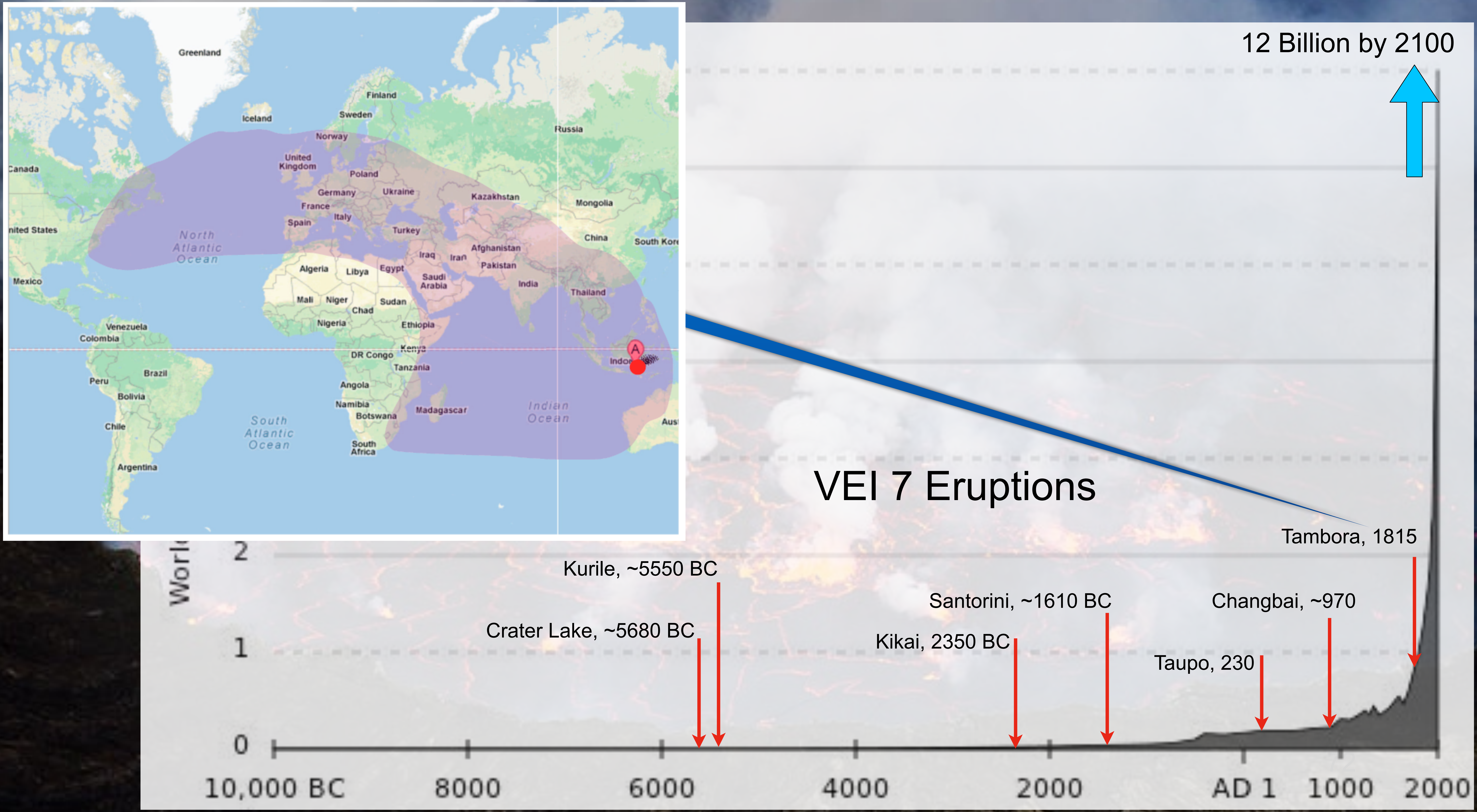


Large Eruptions



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Volcanic Eruptions and Modern Society

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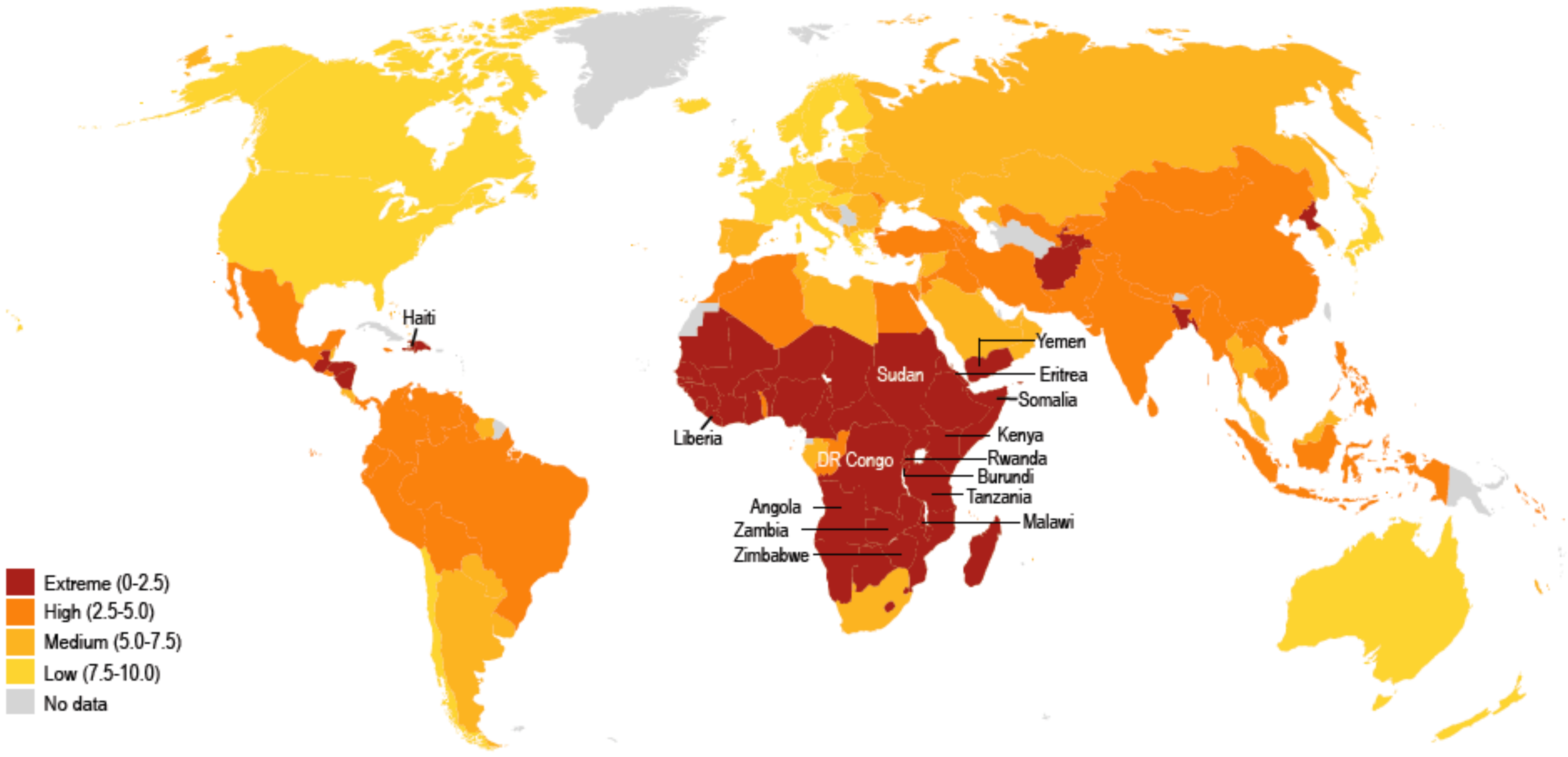
Maplecroft's global map of food security



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

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Comparison

Hazard	Events	Fatalities	Per year	Affected	Per year	Damage	Per year	*R*
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.

Comparison

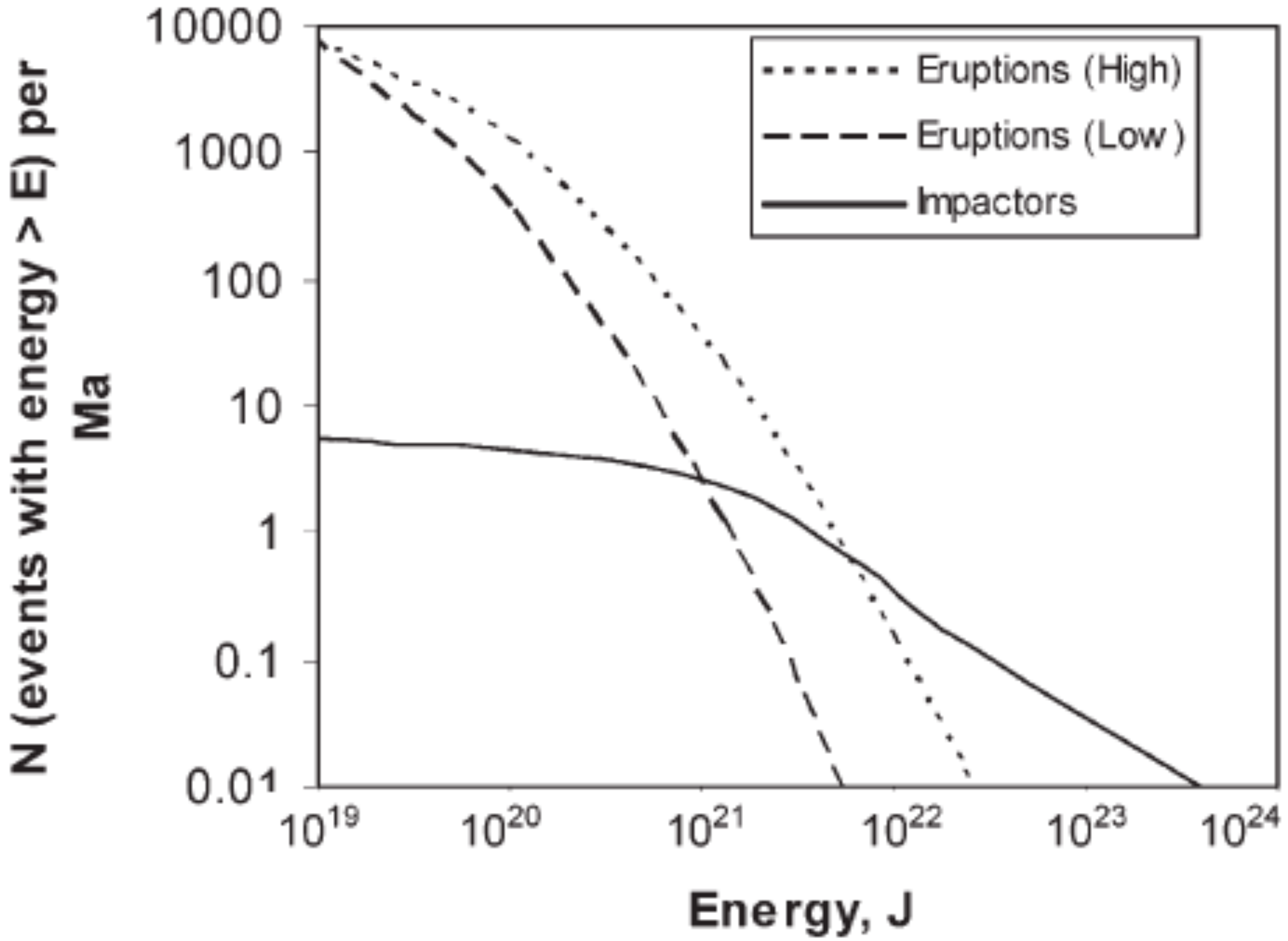
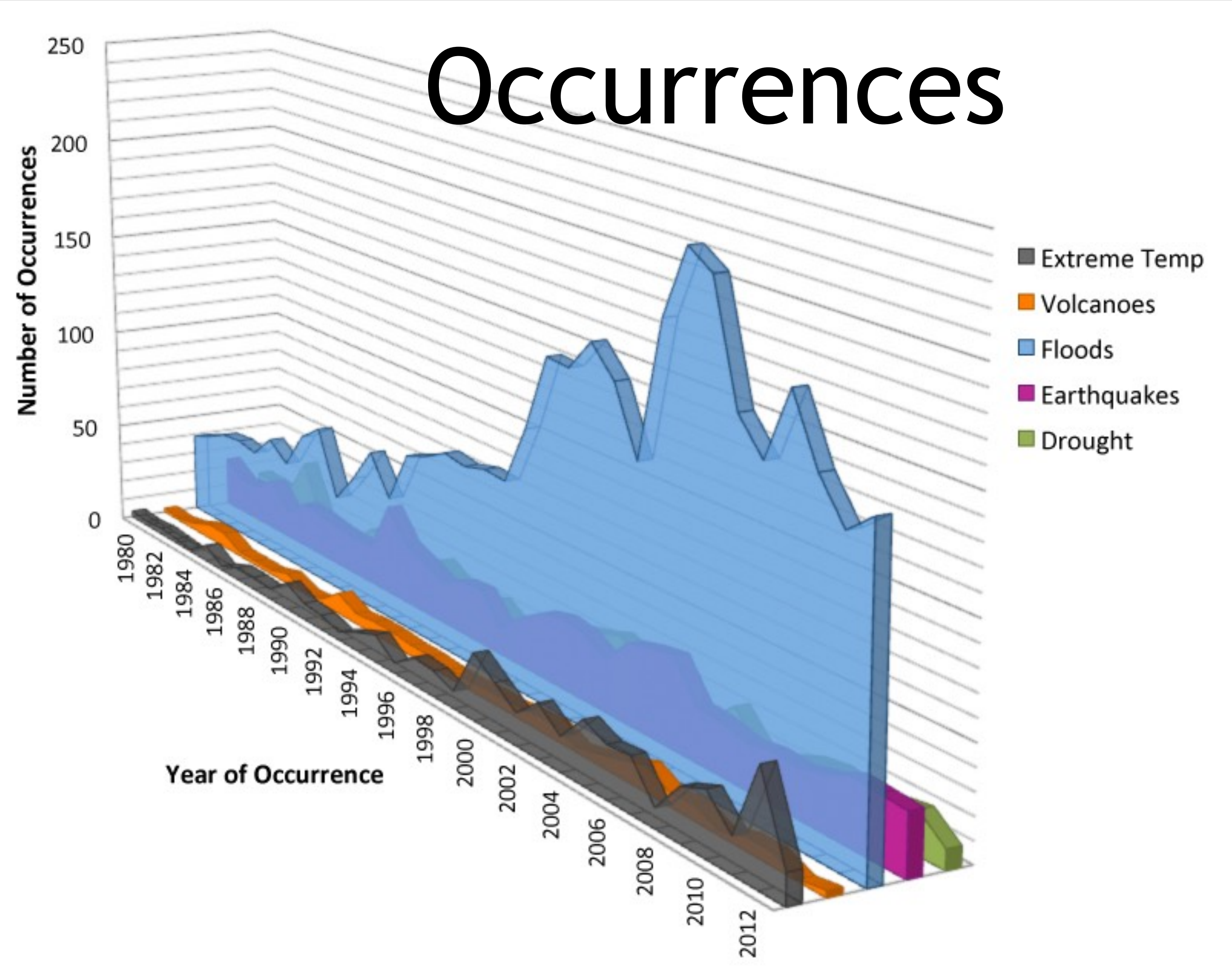
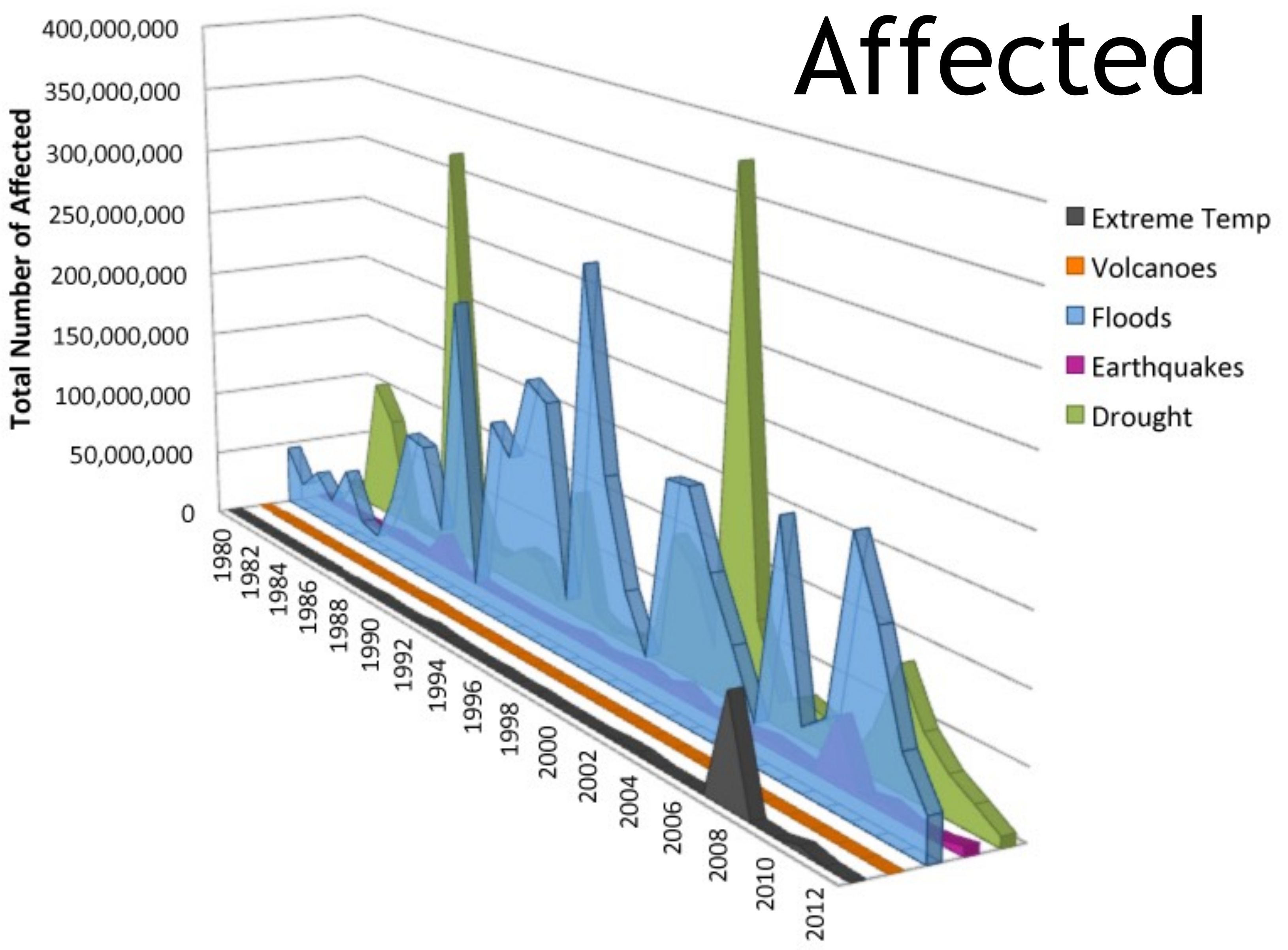


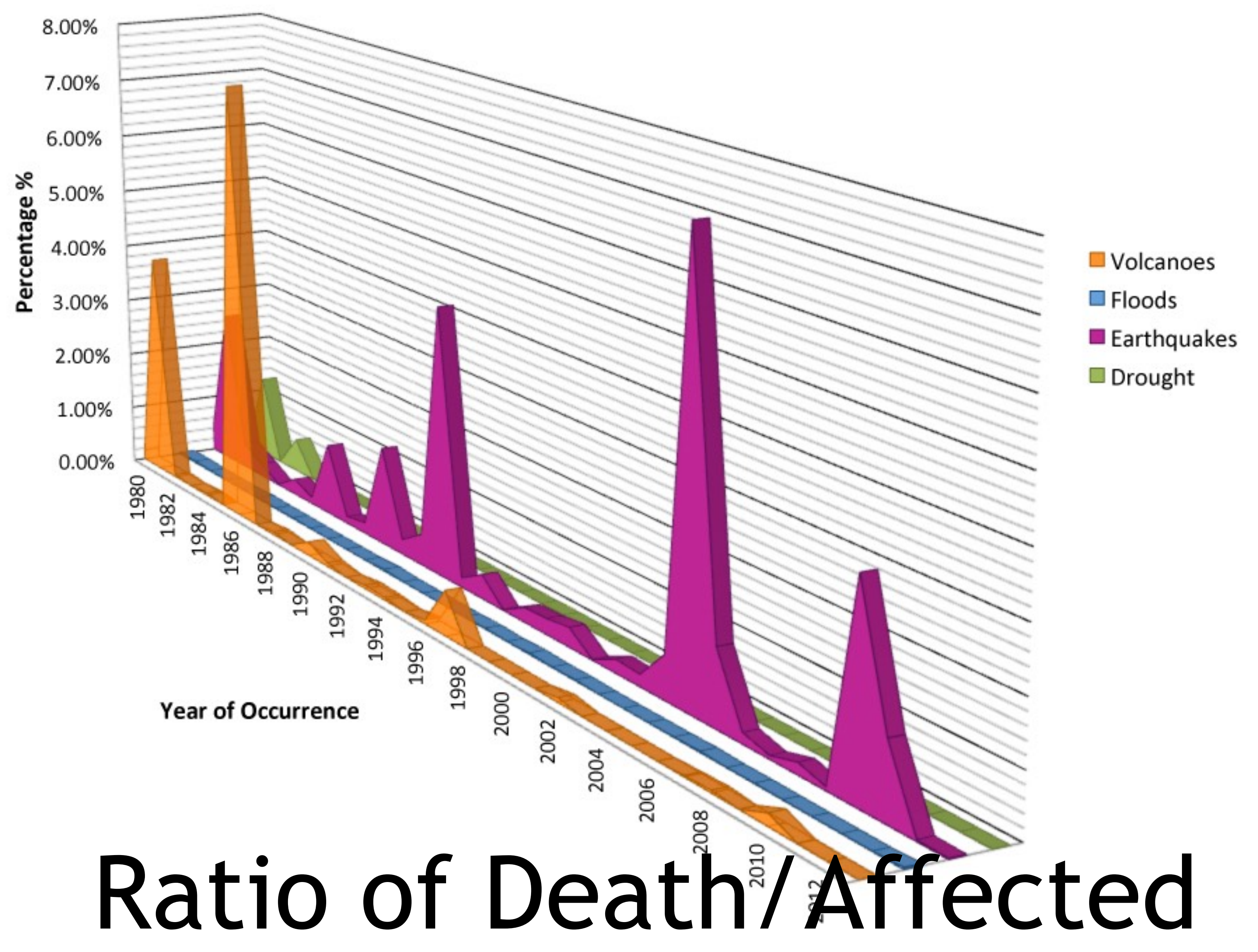
Fig. 9 Comparison of the energy and frequency of large volcanic eruptions and impacting asteroids. The impactor curve is based on estimates of the rate of cratering of Earth's surface over the recent past (Hughes 2000). The volcanic eruption curves are based on the upper and lower estimates of eruption 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 ~10 events/Ma) volcanic eruptions are more frequent than asteroid collisions of equivalent energy

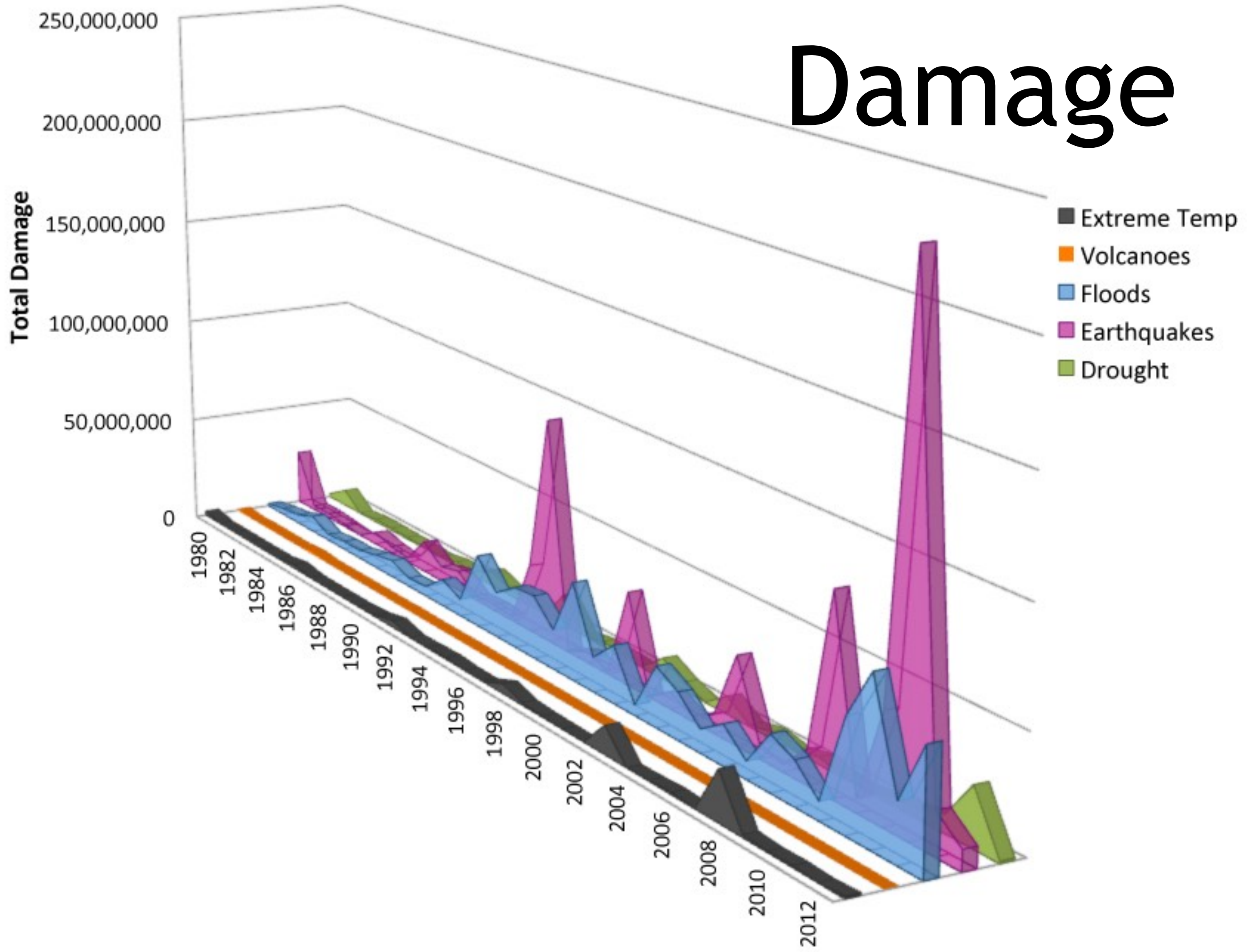
Mason et al., 2004

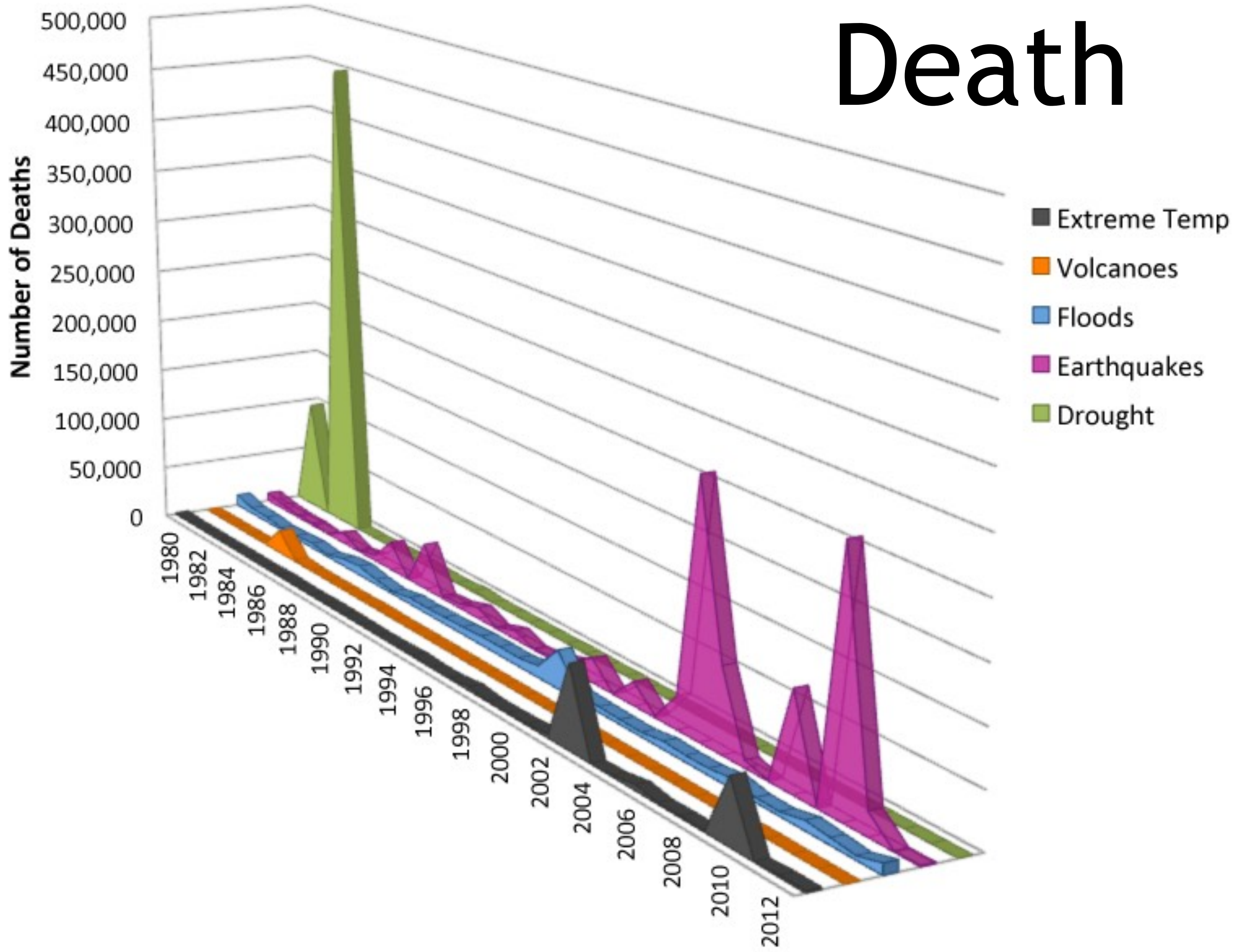
Comparison









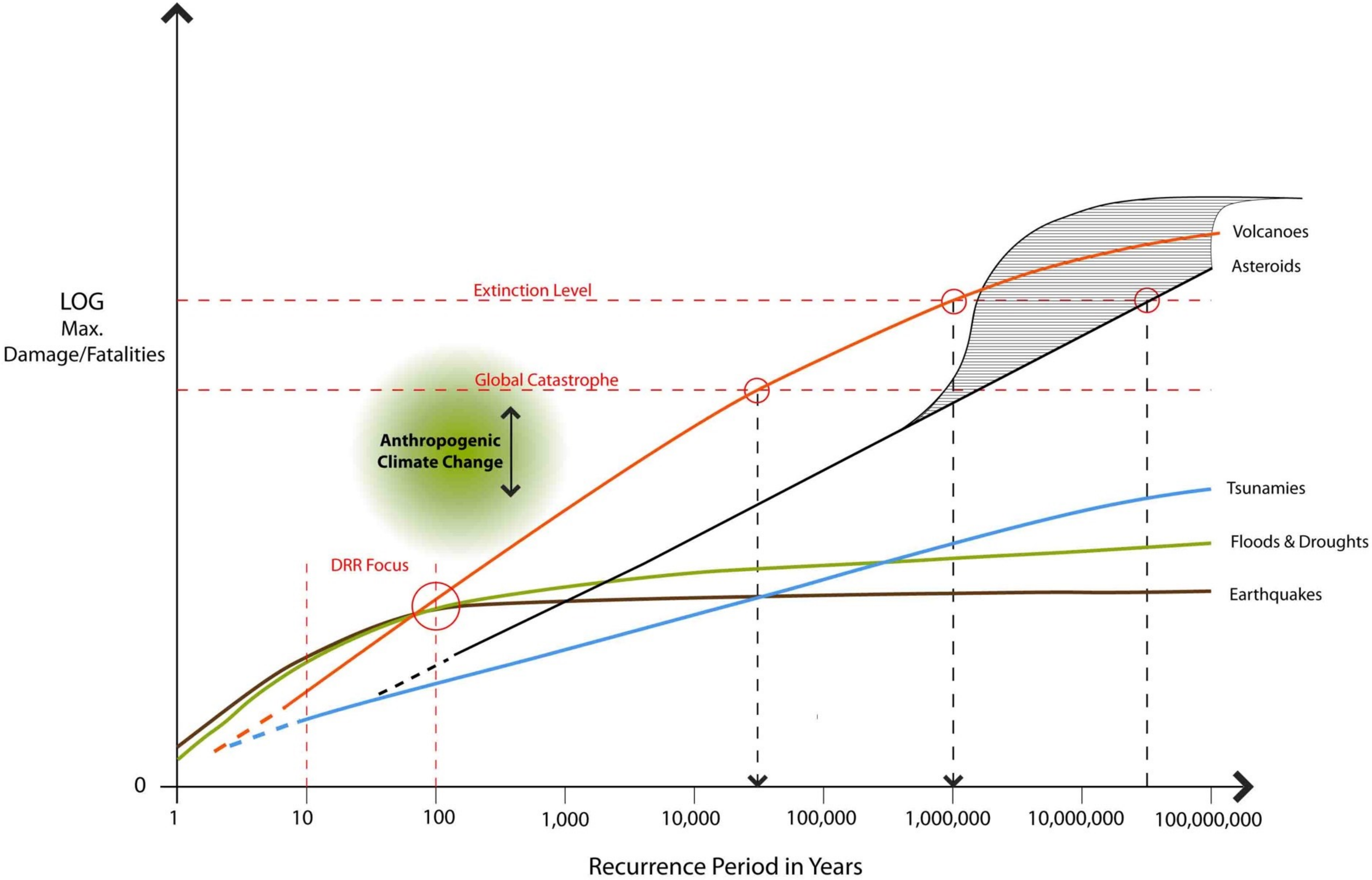


International Disaster Database

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

Comparison

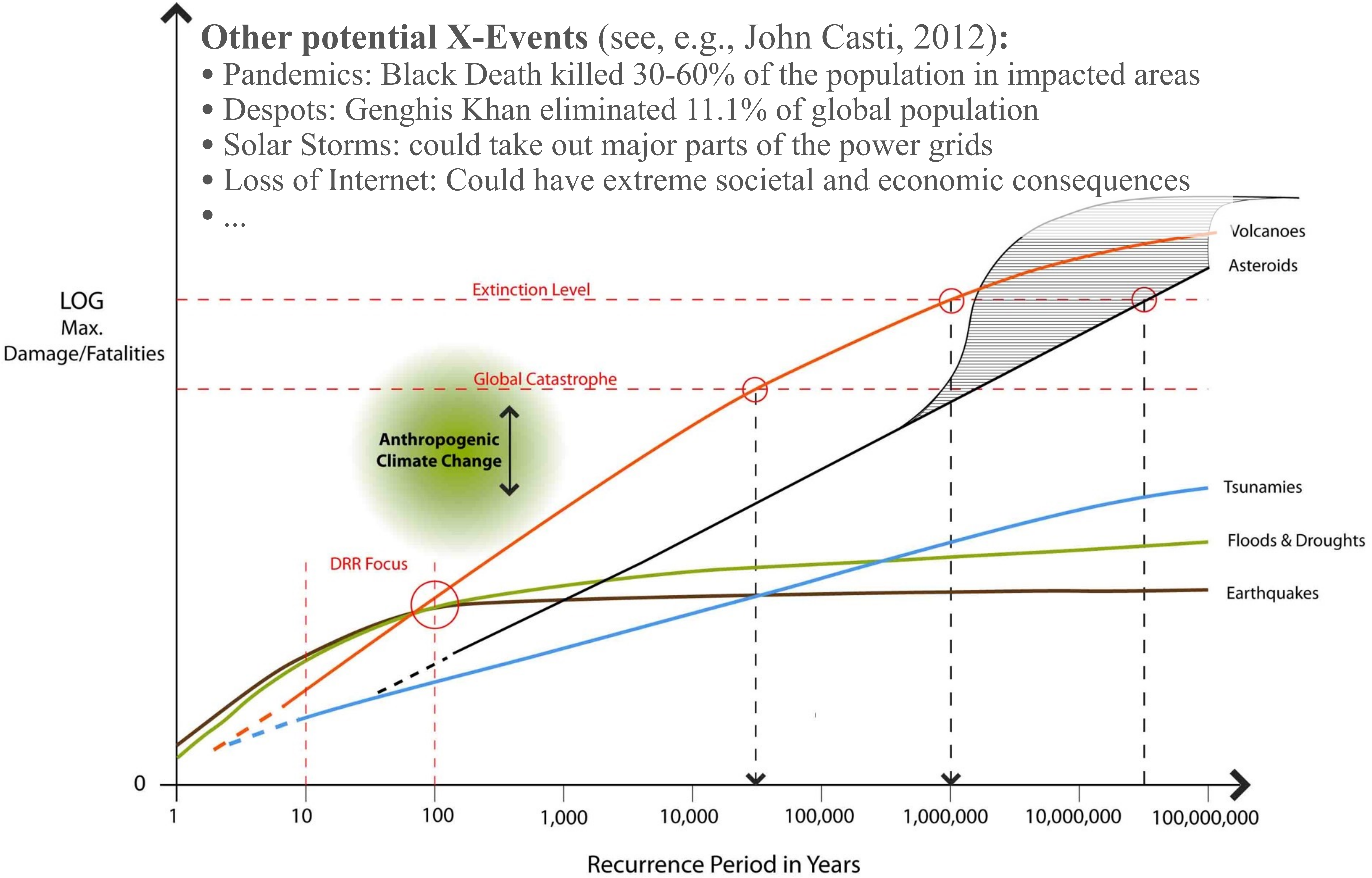
Comparison


LOG
Max.
Damage/Fatalities
Extinction Level
Global Catastrophe
Anthropogenic
Climate Change
DRR Focus
Volcanoes
Asteroids
Tsunamies
Floods & Droughts
Earthquakes
0
1
10
100
1,000
10,000
100,000
1,000,000
10,000,000
100,000,000
Recurrence Period in Years

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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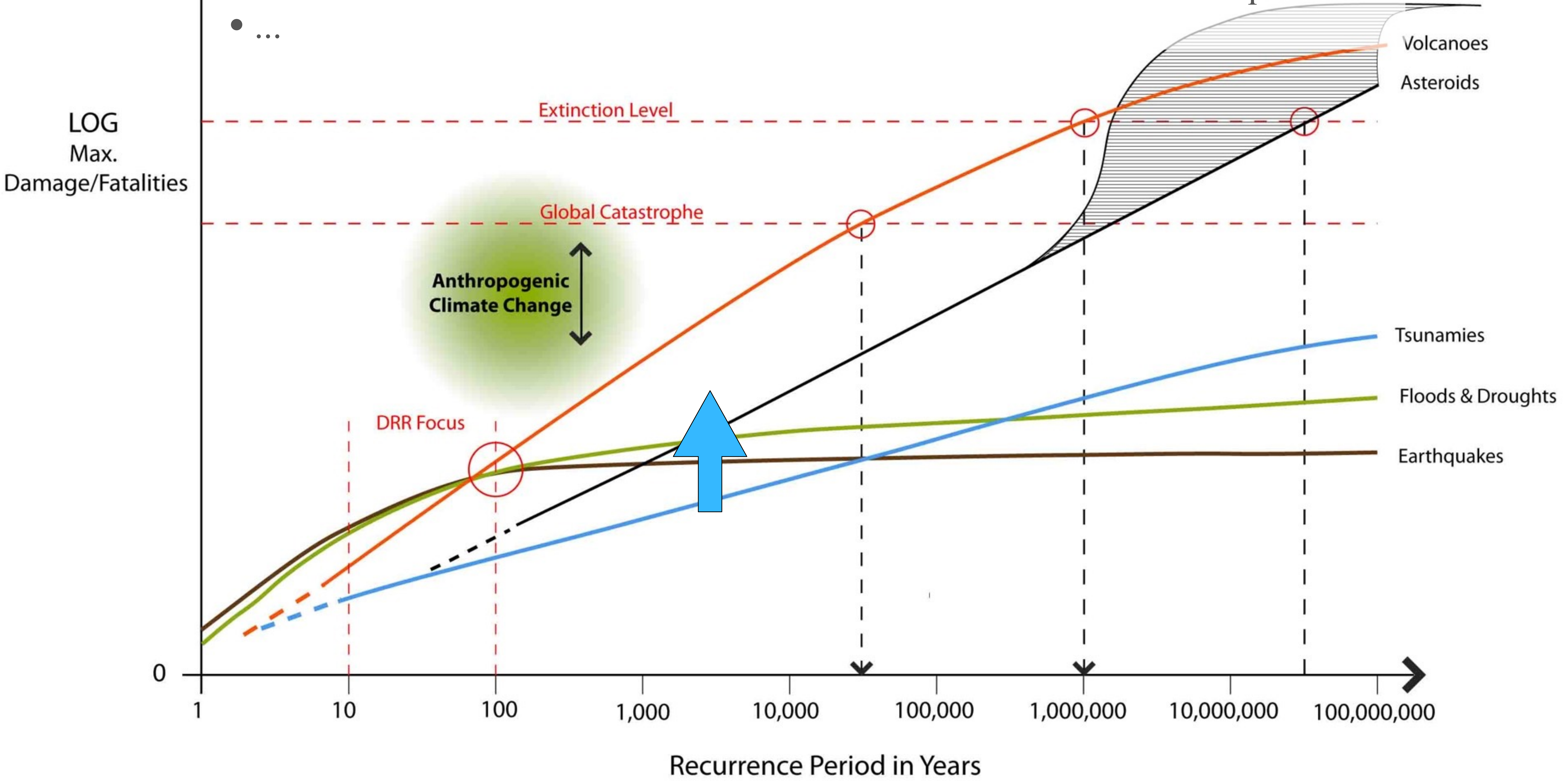

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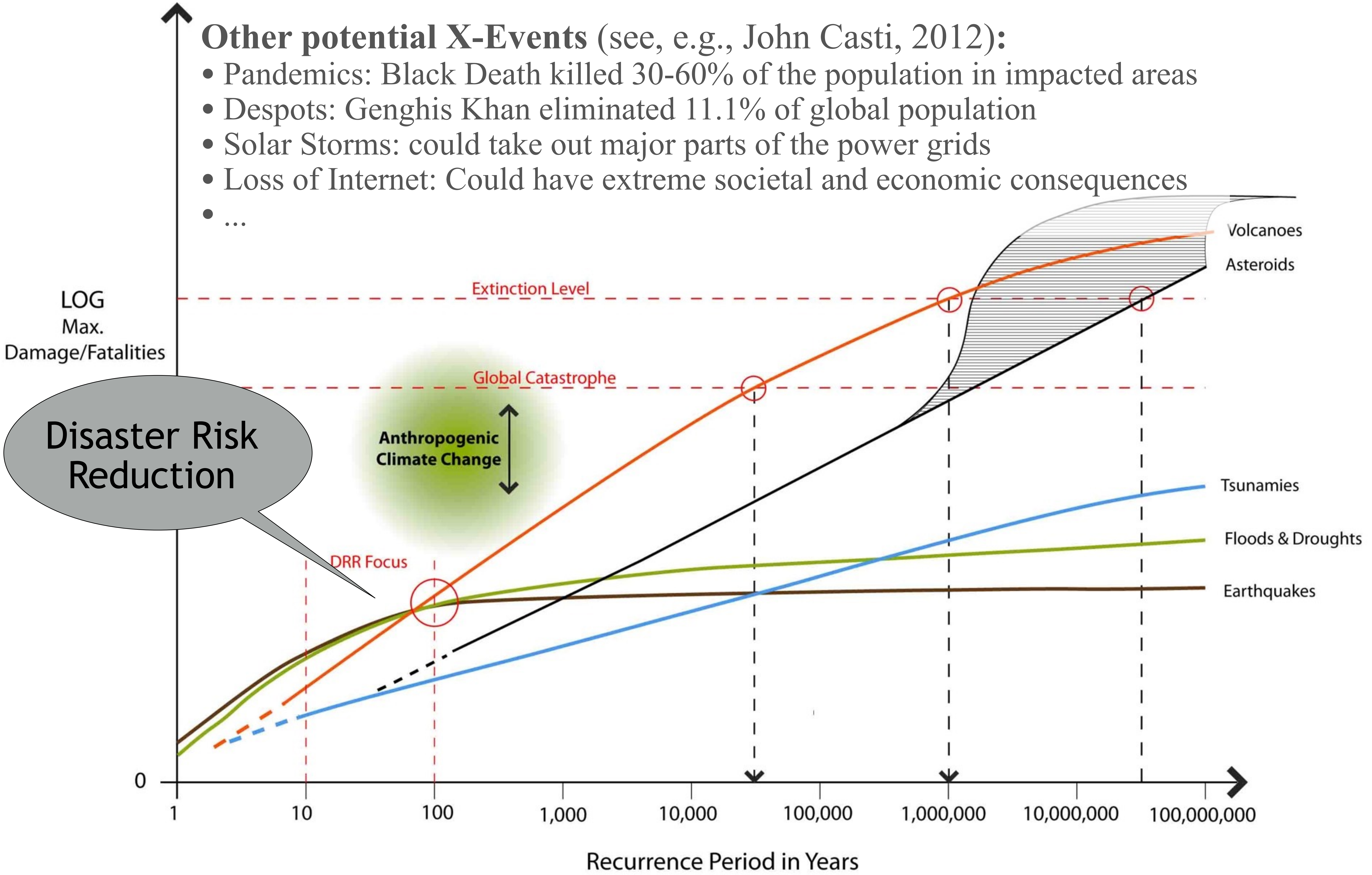

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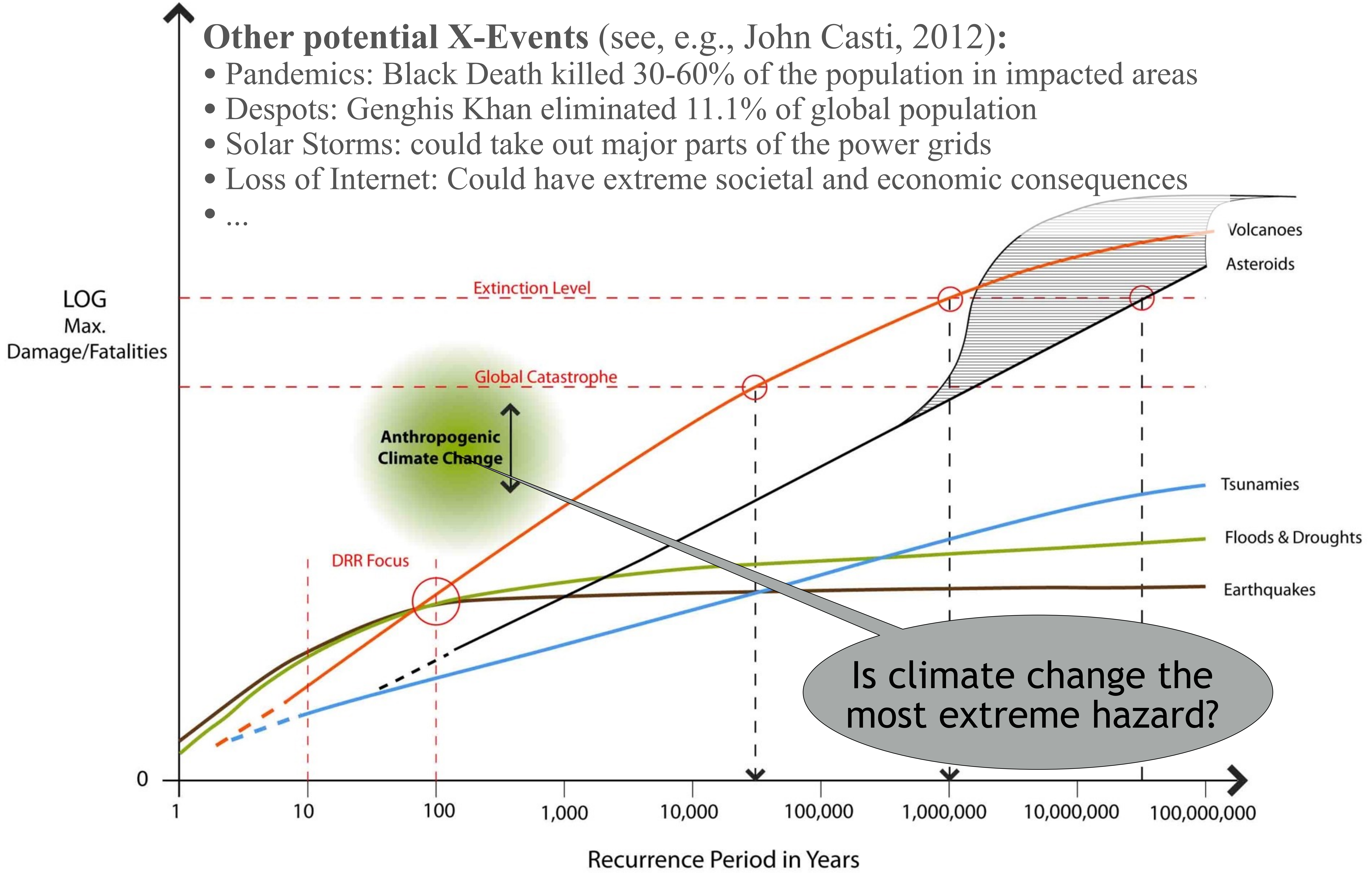

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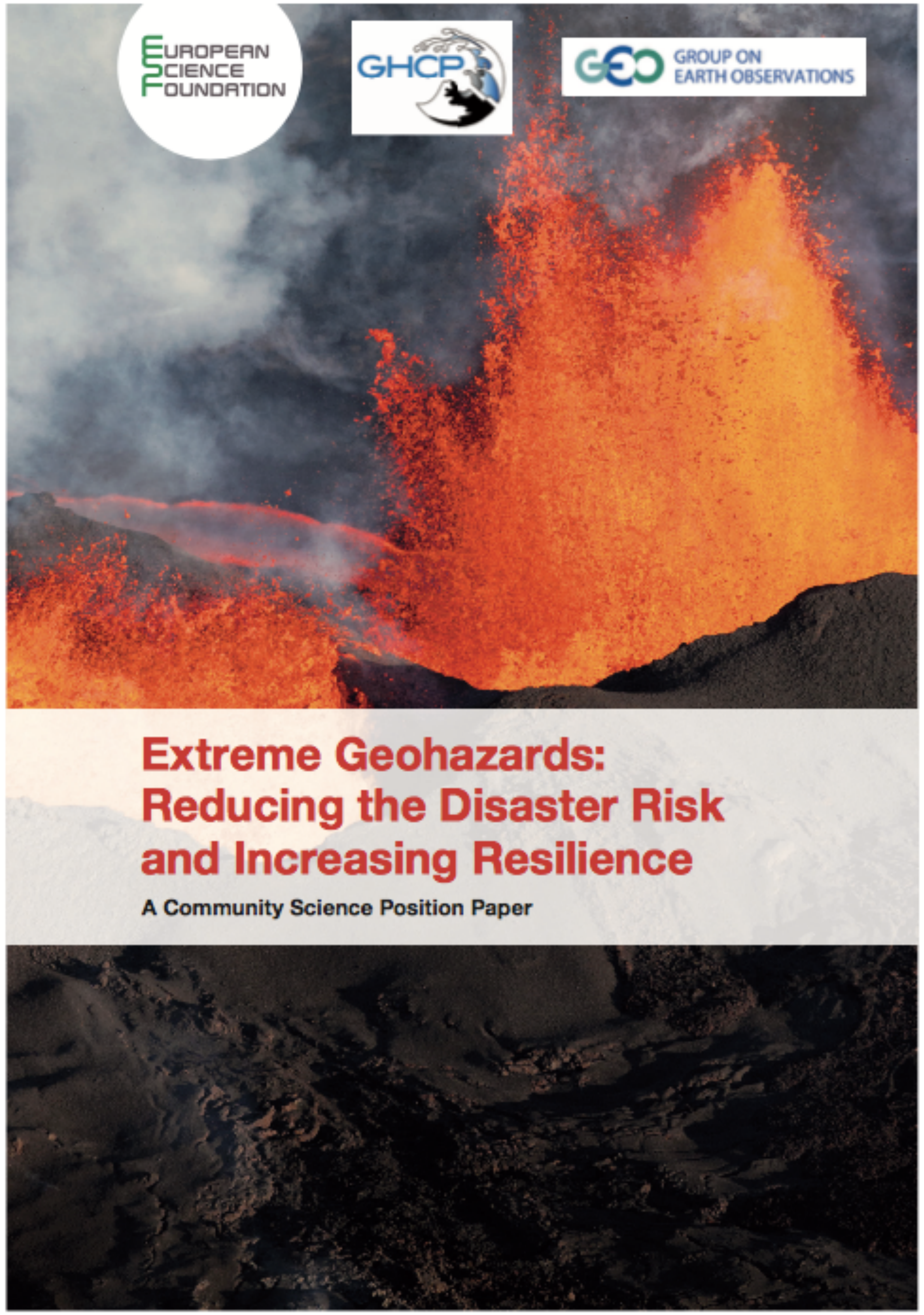
Mitigation and Preparedness

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

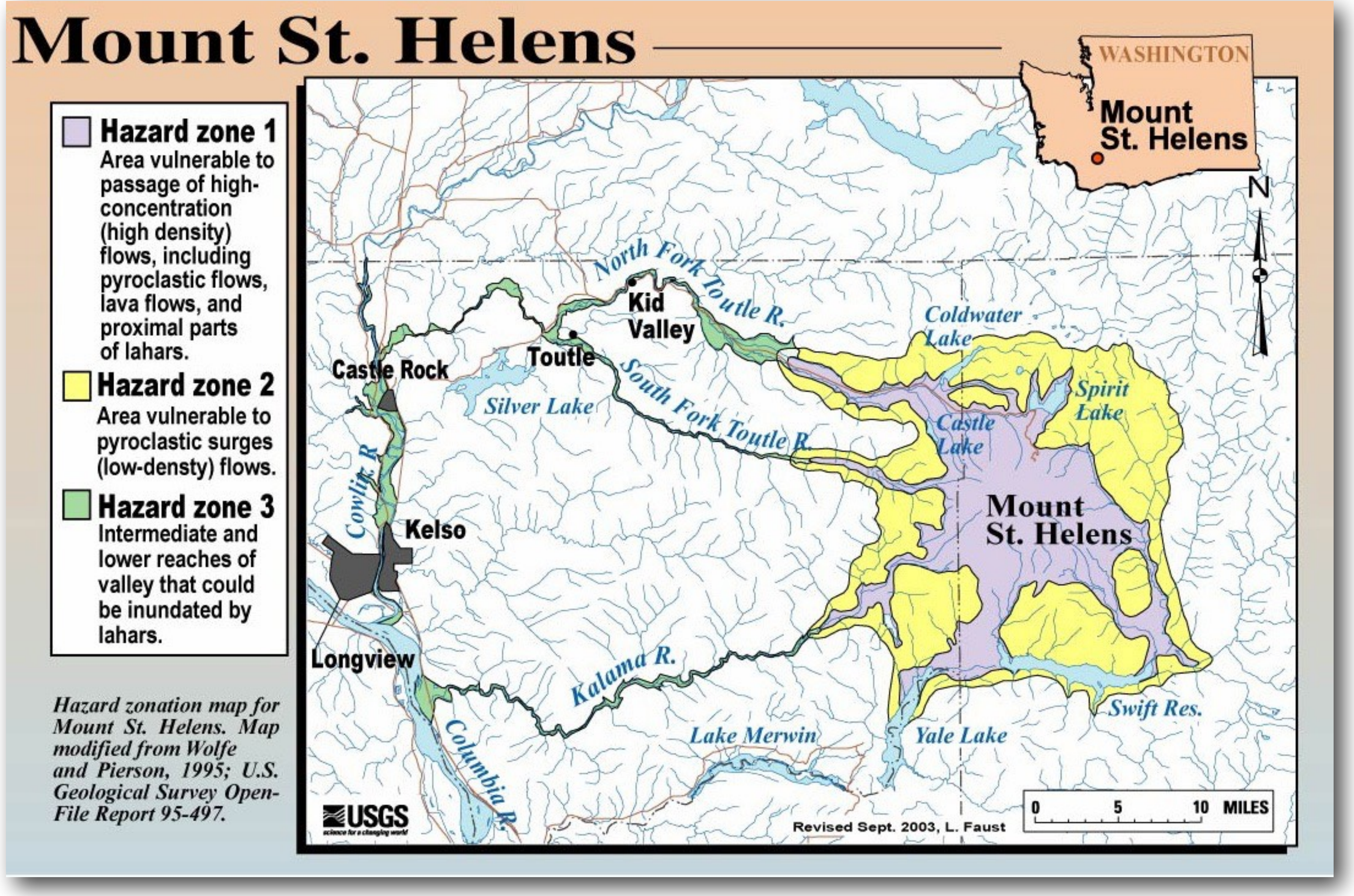
$$T_R = N/n$$

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

Mitigation and Preparedness

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

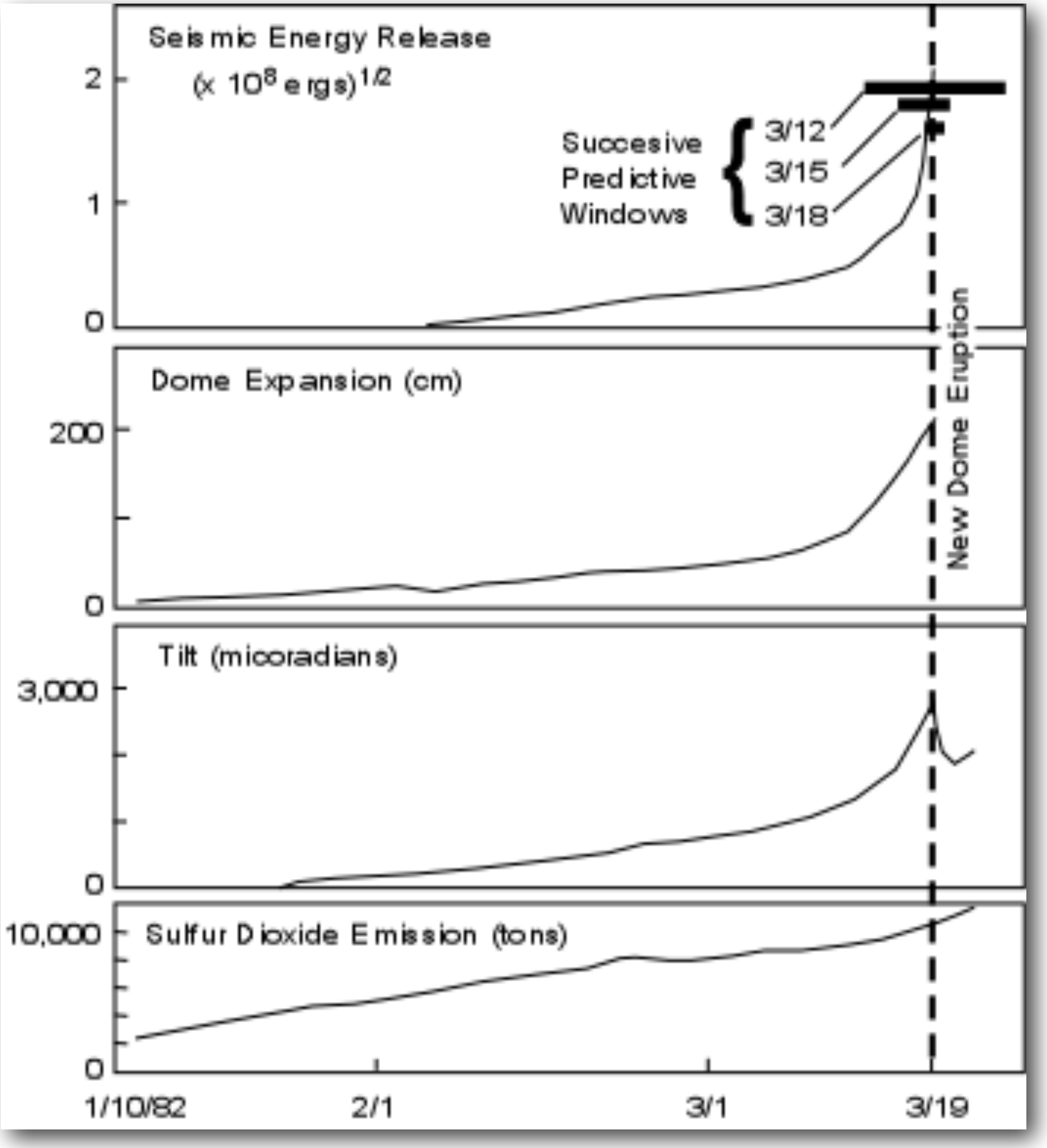
T_R = Recurrence interval (volcanic eruption frequency)

2. Hazard Map

3. Predictors - Early warning signals

Mitigation and Preparedness

Early warning signals include:



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

data from 1982 Mt St Helens eruption

Increase in local earthquake activity

Change of shape of volcano

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