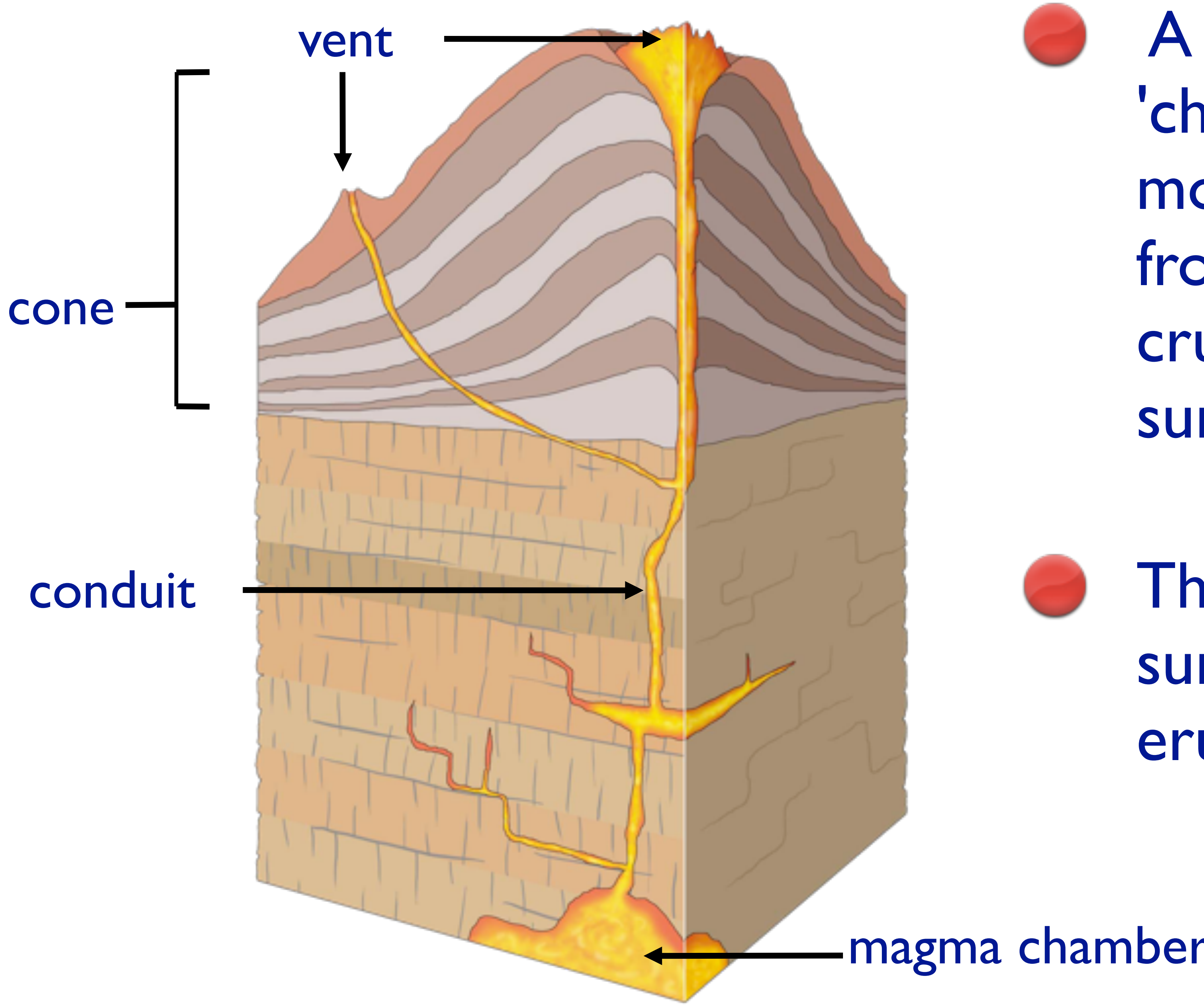
Volcanic Eruptions and Hazards

What is a volcano?



- A volcano is a vent or 'chimney' that connects molten rock (magma) from within the Earth’s crust to the Earth's surface.
- The volcano includes the surrounding cone of erupted material.

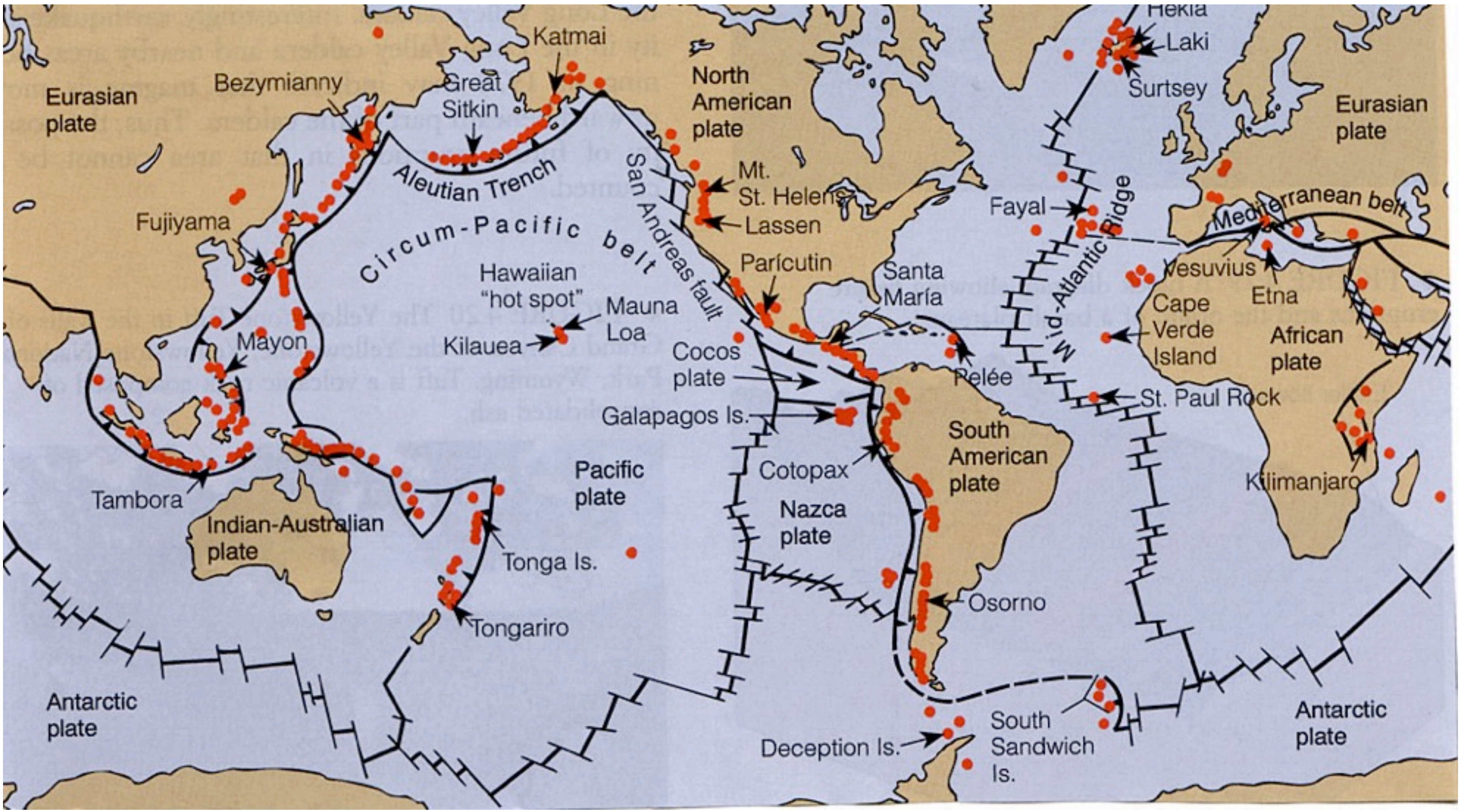
Volcanoes classification

- >1300 volcanoes known to have erupted in Holocene (last 10 000 years)
- ~500 classified as ‘active’ (i.e. known to have erupted in recorded history)
- Remainder classified as ‘dormant’ (may become active again) or ‘extinct’ (not expected to erupt again), but Vesuvius was thought to be extinct before AD 79!

Paricutin (Michoacan, Mexico) shown erupting in 1943 (graphic by Diego Rivera)

http://www.protezionecivile.gov.it/jcms/it/rischio_vulcanico.wp

Distribution of active volcanoes



60% around Pacific; 20% in Mediterranean region

Volcanoes and eruptive style

Eruptive style and hazard depends on:

- Tectonic setting
- Depth of magma formation
- Rate of magma movement to the surface
- Percent and type of volatiles (gases)

How and why do volcanoes erupt?

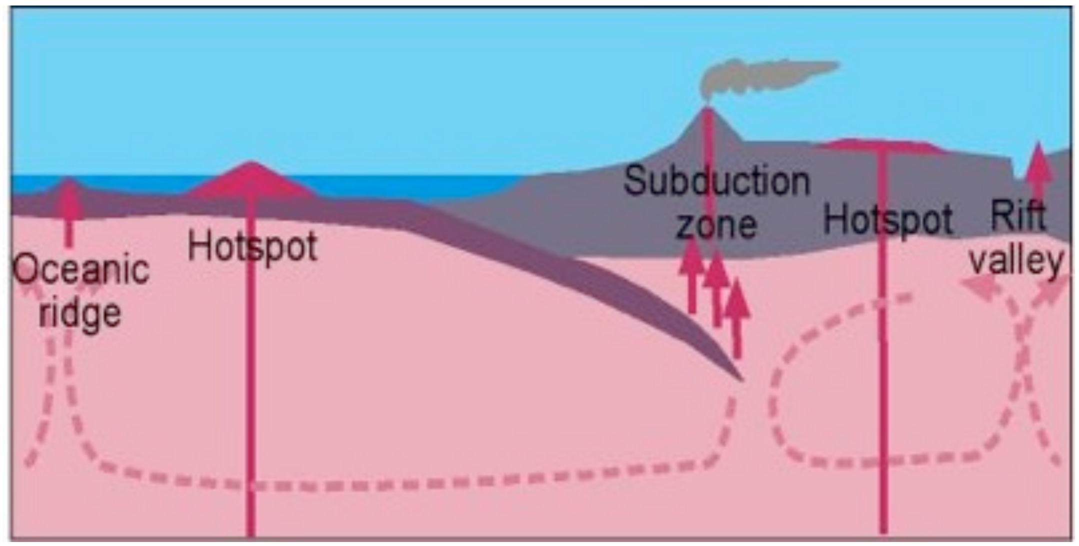
- Hot, molten rock (magma) is buoyant (has a lower density than the surrounding rocks) and will rise up through the crust to erupt on the surface.
- When magma reaches the surface it depends on how easily it flows (viscosity) and the amount of gas (H_2O, CO_2, S) it has in it as to how it erupts.
- Large amounts of gas and a high viscosity (sticky) magma will form an explosive eruption.

Think about shaking a carbonated drink and then releasing the cap

- Small amounts of gas and (or) low viscosity (runny) magma will form an effusive eruption.

Where the magma just trickles out of the volcano (lava flow)

Volcanoes - tectonic settings



Oceanic ridges, hotspots	Subduction zones
Basic/Mafic volcanics	Acidic/Felsic volcanics
Low SiO_2	High SiO_2
Fluid lava (10 m/s)	Viscous lava (3 m/s)
Low gas pressure (little explosive activity)	High gas pressure (explosive activity)

Classification of volcanic eruptions

			Low Risk		High Risk
			Gas Pressure		
			Low	Medium	High
Low	Lava Type	Fluid	Icelandic Hawaiian	Strombolian	Vesuvian
		Inter.	–	Vulcanian	Perretian
High		Viscous	Merapian	Vincentian	Peléean
			Oceanic ridge, Hotspots		Subduction zone

Explosive Eruptions

- Explosive volcanic eruptions can be catastrophic
- Erupt 10's-1000's km^3 of magma
- Send ash clouds >25 km into the stratosphere
- Have severe environmental and climatic effects
- Hazardous!!!

Above: Large eruption column and ash cloud from an explosive eruption at Mt Redoubt, Alaska

Explosive Eruptions

Three products from an explosive eruption:

- Ash fall
- Pyroclastic flow
- Pyroclastic surge

Pyroclastic flows on Montserrat, buried the capital city.

Direct measurements of pyroclastic flows are extremely dangerous!!!

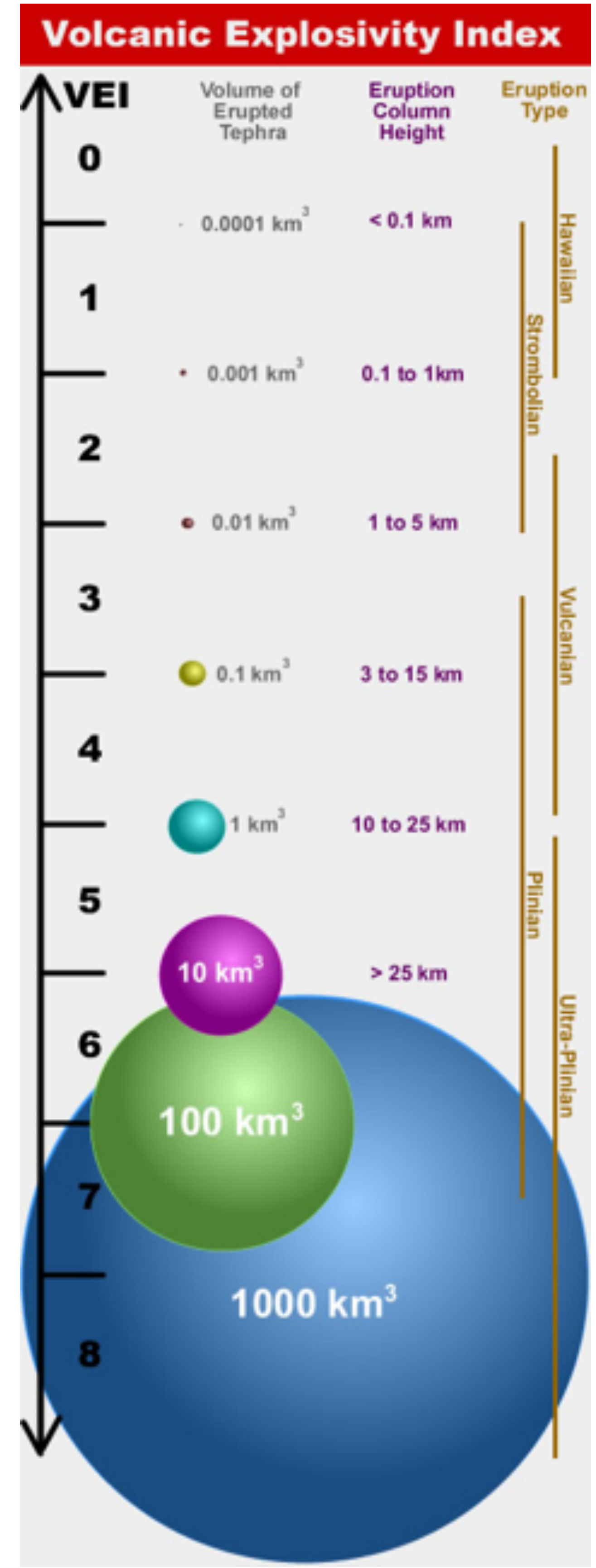
Effusive Eruptions

- Effusive eruptions are characterised by outpourings of lava on to the ground.

Courtesy of www.swisseduc.ch

VEI (Volcanic Explosivity Index)

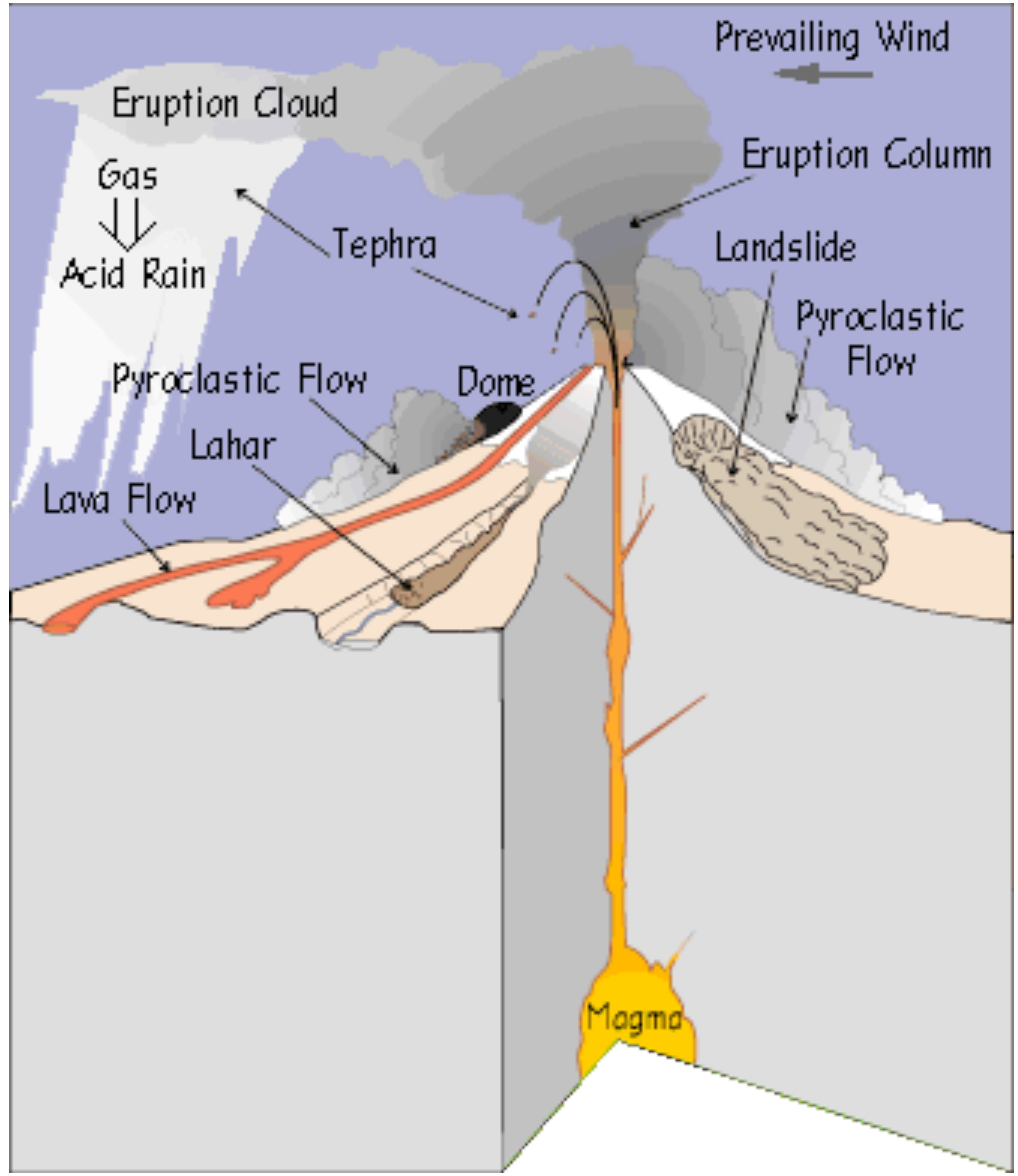
VEI	0	1	2	3	4	5	6	7	8
General Description	Non-Explosive	Small	Moderate	Moderate-Large	Large	Very Large			
Volumn of Tephra (m^3)		$1x10^4$	$1x10^6$	$1x10^7$	$1x10^8$	$1x10^9$	$1x10^{10}$	$1x10^{11}$	$1x10^{12}$
Cloud Column Height (km) Above crater / Above sea level	<0.1	0.1-1	1-5	3-15	10-25	← >25 →			
Qualitative Description	"Gentle," "Effusive"		← "Explosive" →		← "Cataclysmic," "paroxysmal," "colossal" →				
				← "Severe," "violent," "terrific" →					
Eruption Type (see fig. 7)		← Strombolian →			← Plinian →				
	← Hawaiian →		← Vulcanian →			← Ultra-Plinian →			
Duration (continuous blast)	← <1 hr →				← >12 hrs →				
			← 1-6 hrs →						
				← 6-12 hrs →					
Maximum explosivity	Lava flow	← Explosion or Nuée ardente →							
		← Phreatic → - - - - - →							
	Dome or mudflow								
Tropospheric Injection	Negligible	Minor	Moderate	Substantial →					
Stratospheric Injection	None	None	None	Possible	Definite	Significant →			
Eruptions	976	1239	3808	1083	412	168	50	6	0



https://www.wired.com/2013/07/revamping-the-volcanic-explosivity-index-or-tiny-eruptions-need-love-too/

Volcanic Hazards

- Pyroclastic flow
- Lahars/Mud flows
- Pyroclastic fall
- Lava flow
- Noxious Gas
- Earthquakes

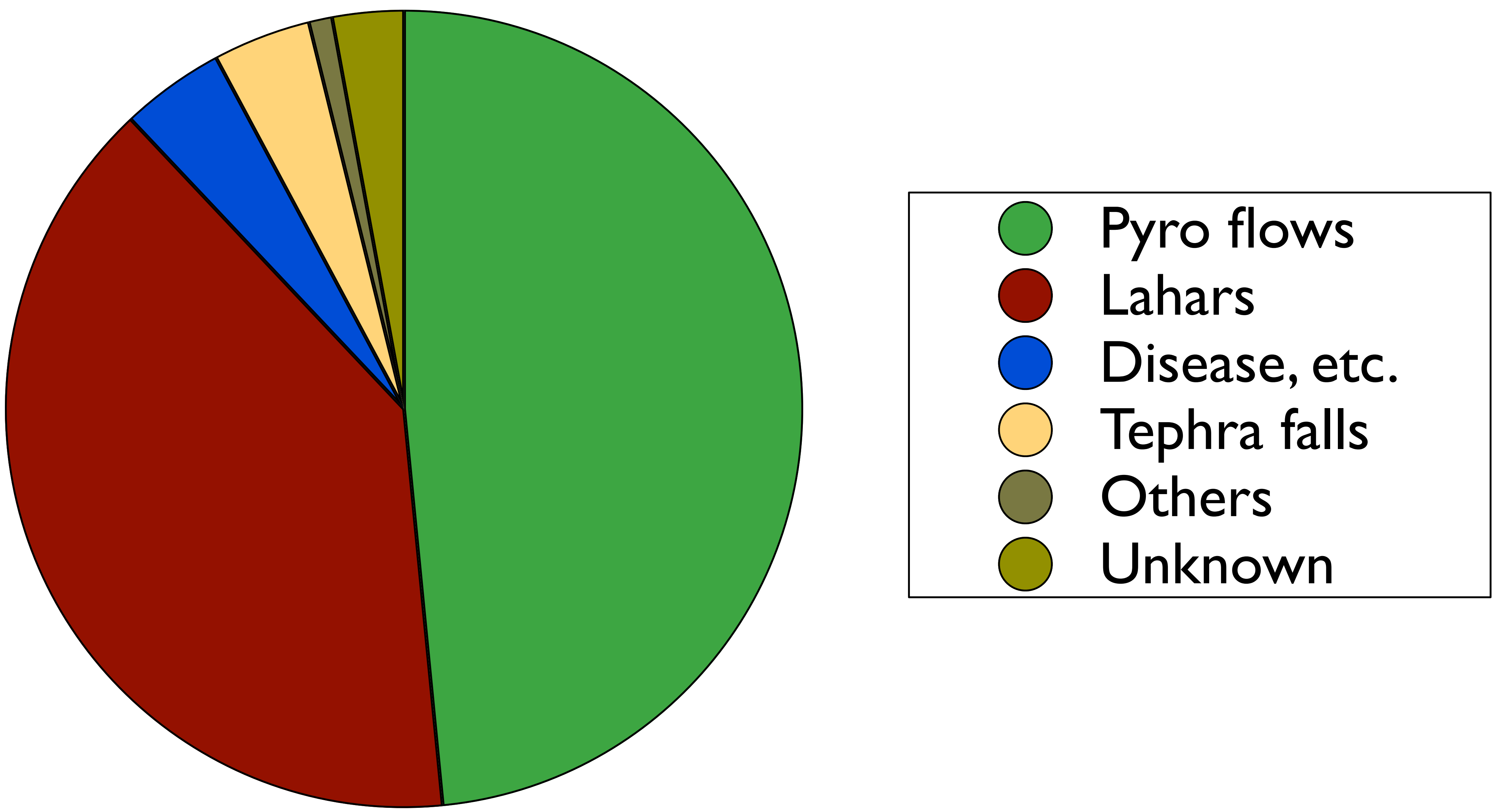


http://volcanoes.usgs.gov/Hazards/What/hazards.html

Major volcanic eruptions since AD1600 (>8000 deaths)

Event	Date	Deaths	Hazard type
Laki, Iceland	1783	9000	Starvation
Unzen, Japan	1792	14300	70% by cone collapse; 30% by tsunami
Tambora, Indonesia	1815	92000	90% by starvation
Krakatoa, Indonesia	1883	36000	90% by starvation; <10% pyro. flows and tephra
Mt. Pelée, Martinique	1902	29000	Pyroclastic flows
Nevada del Ruiz, Colombia	1985	25000	Lahars

Volcanic hazards: deaths (AD 1900-2000)



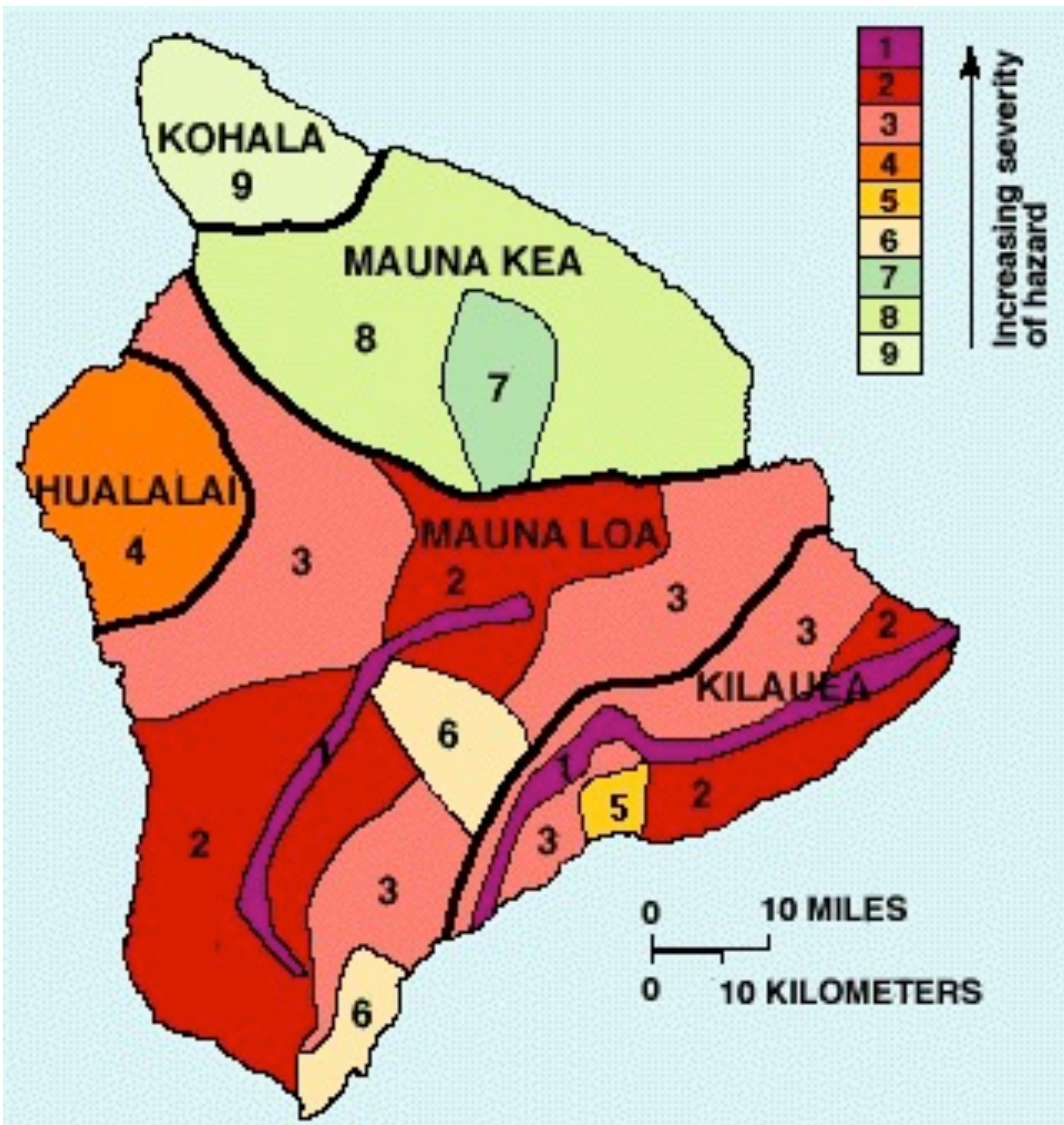
Basaltic lava flows

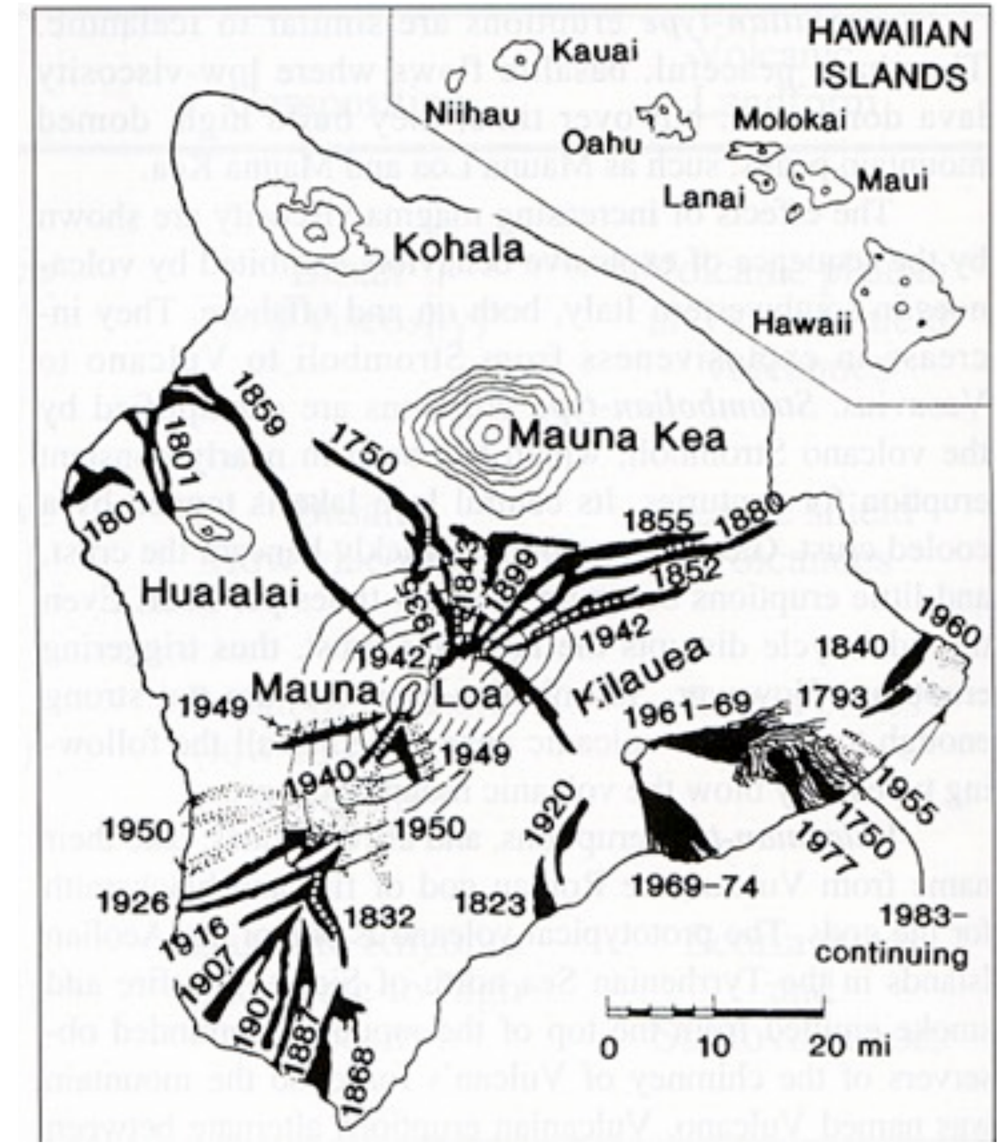
“Aa” (blocky lava) flow, Hawaii

“Pahoehoe” (ropy lava) flow, Reunion

Hazards - property burnt and buried by lava

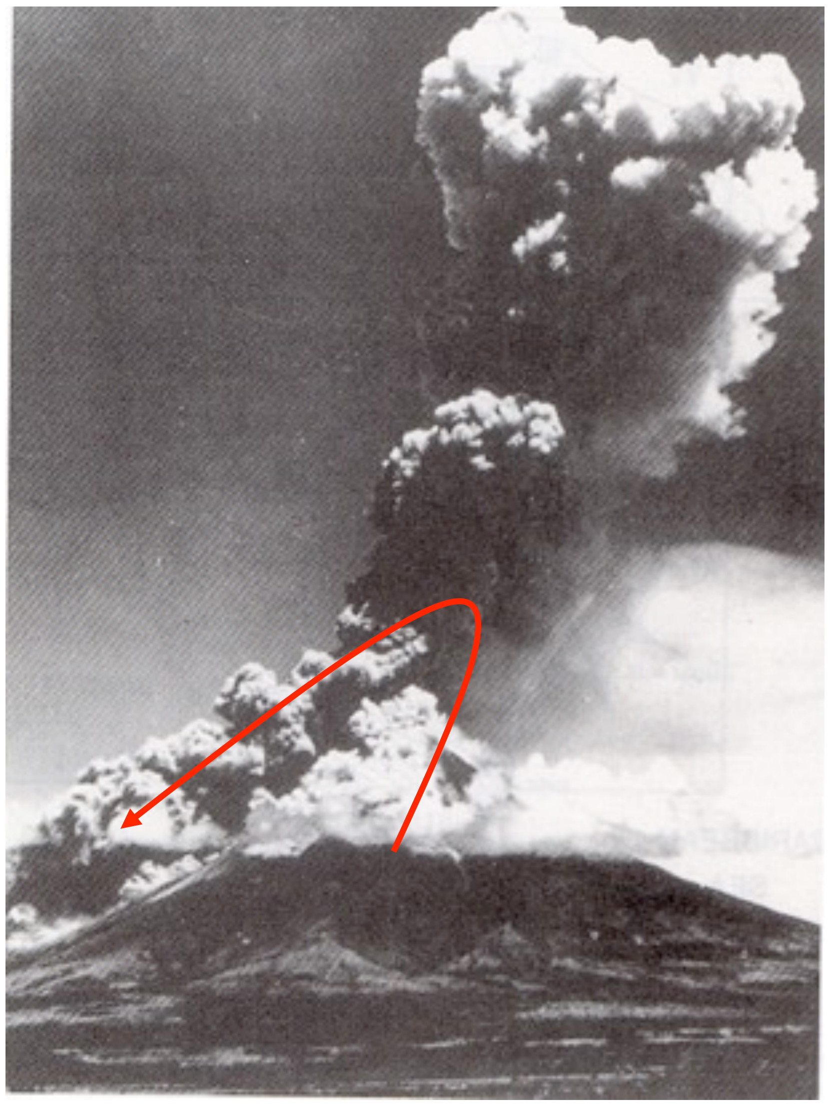
Volcanic hazards - Hawaii





Five active volcanoes;
hazards are mainly lava flows, although tephra and gas emissions also occur.
Hazard profile similar for all three.

Pyroclastic Flow (nuée ardente)



Collapse of eruption column (Mt. Mayon Phillipines, 1968)

Ruins of St. Pierre, Martinique. Pyroclastic flow (>700°C; ~200 km/h) from Mt. Pelée in 1902 killed 30 000 people; 2 survived.

Mt Peleé, Martinique (1902)

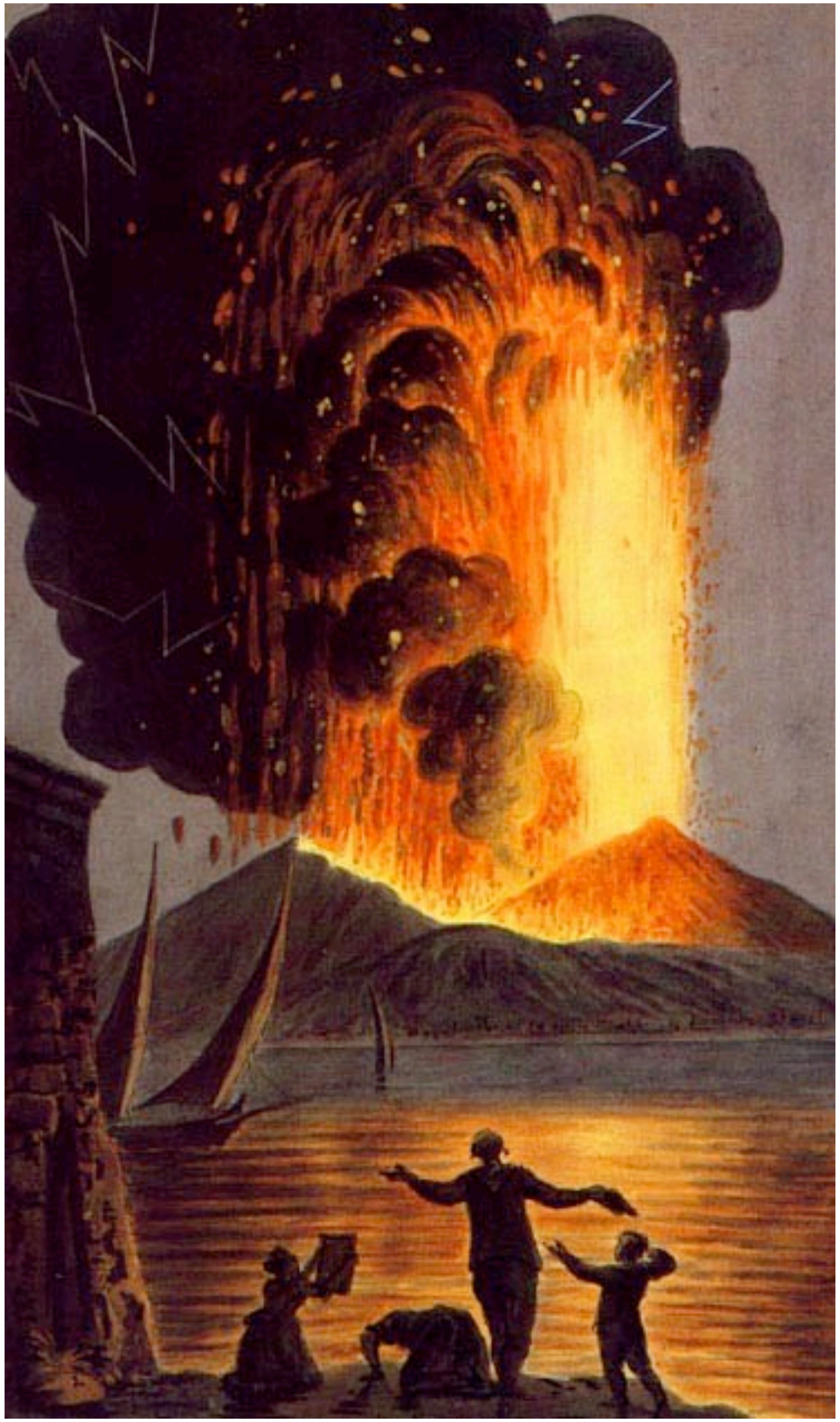
- An eruption of Mt Peleé in 1902 produced a pyroclastic flow that destroyed the city of St. Pierre.

before

after

Pyroclastic Flow

- For example, eruption of Vesuvius in 79 AD destroyed the city of Pompeii

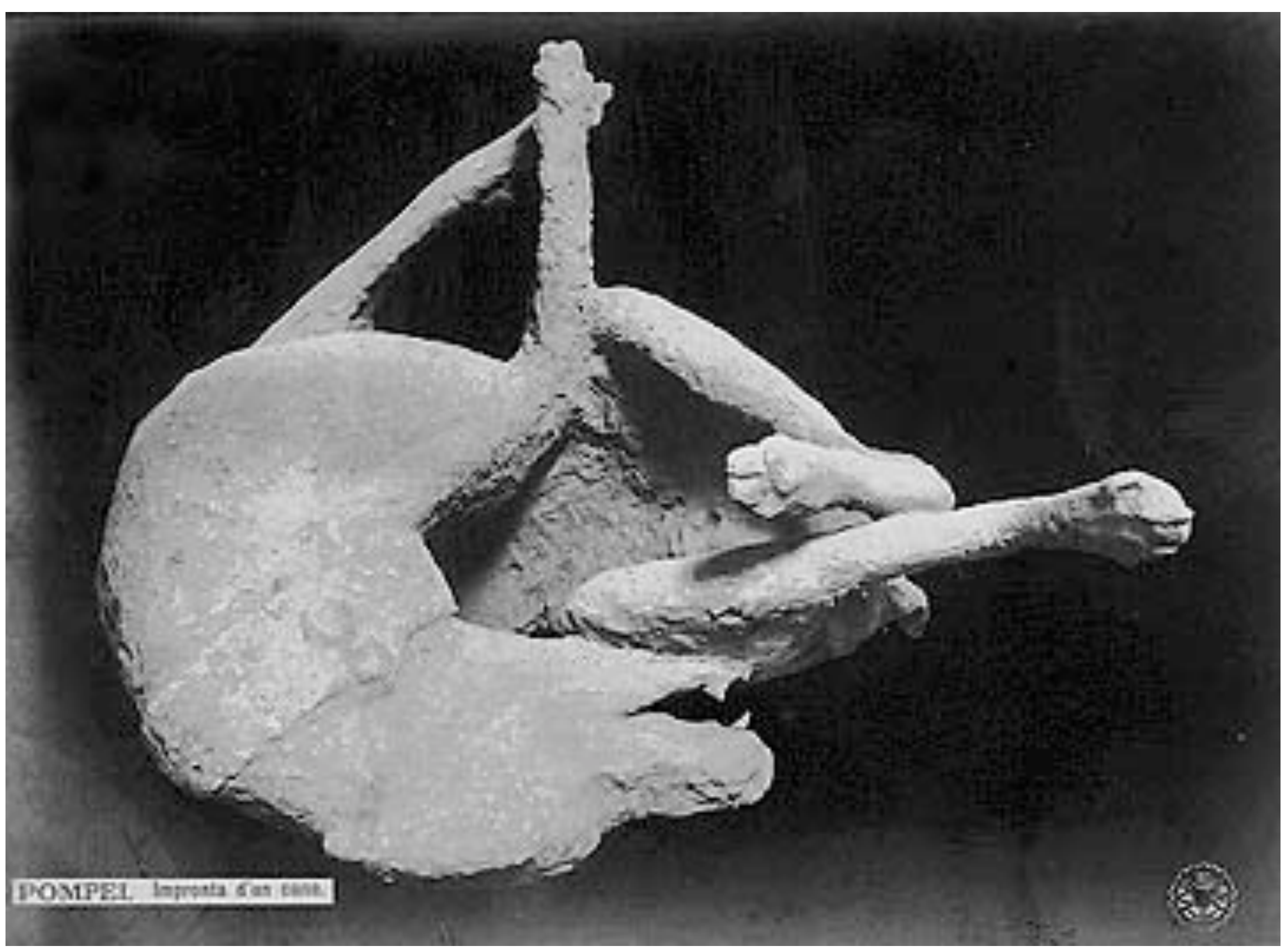


Pompeii (79AD)

On August 24, 79AD Mount Vesuvius literally blew its top, erupting tonnes of molten ash, pumice and sulfuric gas miles into the atmosphere. Pyroclastic flows flowed over the city of Pompeii and surrounding areas.

Pompeii (79AD)

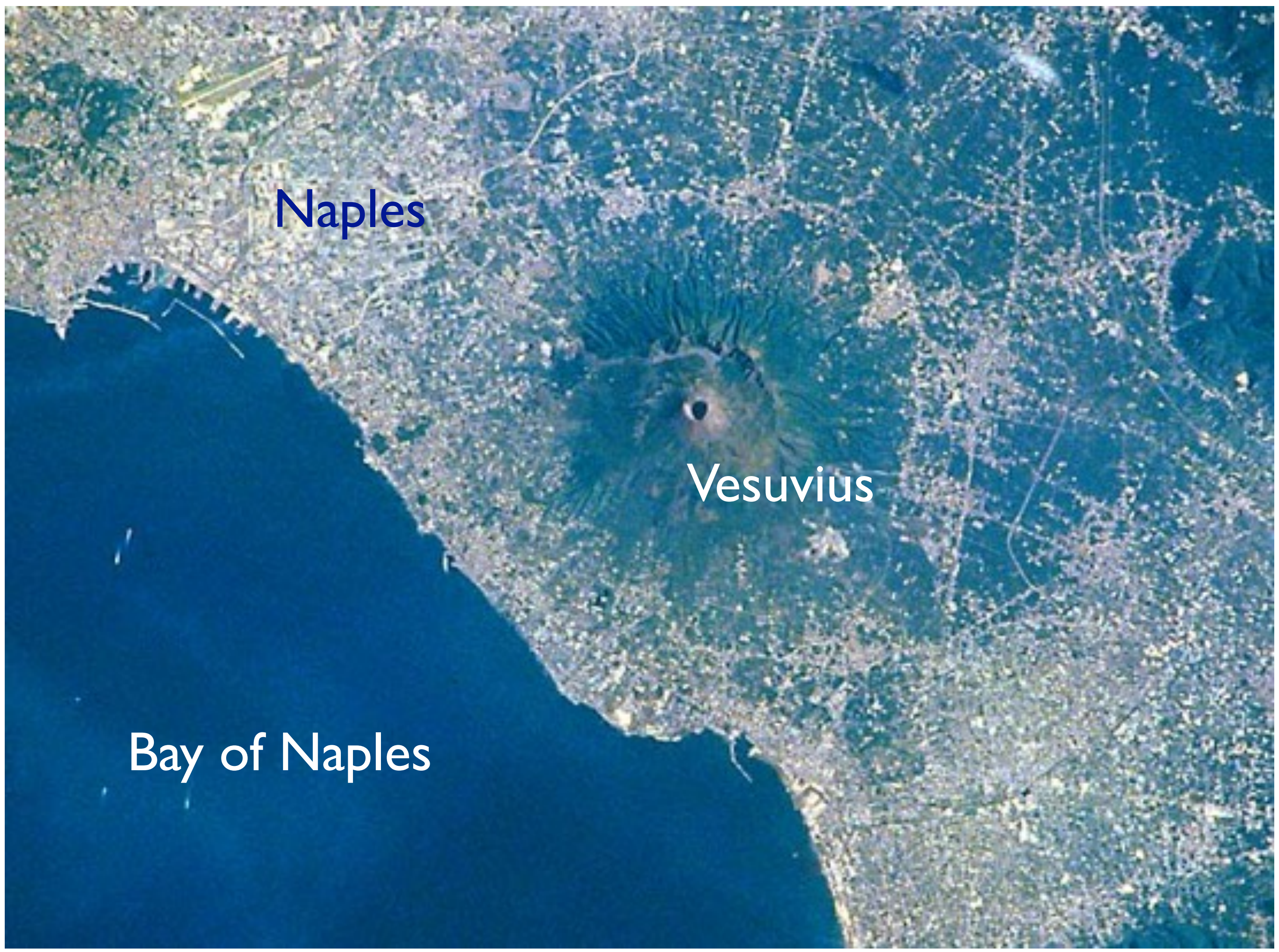
- Pyroclastic flows of poisonous gas and hot volcanic debris engulfed the cities of Pompeii, Herculaneum and Stabiae suffocating the inhabitants and burying the buildings.



Pompeii (79AD)

The cities remained buried and undiscovered for almost 1700 years until excavation began in 1748. These excavations continue today and provide insight into life during the Roman Empire.

Vesuvius today



Courtesy of www.swisseduc.ch

- Vesuvius remains a hazardous volcano with heavily populated flanks:
  - around 1.5 million people live in the city of Naples alone
  - Naples is situated approx. 30 km from Vesuvius
  - Pyroclastic flows can flow up to 100 km from source!

Pyroclastic Flow - direct impact

Courtesy of www.swisseduc.ch

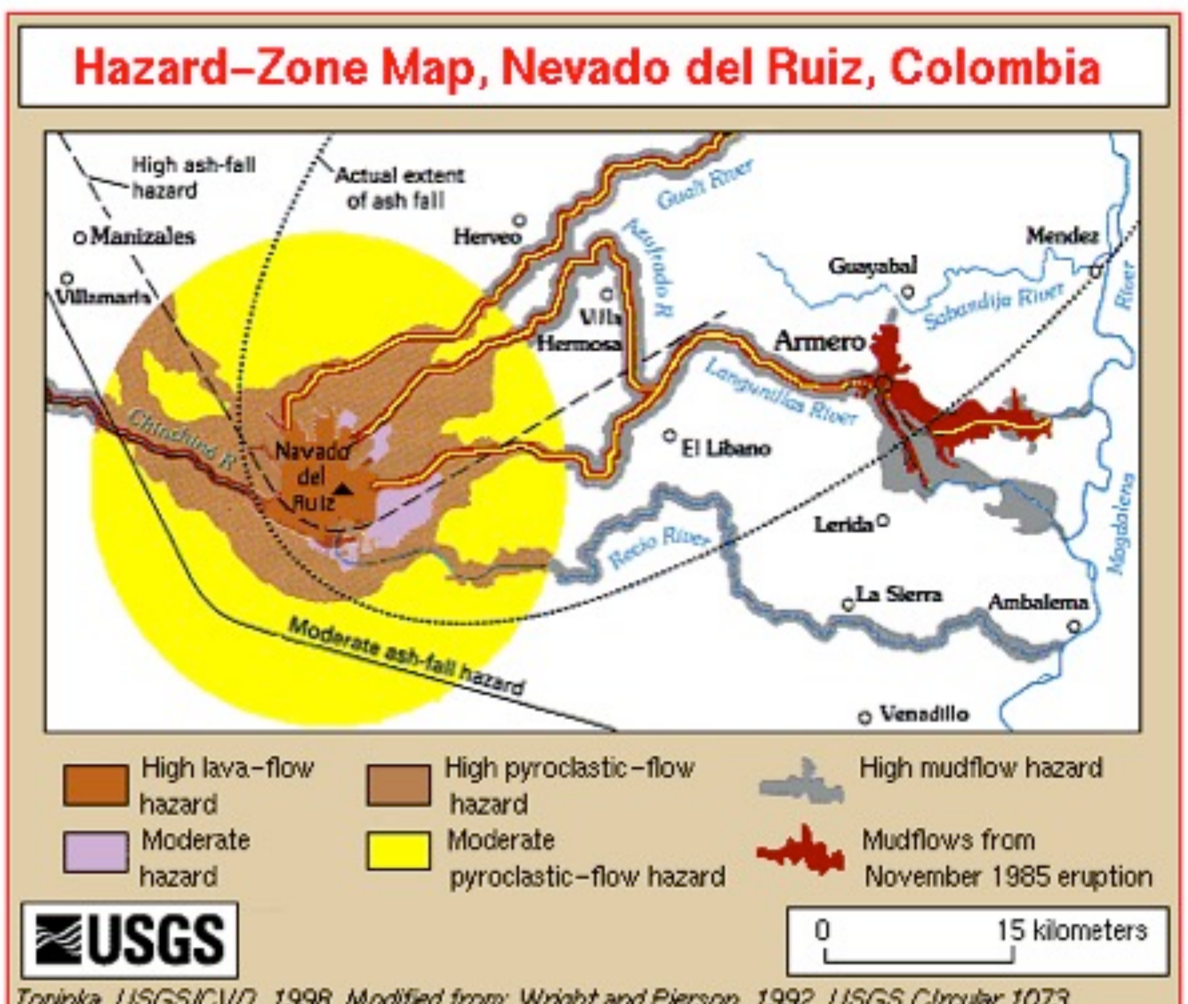
Pyroclastic Flow - burial

Pyroclastic Flow - burns

Pyroclastic Flow - lahars

- Hot volcanic activity can melt snow and ice
- Melt water picks up rock and debris
- Forms fast flowing, high energy torrents
- Destroys all in its path

Lahars



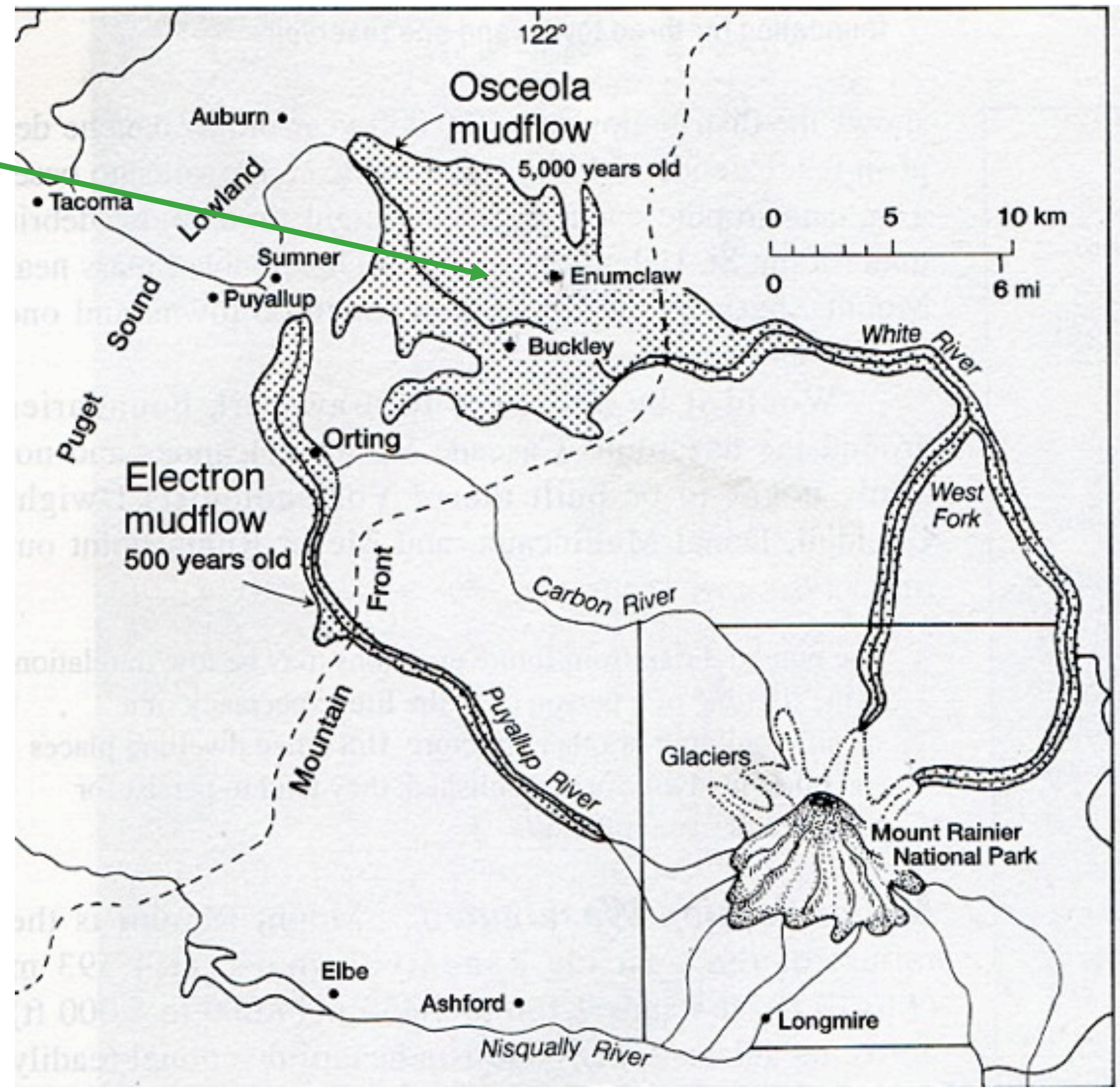
Lahars: volcanic mudflows

Eruptive
"volcanic rain"
(e.g. Herculaneum)
melting of summit snow/ice
(e.g. Nevado del Ruiz)

Post-eruptive
intense rainstorms (e.g. Hurricane Mitch)

Lahars, Mt Rainier

Osceola lahar:
age: 5600 yrs BP
length: 120 km
volume: 40x Ruiz
depth: 20m
velocity: >70 km/h
pop: 100 000

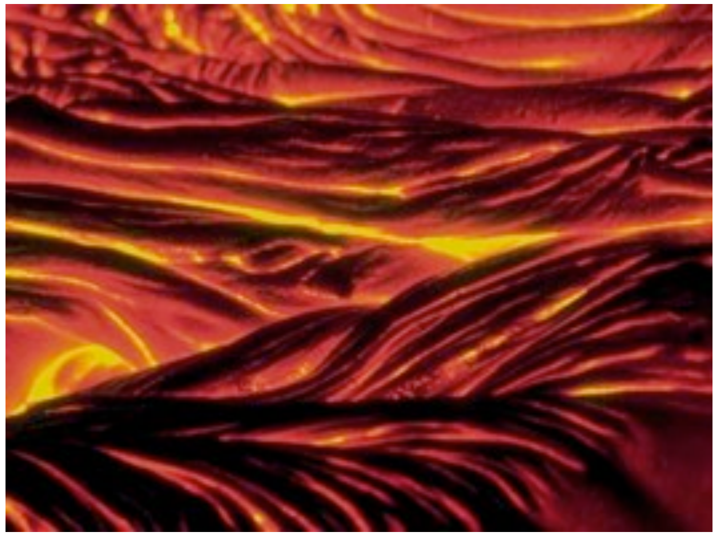


Pyroclastic Fall

- Ash load
- Collapses roofs
- Brings down power lines
- Kills plants
- Contaminates water supplies
- Respiratory hazard for humans and animals

Lava Flow

- It is not just explosive volcanic activity that can be hazardous. Effusive (lava) activity is also dangerous.


Lava Flow - Heimaey, Iceland

- Iceland, January 23, 1973
- Large fissure eruption threatened the town of Vestmannaeyjar


Lava Flow - Heimaey, Iceland

- The lava flows caught the inhabitants by surprise
- Before the eruption was over, approximately one-third of the town of Vestmannaeyjer had been destroyed

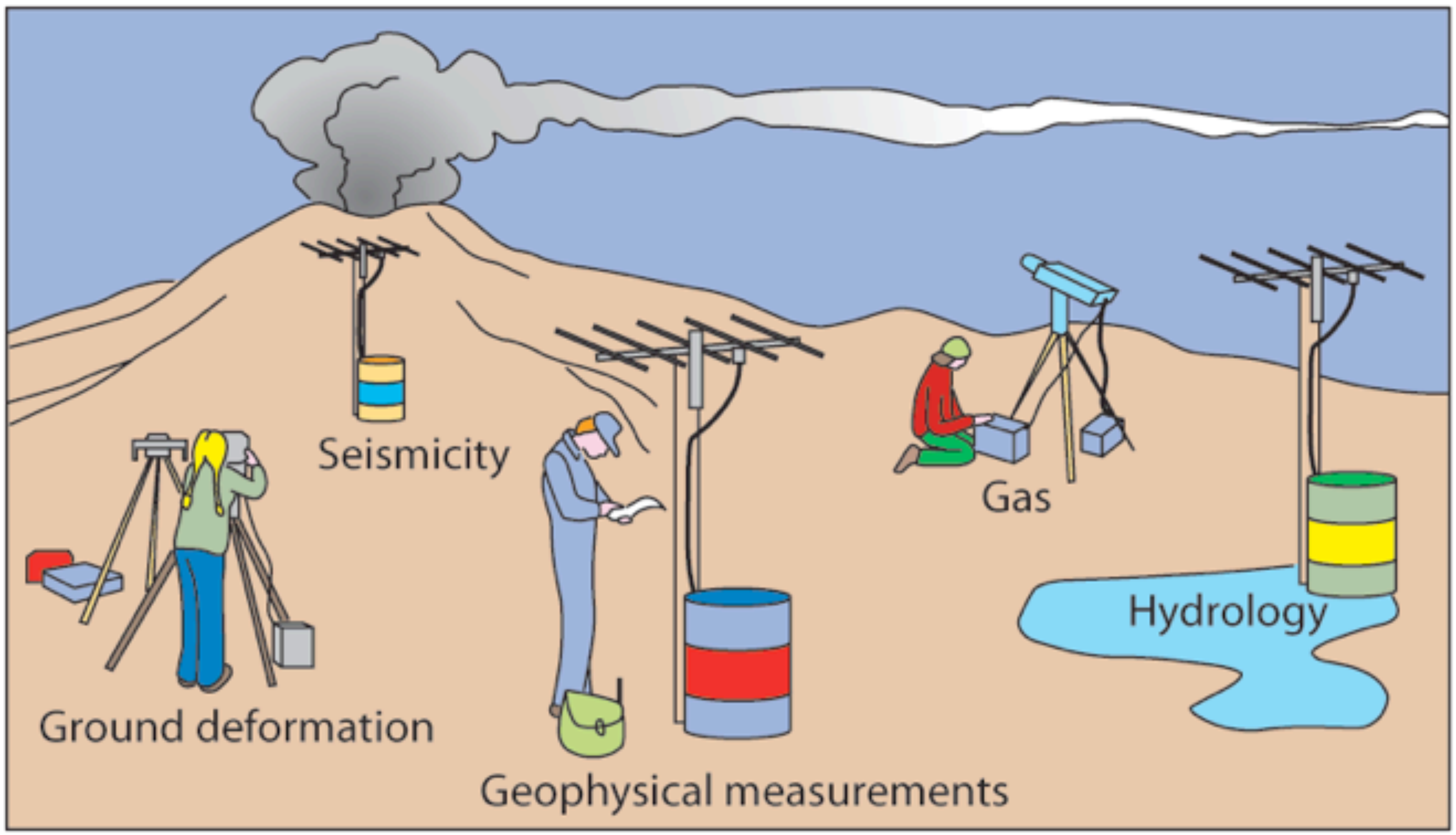
Lava Flow - Heimaey, Iceland

- However, the potential damage was reduced by spraying seawater onto the advancing lava flows.
- This caused them to slow and/or stop, or diverted them away from the undamaged part of the town.

Jokulhlaups (e.g. Vatnajokull, Iceland)

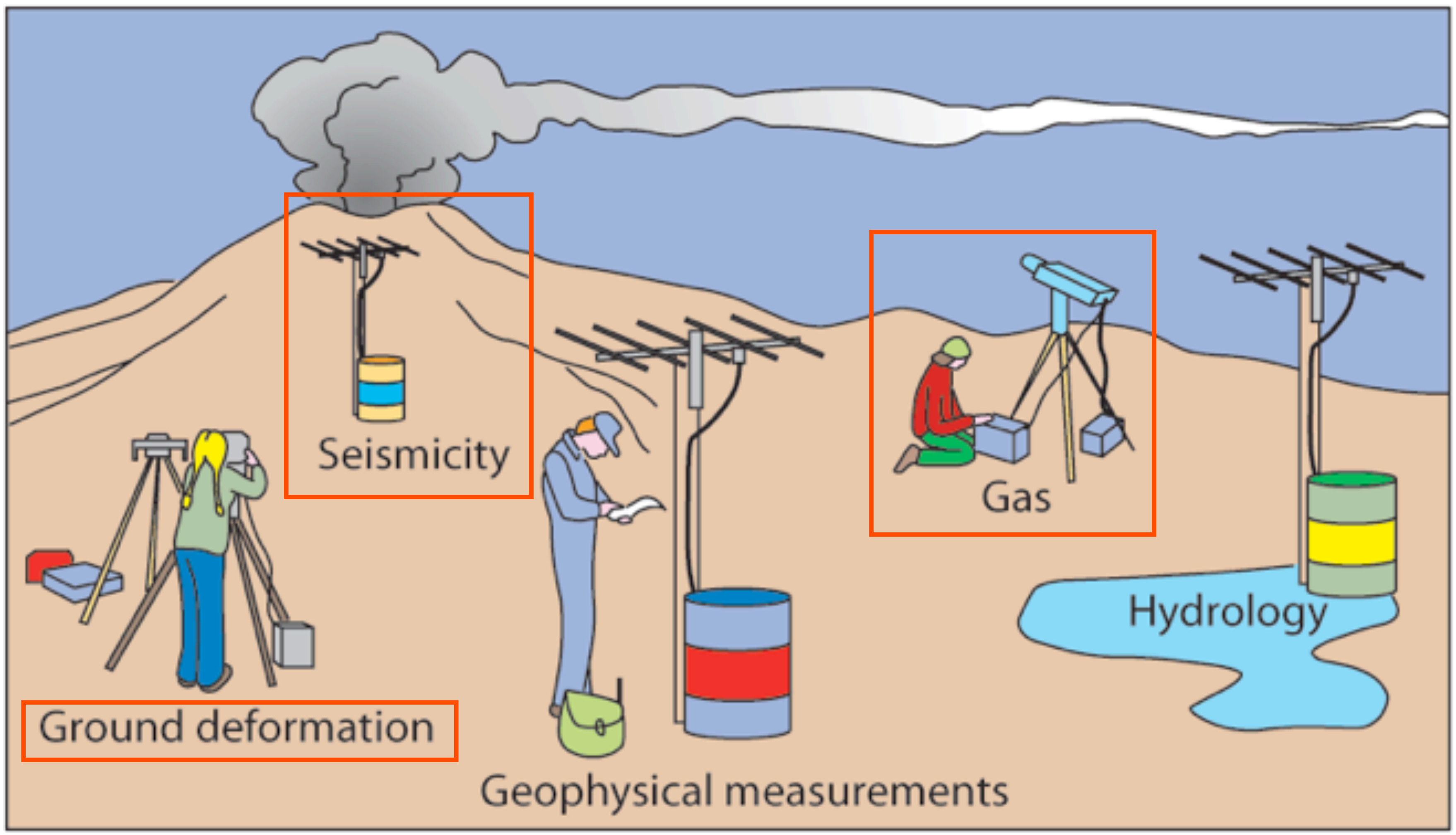
In 1996 a subglacial eruption released 4 km^3 of meltwater

Volcano Monitoring



Volcano Observatories are set up on all active volcanoes that threaten the human population. These are designed to monitor and potentially to predict the eruptive behaviour of the volcano in question.

Volcano Monitoring

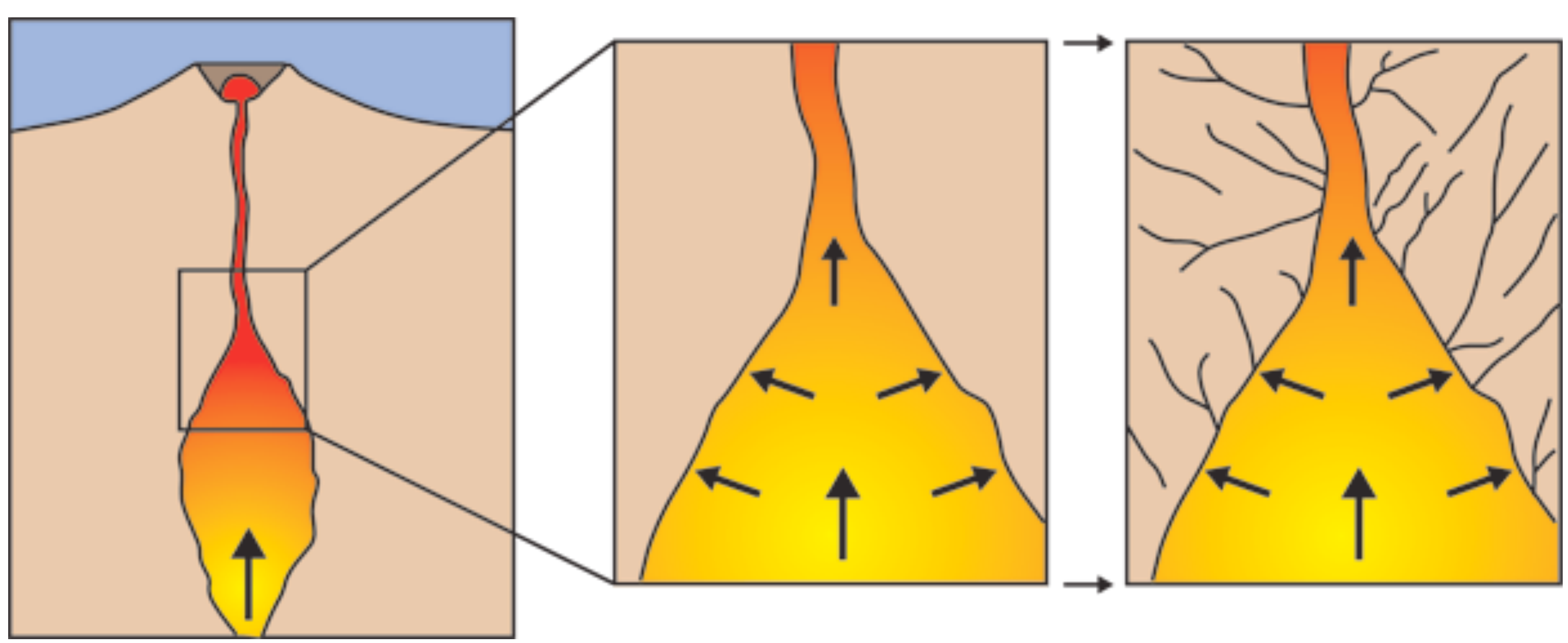


- Seismicity
- Deformation
- Gas Output
  - (on volcano and remote sensing techniques)

These three things are the most important precursors to an eruption.

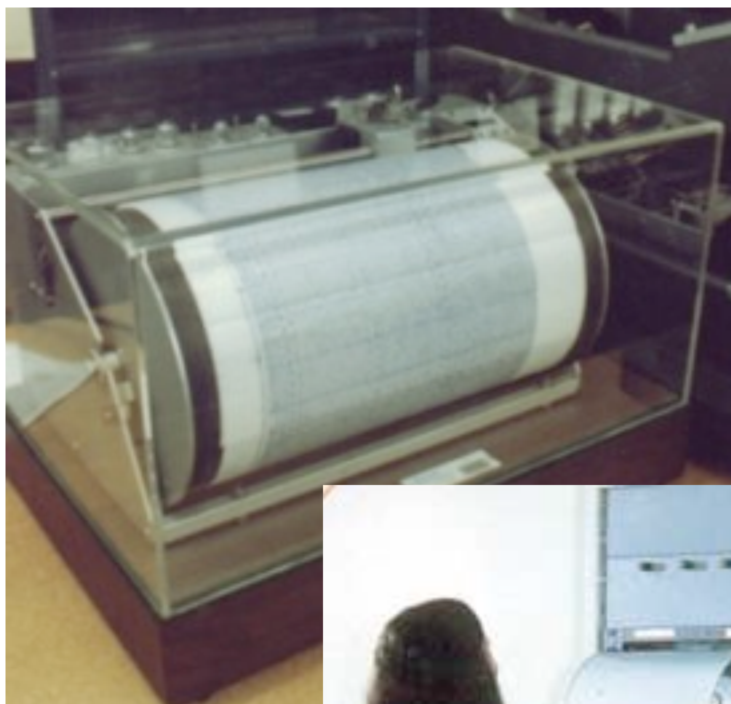
Seismic Activity

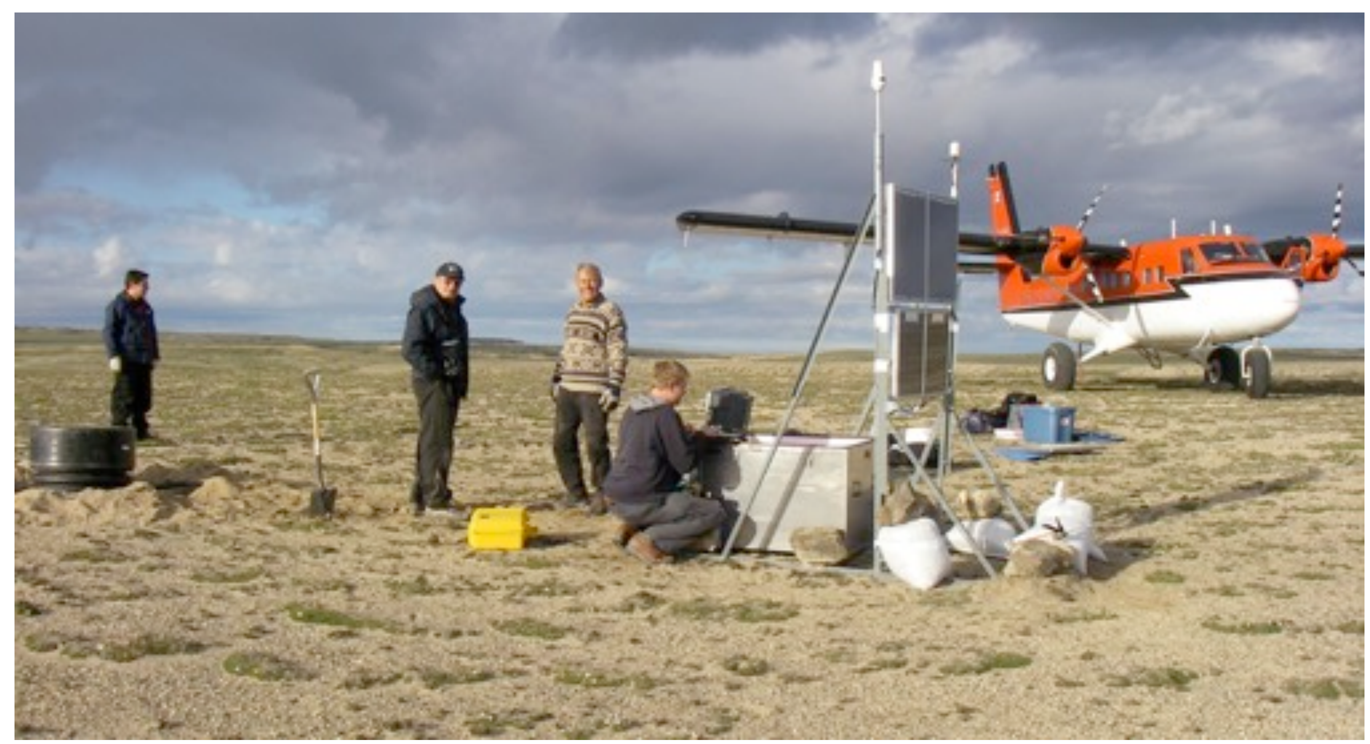
- Earthquake activity commonly precedes an eruption
  - Result of magma pushing up towards the surface
  - Increase volume of material in the volcano shatters the rock
  - This causes earthquakes



Seismic Activity

Earthquake activity is measured by Seismographs
Seismographs are stationed on the flanks of the volcano
These record the frequency, duration and intensity of the earthquakes and report it back to the volcano observatory.

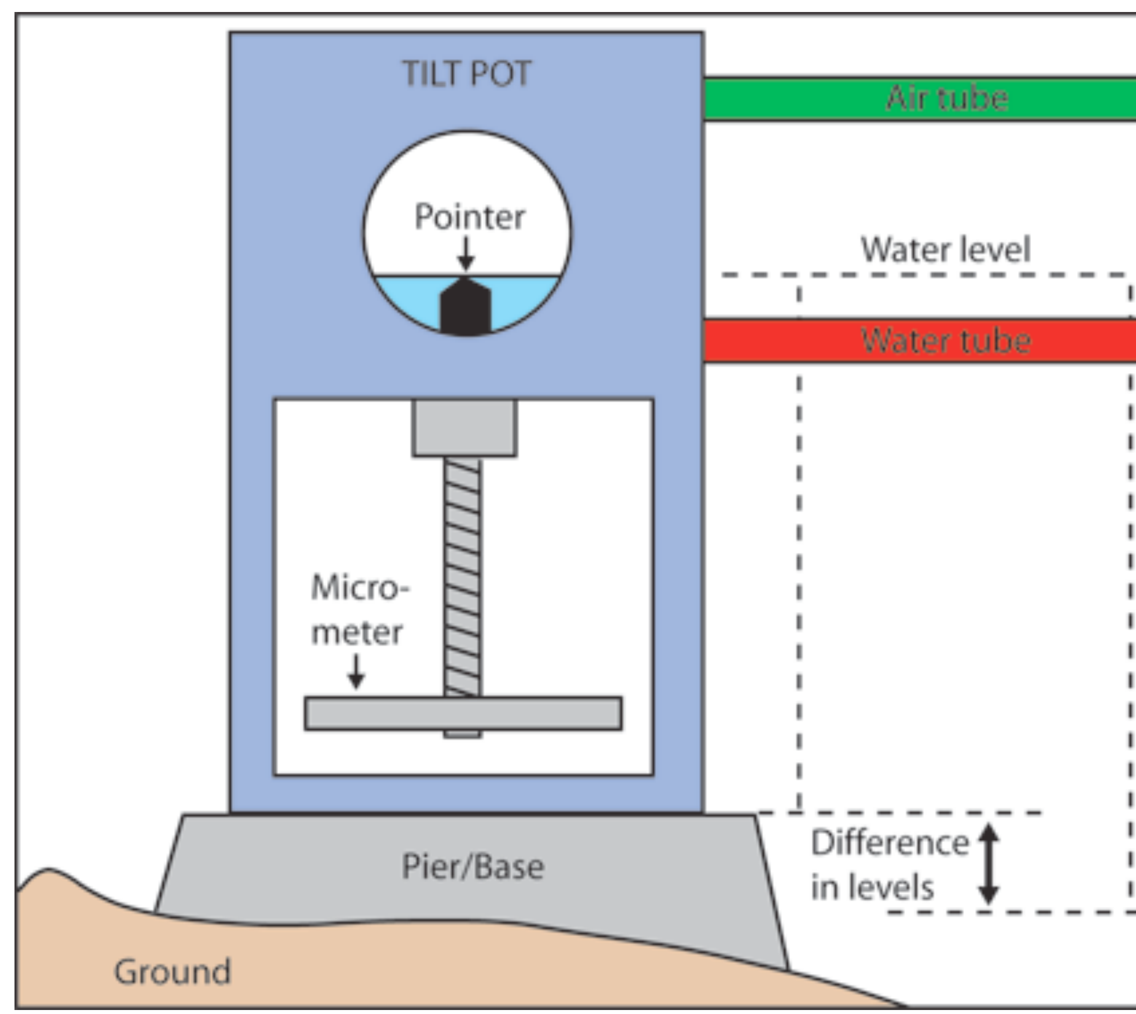




Deformation Monitoring

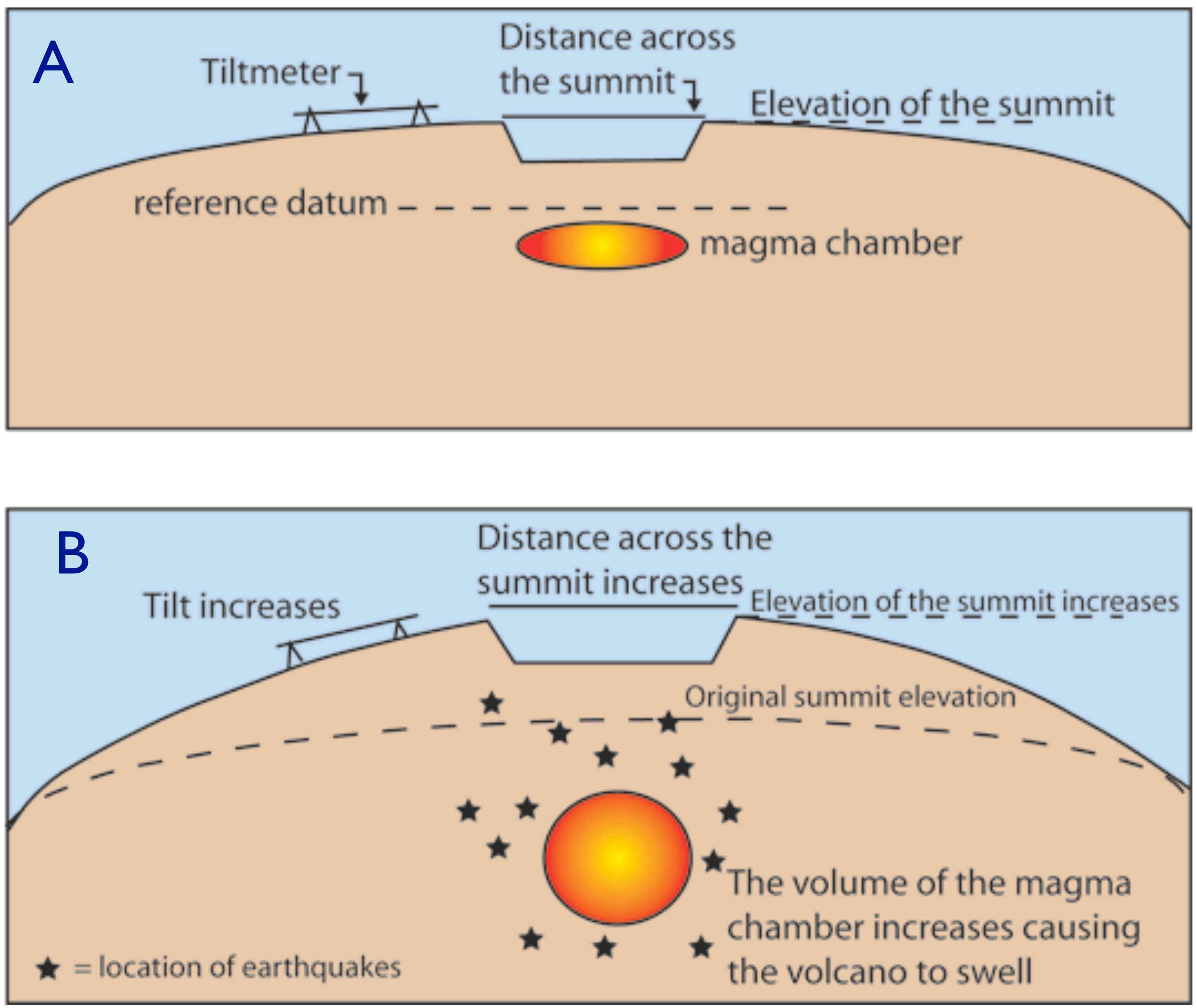
- "Tiltmeters" are used to measure the deformation of the volcano

  - The tiltmeters measure changes in slope as small as one part per million. A slope change of one part per million is equivalent to raising the end of a board one kilometer long only one millimeter!



Deformation Monitoring

- Tilltmeters can tell you when new material enters the magma chamber.



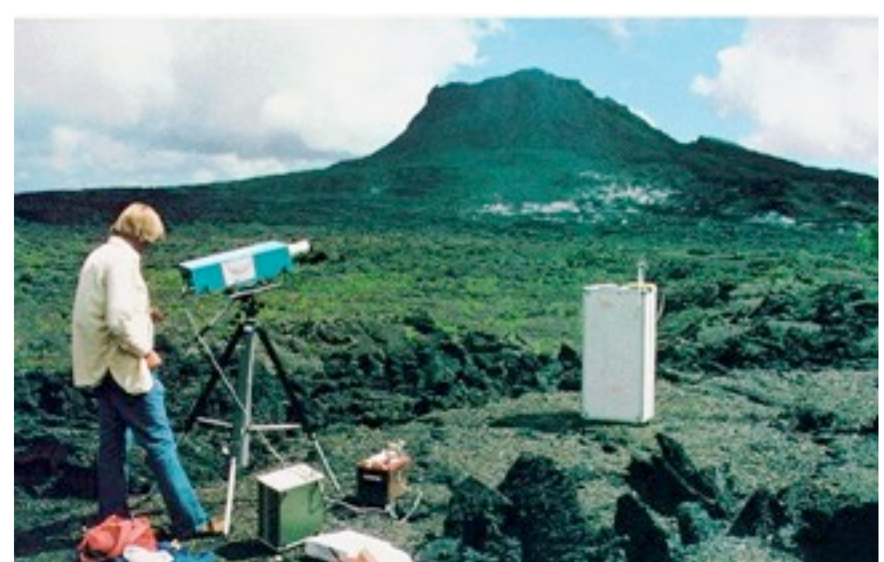
Note the presence of earthquakes in relation to the deformation. Often it is a combination of events that fore-warns of an eruption.

Gas Monitoring

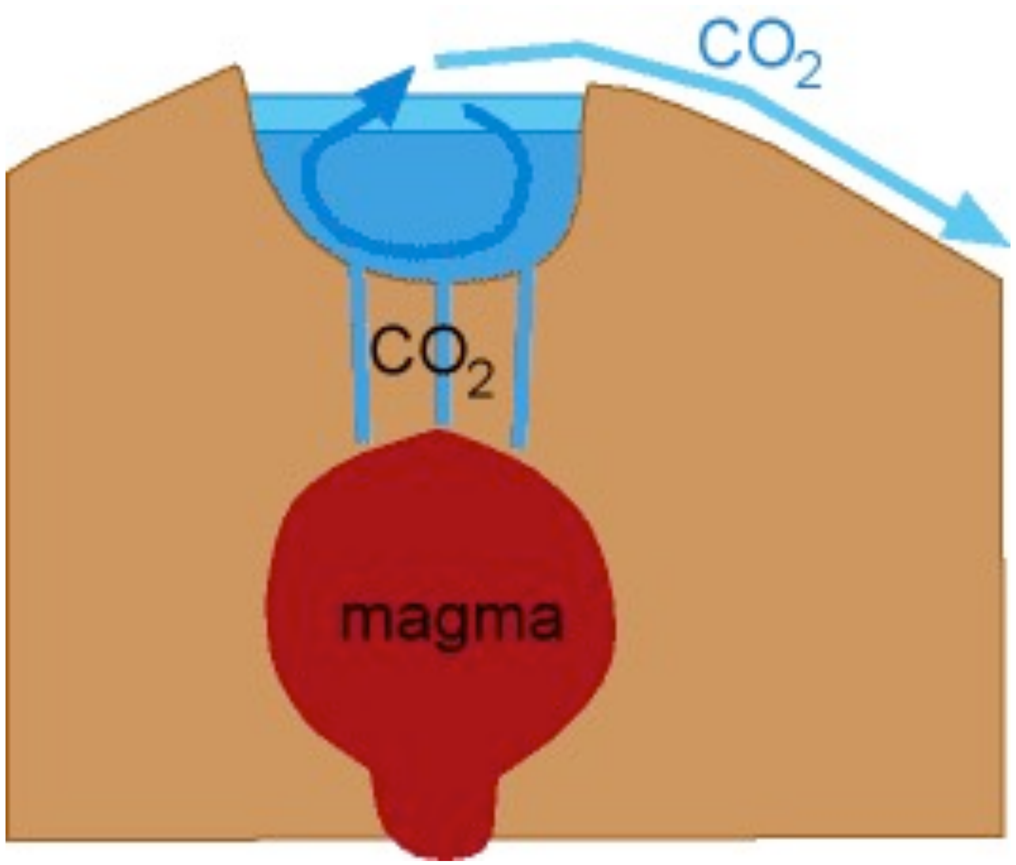
- Commonly gas output from a volcano increases or changes composition before an eruption.
  - As magma rises to the surface it releases (exsolves) much of its gas content.
  - This can be measured

Gas Monitoring

- Gas samples are collected from fumaroles and active vents.



Volcanic gases



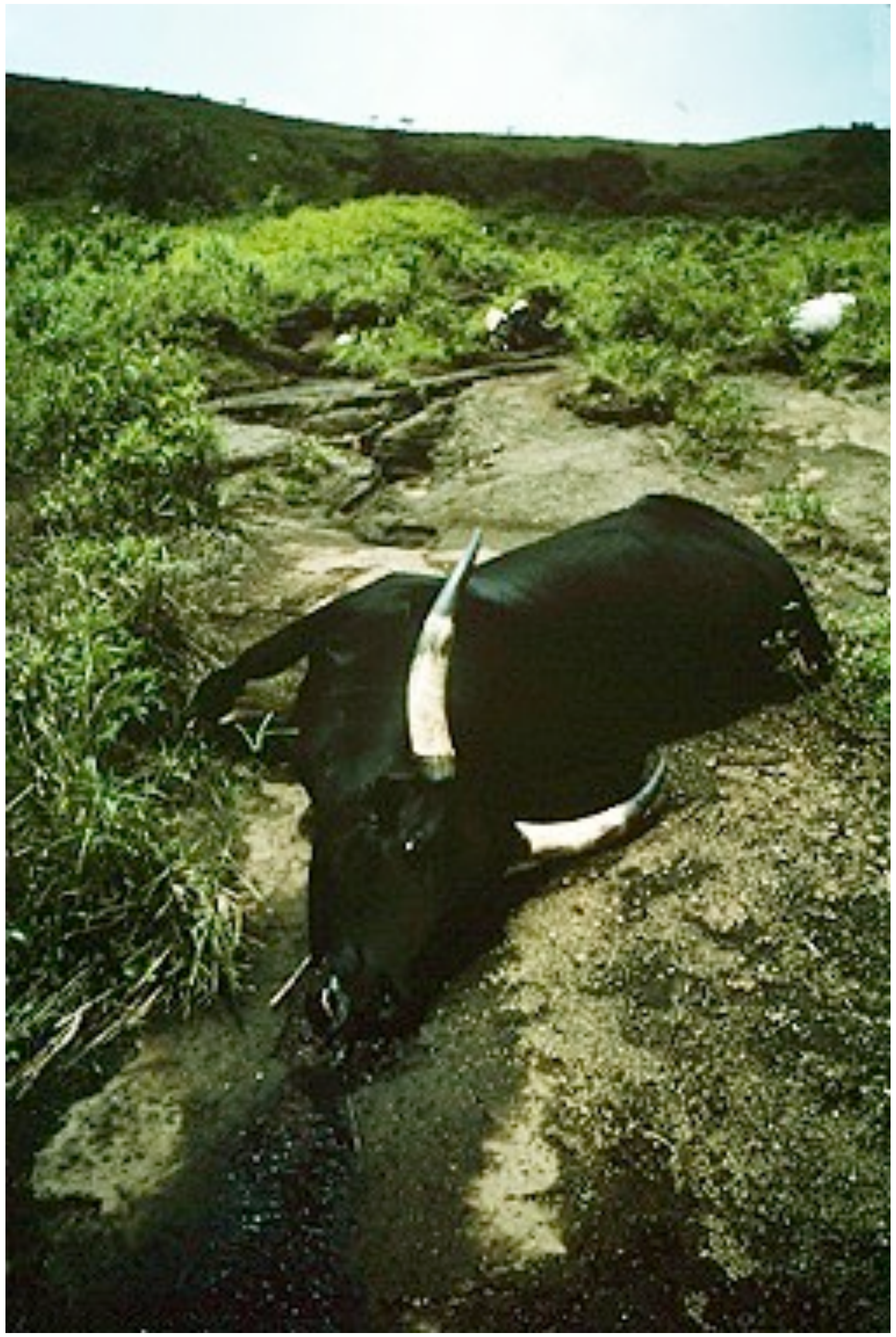
Lake Nyos (Cameroon, 1986)

More than 1700 people killed as a result of a massive release of $CO_{2;}$ formed a 'river' about 50m deep that flowed for 25 km. L. Nyos currently contains about 350 M m^3 of CO_2. Similar event at L. Monoun (Cameroon) in 1984 resulted in 37 deaths.

In 1783 a massive fissure eruption near Laki, Iceland released huge amounts of basaltic lava (5 000 m^3/s), and a 'dry fog' rich in SO_2 and flourine. Some 75% of stock animals in Iceland died, the subsequent famine killed 10 000 people.

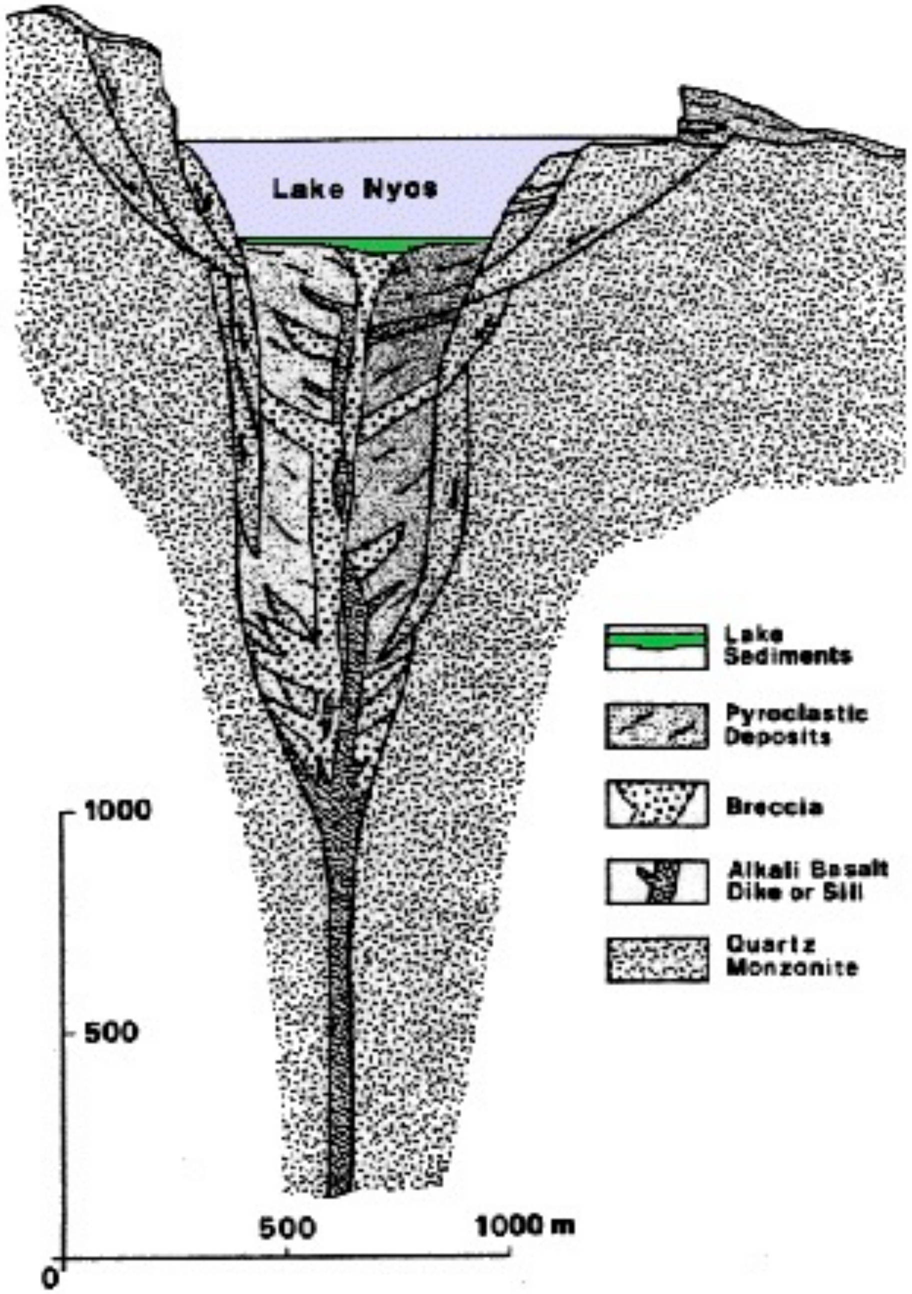
Noxious Gas

- 1,700 people living in the valley below Lake Nyos in northwestern Cameroon mysteriously died on the evening of August 26, 1986.



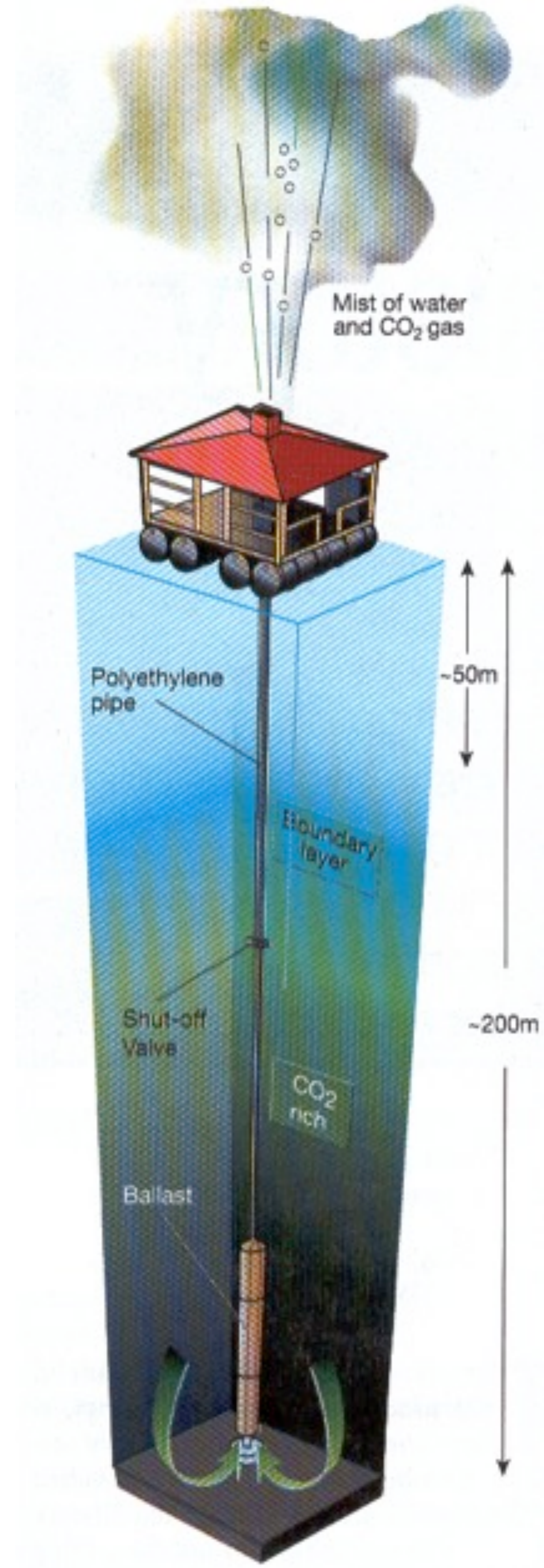
Noxious Gas

- Lake Nyos is a crater lake inside a dormant volcano.
- The lake had become laden with carbon dioxide gas.
- This gas had suddenly bubbled out of the lake and asphyxiated nearly every living being in the surrounding valley.

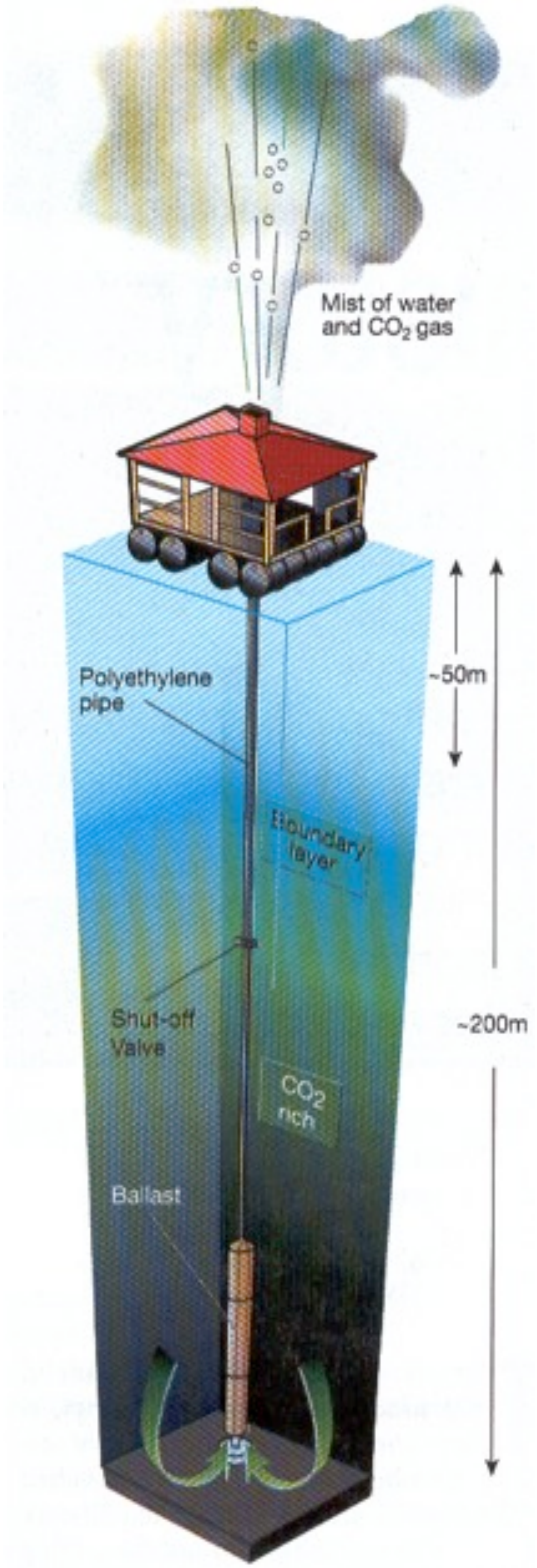


Noxious Gas

- A management plan has been developed to remove gas from the lake to prevent a further tragedy.
- An artificial vent to the lake surface was created with pipe.
- Water is pumped from the bottom of the lake to the surface through the pipe, where it can degas.



Noxious Gas



Mist of water and CO_2 gas
Polyethylene pipe
~50m
Boundary layer
Shut-off Valve
~200m
CO_2 rich
Ballast

Noxious Gas

Noxious Gas

- The Lake Nyos incident was not unique.
- Two years earlier, Lake Monoun, 60 miles to the southeast, released a heavy cloud of toxic gas, killing 37 people.
- A third lake, Lake Kivu, on the Congo-Rwanda border in Central Africa, is also known to act as a reservoir of carbon dioxide and methane, which is a valuable natural gas that is gathered from the lake and used locally.

Earthquakes

- Large volumes of magma moving through the shallow crust can cause large earthquakes.
- This can lead to building collapse, slope failure and avalanches

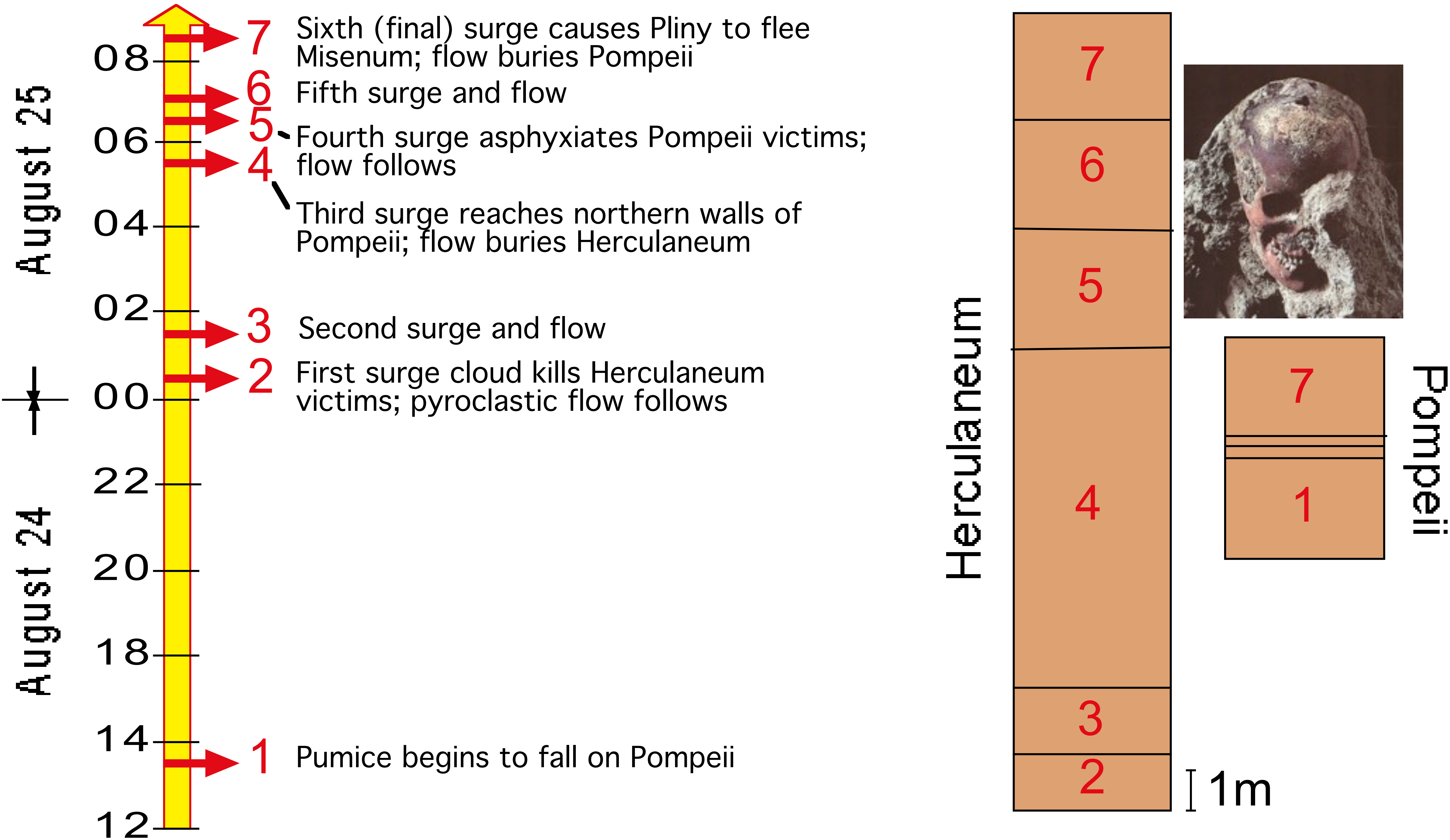
Destruction after a volcanic induced earthquake in Japan

Volcanoes of the Mediterranean

Mount Vesuvius: recent major eruptions

- A.D. 79: destruction of Pompeii and Herculaneum;
- 80 eruptions since then -
  most violently in 1631 and 1906;
  quiet since 1944

from Pliny's letters / Volcanic deposits

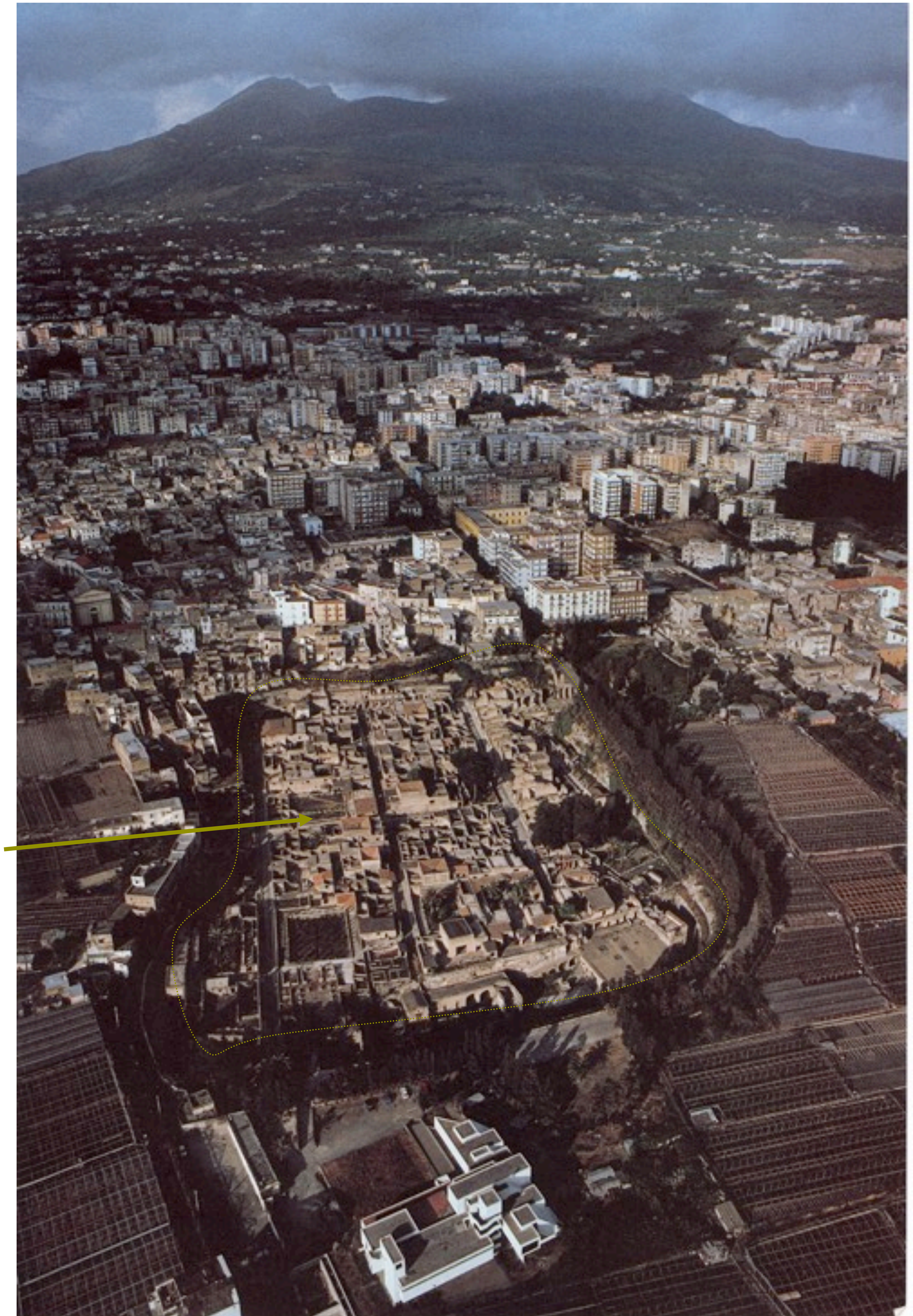


Eruption of Vesuvius, A.D. 79

Mt. Vesuvius

modern
Herculaneum

excavated area of
Roman
Herculaneum
(20 m below
modern city)

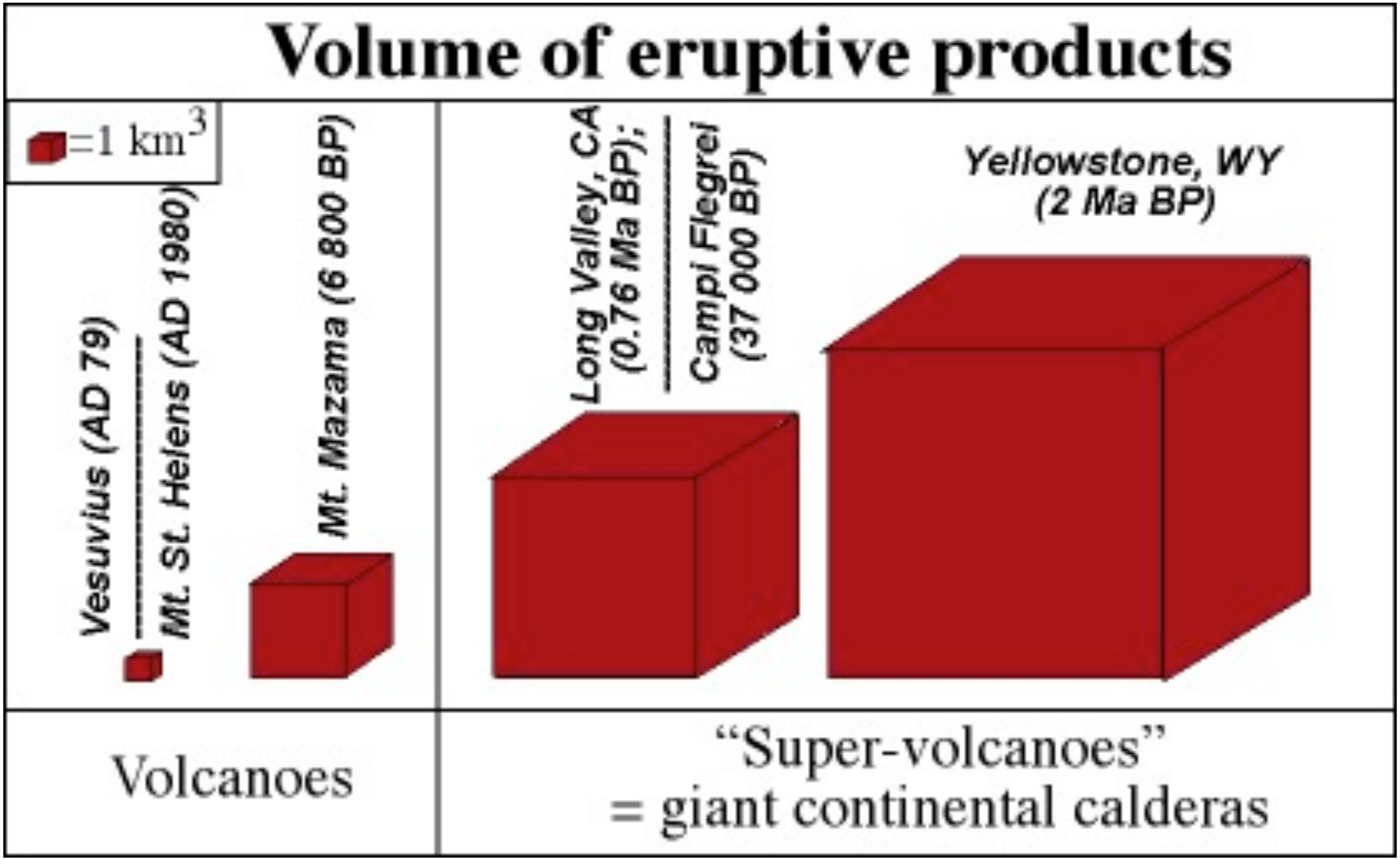


Why wasn't Vesuvius recognized as high-risk by the Romans?

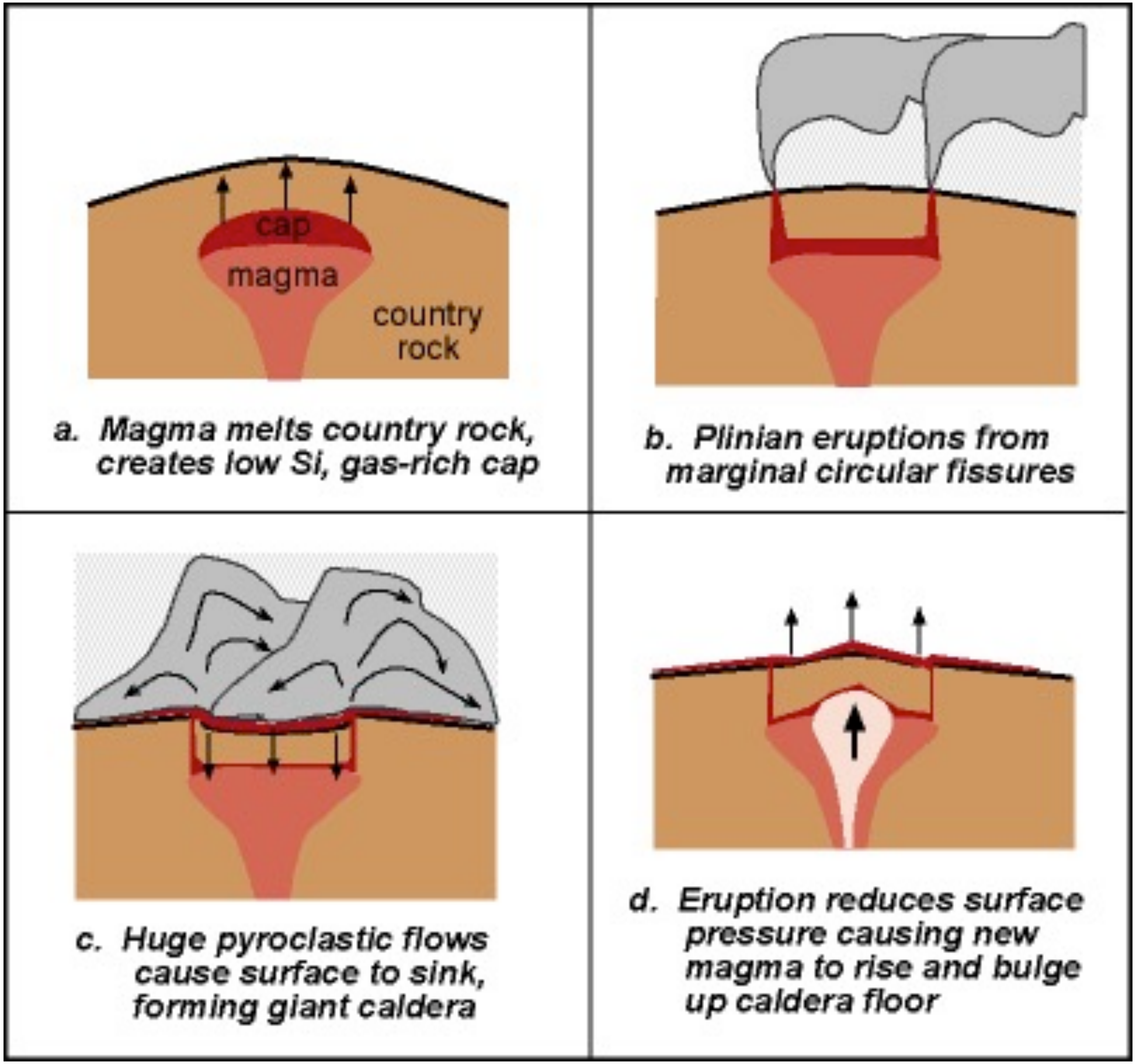
Bed	Date (BP)	Eruptive style	Volume (km^3)
Pompeii	~1900	Plinian	2.8
AP6	~2200	Strombolian	?
AP5	?	Strombolian to Vulcanian	0.08
AP4	?	Phreato-Plinian	0.12
AP3	~2700	Strombolian to Vulcanian	0.15
AP2	~3000	Sub-Plinian to phreato-Plinian	0.14
AP1	~3300	Sub-Plinian to phreato-Plinian	0.15
Avellino	~3450	Plinian	1.5

From data in: Andronico, D. and Cioni, R. 2002. Bull. Volcanology 64, 372-391.

Super Volcanoes



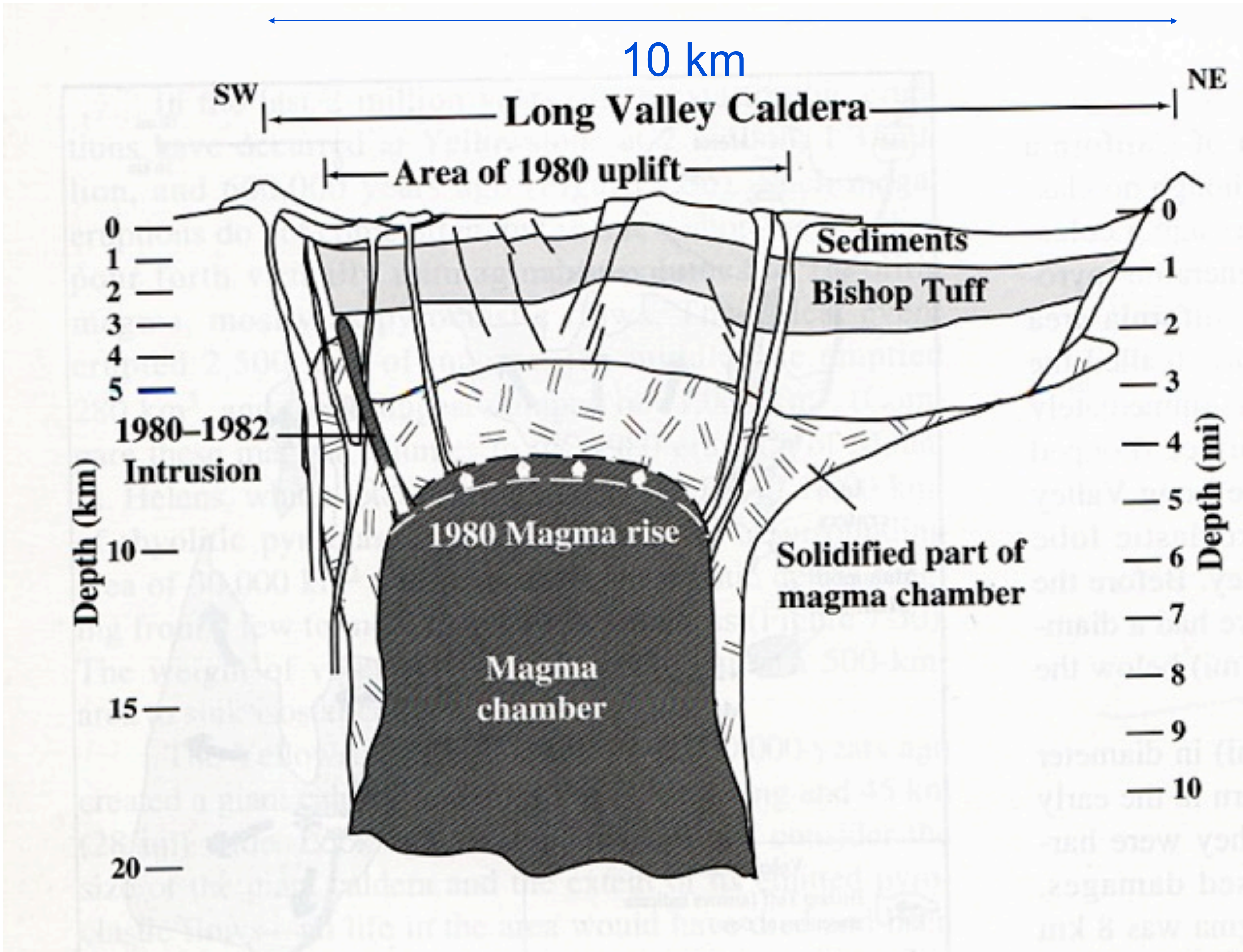
Continental caldera formation



The after-effects of a super-eruption

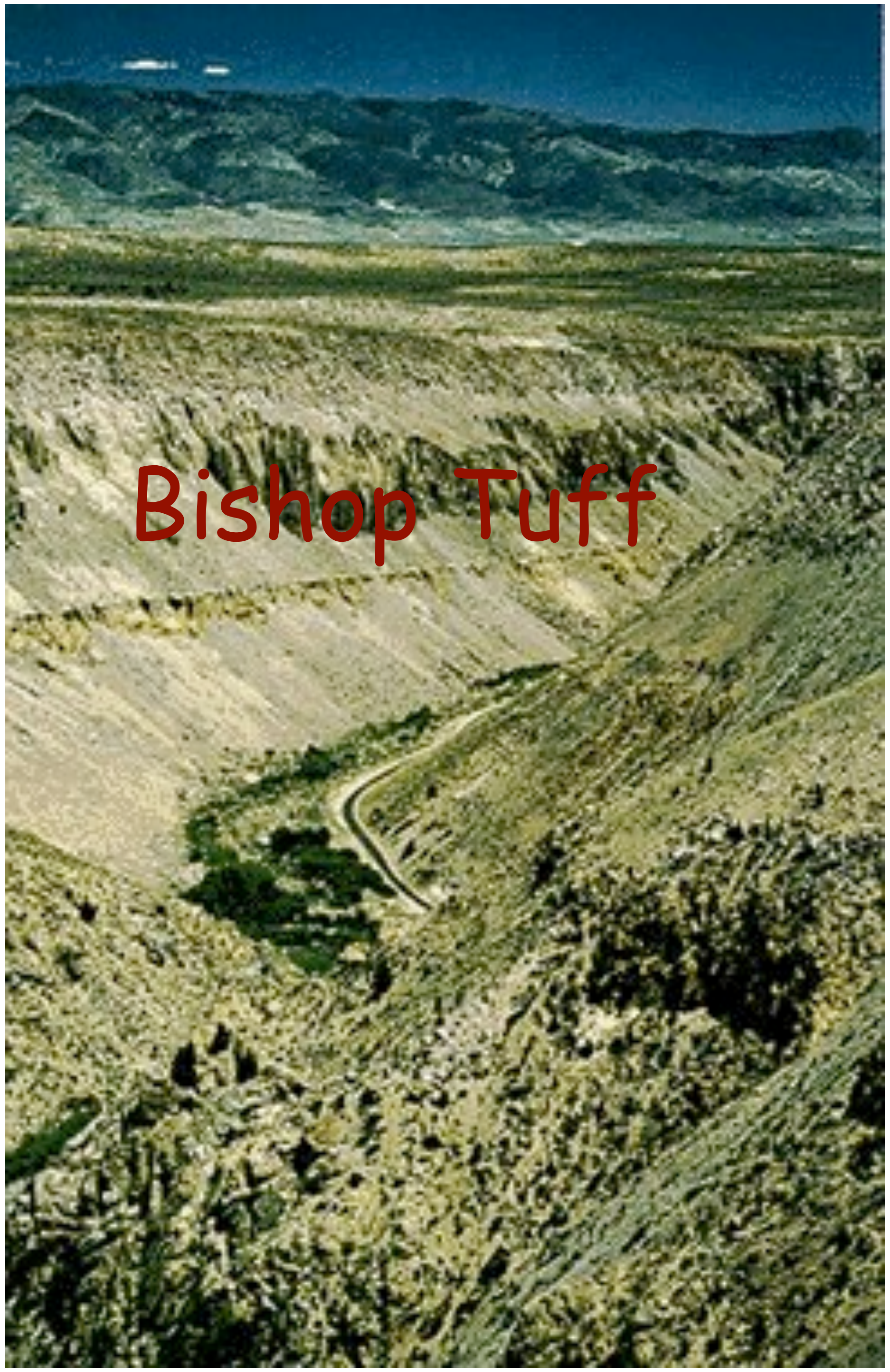
- Stratospheric loading of ~1000 Mt of SO_2 and sulphate aerosols
- Aerosol veil persists for 5 - 10 years
- Global cooling of 3-5°C (locally 15°C)
- Collapse of agricultural production for several years --> famine --> conflict
- Last great supereruption (Toba, ~73,000 BP) may have reduced human population to ~10,000 people (Ambrose, 1998, J. Human Evolution., v. 34, 623)

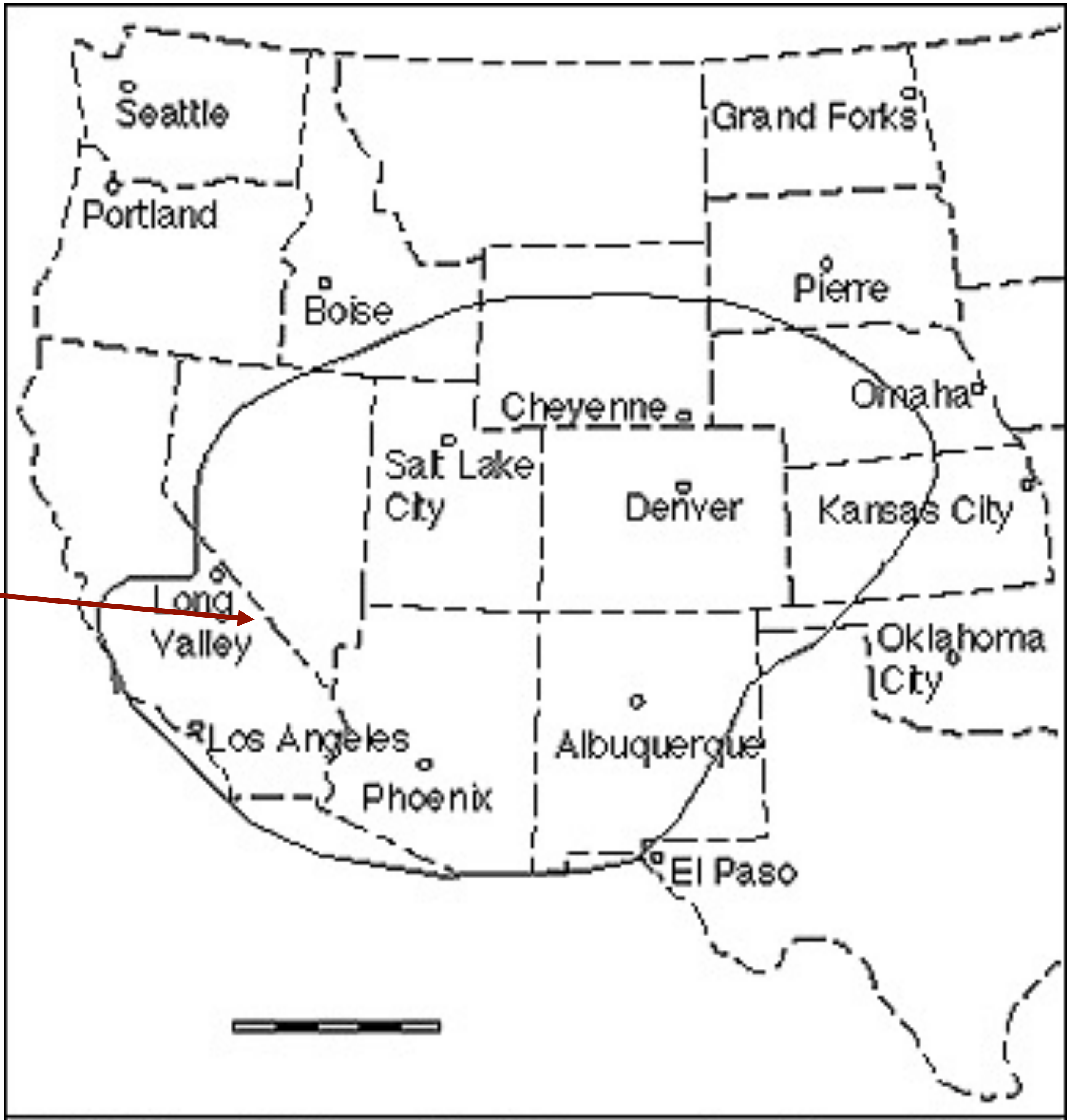
(Rampino, 2002, Icarus, v.156, p. 562)



Since 1980 some 2M m^3 of CO_2 released and substantial earthquake activity (some quakes M ~ 6) associated with intrusion of magma tongue

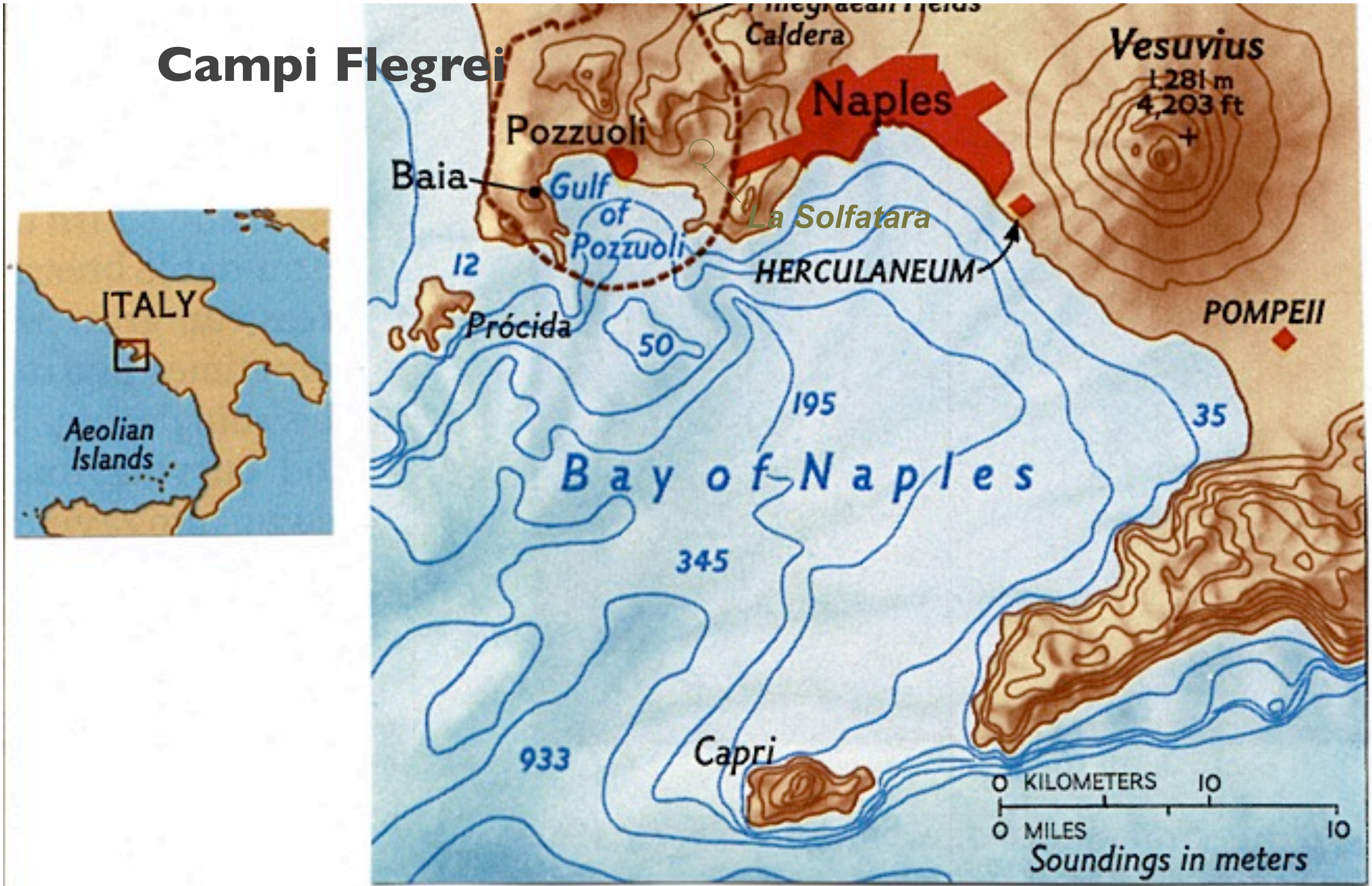
The last super-eruption from Long Valley caldera





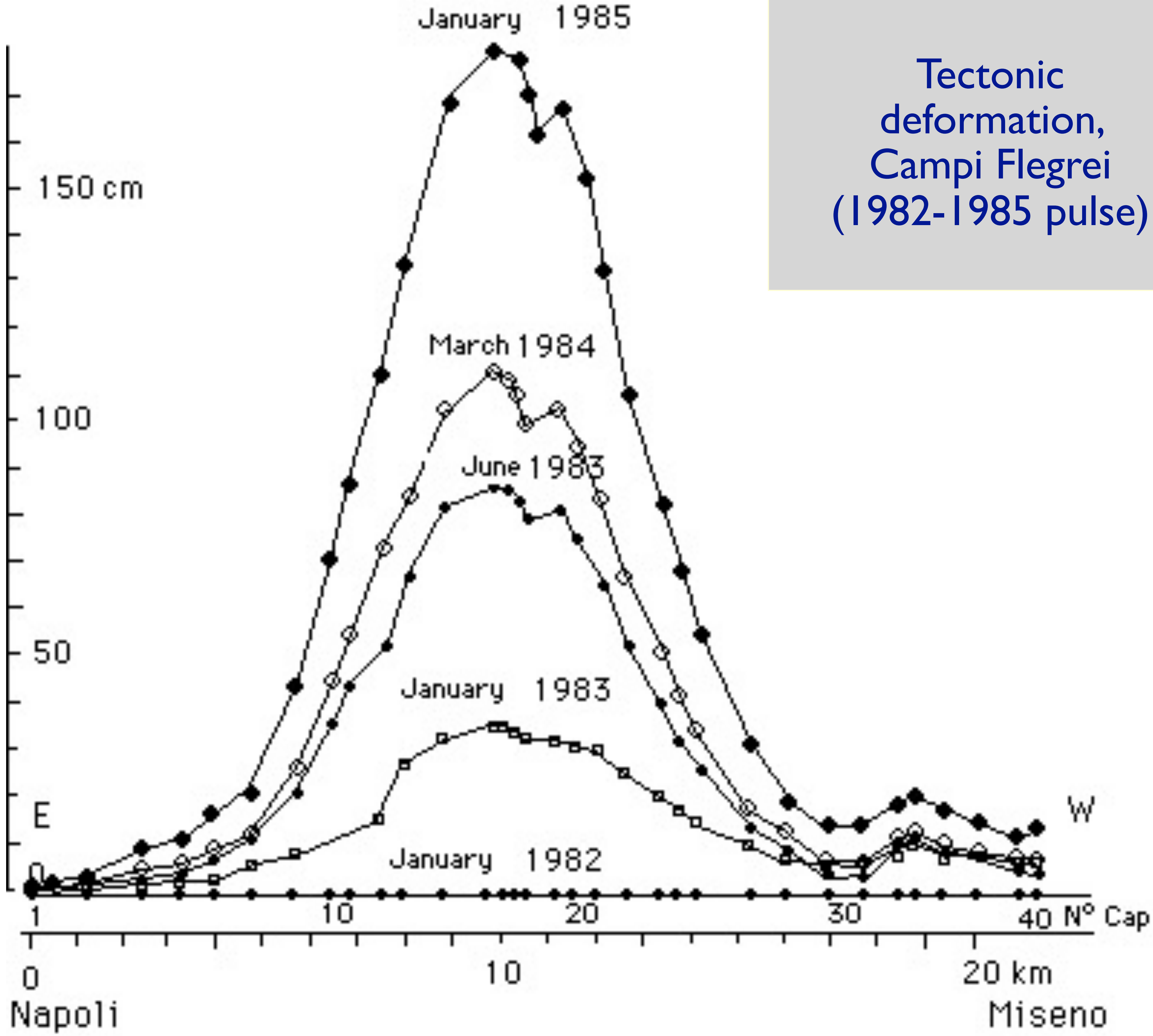
Distribution of Bishop ash beds from eruption at Long Valley caldera. From Izett and others (1982).

Volcanic hazards in the Naples region

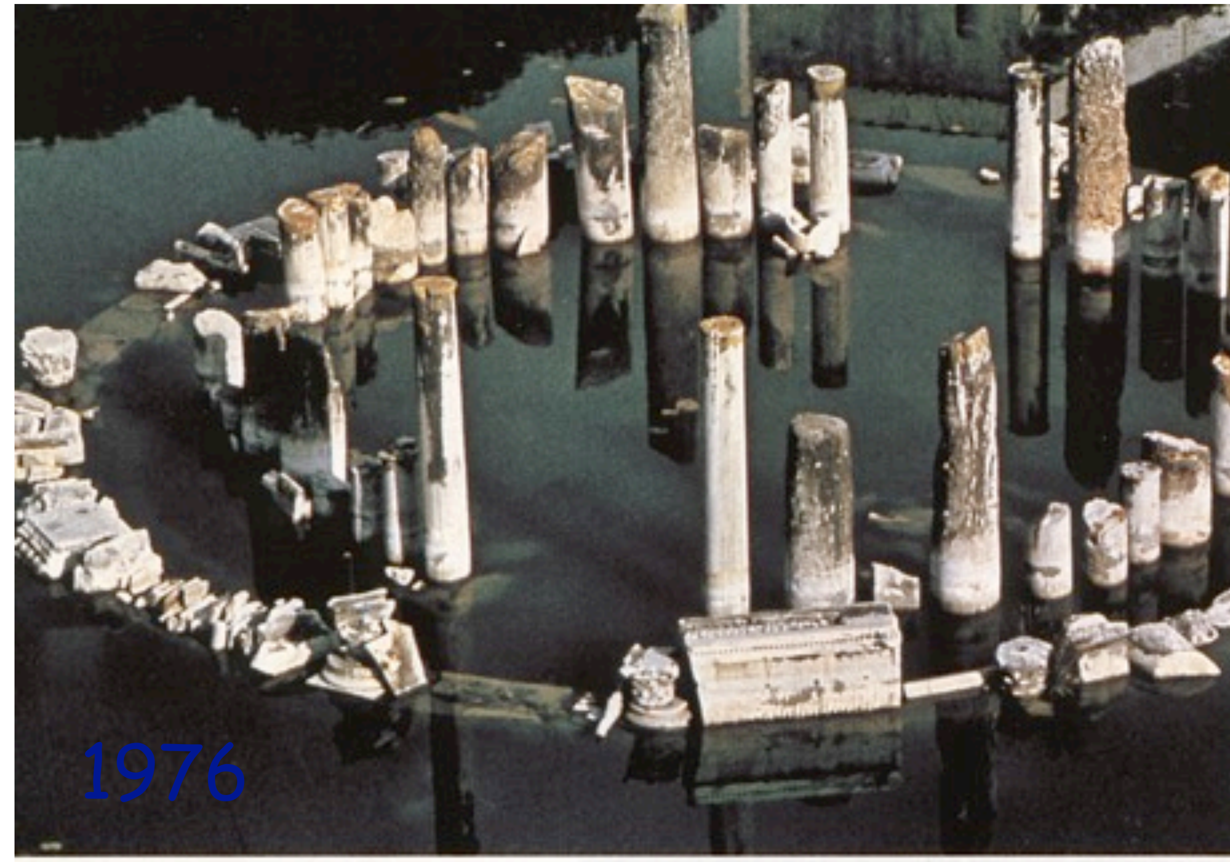


http://www.ov.ingv.it/ov/doc/vulcani_napoletani_HQ.pdf

Tectonic deformation, Campi Flegrei (1982-1985 pulse)



Ruins of Roman market, Pozzuoli; inundated by sea, uplifted by 2m in <10 years as a result of volcano-tectonic forces beneath Campi Flegrei caldera



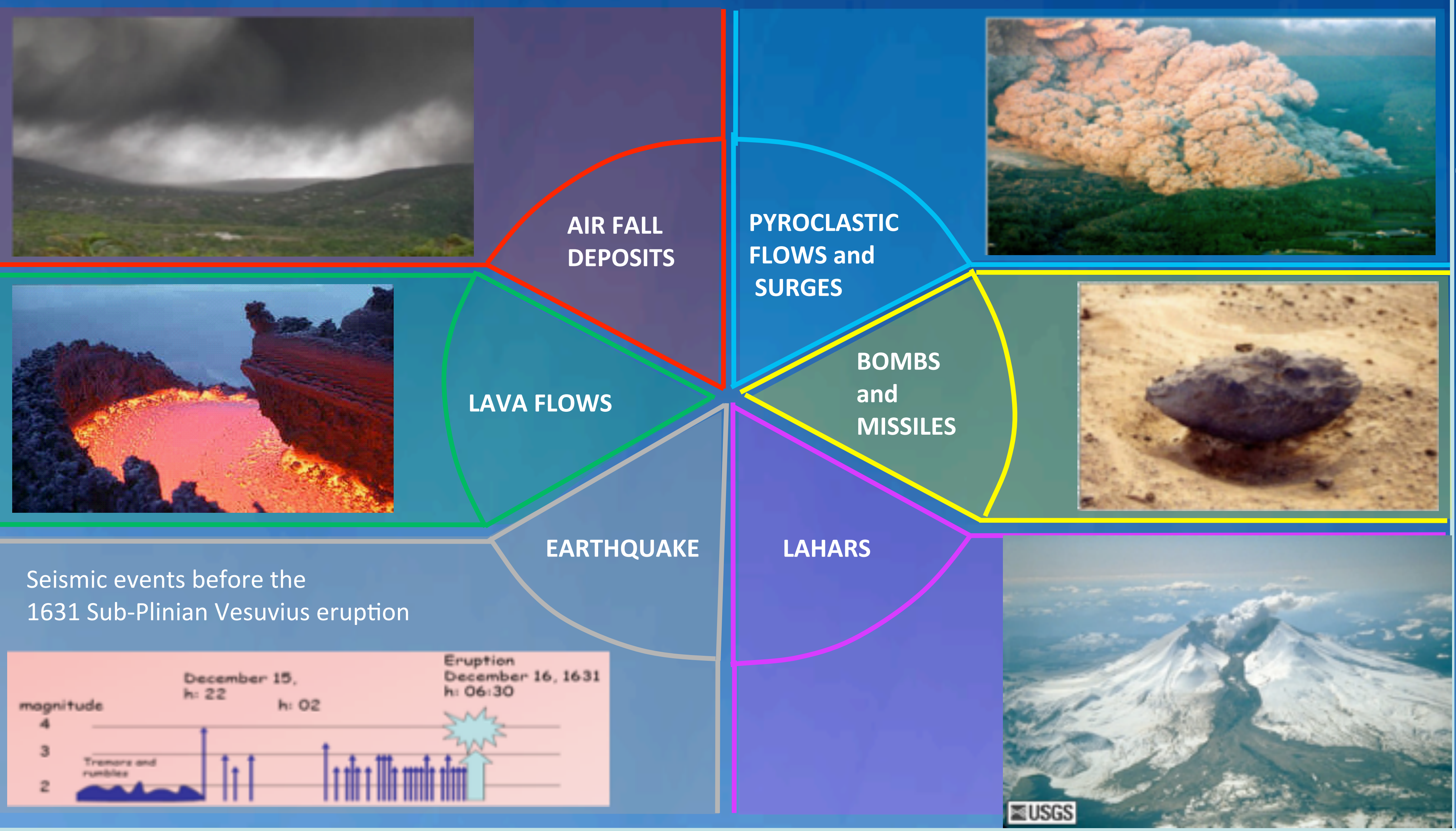
Earthquake damage,
Church of Purgatory,
Puzzuoli
1982

La Solfatara,
one of several small active craters in the Campi Flegrei

The effect of VOLCANIC ACTIONS

DESCRIPTION

ACTIONS



DESIGN METHODOLOGY FOR TECHNICAL RETROFIT

Cumulative effects given by a complex eruptive scenario (SpeeD and EXPLORIS projects for Vesuvian area)

The effect of VOLCANIC ACTIONS

MITIGATION ACTIONS

EARTHQUAKE:

SEISMIC REINFORCEMENT: iron chains in masonry building, insertion of infill panels or resistant elements in soft floors of reinforced concrete buildings

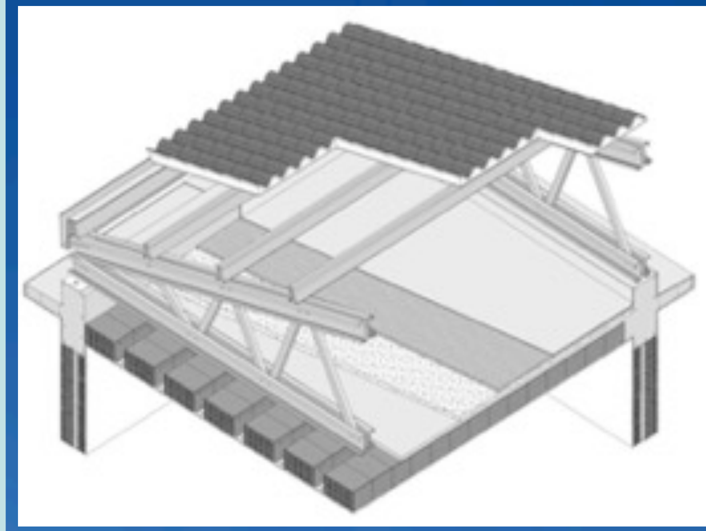
ASH FALL DEPOSITS

Vuln. classes	Roofing type	Load [kPa]	Collapse prob. [%]
A	Weak pitched wooden roof	2,0	50
B	Standard wooden flat roof; Flat floor with steel beams and brick vaults; Sap floors	3,0	50
C1	Flat floor with steel beams and hollow bricks ; R.C flat slab (more than 20 year old)	5,0	60
C2	R.C flat slab (less than 20 year old); Last generation R.C. flat slab	7,0	51
D	Last generation R.R. pitched slab ; Last generation steel pitched roof	12,0	50

1. **pitched roofs by overlapping light structures (CFS, Cold Formed Steel; UHPC, Ultra High Performance Concrete)**
2. **the reinforcement of the roof slab:**

- FRP, Fiber Reinfor… mers
(physical and mechani… degrade in range above 60-80°C)

- FRCM (Fiber Reinforced Cementitious Matrix)



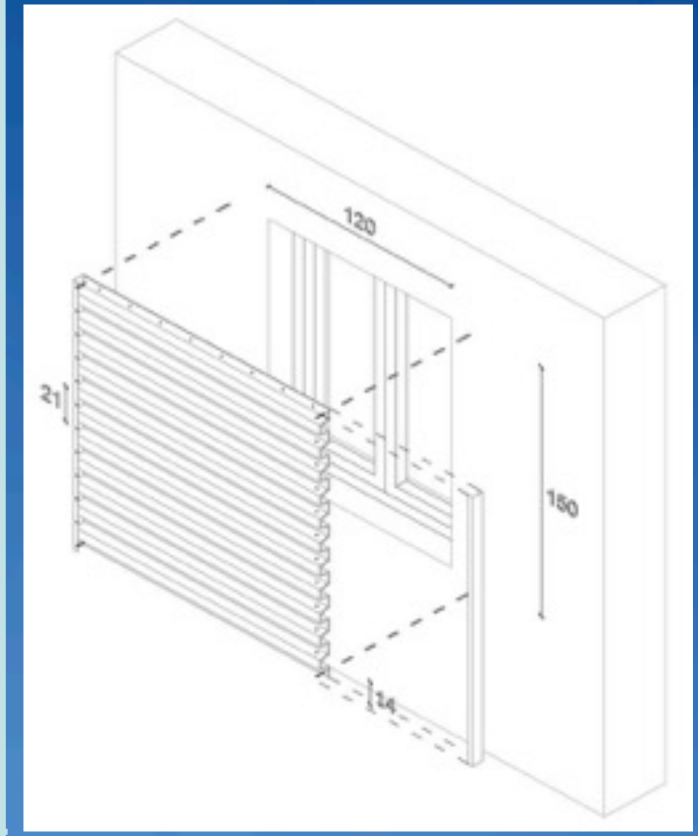
The effect of VOLCANIC ACTIONS

MITIGATION ACTIONS

1. WATER
2. SNOW
3. WIND
4. LANDSLIDES
5. **VOLCANIC ACTIONS**
6. VOLCANIC RISK

PYROCLASTIC FLOWS

RESISTANCE TO LATERAL PRESSURE OF STRUCTURAL ELEMENTS FOR BUILDING TYPE.	
TECHNICAL ELEMENT	**CRITICAL PRESSURE [kPa]**
Wooden seasonal structures	3,5
3-4 floors weak masonry buildings with deformable floors	3,5 - 5
4+ floors weak or strong masonry building	
6+ floors r.c. buildings	4 - 5
Weak tuff walls (thickness ≤40cm, span>4m)	4 - 7,5
4-6 floors r.c. buildings	4,5 - 6
Non aseismic weak r.c. buildings	4,5 - 8
1-3 floors r.c. buildings	6,5 - 9
Medium strength tufo walls (thickness ≥40cm, span>4m)	7 - 9
Non aseismic strong r.c. buildings	
1-2 floors weak masonry buildings with deformable floors	11 - 18
3-4 floors masonry buildings with rigid floors	
1-2 floors masonry buildings with rigid floors	14 - 19



PROTECTION OF OPENINGS :

- Overlay steel anchored along the external perimeter
- Fire safety shutters of steel or alluminium
- Special protective films on glass surfaces

LAHARS ⇨ PYROCLASTIC FLOWS and LANDSLIDES

The effect of VOLCANIC ACTIONS

MITIGATION ACTIONS

CHOICE OF THE TECHNICAL OPTIONS

To assess the effectiveness of mitigation actions, it is necessary a comprehensive analysis of technological options.

A qualitative judgment can be expressed by six key indicators:

1. **Quick installation**
2. **Storability**
3. **Lightness**
4. **Cost;**
5. **Preservation of constructive and architectural features;**
6. **Multifunctionality (ability of the technical solution to respond to different phenomena).**

Through four categories:

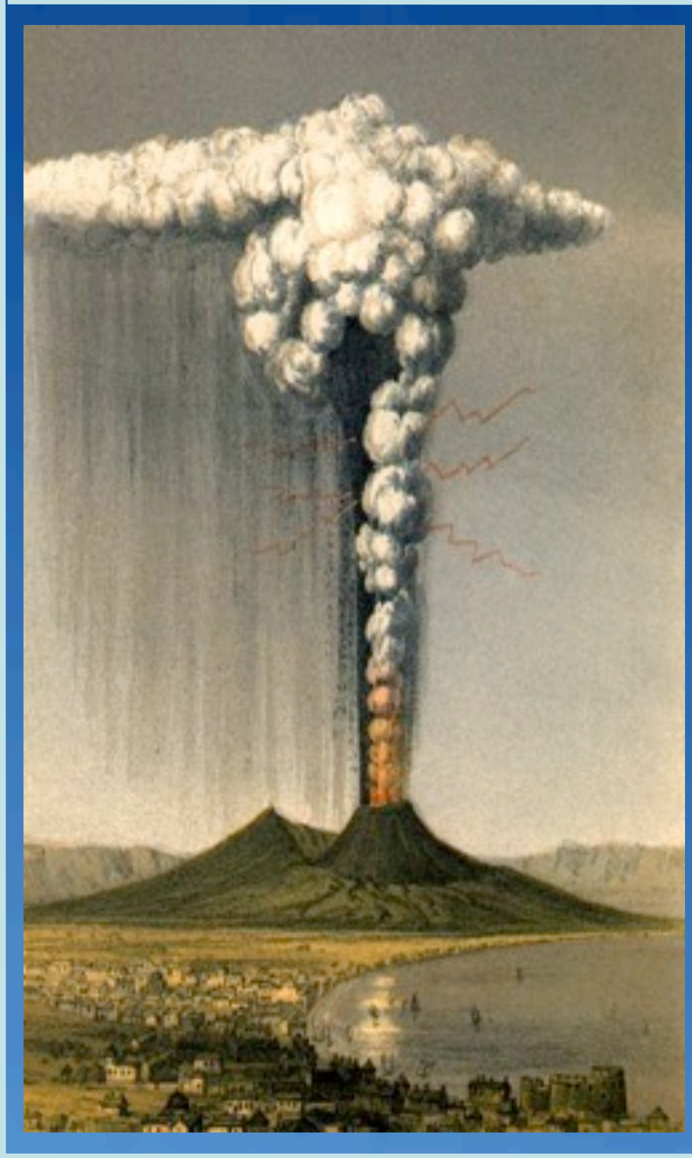
SE – Interventions on elevation structures
SV – Interventions on vertical surfaces
SO – Interventions on horizontal structures
AP – Interventions on openings

VOLCANIC RISK

SECURE COHABITATION WITH THE VOLCANO

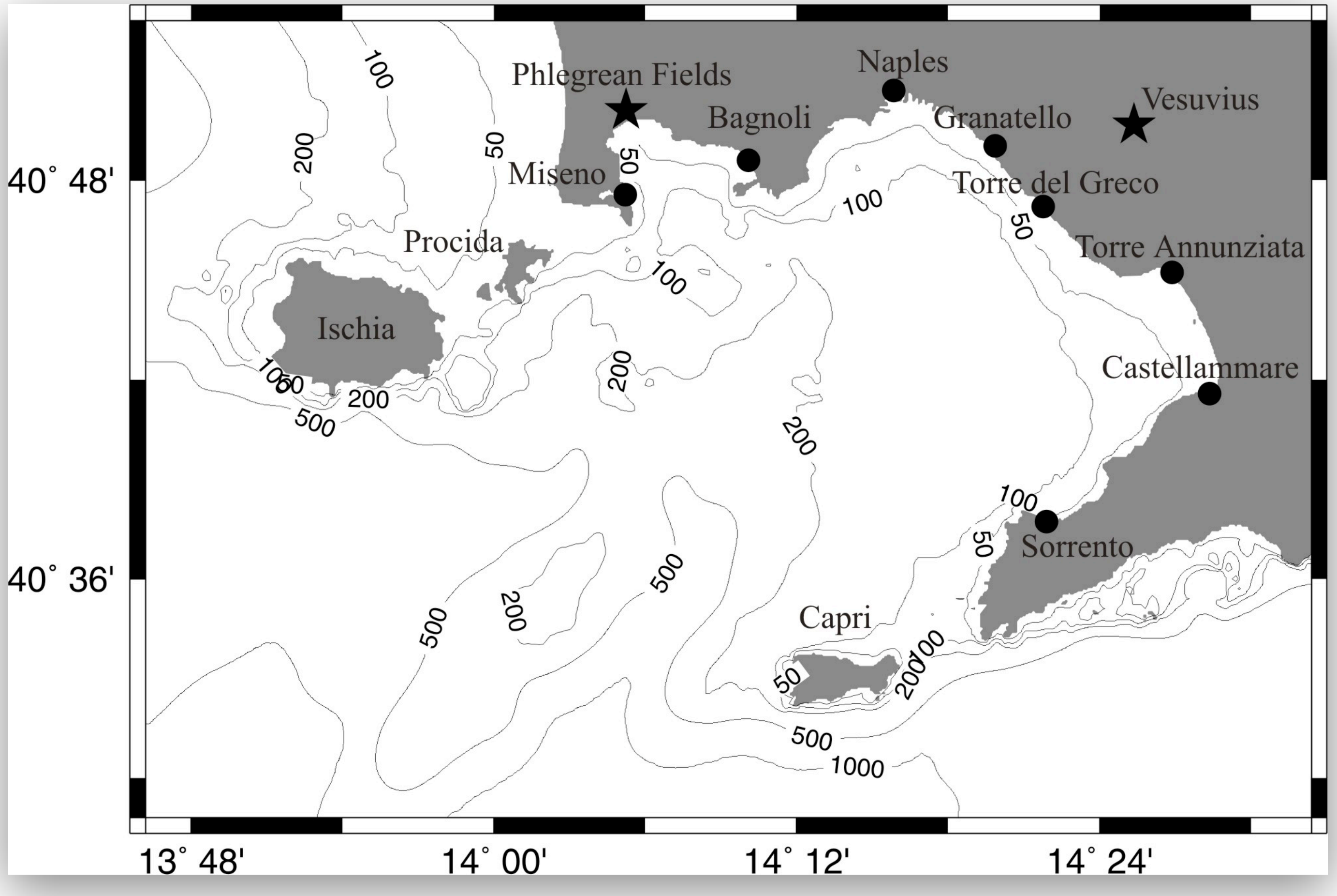
MAIN OBJECTIVES
(Vesuvian area):

- **Development of accurate volcanic models (physical and mathematical), assessing future eruption scenarios and their consequences on the surrounding territory.**
- **Assessment of the global vulnerability and potential damage induced by the volcano on the entire system (population, built environment, infrastructure, etc.).**
- **Production of volcanic risk-reduction guidelines for communities and local/ national governments.**
- **Promotion of a socio-cultural methodology enhancing consciousness and auto-regulation of the territory.**
- **Identification of alternative people settlements and the reorganization of the entire infrastructural network in the whole region, relieving the current situation to more manageable scenarios.**



Tsunami hazard in the Gulf of Naples

The Gulf of Naples belongs to the Tyrrhenian sea and is a 40 km long and 25 km wide rectangular basin elongated approximately SW-NE



The gulf is shallow with the lowest bathymetric gradients that are found in the south-east corner at the base of the Sorrento peninsula around Castellammare (~1:10 near- shore slope). The sea bottom lies mostly between 100 m and 200 m depth. The offshore side of the basin can be taken to correspond to the sharp transition from 200 m down to 500 m depth: this has a quite complex shape, due mostly to a low-altitude relief located in the sea floor at mid-distance between the islands of Ischia and Capri.

Simulation of tsunamis induced by volcanic activity in the Gulf of Naples (Italy)
Tinti, Pagnoni & Piatanesi, 2003. Natural hazards, 311, 320.

Historical tsunamis in Campania

Date	Coordinates	I	M	Reliab.	Cause	VEI	Description
8-24-79	40°49’,14°26’			2	VA	5	Sea retreat in the Gulf of Naples
6-20-1112				2	UN		Sea withdrawal of about 200 steps
12-17-1631	40°49’,14°26’			4	VA	4	Sea retreat at Pizzo Calabro
5-14-1698	40°49’,14°26’			2	VA	3	Sea oscillations in Gulf of Naples
6-30-1714	40°49’,14°26’			0	VA	2	Sea withdrawals in Gulf of Naples
6-16-1760	40°51’,14°16’	VI	4.3	2	ER		Sea withdrawal in Portici
7-26-1805	41°30’,14°28’	X	6.6	4	EA		Sea rise in the Gulf of Naples
5-17-1813	40°49’,14°26’			1	VA	2	Sea withdrawal in Gulf of Naples
8-26-1847				0	UN		Sea level lowering in Naples
4-4-1906	40°49’,14°26’			4	VA	3	Sea oscillations in Naples Gulf

Tinti S., Maramai A., Graziani L. (2007). The Italian Tsunami Catalogue (ITC), Version 2.
http://www.ingv.it/servizi-e-risorse/BD/catalogo-tsunami/catalogo-degli-tsunami-italiani

Tsunami hazard in the Gulf of Naples

Tsunamis associated with Vesuvius activity are rare. However, according to historical documents, anomalous sea oscillations and waves in the Gulf of Naples were observed not only concomitantly to the largest eruptions (79 AD and 1631), but also to some of the smaller events, such as the cases of 14 May 1698, 17 May 1813 and April 1906.

There are no records of catastrophic tsunamis and the tsunamigenic mechanism of the Vesuvian tsunamis is not certain.

They may be attributed to:

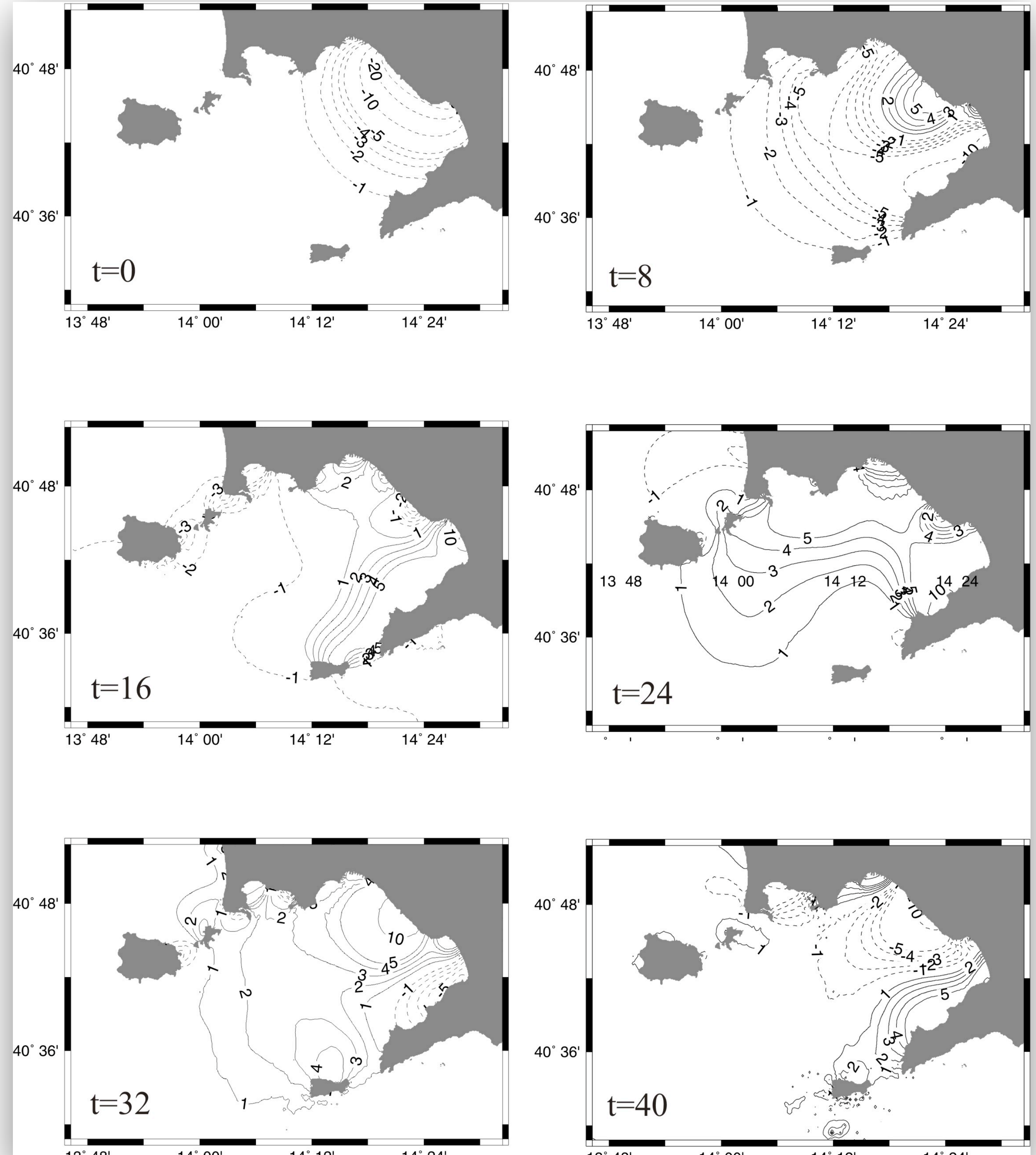
- sea floor displacement determined by the earthquakes accompanying the volcanic activity,
- to rapid inflation or deflation of the volcanic flanks involving the submarine area of the Gulf of Naples,
- to pyroclastic flows affecting the sea.

Simulation of tsunamis induced by volcanic activity in the Gulf of Naples (Italy)
Tinti, Pagnoni & Piatanesi, 2003. Natural hazards, 311, 320.

Hydrodynamic characteristics

Hydrodynamic characteristics of the Gulf of Naples seen as an open basin subjected to long-wave excitation for a scenario of the largest expected eruption the Italian Department of Civil Protection makes use of in order to plan emergency actions (DPC, 1995).

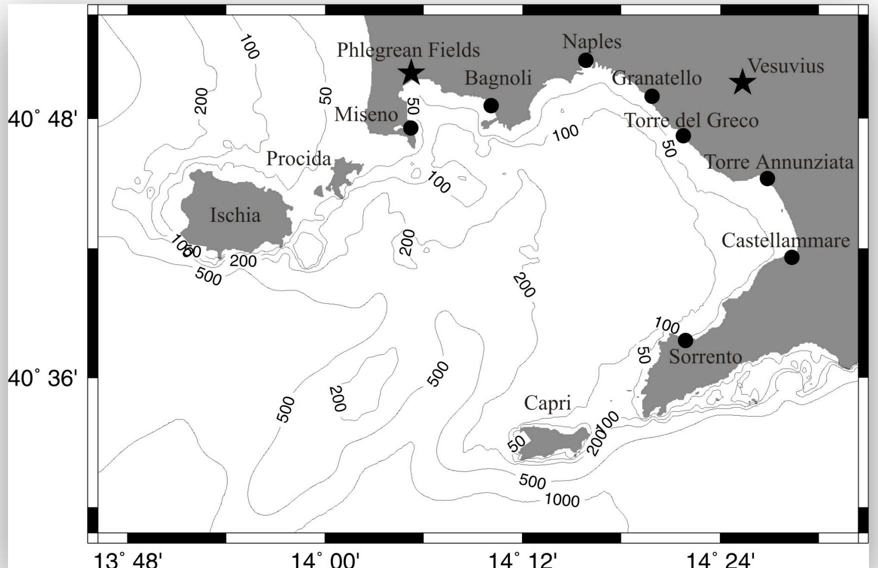
- shallow water approximation theory
- simulate a tsunami produced by an instantaneous displacement of the sea surface as the one that is associated with a submarine earthquake

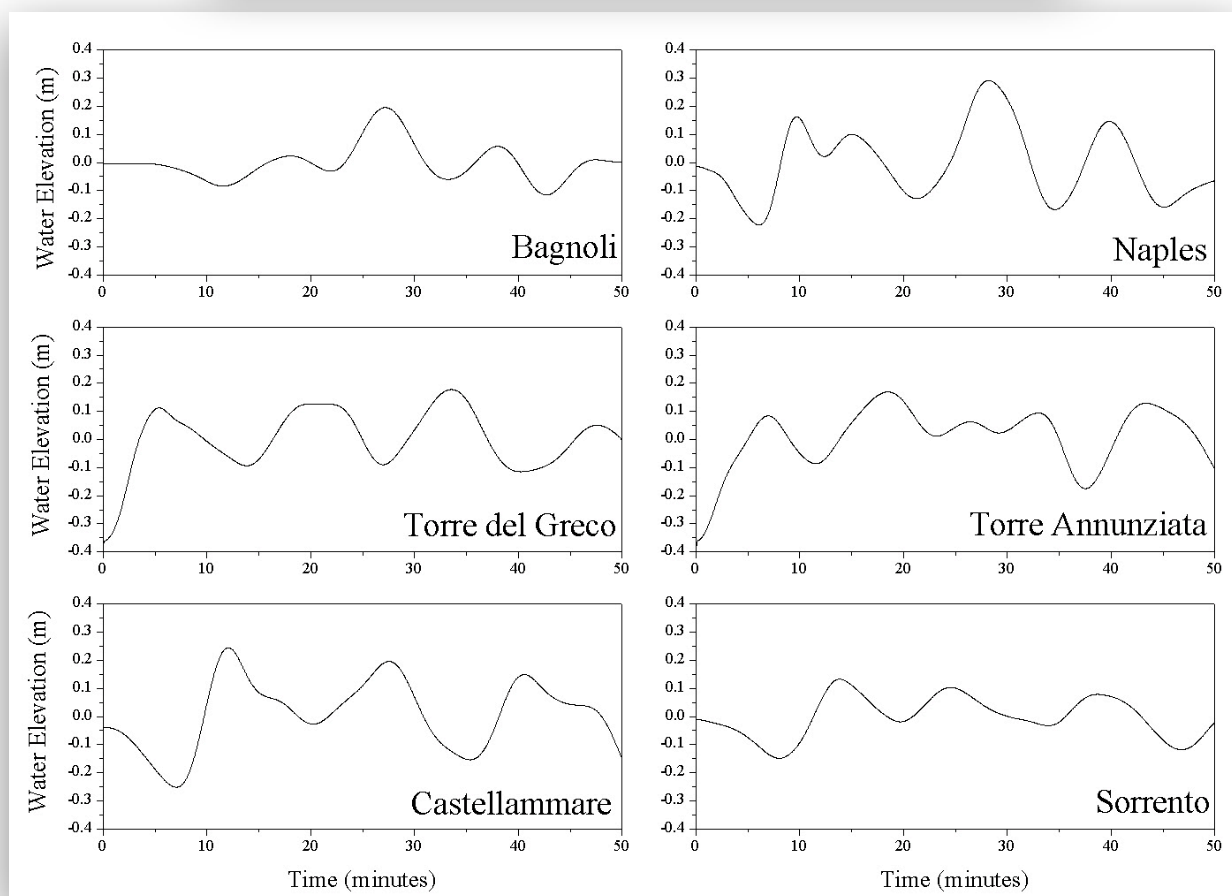


Water elevation fields plotted every 8 min until 40 min after tsunami initiation

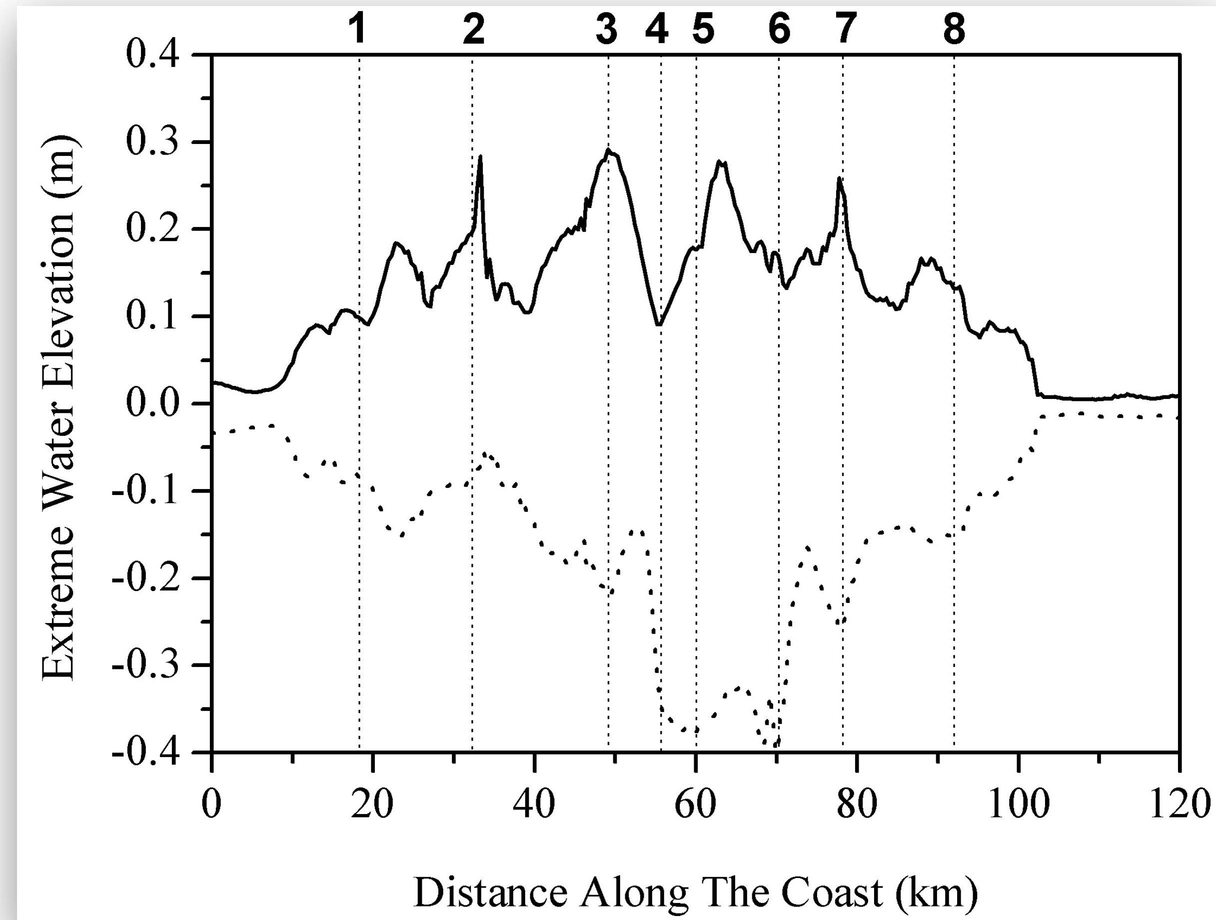
Simulation of tsunamis induced by volcanic activity in the Gulf of Naples (Italy)
Tinti, Pagnoni & Piatanesi, 2003. Natural hazards, 311, 320.

Earthquake source





Tsunami records computed at various coastal nodes of the grid until 50 min after the tsunami excitation

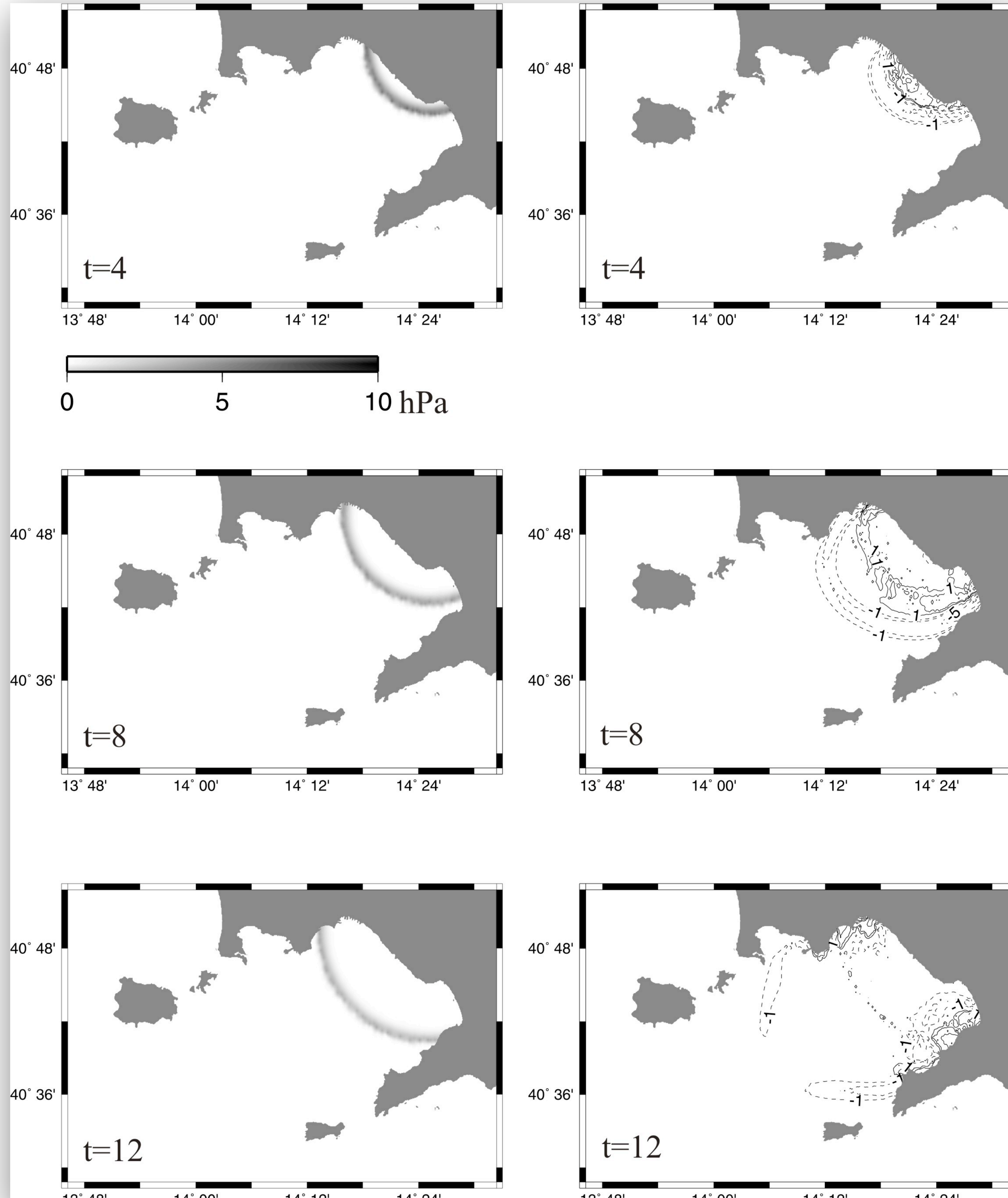


Maximum (solid) and minimum (dashed) water elevation computed along the mainland coastline. Vertical lines mark the position of the localities shown in Fig. 1: 1-Miseno, 2- Bagnoli, 3- Naples, 4- Granatello, 5- Torre del Greco, 6- Torre Annunziata, 7- Castellammare, 8- Sorrento. On the coast outside, the level remains almost unperturbed.

Pyroclastic flows

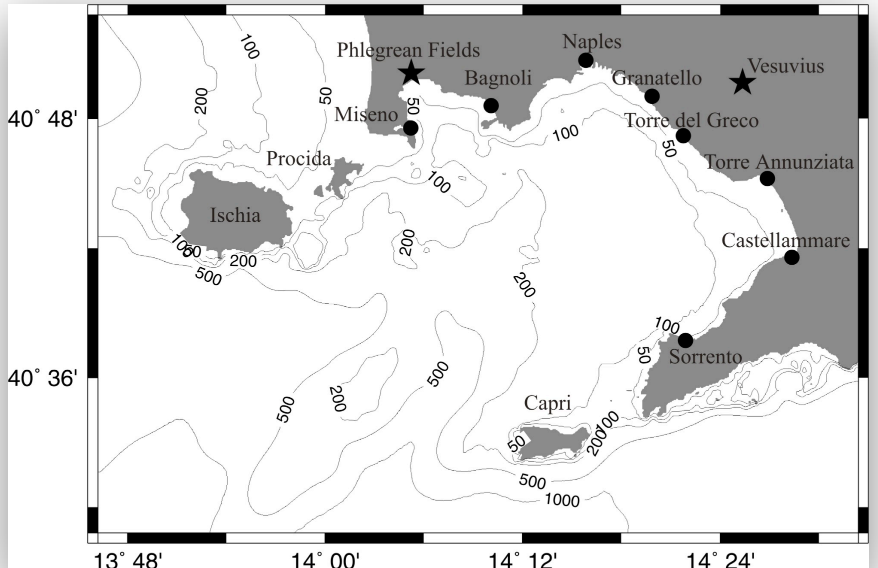
Pyroclastic flows have been sometimes speculated to be the cause of tsunamis, though their potential to produce tsunamis is largely unexplored and geological and numerical studies on this topic are not frequent.

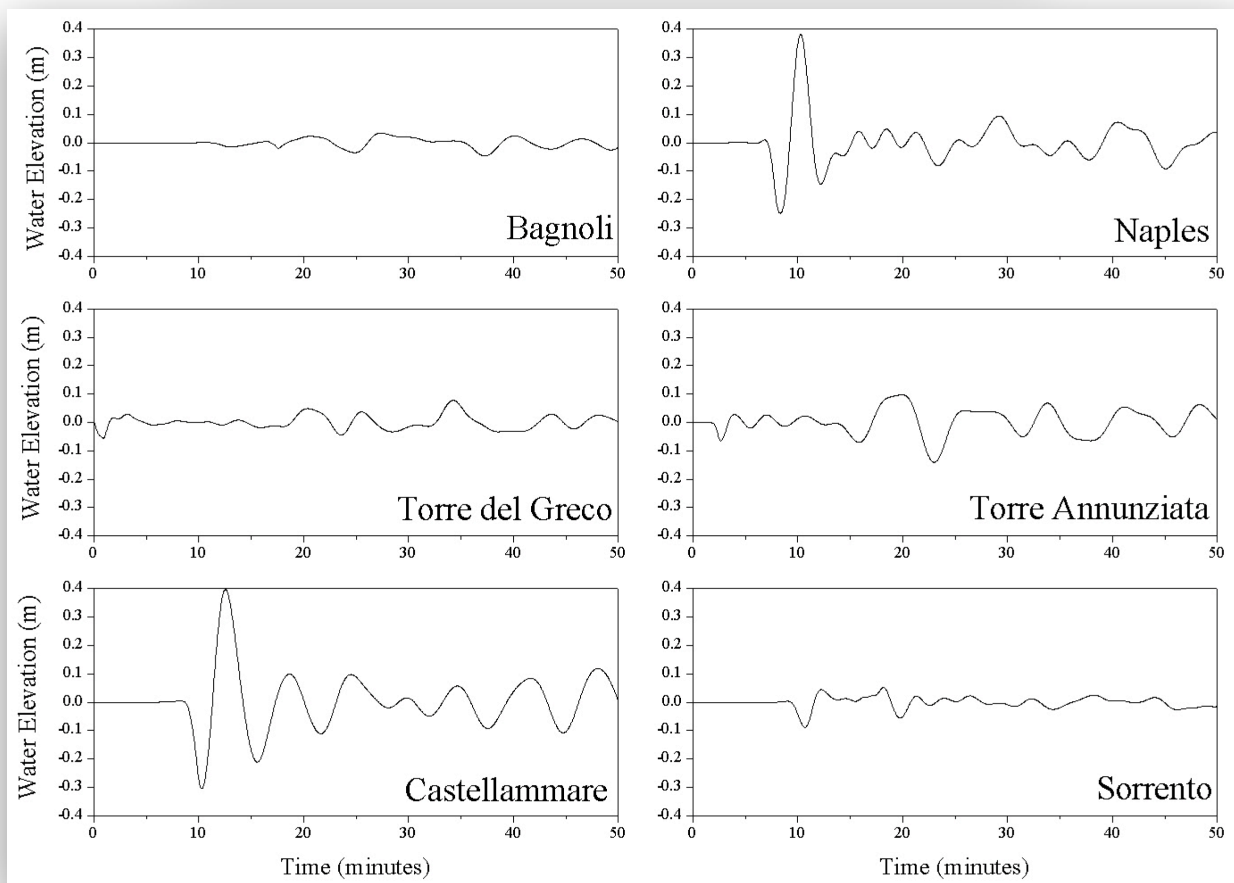
- very dense flows penetrating underwater,
- light flows running on the sea surface



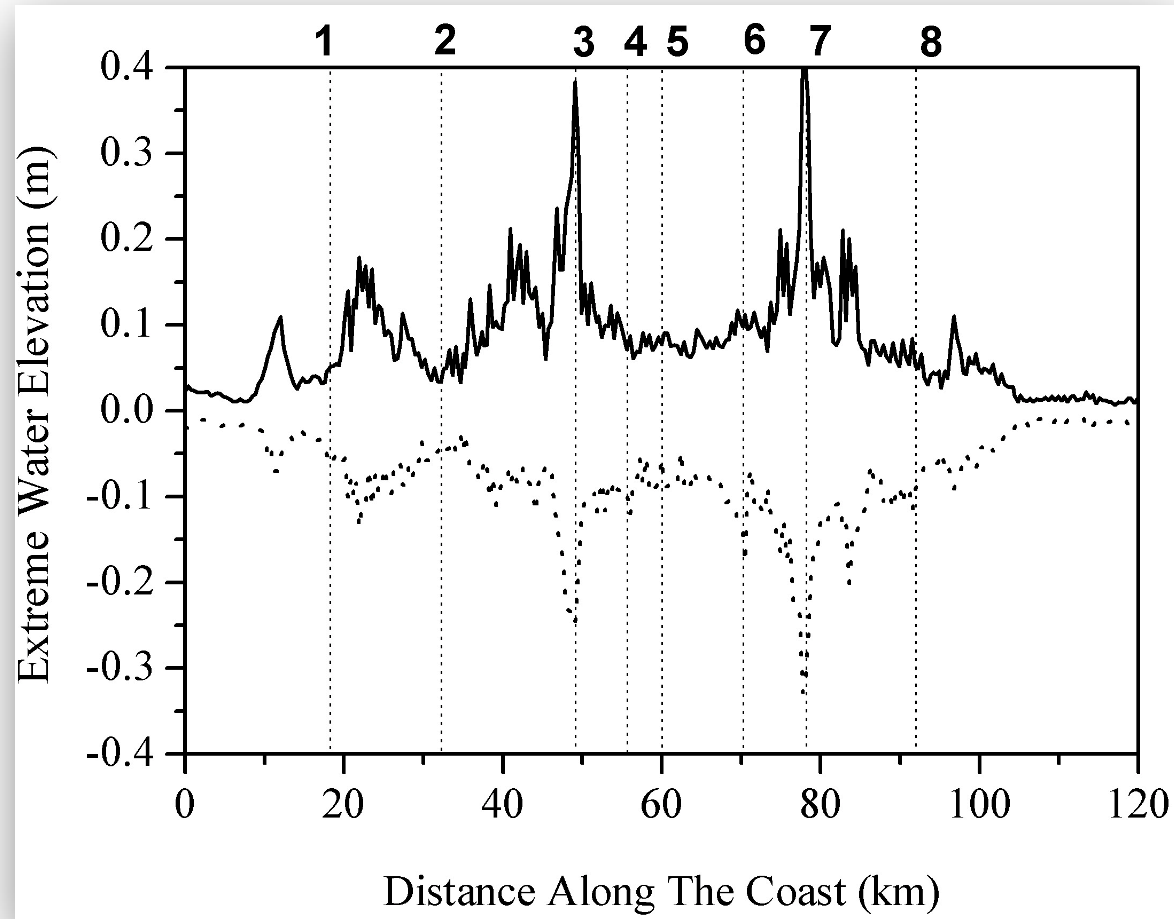
Pressure pulse fields (on the left) computed at different times, given in minutes. Water elevation fields (on the right) computed at the same instants. Time is measured from tsunami origin time and contour line labels are in cm

Pyroclastic source





Tsunami records computed at various coastal nodes



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On the coast outside, the level remains almost unperturbed.

Conclusions

- The tsunami amplitude computed is modest. Such a tsunami cannot be considered hazarduous, and in terms of the Ambraseys-Sieberg scale adopted for European tsunamis its intensity would be not larger than 2.

- Varying parameters (e.g. amplitude&velocity of the pressure pulse) , provided however that they remain within the reasonable limits required by the pyroclastic flow dynamics, will probably produce more sizeable tsunamis.

- If a large plinian or subplinian eruption of Vesuvius occurs, the associated low-density component of the pyroclastic flows are expected to produce a tsunami that affects the Gulf of Naples, but the tsunami is expectedly not catastrophic, and it will be at most as large as the one observed in the second day of the 1631 eruption.

Simulation of tsunamis induced by volcanic activity in the Gulf of Naples (Italy)
Tinti, Pagnoni & Piatanesi, 2003. Natural hazards, 311, 320.

Seismic input for isolated sites - Ercolano

- First application in the world to archaeological heritage of a three directional SIS, developed in the EC-funded SPACE project, which provides isolation from both horizontal and vertical
- Shaking table testing and numerical calculations have been carried out, in order to confirm the SIS performance, together with a study of the seismic characterization of the site

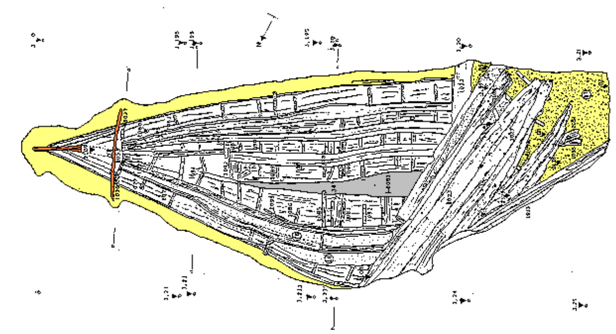
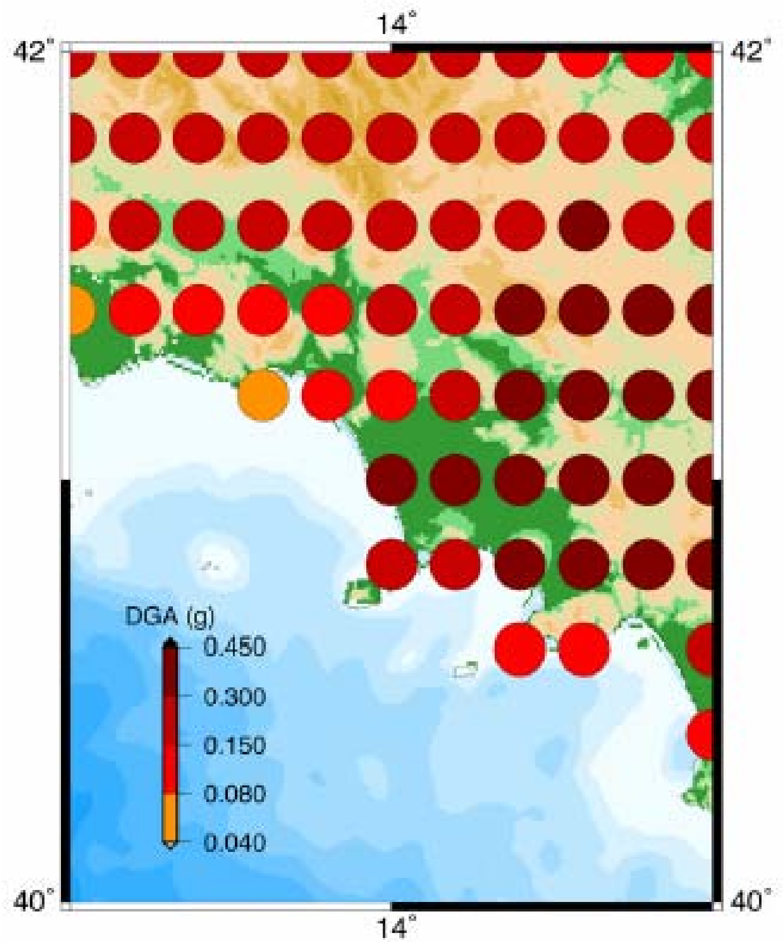


Figure 1. Sketch of the Roman ship after excavation.

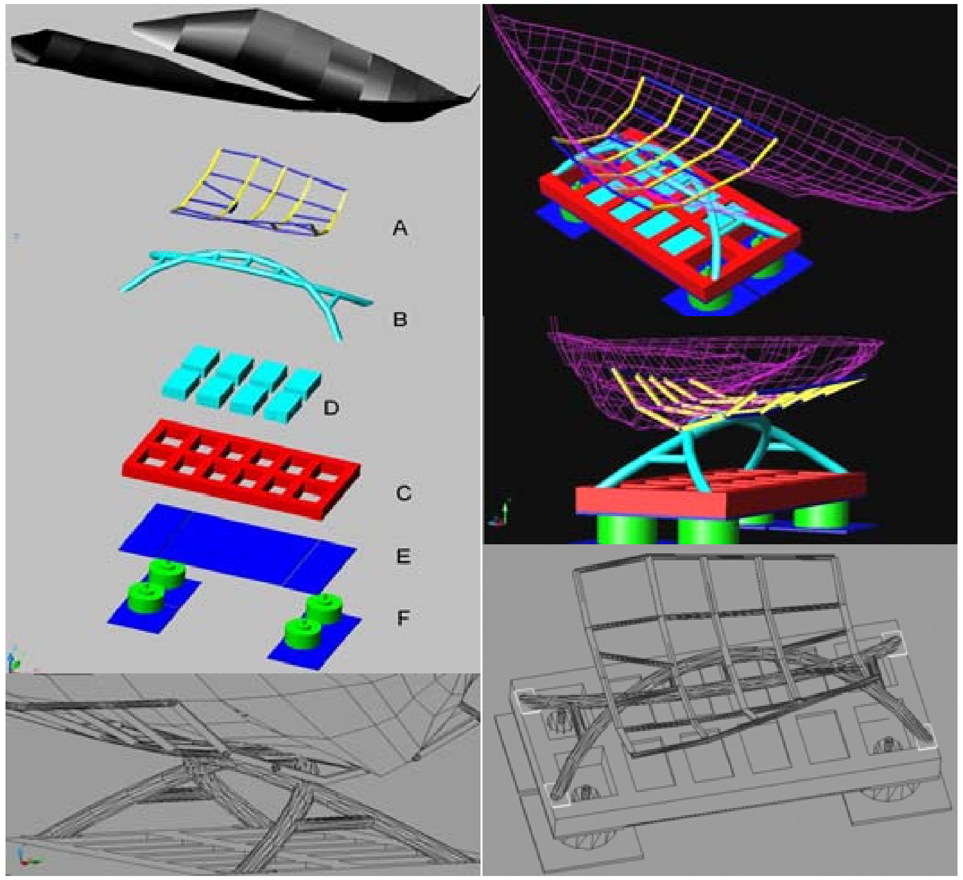
Figure 2. The ship in its metallic frame.

Figure 3. The wreck in its protective shell.



3D SIS device (left) and rolling-ball element (right)

Map of maximum design ground acceleration (DGA), obtained as the result of the deterministic zonation at national scale, for the Campania region.



Sketches of the ship supporting system