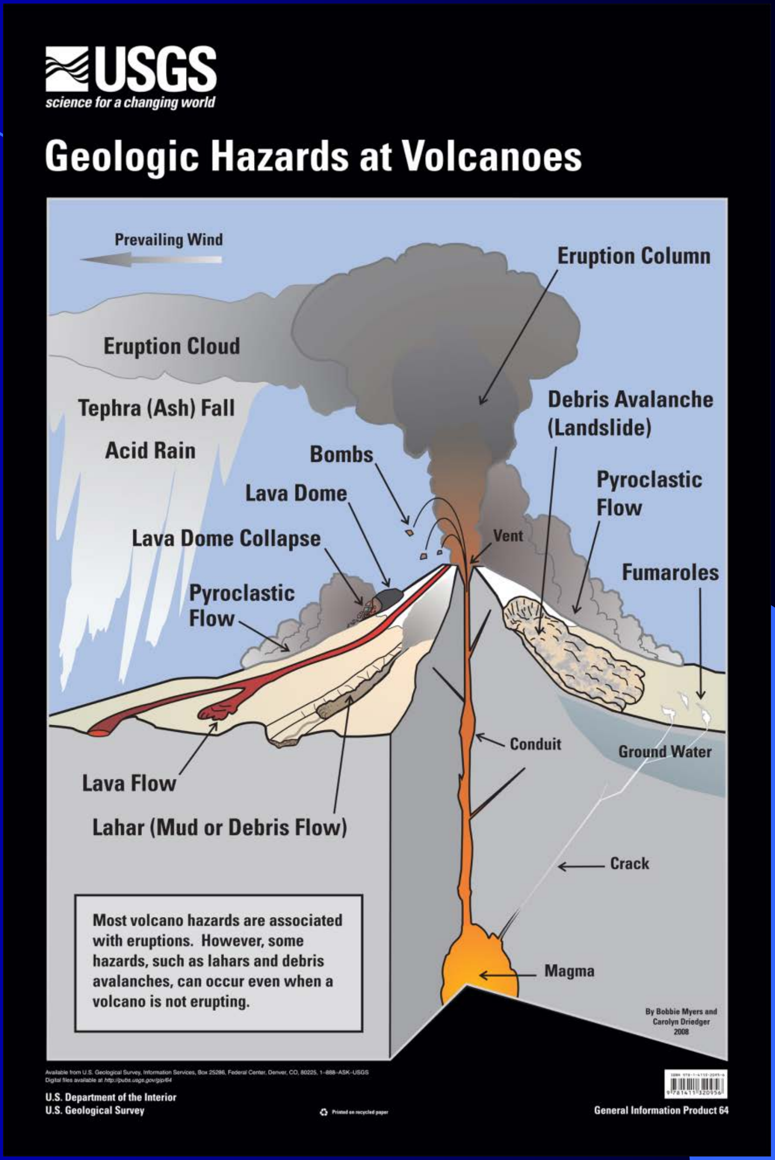
Civilization exists by geologic consent, subject to change without notice

William Durant

Volcanic Hazards

Types of Volcanic Hazards

- Lava flows: e.g. Hawaii, 1998
- Gas: e.g. Lake Nyos (Cameroon), 1984 (1700 people killed)
- Ash fall: e.g. Mt. Pinatubo, 1991
- Pyroclastic flows: e.g. Mt. Pelee, 1902 (28,000 killed)
- Lahars (mudflows): e.g. Nevado del Ruiz, 1985 (23,000 killed)
- Tsunami: e.g. Krakatoa, 1883 (36,417 killed)



Notable Volcanic Disasters

Primary Cause of Death

Volcano	Country	Year	Pyroclastic flow	Lahar	Tephra	Landslide	Tsunami	Gas	Posteruption starvation
Kelut	Indonesia	1586		10,000					
Vesuvius	Italy	1631	>4,000						
Raung	Indonesia	1638		>1,000					
Merapi	Indonesia	1672	300						
Awu	Indonesia	1711	~3,000						
Oshima	Japan	1741					1,481		
Makian	Indonesia	1760		~2,000					
Papadanyan	Indonesia	1772				2,960			
Gamalama	Indonesia	1775	1,300						
Lakagígar	Iceland	1783							9,340
Asama	Japan	1783	466	~1,400					
Unzen	Japan	1792					~15,000		
Mayon	Philippines	1814	1,200						
Tambora	Indonesia	1815	12,000						80,000
Galunggu	Indonesia	1822		4,000					
Nevado del Ruiz	Colombia	1845		1,000					
Awu	Indonesia	1856		3,000					
Cotopaxi	Ecuador	1877		>300					

Notable Volcanic Disasters

Primary Cause of Death

Volcano	Country	Year	Pyroclastic flow	Lahar	Tephra	Landslide	Tsunami	Gas	Posteruption starvation
Krakatau	Indonesia	1883	~5,000				~31,417		
Ritter	Papau New Guinea	1888					3,000		
Awu	Indonesia	1892	1,532						
Soufrière	St. Vincent	1902	1,680						
Mount Pelée	Martinique	1902	29,000						
Santa Maria	Guatemala	1902	~1,500						
Taal	Philippines	1911	1,335						
Kelut	Indonesia	1919		5,110					
Merapi	Indonesia	1930	1,369						
Rabaul Caldera	Papua New Guinea	1937	507						
Lamington	Papua New Guinea	1951	2,942						
Hibok-Hibok	Phillipines	1951	>500						
Agung	Indonesia	1963	>1,148						
El Chichón	Mexico	1982	>2,000						
Nevado del Ruiz	Colombia	1985		>23,000					
Lake Nyos	Cameroon	1986						1,700	
Mount Pinatubo	Philippines	1991-1996		>500	300				

Notable Volcanic Disasters

Summary of Primary Causes of Death

Pyroclastic flow	>70,779
Lahar	>51,310
Tephra	300
Landslide	2,960
Tsunami	>50,898
Gas	1,700
Posteruption Starvation	89,340
Total Deaths	>267,287

Lava Flows

Property damage

Don't fall in

Mount Cameroon lava flow cutting road

Tephra

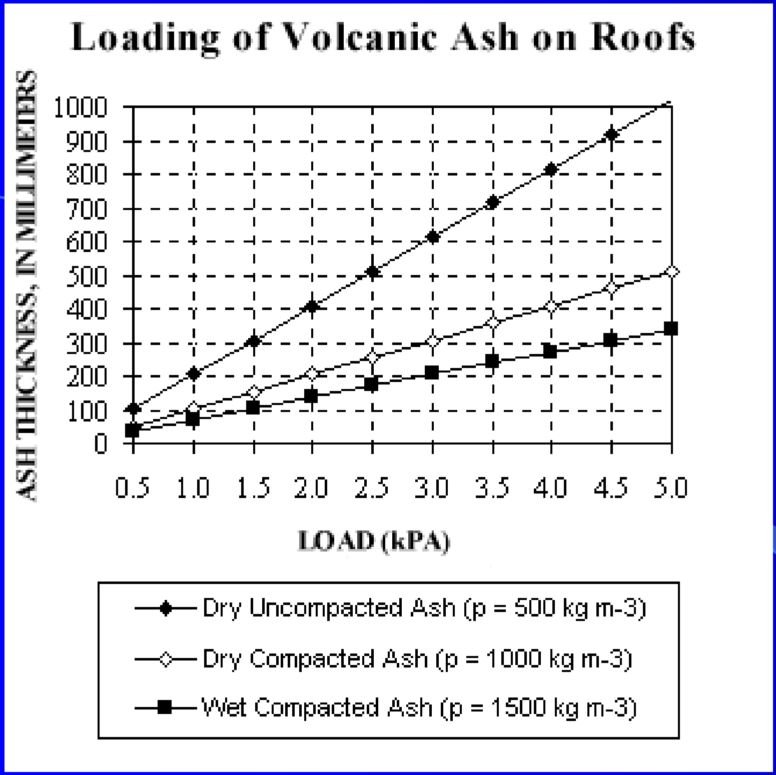
Power outages

Reduced visibility

Roof collapse

Slippery roads

Ash Loading on Roofs



$$L = \frac{dpg}{1000}$$

L is volcanic ash load (pressure in kPa)
d is ash depth (m)
p is ash density (kg/m^3)
g is the gravitational acceleration (9.8 m/s^2)

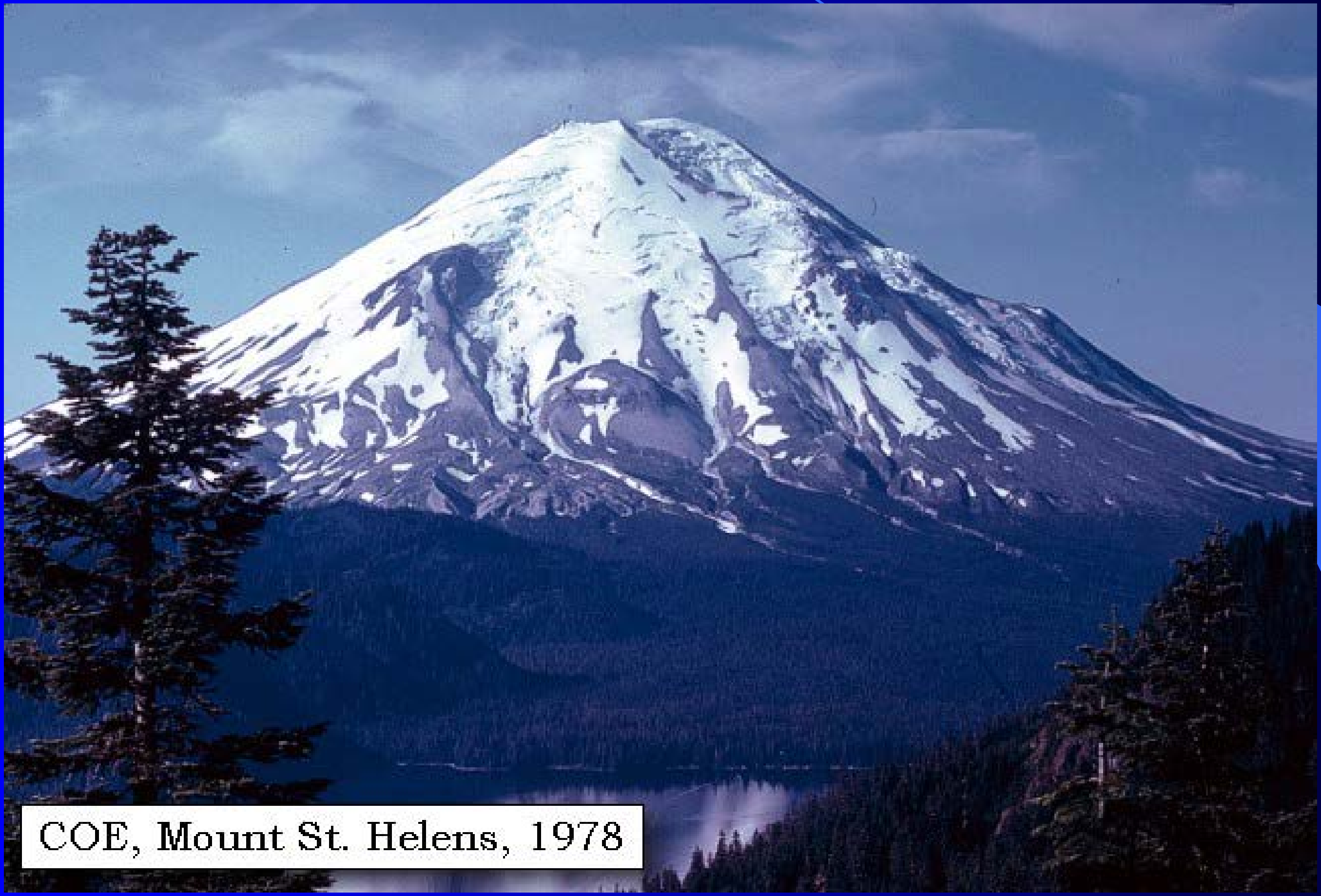
Chile Restaurant

Raboul

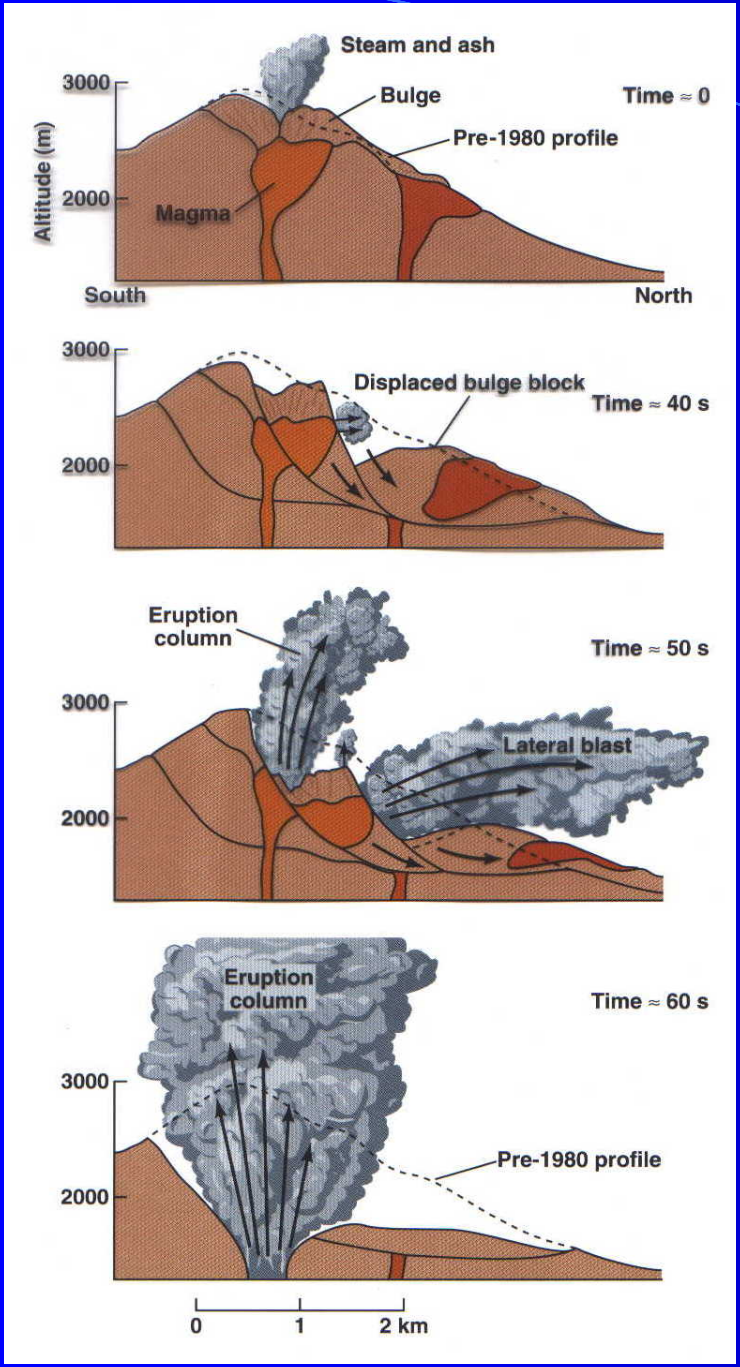
Philippines Clark Air Force Base

Pyroclastics and Landslides

Mt. St. Helens (May 18, 1980)

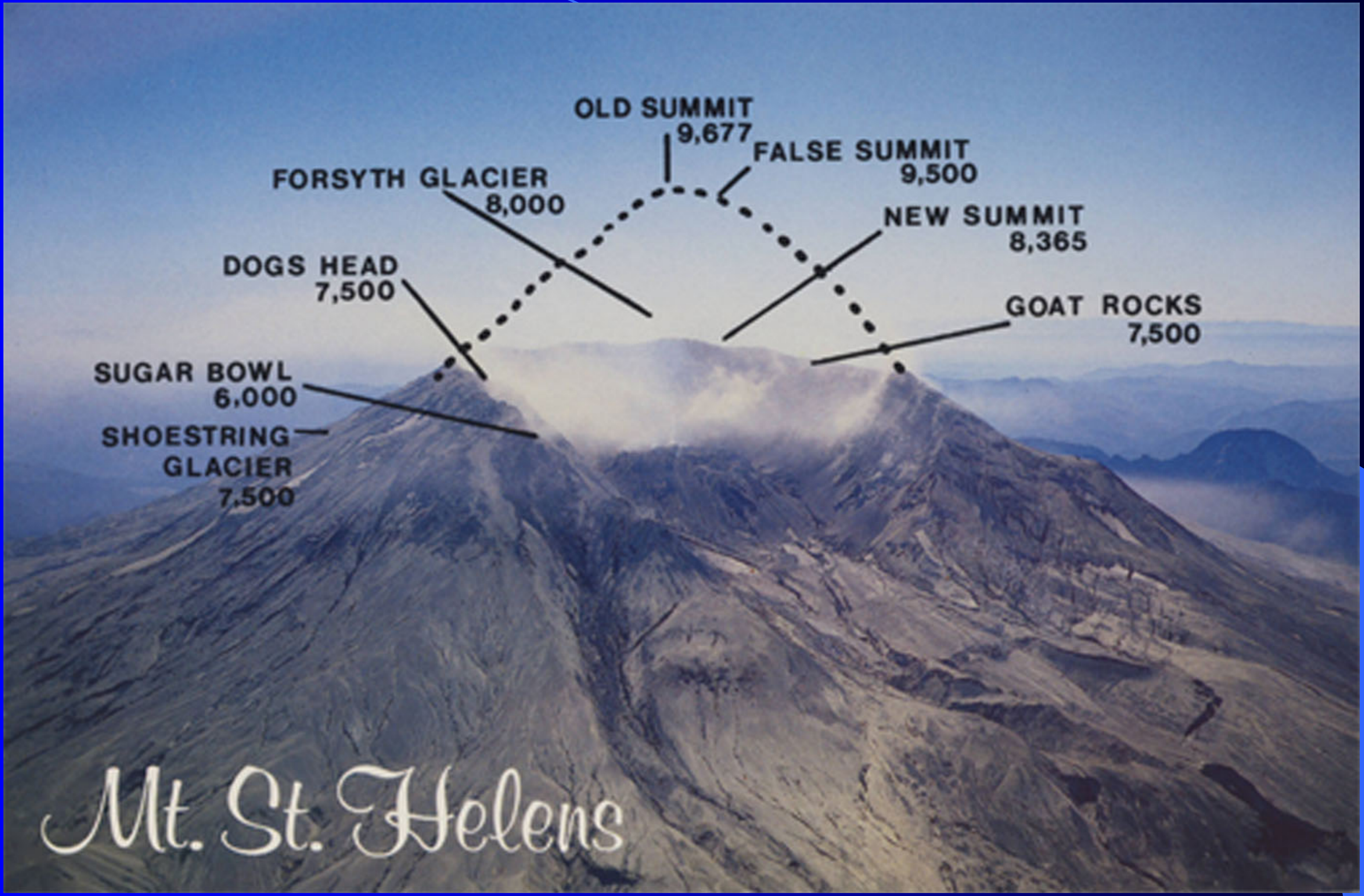


Mt. St. Helens start of eruption



Mt. St. Helens Eruption

Mt. St. Helens after the eruption



Mt. St. Helens - the aftermath

Landslide deposits

Flattened trees

Trees in Cowlitz river

Destroyed logging trucks

Mt. St. Helens - today

Mt. St. Helens today

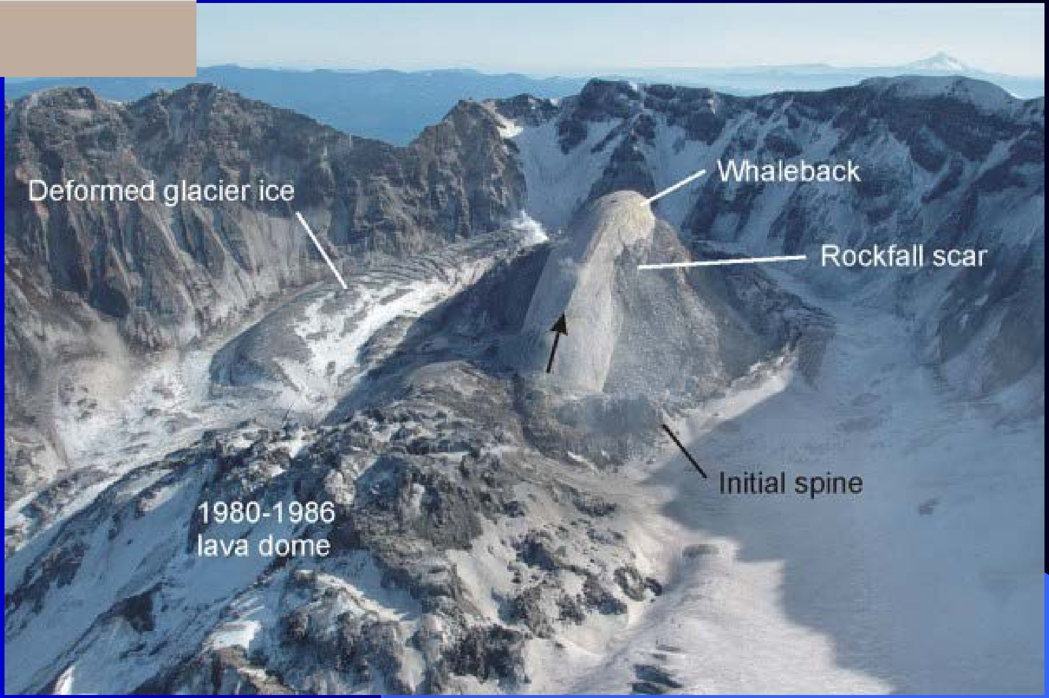
Regrowth

Spirit Lake

Demolished car

Growth of lava dome in the Mt. St. Helens crater.

Crater and dome of Mount Saint Helens in 1989.
Photo by Lyn Topinka, U. S. Geological Survey

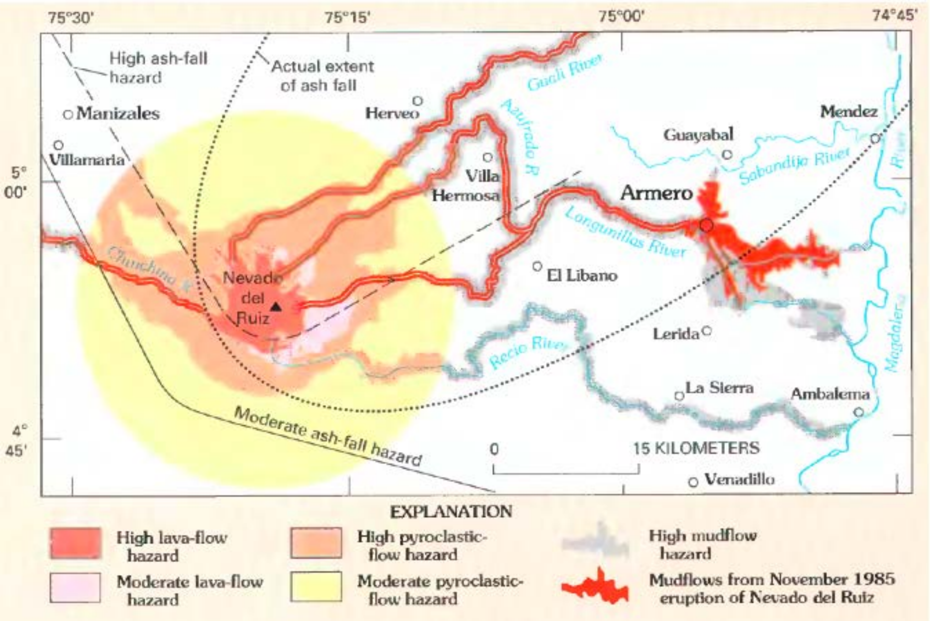


Lahars

Nevado del Ruiz (November 13, 1985)

An explosive eruption from Ruiz's summit crater at 9:08 PM generated an eruption column and sent a series of pyroclastic flows and surges across the volcano's broad ice-covered summit. In this view, the dark pyroclastic-flow deposits are partly covered with fresh snow.

Hot rock fragments of the pyroclastic flows and surges quickly eroded and mixed with Ruiz's snow and ice, melting about ten percent of the volcano's ice cover. Flowing mixtures of water, ice, pumice and other rock debris poured from the summit and sides of the volcano into rivers draining the volcano.



Lahars merge at the base of the volcano. Headwaters of the Gualí river.

Lahars grow in size through erosion. Gualí river valley

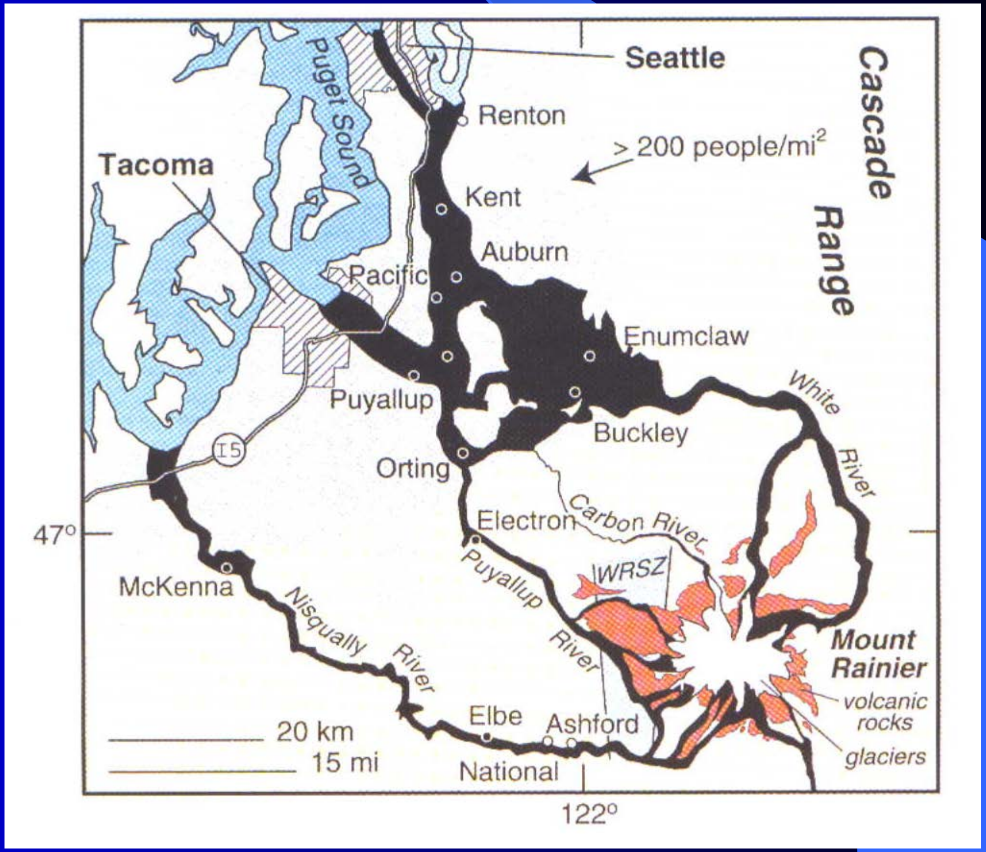
High ground means safety. Gualí river.

Río Lagunillas, former location of Armero. Bottom, remains of Armero. 75% of the population of 28,700 perished when lahars buried the town. There were multiple pulses with flow depths of 2 to 5 m.

Lahars

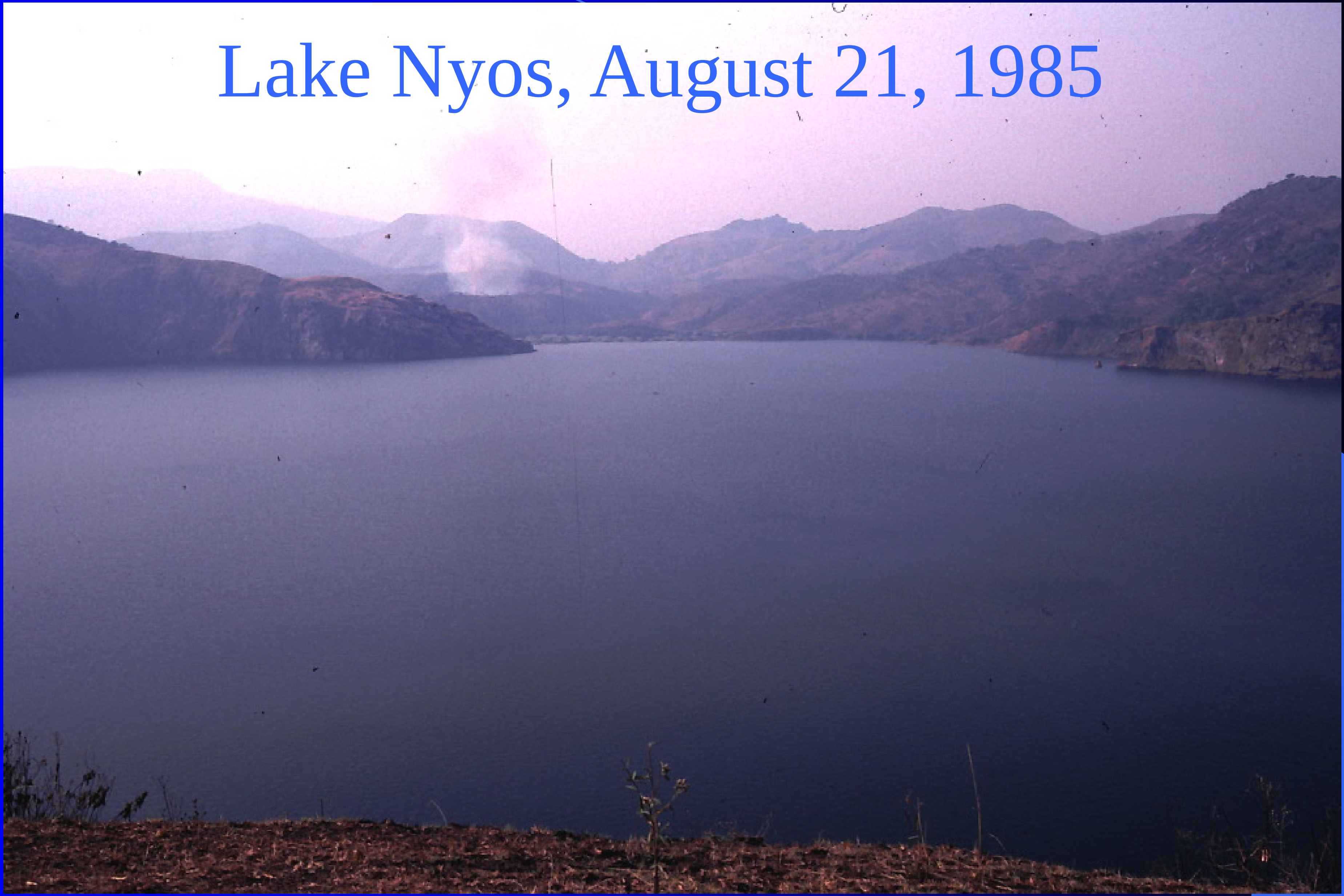
Lahar near Enumclaw. 1 m thick layer at top of quarry. Note distance to Mt. Rainier

Paleo-lahars surround Mt. Rainier. Recent developments are built on these lahars.



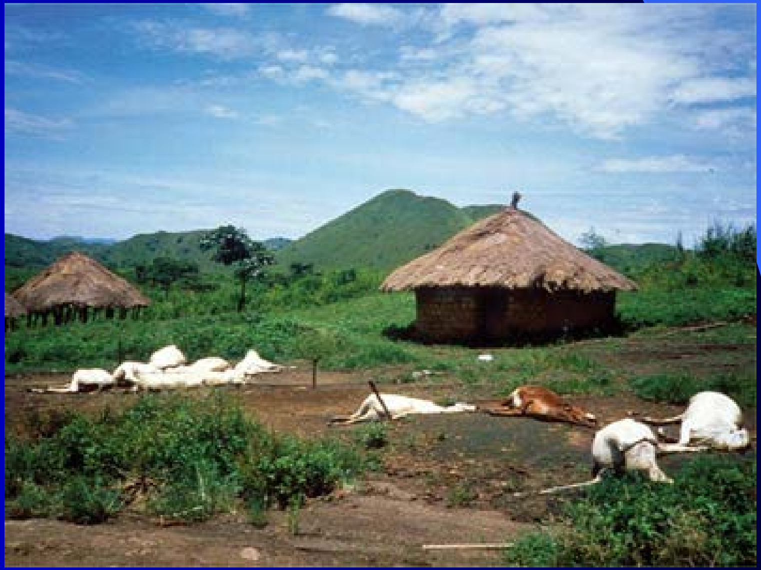
Lahars can originate from Mt. Rainier without volcanic activity. Hydrothermal alteration of volcanic rocks by acid gases oxidizes the ferromagnesian silicates and converts the feldspars to clay minerals. The resulting weak altered layers can fail under gravitational loading. Downslope movement of material with entrainment and melting of glacial ice and snow leads to the formation of a volcanic mudflow (lahar).

Gas release



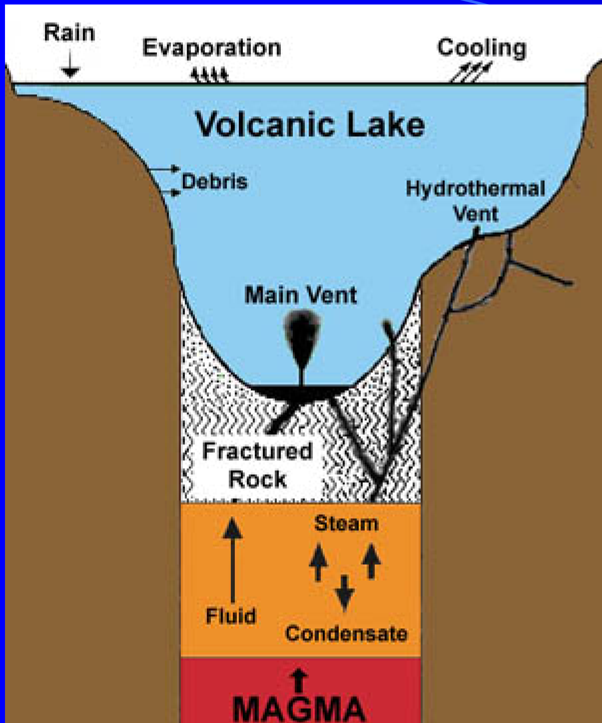
Lake Nyos pyroclastic dam, valley and town of Nyos.

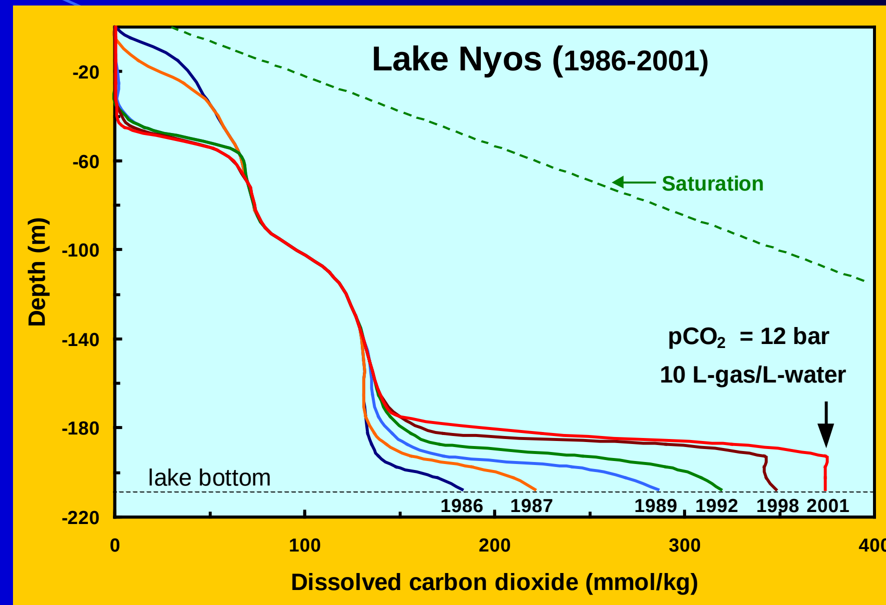
Orange color of Lake Nyos immediately after the gas release. The color is due to the oxidation of iron and the formation of ferric hydroxides

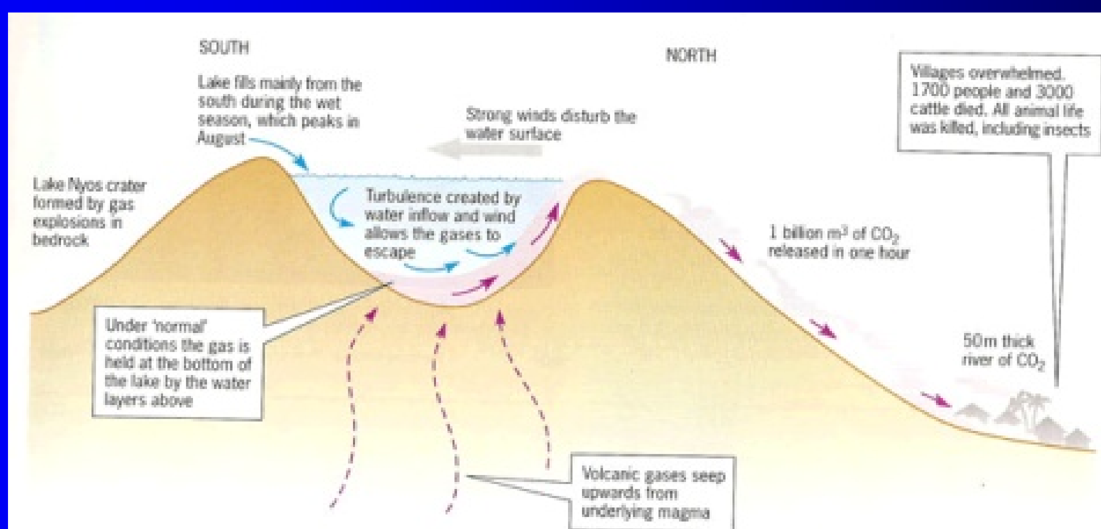


Dead cows in Nyos village. Over 1700 people perished as a result of the CO_2 release.

Disaster due to build-up of CO_2 in deep waters. Overturn leads to catastrophic release of CO_2.





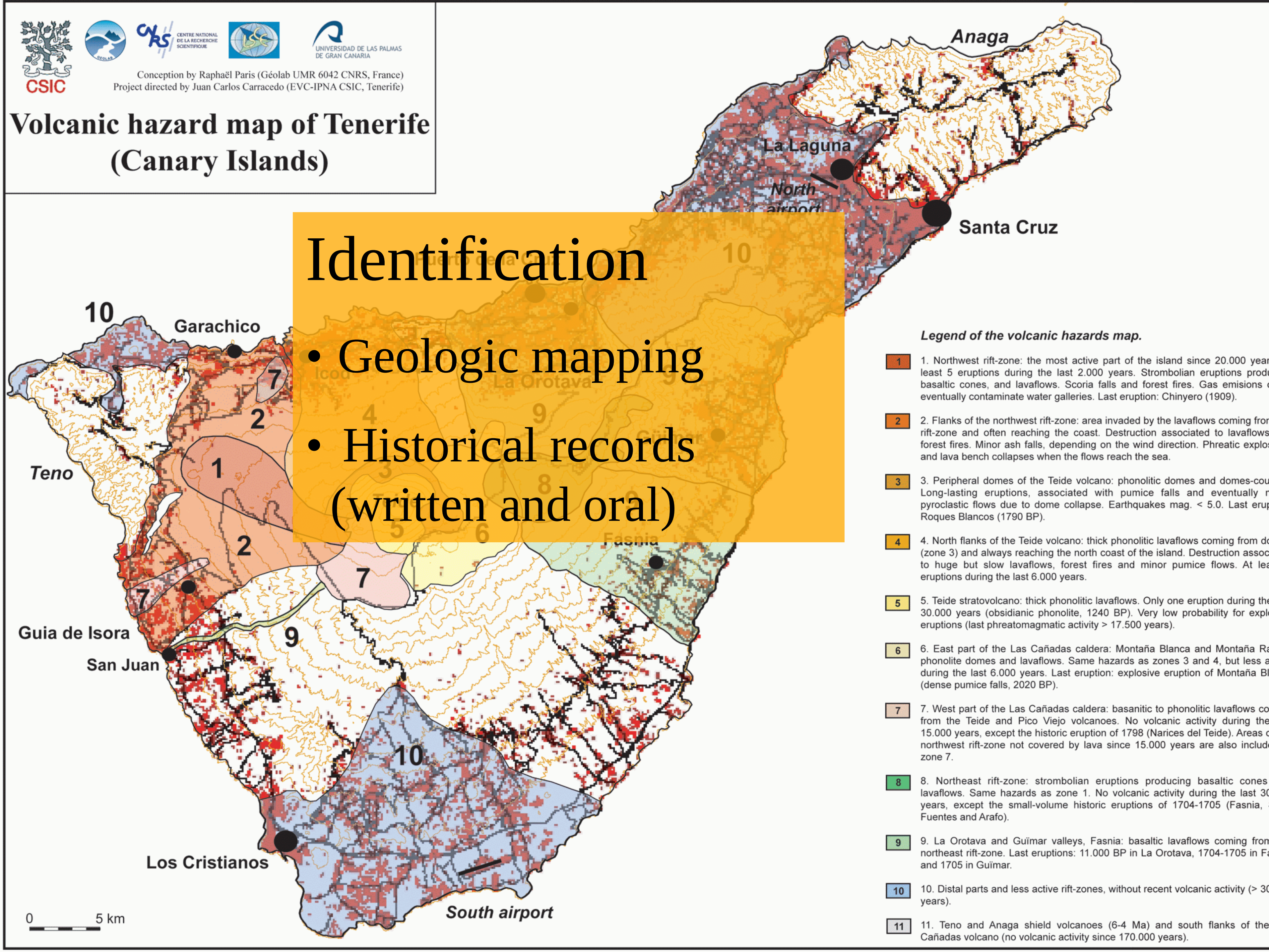


Volcanic Hazards

- Identification
- Monitoring and prediction
- Response

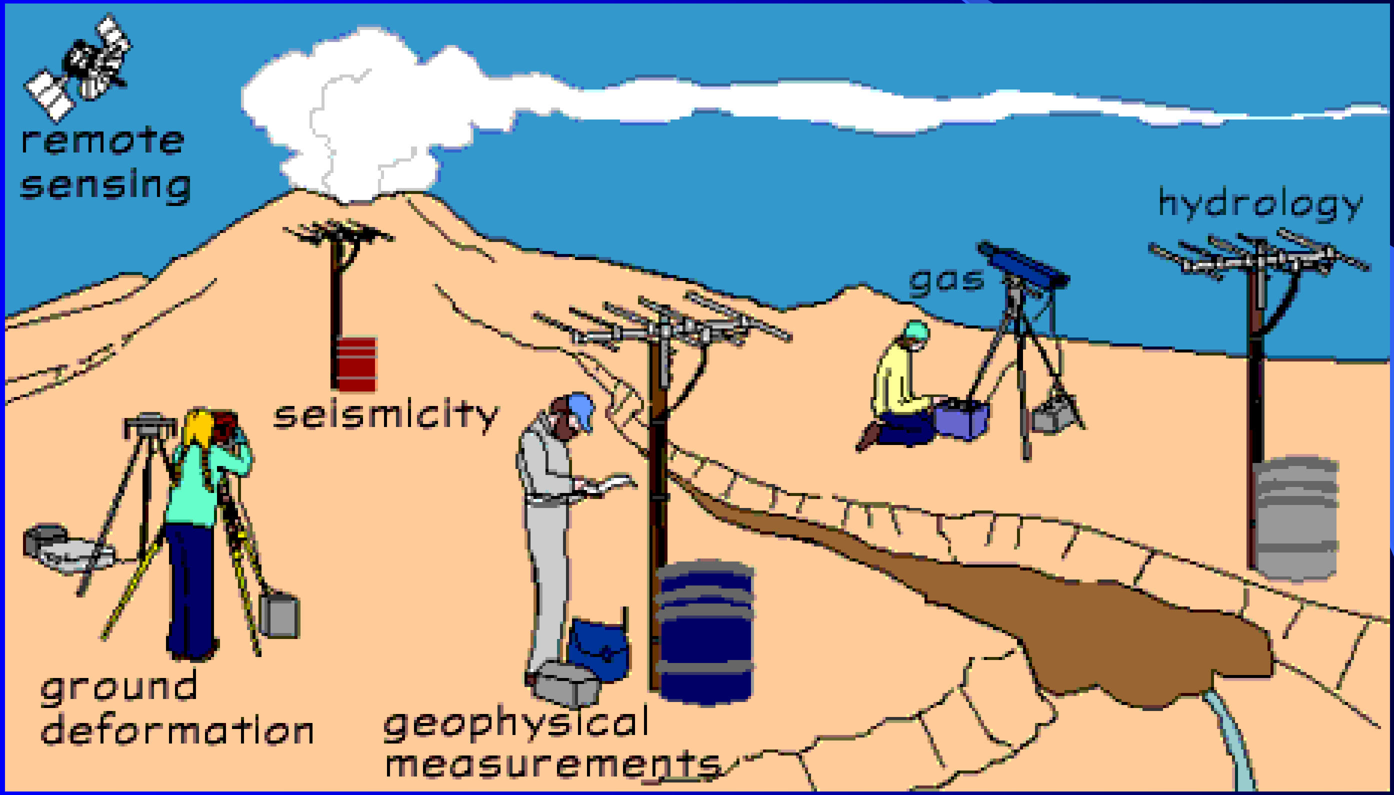
Identification

- Geologic mapping
- Historical records (written and oral)



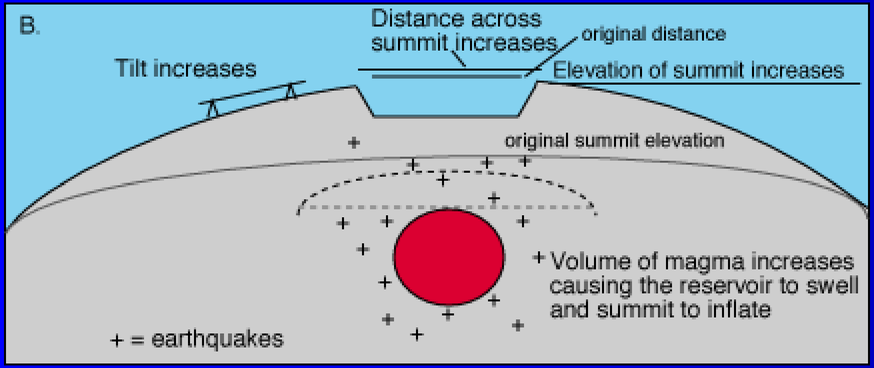
Monitoring and Predicting

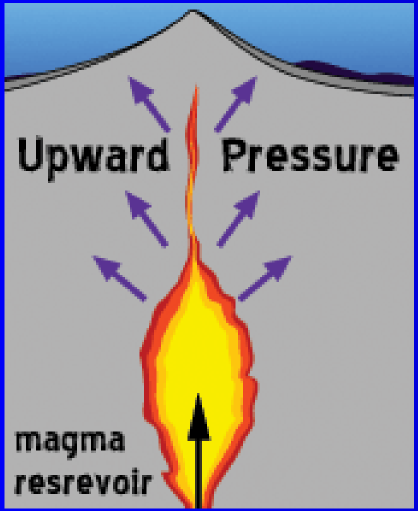
Volcanic Eruptions



Ground deformation

Rising magma intrudes volcano and changes its shape



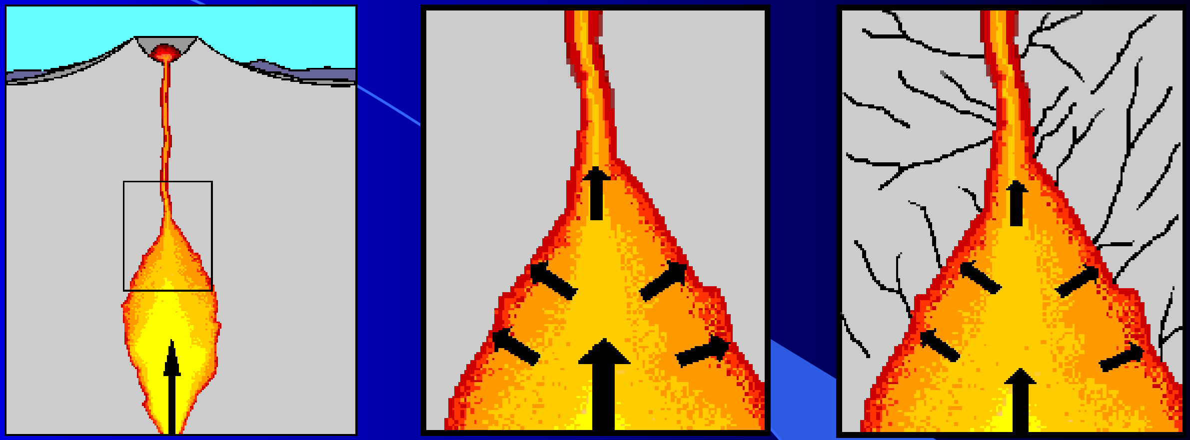


Installing tiltmeter

Tiltmeter

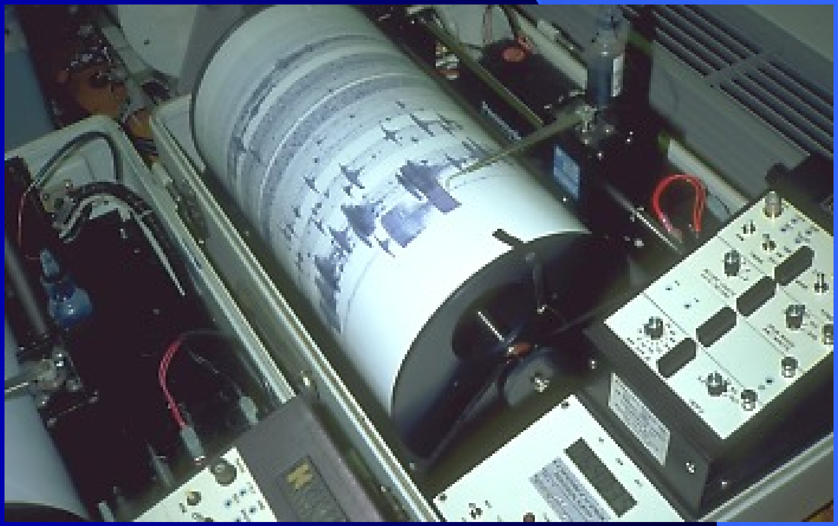
Seismicity

Rising magma exerts pressure on the surrounding rock which leads to fracturing and small earthquakes



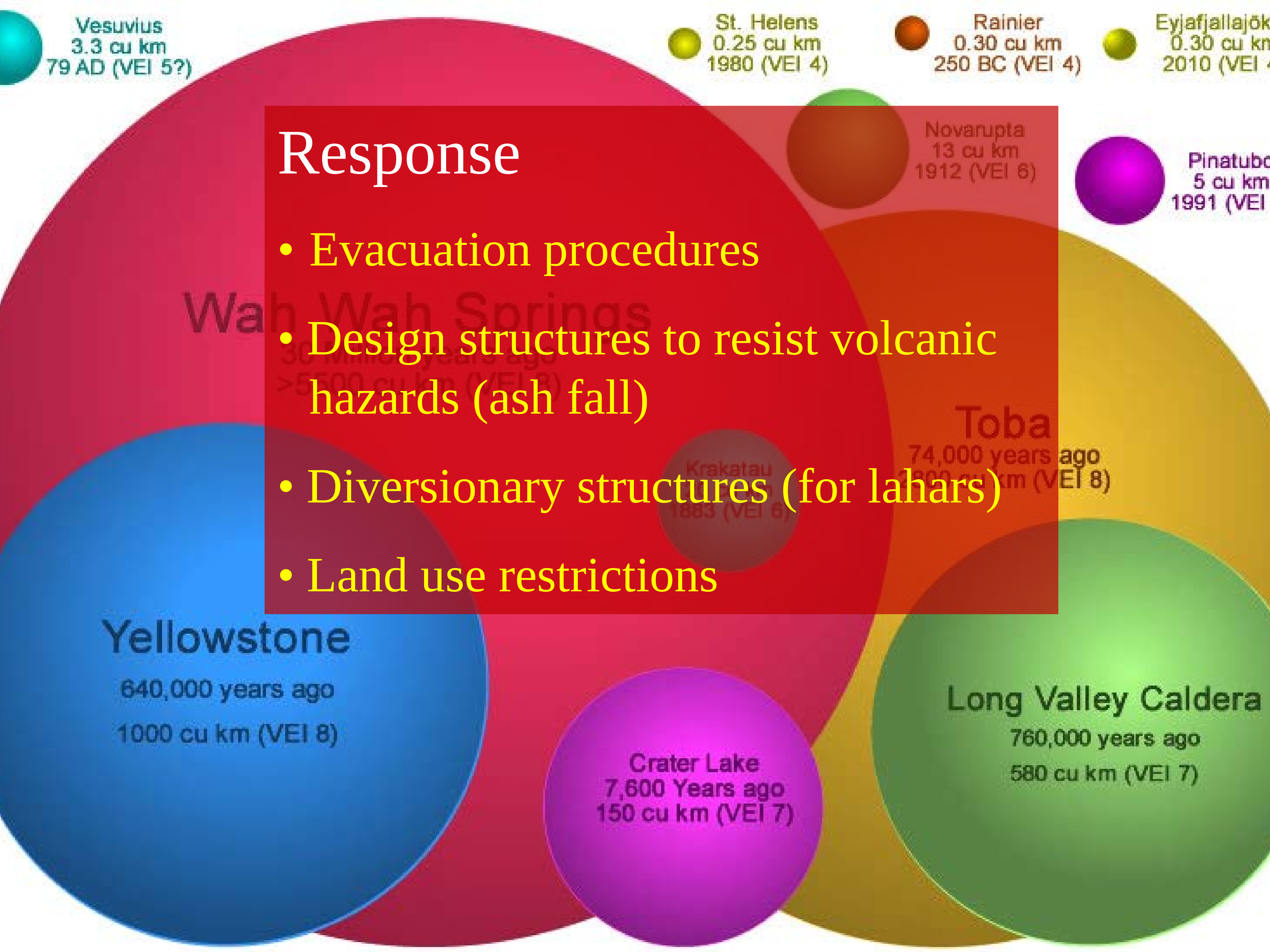
Installing seismometer

Seismograph, Mt. Pinatubo



Gas monitoring

Monitor emission of carbon dioxide and sulfur dioxide. The emission rate may increase immediately before a volcanic eruption and sulfur dioxide may become a more important component of the gas stream.



Response

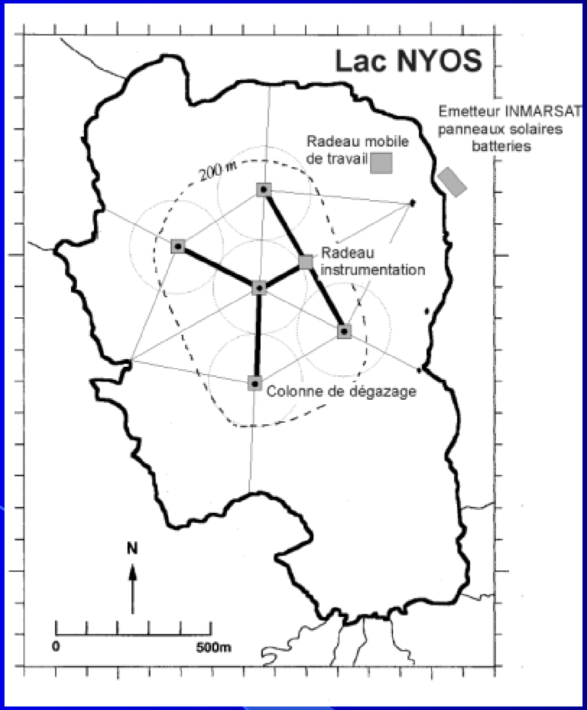
- Evacuation procedures
- Design structures to resist volcanic hazards (ash fall)
- Diversionary structures (for lahars)
- Land use restrictions

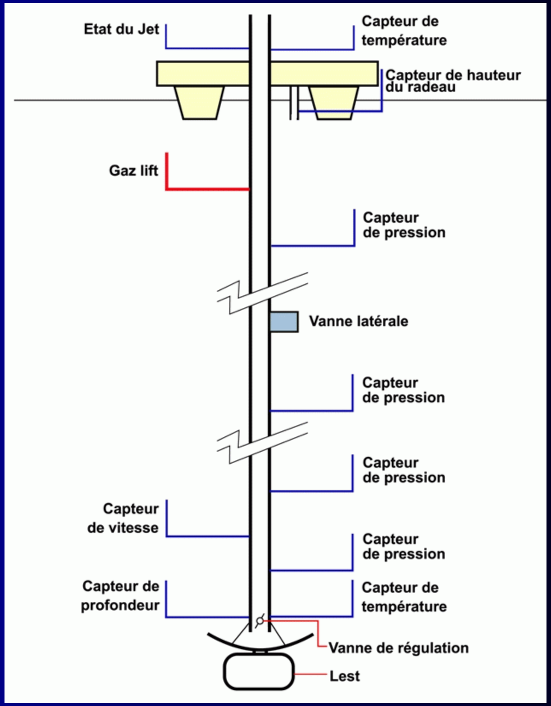
Monitoring and alert system (Lake Nyos)

- CO_2 gas monitoring system
  - Solar powered with battery back-up
  - Infrared sensor
  - Both visual and audio alert
- Response plan and designation of responsible individuals


Carbon dioxide
continuous monitoring
WEST
westsystems.com

Remediation – Degassing Lake Nyos





Volcano Links

- USGS Volcanic Hazards Program
  - http://volcanoes.usgs.gov
- Smithsonian Global Volcanism Program
  - http://www.volcano.si.edu
- Volcano World
  - http://www.volcanoworld.org

Bedtime Reading

- *Surviving Galeras* - Williams & Montaigne
- *No Apparent Danger* - Victoria Bruce