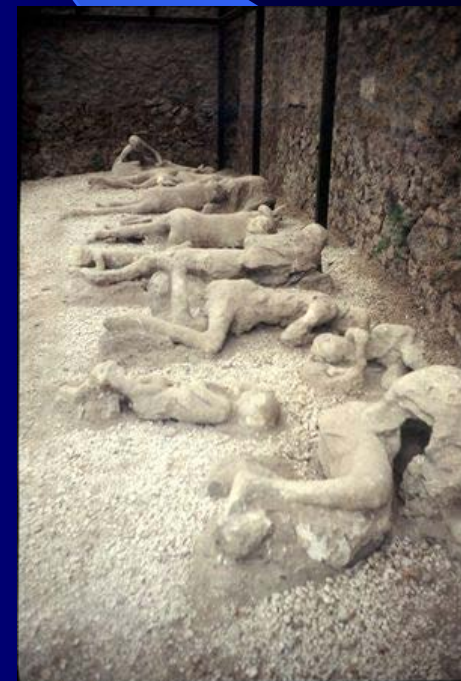


Civilization exists by geologic consent, subject to change without notice

William Durant



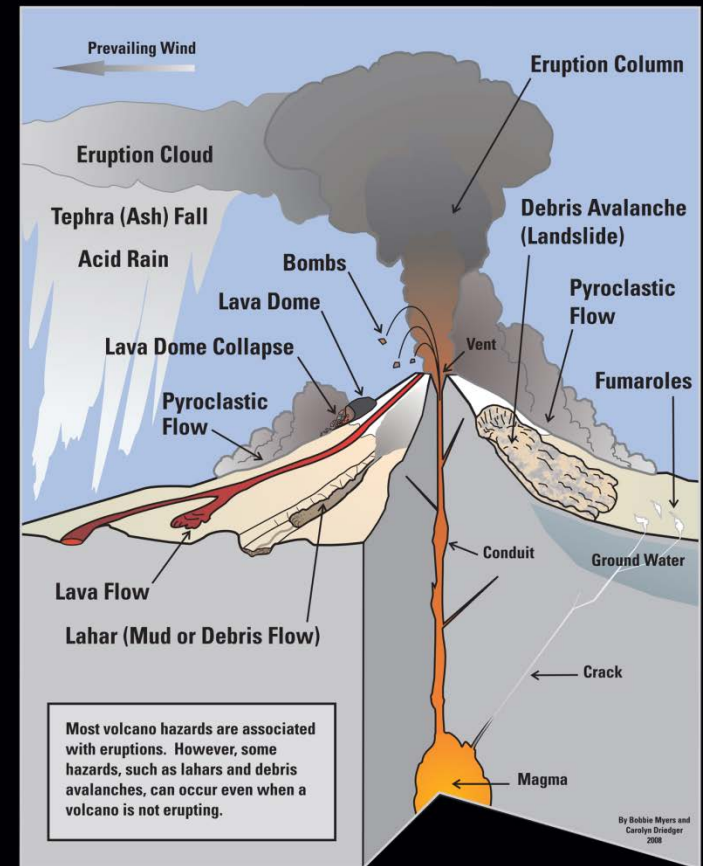
Volcanic Hazards

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)



Geologic Hazards at Volcanoes



Available from U.S. Geological Survey, Information Services, Box 25086, Federal Center, Denver, CO, 80225, 1-888-451-4802
Digital files available at <http://pubs.usgs.gov/gifdata/>

U.S. Department of the Interior
U.S. Geological Survey

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General Information Product 64

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	Papua 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

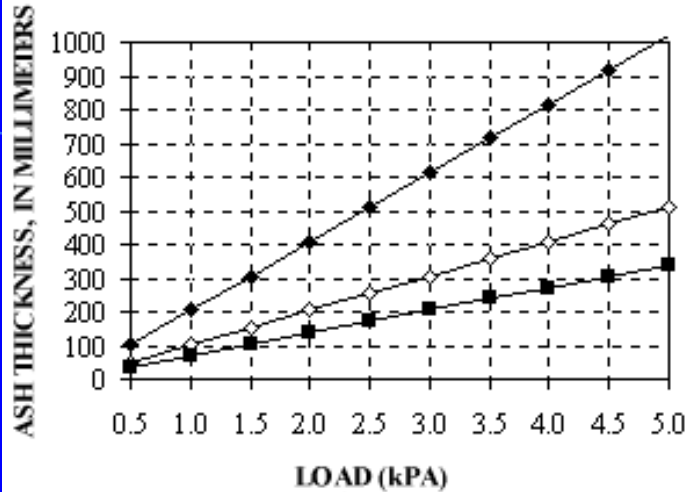


Slippery roads



Ash Loading on Roofs

Loading of Volcanic Ash on Roofs



- ◆ Dry Uncompacted Ash (p = 500 kg m⁻³)
- ◊ Dry Compacted Ash (p = 1000 kg m⁻³)
- Wet Compacted Ash (p = 1500 kg m⁻³)

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

L is volcanic ash load (pressure in kPa)
d is ash depth (m)
p is ash density (kg/m³)
g is the gravitational acceleration (9.8 m/s²)

Chile
Restaurant



Raboul



Philippines
Clark Air
Force Base



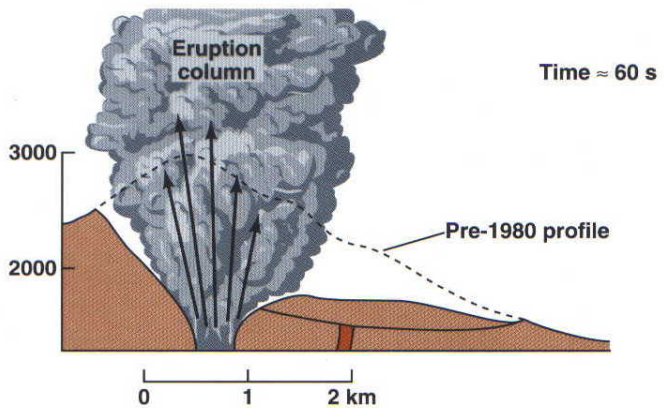
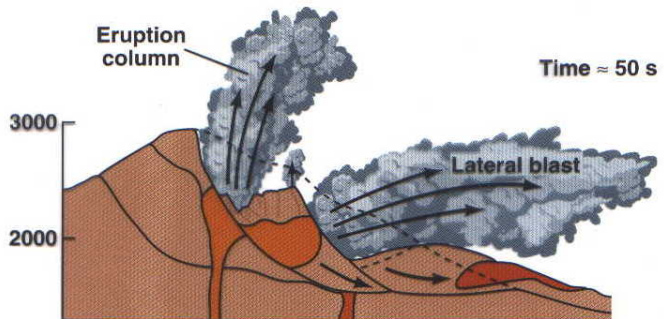
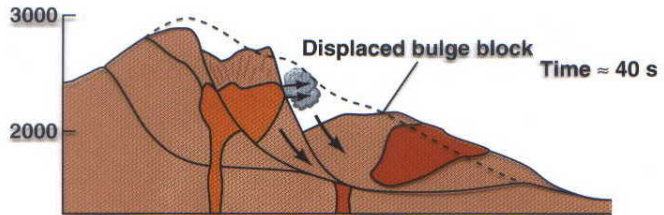
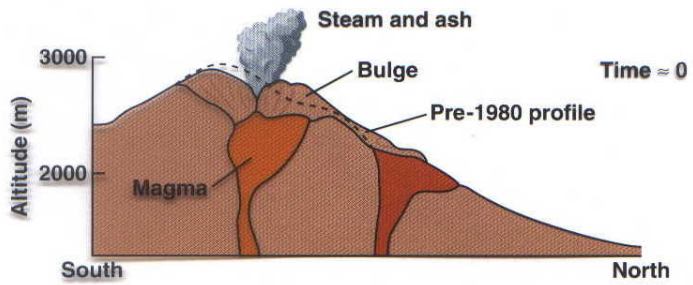
Pyroclastics and Landslides

Mt. St. Helens (May 18, 1980)



COE, Mount St. Helens, 1978

Mt. St. Helens start of eruption

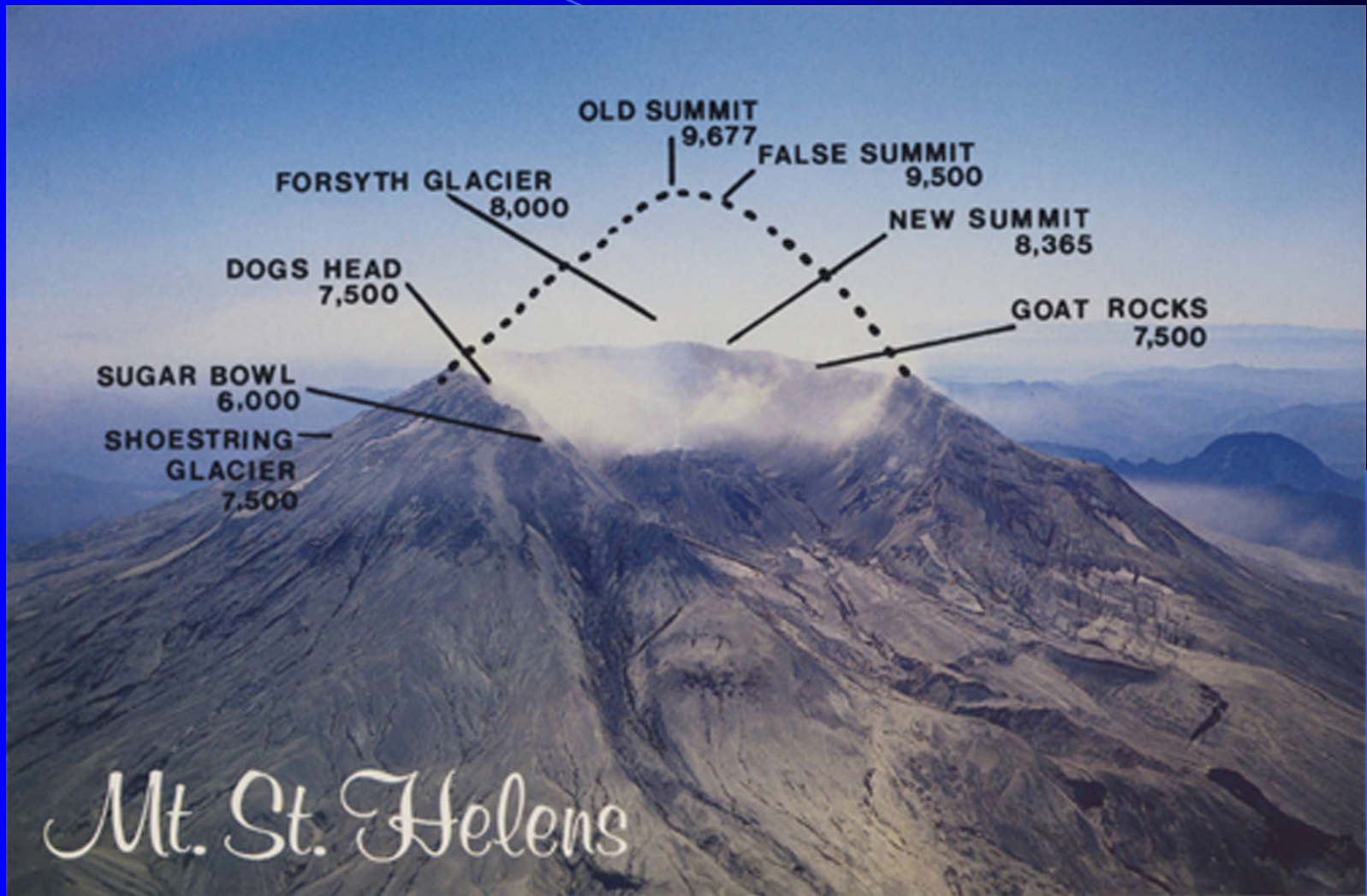


Mt. St. Helens Eruption





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

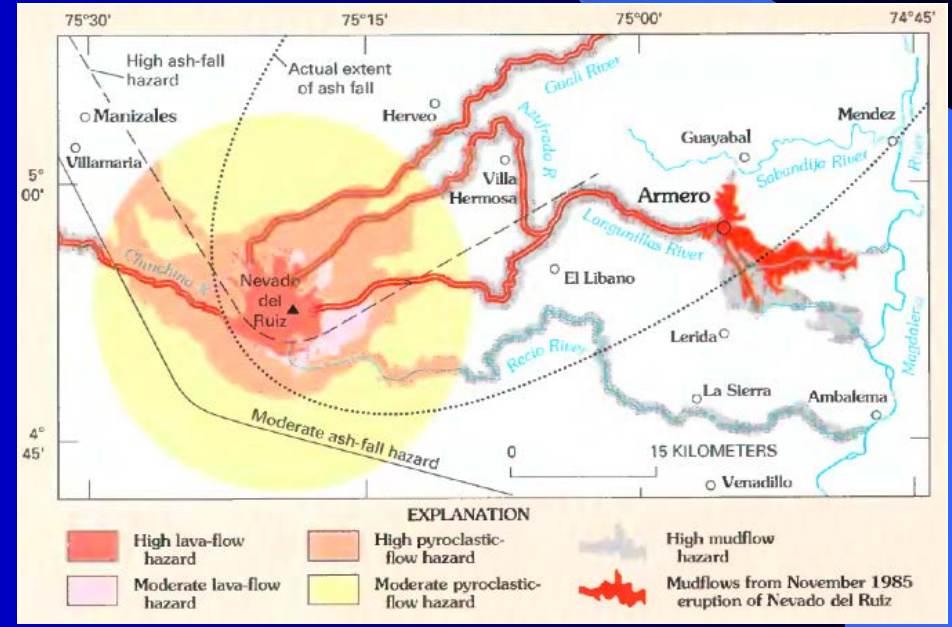
Nevado del Ruiz (November 13, 1985)





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

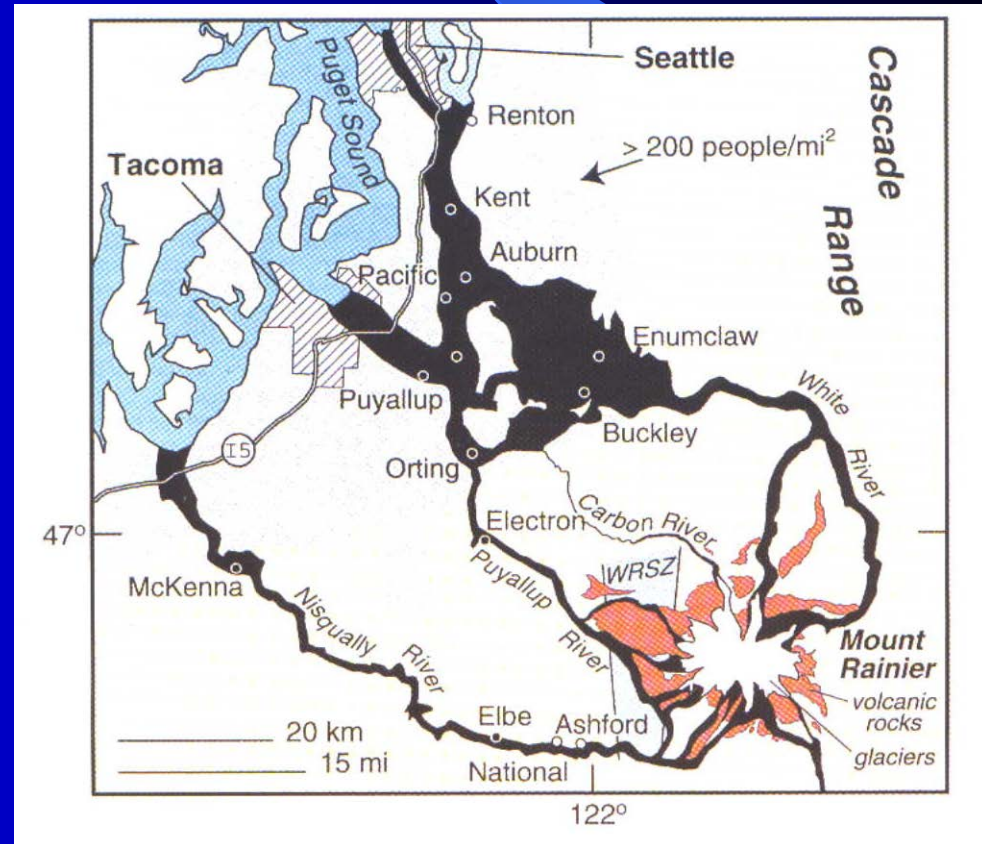
Mt. Rainier



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



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

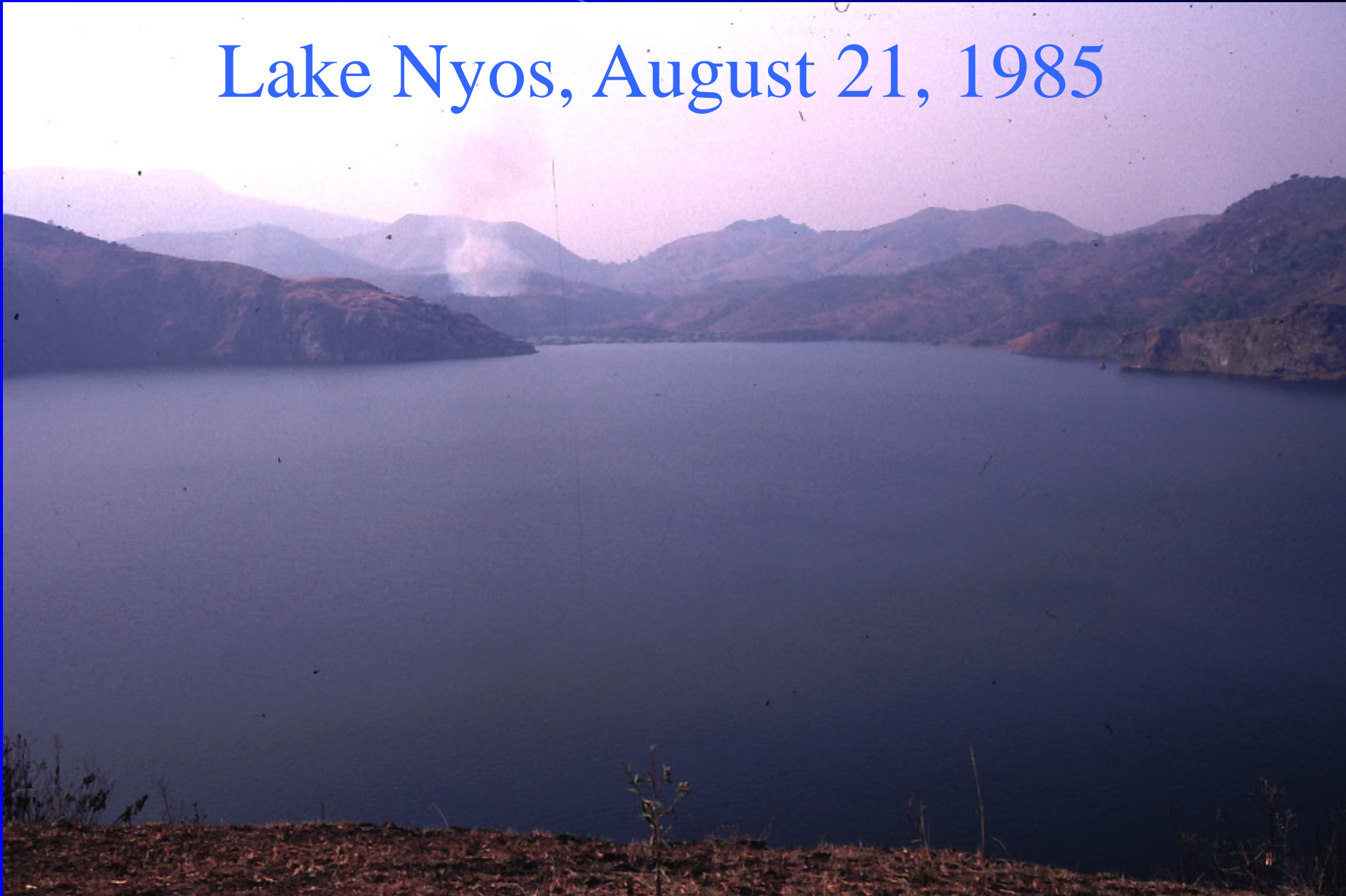


Lahars can originate from Mt. Rainier without volcanic activity. Hydrothermal alteration of volcanic rocks by acid gases oxidizes the ferromagnesian silicates and converts the feldspars to clay minerals. The resulting weak altered layers can fail under gravitational loading. Downslope movement of material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



Gas release

Lake Nyos, August 21, 1985





Lake Nyos pyroclastic dam, valley and town of Nyos.



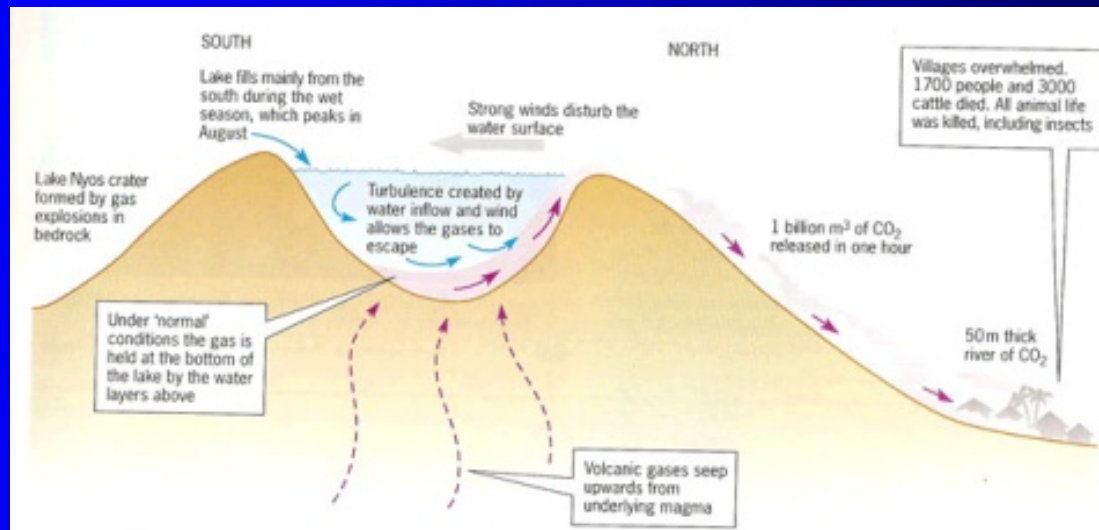
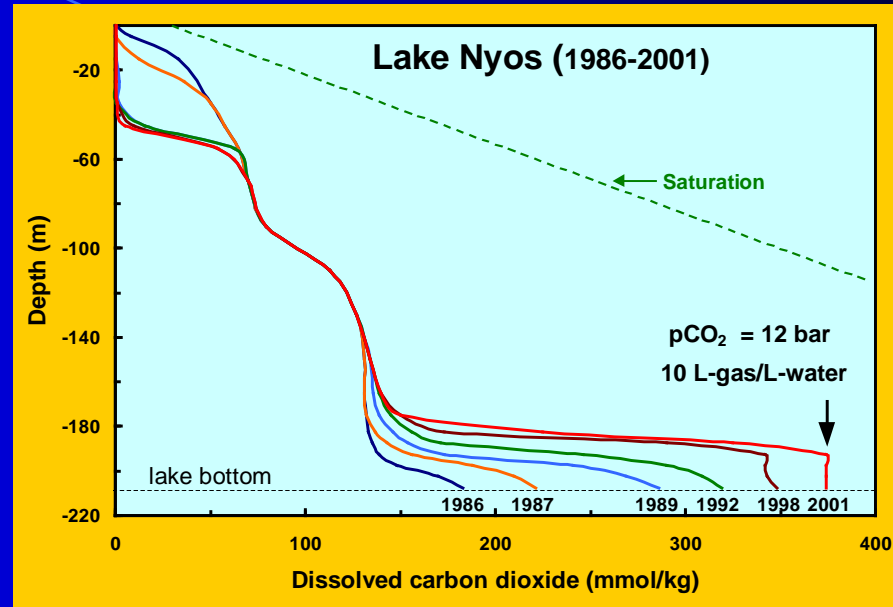
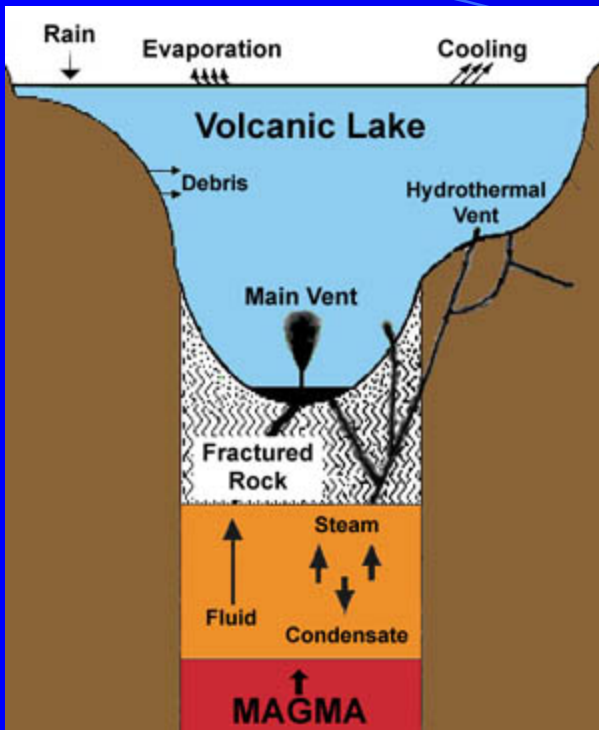
Orange color of Lake Nyos immediately after the gas release. The color is due to the oxidation of iron and the formation of ferric hydroxides



Dead cows in Nyos village. Over 1700 people perished as a result of the CO₂ release.



Disaster due to build-up of CO₂ in deep waters. Overturn leads to catastrophic release of CO₂.



A photograph of a volcanic landscape. In the foreground, a dark, jagged lava flow is visible, with a bright orange-red lava flow running through it. The background shows a forest of charred, black trees, suggesting a volcanic eruption. The text "Volcanic Hazards" is overlaid in yellow, and a list of three items is overlaid in white.

Volcanic Hazards

- Identification
- Monitoring and prediction
- Response

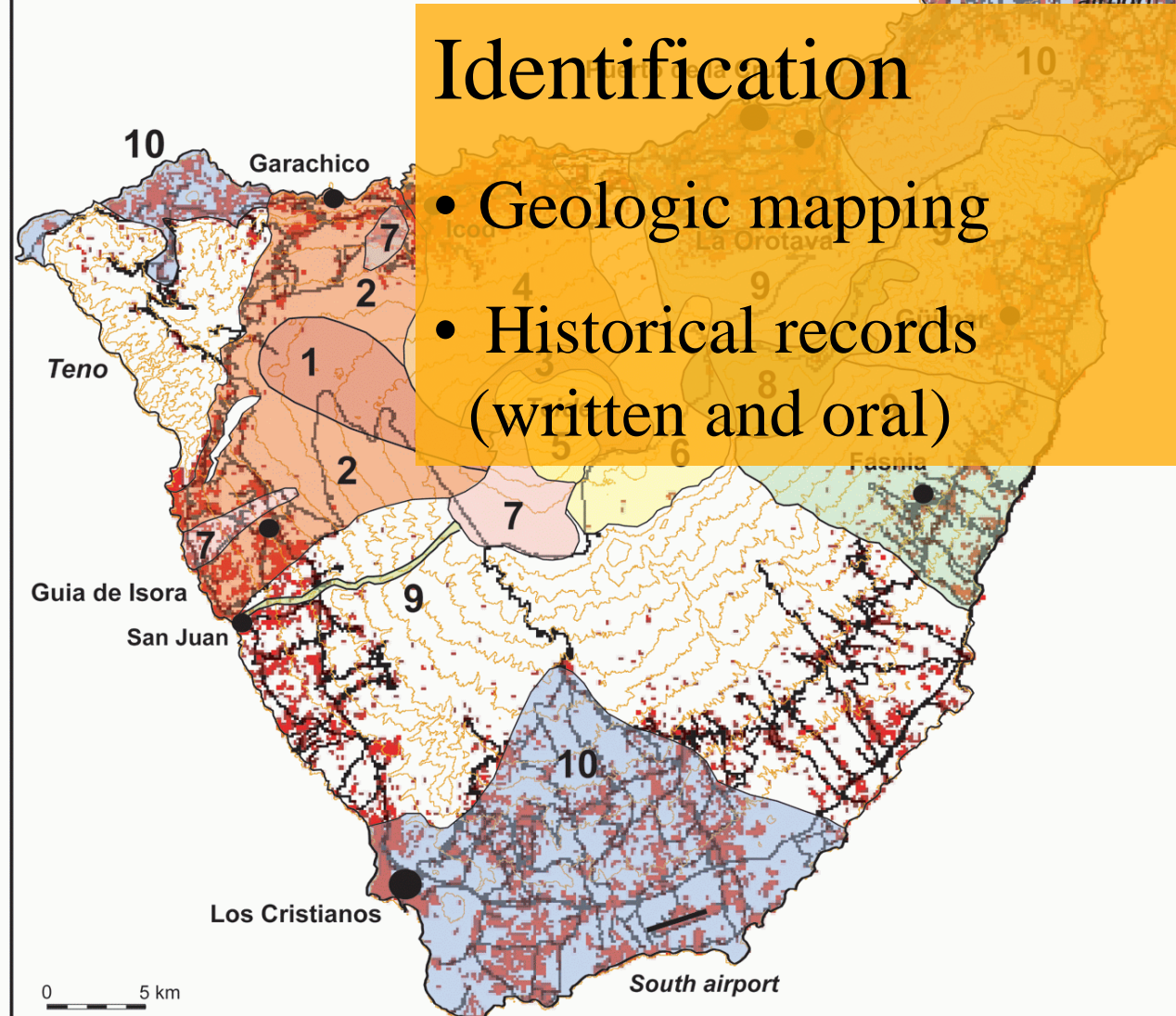
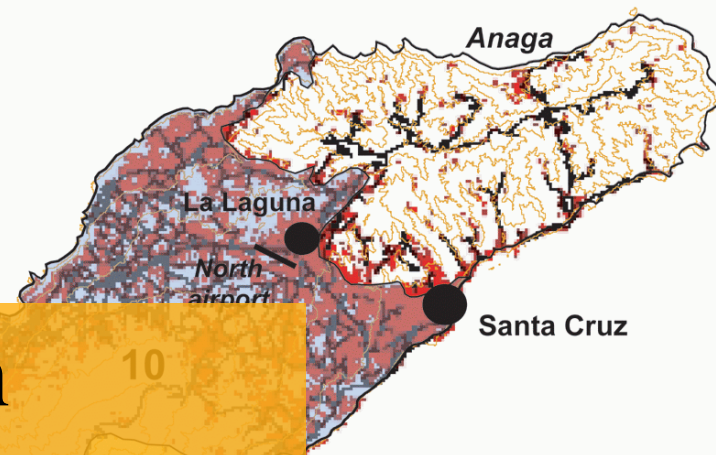


Conception by Raphaël Paris (Géolab UMR 6042 CNRS, France)
Project directed by Juan Carlos Carracedo (EVC-IPNA CSIC, Tenerife)

Volcanic hazard map of Tenerife (Canary Islands)

Identification

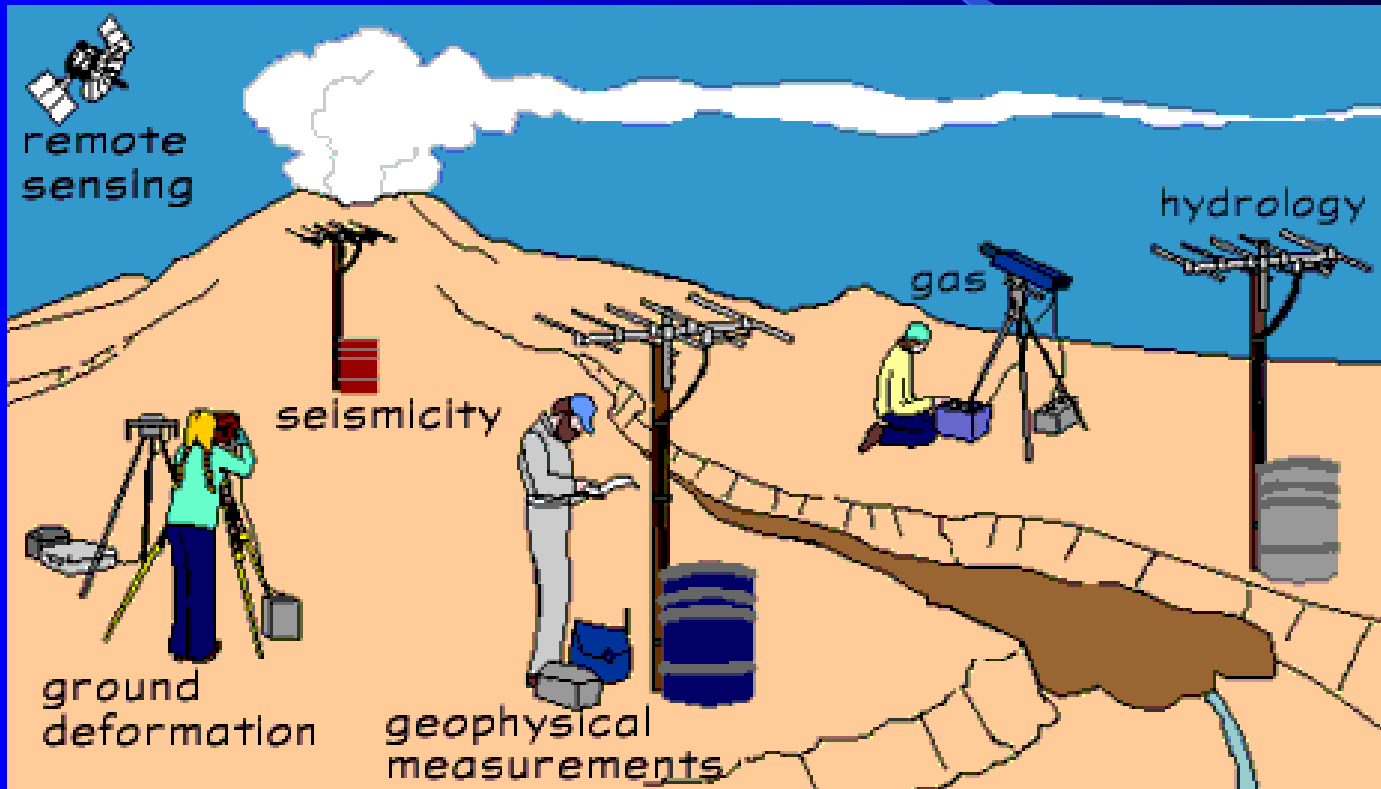
- Geologic mapping
- Historical records (written and oral)



Legend of the volcanic hazards map.

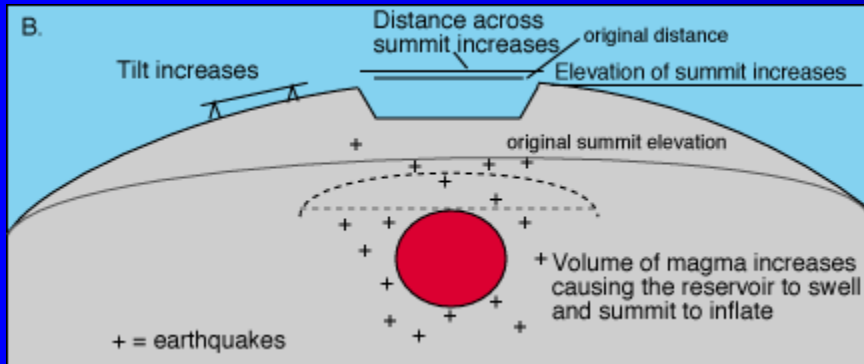
1. Northwest rift-zone: the most active part of the island since 20,000 years. At least 5 eruptions during the last 2,000 years. Strombolian eruptions producing basaltic cones, and lavafloWS. Scoria falls and forest fires. Gas emissions can eventually contaminate water galleries. Last eruption: Chinyero (1909).
2. Flanks of the northwest rift-zone: area invaded by the lavafloWS coming from the rift-zone and often reaching the coast. Destruction associated to lavafloWS, forest fires. Minor ash falls, depending on the wind direction. Phreatic explosions and lava bench collapses when the flows reach the sea.
3. Peripheral domes of the Teide volcano: phonolitic domes and domes-collapse. Long-lasting eruptions, associated with pumice falls and eventually minor pyroclastic flows due to dome collapse. Earthquakes mag. < 5.0. Last eruption: Roques Blancos (1790 BP).
4. North flanks of the Teide volcano: thick phonolitic lavafloWS coming from the Teide (zone 3) and always reaching the north coast of the island. Destruction associated to huge but slow lavafloWS, forest fires and minor pumice flows. At least 10 eruptions during the last 6,000 years.
5. Teide stratovolcano: thick phonolitic lavafloWS. Only one eruption during the last 30,000 years (obsidianic phonolite, 1240 BP). Very low probability for explosive eruptions (last phreatomagmatic activity > 17,500 years).
6. East part of the Las Cañadas caldera: Montaña Blanca and Montaña Redonda. Phonolite domes and lavafloWS. Same hazards as zones 3 and 4, but less active during the last 6,000 years. Last eruption: explosive eruption of Montaña Blanca (dense pumice falls, 2020 BP).
7. West part of the Las Cañadas caldera: basanitic to phonolitic lavafloWS coming from the Teide and Pico Viejo volcanoes. No volcanic activity during the last 15,000 years, except the historic eruption of 1798 (Narices del Teide). Areas of the northwest rift-zone not covered by lava since 15,000 years are also included in zone 7.
8. Northeast rift-zone: strombolian eruptions producing basaltic cones and lavafloWS. Same hazards as zone 1. No volcanic activity during the last 30,000 years, except the small-volume historic eruptions of 1704-1705 (Fasnía, Fuentes and Arafo).
9. La Orotava and Guímar valleys, Fasnía: basaltic lavafloWS coming from the northeast rift-zone. Last eruptions: 11,000 BP in La Orotava, 1704-1705 in Fasnía and 1705 in Guímar.
10. Distal parts and less active rift-zones, without recent volcanic activity (> 30,000 years).
11. Teno and Anaga shield volcanoes (6-4 Ma) and south flanks of the Las Cañadas volcano (no volcanic activity since 170,000 years).

Monitoring and Predicting Volcanic Eruptions



Ground deformation

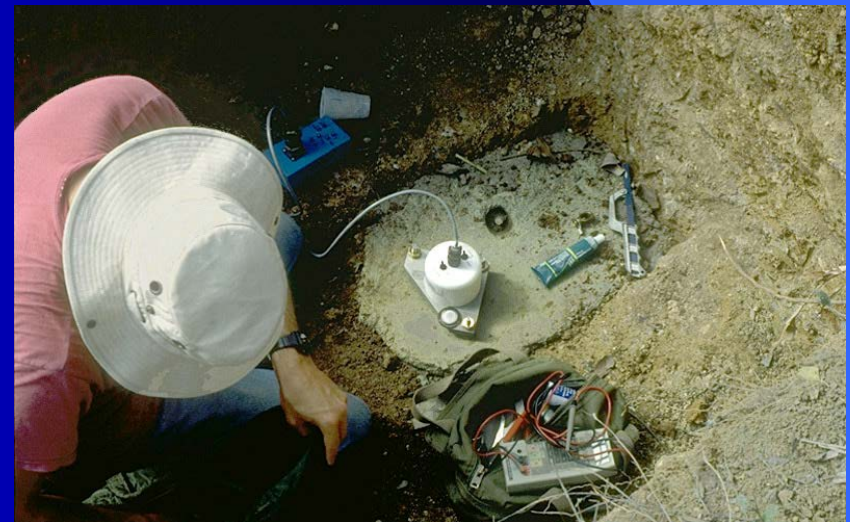
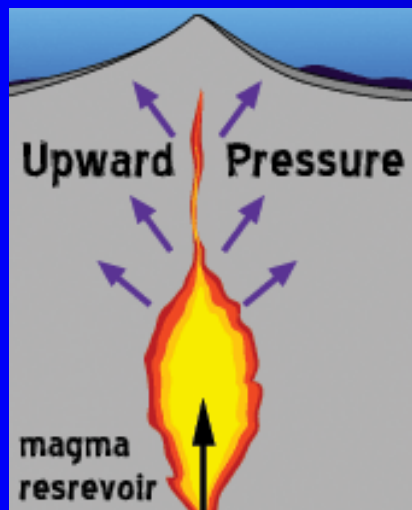
Rising magma intrudes volcano and changes its shape



Installing tiltmeter

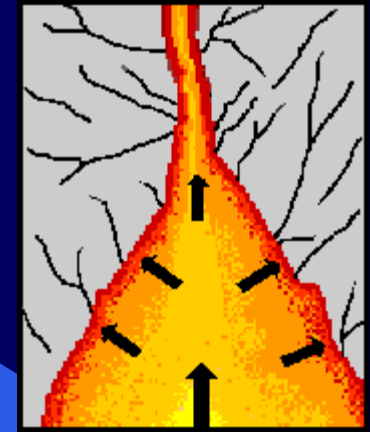
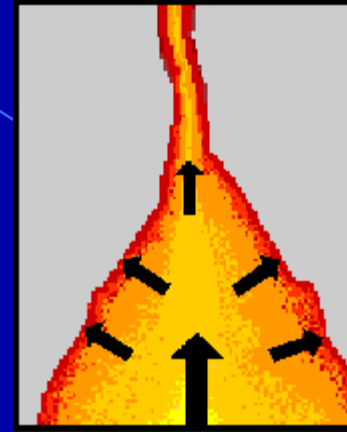
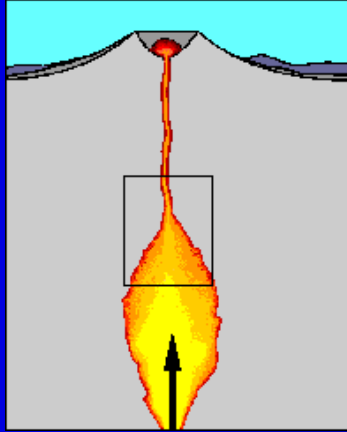


Tiltmeter



Seismicity

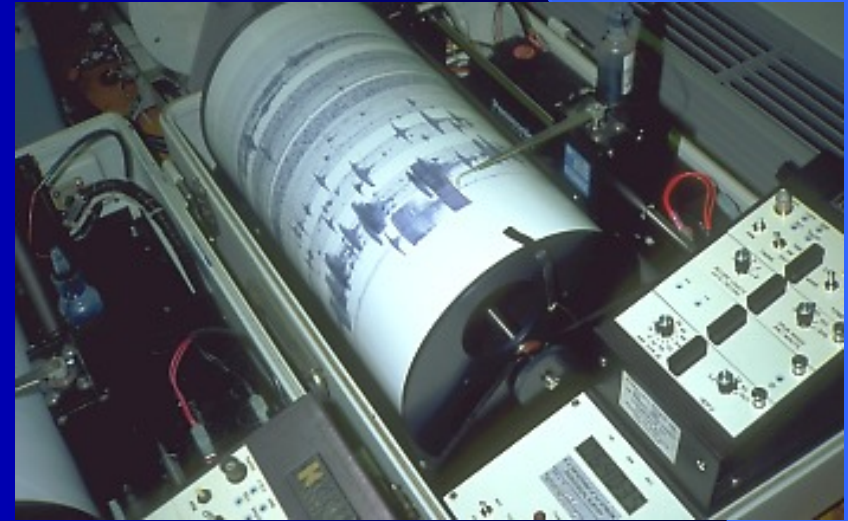
Rising magma exerts pressure on the surrounding rock which leads to fracturing and small earthquakes



Installing seismometer

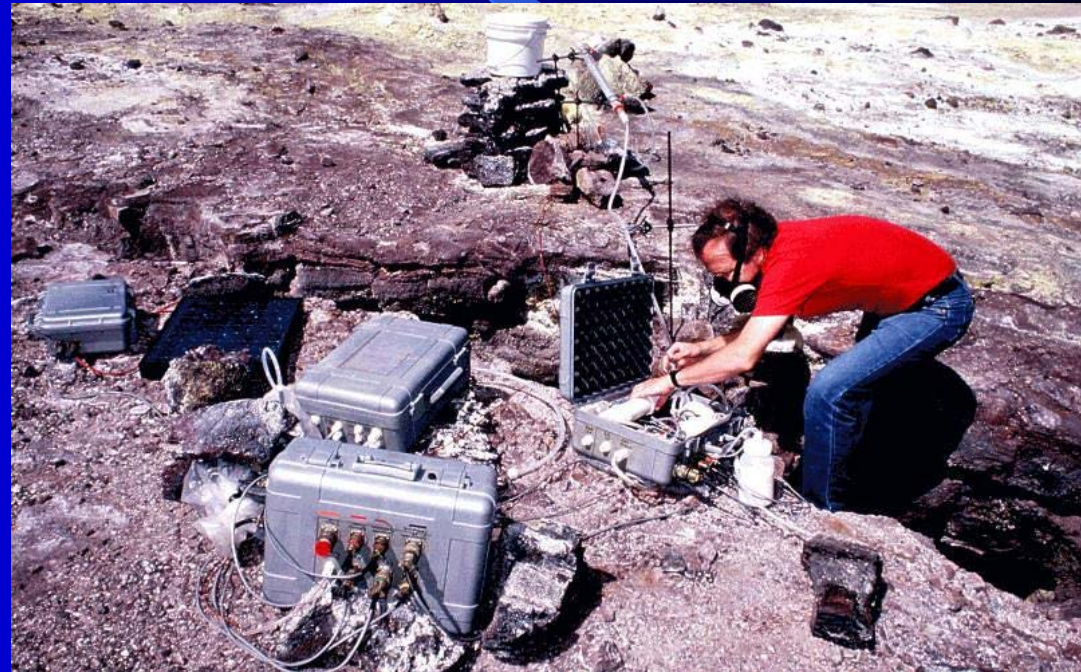


Seismograph, Mt. Pinatubo



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.



Vesuvius
3.3 cu km
79 AD (VEI 5?)

St. Helens
0.25 cu km
1980 (VEI 4)

Rainier
0.30 cu km
250 BC (VEI 4)

Eyjafjallajökull
0.30 cu km
2010 (VEI 4)

Response

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

Wah Wah Springs
30,000 years ago
> 5,500 cu km (VEI 9)

Krakatau
1883 (VEI 6)

Toba
74,000 years ago
2,800 cu km (VEI 8)

Pinatubo
5 cu km
1991 (VEI 6)

Yellowstone

640,000 years ago
1000 cu km (VEI 8)

Crater Lake
7,600 Years ago
150 cu km (VEI 7)

Long Valley Caldera

760,000 years ago
580 cu km (VEI 7)

Monitoring and alert system (Lake Nyos)

CO₂ gas monitoring system

Solar powered with battery back-up

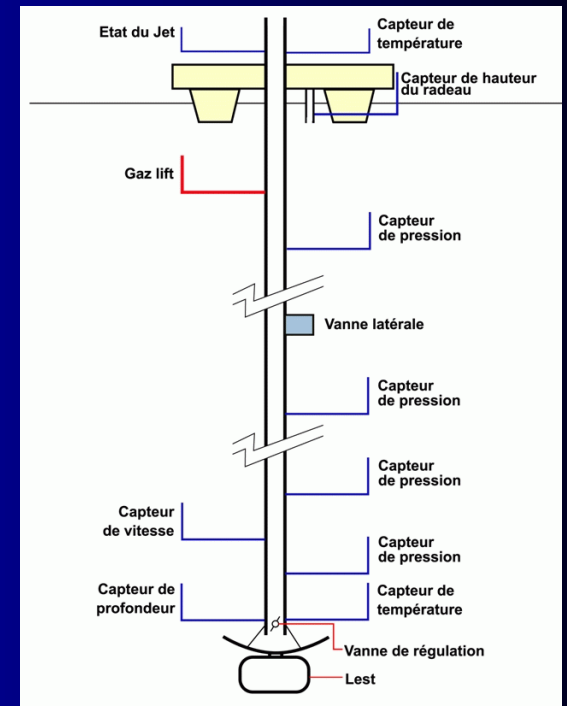
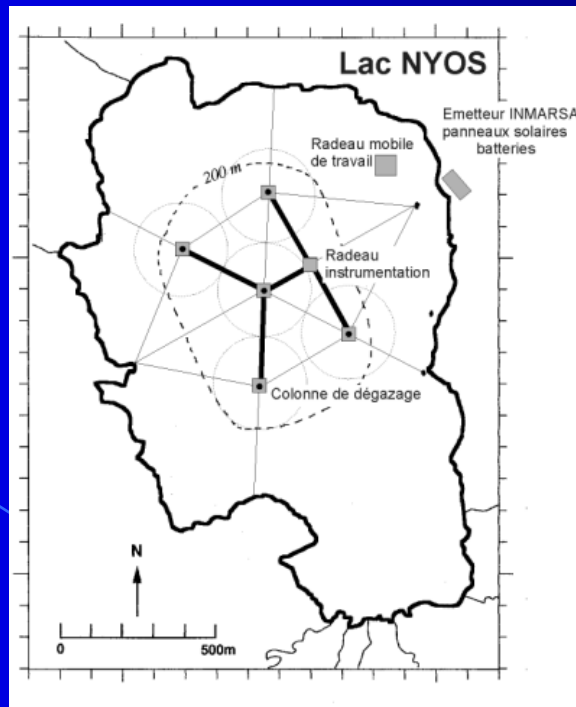
Infrared sensor

Both visual and audio alert

Response plan and designation of responsible individuals



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