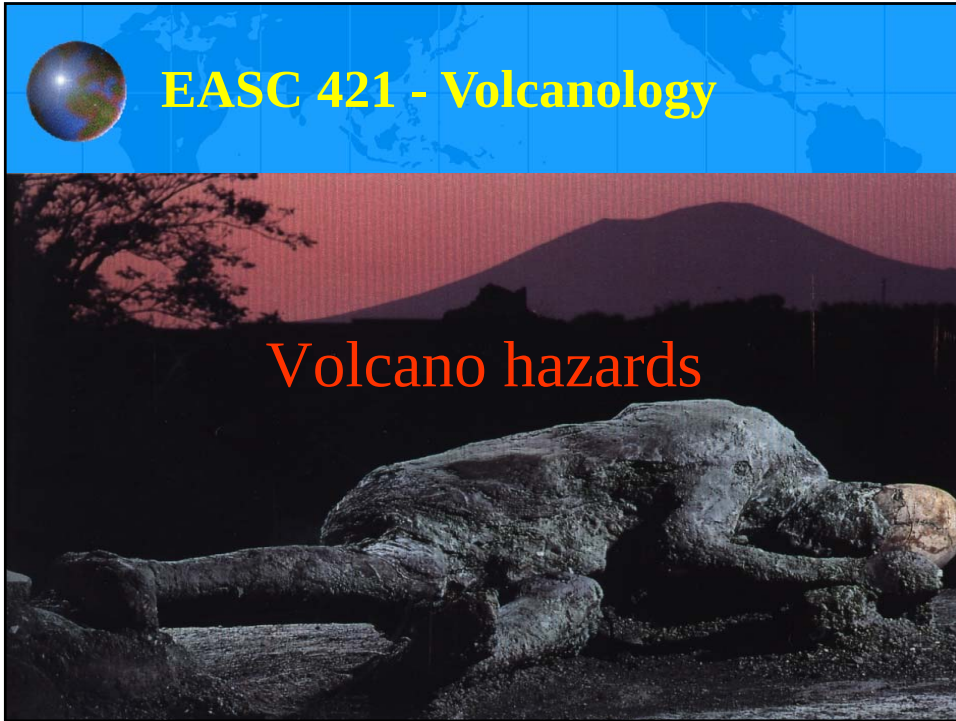


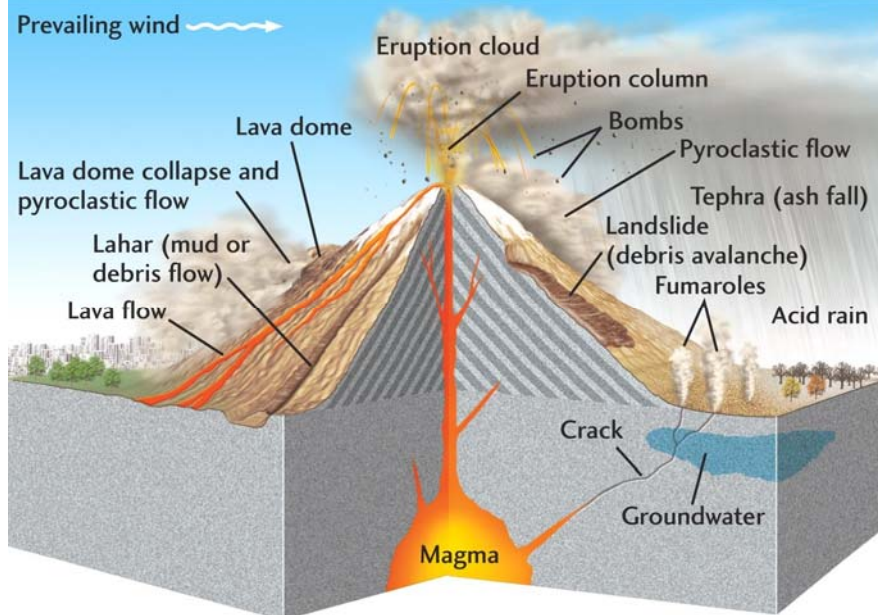
EASC 421 - Volcanology

Volcano hazards



The Hazards

EASC 421





Hazard

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✦ **hazard:** the probability of an area being affected by destructive volcanic processes in a given time

- ✦ **volcanic hazard:** volcanic activity that endangers the lives of people & property both close to & far away from a volcano
- ✦ activity involves the explosive ejection or flowage of rock fragments & molten rock
- ✦ can be hot or cold, wet or dry, & fast or slow



Risk

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✦ **Risk:** the possibility of loss (life, property, economy, etc.) due to a hazard

✦ $\text{Risk} = (\text{value}) \times (\text{vulnerability}) \times (\text{hazard})$

✦ where

- *value* = number of lives, property value, economic capacity
- *vulnerability* = 0-100% of the value lost in an event
- *hazard* = (0-100% damaging capacity) x (hazard frequency)

✦ Risk much greater if numerous small towns built in valleys surrounding moderately active volcano (e.g., S. America or Indonesia)

✦ versus risk of caldera eruption occurring in a remote region



Relative Importance

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- ✦ volcanic disasters
 - ✦ less frequent, affect fewer people, less loss than other natural disasters
- ✦ ~1500 active volcanoes globally with the ability to affect ~ 10% of the world's population (local to regional hazards)
 - ✦ ~ 40% living near major EQ faults or 60% vulnerable to flood / drought
- ✦ Deadliest disasters:
 - ✦ volcano: Tambora, Indonesia (1815): ~92,000
 - ✦ hurricane: Bangladesh (1970): ~500,000
 - ✦ earthquake: China (1556): ~820,000
 - ✦ tsunami: Indonesia (2004): ~300,000
- ✦ N. America, far more likely to be hit by lightning than affected by a volcanic hazard
- ✦ in Japan & Indonesia, 20-50x greater chance



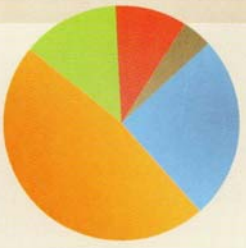
The numbers

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1600 – 1899

Total:
186 000

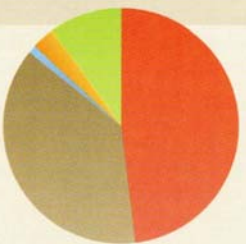
Fatalities /a
(average):
620



1900 – 1986

Total:
76 000

Fatalities /a
(average):
880



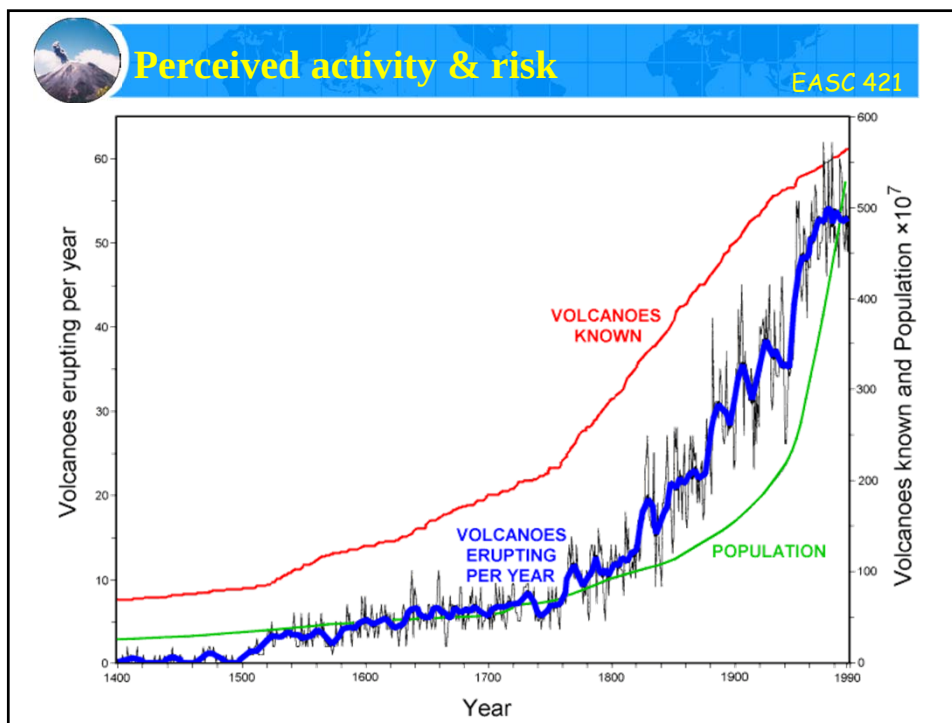
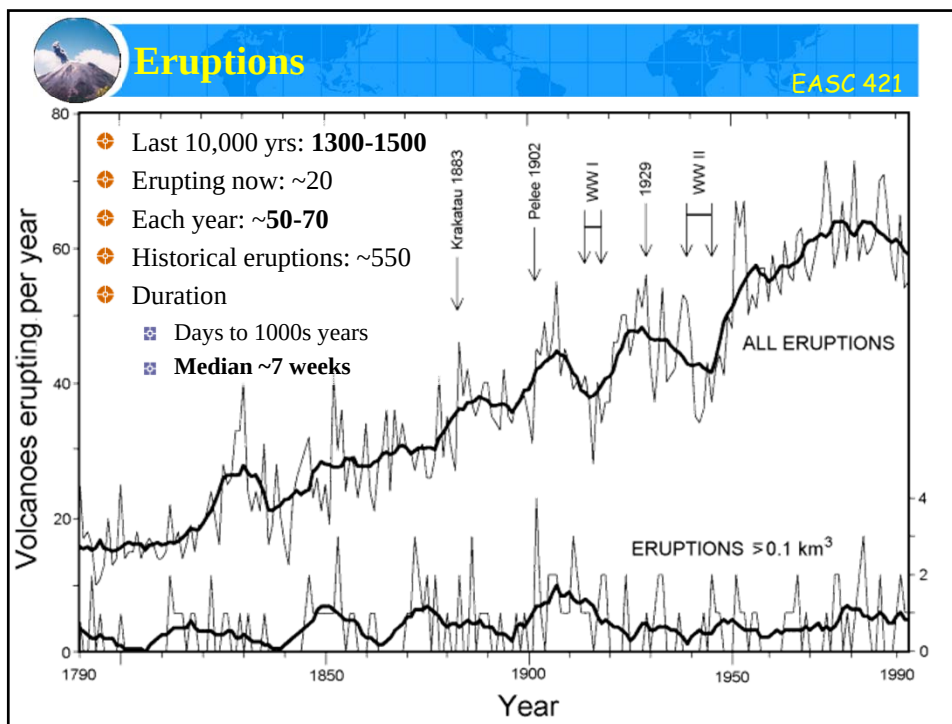
■ Pyroclastic flows ■ Lahars ■ Famine
■ Others ■ Tsunamis

✦ **Statistics are commonly misleading**

- ✦ no reliable data gathering agency for these disasters
- ✦ “official” government reports can be wrong
 - e.g.: China reports only 240,000 dead in the 1976 EQ
- ✦ volcanic-related deaths by region (1600 - 1995):

• Indonesia	165,000*
• Caribbean	31,000*
• S. America	26,000*
• Japan	21,000
• Iceland	10,000
• Others	20,000

* large singular events: Krakatau, Tambora, Pelée, Ruiz





Lava flows

- ✦ Slow moving - generally <1 km/h
- ✦ Very hot: 500 to 1000°C
- ✦ In some cases lava flows have caused fatalities
 - ✦ Etna, Italy (1843) 59 dead
 - ✦ Nyiragongo, Congo, (1977)
 - 2000 dead (30-100 km/h)



Kilauea, Hawaii (2003)



Oldoinyo Lengai, Tanzania



Tseax River, NE BC



Nyiragongo, Congo, (2002)



Lava flows

- ✦ Economic and social cost of lava flows is significant
- ✦ Lava flows destroy houses, towns, infrastructure, agricultural land



Kilauea, Hawaii (1987)



Etna, Italy (2001)



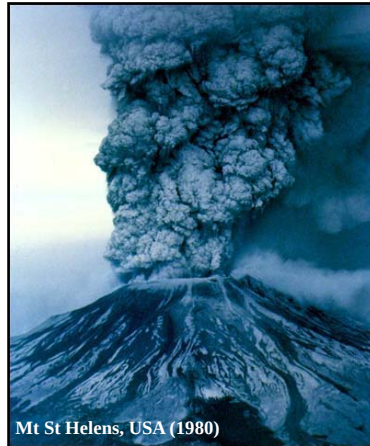


Eruption Columns

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Arenal, Costa Rica
(1995)



Mt St Helens, USA (1980)



Pinatubo, Philippines (1980)



White Island, NZ

- ✦ Small (< 1 km) to large (> 20 km height)
- ✦ Buoyant rise – hot gases -> loses energy with height -> Collapses!
- ✦ Potential climatic effects



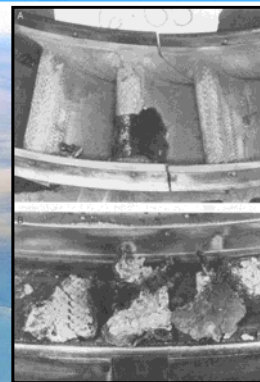
Ash Hazards: Planes

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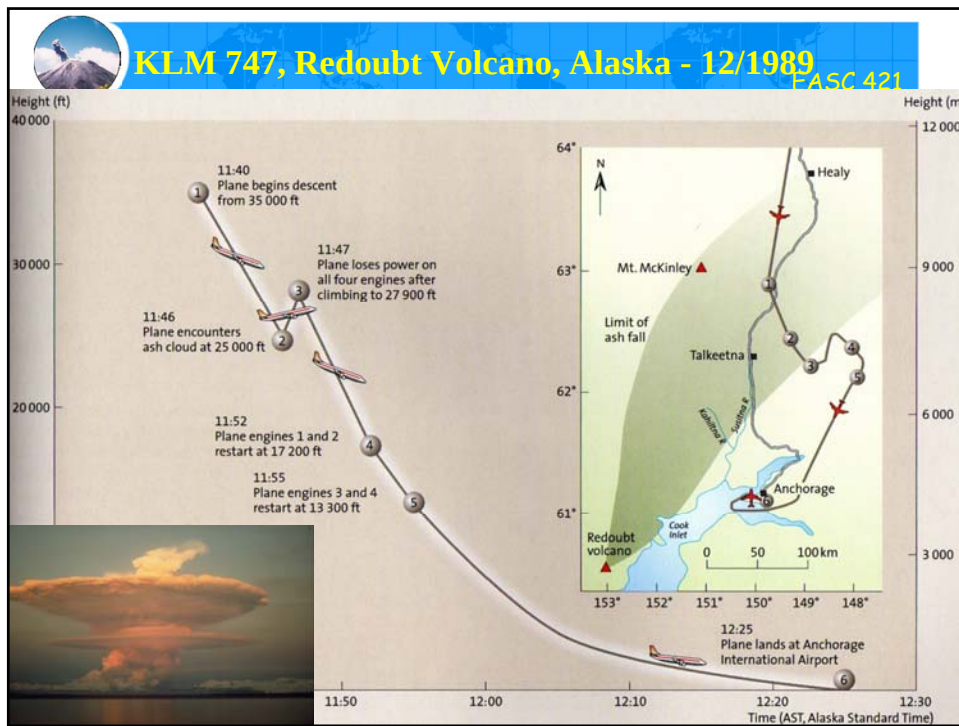
- ✦ 100 encounters between 1980 & 1999
 - ✦ June 1982, BA 009, Galunggung, Indonesia
 - ✦ December 1989, KLM 867, Redoubt Volcano, Alaska

- ✦ **Economic impacts:** Airport closure, re-routing / cancellation, grounding of airplanes & **repairs**

- ✦ **Volcanic Ash Advisory Centres:** provides aviation industry with warnings about volcanic eruption clouds



Pinatubo, Philippines (1991)



Tephra fall

- ✦ **Roof collapse**
 - ✦ Weight of ash > strength of roof material or support structures
- ✦ Aggravated by rain
- ✦ Motors, machinery, breathing...
- ✦ Can cause fires & lead to lahars



Galunggung, Indonesia (1982)



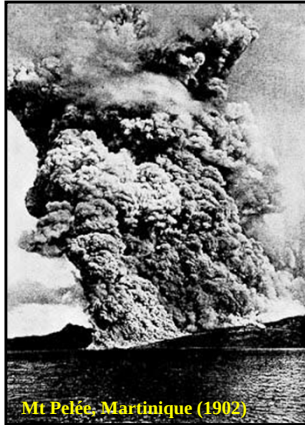

Rabaul, PNG (1998)



Pyroclastic flows

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- ✦ Gas-pyroclast, gravity-driven flows.
- ✦ Flow down slope & tend to be channelled in valleys
- ✦ Velocity: >10 m/s to 100 m/s (40 to 400 km/h!!)
- ✦ Temperatures: 100 to ~800°C



Mt Pelée, Martinique (1902)



“Nuee Ardentes”
or “glowing
avalanches”



Unzen, Japan (1993)



Mayon, Philippines (1984)



Pyroclastic density currents

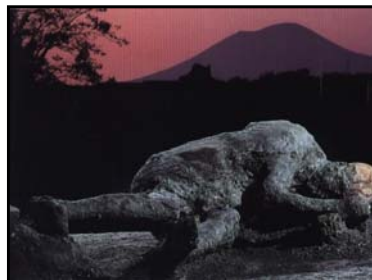
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- ✦ Most common direct cause of death in eruptions during last 400 years
 - Mt Pelée, Martinique (1902) ~29,000
 - Mount Lamington, PNG (1951) ~3,000
 - Vesuvius, Italy (79 AD) ~1000s



Mt Pelée, Martinique (1902)

Death & injury
most commonly
caused by burial,
obliteration,
burns, asphyxia,
trauma



Vesuvius, Italy (AD 79)





Lahars

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- ✦ Hyperconcentrated volcanic mud-flows - up to 75% solids
- ✦ Very erosive - pick up material as they flow downhill
- ✦ May occur during or after an eruption
- ✦ Nevado del Ruiz, Colombia (1985)
Eruption melted summit glacier.
Lahars travelled 100 km. ~23,000 dead



Fraser river valley

Mount Baker, USA



Nevado del Ruiz, Colombia (1985)



Volcanic landslides

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- ✦ Sector collapse triggered by:
 - ✦ Magma intrusion
 - ✦ Explosive eruption
 - ✦ Earthquake
 - ✦ Gravitational collapse
 - ✦ Sub-volcanic basement spreading

Mount St. Helens, USA (1980)



© Copyright Gary Rosenquist 1980

- ✦ **Huge** volumes and run out distances
 - ✦ Mt Shasta, USA ~26 km³, 50 km
 - ✦ Socompa, Chile ~ 15 km³, 35 km
- ✦ Although **rare** these events are catastrophic



Volcanic Tsunamis

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- A high wave or surge produced by **eruptive** or **non-eruptive** processes at volcanoes



Krakatoa, Indonesia (1883)

Anak Krakatau

Krakatau

> 9 different causes:

1. Volcano-tectonic earthquakes
2. Submarine eruptions
3. Pyroclastic flows
4. Caldera collapse
5. Sector collapse
6. Lahars
7. Phreatomagmatic explosions
8. Explosive eruptions
9. Lava bench collapse

Although rare, responsible for 25% of all volcanic fatalities in last 250 years



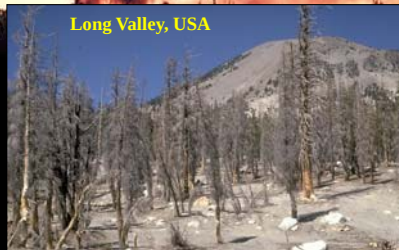
Volcanic gases

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- Directly responsible for ~3% of volcano-related deaths this century
- Indirectly, through crop destruction, gas emissions have resulted in starvation and disease, ~40% of volcano-related deaths since 1600



Laki, Iceland (1783)



Long Valley, USA





Volcanic gases: Toxicology

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- ✦ Human health hazard:
 - ✦ Gas species (SO_2 , CO , ...)
 - ✦ Dispersion of gas plumes
 - ✦ Longevity of degassing



Masaya, Nicaragua (1999)



Masaya, Nicaragua

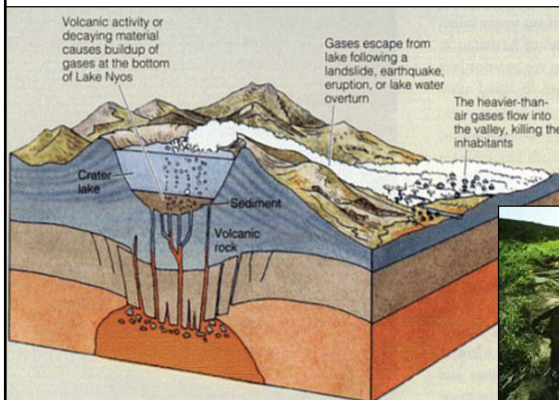
- ✦ CO_2 : High concentrations cause unconsciousness & asphyxiation
- ✦ SO_2 : Inflammation and irritation of eyes & respiratory tract
- ✦ H_2S : Eye and throat irritation, lung paralysis, **death!**
- ✦ HCl , HF , H_2SO_4 : Irritation of mucus membranes, coughing, choking



Lake Nyos, Cameroon

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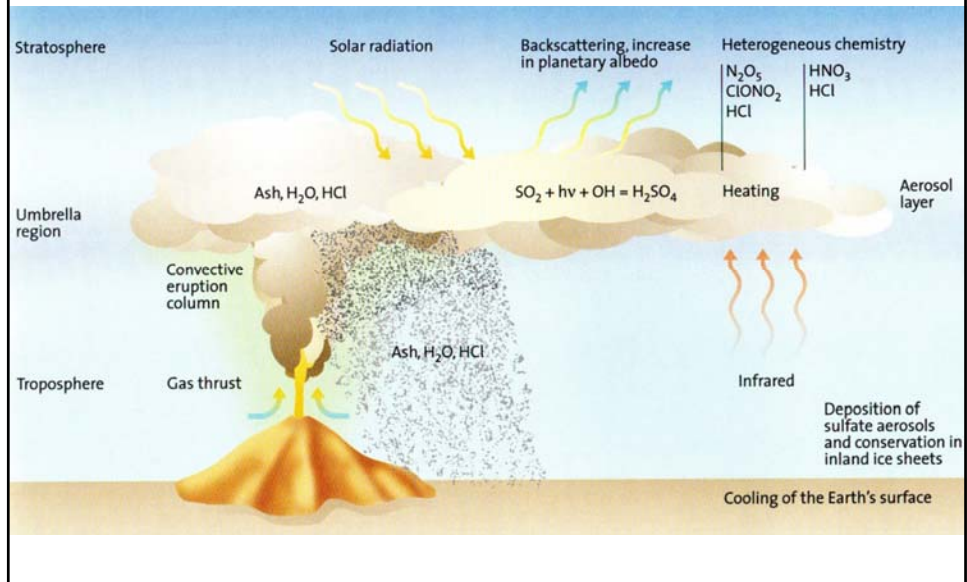
- ✦ Slow CO_2 release by dormant volcano → bottom of lake in crater
- ✦ Suddenly overturned and released CO_2 which is heavy and hugged the ground suffocating ~1700 people



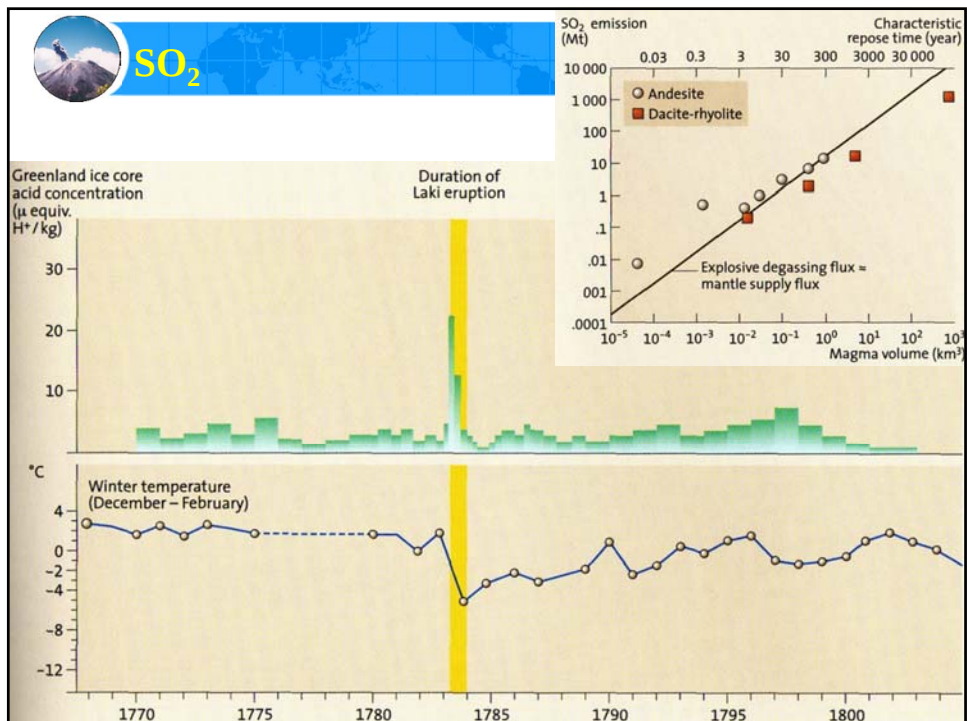


Volcanic gases: Climatic effects

EASC 421



SO₂





Volcanic gases: Climatic effects

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✦ Pinatubo, Philippines (1991)

- ✦ 20 Million tonnes of SO₂ gas
- ✦ Reduced solar radiation by 1-5%
- ✦ caused 0.1 to 0.5°C drop for 3 yrs



Week 1 Sulfur dioxide from Mt. Pinatubo, 1991

✦ El Chichon, Mexico (1982)

- ✦ 20 MT SO₂
- ✦ caused 0.3°C drop



Week 6



Week 12



Identifying & Mapping Volcanic Hazards

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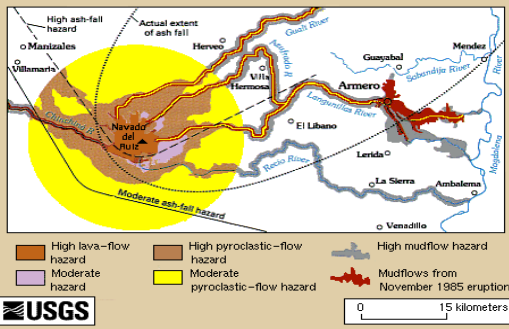
- ✦ ~90 High risk volcanoes have been identified
 - ✦ 42 in Southeast Asia
 - ✦ 40 in the Americas & Caribbean
 - ✦ 7 in Europe & Africa
- ✦ Lack of information, or long dormant period, may exclude potentially hazardous volcanoes from this list (e.g. Mount Lamington, 1955; El Chichon, 1982).
- ✦ Based on a careful study of the geological record of a volcano & the surroundings.
- ✦ Map distribution & extent of lava flows, ash-fall, PFs & mud flows. Provides information on type & size of past eruptions.
- ✦ Dating these events is critical in order to understand frequency of eruptions.
- ✦ All of this is based on assumption that the geological past provides a useful guide to future activity.
- ✦ **Problem:** Very few (24/89) high-risk volcanoes have been studied in such detail, particularly in underdeveloped countries.



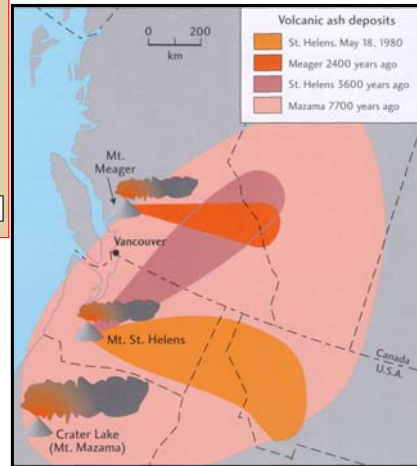
Hazard Zonation maps

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Hazard-Zone Map, Nevado del Ruiz, Colombia



Armero was built on mudflows that occurred in 1595 & 1845!



- Forecast future hazards on basis of past activity
- Constructed for single or all hazards
- Dependent on representative preservation
- Need detailed geological mapping, dating & correlation
- Aided by computer simulations
- Boundaries are **approximate & conservative**

