

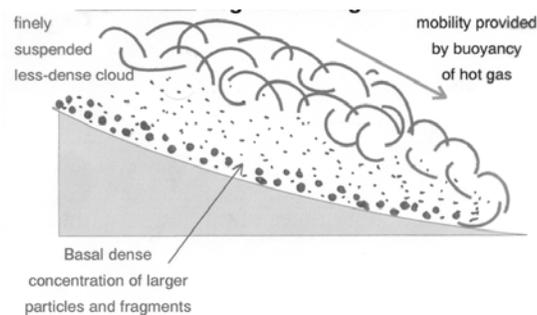
## Pyroclastic Flows and Surges

Also known as glowing ash clouds, glowing avalanches and nuées ardentes (French).

- ❑ These are the most hazardous of all volcanic processes.
- ❑ Estimated to have caused about 55,000 deaths since 1600 A.D. (about 48% of all volcano-related fatalities).
- ❑ Causes of death are:-
  - ❑ Asphyxiation by hot ash and dust.
  - ❑ Burning, boiling and dehydration during brief periods of high temperature (200 - 800 °C).
  - ❑ Impact by ash and debris driven at high speeds.

## What are pyroclastic flows and surges?

- Hot mixture of ash, pumice blocks and gases that form:-
- Gravity-driven clouds that travel at great speed.
- Speeds are typically 20-70 mph, but speeds up to 300 mph have been recorded (Mount St. Helens).
- Temperatures are highly variable from less than 200 to 800 °C.



## Sources of Energy

1. Gravity – remember rock avalanches have sufficient gravitational energy that they can travel across valley floors and move up-slope.
2. Fluidization – buoyancy created by entrained and heated air – plus hot gases released from particles and clasts

**Pyroclastic Flows** – can travel large distances from a volcano, typically about 10 – 15 km, but sometimes up to 100 km.

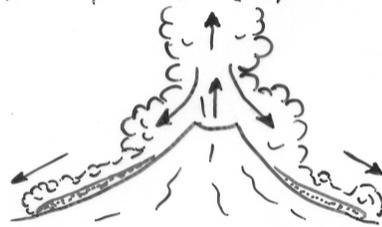
Mostly they follow drainage patterns – but they may also have sufficient kinetic energy to surmount hills and ridges

They include some of the world's largest volcanic deposits:-

	Age	Volume (km <sup>3</sup> )
Yellowstone	600 ka	>1000
Long Valley	700 ka	>2000
Toba (Sumatra)	75 ka	~2000
Tambora (Indonesia)	1815 AD	35-50
Katmai (Alaska)	1912 AD	10-15
Pinnatubo (Philippines)	1991 AD	4-5

## Three ways that they form

- Collapse of the eruption column.



Soufrière Type  
(St Vincent  
1902)

Soufrière Type – the eruption column can no longer be sustained (due to loss of pressure), so the column collapses forming pyroclastic flows on the flanks of the volcano (St Vincent, 1902). They tend to be cooler than the others.

- Explosive dome eruption.



Pelée Type  
(Martinique  
1902)

If very  
violent may  
form a lateral  
blast.

Pelée Type – a dome of viscous magma (rhyolite, dacite) is blocking the conduit. Eventually it explodes under pressure, blasting pyroclastic material down one of the flanks of the volcano (Mont Pelée, 1902). If it is extremely violent it could produce a lateral blast.

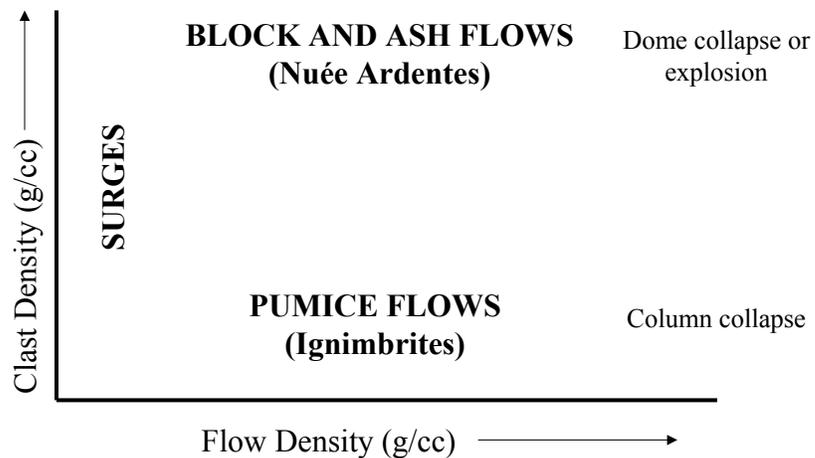
● Gravitational collapse of dome.



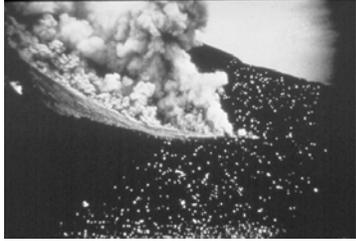
Merapi Type – a dome of viscous magma (dacite, rhyolite) grows in the crater. Eventually it gets so large, it collapses under gravity, producing a pyroclastic flow (Merapi, Indonesia, 1951; Unzen, Japan, 1991; Montserrat, West Indies, 1996).

Basic Terminology

Process



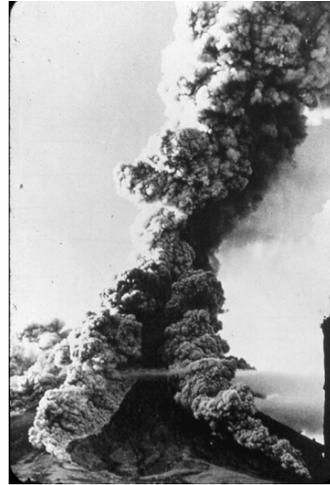
## Pyroclastic Flows



Mount Lamington, Papua, 1955



Fuego, Guatemala, 1974



Mount Mayon, Philippines  
1968

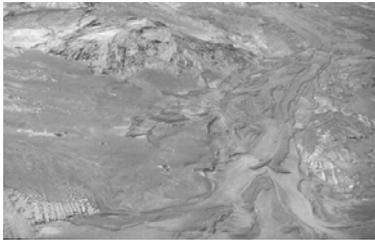


Pyroclastic flow descending  
Merapi volcano, Indonesia. The  
white areas are previous flow  
deposits.

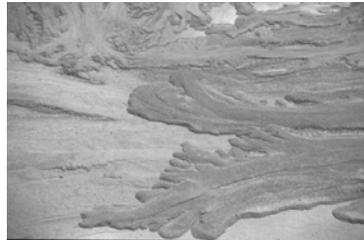


Pyroclastic flow at  
Mount St Helens, 1980

## Pyroclastic flow deposits



Mount St Helens flows



Mount St Helens flows

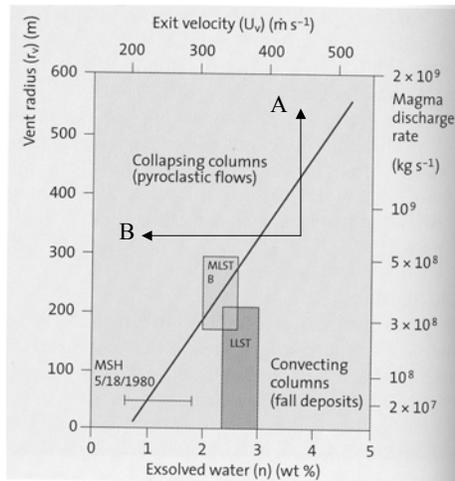


Mount St. Helens – close up



Pyroclastic flows fill a valley at  
Pinatubo

## Collapse of an Eruption Column (Soufrière Type)

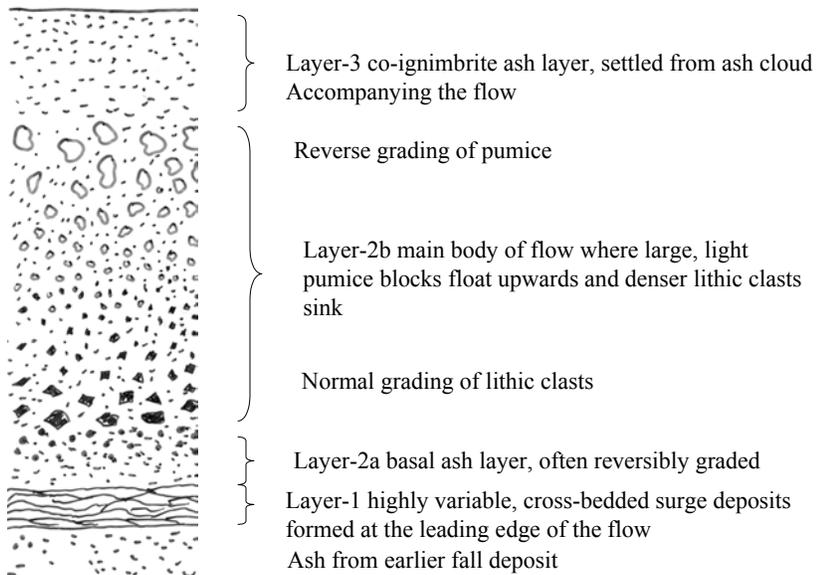


Critical factors are:-

- 1) Exit velocity, which is related to the water content of the magma.
- 2) Magma discharge rate, which is related to the size of the vent.

- A. Widening of the vent leads to column collapse.
- B. Fall in exit velocity, possibly due to tapping deeper, less volatile rich magma also results in column collapse.

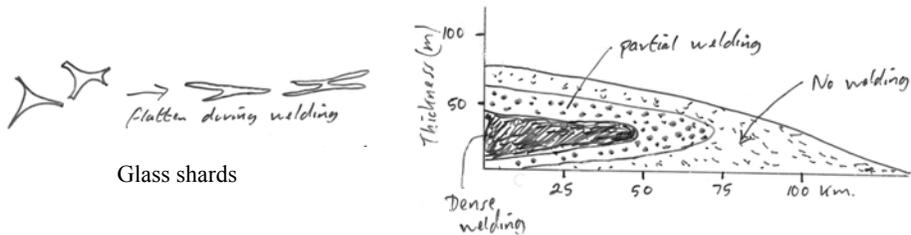
## Typical Cross-Section through a Pumice Flow



## Welding of Pyroclastic Flows

Prior to the classic paper “Ash Flows” by R. L. Smith (1960), most ignimbrites were thought to be rhyolite/dacite lava flows. Has the pendulum now swung the other way?

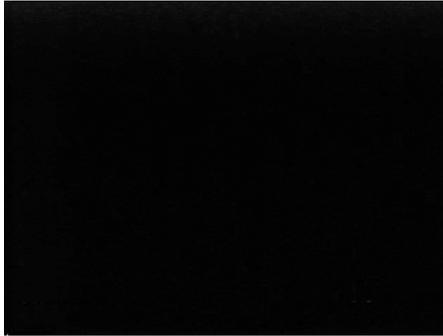
Rhyolite glass and pumice begins to weld at 600-750 °C. Consequently, many thick pyroclastic flows tend to be welded, and even develop columnar jointing on cooling. The evidence that these are not lava flows, comes from the presence of glass shards, and changes in the degree of welding within and along the flow.



Block and Ash flow resulting from the collapse of a dacite dome at Unzen Volcano, Japan in 1991.

## Pyroclastic flows and surges

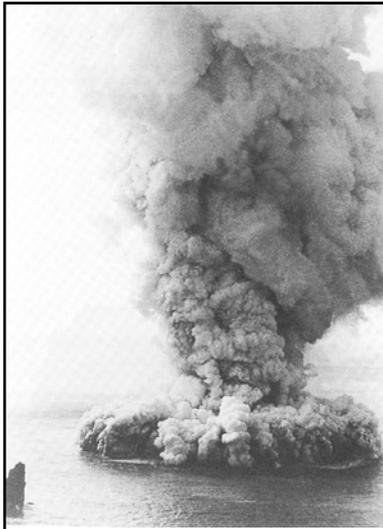
Montserrat, West Indies, 1996



The difference between a pyroclastic flow and a pyroclastic surge is one of degree:-

- Flows are more dense than surges, consequently they tend to follow topography along predictable paths.
- Surges are less dense, they move more quickly and can surmount topography such as hills and ridges. Therefore, their effects are more widespread and less predictable.
- They often occur together. A flow may generate a surge – which can move ahead of, or away from, the flow (Mt Pelée, Martinique, 1902 – totally destroying the town of St. Pierre).

**Three types of surges are recognized:-**



Base Surges – first recognized at Taal volcano by Jim Moore in 1967. Very similar to the ground-hugging blasts associated with nuclear explosions. They develop from the interaction of magma (often basaltic) and water to form thin wedge-shaped deposits characteristic of Maars. Deposits rarely extend beyond 5-6 km



Ground Surges – these deposits are often found at the base of pyroclastic flows (remember layer-1). They are thinly bedded, laminated and often cross-bedded. Typically they are about 1 m. thick and consist mostly of lithic and crystal fragments (fine ash elutriated away?).

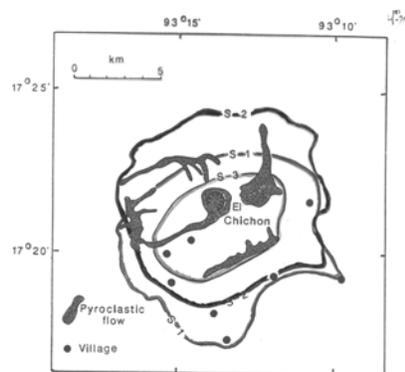
They appear to form from the flow itself, but the mechanism is not clear. One possibility is that at the head of the flow expands through entrainment of air (which is then heated). This then results in the flow front surging forward, which is then over-run by the rest of the flow.

**Ash Cloud Surges** – these are the most devastating. They form thin deposits, but travel at great speed (10 – 100 m/sec) carrying abundant debris such as trees, rocks, bricks tiles etc. They are so powerful that they often blast and erode material (like sand-blasting).

How do they form?

They are possibly produced when conditions in an eruption column are close to the boundary conditions separating convection from collapse. That is, switching rapidly from one condition to the other.

## El Chichon, Mexico, 1982



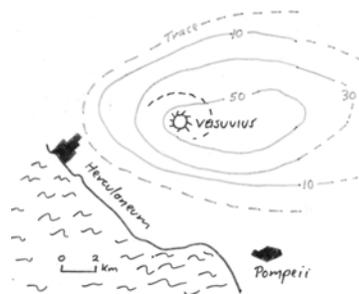
El Chichon was not recognized as an active volcano prior to its eruption in 1982.

- Over 2,000 people were killed by a succession of three pyroclastic surges. The first surge (purple) devastates all the villages.
- Note the limited extent and damage caused by pyroclastic flows.

## What happened to Pompeii in 79 A.D.?

- Vesuvius erupted, totally destroying Pompeii and Herculaneum – both prosperous Roman towns.
  - Pompeii – about 16,000 people
  - Herculaneum – about 5,000 people
- Romans did not realize Vesuvius (6,000 ft) was a volcano! Last erupted about 3,500 B.P. (might an earthquake in 62 A.D. have been a precursor?)
- Consequences:-
  - Pompeii – totally destroyed and buried. Most people escaped, about 2-3,000 died.
  - Herculaneum – totally destroyed and the entire population wiped out.

**First Event** - small explosions, possibly vulcanian, produced a low ash cloud, blown to the east.

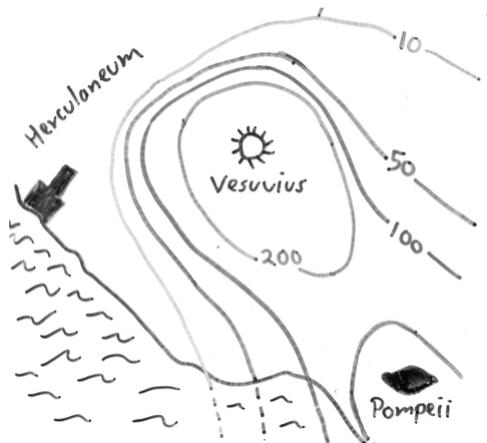


Isopach map showing thickness of the ash (cm) produced by the first event.

Timing of the first event is uncertain, probably August 23<sup>rd</sup>.

Note that no ash fell on Pompeii or Herculaneum - probably no great cause of alarm!

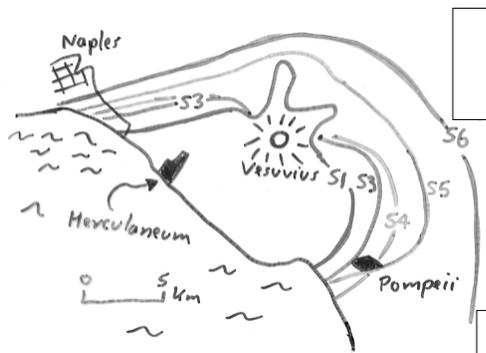
**Main Event** - started at 1:00 a.m. on August 24th. Ash fall is the major problem in the first 12 hours.



- Plinian eruption column 27-33 km high.
- Ash falls to the S.E. depositing about 2.5 m. on Pompeii.
- No ash falls on Herculaneum.
- By 5:30 a.m. roofs begin to collapse in Pompeii.
- Some people killed, but most people flee south.

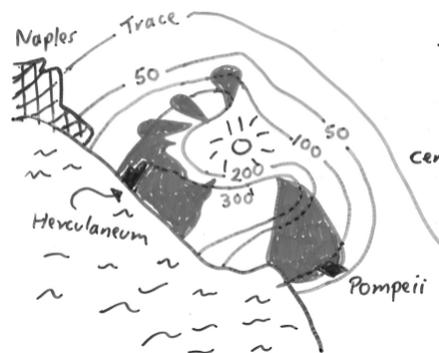
Thickness of ash in cm.

**Second Day** (August 25th) - a series of six pyroclastic surges and flows devastate Pompeii and Herculaneum.



- Surge-1 at 1:00 a.m. destroys Herculaneum
- Surge-2 at 2:00 a.m. reaches outskirts of Pompeii
- Surge-3 at 6:30 a.m. devastates Pompeii
- Surge-5 at 7:30 a.m. is the largest of all.
- Surge-6 at 8:00 a.m. is the largest of all.

## Pompeii and Herculaneum afterwards



Map showing total thickness of surge deposits (cm) and location of pyroclastic flows (red areas).

Herculaneum - destroyed and buried under 6 - 9 ft. of surge deposits.

Pompeii - buried under 8 ft. of ash and about 2 - 3 ft of surge deposits.

## Views of Pompeii



Arch of Nero



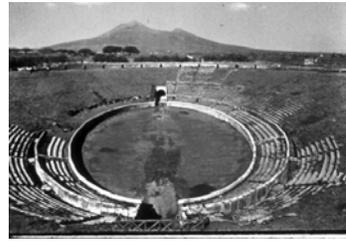
Vesuvius from the Civic Square



Atrium in a well-preserved villa



The Theater



The Games Arena



A Pizza Joint



A Wine Bar



Mosaic entrance to a villa



Paintings on the wall



During excavation, cavities were found in the ash where victims had been buried. Pouring plaster into these holes resulted in replicas of the victims. Here is a man and a dog.

## Lateral Blasts

- ❑ First recognized during the Mount St. Helens eruption (1980). They have since been identified as an important process at other volcanoes (Bezymianni, 1956).
- ❑ Still poorly understood – but with similar attributes to pyroclastic surges – but even more violent and devastating!
- ❑ Caused by a sudden release of pressure on a volcano's magmatic system –such as by a landslide (like taking the lid of a pressure cooker).
- ❑ Produces a low-angle blast, traveling at over 200 mph – destroying everything in its path by blast, impact and abrasion.