Oldest known meteorite impact crater

- Geologists from Curtin University in WA have found evidence for the oldest known impact crater on Earth (3.47Ga) located near the North Pole Dome in the Pilbara region , WA ~40km west of Marble Bar
- conical shaped shatter cones caused by compression on impact or tension as the rocks rebound, provided the first evidence of the impact
- spherules, (mm sized glass beads) created by the vapourisation of rock at impact were found beyond the shatter cones and as far away as South Africa
- ring faults surrounding a central uplift are also classical features of impact craters

Oldest known meteorite impact crater

- geophysical surveys revealed circular magnetic and gravity anomalies
- North Pole Dome (40-45km wide) may be eroded central uplift of impact
- impacting meteorite estimated to be several km in diameter, as much as 10km
- the diameter of the crater was estimated to be 70-100km
- the crater has long vanished after 3.47Ga

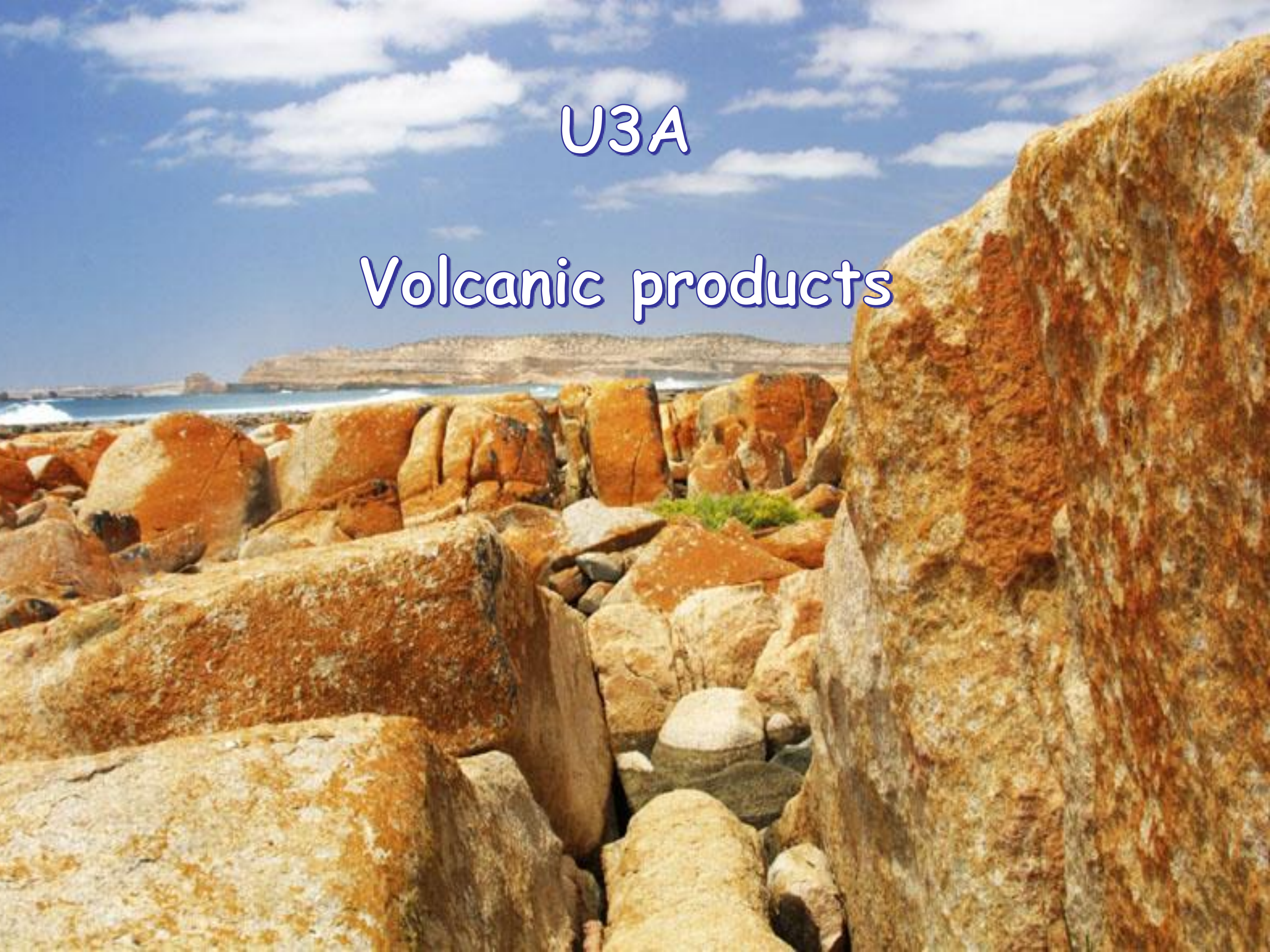
Shatter cones

Shatter cones, Pilbara ,WA

Shatter cones, Sudbury, Canada

U3A

Volcanic products



Introduction

- Volcanic activity gives rise to a variety of volcanic products including gases, volcanic dust, volcanic ash, volcanic rock fragments and lava
- the type of material depends on composition of melt and the type of eruption

Products of volcanic activity

- Gases
  - Mainly water vapour (H_2O)
  - Carbon dioxide (CO_2)
  - Sulphur gases (SO_2, H_2S)
  - Hydrogen Chloride (HCl)

- Pyroclastic material (Tephra)
  - Fragments of solidified lava forming during eruption
  - Volcanic bombs - large blocks of basalt
  - Scoria - small blocks of chilled, gas-rich basalt. The gas bubbles in lava are called vesicles.
  - Pumice - a light foam of rhyolitic glass
  - Volcanic ash - fine-grained tephra also called tuff

- Lavas

Volcanic gases

- Volcanoes commonly evolve vast amounts of gases
- a large volcano can produce tens to hundreds of millions of tonnes of gas comprising between 1 and 9% of most magmas
- the main gas is water vapour, there may be significant amounts of CO_2
- generally water and CO_2 combined compose 90% of volatiles
- volatiles tend to increase fluidity of magma but can also increase violence of eruptions
- some components of gases (e.g. SO_2, H_2S) subject to oxidation and hydration → form H_2SO_4 droplets

Steam from Halemaumau pit, Kilhauea volcano, Hawaii

Sulphur crystals around fumarole - Vulcano, Italy

Pyroclastic material

- Build up of gas pressure in rising magma can be suddenly released causing explosive eruptions
- explosive eruptions eject lava into the atmosphere where it solidifies rapidly producing fragmental material of different sizes from fine ash to large blocks called (volcanic bombs)
- most energetic pyroclastic eruptions are associated with thicker more viscous siliceous lavas that tend to trap more gases
- pyroclastic materials may travel through the air to form dense, flows that hug the ground and are more dangerous than lava flows

Lava fountain - Kilauea, Hawaii

Tephra

- Tephra → fragmented volcanic rock and lava ejected into the air during an eruption
- tephra normally accumulates in layers where it is deposited
- these layers record the frequency and intensity of volcanic activity
- tephra may be deposited as unconsolidated material or it may be welded together to form welded tuff or ignimbrite
- generally the coarser-grained and thicker the tephra layer is, the closer to the source

Bedded pyroclastic material, ash and lapilli, covered by lava spatter, Kilauea, Hawaii

Volcanic bombs

Large volcanic bomb surrounded by smaller blocks of scoria, Craters of the Moon National Monument, Idaho, USA

Cinders from scoria cone, Western Victoria

Pumice

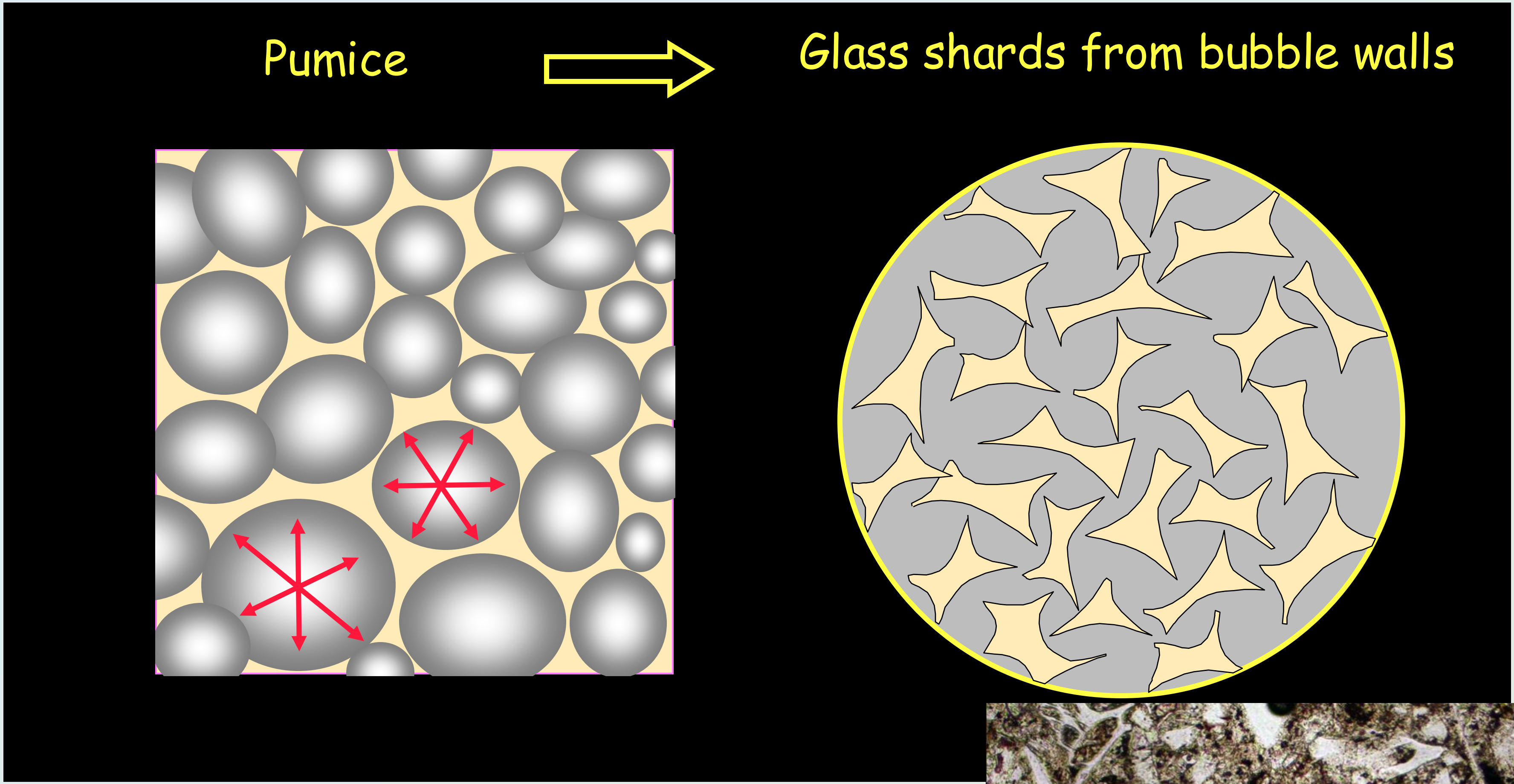
- Pumice → light-coloured, porous, siliceous volcanic rock formed when gas-rich, froth of glassy rhyolite lava solidifies quickly
- light coloured, low density → floats on water
- when Krakatoa erupted in 1883, ships were trapped for days by floating rafts of pumice in the Sunda Strait

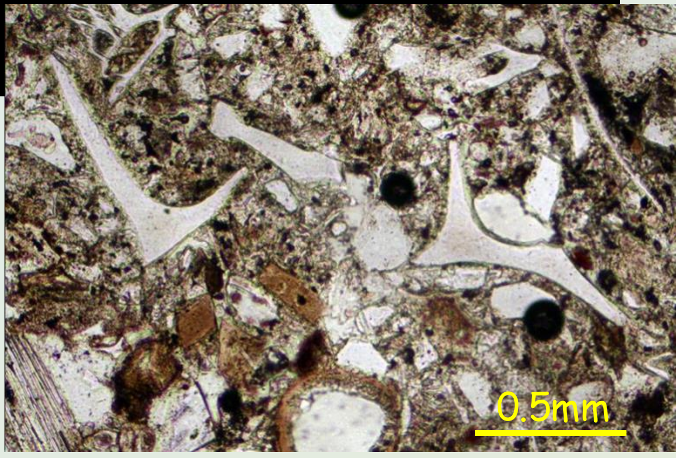
pumice

Formation of volcanic ash

- As magma nears the surface in a volcanic eruption, volatiles evolve, bubble out through the magma and are released as clouds of gas
- in high silica content magmas, gas can be trapped by the high viscosity of the magma under pressure as magma solidifies
- with further decrease in pressure on eruption, internal pressure in trapped bubbles exceeds confining pressure → solid material explodes to form glass shards → fragments of bubble walls
- glass shards are principal components of volcanic ash along with crystal and rock fragments

Formation of volcanic ash





Photomicrograph
of volcanic ash, PPL

Bedded rhyolite ash (grey) in Pliocene lake sediments (light brown), Northern Kenya

Dangers of volcanic ash to aviation

- Volcanic ash is composed of fine pulverised rock accompanied by gases that are converted into droplets of H_2SO_4 and HCl
- potentially deadly to aircraft and their passengers
- in June 1982 British Airways 747 flew into an ash cloud from Mt Galuggung in Indonesia → lost all 4 engines and sustained damage → descended from 7 to 2km before able to restart engines
- ash can melt from engine heat → forms glass coating on components causing loss of thrust and possible flame out
- also possible abrasion of engine parts, clogging of fuel

Ash cloud

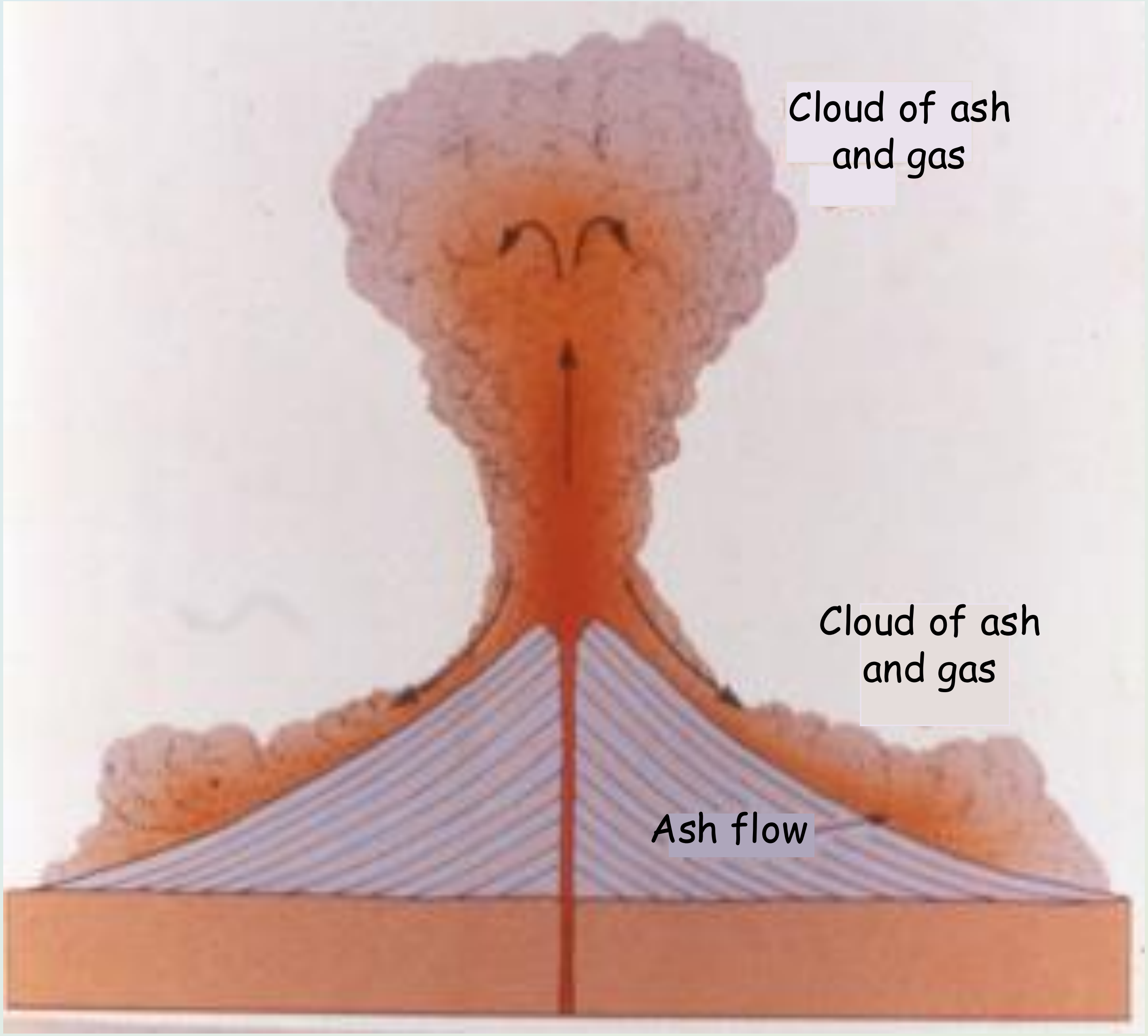
- Ash cloud → cloud formed from tiny ash particles and gases blasted from a volcano
- wind can carry ash thousands of km affecting large areas
- very fine volcanic dust can remain suspended in the atmosphere for periods up to 12months
- coarser volcanic ash (up to 2mm) generally only remains in suspension for a few hours or at most a few days

Ash cloud

Ash plume from the May 1980 eruption of St Helens, Washington, USA

Ash flows

- Ash flows are fast moving clouds of incandescent ash, suspended in hot gases.
- also called glowing avalanche or nueé ardente
- the volcanic 'ash' is mainly shards of volcanic glass, pieces of pumice and shattered minerals
- can move at speeds in excess of 100km/hr over long distances
- when they come to rest, the ash is still so hot that it may fuse together
- the resulting rock is called a welded tuff or ignimbrite



Formation eruption column during a Plinian eruption

Pyroclastic flows

- Pyroclastic flow → fast moving mass of destructive very hot ash, lava fragments and gases ejected from a volcano
- flows hug the ground at average speeds of 100km/hr but capable of speeds of 700km/hr
- gases and tephra can reach temperatures of ~1000°C
- earliest recorded pyroclastic flows (from Mt Vesuvius), destroyed Pompei in 79AD
- in 1902 a nueé ardente from Mt Pelee on the island of Martinique destroyed the town of St Pierre killing almost 30,000 residents

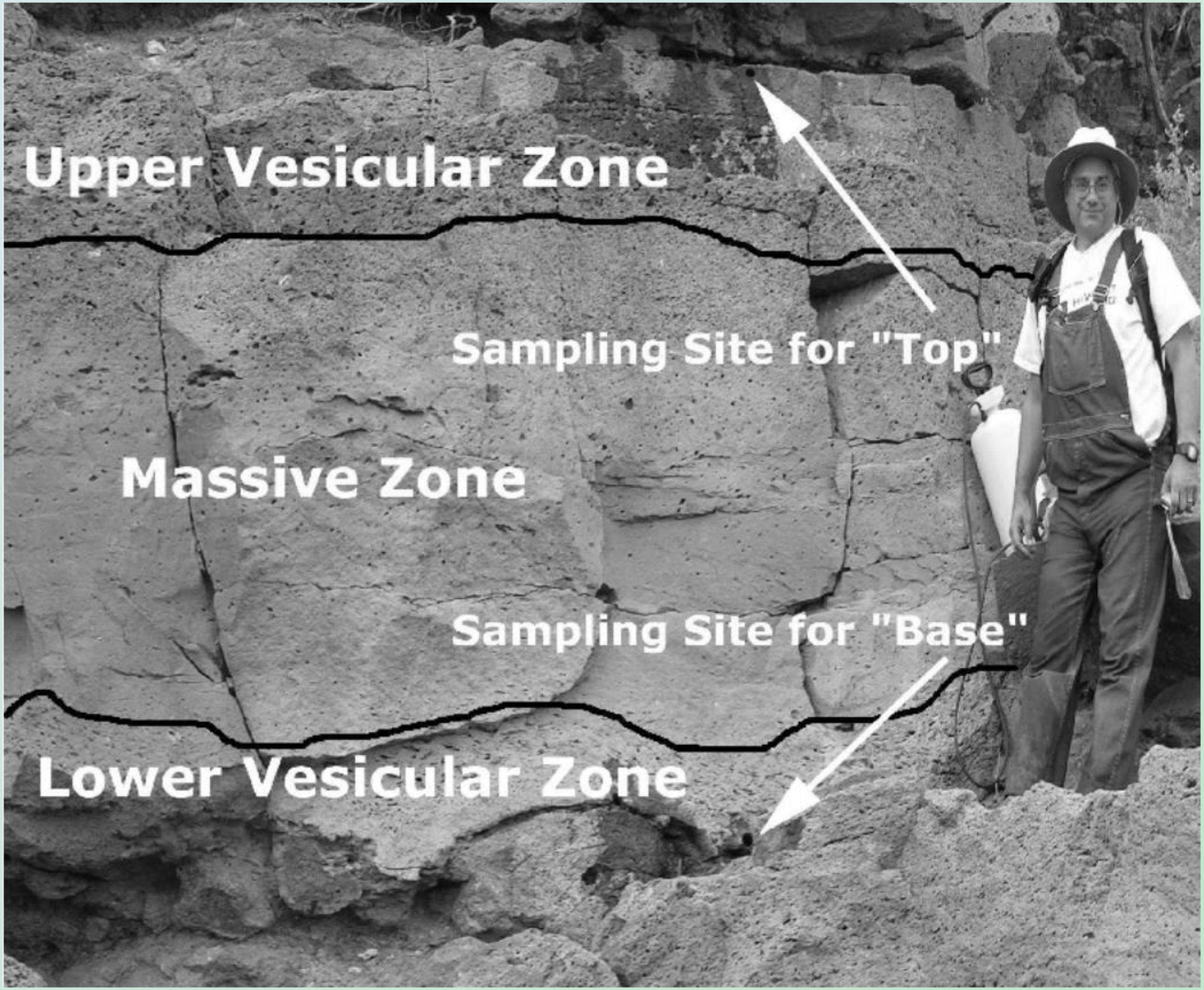
Ash flow - Mt Pinatubo, Philippines, 1991

Pompei ruins, Vesuvius 79AD eruption

Lavas

- Lavas have similar compositions to parent magmas → only difference being loss of volatiles (degassing) during eruption
- nature of lavas dependent on their composition and temperature
- because of lava viscosity, a proportion of gas bubbles (vesicles) remain trapped when lava cools
- faster cooling tops and bottoms of lava flows → more typically vesicular than centre that loses most gas bubbles → compression
- basalt lavas often erupted in highly fluid state → may be fast moving at 20-30km/hr

Zoning in basalt flow



Basalt lava flows

- Pahoehoe lava
  - produced by hot, fluid basalt
  - usually quite fast-moving, ~20-30km/hr
  - when solidified → ropy appearance; smooth, wrinkled surface
- Aa lava
  - cooler, more viscous basalt flows
  - very slow moving
  - rough, dark-coloured blocky lava flows
- Lava tubes
  - basalt flows often ‘freeze-over’ forming a solid roof
  - flows can keep them moving in a large tube
  - can travel large distances (up to 40km) over months
  - can leave a long empty lava tube when eruption stops

Pahoehoe lava

- as crust of lava cools → produces smooth undulatory surface

- underlying fast moving lava may deform the stiff crust causing it to be folded and wrinkled

Pahoehoe lava flow, Kilhauea, Hawaii

Aa lava

- slower moving, forms thicker flows than pahoehoe
- as flow moves forward, clinker blocks tumble down steep frontal slope

Aa lava flow overlying pahoehoe flow Kilauea, Hawaii

Aa lava flows

Aa lava flow Hawaii

Aa lava flow Kihauea

Lava river flowing from Mauna Loa, Hawaii, 1984

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Lava tube Mauna Loa, Hawaii

Fossil lava tube with lava bridge - El Malpais, New Mexico

Other Lava Structures

- Pillow lavas

  - characteristic form of basalt lava that flows under water
  - in x-section the flow lobes appear like elliptical pillows

- Columnar jointing

  - characteristic pattern of fracturing in many lava flows
  - mainly in thick basalt flows
  - flow is broken up into near vertical columns
  - columns have a hexagonal or pentagonal outline
  - due to shrinkage of lava as it cools

- Baked contact

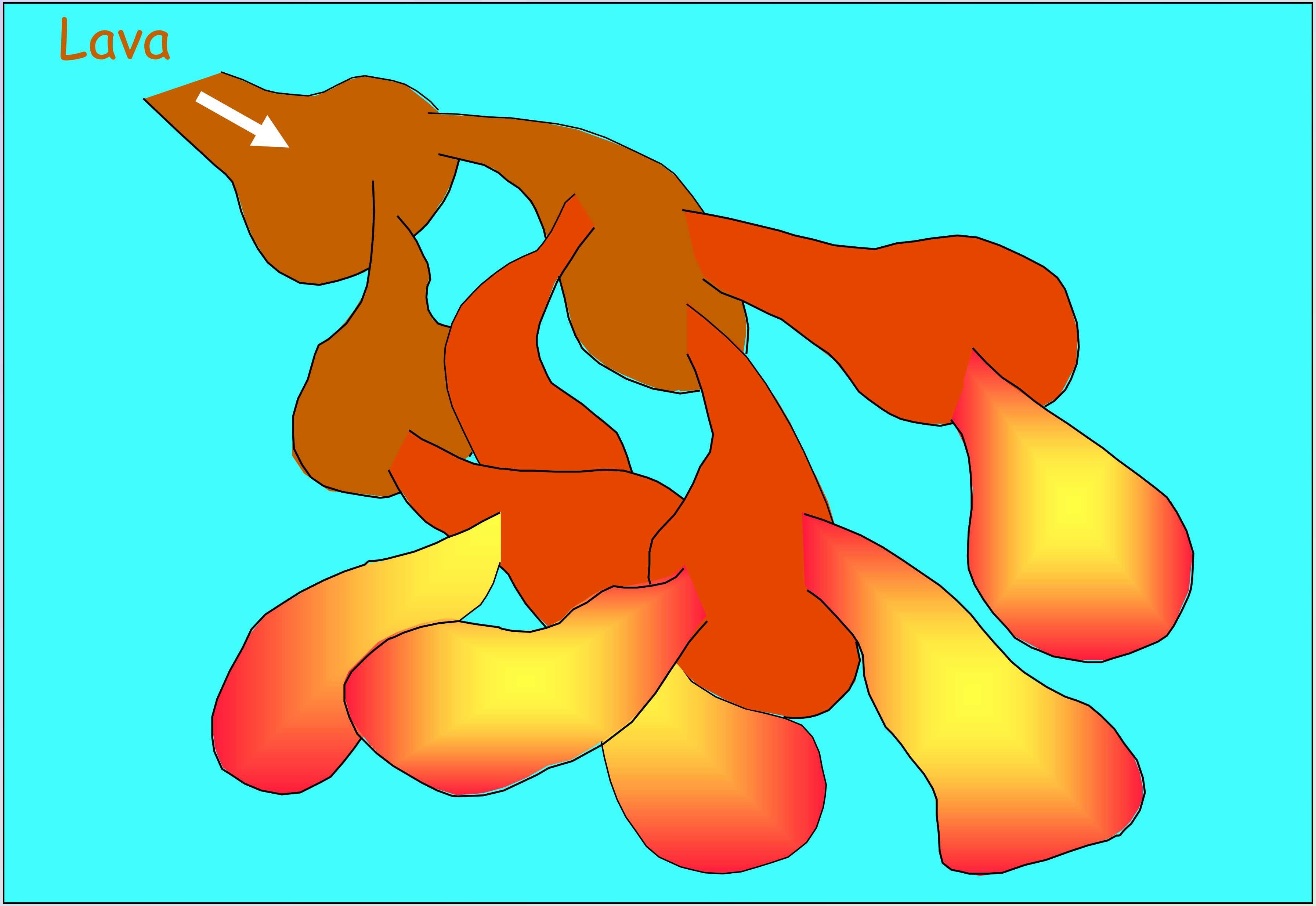
  - soils beneath lava flows are often baked by heat

Pillow Lava Structures

Pillow lavas

- Pillow lavas are rounded lobate basalt lavas erupted under water
- vary in size from a few cm to a few metres in diameter
- called pillow lavas because in x-section they resemble elliptical pillows
- pillow lavas form when lava is extruded into cold water and the surface is immediately chilled
- a thin skin forms over bulbous extrusion
- as pillow expands, surface cracks allowing extrusion of another pillow

Pillow lavas



Pillow basalts on sea floor,

East Pacific Rise

Basalt pillow lavas,

Avila Beach,

California, USA

Pillow basalts Gaussberg, Antarctica

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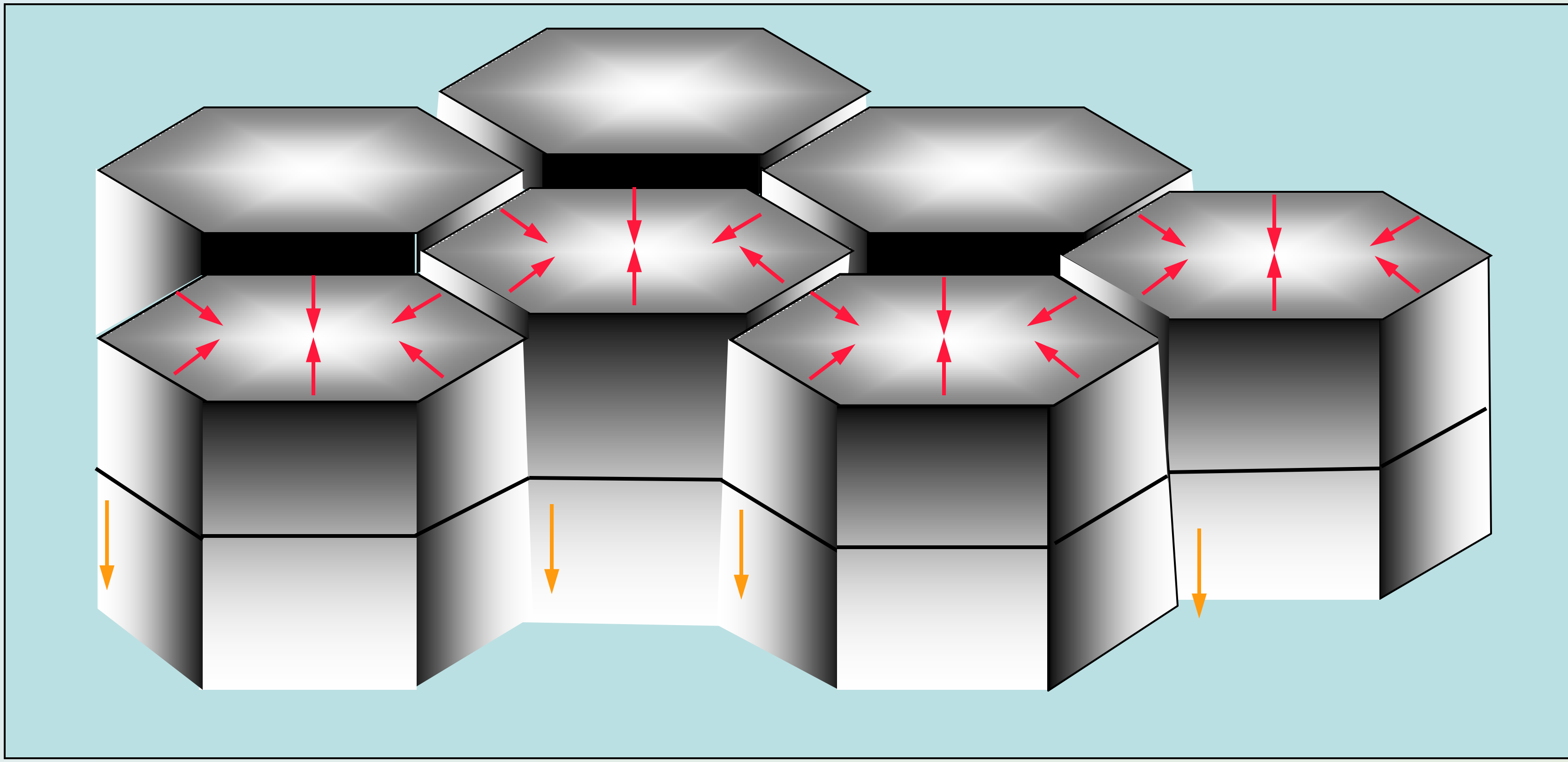
Columnar jointing



Columnar jointing, Hofsos, Iceland

Organ pipes columnar jointing, Keilor, Victoria

Surface outcrop columnar basalt, Hofsos, Iceland

Baked contacts

- As lava flows across land surface → loses heat to underlying ground
- baked soils between the flows show up as red coloured layer

Basalt lava flows near Cape Schank in southeastern Victoria.