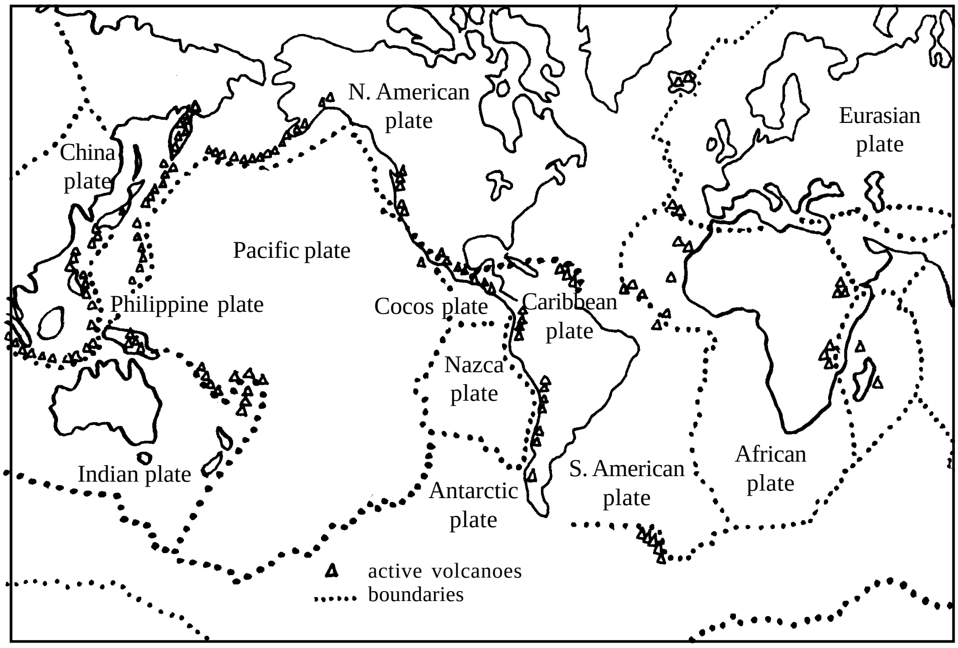
Geo Factsheet

Number 30

Volcanic Activity - Causes and Consequences

Fig1. Plate Boundaries and Volcanic activity



Causes
Volcanic activity is closely related to plate tectonic processes and is chiefly located along the edge of major plate margins (see Figure 1). Three main areas of activity can be identified:

- Oceanic rifts
- Continental rifts
- Subduction zones.

Oceanic Rift Volcanism
Ocean ridges occur due to the ocean lithosphere being stretched and thinned by tectonic forces. This thinning allows mantle material to rise which causes widespread melting and volcanism. This volcanism mainly takes the form of fissure eruptions along spreading **Mid Oceanic Ridges** (MORs) such as the Mid Atlantic ridge. Such volcanoes tend to produce basic or basaltic lavas with silica contents around 45%. These lavas have a relatively low viscosity and are mobile, forming gently sloping lava domes, called **shield volcanoes**.

Continental Rift Volcanism
The mechanism here is very similar to that of oceanic rifts; the lithosphere is thinning, allowing the mantle to rise. This occurs within vast rift valleys. Many theories exist to explain the formation of these structures and their associated volcanism, including the break up of continents by tensional forces and the formation of crustal domes due to the slow emplacement of magmatic material deep in the crust. The most notable example of this form of volcanism is along the **East African Rift Valley,** which extends for over 4000km. The characteristics of these two types are summarised in Table 1.

Table 1. Oceanic and Continental Volcanoes

	Oceanic Rift	**Continental Rift**
Eruption	Less violent	Violent - release of gas bubbles
Chemistry	Basic 45% Si Rich in Ca Fe Mg	Acid 70% Si Small amounts of Ca Fe Mg
Cooling	Slower	Rapid
Viscosity	Low viscosity	High viscosity (100 x Oceanic)
Mobility	High	Low
Landforms	Wide base and gently sloping sides	Tall with steep slopes

Subduction Zone Volcanism
This occurs when cold oceanic lithosphere is subducted i.e. forced down into the mantle. At depths of approximately 125km this basaltic material, which is wet and laden with sediment, begins to melt and yields a magma. This magma then begins to rise, as it is less dense than the surrounding rock, and erupts at the surface to form island arc volcanoes. The main examples of this style of volcanism occur along the Pacific orogenic belt **(the ring of fire)**, the **Alpine-Mediterranean-North African Himalayan** belt (which stretches down through Indonesia) and the **Caribbean orogenic belt**. Such volcanoes tend to produce acidic andisitic lavas containing about 70% silica which are highly viscous and hence relatively immobile. Volcanic events tend to be explosive, creating explosion vents, ash and cinder cones or steeply sloped **stratovolcanoes** (also called composite volcanoes) with alternating beds of ash and other pyroclastic material.

Other Volcanoes
Volcanoes can also occur within plates - over **hot spots** which are associated with localised pockets of molten magma rising as plumes to penetrate the surface, a good example being the **Hawaiian Islands**. Such lavas usually contain higher proportions of sodium and potassium reflecting a deeper source. Mid-Ocean plate volcanoes are invariably basaltic, whereas Continental hot spots may give rise to volcanoes erupting rocks with a range of silica and alkali contents.

Activity
Volcanoes are generally classified as active, dormant or extinct. This classification is carried out by examination of geological evidence of recent activity. However, some caution must be exercised; it is not unknown for "dormant" or even "extinct" volcanoes to erupt - when Vesuvius erupted in AD79 it had been widely considered to be extinct. Hot spot volcanoes often become extinct due to the lithosphere moving over the plume; the Hawaiian chain of volcanoes is the result of such a moving hot spot.

Table 2: Volcanic Effects -origin, characteristics and potential for harm

	Origin	Characteristics	Harmful Effects
Pyroclasts	All explosive eruptions	Hot broken fragments of rock ejected with great velocity	Rocks may be very large and cause damage on impact
Tephra	All explosive eruptions	Collective term for all airborne or ground-flowing pyroclasts including solidified magma. Tephra is classified according to size: Bombs: > 64mm diameter Lapilli 2-6mm diameter Ash <2mm diameter	Tephra may be spread over distances of 1500km or more causing major and minor damage
Eruption Column	Explosive eruptions of silica-rich and gaseous magmas - gases decompress rapidly to produce upthrusting gases and tephra	May include a white cloud column from emission of steam, dark masses of pyroclastic material and clouds of fine ash. "Mushroom cloud" often produced due to the perturbation of atmospheric temperature and pressure; moist air near the column is drawn up and condenses to form the "mushroom"	Fallout may be destructive and widespread
Pyroclastic Flow	Explosive eruptions May also be caused by collapse of eruption column	Hot, and often gas-charged, high velocity flow of tephra. Often composed of a mixture of bombs, lapilli, ash and extremely hot gases. The resultant deposit, high in pumice, is termed an ignimbrite	May extend many kilometres from source and travel at high velocity (average 300kmh^{-1}) May therefore represent a lethal mix of bombs, lapilli, ash and hot gases
Atmospheric effects	Eruption columns which may extend hundreds of kilometres into the atmosphere allowing ash, for example, to be transported by high level winds	Ash and dust particles including acidic aerosols. Light-scattering leads to unusual optical effects	Clouding reduces sunlight reaching earth's surface, cooling the troposphere, but release of greenhouse gases contributes to tropospheric warming
Landslides	Dislocation of land and rocks by magmatic pressure	May form huge flows of rocks, mud and tephra	Destruction of property and land
Lahars	Rain or meltwater may loosen tephra	Volcanic mud-flows which may move downhill very rapidly, as determined by topography	Extensive destruction to property and often loss of life eg **Nevado del Ruiz, Columbia 1985, Mount Pinatubo 1991**
Lateral Blasts	Rapid decompression of dissolved gases due to exposure of a mass of magma by a landslide	Sideways and sudden release of pulverised rock and hot gases	May travel at speed of sound. Lethal within blast zone which, in the case of **Mount St Helens** extended to 600km^2
Lava Flows	Any eruption	Flow rate dependent on temperature - as lava cools, its viscosity increases and speed reduces until it is less than walking speed. As it cools, a solidified surface is produced. Volume and range of flow variable - may extend up to 100km from source	Can cause ignition of fires and burial of land and objects, but in general the relatively slow flow rate means it poses little risk to life
Poisonous Gases	Any eruption	Ash-laden gases including carbon monoxide, carbon dioxide, hydrochloric acid, hydrofluoric acid, sulphur dioxide	Many are directly toxic and contribute to acid rain. 1700 people were asphyxiated by CO_2 in the 1986 eruption at **Lake Monoun, Cameroon**. May also cause long term starvation and disease
Flooding	Submarine eruptions displacing large volumes of rock and hence water. Blockage of rivers by lahars or lava flows	Inundation of fresh or salt water. May be gradual or rapid	Dramatic changes in erosion and deposition pattern of rivers. Destruction of property and agricultural land

The Beneficial Effects of Volcanism

Although volcanic activity is usually perceived as solely harmful, there are a number of beneficial effects:

- The scenic landscapes produced increase the potential for **tourism**
- **Soils** derived from basic lava are particularly fertile; volcanic ash falls are often rich in potassium and phosphorus and act as natural fertilisers. This explains the prevalence of settlements near many volcanos
- **Industrial materials** and **chemicals** are derived from volcanic rock - sulphur, pumice, boric acid and ammonia are examples.
- **Geothermal water** which reaches the surface may be harnessed for energy. In **Reykjavik, Iceland**, homes are heated by this method and in **Italy, New Zealand**, the **US, Mexico** and the former **Soviet Union**, naturally occurring steam is used to produce electricity.

Case Study: Soufriere Hills , Montserrat

Soufriere Hills Volcano sits on the Southern end of Montserrat Island in the West Indies. Before the most recent eruption in June/July 1997 the summit consisted of ESE-trending lava domes, the flank deposits were made up of block-and-ash flow and surge units formed as the domes periodically expanded.

Chronology

Jan 92-June 94 *- Early seismic activity.*

18th Jul 95 - 21st Aug 95 *- Start of eruption of steam, gas and ash.*

Late Sep 95 - Mar 96 *- Dome growth.*

29th Mar 96 - early Sep 96 - *Dome collapse and pyroclastic flows.*

17th-18th Sep 96 *- Explosive activity - first magmatic eruption occurs. Rocks and pumice hurled through the air destroying houses to the south. Ash plumes result in 60 000 tonnes of ash falling in southern Monserrat.*

1st Oct 96-11th Apr 97
Landslides, occasional pyroclastic flows, partial collapse of old crater walls.

14th May 97 - early Jul 97
Continued dome growth, small explosions resulting in some ballistic projectiles. Peaked on 25 June with pyroclastic flows from eruption of 4 to 5 million cubic metres of dome covering an area of 4 km^2. Flows down the northern flanks of the volcano following Paradise River almost reaching the sea. Flows and surges damaged between 100 to 150 houses. At least 9 confirmed dead, over 50 people rescued by helicopter added to which over 800 evacuees have been living in shelters for over a year. Flows on 26 June come within 50m of Bramble Airport.

Prediction

For several weeks before the main event, dome growth was observed along with repetitive earthquakes and dome deformation cycles as pressure increased. This meant that the large event was expected and hazard maps and warning systems already in place predicted the eruption fairly well.

Montserrat location map

Case Study: Popocatepetl

Popocatepetl, *situated 72km Southeast of Mexico City in the Mexican central volcano belt, is a 5,452 metre high stratovolcano in one of the most densely populated areas in the world. At present some 20 million people live within a 80km radius of the site, with over one hundred thousand living close enough to be directly effected by an eruption.*

Chronology

1993 *- Seismic activity and fumarole gas emission.*

1994 *- Increased activity culminating in a series of explosions within the crater on 21st December. Ash falls on Puebla and several small towns Northeast of the volcano precipitating the evacuation of 75,000 people.*

1995 *- Ash emissions several times a day lasting 5-20 minutes throughout the year.*

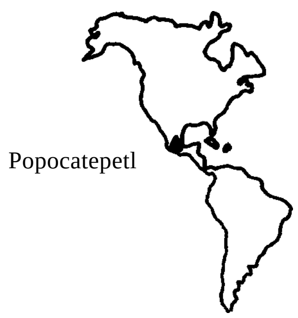
1996 *- March - Lava dome begins to grow on the crater floor of the volcano.*

1997 *- Lava dome currently fills 20% of the craters volume, larger than the 1919-27 dome. Small explosions throw incandescent blocks onto the upper slopes of the volcano.*

Monitoring

Managing the potential volcanic risks to the densely populated area surrounding Popocateptl is an extremely difficult task as no one knows to what extent the current spate of activity will develop. Scientists have learned many valuable lessons from recent eruptions such as Mount Pinatubo in the Phillipines. When early warning signals were rapidly identified by monitoring stations and coded warnings were transmitted on all radio frequencies. This is beleived to have significantly reduced the final casualty rate. Similarily a comprehensive surveillance system has therefore been set up around Popocatepetl to observe changes in emission chemistry, ground movements and real-time seismic monitoring.

Popocatepetl location map



This has enabled a response code to be established based on three hazard alert levels ranging from green (low), through yellow, up to red (high). These alert levels are used to identify the appropriate actions of the civil authorities, scientific community and the endangered population.

Acknowledgements;

This Geo Factsheet was researched and written by Anna Jeffcoat and Bryan Robinson.

Geo Press, 10 St Paul's Square, Birmingham, B3 1QU

ISSN 1351-5136