VOLCANISM AND HOTSPOTS

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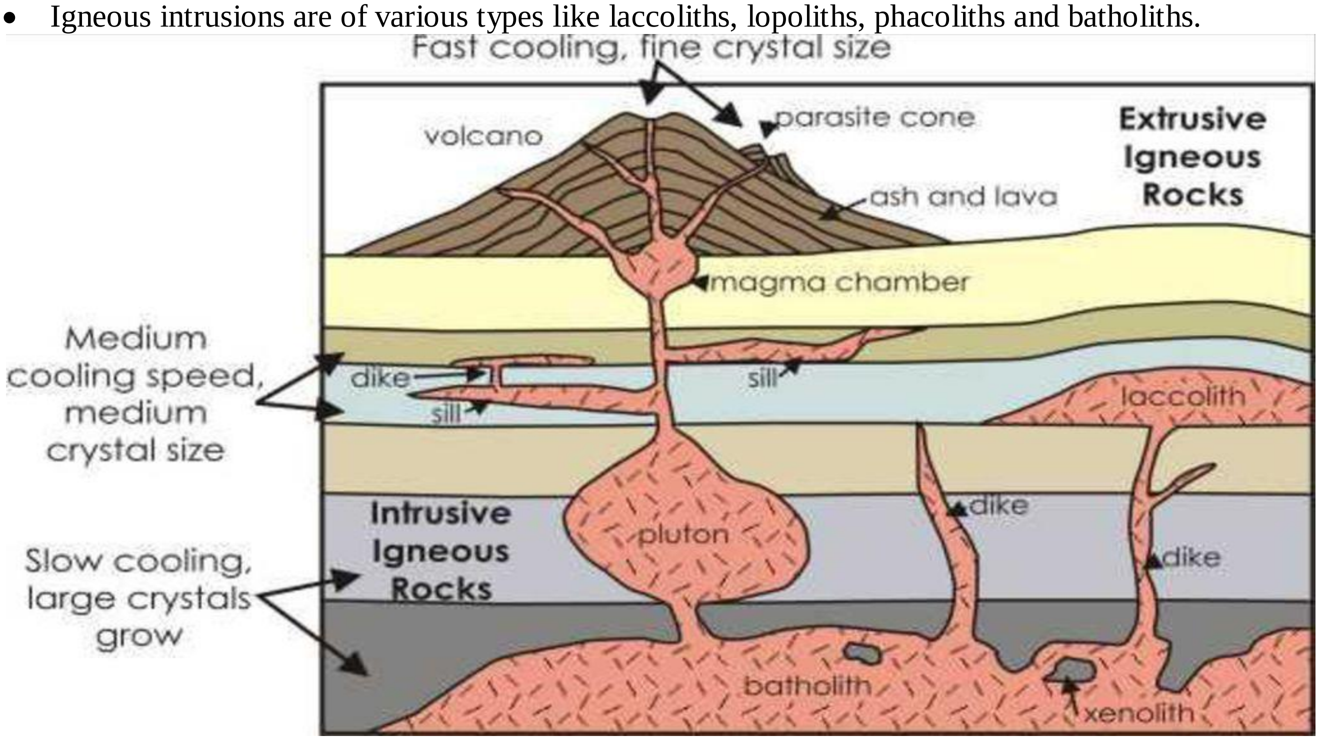
Landforms associated with volcanic activities

- Vulcanic activities have a profound influence on the earth's landforms.
- Molten magma is mobile rock that forces its way into the planes of weakness of the crust to escape quietly or explosively to the surface.
- Magma while thrusting its way up to the surface may cool and solidify within the crust as plutonic rocks resulting in intrusive landforms.
- Magmas that reach the surface and solidify form extrusive landforms.

Landforms of igneous intrusions

- When an intrusion of molten magma is made horizontally along the bedding planes of sedimentary rocks, the resultant intrusion is called a sill.
- Similar intrusions when injected vertically as narrow walls of igneous rocks within the sedimentary layers are termed as dykes.
- When exposed to denudation, dykes appear as upstanding walls or shallow trenches depending on whether they are more or less resistant than the rocks in which they are emplaced. E.g. Cleveland Dyke of Yorkshire.
- Igneous intrusions are of various types like laccoliths, lopoliths, phacoliths and batholiths.



- A laccolith is a large blister or igneous mound with a dome-shaped upper surface and a level base fed by a pipe-like conduit from below and arching up the overlying strata of sedimentary rocks. E.g. Henry Mountains in Utah, USA.
- A lopolith is of saucer shaped and a shallow basin formed in the midst of the country rocks. E.g. The Bushveld of Transvaal, South Africa.
- A phacolith is a lens-shaped mass of igneous rocks occupying the crest of an anticline or the bottom of a syncline and being fed by a conduit from beneath. E.g. Corndon Hill in Shropshire, England.
- A batholith is a huge mass of igneous rocks forming a massive and resistant upland region such as the Wicklow Mountains of Ireland, the uplands of Britanny, France and the Main Range of West Malaysia.

Origin of Volcanoes

- Geologists and vulcanologists have ascertained that volcanic activity is closely connected with crustal disturbances, particularly where there are zones of weakness due to deep faulting or mountain folding.
- As temperature increases with increasing depth below the earth's crust, the interior of the earth is in semi-molten state comprising solid, liquid ad gaseous materials collectively termed as magma.
- The magma is heavily charged with gases such as carbon dioxide, sulphurated hydrogen and small proportions of nitrogen, chlorine and other volatile substances increasing the mobility and explosiveness of the lavas which are emitted through the orifice or vet of a volcano during a volcanic eruption.

There are two main types of lavas – basic lavas and acid lavas.

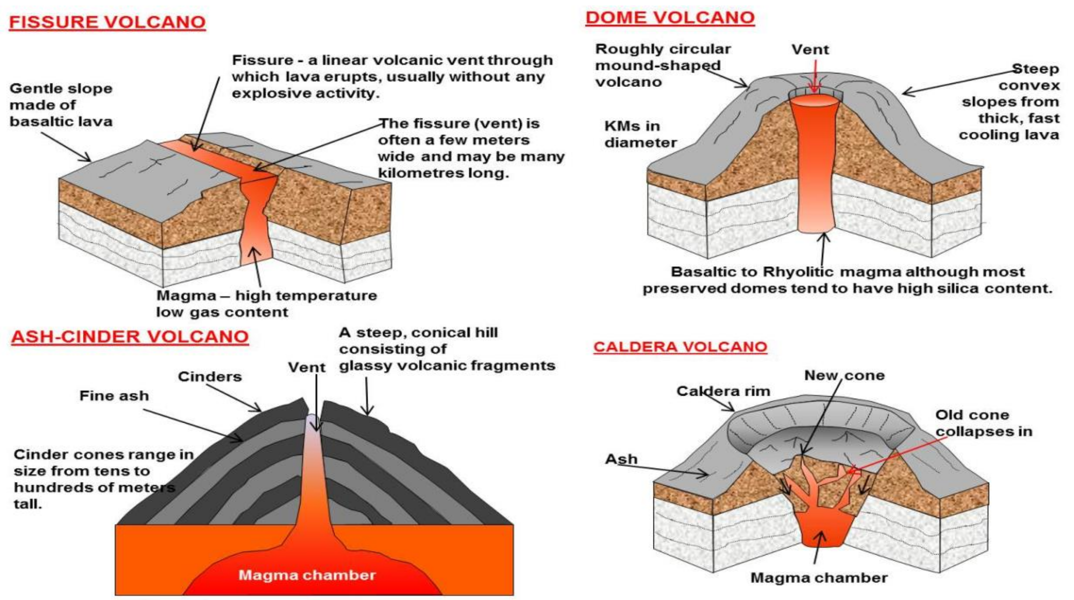
- **Basic lavas:** These are the hottest lavas, about 1000 C and are highly fluid, dark coloured, rich in iron and magnesium and poor in silica. They flow quietly and due to their high fluidity, they flow readily with a speed of 10 to 30 miles per hour affecting extensive areas spreading out as thin sheets over great distances before they solidify. The resultant volcano is gently sloping with a wide diameter and forms a flattened shield or dome.
- **Acid lavas**: These lavas are highly viscous with a high melting point, light coloured of low density having a high percentage of silica. They flow slowly and seldom travel far before solidifying. The rapid congealing of lava in the vent obstructs the flow of the out-pouring lava resulting in loud explosions throwing out may volcanic bombs or pyroclasts. Sometimes the lavas are so viscous that they form a spine or plug at the crater like that of Mt. Pelee in Martinique.

Types of volcanoes

- There are three types of volcanoes – active, dormant and extinct.
- In active volcanoes, they frequently erupt or at least when they have erupted within recent time.
- Those that have been known to erupt and show signs of possible eruption in the future are described as dormant.
- Volcanoes that have not erupted at all in historic times but retain the features of volcanoes are termed distinct.

Extrusive landforms

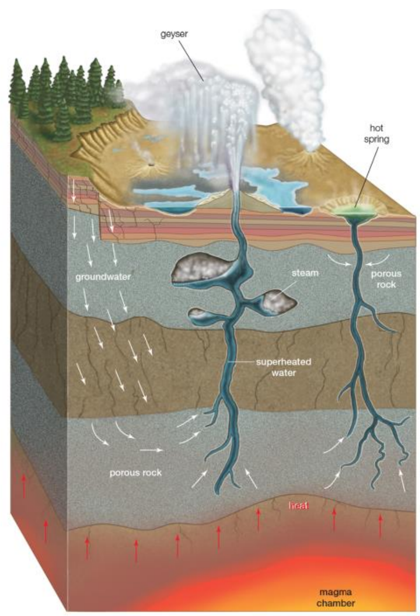
- They are determined by the nature and composition of the lava and other ejected materials that reach the surface of the earth.
- The fluid basic lava flowing for long distances produces extensive lava plains and basalt plateau such as the Snake Basin, USA.
- The highly fluid lavas build up lava domes or shield volcanoes with gently rising slopes and broad, flattened tops. E.g. volcanoes of Hawaii.



- The less fluid lavas that explode more violently form ash ad cinder cones with large central craters and steep slopes. They are typical of small volcanoes occurring in groups and seldom exceeding 1000 feet in height such as Mt. Nuovo, near Naples and Mt. Paricuin in Mexico.
- When the lavas are confined in valleys, they form lava tongues and lava-dammed lakes when they dam a river valley besides lava bridges and lava tunnels.

- A volcanic region may be strewn with solid materials hurled from the vent of the volcano and travelling round the world several times before it comes to rest and these are called volcanic dust.
- The highest and most common volcanoes have composite cones built up by several eruptions of lava, ashes and other volcanic materials from the main conduit which leads down a reservoir of magma.
- From the main conduit, subsidiary dykes or pipes may reach the surface as feeders to parasitic cones and Mt. Etna has hundreds of such cones.
- During an eruption, material from the top of the cone is blown off or collapses into the vet widening the orifice into a large crater.

Geysers and Hot springs



- Geysers are fountains of hot water and superheated steam that may spout up to a height of 150 feet from the earth beneath.
- The jet of water is usually emitted with an explosion and is often triggered off by gases seeping out of the heated rocks.
- Almost all the world's geysers are confined to three major areas – Iceland, the Rotorua district of North Island, New Zealand and Yellowstone Park of USA.
- Hot springs or thermal springs are more common and may be found anywhere in earth where water sinks deep enough beneath the surface to be heated by the interior forces.
- The water rises to the surface without any explosion and such springs contain dissolved minerals which may be of some medical value. Iceland has thousands of hot springs.

Hotspots

Although earthquakes and volcanoes are two of the hall marks of plate boundaries, active volcanism also occurs in certain isolated areas that lie far from any plate boundary. Termed "hotspots", these puzzling features are not readily accounted for by plate tectonic theory, yet they are thought to play a fundamental role in the breakup of continents and their existence has been used to document plate motions.

Although plate tectonic theory explains many of the world's major crustal features, like mid-oceanic ridges and mountain ranges, others are not fully accounted for. Hotspots, whose existence was first proposed by the eminent Canadian geophysicist, J. Tuzo Wilson, are one of the more puzzling features of plate tectonic theory and their origin is uncertain. As their name suggests, hotspots are relatively small areas of higher than average heat flow associated with volcanoes. Although hotspots are essentially fixed point-sources of heat, over time they often create a line of extinct volcanic features that ends in an area of active volcanism. In the oceanic realm, hotspots form volcanic islands which slowly subside on becoming extinct. As a result, the lines of extinct volcanic features first develop fringing reefs, and then become atolls. Finally, they become submerged seamounts as they get older.

Although some hotspots lie on plate boundaries, most occur in the interior region of plates. Therefore, unlike most volcanic activity, hotspots cannot be directly tied to processes occurring at plate boundaries. Instead, they are widely attributed to giant plumes of heat welling up from the deep mantle. These mantle plumes, the existence of which was first proposed by Jason Morgan at Princeton University, push against the lithosphere, doming it like a blister. So, in contrast to plate boundary volcanism, the source of hotspot volcanism apparently lies deep in the mantle beneath the realm of plate tectonics.

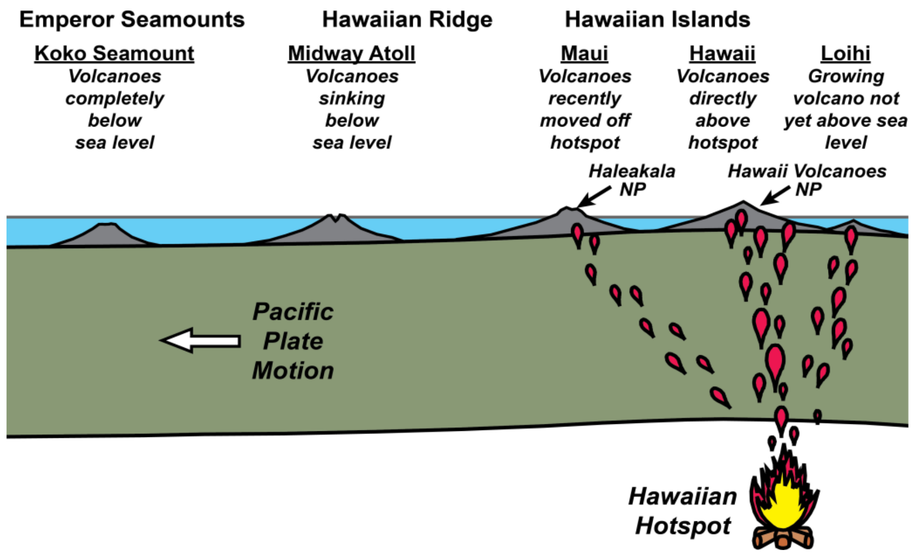
Wherever hotspots burn through plates, volcanoes erupt. But the volcano is built on a moving plate whereas the plume beneath it is fixed. Just as a sewing machine generates a line of stitches as the cloth moves past the needle, so a plume repeatedly punctures the crust as the plate moves past. In this way, a line of volcanoes is produced as the moving plate carries each hotspot-built mountain away while a new volcano is built over the plume. Where the plate is oceanic, the line of volcanoes forms a volcanic island chain, which eventually becomes a seamount chain as the ocean floor cools and subsides and the volcano is eroded by the sea.

Although this model explains the pattern of volcanism, the origin of hotspots remains a mystery because they often lie far from plate boundaries where most volcanoes are located. Given that they remain in relatively fixed positions over very long periods of time, many geologists think that hotspots must arise from a very deep source. The most commonly cited explanation is one of deep-seated convection in which columns of heat rise from a thermally unstable layer thought to exist at the core-mantle boundary. At this boundary, the solid lower mantle is in contact with the liquid outer core. What initially creates these rising columns is very speculative and some have even suggested that they might be deep expressions of extraterrestrial impacts. Other geologists, however, have proposed much shallower sources immediately beneath the plates, created by processes that include the development of crustal rifts, friction between the plate and the mantle, and the local accumulation of mantle heat produced by the thermal blanketing effect of continental crust. Thermal blanketing occurs because continent crust does not dissipate heat as effectively as oceanic crust. So large continents are thought to trap mantle heat. The number of hotspots is also uncertain with estimates ranging from 20 to 120 depending on such criteria as the level of activity, lava chemistry, and degree of doming.

Two types of hotspots, oceanic and continental, are distinguished on the basis of the type of crust on which they occur. While the origin of the two types may be the same, there are major differences in the nature of their volcanism.

Oceanic Hotspots

Best known of all the world's hotspots is Hawaii. The Hawaiian-Emperor seamount chain marks the passage of the Pacific plate over a plume for the past 70 million years. The oldest seamounts, now eroded by time, stand at the line's northern end where the Pacific plate dives beneath the Aleutian Trench. Although Hawaii may be the best-known, other hotspots pepper the Pacific. Bora Bora, and the Society Islands, for example is the product of a younger hotspot than Hawaii but record the typical sequence from volcanic island to fringing reef to atoll to seamount, produced as each volcano cools, sudsides, and is beveled by erosion as it moves off the hotspot. Easter Island and Darwin's Galapagos Islands in the eastern Pacific have formed over other plumes. In the Atlantic Ocean, the Azores and Canary Islands formed above

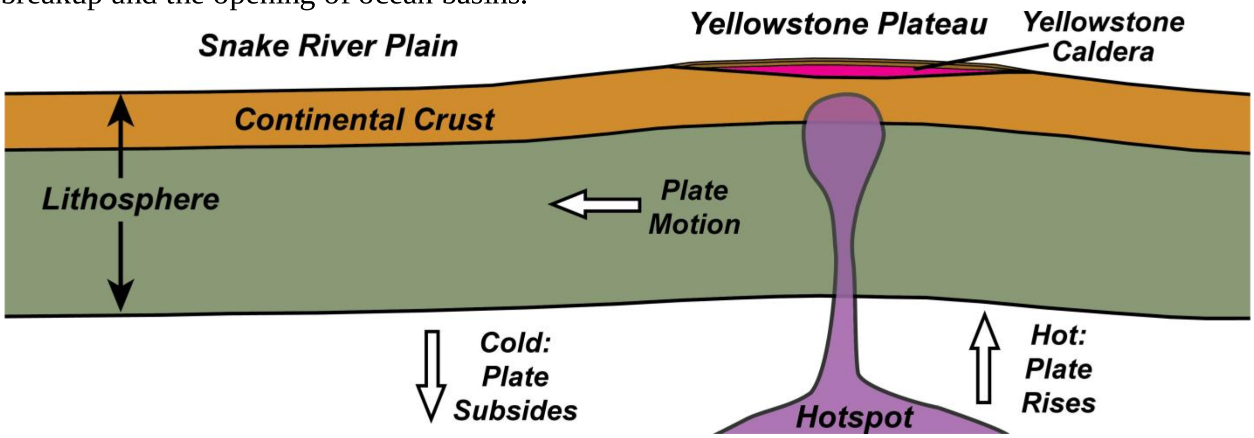


plumes, although the latter has been inactive for 150 years. Likewise, the island of Reunion lies above a plume far from rifts and subduction zones in the Indian Ocean.

The progressive increase in the age of volcanic activity to the northwest of Hawaii is evident in the increasingly eroded and, hence, older appearance and lower elevation of the volcanoes in this direction. This apparent increase in age is also borne out by radiometric dating. Present-day volcanic activity is observed on Mauna Loa and Kilauea which lie over the Hawaiian plume on the southeast side of Hawaii. Further southeast, the submarine volcano Loihi, which has reached to within 960 m (3170 ft) of the sea's surface, is munching its way towards island hood, and will one day become the newest member of the chain as the islands move northwest.
This idea has since been borne out by dating, the progressive northwestward increase in the age of volcanism along the Hawaiian chain continuing in an uninterrupted fashion along the length of the Emperor Seamount chain.

Continental Hotspots

While oceanic hotspots provide dramatic evidence of the movement of the Earth's lithosphere plates, continental hotspots may play as active role in determining the position of certain plate boundaries. Many scientists believe that hotspots and underlying plumes drive the wedge that splits continents apart, first doming and then cracking the continental crust into characteristic Y-shaped rifts which meet at a triple point like that of Ethiopia's Afar Triangle at the southern end of the Red Sea where the East African Rift meets the Gulf of Aden. If this is the case, then continental hotspots play a fundamental role in the initiation and geometry of continental breakup and the opening of ocean basins.



They may also be responsible for the development of many oceanic hotspots into which they must evolve if their activity persists after continental breakup.

Typically two of the rifts that meet at a triple point widen into oceans while the third may either widen as well or becomes inactive to form a special type of failed rift called an aulacogen (from the Greek *aulax*, a furrow) that will later channel major streams into the new ocean and slowly become filled with sediment. An excellent example of an aulacogen occurs at the elbow of Africa's west coast where the Benue Trough brings the River Niger to the Atlantic Ocean. Following continental breakup, the hotspot beneath such a triple point will ultimately lie near a mid-oceanic ridge, accounting for the large number of hotspots located at or close to the Mid-Atlantic Ridge and the mid-oceanic ridges of the southern Indian Ocean

So hotspots can be both related and unrelated to plate tectonics. Because they are stationary, their origin must be independent of plate tectonic processes, the most popular theory for their formation suggesting that they are the manifestation mantle plumes that rise in narrow columns from the core-mantle boundary. Yet in providing the wedge that splits continents apart, hotspots may control the location of divergent plate boundaries. In so doing, they tend to become associated with mid-oceanic ridges, and so show a relationship with plate tectonic processes.
Because they are stationary, hotspots also provide dramatic evidence of plate tectonics, recording not only the direction but also the speed of the plates through which they burn. But they do not tell us why the plates are moving.