IGNEOUS ACTIVITY AND VOLCANOES

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Igneous activity is the general name for a two fold process:

a. **The making of hot liquid material within the earth and its rising within the lithosphere or onto the surface of the earth, and**

b. **The cooling of this liquid material to form solid igneous rocks.**

It also includes: movement and effects of molten rock before it solidifies.

Volcanic activity: It is the surface expression of igneous activity.

Definition of a Volcano

A volcano is the vent through which the molten rock material and associated gases pass upward to the earth's surface. In other words it is a site where molten rocks (magma) have been erupted at the surface of the earth.

Strictly speaking the volcano is defined in terms of the existence of the vent, not the piling up of the material. The volcano becomes active the moment gases start to come out of the vent. Some vent only releases gases.

The principles governing activity apply not only to earth, but also to other planets and moons.

PRODUCTS OF VOLCANOES

Smoke and ashes: During the middle ages they were called the "Fires of Hell". Heklafeld in Iceland was thought to be the gate to the underworld. In late eighteenth century, some persons considered volcanoes to be the vent of great fires burning within the earth.

The complex and variable products of volcanoes include:

a. Liquids
b. Solids
c. Gases

Generally the gases and molten liquid are mixed together when they leave the vent and separate in the atmosphere. In some cases the gases are mixed with solids.

The key process of volcanic activity is the separation and escape of gases from their associated liquids and solids.

Volcanic gases

Mainly consists of elemental gases rather than combined gases. They include CO_2, N_2O, SO_2, smaller proportion of H, CO, S, Cl, H_2S, HCl, and other acids.

Virtually all the gases of the earth's atmosphere and all the water of the earth's ocean are thought to have been released by igneous activity.

The release of these gases provides the driving force to expel the liquid and solid volcanic products.

a. **Although gases compose only 1-2 per cent of the total weight of erupting magma, they expand into bubbles as the pressure decreases near the earth's surface. Gas formerly held in solution by pressure suddenly forms bubbles and rush to the top of the liquid.**

b. **Much volcanic gas consists of water vapor. The 1945 eruption of Particutin in Mexico blew off 15,000 tons of steam per day.**

Steam from volcano can come from two sources:

a. **From water locked up within the lattices of some minerals in the earth's mantle (Juvenile water- new water).**

b. **From groundwater, water held within the underground pores of sediments and sedimentary rocks which the rising magma vaporizes as it approaches the earth's surface.**

Volcanic liquids

The lava ejected by volcanoes is a molten melt of silicates whose physical properties are controlled to a larger degree by the chemical composition.

Lava may be:

a. Mafic, or
b. Felsic in composition.

Mafic Lava

They contain abundant Mg and Fe and which upon cooling, form ferromagnesian silicate minerals and calcium rich plagioclase.

They are hot (1000 -1200 ^{0}C) and tend to be liquid and free flowing.

Felsic lavas

They are containing small amounts of Mg and Fe but abundant Al, Na and K, which solidify to form potassium feldspar, sodium rich plagioclase, and quartz.

Felsic lavas are somewhat cooler than mafic lavas (800- 1000 ^{0}C) and tend to be sluggish or viscous.

Volcanic activity varies with the viscosity of the lava. In mafic type the gas can escape continuously whereas in felsic lavas gas can escape only after they have built up great pressures and cause violent explosions.

Smooth flowing mafic lavas typically forms a pliable crust that can be bent and twisted into intricately curved forms.

The Hawaiian word pahoehoe is applied to such twisted ropy-looking lava (ropy lava). A contrasting type of lava is aa (ah ah) another Hawaiian word.

Aa is more viscous than pahoehoe lava and has jagged, uneven surface, characterized by spines.

Block lava

Rich in silica, it resembles aa without the spines. Some block lava is so viscous that it may move only a few meters a day, breaking itself into blocks as it flows over the ground.

Vesicles

Gas expanding within lava can create a froth that my solidify to a rock full of open spaces. These cavities are named vesicles.

Pumice

Vesicular felsic lava solidifies to light coloured pumice that contains so many empty non-connecting spaces that it may float on water.

Scoria

Gas expansion into mafic lava creates larger individual spaces that may or may not be connected to adjacent cavities. The resulting highly vesicular rock is a dark coloured jagged product named scoria.

Amygdaloidal Rock

If vesicles become filled with minerals, the resulting rock is amygdaloidal.

Volcanic solids (Tephra or Pyroclastic material)

Various kinds of tephra are labeled according to shapes and sizes. Here we mention only the larger size (>32 mm i.e. volcanic ash).

a. Volcanic blocks
b. Volcanic bombs

Volcanic blocks are large, angular solids. Commonly associated with blocks are bombs. Tephra that were ejected as clots of molten lava but solidified in the atmosphere are the bombs. They are normally almond shaped with twisted bends. The friction between the air and the moving clots of lava and the rotation of the clots usually produce almond shaped objects with twisted ends.

Volcanic bombs are related to ropy pahoehoe lavas and blocks are akin to block lava or aa. Volcanic ash are the tephra from the violently explosive volcanic eruptions. Tephra from violently explosive volcanic eruption can be spread through tens of thousands of sq km within a few days. Such ash are good for dating the eruption.

VOLCANIC CONES

The most familiar of volcanic landforms are volcanic cones. Several varieties are recognized depending on the materials composing them:

1. Tephra cones (ash or cinder cones)
2. Spatter cones
3. Complex volcanic cones
4. Composite volcanic cones

1. Tephra cones

Tephra cones consist of fine grained, usually uniformly sized tephra that were ejected from a circular volcanic vent, fell back as solids, and were piled up surrounding the vent. The angle of sloping sides of nearly every tephra cone in the world is 25-30 ^{0}. They are rarely higher than about 450m.

2. Spatter cones

Eruptions of small clots of liquid lava (spatter) may build small, steep sided spatter cones rarely exceeding 30 m high. Their walls are nearly vertical.

3. Complex volcanic cones

They are composed of sloping layers of tephra and reinforcing layers of extrusive igneous rocks, i.e. by cooling of lava flows. In these cones, lava from the central vent pushes outward through the sides of the cones as flank eruptions. Eventually, the cone’s sides my be so strengthened by the sheets of igneous rocks that it is a possible for lava to rise to the top of the cone and to issue forth as summit eruptions.

4. Composite volcanic cones:

There are combinations of complex cones built atop volcanic shields. The Tephra cone is the beginning stage. Great conical peaks such as Fuji in Japan, Vesuvious in Italy, Mayon in Philippines are famous for their beauty and symmetry.

Volcanoes may be classified on the basis of their activities as follows:

Extinct:	If all activity has forever ceased
Inactive:	If not erupted within historic time (10,000 yr)
Dormant:	If known to have active but quiet during last 50 years
Active:	If it has erupted within the last 50 years
Recently active:	Active within the last one thousand years

The world distribution of volcanoes

During the last 400 years about 500 volcanoes are known to have erupted. Volcanoes are found in nearly all parts of the world, both on land and on the sea floor. More than 3/4th of the worlds subaerial volcanoes are distributed around the margins of pacific plates in a pattern called ring of fire. An off shoot of this ring extends westward through Indonesia.

14% of the world's active volcanoes are located along this boundary. Another series of volcanoes is scattered in the middle of the Atlantic ocean e.g. Iceland, Azores etc. The Mediterranean contains a group of active volcanoes in Italy and south of mainland Greece.

Within African plate along the rift valley in eastern Africa, are another group of volcanoes.

Antarctica, floor of pacific ocean contains a number of volcanoes.

Antarctic near South Pole called Mt. Early is the world's southernmost volcano. Next is the Graham Land Peninsula and eastward to south Sandwich island.

Mt. Burney, the southernmost volcano in South America, then continues intermittently for 7,000 km of Andes. In all there are thousands of extinct or dormant volcanoes, but only 45 are considered to be active. 6000 m high San Pedro in Chile is one of the important volcanoes of the world.

Japan, Iceland, Hawaii, Italy, Newzealand look no relation. But they have one thin in common: They are very near to the sea. Almost all the volcanoes in the world are within a couple of hundred kilometers of the sea. There are remarkably few active volcanoes in the center of the continents. Non at all in South and North Americas away from the Andean-Rockies mountain belt. None in central Asia. Non in Australia and only one away from the coast in Antarctica.

There are exceptions in Africa and some recently dead volcanoes in France and Germany. They are specialized, distinct group.

If one plots the sites of all the recently active volcanoes in the world on a map, one finds that several distinct, narrow chains exist

1. Some running along the edge of continental land masses
2. Some along island arcs
3. Some through the ocean/sea (mid ocean volcanoes)

Continental margin volcanoes:

The first chain starts right down in the Antarctic, a few hundred km from the south pole. Mt. Early is the world's, southernmost volcano. Further north along ice-bound coast of Marie Byrd Land are more volcanoes then continue to Graham Land peninsula. Swing to east ward South Sandwich Island then to Mt. Burney, the southernmost volcano of South America.

From Mt. Burney northwards, volcanoes occur intermittently along almost the entire 7,000 km length of the Andes. In all there are thousands of extinct or dormant volcanoes, but only 45 are considered to be active. Costa Rica, Nicaragua, El Salvador, Guatemala contain many volcanoes. Mexico contains many active volcanoes. Moving north US has rather fewer volcanoes Mt. Shasta, Mt. Rainer etc. are over 4,000 m high.

Canada has no major volcanoes, but there have been some eruptions in the prehistoric times.

In the SW of Alaska, the volcanic chain picks up again strongly, and swings out to sea to form the long arcs of the Aleutian and Kurile islands.

Kurile back up northwards towards the Kamchatka Peninsula of former USSR, an intensely active volcanic province. The south sides heads towards Japan. From Japan the chain goes on to Taiwan, through the Philippines and into the Celebes. From Celebes branch off one goes to Indonesia where volcanoes has killed more people than any where else in the world. Another branch goes to eastward through New Guinea and the New Hebrides and finally to Samoan Islands to join Samoa Tonga-Kermadec chain which extends southwards again into Newzealand.

There are no volcanoes in south of Newzealand and dies out here.

The only volcano further south are in Antarctica over 1,500 km away that is Buckle Island, Mt. Erebus. Thus it makes a pacific circle of 40,000 km Ring of Fire.

Mid-Ocean Volcanoes

In the north between Greenland and Arctic Norway in the ice gripped island we have Jan Mayen -Beerenberg volcano which erupted in 1970 last.

Then Iceland built entirely of volcanic rocks and famous for its volcanoes and geysers. Iceland has 22 volcanoes, mainly in westmann island, just off the south coast.

Surtesy was built up by an eruption which started in 1963 and continued intermittently until 1967.

Azores 1,300 km from Portuguese coast, a small group of islands which are entirely built of volcanic rocks where eruptions took place in 1957 and 1973.

Canary islands 100 km from the African coast has recent volcanism.

St. Helena (Trinidad), Tristan da Cunha, Bouvet island last southernmost ice bound inaccessible.

Volcanic Landforms (or volcanic forms)

The popular concept of a volcano is a conical mountain with a circular base and a pointed top. In deed, many volcanoes have built features matching their image. However, depending upon the nature of the products and how they accumulate, volcanoes build a variety of land forms. These volcanic landforms include:

a. volcanic plains
b. volcanic plateaus
c. volcanic shields (shield volcanoes)
d. volcanic cones
e. craters volcanic cones and related forms
f. calderas

Volcanic plains and plateaus

Flat sheets of extrusive igneous rocks are called volcanic plains or volcanic plateaus. These features are formed from extremely fluid mafic lavas or from mixtures of particles dispersed in volcanic gases that were highly mobile and flowed with great speed as if they were liquid. If their lavas issued from fissures, they form on earth's surface through fissure eruptions.

The most voluminous eruption in recorded history took place in 1783 at Laki, Iceland from a fissure of 32 km long. 12 cubic km of lava were discharged. Spread to an area of 558 sq km. Extended 64 km and 48 km on sides. Volcanic plains and volcanic plateaus are usually regional in extent. They can cover 250,000 sq km. The volume can reach up to 400,000 cubic km.

The difference between a volcanic plain and a volcanic plateau is the height of the surface compared to the surrounding country side.

A volcanic plain is a low lying area in which the volcanic rocks usually are thin. A volcanic plateau is a high standing area usually built by the accumulation of thick sheets of extrusive igneous rocks.

Famous volcanic plateaus are Deccan plateau, Columbia basalt plateau and plateaus on the ocean floors.

Welded Tuff

In many eruptions of felsic lavas the continuity of the liquid phase is disrupted by the violently escaping gases. As a result hot blebs (blisters or bubbles) and clots of lava form a gas and particle mixture known as tephra flow. They behave as if they were fluids or fast moving lava flows.

They travel 30m-100 km/hr. Temperature inside exceeds 1000°c. They form flat-lying layers of particles. They are still hot so they melt together to form the rock welded tuff.

Volcanic Shields (shield volcanoes)

Repeated, quiet eruptions of highly fluid mafic lava from a circular vent or from a rift zone may create a broad, gently sloping conical mound of volcanic rock. They are called volcanic shields. Examples are from Iceland. But largest examples are the Hawaiian islands and other mid pacific islands.

In Hawaii, the volcano **Mauna Loa** was built up slowly from the sea floor 5000 m to sea level and an additional 4,200m more above sea level. Its total relief, therefore, is more than 9,000m. More than Mt. Everest (8848m).

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1. Tephra cones

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The angle of sloping sides of nearly every tephra cone in the world is 25-30 ^{0}. They are rarely higher than about 450m. It can attain this height in several months or a few weeks.

A tephra cone requires considerable reinforcing by lava before it is strong enough to support the weight of a column of lava high enough to flow out the top.

2. Spatter cones

Eruptions of small clots of liquid lava (spatter) may build small, steep sided spatter cones rarely exceeding 30 m high. Their walls are nearly vertical.

3. Complex volcanic cones

They are composed of sloping layers of tephra and reinforcing layers of extrusive igneous rocks, i.e. by cooling of lava flows.

In these cones, lava from the central vent pushes outward through the sides of the cones as flank eruptions. Eventually, the cone's sides my be so strengthened by the sheets of igneous rocks that it is a possible for lava to rise to the top of the cone and to issue forth as summit eruptions.

4. Composite volcanic cones:

There are combinations of complex cones built atop volcanic shields. The Tephra cone is the beginning stage. Great conical peaks such as Fuji in Japan, Vesuvious in Italy, Mayon in Philippines are famous for their beauty and symmetry.

5. Craters:

A circular volcanic orifice having a diameter of less than 1.5 km is a crater. It is opened up by a concentrated jet of hot gases escaping upward through bed rock.

Many craters are situated at the apexes of volcanic cones. Such craters may enlarge as a result of explosive eruptions or as a result of collapse following the withdrawal of lava form the cone.

6. Calderas

A circular feature having a diameter greater than 1.5 km and formed by collapse is a caldera. Calderas differ from craters not only in size, but also in their relationship to the life histories of volcanoes. The world's largest modern caldera is at Mt. Aso, Japan. It measures 16 x 45 km.

TYPES OF VOLCANIC ERUPTIONS

It is difficult to classify as they are complex phenomena. Two principle ways of classification are:

A. Spatial method. It groups eruptions according to the shapes of the volcanic vent.

B. The character of the eruption itself.

A. Spatial groupings:

1. Central eruption
2. Fissure eruption
3. Eruption related to the preexisting volcano

Central vent and fissure eruptions represent the two basic ways in which magma can reach the surface.

Central vent eruptions

Central vent eruptions are the best known kind. Here the lava and the other material is ejected from a hole in the gound, or crater, which is fed by a single pipe-like supply channel, extending deep down below ground.

As the eruption contines, the ejected material piles up round the vent, building up that heap of material that is called a volcano. The standard Fuji-like conical volcanoes are constructed in this way. This can form in any environment like mid-Atlantic ridge, destructive plate boundaries, African rift valleys etc.

Fissure Eruptions

They are different than the central vent erruption. They occur in areas where earth's crust is subjected to tensional forces, trying to pull it apart. When this happens, the crust may actually break gaping open long, narrow slot-like vertical crack. At the surface these cracks may remain open and empty, forming deep clefts, but deeper down, magma forces its way up into the cracks widening it. These magma filled cracks are known as dykes.

If the magma pressure is great enough, it will force its way right up the dyke to the surface, spilling out toform lava flows. It will simultaneously happen all along the length of the syke, and hence called the fissure eruption. Mid oceanic ridges are the favourate sites for tis kind of activity.

Iceland, astride (with one leg on each side, e.g. riding astride) the mid-Atlantic Ridge, provides an excellent example. With the Atlantic ocean floor spreading away in opposite directions from the ridge, Iceland is getting wider at a rate of about half a cm/ year. Most of the material is injected in the form of dykes. Within the last 90 my, the thickness of dyke has reached 400 km.

When paarticularly large volumes of Basalt are involdved, such eruptions are commonly known as basaltic flood eruptions. The most recent example of this kind took place in 1783 when lava was erupted from the 25 km long laki fissure in southern Iceland.

However, in past continental basaltic flood eruptions have occurred in USA, India, S. Africa and S. America. It may be due to the formation of mid-ocean below the continents, but before the proper ocean had opened up. They welled up a vast quantity of basalt. In western USA it covers about 130,000 sq. km.

some times distinction between the central vent volcano and fissure type is difficult and confusive. It depends upon the scale it is considered. For example, Laki eruption is a splendid example of fissure eruption but along its length of 25 km dozens of small volcanic cones were built up, none of them very big, thus each of them can be considered as central vent volcano.

B. Groupings based on the characters of eruption
(Types of central eruption)

1. Hawaiian type eruption
2. Strombolian type eruption
3. Vulcanian type eruption (ultra vulcanian)
4. Vesuvian type eruption (or sub-Plinian)
5. Plinian type eruption
6. Krakatoan type eruption
7. Peleean type eruption

1. Hawaiian eruptions

They are the mildest of all and are characteristic of the Hawaiian island volcanoes e.g. Halemaumau, Kilauea and Mauna Loa. They are right at the middle of the Pacific, they are basaltic , hot and fluid. They are so fluid that they are called “rivers of fire”. Here, since the gas can escape through the fluids easily, so no explosion occurs. There are fountains of lava.

Someties, when eruptions takes place within a large crater, the lava coannot flow away and gets ponded up in the crater. For example in halemaumau volcano, it has adeep circular pit-like crater about 1.5 km across at its summit.

The crater of ten gets filled with lakes of lava which remain molten for long period, e.g. 100 years before 1924. Then after appeared and disappeared several times. it is called the” house of everlasting fire”.

The ease at which the dissolved high pressure gases can escape form Hawaiian magmas lelads to some very spectacular eruptions and make fountains sometimes 400 m high. Sometimes these fountains remain for hours. These are common on oceanic island volcanoes, Because here fluid basalt lavas can be found. In these lavas Pele’s hairs are formed. They develop when caught by a strong wind

2. Strombolian eruptions
(Stromboli volcano lies between Italy and Sicily)

They are slightly more explosive. Stromboli has been showing the same kind of activity more or less continuously for centuries and is often called the “Light house of the Medeterranean”.

In a typical Strombolian eruption basaltic lava is agian involved, but it is not as fluid as that of Hawaiian eruptions. Gas escape takes place spasmodically in minor explosions every few minutes. Each explosion shoots out glowing fragments of semi-solid lava high into the air. Thus it is a bit noisier than Hawaiian type. But still not particularly dangerous. Mt. Erebus (4,045 m) in Antartic, Mt. Etna, Pacaya volcano near (32 km) Guatemala city are other examples and are not dangerous.

3. Vulcanian eruption (near Stromboli)

They are different from Strombolian type of eruption. They differ in the following manner:

a. They dont occur often during the life of the colcano, but when they do, they may continue intermittently for several months.

b. The magmas involved are much more viscous than those in strombolian eruptions, so that the explosive activity tends to be voilent, often demolishing parts of the volcanic structure. In a vulcanian eruption, the ejected material comes in the rom of soild blocks, and highly fragmented ash, andthe explosions are often powerful enough to hae blocks weighing many tons clear the crater.

4. Vesuvian type eruption (sub-Plinian type)

Vesuvian eruption are one step further on from Vulcanian, their principal distinguishing fearure being that rather than intermittent explosions there is a failry sustained blast of escaping gas from the throat of the volcano, which carries the cauliflower ash nuch higher into the air. They eject large volume of ash whcih is always new magmatic material.

5. Plinian eruption
(79 A.D. eruption of Vesuvious described by Pliny)

It is the most violent of all the sequences we have been considering. Although their effects are more extensive Plinian eruptions are not basically very different qyalitatively from Vesuvian type.

The one thing most important about Plinian eruption is shear volume of the fragmentary material ejected by the gas blast. Pompeii, approximately 8 km form Vesuvious was burried over three meters deep in pumice in AD 79. In 48 hours 3 cubic kilometers of ash was produced. There are major structural changes in the volcano. Krakatoa was similar to Plinian eruption but lst four blasts were more voilent in which the sound was heard 4000 km away.

6. Peleenian eruption (1902 Mt. Pelee)

It is a short lived side-shows of Vesuvian and Plinian eruptions. The characteristic feature is the presence of nuee ardente or glowing cloud.

Nuee ardente: Avalanche of an exceedingly dese mass of hot highly gas-charged and constantly gas emitting fragmental lava, much of it finely divided, extraordinarily mobile and practically frictionless because each particle is separated from its neighbour by a cushion of compressed gas.

c. most conspicuous is the great plume of gas and ash rise above the crater, rolling upward in tifght turbulent convolutions often to a height of several kilometers (cauliflower structure).

UNDERGROUND THERMAL ACTIVITY AND THE DISCHARGE OF VOLCANIC GASES

Fumaroles: A volcano that is discharging gas non-explosively is a fumarole (Italian for smooking crack). Gases are CO_2, H_2S, H_2O (vapour).

Geysers: A geyser is a special kind of hot spring that spouts water periodically. It can form only where a connected network of irregular underground opening exists in which the water can accumulate and from which it can escape quickly.