Mountain Building

Component-I (A) - Personal Details

Role	Name	Affiliation
Principal Investigator	**Prof. Masood Ahsan Siddiqui**	Jamia Millia Islamia, New Delhi
Paper Coordinator, if any	**Dr. Sayed Zaheen Alam**	Department of geography, Dayal Singh College, DU
Content Writer/Author (CW)	Dr. Isha Kaushik	Department of Geography, Delhi School of Economics
Content Reviewer (CR)	**Dr. Anshu**	Kirori mal College, DU
Language Editor (LE)		

Component-I (B) - Description of Module

Items	Description of Module
Subject Name	Geography
Paper Name	Geomorphology
Module Name/Title	Mountain Building
Module Id	GEO-6
Pre-requisites	Understanding processes of Mountain Building
Objectives	To comprehend processes of Mountain Building
Keywords	Accredation, Plate tectonics, Convergence

Mountain Building

Orogeny is an essential process in the differentiation of the earth's crust . GK Gilbert (1890) coined the term Orogeny to explain the process of mountain building .Mountains are basically landforms of the second order disseminated all over the globe not only located on the continents but also upon the ocean floors .

The conundrum of mountain building has long perplexed geologists however there has been no dearth of theories to elaborate on the process. Since long Geologists have known that the Fold Mountains have been built up of gigantic accumulation of sedimentary deposits which have been compressed, folded and uplifted but the specific mechanism whereby this was effected has long dodged them.

In view of the fact that Fold Mountains represent the world's major and most complex mountain systems the process of mountain building is frequently described in terms of their formation . On the other hand mountains can be classified according to their for the most part dominant characteristics and the process of formation.

1.)**Residual/Relict Mountain** –They are the remnants of former (old) mountains and plateaus,which have been subject to severe denudation .They are formed by differential erosion because of differing solubility and erodability of rocks in the region .Certain resistant areas may hold out the lowering by agents of denudation as in mountain Monodnock USA and also a plateau may be dissected by rivers as in Deccan Plateau , by leaving behind residual mountains.

2.)**Volcanic Mountains**- They are formed by the accretion of volcanic material round the zone of volcanic eruption .Oceanic ridges are formed by dispersion boundary volcanism .Converging boundary volcanism produces island archs like the Japanese arc .In plate volcanism at hotspots may perhaps manufacture volcanic mountains like in Hawaii.

3.) **Fault/Block mountains**-These are formed by vertical movements of blocks next to faults because of tensional forces or occasionally compressional ones at work in a region .As a result the block is moved up relative to the neighboring areas ,forming the mountains. Black forest ,Vosges and Hunsruck mountain offer good examples

4.) **Upwarped Mountains**-These are shaped by up warming of continental crust compared to the surrounding .Magmatic interruption which more often than not causes the up warming is eventually exposed due to erosion of the overlying materials .Upwarming in a limited area forms dome mountains which look like blisters in the earth's surface .Large scale upwarming when dissected by agents of denudation forms a mountain range.

5.) **Fold Mountains-** They encompass the principal and the most multifaceted mountain systems . Even though fold mountains be at variance from one another on scrupulous details but all have some universal features;

(a) They are arranged in linear belts usually consisting of more or less parallel ridges.

(b) They consist of broad sedimentary sequences the largest part of which are of shallow marine origin.
(c) They all have folded structure
(d) Faulting, thrusting, metamorphism and igneous activities are present in changeable degrees. Examples of Fold Mountains are Himalayan, Alps, Andes, Appalachian, Urals etc.

Quite a lot of theories have been suggested to account for succeeding orogenies throughout the course of the earth's history .The major orogenies have occurred at intervals of 20 to 100 my .For convenient purposes , conversely ,these periods of mountain building may be divided in to three broad groups

(a) Young mountain building
(b) Old mountain building
(c) Ancient crystalline shields

Near the beginning theories of Fold Mountain Orogeny were conquered by contractionist approach .The contractionists considered the earth as a heat engine running down i.e. cooling and contracting .Based on the fundamental assertion they put forward their theories of Mountain building.eg.

1) Harold Jeffreys suggested that Fold mountains are simply wrinkles in the earth's crust produced as the earth cooled from its original semi molten state.
2) Joly suggested periodic melting and solidification of the simatic layer due to radioactive heat and consequent sinking of buoying up of the sialic layer (continental crust). Thus process creates horizontal compressive forces causing folding, thrusting and upliftment of sediments at the continental, margins resulting in to formation of the mountains.
3) These two and many other early theories could not achieve extensive acceptance .Any variable theory must explain the deposition of thick sedimentary sequences in shallow marine water their compaction ,folding, upliftment, faulting, thrusting, metamorphism and associated igneous activity.

Geosynclinal theory

Geosynclinal theory was the first theory to obtain extensive acceptance because it hurled light on the most of the distinguishing feature of Fold mountains and the process involved in their formation. It was during 1850 by James Hall and; later on modified by Dana throughout 1870 .They were the first to talk about the subsistence of long linear trough called syncline and subsidence of crust under the weight of deposition . These theorists necessarily give details about the Orogeny in Five stages.

(a) Geosynclinal Stage- In this stage gigantic amounts of sediments mount up on a large linear trough which keeps subsiding under the weight of deposition. Owing to isostatic adjustments the layer below sediment deposition in the continental shelves become synclinal.

(b) Lithogenesis;It is the process in which compaction and cementation work therefore deposited sediments are converted in to solid rocks
(c) Tectogenesis;It is the process by which the earth's crystal rocks are deformed and their structures created .When such processes act regionally they contribute to orogenesis.
(d) Orogenesis : It is a process which comprises of folding. Faulting and thrusting during which sediments within geosynclines are bulked and deformed as they are compressed in to long linear mountain chains. At the same time some sediment , on being pushed much deeper, melts to produce magma ,which moves upwards and impinges the overlying sediments . Consequently a complex mountain chain consisting of folded and faulted sedimentary and volcanic rock surrounding a core of igneous intrusions and metamorphic rock is created .This stage is transitory.
(e) Glyptogenesis:It is the mainly orogenetic phase during which the distinguishing surface forms are sculptured by erosion .Removal of material form the top and resultant upward isostatic adjustment exposes the batholith from underneath the mountain in due course forming a shield. Even though the geosynclinal theory provides for the basic steps in mountain building the underlying cause of orogenesis was not explained and there were many missing links .A number of objections were raised against the theory .What produced the subsidence in the geo syncline?Why did sediments mount up, comparatively undisturbed for million of years , and all of a sudden go through a period of deformation? Such unanswered questions forced geologists to continue to appraise the complex problem of mountain building.

Plate Tectonic Model

It is an improvement over the geosynclinal idea.It throws light on an assortment of processes in mountain building and decodes many of the puzzling aspects.Orogenesis results as huge segments of earth's lithosphere are displaced according to this theory. Fold mountains orogeny occurs along converging plate boundaries .Here the colliding plates supply for the compressional stress to fold, fault, metamorphose, thrust, and uplift the thick sedimentary accumulations along the margins of continents at the same time as melting of the sub ducted oceanic lithosphere provides a source of magma that intrudes and extrudes ,further deforming and metamorphosing these deposits. On the other hand the characteristics of mountain belts and the sequence of events vary depending on the type of interaction at plate margins and the type of rock sequence involved in the deformation. There are three type of converging interactions –ocean to ocean ,continent to ocean and continent to continent collisions.

Mountain Building and Island Arcs

Over an extended period, plentiful episodes of volcanism , coupled with the buoyancy created by intrusive igneous masses , slowly but surely increase the size and elevation of developing the arc. The arc's greater height accelerates the erosion rate and as a result the amount of sediment added to the adjacent sea floor and to the back are basin Moreover to the sediments derived from land, deep water deposits are also scraped off the descending oceanic plate. As these sediments are piled up in front of the overriding plate, they form what is known as an accretionary wedge.

The compressional stresses wielded by the converging plates cause the accretionary wedge ,along with the silvers of oceanic crust that have been sheared from descending plate. To become long-winded folded and cut by copious thrusts faults. Continued growth can build an accretionary wedge that is in due course large enough to stand above sea level..

Landward of the trench, in the volcanic arc, sediments are also being deformed and metamorphosed .Where as metamorphism in the accretionary wedge is primarily the result of strong comptressional forces created by converging plates , metamorphism in the vicinity of the volcanic arc is associated with the emplacement of large magma bodies. These diverse activities result in the creation of a mature island arc composed of two roughly parallel orogenic belts.

Geologists have only recently come to realize their significance of island arcs in the process of mountain building .There is now general agreement that the processes operating at modern island arcs represent one of the stages in the formation of the earth's major mountain belts. Because island arcs are carried by moving oceanic plates , it is possible for two arcs to collide and sutured together to form a larger crustal fragment. Moreover island arcs may also be accreted to continent –sized blocks , in which case they become incorporated in to a mountain belt.

Subduction –type Orogenesis Along Continental Margins

The first stage in the development of Andean –type mountain belt occurs prior to the formation of the subduction zone .During this period the continental margin is passive; that is, it is not a plate boundary but a part of the same plate as the adjoining oceanic crust . Here deposition of sediments on the continental shelf is producing a thick wedge of shallow water sandstones, limestones and shales . Beyond the continental shelf turbidity currents are depositing sediments on the continental slope and rise.

At some point the continental margin become active , a subduction zone forms and the deformation A good plate to examine an active continental margins the west coast of South America .Here that Nazca plate is being subducted beneath the South American plate along the Per-hile trench.

Once the oeanic plate descends to about 100 kilometers, partial melting generates magma that migrates upward ,intruding and supplementary deforming these strata. Andean- type mountain belts, like mature island arcs are composed of two roughly parallel zones. The landward segment is the volcanic arc , which is made up of volcanoes and large intrusive bodies intermixed with high temperature metamorphic rocks. The belt located seaward of the volcanic arc is the acretionary wedge. It consists volcanic debris.

Continental collisions

The development of a mountain system produced by a continental collisions is believed to occur as follows:

1. After the breakup of a continental landmass , a thick wedge of sediments is deposited along the passive continental margins, thereby increasing the size of the newly formed continent.
2. For reasons not yet understood, the ocean basin begins to close and the continents begin to converge.
3. Plate convergence results in the subduction of the intervening oceanic slab and initiates an extended period of igneous activity . The activity results in the formation of a volcanic arc with assoiated granitic intrusions.
4. Debris eroded from the volcanic arc and material scraped from the descending plate adds to the wedges of sediment along the continental margins.
5. In due course the continental blocks collide. This event which often involves igneous activity severely deforms and metamorphoses the entrapped sediments. Continental convergences cause these deformed materials , and intermittently slabs of crustal material , to be displaced up on to the colliding plates along the thrust faults .This activity shortens and thickens the crustal rocks., producing elevated mountain belts.
6. Eventually, a hange in the plate boundary ends the growth of the mountain. Only at this point do the processes of erosion become the overriding forces in altering the landscapes. Large quantities of coarse sediments are deposited in basins found within and coupled with isostatic adjustments eventually reduce this mountainous landscape to the average thickness of the continents.

This sequence of events is thought to have been duplicated many times throughout geologic and climatic settings varied in each case in point. Thus the formation of each mountain chain must be regarded as a exceptional event.

Orogenesis and Continental Accretion

Recent investigations now point out that yet another mechanism of mountain building exists. This new proposal suggests that relatively small crustal fragments collide and merge with continental margins and that through this process of collision and accretion , many of the mountainous regions rimming the Pacific have been generated . Researchers believe that prior to their accretion to a continental block, some of the fragments may have been micro continents similar in nature to the present day island of the Madagascar. Many others were island arcs , such as Japan , the Philippines , and the Aleutian islands, which presently rim the pacific.

The widely accepted view today is that as oceanic plates move, they carry the embedded island arcs and micro continents ton a subduction zone. Here the upper portions of these thickened zones are peeled from the descending plate and thrust in relatively thin sheets upon the adjacent continental block . This newly added material increases the width of the continental.

Geologists refer to these accreted crustal blocks as terranes . Basically the term terrane designates any crustal fragment whose geologic history is distinct from the adjoining terrane. Terranes come in a variety of shapes and sizes . Some are just small volcanic islands. Others such as the one composing the entire Indian subcontinent are much larger.

The removal of thrust sheets from subducting plates manifestly plays a key role in this accretionary process on the other hand, the manner in which thin sheets are peeled from the descending oceanic lithosphere remains doubtful. Auxiliary in many locations where accretion is thought to have occurred, substantiation of the volcanic activity normally associated with subduction is lacking.

In the face of these problems and many other questions which are unanswered, the plate tectonics theory appears to hold the maximum guarantee for understanding the origin and evolution of the earth's major mountain belts. The geologic history of each mountain system will surely be reevaluated in terms of this model. Such work will shed new insight on their evolutionary histories and will also be fruitful in evaluating the theory itself. In this way new insights in to the workings of our dynamic planet will surface.

The Origin and Evolution of Continental Crust

What roles have plate tectonics and mountain building played in events that led to the origin and evolution of the continents? At this time no solitary answer to this question has met with awe-inspiring acceptance.

At one extreme is a proposal that most , if not all continental crust originated during the primeval molten stage and coincided with the segregation of material that produced the earth's ore and mantle.

A differing view, which has obtained support in recent years, contends that the continents have grown larger through geologic time by the gradual accretion of material derived from the upper mantle. A main tenet of this hypothesis is that the primitive crust of an oceanic type and the continents were small or possibly nonexistent then, through the chemical differentiation of mantle material, the continents slowly grew.

This view proposes that the formation of continental material takes place in numerous stages. The first step occur in the upper mantle directly beneath the oceanic ridges .Here partial melting of the rock peridotite yields basaltic magma which rises to form oceanic crust.

As new ocean floor is generated at the ridge crests, older oceanic crust is being destroyed at the oceanic trenches. In trench regions , the sub ducted oceanic crust is heated sufficiently to cause partial melting .This gives rise to some relatively light , silica-rich rocks which are then emplaced in the volcanic arcs .The subducted oceanic crust , depleted of its lighter constituents , continue to sink and is no longer involved in the process of generating crustal rocks .

According to one view, the earliest continental rocks came in to existence at a few isolated island arcs. Once formed, these island arcs came together to form larger continental masses, at the same time as deforming the volcanic and sedimentary rocks that were deposited in the superseding oceans. In due course this process generated masses of continental crust having the size and thickness of modern continents.

Evidence supporting the view of continental growth comes from research in regions of plate subduction ,, such as Japan and the western flank of America. Equally vital, on the other hand has been the research conducted in the stable interiors of the continents , predominantly in the shield areas.

Topical indicators are that the rocks of the shield areas are mineralogically and structurally similar to the rocks found at active continental margins where oceanic crust is being consumed .More specifically the granite gneiss terranes are chemically similar to the intrusive igneous bodies .

Radiometric dating of rocks from sheld areas, including those in Minnesota and Greenland has revealed that the oldest terranes formed some 3.8 billion years ago . This date is believed to represent one of the earliest periods of mountain building.At that time , possibly only 10 percent of the present continental crust existed .The next major period of continental evolution may have taken place between 3 and 2.5 billion years ago as indicated by radiometric dates of similar terranes found in the shield areas of Canada, Africa, and Western Australia.

It is not known with certainty how many periods of mountain building have occurred since the formation of the earth .The last major period evidently coincided with the closing of the proto—Atlantic and other ancient ocean basins during the formation of the supercontinent Pangea.

If the continents do in fact grow by accumulation of material to their flanks, then the continents have grown larger at the cost of the oceanic crust. This view assumes the buoyancy and indestructibility of continental crust .Even the sediment derived from the erosion of continental material that is subducted along with oceanic plate melts and returns to the continents. Even though continental crust apparently remains afloat indefinitely, some continents are occasionally fragmented and carried along in a conveyor belt fashion until they collide with other landmasses . Presently, Australia , which separated from Antarctica , is being rafted northward and well [probably join Asia in much the same manner as India did about 45 million years ago . Consequently according to this view , fragmentation and the formation of new crustal blocks that accompanied the reshuffling of these fragments are responsible for the present volume structure and configuration of continents.

Plate tectonics comes into sight to be the major force in crustal evolution over last 2 billion years . However, during the early history of the earth , the heat released by the decay of uranium , thorium, and potassium must have been more than twice as great as it is today .