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Component-I (B) Description of Module

Items	Description of Module
Subject Name	**Geography**
Paper Name	**Geomorphology**
Module Name/Title	**Earth Movements: Epeirogenic, Orogenic, Cymatogenic**
Module Id	**GEO-04**
Pre-requisites	**Plate Tectonics, Folding and Faulting, Volcanism**
Objectives	**Total Six**
Keywords	**Exogenetic, Endogenetic, Diastrophic, Glacial isostasy, Epeirogenic, Cratons, Orogeny, Cordilleran, Cymatogenic**

Earth Movements: Epeirogenic, Orogenic, Cymatogenic

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The objectives of present module are as follows:

1. **Introduction**
2. **Earth Movements**
3. **Type of Earth Movements**
4. **Epeirogenic Movements**
5. **Orogenic Movements**
6. **Cymatogenic Movements**

1. Introduction

Earth's surface is not stable but is changing constantly. None of the landforms found on the earth surface are forever. There are various geomorphic processes working on the landforms. These processes were working in the past and also working presently though with varying degree and intensity. The earth's crust is influenced by both internal and external forces, which may affect the earth on both major and minor scale. Internal forces may include upliftment, contraction, expansion, disruption, distortion and outpouring. External forces would include forces of denudation like weathering and erosion. The description of the landforms cannot be explained only through these forces since these changes are so slow that they go unnoticed. But when these changes are sudden like volcanic eruptions, landslide and earthquakes we can observe and notice these changes. The present landforms are a manifestation of complex and intricate interaction of earth's material facing resistance on one hand from and tectonically- and climatically-derived forces.

2. Earth Movements

As we already know that earth's crust is constantly effected by the internal forces. The main causes of such internal forces can be the radio activity originating within the deep interiors of the earth's crust or substratum and the resultant convection currents caused by it. These convection currents cause the crust to move which further causes sudden and rapid movements like earthquakes or extremely slow movement like mountain building and continental building which may take millions of years. These movements can cause **upliftment, warping, turning, twisting, tilting, fracturing, subsidence and distortion of crust** and some may even cause, squeezing of the rocks which would give rise to high mountain ranges.

3. Type of Earth Movements

There are broadly two kind forces that causes earth movements. They are as follows:

3.1 Exogenetic forces/Exogenic/Epigene

Exogenetic is mostly **destructive forces**, which through various processes would try to change the various relief features on the earth surface by smoothening, carving and molding these features.

3.2 Endogenetic/Endogenic/Hypogene: (In Greek 'endo' means within and 'genera'-origin)

Endogenetic forces can **give rise to various structural features** on earth's surface, which are related to uplifment and subsidence, folding, faulting, fracturing and volcanic eruption. All the landforms and relief features found on the earth are formed of earth's materials. The landforms are formed because of various geomorphic processes operating on and beneath the earth's surface at differential rate. The exogenetic processes derive their energy from Earth's internal (endogenetic) which gives mobility to the earth's crust (tectonism) and from climate which takes further help from the sun which is its driving force.

3.2.1 **Endogenetic movements** can be of two types –

i) **Diastrophic and**

ii) **Sudden movements**.

In Greek 'diastropos' means turned, twisted and distorted. Diastrophic forces are the ones that generally **originate from deep beneath the earth's surface** and acts as vertical force, and work against the exogenetic forces like **gradational processes**. They disrupt the process of reducing the earth to the sea level by forming various landform features on it.

3.2.1.1 Diastrophic forces can be classified into three categories –

i) **Tectonic**, ii**) Isostatic** iii) **Eustatic**

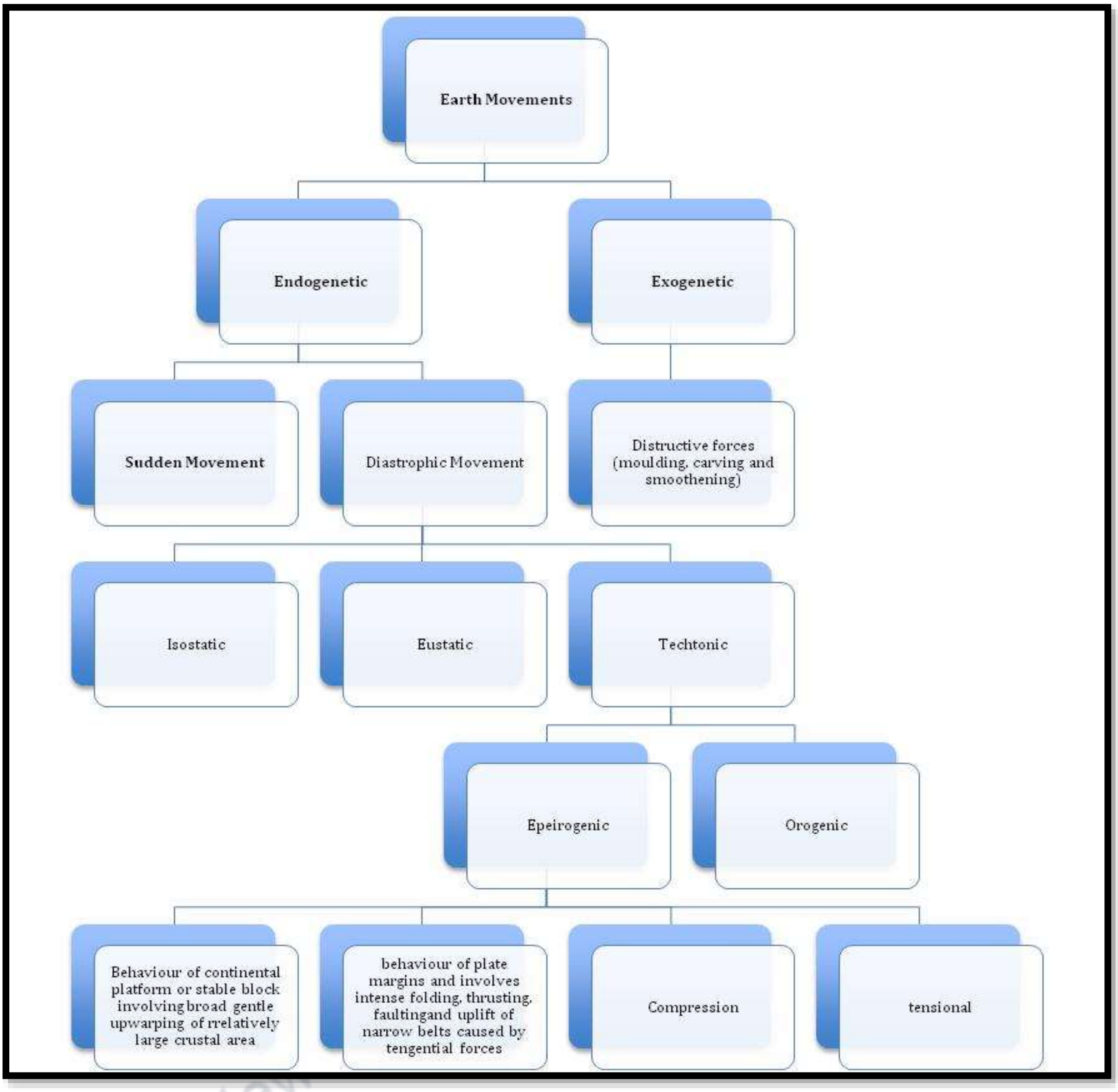
Within diastrophic forces Tectonic, (In Greek 'tekton' means builder) is the most commonly used word as it has very wide connotations. Tectonic movements can be

Epeirogenic Movements and **Orogenic Movements.** These energy forces which emanate from within the earth's crust include **nop-isostatic or crustal warping within the mantle** (which is called epeirogenesis), earthquakes, folding (which is mountain building or orogenesis), faulting, metamorphism due to heat flow and vulcanism.

Endogenetic processes receives less importance in geomorphological studies. But these forces are increasingly gaining importance and appreciation because of the effects of such movements, in certain areas of the world such as the **circum-Pacific belt** and areas of **young-fold mountain.** They are expressed and studied for the earthquake activity and in vulcanicity in the said areas their important influences on such areas. In such areas where the endogenetic influences are more powerful can alter the changes brought by the exogenetic processes. **Gilbert** had defined epeirogeny as the process of **continental building** and in parallel to this he had defined orogeny as the process of mountain formation. These two sets of processes differ enormously in the scales of space and time.

In Many regions of the earth where the vertical crustal movements is very slow and is measured in millimeters per year (1 mm/yr = 1 m/1000 yrs. = 1 km/million yrs.) have persisted throughout late Cenozoic time, the rate of cumulative uplift has outpaced erosional lowering. Such tectonic geomorphology is associated with the construction of the landscapes. These are regions, of erosional landscapes in which the tectonic origins are still obvious.

Fig. 1 shows a chart, which explains the division of the major earth movements.



4. Epeirogenic Movements

Eperiogenic movements are the ones, which operates vertically from the center of the earth to its surface caused by radial forces (Convection Currents). (Fig.2). It is causes regional upliftment but on a large scale therefore, not much noticeable deformation of the surface takes place.

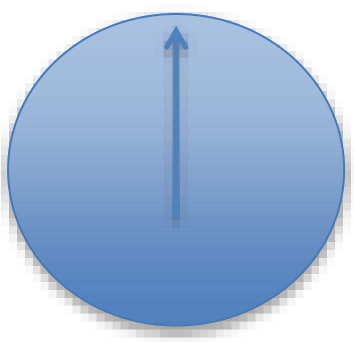


Fig. 2, Vertical Movements

In Greek '**epeiroes**' means a continent. They are very wide and large scale movements, spreading over the continental platform or the stable block of land. Therefore these processes are also known as continental formation. They characterizes by broad, gentle and wide spread warping, subsidence, upliftment, emergence, submergence, of large land areas. These movements are so slow and widespread that no obvious folding and fracturing can be seen in the rocks.

Bloom has defined epeirogeny as continental vertical tectonic movement of low amplitude relative to its wavelength, not within an orogenic belt, that does not deform rocks or the land surface to an extent that is measurable within a single exposure.

This broad regional tectonic movement with no local deformation can be either positive movement like upliftment or negative movement like subsidence. Upliftment movement causes the upliftment of the continental masses. Either whole continent, or the part of it. It also causes upliftment of the coastal land of the continents. Such type of upliftment is called emergence.

Subsidence of the continental masses again happens in two ways – one is subsidence of the land area called subsidence, alternately the land near the sea coast is moved downward or is subsided below sea level and is thus submerged under sea water. Such movements are called submergence.

Glacial isostasy, is one more kind of epeirogeny, in which the reason for the regional subsidence is the weight of an ice sheet. **Deglaciation** as result of the removal of this load and postglacial recovery has resulted in its discovery. **For detail refer module number 8 on Isostacy.**

Did You Know?

These large-scale movements were prevalent in all continents of the earth's surface including Antarctica. Various evidences have proved both upward and downward movements, since Precambrian times. For example, presence marine sedimentary rocks of Palaeozoic, Mesozoic and Cenozoic age, which lie on all continents, upon the much eroded older rocks.

4.1 Epeirogenic Landforms

Prevailing **isostatic equilibrium** has maintained the average continental crustal "freeboard" within less than 100 meters of sea level throughout Phanerozoic geologic history. The "freeboard" of a continent is the amount exposed above sea level. These freeboards are supported by **isostatic buoyancy**. If a continent has crustal thickness as just 30 kms and density of 2.8 g/cm3, it will not be having any freeboards but will be at isostatic equilibrium just at sea level. Only at the orogenic belts where the crust more thickness, otherwise continental crust is typically not thicker than 33 kms., therefore even the minor changes in the sea level owing to the epeirogenic_movements can lead to the flooding of extensive areas of the continent and deposition of the layers of sediments. There are many examples to prove such kind of Subsidence. **For detail refer module number 8 on Isostacy.**

Over a very large area of the continent one can find sedimentary rocks of 1000 to 2000 m in total thickness. These rocks are **undeformed marine sedimentary rocks**, which over lay over igneous and high-grade metamorphic rocks of the continental crust. They are as old as the early Paleozoic Era. These sedimentary rocks are like platform separated by disconformities that have only minor relief. They were never high enough above sea level to be subjected to deep fluvial dissection. These **platform sedimentary rocks** that are almost in their initial depositional attitude, are almost completely eroded from its continental landscape before any relief feature of significance can emerge over it. In such landscape erosional features like broad structural domes cover crust and basins with epeirogenic tectonic relief of a few hundred meters over distances of hundreds of kilometers are common. Whereas the submergence of strata is very less and undetectable, usually less than 1 per cent.

At the central region **topographic basins** are formed when these epeirogenic dome are subjected to erosion. The rate of tectonic upliftment is extremely slow and less compared to the rate of erosion. The result is **topographic inversion** by erosion on epeirogenic structures.

Movements of greater magnitude are to be seen by the sedimentary successions built upon the continental shelves within the continent themselves. Vast depression is recorded towards the end of Cretaceous period, with series transgressed sediments deposited in epicontinental seas. On the stable blocks of the continents one can notice the various kinds of sedimentary deposits. They could include Aeolian deposits, lacustrine deposits, coal, evaporates and tillities also the arkores formed out of decayed uplifted mountains. A sequence of such long continuous deposits can be seen in the interior of low and stable continental margins of the Karroo sediments of South Africa. Lake Victoria and Lake Kyogo in E Africa is another example illustrating the shallow basin with sinuous outlines, indicating drowning of land.

Cratons also known as **continental cratons** are the extensive continental crust or **shields.** They are a complex of deeply eroded accreted orogenic terrains and can be ranged to various ages. It has crystalline shields or platforms of thin, old sedimentary rocks, which monotonous, low altitude and low relief not far above sea level, and can date back to many centuries. About one-third of the sub aerial landscape is eroded from exposed ancient igneous and metamorphic rocks of the continental crust, without any sedimentary cover. They are exposed rocks which must have solidified from magma or metamorphosed at depths of 10 to 20 km or more. For example, present relief on the Canadian Shield continues as an unconformity under the Paleozoic and Mesozoic sedimentary rocks on its periphery. The **Australian craton** is a region of exceptionally low relief and tectonic stability, with landforms alleged to be $10^7$to 10^s years old. Fig. 3.

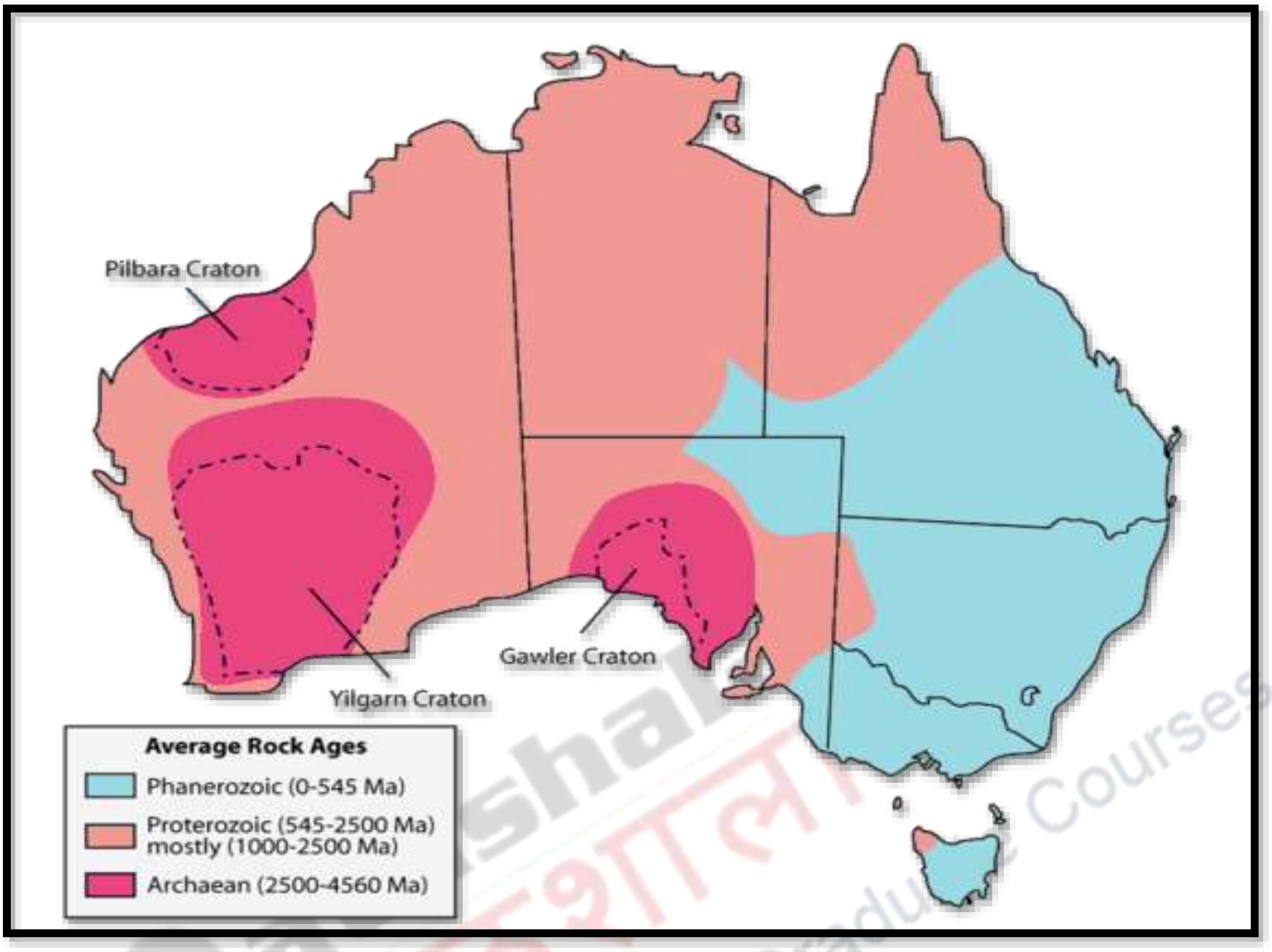


Fig. 3

Source: https://upload.wikimedia.org/wikipedia/commons/thumb/b/bd/Australian_rock_ages-MJC.png/568px-Australian_rock_ages-MJC.png

If Cratons are such large low lying platforms of thin, old sedimentary rocks, then what tectonic processes could cause the epeirogenic uplift of other large continental areas. A very characteristic behavior of craton is **long continuous rise of localized plateau**. The local circulation causes elevation. These elevations are caused by **mantle plumes** deep beneath the areas of continental crust or due to collision of two continental pates. This elevation can be as fast as 8 mm per year. The up-arching of the continental crust by the hypothetical plume head may also have caused the **surface rifting** and **volcanism i**n the **Columbia Plateau** and **Snake River Plain** to the north. This plum migrated to the west with its tail in the fixed in the mantle, therefore it appears to have migrated eastward from Columbian plateau to ita present position under Yellowstone volcanic plateau.

Did You Know?

The west of Yellow stone National Park covers about 8000 sq kms. The area is rising slowly at the rate of about 3 to 5 mm per year. From 1955-73 the Central Adirondacks in New York State rose by 40 mm and its northern margins subsided to about 50 mm. The rate at which the Rhine Massif is rising is about 0.35mm per year. The Colorado Plateau have risen for about 550 mm at the rate of 0.1mm per year in the late Cenozoic and the Deccan Plateau in India has uplifted in the Tertiary and Quaternary and continues at present at the rate of 0.36mm per year.

5. Orogenic Movements

Orogenic Movements are the ones, which work horizontally to the surface of the earth like tangent to the surface of the earth therefore they are also called **tangential forces**. These forces work in two ways 1) opposite direction which means, **tensional force** or divergent forces and 2) towards each others which means, **compressional forces** or convergent forces. Such tectonic geomorphology is associated with the construction of the landscapes. The rate of the crustal movement can be measured in millimeters per year (1 mm/yr = 1 m/1000 yr = 1 km/million yr). The results these strain and stress of the rocks have produced great folded ranges of mountains and therefore it is called 'oros' which in Greek means mountains.

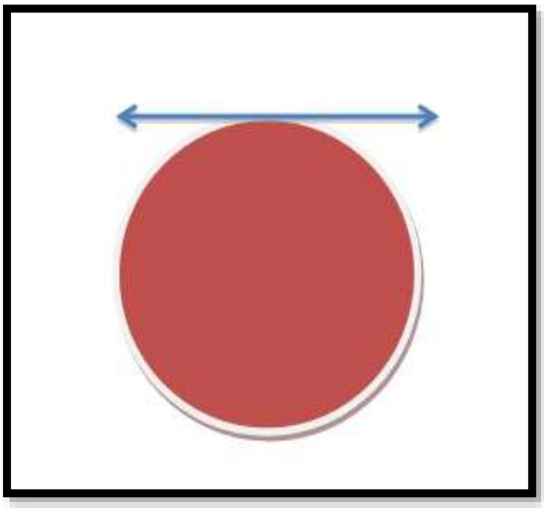


Fig. 4 Horizontal Movement

There are many regions of the earth's surface where the vertical crustal movements have persisted throughout late Cenozoic time. The rate of cumulative uplift has outpaced erosional lowering. Such tectonic geomorphology is associated with the construction of the landscapes. There are regions, of erosional landscapes in which the tectonic origins are still obvious, constructional landscape of such region is called **tectonic geomorphology**. **Orogeny** clearly refers to mountain formation. Unfortunately, in geologic usage, the term has assumed much more complex and contradictory implications. Gilbert (1890) formalized the term: "Displacements of the earth's crust which produce mountain ridges are called orogenic"

5.1 Compressional Forces

Crustal Bending:

When due to horizontal movement which is working towards each other crustal rocks are forced to bend it is called crustal bending.

It can be of two kinds:

5.1.1 Warping: when the large area of the earth's crust is affected by crustal bending. When the crust is bending upward it is called up warping and when the crustal part is bent downwards like a basin or depression then it is called down warping.\

5.1.2 Folding: When the crust is layered and bedded with sedimentary or igneous rocks and already have a preexisted rock structure. In such cases a slight fold in any such structures would result in a wave like structure. The up folded rock strata is called **anticline,** down folded strata is called **syncline.** Fig. 5. Two sides of fold are called **limbs**.

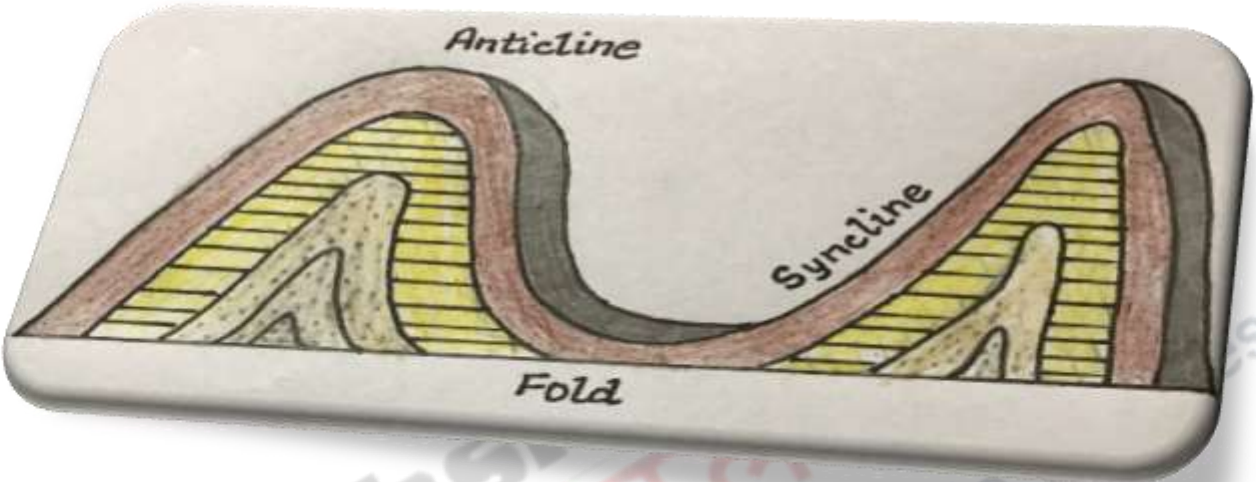


Fig. 5

The axis of the syncline and anticline are called **axis** of syncline and anticline and area in-between them is called **axial plain**. Fig. 6.

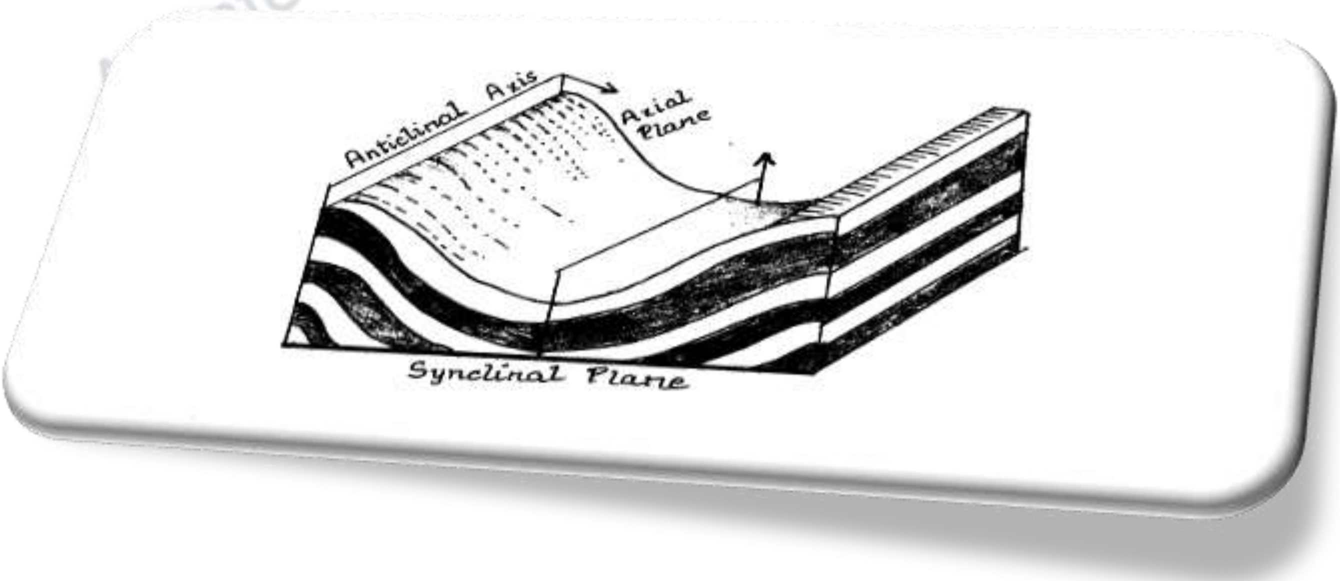


Fig. 6

Different kind of folds depends upon different factors like nature of the rocks involved (elasticity and rigidity), intensity and duration of the compressive forces (magnitude). Difference in the elasticity and the magnitude give rise to leads to difference in the inclinations of the limbs.

1. **Symmetrical folds**: both limbs inclined uniformly
2. **Asymmetrical folds**: both limbs inclined at different angles.
3. **Monocline folds**: one limb inclined moderately and one steeply inclined.
4. **Isocline folds**: both limbs become parallel to each other due to immense force but are not horizontal.
5. **Overturned fold**: limbs folded beyond vertical and turn so much that both the limbs bend in same direction.
6. **Recumbent fold**: The compressive force is so strong that both the limbs bed and become parallel to each other.
7. **Nappes**: When the pressure of the compressive force continuous and as a result the root of one of the limb is uprooted and thrust on the opposite limb.

For detail kindly refer module number 5 on Folding and faulting.

5.2 Tensional force

Faults are formed due fracture in the crustal block and their displacement.

Fault Plain is the plane along which the vertical or the horizontal displacement takes place. **Upthrown side** and **downthrown sides** are the two sides representing upper block and the lower block respectively. Angle between the fault plain and horizontal plain is called **fault dip**. Fig. 7.

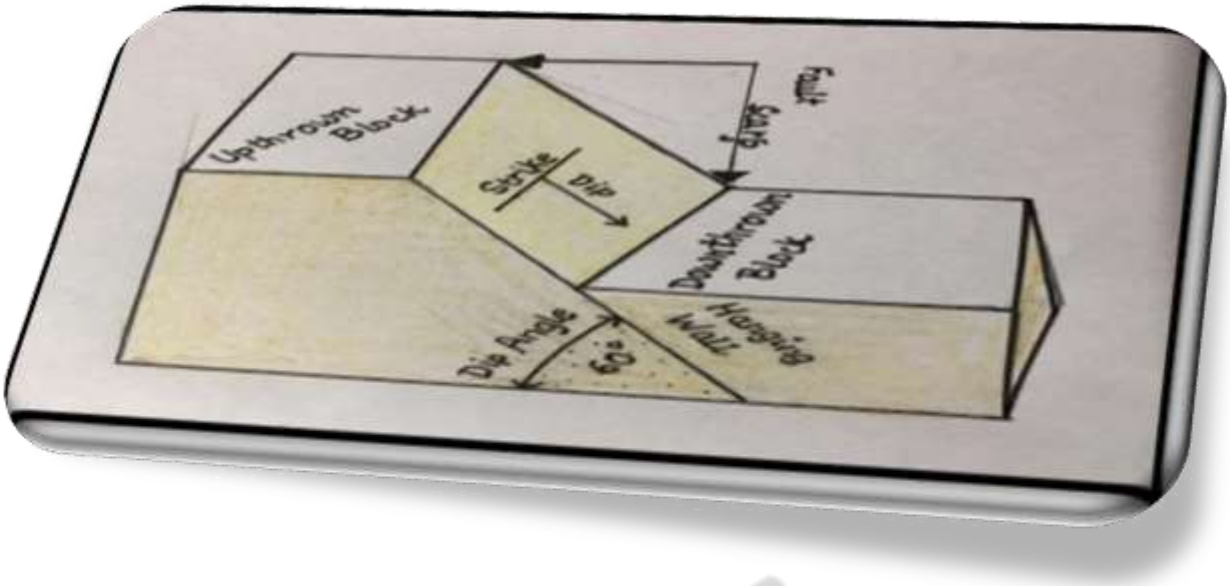


Fig. 7

The direction of the displacement of the crustal blocks defines the type of fault, which can be dip-slip fault, or strike- slip fault.

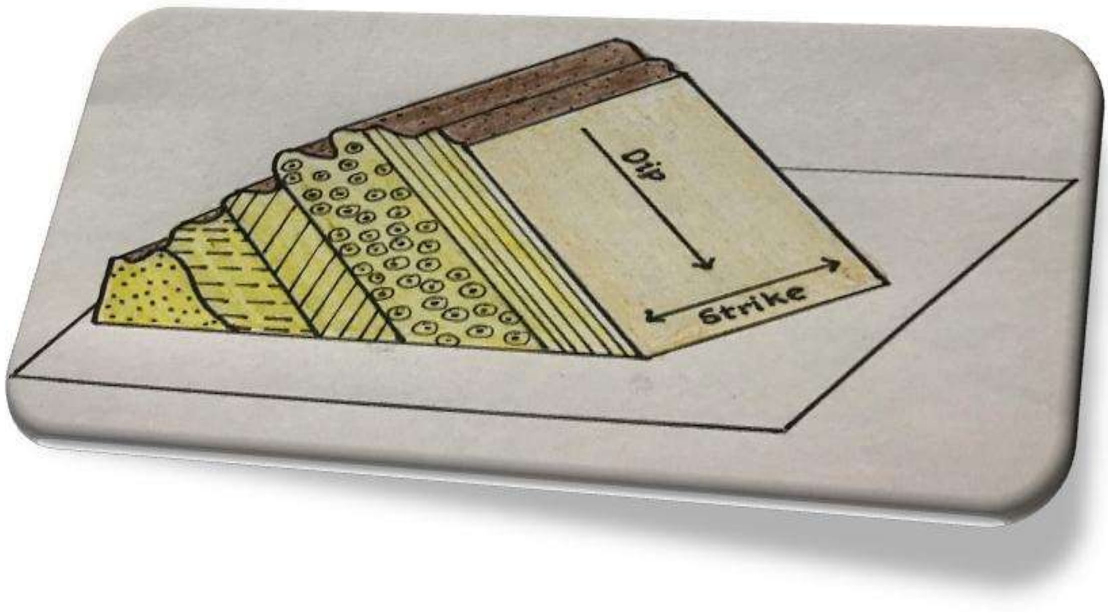


Fig. 8.

1. **Normal Fault**: when the tensional force pull apart the crustal block in the opposite direction. Down dropped block, is graben or rift, upthrust block is a horst.

2. **Reverse fault:** when the movement of the fractured block is towards each other due to compressional forces, hence also called compressional fault. Fig. 9.

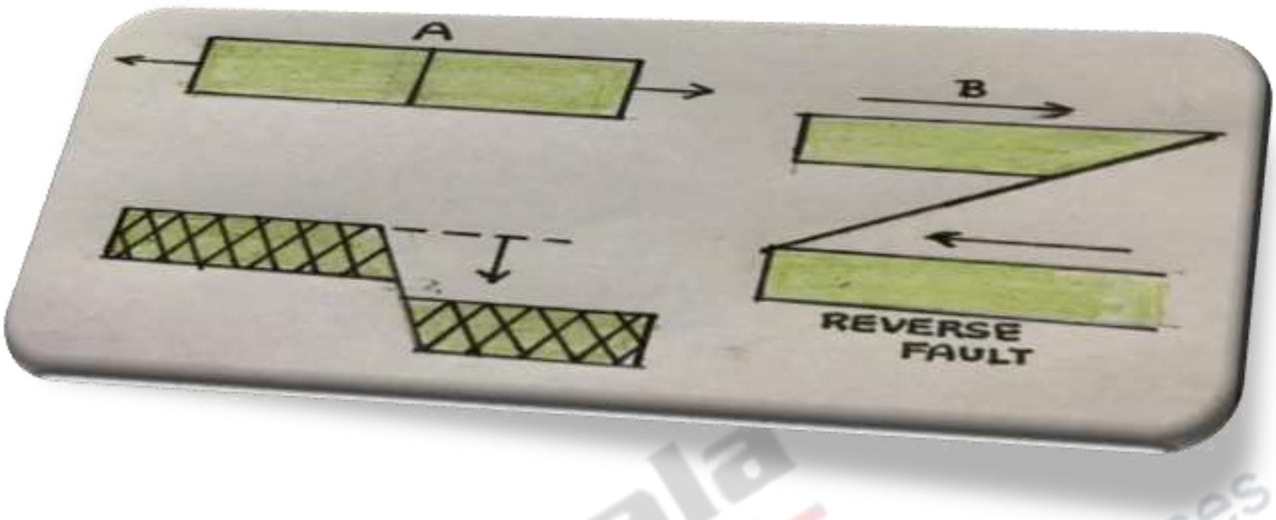


Fig. 9

3. Lateral fault: also called strike slip fault is when the displacement is horizontal. Fig. 10.

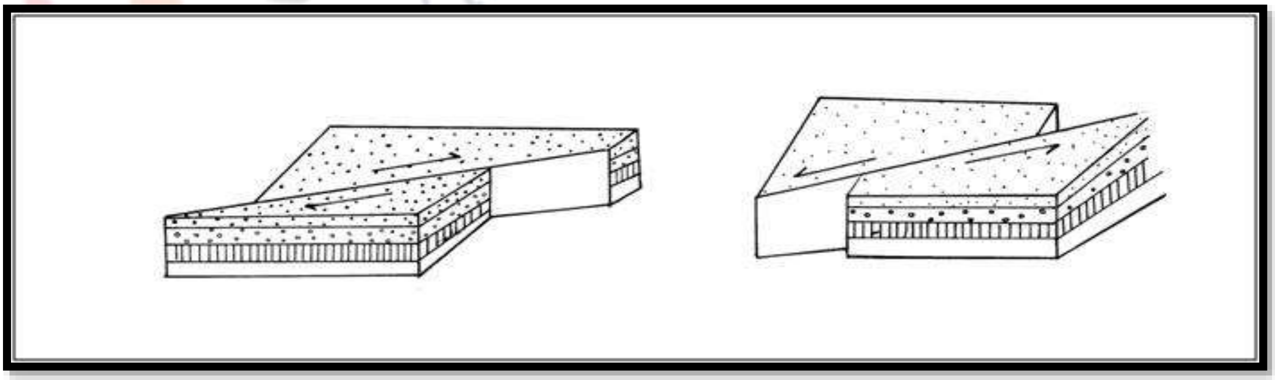


Fig. 10

4. Step fault: series of faults with their slopes in one direction.

For detail kindly refer module number 5 on Folding and faulting.

5.3 Mountains and Orogeny

The process of mountain building runs in a cyclic motion, which reoccurs periodically throughout the geological time scale. Between two periods there can be long periods where the earth's crust remains relatively stable.

All orogenic belts are on or near converging plate margins. Plate boundries can be wide if they are embedded within the continents, as in central Asia (Gordon and Stein, 1992, p. 334). Mountain ranges embedded within continents, such as the Himalaya Mountains and the Ural Mountains of Asia, have been shown to have been near plate margins at their time of formation. The new continental terranes are accreted to them later. In Orogenic movements it is not necessary that vertical movements are more rapid than broad, regional movements. However, they seem to be more continuous through time.

It is to that not all orogenic mountain belts are randomly placed but are in some distinctive patterns over the earth's surface. Even though there is no direct relationship of the earthquake zone area and the orogenic belt but we find circum-Pacific belt associated with active volcanoes along subduction zones. Three distinct types of orogenic belts can be identified on converging plate margins:

5.3.1 Island arcs and trenches: Along thousands of kilometers of weatern pecific margins along Indonesia, in the Caribbean Sea, there are subduction zones between two portions of oceanic plates or lithosphere. The plate which is drowning, flexes upward in a broad outer swell seaward of the trench, into which it descends beneath the overriding plate. When the plate submerges it rubs with inner trench wall and scraps the accumulated sediments consisting of deformed mudstone and sandstone. Many times such deformed sedimentary rocks rises above sea level to form **frontal arc** of mountainous islands. Volcanic arcs of andesitic composite cones can follow **island arcs**. The upper plate spreading in response to the buoyancy of the subducted plate. Fig.11.

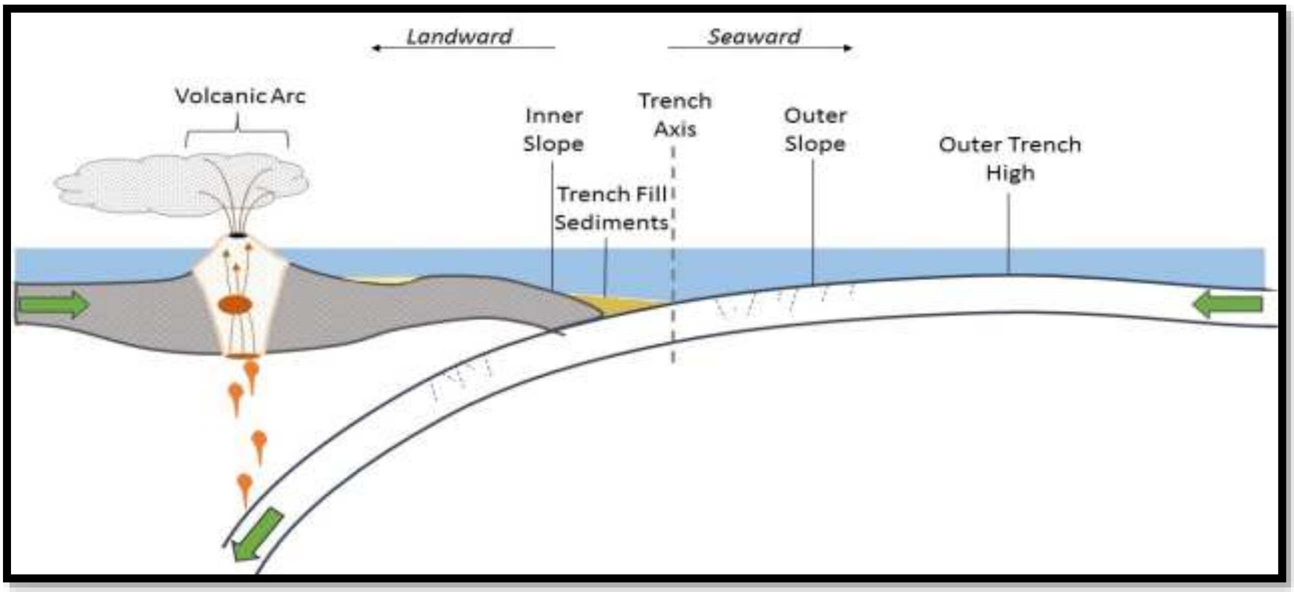


Fig.: 11
Source: https://upload.wikimedia.org/wikipedia/commons/9/91/Subduction_Trench_Schematic.jpg

5.3.2 Cordilleran-Type Mountain Ranges: On the cordilleran type of converging plate margin, (like the Andes Mountains of South America), complicated mountain ranges evolve, where the oceanic lithosphere subducts under thicker continental lithosphere. Narrow coastal ranges may be formed on the edge of the continent as a result of accretionary prism of trench sediments or to faulting and uplift of continental crustal blocks along with an elongate longitudinal valley, parallel to the coast. With older sedimentary and metamorphic rocks as the axial part of the belt, the volcanic peaks on a cordilleran type of mountain belt rise above a broad plateau. Due to heavy compression the central mountain range becomes thick and continental crust makes it rise because of isostatatic adjustment. The continental platform and can later be folded and thrust toward the continental interior. In the northwestern United States, the Olympic Mountains are part of the coastal ranges, the Puget Sound Lowland and Willamette Valley are part of the longitudinal valley, and the Cascade Range is the volcanic arc. Fig. 12.

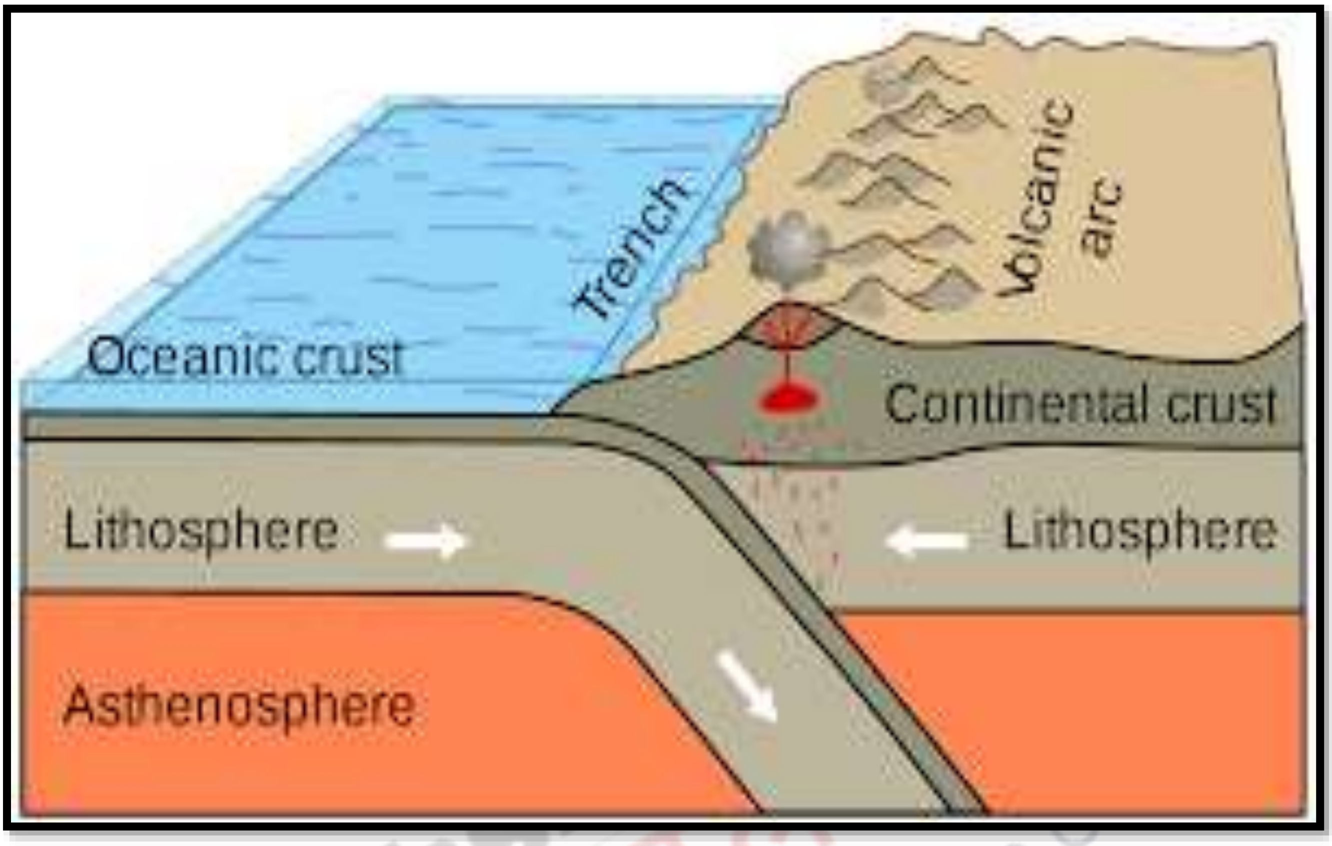


Fig.: 12

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5.3.3 Collisional mountain belts: island arc or another plate of continental lithosphere, when due to convergence and subduction, come into contact with the overlying plate of the subduction zone create, collisional mountain belts. Due to their low density the island arcs and continental rocks instead of going into the mantle gets thrusted over each other in the process forming high mountain ranges. High mountain ranges such as the Himalayas or Alps, with intensely deformed rocks of contrasting lithology are good examples. Fig. 13.

Fig.:13

Source: https://upload.wikimedia.org/wikipedia/commons/thumb/e/e2/Continental-continental_destructive_plate_boundary.svg/205px-Continental-continental_destructive_plate_boundary.svg.png

For detail kindly refer module number 10 on Plate tectonics and module number 11 on volcanism.

5.3.4 Extensional Mountains: A fourth type of mountains are built by extensional and strike-slip plate motions in a variety of tectonic settings. Rift valley formation is relatively localized and is considered a special style of orogeny. continental breakup are characterized by an elongate swell or bulge along which the faulting generates creating rift valleys. Strike-slip faults are the cause of some of the most complex tectonic mountain ranges. The Transverse Ranges of southern California have a similar origin in their relation to the San Andreas Fault.

6. Cymatogenic Movements

Geomophic processes both exogenetic and endogentic use earth's internal energy as the source or power. These in turn are the base for the formation of all the landforms on the earth. The atmosphere or the climate further modifies the these landforms. Atmosphere and climate acquire energy from the sun. ***Hence the landforms are not the result of just one force but it is is the result of extreamly complex system of processes derive from interaction of earth material resistance on the one hand and tectonically-and climatically derived forces on the other***. Endogenetic processes which emanate from within the earth's crust and include crustal or non-isostatic warping within the mantle (eperogenesis), earthquakes, folding (orogenesis), faulting, metamorphism due to heat flow and volcanism. In 1959, **L. C. king** introduced the concept of **cymatogency**, whereby a landscape, often hundreds of kilometers wide, is either arched or domed to thousands of meters with minimum rock deformation. According to king, modern mountain ranges are usually cymatogenic, not orogenic, and any local rock deformation is presumed to antedate the simple cymatogency that, followed by erosion and valley cutting, has created modern day mountain terrain.