Directorate of Distance Education

UNIVERSITY OF JAMMU

JAMMU

SELF LEARNING MATERIAL

B.A. SEMESTER - I

SUBJECT : GEOGRAPHY **UNIT I - IV**

CODE No. GG - 101

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GEOGRAPHY

PHYSICAL GEOGRAPHY

Course No. GG 101 **Title : Physical Geography**
Duration of Exam. : 3 Hrs **Total Marks : 100**
Theory Examination : 80
Internal Assessment : 20

Objectives :

The objective of this course is to introduce the latest concept in Physical Geography, essentially Geomorphology to the students of geography in a brief but adequate manner.

Unit-I.

1.1 Definition, Nature and Scope of Geography

1.2 Division of Geography

1.3 Physical Geography and its components

1.4 Geography and other disciplines

Unit-II

2.1 Theories regarding origin of the Earth Nebular, Kant and Planetesimal Hypothesis

2.2 Theory of Continental Drift

2.3 Theory of Plate Tectonics

2.4 Geological Time Scale

Unit-III

3.1 Interior of the Earth

3.2 Rocks and their Types

3.3 Earth Movements - Earthquakes and Volcanoes

3.4 Weathering and Erosion

Unit-IV

4.1 Fluvial and Glacial Landforms

4.2 Karst and Aeolian Landforms

4.3 Soil Erosion and Conservation

4.4 Landslides and Avalanches

Note for Paper Setters :

The question paper shall comprise of two sections A and B. Section A shall be compulsory and shall comprise of 8 short answer questions of 2 marks each. Answer should be limited to 20 words. Candidate shall be required to attempt all the 8 questions. Section-B shall comprise of 8 questions from 4 units. Candiates shall be required to attempt one question from each unit and each question shall be of 16 marks. Answer should be limited to 450 words for each questions.

Internal Assessment (Total Marks : 20)

20 marks for theory paper in a subject reserved for internal assessment shall be distributed as under :-

(i)	Class Test	:	10 marks
(ii)	Two Written Assignments	:	10 marks
			(05 marks each)

Suggested Readings

1. Monkhouse, F .J: Principles of Physical Geographv. Hodder and Stoughton, London, 1960.
2. Singh, Savindra : Physical Geography, Prayag Pustak Bhawan, Allahabad, 1998.
3. Strahler, A. N. Environmental Geo-Science, Hamillon Publishing, Santa Barbara, 1973.
4. Strahler, A. N. and Strahler, A. H., Modern Physical Geography John Wiley and Sons, Reised Edition, 1992.
5. Thornbury, W.D., Principles of Geomorphlogy, Wiley Eastern, 1969.
6. Wooldrige S. W. and Morgan, R. S. Te Physical Basis of Geography and Geomorphology, Longman Green & Co. London 1959.

PHYSICAL GEOGRAPHY

CONTENTS

1.1 Definition Nature & Scope of Geography

The word of Geography is derived from two Greek words 'geo' mean earth 'graphein' means description. As a discipline Geography is focus on description of the earth surface as a world of man. Eratosthenes was the first Greek scholar who coined the term Geography as "The study of Earth as a home of man". The roots of modern Geography are traced back to the thought of ancient Greek Roman, Indian and Arab scholars. In the beginning a person knowing the name of the countries, continents, river length height of mountain etc. was know as a Geographer and study of these things was called as geography. But with the passage of time by including more and more aspect for scientific investigation under the subject matter of Geography, it goes on increasing day by day and all the information with earth were included under it. The foundation of modern scientific geography has been laid down by he ancient Greek scholars. Both literary and mathematical tradition can be traced in the works of Greek philosophers.

They produce topographical description of places in the known worlds, discussing both natural conditions and the culture both natural conditions and the culture of the inhabitants. They also developed the knowledge of astronomy. The town of Millets on the eastern side of Aegean sea emerged as the centre of geographic philosophy. Thales was the first among Greek scholars to be concerned about measnurement and location of things on the face of the Earth during the 7th and 6th centuries B.C

After the Greeks, the Roman, the Arab and the Indian Geographer contribute more in development of knowledge of Geography. Before the rise of Hellenic culture, geography was regarded as the knowledge of topographical features, mountains, rivers and places of one's own country and its boundaries. Later on maritime trade and commercial relations provides a store of geographical information. Thus Geography is the study of the

features of the earth's surface including their spatial distribution and interrelationship and interaction of man with them.

Nature of Geography

According to Richard Hart stone - "Even more important is the need for each individual who proposes to devote his professional life to the field of Geography, to have the field of Geography, to have clear picture of the scope and nature of that feild".

Geography is concerned with places understanding the nature and causes of arial differentiation on the global surface has been the geographics task. Since peoples first notices difference between places through geography we seek to understand these differences in pattern of human distribution, interrelationship between, human, society and physical environment, peoples use of the earth in time and space, and how these difference are related to people's will being. The pursuit of understanding 'Where ?', 'When ?', 'Why ?' questions are central in geography. However, geographers ask a fourth, very important question i.e. 'What if ?' as means of seeking alternatives and giving the subject and applied dimension that can benefit the decision makers in planning and development at a variety of geographical scales.

The following points make us understand the nature of Geography.

(i) **Geography as an Earth Science :** Physical geography deals with the weather phenomenon and relief of the earth. This part can also be termed as earth science. It is essentially a science of mankind, because its centre of study is man. It studies various physical and weather phenomenon because these features and weather phenomenon has a great influence of mandkind, his food and clothing, his customs and beliefs. Even his social customs that is why geography studies the earth and atmosphere.

From the field of astronomy, geography does study only the rotation and revolution of earth because it is responsible for the formation of days, nights, months and year. Similarly, Geography studies the ocean water, tides etc. It is also deals with Lithosphere, Hydrosphere etc.

(ii) **Geography as an Environment Science :-** Geography as a science which involve a study of the relationship that exist between man and its environment". It include the study of all the three types of environment i.e. physical, biological and social environment. Physical environment include mountains, plains, rivers, temperature, pressure, soils, mineral size and shape of earth.

The natural environment play vital role in modifying the life and habits of mankind, This leads to the origin of the "theory of determinism". According to them nature os active and man is passive agent.

(iii) **The Influence of Climate on Man :-** It has been accepted by medical science that high temperatures combined with high humidity makes the climate enervtive. A relative humidity of 50 to 60% is considered ideal for maintain good health.

The climate conditions are clearly reflected in the dress of people, the type of clothing varies according to the change in the weather and climate. In hot humid, equitorial region, man lives half naked. In cold areas, people use tight woolen cloth. In tundra region people put on fur clothes to protect the body from cold.

The man build his home to suit the various elements of climate such as temperature, rainfall etc. The roofs of houses at Shimla and Kashmir are stanting to drain off the rain water.

(iv) **Science of Relationship between Nature and Man :-** Land Man relations are important because both man and nature play a role in creating the various regions and countries of the world.

Topography, land forms and climate have strong influence on the ways man uses the land. For e.g. land form helps to determine the location of farming and mining regions and routes of major transporation lines. The relationship between man and features of the natural environment as plains and animals.

The view of geography presented here is that of a core sharphy focused on the concept of place; one in which both physical and human elements play and important part in yielding knowledge of the earth in a manner that is integrative of people

and the land. It's is study in fact requires spatial reasoning over a wide range of intellectual orders, there by making it a valuable means of developing thinking skills.

SCOPE OF GEOGRAPHY

Geography is a science that studies interactive between man and his environment so geography has clear objects and scope. The objects of geography has clear objects and scope. The objects of geography basically divided into two parts.

(1) **Material Objects :-** The material objects of geography are geospheric phenomenon that cover several layers, they are lithosphere, atmosphere, hydrosphere, biosphere and anthrosphere. Meanwhile, the formal objects correspond to points of view on a spatial phenomenon on earth's surface.

(2) **Formal Objects :-** Formal objects of geography are indicators and different from other science, while the scope of geographical study enables man to get answer to questions from the world around that emphaize on spatial and ecological aspects.

Geographical study involves the earth its aspects and formation process, causal and spatial relations of humand with the environment. Also the interaction of humans with the environment around them

Rhoad Murphy in the book " The scope of Geography" proposed three scopes of geographical study;

(i) Geography learns the spread and relation of mankind on earth's surface. Besides, its studies about aspects of human living place also how to use it.

(ii) Geography studies mutual relationship between man with physical environment (nature) as a part of regional diversity study.

(iii) Geography studies a regional frame and analyses a region that has specific charateristics.

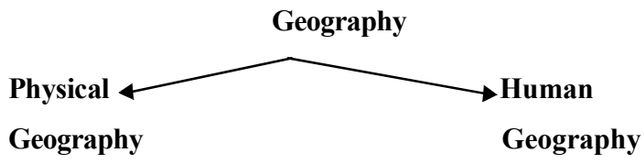
From the above analysis, it is clear that the scope of geography is undivideable

from natural aspects and human aspects.

The scope of geography can be more precisely, when we discuss separately the scope of physical geographjy and scope of human geography.

Now in the present day Geography is concerned with providing accurate, orderly, and rational description and interpretations of the variable character of the earth surface. On the work of **Yeates**, "geography can be regarded as a science concerned with the rational development, and testing of theories that explain and predict the spatial distribution and location of various characteristic on the surface of the earth."

1.2 Division of Geography :



Physical Geography : Physical Geography may be defined as the integrated study of the natural environment on or close to the earth's surface, Environment in its broadest sense includes all energy and matter capable of influencing man from the astronomic to sub atomic level. But practically the scope of Physical Geography is extended to the visible natural environments. Physical Geography has been described as an integration or over view of earth and life sciences which give insight into the nature of man's environment.

In short, we can say that Physical Geography is the study of the features of the earth which form the environment of the man and their development through time.

Physical Geography is systematic in nature. It is the study of physical and natural features of the earth, like mountains, rivers landforms, vegetation, soil, earth movements and climae, etc.

Physical Geography is further divided into following branches :

1. **Geomorphology :** It is the description and interpretation of the landforms. It is the study of the physical features on the surface of the earth as envisaged in the light of endogenic and exogenic forces.

2. **Climatology :** It is the study of climate. It includes the study of climatic phenomena and their influence on natural environment. It is the scientific study of the climate of a particular region or area. It also explains the

nature of climate as it differs from place to place. It is dependent upon metrology for statistic regarding temperature, pressure and precipitation.

3. **Oceanography :** It is the scientific study of all aspects of the ocean including the nature of the water (salinity chemical composition), temperature, movemnet (tides, currents and waves), depth and biology (fauna and flora).

4. **Soil Geography :** It deals with various types of soil, their formation and distribution. It also helps in studying the land use of an area.

Human Geography

According to the father of Human Geography Vidal De la Blache', Human Geography is a recent sprout from venerable Trunk of Geographical Sciences. The relationship of man and nature is the subject matter of Human Geography and it offers a new conception of the interrelationship between the earth and man.

In the words of Miss Semple, "Human Geography is the study of changing relationship between the unresting man and unstable earth. Human Geography deals with conditions on the earth, The distribution of people on the earth's surface and finally relationship of man to the environment."

In general, Human Geography has two fold importance :

1. Scientific for the development of geography and

2. Practical for the planning of national economy in particular the full use of natural advantages, the response to the adjustment of nature which depends on the technical skill and degree of civilization of human group living in the region.

Its scientific importance derives from the basic facts :

That Human Geography brings all the important relationships between man and his activities.

That Human Geography similar to other Geographical Sciences has to begin with study to some concrete material phenomenon.

Human Geography may also be divided into a number of sub fields :

1. **Economic Geography :** It deals with the economic activities, natural resources, industries agriculture, etc. It studis the distribution and utilization resources of the earth. It also studies the products in the form production, consumption and exchange.

   The subject has a vast scope and is further subdivided into different fields, such as:

   (i) Agricultural Geography

   (ii) Industrial Geography

   (iii) Geography of Transport / Transport Geography

   (iv) Commercial Geography

2. **Political Geography :** It studis the political phenomenon including state and frontiers, their variations, interrelationship and their form and impact on the earth's surface it focuses attention on both internal and external relationships of the state.

3. **Social Geography :** This is concerned with study of the spatial arrangement of social phenomena in relation to the total environment. It studies social aspects, like ; caste, religion or stratification of society. It studies the racial groups blacks and whites in relation to their social implications. It also includes the study of tribes, customs traditions, etc.

4. **Historical Geography :** It is the branch of geography which is concerned with the past. As History has Geography on its back Similarly Geography too has History of its own development. The two main aspects of this are the reconstruction of past environment and the study of sequence of changes that take place with the passage of time at a place.

5. **Population Geography :** It describes and explains the number of people living in an area. It explains different characteristics of human population, such as; sex ratio, age, sex composition literacy, man power, density and distribution of population, fertility mortality and migration etc.

6. **Settlement Geography :** It deals with the nature of human shelter, its origin, various forms, development of early settlement, geographical location and relationship of settlement with natural environment.

7. **Biogeography :** The term includes the study of plants and animals, We study the habitat of various species of plans and animals and their relationship to man and Geographical environment.

8. **Urban Geography :** It is a systematic study of urban settlement. It includes the functions, morphology, concepts and planning of urban units.

9. **Cultural Geography :** It deals with the cultural aspects of different human groups. It includes shelter, food, clothing, skills, tools, languages and religions etc.

1.3 Physical Geography and its Components

Physical Geography studies the spatial patterns and spatial relationship of environmental components of the globe in regional content. Undr physical geography we study the things like mountains, rivers, natual vegetarian and animals life etc.

The components of physial Geography are as Atmosphere, Hydrospheric, Lithospheric and Biospheric.

In the study of first component.

Atmospheric : We study the atmospheric e.g. composition of the atmosphere, structure of atmosphere, elements of weather and climate, terrestrial radiation balance and human factors causing inbalance. It also include the study of atmospheric temperature, air pressure and winds. It also study the characteristics and origin of Monsoon. It also study the biosphere. It also study the atmospheric disturbance such as cyclons, floods drought, humidity (moist content in air).

In the second component.

Lithospheric :- The main focus of physical geography is to study the land forms. It takes into account the study of earthquakes and plate electronic movements. It involves the process of weathering and erosion. It is the special branch of physical geography. It is also called the heart of physical geography. It provide the base for the geographical. Land form are of great important in shaping the humand environment.

In the third component

Hydrospheric :- The role of physical geography is to study the relief of the ocean basins such as continental shelves, continental slopes, submarine canyons, deep sea plains, ocean,

depth etc. It also study the characteristics of ocean water salinity, ocean deposits, ocean tides,ocean waves, ocean currents and coral reafs. It also study the ocean temperature etc.

In the fourth component

Biospheric : We study the biosphere in details in physical Geography. It is the study to know about floura and fauna. The most important feature of Biospheric component is the study of man-environment relationship. In it we also study the influence of pollution, ozone depletion, green house effect, global warming, extinct species on man and its surrounding area.

Hence we can say that the role of physical geography is to study the earth in detail. Its components atmospheric, hydrospheric, lithospheric and Biospheric are also co-relate the with man and his environment.

1.4 Geography and other Disciplines

Geography is sometimes considered as the mother of all science dues to its links and influences on a range of other scientific fields including biology, mathematics, anthropology, geology, astronomy and chemistry. The exploration and discovery of new places, new ideas and new cultures is something that is fundamental to the human knowledge. Geography is define as the science that studies Earth and its land, inhabitants, features and phenomena. The term was coined by Eratosthenes between 276 and 194 BC and has been in common use ever since. The field of Geography was historically categorized into four different subject areas. These areas were the spatial analysis of natural and human phenomena, research in earth Sciences, the study of man-land relationship and area studies. Amore modern breakdown of Geography is into a number of different branches. These branches often include physical Geography, human Geography, environmental Geography, regional Geography and geomatics. The most common division made is between Geography and Physical Geography.

Human Geography is the branch that focuses its attention on the study of processes and pattern that shape and determine human's interaction with a variety of environments. Attention to detail is on human's affect on the landscape, rather than the phycial landscape itself. Human Geography can then be broken down into a number of categories including cultural Geography, economic Geography, health Geography and religion Geography. The other main division, physical Geography, focuses primarily on Geography as Earth Sciences. It considers issues and problesm in the lithosphere, atmosphere, hydrosphere and pedspyhere as well as within flora and fauna. Again, this can be categorized by a number of different topics including Biograhy, coastal Geography and oceanography. The vast range of topics and Sciences that are covered and understood by Geography give rise to its common definitions as the 'mother of all sciences".

Relationshp between Geography and Other Disciplines : Geography has its strong relation with mathematics, natural Sciences and social Sciences. While other Sciences deal with distinctive types of phenomena, Geography studies several kinds of phenomena, each already sudied by another Science. In an integrated manner thus, Geography has firmly established itself as a discipline of synthesis. Geography is a Science of space. Geography is both a natural and social science as it studies both environment and the people. It connects the physical and cultural world. Physical Geography studies the earth systems that create natural environment. Humand Geography is concerned with the political, economic, social cultural and demographic processes. It is concerned with the different ways in which resources are used.

Geography and Environment Science :- Geography is the study of man and the environment while environmental science is the study of the environment. Both the subjects are interconnected with each other. Environmental geography deals with the environmental conditions including the rate of increasing pollution, impact of increasing population on environmental and vice versa.

Geography and Political Science : Political Science is the study of man and how he governs himself while Geography looks at how man's policies affect the environment. Political Science is an academic and research discipline that deals with the theory and practice of politics and the description and analysis of political systems and political behaviour. Fields and subfields of political Science include political economy, political theory and and philosophy, civics and comparative politics, theory of direct democracy, apolitical goverance, participatory direct democracy, national systems, cross-national political analysis, political development, international relations, foreign policy, international law, politics, public administration , administrative behaviour, public law, judicial behaviour, and public policy. Political Science also studies power in international relations and the theory of great powers and superpowers.

Geography and Mathematics : Mathematics is the study of numbers while in Geography you use mathematics calculate time, distance and so on. Mathematics plays an important role in geographical analysis of area. It not only helps in measurement but also plays an important in determing the exact locations and estimation of resources available in a particular area.

Geography and History : History deals with events that happend in the past while in Geography emhasized upon the reasons and relationships of events in the past or present. According to Herodotus there is no history with Geography and there is no Geography without history. In this context both the subjects are interrelated with each other. History deals with the study of happenigns, origins and evaluation of man along with their different activities through times. Geography on the hand also deals with transformation of shape of earth, growth and development of man through ages on spatial context. The eminent historical geographer Donald Meinig views that Geography and history as complementary and interdependent bound together by the very nature of things. This relationship, he states, "is implied by such common terms as space and time, area and era, places and events, pairs that are fundamentally inseparable. In practice the two fields are differentiated by the proportionate emphasis ech gives to these terms." However, he warns that it is important to realize that "Geography is not just a physical stage for the historical drama, not just a set of facts about the earth. It is a special way of looking at the world. Geography, liek history, is an age-old and essential strategy for thinking about large and complex matters.

Geography and Agriculture Science :- Agriculture Science is the study of the rearing of animal and production of crops while Geography looks at how farming activities are distributed due to environmental.

Geography and Anthropology :- Anthropology is the holistic "Science of man", a science of the totally of human existence. The discipline deals with the integration of different aspects of the social Sciences, humanities and human biology. In the twentieth century, academic disciplines have often been institutionally divided into three broad domains. The natural Sciences seek to derive general laws through reproducible and verifiable experiments. The humanities generally study local traditions, through their history, literature, music, and arts, with the emphasis on understanding particular individuals, events, or eras. Geography has generally attempted to develop scientific methods to understand social phenomena in a generalizable way, through usually with methods distinct from those of the natural sciences.

Geography and Economics :- Economics is a social Science that seeks to analyze and descriptive the production, distribution, and consumption of wealth. The word "economics"

is from the Greek oikos meaning "family household, estate," and nomos meaning "custom, law," and hence it means "household management" or "management of the state". An economist is a person using economic concept and data in the course of employment, or someone who has earned a degree in the subject. The classic brief definition of economics, set out of Lionel Robbins in 1932, is "the Science which studies human behaviour as a relations between scarce means having alternative uses." Without scarcity and alternative uses, there is no economic problem. Briefer yet is "the study of how people seek to satisfy needs and wants" and "the study of the financial aspects of human behaviour." Contrary to this Geography analysis various factor responsible for growth and development of different economics sectors required for sustainable development of mankind. Geographers attempt to understand the earth in terms of physical and spatial relationships. The first geographers focused on the science of mapmaking and findings ways to precisely project the surface of the earth. In the sense, geography bridges some gaps between the natural Sciences and Social Sciences.

Geography and Education :- Education encompasses teaching and learning specific skills, and also something less tangible but more profound the imparting of knowledge, positive judgements and well-developed wisdom. Education has as one its fundamental aspects the imparting of culture from generation to generation. Geography focuses largely on the built environment and how space is created, viewed and managed by humans as well as influence humans have on the space they occupy. The may involve cultural Geography, transportation, health, military operations and cities. The latter examines the natural environment and how the climate, vegetation and life soil, oceans, water and landforms are produced and interact.

Geography and Psychology :- The word psychology comes from the ancient Greek psyche ("Soul", "Mind") and logy ("Study"). Psychology is an academic field involving the study of behaviour and mental processes. Psychology also refers to the application of such knowledge to various spheres of human activity, including problems of individuals daily lives and the treatment of mental illness while the geographical analysis seeks more or less the similar components.

Geography and Sociology :- Sociology is the systematic study of society and human social action. The meeting of the word comes from the suffix "-ology" which means "study

of," derived from Greek, and the stem "soci-" which is from the Latin word socius, meaning "companion", or society in general.

The field generally concerns the social rules and processes that bind and separate people not only as individuals, but as members of associations, groups, communities and institutions, and include the examination of the organization and development and development of human social life. One useful way to describe the discipline is as a cluster of sub-fields that examine different dimensions of society. For example, social stratification studies inequality and class structure; demography studies changes in a population size or type, criminology examines criminal behaviour and deviance; and political sociology studies the interaction between society and state. Almost study encompasses the field of Geography.

Geography and Archaeology : Archaeology is the Science that studies human cultures through the recovery, documentation, analysis, and interpretation of material remains and environmental data, including architecture, artifacts, featues, biofacts and landscapes which are also studies in geographical literature.

Geography and Demography :- Demography is the statistical study of all human populations. Development studies a multidisciplinary branch of social Science which addresses issues of concern to developing countries. Environmental social science is the broad, trans-disciplinary study of interrelations between humans and the natural environment. All these are the core issues of Geography.

Geography and Physics :- Physics relates to all laws of nature and that's where Geography comes in since it studies the earth and processes within it.

Geography and Chemistry :- Chemistry deals with the study of chemical composition and their resultant reaction of different geographical attributes of earth surface.

Geography and Biology :- They are interrelated because each geographical area has a variance in what biological life forms exist in each geographic area. Geography influences the living things in a region or area. If affects the weather, climate, temperature and whether the specific species can exist there. Geography also affects the interactions of the living things in the region / area.

Geography and Geology :- Both the subjects study the earth surface. The main difference betwen Geography and Geology is that Geography is mostly dealing with the physical overall shapes of the land. Geology is a science that is interested in how the land got into the shape it did . Geology is mostly about what the ground is made up of from a natural perspective. What kinds of rocks it contains and how those rocks of layers or rocks got there. Geography is mostly dealing with mapping the extent of landforms, how far rivers are, how long mountain ranges are, how long the coast line is. This is often from the perspective of people or culture.

BOOKS RECOMMENDED :-

Hussain Majid (1999). : *Human Geography,* Rawat Publication New Delhi.

Hussain Majid : *Geographic Thought,* Rawat Publication New Delhi.

Manzoor S (2005) : *Geography,* Narendra Publishing House Jammu.

Singh Savindra (2000) : *Physical Geography,* Prayag Pustak Bhawan, Allahabad

2.1 Theories Regarding the Origin of Earth Nebular & Planetesimal Hypothesis

The earth is an important planet of the solarsystem. It is the planet which has life and atmosphere only. It is also called as watery planet. It is one of the inner or terrestial planets with a diameter of 12740 km and lies and everage distance of 149 million km from the sun. The age of the earth belived to be 4.7 billion years. The origin of the earth is a matter of great speculation and discussion. Man has propounded many theories of the origin of the earth. Historical and political circumstances, religious sentiments and the progress of scientific thoughts have forced man to make change in his theories. In the search of truth the views of many philosphers were proved wrong and new theories came into existance. In fact no theory is wholly wrong or right. Every theory tries to explain facts to the greatest extent and connects thems withthe prevailing concept of things. Exact process of her origin has not been known till now. As a member of solarsystem the process of its origin can be understand in the genesis of solar sysem. Different scientists have put forward various theories to explain the origin of earth. Some of the Important are as under.

Nebular hypothesis : On the basis of earlier work. of *Kant* the french scientist *Laplace* (1794) propounded Nebular hypothesis to explain the origin of the earth. His hypothesis evaked great Intrest among the thinkers and scientists of 19th century. The important features of this theory are given below :

* There was a hot gaseous mass rotating in the space called “nebule”.

* Due to cooling effect by radation and temperature the nebula contracted and shrinked gradually. Due to decreasing volume by contracted and shrink. The rotation of nebula incressed. The mass of nebula begain to shift towards equator.

* Due to incress in rotation the centrifugal forces also increases. The matter of

nebula was attracted towards the centre of nabulla on account of the force of gravitation. These the two forces (centrifugal gravitational) oppose to each other. When the centrifugal force become equal to gravitational force the excess matter arround the equator seperate from the equator in the form of ring and became weightless. With time as nabulla cooled further. Its rotation incressed which increased its centrifugal force. When the centrifugal force exceeded the gravational force the ring moved away from the nabulla and broke into many smaller rings. These rings on cooling took the form of planets and sub-planets.

* The central part of the nebula which remained behind became the sun.

Criticism : The nebular hypothesis was widely accepted during the past century owing to the confirmation of different characterstics of present solar system with the Idea develop by Laplace : The merits and demerits of his hypothsis are as follows :

MERITS :

* ***Rotation and revolution of the planets explained*** : It explains the rotation and revolution of planets and sub-planets because it assumes a hot and rotating nabulla.

* ***From ring to planet :*** The rings seperating from the rotating nubulla must also be rotating and could take the form of a planet.

* ***Same plane*** : Laplace explains that the planes form from the same ring revolves arround the sun in same direction, in same plane an innearly circular orbits.

* **Hot interior** : The inner molten and upper solid part of the earth is confirmed by this theory. This explains that planets were formed from cooling of hot gaseous rings separated from nabulla. Thus the upper part become solid and inner remained liquid.

* ***Same elements in composition :*** The fact that all the planets are composed by same elements supports laplace's hypothesis because all the planets have

been formed from the same ring.

* ***DEMERITS*** : Laplace's hypothesis suffers from a number of shortcoming which are as under :

* ***Rings into solid planets not explained*** : Laplace did not explain how the parts of the ring took the form of solid masses. It fact, the ring should disappear by disintegration into tiny particcles.

* ***Opposite revolution not explained*** : Some of the subplanets of Uranus and saturn revolve in direction opposite to those of other planets. This fact can't be explained on the basis of this theory.

* ***Why only one ring*** : According to laplace only one ring seperated out but the process of seperation of the ring should have continued uninterrupted. However the ring should have continued uninterrupted. How ever Roche's modification eleminate this draw back.

* ***Why not binary stars*** : According to laplace, the nabulla should have been converted into binary stars. In this system both the stars revolve round each other. The structure of the present solarsystem does not favour this hypothesis.

* ***Why does the sun rotate slowly*** : According to this hypothesis the rotation of the sun should much faster than that of the planets. The sun should also rotate about its axis in the same way as the planets do but its speed of rotation is very low as compared to the rotation of planets.

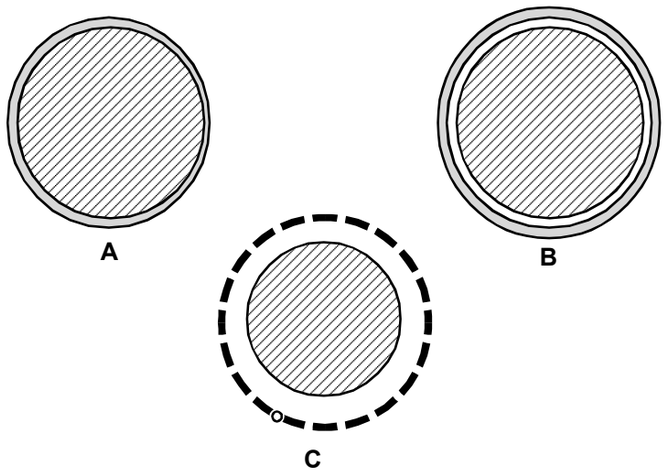
* ***Why no buldge*** : If the sun is remaining part of the orignal nabulla, there should be a buldge visible an middle part of the sun signifing another ring in the offering there is no such bulge in the sun.

* ***Why only nine planets*** : It is also clear that why the ring broke into only 9 planets. It can proved mathematically that the ring will disintegrate into numerous small meteors. The formation of such giant planets as jupiter and saturn can in no way be explained on this hypothysis.

* ***Molton's Objection*** : According to Molton the ring should disintegrate into small planets of unequal size.

* ***Cooling period too short*** : The sun is about 4 billion year old. If it is believed that nabulla in the beginning spread over the whole space of the solar system it cannot be contracted into the present volume of the in such a small period of time.

Fig. A — C Nebular Hypothesis of Laplace



A) Nebula (Shaded) Bulging at the equatorial zone (Bulged portion dotted)

B) Bulged portion seperated out in the form of a ring.

C) Ring coalsced to form a globe or planet which rotate around nabula in its orbit (dotted line)

PLANETESIMAL HYPOTHESIS :

Two Amercian scientists *Chamberlin* and *Moulton* (1904) propounded a new theory called as planetesimal hypothesis. In this hypothesis they attempt to overcome the objections raised against nebular hypothesis. The process of formation of solar system was explained in he following manner :-

* According to them there was a cold proto-sun and an intruding star of considerable size moving in the space.

* The intruding moving star approached the proto-sun and a tidal bulge was caused on the surface of sun due to gravitational force of the star.

* The ejected mass of the sun was scattered in the form of solid particles arround the sun. These particles are called planetesimats.

* These solid particles coalesced and bigger pieces and ultimately took the form of planes.

* A lot of heat was generated in this process and the temperature of the planets rase high.

* The rise of temperature was contributed by four processes.

  — Due to collision of particles.

  — By the synthesis of nuclie of the particles.

  — Due to the high pressure experienced by the nuclie on acount of the incress of mass.

  — The formation of bigger malecules by collison of smaller molecules under tremendous pressure.

* In the begning there was no atmosphere on the earth when the earth get bigger by coaleseing with smaler particles its gravitational pull attracted the gas molecules which previously moved about freely. Later on the atmospher was strengthened by the gases which came out from valeanic eruptions. The atmosphere gradualy grew denser.

* Due to high pressure the melted material of the earth came out and spread over the earth surface while the inner part grew heavy and hot.

* The increasing content of water vapours started to condense due to cooling of the atmospher and consequently rainfall occured for a long time and oceans were formed on the earth.

MERITS :

* **Hot beginning :** The hypothesis rejected the concept of earth being cold in the begining and thus free from much criticism.

* **Origin of Oxygen** : It has now been proved hat Oxygen is a part of the gases emitted by volcanoes. In this way the presence of oxygen in the atmosphere is explained properly.

* **Formation according to its structure** : The process of formation of earth confirms to its structure.

* **Formation of volcanoes :** The volcanoes was formed by the motten pocket which were forced up by high pressure.

* **Formation of planets** : The planets were formed by smal seperated matter of the mother star (sun). The fact that the total mass of the planets is about 1/700 of the solar system is readily explained by this hypothesis.

* **Demerits** : *Jeffreys* thinks that the formation of big planets by a process of coalescence of small particles does not appear credible and is based upon insufficient facts.

* **Collision does not promote growth** : The particles after collision should become gas and not grow in size which appear improbable.

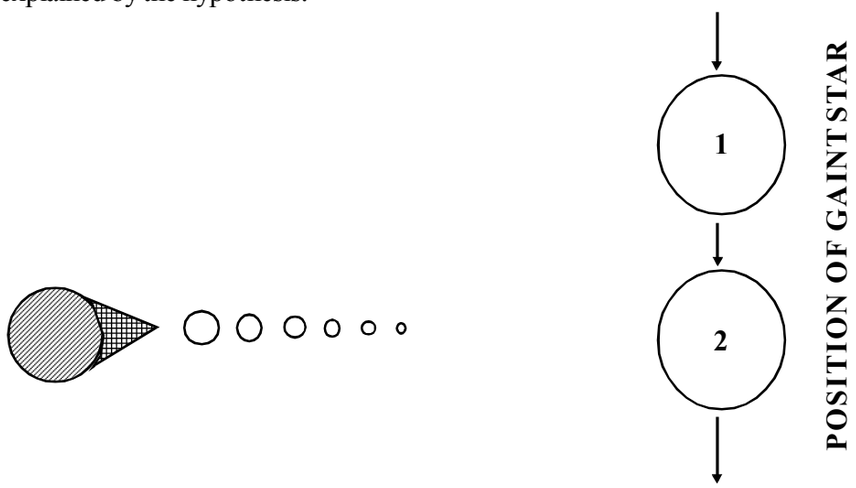
* **Pressure Insufficient for mountain formation** : This hypothesis has hinted at insufficient pressure for the formation of mountains. he pressure explained in this hypothesis in insufficient for this process.

* **Atmosphere formation not clear :** The principle explaining the formation of the atmosphere is defective. In the beginning when the planetsimals were small their

gravitational pull was insufficient to prevent them setting free. The atmosphere which was absorbed with the planetesionals could not come out because it was buried thousands of kilometer under the surface of planet. It means the atmosphere can only be produced from planetesmials which are like present meters. The then planetesimals should not have been without atmosphere as the present meteors are. This is a defect which could not explained by the hypothesis.

* **Shape of the orbit** : Due to collision of planetesimals the orbit of the planets should not be near circular as it is at present.

* **Problem of momentum** : The low angular momentum of the plates are not explained by the hypothesis.



Planetesimal Hypothesis of Chamberlin and Moulton.

2.2 THEORY OF CONTINENTAL DRIFT

Professor Alfred Wegener of Germany was primarily a meteorologist. He propounded his concept on continental drift in the year 1912 but it could not come light till 1922 when the elaborated his concept in a book entitled **"Die Entstehung der Kontinente and Ozeane'** and his book was translated in English in 1924. Wegener's Displacement Hypothesis was bases on the works and findings of a host of scientists such as geologists, palaeo-climatologists, palaeontogists, geophysicists and others. The main problem before Wegener, which needed explanation, was related to climatic changes. It may be pointed out that there are ample evidences which indicate widespread climate changes throughout the past history of the earth. In fact the continental drift theory of Wegener 'grew out of the need of explaining the major variations climate in the past'. The climatic changes which have occurred on the globe may be explained in two ways.

(1) If the continents remained stationary at their places throughout geological history of the earth, the climate zones might have shifted from one region to another region and thus a particular region might have experienced varying climatic conditions from time to time.

(2) If the climatic zones remained stationary, the land masses might have been displaced and drifted.

Wegener opted for the second alternative as he rejected the view of the permanency of continents and occean basins. Thus, the main objective of Wegener behind his 'displacement hypothesis' was to explain the global climatic changes which are reported to have taken place during the past earth history.

Basic Premise of the Theory :- Following Edward Suess, Wegener believed in three system of the earth e.g. outer layer of **'Sial',** intermediate layer of **'Sima'** and the lower

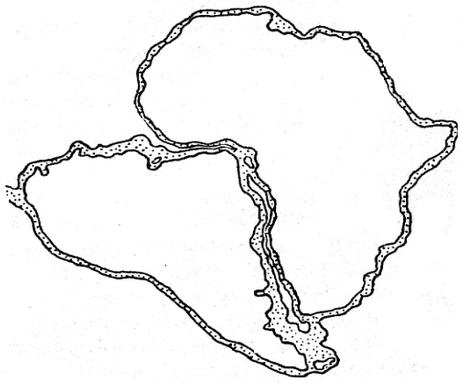
layer of **'Nife'.** According to Wegener sial was considered to be limited to the continental masses alone whereas the ocean crust was represented by the upper part of sima. Continents or sialic masses were floating on sima without any resistance offered by sima. He assumed, on the basis of evidences of palaeo-climatology, palaeontology, palaeobotany, geology and geophysics, that all the landmasses were united together in the form of one landmass, which he named **Pangaea,** in Carboniferous period. There were several smaller inland seas scattered over the Pangaea which was surrounded by a huge water body, which was named by Wegener as 'Panthalasa', representing primaeval pacific ocean. Lauratia consisting of present North America, Europe and Asia formed northern part of the Pangaea while Gondwanaland consisting of South America, Africa, Madagascar (now Malagasy), Peninsular India, Australia and Antarctica represented the southern part of the Pangaea. South pole was located near present Durban (near Natal in Southern Africa) during Carboniferous period. Thus, Wegener's theory of continental drift begins from Carboniferous period, he does not describe the conditions during pre-Carboniferous times 'but the postulation of a Carboniferous times 'but the postulation of a Carboniferous Pangaea does not mean that he disbelieves in pre-Carboniferous drift events before this time are known with much less certainty, and the distribution of plants and animals can largerly be explained by movements which have taken place since the Carboniferous' (J.A. Steers , 1961, p. 160). The Pangaea ws disrupted during subsequent periods and broken lanmasses drifted away from each other and thus the present position of the continents and ocean basins became possible.

Evidences in support of the Theory :- Wegener has successfully attempted to prove the unification of all landmasses inthe form of a single landmass, the Pangaea, during Carboniferous period, on the basis of evidences gathered from geological, climatic and floral records. He claimed that all the present-day continents could be joined to form Pangaea. The following evidences support the concept of the existence of Pangaea during Carboniferous period.

(1) According to Wegener there is geographical similarity along both the coasts of the Atlantic Ocean. Both the opposing coasts of the Atlantic can be fitted together in the same way as tow cut off pices of wood can be refitted (Jia-saw fit)

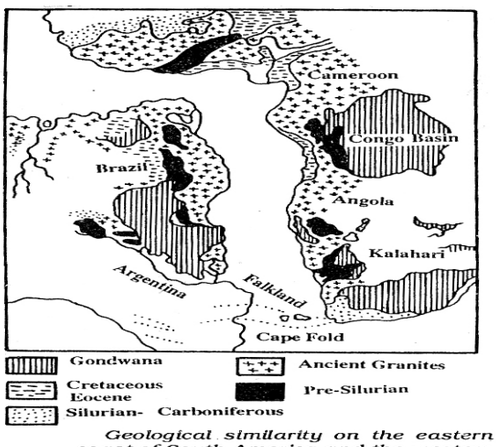
(2) Geological evidences denote that the Caledonian and Hercynian mountain systems

of the western an eastern coastal areas of the Atlantic are similar and identical. The Applachians of the north-eastern regions of North America are compatible with the mountain systems of Ireland, Wales and north-western Europe.



Jig-saw fitting (juxtaposition) of South America and Africa.

(3) Geologically, both the coasts of the Atlantic are also identical. Du Toit, after detailed study of the eastern coasts of South America and western coast of Africa, has said that the geological structures of both the coasts are more or less similar. According to Du Toit both the landmasses (i.e South America and Africa) cannot be actually brought together but near to each other because a gap of 400-800 km would separate the due to the existenc of continental shelves and slopes of these two landmasses.



Geological similarity on the eastern coast of South America and the western coast of Africa.

(4) There is marked similarity in the fossils and vegetarian remains found on the eastern coast of South America and the western coast of Africa.

(5) In has been reported from geodetic evidences that Greenland is drifting westward at the rate of 20 cm per year. The evidences of seafloor spreading after 1960 have confirmed the movement of landmasses with respect to each other.

(6) The lemmings (the small size animals) of the northern part of Scandinavia have a tendency to run westward when their population is enormously increased but they are foundered in enormously increased but they are foundered in the sea water due to absence of any beyond Norwagian coast. This behaviour of lemmings prove the fact that the landmasses were united in the ancient times and the animals used to migrate to far off places in the western direction.

(7) The distribution of Glossopteris flora in India, South Africa, Austrialia, antarctica, Falkland island etc. proves the fact that all the landmasses were previously united and contiguous in the form of Pangaea.

(8) The evidences of Carboniferious glaciation of Brazil, Falkland, South Africa, Peninsular India, Australia and Antarctica further prove the unification of all landmasses in one landmasses (Pangaea) during carboniferous period.

Process of the Theory :- As stated earlier the main aim of Wegener behind the postulation of his 'drift theory' was to explain major climate changes which are reported to have taken place in the past geological history of the earth, such as Carboniferous glaciation of major parts of the Gondwanaland. Besides, Wegener also attempted to solve other problems of the earth e.g. origin of mountains island arcs and festoons, origin and evoluation continents and ocean basins etc.

(1) Force responsible for the Drift :- According to Wegener the continents after breaking away from the Panagaea moved (drifed) in two directions e.g. (i) equatorward movement and (ii) westward movement. The equatorward movement of sialic blocks (continental blocks) was caused by gravitational differential force and force of buoyancy. As already stated the continental blocks, according to Wegener, were formed of lighter sialic materials (silica and aluminium) and were floating without and friction on relatiely

denser 'sima'. Thus, the equatorward movement of the sialic blocks (continental blocks) would depend on the relation of the centre of gravity and the centre of buoyancy of the floating contiental mass. Generally, these two types of forces operate in opposite directions. But because of the ellipsoidal form of the earth, these forces are not in direct opposition, but are so related that, if the buoyancy point lies under the centre of gravity, the resultant (force is directed toward the equator (J.A. Steers, 1961 P. 164)

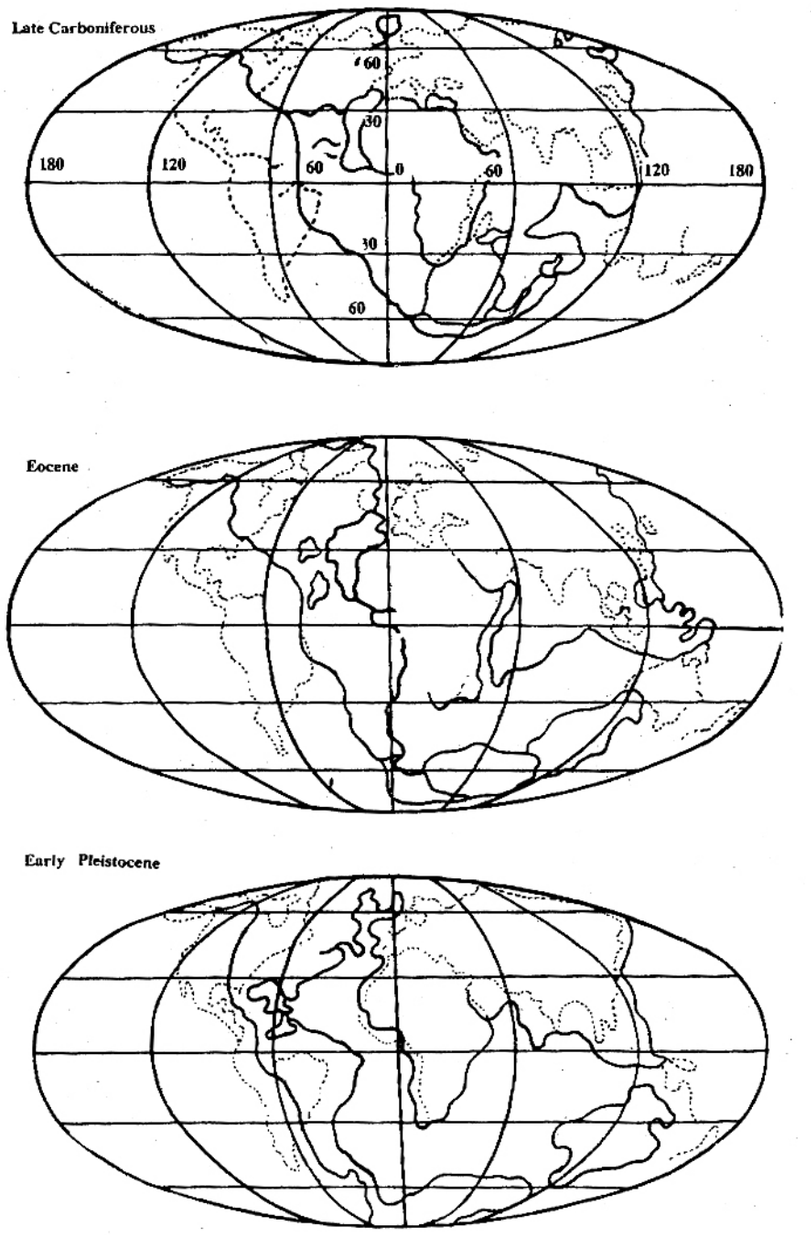
The westward movement of the continents was caused by the tidal force of the sun and the moon. According to Wegener the attractional force of the sun and the moon, which was maximum when the moon was nearest to the earth, dragged the outer sialic crust (continental blocks) over the interior of the earth, towards the west. It may be pointed out that in any drift theory the weakest point and the most difficult problem is related to the competent force responsible for the movement of the contiunents. 'Such a force (tidal force/attractional force of the sun and the moon) is extraordinarily small, but, as in the case of other forces, the question of time is all important gives sufficient time, it is claimed that even these very small forces are able to cause movements'. (J.A. Steers, 1961 P. 164)

(2) Actual Drifting of the Continents :- The disruption, rifting and ultimately drifting of the continental block began in carboniferous period. The movement of the continental blocks away from the poles was dramatically called by Wegener as **'the flight from the poles'**. Pangaea was broken into two part due to differential gravitaional force and the force of buoyancy. The northern part became Lauratia (Angaraland) while the southern part was called by Wegener as Gondwanaland. The intervening space between these two glant continental blocks was filled up with water and the resultant water body was called Tethys Sea. This phase of the disruption of Pangaea is called 'Opening of Tethys'. Gondwanaland was disrupted during Cretaceous period and Indian penisula, Madagascar, Australia and Antaractica broke away from Pangaea and drifted apart under the impact of tidal force of the sun and the moon. North America broke away from Angaraland and drifted westward due to tidal force. Similarly, South America broke away from Africa and moved westward under the impact of tidal force. Due to northward movement of Indian Peninsula Indian ocean was formed due to westward movement of two Americas. It may be mentioned that North and South Americas were drifting westward at different rates and hence 'S' shape of the Atlantic Ocean could be possible. Arctic and North Sea were

formed due to flight of the continental blocks from the north pole. The size of the Panthalasa (Primitive Pacific Ocean) was remarkably reduced because of the movement of continental blocks from all sides towards Panthalas. Thus, the remaining portion of panthalasa became the pacific ocean. It may be mentioned that disruption, firting and displacement (drifting) of continental period to pliocence period when the present when the present pattern and arrangement of the continents and ocean basins was attained. There have been frequent changes in the positions of the equator and the poles as given in table

Shifting of the position of the Poles

Period	North Pole	South Pole
Silurian	14^0N Latitude	to the north-west of
	124^0 W longitude	Madagascar
Carboniferous	16^0N Latitude	near Durban in
	147^0W Longitude	Natal
Tertiary	51^0N Latitude	near 53^0S Latitude to the
	153^0W Longitude	South of Africa



Disruption of Pangaea and drifting of continents. The dotted lines denote the present position of continents and ocean basins.

Equator was located at the most northerly location during Silurian period as it passed north of Norway. It passed through London during Carboniferous periode and through present locations of the European Alpine mountains during Tertiary period (fig 4.6) The South pole and Equator obviously moved into accordant positions. The prevaliling westward and equatorward movement must be referred to these position (J.A. Steers, 1961, P. 166)

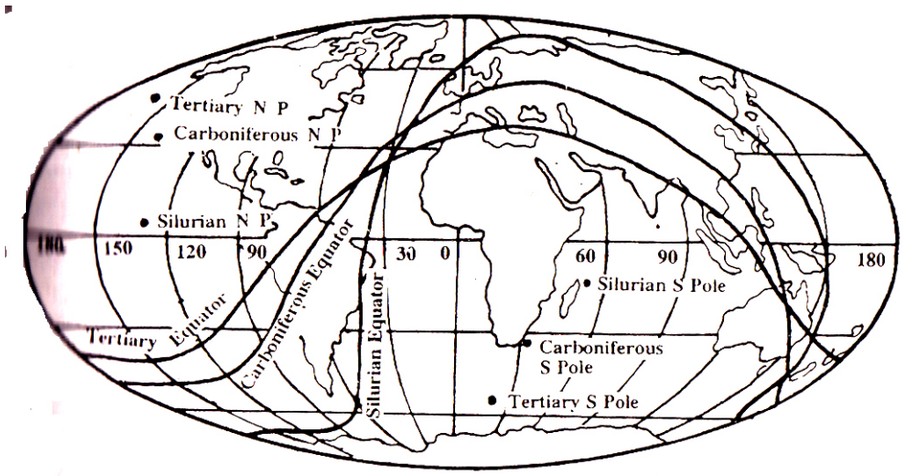


Fig.4.6 : Different positions of Poles and Equator.

(3) Mountain Building :- A.G. Wegener also attempted to solve the problem of the origin of folded mountains of Tertiary period on the basis of his continental drift theory. The frontal edges of westward drifting continental blocks of North and South Americas were crumpled and folded against the resistance of the rocks of the sea-floor (Sima) and thus the western Cordilearas of the two americas (e.g. Rockies and Andes and other mountain chains ssociated with them) were formed. Similarly, the Alpine ranges of Eurasia were folded due to equatorward movement of Eurasia and Africa together with Penisular India (equator was passing throiugh Tethys sea at the time). Here, Wegener postulated contrasting view points. According to Wegener sia (continental blocks) was floating upon sima without any friction and resistance but during the later part of his theory he pointed out that mountains were formed at the frontal edges of floating and drifting continental blocks (sialic crust) due to friction and resistance offered by sima. How could it be possible ? The question remains unanswered. Inspite of this serious flaw in the continental drift theory of Wegener,

S.W. Wooldridge and R.S. Moran have remarked, 'certainly the problem of mountain building is one in which the hypothesis of continental drift solves more difficulties than it creates.

(4) Origin of Island Arcs :- Wegener has related the process of the origin of island arcs and festoons (of eastern Asia, West Indies and the arc of the southern Antilles between Tierra del Fugo and Antarctica) to the differential rates of continental drift. When the Asiatic block (part of Angaraland) was moving westward, the eastern margin of this block could not keep pace with the westward moving major landmass, rather lagged behind, consequently the island arcs and festoons consisting of sakhalin, Kurlie, Japan, Phillippines etc. wer formed. Similarly, some portion of North and South Americas, while they wer moving westward, were left behind and the island arcs of West Indies and Southern Antilles were formed.

5) Carboniferous Glaciation :- There are ample evidences to demonstrate that there was large-scale glaciation during Carboniferous period when Brazil, Falkland, Southern Africa. Peninsular India, Australia, Antarctica etc. were extensively glaciated. According to Wegener all the continetal blocks were united together in the form of one land mass called as Pangaea. South Pole was located near the present position of Durban in Natal. Thus, South pole was located in the middle of Pangaea. Consequently, ice sheets might have spreadd from south pole, might have been covered with thick ice sheets. At much later date, these land areas might have parted away due to disruption of Pangaea and related continental drift Glossopteris Flora might have also been distributed over the aforesaid areas when these were united together.

Evaluation of the Theory : It may be pointed out that Wegener's continental drift theory widely departed from the contemporary orthodox geological ideas of the nineteenth century and the time - honoured thermal contraction theory of the mountain building and thus it was obvious that the believers of contraction theory should not only critisize the new theory of horizontal displacement of the continents but should also discard it. It is now widely agreed that the (Wegener) handled his case as an advocate rather than as an impartial scientific observer, appearing to ignore evidences unfavourable to his ideas and distort other evidences in harmony with the theory (S.W. Wooldridge and R. S. Morgan, 1959. P. 40) The critics of Wegener's contiental e.g. (i) the crictics and writers who always

attempted to search erors and discrepancies in Wegener's original synthesis and (ii) the scientists who attempted to modify, enlarge and correct the original theory of wegener while retainig its basic tenet. The following flaws and defects have been pointed by different scientists in Wegener's theory of continental drift.

(i) The forces applied by Wegener (differential gravitational force and the force of buoyancy and tidal force of the sun and moon) are not sufficient enough to drift the continents so apart. "The tidal force as invoked by Wegener to account for the supposed westerly drift of the continents would need to be 10,000 million times as powerful as it is at present to produce the reqired effects, and, if had such a value, it would stop the earth's rotation completely in a year' (S.W. Wooldridge and R. S. Morgan 1959 P. 40) Similarly, the differntial gravitational force and the force of buoyancy are also not adequate to cause equatorward movement of the continets instcad the force. If so enormous, might have caused the concerntration of the continents near the equator.

(2) Wegener has described several contrasting view points. Initially, sialic masses (continents) were considered by Wegener as freely floating over 'Sima' without any friction offere by 'Sima' but in later part of his theory he has described forceful resistance offered by 'Sima' in the free movement of sialic continents to explain the origin of mountains along the frontal edge of floting continents. Moreover, it is difficult to show how the sial blocks, in their passage through the sima, would crumple at their passage through the sima, would crumple at their frontal edges and produce mountains (J.A. Steers 1961 P. 165) According to Willis no compression could be possible to form than the 'Sial' Bowl has maintained that sima has no strength to crumple sial to form mountains.

(3) Both the coasts of the Atlantic Ocean cannot be completely refitted. Thus, the concept of juxtaposition' or 'jig-saw fit' cannot be validated.

(4) Wegener has not elaborated the direction and chronological sequence of the displacement of the continents. He did not describe the situations of pre-carboniferous times. Many question remain unanswered such as. What kept Pangaea together till its disruption in Mesoxoicera ? Wny did the process of continental drift not start before Mesozic era ? etc. Some writers argue that 'it is not a fair criticism to say that any pre-

Carboniferous mountain building cannot be explained on Wegener's hypothesis merely be cause he does not develop his scheme in earlier geological times' (J.A. Steers, 1961. PP. 161-161)

It may be conluded that 'even if all the mater of his theory is wrong, geologists and others can but remember that it is largely to him that we owe our more recent views on world tectonics' (J.A. Steers, 1961 p. 174) Though most point of wegener's theory was rejected but its central theme of horizontal displacement was retained. In fact, the postulation of plate tectonic theory after 1960 is the result of this continental drift theory of wegener. Wegener is, thus given credit to have started thinking in this precarious field.

2.3 THEORY OF "PLATE TECTONIC"

Introduction :

New concepts and theoris based on evidence and interpretation of sea-floor spreading and palaeomagnetic field have been advanced after 1960 in the field of Geology, geophysics and geomarphology of this theory of plate tectonic is most significant. This concept divides earth surface into about 20 plates in which 7 plates are major and the rest are minor.

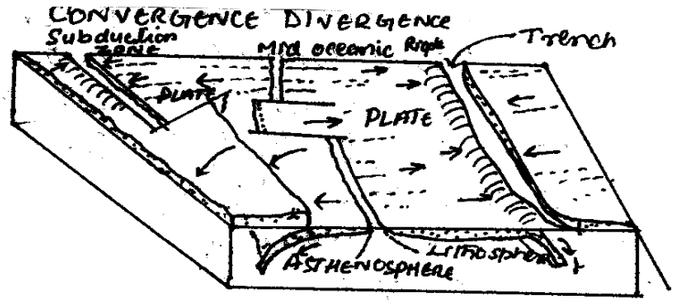
Meaning & Concept :

The word Tectonic is derived from Grek word 'tekton' means 'builder' applied to all internal forces which build up or form the features of the earth crust, including both Diastrophism and vulcanicity.

The rigid lithospheric slabs or rigid and solid rustal layers are technically called *Plates* . Tectoics simply means the study of rocks structure involved in earth movement. Plate tectonic deals with such site. as are in the form of plates.

The study of whole mechanism of evolution, nature and motions of plates, deformation with in plates and interractions of plates margins with each other is collectively called as *Plate tectonics.* Plate tectonics tells us that it is not only the continent that are in motion, but the ocean as well. This is so because the top crust of the earth is not an unbroken shell of granite and basalt, but a mosaic of several rigid segments called plates. In other words, the whole process of plate motion and resulent deformation is referred to as plate tectonics. These plates include not only the earth's solid upper crust, but also parts of the denser mantle below. They have an average thickness of hundred kilometres. They float on the plastic upper mantle of the earth called *Asthenosphere* and carry the continents and oceans on the backs like *mommoth rafts.*

History : It may be mentioned that the term 'Plate' was first used by canadian geophysicists. ***J. Tuzo Wilson*** in 1965. ***Mackenzie*** and ***Parker*** discussed in detail the mechanism of plate motion on he basis of Euleu's geometrical theorem in 1967. ***W. J. Morgan*** and ***Le Pichon*** elaborated the various aspect of plate tectonic in 1968. It may thus be pointed out that theory of plate tectonics is not gelated to any individual scientist rather a host of scientists of various scientific deciplines and research groups and expeditions have contributed in he development of this value able concept of the second half of the 20th century.



Diagramatic presentation of main aspects of plate tectonics. And also the type of plate bounderies.

Movements of Plates :

All the plates are in the stationary position but they move into different direction at different rates. Their rate of motion varies between 2 to 20 cm per year. There are three ways in which plate motion takes place. First

* Convergent in which the plate comes closer from different direction.
* The second is divergent where plate move apart while
* The third is parallel in which plates moves paralled to one. The nature of plate motion is associated with particular types of tectonic phenomena.

Plate margins or Boundaries & Earth movements :

It may be highlighted that tectonically plate boundries or plae margins are most significant because all the tectomic activities occur along plate margins e.g., seismic activities vulcanicity, mountain building and faulting etc.

There are three types of plate boundries on the basis of direction of their movement with relation to each other. They are

i) Convergent plate boundries.

ii) Divergent plate boundries.

iii) Transform plate boundries.

Along these boundries various kinds of tectonic features are formed. They are discuss in the following lines.

Convergent plate margin : are also called as '*destructive plate margins*' or '*consuming plate margin'* because two plates moves toward eachother (face to face) or two plate converge along a line and collide where in leacting edge of one plate (of relatively lighter material) overrides the other plate (of relatively denser material) and the overidden plate is subducted or thrust into upper mentle and thus a part of the crust is lost in the mentle, this is why the *convergent plate* margin is called as destructive plate margin and also called as '*collision zone' 'Subduction zone'* and *Benioff zone* (after the scientist Hugo Benioff).

The following Important geological phenomena lakesplace along the covergent boundry.

i) Occurance of volcanic activity in the oceanic area near the trench. For example ring of fires in pacific ocean.

ii) Formation of sea ares and island. i.e., sea ares in pecific ocean including Japan, phillipine etc.

iii) Earth Quares occurance ; and

iv) Foumatier of fold mountain and trenches.

Divergent Plate Margin : are also called as conservative plate margin and also shear plate margin and parallel/transform fault boundries where two plates are moving a part in opposit direction from a common line. These are called conservative because crust is neither created.

Divergent Plate boundary : also called as *constructive plate margin* or *accreting* plate boundries. The plates divergent boundry is one in which plates are moving apart in opposit direction from a common line. Due to moving away of the plates, a rift is formed along this boundry or margin. The width of rift or fracture is width of rift or fracture is widening a long as plates moves. Through this passage of fracture, motten materials are up welling and deposited both sides of the fracture. Such margin occur usally in ocean and along the mid-oceanic ridges. Along the *mid-oceanic ridge* especially in *Atlantic ocean,* due to deposition of new edjected motten material, new oceanic floor is created. the creatian of new ocean floor is described as ocean floor spreading. Hence the divergent margin is also called as construction margin as new crust is formed. The following events are associated along this margin.

i) Formation of rift or fracture

ii) Upwelling of motten materials from the mantle.

iii) Formation of ocean floor spreading.

iv) Occurance of fissure type volcanic eruption.

Transform Margin or Conservative Margin :

All the plates from two sides (both converging and diverging plates) moves parallel to each other and slide along common margin. Such margin is called as *Transform margin* because transform fault is formed. Plates in this process may join *ridge* to *ridge* , a *ridge* to *trench* or a *trench* to *trench.*

A ridge trench transform will always change length with time, A trench to trench transform may either lengthen, shrink or remain constant depending on which of plates, that form of subduction system, is the downgoing plate and the transform which join two ridge owe's will change in length with time.

The following events taking place along the transform plate margin.

i) Formation of Transform Faults.

ii) Earthquakes.

The conservative plate margin include no volconic activities, Seismic events, creation of ridges and valley, fracture zone etc.

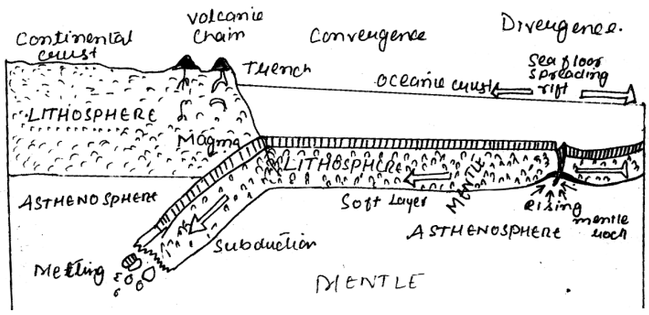


Fig. Diagramatic presentation of different types of plate margins.

Division of crust into plates :

The earth crust can be divided into six major lithospheric plates and six minor plates.

Major Plates :

1. Indian Plate
2. Pacific Plate
3. American Plate
4. African Plate
5. Eurasian Plate
6. Antarctica Plate

Minor Plates

1. Arabian Plate
2. Phillippines Plate
3. Cocos Plate
4. Caribbean Plate
5. Nusch Plate or East Pacific Plate

6. Antarctica Plate

Table : Summary of plate tectonic Movement and Tectonic phenomenon on the earth's surface.

Boundaries with reference to nature of plates

Margin	Ocean Ocean Plate	Ocean continental Plate	Continental Continental Plate
Convergent	1. Trench Formation 2. Island Formation 3. Earthquake	1. Subduction 2. Volcanic eruption 3. Formation of Treanch. 4. Earth quakes 5. Young mountain	1. Formation of fold mountain 2. Earthquakes
Divergent	1. Fissure eruption 2.Ocean Floor spreading Ridge Formation 3. Earthquakes	---- ---- ----	1. Formation of Rift Valley 2. Inland Sea 3. Volanism 4. Earthquake
Conservative (Parallel)	1. Transform fault 2. Ridge and Valley fracture 3. Earthquakes	---- ----	1. Transform 2. Earth quakes

2.4 GEOLOGICAL TIME SCALE

Radio metric dating has made possible the specific or absolute dating of rock, units which represent various events in the earth's distant past. The geological history of the earth or the 'geological clock' refers to the reconstruction of evolutionary sequence of the geological events involving the informations of various Zones (Crust, Mantle & Core) of the earth, formation of evolution of geomaterials (rocks), formation of development of mountains of faults, evolution of different lives etc. The when geological history right from he origin of the earth to its present form has been disded into major or minor periods on the basis of forms of life (organic remains), characterstic rock densities, places of rock formation, major tectonic events etc.

The history of the earth has been divided in to 2 Eon.

1. Cryptozoic Eon.

2 Phenerozoic Eon.

1. Cryptozic Em : In this Eon, the life was in hidden form. It has been divided into 1 Era of 2 periods.

1) Pre-Cambrian Era

2) Azoic period

3) Proteriozoic period

Pre Cambrian Era : It is the history of the period begining from the birth of earth of ending 600 million year ago. When the earth could formed from gas state into liquid, a

thin solid crust must have fomed over the surface of the liquid intution. The solid crust was the first rock.

Azoic Period : During this period, earth was formed, cooled of and underwent many changes. The upper Guest of the earth has cooled but there was inorganic activity in the interior part of the earth. This is in reality an Era of violent volcanism, large scale contraction of the earth has taken place. There was neither any sign of life nor the earth was suitable for sustaining life. Therefore rock of this era enhibit no forms of organisms. Therefore, this era is called Azoic.

Proteriozoic Period : This period have started about 2,000 million years ago and was spread out for 1,500 million year. Fossils of bacteria, blue green algae fungi, gelly fish, round worm of brachiopods in animal have been found. This period is further divided into different epoch.

2. Phenerozoic Eon : Life start its development is phenerozoic Eon. In this Eon, the londitins became suitable for sustaining life. It is divided into different periods of epchs.

The four periods are :

1) Palaeozoic Era

2) Mezozoic Era

3) Cainozoic Era

4) Neozoic Era

1. Palaeozoic Era : This era is the indication of ancient life. It is also called Primary Era, of persisted for about 370m yrs. It is composed of 6 important periods.

a) Cambrian Period : The name given to this period is after the name 'Cambria' lation name of wales. The duration of this period is of 70m yrs. This period saw the transgremion of sea over the land surface of the rocks of this period are quiet entensins. They have light limestones at the bottom over which are laid the layers of sand stone, shale of at the top is a thin layer of limestone again. The layus hold the first evidence of life.

b) Ordovician Period : The name of this period is after 'Ordovices' - a tuibe of walisef its duration is of 65m yrs. This period saw a large portion of land surface being submuged under water. Several volcanic eruptima also took place in this period. The animal life evolmed still further of the sea-grass was the main vegetation. Towards the end of this period a mountain building movement occured, fit brought out the mountain system in the state of Manachursets (USA). Climate appeared warm with no climatic zone.

c) Silurian Period - Its name is after 'Silurs' tribe of walse. Its duration is of 40 m yrs. This period is important for the birth of fish of large vegetation. The spineless animals reached a huge dimension of for the first time the animals which could breathe came into existence. Levels of seas tended to rise and fall. Plants adapted themselves on land for the first time but were leafless. Coral ruf formation was maximum in this period. The red sandstone is a product of this period.

d) Devonian Period : The name is after 'Divon' in S-W- England. The period saw at, its beginning the well known mountain building movement - the caledonian movement. This resulted in the folding and faulting of the area fum scandinaisa to greenhand. The second important activity of this period was another onslaught of sea on the land. The chief rock is the red sandstone of the chief creatures of this period were predimenanty equatic. Spiders, Willipeds of wingless insects also apperead on land.

e) Carboniferous or Coal Age Period : This is the period when the coal - bids of the earth came to be formed. Hence it is also known as the 'Coal Age'. This period also saw the biginning of such animal life that could live on both land or sea. The duration of this period was of 65 m yrs. Most of the Europe and large part of Russia was under water. Coal mainly found in N. Hemisphere Climate became dry in the interior land of coastal areas were warm of moist. Giant evergreen trees evolved in this period, also called 'Selvas'.

f) Permian Period : Its name is after the word 'Perm' a province is earstwhile USSR is of 55 m yrs. duration. It was the time when the Hircijnian mountain - building movement occured. This movement life its mark in Europe, North America of several other areas. The animals which could live on both land or sea evolved. Towards the end of this period, the climate of the earth became dry and the temperature began to rise.

2. Mesozoic Era : This is also known as the age of reptiles and consists of three distinct period as detailed below.

a) Trassic Period : The name trassic is after the three fold division of depesists in Germany and its duration is of 32 m yrs. During this period, South of central Africa, South India, Madagascar of Australia were part of one compact landmas known as Gondwanaland. During this very period, the Gondwanaland which was near the South pole began to drift northwards. Flying fish evolved of first habster (sea creatore) appeared. Reptiles dominate on land. Dinasaur are also there but it was 6" feet long. Flies of termites came into being.

b) Jurassic Period : Its name is after 'Jura' mountain in Switzerland and is of 60 m yrs. This period saw the reptiles to reach their greatest proportions. They dominated the land, sea and perhaps the air also. But with increasing heat of dryness, They were gradually disappearing. The fonits of the first bird of the earth belongs to this period.

c) Cretaceous Period : Its name is after latin word 'Creta' means chalk and is of 72 m yrs. The period is well known for its widespread deposits of chalk. In Europe of N. America, widespread layers of chalk were deposited. The other main rocks of this period are soft sandstone, clay of limestone. It was during this period that the decidrous trees appeared. Birds of early mammels also appreand in this period. Besides several mountain - building movement in Europe of N. America, this period was characterized with aftusions of lava in South India.

3. Cainozoic Era :

This period is of 63 m yrs. duration of also called Tertiary Era. This period is sub-divided into 5 periods. These are Eolene (Eos means day break) Oligocene (Oligos means tittle), miocence (Mammals means smaller), Pliocene (Plio means greater). Tertiary is the period when the old animals were replaced by mammals such as horses, elephants, dogs, pigs, bears, monkeys etc. There was also considerable development of decidious trees, flowering plants of gramland. It is also the period of mountain building and earth

movement. The Mezoic geosyncline were folded and uplifted to form the intensive mountain ranges in the Tertiary. The Tethy's sea disappeared from Europe and Asia by the Plioceno. In India, the folding of uplift of the Himalayas in the estern part of the Tethy's sea began towards the end of the Eocene and reached its peak in the Mid-Miocene. In Peninsulas India, The Deccan trap (lava) was formed, which is nearly 5,000 ft. thick of covers even at present time, an area and about 2 lakh sq. miles. The Rockies of the Andes of North America and South America were also formed.

4. N eozoic Era : This is the most recent of the periods of geological history. At the beginning of this period, the temperature of the atmosphere became so low that the surface of the earth came under a vast ice-sheet. Scandinais'a was the centre of moving glaciour - like wise, great areas of Canada and N.USA were also under ice. Besides, there were small patches of ice-caps on the Himalayan of the Alps. Therefore, this era is known as 'Great Ice-Age'. The allumial dyvesits of the would were laid in this very era. This very era saw the evolution of man of he growth of his intellect. Birds were also quite developing in the beginning of this era. This era is continuing even today.

Geological Time Table

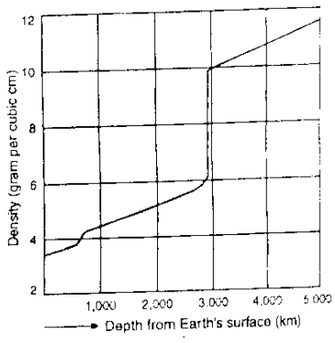
From Youngest to Oldest

ERAS	Epochs	Periods	Duration	Starting Time before present (million years)
		2. Holocene		
NEOZOIC	Quaternary	1. Plecistocene	0.990	1.000
		4. Pliocene	10m yrs.	11.000
		3. Miocene	14 m yrs.	25.00
		2. Oligiocene	15 m yrs.	40.00
ENOZOIC	Tertiary	1. Eocene	30 m yrs.	70.00
		3. Cretaceous	72m yrs.	135.00
		2. Jurrasic	60m yrs.	180.00
MESOZOIC	Secondary	1. Triassic	32 m yrs.	225.000
		6. Permian	55m yrs.	270.000
		5. Carboniferous	65m yrs.	350.000
		4. Devonian	55m yrs.	400.00
		3. Sillurian	40m yrs.	440.000
		2. Ordovician	65 m yrs.	500.00
		1. Cambrian	70m yrs.	600.00
PALAEOZOIC PRIMARY				
Pre-Palaeozoic		Pre cambrian or Algonican		700.00
Azoic a Archaen		Archaean		800.00

3.1 INTERIOR OF THE EARTH

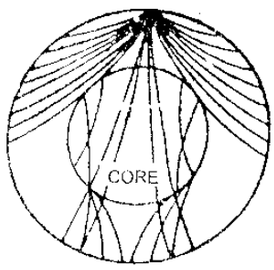
Introduction:

It is essential to study the earth's interior and its structural composition because the forces originating and operating in the interior have an impact on the surface of the earth as well. From ancient times man's inquisitive mind has been filled with curiosity about what lies below the surface. With time many views were put forwarded and subjected to criticism regarding earth's interior. Since thge interior at various times ejected all types of materials upon the surfgace - solid, liquid and gas, it was difficult to pinpoint the exact composition of the earth's interior. It was with regard to the scismological evidences that the nature of structural composition of the earth'sw interiof began to the brought to light.



VIEWS/EVIDENCES REGARDING EARTH'S INTERNAL STRUCTURE :

A collection of various scientific evidences are responsible for forming the modern views regarding earth's internal structure. The detailed study of earth's physical characteristics lead us to the true identification of its structure. However certain variations exist with regard to the interspretation of such physical characteristics.



The passage of Earthquake wave in the Earth's interior

(a) Density Related Evidences :

The upper rock layers have an estimated density of 2.7 while the total estimated density of the Earth has been scientifically varified to be 5.5. However the lower rocks in the interior have an estimated density ranging between 11 and 12. The calculation of increasing density towards the interior has been made by Bullen. He even prepared a graph which clearly indicates increase in the density with increase in the depth. **(b) Temperature Related Evidence:**

As with density, it appears that temperature too increases with depth. Infact it is documented that there is an increase in the temperature at the rate of 1°c with every 32 metres of depth. Other studies have indicatyed that the volcanic material ejected from the surface of the Earth comes from an approximate depth of 50km. The temperatuyre at that depth should therefore be about 1500°c which further proves that the interior of the Earth lies in a molten state.

(c) Seismological Evidences :-

The waves produced at the time of earthquakes are known as seismic waves and these are of three different types.

(i) P-waves which are also called longitudinal waves and traves at a speed ranging between 5 to 12 km per second.

(ii) S-waves which are also called transverse waves and travel at a speed ranging between 3 to 7 km/sec.

(iii) L-Waves which are also known as surface waves and travel at a speed considerably lower than even the S-waves.

During their movement the P and S waves encounter certain interruptions which tend to split them into many parts. As a result certain different types of waves have also been detected. Such obstacles in the path of the waves are different layers having different densities which gives strength to the argument that the Earth is composed of different layers or shells.

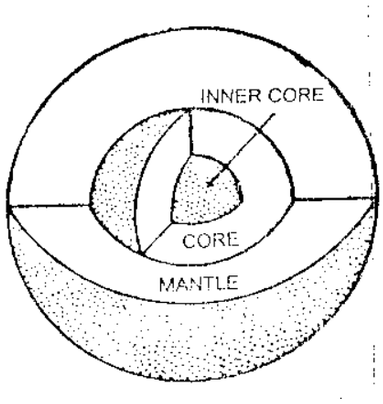
Based upon the presentation of these evidences, Jeffray provided a three pronged classification of the Earth's interior. According to him the interior of the earth was divided into three layers - (i) Lithosphere (ii) Pyrosphere (iii) Barysphare.

Later based upon their composition German scientist Vander Gracht renamed these layers.

Internal Structure of the Earth according to Vander Gracht

Vander Gracht modified the earlier work of such scientists as Jeffrrey, Leinck and Gutenburg to present his own view of the internal structure of the Earth. According to him there are three distinct or major layers into which the earth is divided

	Layer	**Relativedensity**	**Thickness**
1.	Sial Layer	2.75-2.90	Upto 60 km
2.	Sima Layer	3.10-4.75	1400 km
3.	Mixed Silicates	4.75-5.0	1700 km
4.	Metallic Nucleus	11.0	3400 km



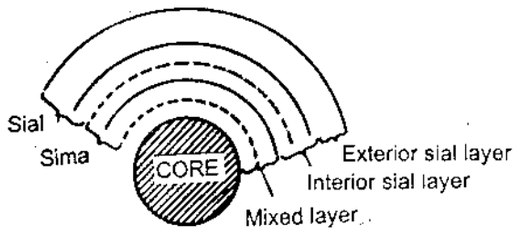
Mantle core and inner core of the Earth

Detailed Composition :

Name of Layer	Relative Density	Depth (In km)	Composing Elements
External Sial Layer	2.75-2.90	(i) 60 km below continents (ii) 29 km below Atlantic Ocean	Mostly Silicon and aluminium with traces of oxygen, potassium Magnesium etc.
Internal3.1-4.75 Sial Layer	60-1200	Mostly silicon	and Magnesium with traces of aluminium, Potassium, Sodium etc.
Mixed Silicate Layer	4.75-5.0	1200-2900 Magnesium and Silicion	Oxygen, Silicon mixture of iron and nickel
Nucleus	7.8-11.0	2900-6371	Nickel and Iron

Some other views of Earth's Internal Structure :-

(1) According to Suess emphasised the chemical composition of the Earth's interior. The Earth's crust according to him is covered by a thin layer of sedimentary rocks of low density. The identified three distinct zones of different matter just below the outer sedimentary cover (fig 1.4).



(a) Sial Layer - The outer layer dominated by silicon and aluminium, hence SL+AL = SIAL.

(b) Sima Layer - The basaltic layer located below the sial and dominated by silicon and magnesium, hence SI+MA = SIMA.

(c) Nife Layer - Layer of heavy metal located belowSima and dominated by iron (fe) and nickel (ni), hence - NIFE.

(2) According to Daly :-

Daly has recognized three layers of differing density and thickness as -

(a) Outer Zone- This layer is composed of silicates, has an average density of 3.0 with a thickness of approximately 1600 km.

(b) Intermediate Zone- This layer is composede of a mixture of iron and silicates, has an average desity ranging between 4.5 and 9.0 with a thickness of 1.280 km.

(c) Central Zone - This layer is composed of iron and is in a solid state. The average density is 11.6 and its diametre is about 7,000 km.

(3) According to Harold Jeffreys :-

On the basis of the study of seismic waves, Jeffrey has identified four layers.

(a) Outer layer of sedimentary rocks

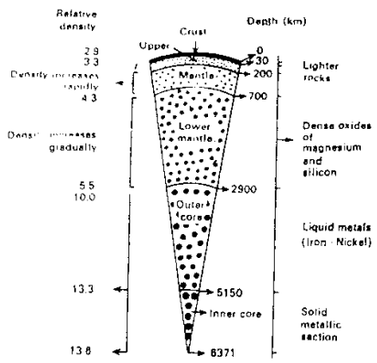
(b) Second layer of granites

(c) Third layer of thachylyte or diorite

(d) Fourth layer of clumte, peridotite and eclogite.

(4) Recent views :-

Three zones of varifing properties have been identified in the earth on the basis of changes in the velocity and passage of seismic waves. (fig 1.5 Each zone has varying properties of density, depth and thickness.



(a) **Crust** - It is further divided into two layers

- Upper crust

- Lower crust.

The average density of upper and lower crust is 2.8 and 3.0 respectively. The thickness of the crust ranges between 50 - 100 kms.

(b) **Mantle** - It is also divided into two sub layers.

- Upper mantle (Density 3.0-4.5)

- Lower mantle (Density 4.5 - 5.5)

The mantle extends upto a depth of 2900 kms. It also contains 83 percent of the total volume and 68 percent of the total mass of the earth.

(c) **Core** - It is divided into two sub layers.

- Outer core (density 10.0 - 12.3)

- Inner core (density 12.3 - 13.6)

The core extends upto a depth of 6371 kms. It's density is more than twice the density of the mantle but only 16 percent of its volume.

3.2 ROCKS & THEIR TYPES

The Earth's Crust :-

The Earth has a solid crust which has a thickness of about 64 kms. Both the lithosphere and the hydrosphere are included in the crust. A major part of the study of the Earth's crust includes an analysis of its composition. As many as 98 different elements in varying composition have been found to be present in the crust. However the distribution of these elements is highly uneven. There are eight major elements which account for more than 98% of the composition. The rest 90 elements account for approximately 1.5% of the earth's crust. Even out of these 90 only fifteen elements e.g. titanium, hydrogen, phosphorous, manganese etc. account for 1.25% of the crust while the rest 75 elements are called trace elements account for only about 0.25% of the crust.

Rocks :-

The elements forming the Earth's crust generally combine with each other to form a specific compound which has definite chemical composition and physical properties. Such compounds are called minerals. Although most minerals are composed of multiple elements, these are certain prominent minerals which are composed of a singular element eg. gold. In these turn, then minerals combine with each to form a new compound which is an immdiate part of the Earth's crust. Such mineral formed compounds are known as rocks.

Definition of Rock:

* An aggregate of minerals is referred to as a rock.

* The substance formed of one or more minerals and is a part of the Earth's crust is called rock.

Contrary to common belief rocks are not a always hard but can also be soft eg. graphite. They also vary in size from large size eg. basalt to fine grained eg. sand. As with the predominance of few elements in the composition of the crust rocks too are mostly composed of six major minerals. These minerals are feldspar, quartz, pyroxenes amphiboles, mica and divine.

Classification of Rocks:-

The Most universally accepted classification of rocks is the one which is based on the mode of formation. Although the rocks are composed of minerals, their mode of formation determines the following characteristics of rocks-

(a) Level of mineral composition

(b) Chemical composition

(c) Physical attributes and properties

(d) Rock structure and form.

On the baisis of the mode of formation rocks are divided into three major types-

(1) Igneous Rocks

(2) Sedimentary Rocks

(3) Metamorphic Rocks

Each type of rock has definite physical and chemical properties as well as chemical composition.

1) Igneous Rocks :-

In the initial stages of its formation the Earth was composed of molten matter which gradually started to cool down and due to the action of water, wind and glaciers began to take on a compact and consolidated form. This solidification of the molten material led to the formation of the igneous rocks. In other words, whenever magma reaches the surface of the Earth it starts to cool down and solidified magma is called igneous rock.

Characteristics of Igneous Rock :-

1) Layers of solidified and compact magma represent igneous rocks.

2) Most igneous rocks are non-porous in nature ie. water cannot percolate through them.

3) Igneous rocks are generally resistant to erosion

4) Igneous rocks are both crystalline and non-crystalline in nature. When the magma cools down at a fast rate the igneous rocks formed are non-crystalline in nature and vice-versa.

5) Silica content ranges between 40-80 percent

6) Due to their solidity and compactness, igneous rocks do not form fossils.

Classification of Igneous Rocks :-

Igneous rocks can be classified on many bases but generally three types of classifications are recognized.

(a) On the basis of mineral composition :

On the basis of their mineral composition igneous rocks are divided into two subtypes-

(i) Acid Igneous Rocks :- Such igneous rocks have an excess of silicon oxide which imparts acidic nature to the rocks. Other elements present are magnesium, sodium, potassium etc. The common example is granite. Acidic igneous rocks are poorly eroded.

(ii) Basic Igneous Rocks :- The silicon content in these type of rocks is less than 40%. In addition it also possesses 40% magnesium and about 20% of the rest is composed of iron, aluminium, potassium etc. Common examples are basalt, gabbro and dolerite.

(b) On the basis of place of formation :

Although igneous rocks are formed due to the cooling down of the magma, the process of cooling takes place both above and below the surface of the Earth. On this basis two sub-types of igneous rocks are identified

(i) **Extrusive Igneous Rocks :-** When the molten material cools above the surface, the type of rocks formed are called extensive or extrusive igneous rocks. eg. Basalt and Gabbro.

(ii) **Intrusive Igneous Rocks :-** When the magma lacks intensity and pressure it cannot reach the surface. As a result it starts to cool down below the Earth's surface at various depths. According to their situation below the surface three types of intrusive igneous rocks are identified-

* **Minor Igneous Rocks**

* **Intermediate Igneous Rocks**

* **Major Igneous Rocks.**

(c) On the basis of form and shape :

The molten magma begins its cooling process in various crevices, depressions or cavities. Consequently it's shape resembles the shape of the cavity where it solidified. Therefore, on this basis five sub-types of igneous rocks are identified all with unique and distinctive form, shape and size.

(i) **Laccoliths :-** Magma with a comparitively highter concentration of silica gets solidified at normal temperature. However, accumulation of hot magma below the hardened rock layer exerts pressure on it and the layer rises in the form of a dome. Such dome like formations are called laccoliths

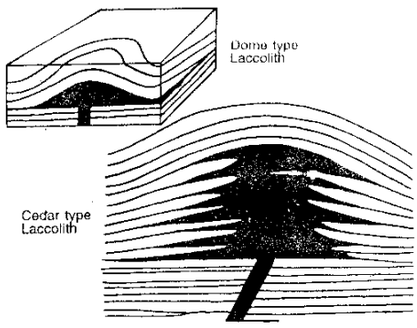


Fig 2 Fig 43. Dome Type and Cedar type Laccolith.

(ii) **Batholiths :-** Sometimes the magma on acquiring a large space spreads over the entire area and begins to cool. It's extent is extremely lartge and on some occasions exhibits cylindrical formations with it. These are known as batholiths (fig 2.2) and a common example can be observed in the British Columbia state where a batholith formation stretching for 2,400 km in length and 160 km in width can be found.

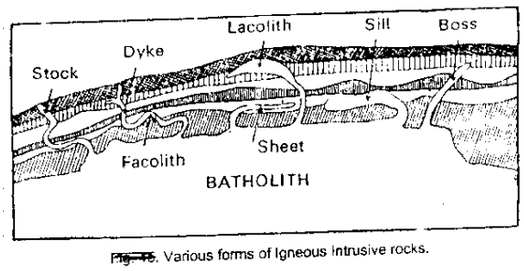


Fig 45. Various forms of Igneous Intrusive rocks.

(iii) **Lopoliths :-** When batholiths are deposited in concave form, they are kwon lopoliths. It is a common feature of South African topography.

(iv) **Phacoliths :-** When magma is deposited in a wave like form it is known as Phacolith eg. Saddle Reef in Australia.

(v) **Dykes :-** After the process of cooling, the magma appears to make an angle of almost 90° with its surrounding layers. This formation is known as a dyke eg. Colorado and Columbia in U.S.A.

2) Sedimentary Rocks:-

Although a vast majority of crustal rocks are igneous, sedementary rocks account for more than 80 percent of surface rocks. Such rocks are formed due to the weathering and erosion of existing rocks and their layers by layer deposition Sedimentary rocks are created in four step formation after the weathering of rocks takes place.

(i) Transportation:- Agents like water and wind are responsible for transporting and modifying weathered loose materials.

(ii) Deposition:- As the intensity and carrying capacity of the transpoting agent is reduced it deposets the material at various locations eg. bed of water bodies, along their banks or on the surface. The deposition takes place layer by layer and the process is called stratification.

(iii) Cementation:- Water containing loose rock materials: enters into caracks and opening of rock layers. It joins the layers with each other and the process is called comentation.

(iv) Consolidation:- As the number of layers go on increasing, the Upperf layers start to exert pressure on the lower layers. Due to this pressure the layers become compact and the space between them gets reduced. This process is called consolidation.

Characteristics of Sedimentary Rocks :-

(1) Sedimentary rocks clearly show distinct layers.

(2) Since different size particles compose these rock, they are of a porous nature.

(3) Layered deposition over an extended period of time means such rocks also show fossils of plants and animals which also helps in datring them.

(4) Sedimentary rocks are generally susceptible to eriosion.

(5) Coastal rocks show imprint of sea waves which are known as ripple marks.

Classification of Sedimentary Rocks:-

Sedimentary rocks may be classified on the following bases.

(a) On the basis of structure:-

This classification of sedimentary rocks is made on the basis of the contributing particles in their formation which determines their structure.

(i) **Calcerous Rocks :-** When the deposited particles are predominantly of lime content, such type of rocks are formed. Limestone and dolomite are common examples.

(ii) **Carboneceous Rocks:-** Sediments amounting in coal content from trees are responsible for formation of such rocks which have high carbon content.

(iii) **Sandstone Rocks:-** Sedimentary rocks formed predominantly from sand are called sandstone rocks and have reddish colours.

(iv) **Conglomerate Rocks:-** These type of sedimentary rocks are formed when particles ranging from small graus to large rocks are most easily eroded if cementing process fails to take place.

(b) On the basis of place of formation:-

Various types of agents are responsible for the formation of sedimentary rocks. These rocks therefore can also be classified on the basis of the agent that is responsible for its formation.

(i) **Aqueous Rocks:-** These rocks are formed when water is the principal agent in their formation.

(ii) **Lacustrive Rocks:-** These sedimentary rocks which are formed due to particle accumulation on lake beds.

(iii) **Riverine Rocks:-** When river enters a plain area, its particle carrying capacity is reduced. It therefore deposits its load on its bed or along its

banks. Allwvium is a common example of sedimentary formation along rivers.

(iv) Aeolian Rocks:- These rocks are formed in dry areas where the main agent of formation is wind.

(v) Glacial Rocks:- When glacier acts as an agent of erosion it deposits material along its floor or along the banks of the water body such rocks called Glacial rocks are common in areas of higher latitudes.

1.8 Metamorphic Rocks:-

The rocks which are formed from both igneous and sedimentary rocks but having properties different from both the types are called metamorphic rocks. Infact, metamorphic rocks are said to form under two conditions-

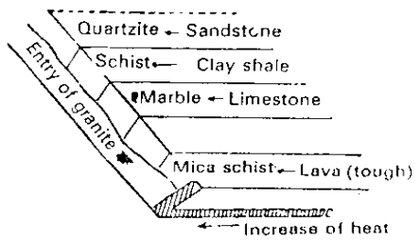
(i) When either igneous or sedimentary rocks undergo conditions of extreme heat and pressure.

(ii) When there is a change in the structure of igneous or sedimentary rocks due to mechanical or chemical changes.

Causes of Metamorphism :-

(i) On certain occasions mountain building or orogenic forces exert so much pressure on the rocks that they became warped and compressed. This changes their form, shape and structure.

(ii) Conditions of high temperature and pressure are triggered by lava which occupies empty spaces in between rocks. (fig 2.3)



(iii) Underground water dissolves existing rocks and transports them to another place where they are reformed with different physical and chemical properties.

(iv) Existing rocks undergo conditions of extreme pressure due to the work of geodynamic forces.

Types of Metamorphism :-

Two types of metamorphism are observed-

(i) On the basis of Agency : On this basis metamorphism of rocks may take place by either thermal or dynamic agencies.

(a) Thermal Metamorphism: Heat is a common cause of metamorphism and is generated through following agencies:-

* Hot Magma
* Hot gases, vapours or liquids.
* Mutual Friction; and
* Geothermal Heat.

(b) Dynamic Metamorphism:- Pressure is also a common cause of metamorphism and is generated by the operation of geodynamic force.

(ii) On the basis of Zones of Influence: On this basis the metamorphism is also of two types-

(a) Contact Metamorphism:- When the empty spaces between rocks are filled by magma, conditions of high temperature and pressure are exerted on the rocks in immediate vicinity or contact zone.

(b) Regional Metamorphism:- The pressure exzerted on the rocks developed in geosynclines are responsible for this type of metamorphism. This metamorphism is commonly observed in major mountain ranges like Himalayas.

Metamorphic Transition:-

As is understood that metamorphic rocks are formed from igneous and sedimentary rocks, it is relevant to give examples of igneous or sedimentary rocks and their metamorphorsed form

TYPE OF ROCK	METAMORPHIC ROCK FORMED AFTER METAMORPHISM
(1) **Igneous Rock**	
(i) Mica Rocks	Schist
(ii) Granite	Gneiss
(2) **Sedimentary Rocks**	
(i) Sandstone	Quartzite
(ii) Limestone	Marble
(iii) Clay	Shale, Slate, Phyllite, Schist.
(iv) Peat	Ligmate, Bituninars, Anthracite.

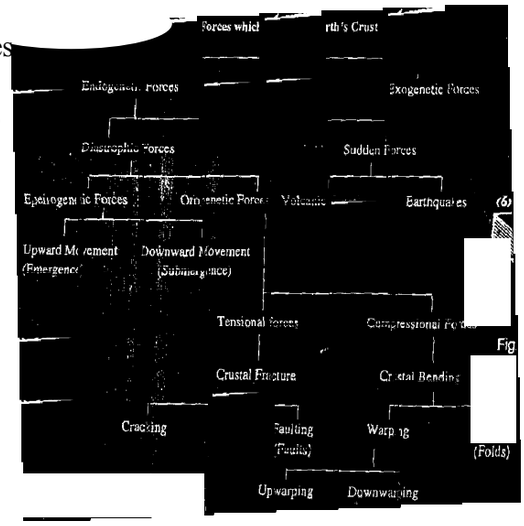
3.3 EARTH MOVEMENTS :- EARTH QUAKES & VOLCONES

Earth Movements :-

Earth movements refer to all those forces which operate from within and without the earth's crust and are responsible for constantly changing and modifying the earth's crust and all types of relief features that are located both on the earth's surface as well as its interior. Such movements or forces may be so gradual that they are barely noticeable and their effect may be felt over thousands of years. However there are also certain forces which make their impact felt within seconds. Earth movements therefore include a very wide variety of such movements or forces which are constantly shaping or reshaping the earth and its relief. Based upon their operation and origin earth movements are classified into two types of major forces as :

(1) Endogenetic Forces

(2) Exogenetic Forces



Schematic presentation of forces (endogenetic)affecting the earth's crsut

1) Endogenetic Forces :-

These forces originate from the earth's interior and include a wide variety of other forces. Endogenetic forces generally cause both vertical as well horizontal movements in the earth. Irregularities of the earth's relief are also attributed to these forces. Such forces are usually differentiated on the basis of their intensity. They include both long period as well as short period changes the endogenetic forces are classified into two main categories based upon their intensity.

A) Diastrophic Forces B) Sudden Forces

A) Diastrophic Forces :-

These are also sometimes called the long period canges as they move very slowly and their effect is becomes visible after passage many thousand years. In opposition to the sudden forces which are usually the cause of destruction, the diastrophic forces are called forces of constructioon. They are responsible for providing character to the earth's relief by assisting in mountain building processes. Their impact is felt on all major relief features on the earth. The diastrophic forces are further divided into two types of forces.

(1) Epeirogenetic Forces :- These forces consist of upward and downward movement which leads to the upliftment and subsidence of continental land masses respectively. Upliftment can be of the whole contenent or a part of it. Upliftment can also be in the form of emergence of coastal land. The downward movement or subsidence means the subsiding of land area or coastal area below sea level which is termed as submergence.

(2) Orogenetic Forces :- Such forces are a result of the horizontal movement of endogenetic movements. They are of furthur two types.

(i) Tensional forces :- When orogenetic forces work in opposite directions they are called divergent or tensional forces. Tensional forces are responsible for the following activities.

(a) Rupture (b) Cracking (c) Faulting (d) Fracture

Therefore such forces create openings and cracks in crustal parts of the earth.

(ii) Compressional forces :- When orogenetic forces act in the same direction they are called convergent or compressional forces. They are responsible for the following activities :-

(a Crystal Bending

(b) Crustal Warping - Both anticlines and Synclines.

(c) Folding - Both anticlines and Synclines.

B) Sudden Forces : -

These are short period chages that make their effect felt within a few minutes or even seconds. They are very sudden and are generally associated with destruction and as such are also called destructive forces. The two main events associated with sudden forces or movements are :-

(i) Volcanic Eruptions; and (ii) Earthquakes.

Both the above movements originate in the interior but their effect is felt on the surface as well.

2) Exogenetic Forces :--

The exogenetic forces originate and operate on the surface of the earth. They are sometimes also called denudational forces which through their effect break down and modify those relief features created by endogenetic forces particularly diastrophic forces. They include three main activies :

(i) Weathering-

(a) Physical b) Chemical c) Biological

(ii) Erosion (iii) Deposition.

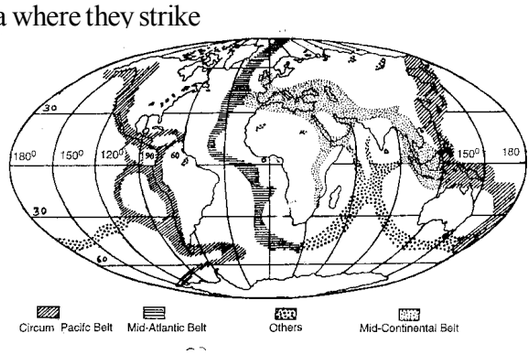
The weathering and erosional activities are denudational in nature while the activity of deposition is a constructional process.

Earthquakes-

Earthquakes are a phenomena which is part of sudden Endogenetic forces. It is defined as -

"Earthquakes are tremors which are produced by the passage of vibratory waves through the rocks of the Earth".

They are associated with death and destruction because they have a great capacity of changing the entire area where they strike



World distribution of earthquakes

In India Assam and Gujarat have been witness to the most devastating earthquakes ever witnessed in the country. Movement along the San Andreas fault is the cause of frequent earthquakes.

While studying the phenomenon of earthquakes it is important to know about the following things :-

(1) Causes of Earthquakes

(2) Intensity of Earthquakes

(3) Consequences of Earthquakes.

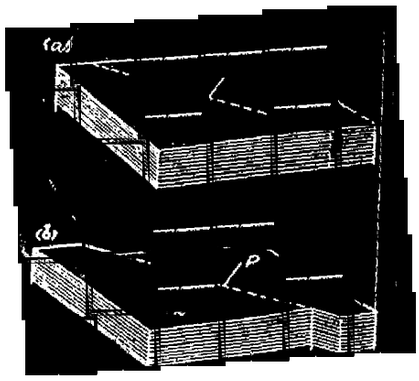
(1) Causes of Earthquakes

i) **Volcanic Activity :** It is commonly observed that volcanic erriptions are followed by earthquakes. The emission of lava takes place under tremendous

pressure. Once emitted, the pressure is released on the underlying layers which leads to disturbance in the earth's crust and ultimately earthquakes.

ii) **Local Causes :** Volcanie activity is also considered a local cause of earthquakes. Other local causes include landslides, water vapour emission from rocks and collapse of karst topography.

iii) **Faulting :** Perhaps the most important and common cause of earthquakes is faulting and movement along existing faults. Son Andreas fault line is a prime example of earthquakes being caused due to movement along fault line.



Movement of San Andreas drift.

(2) Intensity of Earthquakes:

The intensity of the earthquakes is defined as the impact which they have on life and property. Therefore a scale is devised on that basis which can measure the intensity of the earthquakes Mercalli was the first to come with a qualitative scale which had 12 classes depending upon the destruction caused by the earthquake. However this scale has since been rejected as it does not offer a scientific viewpoint and the intensity can be known only after assessing the loss to life and property.

For some time the intensity of earthquakes have been measured by the Richter scale named after the scientist Richeter who devised it. It measures the intensity with the help of a machine called seismograph which present out a graph of the ECG machine. Unlike Merrali has not restricted the upper limit but till date . Earthquake have not crossed the intensity of 9. The is oseimal line is the imaginary line which gains the plants of an area having equal earthquake intensity. The point of origin of an earthquake is called focus. The point on the earth's surface vertically above the focus is called epicentre. The earthquake and spreads is all directions. The extent to which the earthquake is felt depends upon its intensity.

(3) Consequence of Earthquakes:

Contrary to common belief earthquakes do not cause only destruction they have certain advantage as well the disadvantages and advantages of earthquakes may be given as :-

(i) Disadvantages

(a) The earthquakes travel in waves around the epiecentre and creates cracks and fissures in the land surface.

(b) Buildings, houses etc are destroyed.

(c) The communication liens are completely broken down including roads and railways.

(d) Floods result due to river water encroaching upon land

(e) Electric fires break out.

(f) Landslides occur and cover houses, agricultural fields

(g) Water receeds from the ports but returns in the form tsunami waves

(ii) Advantages:

(a) Water is flushed out of lakes and other small water bodies and the exposed area proves to be fertile agricultural land

(b) Subsidence of sea floor gives rise to the formation of sea ports

(c) High altitude areas are lowered and in the long sun helps in communication, connectivity and transportation.

(d) Mineral deposits are uncovered.

(f) New streams, springs and waterfalls are created

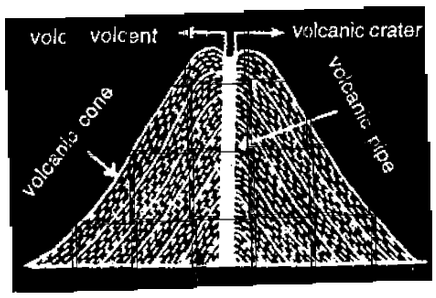
(g) New layers of soil are formed due to destruction of rock layers

Volcanoes :-

Volcanoes and volcanic explosions are considered almost as deadly a phenomena as earthquakes. Mountains with active volcanoes eject molten material from an opening in their top. This molten material is called magma or lava and includes a mixture of chemicals, rocks and gases emitting from the mountain at an extremely high temperature. Volcanoes are a part of the sudden endogenitic forces which originate within the earth's interior. There are many active volcanoes in the world which explode with a varying frequency. Mount Etna, Vesuvious and Stromboli are three active volcanic peaks all situated in Italy. The word volcano is derived from the name of the Roman god Vulcan. The process which includes all the phenomena associated with the movement of molten material from he enterior of the earth to its surface, is called Vulcanism.

Structure of a Volcano :-

A Valcano is defined as a group of closely spaced vents through which molten material is effected from deep within the earth's interior. the structure of a volcano reveals the following parts :



Different components of a volcano.

i) **Vent :** It is an irregular shaped opening in the crustal rock layer of h earth through which hot molten material is ejected.

ii) **Pipe :** The material from the vent travels through a cylindrical pipe like structure towards the top.

iii) **Cone :** Continuous emission of magma leads to the formation of a series of cones over the vent. These cones increase the size of the volcanic peak.

iv) **Crater :** The opening on mouth at the top of the volcanic peak from which magma is released on the earth's surface is called crater.

Volcanic Material :

Different types of materials come out of the volcano. A classification of that material is as follows :

i) **Solid Materials :** Large and small rocks are part of the solid materials. The diametre of such particles ranges between 5-50 mm. Large pieces are called volcanic blocks while the tiny ones are ash particles.

ii) **Liquid Materials :** The liquid material is cllectively called magma. It is nothing but liquid rocks and chemicals at a very high temperature. Its major composing element is silica.

iii) **Gaseous Materials :** Hot gaseous materials are an intergral part of the volcanic materials. Stream and water vapour are in abundance. Carbon dioxide is also present as are sulphur, chlorine, flourine and boron in gaseous form.

Classification Based on Activity : There are three known categories of volcanoes based on the frequency of their eruptions.

i) **Active Volcanoes :** Those volcanoes which erupt with regularity are active. The frequency of their activity can range between a few minutes to

a few years. Mount Stromboli in sicily is called the light house of the world ecause it explodes in varying degrees every 15 minutes on average.

ii) **Dormant Volcanoes :** Those Volcanoes which have stopped exploding for a great period of time are called sleeping or dormant volcanoes. However they can be expected to become active at any time in the future. Mount vesuvious in Italy is an example of dormant volcanoes. It is difficult to predict with certainity the explosion of dormant volcanoes.

iii) **Extinct Volcanoes :** Those vlcanoes which were active a long time into the past but are dead are called extinet volcanoes. There is very little change of such volcanic peaks exploding. However it is difficult to distinguish between dormant and extinct volcanoes.

Causes of Volcanoes :-

There are some important causes of volcanic explosions.

i) **Water :** Water from the surface seeps underground through fissures. The lava present in the interior comes into contact wih this water and the water dissolves in the Lava. Due to crystallisation of lava this water which is at an extremely high temperature and pressure is freed in the form of steam. This steam rises up and exerts pressure on the surface. If it has enough pressure it creates an opening and reaches the surface followed by magma.

ii) **Folds :** The magma lies in layers and the pressure of layers keeps the magma in unmelted state. Due to orogenetic action sedementary rocks rise in folds and pressure on the lava is released. This causes it to melt and rise towards the surface. Due to release of immense pressure the lava explodes out of the volcano and onto the surface.

iii) **Radio Activity :** Scientific studies have proved that magma contains certain radio active particles. There is a belief that the heat generated by these radio active elements melts and heats the magmatic materials and ultimately forces it out of the surface.

3.4 "WEATHERING & EROSION

Weathering :-

Due to constant actions of such agents as temperature, air, water etc, rocks start to break down into smaller particles. The breakdown occurs as a result of disintegration through physical action and decomposition through chemical action. The broken down and loose rock material is deposited over the bedrock and is called regolith. Weathering also takes place when layer by layer of rocks are periodically peeled off. This particular process is termed as Exfoliation. Although both weathering and erosion are responsible for breaking down rocks into smaller particles. Weathering process takes place at the point of origin without any movement of the particles as associated with erosion. Therefore, weathering always preceeds erosion.

Definition:- The definition which truly identifies the true meaning of the term weathering is as follows.

"Weathering is the mechanical fracturing and chemical decomposition of rocks 'in situ' by natural agents at the surface of the earth".

In the above definition the latin term 'in situ' refers to the breakdown of the rocks at their original site or situation. The broken down smaller particles then can be carried away easily by an agent of erosion.

Types of Weathering :-

Since weathering is defined as both the 'mechanical' as well as 'chemical' breakdown of rocks, therefore it is of two distinct types

(a) Physical or Mechanical Weathering

(b) Chemical weathering

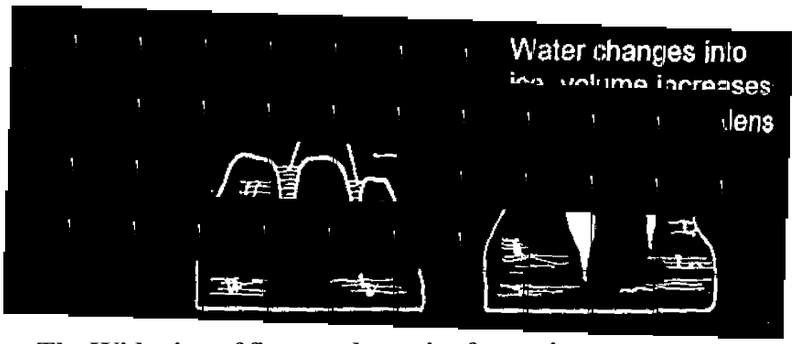
The climate and topography of a place determines the type of weathering a rock undergoes. Hot and humid climates with abundance of rainfall promote chemical type of weathering while arid and semi-arid type of regions generally promotes physical type of weathering. However both these processes are not exclusive of each other. The breakdown of a rock is well and truly brought about by both physical and chemical types of weathering acting alternately or simultaneously on a rock.

A) Physical or Mechanical Weathering :- The main factors which are responsible for physical weathering are as follows.

(a) Temprature:- Temperature as an active agent of weathering is most evident in those areas where daily range of temperature is very high. During day time when the temperature is high the rocks tend to expand. However as the temperature drops especially during night time the rocks start to contract. Over a long period of time continuous expansion and contraction leads to a pressure exertion on the rocks. This pressure starts to affect the outer surface of the rocks and the process of exfoliation sets in. Apart from exfoliation temperature change also leads to cracks and fissures developing in the rock surface which ultimately leads to breakdown.

(b) Pressure and Release:- Many types of rocks especially metamorphic rocks are created under conditions of extreme pressure. This pressure provides stability to the rock and it retains it form. However weathering in the upper layers lead to release of this pressure on the lower layers. The lower rock layer this exposed are prone to weathering. Release of pressure also leads to cracks appearing on the rock surface.

(c) Freeze and Thaw :- Those rocks which already possess cracks and fissures are most likely to be affected by freeze and thaw action. In areas of cold climate water gets logged into rock openings. During night time when there is sudden drop in mercury that water freezes into ice. Consequently there is an increase in the volume which exerts pressure on the rock. This leads to the widening of the cracks and ultimately to splitting upto of the rock.



The Widening of fissures due to ice formation.

(d) Gravity :- Large jointed rocks especially those found on slopes are most affected by gravity. Rocks roll down slope and get crushed in the process.

(e) Biological/Organic Action :- Plants and animals also contribute towards the process of physical weathering. The roots and branches of plants and trees have a tendency to enter cracks in the rock. As these roots start to extend and strengthen they exert a great deal of pressure on the rocks until they finally break into smaller parts. Animals especially grazing animals and insects like worms are responsible for weathering of rocks.

B) Chemical Weathering :-

Oxygen and corbondioxide of the atmosphere become very active in the presence of water and water vapour and bring about chemical changes in the rock composition. Therefore, chemical weathering is much more evident in areas having hot and humid type of climate. Chemical weathering of rocks takes place through the following Process :-

(a) Oxidation :- Atmospheric oxygen reacts with the mineral compounds of rocks in the presence of water oxidation is most evident among rocks rich in iron content as the action of water changes ferrous state of iron to ferric. In other words, water starts to rust the iron of the rocks. From pyrites are also affected by water and this produces sulphuric acid which proceeds to dissolve the pyrites and remove them from the rocks.

(b) Corbonation :- Humid areas commonly experience the process of corbonation during excessive rainfall. Calcium carbonate content of the rocks readily reacts with the rain water which possesses carbonic acid. Calcium carbonate and magnesium carbonate in presence of the carbonic acid are converted into bicarbonates of calcium and magnesium.

Rocks rick in lime content also readily loose their lime content in presence of rain water.

(c) Hydration :- In this type of chemical weathering water is absorbed and in corporated into the mineral content of the rocks. This leads to swelling up of the rocks and then the breakdown of rocks especially coarse grained rocks, eg. hydration leads to the formation of gypsum from calcium sulphate.

(d) Hydrolysis :- This process leads to the formation of a new mineral in the presence of water. The granite rock commonly undergoes hydrolysis. The feldepas content of granite rock gets converted into kaolin.

(e) Desilication :- Running water separates silica content of rocks. Continuous desilication leads to disintegration of the rock.

C) BIOTIC WEATHERING : Plants and animals including man largely control the breakdown the rocks. It may be pointed out that in all types of weathering in all climatic regions biotic communities play some roles in one way or the other. This is why B.B. Polynov (1937) believed that completely **sterlie weathering** was impossible. It may be mentioned that it does not mean that biotic communities always indulge in destructive work by disintegrating and decomposing the rocks but the burrowing animals posing help in the transfer of soils f rom lower to upper and upper to lower horizons and thus the mixing of geomaterials activates weathering. Though vegetations protect the rocks by binding them through their roots but different types of acids (e.g. humic acids, bacterial acids, microfloral acids etc.) produced by them faciliate **biochemical weathering.** Recently, man has become the most powerfeul weathering agent because of the development of modern technologies. Biotic weathering, thus, is divided into 3 types e.g. (i) faunal weathering , (ii) floral weathering and (iii) anthropogenic weathering.

1. Faunal Weathering : The burrowing animals, worms and other organisms help in gradual breakdown rocks on fragments thereof. Burrowing animals include gophers, prairie dogs, foxes, rabbits, jackals, termites, rats etc. which dug out burrows and tunnels in the rocks and unconsolidated geomaterials as their living places (homes). By doing so they weather the rocks and geomaterials roles in rock and soil weathering. These organisms repeatedly mix up the soil materials and thus always expose fresh materials to weathering agents. They also help in moving the organic matter downward into the soil profiles and

thus extend the weathering at greater depths which otherwise would have not been possible.

It is believed that there are about 1,50,000 creatures, big and small, in one acre of land and these organisms bring about 15 tonnes of soils at the surface from below every year. According to the estimate of Charles Darwin the soil organisms bring about 25.4 thousand kilograms of soil at the surface every year in the English gardens. Termites play very important role in sorting and rearranging the soil materials in the upper horizons of soil profiles in tropical regions. Termitaria are the evidences of soil weathering by termites. According to Ponomareva (1950) earth worms burrow to about 1.5m and pass 10 tons per acre per year as a mean and 20 tons per acre per year as a maximum of soil materials. Rabbits, prairie dogs etc. destroy the soil structure and they obstruct the leaching and other horizon forming processes by constantly remixing the soil materials.

2. Floral Weathering : Weathering of rocks by vegetations takes place in two ways viz. (i) physical weathering and (ii) chemical weathering which is called as biochemical weathering, which will he discussed under separte heading. It may be pointed out that floral weathering does not take place independently rather it helps the physical and chemical processes of weathering. Larger plants affect and control weathering in a number of ways. (i) Cracks are widened by root penetration and consequent root pressure. (ii) Dense vegetation cover generates distinct microclimate at the ground surface. The soil atmosphere is largely affected by root respiration, human content, increased moisture due to low rate of evaporation, increased content of organic CO_2, low temperature, all of which activate chemical weathering. It may also be mentioned that vegetations also protect the rocks and soils from weathering processes.

3. Anthropogenic Weathering : Man being a biological agent accelerates and decelerates the natural rates of weathering by many folds. The 'economic and technogical man' lashed with modern technologies has become the most powerful weathering and erosion agent. Mining activities for extraction of minerals, blasting of hills and ridges by dynamities for road and dam construction and mineral extraction, quarrying for industrial (limestones for cement) and building materials etc. result in such a fast rate of disintegration of geomaterials (rocks) that this may be accomplished by natural weathering processes in thousands to millions of years. Man accelerates the rate of weathering on hillslopes by modifying the ground surface through deforestation which reduces the mechanical

reinforcement and cohesion of unconsolidated geomaterials and thus increases slope instability which causes slope failures and mass movement of material down the slope in the form of landslides, slumping and debris fall and slides.

EROSION

In order for erosion to occur it requires a transporting agent to carry the rock along. In nature these transporting agents are :-

Gravity

Weathered rocks falling under the action of gravity are transport from the site of weathering to a place further away, on route they can erode other rocks they strike. For example weathered rocks falling off a cliff face or mountain or rock being transported during a mudslide.

Wind Erosion

Wind Erosion, though it may be small where you live, can take quite a toll on areas of the world covered in desert. Wind erosion is simple... light objects, such as rocks and pebbles are carried by the wind and can hit landforms, eroding materials off them, that are carried off in the wind. Wind can carry small particles of rock, dust and sand over vast distances. When the particles come across other rock features they can cause erosion via there collisions against these features.

Water Erosion

Water erosion occurs from the chemicals in the water, and the force of the flow of water in the river. There are many chemicals in the water of a river, and those chemicals can break down certain rocks, such as limestone or chalk. This eroded rock is carried down the river. Sometimes, a crack or crevice develops. When the force of the flowing river smashes into that crack, the rock can break away, and again be carried down the river.

As you can see, erosion creates a load in the river. When rocks, pebbles or even

boulders smack the riverbed, or side, this can cause further erosion. Also, if a boulder is stuck in an eddy, it can create a pathole in the riverbed. Rivers can wind around, but that will be looked at in the next section. Weathered rocks can be transported vast distance by streams, rivers and oceans. The abrasive action of the transported rock can further erode the river beds and river banks.

Glacier Erosion

Glacier can transport weather rocks which become embedded in the rice, these rocks then grid against the rocks beneath the glacier resulting in erosion. Ice erosion, besides that of hail, comes mostly in the form of glacier erosion. Glaciers are giant bodies of ice that can pick up huge pieces of rock, some even as big as houses. A combination of the water, ice, and picked up sediment, create a powerful eroding machine. The more sediment that's picked up, the greatest the force of erosion. The erosion can smooth out areas that were once rugged and rocky. Glaciers can carry almost anything, and like sandpaper, the sediment just keeps increasing. Glaciers are such a powerful force that they can carve valley, deposit moraines, or lead to the creation of landforms such as deltas.

Sea Erosion

Erosion in the Sea also occurs. The salts and other chemicals can erode weak rocks on the coast, such as limestone and chalk. The eroded materials are carried up the shore by the means of a long shore drift Waves crashing against the shore can create air pressure inside cracked rocks, that can eventually break them. Further more, if rocks, pebbles or sediment is carried in the waves, they can smash up against the shore and erode it even more.

Soil Erosion

Soil erosion pays the biggest price to farmers. Flooding, wind etc. can carry the topsoil away from farmlands, and make the soil unfertile. I will have more information in the pages ahead.

4.1 Fluvial & Glacial Landform's

Rocks are the dominant feature of the earth's surface and are constantly affected by climatic phenomena and other agents which work to modify the character of earth's surface. Weathering breaks down the rocks into smaller particles 'in situ'. However the broken down rock pieces may then be transported forward to a different location due to the action of aforementioned agents. Therefore, whenever there is movement or displacement of material from its original position, the process is known as erosion. Erosion usually accompanies or follows weathering and is defined as that process by which weathered materials are transported and deposited in different locations by the action of various agents which may collectively be referred to as the agents of erosion.

Agents of Erosion :-

Due to the action of weathering the earth's surface is covered by a layer of loose rock material called Regolith. This regolith which is an unconsolidated rock mixture undergoes the process of erosion through the action of various agents of erosion.

(i) Running water : Water is an important erosional agent particularly when it is in motion. Running water therefore can be considered as a very important agent of erosion as well as transportation. River water has great capacity for erosion and also possesses a vast carrying capacity for load which includes sediments, rock mixture, sand etc. A river can carry out all three activities of erosion, transportation and deposition. Through its action running water can create both erosional as well as depositional landforms. Such type nof landforms are known as fluvial landforms.

(ii) Moving Ice :- The intensity of moving ice i.e glaciers as an agent of erosion is comparatively less than that of running water. Glaciers have the

capability to erode large blocks of lands or even part of a mountain side. Since they are in motion they also carry out the activity of transportation. However when the speed of glaciers is reduced, it deposits the transported materials along the banks of the water body over which it is travelling or even on the body of the glaciers. As with rivers, the glaciers also form erosional as well as depositional landforms.

(iii) Wind :- Winds as erosional agents are mostly active in arid type of climate. Wind by itself does not carry out erosion but the material that it carries with it erodes mountain sides, rocks and even large boulders. Arid type of landforms which are both erosional as well as depositional in nature are created by the action of wind.

Process of Erosion :-

The process of erosion can be divided into the following steps :-

(i) Picking and Plucking :- An erosional agent with sufficient intensity can pluck or break off a piece of a rock and carry it forward. Picking generally involves the collection of regolith that lies over the bedrock.

(ii) Transportation :- After picking up the weathered particles the erosional agent proceeds to transport it from its place of weathering to another location. The process of erosion continues through transportation as well because erosional agents tend to rub, scrape, scratch, abrade and disintegrate the rock pieces further while in motion. Although landforms are not actually created during transportation but the shape, nature and size of depositional features is dependent upon the activity of transportation.

(iii) Mutual Friction : - Erosion is caused not only by wind, water and ice but weathered pieces of rocks also become agents of erosion. These rock pieces collide with each other and modify their shape, size and texture. Angular edges of rocks due to constant contact with other rock pieces, become rounded and smooth. The rock pieces being transported also affect the river banks, bed and floor of the river by creating depression like features.

(iv) Deposition :- The process of erosion ends with deposition. Transportation and mutual friction can continue only till the agent has the capability to carry the material forward. At the point where carrying capacity diminishes, the load is deposited. The larger pieces are deposited earlier than the smaller pieces. This furthur loads to the formation of depositional landform features.

Fluvial Erosion :-

Running water is an extremely active agent of erosion and is capable of creating a great variety of landform features. The landforms created during the different stages of a river are collectively called fluvial landforms. A river carries out the process of erosion in three different ways :-

(i) Hydraulic Action:- Due to its velocity the river water lifts rocks and debris and pushes them forward. Size of the eroded material depends upon the flow intensity of the water.

(ii) Abrasion Action :- The impact of the running water loosens pieces of rocks and as they are pushed forward they start to strike and rub against each other. As a result they get broken down further. This process is called abrasion or corrasion.

(iii) Solution Action :- Some types of rocks contain certain soluble elements. As they come into contact with the water the soluble components dissolve in the water and rocks loose their original shape, form and structure.

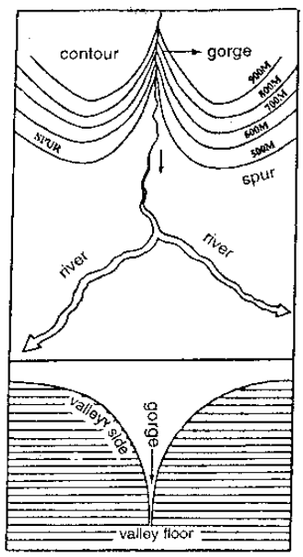
Fluvial Erosional Landforms :

As a consequence of fluvial erosion many unique type of erosional landforms are created. The important ones are :-

(i) River Valleys :- Valleys are the most common type of landform feature created by fluvial action. Valleys are formed during different stages of the river course. In the youthful stage V-shaped valleys having very steep sides are formed. During the mature stage the valley are slowly broadened with flat floor and uniform gentle sides. In the old

stage the valleys are furthur modified into broad and shallow valleys with concave sides. River valleys are of two main types-

(a) Gorge : These are the narrow and deep valleys formed during the youthful stage of the river. They are a common feature in the Himalayan rivers.



Contour plan of gorge and spurs and cross section of a gorge.

(b) Canyon : These are generally referred to as extended form of a gorge. The Grand Canyon on Colorado River, USA is an example. It extends to about 500 kms and has a depth of about 2000 mtrs.

Valleys can also be classified on the basis of their origin :-

a) **Consequent Valleys :-** Valleys formed as a result of land upliftment.

b) **Subsequent Valleys : -** Valleys formed due to erosional action of streams flowing over layers of weak rocks.

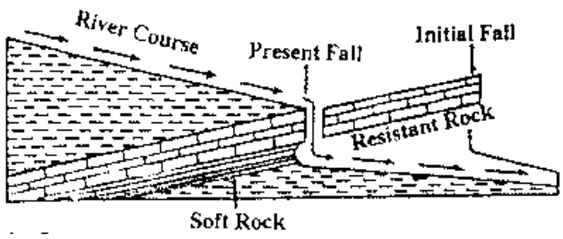
c) **Obsequent Valleys :-** Valleys in which the flow of water is opposite direction to that in a consequent valley.

d) **Insequent Valleys :-** Valleys formed by the accumulation of water in some depression.

e) **Inconsequent Valleys :-** The slope of the land controls the stream. The valleys formed where the river is not able to make complete adaptation with the land are called inconsequent valleys.

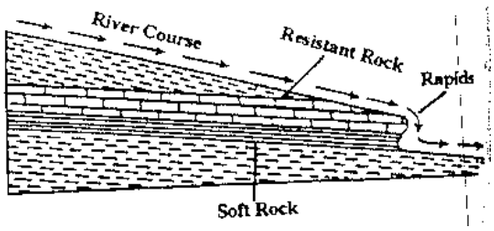
f) **Resequent Valleys :-** When the stream erode the upper layers of the rocks and flow on the exposed underlying layers, resequent valleys are formed.

(ii) Waterfalls :- Generally waterfalls are caused in those areas where a layer of hard resistant rocks is followed by an extended layer of soft rocks. The soft rock layer is eroded causing the stream to abruptly fall. Waterfalls can be formed either when rock beds are in a vertical position or in a horizontal position. The Angel Falls in Venezuela are considered the highest waterfall in the world with a height of 979 mts. Niagra falls in Canada have the greatest volume of water.



Origin of waterfalls when the rocks dip upstream.

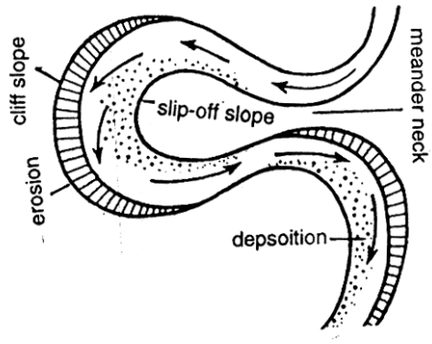
(iii) Rapids :- Rapids are a series of falls in the cause of a river. They are formed in those areas where hard and soft rock layers are found alternately. The flow of the river where rapids are formed is extremely variable and rough.



Formation of rapids when the rock beds dip downstream.

(iv) River Meanders :- S-shaped formations in the river course are called meanders. They are formed when the river starts to erode its banks. The place where the banks are eroded, the river appears to have a curved appearance. Meanders are semi-circular in shape with alternating concave and convex sides. They can be further divided on the basis of the type of erosion.

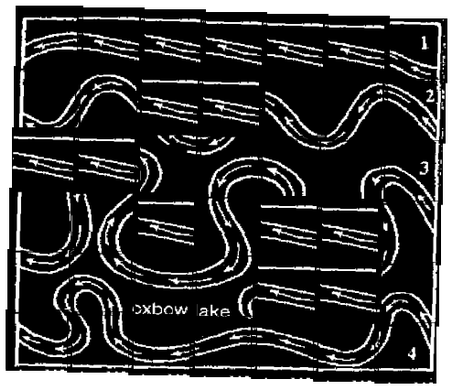
(a) Normal Meanders : Those meanders which are formed as a result of lateral erosion.



Components of a meander loop

b) Incised Meanders : Those meanders which are formed as a result of vertical erosion.

(v) Oxbow Lakes :- When extensive erosion takes place the meanders become more curved and two curves extend towards each other. One end of a meander gets connected to the end of a succeeding meanders. Later the stream abandons its meandering cause and the abondoned end begins to fill with rock debris. Therefore a detached body of water having a creascent shape is created alongside the river. This known as an Oxbow lake.

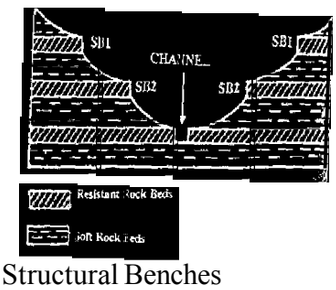


Stages of the formation and development of meanders.

1-2. wavy meander, 3. horse shoe mender and 4. ox-bow or bracle type of meander

(vi) Structural Benches :-

Such type of erosional landforms are formed as a result of differential erosion. It derives its name due to its step-like formation along both banks of the river. The hard rock layers remain resistant and project out while the soft rock are eroded and curve inwards. Therefore structural benches appear as that steps of hard rocks alternating with a concave layer of soft rocks

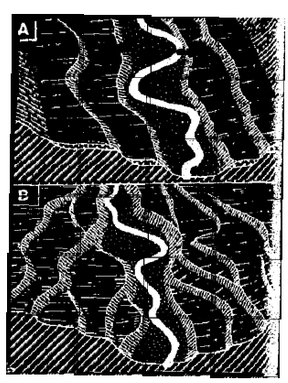


Structural Benches

Structural Benches : SB = Structure Benches.

(vii) Pot Holes:- These are 'tea pot' shaped erosional features. They are cylindrical depressions formed in the river beds as a result of the erosion soft and sandy type of rocks. The diametre of pot holes is directly proportional to their age as erosion continues to widen and deepen them. They are a common feature at the base of waterfalls.

(viii) River Terraces:- As their name indicates, river terraces are step-like structures formed on either side of valley floor. The number of terraces formed along a river valley can vary with valley depth. Their structure, form and location can differ on the basis of their mode of formation and the type and intensity of erosion. They are of two main types -



(a) **Paired Terraces :-** Here the valley floor is characterised by corresponding pains of terraces on either slope of the river valley.

(b) **Unpaired Terraces :-** Such type of river terrace are characterized by isolated terrace formation without the formation of an adjacent terrace.

GLACIAL LANDFORMS

Glaciers :-

By common definition glaciers are described as moving rivers of ice. However a glacier does not consist of ice alone as it has several peculiarities in its structure. The upper surface of a glacier is comparatively very hard and brittle. When a glacier descends down a slope its surface suffers many cracks which are known as crevasses. Crevasses can be as deep as 50-60 mts. Although the movement of a glacier is slow it still acts as an effective agent of erosion. The movement of a glacier can be classified under two categories-

(i) **Gravity Flow :-** Earth's gravitational pull forces the ice particles to flow from higher to lower levels.

(ii) **Extrusion Flow :-** Gravitational force is neutralized in areas with level or gentle slope. As ice continues to accumulate the extract pressure on the terminal layers and this pushes the glacier forward.

Glacial Erosion :-

Glacier performs the activity of erosion by the following ways:

(i) Abrasion :- Rocks, stones and pebbles are present at the base of the glacier. As the glacier moves it rubs against these rock pieces and then ends are rounded off. The rock pieces are also modified by mutually striking against each other.

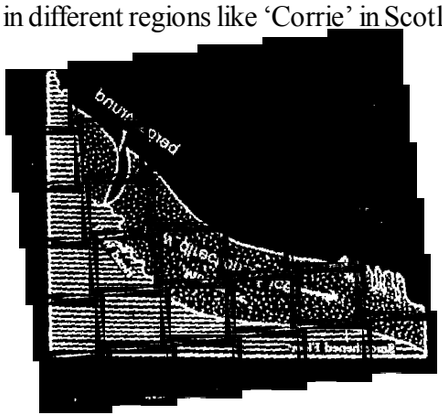
(ii) Plucking :- The glacier by its sheer volume has the capability to pick large rocks and move them forward. In this process rocks are broken down into smaller pieces. A glacier can also affect a mountain side or a large boulder in a similar way.

(iii) Frost Wedging :- Water generally enters into the cracks of rocks. Due to proximity of a glacier this water freezes and exerts pressure on the sides of the rock ultimately splitting it. This process also takes place on the glaciers when water enters the crevasses.

GLACIAL EROSIONAL LANDFORMS-

Some of the important landforms produced by glacial action are:

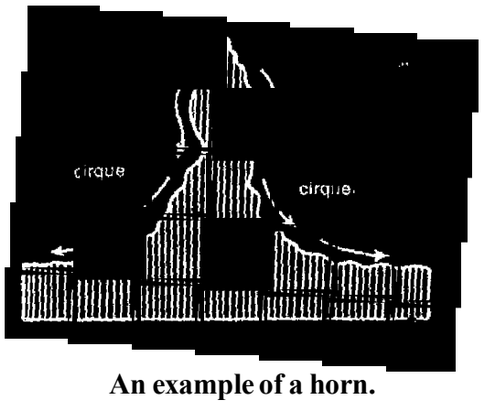
(i) **Cirque :-** It is an extended form of a crevasse which is formed on the slope of the glacier. Areas having cirques are sometimes referred to as areas of 'armchair topography' because a cirque resembles an armchair. Its slope is steep, sometimes almost vertical while the base is gentle and level. It is called by different names in different regions like 'Corrie' in Scotland and 'Cwom' in Wales.



Cirque and its components

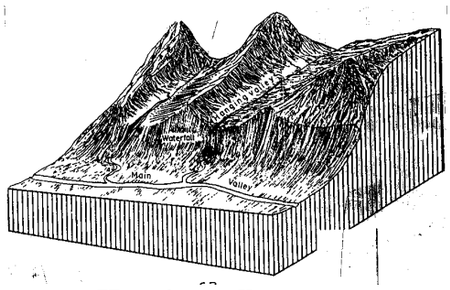
(ii) **Arete :-** When two cirques are formed on the same slope, they tend to cut towards each other due to continuous erosion. There comes a time when the two cirques meet each other and as a result the mountain peak is destroyed. The peak appears irregular with sharp edges. This kind of structure is known as arete.

(iii) **Horn :-** When three cirque are created on the same slope a triangular or pyramid shaped structure is formed on the summit. The peak resembles a pyramid with a narrow base. This kind of peak is called horn. Due to continued erosion the horn falls off and an arete is created



An example of a horn.

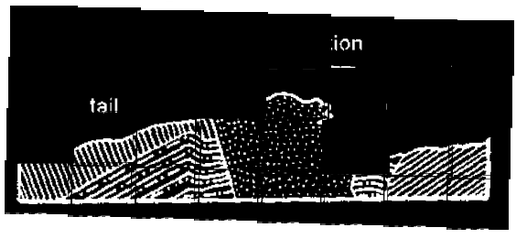
(iv) Hanging Valley :- Most glaciers are accentuated with the aid of tributary glaciers. The valleys of tributary glaciers are at a higher level than those of the main glacier. The ice of the tributary glacier descends to the main glaicer and its valley appears to be hanging over the main glacier. This is known as a hanging valley and it is responsible for many waterfalls or ice falls.



Hanging valley

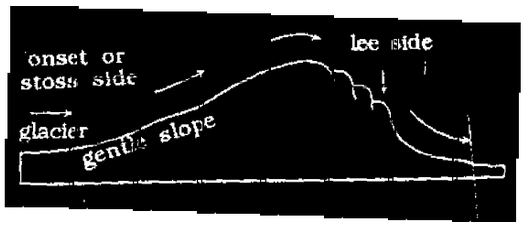
(v) Fiords :- Fiords are a common feature in the northern arctic regions. They are actually U-shaped valley which are formed due to glacial erosion. The characteristic feature of a fiord is that its base is usually submerged inside the water.

(vi) **Roche Moutonness :-** Hard and resistant rock layers act as obstacles in the path of travelling glaciers. Glaciers simply move over the rock layers and descend over the other side. The slope over which the glacier ascends is smothened out while the part where it descends is broken down and irregular. Such rock mounds which have a smooth and gentle slope on one end and an irregular slope on the other are called rocks moutonness.



Roches moutonnes

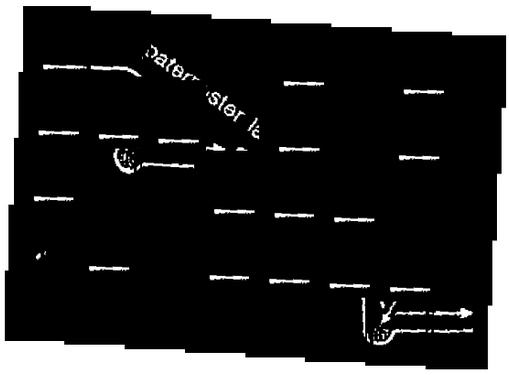
(vii) **Crag and Tail :-** Areas of soft rocks are quickly eroded by glaciers. The glacier continues to move forward. The material on the descending side is protected by ice. It appears as if the layer of the rocks over which the glacier has moved has a long tail attached to it. This kind of feature is called crag and tail.



Crag and tail

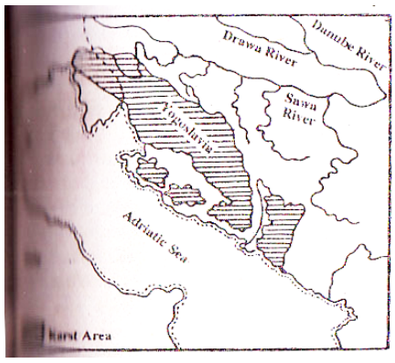
(viii) **Pass :-** When the cirgues from opposite sides of a hill develop and meet each other the mountain top or peak is lowered. This creates a pathway for commutation. This pathway is called a 'Pass' or 'Col'. These are a common feature of the Alps mountain region.

(ix) Paternoster Lakes :- Layers or steps of the glacier form lakes of varying sizes on the glacial body. This topography appears as a stepwise formation of small lakes. These are known as paternoster lakes.



4.2 Karst & Aeolian Landform

Meaning : Landforms produced by chemical weathering or chemical erosion of carbonate rocks mainly calcium cabronate ($CaCO_3$, limestones) and magnesium carbonate (dolomites) by surface and subsurface water (ground water) are called Karst Topography which refers to characteristic landforms produced by chemical erosion on crystalline jointed limestones of Karst region of earstwhile. Yugoslavia situated along the eastern margin of Adriatic Sea. The Karst region of the earstwhile western Yugoslavia extends for 480 km in length and 80 km in width. The region having folded limestones rises to the height of 2500 m AMSL. The surface studded with numerious solution holes, ravines, gullies, elefts, lapies and narrow valleys has become so corrugated and rough that it becomes practically impossible to walk with bare feet. Numerous caves and stalaginites and stalaciites have been formed below the surface. Thus, the limestones topography all over the world having characteristic features similar to the Karst Region of earst while Yugoslavia is universally called Karst Topography.



Karst Region of earstwhile Yugoslavia

Distribution of Karst Areas : Karst topograhy generally develops in those areas where thick beds of massive lime stones lie just below the layer of surficial materials. Besides, karst topography also develops on dolomite, dolomitic limestones and chalks. Besides typical Karst Region of earth while Yugoslavia, Karst topography has well developed in Causes Region of Southern France; Spanish Andalusia Nothern Puertoric;

Western Cuba Jamaica; Southern Indiana, West Central Kentucky, Virginia, Tennessee and Central Florida of the USA. These areas are classified as major karst areas. Besides there are few minor karst areas e.g. Carlsbad area of the USA, chalk area of England (Peak District), Chalk area of France, parts of Jura mountains, some parts of Alps and Apennines, Limestones topography in India has not been properly identified and studied because of non-existence of extensive thick limestones of formations near the surface. Most of limestones of Vindhyan Formations are buried under thick cover of sandstones and shades. For example, Rohtas stage limestones having famous Guptadham Cave in Rohtas plateau (South-Western Bihar) are buried under 90 m thick cover of massive sandstones. A few areas of limestones topography have been identified in the Himalayas (mainly Jammu and Kashmir; Sahasradhara, Rovers cave and Tapkeshwar temple near Dehra Dun in U.P.; Eastern Himalayas; Pachmarhi (Madhya Pradesh), Bastar district (Madhya Pradesh) coastal area near Visakhapatnam etc.

Essential Conditions for the Development of Karst Topography :- The following conditions of true karstic topography

(1) The limestones must be massive, thickly bedded, hard and tenaceous, well cemented and well jointed (high density of joints).

(2) Limestones should not be porous wherein permeability is largely controlled by joints and not by the mass of rocks because of limestones are porous, the water may pass through the rock mass and thus whole rock mas will become weak and will collapse. On the other hand, if limestones are non-porous and thickly bedded, water will infiltrate through joints resulting into effective corrosion of limestones along with joints and solution holes would be formed.

(3) The position of limestones should be above the groundwater table so that surface drainage may disppear through sinks, blind valleys and sinking creeks to have subterranean (subsurface) drainage so that cave, passages and galleries and associated features may be formed.

(4) The limestones should be widely disributed in both areal and vertical dimensions.

(5) The carbonate rocks should be very close to the ground surface so that rainwater

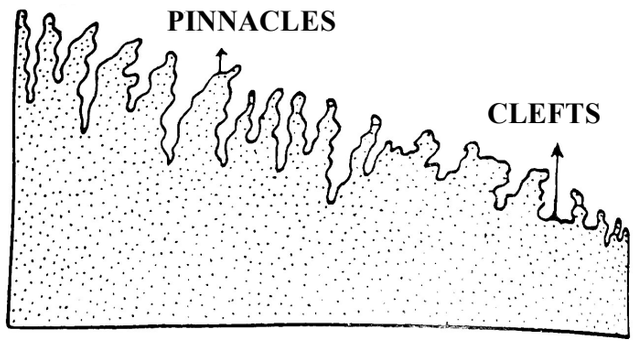
may easily and quickly infiltrate into the beds of limestones and may corrode the rocks to form solutional landforms.

(6) The limestones should be highly folded, or fractured or faulted.

(7) There should be enough rainfall so that required amount of water is available to dissolave carbonate rocks.

Erosional Landforms

Lapies : The highly corrugated and rough surface of limestones lithlogy characterized by low ridges and pinacles, narrow clefts and numerous solution holes is called lapies (a French term). In fact, lapies represent a fretted and fluted topography marked by small rills and gullies, minor ridges or pinacles and deep clefts. Lapies are variously named in different parts of the world e.g. clints or grykes in North England Karren in Germany, bogaz in earstwhile Yugoslavia etc. Lapies are generally formed due to corrosion of limestones along their joints when limestones are well exposed at the ground surface. The weathering residues left at the surface are called terra rosa which means red residual soils or red earth.



Lapies

Solution Holes and Associated Features : Chemically active rainwater (changed with atmosphere carbon dioxide) dissolves limestones and other carbonate rocks along their joints and other carbonate rocks along their joints and thus numerous types of solutions holes (e.g sink holes, dolines etc.) are developed at the ground surface when limestones

are directly exposed to the atmospheric processes. Smaller holes are called sink holes which are generally of two types viz. (i) Funnel shaped sink holes and (ii) cylindrical sink holes. The depth of sink holes range from a few centimetres to 10 metres but generally average depth remains between 3 to 10 m. Area varies from a few sqare meters to few acres. Gradual enlargement of sink holes due to continous dissolution of limestones results in the coalescence of closely spaced sink holes into one large hole which is called "Swallon hole". Some swallow holes are further enlarged due to continous solution into larger depressions which are called 'dolines' in the Karst Region and 'dolinas' in Serbia. The solution holes enlarged due to collapse of some portion of upper surface because of formation of cavities below the ground surface are called "collapse sinks". The diameter of doline ranges from a few metres to 1000 metres while the depth varies from a few metres to 300 metres.

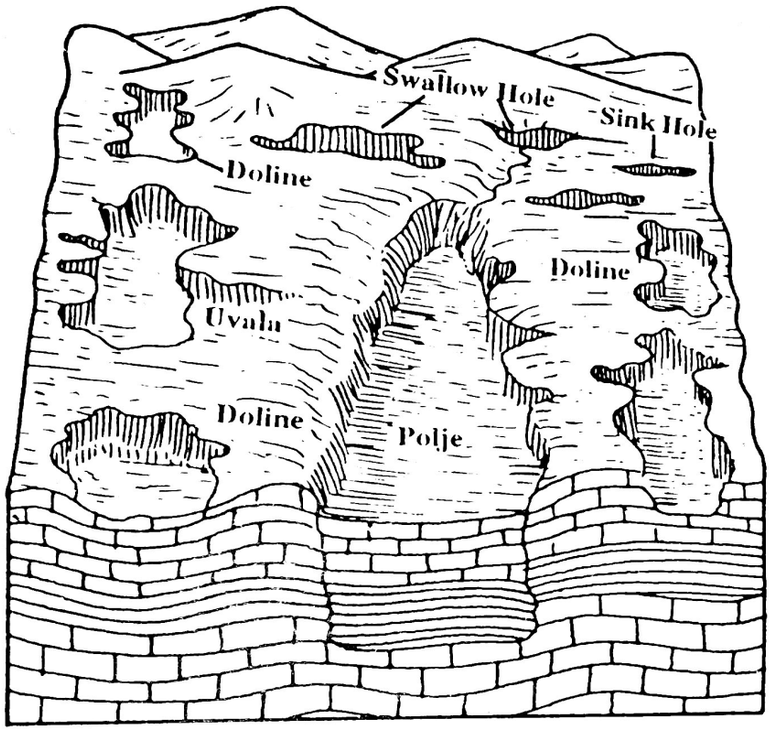
A feature almost similar to doline in appreance but with shallow depth and large areal extent is called 'solution pan'. The solution pan of the Lost River of Indiana (USA) is 30 acres in area. Some times, the floor of dolines is plugged due to deposition of clay, with the result water cannot percole downward and thus doline is filled with water. Such dolines full of water are called "Karst Lakes". Rock-walled steep depression caused by the collapse of ground surface are called "Cockpits".

'Karst Window' is formed due to collapse of upper suface of sink holes or dolines. These windows enable the investigators to observe subsurface drainage and other features formed below the ground surface.

Extensive depression are called 'uvalas' which are upto one kilometre across. They are formed in a number of ways e.g. (1) due to coalescence of several dolines due to continuous solution and enlargement of dolines. (2) due to collapse of upper roof of large cavities formed undergfound (3) due to coalescence of various sink holes etc. Elongated uvalas are formed either due to (i) the elongated pattern to joints or (ii) due to coalescence of numerous sink holes aligned in a line. Smaller uvalas are called aligned in a line. Smaller uvalas are called 'Jamas'. Uvalas are so extensive that surface drainage is lot in them and takes subterrancean course. C.A. Malott has termed such uvalas as 'Karst Windows'. Uvalas are called as 'Compound Sinks' because of coalescence of several sink holes. The

sides of uvalas are very steep. They are generally dry depressions. The floors are generally characterized by the deposition of clay but they are usually of even surface.

Poljes : Most extensive, larger than dolines, depressions are called 'poljes'. They are characterized by vertical side walls, flat alluvial floors, independent surface drainage systems on their floors, irregular border and central lake. Poljes are, in fact, closed basins of elliptical shape (fig. 18.5) having area upt 258 km2. They are frequently found in Karst Region of earst while Yogoslavia and in Jamaica. The livno polje of the Balkan Region of Europe is 64 km loing and 5 to 11 km wide. There is difference of opinion about the formation of polje. They are believed to be formed due to downfolding and downfaulting of limestone areas due to earth movements. The resultant grabens are then modified by solution work of water. According to B.W. Sparks (1972) the poljes are probably not solution forms at all but tectonic depresson modified by solution of limestone preserved in them".

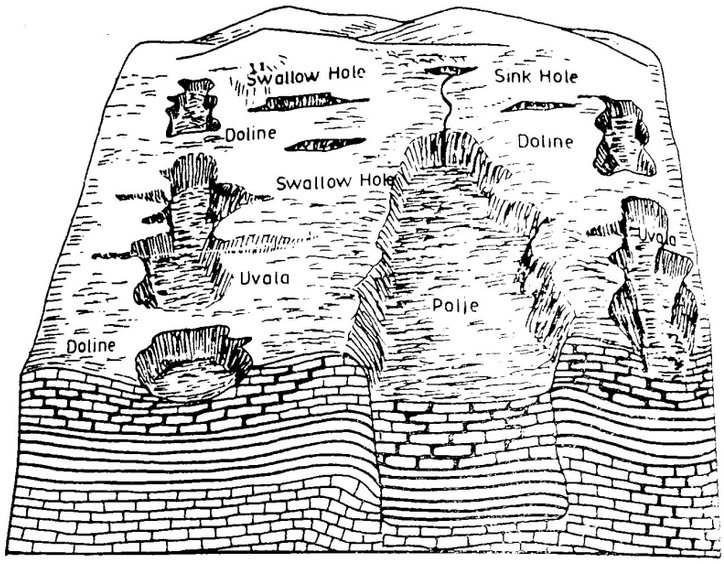


Sink Holes, Swallow holes, dolines, uvalas and poljes

Valleys of Karst Region : The upper surface having several sink holes in the region of limestones having horizontal beds or slightly inclined beds is called 'karst plain' on which surface drainage systems develop various types of valley and typical landforms. Almost all of the valleys are related to sink holes or swallow holes in one way or the other. The following types of valleys are more important

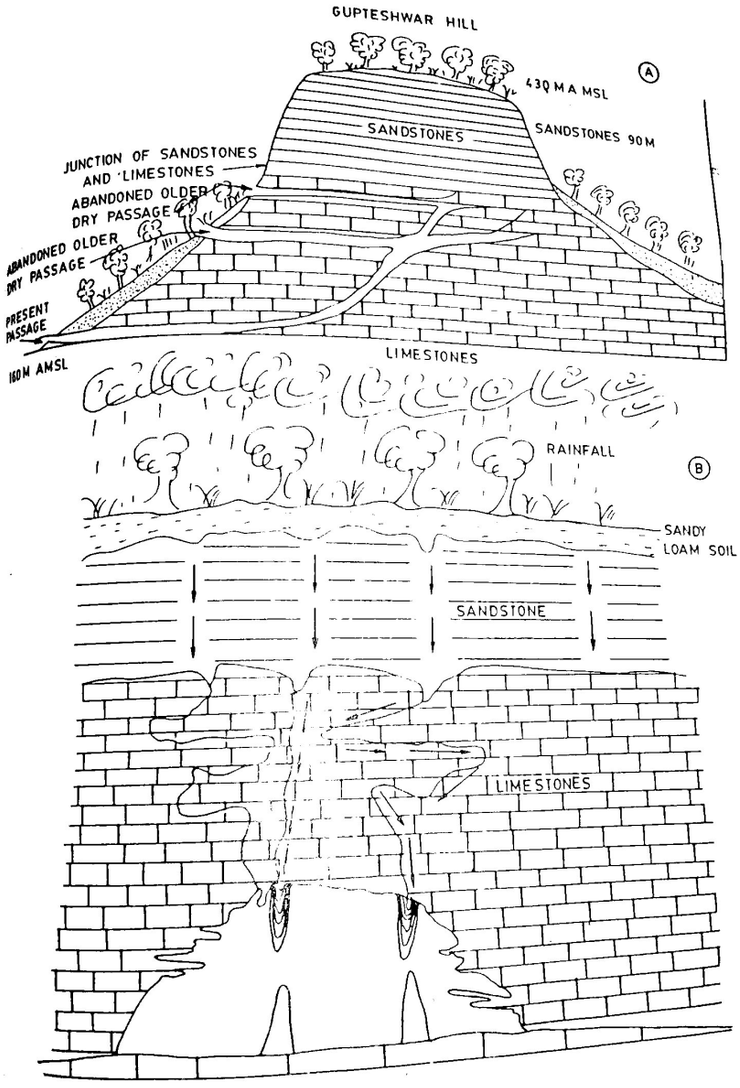
(1) Sinking Creek : The surface of the karst plain looks like a sieve because of development of closely spaced numerious sink holes. These sink holes act as funnels because surface water disappears to go undergound through these holes. When surface water disppears through numerous sink holes located in line, the resultant features is called 'Sinking Creek' and the point through which water goes downard, is called 'sink' (fig. 18.6) The water of short rivers disppears through a single 'sink' white that of large streams dispears through many 'sinks'.

(2) Blind Valley : Blind valley refers to the valley of that surface stream which disppears in limestones formation through a swallow hole or sink hole. In other words, that valley is caleld blind valley the flow of which terminates at a swallow hole and the valley looks dry valley. According to O.D. Von Engeln blind valleys are developed on uvala floora



Development of sink holes, swallow holes, uvalas, sinking creek, blind valley and karst valley

(3) Karst Valley : Surface streams develop their U-Shaped valleys on limestones formation. Such wide U-Shaped valleys developed on limestones are called 'solution valley's or 'karst valley'. Such valleys are always temporary because generally water disppears through swallow or sink holes and the valleys become dry.



A - Probable sequence of cave passages and
B - Dissolution of limestones and formation of Guptadham Cave (Bihar)

Caves or Caverns : Caves or Caverns are volds of large dimension below the ground surface. In fact, caves are the most significant landorms produced by erosional work (mainly corrosion or solution and abrasion) of ground water in limestones lithlogy. Caves vary in sizes and shape ranging from smaller size or large caves. Large caves are formed in the regions of pure, massive and thickly bedded limestones. Carlsbad and Mammoth caves of the USA are the examples of very extnsive caves. Carlsbad cave of New Mexico state of the USA, having a dimension of 1219 m length, 190.5 m width and 300 m depth, consists of several chambers. The ceiling is about 83.3 m high from the floor. The largest chamber is know as Big Room.

Limestone caves are found in India near Dehra Dun in Uttar Pradesh (Rover Cave, Sahasradhara), in South Western Bihar (Guptadham Cave, 1.5 km long), in Bastar district of Madhya Pradesh (Kutumbsar Cave), in Pachmarhi hill (Madhya Pradesh), in Chitrakut area of Satna District of Madhya Pradesh (Gupta Godavari Cave), near Visakhapatnam Coast tc.

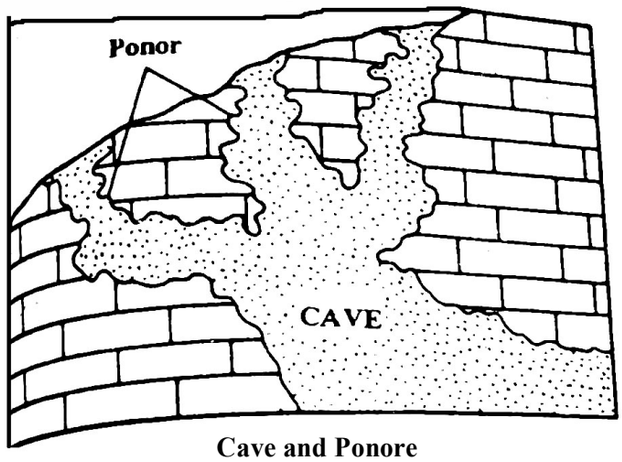
The Guptadham cave of the Rohtas plateau (located in the south western corner of Bihar) is an exmple of galleried cave and has been formed due to dissolution of Rohtas stage limestones of Vindhyan formation lying below 90 m thick capping of quartzitic sandstones. The cavern is characterized by horizontal passages and amphitheatre-like extensive areas at the junctions of tunnels (cave crossings).

The formation and development of limestone caverns is most debatable of all the karstic landforms. Various contrasting theories have been put forward by different geomorphologists to account for the origin and development of limestone caves viz. (1) Corrasion Theory of Lapparent, Martonne, Martel, Weller and C.A. Malott (2) Two Cycle Theory of W. M. Davis and Supported by J. H. Bretz (3) Water Table Theory of A.C. Swinnerton. (4) Static Water Zone Theory of J. H. Gardner (5) Invasion Theory of C.A. Malott etc. It may be pointed out that difference of opinons about the formation sof caverns and galleries is related to solution process, water table of groundwater and corrasion process.

According to 'Corrasion theory' caves are formed due to corrasion (abrasion) of limestones by groundwater in the 'Vadose Zone' above the water table of round water. W.

M. Davis contradicted the corrasion theory in 1930 and postulated his 'two-cycle theory' for the development of limestone caverns. According to him caves are formed by 'phreatic water' i.e. water under hydrostatic pressure below water table. In the first cycle or stage caves are formed due to solution of limestones in the phreatic zone below water table. In the second cycle or stage the area is uplifted and thus the cave comes under vadose zone because of lowering of water table and the cavern becomes dry resulting into the formation of depositional landforms (speleothems). "Water table theory' of A.C. Swinnerton states that caves are not formed by phreatic water under hydrostatic pressure but are formed by lateral flow of water in the vadase zone of by freely moving water at the level of water table. According to 'Static water zone theory' of J.H. Gardner caves are formed due to solution of limestones above the water table. The 'invasion theory' of C.A. Malott States that most of the present caverns and galleries in limestones regions have been formed by the subteranean streams. According to Malott surface streams disppear at sink holes and take underground courses where they dissolve and abrade limestones to form their passages. These passages are gradually enlarged due to corrosion and abrasion of limestones and thus caverns and galleries are formed.

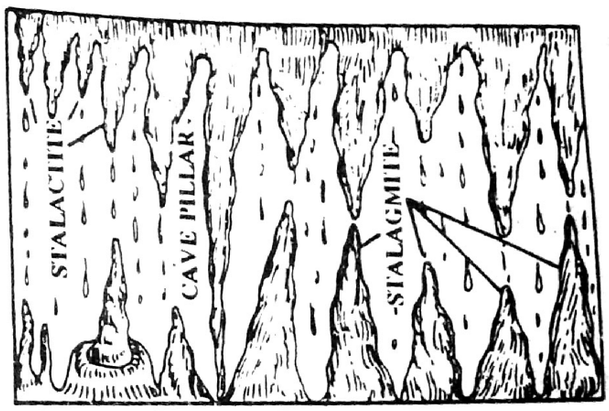
Ponores : The vertical pipe-lie chasmas or passage that connect the caves and the swallow holesa re called 'Ponores' is Serbia and 'Avens' in France. Ponores are formed due to downward extension of sink holes through continouous solution of carbonate rocks. Ponores may also be inclined.



Cave and Ponore

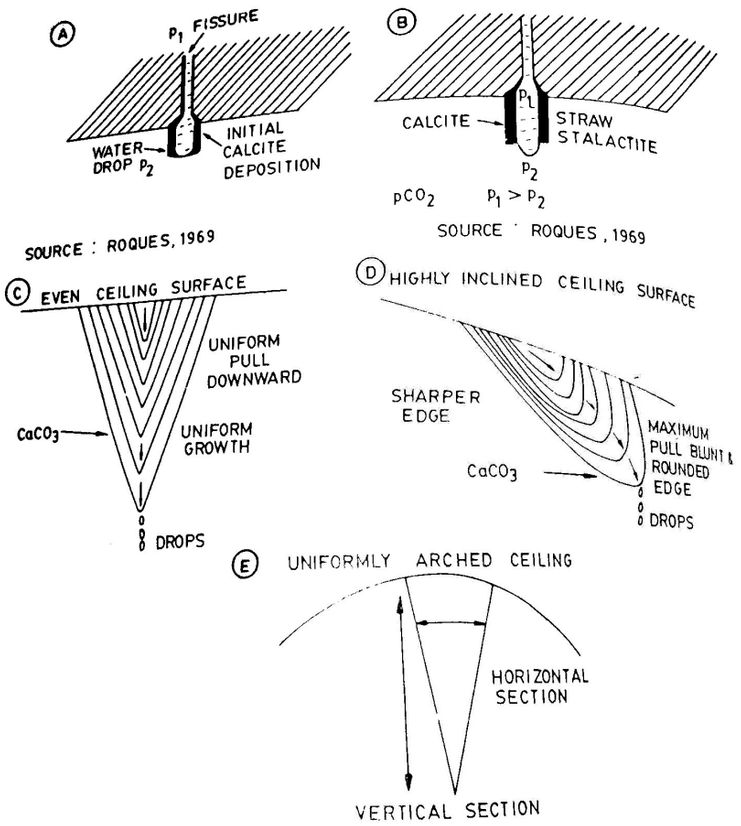
Natural Bridge : Natural Bridges in limestone areas are formed in two ways viz. (1) due to collapse of the roofs of caves and (2) due to disapperance of surface streams as subterranean stream, formation of valleys below the ground surface and reapperance of disppeared (subterranean) stream on the ground surface. Like caves various theories have been put forth to account for the origin of natural bridges and natural tunnels in limestone regions e.g (1) solutions theory of F.W. Glimer (2) Thoery of C.D. Walcott, (3) subterranean stream piracy of H.P. Woodward (4) subterranean stream cut off theory of C.A. Malott and R.R. Shrock etc.

Depositional Landforms : All types of deposits in the caverns are collectively called 'Speleothems' of which calcite is the common constituent. Banded calcareious deposits are called 'travertines' whereas the calcareous deposits, softer than travertine, at the mouth of the caves are called 'tufa' or 'calc-tufa'. The calcareous deposits from dripping of water in dry caves are called 'dripstones'. The columns of dripstones hanging from the cave celling are called 'stalactites' while the calcareous columns of dripstones growing upward from the cave floor are known as 'stalagmites'. Cave pillars are formed when salactites and stalagmites meet together. Numerous needle-shaped dripstones hanging from the cave celling are called 'drapes' or 'curtains'. The dripstones growing sideward from stalactites and stalagmites are called 'helicites' and 'heligmites' respectively. The helicites of globular structure are called 'globulites'. Floor deposits caused by seepage water and water flowing out of stalagmites are called 'flowstones'.



Formation of stalactites, stalagmites and cave pillars (various forms of speleothems)

Stalacities are formed due to deposition of calcareous solutes which are carried by water dripping through the cave ceilings in dry environment. The water is evaporated and solutes are deposited in incicle-like or needle-like forms. These structures have broad bases stuck to the cave celling and tapering ends hanging downward from the cave celling. There is gradual increase in the length and thickness of stalacities. The shapes of stalactites are controlled by the shape of cave celling. The stalactites become uniform and their tapering lowe ends are directly pointed towards the cave floor when the cave celling is flat or is uniformly arched. The stalacties hanging downward are almost perpendicular to the cave celling. When the cave celling is steeply inclined, inclined and elongated stalactites are formed (D) When the cave ceiling is flat but is gently inclined towards one side, slightly inclined and elongated stalactites are formed.



Nature of cave ceiling and formation of stalactites

The solution that drops on the cave floor is also precipitated and crystallized and forms a column-like structure of stalagmites at various centres. When a group of stalamites is formed together from closely spaced centres the resultant stalagmites are called 'compound stalamites'.

AEOLIAN LANDORM (WIND LANDFORMS)

WIND :-

Air in motion is defined as wind. It is also an important agent of erosion. Winds agents erosion are particularly active in dry or a desert areas. This is because there is no denses vegetation and trees to hamper its movement. It is estimated that the speed of wind should at least be 5 metres per second so that it is able to lift small particles. Light and fine particles especially sand and lifted with ease by the wind and consequently are also carried to great distances. In order to lift heavier particles like rocks and stones the velocity of wind needs to be much higher . The activity of wind can best be observed in the 'Dust Bowl' area of USA. Such a large amount of dust is blown here by the wind that visibility becomes impossible. Therefore it can be concluded that the winds possess great capability of lifting sand and dust particles and cause a great deal of erosion especially in arid areas.

WIND EROSION -

In dry areas especially the wind acts as a very active agent of erosion. It causes erosion in three different ways :-

(i) Deflation:- Loose particles lying over the rock layers are blown away by the winds. This is called deflation action. Deflation becomes more prominent and uninterrupted when there is little or no vegetal cover to hamper the flow of the wind.

(ii) Abrasion:- The different types of particles lifted up by the wind themselves becomes agents of erosion by rubbing, scraping and striking against rocks and eroding them. This action is called abrasion. It is comparable to the work of a sand paper rubbing against a surface.

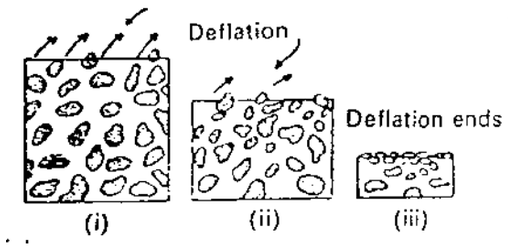
(iii) Attrition:- While in the air the particles strike against each other as well and further modify thir shape.

WIND EROSIONAL LANDFORMS OR ARID TOPOGRAPHY

Some of the important types of landforms created by wind erosion are as :-

(i) Deflation Basin :- Deflation action of winds lifts up particles from a particular areas and carries them forward. As such depressions are formed in those areas which loose the particles. These depressions are called deflation basins. Their diametre usually ranges between 1-2 kms and depth between 2-3 mts.

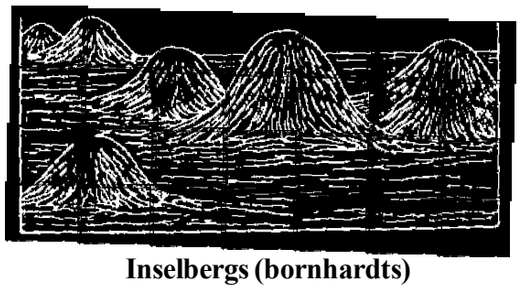
(ii) Deflation Armour :- Lighten particles are lifted and carried away easily by the wind while the heavier particles like stones and rocks are lift behind. With the passage of time the number of heavier particles goes on increasing. There comes a time when they form a wall like structure. This is known as a deflation armour and is a common sight alongside a deflation basin or sometimes even inside one.



Deflation activity and the development of deflation armour

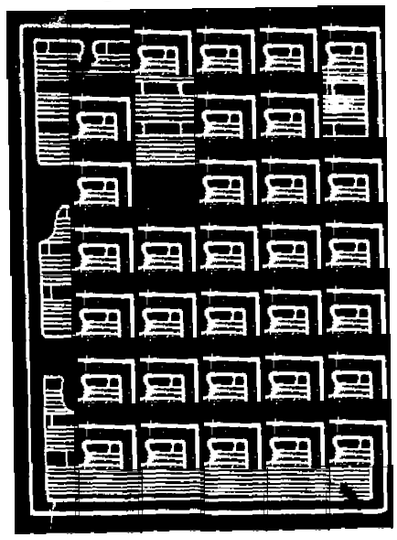
(iii) Blow Outs :- Sand dunes are the most common feature of desert topography. Deflation action of wind is particularly active on sand dunes. However wherever a small piece of vegetation like cactus is located on the dune it blocks the wind's action to lift the sand particles. Therefore winds lift the sands from exposed areas while other areas (where vegetation exists) remain undisturbed. Small depressions are caused in those areas where the sand is eroded and they are known as blow outs.

(iv) Inselbergs:- Inselbergs is a word of German origin and literally means an 'ialand mountain'. The Inselbergs are identified as a mountain top rising suddenly from the plains and plateaus. Their height ranges between a few metres to several hundred metres and are predominantly composed of gneiss. Due to wind erosion continuing to take place the sides of an inselberg become very steep.



Inselbergs (bornhardts)

(v) Zeugen :- Differential wind erosion takes place in those areas where layers of hard and soft rocks are found alternatly. The lower portion of soft rocks are eroded while the hard rocks remain resistant. These hard rocks appear as table like formation on the lower layers. These are known as Zeugens and if their basis are eroded, the Zeugens fall down and disintegrate.



Stages of the formation of Zeguens

(vi) Yardangs :- Wind erosion in areas of hard and soft rocks gives rise to the formation of a strange type of landform. The rocks which remain unaffected by erosion appear as rib like structures with steep slopes. These are known as Yardangs. They are usually formed in series and can be as high as 7-10 metres.

Yardangs

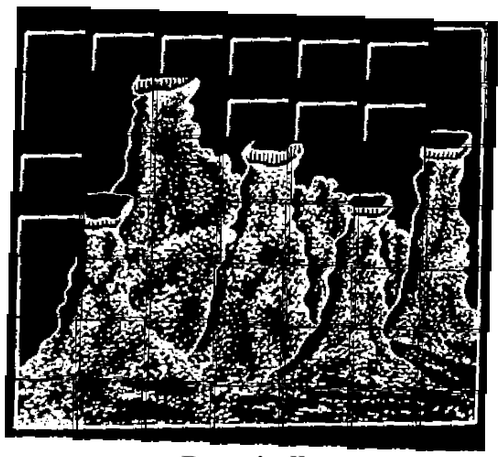
(vii) Mushroom Rocks :- Due to action of wind the lighten particles blow above the ground while the heavier particles roll down. If the lower portions possess soft rocks on sands they get eroded and the lower and becomes very narrows. The upper area appears to be a dome like structure supported on a narrow base. This unique feature is called a mushroom rock.

Example of mushroom rock or gara

(viii) Hammada: The exposed lower layers of rocks after extensive wind srosion are called hammadas. They have a level surface and then height differs from area to area.

(ix) Wadi :- Occasional showers in arid areas make valleys which are as much as 40 metres deep and about a 100 metres broad. Such valleys are called Wadis and are a common feature of the Sahara desert.

(x) Demoiselle :- The upper parts of rocks are constantly subjected to abrasion action. However the lower parts remain unaffected. The wind also affects one end of the rock layers giving it an irregular appearance. Such pillar like structures with one end eroded and the other seemingly smooth are called demoiselles.



Demoiselles

4.3 SOIL EROSION & CONSERVATION

Soil erosion is the removal or destruction of to layer of soil by natural forces such as water and wind more rapidly than the various soil forming processes can replace it or in other words soil erosion is the removal of top soil from one place to another with the help of natural agents like running water, wind etc. Soil erosion makes the land unsuitable for cultivation. Soil erosion is mainly due to men's ill-judged activities such as deforestation, over-grazing and faculty erodes soil it is called gully erosion. Large part of soil is blown away by strong winds in dry area. As a result of this, the top layer of soil is eroded. This is known as sheet erosion. The erodability is influenced by the inner properties of the soil, texture, structure, consistency, and cohesiveness. On a gently slope, adequately clothed by a vegetation cover, clay soil will resist erosion to a great extent. On such a soil, channel erosion will succeed but not sheet erosion. Here ploughings are done across the contour lines.

Factors Responsible for Soil Erosion

The various agents of Erosion, i.e. running water, winds and glaciers, etc. and now man with his technological tools are busy in destroying the soil. The process of soil erosion has done a great harm to the productivity of crops in India.

The following factors are mostly responsible for soil erosion.

1. Sand Storm: Before the onset of rainy season sand storms are common. These storms take away the particles of upper surface of the soil. The greater, the intensity of these way, the fertility of soil is reduced. The soils of Sr Punjab, Haryana, Rajasthan, U.P. and Bihar etc. are rendered unproductive every year.

2. Methods of Agricultural process: The older methods of Agriculture were wasteful and have destroyed the soil cover in many areas. The Jhooming as practiced in

North Eastern states, the subsistence Agriculture, etc. have rendered large fertile land almost barren. The scientific methods can prevent the soil erosion to a great extent.

3. Deforestation : Man has been destroying forests without knowing the harm that is being done to preservation of soil. Due to eroding away of the upper zone of vegetation cover, the water starts flowing faster and destroys soil. It is estimated that harm is to the extent of 300 tonnes per hectare but it is quite less in the grass land area and forest area.

4. Grazing : Due to over grazing of animals the vegetation becomes too thin to protect the soil. While grazing the animals ull the roots of the plants out and there by soil becomes open to rapid erosion due to rain and wind. Now a day efforts are being made to protect the soil and control the grazing.

5. Steep Slopes : The steep slopes increase the spread of the flow of water and therefore increase the erosion of soil. Such slopes should be covered with vegetation so that the fast flow of water is obstructed.

6. Torrential rainfall : Heavy rainfall loosens the soil particles and scoopes out the soil forming gullies and ravines. This gives rise to a dissected surface called bed land in Chambal valley of India.

7. Over cropping : Crop rotation maintains soil fertility. But over cropping and shifting cultivation renders soil infertile.

SOIL CONSERVATION:

Methods by which soil is prevented from being eroded constitute soil conservation. Soil conservation has an urgent significance throughout the world because of the slow rate of soil formation. In tropical and humid temperature areas for example, one centimeter deep soil is formed during about 200 and 150 years respectively. Soil erosion, on the other hand, can take place in a short time.

METHODS OF SOIL CONSERVATION :

All methods of soil conservation ultimately have to aim at reducing the amount and

velocity of surface run-off and of the erodability of the soil. Following few methods are adopted for soil conservation:

1) **Vegetation Cover :** The cover of the vegetation not only reduces the surface run-off but also binds the soil particles through the roots and increases its strength. Thus, vegetation cover protects the soil from the attack of erosional processes. The planting of forests has been the most important of the soil conservation techniques. The planting of forests in areas from where the original vegetation has been removed by man is termed reforestation. The planting of forests in those areas which have never had any vegetation is termed afforestation. Both reforestation and afforestation are needed more specifically on slopes where trees retard the surface run-off and bind the soil.

2) **Erecting Dams :** Many rivers cause heavy erosion of soil in rainy season due to swift flow of the water current. This can be checked by erecting dams across the rivers.

3) **Preventing Overgrazing :** An indirect passive measure is to prevent the slopes from being grazed intensively by sheep and goat and other livestock. Overgrazing causes a packing of the soil and decreases of its water permeability .

4) **Changes in agricultural practices:** We can check soil erosion to a great extent by bringing about some basic changes in our agricultural practices. This includes crop rotation, crop combination, terraced cultivation etc. Contour ploughing is a very effective method of checking soil erosion on hill slopes. This is the practice of ploughing along the contours rather than ploughing up and down the slope. Viewed from above, the resulting furrows look like contour lines on maps. By this method, the surface run-off of the rain and irrigation water is checked and soil is prevented from being washed away.

4.4 LANDSLIDES & AVALANCHES

Landslide : Landslides are a destructive and dangerous force of nature that occurs when the structure of a slope of land subsides and collapses. The resulting effect can be either a small movement of the ground of the slope or large amounts of soil and sediment that can cause great damage to the surrounding landscape and even put human live a risk. But why do landslides occur. What is it that causes these phenomenon and what are the effects of landslides. There are several things that can trigger landslides. Not all landslides are caused by the same thing.

The term "landslide" describe a side variety of process that result in the downward and outward movement of slope-forming materials including rock, soil, artificial fill, or a combination of these. The materials may move by falling, toppling, sliding, spreading, or flowing. Although landslides are primarily associated with mountainous regions, they can also occur in areas of generally low relief. In low-relief areas, landslides occur as cut-and fill failures i.e. roadway and building excavations, river bluff failures, lateral spreading landslides, collapse of mine-waste piles (especially coal), and a wide variety of slope failures associated with quarries and open-pit mines. The most common types of landslides are described and ilustrated at right.

Types of Landslides

Slides : Although many types of mass movements are included in the general term "landslide," the more restrictive use of the term refers only to mass movements, where there is a distinct zone of weakness that separates the slide material from one stable underlying material. The two major types of slides are rotational slides and translational slides.

Flows : There are five basic categories of flows that differ from one another in fundamental ways. Although there are multiple types of caused of landslides, the three cause most of the damaging landslides around the world are these :

Landslides and Water : Slope saturation by water is a primary cause of landslides. This effect can occur in the form of intense rainfall, snowmelt, changes in ground-water levels, and water level changes along coastlines, earth dams, and the banks of lakes, reservoirs, canals, and rivers, Land sliding and flooding are closely allied because both are related to precipitation, runoff, and the saturation of ground of water. In addition, debris flows and mudflows usually occur in small, steep stream channels and often are mistaken for floods; in fact, these two even often occur simultaneously in the same area. Landslides can cause flooding by forming landslide dams the blocks valleys and stream channels, allowing large amounts of water to back up. This causes backwater flooding and, if the dam fails, subsequent downstream flooding. Also, solid landslide debris can "bulk" or add volume and density to otherwise normal stream flow or cause channel blockages and diversion creating flood conditions or localized erosion. Landslides can also cause overtopping of reservoirs and / or reduced capacity of reservoirs to store water.

Landslides and Seismic Activity : Many mountains areas that are vulnerable to landslides have also experience at least moderate rates of earthquake occurence in recorded times. The occurrence of earthquakes in steep landslide-prone areas greatly increase the likelihood that landslides will occur, due to ground shaking alone or shaking - caused or soil materials, which allows rapid infiltration of water.

Landslides and Volcanic Activity : Landslides due to volcanic activity are some of the most devastating types. Volcanic lava may melt snow at a rapid rate, causing a deluge of rock, soil, ash, and water that accelerates rapidly on the steep slopes of volcanoes, devastating anything in its path. These volcanic debris flow (also known as lahars) reach great distances, once they leave the flanks of the volcano, and can damage structures in flat areas surrounding the volcanoes.

Causes of Landslides : The causes of landslides are usally related to instabilities in slopes. It is usually possible to identify one or more landslide causes and one landslide trigger. The difference between these two concepts is subtle but important. The landslide causes are the reasons that a landslide occured in that location and at that time. Landslide causes are listed to a following table, and include geolkogical factors, morphological factors, physical factors and factor associated with human activity.

Causes may be considered to be factors that made the slope vulnerable to failure that predispose the slope to becoming unstable. The trigger is the single event that finally initiated the landslide. Thus, causes combine to make a slope vulnerable to failure, and the trigger finally initiates the movement. Landslides can have many causes but can only have one trigger as shown in the next figure. Usually, it is relatively easy to determine the trigger after the landslide has occured (although it is generally very difficult to determine the exact nature of landslide triggers ahead of a movement event).

Occasionally, even after detailed investigations, no trigger can be determined - this as the case in the large Mount Cook landslide in New Zealand 1991. It is unclear as to whether the lack of a trigger in such cases is the result of some unknown process acting thin the landslide, or whether there was in fact a trigger, but it cannot be determined. Perhaps this is because the trigger was in fact a slow but steady decrease in material length associated with the weathering of the rock - at some point the material becomes weak that failure must occur. Hence the trigger is the weathering process, but this is detectable externally. In most cases we think of a trigger as an external stimulus that reduces an immediate or near-immediate response in the slope, in this case in the form of the movement of the landslides. Generally this movment shear stress or decreasing the effective normal stress, or by resistance to the movement perhaps by increasing the shear strength of the materials within the landslide.

CAUSES OF LANDSLIDES

Geological Causes	Morphological Causes	Physical Causes	Human Causes
Weathered Material e.g heavy rainfall	Slope Angle	Intense rainfall	Excavation
Sheared Material	Uplift	Rapid Snowfall melt	Loading
Jointed of fissured materials	Rebound	Prolonged precipitation	Draw-down
Adversely oriented discontinuities	Fluvial Erosion	Surface Runoff Seismic Activity	Land use (e.g. construction of roads, Houses etc.)
Permeability contrasts	Wave Erosion	Earth Quake	Water Management
Material Contrasts	Erosion of lateral margins	Volcanic Eruption	Mining, Pollution Deforestation, Water leakage
Rainfall and snow fall	Subterranean erosion	Thawing, Soil Erosion	Quarrying Land use pattern
Earthquakes	Vegetation change	Freeze thaw	Vibration
Working or machinery	Erosion	Ground water Changes	

Effects of Landslides

Landslides are a major catastrophe the world as it is widespread and significant impact, including Malaysia. The effects of catastrophic landslides are dangerous to humans and to other living things For example, the slope of the saturated with water to form debris flow or mudflows. Concentrated mixture of rock and mud may destroy the trees, houses, and cars and blocking the bridge. Mud mixed with river flow can cause devastating flooding along the route. Similarly, the ice floes formed in the river caused by ice clogging the rivewrs and flows more slowly. However, it can produce enough energy to destroy the bridge. Ice may accumulate on the edge or on top of weak layers of snow or unstable causes crash occured. Pyroclastic flows (pyroclastic) arising from dust debris of ash, poisnonous gas and hot rock from volcanic eruptions that spread quickly to eat anything that traveled to the effects of destruction and death. Other social effects that can be described as :

1. Economic Decline : Landslides are certainly cause damage to property. This brings losses to the economy of a country. Economic rehabilitation is also needed in the area that has experienced a landslide. This would cost a lot and some of the offending country economy. Example 1. As an average, these landslides caused loss of $ 1-2 billion U.S. dollars and 25 disaster in the United States each year. 2. At Utah, U.S. in 1983, the total cost to repair the landslide area of 500 millin dollars and it is financing the cost of the most expensive landslid in U.S. history 3. Loss due to landslides in the United States is estimated at 1.5 billion dollars annually. 4. Earthquake the earth Loma Prieta in October 1989 caused thousands of landslides covering in area of 5400 square feet. Causing losses of at least $ 10 million dollars.

2. Damage to Infrastructure : Landslides can lead to damage to property resulting from the force flow or mud. Infrastructure land such as building, roads, places of leisure and so on can be destroyed by the landslide occured. Example 1. Destruction a building and placement., 2. Land massive collapse can cause the destruction of a city., 3. Damage to roads., 4. Affect communication system of roads and communication systems. 5. Great loss to humand life and property.

3. Loss of Life : Loss of life is a dangerous effect upon the occurrence of a landslide and it is difficult to avoid. Many lives will be lost upon the occurrence of landslides. Example 1. Landslide Estate Park Hill View occurs on 20 November 2002 destroyed a house killing eight bungalows and family life. 2. Landslide in Highland Tower, Ulu Kelang cause of 48 people were killed and many injured 3. Landslide in Wales in the UK involves the rotation of the fine debris that occurs on hill slopes have been destroys a school causing 144 people were killed, including 116 school children involved, aged 7 to 10 years.

PREVENTATION AND REMEDIATION OF LANDSLIDES

Vulnerability to landslide hazads is a function of location, type of human activity, use, and frequency of landslide events. The effects of landslides of people and structures can be lessened by total avoidance of landslide hazard areas or by restricting, prohibiting, or imposing conditions of hazad-zone activity. Local governments can reduce landslide effects through land-use policies and regulations. Individuals can reduce their exposure to hazards by educating themselves on the past hazard history of a site and by making inquires

to planning and engineering departments of local governments. They can also obtain the professional services of an engineering geologist, a geotechnical engineer, or a civil engineer, who can properly evaluate the hazad potential of a site, built or inbuilt. The hazad from landslides can be reduced by avoiding construction on steep slopes and existing landslides, or by stabilizing the slopes. Stability increase when ground water is prevented from rising in the landslide mass by (1) covering the landslide with an impermeable membrae, (2) directly surface water away from the landslide, (3) draining ground water away from the landslide, and (4) minimizing suface irrigation. Slope stability is also increased when a retaining structure and / or the weight of a soil / rock berm are placed at the toe of the landslide or when mass is removed from the top of the slope.

Many methods are used to remedy landslide problems. The best solution, of course, is to avoid landslide-prone areas altogether. Before purchasing land or an existing structure or building a new structure, the buyer should consult and engineering geologist or a geotechnical engineer to evaluate the potential for landslide and other geology-related problems.

Listed below are some common remedial methods used when landslide-prone slopes cannot be avoided. There is no guarantee that any one method or combination thereof will completely stablize a moving hillside.

1. Improving surface and subsurface drainage : Because water is a main factor in landslides, improving surface and subsurface drainage at the site can increase by stablity of landslide-prone slope. Surface water should be diverted away from the landslide-prone region by channeling water in a lined drainage ditch or sewer pipe to the base of slope. The water should be diverted in such a way as to avoid triggering a landslide adjacent to the site. Surface water should not be allowed to pond on the landslide-prone slope. Ground water can be drained from the soil using trenches filled with gravel and perforated pipes or pumped wate wells. Swimming pools, water lines, and sewers should be maintained to prevent leakage, and the watering of lawns and vegetation should be kept to a minimum. Clayey soils and shales have low hydraulic conductivity and can be difficult to drain.

2. Excavating the head : Removing the soil and rock at the head of the landslide decreases the driving pressure and can slow or stop a landslide. Additonal soil and rock

above the landslide will need to be removed to prevent a new landslide from forming upslope. Flattening the slope angle at the top of the hill can help stabilize landslide-prone slopes

3. Buttressing the toe : If the toe of the landslide is at the base of the slope, fill can be placed over the toe and along the base of the slope. The fill increases the resisting force along the failure surface in the toe area. This, in turn, blocks the material in the head from moving toward the toe. However, if the toe is higher on the slope, adding fill would overload the soil and rock below the toe, thus causing a landslide to form down slope of the fill.

4. Constructing piles and retaining walls : Piles are metal beams that are either driven into the soil or placed in drill holes. Properly placed piles should extend into a competent rock layer below the landslide. Wooden beams and telephone poles are not recommended for use as piles because they lack strength and can rot.

Because landslides can ooze through the gaps between the piles, retaining walls are often constructed. Retaining walls can be constructed by adding lagging (metal, concrete, or wooden beams) horizontally between the piles. Such wasll can be further strengthened by adding tiebacks and buttressing beams (fig. 5) Tiebacks are long that attach to the piles and to a competent rock layer below the ground surface. Buttressing beams are placed at an angle down slope of the piles to prevent the piles from toppling or tilting. Retaining walls also are constructed to concrete, cinder blocks, rock, railroad ties, or logs, but these may not be strong enough to resist landslide, movement and could topple.

5. Removal and Replacement : Landslide-prone soil and rock can be removed and replaced with stronger materials, such as silty or sandy soils. Because weathering of shales can form landslide-prone soils, the removal and replacement procedure must include measures to prevent continued weathering of the remaining rock. Landslide material should never be pushed back up the slope. This will simply lead to continued motion of the landslide.

6. Preserving vegetation : Trees, grasses and vegetation can minimize the amount of water infiltrating into the soil, slow the erosion caused by surface-water flow, and remove water from the soil. Although vegetation alone cannot prevent or stop a landslide, removal

of vegetation from a landslide-prone slope may initiate a landslide.

7. Rock fall protection : Rock falls are contained by (1) ditches at the base of the rock exposure, (2) heavy-duty fences, and (3) concrete catch walls that slow errant boulders that have broken free from the rocky outcrop. In some cases, loose blocks of rock are attached to bedrock with rock bolts, long metal rods that are anchored in competent bedrock and are threaded on the outside for large nuts. A metal plate with a center hole, like a very large washer, is placed over the end of the rod where it extends from the loose block, and the nut is then added and tightened. Once constructed, remedial measures must be inspected and maintained. Lack of maintenance can cause renewed landslide movement.

8. Personal measures : Reinforcement of floor slabs and external walls in exiting buildings. Installation of drainage pipes for rainwater, slope drainage. Planting of slopes that are vulnerable to landslides with deep-rooted trees and shrubs.

9. Technical / biological measures : Drainage and / or grading of slope profiles increase the shear resistance, supporting structures such as anchors and piles (pinning of slip plane) can restrain landslides, removal of material in the 'driving' section, or material deposition in the 'braking' section, can prevent further descent of the sliding body and protective forest.

10. Planning measures and local protection : The use of slopes prone to landslides must be avoided, or uses suitably modified. Hydraulic and electrical connections must be flexible.

11. Organizational measures : The relatively long advance warning period permits timely evacuation.

AVALANCHES

Technically, an avalanche is any amount of snow sliding down a mountainside. It can be compared to a landslide, only with snow instead of earth. Another common term for avalanche is "snow slide". As an avalanche becomes nearer to the bottom of the slope,

it gains speed and power, this can cause even the smallest of snow slides to be a major diaster.

There are two common types of avalanches, a Surface Avalanche that occurs when a layer of snow with different properties slides over another layer of snow. For example, when a layer of dry loosely packed snot slides over a dense layer of wet snow. The other common avalanche is known as a Full-Depth Avalanche which, as its name would lead you to believe, occurs when an entire snow cover, from the earth to the surface, slides over the ground.

An avalanche can be composed of many different kinds of snow depending on the region, temperature and weather. It could be compiled of loosely packed light fluffy snow, which can still be very dangerous even though it may not appear threatening. It could also consist of a thick "slab" which is an area of tightly packed together snow that separates itself from the surroundings.

The snow packed down on the surface cannot support itself with all the weight. When another factor is introduced, such as a person's step, this helps to loosen the snow and an avalanche occurs. Major temperature changes, rapid wind speed and man-made influences are the main causers of why avalanches occur.

Most avalanches begin within weak layers of snow, which evolve within the snowpack or form on top of the snow and become buried. Eventually these weak layers can no longer hold up the weight on the overlying snow, and will give way causing the snow above them to break free and slide downhill.

Avalanches happen on mountains with extreme amounts of slow fall and build-up. Wherever snow is lying on ground on an extreme and sufficient angle there is potential for a sleeping avalanche. The steadily increasing numbers in popularity of winter activities along with the growth of interest in skiing has resulted in a much greater hazad. There are many sites around th world that are potential or have already experience avalanches. Europe, France, Swiss mountains, Western Canada, Utah, Alaska anc Colorado are just a few places that have high probability of avalanches. All of these locations go through a

thaw and freeze during the year at the bases of though mountains. This is very stressful on the snow built up above and packs it tighter together.

Three main factors effect whether or not avalanches are probable to occur. These three factors are the weather, the snow pack and the terrain. The weather is the most important when deciding whether avalanches are likely to happen. The height of the snowpack is dependent on the weather also. From the weather the temperature, wind speed and direction are the factors to watch. With a quick change in any of the weather factors an avalanche could is expected. For example, if the temperature were to have a rapid increase then a wet slab avalanche is likely to occur.

Many avalanches that occur are cornice (an over-hanging mass of snow above a cliff, pictured above) trigged. These happen during showstorms, strong winds (where snow drifts from quickly), and usually occur one to two days after of shortly after a quick thaw or temperature rise. Finally the terrain factor of avalanches depends on the slope angle, ground surface and slope profile. Any slope that is between 25 to 45 degrees is susceptible to snow movement. The smooth or roughness of the ground and rocks located under the snow will determine how easily the snow will move. The larger the rocks the slower and less chance the snow have to move. But a warning, that once enough snow has fallen and the rough terrain has ben covered these rocks will not yield the avalanche. While the slope profile should also be considered. If the slope is a convex slope more tension occurs in the snow causing the chances of a slab avalanche to increase. All slopes should be avoided after storms or high wind speeds. Avalanche locations will move according to the direction of the wind.

Obviously after Mother Nature has done a chore (such as a storm or high winds) the chances of an avalanche increase. Rapid snow build-up (usually more that 2 cm/hr) will produce very unstable conditions. More than 30 cm of build up within 24 hours is very hazardous. Lose snow and air packets caught under the snow will make danger levels increase. Sudden temperature change, wind speed and direction also alter snow stability. Most importantly above all is human interference. 90% of all avalanches happen during snowstorms, with 90% percent of all avalanches being people trigger accidents.

How do you avoid getting caught in an avalanche ?

The most simplistic way of avoiding getting caught in an avalanche is to recognize where one is most likely to occur. If you understand that there is high possibility of an avalanche you are less likely to fall victim to the surprise occurrence of one. This can be accomplished understanding how the path of an avalanche appears. Most avalanche paths are obvious, appearing as an open slope, bowl or gully shape. Other common give-always are bent or damaged trees. Although it is a very popular myth, loud noises do not usually cause avalanches. The pressure of someone or something that is making the noise usually causes them.

Types of Avalanches

To help in understanding of avalanches, they have been classified into four types :

1. Loose Snow Avalanches : First of these are the loose Snow Avalanches. They are common on steep slopes and are seen after a fresh snowfall. Since the snow does not have time to settle down fully or has been made loose by sunlight, the snow-pack is not very solid. Such avalanches have a single point of origin, from where they widen as they travel down the slope.

2. Slab Avalanches : Loose snow avalanches in turn could cause a Slab Avalanche, which are characterized by a fall of a large of ice down the slopes. Thin slabs cause fairly small amounts of damage, while the thick ones are responsible for many fatalities.

3. Powder Snow Avalanches : Powder Snow Avalanches are a mix of the other forms, Loose Snow and Slab. The bottom half of this avalanche consists of a slab or a dense concentration of snow, ice and air. Above this is a cloud of powdered snow, which can snowball into a larger avalanche as it progresses down the slope. The speed attained by this avalanche can cross 190 miles per hour and they can cross large distances.

4. Wet Snow Avalanches : Finally, there are Wet Snow Avalanches. These are quite dangerous as they travel slowly due to friction, which collects debris from the path fairly easily. The avalanche comprises of water and snow at the beginning, but understanding of avalanches has showed us that it can pick up speed with ease.

CAUSES OF AVALANCHES

There is no one reason behind the development of avalanches. It was believed for long that the echo of a human voice in the mountains could dislodge enough snow to start one. Similarly, a person's weight can cause a avalanche too. The sudden addition of weight can fracture a weak are of snow. However, scientific understanding of avalanches shows us that there are many environmental factors at work.

1. Snowstorm and Wind Direction : Heavy snowstorms are more likely to cause Avalanches. The 24 hous after a storm are considered to be the most critical. Wind normally blows from one side of the slope of mountain to another side. While blowing up, it will scour snow of the surface which can overhang a mountain.

2. Heavy snowfall : Heavy snowfall is the first, since it deposits snow in unstable areas and puts pressure on th snow-pack. Precipitation during the summer months is th leading causes of wets now avalanches.

3. Human Activity : Humans have contributed to the start of many avalanches in recent years. Winter spots that require steep slopes often put pressure on the snow-pack which it cannot deal. Combined with the heavy deforestation and soil erosion in mountain regions, it gives the snow little stability in the winter months. Further natural causes include earthquake and tremors, since they can often create cracks in the snow-pack.

4. Vibration or Movement : The use of all Terrain Vehicles and Snowmobiles creates vibrations within the snow that it cannot withstand. Couples with the gravitational pull, it is one of the quickest ways to cause an avalanche. The other is construction work done with explosives, which tend to weaken the entire surrounding area.

5. Layers of Snow : There are conditions where snow is already on the mountains and has turned into ice. Then, fresh snow falls on top which can easily slide down.

6. Steep Slopes : Layers of snow build up and slide down the mountain at a faster rate as steep slopes can increase the speed of snow. A rock or piece of huge ice shake the snow and cause it to come down.

7. Warm Temperature : Warm Temperature that can last several hours a day can weaken some of the upper layers of snow and cause it to slide down.

Effects of Avalanches :

As such, there is little damage to the overall ecological system due to avalanches. They are a part of nature and have been happening for thousands of years. However, they are a major natural hazard for the local human population.

1. Damage to Life and Property : A large number of casulties take place after avalanches hit heavily populated areas. Infrastructure is damaged and the blockage caused, impacts the livehoood of many. People who enjoy skiing, snow boarding and snowmobiling are at a greater risk of losing their lives. A powerfrul avalanche can even destroy buildings and power supplies can be cut off.

2. Flash Floods : When an avalanche occurs, it brings down all the debris with it and can cause havoc in low lying areas. Flash Floods are seen to happen after avalanches, which is a long term problem many villagers and townspeople have to deal with. They can also change weather patters and cause crop failure in farms present on the lower fields.

3. Economic Impact : An avalanche can block anything in its path and even restrict the normal movement of traffic. Various ski resorts depend on toursists to run their business successfully. Ski resorts and other businesses are forced to close until the avalanche decreases and weather conditions become suitable.

MANAGEMENT OF AVALANCHES

The areas in which avalanches occur may also be used for human activities, such as skiing. Villages and towns are also often located in the villeys. It is important for the people, economy, and the environment that avalanches are managed.

There are several ways in which avalanches can be manged.

1. Prediction : People try to predict when avlanches are going to occur. The alps has an ‘avalanche season’ between January and March when most avalanches happen.

Where avalanches are going to occur is hard to predict. Historical data, weather information and information about the actaul snow on the mountainside is collected together to try and forecast the likelihood of an avalanche.

2. Explosions : Avalanches can be started deliberately in order to prevent the snow building up. This is one of the most important ways of preventing avalanches.

3. Communication : Signs of risk of avalanches can be displayed in villages and also by the ski lifts. In the Alps the risk is assessed on a five-point scale. Areas can be sealed off which are considered too dangerous to ski on. Early warning systems are also used.

4. Land-use zoning : Land can grouped into red, yellow and green areas. The red are considered too dangerous to be built on. The organge areas can be built on with restrictions, such as reinforcing building. Roads and railways can be protected by tunnels over them in the areas where an avalanche path is likely to travel.

5. Snow fence and barriers : These can be used to divert and break up the path of the avalanche.

6. Reforestation : Trees can be planted, increasing stability of the slope and helping to reduce the damage further down the valley.