B.A. First Year

Geography, Paper - I

PHYSICAL GEOGRAPHY (LITHOSPHERE)

मध्यप्रदेश भोज (मुक्त) विश्वविद्यालय – भोपाल

MADHYA PRADESH BHOJ (OPEN) UNIVERSITY – BHOPAL

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Published by Registrar, MP Bhoj (Open) University, Bhopal in 2020

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VIKAS® PUBLISHING HOUSE PVT. LTD.
E-28, Sector-8, Noida - 201301 (UP).
Phone: 0120-4078900 • Fax: 0120-4078999
Regd. Office: A-27, 2nd Floor, Mohan Co-operative Industrial Estate, New Delhi - 1100 44.
• Website: www.vikaspublishing.com • Email: helpline@vikaspublishing.com

SYLLABI-BOOK MAPPING TABLE

Physical Geography (Lithosphere)

Syllabi	Mapping in Book
Unit 1 Introduction to Geography: Definition, Nature and Scope of Physical Geography. Relation of Physical Geography with Other Branches of Earth Sciences. Solar System. Earth and its Planetary Relations. The Origin of the Earth, Age of the Earth. Geological Time Scale. Important Hypothesis Related to Origin of the Earth: Nebular, Tidal, Planetesimal, Ottoschmidt and Supernova.	**Unit 1:** Introduction to Geography **(Pages 3 – 67)**
Unit 2 Interior of the Earth, Continental Drift Theory of Wegener, Plate Tectonics. Earth Movements – Folds and Faults.	**Unit 2:** Interior of the Earth **(Pages 68 – 123)**
Unit 3 Theory of Isostasy, Earthquakes and Volcanoes. Rocks – Origin, Types and Composition, Weathering.	**Unit 3:** Theory of Isostasy, Earthquakes and Volcanoes **(Pages 124 – 170)**
Unit 4 Geomorphic Agents and Processes, Masswasting. Evolution of Landforms, Concept of Cycles of Erosion, Views of Davis and Penck.	**Unit 4:** Geomorphic Agents and Processes **(Pages 171 – 235)**
Unit 5 Fluvial, Arid, Glacial, Karst and Coastal Landforms. Application of Geomorphology to Human Activities.	**Unit 5:** Landforms and Geomorphology **(Pages 236 – 300)**

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INTRODUCTION

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The huge scope construction of the earth is brought about by geodynamic measures which are clarified utilizing enthusiastic, kinematic and dynamic depictions. While "geodynamic measures" are perceived to incorporate a huge assortment of cycles and the term is utilized freely, the strategies for their depiction include obvious fields. Enthusiastic depictions are associated with distribution of energy in our planet, regularly communicated as far as warmth and temperature. Kinematic portrayals depict developments utilizing speeds, strains and strain rates. Dynamic depictions demonstrate how stresses and powers act. In the field, we archive just the outcomes of topographical cycles. The hidden causes are a lot harder to oblige straightforwardly. All things considered, on the off chance that we need to clarify the structural development of our planet, we need to decipher these causes or: "main impetuses". For this, we need to track down a powerful depiction of topographical cycles that is reliable with our perceptions. Our depictions relate causes and results – structural cycles with field perceptions.

Current Earth science experiences fracture into an enormous number of sub-disciplines with restricted discourse among them, and fake qualifications between the outcomes dependent on various methodologies. This issue has been especially intense in lithospheric research, where distinctive geophysical methods have brought about a large number of meanings of the lithosphere – seismic, warm, electrical, mechanical, and petrological. This book presents an intelligent blend of the cutting edge in lithosphere contemplates dependent on a full arrangement of geophysical techniques (seismic reflection, refraction, and collector work strategies; versatile and anelastic seismic tomography; electromagnetic, magnetotelluric, warm and gravity techniques; and rheological demonstrating), supplemented by petrologic information on mantle xenoliths and research facility information on rock properties. It's anything but a basic conversation of the vulnerabilities, suppositions, and goal gives that are intrinsic in the various strategies and models. Above all, it talks about the connections among strategies and presents headings for their joining to accomplish a superior comprehension of the cycles that influence the lithosphere and accordingly shape the Earth on which we live. Multi-disciplinary in scope, worldwide in topographical degree, and covering a wide assortment of structural settings over 3.5 billion years of Earth history, this book presents an extensive outline of lithospheric design and advancement. It's anything but a center reference for scientists and progressed understudies in geophysics, geodynamics, tectonics, petrology, and geochemistry, and for petrol and mining industry experts.

The book is an impression of the writer's astonishing handle of different features of geodynamic measures, actually a troublesome subject to convey – talked about in most clear terms. This book varies from its archetype Geodynamics by Turcotte and Schubert, an exemplary reading material by its own doing, in that the intended interest group purportedly is the field geologists.

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The new book additionally varies in its accentuation on orogenesis, transformation, heat transport, crustal thickening and geomorphology, likely a sign of the writer's own inclinations as a geologist. The high mark of the book is its treatment of arithmetic and the manner by which it is made open to field-situated geologists. Here is a book that is exceptionally qualified to be remembered for the geography graduate investigations under our colleges. "I likewise urge our geologists to peruse this educative book, undoubtedly an important expansion to the extending data base on quantitative geodynamics."

The Earth's surface morphology is a result of predominant constraining like structural elevate, disintegration, residue transport, and environment. As of late, the Earth science local area additionally began to consider biota as a geomorphological specialist that has a part in forming the Earth surface, regardless of whether at an alternate scale and extent than that of other major forcings. Human exercises straightforwardly or in a roundabout way move huge amounts of soil, which leave clear geographical marks on the Earth's morphology. These marks have the ability to influence Earth surface cycles. This article gives an outline of the part of people as a land specialist in forming the morphology of the Earth. We think about horticultural scenes, mining exercises, and street organizations. We give models in various locales of the world. The last segment thinks about finishing up perceptions and open difficulties, where we center around future difficulties, identified with Anthropocene, in the Earth science local area.

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UNIT 1 INTRODUCTION TO GEOGRAPHY

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Structure

1.0 INTRODUCTION

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Geography is a discipline of science committed to the take a look at the lands, capabilities, inhabitants, and phenomena of the Earth and planets. Geography is frequently defined in terms of branches: human geography and bodily geography. Human geography is that branch of geography this is associated with the examine of people and their communities, economies, cultures, and interactions with the surroundings by using studying their relations with and throughout area and vicinity. Physical geography is concerned with the have a look at of procedures and patterns in the natural environment just like the ecosystem, geosphere, biosphere and hydrosphere.

The 4 historical traditions in geographical research are spatial analyses of natural and the human phenomena, vicinity research of locations and areas, studies of human-land relationships, and the Earth Sciences. Geography has been known as "the world area" and "the bridge between the human and the physical sciences".

1.1 OBJECTIVES

After going through this unit, you will be able to:

- Definition, nature and scope of physical geography.
- Relation of physical geography with other subjects.
- Solar system.
- Origin and evolution of earth and its age.
- Various hypotheses related to origin of earth.

1.2 DEFINITION OF PHYSICAL GEOGRAPHY

Physical geography or physiography is one of the fields of geography. Bodily geography is the department of herbal technological know-how which is associated with the medical have a look at of the herbal functions of the Earth's floor, consisting of currents, land formation, weather, and distribution of plant life and fauna.

It is the study of methods and patterns inside the herbal surroundings inclusive of the ecosystem, hydrosphere, biosphere, and geosphere, in preference to the cultural or constructed surroundings, the area of human geography.

Physical geography is to a look at the earth's surface, take a look at of the natural features the earth's floor, mainly in its current factors, including land formations, climate, currents, and distribution of flora and fauna. To observe the environment and weather, capabilities and nature of the earth's strong surface and oceans, distribution of plant and animal life, and many others.

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The scientific study of the natural features of the Earth's surface, especially in its current aspects, including land formation, climate, currents, and distribution of flora and fauna.

Merriam Webster Dictionary, "Geography offers with the outdoors physical features and modifications of the earth."

Cambridge Dictionary, "The study of the natural features of the earth, such as mountains and rivers."

Divisions of Physical Geography

Physical geography can be divided into several branches or related fields, as follows:

Biogeography is the technological know-how that is associated with geographic patterns of species distribution and the procedures that result in those patterns. Biogeography emerged as a area of study because of the paintings of Alfred Russel Wallace, even though the sector prior to the past due twentieth century had in large part been considered as historical in its outlook and descriptive in its method. The main constraints of the field in view that its founding has been that of evolution, plate tectonics and the theory of island biogeography. The sector can largely be divided into 5 sub-fields: island biogeography, paleobiogeography, phylogeography, zoogeography and phytogeography.

Geomorphology as a field has numerous sub-fields that are worried with the unique landforms of numerous environments e.g., barren region geomorphology and fluvial geomorphology; but, these sub-fields are united by using the center procedures which purpose them, in particular tectonic or climatic processes. Geomorphology is concerned with knowledge the surface of the Earth and the processes through which it is shaped, both at the existing as well as in the beyond. Early studies in geomorphology are the foundation for pedology, one among important branches of soil technological know-how. Geomorphology seeks to recognize landform records and dynamics, and predict future changes through a combination of discipline remark, bodily experiment, and numerical modeling. (Geomorphometry).

Glaciology is the study of glaciers and ice sheets, or more usually the cryosphere or ice and phenomena that involve ice. Glaciology corporations ice sheets as continental glaciers and glaciers as alpine glaciers. Although studies within the areas is similar to studies undertaken into each the dynamics of ice sheets and glaciers, the former tends to be involved with the interaction of ice sheets with the present climate and the latter with the impact of glaciers on the panorama. Glaciology additionally has a widespread array of sub-fields inspecting the factors and approaches concerned in ice sheets and glaciers e.g. snow hydrology and glacial geology.

Hydrology has historically had an essential relation with engineering and has for that reason evolved a in large part quantitative technique in its research; but, it does have an earth science side that embraces the systems technique. Hydrology is mainly related to the quantities and high-quality of

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water transferring and gathering at the land surface and inside the soils and rocks near the floor and is typified through the hydrological cycle. Accordingly the sphere accommodates water in lakes, rivers, aquifers and to an volume glaciers, in which the field examines the technique and dynamics worried in those bodies of water. Hydrology has sub-fields that observe the specific bodies of water or their interaction with different spheres e.g. limnology and ecohydrology.

Soil geography is attached with the distribution of soils across the terrain. This subject is essential to each bodily geography and pedology. Pedology is the science of soils of their natural surroundings. It offers with pedogenesis, soil morphology, and soil class. Soil geography is the technology of the spatial distribution of soils because it relates to topography, climate (water, air, temperature), soil lifestyles (micro-organisms, vegetation, animals) and mineral substances inside soils (biogeochemical cycles).

Meteorology phenomena are observable climatic events that illuminate and are defined via the technology of meteorology. Meteorological is the interdisciplinary medical mastering of the environment that makes a speciality of weather processes and quick time period forecasting (in assessment with climatology). Meteorological studies within the area stretch again millennia, even though sizeable development in meteorology did not occur till the eighteenth century.

Climatology examines each the nature of micro i.e., neighborhood and macro i.e., worldwide climates and the natural and anthropogenic affects on them. Climatology looks at of science of the climate, scientifically described as weather conditions averaged over an extended time frame. The sector is similarly sub-divided largely into the climates of various areas and the observe of particular phenomena or time intervals e.g. tropical cyclone rainfall climatology and paleoclimatology.

Coastal geography is the examine of the dynamic interface between the ocean and the land, incorporating both the bodily geography (i.e., coastal geomorphology, geology, and oceanography) and the human geography of the coast. It involves an expertise of coastal weathering processes, specifically wave action, sediment movement and weathering and additionally the methods wherein human beings engage with the coast. Coastal geography, even though predominantly geomorphological in its studies, isn't simply involved with coastal landforms, however, additionally the reasons and impacts of sea degree alternate.

Palaeogeography is a move-disciplinary observe that examines the preserved cloth within the stratigraphic record to decide the distribution of the continents via geologic time. almost all the proof for the positions of the continents comes from geology in the form of fossils or paleomagnetism the use of this facts has ended in proof for continental float, plate tectonics, and supercontinents. This, in turn, has supported palaeogeographic theories along with the Wilson cycle.

Quaternary technology studies the remaining ice age and the recent Holocene. It uses proxy evidence to reconstruct the beyond environments during this period to infer the climatic and environmental changes which have occurred. It's miles an interdisciplinary area of examine focusing on the Quaternary period, which encompasses the closing 2.6 million years of formation of ice age.

Oceanography is the department of physical geography that research the Earth's oceans and seas. It covers a huge variety of topics, including marine organisms and surroundings dynamics (organic oceanography); ocean currents, waves, and geophysical fluid dynamics (bodily oceanography); plate tectonics and the geology of the ocean floor (geological oceanography); and fluxes of various chemical substances and bodily houses inside the ocean and throughout its boundaries (chemical oceanography). these diverse topics replicate a couple of disciplines that oceanographers mixture to similarly know-how of the world ocean and know-how of processes inside it.

Geomatics is the field of gathering, storing, processing and delivering geographic statistics or spatially referenced statistics. Geomatics includes geodesy (scientific subject that deals with the measurement and representation of the earth, its gravitational field, and other geodynamic phenomena, along with crustal motion, oceanic tides, and polar movement), geographical information technology (GIS) and remote sensing (the fast or massive-scale acquisition of information of an item or phenomenon, by way of the usage of either recording or actual-time sensing gadgets that are not in bodily or intimate touch with the item).

Environmental geography is a branch of geography that analyzes the spatial factors of interactions among human beings and the natural international. The branch bridges the divide between human and physical geography and therefore, calls for an know-how of the dynamics of geology, meteorology, hydrology, biogeography, and geomorphology, as well as the approaches wherein human societies conceptualize the environment. Despite the fact that the branch turned into formerly greater visible in studies than at gift with theories inclusive of environmental determinism linking society with the surroundings. It has largely become the domain of the study of environmental management or anthropogenic impacts.

Landscape Geography is a sub-field of ecology and geography that address how spatial version within the landscape influences ecological processes which include the distribution and float of power, materials, and people inside the environment (which, in flip, may additionally have an impact on the distribution of panorama "factors" themselves along with hedgerows). the sector was in large part funded by means of the German geographer Carl Troll. landscape ecology normally deals with issues in an applied and holistic context. the primary distinction between biogeography and panorama ecology is that the latter is involved with how flows or electricity and fabric are modified and their impacts on the landscape whereas the previous is concerned with the spatial patterns of species and chemical cycles.

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Check Your Progress

1. The study of the internal dynamics and effects of glaciers is called __________.
2. __________ is the study of geographical features at periods in the geological past.

1.3 NATURE OF PHYSICAL GEOGRAPHY

A number of the earliest questions formulated by using primitive man were associated with the nature of his natural environment. Guy like many other animals, identifies a particular quantity of territory as his dwelling area, and is curious to realize approximately the world outdoor his very own living area. This curiosity compels him to explore what it is like past the frontiers of his own home ground. Geography become born to fulfill this fold interest, and to allow guy to accumulate understanding approximately the lands and people lying beyond his familiar international, so the history of geographical thoughts, consequently, constitute the document of guy's attempt to present an increasing number of logical and useful knowledge of the human habitat, and guy's spread over the earth surface.

This journey starts off evolved even before the Greek period, to Greek, Romans, darkish age in Europe and consequent development on Arab lands, Age of Exploration and it's impact on geographical know-how, then, Debate on man-environment courting that if guy is lively or passive agent in environment and related philosophy like Environmental Determinism, possibalism, Neo-Determinism, and so on.

In Nineteen Fifties and 60s the marked debate between Richard Hartshorn and Schaefer, and associated Quantitative Revolution in Geography, then after rise of Behavioural and Humanistic Geography due in dissatisfaction with quantitative methods in geography, then after many trend like Marxist Geography, Radical Geography, Postmodernism and publish structural Geography etc.

Exceptionally stages that befell in special phases of time represent the Geography of nowadays.

Geography as a area of gaining knowledge of is related to significance of region and Spatial family members of factors and events.

Asking questions about places is one of the distinguishing characteristics of the field of observe we call Geography.

So, Geography is involved with the observe of issues related to vicinity, inside the identical manner as records is involved with hassle involving sequences of activities inside the beyond.

Geography continues to be the sector that offers with the affiliation of phenomena that give character to precise place, and with likenesses and variations amongst places.

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So nature of Geography had not been equal in distinct intervals of time if we see the choronology of Geography, however whatever the context, Geography is always involved with the characteristics of places on the floor of the Earth.

So we can conclude that:

1. By, its nature, Geography is related with almost everything on the surface of the Earth, in other words, with any phenomena (physical or human) that is irregularly distributed over the earth surface can be studied by the Geographic method.
2. It has Spatial Nature
3. It has temporal nature
4. It has quantitative nature
5. It has qualitative nature

Scope of Geography

Scope means, what is the domain of it, i.e., what we study in it.

Frequently people classify it in Human and bodily elements of Geography which represents Human and bodily Geography respectively, however this department could be very puzzling, be aware that this division is made simply simplest for the ease of have a look at neither such division in reality exist in nature nor in Geography, due to the fact human and physical phenomena aren't unbiased however, depending on every other, so Geography targets to take a look at the Spatial Manifestation of guy-environment relationship, which comprises the scope of it i.e., how human and bodily phenomena (that are dependent on each other), spatially distributed over the earth surface, with regard to 3 basic questions:

1. Wherein it's miles?
2. What it is like?
3. What does it imply

So It's scope includes the answers of five fundamental questions that a geographer try and know or ask:

1. **General questions:** Questions referring to distribution of phenomena on earth surface.
2. **Genetic Questions:** Questions involved with the sequences of occasions and Interactions that have gone into the making of the modern-day landscape.
3. **Theoretical questions:** Referring to system of regulation-like statements.
4. **Remedial Questions:** Concerned with the software of Geographic concepts to the answer of the real existence issues.
5. **Methodological Questions:** Involved with development of our medical capabilities.

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As a result the Geographer learns about the biophysical capabilities of the Earth; is deeply interested in the interrelationship among society and habitat; need to examine the Cultural panorama as the Earth-engraved expression of guy's interest; inspects and compares distributional patterns; and formulates principles and standards.

Meander Formation

Hydrology is transcendently concerned about the amount and nature of water moving and aggregating on the land surface and in the dirts and rocks close to the surface and is epitomized by the hydrological cycle. Consequently the field envelops water in streams, lakes, springs and to a degree icy masses, where the field looks at the cycle and elements associated with these waterways. Hydrology has verifiably had a significant association with designing and has accordingly fostered to a great extent quantitative technique in its examination; nonetheless, it's anything but a geology side that accepts the frameworks approach. Like most fields of actual topography it has sub-handle that inspect the particular waterways or their association with different circles for example limnology and ecohydrology.

Glaciology is the investigation of ice sheets and ice sheets, or all the more regularly the cryosphere or ice and marvels that include ice. Glaciology bunches the last mentioned (ice sheets) as mainland icy masses and the previous (glacial masses) as high glacial masses. Despite the fact that exploration in the spaces is like examination embraced into both the elements of ice sheets and ice sheets, the previous will in general be worried about the communication of ice sheets with the current environment and the last with the effect of glacial masses on the scene. Glaciology additionally has a huge swath of sub-fields looking at the components and cycles engaged with ice sheets and ice sheets for example snow hydrology and chilly geography.

Biogeography is the science which manages geographic examples of species conveyance and the cycles that outcome in these examples. Biogeography arose as a field of study because of crafted by Alfred Russel Wallace, albeit the field before the late 20th century had to a great extent been seen as noteworthy in its viewpoint and elucidating in its methodology. The principle boost for the field since its establishing has been that of advancement, plate tectonics and the hypothesis of island biogeography. The field can to a great extent be separated into five sub-fields: island biogeography, paleobiogeography, phylogeography, zoogeography and phytogeography.

Climatology is the investigation of the environment, logically characterized as climate conditions found the middle value of throughout a significant stretch of time. Climatology analyzes both the idea of miniature (nearby) and full scale (worldwide) environments and the normal and anthropogenic effects on them. The field is additionally sub-partitioned to a great extent into the environments of different locales and the investigation of explicit marvels or time-frames for example typhoon precipitation climatology and paleoclimatology.

Meteorology [dubious – discuss] is the interdisciplinary logical investigation of the air that spotlights on climate cycles and momentary estimating (interestingly with climatology). Studies in the field stretch back centuries, however huge advancement in meteorology didn't happen until the eighteenth century. Meteorological marvels are perceptible climate occasions that enlighten and are clarified by the study of meteorology.

Soil geology manages the conveyance of soils across the landscape. This order is crucial to both actual geology and pedology. Pedology is the investigation of soils in their indigenous habitat. It manages pedogenesis, soil morphology, soil characterization. Soil geology examines the spatial dispersion of soils as it identifies with geography, environment (water, air, temperature), soil life (miniature living beings, plants, creatures) and mineral materials inside soils (biogeochemical cycles).

Palaeogeography is a cross-disciplinary investigation that analyzes the protected material in the stratigraphic record to decide the appropriation of the mainlands through geologic time. Practically all the proof for the places of the landmasses comes from geography as fossils or paleomagnetism. The utilization of these information has brought about proof for mainland float, plate tectonics, and supercontinents. This, has upheld palaeogeographic speculations, for example, the Wilson cycle.

Beach front geology is the investigation of the unique interface between the sea and the land, consolidating both the actual topography (for example beach front geomorphology, topography, and oceanography) and the human geology of the coast. It's anything but a comprehension of seaside enduring cycles, especially wave activity, silt development and enduring, and furthermore the manners by which people cooperate with the coast. Seaside topography, albeit overwhelmingly geomorphological in its exploration, isn't simply worried about waterfront landforms, yet additionally the causes and impacts of ocean level change.

Oceanography is the part of actual geology that reviews the Earth's seas and oceans. It's anything but a wide scope of points, including marine organic entities and environment elements (natural oceanography); sea flows, waves, and geophysical liquid elements (actual oceanography); plate tectonics and the topography of the ocean bottom (land oceanography); and motions of different compound substances and actual properties inside the sea and across its limits (synthetic oceanography). These assorted subjects mirror different controls that oceanographers mix to additional information on the world sea and comprehension of cycles inside it.

Quaternary science is an interdisciplinary research field that focuses on the Quaternary, including the past 2.6 million years. This field studies the last ice age and the recent Holocene, and uses proxy evidence to reconstruct the past environment during this period to infer climate and environmental changes that have occurred.

Landscape ecology is a branch of ecology and geography, which studies how the spatial changes of the landscape affect ecological processes, such as

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the distribution and flow of energy, materials, and individuals in the environment (which, in turn, may affect the distribution of the landscape) "Elements" Itself, such as a hedge). This field is mainly funded by the German geographer Karl Troll. Landscape ecology usually deals with issues in the context of application and overall. The main difference between biogeography and landscape ecology is that the latter focuses on changes in flow or energy and matter and its impact on the landscape, while the former focuses on the spatial pattern of species and chemical cycles.

Geoinformatics is the field of collecting, storing, processing and transmitting geographic information or spatial reference information. Geoinformatics includes geodesy (processing the earth, its gravitational field, and other geodynamic phenomena, such as crustal movement, ocean tides, and polar movements), geographic information science (GIS), and remote sensing (the scientific discipline of measuring and representing the earth) Obtain information on objects or phenomena in a short-term or large-scale by using recording or real-time sensing devices that have no physical or intimate contact with the object).

Environmental geography is a branch of geography that analyzes the spatial aspects of the interaction between humans and the natural world. This branch bridges the gap between human geography and physical geography, so it is necessary to understand the dynamics of geology, meteorology, hydrology, biogeography, and geomorphology, as well as the way human society conceptualizes the environment. Although this branch was more obvious in research before than it is now, for example, environmental determinism connects society with the environment. It has largely become the field of environmental management or human influence research.

Check Your Progress

3. Define geography according to Cambridge dictionary.
4. Nature of geography is __________, __________, __________ and __________.

1.4 RELATION OF PHYSICAL GEOGRAPHY WITH OTHER BRANCHES OF EARTH SCIENCES

Physical geography is the heart of the science. It has been indicated clearly however, effectively the connection between geography and many different fields from which it draws a lot of the concern rely.

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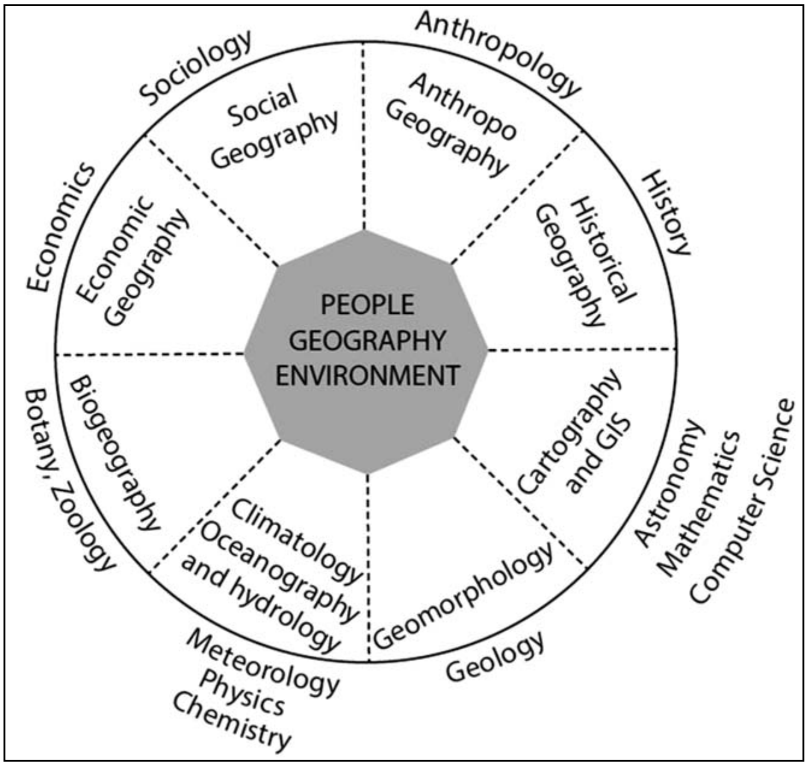

Fig. 1.1: Relation of Geography with other Subjects

1.4.1 Astronomy and Geography

Astronomy deals with the celestial bodies (their movement in the universe) which encompass the specific Suns and their planets, satellites, their movement, constellations, in addition to one-of-a-kind kinds of phenomena going on within the outer area. it is a natural herbal science and systematically offers with the concrete items and phenomena that have a recognized scenario within the Universe. Geography's hyperlink with astronomy has evolved mainly as it additionally offers with unique phenomena. Geography attempts to identify and degree the impact of the motion of the celestial bodies at the floor of the Earth. How the phenomena at the spatial phase of the Earth's surface been inspired by means of the items of the celestial space? This has necessitated in geography to take a look at the form, size and movement and motion of celestial bodies, specifically of the solar, the Earth and the Moon, and their corresponding position in the sun machine. Geography additionally tries to decide the location of the celebrities and the constellation within the horizon, the quantity of the celestial sphere and other celestial phenomena, including to locate new planets, their satellites and stars. It's miles the mathematical culture in geography which has added each astronomy and geography towards every different. With the help of mathematics the appropriate area, nature of motion and motion, volume of celestial sphere, form, and length of celestial our bodies, along with the ones of the solar, the earth, and the moon were effectively determined. Astronomy and geography each are similarly worried with those aspects, and in a sense, they are collectively interdependent. The interplay of astronomy and geography

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within the mathematical framework has given upward thrust to cartography in geography which treats the unique phenomenon of place approximately geodesy (paperwork, shapes, size of the earth, range, and longitude, etc.) and celestial objects.

1.4.2 Ayurveda, Medicine and Geography

Ayurveda is one of the most outstanding and conventional systems of medication that has survived and flourished from a long time till date. With the great understanding of nature-based totally medicine, the connection of human frame constitution and function to nature and the elements of the universe that act in coordination and have an effect on the residing beings, this gadget will retain to flourish in ages nonetheless to come. Ayurveda believes that the complete universe is made of 5 elements, i.e., Jala (Water), Vayu (Air), Prithvi (Earth), Aakash (space or ether), and Teja (hearth). These types of elements (referred to as Pancha Mahabhoota in Ayurveda) are believed to shape the 3 basic senses of humor of human body in various mixtures.

The three senses of humor; Vata dosha, Pitta dosha and Kapha dosha collectively referred to as "Tridoshas," and they manipulate the basic physiological capabilities of the frame along side five sub-doshas for every of the foremost doshas. Clinical geography these days is gaining significance in cutting-edge medication and has its beginning from Hippocrates. However, Charaka Samhita which was written lengthy earlier than Hippocrates intricately speaks about medical geography. Although the manuscript gives a extensive define of geography regarding Jangala, Aanoopa, and Sadharana; it additionally discusses numerous locations of the then India.

Health geographers are in the main involved with the prevalence of various sicknesses together with a few scales from the country wide to worldwide, and study the herbal global, in all of its headaches, for correlations between illnesses and their locations. This method locations health geography alongside the alternative sub-disciplines of geography that trace the person and surroundings members of the family. Fitness geographers use modern-day gear to research the diffusion of numerous sicknesses on maps, as people get affected themselves, and across wider spaces, as they migrate. fitness geographers also recollect all types of spaces as imparting fitness dangers, from natural disasters to interpersonal violence, pressure, and different potential risks. In a nutshell, geography affords space to Ayurveda and Healthcare.

Ayurveda is considered as one of the oldest of the traditional systems of medicine (TSMs) accepted worldwide. The ancient wisdom in this traditional system of medicine is still not exhaustively explored. The junction of the rich knowledge from different traditional systems of medicine can lead to new avenues in herbal drug discovery process. The lack of the understanding of the differences and similarities between the theoretical doctrines of these systems is the major hurdle towards their convergence apart from the other impediments in the discovery of plant based medicines. This review aims to bring into limelight the age old history and the basic principles of Ayurveda. This would help the budding scholars, researchers and practitioners gain deeper perspicuity of traditional systems of medicine, facilitate strengthening of the commonalities and overcome the challenges towards their global acceptance and harmonization of such medicinal systems. A Geographical Indication (GI) is a sign or tag used on agricultural, natural or manufactured products which correspond to a specific geographical location. They are part of the intellectual property rights that comes under the Paris Convention for the Protection of Industrial Property. Medicinal plants are among the most precious bio-resources of the planet, and are also among the most threatened. GI tagging of medicinal plants is important for quality-assurance and trade, as well as for conservation of these species. It also helps to supplement the incomes of the farmers.

1.4.3 Geology and Geography

Geology is the natural technology which has traditionally been closest to geography due to the fact both of them have strong hyperlinks with the idiographic way of life. Geology describes and clarifies 'concrete' easy phenomena and puts them into a geological chronology and classification.

Geography also attempts to deal with 'concrete' recognizable phenomena happening at the surface of the earth, classifying them into various classes. Both take a look at such concrete phenomena which have recognised the situation in time and space. Geology is the study of the rocks, their format, and preparations, types, minimum materials, resistance and age, distribution, dip, and alignment, etc. These are all concrete phenomena, and need now not be quantified. Geography is basically the look at of the Earth's surface, particularly the morphology of the floor. Morphology of the Earth's surface is the manifestation of the rock structure in special bureaucracy. So one has to take a look at geology to provide an explanation for the morphology. The analogy, "panorama is the observe of shape, process and level" virtually demonstrates the closest relation between geology and geography. The time period 'structure' refers to geology and the phrases 'manner', and 'degree' consult with geography. The sentence makes both complementary to every different. Geology and geography both study the distribution of diverse sorts of rocks and minerals, their mode of incidence, chemical and bodily additives, hardness, precise gravity and lots of other things which can be concrete and recognizable. The interaction between geology and geography results in Geomorphology or landform geography. However, positive styles of phenomena research in geography are quantifiable. They require the method, verification or rejection of hypotheses through experiments and the establishment of universal medical legal guidelines. because of this converting fashion in geography, the subject indicates a few deviation from its traditional ideographic hyperlink with geology.

The first of our subjects, geography, is the science of describing the surface of the globe, while geology has for its object the description of the interior of the earth, and tracing the history of the rocks of which it is composed. Any one looking at a map will at once perceive the amount of talent, observation and calculation necessary to perfect such a drawing, and the same

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is equally true of a geological chart or section. We wish, in this article, to show the necessity of a perfect description of our earth, and also indicate the means at command for performing the labor, and, so to speak, for jotting down the items in the great encyclopedia of facts. It is of the utmost importance to the mariner, and all who trust themselves upon the ocean, that there should be perfect and reliable charts and instructions, deduced from practical observations, of the route they are about to travel. It is equally necessary that every current should be indicated and soundings taken, and the depth of water, at various points, marked on the charts, so that every ocean and sea may become as well known as the Atlantic, from New York to Liverpool. Commerce demands geographers to work in this field, and the saving of human life is their reward. Again, it is necessary that the land should be equally well mapped out, in order that boundaries may be accurately determined, and the divisions of States and countries may be truly known. It may seem surprising to some of our readers, that the destiny of a nation often depends on a geographical question. The late war between Great Britain and Russia was one of boundary, and the Paris Conference was called to settle the question; and there are many parallel cases in history where one geographer would have settled a question which took many battles and victories to determine. Geology is important, as developing the resources of a country its explorations are requisite to make out where the coal, iron and mineral veins are concealed to discover the locality of building stones, and marbles, and of clays for bricks, and also to determine their extent, and the best places to commence their working. Now, let us inquire the means at command for attaining these objects. The governments of nearly every country having any pretensions to civilization have now an organized body of scientific men to make these geographical and geological charts, sections and maps. We have a Coast Survey, and we are occasionally sending out exploring expeditions whose aim is to do the work we have mentioned. Each state has its geologist and scientific corps for exploring and giving to the world an account of its resources and capabilities. Great Britain has her Ordnance Survey, and her ships of war are always carrying on this work of mapping the globe. Germany has her great band of scientific amateurs, and the learned of each nation are voluntarily doing their utmost for the good of the world. A vast amount of labor has been done in this field by the means we have specified, but there yet remains much to be done, and we would point this out as a sphere of enterprise in which many can engage, and by first making a chart of their own district they may extend their labors to wider and unexplored fields.

1.4.4 Physics and Geography

Geography has long been related to Physics. As geography is the study of variable phenomena on the earth's surface, the mechanism of the phenomena requires being studied in the framework of physics. The physics of the surroundings, known as meteorology, uses the methods of physics to interpret and explain atmospheric techniques. Similarly, the physics of hydrosphere is referred to as oceanography, which too applies the ideas of physics to give an explanation for and interpret hydrosphere procedures. Even lithospheric tactics and modifications are studied in the framework of physics. The traits of phenomena studied in meteorology and oceanography show that targets are quantifiable. Some of their phenomena are extra summary than the ones studied by means of geologists and biologists.

Geography, as a science of synthesis, seeks to draw within its circumference the center principles of meteorology and oceanography in a clear attempt to explain and interpret 'the interrelated capabilities' and 'terrestrial phenomena.' Interplay with meteorology has given upward thrust to a systematic department of climatology in geography. Weather interested by 'the system' of change of energy and mass between the earth and the environment due to the fact that consequences in conditions for the weather. It's miles the climate that is a high issue for analyzing and classifying the terrestrial phenomena taking place in the world's surface. To recognize the variable phenomena, one has to take into consideration the simple ideas of meteorology and hydrology, then to proceed with an explanation, to account for the interdependence of phenomena.

Physical geography is greatly connected with physics. Physical geography studies about physical features of earth, internal and external part of earth and also out part of earth that is called astronomy. On the other hand, physics also studies about earth and its structure, motion, physical object etc. Astrophysics is very well connected to astronomy. Geography and physics are **inter-related**. Geography studies environmental phenomena and an environmental phenomenon is studied within the framework of physics. The field of meteorology is largely studied in geography as well as in physics.

1.4.5 Botany and Geography

It's far the ideographic way of life in geography which seeks to indicate its close link with biology and zoology. The systematic branches of botany and zoology have traditionally been restricted to a class and outline of diverse varieties of species on the planet's surface which tend to shape unique functions and phenomena. Geography, being the observe of the spatial segment of Earth's surface, additionally attempts to discover the distributional components of floral phenomena and additionally affords their category. Once more, we come to the point that the distributional nature of floral phenomena both botany and geography are seeking for to explain and classify the spatial pattern of actual phenomena and placed them into distinct classifications in line with spatial situations. Geography is closely related to zoology. Because each seek to interpret: (i) The distribution of the person genera and species of animals; (ii) The distribution of the interrelated phenomena of genera and species of animals over the spatial section of the Earth floor; and (iii) both are worried with the difference in the faunal equipment of the different lands. It's far the ecological culture in botany and zoology which introduced them lots toward geography. Ecology is the take a look at of the relationships among animals, plant life and their environments. Ecologists, therefore, take a look at the herbal relationships whereby unique species of flowers and animals are dependent on every different and the non-organic environment. This aspect of ecology exerts its affect on guy's organic nature and his dating to the natural

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surroundings. Geography, particularly population geography and synecology (which treats the development of plant and animal communities in a place), can be said to parallel conventional organic ecology. During current decades, ecology has emerge as a primary interest of research in botany, zoology, and geography. This is due to the development of a brand new course within ecology – referred to as structures ecology – which research construction and feature of the atmosphere. An surroundings includes the biological network at a specific location and the environmental, bodily instances which affect and are motivated through the organic network. It manifests the interdependence and interrelationship among botany, zoology, and geography.

1.4.6 Economics and Geography

Economics and geography are lengthy related to each different, and need to be seemed united and inseparable because both observe "concrete phenomena that have recognised state of affairs and time', that specialize in guy. Economics is worried with guy's economic activities, and the standards governing the location of units of manufacturing, forces of production, members of the family of manufacturing, the department of exertions, and a number of institutional aspects inclusive of fitness, capital investment, and belongings, entrepreneurial skills, era, investment budget, and so forth. In brief, economics is concerned with how human want and desires are happy in a world of restrained resources, in which anyone cannot have as a lot as she or he needs of the whole lot all of the above phenomena concerning economics have a recognized situation and time. They should be research in spatial and temporal context. each human hobby, coping with pleasurable wants and needs, have to have a exact location (place), time and distribution. as an instance, mining activities talk to the area of prevalence of minerals, their distribution and the period of extraction. The purpose of the interest is manufacturing. each unit of manufacturing on this planet's surface is variable inside the context of place, time and distribution. In view that geography is the examine of an ensemble of phenomena about the vicinity, localization, time and distribution, it's miles similarly concerned with the variable person of the economic activities. Agricultural sports and business activities do have recognised locations, localization, time and distribution on the various spatial sections of the Earth's floor. Forces of manufacturing, family members of production, devices of production, a division of hard work, the material circumstance and the entrepreneurial skill, all have a tendency to have 'areal expression' with a recognised time and scenario. This makes economics and geography interdependent. Current geography which makes a speciality of checking out, of the empirical validation of hypotheses concerning variable monetary phenomena, has advanced a far stronger affinity with economics. This has been efficient of new thoughts and strategies for the reason that Nineteen Fifties. The advent of vicinity concept into geography is primarily based on concepts from 'Neoclassical Economics' (which bureaucracy the idea of the view of the way financial pastime functions) as conventionally followed in capitalist society. Geography's interaction with economics has given upward push to monetary geography, which is the take a look at of the spatial variation on this planet's surface of sports related to producing, replacing and eating items and offerings.

1.4.7 Sociology and Geography

Sociology is mainly concerned with the institutional elements of the society which widely include social corporation of communities, family shape and gadget, rituals, tradition, customs, social gadget, and universal the whole manner of dwelling. Considering some of these aspects have a tendency to represent wonderful phenomena which have regarded situation and time, they have to be research in spatial context. Every spatial section of the Earth surface is diagnosed by its awesome 'genre de vie', which ends into 'social phenomena' and when one research the variable individual of its social phenomena on the earth's surface, he seeks to integrate sociology with geography.

As an example, when a sociologist or a geographer studies the institutional elements of the social agency of the predominant groups of India, he or she takes under consideration the geographical components and bases of the social corporations of the fundamental communities, every with a distinct manner of life and having 'place', localization' and 'distribution' in exceptional sections of the USA. This indicates the interrelationship among sociology and geography. Geography's conventional hyperlink with sociology seems to have developed often as a result of the idiographic culture. But, the creation of the place idea into sociology has in addition reinforced its ties with geography and vice versa. Geography has drawn some of its principles from contemporary sociology which might be related to the formula of empirical generalizations or legal guidelines via mathematical techniques and statistical techniques. Some of the studies of relations among social conduct of movement of people between city facilities, of spatial interactions between social companies, of the connection among innovation and tradition in rural and urban regions, have been made "both in sociology and geography with the aid of models. Social geography is the logical expression of the interplay between sociology and geography as it research social phenomena in spatial context.

1.4.8 Anthropology and Geography

Anthropology attempts to take a look at human races, their physical traits, organic developments, cultural developments, and agencies, and seeks to categorise them therefore, bodily and biological tendencies of human races and their employer are merchandise of nature. Races were identified on the premise of numerous indices, along with head index, nasal index and cephalic index and pores and skin color, hair texture and stature and are as a consequence classified as Negrito, Negro, Australoid, Mediterranean, Nordic, Alpine, and Mongolic. Every of them has wonderful organic trends and habitats and cultural trends and try to examine the variable racial phenomena on the spatial phase of the Earth's floor. The reciprocal dating between anthropology and geography has resulted within the development of 'anthropogeography' or ethnology which treats one of a kind human agencies in terms of the natural situations and the geographical distribution of races (men). The examine of 'apartheid' (the policy of spatial separation of races) as carried out in South Africa forms an inseparable a part of anthropogeography or ethnology.

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In recent years anthropologists have been engaged in intensive research on a number of topics that have been of traditional interest to geographers. Although this research covers a wide range of anthropological specializations (e.g., social organization, tribal and peasant economies, cultural evolution), it is most clearly expressed in the abundant literature on cultural ecology. Viewed from the standpoint of the prior commitment of geographers, and especially cultural geographers, the studies examined in this review show convergence and even overlap in substantive research, whereas the trend of philosophical or methodological writings has been one of independent but mainly parallel development. This generalization, which constitutes the main finding of the review, is derived from a survey of the history and current orientations of anthropology and a critical analysis of some studies that are especially relevant to geography. The growing popularity among anthropologists of cultural ecology and other geographic perspectives could lead to fruitful collaboration between two disciplines that have been linked thus far only by a rather vague awareness of their mutual interests and common ancestry.

1.4.9 History and Geography

History and geography top off the whole circumference of our perception; history that of time, and geography that of area. As Herodotus has rightly stated that records without Geography has no roots and Geography without records has no fruits. History differs from geography best in the attention of time and area. the former is a document of phenomena that follow each other and has reference to time. The latter is a record of phenomena except every other in area. Records is a narrative, geography is an outline, history gives the framework into which the multiplicity of historical records are ordered, the place offers the skeleton for geography, and both the fields are worried with integrating exclusive styles of phenomena. Therefore, history and geography are traditionally idiographic and are at the same time interdependent. Geography's inclination closer to physics seems to had been further intensified as a consequence of its increasing dependence at the hypothetic-deductive approach. It's been by and large evolved in Physics, Geography's increasing tendency to adopt the hypothetic-deductive approach has been especially because of the sort of questions regarding the variable phenomena to be responded and the nature of empirical statistics to be studied. It's far characteristic of the phenomena now studied in geography and physics that targets are quantifiable. Some of the phenomena of theoretical geography are, but, a lot extra abstract, and some of them cannot be immediately discovered, but the approach of measurement has given a theoretical supposition in their lifestyles. Theoretical geography, like theoretical physics, operates in an abstract milieu, seeking cohesion and association via mathematical and statistical hypotheses and postulates. It's far from physics that theoretical geography has been capable of become model building, exactly because it works with summary and quantifiable phenomena.

The relationship between history and geography is especially close because they represent two fundamental dimensions of the same phenomenon. History views human experience from the perspective of time, geography from the perspective of space. Historical geography is the branch of geography that studies the ways in which geographic phenomena have changed over time. It is a synthesizing discipline which shares both topical and methodological similarities with history, anthropology, ecology, geology, environmental studies, literary studies, and other fields. Although the majority of work in historical geography is considered human geography, the field also encompasses studies of geographic change which are not primarily anthropogenic. Historical geography is often a major component of school and university curricula in geography and social studies. Current research in historical geography is being performed by scholars in more than forty countries.

Geography and history are complementary subjects best taught together within the social studies curriculum. It is part of the collected wisdom of teachers that one cannot teach history without geography or geography without history. But what exactly is the nature of the relationship? What are the key concepts in geography that contribute to the teaching of history? And, what strategies can teachers use most effectively to link them together? Geography is a rich and complex discipline with two key perspectives: (1) the spatial perspective, which centers on location and an understanding of what may be called whereness; and the ecological perspective, which considers how humans interact with their physical environment. "The discipline of geography brings together the physical and human dimensions of the world in the study of people, places, and environments." (2) It studies the patterns produced by human and physical phenomena on Earth's surface, and the processes that shape these patterns. This is in contrast to the historical perspective, which is temporal, and views human events primarily in terms of a chronological framework.

The geographic perspective is not strongly represented in the modern social studies curriculum. This is because most social studies teachers receive their training in history, and have little or no background in geography. Geography is typically defined as the physical environment (i.e., landforms and climates) and viewed as the backdrop before which history unfolds. Yet, more often than not, geography intrudes into the drama of historical change, rather than merely providing an arena for history.

Linking Geography and History

What are the links between geography and history? The answer involves three assumptions:

- It is impossible to understand the present without understanding geography.

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- It is impossible to understand the present without understanding the past.
- It is impossible to understand the past without understanding geography.

In other words, the rationale for history (studying the past to understand the present) requires knowing geography: today's geography and the geography of different places at different times in the past.

1.4.10 Tourism and Geography

Tourism geography is the look at of tour and tourism, as an industry and as a social and cultural activity. Tourism geography covers a wide range of interests such as the environmental effect of tourism, the geographies of tourism and enjoyment economies, answering tourism industry and control worries and the sociology of tourism and locations of tourism. Tourism geography is that branch of technological know-how which offers with the observe of travel and its effect on places. Geography is essential to the study of tourism because tourism is geographical in nature. Tourism happens in locations, it involves movement and sports among locations and it's miles an hobby in which each region characteristics and personal self-identities are formed, through the relationships which might be created amongst locations, landscapes, and those. Bodily geography provides the vital background, in opposition to which tourism locations are created and environmental influences and worries are main problems that ought to be considered in managing the development of tourism places.

The mutual contribution that Geography and Tourism can give to each other originates from their respective nature, attitude and research field. In particular, Geography can share with Tourism a wide range of knowledge and interpretations linked to those environments that are indeed valorised by tourism. On the other hand, Tourism is likely to arise interest in unknown cultures and places, on which Geography (alongside with other disciplines) has accumulated over time a huge knowledge. Thus, a good geographer focusing his studies on a particular area can also have a relevant role as a tourist group's tour leader, provided that he can use the language and understand the people's specific interests. On the other hand, an intelligent tourist proves to be a geographer's best companion in field surveys, by combining his curious attitude with the researcher's interests. One might think that this is just imagination, hard to turn into reality. Yet some directions can be provided in order to integrate the tourism experience with the knowledge Geography has to offer.

Tourism geography is **the study of travel and tourism**, as an industry and as a social and cultural activity. Tourism geography is that branch of human geography that deals with the study of travel and its impact on places. Geography is fundamental to the study of tourism, because tourism is geographical in nature.

Geographic Factors that Affect Tourism

- Climate - appropriate for specific type of tourism (e.g. sunny for beaches, snowy for ski resorts etc.)
- Natural environment (e.g. beaches, beautiful scenery, mountains, coral reefs)
- Ecology (e.g. wild animals for safari, rich reef life, jungle)

1.4.11 Political Science and Geography

Positive writers hold that geographical and physical situations substantially affect the character, the national well-being of the human beings, and their political wondering. Aristotle turned into of the opinion that devoid geography neither political nor strategically wisdom may want to flow beforehand. Bodeoun became the primary modern creator who formulated a courting between Political science and Geography. Rousseau also tried to set up a relationship among climatic situations and varieties of government. He contended that heat climates are favourable to despotism or dictatorship, cold climates to barbarism and moderate climates to an awesome coverage. Montesquieu, every other French pupil, additionally laid emphasizes upon the influence of bodily environments at the styles of government and liberty of the humans.

Nevertheless, Buckle excels all. In his history of Civilization, he considered that 'the actions of fellows, and therefore of societies, are determined through the mutual interplay between the thoughts and outside phenomena of human existence'. He emphasized that the actions of the person and societies be influenced by using the physical environments, specifically meals, climate, soil, and the "not unusual aspects of nature." In brief, Buckle rejected the formerly widely wide-spread idea that the unfastened will of man regulates the movements of the man or woman and society. It's far proper that geographical location is a main factor in moldings the fortune of every kingdom, and it significantly impacts its countrywide as well as global rules and political institutions. moreover, to fathom the actual impact of geographical factors on the political life of a kingdom, mainly about its overseas policy, a brand new area of Geopolitics has evolved. In a rustic like India Political institutions (elections) and Geography are just like the faces of a coin and can't exist without every different therefore, it is no overstatement to mention that geographical phenomena always performs a major position in measuring the cause of national regulations and to a few diploma the individual of the political institutions of any vicinity.

The interaction between the physical environment and human beings is described very succinctly by a poet in the following dialogue between "man" and "nature" (God). You created the soil, I created the cup, you created the night, and I created the lamp. You have created wilderness, hilly areas and deserts; I have created flower beds and gardens. Human beings have made their own contributions using natural resources. With the help of science and technology, mankind has moved from the inevitable stage to the free stage.

They put their mark everywhere and created new possibilities in their cooperation with nature.

As a result, we now have humanised nature and naturalised humans, and geography analyses this interaction. With the support of transportation and communication networks, the space was organised. The space was gradually organised as the links (routes) and nodes (settlements of various forms and hierarchies) merged it. Geography is a social science study that investigates the 'spatia':

(i) A few questions concern the identification of patterns of natural and cultural features observed on the earth's surface. What are these inquiries about?

(ii) Some questions concern the distribution of natural and human/cultural traits across the earth's surface. These are the whereabouts concerns. Both of these concerns, when taken together, address the distributional and locational aspects of natural and cultural components. These questions elicited inventoried information on which features were present and where they were located. During the colonial time, it was a fairly common strategy. Until the third question, geography was not considered a scientific discipline.

(iii) The third question concerns the explanation or causal links between characteristics, processes, and phenomena. This feature of geography is linked to the question, "Why?" Geography is a science that deals with space and analyses spatial properties and attributes. It investigates the patterns of distribution, location, and concentration of phenomena over space and analyses them to provide explanations. It analyses the links and interrelationships between occurrences throughout space and provides explanations for these patterns. It also considers the connections and interconnections among the phenomena that occur from the dynamic interaction of humans with their physical surroundings.

Geography as an Integrating Discipline

Topography is an order of combination. It endeavours spatial combination, and history endeavours worldly amalgamation. Its methodology is all encompassing in nature. It perceives the way that the world is an arrangement of interdependencies. The current world is being seen as a worldwide town. The distances have been diminished by better methods for transportation expanding openness. The general media and data innovation have enhanced the information base. Innovation has given better odds of checking regular marvels just as the financial and social boundaries. Topography as a coordinating control has interface with various regular and sociologies. Every one of technical disciplines, regardless of whether regular or social, have one fundamental target, of understanding the truth.

Topography endeavours to understand the relationship of marvels as related in areas of the real world. Each order, worried about logical information is connected with topography as large numbers of their components differ over space. Geology helps in understanding the truth in entirety in its spatial point of view. Geology, subsequently, not just observes the distinctions in the wonders from one spot to another yet incorporates them comprehensively which might be diverse at different spots. A geographer is needed to have an expansive comprehension of the multitude of related fields, to have the option to consistently incorporate them. This joining can be perceived for certain models. Geology impacts verifiable occasions. Spatial distance itself has been a powerful factor to adjust the direction of history of the world. Spatial profundity gave defence to numerous nations, especially somewhat recently. In customary fighting, nations with huge size in region, acquire time at the expense of room. The guard given by maritime territory around the nations of the new world has shielded them from wars being forced on their dirt. On the off chance that we take a gander at the authentic occasions world over, every single one of them can be deciphered topographically.

In India, Himalayas have gone about as incredible hindrances and gave security yet the passes gave courses to the transients and intruders from Central Asia. The ocean coast has supported contact with individuals from East and Southeast Asia, Europe and Africa. Route innovation helped European nations to colonize various nations of Asia and Africa, including India as they got availability through seas. The geological variables have altered the course of history in various pieces of the world.

There is close relationship between Political Science and Geography. Political Science studies about the state. One of the main elements of state is territory. Area of land is studied under Geography. Geography is related to earth, its size, shape, minerals, atmosphere, etc. Geographical conditions definitely affect the Political structure and life of a country. Aristotle and Bodeoun had accepted the close relationship of Political Science and Geography and had explained a close relation between different forms of government and climate. Hot climate is suitable for dictatorship, cold for barbarous and mild climate is suitable for democratic government. Montesque had accepted the maximum effect of geographical conditions on social and political institutions, especially on liberty. Geography affects not only home policy, but foreign policy also. The main reason of increase of power of countries like USA is their natural resources. The global importance and influence of western Asian countries is due to their geographical situation, minerals and mineral oils. Due to its favorable geographical conditions, direct democracy has been successful in Switzerland. Due to the lack of natural resources countries such as Nepal and Bhutan are backward with political viewpoint. Modern political thinkers also accept the effect of geographical conditions on Politics. As a result, a new subject has been developed which studies the political effect of geographical conditions, which is known as Geopolitics.

Check Your Progress

5. Ayurveda believes that entire universe is made up of __________ , __________, __________, __________ and __________.

6. __________ of the earth's surface is the manifestation of the rock structure in different forms

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1.5 SOLAR SYSTEM

The solar system is assumed to be shaped almost 4.6 billion years in the past from the gravitational crumble of a large molecular cloud. It consists of the sun and the objects that orbit it, whether they orbit it without delay or with the aid of orbiting other objects which orbits it immediately of these objects that orbit the solar immediately, the biggest nine are the planets that form the planetary system around it, at the same time as the remainder is appreciably smaller gadgets, such as dwarf planets and Small solar device our bodies (SSSB's) along with comets, and asteroids, and many others. All planets vary size-wise. The planets located in the center of the solar machine are larger in length than the ones on the sides. Geophysicists called this arrangement of planets as 'cigar formed'. The planets of the sun device may be categorised into two types: internal or terrestrial planets and outer planets.

Internal or terrestrial planets: The inner circle consists of 4 planets which includes Mercury, Venus, Earth in conjunction with Mars and Asteroids. Those planets are referred to as internal planets as they lie between the solar and the belt of asteroids and are in the direction of solar. They may be known as terrestrial because of this Earth like, as they may be made up of rocks and metals. These planets are relatively small in size and have relatively higher density. Their velocity of rotation is less. They both have no satellite tv for pc or very much less satellites for instance the Earth has only one and Mars have two satellites.

The outer planets: they may be also referred to as the massive planets or Jovian planets (Jupiter like) – the outer circle consists of 5 planets namely Jupiter, Saturn, Uranus, Neptune and Pluto. Those planets are larger in length and are much less dense. They have thick atmosphere normally composed of helium and hydrogen. Their pace of rotation and variety of satellites are greater as compared to the inner planets.

The 4 smaller internal planets, Venus, Earth, Mars and Mercury also referred to as the terrestrial planets, are often composed of rock and metallic. The four outer planets, called the gasoline giants, are appreciably more big than the terrestrials. The 2 biggest specifically, Jupiter and Saturn, are composed particularly of hydrogen and helium. The two outermost planets, Uranus and Neptune, are composed in large part of substances with particularly high melting factors (as compared with hydrogen and helium), known as ices, consisting of water, ammonia and methane, and are often noted separately as "ice giants". All planets have almost circular orbits that lie inside a nearly flat disc referred to as the ecliptic aircraft.

Majority of the device's mass is within the sun, with maximum of the last mass contained in Jupiter. The sun system also carries areas populated by means of smaller items. The asteroid belt, which lies among Mars and Jupiter,

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in general carries items composed, like the terrestrial planets, of rock and metal. beyond Neptune's orbit lie the Kuiper belt and scattered disc, connected populations of trans-Neptunian gadgets composed frequently of ices. within those populations are numerous dozen to extra than ten thousand objects that may be massive enough to were rounded by their own gravity. Such items are known as dwarf planets.

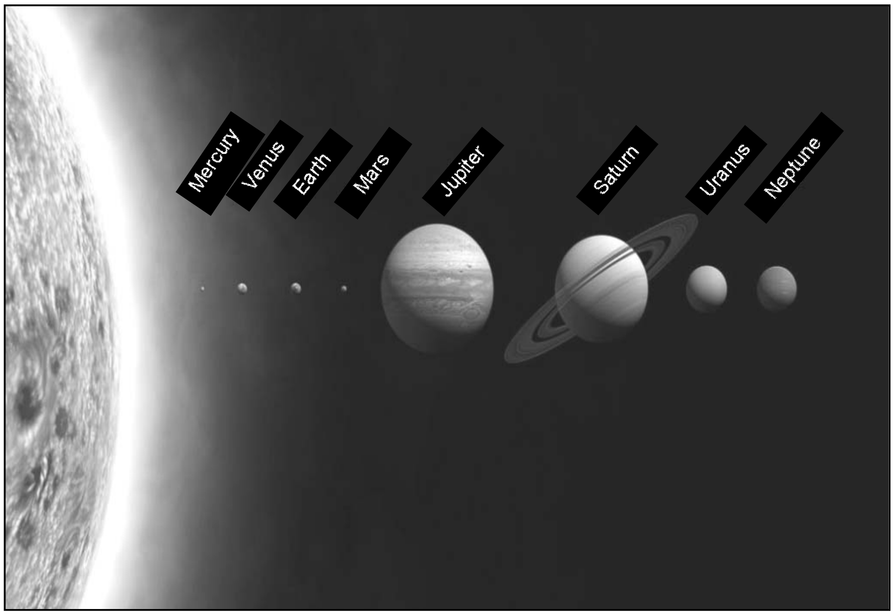

Fig. 1.2: Solar System

Identified dwarf planets include the asteroid Ceres and the trans-Neptunian objects Pluto and Eris. In addition to these two regions, various other small-body populations, including comets, centaurs and interplanetary dust, freely travel between regions. Six of the planets, at least three of the dwarf planets, and many of the smaller bodies are orbited by natural satellites, usually termed "moons" after Earth's satellite Moon. Each of the outer planets is encircled by planetary rings of dust and other small objects.

The solar wind, a flow of plasma from the Sun, creates a bubble in the interstellar medium known as the heliosphere. It extends out to the edge of the scattered disc. The Oort cloud, which is believed to be the source for long-period comets, may also exist at a distance roughly a thousand times further than the heliosphere. The heliopause is the point at which pressure from the solar wind is equal to the opposing pressure of interstellar wind. The Solar System is located within one of the outer arms of the Milky Way, which contains about 200 billion stars.

Check Your Progress

7. Name the inner planets of solar system.
8. Name the outer planets of solar system.

1.6 EARTH AND ITS PLANETARY RELATIONS

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- There are eight planets in our solar system.
- In order of their distance from the sun, they are:
  1. Mercury
  2. Venus
  3. Earth
  4. Mars
  5. Jupiter
  6. Saturn
  7. Uranus and
  8. Neptune

Inner Planets

- These planets are very close to the sun.
- They are made up of rocks.
- Inner planets are:
  - MERCURY – One orbit around sun – 88 days. One spin on axis – 59 days.
  - VENUS – One orbit around the sun – 255 days. One spin on axis – 243 days.
  - EARTH – One orbit around the sun – 365 days. One spin on axis – 1 day. Number of moons – 1.
  - MARS – One orbit around the sun – 687 days. One spin on axis – 1 day, number of moons – 02.

Outer Planets

- Very far from the sun are huge planets made up of gases and liquids:
  - JUPITER – One orbit around the sun – 11 years, 11 months about 12 years. One spin on axis – 9 hours, 56 minutes, number of moons – 16.
  - SATURN – One orbit around sun – 29 years, 5 months. One spin on axis – 10 hours 40 minutes, number of moons – about 18.
  - URANUS – One orbit around the sun – 84 years. One spin around an axis – 17 hours 14 minutes, number of moons – about 17.
  - NEPTUNE – One orbit around the sun – 164 years. One spin on axis-16 hours 7 minutes, number of moons – 8.

1.6.1 Sun-Earth Relationship

The earth receives almost all its energy from the Sun's radiation. Sun also has the most dominating influence on the changing climate of various locations on Earth at different times of the year. The Earth rotates about on a fixed plane that is tilted 23.5° with respect to its vertical axis around the sun. The Earth needs 23 hrs 56 mins to complete one true rotation, or one sidereal period, around the sun. The solar day, on the other hand, is the time needed for a point on earth pointing towards a particular point on the sun to complete one rotation and return to the same point. It is defined as the time taken for the sun to move from the zenith on one day to the zenith of the next day, or from noon today to noon tomorrow. The length of a solar day varies, and thus on the average is calculated to be 24 hrs. In the course of the year, a solar day may differ to as much as 15 mins. There are three reasons for this time difference:

1. The earth's motion around the Sun is not perfect circle but is eccentric;
2. The Sun's apparent motion is not parallel to the celestial equator;
3. The precession of the Earth's axis.

For simplicity, we averaged out that the Earth will complete one rotation every 24 hrs (based on a solar day) and thus moves at a rate of 15° per hour (one full rotation is 360°). Because of this, the sun appears to move proportionately at a constant speed across the sky. The sun thus produces a daily solar arc, which is the apparent path of the sun's motion across the sky. At different latitudes, the sun will travel across the sky at different angles each day.

The rotation of the earth about its axis also causes the day and night phenomenon. The length of the day and night depends on the time of the year and the latitude of the location. For places in the northern hemisphere, the shortest solar day occurs around December 21 (winter solstice) and the longest solar day occurs around June 21 (summer solstice). In theory, during the time of the equinox, the length of the day should be equal to the length of the night.

The average time the earth takes to move around the sun in approximately 365 days. This path that the earth takes to revolve around the sun is called the elliptical path.

Equinoxes and Solstices

Equinoxes happen when the ecliptic (sun's apparent motion across the celestial sphere) and celestial equator intersect. When the sun is moving down from above the celestial equator, crosses it, then moves below it, that point of intersection between the two planes is when the Autumnal Equinox occurs. This usually happens around the 22nd of September. When the Sun moves up from below the celestial equator to above it, the point of intersection between the sun and the celestial equator is when Spring (Vernal) Equinox occurs. It usually happens around the 21st of March. During the equinoxes, all parts of the Earth experiences 12 hours of day and night and that is how equinox gets it name as equinox means equal night. At winter solstice (21st Dec), the North Pole is inclined directly away from the sun. 3 months later, the earth will reach the date point of the March equinox and that the sun's declination will be 0°. 3

months later, the earth will reach the date point of the summer solstice. At this point it will be at declination –23.5°. This cycle will carry on, creating the seasons that we experience on earth.

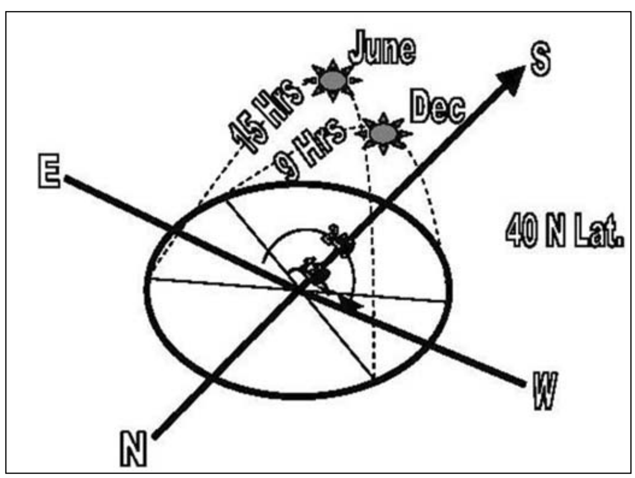
The earth is tilted 23.5°, so is the ecliptic, with respect to the celestial equator, therefore the Sun maximum angular distance from the celestial equator is 23.5°. At the summer solstice which occurs around 21st of June, the North Pole is pointing towards the sun at an angle of 23.5° as shown in figure 1.3. Therefore the apparent declination of the sun is positive 23.5° with respect to the celestial equator. At the Winter solstice which occurs around 21st December, the North Pole is pointing away from the sun at an angle of 23.5°. Therefore the apparent declination of the sun is negative 23.5° with respect to the celestial equator.

Change of Seasons

Seasons are caused by the Earth axis which is tilted by 23.5° with respect to the ecliptic and due to the fact that the axis is always pointed to the same direction. When the northern axis is pointing to the direction of the Sun, it will be winter in the southern hemisphere and summer in the northern hemisphere. Northern hemisphere will experience summer because the Sun's ray reached that part of the surface directly and more concentrated hence enabling that area to heat up more quickly. The southern hemisphere will receive the same amount of light ray at a more glancing angle, hence spreading out the light ray therefore is less concentrated and colder. The converse holds true when the Earth southern axis is pointing towards the Sun.

Sun's Apparent Movement

From the heliocentric point of view, the Earth rotates and revolves around the sun in a counterclockwise direction. However, when we look at the Sun on earth, it appears to be moving in a clockwise direction. This phenomenon is known as the apparent motion of the sun.



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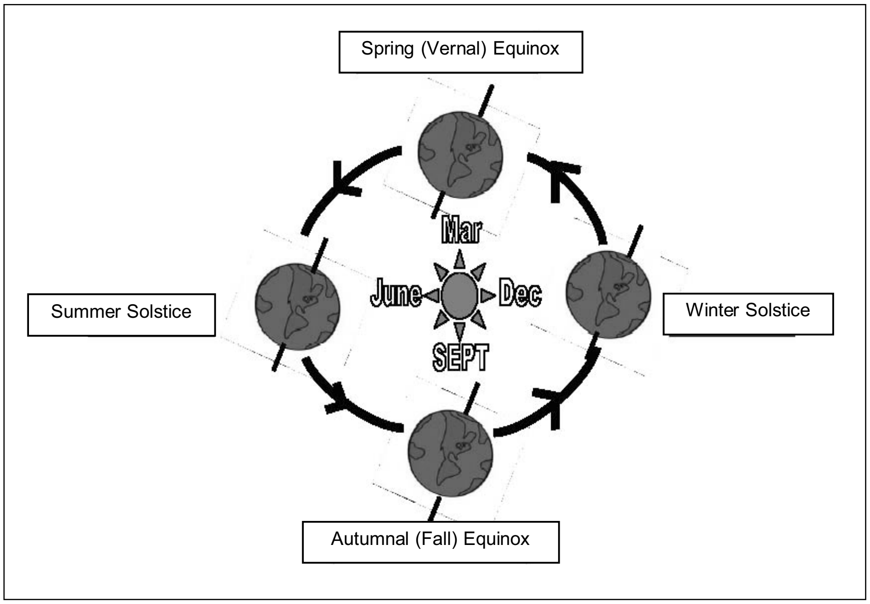

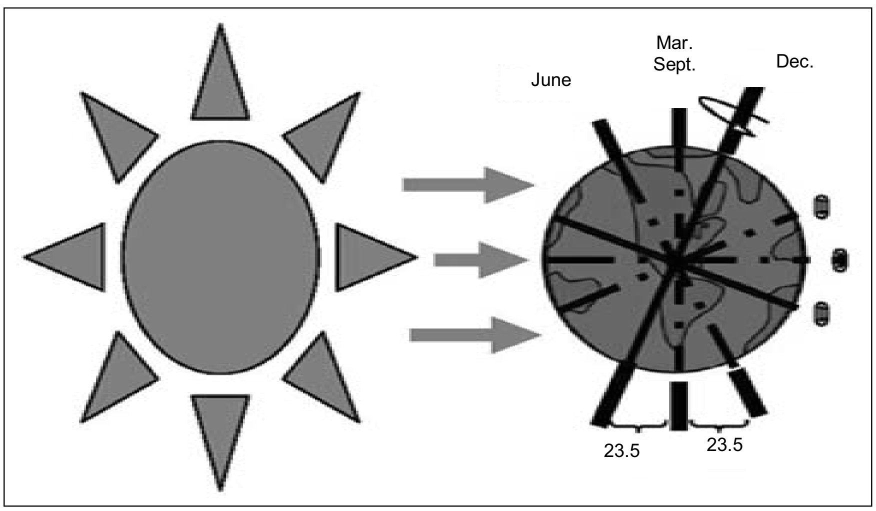

Fig. 1.3: Sun's Apparent Movement

1.6.2 Relationship of Earth and Mercury

The diameter of Mercury is 4,879 km, which is approximately 38% the diameter of Earth. In other words, if **you put three Mercurys side by side**, they would be a little larger than the Earth from end to end. In other words, you could fit Mercury inside Earth 18 times over and still have a bit of room to spare. By using a more accurate method for estimating the average distance between two orbiting bodies, we find that this distance is proportional to the relative radius of the inner orbit. In other words, Mercury is closer to Earth, on average, than Venus is **because it orbits the Sun more closely**. Earth's magnetosphere is strong enough to protect us from the solar wind's radiation, but Mercury's magnetic field is **comparatively weaker**. "From our magnetic measurements, we can tell that Mercury is managing to stand up to a lot of the solar wind and protect the surface of the planet, at least in some spots."

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1.6.3 Relationship of Earth and Venus

Venus and Earth are **planets in our solar system**, with Venus being the second closest planet and the Earth being the third closest to the sun. The mass of the earth is about 1.23 times the mass of Venus. Being closer to the sun, Venus is a lot hotter than the Earth. Venus is not the planet closest to the sun, its dense atmosphere traps heat in a runaway version of the greenhouse effect that warms Earth. Venus is sometimes called Earth's twin because Venus and Earth are almost the same size, have about the same mass (they weigh about the same), and have a very similar composition (are made of the same material). They are also neighboring planets. However, Venus and Earth are also very different. Venus has an atmosphere that is about 100 times thicker than Earth's and has surface temperatures that are extremely hot. Venus does not have life or water oceans like Earth does. Venus also rotates backwards compared to Earth and the other planets.

1.6.4 Relationship of Earth and Mars

Mars is only about one-half the diameter of Earth, but **both planets have roughly the same amount of dry land surface area**. This is because over two-thirds of the Earth's surface is covered by oceans, whereas the present surface of Mars has no liquid water.

Earth and Mars are similar when it comes to their basic makeups, given that they are both terrestrial planets. This means that both are differentiated between a dense metallic core and an overlying mantle and crust composed of less dense materials (like silicate rock). However, Earth's density is higher than that of Mars – 5.514 g/cm^3 compared to 3.93 g/cm^3 (or 0.71 Earths) – which indicates that Mars' core region contains more lighter elements than Earth's.

Earth's core region is made up of a solid inner core that has a radius of about 1,220 km and a liquid outer core that extends to a radius of about 3,400 km. Both the inner and outer cores are composed of iron and nickel, with trace amounts of lighter elements, and together, they add to a radius that is as large as Mars itself. Current models of Mars' interior suggest that its core region is roughly 1,794 ± 65 kilometers (1,115 ± 40 mi) in radius, and is composed primarily of iron and nickel with about 16-17% sulfur.

Both planets have a silicate mantle surrounding their cores and a surface crust of solid material. Earth's mantle – consisting of an upper mantle of slightly viscous material and a lower mantle that is more solid – is roughly 2,890 km (1,790 mi) thick and is composed of silicate rocks that are rich in iron and magnesium. The Earth's crust is on average 40 km (25 mi) thick, and is composed of rocks that are rich in iron and magnesium (i.e., igneous rocks) and granite (rich in sodium, potassium, and aluminum).

Comparatively, Mars' mantle is quite thin, measuring some 1,300 to 1,800 kilometers (800 – 1,100 mi) in thickness. Like Earth, this mantle is believed to be composed of silicate rock that are rich in minerals compared to the crust, and to be partially viscous (resulting in convection currents which shaped the surface). The crust, meanwhile, averages about 50 km (31 mi) in thickness, with a maximum of 125 km (78 mi). This makes it about three times as thick as Earth's crust, relative to the sizes of the two planets.

Ergo, the two planets are similar in composition, owing to their common status as terrestrial planets. And while they are both differentiated between a metallic core and layers of less dense material, there is some variance in terms of how proportionately thick their respective layers are.

1.6.5 Relationship of Earth and Jupiter

Astronomers believe that one reason Earth is habitable is that **the gravity of Jupiter protects it from long-period comets**. … The big planet's gravity is so strong that it can even trap dangerous comets and asteroids inside its orbital space. And that's why our solar system today has an asteroid belt.

In other planetary systems, we see evidence that giant planets like Jupiter can migrate from where they originally formed, spiraling inward to an orbit closer to their stars. When these giants wander toward their stars, any small, rocky planets that stand in the way can be swallowed up or, due to the giants' strong gravity, flung out of the star system altogether.

But if Jupiter-like planets remain distant from their stars, they can serve as the gatekeepers to their planetary systems. They protect their fellow planets on inner orbits, allowing them to maintain nearly circular orbits that provide stable climates over extended periods of time. Long, elliptical orbits cause extreme climate shifts for an Earth-like planet, possibly preventing any sort of sustained life from evolving.

In our solar system, Jupiter can eat up any asteroid or comet that ventures near, earning the nickname "vacuum cleaner of the solar system". The asteroid belt in between the orbits of Mars and Jupiter is another example of the gas giant's influence. Its gravity likely prevented the asteroids from combining into a planet.

Jupiter can also radically alter the orbits of small bodies that stray close, hurling them on long orbits that take hundreds or even thousands of years for those bodies to return. We think this is how comets got the extreme orbits that carry them to the far-flung reaches of the solar system. They spend most of their time out there, forming a cometary collection called the Oort cloud, which may extend as far as halfway to the nearest star.

While Jupiter often protects Earth and the other inner planets by deflecting comets and asteroids, sometimes it sends objects on a collision course straight toward the inner planets. Earlier in the solar system's history, when there were more objects flying around, the increased amount of impacts would have brought to Earth water and other ingredients for life. Of course, other collisions would have been disastrous, such as the impact that likely led to the extinction of the dinosaurs 65 million years ago.

1.6.6 Relationship of Earth and Saturn

Earth's comfortable temperatures may be thanks to Saturn's good behaviour. If the ringed giant's orbit had been slightly different, Earth's orbit could have been wildly elongated, like that of a long-period comet.

Our solar system is a tidy sort of place: planetary orbits here tend to be circular and lie in the same plane, unlike the highly eccentric orbits of many exoplanets. Elke Pilat-Lohinger of the University of Vienna, Austria, was interested in the idea that the combined influence of Jupiter and Saturn – the solar system's heavyweights – could have shaped other planets' orbits. She used computer models to study how changing the orbits of these two giant planets might affect the Earth.

Earth's orbit is so nearly circular that its distance from the sun only varies between 147 and 152 million kilometres, or around 2 per cent about the average. Moving Saturn's orbit just 10 percent closer in would disrupt that by creating a resonance – essentially a periodic tug – that would stretch out the Earth's orbit by tens of millions of kilometres. That would result in the Earth spending part of each year outside the habitable zone, the ring around the sun where temperatures are right for liquid water.

Tilting Saturn's orbit would also stretch out Earth's orbit. According to a simple model that did not include other inner planets, the greater the tilt, the more the elongation increased. Adding Venus and Mars to the model stabilised the orbits of all three planets, but the elongation nonetheless rose as Saturn's orbit got more tilted. Pilat-Lohinger says a 20-degree tilt would bring the innermost part of Earth's orbit closer to the sun than Venus.

1.6.7 Relationship of Earth and Uranus

How is Uranus related to Earth?

With a radius of 15,759.2 miles (25,362 kilometers), **Uranus is 4 times wider than Earth**. From an average distance of 1.8 billion miles (2.9 billion kilometers), Uranus is 19.8 astronomical units away from the Sun. One astronomical unit (abbreviated as AU), is the distance from the Sun to Earth. Gravity on Uranus is only **about 90 percent that of Earth**; if you weigh 100 lbs. at home, you would only weigh 91 lbs.This is because **Uranus is made up of gases and is not solid like Earth**.

Uranus is **an ice giant**. Most of its mass is a hot, dense fluid of "icy" materials – water, methane and ammonia – above a small rocky core. If you tried to land a spacecraft on Uranus, it would just **sink down through the upper atmosphere of hydrogen and helium**, and into the liquid icy center. And this is why the surface of Uranus has its color.

1.6.8 Relationship of Earth and Neptune

Although they share a solar system, Earth and Neptune are vastly different. While Earth supports life, Neptune is a mysterious planet on the outer edges of the solar system. Comparing the two planets highlights their unique characteristics.

Neptune is nearly four times larger than Earth, according to the National Aeronautics and Space Administration (NASA). Neptune's diameter is 30,775 miles across the equator, while Earth's diameter is only 8,000 miles.

Neither Earth nor Neptune orbit the sun in a perfect circle; their orbits are more oval-shaped, or elliptical. While Earth circles the sun once a year, Neptune takes 165 Earth years to complete its orbit.

Rocks and water cover the surface of the Earth, giving humans and animals a firm footing. Meanwhile, Neptune has no solid surface. Like Earth, Neptune's surface is composed of silicates and water, as well as hydrogen and helium.

NASA states that clouds on Neptune whip around the planet at a rate of up to 700 miles per hour. The fastest winds recorded on Earth were 231 miles per hour in 1934, according to Mount Washington Observatory.

Earth has only one moon, but Neptune has 11. Neptune also has three rings - a trait Earth lacks.

1.6.9 Relationship of Earth and Moon

The Moon is Earth's only natural satellite. At about one-quarter, the diameter of Earth (comparable to the width of Australia), it is the largest natural satellite in the Solar System relative to the size of a major planet, the fifth largest satellite in the Solar System overall, and is larger than any known dwarf planet. The Moon is a planetary-mass object that formed a differentiated rocky body, making it a satellite planet under geophysical definitions of the term. It lacks any significant atmosphere, hydrosphere, or magnetic field. Its surface gravity is about one-sixth of Earth's (0.1654 g); Jupiter's moon Io is the only satellite in the Solar System known to have a higher surface gravity and density.

Orbiting Earth at an average distance of 384,400 km (238,900 mi), or about 30 times Earth's diameter, its gravitational influence slightly lengthens Earth's day and is the main driver of Earth's tides. The Moon's orbit around Earth has a sidereal period of 27.3 days. During each synodic period of 29.5 days, the amount of visible surface illuminated by the Sun varies from none up to 100%, resulting in lunar phases that form the basis for the months of a lunar calendar. The Moon is tidally locked to Earth, which means that the length of a full rotation of the Moon on its own axis causes its same side (the near side) to always face Earth, and the somewhat longer lunar day is the same as the synodic period. That said, 59% of the total lunar surface can be seen from Earth through shifts in perspective due to libration.

The most widely accepted origin explanation posits that the Moon formed about 4.51 billion years ago, not long after Earth, out of the debris from a giant impact between the planet and a hypothesized Mars-sized body called Theia. It then receded to a wider orbit because of tidal interaction with the Earth. The near side of the Moon is marked by dark volcanic maria ("seas"), which

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fill the spaces between bright ancient crustal highlands and prominent impact craters. Most of the large impact basins and mare surfaces were in place by the end of the Imbrian period, some three billion years ago. The lunar surface is relatively non-reflective, with a reflectance just slightly brighter than that of worn asphalt. However, because it has a large angular diameter, the full moon is the brightest celestial object in the night sky. The Moon's apparent size is nearly the same as that of the Sun, allowing it to cover the Sun almost completely during a total solar eclipse.

Both the Moon's prominence in the earthly sky and its regular cycle of phases have provided cultural references and influences for human societies throughout history. Such influences can be found in language, calendar systems, art, and mythology. The first artificial object to reach the Moon was the Soviet Union's Luna 2 uncrewed spacecraft in 1959; this was followed by the first successful soft landing by Luna 9 in 1966. The only human lunar missions to date have been those of the United States' Apollo program, which landed twelve men on the surface between 1969 and 1972. These and later uncrewed missions returned lunar rocks that have been used to develop a detailed geological understanding of the Moon's origins, internal structure, and subsequent history.

The Moon's Influence on Us

Turbulent Beginnings

Throughout this long history, the Moon has been Earth's companion in space. They shaped each other through the invisible connection of their gravitational pull. The Moon's gravitational pull is relatively weak compared to Earth's. (Apollo astronauts were able to leap across the lunar surface because of this weaker pull.) Yet, the Moon's gravitational pull is responsible for Earth's current length of day, stable seasons, and tides.

Length of Day: Early Earth was spinning at a much faster rate: according to computer models, Earth had a six-hour day 4.5 billion years ago. Since then, with the help of our Moon, Earth has been slowing down and our days have been getting longer. Evidence includes growth rings in fossil corals and shells and ancient photosynthetic bacteria layers, called stromatolites. Stromatolites living 850 million years ago record a day length that was about 21 hours long. Fossil corals from 400 million years were living on an Earth with 22-hour days.

Over time, the Moon's gravitational pull on the Earth "stole" some of Earth's spin energy, launching the Moon slowly into higher and higher orbits. [The Apollo laser experiments confirmed that the Moon is moving away at the rate of two inches (five centimeters) per year.] The distance between Earth and Moon increased and the spins of both decreased. Today, Earth spins once every 24 hours.

Today's more distant Moon takes over 27 days to complete one full orbit around Earth. Just like Earth, our Moon rotates on its own axis and experiences daylight and dark cycles. Our Moon's day and night cycles are longer than

Earth's — the Moon spins on its axis once every 27.3 days. The Moon takes the same amount of time to spin around once as it does to orbit completely around Earth. This means that Earth observers always see the same side of the Moon (the nearside). The side we do not see from Earth (the farside) has been mapped during lunar missions.

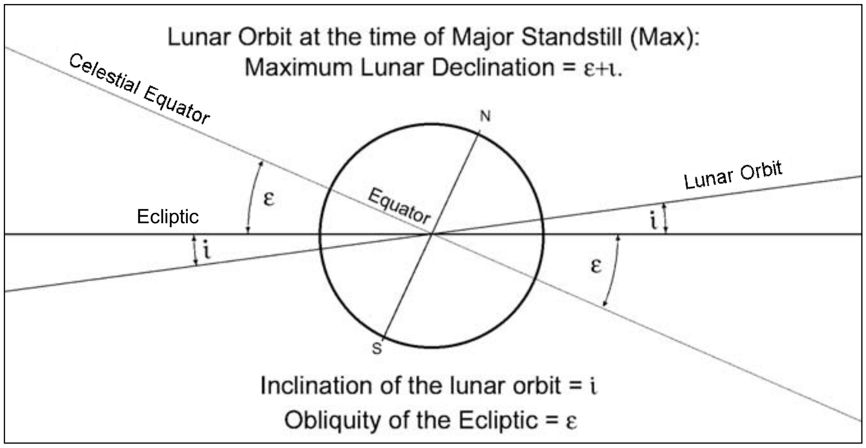

Fig. 1.4: Relationship of Earth and Moon

Stable Seasons: The giant impact that formed the Moon may have tipped the Earth a little and contributed to the 23.5° tilt of our North Pole away from "straight up." This tilt gives us our seasons.

The very presence of the Moon helps to keep this tilt relatively stable The Moon's gravitational pull acts like training wheels for Earth on its journey around the Sun. It keeps Earth's axis pointed at a consistent angle. Without the Moon, the Earth's stately progression through spring, summer, fall, and winter would have fluctuated widely over eons.

Tides: The Moon's gravitational pull tugs on Earth — especially the portion that is nearest to the Moon. Earth's crust rises slightly (several centimeters) due to this force. Ponds and lakes — such as the Great Lakes — experience small tides, as well. Earth's oceans (and atmosphere), however, are free to lift many feet in response this tug. As the Moon orbits the Earth, it drags along behind it a "bulge" in the oceans. On the side of Earth opposite the Moon, the gravitational pull is less than on any other part of the Earth and the oceans are "left behind" in another bulge.

The Moon's contribution to Earth's tides is significant because it is so close. The Sun, of course, also exerts a powerful gravitational pull on Earth — that's what keeps Earth in a steady orbit. Earth's oceans are pulled toward the Sun, but the difference between Sun's gravitational pull on Earth's near side and far side is much less; the Sun's gravity contributes only about a third of the tides' height.

Early in Earth's history, the Moon was even closer to Earth. Billions of years ago, the Moon was 10 times closer and tides were 1000 times higher. Scientists believe that these extreme tides occurred once every three hours because the Earth was spinning more rapidly. The tides eroded the coastal areas,

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adding minerals to the oceans. These minerals may have been essential for life to evolve as quickly as it did.

Shining Light: Just like the planets, our Moon does not produce its own light. It "shines" because it reflects the Sun's light. While careful statistical studies have shown no correlation between the full Moon and strange behavior, the full Moon's light does make it easier for humans and other animals to see — and be seen. Studies have documented changes in the success rates of predators and foraging patterns of prey animals due to this added nighttime illumination. Corals time their mating events by the light of the Moon. Most other animal behaviors relating to the Moon are because the tides change the coastal environment.

The Size of It: Despite the exaggerated size of the Moon in movies, books, and art, the Moon's apparent size is relatively small in the sky. Nearly everyone has experienced the illusion that the Moon's appearance is magnified on the horizon. However, it takes up about the same number of degrees in the sky when it is near the horizon and straight overhead.

Changing Shape: The changing appearance of the Moon has inspired stories, songs, poems and words (e.g. "month"). It is used to keep time (e.g. lunar calendar). Our Moon's shape doesn't really change; the "amount" of Moon that we see as we look from Earth changes in a cycle that repeats about once a month (29.5 days).

Nearby Stepping Stone to the Cosmos: The Moon has sparked revolutions in scientific thought. Galileo's telescopic view of the moon's rough surface challenged the long-held belief of the heavens as the realm of perfection. The Moon rocks brought back by the Apollo astronauts unlocked the origin of craters not only on the Moon, but on Mercury, Venus, and Mars from impacts rather than volcanos. They also overturned existing hypotheses of the Moon's formation and led to the Giant Impact hypothesis as the predominant explanation of its beginnings.

Many astronomers, geologists, planetary scientists, engineers, and astronauts owe their productive careers to childhood memories of the Moon. What other great personal, cultural, and scientific achievements will the Moon inspire next?

How would Earth and life itself be different without the Moon?

	On Companion Earth	On Moonless Earth	Implication
Length of day	24 hours	8 hours	Life has altered patterns of waking, sleeping, mating, and hunger. Winds blow at 100 mph due to Earth's faster rotation
Seasons	Earth's large Moon stabilizes the variation of its tilt so that it "wobbles" only about	Gravitational pull of the giant planets causes Earth's tilt to vary wildly over the	Only the hardiest bacteria or other simple life forms can endure the

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	3° over a cycle of about 41,000 years	eons between 0 and 80°	drastic climate changes
Tides	Governed by Moon's gravitational pull	Caused only by the Sun and rise only about 1/3 current height	Life takes longer to evolve without the benefit of minerals mixed into the global ocean by tides
Phases	The Moon changes its appearance in the sky through a predictable pattern	Venus and Mercury undergo phases, but these are not discovered before the invention of a telescope	Science advances more slowly without the repeating pattern of lunar phases to inspire astronomers to explain the phenomenon scientifically
Moonlight	Sunlight reflects off of the lunar surface, making the Moon visible in the sky	The Sun, other stars, and planets are the only celestial objects in the sky	Some unique animals behaviors (e.g. coral spawning events, moon wrasse foraging, salmon biological changes) do not occur or are tied to some other external stimulus
Astronauts	Astronauts walk on the Moon during the Apollo missions, 1969-72	There are no objects within the technological reach of current rockets and radiation shielding that are appropriate for manned explorations	Humans are not able to visit another world so early in their technological lifetime and may not be inspired to do so without a nearby goal

Check Your Progress

9. __________, __________, __________ and __________ are inner planets of solar system.
10. Mars takes __________ days to revolve round the sun.

1.7 THE ORIGIN OF THE EARTH

Earth, along side the opposite planets, is assumed to were born 4.5 billion years ago as a solidified cloud of dust and gases left over from the introduction of the sun. For possibly 500 million years, the indoors of Earth stayed solid and relatively cool, perhaps 2,000° F. the principle ingredients, in keeping with the high-quality available proof, have been iron and silicates, with small amounts of other elements, a number of them radioactive. As thousands and thousands of years exceeded, electricity launched via radioactive decay — primarily of uranium, thorium, and potassium — steadily heated Earth, melting a number of its components. The iron melted before the silicates, and, being heavier, sank closer to the center. This compelled up the silicates that it determined there.

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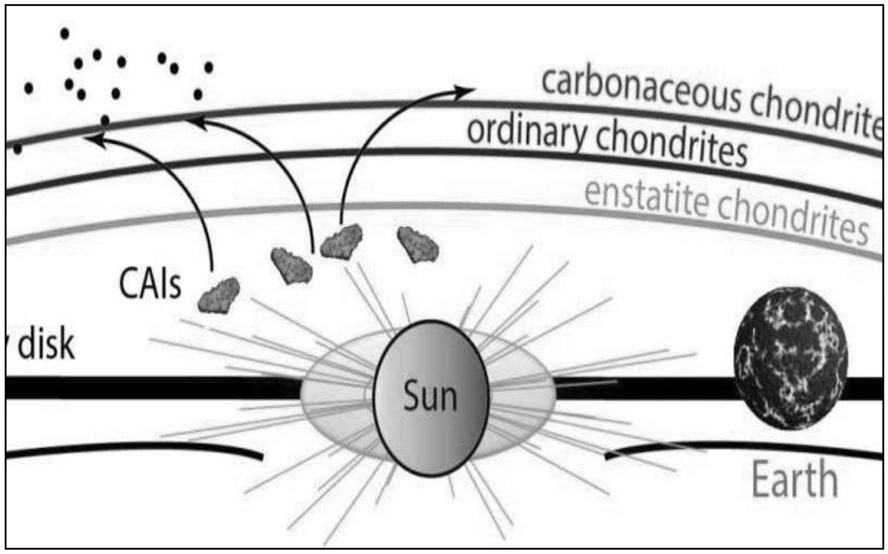

Fig. 1.5: Origin of the Earth

After a few years, the iron reached the middle, almost 4000 mi deep, and began to build up. No eyes had been round at that time to view the turmoil that ought to have taken area on the face of Earth — big heaves and bubblings on the floor, exploding volcanoes, and flowing lava masking everything in sight. Eventually, the iron within the center accumulated because the middle. round it, a skinny but fairly stable crust of solid rock formed as Earth cooled. Depressions inside the crust have been natural basins in which water, rising from the indoors of the planet thru volcanoes and fissures, collected to form the oceans. Slowly, Earth acquired its present appearance.

Our solar device is having a star that we call the sun and the planets which might be Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. It also includes the satellites of the planets, a large wide variety of comets, asteroids, and meteoroids. The solar is the richest supply of electromagnetic power which is in the shape of warmth and light.

The red dwarf celebrity i.e., Proxima Centauri is the Sun's nearest stellar neighbour. We are able to see the entire solar system, collectively with the nearby stars in a clear night time. Our own home galaxy is a spiral disk of 2 hundred billion stars and referred to as Milky Way.

This Milky Way has two small galaxies orbiting it close by, which are visible from the southern hemisphere. Those two are referred to as the Large Magellanic Cloud and the Small Magellanic Cloud. The nearest huge galaxy to it is the Andromeda Galaxy. This galaxy is in a spiral shape, just like the Milky Way but is four times as massive and is 2 million light-years away. Our galaxy is one of the billions of galaxies acknowledged.

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The solar system contains 8 planets and one planetoid, or dwarf planet that is Pluto. In this solar system, the internal four planets are Mercury, Venus, Earth, and Mars. Those are also known as terrestrial planets. Those are smaller, strong and just like Earth.

The outer four planets i.e., Jupiter, Saturn, Uranus, and Neptune are termed as Jovian planets. Those are huge, normally gaseous and are similar to Jupiter. Pluto changed into declassified as a planet in 2006, as it is extra strongly akin to an oversized comet than anything else.

The Earth is our very own planet and one of the three nearest planets to the sun. The shape of the earth is referred to as geoid due to the fact that it is slightly flattened at the poles. Positive critical situations which might be necessary to support lifestyles exists best on the earth. If we looked from outer space, the earth seems blue.

That is because, a two-third floor of the earth, is blanketed with water. that is the cause that Earth is likewise referred to as the blue planet. Its diameter is 7,926 miles i.e., 12,760 km with orbit duration of 365.24 days.

The third planet from the sun i.e. Earth is a water world. It's the simplest globe regarded to harbor life. The atmosphere at Earth ecosystem is rich in existence - maintaining nitrogen and oxygen. Its floor rotates approximately its axis at 467 meters in keeping with 2d. The planet does revolve across the sun at more than 18 miles consistent with second.

Our Earth is positioned within the Virgo Supercluster of galaxies. A supercluster is a group of galaxies which can be held together by gravity. Inside this supercluster, we are dwelling in a smaller group of galaxies known as the neighbourhood institution. Earth is inside the 2nd-biggest galaxy of the nearby group that's Milky Way. Earth is placed in one of the spiral palms of the Milky Way which is called the Orion Arm.

Check Your Progress

11. Milky Way has two galaxies __________ and _________.
12. __________ is nearest star to sun.

1.8 AGE OF THE EARTH

Primarily based on available statistics, the planets completed their formation technique very soon after the oldest components of primitive meteorites condensed out of the solar nebula, some 4.54 billion years ago (±0.5 billion years; Taylor and McLennan 1985; Windley 1995; Condie 1997). Earth grew in size as increasingly more planetesimals joined collectively. Through this method, severe warmth become generated inside the planet; short-lived radioactive factors created in the course of the earth's formation were decaying, and giving off greater electricity. It's miles believed that at one point of time, our earth changed into so warm that it may had been totally molten these hot conditions allowed the heavier factors which include iron and nickel to sink

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into the earth's middle and eventually formed its core. The lighter factors remained inside the Mantle and a number of them fashioned the earth's rigid Crust (Clarke and Washington, 1924). As the planet became cooling off, numerous gases had been launched from the earth's indoors, which include water vapour.

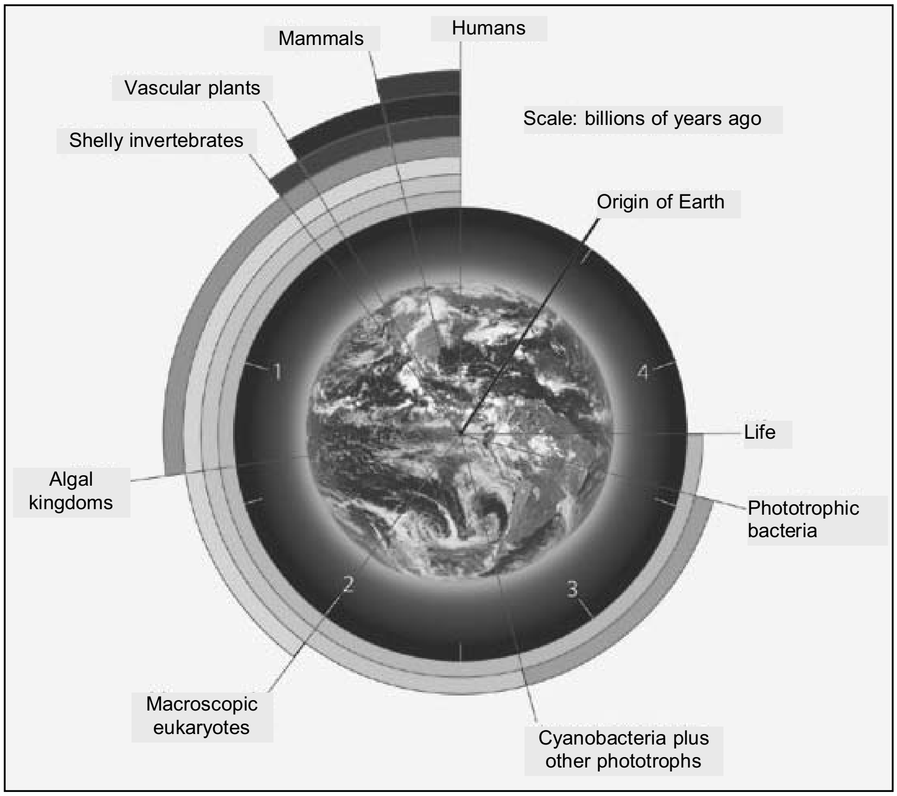

Fig. 1.6: Age of the Earth

They enshrouded the planet in a dense cocoon, as a consequence, forming the primordial atmosphere. It contained little, if any, oxygen. while temperatures cooled enough, water vapour rained out of the atmosphere and the oceans were formed, lamentably, to this point, scientists have now not been able to discover a manner to decide the exact age of the earth immediately from its rocks as oldest rocks had been recycled and destroyed with the aid of the method of Plate Tectonics. If there are any of these primordial rocks left in their original state, they have not now been determined. Nevertheless, scientists were able to decide the likely age of the solar system and also were capable of calculating the age for earth with the aid of assuming that earth and the rest of the solid bodies inside the solar system formed at the same time and are, consequently, of the equal age. The generally commonplace age for the earth and the rest of the solar system is ready 4.54 billion years (±0.5 billion years) (Wilde et al., 2001). Thousands of meteorites, which can be fragments of asteroids that fall to earth, perhaps offer the best estimate of a while for the period of formation of our solar system. The distribution of impact craters that had been because of the fall of meteorites internationally, number around one hundred forty (those range in size from 1 to 200 km across).

Of these, ages of more than 70 meteorites had been measured using radiometric-dating strategies and results display that the meteorites, and through extension, the solar system, shaped between 4.53 and 4.58 billion years in the past. The best age for the earth comes not from dating individual rocks but by considering that the earth and meteorites are part of the equal evolving system wherein the isotopic composition of lead, mainly the ratio of lead-207 to lead-206 adjustments over time thanks to the decay of radioactive uranium-235 and uranium-238, respectively.

Scientists have used this technique to determine the time required for the isotopes within the earth's oldest lead ores, to adapt from its primordial composition, as measured in Uranium-free phases of Iron meteorites, to its compositions at the time those lead ores separated from their mantle reservoirs. Those calculations result in an age for the earth and meteorites, and hence, of the sun device to be 4.54 billion years with an uncertainty of 1%. This age, consequently, represents the closing time that the lead isotopes were homogeneous at some point of the inner solar system and the time that lead and uranium had been incorporated into stable our bodies of the solar system. for that reason, as of these days, the age of the earth is 4.54 billion years (4.54 10^9 years ± 0.5 billion years) and is likewise constant with the ages of the oldest known terrestrial and lunar samples.

In the world, the vintage rocks, exceeding 3.5 billion years, are observed on all continents (Bowring and Williams, 1999). However, a latest observe discovered that the tiny crystals of mineral zircon (detrital) from the Yilgarn Block, Western Australia (Wilde et al., 2001) gave an age upwards of 4.4 billion years (the decay of radioactive Uranium was used for calculating this age). Preceding oldest information had been dated at 4.03 billion years from the Acasta Gneisses in NW Canada near the awesome Slave Lake (Bowring and Williams, 1999). An exciting feature of these historic lake rocks is that they may be no longer from any form of "primordial crust" but are lava flows and sediments that were deposited in shallow waters (including detrital zircon), an illustration that earth's records began nicely earlier than these rocks have been really deposited. Therefore, the existence of liquid water at 4.4 billion years ago has fundamental implications for the evolution of life on this planet. Contextually, microfossils data do also date back to 3.5 billion years.

Check Your Progress

13. __________ > __________ > __________ > __________ > __________ is the descending order of time scale.
14. __________, __________ and __________ are three recognized eras.

1.9 GEOLOGICAL TIME SCALE

Geological time scale is a system of chronological size of time, and it is also referred through Earth scientists to describe the timing and the relationships

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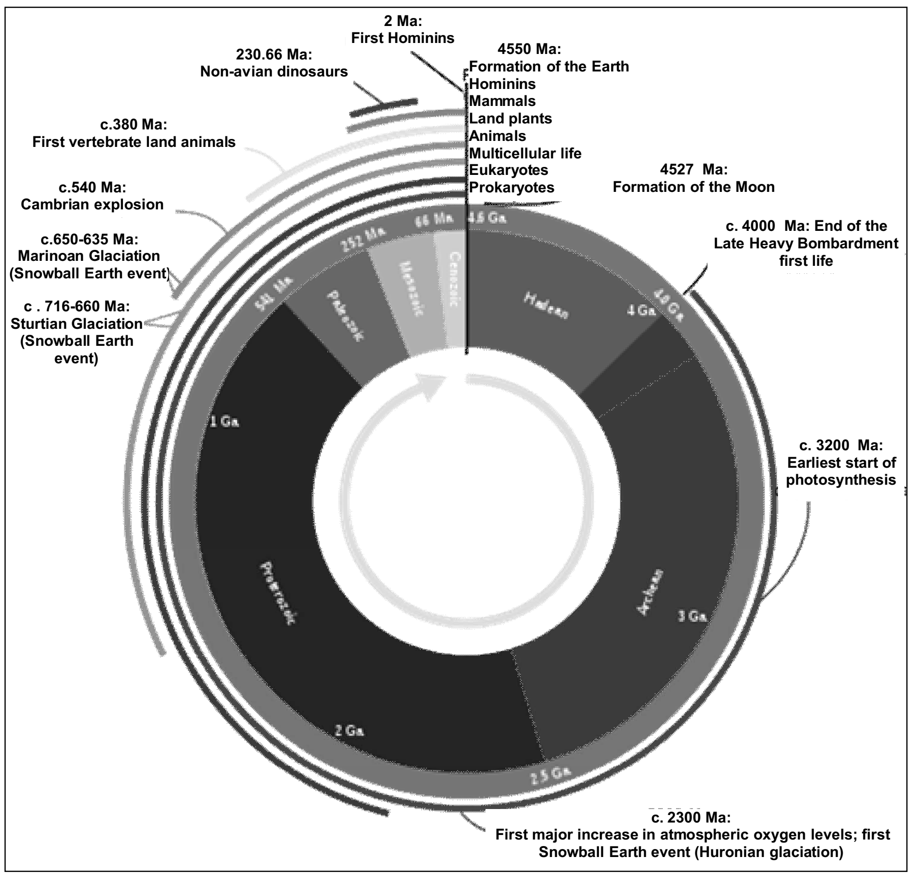
among events that have passed off at some point of Earth's records since its inception. There are few particular phrases used in this time scale which need to be defined for higher understanding of the time scale.

The critical factor is the division of geological time scale. The names used (e.g., Cambrian) come from specific localities (normally in Europe) in which mainly properly uncovered rocks of that unique location are well exposed. It's also stated that there are dates assigned to every location. These are absolute dates based totally upon radiometric courting of substances inside positive rocks (we get into this within the next lecture). The dates are often changed if higher radiometric analyses are evolved. But the divisions themselves are constant. They constitute most important modifications in the fossil report. As an instance, the boundary among the Mesozoic and Cenozoic Eras (65 Ma) represents a major extinction event (the dinosaurs all died off). The boundary among the Paleozoic and Mesozoic (251 Ma) represents an excellent bigger extinction. Radiometric dating places an absolute date on the geological divisions, but the divisions are in large part paleontological in nature.



Source: commons.wikimedia.com

Fig. 1.7: Geological Time Scale

Geological time is broken up into attainable bits. The largest divisions are Eons. To nineteenth century geologists, the rocks may be broken up into two divisions: (1) those containing seen symptoms of life (e.g., fossils) and people without lifestyles (e.g., pre-fossils). The fossils bearing rocks were

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categorised as Phanerozoic ("visible existence; 542 Million years to the prevailing) and people thought to lack fossils had been classified as Proterozoic (before life; as much as 544 Million years). A few Proterozoic rocks did in truth contain primitive existence (bacteria and in a while gentle-tissued organisms), however no longer beasties that produced skeletal stays. The Proterozoic is now described as a specific interval of time (2.5 billion years to 542 million years). Extra Eras were introduced to the Geological Time Scale; The Archean (4.0 to 2.5 billion years) and the Hadean (4.6 to 4.0 billion years). You'll analyze greater about these in GY 112. Don't worry about them now.

Eon	Era	Period		Epoch	m.y.
Phanerozoic	Cenozoic	Quaternary		Holocene	
				Pleistocene	1.5
		Neogene		Pliocene	
				Miocene	23
		Paleogene		Oligocene	
				Eocene	
				Paleocene	65
	Mesozoic	Cretaceous			
		Jurassic			
		Triassic			250
	Paleozoic	Permian			
		Carboniferous	Pennsylvanian		
			Mississippian		
		Devonian			
		Silurian			
		Ordovician			
		Cambrian			540
Precambrian	Proterozoic				2500
	Archean				3800
	Hadean				4600

Fig. 1.8: Geological Time Scale

The usage of fossils for dating rocks changed into of path constrained to those rocks which contained fossils (i.e., the Phanerozoic). in view that there have been lots of different fossils that got here and went, it appeared logical to break the Phanerozoic up into smaller divisions referred to as Eras. 3 Eras are identified:

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- Cenozoic (zero to 65 million years BP)
- Mesozoic (sixty five to 251 million years BP)
- Paleozoic (251 to 542 million years BP*)*

The Eras are in addition subdivided into smaller durations and the intervals can be further subdivided into Epochs. The nice way of illustrating that is to expose you the way these subdivisions work for the Phanerozoic. That occurs inside the subsequent and ultimate section for today.

- Eon > era > period > Epoch > Age is the descending order of time scale used to describe the geological time history.
- The ongoing Epoch is Holocene, it's also known as the age of human beings.

Check Your Progress

15. What is the other name for human being?
16. What is the age of earth?

1.10 IMPORTANT HYPOTHESIS RELATED TO ORIGIN OF EARTH

100 years prior a wonderful gathering of men was talking about here the incredible issue of the historical backdrop of the earth. James Hutton, after numerous long stretches of movement and reflection, had imparted to the Royal Society, of this city, in the year 1785, the main frameworks of his celebrated "Theory of the Earth." Among those with whom he consulted the elaboration of his convention were Black, the famous pioneer of "fixed air" and "inert warmth;" Clerk, the smart creator of the arrangement of breaking the enemy's line in maritime strategies; Hall, whose rich inventiveness concocted the main arrangement of investigations in outline of the construction and beginning of rocks; and Playfair, through whose thoughtful energy and artistic expertise Hutton's perspectives came at last to be perceived and valued by the world on the loose. With these companions, so well ready to fathom and reprimand his endeavors to penetrate the cloak that covered the historical backdrop of this globe, he paced the roads in the midst of which we are currently assembled; with them he looked for the craigs and gorges around us, wherein Nature has exposed such countless noteworthy records of her past; with them he sailed forward on those essential campaigns to far off places of Scotland, hence, he returned weighed down with treasures from a field of perception which, however, now so recognizable, was then practically untrodden.

The centennial of Hutton's "Hypothesis of the Earth" is an occasion in the chronicles of science which appears to be most fittingly celebrated by a gathering of the British Association in Edinburgh. Hutton's hypothesis of the earth. It was a major convention of Hutton and his school that this globe has not generally worn the viewpoint which it bears at present that, unexpectedly, confirmations may wherever be winnowed that the land which we currently see has been shaped out of the disaster area of a more seasoned land. Among these evidences, the most clear are provided by a portion of the more natural sorts of rock, which instruct us that, however they are currently segments of the dry land, they were initially sheets of rock, sand and mud, which had been worn from the essence of since quite a while ago evaporated landmasses, and in the wake of being fanned out over the floor of the ocean were solidified into minimized stone, and were at last separated and raised again to frame part of the dry land. This pattern of progress included two incredible frameworks of common cycles.

From one perspective, men were instructed that by the activity of running water the materials of the strong land are in a condition of ceaseless rot and transport to the sea. Then again, the sea depths is at risk every once in a while to be lifted by some staggering inner power similar to that which leads to the spring of gushing lava and the seismic tremor. Hutton further apparent that not just had the united materials been upset and raised, however that masses of liquid stone had been pushed vertically among them, and had cooled and solidified in huge assortments of stone and other eruptive rocks which structure so unmistakable a component on the world's surface. It was an uncommon trait of this philosophical framework that it looked for in the progressions now in progress on the world's surface a clarification of those which happened in more established occasions. Its author would not design causes or methods of activity, for those with which he was recognizable appeared to him satisfactory to tackle the issues with which he endeavored to bargain.

No place was the significance of his understanding more surprising than free, positive manner by which he announced and emphasized his regulation that all aspects of the outside of the mainlands, from peak to coastline, is constantly going through rot, and is in this way gradually making a trip to the ocean. He saw that no sooner will the ocean bottom be raised into new land than it should fundamentally turn into a prey to this general and continuous debasement. He saw that, as the vehicle of deteriorated material is continued mostly by running water, waterways should gradually uncover for themselves the directs in which they stream, and along these lines that an arrangement of valleys, transmitting from the water-splitting of a nation, should fundamentally result from the plummet of the streams from the mountain peaks to the ocean.

He perceived that this perpetual and inescapable rot would at last prompt the whole destruction of the dry land; however he battled that from time to time this disaster is forestalled by the activity of the underground powers, whereby new landmasses are lifted from the bed of the sea. What's more, subsequently in his framework a due extent is kept up among land and water, and the state of the earth as a livable globe is protected.

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A hypothesis of the earth so straightforward in layout, so striking in origination, so brimming with idea, and laying on so wide a base of perception and reflection, should, we may think, to have directed without a moment's delay the consideration of men of science, regardless of whether it didn't quickly stir the interest of the rest of the world; however as Playfair tragically conceded, it pulled in notice truth be told, gradually, and quite a long while passed before any one showed himself freely worried about it, either as a foe or a companion. Some of its earliest pundits pounced upon it for what they declared to be its skeptical inclination—an allegation which Hutton disavowed with much warmth.

The jeer evened out by Cowper a couple of years sooner at all investigations into the historical backdrop of the universe was completely common and clear from that artist's perspective. There was then an inescapable conviction that this world appeared somewhere in the range of 6,000 years prior, and that any endeavour incredibly to build that artifact was implied as a hit to the authority of Holy Writ. Up until now, notwithstanding, from focusing on the defeat of conventional convictions, Hutton clearly respected his "Hypothesis" as a significant commitment in guide of common religion. He harped with unfeigned joy on the huge number of verifications which he had the option to aggregate of an efficient plan in the tasks of Nature, rot and remodel being so pleasantly adjusted as to keep up the tenable state of the planet. In any case, as he wouldn't concede the prevalence of savage activity in earthbound changes, and actually fought for the viability of the tranquil, persistent cycles which we can even now see at work around us, he was compelled to require a limitless length of past an ideal opportunity for the creation of those unrests of which he saw such clear and plentiful evidences in the outside layer of the earth.

The overall population, in any case, neglected to understand that the principle of the great vestige of the globe was not conflicting with the similarly ongoing appearance of man—a qualification which appears to be so clear at this point. Playfair's composition of Hutton's hypothesis. Numerous years may have passed before Hutton's instructing met with wide acknowledgment, had its acknowledgment relied exclusively upon the writings of the scholar himself. For, notwithstanding his strong handle of general standards, and his dominance of the minutest subtleties, he had obtained an abstract style which, it should be conceded, was uniquely ugly.

Luckily for his theory, just as for the reason for science, he gave companion and devotee, Playfair, on the double set himself to draw up a composition of Hutton's perspectives. Following five years of work on this errand there seemed the exemplary "Representations of the Huttonian Theory," a work which for iridescent treatment and smooth word usage stops without an adversary in English handwriting. In spite of the fact that maintaining only to present his companion's regulations, Playfair's composition was in numerous regards a unique commitment to study of the highest value. It put without precedent for the most clear light the entire way of thinking of Hutton in regards to the historical backdrop of the earth, and implemented it with an abundance of thinking and bounteousness of representation which got for it a wide appreciation.

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From long chat with Hutton, and from significant reflection himself, Playfair acquired such an appreciation of the entire subject that, disposing of the unimportant pieces of his lord's instructing, he had the option to give so clear and exact a piece of the overall plan of Nature's procedure on the outside of the globe, that with just slight remedies and extensions his composition may fill in as a course reading to-day. In certain regards, in fact, his volume was long ahead of now is the right time. Just, for instance, inside the current age has the reality of his educating as to the beginning of valleys been by and large conceded. Different causes added to impede the advancement of the Huttonian teachings. Particularly intense was the impact of the instructing of Werner, who, however he saw that a distinct request of grouping could be perceived among the materials of the earth's outside, had framed uniquely limited originations of the extraordinary cycles whereby that hull has been developed. His excitement, be that as it may, terminated his pupils with the enthusiasm of converts, and they spread themselves over Europe to lecture wherever the counterfeit framework which they had learned in Saxony.

By an inquisitive destiny Edinburgh got one of the incredible central command of Wernerism. The companions and adherents of Hutton ended up assaulted in their own city by extremists who, pleased with prevalent mineralogical acquirements, flipped around their most treasured thoughts and pounced upon them in the awkward language of Freiberg. Since underground warmth had been summoned by Hutton as a power generally instrumental in combining and lifting the antiquated residue that presently structure so incredible a piece of the pry land, his devotees were nicknamed Plutonists.

Then again, as the office of water was practically alone conceded by Werner, who accepted the stones of the world's outside to have been primarily synthetic encourages from an antiquated all inclusive sea, the individuals who embraced his perspectives got the similarly graphic name of Neptunists. The clash of these two fighting schools seethed wildly here for certain years, and however for the most part from the young, enthusiasm and energy of Jameson, and the impact which his situation as teacher in the college gave him, the Wernerian regulations kept on holding their place, they were at last deserted even by Jameson himself, and the obligation because of the memory of Hutton and Playfair was delinquently recognized.

The Neptunists and The Plutonists

The pursuits and the squabbles of scholars have from early occasions been a most loved subject of cheer to the rest of the world. Such a fight as that between the Plutonists and Neptunists would make certain to outfit plentiful matter for the satisfaction of this penchant. Among the names of the companions and adherents of Hutton there is one which on this event has the right to be held in particular honor, that of Sir James Hall, of Dunglass. Having went with Hutton in a portion of his trips, and having examined with him the issues introduced by the stones of Scotland, Hall knew about the perspectives on his lord, and had the option to supply him with new representations of them from various pieces of the country. Talented with exceptional innovation and ingenuity, he before long apparent that a portion of the inquiries engaged with the hypothesis of the earth could presumably be tackled by direct actual examination. Hutton, notwithstanding, doubted any endeavour "to decide' of the extraordinary tasks of Nature by only fuel a fire, and investigating the lower part of somewhat pot." Out of reverence to this prejudice Hall postponed to do his expectation during Hutton's lifetime. In any case, subsequently he established a momentous arrangement of explores which are significant throughout the entire existence of science as the main systematic undertaking to test the worth of topographical theory by. an appeal to real analysis.

The Neptunists, in scorning the Huttonian doctrine that basalt and comparative rocks had once been liquid, affirmed that, had such been their starting point, these masses would now be found in the state of glass or slag. Corridor, however, triumphantly vindicated his companion's view by demonstrating that basalt could be combined, and from that point by lethargic cooling could be made to resume a stony surface. Once more, Hutton had declared that under the immense pressing factors which should be viable, profound inside the world's covering, substance responses should be intensely impacted, and that under such conditions even limestone may possibly be liquefied without losing its carbonic corrosive. Different plausible contentions had been illustrated against this recommendation, however by an astutely contrived arrangement of tests Hall prevailing with regards to changing over limestone under extraordinary tension into a sort of marble, and surprisingly combined it, and found that it at that point acted overwhelmingly on different rocks.

These praiseworthy investigates, which established the frameworks of trial geography, comprise not the most un-noteworthy of the administrations delivered by the Huttonian school to the advancement of science. Smith's law of natural progression. Clear similar to the knowledge and canny the inductions of these extraordinary experts concerning the historical backdrop of the globe, their vision was fundamentally restricted by the nearly limited scope of discovered reality which up to their time had been set up. They trained men to perceive that the current world is worked of the remains of a previous one, and they clarified with outstanding perspicacity the activity of the cycles whereby the corruption and redesign of land are achieved. Yet, they never dreamed that a long and methodical arrangement of such progressive annihilations and recharges had occurred, and had left their records in the outside of the earth.

They never envisioned that from these records it is feasible to build up a determinate order that could be perused all over, and applied to the clarification of the remotest quarter of the globe. It was by the essential perceptions and speculations of William Smith that this immense expansion of our insight into the previous history of the earth got conceivable. While the Scottish rationalists were developing their hypothesis here, Smith was discreetly finding out by expanded excursions that the delineated rocks of the west of England happen in a clear arrangement, and that each very much checked gathering of them can be separated from the others, and recognized the nation over through its enclosed natural remaining parts.

It is almost a long time since he spread the word about his perspectives, so that by an inquisitive incident we may fitly celebrate on this event the centennial of William Smith just as that of James Hutton. No single revelation has at any point affected the advancement of a science than that law of natural progression which Smith set up. From the outset it served only to decide the request for the separated rocks of England. Be that as it may, it before long demonstrated to have an overall worth, for it was found to outfit the way in to the construction of the entire separated outside layer of the earth. It showed that inside that outside layer lie the annals of a long history of plant and creature life upon this planet, it provided the methods for orchestrating the materials for this set of experiences in obvious ordered arrangement, and it along these lines opened out an eminent vista through an immense arrangement of ages, each set apart by its own unmistakable sorts of natural life, which, in relation to their relic, left increasingly more from the part of the living scene.

The Modern Science of Geology

Subsequently 100 years prior, by the splendid hypothesis of Hutton and the productive speculation of Smith, the investigation of the earth got in our country the stimulus which has brought forth the advanced study of geography. From the soonest times the characteristic highlights of the world's surface have captured the consideration of humanity. The tough mountain, the split gorge, the scarped bluff, the lone bowlder, have animated interest and incited numerous a hypothesis as to their origin. The shells inserted by millions in the strong rocks of slopes far eliminated from the ocean have even additionally squeezed home these "willful questionings." But for some long hundreds of years the development of inquiry into such matters was captured by the central impact of customary philosophy. It was not just that the congregation went against itself to the basic and clear translation of these normal marvels. So certain had confidence become in the acknowledged perspectives on the world's age and of the historical backdrop of creation, that even laymen of insight and learning set themselves, unbidden furthermore, in wonderful great confidence, to rationalize the challenges which Nature so diligently raised up, and to accommodate her lessons with those of the scholars. In the different hypotheses in this manner starting the measure of information on common law normally remained in opposite proportion to the offer played in them by an uncontrolled creative mind. The hypotheses, for instance, of Burnet, Whiston, Whitehurst, and others in this nation can't be perused now without a grin. In no sense were they logical explores; they must be viewed as exercitations of learned obliviousness.

Springing essentially out of a praiseworthy longing to elevate what was accepted to be the reason for genuine religion, they assisted with impeding request, and practiced in that regard a pernicious impact on scholarly advancement. It is the uncommon greatness of the Edinburgh school of topography to have thrown away this whimsical piddling. Hutton strikingly

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announced that it was no essential for his way of thinking to represent the start of things. His anxiety lay uniquely with the proof outfitted by the actual earth regarding its starting point. With the instinct of genuine virtuoso, he early saw that the solitary strong premise from which to investigate what has occurred in era long since past is an information on what is occurring today. He hence, established his framework upon a cautious investigation of the cycles whereby land changes are presently achieved. He felt guaranteed that Nature should be steady and uniform in her working, and that just in extent as her tasks right now are watched and perceived will the antiquated history of the earth become coherent. Subsequently, in his grasp, the examination of the present turned into the way to the understanding of the past. The foundation of this extraordinary truth was the initial move toward the introduction of a genuine study of the earth. The tenet of the consistency of causation in Nature turned into the productive standard on which the design of current geography could be developed.

Uniformity of Causation

New life was presently inhaled into the investigation of the earth. Another soul appeared to quicken the development along each pathway of request. Realities that had for quite some time been natural came to have a more extensive and more profound significance when their association with one another was recognized as parts of one incredible agreeable arrangement of consistent change. In no branch of Nature for model, was this more extensive vision more amazingly showed than in that wherein the dissemination of water between land. Also, ocean has the most prominent influence. From the most punctual occasions men had watched the happening to mists, the fall of downpour, the progression of waterways, and had perceived that on this pleasantly changed apparatus the magnificence and ripeness of the land depend. Be that as it may, they presently "discovered that this excellence and ripeness include a persistent rot of the, earthbound surface; that the dirt is a proportion of this rot, and would stop to bear the cost of its upkeep were it not consistently eliminated and reestablished; that through the interminable vehicle of soil by streams to the ocean the substance of the land is gradually brought down in level and cut into mountain and valley. Furthermore, that the materials hence borne outward to the floor of the sea are not lost yet gather there to frame rocks, which in the end will be upraised into new grounds.

Rot and remodel, in even extents, were along these lines demonstrated to be the framework on which the presence of the earth as a livable globe had been set up. It was difficult to imagine that the economy of the planet could be kept up on some other premise. Without the flow of water the existence of plants and creatures would be unimaginable, and with that course the rot of the outside of the land and the remodel of its deteriorated materials are essentially included. As it is presently, so should it have been in past time. Hutton and Playfair highlighted the defined rocks of the world's outside layer as exhibits that similar cycles which are grinding away today have been in activity from a distant vestige.

By in this way setting their hypothesis on a premise of real perception, and giving in the investigation of existing activities a manual for the understanding of those in past occasions, they saved the examination of the historical backdrop of the earth from the theories of scholars and cosmologists, and set up a spot for it among the perceived inductive sciences. To the controlling impact of their philosophical framework the colossal steps made by current topography are in huge measure to be ascribed. Furthermore, here in their own city, after the slip by of 100 years, let us offer to their memory the appreciative tribute of all who have benefited by their works.

However, while we perceive with deference the expansive impact of the regulation of consistency of causation in the examination of the historical backdrop of the earth, we should upon reflection concede that the principle has been pushed to a limit maybe not pondered by its unique organizers. To take the current states of nature as a foundation of real information from which to begin in an investigation into previous conditions was sensible and reasonable. Obviously however, human experience, in the years and years during which consideration has been gone to such subjects has been too concise to even consider justifying any fanatical supposition that the different characteristic cycles probably been carried on in the past with a similar energy and at a similar rate as they are continued at this point.

Varieties in energy may have been authentically surrendered as could be expected, however, not to be permitted without sensible confirmation in support of themselves. It was on the whole correct to decline to concede the activity of speculative reasons for change when the wonders were fit for regular and sufficient clarification by reference to causes that can be watched and explored. Yet, it was a mistake to underestimate that no other sort of cycle or impact nor any variety in the pace of movement save those of what man has had genuine perception, has played, a section in the earthbound economy.

The uniformitarian liters exposed themselves to the charge of keeping a sort of unending movement in the apparatus of nature. They could discover in the records of the world's set of experiences no proof of a start, no possibility of an end. They saw that numerous progressive remodels and obliterations had been affected on the world's surface, and that this long queue of changes framed a progression of which the soonest were lost in ancient times while the most recent were as yet in progress toward an evidently illimitable future movement in natural.

Types

The disclosures of William Smith, had they been sufficiently perceived, would have been believed to bring to the table a remedial to this unbendingly uniformitarian origination for they uncovered that the hull of the earth contains the long record of an undeniable request of movement in natural kinds. They demonstrated that plants and creatures have changed broadly in progressive times of the world's set of experiences, the current state of natural life being hands down the most recent period of a long going before arrangement, each phase of which retreats further from the current part of things as we follow it in

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reverse into the past. Furthermore, however no relic had at this point been found, or in fact was at any point prone to be found, of the principal living things that showed up upon the world's surface, the show disentanglement of types in the more established arrangements pointed compellingly to some start from which the long parade had taken its beginning.

Assuming, at that point, it could accordingly be shown that there had been upon the globe a systematic walk of living structures from the lowliest grades in early occasions - to man himself today, and subsequently that in one division of her area, stretching out through the more prominent bit of the records of the world's set of experiences, nature had not been uniform however had followed a huge and respectable arrangement of advancement, doubtlessly it may have been normal that the individuals who found and spread the word about this arrangement would try to discover whether some practically equivalent to actual movement from a clear start probably won't be detectable in the system of the actual globe. However, the early bosses of the science toiled under two extraordinary detriments.

In any case, they tracked down the most seasoned records of the world's set of experiences so separated and destroyed as to be not, at this point neat. What's more, in the subsequent spot, they lived enthralled of that solid response against hypothesis which followed the harsh debate between the Neptunists and Plutonists in the previous many years of the century. They viewed themselves as bound to look for realities, not to develop hypotheses; and as in the covering of the earth they could discover no realities which illuminated the primitive constitution and ensuing advancement of our planet, they shut their ears to any hypothetical translations that may be offered from different divisions of science. It was sufficient for them to keep up, as Hutton had done, that in the noticeable design of the actual earth no follow can be found of the start of things, and that the most established earthbound records uncover no states of being basically not quite the same as those wherein we actually live.

They without a doubt tuned in with interest to the hypotheses of Kant, Laplace, and Herschel, on the plausible advancement of nebulae, suns, and planets; however it was with the lazy interest appending to thoughts that lay outside of their own area of exploration. They perceived no reasonable association between such theories and the information outfitted by the actual earth regarding its own set of experiences and progress the start of things. This inquisitive laziness as for hypothesis with respect to men who were prevalently viewed as among the most speculative supporters of science would presumably not have been quickly scattered by any revelation made inside their own field of perception. Indeed, even now after numerous long periods of the most persistent examination, the principal sections of our planet's set of experiences stay unseen or undecipherable. On the extraordinary earthly palimpsest the soonest engravings appear to have been pitifully destroyed by those of later ages.

Yet, the topic of the antiquated condition and resulting history of the planet may be considered from the side of cosmology and physical science. What's more, it was by examinations of this nature that the topographical lethargy was in the long run dispersed. To our renowned previous President, Lord Kelvin. who involved this seat when the affiliation last met in Edinburgh, is fundamentally due the animating of consideration to this subject. By the most persuading contentions he showed that it was so difficult to have faith in the limit principle of uniformitarianism. Furthermore, though owing to vulnerability with respect to a portion of the information. wide restrictions of time were hypothesized by him, he demanded that inside these constraints of time the entire advancement of the earth and its occupants should have been comprised.

While, in this way, the land regulation that the current request of nature should be our manual for the understanding of the past stayed as evident and productive as ever. It had now to be enlarged by the gathering of proof outfitted by an investigation of the earth as a planetary body. The mainstream loss of warmth, which evidently happens both from the earth and the sun, made it very sure that the present couldn't have been the first state of the framework. This decrease of temperature with every one of its outcomes is anything but a simple matter of theory, however an actual certainty of the here and now as much as any of the natural actual offices that influence the outside of the globe. It focuses with indisputable explicitness to that start of things of which Hutton and his adherents could track down no sign of 'earthly disasters'.

Another adjustment or broadening of the uniformitarian tenet was achieved by proceeding with examination of the earthbound outside layer and ensuing increment of information regarding the historical backdrop of the earth. However, Hutton and Playfair had confidence in periodical fiascoes, and to be sure required these to repeat to reestablish and save the habitat.

1.10.1 Nebular Hypothesis

It describes that the solar system is formed from a giant cloud of molecular gasoline and dirt. Scientists believed that every planet of the solar system have been formed at the same time from a nebula cloud, 4.5 billion years in the past.

Something passed off that precipitated the cloud to crumble but then the cloud was collapsed gravitationally at the cease of the cloud. Due to this the gas and dirt started out to collect in denser areas, started out rotating and started to warm up. Most of them changed into most effective left as a ball within the center, this gave start to the solar and the rest of the matter circled around the ball on the middle (sun), the matter which turned around across the solar are all the planets in our solar system which later have become few due to the excessive boiling factors.

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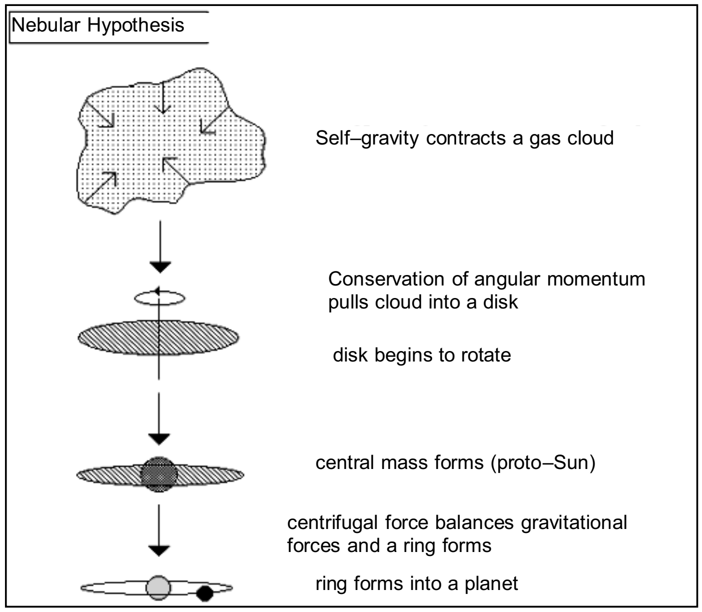
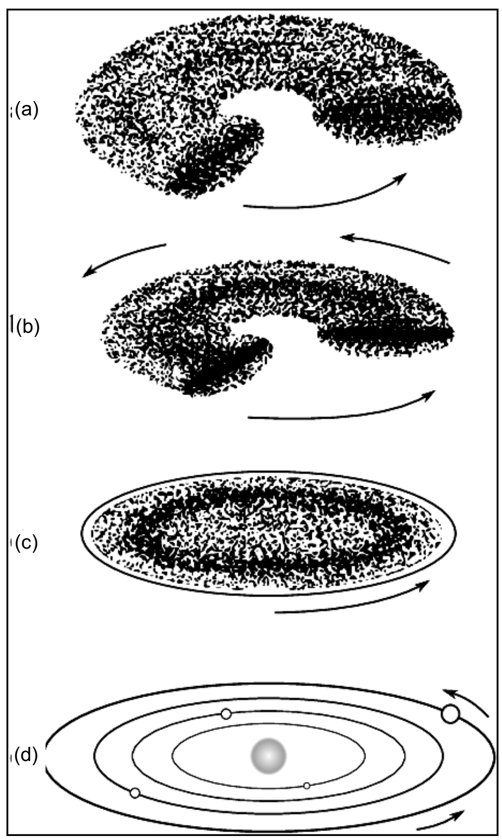


Source: Wikipedia.com

Fig. 1.9: Nebular Hypothesis as Suggested by Laplace



Source: Encyclopaedia.com

Fig. 1.10: 3D Image of Nebular Hypothesis

The planets are shaped from rocky clumps that escaped the cloud. Due to the spinning of the clouds it was a fraction and for that reason forms the planet Earth.

1.10.2 Tidal Hypothesis

The tidal hypothesis is one of the present day hypotheses of the origin of the earth and the solar system. Denims postulated his hypothesis on the premise of positive axioms. Even as Newton defined the tides with the aid of describing the tide-generating forces and Bernoulli gave an outline of the static response of the waters on this planet to the tidal potential.

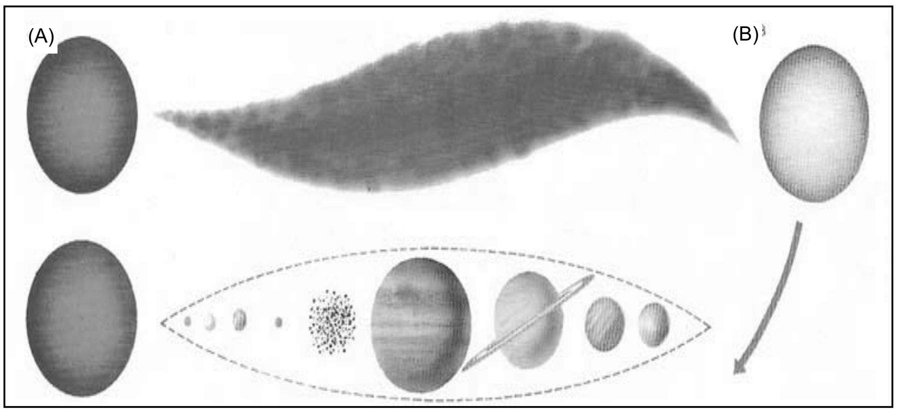


Fig. 1.11: 3D Image of Tidal Hypothesis

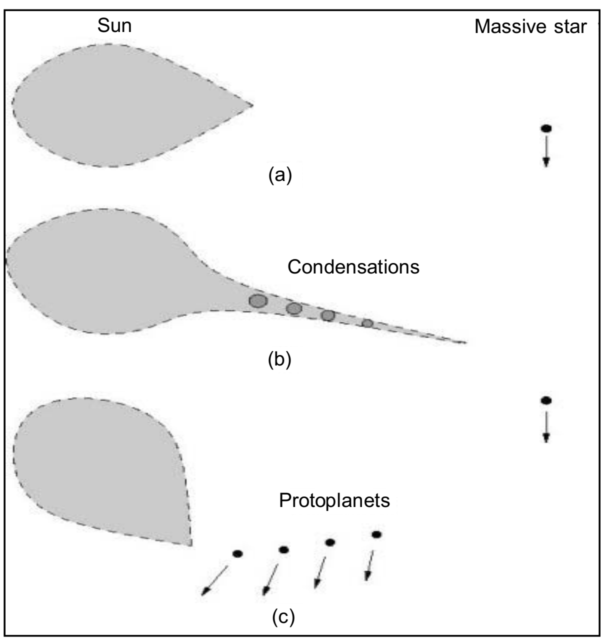


Fig. 1.12: Sketch of Tidal Hypothesis

Tidal hypothesis is as follows:

- Initially, the sun was a big incandescent gaseous mass of matter.
- Excluding the Sun there is another star termed as 'intruding star' in the universe. This star was much "larger in size" than the primitive sun.

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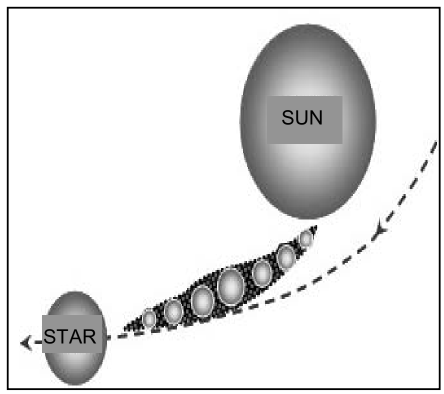
- The sun rotating on its axis was stationary, also whereas the intruding star was moving along a path in which it was predestined to come "nearer to the primitive sun".
- The tidal force "affected the intruding star" on the surface of the "primitive sun".

1.10.3 Planetesimal Hypothesis

Planetesimal speculation, a idea of the starting place of the sun machine. It was proposed by means of Forrest R. Moulton and Thomas C. Chamberlin approximately 1900. The idea states that the planets had been formed with the aid of the accumulation of extremely small bits of be counted planetesimal that revolved across the sun. This depend changed into produced whilst a passing big name almost collided with the solar throughout the close to-collision, warm gases had been pulled out of each stars and the gases then condensed. The planetesimal speculation become extensively common for approximately 35 years.



Source: Study.com

Fig. 1.13: Planetesimal Hypothesis

The biggest flaw in the idea is the assumption that the material drawn out of the celebs would condense. The extraordinarily hot gases that make up a star are held together with the aid of the gravitational forces in the big name. Once the material become pulled away to where the gravitational forces were weaker, it might make bigger due to its warmth. Earlier than condensation ought to take place, the gases would have nearly totally dissipated. The planetesimal hypothesis is not taken into consideration a possible rationalization of the beginning of the solar device.

1.10.4 Ottoschmidt Hypothesis

'Inter-Stellar Dust Hypothesis' was proposed by a Russian scientist Otto Schmidt in 1943 to explain the complex problems of the origin and characteristics of the solar system and the earth. Adequate evidences of the presence of 'darkish count number' inside the shape of 'gas and dust cloud' (fuel and dust debris) inside the universe are given via the scientific researches approximately the universe. Even though mode of starting place of this dark be counted changed into explained with the aid of Otto Schmidt but it may be safely assumed that these gaseous clouds and dust particles might have been shaped from the problem this is coming out of the meteors and stars.

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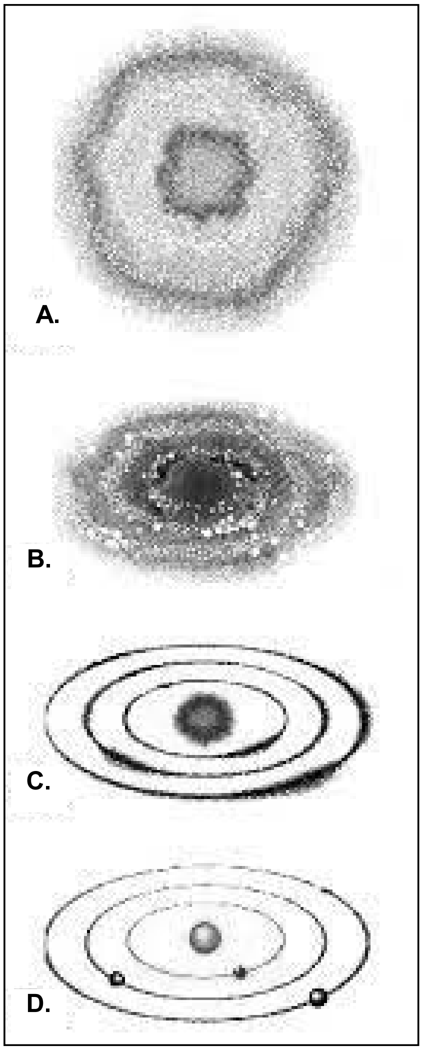

Fig. 1.14: Ottoschmidt Hypothesis

As a concept of Otto Schmidt, the sun in the course of its 'galactic revolution' captured the dark remember of the universe. There may be very own angular momentum of dark remember of gaseous cloud and dirt particles. The darkish count number after being attracted by the sun all through its 'galactic revolution' started out revolving around the primitive rotating solar. Otto Schmidt known as those dark matters 'interstellar dusts'. After the mixture and condensed of dirt debris, were changed into a flat disc of captured darkish matter started out revolving around the sun and beneath the mixed affects of 3 sorts of motions:

1. Gravitational pressure exerted by means of the sun on the dark be counted disc.
2. The rotational motion of the sun itself.
3. The angular momentum of darkish rely of the disc.

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Assessment of Otto Schmidt theory: almost all of the problems of the bizarre function functions of the sun machine are solved by using this speculation. They may be:

1. Close to round and alike planes of orbits of the planets.
2. Revolution within the sun's equatorial plane carefully matching with the orbital planes of the planets.
3. Planets placement consistent with their length on the premise of nicely-based legal guidelines.
4. In the outer circle of the solar machine excessive density planets
5. Big and strange distribution of angular momentum a number of the planets o*f solar system.*

1.10.5 Supernova Hypothesis

The two mathematicians named F. Foyle and Littleton of the Cambridge college supplied their principle called superb Nova hypothesis within the 12 months 1946. Their hypothesis was primarily based on nuclear physics. Power which is emitted by using any celebrity inside the form of light warmth and so forth is generated by way of the procedure known as nuclear fusion. According to them, the heavy factors performed important element within the formation of planets. those heavy factors are formed when atoms of lighter factors mixed beneath intense warmness and stress launched significant amount of strength. Those heavy factors represent 90% of the overall mass of the planets.

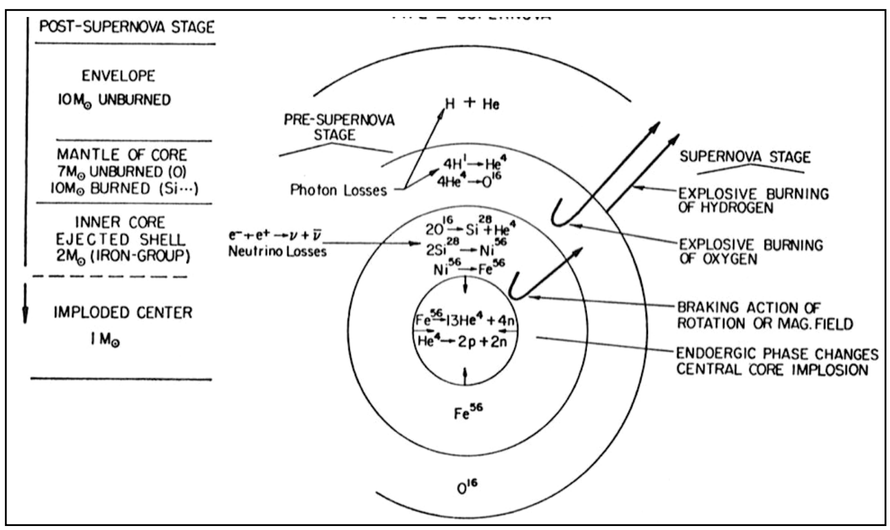

Fig. 1.15: Supernova Hypothesis

The main constituent in the formation of the stars is hydrogen. The planets on the other hand have less than 1% hydrogen. The scientists F. Foyle and Littleton showed that the heavy elements originate even due to the burning of hydrogen. But an ordinary star like Sun can only form an element like helium. The formation of the heavy elements is possible only if the burning of hydrogen takes place at high temperature. Such high temperature is available only in supernova stars. A star becomes supernova star when it is left with very less hydrogen which is not enough to burn. Hydrogen is the source energy which gets converted into helium and generates energy. In the case of scarcity of hydrogen, the star has to shrink in order to produce energy. The speed of rotation of the star increases when it shrinks.

The force at the center increases due to high rotational speed. As a result, the star throws out first the lighter matter and then the heavy elements. The formation of the heavy elements in the Universe is possible in this state only. The cosmic light which is many lakh times more than the light of Sun is visible in the center after the heavy metals are thrown at a distance. These stars with such huge light are termed as nova. According to these scientists, the planets have been formed due to the explosion of one super nova star. The explosion of the super nova star generated intense heat equivalent to 5×10^9 degree celsius which was sufficient enough to start the process of the nuclear fusion. According to them, the two stars present there were the Sun and the super nova star. The distance between these two stars was the same as the distance between the Sun and Jupiter. The explosion of the super nova generated intense heat and pressure from which the primitive Earth was made. Thus, the planets of our Solar System were formed due to the condensation of the matter of the disc form of the matter thrown out of the matter by super nova due to its explosion.

Check Your Progress

17. The other name for human being is __________.
18. The postulate drawn from planetesimal hypothesis is __________ .
19. The name given to dark matter by Otto Schmidt is __________.
20. Supernova hypothesis was presented in the year __________ .

1.11 ANSWERS TO 'CHECK YOUR PROGRESS'

1. Glaciology
2. Paleogeography
3. The study of the natural features of the earth, such as mountains and rivers
4. Spatial, temporal, quantitative and qualitative.
5. Water, air, earth, space and fire
6. Morphology
7. Mercury, Venus, Earth along with Mars and Asteroids.
8. Jupiter, Saturn, Uranus, Neptune and Pluto
9. Mercury, Venus, Earth and Mars
10. 687
11. Large Magellanic cloud and Small Magellanic cloud
12. Proxima Centauri

NOTES

13. Eon> Era > Period > Epoch > Age
14. Cenozoic, Mesozoic and Paleozoic
15. Holocene
16. Some 4.54 billion years ago (±0.5 billion years; Taylor and McLennan 1985; Windley 1995; Condie 1997
17. Jeans
18. that the material drawn out of the stars would condense.
19. interstellar dusts
20. 1946

1.12 SUMMARY

Our solar system consists of a celeb of average size and luminosity known as the sun and the planets, their satellites, several comets, asteroids, meteorites and the interplanetary medium and many others. The planets, most of the satellites and the asteroids revolve across the solar in the identical route (counter-clockwise), in almost circular orbits (ellipses but close to circles). whilst we appearance down from above the sun's North Pole, the planets seem to be orbiting in a counter-clockwise direction. You've got learnt that a brand new elegance of dwarf planets become brought in 2006. Such planets are confined typically inside the Asteroid Belt and the Kuiper Belt as nicely. moreover, the planets orbit the solar in or near the same aircraft known as the ecliptic. Scientist same time calls Pluto as a unique dwarf planet in that, and its orbit is the most relatively willing (18 degrees) and the most extraordinarily elliptical of all the planets. The Sun comprises 99.85% of all of the space within the Solar System.

1.13 KEY TERMS

- **Cosmology:** Science dealing with the nature and origin of the universe
- **Big Bang Theory:** Canon Lemaitre
- **Steady State Theory:** Hermann Bond and Thomas Gold.
- **Pulsating universe theory:** Allan Sandage.
- **One Parsec** = 3.26 light years.

1.14 SELF-ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. Give the geological time scale.
2. Give any five definitions of physical geography.

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3. Discuss the relation between political science and geography.
4. How is the nature of geography?

Long Answer Questions

1. Discuss Tidal hypothesis of earth's evolution.
2. Write a note on earth and its planetary position.
3. Write an essay on 'Age of the earth'.
4. Discuss Nebular hypothesis of earth's evolution.
5. Discuss Supernova hypothesis of earth's evolution.

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UNIT 2 INTERIOR OF THE EARTH

NOTES

Structure

2.0 INTRODUCTION

The Earth is divided into 3 most important layers. The dense, hot inner middle (yellow), the molten outer center (orange), the mantle (pink), and the skinny crust (brown), which supports all existence inside the recognized universe. Earth's interior is usually divided into 3 major layers: the crust, the mantle, and the core. On this unit we're going to observe theories of earth's foundation: Wegener's and Plate Tectonics. We are able to additional see causes of introduction of faults and folds and its diverse sorts.

2.1 OBJECTIVES

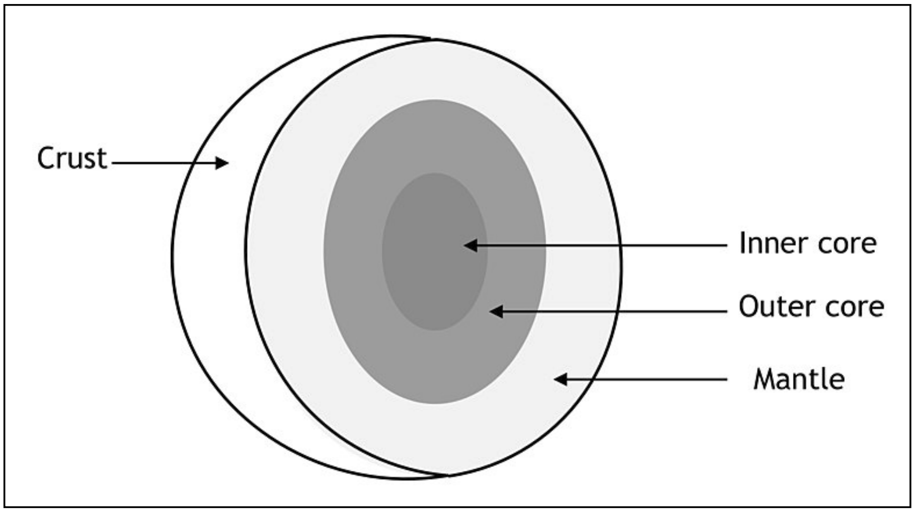
After going through this unit, you will be able to:

- Study various layers of earth and its composition.
- Study continental drift theory of Wegener.
- Study Plate Tectonics theory.
- Study various types of faults and folds.

2.2 INTERIOR OF THE EARTH

The Earth is split into 3 essential layers. The dense, hot internal middle (yellow), the molten outer core (orange), the mantle (red), and the skinny crust (brown), which helps in surviving all lifestyles in the recognised universe.

Earth's indoors is usually divided into three foremost layers: the crust, the mantle, and the core.



Source: wikimedia.org

Fig. 2.1: Interior of the Earth

Inside the Earth

The earth's interior is made up of four layers, three solid and one liquid — not magma but molten metal, nearly as hot as the surface of the sun.

1. The Core

The deepest layer, i.e., the inner middle is a solid iron ball, approximately 1,500 miles (2, four hundred kilometers) in diameter. Although this internal center is white warm, the strain is so excessive the iron cannot melt.

The iron isn't natural, it's far believed to include sulphur and nickel, plus smaller quantities of different factors. Estimates of its temperature range, however it might be somewhere between 9,000 and 13,000 degrees Fahrenheit (5,000 and 7,000 stages Celsius).

Above the inner center is the outer center, a shell of liquid iron. this sediment is cooler however nonetheless very hot, possibly 7,200 to 9,000 tiers Fahrenheit (4,000 to 5,000 tiers Celsius). It too is composed primarily of iron, plus sizable amounts of sulfur and nickel. It creates the Earth's magnetic subject and is about 1,400 hundred miles (2,300 kilometers) thick.

2. Mantle

The next layer is the mantle. Many humans consider this as lava, however it's truly rock. The rock is so hot, but, that it flows below stress, like avenue tar. This creates very slow-transferring currents as warm rock rises from the depths and cooler rock descends.

The mantle is about 1,800 miles (2,900 kilometers) thick and looks to be divided into two layers: the upper mantle and the decrease mantle. The boundary among the two lies about 465 miles (750 kilometers) under the earth's floor.

NOTES

3. The Crust

The crust is the outermost layer of the Earth. It's miles the acquainted panorama on which we live: rocks, soil, and seabed. It stages from approximately five miles (eight kilometers) thick under the oceans to a mean of 25 miles (40 kilometers) thick beneath the continents.

Currents in the mantle have damaged the crust into blocks, called plates, which slowly pass round, colliding to build mountains or rifting aside to shape new seafloor.

Except inside the crust, the interior of the Earth cannot be studied via drilling holes to take samples. alternatively, scientists map the interior by means of looking how seismic waves from earthquakes are bent, contemplated, accelerated, or not on time by the numerous layers.

Continents are composed of particularly light blocks that float high at the mantle, like large, gradual-moving icebergs. Seafloor is made of a denser rock referred to as basalt, which presses deeper into the mantle, producing basins that may fill with water.

Sources of Information about the Interior of the Earth

Direct Sources

1. Rocks from mining area
2. Volcanic eruptions

Indirect Sources

1. Gravitation, that's extra close to poles and less at the equator.
2. Through analyzing the rate of trade of temperature and pressure from the surface toward the indoors.
3. Magnetic sources.
4. Meteors, as they belong to the identical sort of substances earth is made of.
5. Seismic Waves: the shadow zones of frame waves (number one and secondary waves) provide us records approximately the nation of substances inside the interior.
6. Gravity anomaly, that's the alternate in gravity fee consistent with the mass of cloth, gives us facts about the substances inside the earth's interior.

Structure of the Earth's Interior

Structure of the earth's interior **is fundamentally divided into three layers** – crust, mantle and core.

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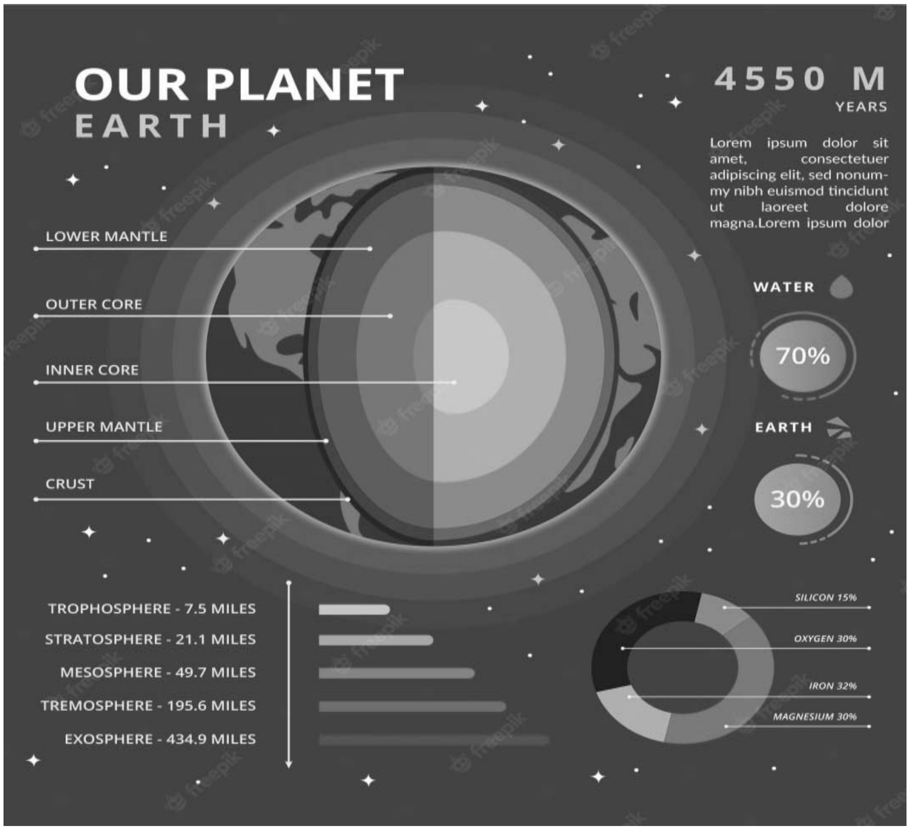

Fig. 2.2: Layers of Earth

Crust

- It is the outermost solid part of the earth, normally about 8-40 kms thick.
- It is brittle in nature.
- Nearly 1% of the earth's volume and 0.5% of earth's mass are made of the crust.
- The thickness of the crust under the oceanic and continental areas are different. Oceanic crust is thinner (about 5 kms) as compared to the continental crust (about 30 kms).
- Major constituent elements of crust are Silica (Si) and Aluminium (Al) and thus, it is often termed as **SIAL** (Sometimes SIAL is used to refer Lithosphere, which is the region comprising the crust and uppermost solid mantle, also).
- The mean density of the materials in the crust is $3g/cm^3$.
- The discontinuity between the **hydrosphere and crust** is termed as the **Conrad Discontinuity**.

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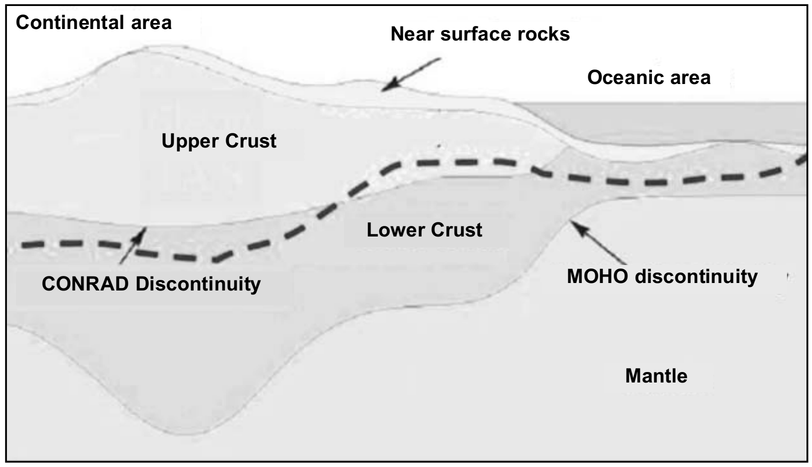

Source: Public domain archive

Fig. 2.3: Earth's Crust

Mantle

- The portion of the interior beyond the crust is called as the mantle.
- The discontinuity between the **crust and mantle** is called as the **Mohorovich Discontinuity** or **Moho discontinuity**.
- The mantle is about 2900 kms in thickness.
- Nearly 84% of the earth's volume and 67% of the earth's mass is occupied by the mantle.
- The major constituent elements of the mantle are Silicon and Magnesium and hence it is also termed as **SIMA**.
- The density of the layer is higher than the crust and varies from 3.3-5.4g/cm^3.
- The uppermost solid part of the mantle and the entire crust constitute the **Lithosphere**.
- The **asthenosphere** (in between 80-200 km) is a highly viscous, mechanically weak and ductile, deforming region of the upper mantle which lies just below the lithosphere.
- The asthenosphere is the main source of magma and it is the layer over which the lithospheric plates/continental plates move (plate tectonics).
- The discontinuity between the **upper mantle and the lower mantle** is known as **Repetti Discontinuity**.
- The portion of the mantle which is just below the lithosphere and asthenosphere, but above the core is called as **Mesosphere**.

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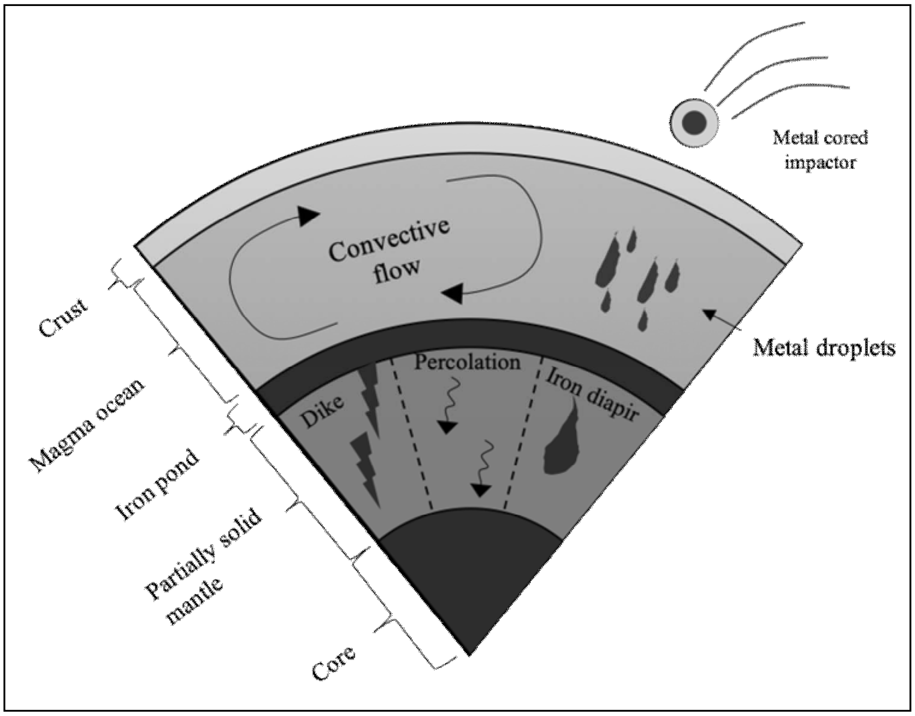

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Fig. 2.4: Earth's Mantle

Core

- It is the innermost layer surrounding the earth's centre.
- The **core is separated from the mantle by Guttenberg's Discontinuity**.
- It is composed mainly of iron (Fe) and nickel (Ni) and hence, it is also called as **NIFE**.
- The core constitutes nearly 15% of earth's volume and 32.5% of earth's mass.
- The core is the densest layer of the earth with its density ranges between 9.5-14.5g/cm^3.
- The Core consists of two sub-layers: the inner core and the outer core.
- The inner core is in solid state and the outer core is in the liquid state (or semi-liquid).
- The discontinuity between the upper core and the lower core is called as **Lehmann Discontinuity**.
- **Barysphere** is sometimes used to refer the core of the earth or sometimes the whole interior.

Temperature, Pressure and Density of the Earth's Interior

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Temperature

- A rise in temperature with increase in depth is observed in mines and deep wells.
- These evidence along with molten lava erupted from the earth's interior supports that the temperature increases towards the centre of the earth.
- The different observations show that the rate of increase of temperature is not uniform from the surface towards the earth's centre. It is faster at some places and slower at other places.
- In the beginning, this rate of increase of temperature is at an average rate of 1°C for every 32 m increase in depth.
- While in the upper 100 kms, the increase in temperature is at the rate of 12°C per km and in the next 300 kms, it is 20°C per km. But going further deep, this rate reduces to mere 10°C per km.
- Thus, it is assumed that the **rate of increase of temperature beneath the surface is decreasing towards the centre** (do not confuse rate of increase of temperature with increase of temperature. **Temperature is always increasing from the earth's surface towards the centre**).
- The temperature at the centre is estimated to lie somewhere between 3000°C and 5000°C, may be that much higher due to the chemical reactions under high-pressure conditions.
- Even in such a high temperature also, the materials at the centre of the earth are in solid state because of the heavy pressure of the overlying materials.

Pressure

- Just like the temperature, the **pressure is also increasing from the surface towards the centre** of the earth.
- It is due to the huge weight of the overlying materials like rocks.
- It is estimated that in the deeper portions, the pressure is tremendously high which will be nearly 3 to 4 million times more than the pressure of the atmosphere at sea level.
- At high temperature, the materials beneath will melt towards the centre part of the earth but due to heavy pressure, these molten materials acquire the properties of a solid and are probably in a plastic state.

Density

- Due to increase in pressure and presence of heavier materials like Nickel and Iron towards the centre, the **density of earth's layers also gets on increasing towards the centre**.

- The average density of the layers gets on increasing from crust to core and it is nearly 14.5g/cm^3 at the very centre.

Check Your Progress

1. Name various layer of earth.
2. What are continents composed of?

2.3 CONTINENTAL DRIFT THEORY OF WEGENER

Continental drift theory was proposed by Alfred Wegener in 1912. It was first put forward by Abraham Ortelius in 1596 before fully being developed by Alfred Wegener. The theory deals with the distribution of the oceans and the continents. According to Wegener's Continental Drift theory, all the continents were one single continental mass (called a Super Continent) – Pangaea and a Mega Ocean surrounded this supercontinent. The mega ocean is known by the name Panthalassa.

Although Wegener's initial theory did not cover mantle convection until Arthur Holmes later proposed the theory. The supercontinent was named Pangaea (Pangea) and the Mega-ocean was called Panthalassa. According to this theory, the supercontinent, Pangaea, began to split some two hundred million years back. Pangaea first split into 2 big continental masses known as Gondwanaland and Laurasia forming the southern and northern modules, respectively. Later, Gondwanaland and Laurasia continued to break into several smaller continents that exist today.

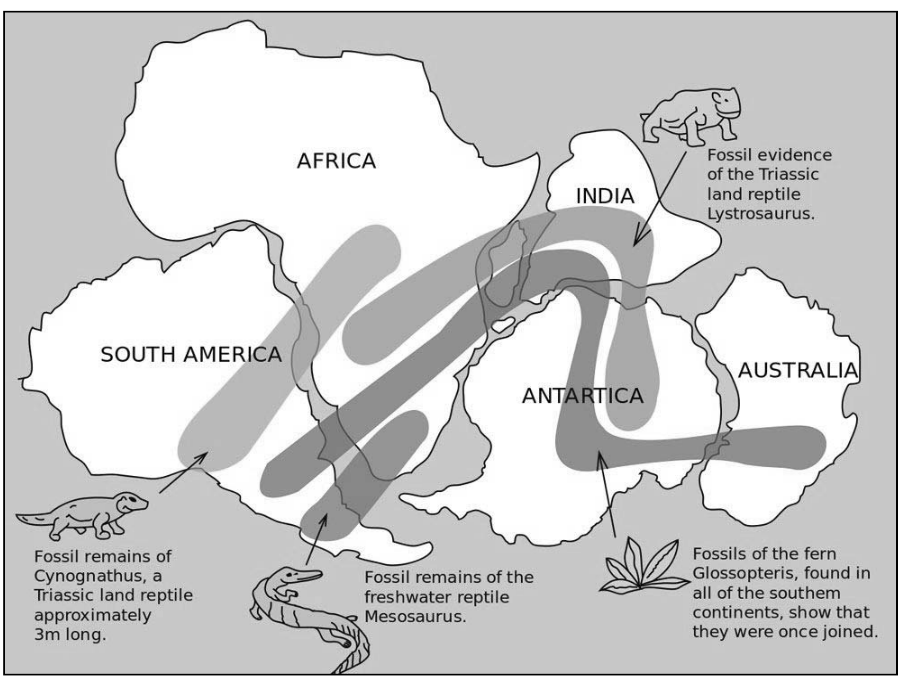

Fig. 2.5: Continental Drift

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2.3.1 Evidences Supporting Continental Drift Theory

1. The Matching of Continents (Jig-Saw-Fit)

- The coastlines of South America and Africa fronting each other have a remarkable and unique match.
- In 1964, Bullard created a map using a computer program to find the right fit of the Atlantic margin and it proved to be quite right.

2. Rocks of the Same Age across the Oceans

- The radiometric dating methods have helped in correlating the formation of rocks present in different continents across the ocean.
- The ancient rocks belts on the coast of Brazil match with those found in Western Africa.
- The old marine deposits found in the coasts of South America and Africa belong to the Jurassic Age. This implies that the ocean never existed before that time.

3. Tillite

- It is the sedimentary rock made from glacier deposits.
- The Gondwana system of sediments from India is recognized as having its counterparts in 6 different landmasses in the Southern Hemisphere.
- Counterparts of this series are found in Madagascar, Africa, Antarctica, Falkland Island, and Australia not to mention India.
- At the base, the system has thick tillite signifying widespread and sustained glaciation.
- Generally, the similarity of the Gondwana type sediments shows that these landmasses had exceptionally similar origins.
- The glacial tillite gives clear evidence for palaeoclimates and the drifting of continents.

4. Placer Deposits

- The presence of abundant placer deposits of gold along the Ghana coast and the complete lack of its source rocks in the area is a phenomenal fact.
- The gold-bearing veins are present in Brazil and it is evident that the gold deposits of Ghana in Africa are obtained from the Brazil plateau from the time when the two continents were beside each other.
- The widespread distribution of Permo-Carboniferous glacial sediments in South America, Africa, Madagascar, Arabia, India, Antarctica, and Australia was one of the major pieces of evidence for the theory of continental drift.
- The continuity of glaciers, inferred from oriented glacial striations and deposits called tillites, suggested the existence of the super continent

of Gondwana, which became a central element of the concept of continental drift.

5. Distribution of Fossils

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- The interpretations that Lemurs occur in India, Africa, and Madagascar led to the theory of a landmass named "Lemuria" connecting these 3 landmasses.
- Mesosaurus was a tiny reptile adapted to shallow brackish water.
- The skeletons of these creatures are found in the Traver formations of Brazil and Southern Cape Province of South Africa.

2.3.2 Forces Behind Continental Drifting According to Wegener

- According to Wegener, the drift was in two directions:
  1. Equator wards due to the interaction of forces of gravity, pole-fleeing force (due to centrifugal force caused by earth's rotation) and buoyancy (*ship floats in water due to buoyant force offered by water*), and
  2. Westwards due to tidal currents because of the earth's motion (earth rotates from west to east, so tidal currents act from east to west, according to Wegener).
- Wegener suggested that tidal force (gravitational pull of the moon and to a lesser extent, the sun) also played a major role.
- The polar-fleeing force relates to the rotation of the earth. Earth is not a perfect sphere; it has a bulge at the equator. This bulge is due to the rotation of the earth (greater centrifugal force at the equator).
- Centrifugal force increases as we move from poles towards the equator. This increase in centrifugal force has led to pole fleeing, according to Wegener.
- Tidal force is due to the attraction of the moon and the sun that develops tides in oceanic waters (tides explained in detail in oceanography).
- According to Wegener, these forces would become effective when applied over many million years, and the drift is continuing.

Evidence for Continental Drift

Other than the manner in which the landmasses fit together, Wegener and his allies gathered a lot of proof for the mainland float theory:

- Identical rocks, of a similar sort and age, are found on the two sides of the Atlantic Ocean. Wegener said the stones had framed next to each other and that the land had since moved separated.
- Mountain ranges with a similar stone sorts, designs, and ages are currently on inverse sides of the Atlantic Ocean. The Appalachians of the eastern United States and Canada, for instance, are very much like

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mountain ranges in eastern Greenland, Ireland, Great Britain, and Norway. Wegener presumed that they framed as a solitary mountain range that was isolated as the landmasses floated.

Fig. 2.6: Plate Tectonics Theory

The similarities between the Appalachian and the Eastern Greenland Mountain ranges are Evidences for the Continental Drift Hypothesis:

- Ancient fossils of the same species of extinct plants and animals are found in rocks of the same age but are on continents that are now widely separated. Wegener proposed that the organisms had lived side by side, but that the lands had moved apart after they were dead and fossilized. He suggested that the organisms would not have been able to travel across the oceans:
  - Fossils of the seed fern Glossopteris were too heavy to be carried so far by wind.
  - Mesosaurus was a swimming reptile but could only swim in fresh water.
  - Cynognathus and Lystrosaurus were land reptiles and were unable to swim

Wegener used Fossil Evidence to Support His Continental Drift Hypothesis. The Fossils of These Organisms are Found on Lands that are Now Far Apart.

- Grooves and rock stores left by old glacial masses are discovered today on various landmasses near the equator. This would show that the ice sheets either shaped in the sea and additionally covered the vast majority of the Earth. Today icy masses just structure ashore and closer the shafts. Wegener imagined that the ice sheets were focused over the southern land mass near the South Pole and the mainlands moved to their current positions later on.
- Coral reefs and coal-shaping marshes are found in tropical and subtropical conditions, however old coal creases and coral reefs are found in areas where today is excessively cold. Wegener recommended that these animals were alive in warm environment zones and that the fossils and coal later had floated to new areas on the landmasses.

Check Your Progress

3. __________ is the sedimentary rock made from glacier deposits.
4. Centrifugal force __________ as we move from poles towards the equator.

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2.4 PLATE TECTONICS

Plate tectonics, theory dealing with the dynamics of earth's outer shell — the lithosphere—that revolutionized Earth sciences by providing a uniform context for understanding mountain-building processes, volcanoes, and earthquakes as well as the evolution of earth's surface and reconstructing its past continents and oceans.

2.4.1 The Concept of Plate Tectonics

The concept of plate tectonics was formulated in the 1960s. According to the theory, Earth has a rigid outer layer, known as the lithosphere, which is typically about 100 km (60 miles) thick and overlies a plastic (moldable, partially molten) layer called the asthenosphere. The lithosphere is broken up into seven very large continental and ocean-sized plates, six or seven medium-sized regional plates, and several small ones. These plates move relative to each other, typically at rates of 5 to 10 cm (2 to 4 inches) per year, and interact along their boundaries, where they converge, diverge, or slip past one another. Such interactions are thought to be responsible for most of earth's seismic and volcanic activity, although earthquakes and volcanoes can occur in plate interiors. Plate motions cause mountains to rise where plates push together, or converge, and continents to fracture and oceans to form where plates pull apart, or diverge. The continents are embedded in the plates and drift passively with them, which over millions of years results in significant changes in earth's geography.

The theory of plate tectonics is based on a broad synthesis of geologic and geophysical data. It is now almost universally accepted, and its adoption represents a true scientific revolution, analogous in its consequences to quantum mechanics in physics or the discovery of the genetic code in biology. Incorporating the much older idea of continental drift, as well as the concept of seafloor spreading, the theory of plate tectonics has provided an overarching framework in which to describe the past geography of continents and oceans, the processes controlling creation and destruction of landforms, and the evolution of earth's crust, atmosphere, biosphere, hydrosphere, and climates. During the late 20th and early 21st centuries, it became apparent that plate-tectonic processes profoundly influence the composition of earth's atmosphere and oceans, serve as a prime cause of long-term climate change, and make significant contributions to the chemical and physical environment in which life evolves.

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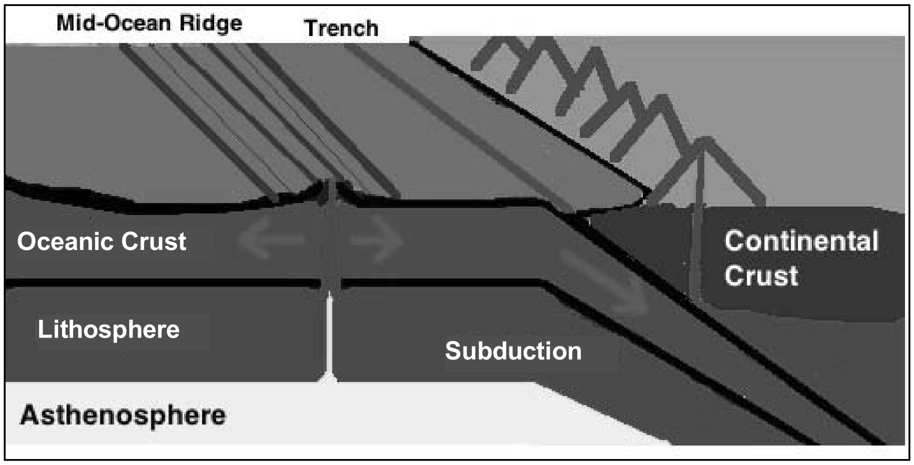

Source: commons.wikimedia.org

Fig. 2.7: Plate Tectonics Basics

There is assortment of proof that upholds the cases that plate tectonics represents: (1) the circulation of fossils on various mainlands, (2) the event of tremors, and (3) mainland and sea depths highlights including mountains, volcanoes, blames, and channels:

1. The mainlands fit together practically like interconnecting pieces shaping Pangaea (one super-landmass).
2. Fossils on various landmasses are like fossils on mainlands that were once associated. At the point when the mainlands split, diverse living things created.
3. Most mainland and maritime floor highlights are the consequence of topographical action and seismic tremors along plate limits. The specific examples rely upon whether the plates are meeting (being pushed together) to make mountains or profound sea channels, (separating) being pulled separated to shape new sea floor at mid-sea edges, or sliding past one another along surface flaws.
4. Most conveyances of rocks inside Earth's outside layer, including minerals, petroleum derivatives, and energy assets, are an immediate consequence of the historical backdrop of plate movements and impacts and the comparing changes in the designs of the mainlands and sea bowls.

   The history is as yet being composed. Landmasses are ceaselessly being molded and reshaped by contending useful and damaging topographical cycles.

Plate tectonics is the generally accepted scientific theory that considers the Earth's lithosphere to comprise a number of large tectonic plates which have been slowly moving since about 3.4 billion years ago. The model builds on the concept of continental drift, an idea developed during the first decades of the 20th century. Plate-tectonics came to be generally accepted by geoscientists after seafloor spreading was validated in the mid to late 1960s.

Earth's lithosphere, which is the rigid outermost shell of a planet (the crust and upper mantle), is broken into seven or eight major plates (depending on how they are defined) and many minor plates. Where the plates meet, their relative motion determines the type of boundary: convergent, divergent, or transform. Earthquakes, volcanic activity, mountain-building, and oceanic trench formation occur along these plate boundaries (or faults). The relative movement of the plates typically ranges from zero to 10 cm annually.

Tectonic plates are composed of the oceanic lithosphere and the thicker continental lithosphere, each topped by its own kind of crust. Along convergent boundaries, the process of subduction, or one plate moving under another, carries the edge of the lower one down into the mantle; the area of material lost is roughly balanced by the formation of new (oceanic) crust along divergent margins by seafloor spreading. In this way, the total geoid surface area of the lithosphere remains constant. This prediction of plate tectonics is also referred to as the conveyor belt principle. Earlier theories, since disproven, proposed gradual shrinking (contraction) or gradual expansion of the globe.

Tectonic plates are able to move because Earth's lithosphere has greater mechanical strength than the underlying asthenosphere. Lateral density variations in the mantle result in convection; that is, the slow creeping motion of Earth's solid mantle. Plate movement is thought to be driven by a combination of the motion of the seafloor away from spreading ridges due to variations in topography (the ridge is a topographic high) and density changes in the crust (density increases as newly-formed crust cools and moves away from the ridge). At subduction zones the relatively cold, dense oceanic crust is "pulled" or sinks down into the mantle over the downward convecting limb of a mantle cell. The relative importance of each of these factors and their relationship to each other is unclear, and still the subject of much debate.

Types of Plate Boundaries

Three types of plate boundaries exist, with a fourth, mixed type, characterized by the way the plates move relative to each other. They are associated with different types of surface phenomena. The different types of plate boundaries are: Divergent boundary, Convergent boundary and Transform boundary:

1. **Convergent boundaries** (destructive boundaries or active margins) occur where two plates slide toward each other to form either a subduction zone (one plate moving underneath the other) or a continental collision. At zones of ocean-to-continent subduction (e.g. the Andes mountain range in South America, and the Cascade Mountains in Western United States), the dense oceanic lithosphere plunges beneath the less dense continent. Earthquakes trace the path of the downward-moving plate as it descends into asthenosphere, a trench forms, and as the subducted plate is heated it releases volatiles, mostly water from hydrous minerals, into the surrounding mantle. The addition of water lowers the melting point of the mantle material above the subducting slab, causing it to melt. The magma that results typically leads to volcanism. At zones of ocean-to-ocean subduction

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(e.g. the Aleutian Islands, the Mariana Islands, and the Japanese island arc), older, cooler, denser crust slips beneath less dense crust. This motion causes earthquakes and a deep trench to form in an arc shape. The upper mantle of the subducted plate then heats and magma rises to form curving chains of volcanic islands. Deep marine trenches are typically associated with subduction zones, and the basins that develop along the active boundary are often called "foreland basins". Closure of ocean basins can occur at continent-to-continent boundaries (e.g., Himalayas and Alps): collision between masses of granitic continental lithosphere; neither mass is subducted; plate edges are compressed, folded, uplifted.

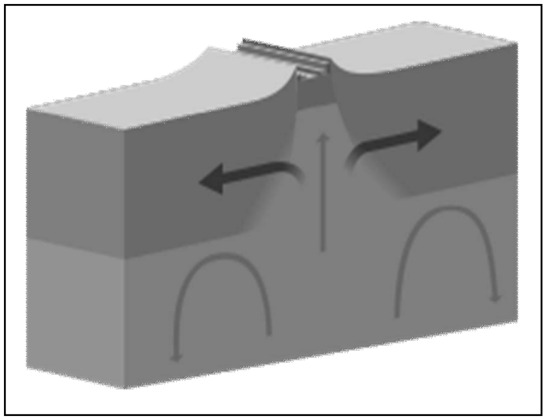

Fig. 2.8: Divergent Boundary

2. **Convergent boundaries** (destructive boundaries or active margins) occur where two plates slide toward each other to form either a subduction zone (one plate moving underneath the other) or a continental collision. At zones of ocean-to-continent subduction (e.g. the Andes mountain range in South America, and the Cascade Mountains in Western United States), the dense oceanic lithosphere plunges beneath the less dense continent. Earthquakes trace the path of the downward-moving plate as it descends into asthenosphere, a trench forms, and as the subducted plate is heated it releases volatiles, mostly water from hydrous minerals, into the surrounding mantle. The addition of water lowers the melting point of the mantle material above the subducting slab, causing it to melt. The magma that results typically leads to volcanism. At zones of ocean-to-ocean subduction (e.g. the Aleutian Islands, the Mariana Islands, and the Japanese island arc), older, cooler, denser crust slips beneath less dense crust. This motion causes earthquakes and a deep trench to form in an arc shape. The upper mantle of the subducted plate then heats and magma rises to form curving chains of volcanic islands. Deep marine trenches are typically associated with subduction zones, and the basins that develop along the active boundary are often called "foreland basins". Closure of ocean basins can occur at continent-to-continent boundaries (e.g., Himalayas and Alps): collision between masses of

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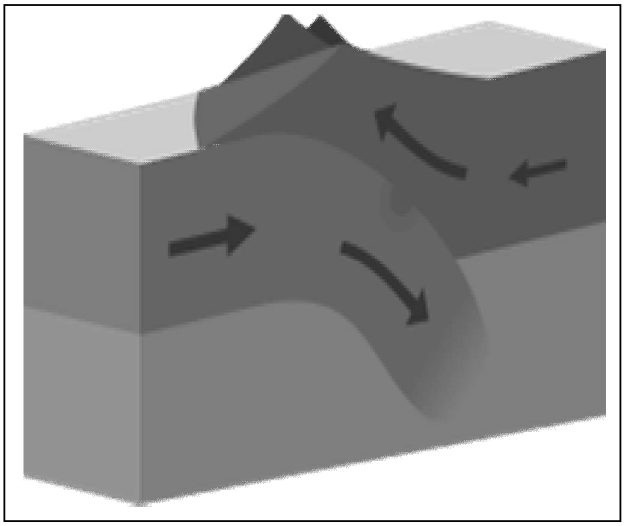

Fig. 2.9: Convergent Boundary

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3. **Transform boundaries** (conservative boundaries or strike-slip boundaries) occur where two lithospheric plates slide, or perhaps more accurately, grind past each other along transform faults, where plates are neither created nor destroyed. The relative motion of the two plates is either sinistral (left side toward the observer) or dextral (right side toward the observer). Transform faults occur across a spreading center. Strong earthquakes can occur along a fault. The San Andreas Fault in California is an example of a transform boundary exhibiting dextral motion.

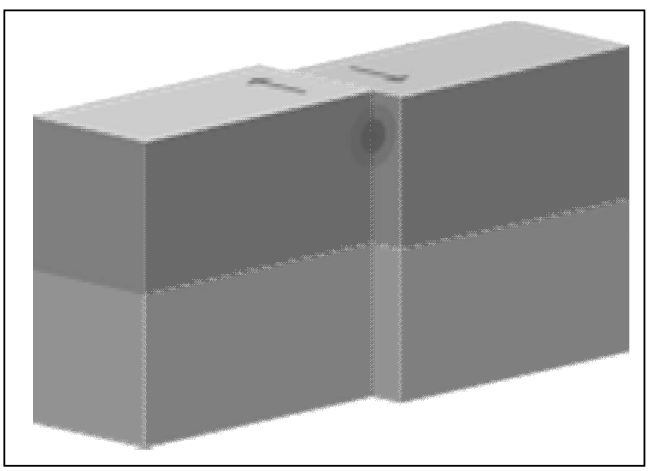

Fig. 2.10: Transform Boundary

4. **Plate boundary** zones occur where the effects of the interactions are unclear, and the boundaries, usually occurring along a broad belt, are not well defined and may show various types of movements in different episodes.

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Driving Forces of Plate Motion

It has generally been accepted that tectonic plates are able to move because of the relative density of oceanic lithosphere and the relative weakness of the asthenosphere. Dissipation of heat from the mantle is acknowledged to be the original source of the energy required to drive plate tectonics through convection or large scale upwelling and doming. The current view, though still a matter of some debate, asserts that as a consequence, a powerful source generating plate motion is the excess density of the oceanic lithosphere sinking in subduction zones. When the new crust forms at mid-ocean ridges, this oceanic lithosphere is initially less dense than the underlying asthenosphere, but it becomes denser with age as it conductively cools and thickens. The greater density of old lithosphere relative to the underlying asthenosphere allows it to sink into the deep mantle at subduction zones, providing most of the driving force for plate movement. The weakness of the asthenosphere allows the tectonic plates to move easily towards a subduction zone.

Although subduction is thought to be the strongest force driving plate motions, it cannot be the only force since there are plates such as the North American Plate which are moving, yet are nowhere being subducted. The same is true for the enormous Eurasian Plate. The sources of plate motion are a matter of intensive research and discussion among scientists. One of the main points is that the kinematic pattern of the movement itself should be separated clearly from the possible geodynamic mechanism that is invoked as the driving force of the observed movement, as some patterns may be explained by more than one mechanism. In short, the driving forces advocated at the moment can be divided into three categories based on the relationship to the movement: mantle dynamics related, gravity related (main driving force accepted nowadays), and earth rotation related.

Driving Forces Related to Mantle Dynamics

For much of the last quarter century, the leading theory of the driving force behind tectonic plate motions envisaged large scale convection currents in the upper mantle, which can be transmitted through the asthenosphere. This theory was launched by Arthur Holmes and some forerunners in the 1930s and was immediately recognized as the solution for the acceptance of the theory as originally discussed in the papers of Alfred Wegener in the early years of the century. However, despite its acceptance, it was long debated in the scientific community because the leading theory still envisaged a static Earth without moving continents up until the major breakthroughs of the early sixties.

Two- and three-dimensional imaging of Earth’s interior (seismic tomography) shows a varying lateral density distribution throughout the mantle. Such density variations can be material (from rock chemistry), mineral (from variations in mineral structures), or thermal (through thermal expansion and contraction from heat energy). The manifestation of this varying lateral density is mantle convection from buoyancy forces.

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How mantle convection directly and indirectly relates to plate motion is a matter of ongoing study and discussion in geodynamics. Somehow, this energy must be transferred to the lithosphere for tectonic plates to move. There are essentially two main types of forces that are thought to influence plate motion: friction and gravity.

Basal drag (friction): Plate motion driven by friction between the convection currents in the asthenosphere and the more rigid overlying lithosphere.

Slab suction (gravity): Plate motion driven by local convection currents that exert a downward pull on plates in subduction zones at ocean trenches. Slab suction may occur in a geodynamic setting where basal tractions continue to act on the plate as it dives into the mantle (although perhaps to a greater extent acting on both the under and upper side of the slab).

Lately, the convection theory has been much debated, as modern techniques based on 3D seismic tomography still fail to recognize these predicted large scale convection cells. Alternative views have been proposed.

Plume Tectonics

In the theory of plume tectonics followed by numerous researchers during the 1990s, a modified concept of mantle convection currents is used. It asserts that super plumes rise from the deeper mantle and are the drivers or substitutes of the major convection cells. These ideas find their roots in the early 1930s in the works of Beloussov and van Bemmelen, which were initially opposed to plate tectonics and placed the mechanism in a fixistic frame of verticalistic movements. Van Bemmelen later on modulated on the concept in his "Undulation Models" and used it as the driving force for horizontal movements, invoking gravitational forces away from the regional crustal doming. The theories find resonance in the modern theories which envisage hot spots or mantle plumes which remain fixed and are overridden by oceanic and continental lithosphere plates over time and leave their traces in the geological record (though these phenomena are not invoked as real driving mechanisms, but rather as modulators).

The mechanism is still advocated to explain the break-up of supercontinents during specific geological epochs. It has followers amongst the scientists involved in the theory of Earth expansion.

Surge Tectonics

Another theory is that the mantle flows neither in cells nor large plumes but rather as a series of channels just below Earth's crust, which then provide basal friction to the lithosphere. This theory, called "surge tectonics", was popularized during the 1980s and 1990s. Recent research, based on three-dimensional computer modeling, suggests that plate geometry is governed by a feedback between mantle convection patterns and the strength of the lithosphere.

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Driving Forces Related to Gravity

Forces related to gravity are invoked as secondary phenomena within the framework of a more general driving mechanism such as the various forms of mantle dynamics described above. In modern views, gravity is invoked as the major driving force, through slab pull along subduction zones.

Gravitational sliding away from a spreading ridge: According to many authors, plate motion is driven by the higher elevation of plates at ocean ridges. As oceanic lithosphere is formed at spreading ridges from hot mantle material, it gradually cools and thickens with age (and thus adds distance from the ridge). Cool oceanic lithosphere is significantly denser than the hot mantle material from which it is derived and so with increasing thickness it gradually subsides into the mantle to compensate the greater load. The result is a slight lateral incline with increased distance from the ridge axis.

This force is regarded as a secondary force and is often referred to as "ridge push". This is a misnomer as nothing is "pushing" horizontally and tensional features are dominant along ridges. It is more accurate to refer to this mechanism as gravitational sliding as variable topography across the totality of the plate can vary considerably and the topography of spreading ridges is only the most prominent feature. Other mechanisms generating this gravitational secondary force include flexural bulging of the lithosphere before it dives underneath an adjacent plate which produces a clear topographical feature that can offset, or at least affect, the influence of topographical ocean ridges, and mantle plumes and hot spots, which are postulated to impinge on the underside of tectonic plates.

Slab-pull: Current scientific opinion is that the asthenosphere is insufficiently competent or rigid to directly cause motion by friction along the base of the lithosphere. Slab pull is therefore most widely thought to be the greatest force acting on the plates. In this current understanding, plate motion is mostly driven by the weight of cold, dense plates sinking into the mantle at trenches. Recent models indicate that trench suction plays an important role as well. However, the fact that the North American Plate is nowhere being subducted, although it is in motion, presents a problem. The same holds for the African, Eurasian, and Antarctic plates.

Gravitational sliding away from mantle doming: According to older theories, one of the driving mechanisms of the plates is the existence of large scale asthenosphere/mantle domes which cause the gravitational sliding of lithosphere plates away from them (see the paragraph on Mantle Mechanisms). This gravitational sliding represents a secondary phenomenon of this basically vertically oriented mechanism. It finds its roots in the Undation Model of van Bemmelen. This can act on various scales, from the small scale of one island arc up to the larger scale of an entire ocean basin.

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Driving Forces Related to Earth Rotation

Alfred Wegener, being a meteorologist, had proposed tidal forces and centrifugal forces as the main driving mechanisms behind continental drift; however, these forces were considered far too small to cause continental motion as the concept was of continents plowing through oceanic crust. Therefore, Wegener later changed his position and asserted that convection currents are the main driving force of plate tectonics in the last edition of his book in 1929.

However, in the plate tectonics context (accepted since the seafloor spreading proposals of Heezen, Hess, Dietz, Morley, Vine, and Matthews see below during the early 1960s), the oceanic crust is suggested to be in motion with the continents which caused the proposals related to Earth rotation to be reconsidered. In more recent literature, these driving forces are:

Tidal drag due to the gravitational force the Moon (and the Sun) exerts on the crust of Earth.

Global deformation of the geoid due to small displacements of the rotational pole with respect to Earth's crust.

Other smaller deformation effects of the crust due to wobbles and spin movements of Earth's rotation on a smaller timescale.

Forces that are small and generally negligible are:

The Coriolis Force

The centrifugal force, which is treated as a slight modification of gravity.

For these mechanisms to be overall valid, systematic relationships should exist all over the globe between the orientation and kinematics of deformation and the geographical latitudinal and longitudinal grid of Earth itself. These systematic relations studies in the second half of the nineteenth century and the first half of the twentieth century underline exactly the opposite: that the plates had not moved in time, that the deformation grid was fixed with respect to Earth's equator and axis, and that gravitational driving forces were generally acting vertically and caused only local horizontal movements (the so-called pre-plate tectonic, "fixist theories"). Later studies (discussed below on this page), therefore, invoked many of the relationships recognized during this pre-plate tectonics period to support their theories (see the anticipations and reviews in the work of van Dijk and collaborators).

Of the many forces discussed in this paragraph, tidal force is still highly debated and defended as a possible principal driving force of plate tectonics. The other forces are only used in global geodynamic models not using plate tectonics concepts (therefore beyond the discussions treated in this section) or proposed as minor modulations within the overall plate tectonics model.

In 1973, George W. Moore of the USGS and R.C. Bostrom presented evidence for a general westward drift of Earth's lithosphere with respect to the mantle. He concluded that tidal forces (the tidal lag or "friction") caused by Earth's rotation and the forces acting upon it by the Moon are a driving force for plate tectonics. As Earth spins eastward beneath the Moon, the Moon's gravity ever so slightly pulls Earth's surface layer back westward, just as proposed by Alfred Wegener (see above). In a more recent 2006 study, scientists reviewed and advocated these earlier proposed ideas. It has also been suggested recently in Lovett (2006) that this observation may also explain why Venus and Mars have no plate tectonics, as Venus has no moon and Mars' moons are too small to have significant tidal effects on the planet. In a recent paper, it was suggested that, on the other hand, it can easily be observed that many plates are moving north and eastward, and that the dominantly westward motion of the Pacific Ocean basins derives simply from the eastward bias of the Pacific spreading center (which is not a predicted manifestation of such lunar forces). In the same paper the authors admit, however, that relative to the lower mantle, there is a slight westward component in the motions of all the plates. They demonstrated though that the westward drift, seen only for the past 30 Ma, is attributed to the increased dominance of the steadily growing and accelerating Pacific plate. The debate is still open.

Relative Significance of each Driving Force Mechanism

The vector of a plate's motion is a function of all the forces acting on the plate; however, therein lies the problem regarding the degree to which each process contributes to the overall motion of each tectonic plate.

The diversity of geodynamic settings and the properties of each plate result from the impact of the various processes actively driving each individual plate. One method of dealing with this problem is to consider the relative rate at which each plate is moving as well as the evidence related to the significance of each process to the overall driving force on the plate.

One of the most significant correlations discovered to date is that lithospheric plates attached to down going (subducting) plates move much faster than plates not attached to subducting plates. The Pacific plate, for instance, is essentially surrounded by zones of subduction (the so-called Ring of Fire) and moves much faster than the plates of the Atlantic basin, which are attached (perhaps one could say 'welded') to adjacent continents instead of subducting plates. It is thus thought that forces associated with the downgoing plate (slab pull and slab suction) are the driving forces which determine the motion of plates, except for those plates which are not being subducted. This view however has been contradicted by a recent study which found that the actual motions of the Pacific Plate and other plates associated with the East Pacific Rise do not correlate mainly with either slab pull or slab push, but rather with a mantle convection upwelling whose horizontal spreading along the bases of the various plates drives them along via viscosity-related traction forces. The driving forces of plate motion continue to be active subjects of on-going research within geophysics and tectonophysics.

2.4.2 Principles of Plate Tectonics

In essence, plate-tectonic theory is elegantly simple. Earth's surface layer, 50 to 100 km (30 to 60 miles) thick, is rigid and is composed of a set of large and small plates. Together, these plates constitute the lithosphere, from the Greek *lithos*, meaning "rock." The lithosphere rests on and slides over an underlying partially molten (and thus weaker but generally denser) layer of plastic partially molten rock known as the asthenosphere, from the Greek *asthenos*, meaning "weak." Plate movement is possible because the lithosphere-asthenosphere boundary is a zone of detachment. As the lithospheric plates move across earth's surface, driven by forces as yet not fully understood, they interact along their boundaries, diverging, converging, or slipping past each other. While the interiors of the plates are presumed to remain essentially undeformed, plate boundaries are the sites of many of the principal processes that shape the terrestrial surface, including earthquakes, volcanism, and orogeny (that is, formation of mountain ranges).

The process of plate tectonics may be driven by convection in earth's mantle, the pull of heavy old pieces of crust into the mantle, or some combination of both.

2.4.3 Plate Boundaries

Lithospheric plates are much thicker than oceanic or continental crust. Their boundaries do not usually coincide with those between oceans and continents, and their behaviour is only partly influenced by whether they carry oceans, continents, or both. The Pacific Plate, for example, is entirely oceanic, whereas the North American Plate is capped by continental crust in the west (the North American continent) and by oceanic crust in the east and extends under the Atlantic Ocean as far as the Mid-Atlantic Ridge.

In a simplified example of plate motion shown in the figure, movement of plate A to the left relative to plates B and C results in several types of simultaneous interactions along the plate boundaries. At the rear, plates A and B move apart, or diverge, resulting in extension and the formation of a divergent margin. At the front, plates A and B overlap, or converge, resulting in compression and the formation of a convergent margin. Along the sides, the plates slide past one another, a process called shear. As these zones of shear link other plate boundaries to one another, they are called transform faults.

Divergent Margins

As plates move apart at a divergent plate boundary, the release of pressure produces partial melting of the underlying mantle. This molten material, known as magma, is basaltic in composition and is buoyant. As a result, it wells up from below and cools close to the surface to generate new crust. Because new crust is formed, divergent margins are also called constructive margins.

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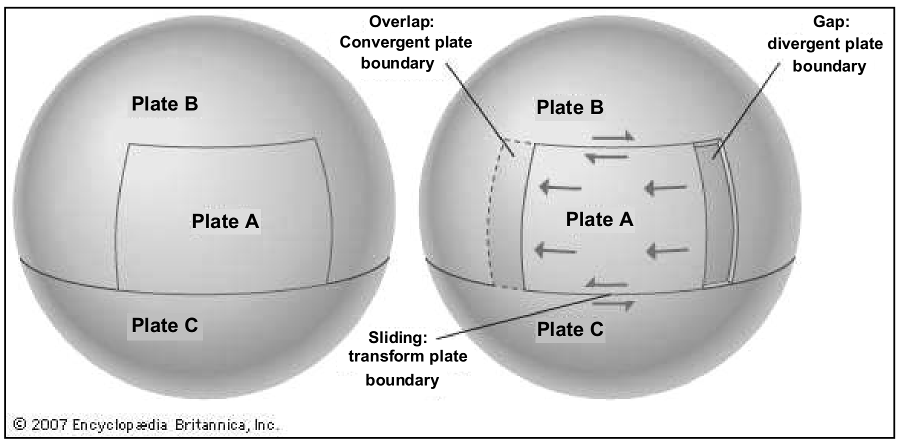
Continental Rifting

Upwelling of magma causes the overlying lithosphere to uplift and stretch. (Whether magmatism [the formation of igneous rock from magma] initiates the rifting or whether rifting decompresses the mantle and initiates magmatism is a matter of significant debate.) If the diverging plates are capped by continental crust, fractures develop that are invaded by the ascending magma, prying the continents farther apart. Settling of the continental blocks creates a rift valley, such as the present-day East African Rift Valley. As the rift continues to widen, the continental crust becomes progressively thinner until separation of the plates is achieved and a new ocean is created. The ascending partial melt cools and crystallizes to form new crust. Because the partial melt is basaltic in composition, the new crust is oceanic, and an ocean ridge develops along the site of the former continental rift. Consequently, diverging plate boundaries, even if they originate within continents, eventually come to lie in ocean basins of their own making.



Source: geologyin.com

Fig. 2.11: Continental Rifting

Seafloor Spreading

As upwelling of magma continues, the plates continue to diverge, a process known as seafloor spreading. Samples collected from the ocean floor show that the age of oceanic crust increases with distance from the spreading centre—important evidence in favour of this process. These age data also allow the rate of seafloor spreading to be determined, and they show that rates vary from about 0.1 cm (0.04 inch) per year to 17 cm (6.7 inches) per year. Seafloor-spreading rates are much more rapid in the Pacific Ocean than in the Atlantic and Indian oceans. At spreading rates of about 15 cm (6 inches) per year, the entire crust beneath the Pacific Ocean (about 15,000 km [9,300 miles] wide) could be produced in 100 million years.

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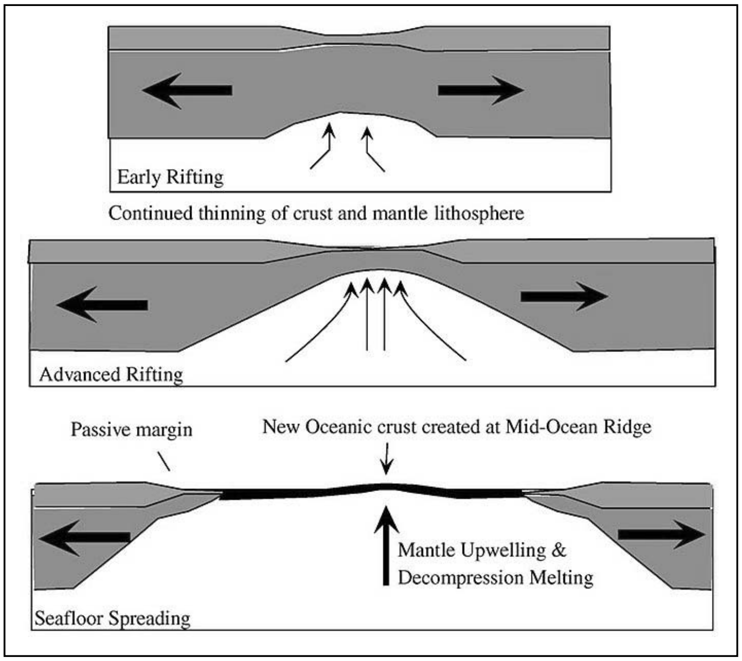


Fig. 2.12: Seafloor Spreading

Divergence and creation of oceanic crust are accompanied by much volcanic activity and by many shallow earthquakes as the crust repeatedly rifts, heals, and rifts again. Brittle earthquake-prone rocks occur only in the shallow crust. Deep earthquakes, in contrast, occur less frequently, due to the high heat flow in the mantle rock. These regions of oceanic crust are swollen with heat and so are elevated by 2 to 3 km (1.2 to 1.9 miles) above the surrounding seafloor. The elevated topography results in a feedback scenario in which the resulting gravitational force pushes the crust apart, allowing new magma to well up from below, which in turn sustains the elevated topography. Its summits are typically 1 to 5 km (0.6 to 3.1 miles) below the ocean surface. On a global scale, these ridges form an interconnected system of undersea "mountains" that are about 65,000 km (40,000 miles) in length and are called oceanic ridges.

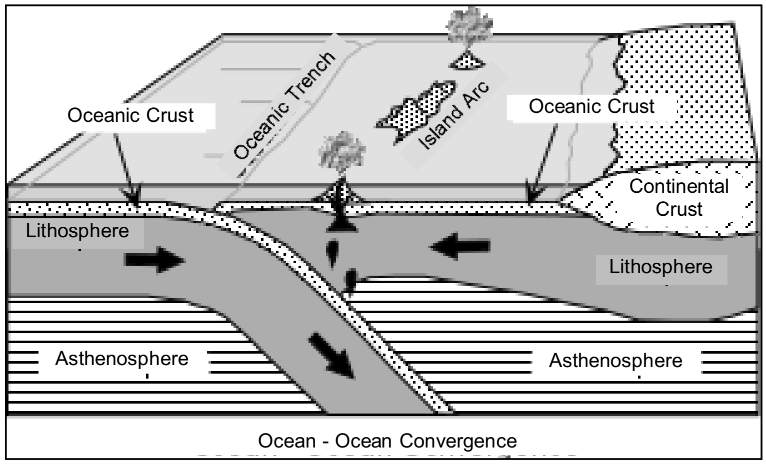
Convergent Margins

Given that Earth is constant in volume, the continuous formation of earth's new crust produces an excess that must be balanced by destruction of crust elsewhere. This is accomplished at convergent plate boundaries, also known as destructive plate boundaries, where one plate descends at an angle — that is, is subducted — beneath the other.

Because oceanic crust cools as it ages, it eventually becomes denser than the underlying asthenosphere, and so it has a tendency to subduct, or dive under, adjacent continental plates or younger sections of oceanic crust. The life span of the oceanic crust is prolonged by its rigidity, but eventually this resistance is overcome. Experiments show that the subducted oceanic lithosphere is denser than the surrounding mantle to a depth of at least 600 km (about 400 miles).

NOTES

The mechanisms responsible for initiating subduction zones are controversial. During the late 20th and early 21st centuries, evidence emerged supporting the notion that subduction zones preferentially initiate along preexisting fractures (such as transform faults) in the oceanic crust. Irrespective of the exact mechanism, the geologic record indicates that the resistance to subduction is overcome eventually.



Source: Wikipedia.org

Fig. 2.13: Convergent Margins

Where two oceanic plates meet, the older, denser plate is preferentially subducted beneath the younger, warmer one. Where one of the plate margins is oceanic and the other is continental, the greater buoyancy of continental crust prevents it from sinking, and the oceanic plate is preferentially subducted. Continents are preferentially preserved in this manner relative to oceanic crust, which is continuously recycled into the mantle. This explains why ocean floor rocks are generally less than 200 million years old whereas the oldest continental rocks are more than 4 billion years old. Before the middle of the 20th century, most geoscientists maintained that continental crust was too buoyant to be subducted. However, it later became clear that slivers of continental crust adjacent to the deep-sea trench, as well as sediments deposited in the trench, may be dragged down the subduction zone. The recycling of this material is detected in the chemistry of volcanoes that erupt above the subduction zone.

Two plates carrying continental crust collide when the oceanic lithosphere between them has been eliminated. Eventually, subduction ceases and towering mountain ranges, such as the Himalayas, are created.

Because the plates form an integrated system, it is not necessary that new crust formed at any given divergent boundary be completely compensated at the nearest subduction zone, as long as the total amount of crust generated equals that destroyed.

Subduction Zones

The subduction process involves the descent into the mantle of a slab of cold hydrated oceanic lithosphere about 100 km (60 miles) thick that carries a

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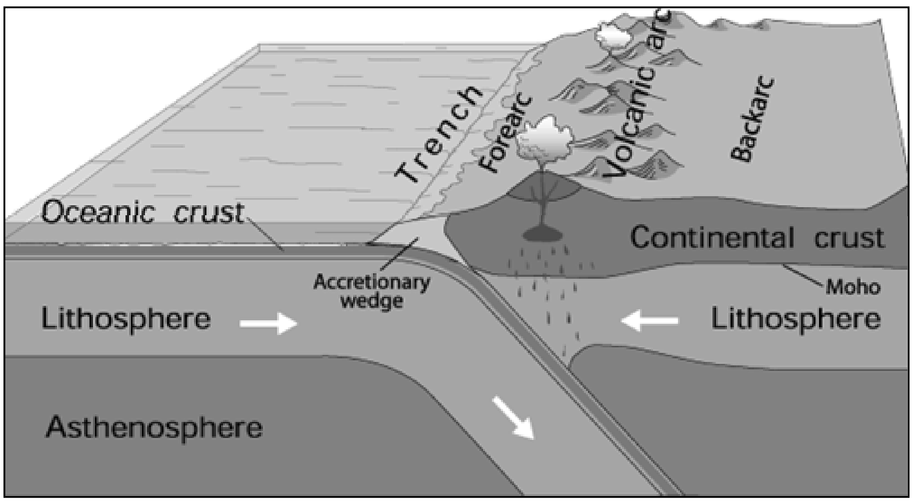
relatively thin cap of oceanic sediments. The path of descent is defined by numerous earthquakes along a plane that is typically inclined between 30° and 60° into the mantle and is called the Wadati-Benioff zone, for Japanese seismologist Kiyoo Wadati and American seismologist Hugo Benioff, who pioneered its study. Between 10 and 20 percent of the subduction zones that dominate the circum-Pacific ocean basin are subhorizontal (that is, they subduct at angles between 0° and 20°). The factors that govern the dip of the subduction zone are not fully understood, but they probably include the age and thickness of the subducting oceanic lithosphere and the rate of plate convergence.

Most, but not all, earthquakes in this planar dipping zone result from compression, and the seismic activity extends 300 to 700 km (200 to 400 miles) below the surface, implying that the subducted crust retains some rigidity to this depth. At greater depths the subducted plate is partially recycled into the mantle.



Source: Wikipedia.org

Fig. 2.14: Subduction Zones of Earth

The site of subduction is marked by a deep trench, between 5 and 11 km (3 and 7 miles) deep, that is produced by frictional drag between the plates as the descending plate bends before it subducts. The overriding plate scrapes sediments and elevated portions of ocean floor off the upper crust of the lower plate, creating a zone of highly deformed rocks within the trench that becomes attached, or accreted, to the overriding plate. This chaotic mixture is known as an accretionary wedge.

The rocks in the subduction zone experience high pressures but relatively low temperatures, an effect of the descent of the cold oceanic slab. Under these conditions the rocks recrystallize, or metamorphose, to form a suite of rocks known as blueschists, named for the diagnostic blue mineral called glaucophane, which is stable only at the high pressures and low temperatures found in subduction zones. At deeper levels in the subduction zone (that is, greater than 30–35 km [about 19–22 miles]), eclogites, which consist of high-pressure minerals such as red garnet (pyrope) and omphacite (pyroxene), form.

The formation of eclogite from blueschist is accompanied by a significant increase in density and has been recognized as an important additional factor that facilitates the subduction process.

NOTES

Check Your Progress

5. Plate tectonics deals with __________.
6. The theory of plate tectonics is based on a broad synthesis of __________ and __________ data.
7. What does subduction process involves in?
8. Upwelling of magma causes the overlying lithosphere to __________ and __________.

2.5 EARTH'S LAYERS

Knowledge of earth's interior is derived primarily from analysis of the seismic waves that propagate through Earth as a result of earthquakes. Depending on the material they travel through, the waves may either speed up, slow down, bend, or even stop if they cannot penetrate the material they encounter.

Collectively, these studies show that Earth can be internally divided into layers on the basis of either gradual or abrupt variations in chemical and physical properties. Chemically, Earth can be divided into three layers. A relatively thin crust, which typically varies from a few kilometres to 40 km (about 25 miles) in thickness, sits on top of the mantle. (In some places, earth's crust may be up to 70 km [40 miles] thick.) The mantle is much thicker than the crust; it contains 83 percent of earth's volume and continues to a depth of 2,900 km (1,800 miles). Beneath the mantle is the core, which extends to the centre of Earth, some 6,370 km (nearly 4,000 miles) below the surface. Geologists maintain that the core is made up primarily of metallic iron accompanied by smaller amounts of nickel, cobalt, and lighter elements, such as carbon and sulfur.

There are two types of crust, continental and oceanic, which differ in their composition and thickness. The distribution of these crustal types broadly coincides with the division into continents and ocean basins, although continental shelves, which are submerged, are underlain by continental crust. The continents have a crust that is broadly granitic in composition and, with a density of about 2.7 grams per cubic cm (0.098 pound per cubic inch), is somewhat lighter than oceanic crust, which is basaltic (i.e., richer in iron and magnesium than granite) in composition and has a density of about 2.9 to 3 grams per cubic cm (0.1 to 0.11 pound per cubic inch). Continental crust is typically 40 km (25 miles) thick, while oceanic crust is much thinner, averaging about 6 km (4 miles) in thickness.

These crustal rocks both sit on top of the mantle, which is ultramafic in composition (i.e., very rich in magnesium and iron-bearing silicate minerals).

The boundary between the crust (continental or oceanic) and the underlying mantle is known as the Mohorovicic discontinuity (also called Moho), which is named for its discoverer, Croatian seismologist Andrija Mohorovičić. The Moho is clearly defined by seismic studies, which detect an acceleration in seismic waves as they pass from the crust into the denser mantle. The boundary between the mantle and the core is also clearly defined by seismic studies, which suggest that the outer part of the core is a liquid.

The effect of the different densities of lithospheric rock can be seen in the different average elevations of continental and oceanic crust. The less-dense continental crust has greater buoyancy, causing it to float much higher in the mantle. Its average elevation above sea level is 840 metres (2,750 feet), while the average depth of oceanic crust is 3,790 metres (12,400 feet). This density difference creates two principal levels of earth's surface.

The lithosphere itself includes all the crust as well as the upper part of the mantle (i.e., the region directly beneath the Moho), which is also rigid. However, as temperatures increase with depth, the heat causes mantle rocks to lose their rigidity. This process begins at about 100 km (60 miles) below the surface. This change occurs within the mantle and defines the base of the lithosphere and the top of the asthenosphere. This upper portion of the mantle, which is known as the lithospheric mantle, has an average density of about 3.3 grams per cubic cm (0.12 pound per cubic inch). The asthenosphere, which sits directly below the lithospheric mantle, is thought to be slightly denser at 3.4-4.4 grams per cubic cm (0.12-0.16 pound per cubic inch).

In contrast, the rocks in the asthenosphere are weaker, because they are close to their melting temperatures. As a result, seismic waves slow as they enter the asthenosphere. With increasing depth, however, the greater pressure from the weight of the rocks above causes the mantle to become gradually stronger, and seismic waves increase in velocity, a defining characteristic of the lower mantle. The lower mantle is more or less solid, but the region is also very hot, and thus the rocks can flow very slowly (a process known as creep).

During the late 20^{th} and early 21^{st} centuries, scientific understanding of the deep mantle was greatly enhanced by high-resolution seismological studies combined with numerical modeling and laboratory experiments that mimicked conditions near the core-mantle boundary. Collectively, these studies revealed that the deep mantle is highly heterogeneous and that the layer may play a fundamental role in driving earth's plates.

At a depth of about 2,900 km (1,800 miles), the lower mantle gives way to earth's outer core, which is made up of a liquid rich in iron and nickel. At a depth of about 5,100 km (3,200 miles), the outer core transitions to the inner core. Although it has a higher temperature than the outer core, the inner core is solid because of the tremendous pressures that exist near earth's centre. Earth's inner core is divided into the outer-inner core (OIC) and the inner-inner core (IIC), which differ from one another with respect to the polarity of their iron crystals. The polarity of the iron crystals of the OIC is oriented in a north-south direction, whereas that of the IIC is oriented east-west.

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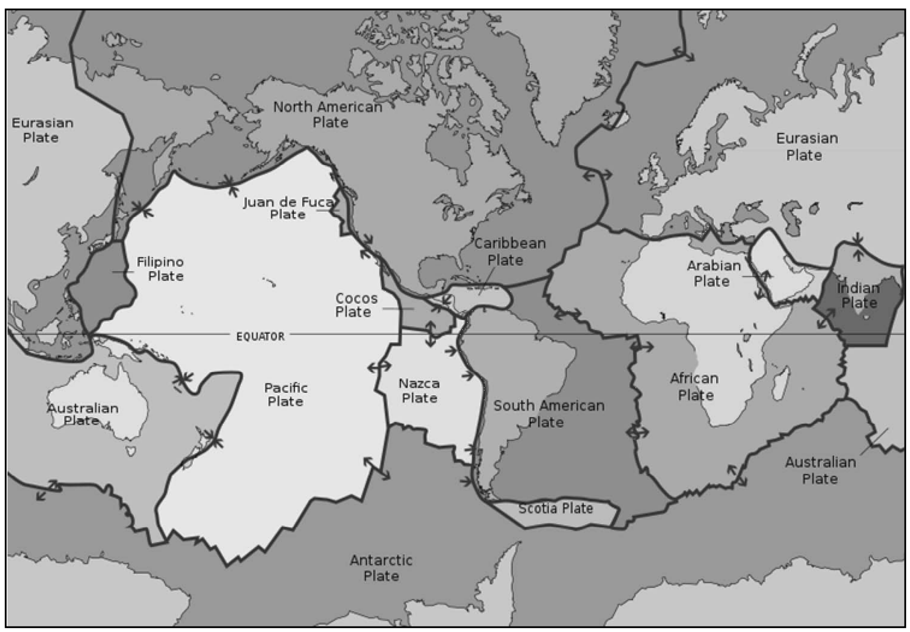
The Earth can be isolated into one of two different ways – precisely or synthetically. Precisely – or rheologically, which means the investigation of fluid states – it tends to be isolated into the lithosphere, asthenosphere, mesospheric mantle, external center, and the inward center. However, artificially, which is the more well known of the two, it very well may be separated into the outside layer, the mantle (which can be partitioned into the upper and lower mantle), and the center – which can likewise be partitioned into the external center, and inward center.

The inward center is strong, the external center is fluid, and the mantle is strong/plastic. This is because of the general softening places of the various layers (nickel–iron center, silicate outside and mantle) and the increment in temperature and pressing factor as profundity increments. At the surface, the nickel-iron compounds and silicates are sufficiently cool to be strong. In the upper mantle, the silicates are for the most part strong however restricted areas of dissolve exist, prompting restricted thickness.

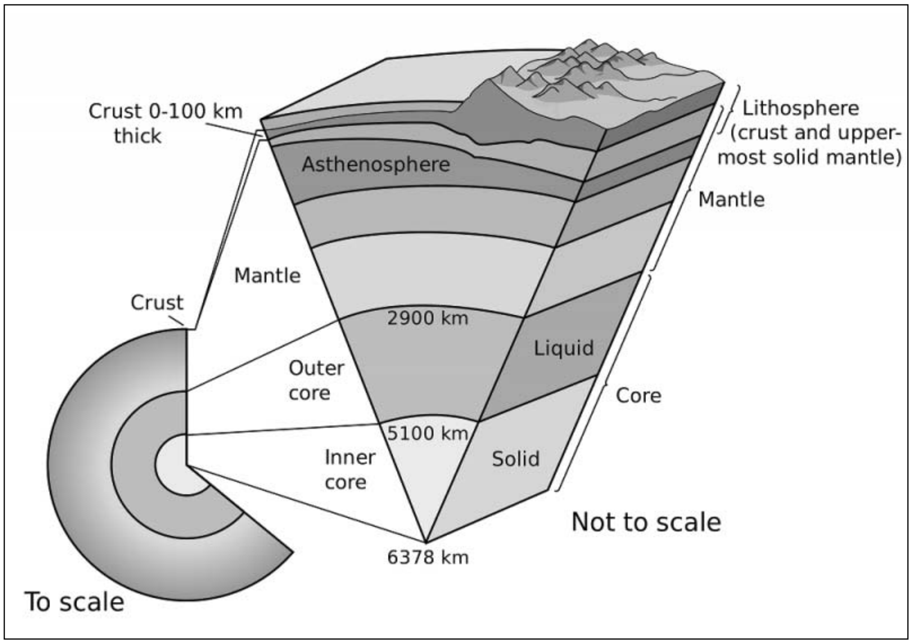
Conversely, the lower mantle is under colossal pressing factor and in this way has a lower thickness than the upper mantle. The metallic nickel–iron external center is fluid on account of the great temperature. Be that as it may, the exceptional pressing factor, which increments towards the internal center, significantly changes the dissolving point of the nickel–iron, making it strong.



Credit: commons.wikimedia.org

Fig. 2.15: Tectonic Plates Map

The differentiation between these layers is due to processes that took place during the early stages of Earth's formation (ca. 4.5 billion years ago). At this time, melting would have caused denser substances to sink toward the center while less-dense materials would have migrated to the crust. The core is thus believed to largely be composed of iron, along with nickel and some lighter elements, whereas less dense elements migrated to the surface along with silicate rock.



Credit: pubs.usgs.gov

Fig. 2.16: The Earth's Layers (Strata) Shown to Scale

Crust

The outside is the furthest layer of the planet, the cooled and solidified piece of the Earth that ranges top to bottom from around 5-70 km (~3-44 miles). This layer makes up just 1% of the whole volume of the Earth, however it makes up the whole surface (the landmasses and the sea depths).

The more slender parts are the maritime hull, which underlies the sea bowls at a profundity of 5-10 km (~3-6 miles), while the thicker outside layer is the mainland covering. While the maritime hull is made out of thick material, for example, iron magnesium silicate volcanic rocks (like basalt), the mainland outside is less thick and made out of sodium potassium aluminum silicate rocks, similar to stone.

The highest part of the mantle (see beneath), along with the covering, establishes the lithosphere – a sporadic layer with a greatest thickness of maybe 200 km (120 mi). Numerous stones presently making up Earth's covering framed under 100 million (1×10^8) quite a while back. Notwithstanding, the most established realized mineral grains are 4.4 billion (4.4×10^9) a long time old, showing that Earth has had a strong hull for in any event that long.

Upper Mantle

The mantle, which makes up about 84% of Earth's volume, is transcendentally strong, however acts as an exceptionally thick liquid in topographical time. The upper mantle, what begins at the "Mohorovicic Discontinuity" (also known as.

the "Moho" – the foundation of the covering) stretches out from a profundity of 7 to 35 km (4.3 to 21.7 mi) downwards to a profundity of 410 km (250 mi). The highest mantle and the overlying hull structure the lithosphere, which is generally inflexible at the top however turns out to be perceptibly more plastic underneath.

Contrasted with different layers, much is thought about the upper mantle, because of seismic examinations and direct examinations utilizing mineralogical and land reviews. Development in the mantle (for example convection) is communicated at the surface through the movements of structural plates. Driven by heat from more profound in the inside, this interaction is liable for Continental Drift, tremors, the development of mountain chains, and various other geographical cycles.

The mantle is likewise artificially particular from the hull, as well as being distinctive as far as rock types and seismic qualities. This is to a great extent because of the way that the outside layer is comprised of cemented items got from the mantle, where the mantle material is mostly dissolved and gooey. This makes inconsistent components separate from the mantle, with less thick material coasting vertically and hardening at the surface.

Credit: Wikipedia Commons/Rick Manning

Fig. 2.17: Illustration of Edmond Halley's Model of a Hallow Earth, One that was made up of Concentric Spheres

The solidified dissolved items close to the surface, whereupon we live, are commonly known to have a lower magnesium to press proportion and a higher extent of silicon and aluminum. These progressions in mineralogy may impact mantle convection, as they bring about thickness changes and as they may ingest or deliver inactive warmth too.

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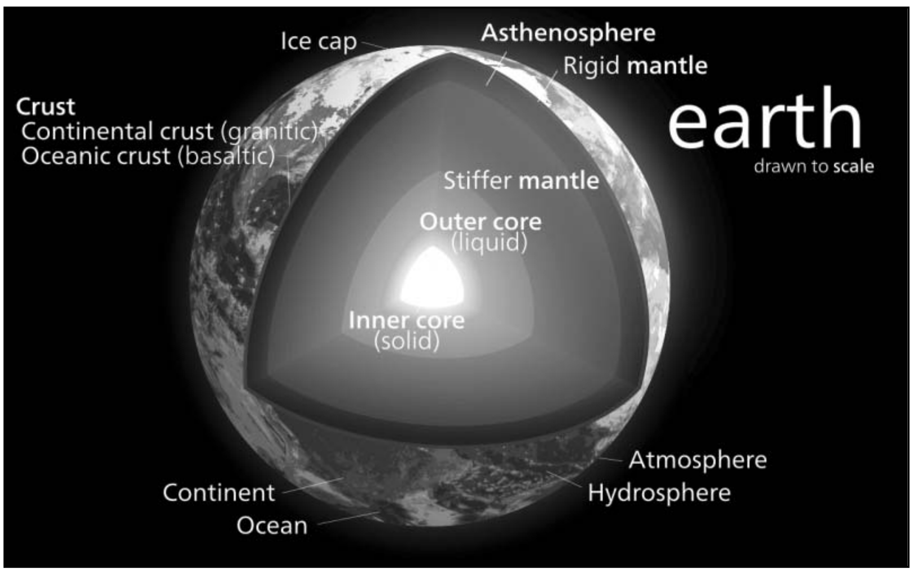
In the upper mantle, temperatures range between 500 to 900°C (932 to 1,652°F). Between the upper and lower mantle, there is additionally what is known as the change zone, which ranges inside and out from 410-660 km (250-410 miles).

Lower Mantle

The lower mantle lies between 660-2,891 km (410-1,796 miles) inside and out. Temperatures in this area of the planet can reach more than 4,000°C (7,230°F) at the limit with the center, boundlessly surpassing the dissolving points of mantle rocks. Nonetheless, because of the colossal pressing factor applied on the mantle, consistency and dissolving are extremely restricted contrasted with the upper mantle. Next to no is thought about the lower mantle separated from that it has all the earmarks of being generally seismically homogeneous.



Credit: Wikipedia Commons/Kelvinsong

Fig. 2.18: The Internal Structure of Earth

Outer Core

The external center, which has been affirmed to be fluid (in light of seismic examinations), is 2300 km thick, stretching out to a span of ~3,400 km. Around here, the thickness is assessed to be a lot higher than the mantle or outside, going somewhere in the range of 9,900 and 12,200 kg/m^3. The external center is accepted to be made out of 80% iron, alongside nickel and some other lighter components.

Denser components, similar to lead and uranium, are either too uncommon to possibly be critical or will in general tie to lighter components and in this way stay in the outside. The external center isn't feeling the squeeze to be strong, so it is fluid despite the fact that it has a creation like that of the internal center. The temperature of the external center reaches from 4,300 K (4,030°C; 7,280°F) in the external locales to 6,000 K (5,730°C; 10,340°F) nearest to the inward center.

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Due to its high temperature, the external center exists in a low thickness liquid express that goes through tempestuous convection and turns quicker than the remainder of the planet. This causes vortex flows to frame in the liquid center, which thusly makes a dynamo impact that is accepted to impact Earth's attractive field. The normal attractive field strength in Earth's external center is assessed to be 25 Gauss (2.5 mT), which is multiple times the strength of the attractive field estimated on Earth's surface.

Inner Core

Credit: minerals.usgs.gov.

Fig. 2.19: The Growing Importance of Mining in the 17t^{h} and 18th Centuries, Particularly for Precious Metals, Led to Further Developments in Geology and Earth Sciences

The growing importance of mining in the 17th and 18th centuries, particularly for precious metals, led to further developments in geology and Earth sciences.

Like the external center, the internal center is made essentially out of iron and nickel and has a range of ~1,220 km. Thickness in the center reaches between 12,600 - 13,000 kg/m^3, which recommends that there must likewise be a lot of hefty components there also – like gold, platinum, palladium, silver and tungsten.

The temperature of the internal center is assessed to be around 5,700 K (~5,400°C; 9,800°F). The lone motivation behind why iron and other weighty metals can be strong at such high temperatures is on the grounds that their liquefying temperatures significantly increment at the pressing factors present there, which goes from around 330 to 360 gigapascals.

Since the internal center isn't unbendingly associated with the Earth's strong mantle, the likelihood that it turns marginally quicker or more slow than the remainder of Earth has for some time been thought of. By noticing changes in seismic waves as they ignored through the center the course of numerous

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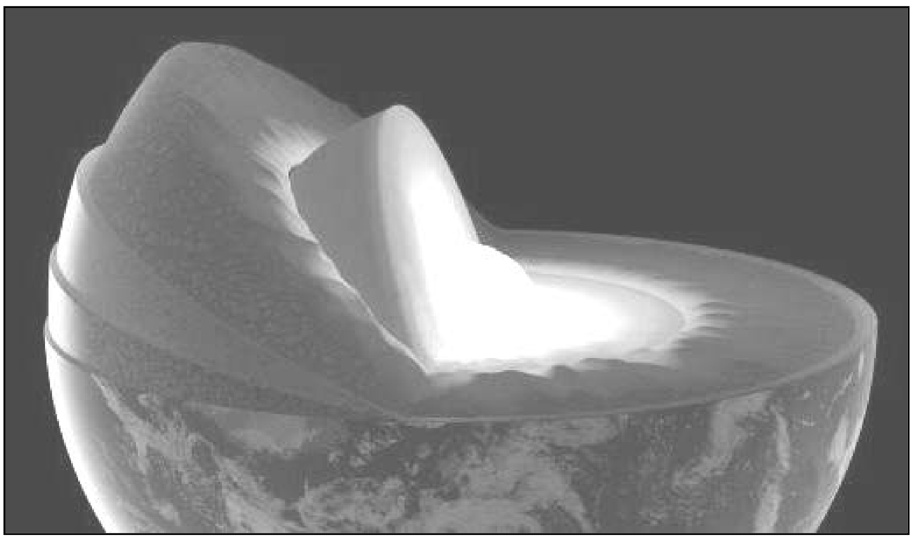
many years, researchers gauge that the internal center turns at a pace of one degree quicker than the surface. Later geophysical appraisals place the pace of revolution between 0.3 to 0.5 degrees each year comparative with the surface.

Ongoing revelations likewise propose that the strong inward center itself is made out of layers, isolated by a change zone around 250 to 400 km thick. This new perspective on the inward center, which contains an internal center, places that the deepest layer of the center estimates 1,180 km (733 miles) in breadth, making it not exactly a large portion of the size of the internal center. It has been additionally estimated that while the center is made out of iron, it very well might be in an alternate translucent design that the remainder of the internal center.

Additionally, late investigations have driven geologists to guess that the elements of profound inside is driving the Earth's inward center to grow at the pace of around 1 millimeter a year. This happens for the most part on the grounds that the inward center can't break up similar measure of light components as the external core.



Credit: Huff Post Science

Fig. 2.20: Artist's Illustration of Earth's Core, Inner Core and Inner-inner Core

The freezing of fluid iron into glass-like structure at the internal center limit produces lingering fluid that contains more light components than the overlying fluid. This is thus accepted to make the fluid components become light, assisting with driving convection in the external center.

This development is accordingly liable to assume a significant part in the age of Earth's attractive field by dynamo activity in the fluid external center. It additionally implies that the Earth's inward center, and the cycles that drive it, are undeniably more perplexing than recently suspected!

Indeed to be sure, the Earth is a bizarre and secret place, titanic in scale just as the measure of warmth and energy that went into making it a long time prior. Also, similar to all bodies in our universe, the Earth is certifiably not a completed item, however a powerful substance that is dependent upon steady

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change. Also, what we think about our reality is as yet dependent upon hypothesis and mystery, given that we can't inspect its inside very close.

As the Earth's structural plates proceed to float and impact, its inside keeps on going through convection, and its center keeps on developing, who can say for sure what it will resemble ages from now? All things considered, the Earth was here some time before we were, and will probably keep on being long after we are no more.

Check Your Progress

9. __________ and __________ are two types of crust.
10. Lithosphere includes __________ and __________.

2.6 EARTH MOVEMENT – FOLDS AND FAULTS

The earth has two kinds of movements, to be specific rotation and revolution. Rotation is the movement of the earth on its axis. The movement of the earth around the sun in a fixed way or circle is called Revolution. The axis of the earth which is a nonexistent line, makes an angle of 23½° with its orbital plane. The plane containing this circle is known as the orbital plane. The earth gets light from the sun. Because of the spherical shape of the earth, just 50% of it gets light from the sun at a time. The portion pointing towards the sun encounters day while the other half away from the sun encounters night. The circle that separates the day from night on the globe is known as the circle of light. This circle doesn't concur with the axis. The earth requires around 24 hours to finish one rotation around its axis. The period of rotation is known as the earth day. This is the everyday movement of the earth.

The second movement of the earth around the sun in its circle is called revolution. It requires 365¼ days (one year) to spin around the sun. We consider a year as comprising of 365 days in particular and disregard six hours for comfort.

On 21st June, the Northern Hemisphere is shifted towards the sun. The beams of the sun fall straightforwardly on the Tropic of Cancer. Thus, these territories get more warmth. The territories close to the posts get less warmth as the beams of the sun are inclining. The North Pole is slanted towards the sun and the spots past the Arctic Circle experience persistent light for around a half year. Since an enormous bit of the Northern Hemisphere is getting light from the sun, it is summer in the places north of the equator. The longest day and the most brief night at these spots happen on 21st June.

As of now in the Southern Hemisphere every one of these conditions are turned around. It is winter season there. The evenings are longer than the days. This situation of the earth is known as the Summer Solstice. On 22nd December, the Tropic of Capricorn gets immediate beams of the sun as the South Pole slants towards it. As the sun's beams fall upward at the Tropic of Capricorn

(23½° S), a bigger segment of the Southern Hemisphere gets light. In this way, it is summer in the Southern Hemisphere with longer days and more limited evenings.

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The opposite occurs in the Northern Hemisphere. This situation of the earth is known as the Winter Solstice. On 21st March and September 23rd, direct beams of the sun fall on the equator. At this position, neither of the shafts is shifted towards the sun; thus, the entire earth encounters equal days and nights. This is called an equinox. On 23rd September, it is fall season in the Northern Hemisphere and spring season in the Southern Hemisphere. The inverse is the situation on 21st March. Let's Do To comprehend the world's tendency a similar way, draw a major oval on the ground and take a banner with a stick. Stand anyplace on the line of the circle. Guide your banner toward a fixed point far away like on a tree-top. Presently move along the oval keeping your banner continually pointing towards that fixed point. Thusly, the hub of the earth stays slanted for all time similarly situated. The unrest of the earth and the tendency of the world's axis a fixed way cause seasons.

Internal Land Forming/Endogenetic Processes

Processes operating in the interior of the earth resulting in the formation of natural physical features or landforms. They are caused by earth movements.

Examples of these processes are folding, faulting and Vulcanicity.

Formation of land forms by internal land forming processes is determined by:

- Nature and age of earth materials,
- Type of movement involved,
- Intensity and scale of movement involved.

Crustal Earth Movements

Displacement of the earth's crustal rocks.

They are brought about by tectonic forces which originate and operate in the interior of the earth e.g., tensional forces (which operate along horizontal plane moving away from each other), compressional forces (which operate along horizontal plane moving towards each other), shear forces (which move past each other with unequal strength) and gravitational forces (which attracts things to the earths centre).

Earth movements are of two types:

1. Horizontal/lateral/orogenic movements
2. Vertical/epeirogenic movements

Horizontal Earth Movements

Movements which act along a horizontal plane within crustal rocks.

They are caused by tensional and compressional and shear forces.

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Effects

They Cause

Strain and stretching of crustal rocks due to stretching caused by tensional forces which cause formation of cracks or faults.

Squeezing and shortening of crustal by compressional forces rocks which cause them also cause formation of faults.

Crustal rocks to shear by slipping past each other or by dividing into layers which is caused by shear forces.

Results of Horizontal Earth Movements

Results in the formation of the following features:

1. Faults
2. Rift valleys
3. Fold mountains
4. Escarpments
5. Basins
6. Tilt blocks
7. Block mountains

Vertical Earth Movements

Movements which occur along the earth's radius or towards the earth's surface or towards its centre.

Effects

Causes

Subsiding/sinking/downwarping or pulling of crustal rocks downwards.

Uplifting/upwarping or pushing of crustal rocks upwards.

Tilting of crustal rocks or shearing in vertical direction due to grater uplift on one side.

Results of Vertical Earth Movements

1. Raised cliffs
2. Tilt blocks
3. Rift valleys
4. Fault scarps/escarpments
5. Plateaus
6. Basins

Causes of Earth Movements

(a) Magma movement within the earths crust.

(b) Gravitational force

(c) Convectional currents in the mantle

(d) Isostatic adjustment

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Magma Movement within the Earths Crust

When magma moves with force pushing crustal rocks horizontally or vertically.

When magma moves from reservoir and leaves empty spaces onto which crustal rocks are pulled inwards.

Gravitational Force

When the attractive force of the earth pulls crustal rocks into empty spaces left after magma escaping from the reservoir.

Convectional Currents within Mantle

When convectional currents in magma in mantle drug crustal rocks by friction.

Horizontal movement of currents cause horizontal movements while vertical cause vertical movements.

Isostatic Adjustment

Rising of continental masses to restore the upset state of balance between sial and sima layers.

Isostacy is the state of balance between sial and sima layers.

It can be disturbed by erosion on continents and melting of continental ice sheets.

The reduced weight causes continental masses to rise.

Theories Explaining the Earth's Movements

A theory is reasoned ideas intended to explain facts or ideas. There are two theories which explain the earth's movements namely the Continental Drift Theory and the Plate tectonics theory.

(i) Theory of Continental Drift

Its proponent was A. Wegener. It explains the origin of six continents.

It states:

- The earth was a single sialic land mass called Pangaea surrounded by a huge ocean called Panthalasa whose floor was a mass of sima.
- Pangaea broke into two parts called Laurasia (N. Hemisphere) which lay around equator and Gondwanaland (S. Hemisphere) which lay around south pole which were separated by a narrow ocean called Tethys (the present Mediterranean Sea).
- Laurasia broke into Laurentian Shield and Fennoscandia (Europe, Asia and N. America) and moved northwards to their present positions.

- Gondwanaland broke into Africa, Australia, S. America and Antarctica and India subcontinent.
- Africa and India drifted northwards.

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Evidences Supporting the Theory

1. Fitting of western coast of Africa and S. America into a jigsaw.
2. Discovery of coal 40°N and 55°N which was formed by burying of tropical vegetation.
3. Considerable displacement of rocks along some faults e.g. along the Great Glen Fault of Scotland.
4. Cape and Buenos Aires folds resemble one another by having east west trend.
5. Red sea shores show evidence of having undergone lateral displacement an indication that it was formed by movement of the earth's crust.
6. Evidence of ancient Glaciation to the south of equator in Africa in Madagascar and India where there is presence of ancient glacial deposits suggesting these areas were once around south pole.

(ii) Plate Tectonics Theory

It states that the earths crust is made of blocks called plates. There are 7 large plates and 9 small plates.

7 Large Plates

1. Eurasian plate
2. Australian plate
3. African plate
4. Antarctic plate
5. N. American plate
6. S. American plate
7. Pacific plate

9 Smaller Plates

1. Indian
2. Arabian
3. Caribbean
4. Cocos
5. Somali plates
6. Juan de Fuca
7. Nazca
8. Philippine
9. Scotia

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- These tectonic plates are of two types:
  1. Oceanic plates, which form fundamental regions of the ocean floor which includes coastal lowland.
  2. Continental plates, which shape the bulk of the continental land mass.
- The plates glide on molten mantle layer called Asthenosphere.
- The plates pass relative to every other because of convectional currents inside the mantle.
- They pass far from each other forming extension or optimistic boundary called so because magma fills the distance among.
- They flow closer to every other forming compressional or unfavorable boundary known as so because materials between are beaten. The moves of those two kinds of plates have the following results:

When Two Oceanic Plates Meet

- There may be subduction and the ocean floor is pulled inwards forming a trench e.g. Java Trench. Subduction is the passing of edge of one plate underneath the threshold of some other.
- Sediments on the ocean ground within the location of subduction are compressed to form Fold Mountains:
  1. While an oceanic plate meets a continental plate, the threshold of the oceanic plate slides underneath the continental plate in a motion referred to as subduction.
- Sediments on the ocean floor inside the region of subduction are compressed to shape Fold Mountains.
- Fold Mountains also are formed at the edge of the continent whilst the sial layer is compressed.
- The threshold of the oceanic plate bends into the mantle forming a trench:
  2. When two continental plates collide, the sial layer is folded into mountains.
- They pass past every different forming rework or conservative boundary known as so due to the fact there may be neither production nor destruction which occurs wherein the plates are separated through a first-rate fault.

Significance of Plate Movements

1. Are sources of earthquakes and volcanic activities.
2. Reasons formation of landforms along with Fold Mountains and ocean trenches.
3. Extraordinary landscapes fashioned are a visitor appeal.
4. Eruption of magma can result in formation of precious minerals.

The motion of the Earth's plates effects in the folding and faulting of the Earth's surface due to techniques consisting of compression, anxiety and shearing, and in doing so, deform and rearrange the Earth's crust.

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In folding, the Earth's crust is pulled and strained, resulting in a variety of various functions that can be commonly visible when inspecting a cliff face. There are 3 elements of a fold: the anticline (high), the syncline (low) and the limbs, generally referred to as the "fingers" of the folds. Folds can be divided into several different types, which include a monocline, wherein the layers journey in the same path, a symmetrical fold, each palms have the equal slope, a asymmetrical fold, the slope of one arm is steeper than the other, and a overfold, whereby the arms have slightly overturned.

Faulting is a system that happens due to the extreme stress on plates, this has persisted through the folding of layers. The stress of compression or tension results in a fracture to occur in the fold, that can shape alongside a fault line. Motion alongside this fault can be horizontal or vertical. Such an instance of a fault line is the San Andreas Fault Line in America.

2.6.1 Folding

Folds, in geography, are undulation or waves inside the stratified rocks of earth's crust. Stratified rocks were in the beginning formed from sediments that had been deposited in flat horizontal sheets, but in some of locations the strata are not horizontal but have been warped. Every often the warping is so mild that the inclination of the strata is slightly perceptible, or the warping may be so reported that the strata of the two flanks may be essentially parallel or lie almost flat (as in the case of a recumbent fold). Folds vary widely in length; a few are several kilometres or maybe loads of kilometres throughout, and others degree only a few centimetres or less. The tops of massive folds are typically eroded away on this planet's floor, exposing the go sections of the inclined strata.

Folds are usually categorised consistent with the mindset of their axes and their look in move sections perpendicular to the trend of the fold. The axial plane of a fold is the plane or surface that divides the fold as symmetrically as possible. The axial plane may be vertical, horizontal, or inclined at any intermediate perspective. An axis of a fold is the intersection of the axial plane with one of the strata of which the fold consists. Although in the simpler varieties of folds the axis is horizontal or lightly inclined, it could be steeply willing or even vertical. The perspective of inclination of the axis, as measured from the horizontal, is referred to as the plunge. The portions of the fold among adjoining axes shape the flanks, limbs, or slopes of a fold.

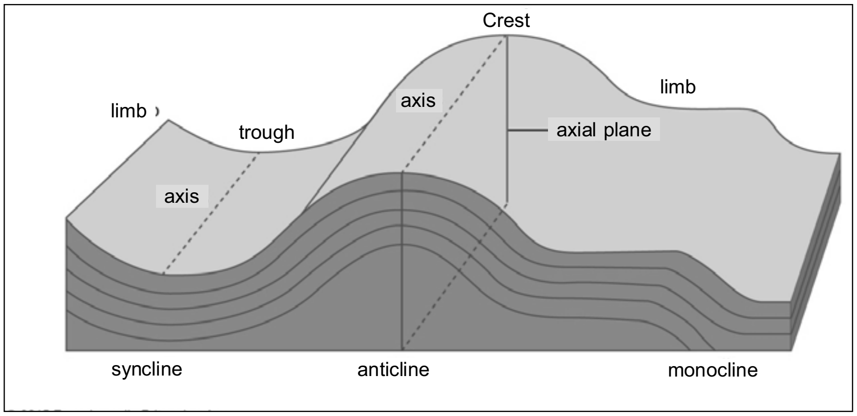

Fig. 2.21: Types of Folds

An anticline is a fold which is convex upward, and a syncline is a fold that is concave upward. An anticlinorium is a big anticline on which minor folds are superimposed, and a synclinorium is a big syncline on which minor folds are superimposed. A symmetrical fold is one wherein the axial plane is vertical. An asymmetrical fold is one in which the axial plane is inclined. An overturned fold, or overfold, has the axial plane inclined to such an volume that the strata on one limb are overturned. A recumbent fold has an essentially horizontal axial plane. When the two limbs of a fold are essentially parallel to each other and for that reason approximately parallel to the axial plane, the fold is known as isoclinal.

Many folds are surprisingly linear; that is, their extent parallel to the axis is regularly their width. Some folds, but, are not linear however are greater or less circular in plan. A dome is any such fold that is convex upward; which means its strata dip outward from a critical area. A basin is a round fold that is concave upward—i.e., the strata dip inward toward a crucial region.

The lengthy linear folds which are characteristic of mountainous regions are believed to have resulted from compressional forces acting parallel to the floor of Earth and at proper angles to the fold. A few geologists believe that many folds are the result of strata sliding from a vertically uplifted place under the crust have an effect on of gravity. The rush exerted by way of an advancing glacier additionally may also throw weakly consolidated rocks into folds, and the compaction of sedimentary rocks over buried hills gives rise to gentle folds. In nature, folds are not often produced by means of a unmarried system however, with the aid of a mixture of processes.

Parts of a Fold

Limbs: Those are the edges or flanks of a fold. An individual fold will have at least two limbs however, while the folds occur in agencies, as they very regularly do, a middle limb could be not unusual to two adjacent folds.

Hinge: In a folded layer, a point can be discovered where curvature is most and one limb ends and the opposite limb starts from that point, that is the hinge factor.

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When rocks occur in a chain and their all hinge factors are joined together, they make a line, known as the hinge line.

Axial surface: When the hinge line is traced at some stage in the depth of a folded collection a surface is acquired which may be planar or non-planar. It's miles is called axial surface.

Axial plane: Axial plane is the imaginary plane that passes through all of the factors of maximum curvature willing or horizontal in nature. A fold surface is plane in nature; otherwise it is a folded collection. It may be vertical, is occasionally referred to as a planar fold if the axial is a non-planar fold.

Axis of a fold: It is truly described as a line drawn parallel to the hinge line of a fold. A greater particular definition of an axis of a fold would be the line representing the intersection of the axial plane of a fold with any mattress of the fold.

Plunge of a fold: The attitude of inclination of the fold axis with the horizontal as measured in a vertical plane is time period of the plunge of the fold.

Crest and Trough: Maximum folds are variations of two standard office work; up-arched and down-arched bends. The line walking through the very satisfactory elements in an up-arched fold defines its crest.

A corresponding line strolling through the lowest factor in a down arched fold makes its trough. The crest and trough can also or won't coincide with the axis of the fold.

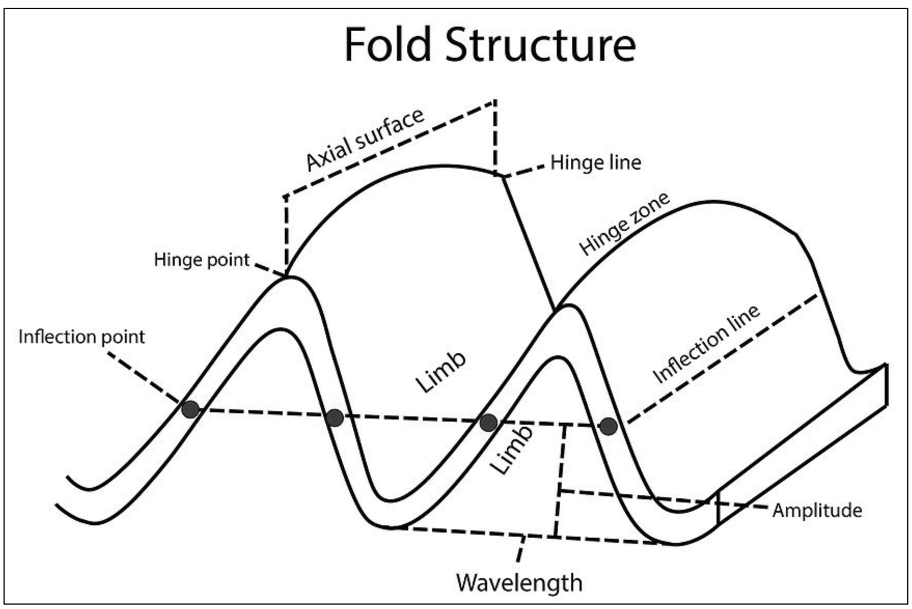

Fig. 2.22: Parts of Folds

Types of Folds

Fold occurs whilst one or a stack of at first flat and planar surfaces, consisting of sedimentary strata, are bent or curved because of everlasting deformation. Synsedimentary folds are the ones due to slumping of sedimentary material before it is lithified. Folds in rocks range in length from microscopic crinkles to mountain-sized folds. They occur singly as remote folds and in sizeable fold trains of various sizes, on a ramification of scales.

1. Anticline

Anticline is a fold that is convex up and has its oldest beds at its center. The time period is not to be confused with antiform, which is a basically descriptive term for any fold that is convex up. Consequently if age relationships among various strata are unknown, the term antiform must be used.

Source: commons.wikimedia.org

Fig. 2.23: Anticline Fold

2. Syncline

A syncline is a fold with younger layers closer to the middle of the structure. Synclines are usually a downward fold, termed a synformal syncline (i.e., a trough); but synclines that factor upwards, or perched, may be found while strata have been overturned and folded (an antiformal syncline).

Source: commons.wikimedia.org

Fig. 2.24: Syncline Fold

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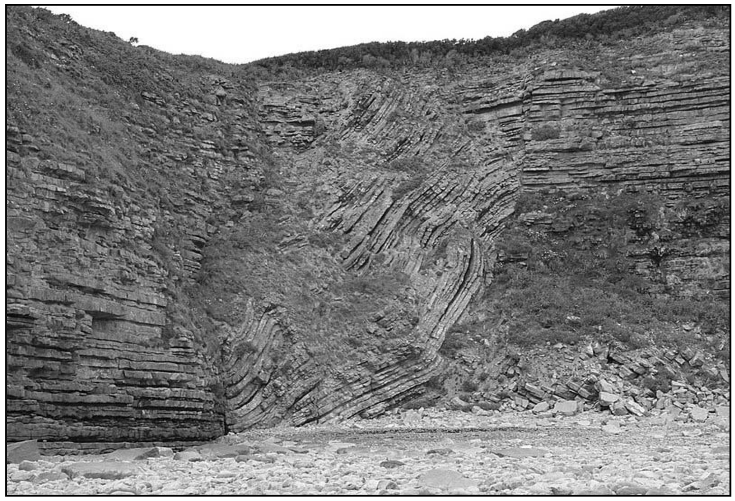
3. Monocline

Neighbourhood warping in horizontal strata. Rock beds lying at two level separated by means of steep inclined limbs. It is formed with the aid of vertical movement and generally discovered fault underneath monocline. A step-like fold in rock strata together with a sector of steeper dip within an otherwise horizontal or lightly-dipping sequence.



Source: commons.wikimedia.org

Fig. 2.25: Monocline Fold

4. Chevron Fold

Chevron folds are a structural feature characterized via repeated properly behaved folded beds with instantly limbs and sharp hinges. Properly developed, these folds broaden repeated set of v-fashioned beds. They increase in reaction to nearby or neighbourhood compressive pressure. Inter-limb angles are generally 60 tiers or much less. Chevron folding preferentially occurs whilst the bedding often alternates between contrasting competences.

Source: commons.wikimedia.org

Fig. 2.26: Chevron Fold

5. Recumbent Fold

Recumbent fold has an essentially horizontal axial plane, linear, fold axial plane oriented at low angle resulting in overturned strata in a single limb of the fold.

6. Isoclinal Fold

Isoclinal folds are just like symmetrical folds, but these folds both have the identical attitude and are parallel to every different. 'Iso' means 'the same' (symmetrical), and 'cline' means 'perspective,' so this call literally way 'same angle.' So isoclinal folds are both symmetrical and aligned in a parallel style.

Source: commons.wikimedia.org

Fig. 2.27: Isoclinal Fold

7. Plunging Fold

A fold whose axis plane isn't always horizontal (no longer Parallel to sea level). Direction of plunge - the course in which the axis is willing nose - imply the path of plunge. In anticline, plunge is directed towards nostril and in syncline it's miles directed far from nose.

Source: Wikipedia.com

Fig. 2.28: Plunging Fold

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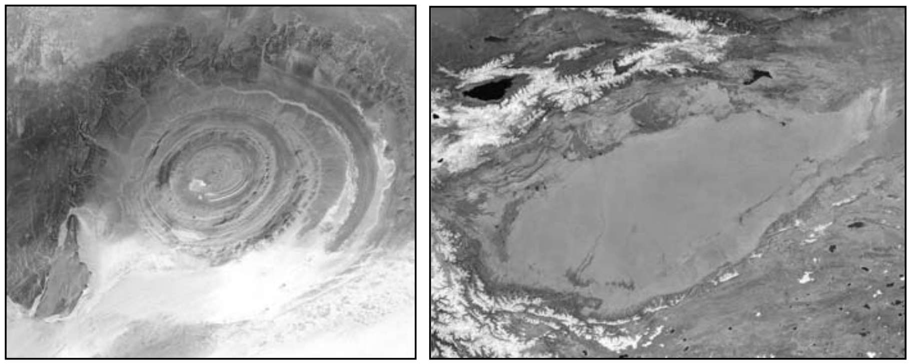
8. Dome and Basin

We additionally have domes, which are like anticlines but instead of an arch, the fold is in a dome form, like an inverted bowl. In addition, there are also basins, which are like synclines however again, in preference to a sinking arch, the fold is in a shape of a bowl sinking down into the ground. Dome: nonlinear, strata dip far from middle in all instructions, oldest strata in middle. Basin: nonlinear, strata dip in the direction of center in all instructions, youngest strata in center.



Source: commons.wikimedia.org

Fig. 2.29: Dome and Basin

9. Ptygmatic Fold

Folds are chaotic, random and disconnected. Ordinary of sedimentary slump folding, migmatites and decollement detachment zones. Ptygmatic folds typically represent situations where the folded cloth is of a miles greater viscosity than the encircling medium.

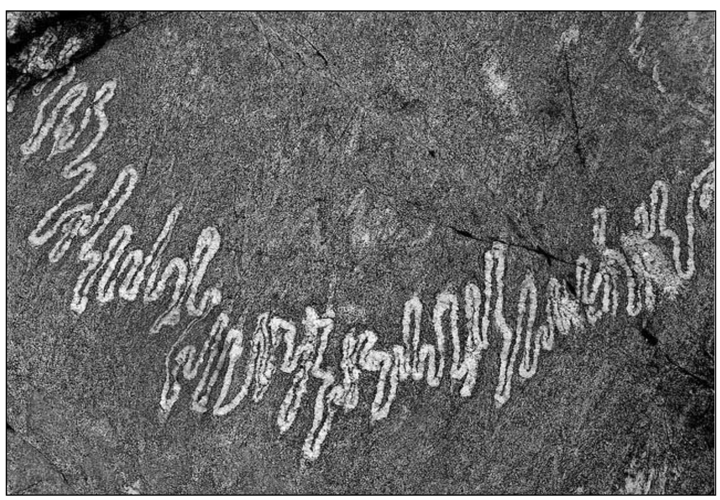


Fig. 2.30: Ptygmatic Fold

2.6.2 Faults

Fault, in geology, a planar or lightly curved fracture within the rocks of Earth's crust, where compressional or tensional forces cause relative displacement of the rocks on the opposite aspects of the fracture. Faults varies in length from some centimetres to many tens of kilometres, and displacement likewise might also range from less than a centimetre to several hundred kilometres alongside the fracture surface (the fault plane). In some instances, the movement is sent over a fault zone composed of many man or woman faults that occupy a belt masses of metres extensive. The geographic distribution of faults varies; a few huge regions have nearly none, others are reduce via innumerable faults.

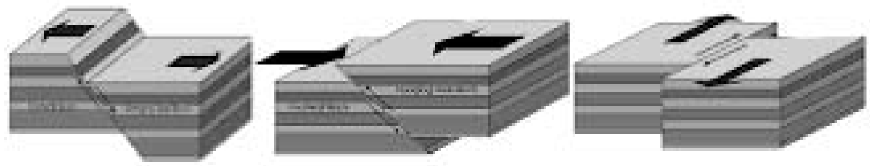


Fig. 2.31: Types of Faults

Faults can be vertical, horizontal, or inclined at any attitude. Even though the perspective of inclination of a selected fault plane has a tendency to be fairly uniform, it could vary considerably alongside its length from vicinity to vicinity. When rocks slip beyond each other in faulting, the top or overlying block along the fault plane is referred to as the placing wall, or headwall; the block underneath is known as the footwall. The fault strike is the direction of the line of intersection among the fault plane and earth's floor. The dip of a fault plane is its attitude of inclination measured from the horizontal.

Parts of a Fault

The principle additives of a fault are: (1) the fault plane, (2) the fault trace, (3) the hanging wall, and (4) the footwall. The fault plane is where the motion is. It is a flat surface that can be vertical or sloping the road it makes on this planet's surface is the fault trace.

Wherein the fault plane is sloping, as with ordinary and opposite faults, the higher aspect is the putting wall and the lower side is the footwall. While the fault plane is vertical, there's no hanging wall or footwall.

Any fault plane can be absolutely defined with two measurements: its strike and its dip. The strike is the course of the fault trace on the earth's floor. The dip is the size of the way steeply the fault plane slopes as an instance, in case you dropped a marble on the fault plane, it'd roll exactly down the course of dip.

Faults are classified in keeping with their perspective of dip and their relative displacement. Regular dip-slip faults are produced by using vertical compression as earth's crust lengthens. The striking wall slides down relative to the footwall. Everyday faults are commonplace; they sure most of the mountain ranges of the arena and most of the rift valleys observed along spreading margins of tectonic plates. Rift valleys are fashioned by using the sliding of the putting walls downward many heaps of metres, where they then grow to be the valley floors.

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A block that has dropped particularly downward among two everyday faults dipping towards each different is known as a graben. A block that has been exceptionally uplifted between ordinary faults that dip faraway from every other is referred to as a horst. A tilted block that lies among everyday faults dipping inside the same course is a tilted fault block.

Opposite dip-slip faults end result from horizontal compressional forces due to a shortening, or contraction, of earth's crust. The putting wall movements up and over the footwall. Thrust faults are opposite faults that dip much less than forty five. Thrust faults with a very low perspective of dip and a completely huge general displacement are referred to as overthrusts or detachments; those are often determined in intensely deformed mountain belts. Huge thrust faults are feature of compressive tectonic plate limitations, such as those which have created the Himalayas and the subduction zones along the west coast of South America.

Strike-slip (also known as transcurrent, wrench, or lateral) faults are in addition resulting from horizontal compression, however they release their power through rock displacement in a horizontal course almost parallel to the compressional force. The fault plane is basically vertical, and the relative slip is lateral along the aircraft. these faults are good sized. Many are located at the boundary between obliquely converging oceanic and continental tectonic plates. Notable terrestrial examples include the San Andreas Fault, which, at some stage in the San Francisco earthquake of 1906, had a most movement of 6 metres (20 ft), and the Anatolian Fault, which, at some stage in the İzmit earthquake of 1999, moved more than 2.5 metres (8.1 ft).

Indirect-slip faults have simultaneous displacement up or down the dip and alongside the strike. The displacement of the blocks on the alternative aspects of the fault plane commonly is measured with regards to sedimentary strata or different stratigraphic markers, which includes veins and dikes. The movement alongside a fault can be rotational, with the offset blocks rotating relative to one another.

Fault slip may additionally polish easy the partitions of the fault plane, marking them with striations called slicken sides, or it is able to crush them to a great-grained, clay-like substance referred to as fault gouge; when the beaten rock is relatively coarse-grained, it's miles called fault breccia. Every now and then, the beds adjacent to the fault plane fold or bend as they withstand slippage because of friction. Areas of deep sedimentary rock cowl regularly show no surface warning signs of the faulting under.

Movement of rock alongside a fault might also arise as a non-stop creep or as a sequence of spasmodic jumps of some metres for the duration of some seconds. Such jumps are separated by using intervals during which stress builds up till it overcomes the frictional forces along the fault plane and causes some other slip. Maximum, if no longer all, earthquakes are because of rapid slip alongside faults.

Types of Faults

A fault is a fracture or zone of fractures among two blocks of rock. Faults allow the blocks to transport relative to every other. This motion may occur rapidly, inside the form of an earthquake – or may also arise slowly, in the form of creep. Faults might also range in length from a few millimeters to hundreds of kilometers. most faults produce repeated displacements over geologic time. in the course of an earthquake, the rock on one aspect of the fault all of sudden slips with recognize to the alternative. The fault floor can be horizontal or vertical or a few arbitrary attitude in among.

A fault plane is the plane that represents the fracture surface of a fault. A fault trace or fault line is the intersection of a fault plane with the floor. A fault trace is also the line usually plotted on geologic maps to represent a fault.

Fault Types

Faults are subdivided according to the movement of the two blocks. There are three or four primary fault types:

Normal Fault

Typical plunge slip issues are delivered by vertical pressure as Earth's outside extends. The hanging divider slides down comparative with the footwall. Typical flaws are normal; they bound a significant number of the mountain scopes of the world and a considerable lot of the fracture valleys found along spreading edges of structural plates. Crack valleys are framed by the sliding of the hanging dividers descending a huge number of meters, where they then, at that point become the valley floors. A square that has dropped moderately descending between two typical issues plunging towards one another is known as a graben. A square that has been generally inspired between two ordinary blames that plunge away from one another is known as a horst. A shifted block that lies between two ordinary flaws plunging a similar way is a shifted issue block

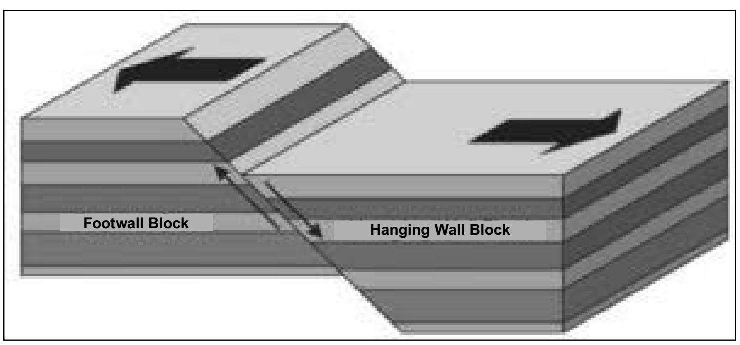

Fig. 2.32: Normal Fault

A dip-slip fault in which the block above the fault has moved downward relative to the block below. This form of faulting takes place in reaction to extension. Occurs while the "placing wall" movements down relative to the "foot wall".

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Reverse Fault

Reverse dip-slip faults result from level compressional powers brought about by a shortening, or constriction, of Earth's hull. The hanging divider goes over-top the footwall. Push shortcomings are converse blames that plunge under 45°. Push deficiencies with a low point of plunge and an enormous all out dislodging are called overthrusts or separations; these are regularly found in seriously distorted mountain belts. Huge push deficiencies are normal for compressive structural plate limits, for example, those that have made the Himalayas and the subduction zones along the west shoreline of South America.

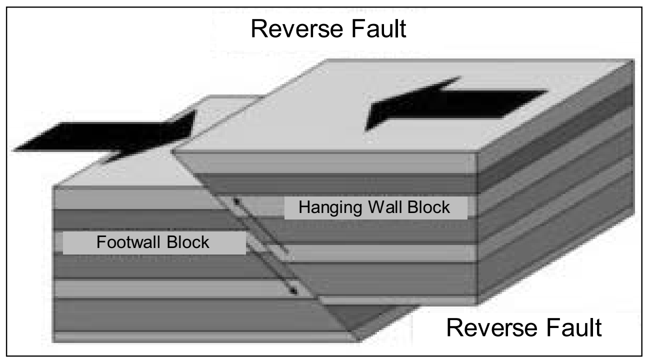

Fig. 2.33: Reverse Fault

A dip-slip fault in which the upper block, above the fault aircraft, moves up and over the decrease block. This sort of faulting is not unusual in regions of compression, when the dip attitude is shallow, a opposite fault is frequently described as a thrust fault. "occurs wherein the "striking wall" actions up or is thrust over the "foot wall".

Strike-slip Fault

Strike-slip (likewise called transcurrent, wrench, or sidelong) issues are comparably brought about by even pressure, yet they discharge their energy by rock dislodging a level way practically corresponding to the compressional power. The shortcoming plane is basically vertical, and the overall slip is sidelong along the plane. These shortcomings are boundless. Many are found at the limit between at a slant combining maritime and mainland structural plates. Notable earthbound models incorporate the San Andreas Fault, which, during the San Francisco seismic tremor of 1906, had a most extreme development of 6 meters (20 feet), and the Anatolian Fault, which, during the Izmit quake of 1999, moved more than 2.5 meters (8.1 feet).

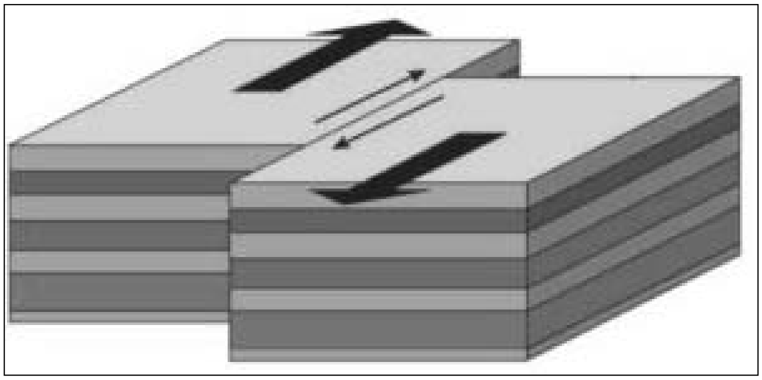

Fig. 2.34: Strike-slip Fault

A fault on which the two blocks slide past one another. The San Andreas Fault is an example of a right lateral fault.

Types of Strike-slip fault movement.

A Left-lateral Strike-slip Fault

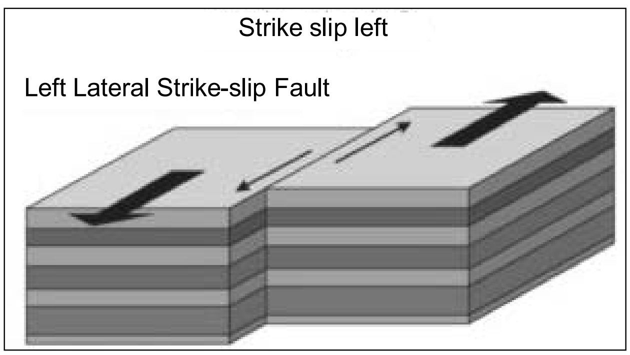

Fig. 2.35: A left-lateral Strike-slip Fault

If you were to stand on the fault and look along its length, this is a type of strike-slip fault where the left block moves towards you and the right block moves away.

A Right-lateral Strike-slip Fault

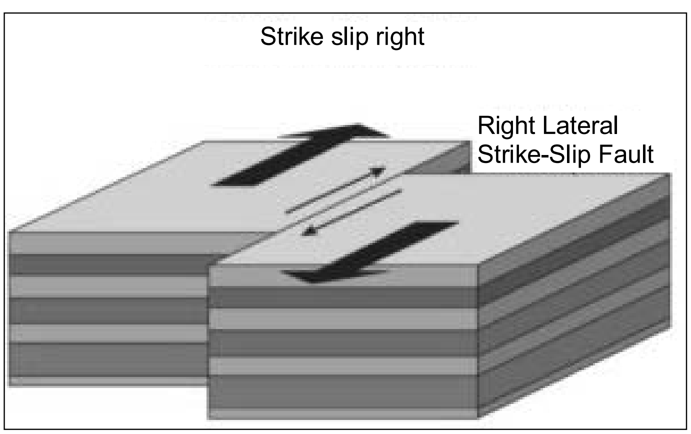

Fig. 2.36: A Right-lateral Strike-slip Fault

If you were to stand on the fault and look along its length, this is a type of strike-slip fault where the right block moves towards you and the left block moves away.

NOTES

Check Your Progress

11. What is folding?
12. What do you mean by fault?

2.7 ANSWERS TO 'CHECK YOUR PROGRESS'

1. Crust, mantle and core.
2. Continents are composed of relatively light blocks that float high on the mantle, like gigantic, slow-moving icebergs.
3. Tillite
4. Increases
5. Lithosphere
6. The theory of plate tectonics is based on a broad synthesis of geologic and geophysical data.
7. The subduction process involves the descent into the mantle of a slab of cold hydrated oceanic lithosphere about 100 km (60 miles) thick that carries a relatively thin cap of oceanic sediments.
8. Upwelling of magma causes the overlying lithosphere to uplift and stretch.
9. Continental and Oceanic
10. Crust and upper part of the mantle
11. In folding, the Earth's crust is pulled and strained, resulting in a variety of different features that can be commonly seen when examining a cliff face.
12. Fault, ingeology, a planar or gently curved fracture in the rocks of Earth's crust, where compressional or tensional forces cause relative displacement of the rocks on the opposite sides of the fracture.

2.8 SUMMARY

At the time that Wegener proposed his concept of continental float, maximum scientists believed that the earth changed into a solid, immobile frame. however, principles of sea ground spreading and the unified idea of plate tectonics have emphasised that both the surface of the earth and the indoors are not static and immobile but are dynamic. The truth that the plates flow is now a properly-common truth. The cell rock underneath the inflexible plates is assumed to be transferring in a circular manner. The heated material rises to the floor, spreads and starts to chill, and then sinks again into deeper depths. This cycle is repeated time and again to generate what scientists call a convection cell or convective waft. Warmth inside the earth comes from two main resources: radioactive decay and residual warmth. The slow motion of warm, softened mantle that lies underneath the rigid plates is the driving pressure in the back of the plate motion.

2.9 KEY TERMS

- **Plate tectonics:** Plate tectonics is the theory that Earth's outer shell is divided into several plates that glide over the mantle, the rocky inner layer above the core. The plates act like a hard and rigid shell compared to Earth's mantle.
- **Continental drift:** Continental drift is the hypothesis that the Earth's continents have moved over geologic time relative to each other, thus, appearing to have "drifted" across the ocean bed. The speculation that continents might have 'drifted' was first put forward by Abraham Ortelius in 1596.
- **Mid-ocean ridge:** A mid-ocean ridge or mid-oceanic ridge is an underwater mountain range, formed by plate tectonics. This uplifting of the ocean floor occurs when convection currents rise in the mantle beneath the oceanic crust and create magma where two tectonic plates meet at a divergent boundary.
- **Mantle convection:** Mantle convection is the very slow creeping motion of Earth's solid silicate mantle caused by convection currents carrying heat from the interior to the planet's surface.
- **Ridge push:** Ridge push (also known as gravitational sliding) or sliding plate force is a proposed driving force for plate motion in plate tectonics that occurs at mid-ocean ridges as the result of the rigid lithosphere sliding down the hot, raised asthenosphere below mid-ocean ridges.
- **Slab pull:** Slab pull is the pulling force exerted by a cold, dense oceanic plate plunging into the mantle due to its own weight. The theory is that because the oceanic plate is denser than the hotter mantle beneath it, this contrast in density causes the plate to sink into the mantle.

2.10 SELF-ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. What are the evidences in support of the continental drift theory?
2. What was the location of the Indian landmass during the formation of the Deccan Traps?
3. Write a note on River of Rocks.
4. Write a note on Plate Tectonics.

NOTES

Long Answer Questions

1. What are the possible causes of plate tectonics?
2. What were the forces suggested by Wegener for the movement of the continents?
3. How are the convectional currents in the mantle initiated and maintained?
4. What is the major difference between the transform boundary and the convergent or divergent boundaries of plates?

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NOTES

UNIT 3 THEORY OF ISOSTASY, EARTHQUAKES AND VOLCANOES

Structure

3.0 INTRODUCTION

Isostacy occurs due to the fact that the mantle is able to convect because of its plasticity and this belongings additionally allows for any other very crucial Earth method. This fundamental system is associated with different phenomenon like volcanoes, earthquakes, and rock formation in this segment, we are going to examine the principle of Isostasy and its postulates and associated phenomenon. Earthquakes and volcanoes result in formation of mountain and rocks. The sort of rocks varies from location to place. It relies upon the magmatic cloth advanced from volcanoes and hence, there are various forms of rocks relying upon their composition.

3.1 OBJECTIVES

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After going through this unit, you will be able to:

- Understand the concept of Isostasy and its postulates.
- Causes and effects of earthquakes.
- Phenomenon of volcanoes
- Various types of rocks and their composition.
- The process of weathering.

3.2 ISOSTASY

Isostasy or isostatic equilibrium is the state of gravitational equilibrium between Earth's crust and mantle such that the crust floats at an elevation that depends on its thickness and density. In the only example, isostasy is the principle of buoyancy in which an object immersed in a fluid is buoyed with a pressure same to the burden of the displaced fluid. On a geological scale, isostasy may be discovered if Earth's sturdy crust or lithosphere exerts stress on the weaker mantle or asthenosphere, which over geological time flows laterally such that the load is accommodated by means of height changes.

There are primary thoughts, advanced in the mid-nineteenth century ethereal's principle and Pratt's concept. It is supposed that isostasy acts to support mountain hundreds. In Pratt's concept, there are lateral adjustments in rock density throughout the lithosphere. Assuming that the mantle below is uniformly dense, the much less dense crustal blocks glide higher to become mountains, while the greater dense blocks form basins and lowlands. whereas in, airy's principle assumes that throughout the lithosphere, the rock density is approximately the equal, but the crustal blocks have different thicknesses. therefore, mountains that shoot up better also enlarge deeper roots into the denser fabric below. Both theories rely upon the presumed existence of a denser fluid or plastic layer on which the rocky lithosphere floats. This deposit is now referred to as asthenosphere, and was confirmed inside the mid 20th century to be present anywhere on the planet because of evaluation of earthquakes - seismic waves, whose velocity decrease with the softness of the medium, skip incredibly slowly through the asthenosphere.

Each theories are expecting a relative deficiency of mass under excessive mountains, however Airy's idea is now known to be a better explanation of mountains within continental regions, whereas Pratt's idea basically indicates the difference among continents and oceans, because the continent crust is largely of granitic composition that is less dense than the basaltic ocean basin.

3.2.1 Introduction to Idea of Isostasy

The term "Isostasy" is derived from "Isostasios", a phrase of Greek language meaning the state of being in stability or equal status or in equipoise. The concept of isostasy briefs, the tendency of the earth's crust to obtain

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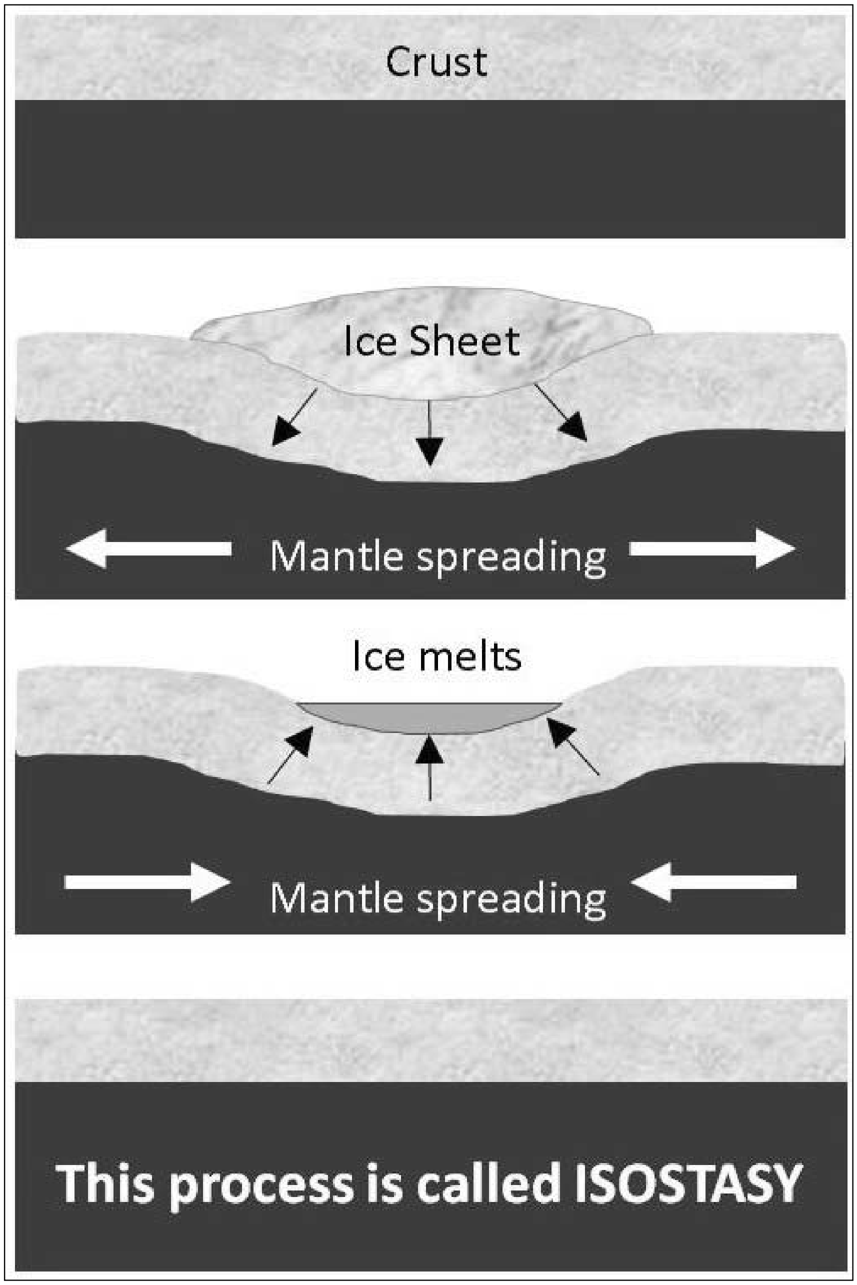
equilibrium and the distribution of the fabric in the earth's crust which conforms to the observed gravity values.



Source: commons.wikimedia.org

Fig. 3.1: The State of Isostasy

Concept of Isostasy, is a significant system in geography, is based totally at the opposing impact of the 2 fundamental forces – Buoyancy and Gravity. It's far the state of gravitational equilibrium among earth's crust and mantle, in which the crust floats at an elevation that depends on its thickness and density. It's miles the idea that the lighter crust ought to be floating at the denser underlying mantle.

3.2.2 Records and Rationalization (Idea of Isostasy)

- Principle of Isostasy turned into invented from gravity surveys in the mountains of India, in 1850. The concept was first coined through Clarence Dutton, an American geologist in 1889.
- This doctrine states that anyplace equilibrium exists inside the earth's surface, same mass have to underlie equal floor areas; in other words a terrific continental mass need to be formed of lighter material than that alleged to constitute the ocean-ground.
- Consequently, there exists a gravitational stability between crustal segments of different thickness in step with Dutton, the extended hundreds are characterised by means of rocks of low density and the depressed basins by rocks of higher density.
- Which will atone for its greater top these lighter continental fabric need to increase downward to a ways below the continent and beneath the ocean-floor level just so unit regions beneath the oceans and continents may additionally remain in strong equilibrium.
- Accordingly, a level of uniform pressure is notion to exist wherein the pressure because of extended loads and depressed areas could be identical. this is referred to as the 'isopiestic stage'.

Check Your Progress

1. What is isopiestic level?
2. Define postulation of Airy.

3.3 THREE IDEAS ABOUT THE CONCEPT OF PRINCIPLE OF ISOSTASY

The theory of Isostasy explains how distinct topographic heights can exists on the earth's floor. The equilibrium of Isostatic is a really perfect nation where the crust and mantle would settle into in absence of worrying forces. These are the examples of techniques that disturbs isostasy–

- The waning and waxing of ice sheets,
- Sedimentation, Erosion, and
- Extrusive volcanism

The bodily residences of the lithosphere (the rocky shell that paperwork Earth's exterior) are stricken by the way the mantle and crust respond to these perturbations. Therefore, knowledge the dynamics of isostasy allows us to make more complex phenomena inclusive of:

- Mountain building
- Sedimentary basin formation
- The destroy-up of continents and
- The formation of new ocean basins

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3.3.1 Postulations of Airy

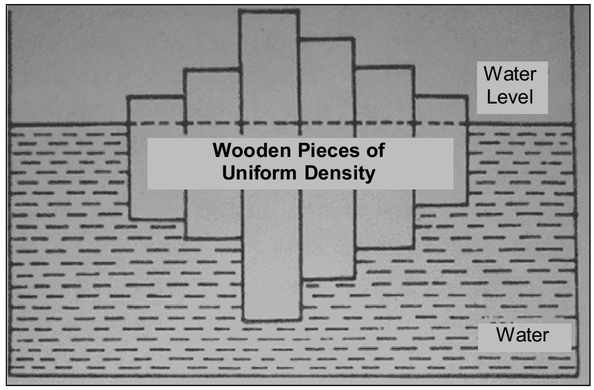

Fig. 3.2: Postulations of Airy

- In line with Postulations of airy, the crust of surprisingly lighter fabric is floating inside the substratum of denser material. Or, it can be said that 'sial' is floating in 'sima'.
- He took into consideration the density of various columns (plains, plateaus, mountains, and so on.) to be the same. subsequently, he proposed the idea of 'Uniform density with various thickness'.

3.3.2 Postulations of Pratt

- Postulations of Pratt assumed that land blocks of various heights to be one-of-a-kind in terms in their density.
- The longer landmass has lesser density and shorter peak capabilities to be denser. If there's a higher column, density will be lesser and if there may be a shorter column, density will be better
- He agreed that every one blocks of different height get compensated at a certain depth into the substratum. Therefore, he rejected the foundation idea of ethereal and conventional the 'concept of a degree of compensation'.

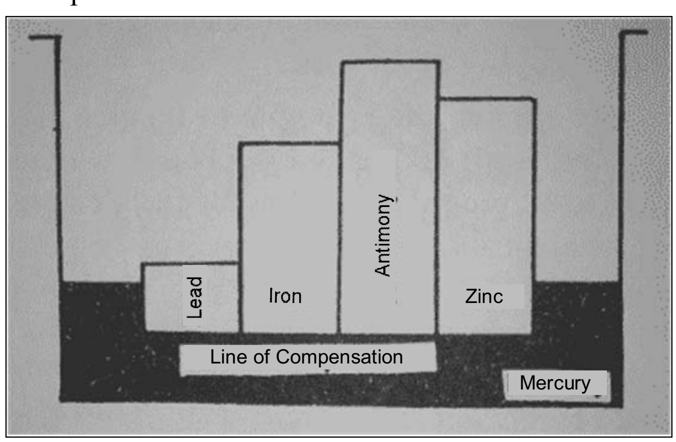

Fig. 3.3: Postulation of Pratt

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3.3.3 Difference between Pratt and Airy Isostasy

Postulations of Airy		Postulations of Pratt	
●	Crustal material have uniform density	●	Crustal material have varying density
●	Crustal material reaches upto varying depth up to which root penetrates	●	Crustal material reaches upto uniform depth up to which root penetrates
●	Deeper root formation below the mountain and smaller beneath plain	●	No root formation, but a level of Compensation

Each theories proposes a relative deficiency of mass below high mountains, but – ethereal's concept is well common to be a better explanation of mountains inside continental regions, whilst Pratt's concept explains the difference between continents and oceans, because the continent crust is largely of granitic composition that is less dense than the basaltic ocean basin.

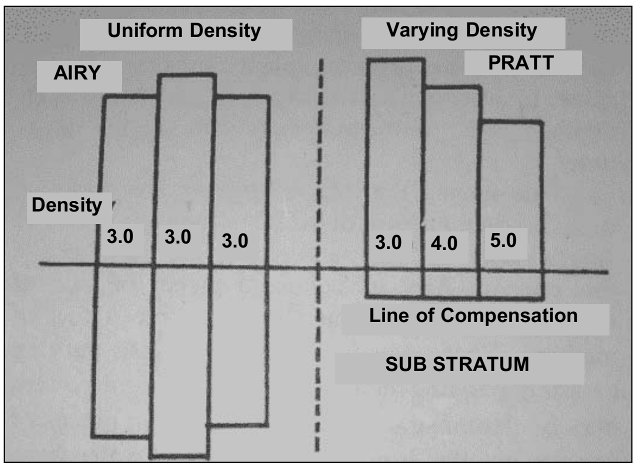

Fig. 3.4: Difference between Pratt and Airy Isostasy

On landmasses similarly as they would on ice shelves and pontoons. An ice shelf will rise farther of the water when the top is dissolved, and a pontoon will sink further when burdens are added. Nonetheless, the change time for landmasses is much more slow, because of the consistency of the asthenosphere. This outcomes in numerous unique topographical cycles that are noticed today. The accompanying passages represent a portion of these models.

The development of ice sheets could cause the Earth's surface to sink. In regions which had ice sheets in the last ice age, the land is currently "bouncing back" upwards since the substantial ice has softened and the heap on the lithosphere is decreased. Proof from topographical highlights incorporate previous ocean precipices and related wave-cut stages that are discovered many meters over the ocean level today. In the Baltic and in Canada, the sum and pace of elevate can be measured. Truth be told, because of the gradualness of bounce back, a large part of the land is as yet rising.

Isostatic elevate likewise makes up for the disintegration of mountains. At the point when a lot of material are out of control from an area, the land will bounce back upwards to be disintegrated further. Because of seepage designs, the disintegration and expulsion of material is more conspicuous at level edges. Isostatic inspire may raise the edge higher than it used to be, so the edge tops can be at a rise extensively higher than the actual level. This component is particularly likely in mountain ranges bouncing levels, for example, the Himalayas and Kunlun Mountains jumping the Tibetan Plateau .

Curiously, given sufficient opportunity and response energy, because of compound changes, the thick crustal root under mountains can get denser and author into the mantle. The expulsion of the thick root can occur by the convection of the fundamental asthenosphere or by delamination. After the root has isolated, the asthenosphere rises and isostatic balance prompts more mountain working at that locale. For example, this is believed to be the purpose for the late Cenozoic elevate of the Sierra Nevada in California. Indeed, seismic information give pictures of outside layer mantle connections during the alleged dynamic foundering of the thick root underneath the southern Sierra Nevada. Apparently thick matter streamed lopsidedly into a mantle trickle underneath the contiguous Great Valley. At the highest point of this dribble, a V-formed cone of covering is being hauled down many kilometers into the focal point of the mantle trickle, prompting the vanishing of the Mohorovicic brokenness (the limit among outside and mantle) in seismic pictures. Moreover, at the northern Sierra Nevada, there is additionally a seismic "opening" known as the Redding irregularity, loaning to the suspicion that lithospheric foundering happened there too. Also, underneath the southern Sierra Nevada, Boyd *et al.* imaged what might be simply the foundering lithosphere when they produced a thickness guide of the area through seismic tomography.

Taking everything into account, isostasy is one more illustration of a misleadingly basic thought in physical science that gives urgent and clearing informative force for different sciences.

Check Your Progress

3. _________ earthquake results from Tectonic Forces.
4. A ________ earthquake are small earthquakes in mines causes by Seismic Waves.

3.4 EARTHQUAKE

An earthquake is what occurs when two blocks of the earth slip over one another. The surface at which they slip is called the fault or fault plane. The location below the earth's surface where the earthquake starts is referred to as the hypocenter, and the vicinity directly above it on the floor of the earth is referred to as the epicenter.

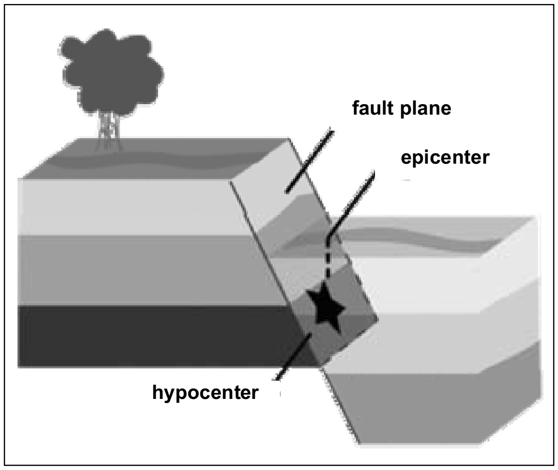

Fig. 3.5: Happening of Earthquake

Seldomly an earthquake has foreshocks. Foreshocks are smaller earthquakes that take region in the same vicinity as the following larger earthquake. It could't be told that an earthquake is a foreshock until the bigger earthquake occurs. The most important, principal earthquake is known as the mainshock. Mainshocks constantly have aftershocks that occur. Those are smaller earthquakes that occur afterwards inside the equal region as the mainshock. Depending on the depth of the mainshock, aftershocks can occur for weeks, months, and even years after the mainshock.

A normal (dip-slip) fault is an inclined fracture where the rock mass over an inclined fault moves down.

3.4.1 Causes of Earthquake

The earth has 4 main layers: the internal middle, outer center, mantle and crust. The crust and the top of the mantle possess thin pores and skin on the surface of our planet.

But this skin isn't all in one piece, it's far made from many pieces forming a huge cover over the floor of the earth. No longer best that, however those layered portions preserve slowly transferring around, sliding over one another and bumping into every different. Those layers are referred to as **tectonic plates**, and the edges of the plates are called the **plate boundaries**. The plate boundaries are made of many faults, and maximum of the earthquakes around the sector occur on these faults. Since the edges of the plates are hard, they get caught at the same time as the rest of the plate continues shifting. Eventually, while the plate has moved far sufficient, the edges unstick on one of the faults and there may be an earthquake.

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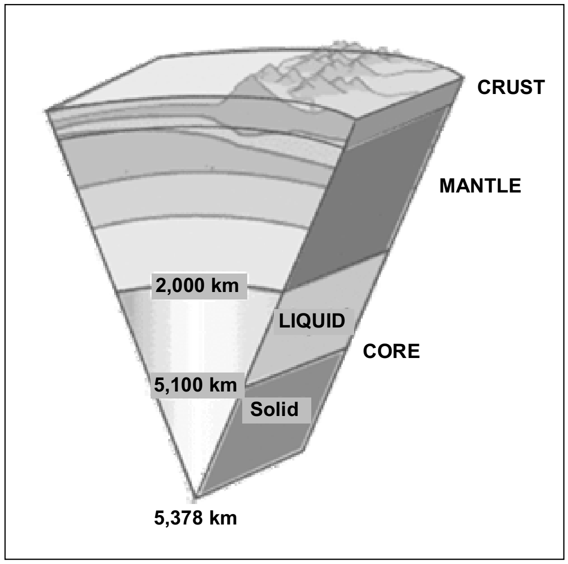


Source: Wikipedia.com

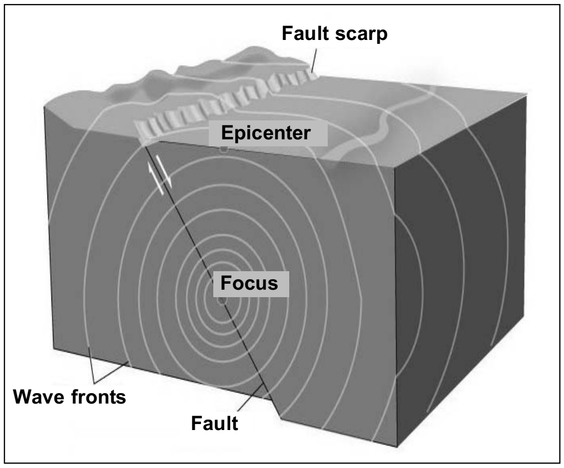
Fig. 3.6: A Simplified Image of the Crust, Mantle and Core, Solid of the Earth

Types of Earthquakes: There are four different types of earthquakes: Tectonic, volcanic, collapse and explosion.

1. A tectonic earthquake is one that takes place whilst the earth's crust breaks because of geological forces on rocks and adjacent plates that purpose bodily and chemical adjustments.

Tectonic plates (Lithospheric plates) are constantly moving as they pass around at the viscous, or slowly flowing, mantle layer underneath. This non-stop motion causes strain on the earth's crust. When the strain gets too huge, it ends in cracks referred to as faults. Whilst tectonic plates flow, it also causes movements on the faults. For that reason, the slipping of land alongside the fault line alongside convergent, divergent and rework obstacles motive earthquakes.

The point from where the power is launched is referred to as the focal point of an earthquake, or hypocentre. The strength waves touring in extraordinary directions attain the floor. The point on the crust, nearest to the point of interest, is known as epicentre. Epicenter is the first one to experience the waves. It's far a factor without delay above the focus.



Source: Wikipedia.com

Fig. 3.7: Tectonic Earthquake

2. A volcanic earthquake is any earthquake that results from tectonic forces which occur along side volcanic activity.

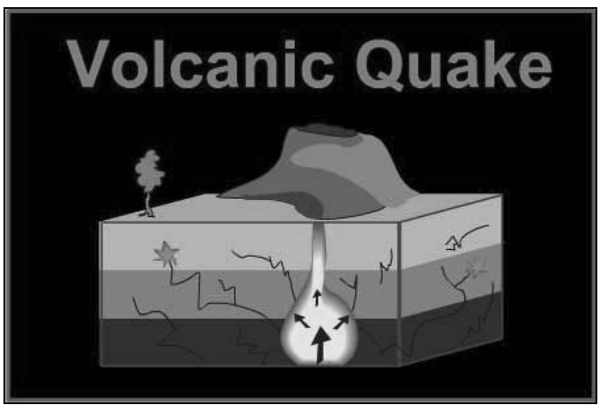


Fig. 3.8: Volcanic Earthquake

A special magnificence of tectonic earthquake is once in a while recognised as volcanic earthquake. But, those are constrained to regions of lively volcanoes. Earthquakes produced by means of pressure changes in stable rock due to the injection or withdrawal of magma (molten rock) are referred to as volcanic earthquakes.

These earthquakes can reason land to subside and might produce massive floor cracks. those earthquakes can arise as rock is transferring to fill in spaces where magma is not present. Volcano-tectonic earthquakes don't indicate that the volcano might be erupting however, can arise at any time.

3. A **collapse earthquake** are small earthquakes in underground caverns and mines that are due to seismic waves constituted of the explosion of rock on the floor.

These styles of earthquakes are generally smaller and most usually occur close to underground mines. They are once in a while known as mine bursts. Crumble earthquakes are instigated via the stress generated within the rocks.

This sort of earthquake ends in the collapse of the roof of the mine instigating extra tremors. Disintegrate earthquakes are widespread in small cities wherein underground mines are located.

NOTES

4. An **explosion earthquake** is an earthquake which is the end result of the detonation of a nuclear and/or chemical tool. Those are due to nuclear explosions. They're, basically, man-caused sort of earthquakes and constitute the most important effect of present day day nuclear war. During the 1930s nuclear test performed with the aid of the United Sates, numerous small towns and villages have been devastated because of this grave act.

Seismic tremors shake the ground surface, can make structures breakdown, disturb transport and benefits, and can cause fires. They can trigger avalanches and tsunami. Earthquakes occur for the most part because of plate tectonics, which includes squares of the Earth moving about the Earth's surface. The squares of rock move past one another along a deficiency. More modest seismic tremors, called foreshocks, may go before the primary quake, and consequential convulsions may happen after the fundamental quake. Quakes are for the most part kept to explicit spaces of the Earth known as seismic zones, which agree primarily with sea channels, mid-sea edges, and mountain ranges. You can't stop tremors, however we can find out additional, in order to find approaches to shield ourselves from them. There are a couple of ways we could help forestall some harm of tremors later on. Numerous structures are developed in spaces of seismic tremor hazard. In the event that a structure is being developed in a city that has encountered seismic tremors, new plans and building materials ought to be utilized to reinforce the structure.

Check Your Progress

5. _______ fault form when the hanging valley moves up.
6. __________ fault happen when the hanging wall moves down.

3.5 SHAKING OF EARTH

Whilst the edges of faults are caught together, and the rest of the block is shifting, the energy that might normally cause the blocks to slip beyond one another is being saved up. whilst the force of the transferring blocks finally overcomes the friction of the jagged edges of the fault and it unsticks, all that stored up power is launched. The energy radiates outward from the fault in all instructions in the shape of seismic waves like ripples on a pond. The seismic waves shake the earth as they pass via it, and when the waves reach the earth's surface, they shake the ground and something on it, like our homes and us.

The Earth comprises of a few layers. A strong center comprising of iron and nickel shapes the deepest layer of the Earth. This center is encircled by a layer of fluid substance which is assessed to be around 2000 kilometers thick. The following layer is known as the Earth's mantle. It comprises essentially of strong stone and is around 2900 kilometers thick.

The peripheral and most slender layer of the Earth's mantle is known as the Earth's hull, which can be portrayed as a mosaic of structural plates of various sizes. Because of the flows streaming in the subjacent layer – the Earth's mantle – the example of structural plates moves ceaselessly. What's more, in spite of the fact that they shift simply by couple of centimeters a year, the grindings made by these developments can have monstrous outcomes.

On the off chance that the structural plates move towards or past one another (which is a typical occasion), these developments, and inconsistencies in the stone, can cause the earth plates to stall out. Contacts and pressing factor between the structural plates increment and in the event that it turns out to be too solid, an unexpected shift of the plates along the all around existing separation point prompts a sudden jerk.

On account of considerable movements, the Earth's surface shudders observably. On the off chance that the occasion of plates stalling out happens beneath the ocean bottom, the release of contact can cause a wave.

The developed rubbing releases and the energy which is delivered during this occasion is emanated from the seismic focus into all directions through wave-like seismic vibrations. The point on the Earth's surface situated over these releases of contact is known as the focal point of the tremor. This is the means by which a quake occur.

Today, the most widely recognized method of estimating the strength of a quake is to group the tremor as indicated by the supposed Richter scale. The deliberate strength – the greatness – portrays seismic energy which is estimated at the focal point of the quake and it is accounted for in focuses.

Beginning at nothing, the Richter scale is fundamentally not restricted upwards. People for the most part don't feel quakes of a lower size than three. From size four onwards, objects begin moving discernibly. Tremors are viewed as solid beginning with extent six on the Richter scale.

Characterization on the Richter scale is accounted for in focuses. Each extra point on the scale implies that a tremor is more grounded by multiple times. Subsequently, a tremor of greatness two doesn't make the earth shake two-times as solid as a quake of size one, yet ten-times as solid.

Seeing how structural tremors are caused, the clarification of why quakes happen especially continuous in certain locales of the Earth comes to be unmistakable. The nations most regularly hit by solid quakes are situated over the lines of abutting structural plates.

The Caribbean Plate, which Haiti is situated on, is an incredibly undermined area, since the plate appends to even a few other structural plates. In the north and east grindings are made because of the North American Plate, while the enormous South American Plate makes pressure from the south. In the west there are the Coca Plate and the Nazca Plate making grindings emerge among them and the Caribbean Plate and this contact is much of the time delivered as tremors.

Likewise Chile and Turkey – nations just recently hit by solid tremors – are situated in such undermined areas. The way that these nations and their occupants' premise of life are annihilated over and over by seismic tremors is thusly to be expected. In any case, monitoring the risk does sadly not advance the circumstance of individuals.

It is areas like Chile and Haiti where individuals earnestly need economical help. In this stage after the tremor they need assistance specifically with remaking their homes to being more secure when the following quake will hit.

Check Your Progress

7. What is dip slip fault?
8. Name various types of earthquakes.

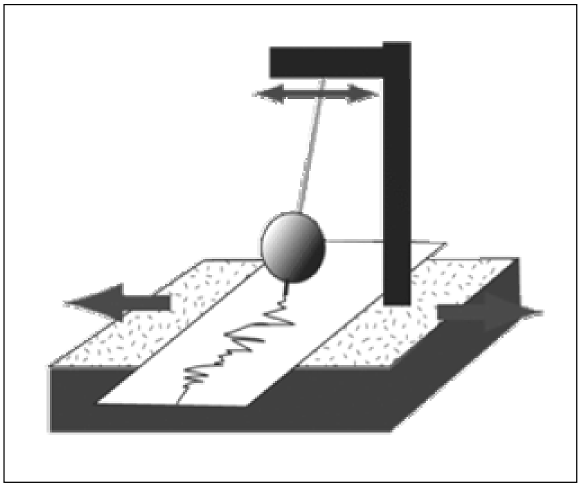
3.6 RECORDING OF EARTHQUAKES

Earthquakes are recorded through gadgets known as seismographs. The recording they make is known as a seismogram. The seismograph has a base that sets firmly in the ground, and a heavy seismic weight that hangs unfastened. When an earthquake causes the ground to shake, the bottom of the seismograph shakes too, but the seismic weight does now not, alternatively the spring or string that it's far striking from absorbs all the motion. The difference in motion among the shaking part of the seismograph and the immobile part is what's recorded.

The illustrative sketch of the seismograph shows how the instrument shakes with the earth below it, but the recording device remains stationary (instead of the other way around).

A significant instrument to examine the Earth's inside is the seismograph. The seismograph is an instrument that records ground movement, or seismic waves, created by tremors. Seismographs can be introduced forever or briefly. Transitory portions are utilized to respond to logical inquiries of geographical interest, for example, here close to the foundation of the Nanga Parbat massif in upper east Pakistan.

Perpetual portions are utilized to consider the general design of the Earth's inside. Seismographs utilized in lasting portions are conveyed at fixed areas all throughout the planet. Current seismographs record and intensify seismic waves electronically, and can identify ground movement as little as 0.00000001 cm (distances of the request for nuclear dividing.)



Source: Wikipedia.com

Fig. 3.9: Recording of Earthquake

The standard by which a seismometer works can be considered as a weighty (seismic) mass openly appended to a casing fixed to the Earth. At the point when seismic waves come to the seismometer, the edge moves alongside the ground. The weighty mass inside the casing stays fixed as a result of its idleness. The general movement between the casing and the mass is an action the of ground movement.

Check Your Progress

9. The _______ earthquake extends from Java to Sumatra.
10. The World's greatest earthquake belt is _____________.

3.7 EFFECTS OF EARTHQUAKES

1. **Harm to homes:** Excessive significance earthquakes can lead to finish crumble of buildings. Debris from collapsing buildings is the main risk in the route of an earthquake due to the fact the falling effects of massive, heavy objects can be lethal to humans. High magnitude earthquakes result in shattering of mirrors and home windows, which additionally present chance to humans.
2. **Harm to infrastructure:** Earthquakes can reason power strains to fall. This is dangerous because the exposed live wires can electrocute humans or start fires. Foremost earthquakes can cause rupturing of roads, gasoline lines, and water pipelines. Broken fuel lines can cause gas to escape. Escaping gasoline can result in explosion and fires, which may be hard to control.
3. **Landslides and rockslides:** Whilst an earthquake occurs, huge rocks and sections of earth placed uphill may be dislodged, consequently, rolling swiftly down into the valleys. Landslides and rockslides can cause destruction and death to the people residing downstream.

NOTES

4. **Can bring about floods:** High magnitude earthquakes can instigate cracking of dam walls, collapsing in the end. This will send raging waters into nearby areas causing big flooding.
5. **Earthquakes can cause tsunamis:** A tsunami is a series of long excessive sea tremors sparked by means of an earthquake or volcanic eruptions beneath the sea. A tsunami can wipe out an entire surrounding coastal vicinity populace. An ordinary example is the March eleven, 2011, earthquake and tsunami that struck the coast of Japan leaving more than 18,000 human beings dead in its wake.
6. **Leads to liquefaction:** Liquefaction is a phenomenon wherein the soil turns into saturated and loses it strength. Whilst sediments which includes high water content material are subjected to constant trembling, water pressure held in the sediment pores slowly boom. In the end, the sediments lose almost all cohesive power and start appearing like liquids. Homes and different structures built on top of this liquefied soil overturn or sink into the ground. Earthquakes are answerable for maximum of the liquefaction happening internationally. An ordinary example of liquefaction phenomenon is the earthquake of 1692 in Jamaica that resulted into the devastation of the town of Port Royal.

Distribution of Earthquakes

Earthquakes can strike any place at any time, however, records shows they arise in the equal fashionable styles year after year, mainly in three large zones of the earth:

- The world's greatest earthquake belt, the circum-Pacific seismic belt, is observed alongside the rim of the Pacific Ocean, wherein about eighty-one percentage of our planet's largest earthquakes arise.
  - It has earned the nickname "Ring of hearth".
  - The belt exists along obstacles of tectonic plates, in which plates of typically oceanic crust are sinking (or subducting) below another plate. Earthquakes in those subduction zones are as a result of slip among plates and rupture within plates.
- The Alpide earthquake belt (mid Continental belt) extends from Java to Sumatra through the Himalayas, the Mediterranean, and out into the Atlantic.
  - This is responsible for about 17 percent of the world's largest earthquakes, consisting of a number of the maximum damaging.
- The 0.33 outstanding belt follows the submerged mid-Atlantic Ridge. The ridge marks in which tectonic plates are spreading apart (a divergent plate boundary).
  - Maximum of the mid-Atlantic Ridge is deep underwater and a long way from human development.

NOTES

Check Your Progress

11. Seismic waves are measured with the help of ___________.
12. Earthquake events are measured according to ______ scale.

3.8 MEASUREMENT OF EARTHQUAKES

- The energy from an earthquake travels through Earth in vibrations referred to as seismic waves.
- Scientists can measure those seismic waves with the help of an instruments known as seismometers.
- A seismometer detects seismic waves underneath the tool and record them as a chain of zig-zags.
- Scientists can decide the time, place and intensity of an earthquake from the information recorded via a seismometer. This record additionally provides facts about the rocks the seismic waves traveled via.
- The earthquake occasions are scaled both in keeping with the significance or intensity of the surprise. The magnitude scale is known as the Richter scale. The importance pertains to the energy released in the course of the quake. The value is expressed in absolute numbers, 0-10.
- The intensity scale is known as after Mercalli, an Italian seismologist. The intensity scale takes under consideration the seen damage as a result of the event. The range of intensity scale is from 1-12.

Seismic Waves (Earthquake Waves)

- Seismic waves are the waves of strength which is end result of earthquakes or an explosion. They're the strength that travels through the earth and is recorded on seismographs.
- Earthquake waves are essentially of kinds — Body waves/Primary waves and surface waves.
- Body waves are generated because of the release of energy at the point of interest and flow in all instructions journeying through the frame of the earth. For this reason, the name body is waves.
  - There are varieties of body waves. They are known as P- and S-waves.
  - P-waves pass quicker and are the primary to reach on the floor. these are also known as 'number one waves'. The P-waves are just like sound waves. They tour via gaseous, liquid and solid materials.
  - S-waves arrive on the floor with some time lag, those are known as secondary waves. An essential truth approximately S-waves is that they can tour most effective through strong substances.

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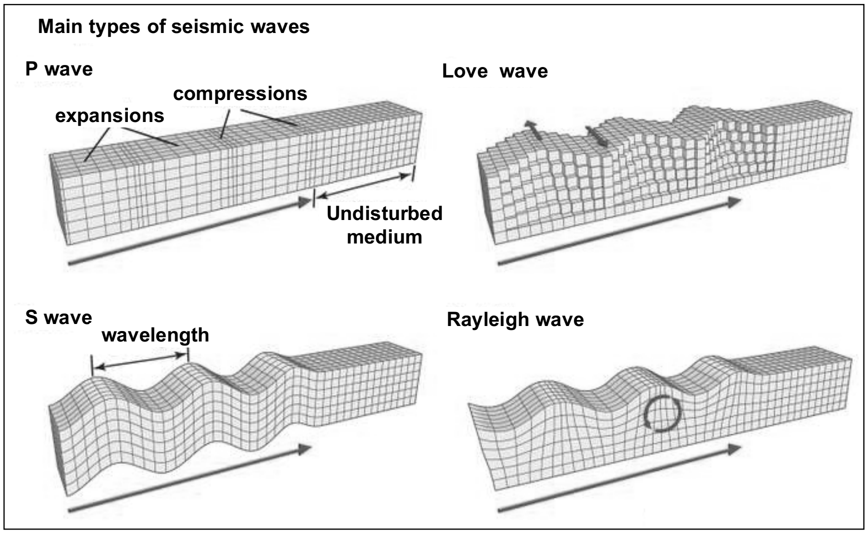
- The body waves have interaction with the surface rocks and generate a new set of waves called floor waves. Those waves flow alongside the floor.
- The floor waves are the final to report on seismographs, these waves are extra detrimental. They purpose displacement of rocks, and hence, the rocks crumble.
- For that reason, the attributes of the seismic waves are pretty essential. It has helped scientists to understand the shape of the interior of the earth.



Source: Wikipedia.com

Fig. 3.10: Types of Seismic Waves

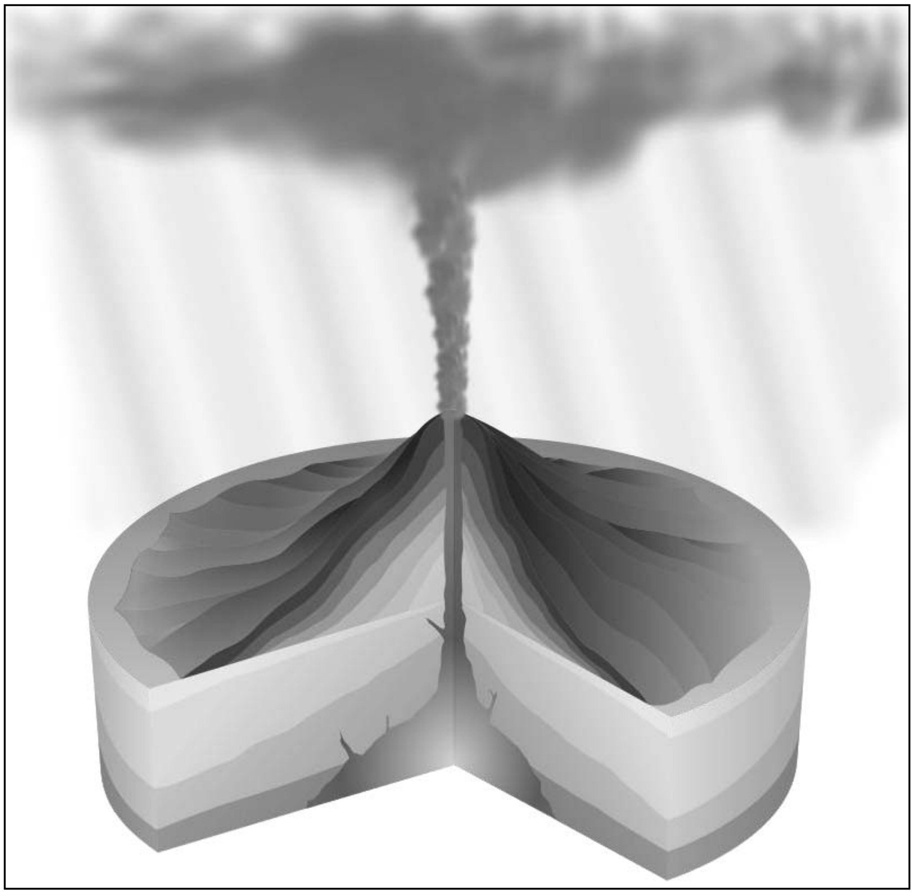
Check Your Progress

13. Weaker zone of mantle is __________.
14. Most explosive earthquake of earth are ________.

3.9 VOLCANO

A volcano is a vent or fissure in Earth's crust through which lava, ash, rocks, and gases erupt. An active volcano is a volcano that has erupted inside the recent past. The mantle includes a weaker zone called the asthenosphere.

Magma is the material that is present within the asthenosphere, matter that flows to or reaches the ground contains lava flows, volcanic bombs, pyroclastic debris, dirt, ash, and gases. The gases can be sulfur compounds, nitrogen compounds, and little amounts of argon, hydrogen, and chlorine.



Source: commons.wikimedia.com

Fig. 3.11: Eruption of Volcano

Types of Volcanoes

- Volcanoes are classified based on the nature of eruption and the form developed at the surface.

Shield Volcanoes

- The Shield volcanoes are the largest of all the volcanoes on the earth, which are not steep and mostly made up of basalt.
- They become explosive if in some way water gets into the vent, otherwise, they are characterized by low-explosivity.
- The lava that is moving upwards does so in a fountain-form and emanates the cone at the vent's top and then develops into a cinder cone.
- E.g: Hawaiian shield volcanoes

Composite Volcanoes

- Composite Volcanoes are characterized by outbreaks of cooler and more viscous lavas than basalt.
- They are constructed from numerous explosive eruptions.

NOTES

- Large quantities of pyroclastic material and ashes find their way to the ground along with lava.
- This material gathers near the vent openings resulting in the creation of layers.
- Mayon Volcano in the Philippines, Mount Fuji in Japan, and Mount Rainier in Washington are the major composite volcanoes in the world.
- The major composite volcano chains are Pacific Rim which is known as the "Rim of Fire".

Caldera

- Calderas are known as the most explosive volcanoes of Earth.
- They are generally explosive.
- When they erupt, they incline to collapse on themselves rather than constructing any structure.
- The collapsed depressions are known as calderas.

Flood Basalt Provinces

- Flood Basalt Province volcanoes discharge highly fluid lava that flows for long distances.
- Many parts of the world are covered by thick basalt lava flows.

Mid-Ocean Ridge Volcanoes

- These volcanoes are found in the oceanic areas.
- There exists a system of mid-ocean ridges stretching for over 70,000 km all through the ocean basins.
- The central region of this ridge gets frequent eruptions.

Check Your Progress

15. When a part of earth's upper mantle or lower crust melts, it forms __________.
16. Amount of dissolved gas in magma at atmospheric pressure is __________.

3.10 CAUSES OF VOLCANOES

When a part of the earth's upper mantle or lower crust melts, it leads to formation of magma. A volcano is essentially an opening or a vent through which this magma and the dissolved gases it contains are discharged. Although there are several factors resulting into a volcanic eruption, three predominate: the buoyancy of the magma, the pressure from the evolved gases in the magma and the injection of a new batch of magma into an already filled magma chamber.

- **The buoyancy of the magma:** As rock inside the earth melts, its volume increases producing a melt that is less dense than the surrounding rock. This lighter magma then rises toward the surface by virtue of its buoyancy, and finally the magma reaches the surface and erupts.

- **The pressure from the gases in the magma:** Magmas also contain dissolved volatiles such as water, sulphur dioxide and carbon dioxide. Experiments have shown that the amount of a dissolved gas in magma at atmospheric pressure is zero, but rises with increasing pressure.

Injection of new magma into a chamber that is already filled with: This injection forces some of the magma in the chamber to move up in the conduit and erupt at the surface.

Although volcanologists are well aware of these three processes, they cannot yet forecast a volcanic eruption. But they have made significant advances in predicting volcanic eruptions. Forecasting involves probable character and time of an eruption in a monitored volcano. The character of an eruption is based on the prehistoric and historic record of the volcano in question and its volcanic products. For example, a tremendously erupting volcano that has produced ash fall, ash flow and volcanic mudflows (or lahars) is likely to do the same in the future.

Check Your Progress

17. Lahars are combination of __________, __________, __________, __________ and __________.
18. Heat from cooling magma can cause __________ of rocks.

3.11 EFFECTS OF VOLCANO

The effects of volcanic eruptions can be divided into primary and secondary outcomes. The primary results are instantaneous and come from the eruption itself while the secondary outcomes result from the primary consequences.

Primary results of a Volcanic Eruption:

- **Volcanic gases:** All magma includes dissolved gases which might be release for the duration of and between eruptions. Those gases are especially steam, carbon dioxide and compounds of sulphur and chlorine.
- **Lava flows:** These are streams of molten rock.
- **Pyroclastic flows:** These are excessive speed avalanches of hot ash, rock fragments and gasoline which move down the edges of a volcano. These flows arise when the vent vicinity or ash column collapses.
- **Tephra:** The explosive electricity of an eruption causes old lava to be blasted into tiny pieces and hurled into the air. The fragments are tephra.

NOTES

Secondary effects of a Volcanic Eruption:

- **Lahars:** These are mixture of water, rock, ash, sand and dust that originate from the slopes of a volcano. Lahars frequently show up due to heavy rainfall eroding volcanic deposits or warmth from a volcanic vent unexpectedly melting snow and ice.
- **Landslides:** Warmness from cooling magma can purpose hydrothermal alteration of the rocks, turning sections of them into clay. This weakens the rocks and will increase the risk of slope screw ups.
- **Flooding:** Great eruptions can exchange the surface regions around a volcano and disrupt drainage patterns, leading to long-time period flooding.

Other Secondary outcomes include:

- Meals/water supply interrupted.
- Homelessness.
- Companies forced to close.
- Value of insurance claims.
- Unemployment.
- Long-term problems with the tourism enterprise.

Check Your Progress

19. Which material is present in asthenosphere?
20. State types of Rocks.

3.12 ROCKS

A rock is any naturally occurring strong mass or aggregate of minerals or mineraloid depend. It is classified by the minerals blanketed, its chemical composition and the way in which it is formed. Rocks are generally grouped into 3 predominant agencies: igneous rocks, metamorphic rocks and sedimentary rocks. Rocks shape the Earth's outer strong layer, the crust, and maximum of its interior, besides for the liquid outer core and wallet of magma within the asthenosphere.

A rock formation is an remoted, scenic, or astounding floor rock outcrop. Rock formations are normally the result of weathering and erosion sculpting the prevailing rock. The time period rock formation can also consult with specific sedimentary strata or different rock unit in stratigraphic and petrologic research.

A rock shape can be created in any rock kind or mixture:

1. Igneous rocks are created when molten rock cools and solidifies, with or without crystallization. They will be both plutonic bodies or volcanic extrusives again, erosive forces sculpt their present day forms.

2. Metamorphic rocks are created by using rocks that have been transformed into any other type of rock, generally by means of a few combination of warmth, pressure, and chemical alteration.
3. Sedimentary rocks are created by way of a spread of strategies however generally regarding deposition, grain via grain, layer through layer, in water or, within the case of terrestrial sediments, on land through the action of wind or once in a while shifting ice. Erosion later exposes them in their present day shape.

Geologists have created some of phrases to explain one-of-a-kind rock structures inside the landscape that can be formed by means of natural methods:

- Butte
- Cliff
- Escarpment
- Gorge
- Inselberg or monadnock
- Mesa
- Height
- Promontory
- River cliff
- Sea cliff
- Stack
- Stone run
- Tor

Starting Place of the Rock

Igneous rocks are fashioned whilst magma cools in the Earth's crust, or lava cools at the ground surface or the seabed. The metamorphic rocks are formed when existing rocks are subjected to such large pressures and temperatures that they're transformed—something that happens, as an example, whilst continental plates collide. The sedimentary rocks are formed via diagenesis or lithification of sediments, which in flip are shaped with the aid of the weathering, delivery, and deposition of current rocks.

Kinds of Rocks

1. Igneous Rocks: Igneous rock is shaped because of the cooling and solidification of magma or lava. The phrase Igneous is derived from the Latin word igneus, which means a fireplace, from ignis that means fire. This magma is derived from partial melts of pre-present rocks in both a planet's mantle or crust. Typically, the melting of rocks is because of one or greater of 3 procedures: a boom in temperature, a lower in pressure, or a change in composition.

Igneous rocks are divided into most important categories:

- Plutonic, also referred to as an intrusive rock, is the result whilst magma cools and crystallizes slowly within the Earth's crust. A common example of this kind is granite.
- Volcanic or extrusive rocks end result from magma reaching the floor either as lava or fragmental ejecta, forming minerals inclusive of pumice or basalt.

The chemical abundance and the fee of cooling of magma generally makes a sequence known as Bowen's response series. Most major igneous rocks are located alongside this scale.

About 65% of the Earth's crust by means of extent includes igneous rocks, making it the maximum abundant category. Of these, 66% are basalt and gabbro, 16% are granite, and 17% granodiorite and diorite. only 0.6% are syenite and 0.3% are ultramafic. The oceanic crust is 99% basalt, that's an igneous rock of mafic composition. Granite and comparable rocks, called granitoids, dominate the continental crust.

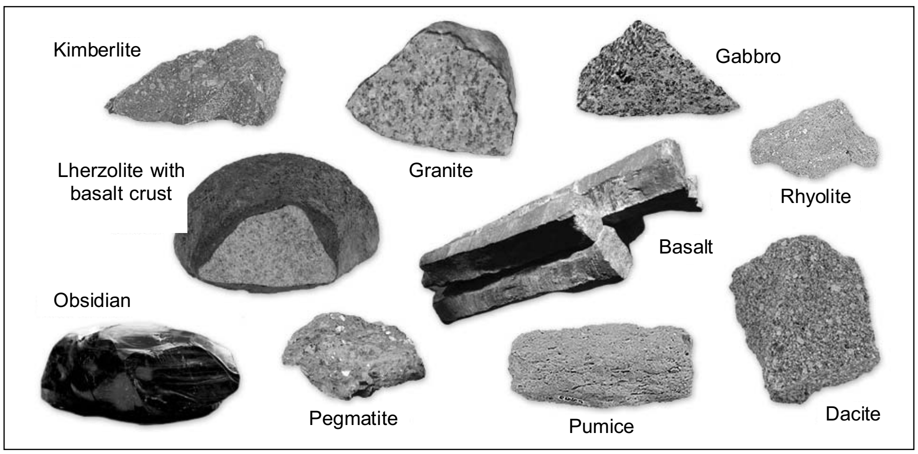


Fig. 3.12: Igneous Rocks

2. Sedimentary Rocks: Sedimentary rocks are shaped like the accumulation and cementation of fragments of in advance rocks, minerals, and organisms or as chemical precipitates and natural growths in water (sedimentation) at the earth's surface. This technique reasons clastic sediments (pieces of rock) or organic particles to settle and acquire, or for minerals to chemically precipitate (evaportie) from a solution. The particulate depend then undergoes compaction and cementation at slight temperatures and pressures (diagenesis).

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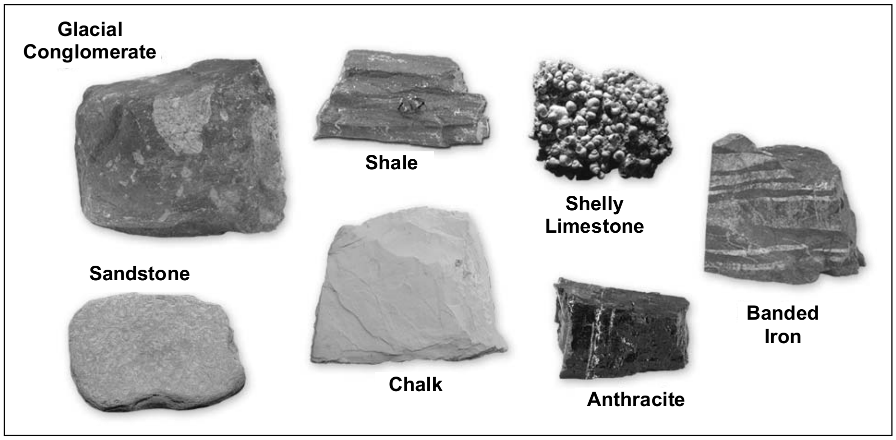

Fig. 3.13: Sedimentary Rocks

Before being deposited, sediments are shaped by weatheing of preceding rocks through erosion in a supply region and then transported to the location of deposition through water, wind, ice, mass motion or glaciers (agents of denudaton), about 7.9% of the crust by way of quantity consists of sedimentary rocks, with 82% of these being shales, at the same time as the rest consists of limestone (6%), sandstone and arkoses (12%). Sedimentary rocks frequently comprise fossils. Sedimentary rocks shape beneath the influence of gravity and typically are deposited in horizontal or close to horizontal layers or strata, and can be referred to as stratified rocks.

Three Metamorphic Rock: Metamorphic rocks are formed by subjecting any rock kind — sedimentary rock, igneous rock or every other older metamorphic rock — to unique temperature and stress situations than those wherein the authentic rock become fashioned. This procedure is called metamorphism, that means to "alternate in shape". The result is a profound change in bodily residences and chemistry of the stone. The authentic rock, known as the protolith, transforms into different mineral types or other sorts of the same minerals, by recrystallization. The temperatures and pressures required for this procedure are usually better than the ones observed at the Earth's floor: Temperatures extra than one hundred fifty to 200°C and pressures of 1500 bars. Metamorphic rocks compose 27.4% of the crust with the aid of quantity.

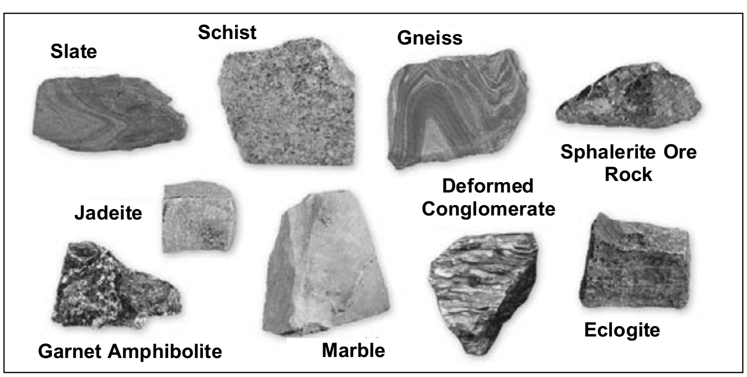

Fig. 3.14: Metamorphic Rock

The 3 principal classes of metamorphic rock are based upon the formation mechanism. An intrusion of magma that heats the encompassing rock causes contact metamorphism - a temperature-dominated transformation. Stress metamorphism occurs whilst sediments are buried deep under the floor; stress is dominant, and temperature performs a smaller position. This is termed burial metamorphism, and it is able to result in rocks consisting of jade. Where each warmth and pressure play a role, the mechanism is termed nearby metamorphism that is typically found in mountain-building areas.

Relying on the structure, metamorphic rocks are divided into standard categories. Those that own a texture are known as foliated; the remainders are termed non-foliated. The call of the rock is then decided based totally on the forms of minerals gift. Schists are foliated rocks which are broadly speaking composed of lamellar minerals together with micas. A gneiss has seen bands of differing lightness, with a commonplace instance being the granite gneiss. Other forms of foliated rock consist of slates, phullites, and mylonite. Familiar examples of non-foliated metamorphic rocks encompass marble, soapstone, and serpentine. This department contains quartzite- metamorphosed shape of sandstone and hornfels.

Check Your Progress

21. What does Plutonic Rock results in?
22. What are oxides?

3.13 COMPOSITION OF ROCKS

Most rocks are composed of minerals. Minerals are described by geologists as certainly going on inorganic solids that have a crystalline structure and a awesome chemical composition. Of path, the minerals discovered in the Earth's rocks are produced by means of a diffusion of different arrangements of chemical factors. A list of the eight most common elements making up the minerals found in the Earth's rocks is described in Table below.

Table 3.1: Common Elements Found in the Earth's Rocks

Element	Chemical Symbol	Percent Weight in Earth's Crust
Oxygen	O	46.60
Silicon	Si	27.72
Aluminum	Al	8.13
Iron	Fe	5.00
Calcium	Ca	3.63
Sodium	Na	2.83
Potassium	K	2.59
Magnesium	Mg	2.09

Over 2000 minerals have been identified by earth scientists. The table below describes some of the vital minerals, their chemical composition, and classifies them in one of 9 groups. The elements group includes over a hundred recognized minerals. Most of the minerals in this magnificence are composed of only one class. Geologists occasionally subdivide this group into metallic and nonmetal classes. Gold, silver, and copper are examples of metals. The elements sulfur and carbon produce the minerals sulfur, diamonds, and graphite which are nonmetallic.

The Sulfide groups are an economically significant class of minerals. Lots of these minerals consist of metallic elements in chemical aggregate with the element sulfur. Most ores of essential metals which includes mercury (cinnabar - HgS), iron (pyrite - FeS_2), and lead (galena - PbS) are extracted from sulfides. Some of the sulfide minerals are identified by their steel luster.

The Halides are a set of minerals whose principal chemical parts are fluorine, chlorine, iodine, and bromine. Many of them are highly soluble in water. Halides also generally tend to have a distinctly ordered molecular shape and a high degree of symmetry. The most well known mineral of this group is halite ($NaCl$) or rock salt.

The Oxides are a group of minerals which can be compounds of one or greater metallic elements mixed with oxygen, water, or hydroxyl (OH). The minerals on this mineral class show the best versions of physical properties. Some are tough, others soft. Some have a metallic luster, some are clear and transparent. Some representative oxide minerals consist of corundum, cuprite, and hematite.

The Carbonates group includes minerals which include one or more metallic factors chemically associated with the compound CO_3. Most carbonates are lightly coloured and transparent while noticeably natural. Generally carbonates are soft and brittle. Carbonates additionally effervesce when exposed to heated hydrochloric acid. Many geologists considered the Nitrates and Borates as subcategories of the carbonates. Some common carbonate minerals encompass calcite, dolomite, and malachite.

The Sulfates are a mineral organization that contain one or extra steel element in combination with the sulfate compound SO_4. All sulfates are transparent to translucent and soft. Some are heavy and a few are soluble in water. Rarer sulfates exist containing substitutions for the sulfate compound. For example, inside the chromates SO_4 is replaced via the compound CrO_4. Two commonplace sulfates are anhydrite and gypsum.

The Phosphates are a set of minerals of 1 or extra metallic element chemically associated with the phosphate compound PO_4. The phosphates are often labeled together with the vanadate, arsenate, tungstate, and molybdate minerals. One commonplace phosphate mineral is apatite. Most phosphates are heavy but gentle, those are normally brittle and occur in small crystals or compact aggregates.

The Silicates are the most important class of minerals. Chemically, those silicates incorporate various quantities of silicon and oxygen. It is easy to distinguish silicate minerals from other groups, however hard to identify person minerals within this institution. None of them are completely opaque. Most are mild in weight. Tetrahedron is the development component of all silicates. A tetrahedon is a chemical structure in which a silicon atom is joined through 4 oxygen atoms (SiO_4). Some representative minerals include albite, augite, hornblende, beryl, biotite, microcline, muscovite, olivine, othoclase, and quartz.

The organic minerals are a rare organization of minerals chemically containing hydrocarbons. Most geologists do no longer classify those substances as real minerals. Be aware that our original definition of a mineral excludes natural materials. However, some natural materials which might be discovered naturally on earth that exist as crystals that resemble and act like true minerals. These substances are called organic minerals. Amber is a great example of a natural mineral.

Table 3.2: Classification of Some of the Important Minerals Found in Rocks

Group	Typical Minerals (and information link)	Chemistry
Elements	Gold	Au
	Silver	Ag
	Copper	Cu
	Carbon (Diamond and Graphite)	C
	Sulfur	S
Sulfides	Cinnabar	HgS
	Galena	PbS
	Pyrite	FeS_2
Halides	Fluorite	CaF_2
	Halite	NaCl
Oxides	Corundum	Al_2O_3
	Cuprite	Cu_2O
	Hematite	Fe_2O_3
Carbonates (Nitrates and Borates)	Calcite	$CaCO_3$
	Dolomite	$CaMg(CO_3)_2$
	Malachite	$Cu_2(CO_3)(OH)_2$
Sulfates	Anhydrite	$CaSO_4$
	Gypsum	$CaSO_4$ -2(H_2O)
Phosphates (Arsenates, Vanadates, Tungstates, and Molybdates)	Apatite	$Ca_5(F,Cl,OH)(PO_4)$
Silicates	Albite	$NaAlSi_3O_8$
	Augite	(Ca, Na) (Mg, Fe, Al) $(Al, Si)_2O_6$
	Beryl	$Be_3Al_2(SiO_3)_6$
	Biotite	K $(Fe, Mg)_3 AlSi_3O_{10}$ $(F, OH)_2$

NOTES

	Hornblende	$Ca_2(Mg, Fe, Al)_5$ $(Al, Si)_8 O_{22}(OH)_2$
	Microcline	$KAlSi_3O_8$
	Muscovite	$KAl_2(AlSi_3O_{10})$ $(F, OH)_2$
	Olivine	$(Mg, Fe)_2SiO_4$
	Orthoclase	$KAlSi_3O_8$
	Quartz	SiO_2
Organics	Amber	$C_{10}H_{16}O$

Rock Cycle

Geologic substances i.e. mineral crystals and their host rock types are cycled via various forms. The method of rock cycling depends on temperature, time, strain, and adjustments in environmental conditions in the Earth's crust and at its floor. The rock cycle illustrated in figure displays the primary relationships amongst igneous, metamorphic, and sedimentary rocks. Erosion consists of weathering (the bodily and chemical breakdown of minerals) and transportation to a domain of deposition. Diagenesis is, as formerly defined, the procedure of forming sedimentary rock via compaction and herbal cementation of grains, or crystallization from water or answers, or recrystallization. The conversion of sediment to rock is called as lithification.

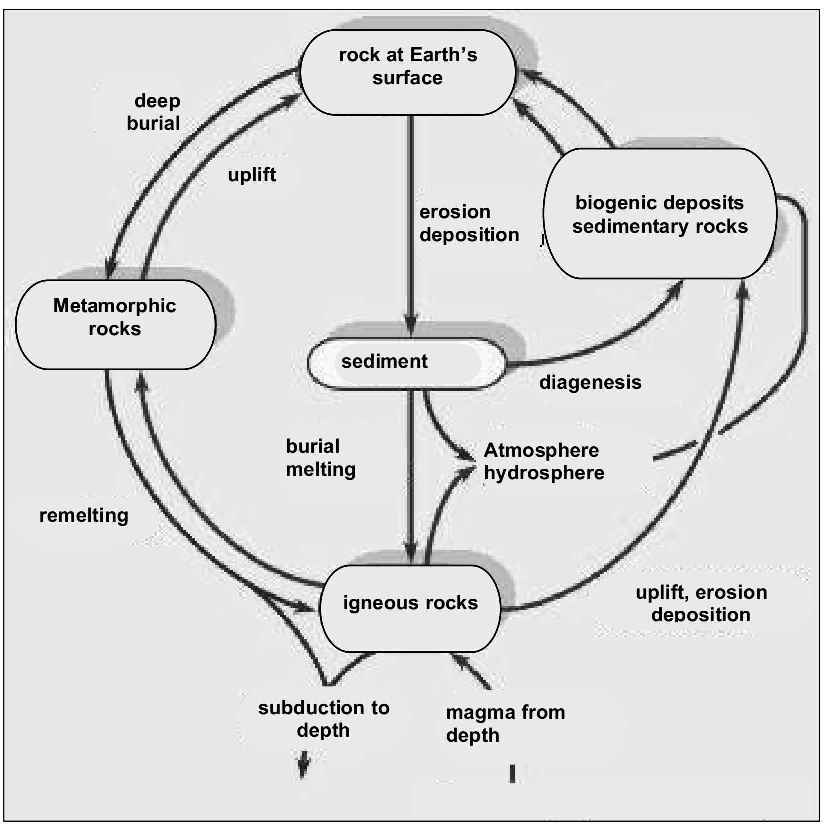

Fig. 3.15: Rock Cycle

NOTES

Texture of Rock

The texture of a rock is the dimensions, form, and association of the grains (for sedimentary rocks) or crystals (for igneous and metamorphic rocks). also of importance are the rock's volume of homogeneity (i.e., uniformity of composition all through) and the degree of isotropy. The latter is the quantity to which the bulk shape and composition are the identical in all instructions within the rock.

Evaluation of texture can yield information approximately the rock's source cloth, conditions and environment of deposition (for sedimentary rock) or crystallization and recrystallisation (for igneous and metamorphic rock, respectively), and next geologic records and change.

Category by Grain or Crystal length

The unusual textural terms used for rock kinds with recognize to the dimensions of the grains or crystals, are given in the table. The particle-length classes are derived from the Udden-Wentworth scale developed for sediment. For igneous and metamorphic rocks, the phrases are generally used as modifiers — e.g., medium-grained granite. Aphanitic is a descriptive term for small crystals, and phaneritic for large ones. Very coarse crystals (the ones large than 3 centimetres, or 1.2 inches) are termed pegmatitic.

For sedimentary rocks, the extensive categories of sediment length are coarse (greater than 2 millimetres, or 0.08 inch), medium (between 2 and 1/16 millimetres), and fine (under 1/16 millimetre). The latter includes silt and clay, which each have a length indistinguishable with the aid of the human eye and are also termed dirt. Maximum shales include a few silt. Pyroclastic rocks are the ones fashioned from clastic (from the Greek phrase for damaged) fabric ejected from volcanoes. Blocks are fragments damaged from stable rock, whilst bombs are molten while ejected.

Porosity

The sedimentary rock refers to the majority extent of the material, together with the grains or crystals in addition to the contained void space. The volumetric part of bulk rock that isn't occupied by using grains, crystals, or natural cementing material is named porosity. This is to say, porosity is the ratio of void extent to the bulk volume (grains plus void area). This void space consists of pore area between grains or crystals, similarly to crack area. In sedimentary rocks, the amount of pore space relies upon on the degree of compaction of the sediment (with compaction commonly increasing with intensity of burial), on the packing association and shape of grains, on the amount of cementation, and on the degree of sorting. Standard cements are siliceous, calcareous or carbonate, or iron-bearing minerals.

Arranging is the inclination of sedimentary rocks to have grains which may be additionally estimated, i.e., to have a tight scope of sizes. Inadequately arranged residue introductions a colossal scope of grain sizes and henceforth has diminished porosity. Very much arranged recommends a grain length appropriation that sensibly speaking uniform. Depending on the sort of close

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pressing of the grains, porosity can be acceptable estimated. It should be referenced that during designing usage - e.g., geotechnical or structural designing - the wording is stated oppositely and is known as reviewing. An all around evaluated residue is a (geographically) ineffectively arranged one, and an inadequately reviewed silt is an appropriately taken care of one.

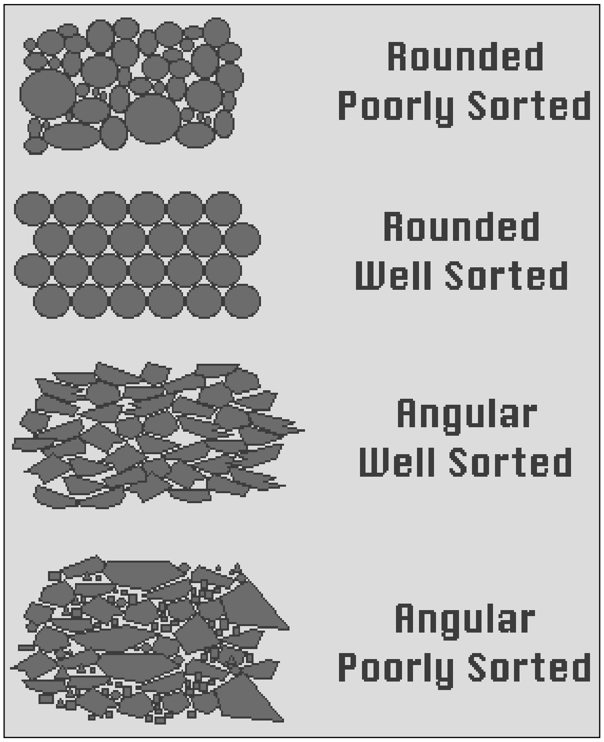

Fig. 3.16: Sorting

Total porosity encompasses all the void space, including those pores that are interconnected to the surface of the sample as well as those that are sealed off by natural cement or other obstructions. Thus, the total porosity (φ_T) is

$$\varphi_T = 100\left(1 - \frac{\mathrm{vol}_G}{\mathrm{vol}_B}\right)\%$$

where vol_G is the volume of grains (and cement, if any) and vol_B is the total bulk volume. Alternatively, one can calculate φ_T from the measured densities of the bulk rock and of the (mono) mineralic constituent. Thus,

$$\varphi_T = 100\left(1 - \frac{\rho_B}{\rho_G}\right)\%$$

where ρ_B is the density of the bulk rock and ρG is the density of the grains (i.e., the mineral, if the composition is monomineralogic and homogeneous). For example, if a sandstone has a ρ_B of 2.38 grams per cubic centimetre (g/cm^3) and is composed of quartz (SiO_2) grains having ρ_G of 2.65 g/cm^3, the total porosity is–

$$\varphi_T = 100\left(1 - \frac{2.38}{2.65}\right) = 10.2\%$$

Clear (successful, or net) porosity is the extent of void space that prohibits the fixed off pores. It along these lines estimates the pore volume that is successfully interconnected and open to the outside of the example, which is significant while considering the capacity and development of subsurface liquids like petrol, groundwater, or defiled liquids.

Physical Properties

Physical properties of rocks are of interest and utility in numerous fields of work, including topography, petrophysics, geophysics, materials science, geochemistry, and geotechnical designing. The size of examination goes from the atomic and translucent up to earthbound investigations of the Earth and other planetary bodies. Geologists are keen on the radioactive age dating of rocks to reproduce the beginning of mineral stores; seismologists form imminent quake expectations utilizing sinister physical or synthetic changes; crystallographers study the union of minerals with uncommon optical or actual properties; investigation geophysicists explore the variety of actual properties of subsurface rocks to make conceivable discovery of normal assets like oil and gas, geothermal energy, and minerals of metals; geotechnical engineers inspect the nature and conduct of the materials on, in, or of which such designs as structures, dams, passages, scaffolds, and underground stockpiling vaults are to be developed; strong state physicists study the attractive, electrical, and mechanical properties of materials for electronic gadgets, PC segments, or superior earthenware production; and petrol repository engineers dissect the reaction estimated on well logs or in the cycles of profound boring at raised temperature and pressing factor.

Since rocks are aggregates of mineral grains or gems, their properties are resolved in huge part by the properties of their different constituent minerals. In a stone these overall properties are controlled by averaging the general properties and some of the time directions of the different grains or gems. Subsequently, a few properties that are anisotropic (i.e., contrast with course) on a submicroscopic or glasslike scale are genuinely isotropic for a huge mass volume of the stone. Numerous properties are additionally subject to grain or gem size, shape, and pressing plan, the sum and appropriation of void space, the presence of regular concretes in sedimentary rocks, the temperature and pressure, and the sort and measure of contained liquids (e.g., water, petrol, gases). Since numerous stones show a significant reach in these elements, the task of agent esteems for a specific property is regularly done utilizing a measurable variety.

A few properties can differ extensively, contingent upon whether estimated in situ (set up in the subsurface) or in the research center under mimicked conditions. Electrical resistivity, for instance, is exceptionally reliant upon the liquid substance of the stone in situ and the temperature condition at the specific profundity.

Density

Density fluctuates essentially among various stone sorts due to contrasts in mineralogy and porosity. Information on the dissemination of underground stone densities can help with deciphering subsurface geologic design and rock type.

In severe utilization, thickness is characterized as the mass of a substance for every unit volume; nonetheless, in like manner use, it is taken to be the load in demeanor of a unit volume of an example at a particular temperature. Weight is the power that attractive energy applies on a body (and accordingly differs with area), while mass (a proportion of the matter in a body) is a basic property and is consistent paying little mind to area. In routine thickness estimations of rocks, the example loads are viewed as comparable to their masses, on the grounds that the disparity among weight and mass would bring about less mistake on the registered thickness than the exploratory blunders presented in the estimation of volume. Accordingly, thickness is regularly decided utilizing weight as opposed to mass. Thickness ought to appropriately be accounted for in kilograms per cubic meter (kg/m^3), yet is still regularly given in grams per cubic centimeter (g/cm^3).

Mechanical Properties

Stress and Strain

At the point when a pressure σ (power per unit region) is applied to a material like stone, the material encounters an adjustment of measurement, volume, or shape. This change, or twisting, is called strain (ε). Stresses can be pivotal - e.g., directional pressure or basic pressure - or shear (extraneous), or all-sided (e.g., hydrostatic pressure). The terms pressure and pressing factor are in some cases utilized conversely, however regularly stress alludes to directional pressure or shear pressure and pressing factor (P) alludes to hydrostatic pressure. For little burdens, the strain is flexible (recoverable when the pressure is eliminated and directly corresponding to the applied pressure). For bigger anxieties and different conditions, the strain can be inelastic, or perpetual.

Elastic Constants

In elastic distortion, there are different constants that relate the size of the strain reaction to the applied pressure. These versatile constants incorporate the accompanying:

1. Young's modulus (E) is the proportion of the applied pressure to the partial augmentation (or shortening) of the example length corresponding to the strain (or pressure). The strain is the straight change in measurement isolated by the first length.
2. Shear modulus (μ) is the proportion of the applied pressure to the contortion (revolution) of a plane initially opposite to the applied shear pressure; it is likewise named the modulus of unbending nature.
3. Bulk modulus (k) is the proportion of the restricting strain to the fragmentary decrease of volume in light of the applied hydrostatic pressing factor. The volume strain is the adjustment of volume of the example partitioned by the first volume. Mass modulus is likewise named the modulus of incompressibility.

Rock Mechanics

The investigation of deformation coming about because of the strain of rocks in light of stresses is called rock mechanics. At the point when the size of the deformation is stretched out to huge geologic designs in the outside layer of the Earth, the field of study is known as geotectonics.

The components and character of the distortion of rocks and Earth materials can be examined through research center trials, advancement of hypothetical models dependent on the properties of materials, and investigation of twisted shakes and designs in the field. In the research center, one can reproduce - either straightforwardly or by proper scaling of exploratory boundaries - a few conditions. Two kinds of pressing factor might be reproduced: limiting (hydrostatic), because of entombment under rock overburden, and inside (pore), because of pressing factor applied by pore liquids contained in void space in the stone. Coordinated applied pressure, like pressure, strain, and shear, is contemplated, similar with the impacts of expanded temperature presented with profundity in the Earth's covering. The impacts of the term of time and the pace of applying pressure (i.e., stacking) as a component of time are inspected. Likewise, the job of liquids, especially on the off chance that they are synthetically dynamic, is examined.

Some straightforward contraptions for disfiguring rocks are intended for biaxial pressure application: a coordinated (uniaxial) pressure is applied while a keeping pressure is applied (by compressed liquid) around the round and hollow example. This reproduces twisting at profundity inside the Earth. A free inward pore-liquid pressing factor likewise can be applied. The stone example can be jacketed with a dainty, impermeable sleeve (e.g., elastic or copper) to isolate the outside pressure medium from the inward pore liquids (assuming any). The example is normally a couple of centimeters in measurement.

Another device for applying high tension on an example was planned in 1968 by Akira Sawaoka, Naoto Kawai, and Robert Carmichael to surrender hydrostatic keeping pressing factors to 12 kilobars (1.2 gigapascal), extra coordinated pressure, and temperatures up to two or three hundred degrees Celsius. The sample is situated on the baseplate; the pressing factor is applied by driving in cylinders with a water powered press. The end covers can be secured to hold the pressing factor for time tests and to make the gadget compact.

Mechanical assemblies have been grown, normally utilizing multianvil plans, which expand the scope of static exploratory conditions - at any rate for little examples and restricted occasions - to pressures as high as around 1,700 kilobars and temperatures of about 2,000°C. Such work has been spearheaded by specialists like Peter M. Chime and Ho-Kwang Mao, who led learns at the Geophysical Laboratory of the Carnegie Institution in Washington, D.C. Utilizing dynamic procedures (i.e., stun from hazardous effect created by firearm type plans), much higher pressing factors as much as 7,000 kilobars (700 gigapascal) - which is almost double the pressing factor at the focal point of the Earth and multiple times more noteworthy than the air pressure at the

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Earth's surface - can be delivered for exceptionally brief time frames. A main figure in such ultrapressure work is A. Sawaoka at the Tokyo Institute of Technology.

In the elite of the Earth, hydrostatic pressing factor increments at the pace of around 320 bars for each kilometer, and temperature increments at a common pace of 20°– 40°C per kilometer, contingent upon ongoing crustal geologic history. Extra coordinated pressure, as can be produced by enormous scope crustal distortion (tectonism), can run up to 1 to 2 kilobars. This is around equivalent to a definitive strength (before crack) of strong translucent stone at surface temperature and pressing factor (see underneath). The pressure delivered in a solitary serious quake - a shift on a deficiency plane - is around 50 –150 bars.

In contemplating the disfigurement of rocks, one can begin with the supposition of ideal conduct: versatile strain and homogeneous and isotropic stress. Actually, for a tiny scope there are grains and pores in residue and a texture of gems in volcanic and transformative rocks. For a huge scope, rock bodies display physical and substance varieties and underlying highlights. Moreover, conditions like broadened time span, limiting pressing factor, and subsurface liquids influence the paces of progress of deformity.

Check Your Progress

23. What are denudations?
24. What is abrasion?

3.14 WEATHERING

Weathering is the cycle that changes strong stone into silt or pieces. With enduring, rock is broken into more modest pieces. When these silt are isolated from the stones, disintegration is the interaction that moves the residue away from it's unique position. The four powers of disintegration are water, icy masses, wind and gravity. Water is the principle specialist for most disintegration. Water can move most sizes of dregs, contingent upon the strength of its power. Wind moves sand-sized and more modest bits of rock through the air. Glacial masses move all sizes of residue, from incredibly enormous stones to the littlest sections. Gravity moves broken bits of rock, enormous or little, from up to the down incline.

Plate tectonics powers work to assemble immense mountains and different scenes, and conversely, the powers of enduring and mass squandering slowly erode those stones and scenes, called **denudation.** Along with disintegration, tall mountains transform into slopes and even fields. The Appalachian Mountains along the east shore of North America were once just about as tall as the Himalayas.

It is past our creative mind, the way toward working of mountains for which requires million of years, nor would anyone be able to envision as those equivalent mountains step by step are eroded. Yet, envision another walkway or street. The new street is smooth and even. More than many years, it will totally vanish, yet what occurs more than one year? What changes could you see? What powers of enduring wear out that street, or rocks or mountains after some time?

3.14.1 Mechanical Weathering

Mechanical weathering, which is likewise called physical enduring, breaks rock into more modest pieces. These more modest pieces are likeness of greater stone, however only more modest in size. That implies the stone has changed genuinely without changing its arrangement. The more modest pieces have similar minerals, in similar extents as the first stone. There are numerous ways that stones can be grounded to pieces into more modest pieces.

Ice wedging, or **freeze-thaw weathering,** is the primary type of mechanical enduring in the environments where temperature routinely cycles above and underneath the edge of freezing over. Ice wedging works rapidly, falling to pieces rocks in regions with temperatures that cycle above and beneath freezing in the day and night, and furthermore that cycle above and underneath freezing with the seasons. Ice wedging falls to pieces such an excess of rock that huge bits of broken stone are seen at the foundation of a slope, these pieces are called bone. Ice wedging is ordinarily found in Earth's polar regions and mid scopes, and furthermore at higher rises, for example, in the mountains.

Abrasion is another type of mechanical enduring. In scraped area, one stone knocks against another stone.

- Gravity causes scraped area as a stone tumbles down a mountainside or bluff.
- Moving water causes scraped spot as particles in the water impact and knock against each other.
- Strong winds conveying bits of sand can sandblast surfaces.
- Ice in ice sheets conveys numerous pieces and bits of rock. Rocks implanted at the lower part of the ice sheet scratch against the stones underneath.
- Abrasion makes rocks with sharp or barbed edges smooth and round. On the off chance that you have at any point gathered sea shore glass or cobbles from a stream, you have seen crafted by scraped area.

Mechanical enduring likewise works in alternate manner, plants and creatures can likewise accomplish crafted by mechanical enduring. This could happen gradually as a plant's roots develop into a break or break in shake and step by step develop bigger, making open the break. Burrowing creatures are likewise specialist of mechanical enduring, they can likewise fall to pieces rock as they burrow for food or to make living spaces for themselves.

Mechanical enduring builds the pace of compound enduring. As rock breaks into more modest pieces, the surface space of the pieces increments.

With more surfaces uncovered, there are more surfaces on which compound enduring can happen.

3.14.2 Chemical Weathering

Chemical weathering is the likewise a sort of enduring. Substance enduring is not the same as mechanical enduring in light of the fact that the stone changes in organization as well. That is, one sort of mineral changes into an alternate kind of mineral. Compound enduring works through substance responses that cause changes in the minerals. Most minerals form at high pressing factor or high temperatures somewhere down in the hull, or now and again in the mantle. At the point when these stones arrive at the Earth's surface, they are currently at extremely low temperatures and pressing factors. This is an altogether different climate from the one wherein they framed and the minerals are not, at this point stable.

In chemical weathering, minerals that were steady inside the outside should change to minerals that are steady at Earth's surface. The most widely recognized minerals in Earth's hull are the silicate minerals. Numerous silicate minerals structure into volcanic or transformative shakes profound inside the earth. The minerals that form at the most elevated temperatures and pressing factors are not steady at the surface. Mud is steady at the surface and substance enduring proselytes numerous minerals to earth. There are numerous sorts of substance enduring relying upon the kind of specialists of compound enduring. Water is the main specialist of synthetic enduring. Two other significant specialists of synthetic enduring are carbon dioxide and oxygen.

Chemical Weathering by Water

A water particle has a basic substance recipe, H_2O, two hydrogen molecules clung to one oxygen atom. Yet, water is really astounding as far as every one of the things it can do.

Water is a polar particle; the positive side of the atom draws in negative particles and the negative side draws positive particles. So water atoms separate the particles from their mixtures and encompass them. Water disintegrates totally a few minerals, like salt. Hydrolysis is the name given to a synthetic response between a substance compound and water. At the point when this response happens, water breaks up particles from the mineral and diverts them. These components have gone through filtering. Through hydrolysis, a mineral, for example, potassium feldspar is drained of potassium and changed into an earth mineral. Mud minerals are more steady at the Earth's surface.

Chemical Weathering by Carbon Dioxide

Carbon dioxide (CO_2) when joins with water, become as raindrops fall through the climate.

This makes a weak acid, called carbonic acid. Carbonic acid is basic in nature where it attempts to break up rock. Contaminations, like sulfur and nitrogen, from petroleum derivative consuming, make sulfuric and nitric acid.

Sulfuric and nitric acids are the two primary segments of acid downpour, which brings about synthetic enduring.

Chemical Weathering by Oxygen

Oxidation is a compound reaction that happens when oxygen reacts with another component. Oxygen is emphatically synthetically reactive. The most recognizable kind of oxidation is when iron reacts with oxygen to make rust. Minerals that are rich in iron separate as the iron oxidizes and forms new mixtures. Iron oxide delivers the red tone in soils. Now that you understand what synthetic enduring is, would you be able to think about some alternate ways compound enduring may happen? Synthetic enduring can likewise be added to by plants and animals. As plant establishes take in solvent particles as supplements, certain components are traded. Plant roots and bacterial rot use carbon dioxide during the process of breathing.

3.14.3 Biological Weathering

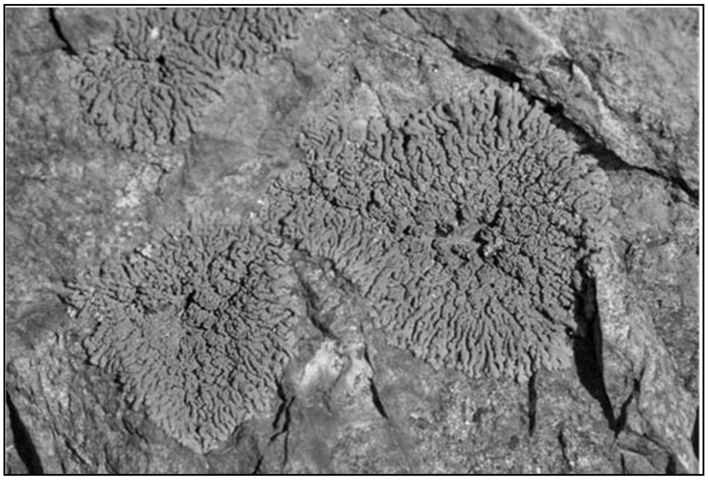
Biological weathering refers to weathering caused by organisms - animals, plants, fungi and microorganisms such as bacteria. While certain forms of biological weathering, such as the breaking of rock by tree roots, are sometimes categorized as either physical or chemical. Biological weathering can be either physical or chemical. Biological weathering can work hand in hand with physical weathering by weakening rock or exposing it to the forces of physical or chemical weathering.

Trees and Other Plants

The roots of trees, grasses and other plants can grow into small spaces and gaps in rock. When these roots grow, they exert pressure on the rock around them, causing the gaps to widen or even crack. Plant roots can also weather rock through chemical processes. When dead roots decompose, they release carbon dioxide; this is sometimes converted into carbonic acid, which chemically breaks down rock into soil.

Microorganisms and Lichens

Not all biological weathering occurs visibly. Many microorganisms in the soil and on the surface of rock can contribute. Some bacteria derive nutrition by taking a combination of nitrogen from the air and minerals - such as silica, phosphorous and calcium - from rock. By removing these minerals, the rock is weakened and is further subject to other weathering forces such as wind and water. Lichens, symbiotic colonies of fungi and microscopic algae that grow on rock, also contribute to weathering. The fungi in a lichen produce chemicals that break down the minerals in the rock. The algae, like the bacteria, use these minerals for nutrition.



Animal Activity

Animals can also contribute to weathering. Animals can walk on rock or disturb it, causing landslides that scrape or smooth rock surfaces. Burrowing animals such as badgers and moles can break up rock underground or bring it to the surface, where it is exposed to other weathering forces. Some animals directly burrow into the rock. The piddock shell is a mollusk, closely related to the clam, that uses its shell to cut a hole in rock, where it lives.

As animals, humans also contribute to biological weathering. Construction, mining and quarrying break up and disturb large sections of rock. Foot traffic over rock causes friction that breaks off tiny particles. Over a long period, foot traffic can cause significant wear and tear on rock surfaces.

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Factors Which Control the Rates of Weathering

Properties of the Parent Rock

1. The mineralogy and structure of a rock affects it's susceptibility to weathering.
2. Different minerals weather at different rates. Mafic silicates like olivine and pyroxene tend to weather much faster than felsic minerals like quartz and feldspar. Different minerals show different degrees of **solubility** in water in that some minerals dissolve much more readily than others. Water dissolves calcite more readily than it does feldspar, so calcite is considered to be more soluble than feldspar.
3. A rock's structure also affects its susceptibility to weathering. Massive rocks like granite generally do not contain planes of weakness whereas layered sedimentary rocks have bedding planes that can be easily pulled apart and infiltrated by water. Weathering therefore occurs more slowly in granite than in layered sedimentary rocks.

Climate

1. Rainfall and temperature can affect the rate in which rocks weather. High temperatures and greater rainfall increase the rate of chemical weathering.
2. Rocks in tropical regions exposed to abundant rainfall and hot temperatures weather much faster than similar rocks residing in cold, dry regions.

Soil

1. Soils affect the rate in which a rock weathers. Soils retain rainwater so that rocks covered by soil are subjected to chemical reactions with water much longer than rocks not covered by soil. Soils are also host to a variety of vegetation, bacteria and organisms that produce an acidic environment which also promotes chemical weathering.
2. Minerals in a rock buried in soil will therefore break down more rapidly than minerals in a rock that is exposed to air.

Length of Exposure

1. The longer a rock is exposed to the agents of weathering, the greater the degree of alteration, dissolution and physical breakup. Lava flows that are quickly buried by subsequent lava flows are less likely to be weathered than a flow which remains exposed to the elements for long periods of time.

Stability of Common Minerals Under Weathering Conditions

1. Iron oxides, Al-hydroxides, clay minerals and quartz are the most stable weathered products whereas highly soluble minerals like halite are the least stable. Silicates fall within the middle range. The stability of silicates is opposite Bowen's reaction series where the last minerals

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to crystallize (quartz and K, Na rich feldspars) being more stable than the early crystallized minerals (olivine and pyroxene).

2. The most common silicates in clastic sedimentary rocks are quartz, K-, Na-feldspars and micas. Amphiboles, pyroxene, olivine and Ca-feldspars are almost never found in sedimentary rocks.

Soils

1. Soils can form in place as residue left behind after weathering.
2. Soils may also form from transported material derived from elsewhere and deposited in a lowland or basin.
3. Residual soils develop on plains and lowlands with moderate to gentle slopes and consist of loose, heterogeneous material left behind from weathering. This material may include particles of parent rock, clay minerals, metal oxides and organic matter. This loose material is collectively called regolith, whereas the term soil is reserved for the topmost layer which contains organic matter.

The Soil Profile

Soils can be grouped into three principal horizons.

1. The **A-horizon** is the topmost layer and is usually a meter or two thick. The upper portion of the A-horizon is often rich in organic matter, called **humus**, and may also contain inorganic material like insoluble clays and quartz. The A-horizon may take thousands of years to develop depending on the climate and acitivity of plants and animals. This is the layer that supports crops and other types of vegetation.
2. The soluble minerals leached from horizon A are precipitated in the **B-horizon** as calcite, quartz, gypsum, salts and/or iron oxides. These precipitated minerals often accumulate in small pods, lenses and coatings. Organic matter is sparse in the B-horizon.
3. The lowest layer constitutes the **C-horizon** and is comprised of cracked and variably weathered bedrock mixed with clays.

Different Types of Soils

Soils can vary significantly in color and composition. The particular type of soil that is produced in a region depends on the available materials, climate and also time.

Laterite

Laterite is a deep red soil found in tropical regions and often developed on mafic igneous bedrock.The high temperatures, heavy rainfall and humidity of tropical regions have driven chemical weathering to the extreme. As a result, feldspars and other silicates have been completely altered while silica and calcite is extensively leached from the soil.

The upper zone of laterite consists of insoluble precipitated iron and other oxides along with some quartz. At best, only a very thin layer of organic matter resides at the top of the soil to support the jungle vegetation. When the jungle vegetation is cleared, the humus oxidizes quickly and soon disappears. For this reason, laterite can only be farmed extensively for a few years after clearing and afterwards must be abandoned.

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Pedocals

Pedocals are the dominant soils in arid regions where rainfall and vegetation are sparse. As a result, very little chemical weathering occurs to alter the original mineralogy. Pedocal soils are generally very thin. The A-horizon is typically leached and can only supported limited, desert vegetation.

Much of the soil water is drawn up near the surface and evaporates between rainfalls, leaving behind precipitated nodules and pellets of calcium carbonate mostly in the B-horizon.

Pedalfers

Pedalfer soils occur in temperate climates experiencing moderate to high rainfall. The relatively thick, organic rich layer makes pedalfers favorable to agriculture. Pedalfers typically form on granitic bedrock, the principle rock type in these regions.

The upper and middle layers of pedalfers contain abundant insoluble minerals such as quartz, clay minerals and iron alteration products. All soluble materials, especially calcium carbonate, have been leached away.

The classification of soils is actually more complex than presented, especially when taking into account significant differences in bedrock. Some of these categories can be related to the soil types previously discussed.

3.15 ANSWERS TO 'CHECK YOUR PROGRESS'

1. A level of uniform pressure is thought to exist where the pressure due to elevated masses and depressed areas would be equal. This is known as the 'Isopiestic-Level'.
2. The crust of relatively lighter material is floating in the substratum of denser material. In other words, 'sial' is floating in 'sima'.
3. Volcanic
4. Collapse
5. Reverse
6. Normal
7. A normal (dip-slip) fault is an inclined fracture where the rock mass above an inclined fault moves down.
8. There are four different types of earthquakes: Tectonic, volcanic, collapse and explosion.
9. Alpide
10. Circum Pacific Seismic Belt

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11. Seismometers
12. Richter
13. Asthenosphere
14. Calderas
15. Magma
16. Zero
17. Water, rock, ash, sand and mud.
18. Hydrothermal alteration
19. Magma
20. Igneous rocks, metamorphic rocks and sedimentary rocks
21. Plutonic or intrusive rocks result when magma cools and crystallizes slowly within the Earth's crust.
22. The Oxides are a group of minerals that are compounds of one or more metallic elements combined with oxygen, water, or hydroxyl (OH).
23. Denudation involves the processes that cause the wearing away of the Earth ' s surface by moving water, by ice, by wind and by waves, leading to a reduction in elevation and in relief of landforms and of landscapes.
24. Rocks break down into smaller pieces through weathering. Rocks and sediment grinding against each other wear away surfaces. This type of weathering is called abrasion.

3.16 SUMMARY

From this unit, we concluded that on a geological scale, isostasy can be observed if Earth's strong crust or lithosphere exerts stress on the weaker mantle. Isostasy is the gravitational equilibrium between crust and the mantle. Here we also studied the causes, types and effects of earthquakes. Volcano is a rupture in the earth's crust. We saw various types of volcanic eruption. We also studied various kinds of rocks, their origin and composition. We studied what weathering is and what are its types.

3.17 KEY TERMS

- **Earth's crust:** "Crust" describes the outermost shell of a terrestrial planet. Earth's crust is generally divided into older, thicker continental crust and younger, denser oceanic crust.
- **Buoyancy:** Buoyancy or upthrust, is an upward force exerted by a fluid that opposes the weight of a partially or fully immersed object.
- **Gravity:** Gravity is a force of attraction that exists between any two masses, any two bodies, any two particles.

- **Postulation:** Something that can be assumed as the basis for argument
- **Epicenter:** The epicenter, epicentre (\ˈɛpɪsɛntər\) or epicentrum in seismology is the point on the Earth's surface directly above a hypocenter or focus, the point where an earthquake or an underground explosion originates.

3.18 SELF-ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. Describe postulation of Pratt.
2. Differentiate Pratt and Airy Isostasy.
3. Describe types of faults.
4. Write a note on Shaking of Earth.
5. Write a note on Recording of Earthquake.

Long Answer Questions

1. How does the oceanic crust form?
2. Why don't continents subduct?
3. Write an essay on types of Volcanoes.
4. What are the causes and effects of Earthquake?
5. Write about origin and composition of Rocks.
6. Define weathering and state its types.

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UNIT 4 GEOMORPHIC AGENTS AND PROCESSES

Structure

4.0 INTRODUCTION

The human population has been expanding dramatically. All the while, as burrowing sticks and prongs have offered approach to wooden furrows, iron spades, steam digging tools, and the present immense earth movers, our capacity and inspiration to adjust the scene by moving earth in development and mining exercises have likewise expanded drastically. As a result, we have now become seemingly the head geomorphic specialist chiseling the scene, and the rate at which we are moving earth is expanding dramatically. As agrarian societies were re-put by agrarian social orders to take care of this extending populace, disintegration from farming fields additionally, as of not long ago, expanded consistently. This comprises an accidental extra human effect on the scene.

4.1 OBJECTIVES

After going through this unit, you will be able:

- To understand the process of Geomorphology.
- To understand difference between Geomorphology process and geomorphology agents.
- To understand the process of origin of various kinds of landforms.

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- To understand mass wasting and the process of erosion.
- To understand the difference between David's and Penck's Cycle of Erosion.

4.2 GEOMORPHOLOGY

The physical and compound communications between the Earth's surface and the regular powers following up on it to deliver landforms. The cycles are dictated by such normal ecological factors as topography, environment, vegetation and base level, to avoid even mentioning human impedance. Geomorphologists try to comprehend why scenes look the manner in which they do, to comprehend landform history and elements and to foresee changes through a mix of field perceptions, actual tests and mathematical demonstrating.

Geomorphology is the investigation of landforms, their cycles, structure and residue at the outside of the Earth (and once in a while on different planets). Study incorporates seeing scenes to work out how the earth surface cycles, like air, water and ice, can shape the scene. Landforms are created by disintegration or affidavit, as rock and dregs is eroded by these earth-surface cycles and moved and saved to various areas. The diverse climatic conditions produce various set-ups of landforms. The landforms of deserts, for example, sand ridges and ergs, are a completely different from the frigid and periglacial highlights found in polar and sub-polar districts. Geomorphologists map the appropriation of these landforms to see better their event.

Earth-surface cycles are shaping landforms today, changing the scene, yet regularly gradually. Most geomorphic measures work at a lethargic rate, yet some of the time a huge occasion, like an avalanche or flood, happens making quick change the climate, and now and then compromising people. So topographical dangers, like volcanic emissions, tremors, waves and avalanches, fall inside the interests of geomorphologists. Headways in far off detecting from satellites and GIS planning has profited geomorphologists extraordinarily in the course of recent many years, permitting them to comprehend worldwide disseminations.

Geomorphologists are additionally "scene criminal investigators" working out the historical backdrop of a scene. Most conditions, like Britain and Ireland, have in the past been glaciated on various events, tens and countless years prior. These glaciations have made their difference on the scene, for example, the precarious sided valleys in the Lake District and the drumlin fields of focal Ireland. Geomorphologists can sort out the historical backdrop of such places by contemplating the excess landforms and the silt – regularly the particles and the natural material, like dust, insects, diatoms and macrofossils protected in lake residue and peat, can give proof on past environmental change and cycles.

So geomorphology is a different control. Albeit the fundamental geomorphological standards can be applied to all conditions, geomorphologists will in general have some expertise in a couple of regions, such aeolian (desert) geomorphology, chilly and periglacial geomorphology, volcanic and structural geomorphology, and surprisingly planetary geomorphology. Most examination is multi-disciplinary, consolidating the information and points of view from two differentiating disciplines, joining with subjects as assorted as nature, geography, structural designing, hydrology and soil science.

The Importance of Geomorphology for Physical Geographers

Geomorphology is the investigation of Earth's landforms made by for the most part physical processes, including physical or synthetic changes and those progressions affected by natural cycles, including land use. Actual geographers apply geomorphological administrators to concentrate how landforms have changed previously, however progressively such directors are significant for current applications. Over long geographical intervals of time, plate tectonics have formed landmasses. Quakes and volcanic action address dynamic change that identify with plate structural developments. Fluvial, or those including water, change is among the main actual variables that shape the Earth at commonly little scopes.

The significance of geomorphology for actual geographers isn't just significant in understanding Earth's actual changes yet in addition in getting ready for dangers. For example, understanding issues of deforestation, soil properties, and occasional precipitation can more readily evaluate frequencies of flooding occasions and their expected risk.

Land use changes, for example, asphalt that forestalls the retention of water, has hurried actual changes in where overflow has expanded in places because of an absence of open ground and vegetation that retains water. Metropolitan conditions are regularly especially powerless against catastrophic events as they quickly change a scene through evacuation of local vegetation and development that clears over land. Metropolitan arranging needs to represent regular geomorphic occasions so particularly that as new metropolitan regions are created geomorphic factors that would influence metropolitan spots could be reproduced through legitimate seepage or utilization of development materials that are best adjusted to the nearby climate, including variables like mugginess, precipitation, and temperature.

Casual settlements, or ghettos, and distinguishing land use change utilizing geomorphological directors isn't just significant in recognizing risks, or regions where territory may be flimsy and powerless to debacles, yet as populace pressures in certain nations have expanded greater settlement is happening in peripheral terrains. An enormous level of individuals, assessed as possibly as high as 33% of the worldwide populace, presently live in ghettos, many possessing landscape that are defenseless against flooding, seismic tremors, or helpless seepage that can make debased water supplies. Geomorphology, as a basic segment of actual topography, is expected to comprehend regular landform changes and possible risks for populaces.

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History of Geomorphology

Albeit the investigation of geomorphology has been around since ancient times, the primary official geomorphologic model was proposed somewhere in the range of 1884 and 1899 by the American geographer William Morris Davis. His geomorphic cycle model was enlivened by speculations of uniformitarianism and endeavored to hypothesize the advancement of different landform highlights.

Davis' speculations were significant in dispatching the field of geomorphology and were inventive at that point, as another approach to clarify physical landform highlights. Today, in any case, his model isn't normally utilized, in light of the fact that the cycles he portrayed are not so orderly in reality. It neglected to consider the cycles saw in later geomorphic examines.

Since Davis' model, a few elective endeavors have been made to clarify landform measures. For instance, Austrian geographer Walther Penck fostered a model during the 1920s that took a gander at proportions of elevate and disintegration. It didn't grab hold, however, in light of the fact that it couldn't clarify all landform highlights.

Geomorphological Processes

Today, the investigation of geomorphology is separated into the investigation of different geomorphological cycles. The majority of these cycles are viewed as interconnected and are effortlessly noticed and estimated with current innovation. The individual cycles are viewed as either erosional, depositional, or both. Geomorphological processes depicts land structures and land structure changes, especially with respect to the paces of activity of these occasions.

An erosional process involves the wearing down of the earth's surface by wind, water, and/or ice. A depositional process is the laying down of material that has been eroded by wind, water, and/or ice. There are several geomorphological classifications within erosional and depositional. Geomorphologists seek to understand why landscapes look the way they do, to understand landform history and dynamics and to predict changes through a combination of field observations, physical experiments and numerical modeling. Geomorphologists work within disciplines such as physical geography, geology, geodesy, engineering geology, archaeology, climatology and geotechnical engineering. This broad base of interests contributes to many research styles and interests within the field.

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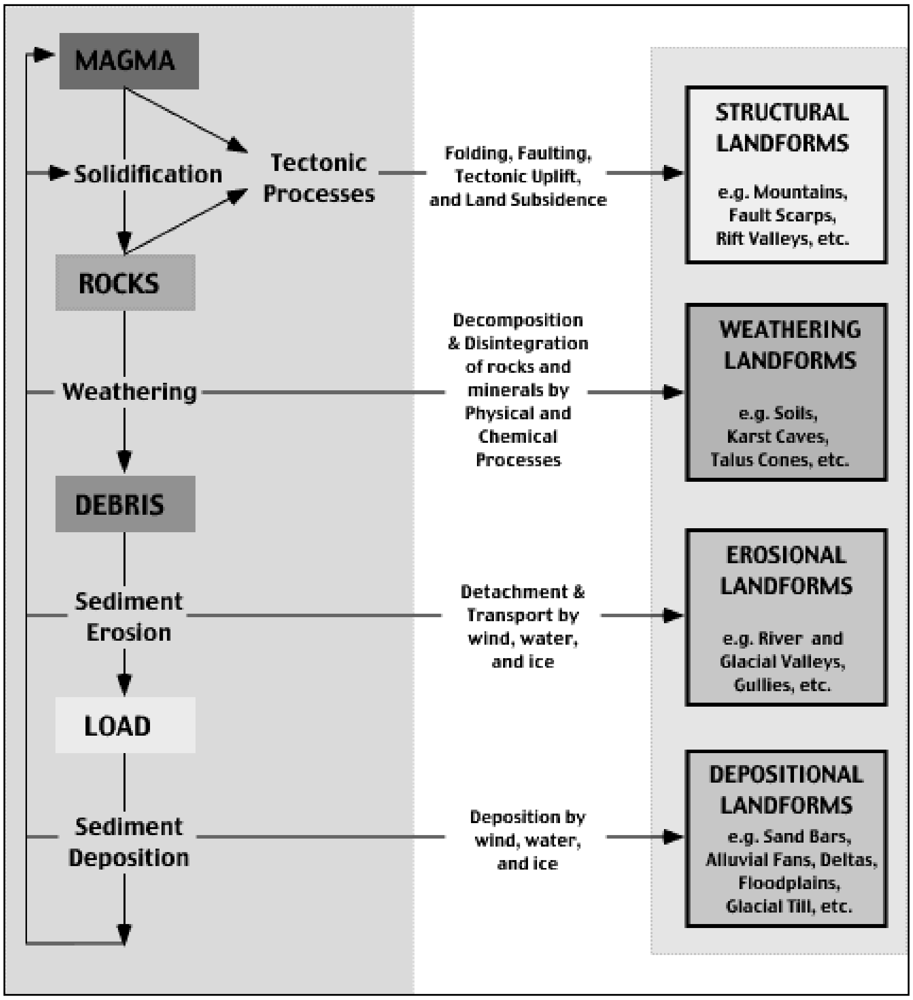

Source: Wikimedia Commons

Fig. 4.1: Geomorphological Process

Fluvial

Fluvial geomorphological cycles are identified with waterways and streams. The streaming water found here is significant in forming the scene twoly. To begin with, the force of the water getting across a scene cuts and dissolves its channel. As it does this, the waterway shapes its scene by developing, wandering across the scene, and at times converging with others to frame an organization of interlaced streams. The ways streams take rely upon the geography of the space and the fundamental topography or rock structure where it moves.

As the waterway cuts its scene, it additionally conveys the dregs it disintegrates as it streams. This gives it more ability to dissolve, as there is more rubbing in the moving water, yet it additionally stores this material when it floods or streams out of mountains onto an open plain, as on account of an alluvial fan.

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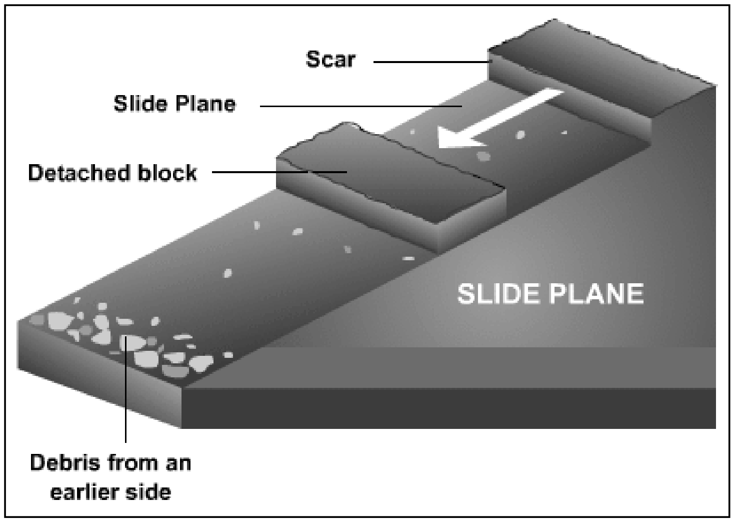
Mass Movement

The mass development measure, likewise in some cases called mass squandering, happens when soil and rock drop down an incline under the power of gravity. The development of the material is called crawling, sliding, streaming, overturning, and falling. Each of these relies upon the speed and arrangement of the material moving. This cycle is both erosional and depositional.



Source: The British Library

Fig. 4.2: Mass Movement

Glacial

Glacial masses are streams of ice, and ice sheets are mainland scale arches of ice. The two glacial masses and ice sheets stream gradually, shipping snow/ice to bring down heights, where it dissolves or is delivered into the ocean as chunks of ice. The size and degree of glacial masses shifts with environment, and they address the most gradually reacting constituent of the worldwide environment framework. In spite of this, icy masses and ice sheets are equipped for amazing and emotional impacts, for example, icy mass floods, and are thought to have been a significant causative segment of the quick environment shifts found in the last ice age.

Ice sheets are found in districts of high rise, for example, in the Alps or the Himalayas, and in polar areas, like Alaska or Svalbard. Ordinary profundities are on the request for many meters, and commonplace lengths are estimated in kilometers: the Bering Glacier in Alaska is one of the longest, at 200 km. Glacial masses structure when snow aggregates to incredible profundity, and is changed through the impacts of strain to frame ice, which at that point crawls gradually down incline, at rates which are regularly estimated in tens to many meters each year.

Ice sheets are the second biggest water safes following the seas and the biggest freshwater vaults; they establish 98.5% of freshwater. Icy masses are quickly going through switches all up the world. In the twentieth century,

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Mount Kilimanjaro in Africa lost around third-fourth of its cold mass. The mass of the glacial masses in Caucasus diminished significantly and the glacial masses on Tien Shan Mountains on the Chinese–Russian boundary shrank by 20% over the most recent 40 years. The glacial masses in New Zealand lost one-fourth of their masses in 20 years.

Glacial masses are perhaps the main specialists of scene change due to their monstrous size converts to control as they get across a space. They are erosional powers in light of the fact that their ice cuts the ground underneath them and on the sides, which frames a U-formed valley, likewise with a valley glacial mass. Icy masses are likewise depositional on the grounds that their development drives rocks and other garbage into new regions. The silt made when ice sheets granulate down rocks is called icy stone flour. As glacial masses liquefy, they drop garbage, which makes highlights like eskers and moraines.

Weathering

Weathering is an erosional interaction that includes the mechanical wearing out of rock by a plant's foundations developing and pushing through it, ice growing in its breaks, and scraped spot from residue moved by wind and water, just as the synthetic separate of rock like limestone. Enduring can bring about rock.

Enduring is the separating of rocks, soils, and minerals just as wood and counterfeit materials through contact with the Earth's air, water, and natural life forms. Enduring happens in situ (i.e., on location, without uprooting), that is, in a similar spot, with next to zero development, and in this manner ought not be mistaken for disintegration, which includes the vehicle of rocks and minerals by specialists like water, ice, snow, wind, waves and gravity and afterward being shipped and kept in different areas.

Two significant arrangements of enduring cycles exist – physical and synthetic enduring; each occasionally includes a natural part. Mechanical or physical enduring includes the breakdown of rocks and soils through direct contact with environmental conditions, like warmth, water, ice and pressing factor. The subsequent grouping, substance enduring, includes the immediate impact of barometrical synthetic compounds or organically created synthetic compounds otherwise called natural enduring in the breakdown of rocks, soils and minerals.While physical enduring is complemented in freezing or extremely dry conditions, substance responses are most extraordinary where the environment is wet and hot. Notwithstanding, the two sorts of enduring happen together, and each will in general speed up the other. For instance, actual scraped spot (scouring together) diminishes the size of particles and in this manner builds their surface territory, making them more defenseless to synthetic responses. The different specialists act in show to change over essential minerals (feldspars and micas) to optional minerals (muds and carbonates) and delivery plant supplement components in dissolvable structures.

The materials left over after the stone separates joined with natural material makes soil. The mineral substance of the dirt is controlled by the parent material; accordingly, a dirt got from a solitary stone sort can frequently be insufficient in at least one minerals required for great richness, while a dirt endured from a blend of rock types (as in icy, aeolian or alluvial silt) regularly makes more ripe soil. Furthermore, a significant number of Earth's landforms and scenes are the consequence of enduring cycles joined with disintegration and re-affidavit.

Significance of Geomorphology

- To comprehend geomorphological cycles of different climate.
- To distinguish regular and natural dangers effectively, for example tremor, flooding, avalanche, tidal wave, volcanism and so forth.
- To recognize different landform highlights and scenes.
- To distinguish different landform highlights from satellite pictures.
- Coastal and stream research.
- Vulnerability contemplates.
- Geology, Geography, Archeology, Engineering, Planning, Mining, Construction, Urbanization.

Geomorphic Process

The endogenic and exogenic forces causing actual anxieties and substance activities on earth materials and achieving changes in the arrangement of the outside of the earth are known as geomorphic measures. Diastrophism and volcanism are endogenic geomorphic measures. These have effectively been talked about in a nutshell in the previous unit. Enduring, mass squandering, disintegration and testimony are exogenic geomorphic measures. These exogenic cycles are managed exhaustively in this section.

Any exogenic component of nature (like water, ice, wind, and so forth) fit for gaining and shipping earth materials can be known as a geomorphic specialist. At the point when these components of nature become portable because of inclinations, they eliminate the materials and transport them over slants and store them at lower level. Geomorphic measures and geomorphic specialists particularly exogenic, except if expressed independently, are very much the same.

An interaction is a power applied on earth materials influencing something similar. A specialist is a portable medium (like running water, moving ice masses, wind, waves and flows and so forth) which eliminates, transports and stores earth materials. Running water, groundwater, icy masses, wind, waves and flows, and so forth, can be called geomorphic specialists.

Mass wasting also called as Mass Movement is defined as the down slope movement of rock and regolith near the Earth's surface mainly due to the force of gravity. Mass movements are an important part of the erosional process, as it moves material from higher elevations to lower elevations where transporting agents like streams and glaciers can then pick up the material and move it to even lower elevations. Mass movement processes are occurring continuously on all slopes; some act very slowly, others occur very suddenly, often with disastrous results. Any perceptible down slope movement of rock or regolith is often referred to in general terms as a landslide. Landslides, however, can be classified in a much more detailed way that reflects the mechanisms responsible for the movement and the velocity at which the movement occurs.

As human populations expand and occupy more and more of the land surface, mass movement processes become more likely to affect humans. The table below shows some of the most deadly movement processes since 1900.

Year	Location	Type	Fatalities
1916	Italy, Austria	Landslide	10,000
1919	Kelud Indonesia	Lahar	5,110
1920	China	Earthquake triggered landslide	200,000
1933	Sichuan. China	Earthquake triggered landslide	3100
1945	Japan	Flood triggered landslide	1,200
1949	USSR	Earthquake triggered landslide	12,000-20,000
1962	Peru	Landslide	4,000-5,000
1963	Italy	Landslide	2,000
1970	Peru	Earthquake related debris avalanche	70,000
1985	Columbia	Mudflow related to volcanic eruption	23,000
1987	Ecuador	Earthquake related landslide	1,000
1998	Nicaragua	Debris avalanche and mudflow triggered by heavy rains during Hurricane Mitch	~2,000
1999	Vargas, Venezuela	debris flows triggered by heavy rain	30,000
2001	El Salvador	Earthquake-induced landslide	585
2006	Philippines	Rain triggered debris avalanche	1126
2009	Taiwan	Typhoon Marakot triggered landslide	~600
2010	Gansu, China	Rain triggered mud flows	1287
2013	Northern India	Heavy rain triggered landslides	5700
2017	Sierra Leone	mudflows	>1140

In a typical year in the United States, landslides cause over $2 billion in damages and 25 to 50 deaths. In other countries, especially less developed countries, the loss is usually higher because of higher population densities, lack of zoning laws, lack of information about mass movement hazards, and lack of emergency preparedness. Between 2004 and 2010, worldwide, landslides caused an average of about 5,330 deaths per year.

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Knowledge about the relationships between local geology and mass movement processes can lead to better planning that can reduce vulnerability to such hazards. Thus, we will look at the various types of mass movement processes, their underlying causes, factors that affect slope stability, and what humans can do to reduce vulnerability and risk due to mass movement hazards.

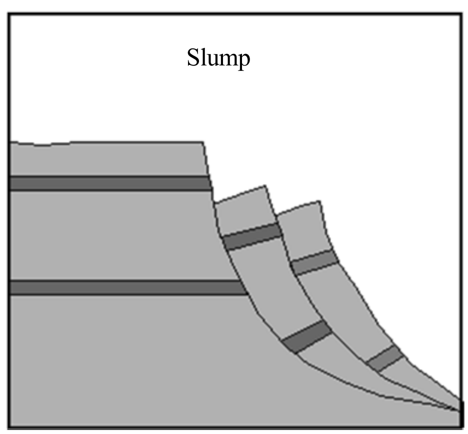
Types of Mass Movement Processes

The down-slope movement of material, whether it be bedrock, regolith, or a mixture of these, is commonly referred to as a ***landslide***. All of these processes generally grade into one another, so classification of such processes is somewhat difficult. We will use a classification that divides mass movement processes into two broad categories (note that this classification is somewhat different than that used by your textbook):

1. **Slope Failures:** A sudden failure of the slope resulting in transport of debris down hill by sliding, rolling, falling, or slumping.
2. **Sediment Flows:** Debris flows down hill mixed with water or air.

Slope Failures

1. **Slumps (also called Rotational Slides):** Types of slides wherein downward rotation of rock or regolith occurs along a concave-upward curved surface (rotational slides). The upper surface of each slump block remains relatively undisturbed, as do the individual blocks. Slumps leave arcuate scars or depressions on the hill slope. Slumps can be isolated or may occur in large complexes covering thousands of square meters. They often form as a result of human activities, and thus are common along roads where slopes have been over steepened during construction. They are also common along river banks and sea coasts, where erosion has under-cut the slopes. Heavy rains and earthquakes can also trigger slumps.



2. **Falls-Rock falls:** Occur when a piece of rock on a steep slope becomes dislodged and falls down the slope. ***Debris falls*** are similar, except they involve a mixture of soil, regolith, vegetation, and rocks. A rock fall may be a single rock or a mass of rocks, and the falling rocks can dislodge other rocks as they collide with the cliff. Because

this process involves the free fall of material, falls commonly occur where there are steep cliffs. At the base of most cliffs is an accumulation of fallen material termed ***talus.***

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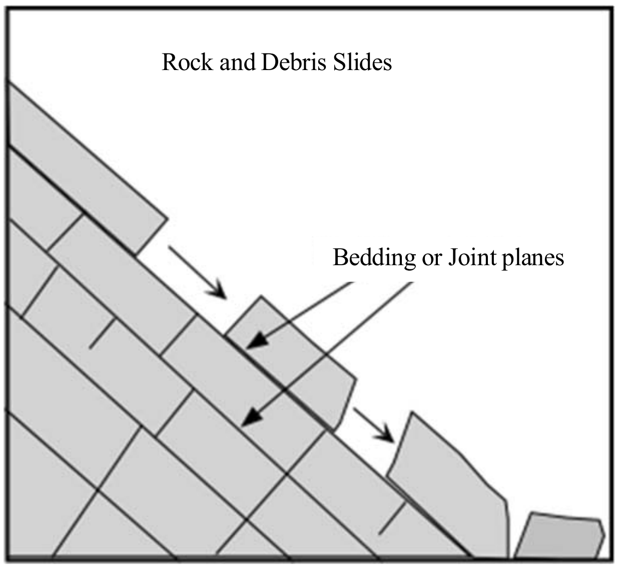
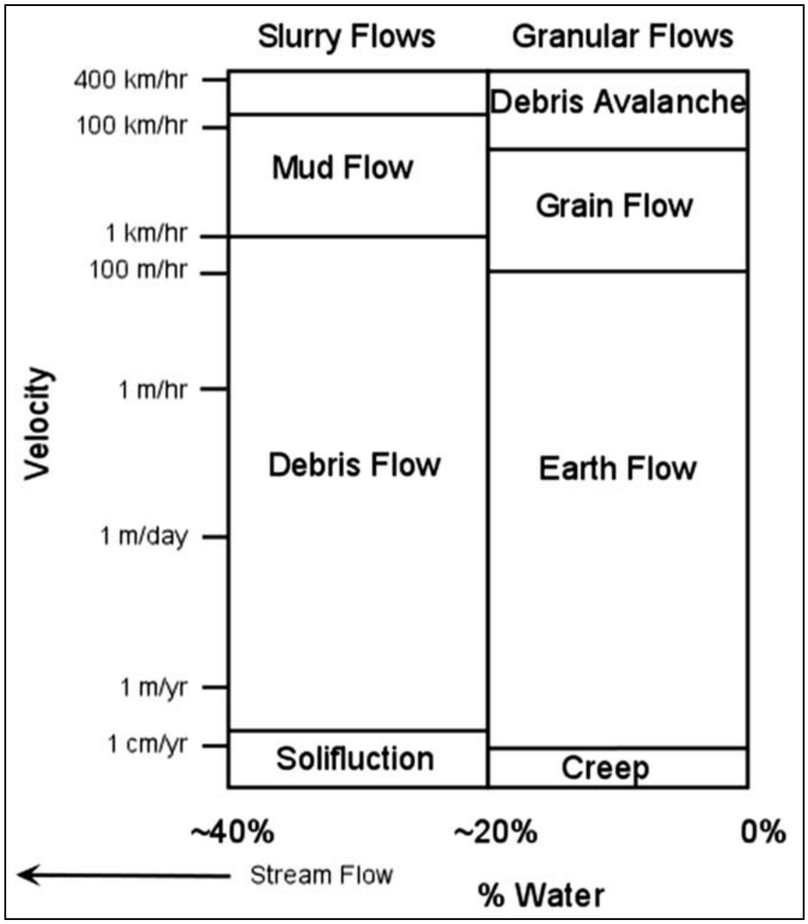
3. **Slides (also called Translational Slides):** Rock slides and debris slides result when rocks or debris slide down a pre-existing surface, such as a bedding plane, foliation surface, or joint surface (joints are regularly spaced fractures in rock that result from expansion during cooling or uplift of the rock mass). Piles of talus are common at the base of a rock slide or debris slide. Slides differ from slumps in that there is no rotation of the sliding rock mass along a curved surface.



Sediment Flows

Sediment flows occur when sufficient force is applied to rocks and regolith that they begin to **flow** down slope. A sediment flow is a mixture of rock, and/or regolith with some water or air. They can be broken into two types depending on the amount of water present:

1. **Slurry Flows:** Are sediment flows that contain between about 20 and 40% water. As the water content increases above about 40% slurry flows grade into streams. Slurry flows are considered water-saturated flows.
2. **Granular Flows:** Are sediment flows that contain between 0 and 20% water. Note that granular flows are possible with little or no water. Fluid-like behavior is given these flows by mixing with air. Granular flows are not saturated with water.



Each of these classes of sediment flows can be further subdivided on the basis of the velocity at which flowage occurs:

- **Slurry Flows**
  - **Solifluction:** Flowage at rates measured on the order of centimeters per year of regolith containing water. Solifluction produces distinctive lobes on hill slopes. These occur in areas where the soil remains saturated with water for long periods of time.
  - **Debris Flows:** These occur at higher velocities than solifluction, with velocities between 1 meter/yr and 100 meters/hr and often result from heavy rains causing saturation of the soil and regolith with water. They sometimes start with slumps and then flow down hill forming lobes with an irregular surface consisting of ridges and furrows.
  - **Mudflows:** These are a highly fluid, high velocity mixture of sediment and water that has a consistency ranging between soup-like and wet concrete. They move at velocities greater than 1 km/hr and tend to travel along valley floors. These usually result from heavy rains in areas where there is an abundance of unconsolidated sediment that can be picked up

by streams. Thus after a heavy rain streams can turn into mudflows as they pick up more and more loose sediment. Mudflows can travel for long distances over gently sloping stream beds. Because of their high velocity and long distance of travel they are potentially very dangerous. As we have seen, mudflows can also result from volcanic eruptions that cause melting of snow or ice on the slopes of volcanoes, or draining of crater lakes on volcanoes. Volcanic mudflows are often referred to as lahars. Some lahars can be quite hot, if they are generated as a result of eruptions of hot tephra.

Note that the media often refers to mudflows (and sometimes debris flows) as mudslides. This is inaccurate because mud flows rather than slides down a slope. Thus, in this course the word "mudslide" is an **illegal word** - one that you should never use.

- **Granular Flows**
  - **Creep:** The very slow, usually continuous movement of regolith down slope. Creep occurs on almost all slopes, but the rates vary. Evidence for creep is often seen in bent trees, offsets in roads and fences, and inclined utility poles.
  - **Earthflows:** Are usually associated with heavy rains and move at velocities between several cm/yr and 100s of m/day. They usually remain active for long periods of time. They generally tend to be narrow tongue-like features that begin at a scarp or small cliff.
  - **Grain Flows:** Usually form in relatively dry material, such as a sand dune, on a steep slope. A small disturbance sends the dry unconsolidated grains moving rapidly down slope.
  - **Debris Avalanches:** These are very high velocity flows of large volume mixtures of rock and regolith that result from complete collapse of a mountainous slope. They move down slope and then can travel for considerable distances along relatively gentle slopes. They are often triggered by earthquakes and volcanic eruptions.
  - **Snow Avalanches:** Are similar to debris avalanches, but involve only snow, and are much more common than debris avalanches. Snow avalanches usually cause hundreds of deaths worldwide each year.

Mass Movements in Cold Climates

Mass movement in cold climates is governed by the fact that water is frozen as ice during long periods of the year. Ice, although it is solid, does have the ability to flow, and freezing and thawing cycles can also contribute to movement:

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- **Rock Glaciers:** A lobe of ice-cemented rock debris (mostly rocks with ice between the blocks) that slowly moves downhill.
- **Frost Heaving:** This process is large contributor to creep in cold climates. When water saturated soils freeze, they expand, pushing rocks and boulders on the surface upward perpendicular to the slope. When the soil thaws, the boulders move down vertically resulting in a net down slope movement.

Subaqueous Mass Movements

Mass wasting processes also occur on steep slopes in the ocean basins. A slope failure can occur due to over-accumulation of sediment on slope or in a submarine canyon, or could occur as a result of a shock like an earthquake.

3 types of mass movements are common, based on degree of disintegration of the material during movement:

1. **Submarine slumps:** Coherent blocks break and slip.
2. **Submarine debris flows:** Moving material breaks apart.
3. **Turbidity currents:** Sediment moves as a turbulent cloud, called a **turbidity current**.

Check Your Progress

1. __________ is the study of landforms, their processes, form and sediments at the surface of the Earth.
2. Fluvial landforms are those generated by __________.

4.3 GEOMORPHIC AGENTS

1. Erosional Work

(i) Corrosion: It includes the disintegration of the dissolvable material through the interaction of crumbling and deterioration of carbonate rocks. The disintegration of solvent materials and minerals from the stones happens through the cycle of arrangement. It further relies upon the idea of rock, dissolvability of solids, contact sort of solvents and solids and proportion between volume of solvents and solids.

(ii) Abrasion: It includes the expulsion of the relaxed materials of the stones by various erosional measures in separate way. The level of scraped area relies on different components like the idea of erosional instruments, nature of erosional measures, nature if geomaterials, power of erosional measures and some more.

(iii) Hydraulic activity: It includes the breakdown of rocks, because of the effort of the pressing factor by flows of water and floods of ocean. This activity is the mechanical extricating and evacuation of material of rocks by water alone. The compound disintegration, scraped spot and pressure driven activity are so much identified with one another that every one of these activities can't effectively work without the other.

(iv) Attrition: It includes the mileage of the erosional devices. The cobbles, stones and boulders while moving downwards with water, gets crash against one another and are divided into more modest pieces. They are so much separated to pieces that they get changed into fine particles of sands and gets moved down in suspension.

(v) Deflation: It includes the eliminating, lifting and blowing endlessly free and dry particles of land and residue by winds. The long and ceaseless flattening eliminates the greater part of the free materials and huge discouragement know as victory are shaped.

2. Transportational Work

(i) The measures like floatation, suspension, arrangement, saltation and foothold achieves certain transportational work.

(ii) Running water moves the residue through footing, suspension and arrangement.

(iii) The cycle of saltation includes the transportation of burden with flows of water, where the heap moves downwards through the valley floor. It's anything but an incredibly lethargic way.

(iv) Traction includes the downstream development of the free materials of the valley floor. The heap are typically rock, stones, cobbles and boulders.

(v) The solvent materials get broken up in water and gotten undetectable and are moved downstream through the strategy for arrangement.

(vi) The materials get broken down in a suspended structure through groundwater.

(vi) The transportational work of ocean wave varies from different specialists of transportation. The materials get shipped from coast towards the ocean and again from the ocean towards the coast.

(vii) The materials engaged with the transportational work of ocean waves uses sand, sediment, rock, stones, cobbles and boulders.

3. Depositional Work

(i) The deposition of the sediments by the streams relies on various variables like abatement in channel inclination, decline in stream speed, decline in volume and release of water, deterrent in channel stream, expansion in residue burden, and spreading of waterway water over enormous regions.

(ii) Depositional work by the streams, is conveyed with a lessening in the speed of stream, which decreases the shipping limit of the streams and thus, it leaves extra dregs to settle down. Sedimentation happens in the flood fields, stream beds and waterway mouths.

(iii) Depositional work by groundwater, happens when water gets blocked or over immersed. The groundwater gets more solutes, because of the

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continuation of the compound disintegration of carbonate rocks. As the development of the groundwater is moderate, it can't convey enough dregs. Therefore, sedimentation and synthetic disintegration happens together. Huge size dregs gets effectively settle down, while the fine residue are kept in the suspended structure.

(iv) Depositional work via ocean waves, is the most factor and impermanent in character on the grounds that, the flows bring the silt seawards and store them at lower portions of wave cut stages. These silt are again taken back to the coast. At the point when a harmony level is accomplished between the approaching stockpile of silt and expulsion of residue, a profile of balance is accomplished.

(v) Depositional work by wind, is huge on the grounds that, highlights like sand ridge and loess are shaped. The residue get kept because of the lessening in the breeze speed and hindrance brought about by woodland, swamps, lakes, waterways, dividers and some more. Sands get stored on both windward and leeward side of these blocks. The amassed sands on opposite side of the check are called sand shadows, while the collected sands between the hindrances are called sand floats.

(vi) The depositional work by ice sheets, which convey the stone flotsam and jetsam are called frosty floats which contains till, ice contact delineated float, out wash and some more. They are partitioned into englacial garbage, that exist on the outside of the ice sheet; superglacial trash, that exist on the outside of the ice sheet; subglacial flotsam and jetsam, that exist on the foundation of the glacial mass.

(vii) These erosional, transportational and depositional work makes certain landforms of the earth which are huge. They are personally interrelated to one another in the manner that, none can be conveyed and worked alone with the assistance of other

Check Your Progress

3. __________ are those which are responsible for shaping the earth by creating certain landforms.
4. __________ is a term of geomorphology used for the removal of solid particles by wind.

4.4 GEOMORPHIC PROCESSES

Mass wasting, which is some of the time called mass development or slant development, is characterized as the huge development of rock, soil and trash descending because of the power of gravity. At the end of the day, the world's external hull is being 'died' on a 'gigantic' scale and tumbling to bring down heights.

Mass squandering is a kind of disintegration, and it is equipped for rolling out enormous improvements to the side of a mountain. These

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progressions can happen out of nowhere, as in one moment the stone is there and the following it is gone, or it can happen all the more gradually over the long haul. You may consider this interaction an avalanche, and this term is in some cases utilized reciprocally with mass squandering. Notwithstanding, the term avalanche is somewhat restricting and doesn't consider a depiction of the a wide range of triggers and kinds of disintegration that can occur on this huge of a scale.

Causes of Mass Wasting

Presently, we referenced that mass squandering is predominantly because of gravity. In this way, we see that mountains have a continuous back-and-forth with gravity. Gravity is continually attempting to pull rock and garbage down the slant of a mountain. Simultaneously, the resistive powers of the mountain, including the strong strength and inward grating between the materials, alluded to as the mountain's shear strength, continually pulls back against gravity.

The shear strength attempts to keep up the incline's steadiness and keep the materials set up. This is a ton like a hiker holding onto the side of a mountain and opposing gravity. The climber utilizes his grasp solidarity to oppose gravity, similar to the mountain utilizes its shear strength.

With this agreement, we see that the reasons for mass squandering happen when gravitational power conquers the resistive powers of the mountain. What's more, since gravitational force is consistently steady, then, at that point we see that mass squandering happens when something changes the mountain's capacity to oppose gravity.

For example, an expanded incline steepness builds mass squandering just on the grounds that the gravitational power following up on a lofty slant is more prominent than the power following up on a delicate slant. Expanding the steepness of an incline is one way man can build mass squandering. For instance, if a street group removes a slant to account for another street yet makes the point of the incline too steep, the slant will be inclined to mass squandering, and you will need to cross your fingers when you drive past this lofty slant so no stones or flotsam and jetsam fall on your vehicle.

Expanded water is another factor that assumes a significant part in mass squandering. Water can wash away little particles that help keep the mountainside flawless. This is like what happens when a wave comes shore wards and washes away a sandcastle. The bountiful water falls to pieces the little sand particles and annihilates the underlying soundness of the palace you went through the early evening time building.

On the off chance that a region has diminished vegetation, it will be more inclined to mass squandering. Vegetation settles soil particles on a superficial level and anchors soil under the surface through its root framework. This is similar as contrasting two sand rises on a sea shore. On the off chance that one sand hill has grasses developing on it, it will oppose the disintegration of water and twist better compared to a sand ridge without vegetation.

Another factor that assumes a part in mass squandering is tremors. The brutal shaking that happens in an area where a seismic tremor happens can sever areas of mountains or slopes, making them slide down the slant.

Classification of Mass Wasting

It's essential to arrange slope failures so we can comprehend what causes them and figure out how to relieve their belongings. The three rules used to portray slant disappointments are:

- The sort of material that fizzled (normally either bedrock or unconsolidated dregs).
- The system of the disappointment (how the material moved).
- The rate at which it moved.
- The sort of movement is the main trait of a slant disappointment, and there are three distinct kinds of movement.
- If the material drops through the air, in an upward direction or almost in an upward direction, it's anything but a fall.
- If the material moves as a mass along a slanting surface (without inward movement inside the mass), it's a slide.
- If the material has inward movement, similar to a liquid, it's a stream.

Lamentably it's anything but regularly that straightforward. Many slant disappointments include two of these kinds of movement, some include each of the three, and by and large, it's difficult to tell how the material moved. The sorts of incline disappointment that we'll cover here are summed up in Table 4.1.

Table 4.1: Classification of Slope Failures based on Type of Material and Type of Motion [SE]

Failure Type	Type of Material	Type of Motion	Rate of Motion
Rock fall	Rock fragments	Vertical or near-vertical fall (plus bouncing in many cases)	Very fast (>10s m/s)
Rock slide	A large rock body	Motion as a unit along a planar surface (translational sliding)	Typically very slow (mm/y to cm/y), but some can be faster
Rock avalanche	A large rock body that slides and then breaks into small fragments	Flow (at high speeds, the mass of rock fragments is suspended on a cushion of air)	Very fast (>10s m/s)

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Creep or solifluction	Soil or other overburden; in some cases, mixed with ice	Flow (although sliding motion may also occur)	Very slow (mm/y to cm/y)
Slump	Thick deposits (m to 10s of m) of unconsolidated sediment	Motion as a unit along a curved surface (rotational sliding)	Slow (cm/y to m/y)
Mudflow	Loose sediment with a significant component of silt and clay	Flow (a mixture of sediment and water moves down a channel)	Moderate to fast (cm/s to m/s)
Debris flow	Sand, gravel, and larger fragments	Flow (similar to a mudflow, but typically faster)	Fast (m/s)

Check Your Progress

5. Name geomorphic agents.
6. What is mass wasting?

4.5 EVOLUTION OF LANDFORMS

After enduring cycles have had their activities on the earth materials making up the outside of the earth, the geomorphic specialists like running water, ground water, wind, glacial masses, waves perform disintegration. It is as of now known to you that disintegration causes changes on the outside of the earth. Statement follows disintegration and as a result of testimony as well, changes happen on the outside of the earth.

A few related landforms together make up scenes, (enormous lots of earth's surface). Each landform has its own actual shape, size, materials and is an aftereffect of the activity of certain geomorphic measures and agent(s). Activities of the majority of the geomorphic cycles and specialists are moderate, and thus the outcomes set aside a long effort to come to fruition.

Each landform has a start. Landforms once framed may change in their shape, size and nature gradually or quick because of proceeded with activity of geomorphic cycles and specialists. Because of changes in climatic conditions and vertical or flat developments of landmasses, either the power of cycles or the actual cycles may change prompting new adjustments in the landforms. Development here suggests phases of change of either a piece of the world's surface from one landform into another or change of individual landforms after they are once framed. That implies, every single landform has a past filled with advancement and changes through time. A landmass goes through phases of improvement fairly equivalent to the phases of life — youth, develop and advanced age.

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Landform evolution is an expression that implies progressive changes in topography from an initial designated morphology toward or to some altered form. The changes can only occur in response to energy available to do work within the geomorphic system in question and it follows:

- As the geomorphic specialists are fit for disintegration and statement, two sets - erosional or destructional and depositional or constructional - of landforms are created by them.
- Many assortments of landforms create by the activity of each of the geomorphic specialists relying on particularly the sort and construction for example folds, issues, joints, breaks, hardness and delicate quality, penetrability and impermeability, and so on.
- There are some other autonomous controls like security of ocean level; structural strength of landmasses; environment, which impact the advancement of landforms.

Landforms Made by Running Water

- In damp districts, which get weighty precipitation, running water is considered the most significant of the geomorphic specialists in achieving the corruption of the land surface.
- Most of the erosional landforms made by running water are related with energetic and young streams streaming over steep angles.

We live on an unstable earth, the surface of which is uneven. While travelling, we come across a variety of landforms such as mountains, hills, plateaus, plains, cliffs and ravines. We also come across tilted, broken and twisted layers of rocks which are originally deposited in horizontal forms. You have already studied about different types of rocks, their formation and characteristics. There is a close relationship between rock types and the shape of landforms. But all deformation on the face of the earth are due to the continuous influence of internal and external forces. In this lesson, we will study about the internal forces deriving their strength from earth's interior and playing their role in shaping what we see on the earth's crust.

Evolution of Landforms Due to Internal Forces

Internal Forces

The variety in the types of land forms on the earth is the end result of two types of forces working simultaneously and continuously both inside and outside on its surface. The forces which originate from within the earth's crust or inside the earth are called internal or endogenetic forces. The sources providing them energy are the internal heat, chemical reactions taking place within the earth, and the transfer of rock materials on the earth's surface by external forces.

Earth Movements

Though we generally hear people using phrase like "as hard as rock" and "as stable as the earth", but these phrases are not true. Neither the earth is stable nor are the rocks of which its crust is made, are so hard. Since the origin of earth,

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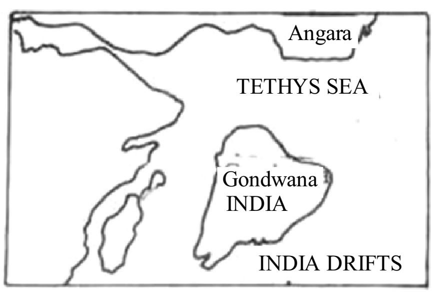
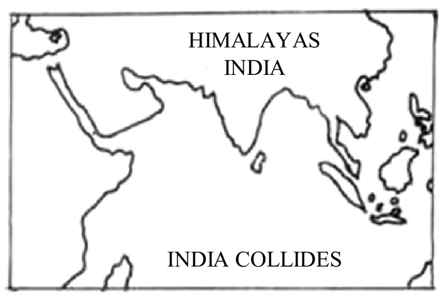
there have been major changes in the distribution of continents and oceans, the land and the oceans. The earth has experienced innumerable earth movements which have brought about vast changes in its surface.

Some of the examples of these movements are submergence of forest in Bombay harbour, the Mahabalipuram temple now standing on the sea and changes in the ground level in Rann of Kuchchh of India. The forces working from inside the earth in turn cause movements in its crust. These movements are called earth movements. Since, these movements pertain to or rise from, the movements of the actual structure of the earths crust, they are also called tectonic movements. The word tectonic is derived from the Greek word, "tekton" which means builders. This word is true to its meaning because these are the earth movements which are constructional and have been responsible for buildings of different types of land forms.

From the figure, it is quite evident that the physiography of India was entirely different about 60 million years ago. The vast Tethys sea existed in that area where the Himalayan ranges and Indo-Gangetic plain exist. The Tethys sea was gradually filled up by the sediments brought by rivers from the surrounding regions. Later, the sedimentary rocks formed in the beds of this sea gradually emerged in the form of the Himalayas in the north and Indo-Gangetic plain to its south.





The Malwa plateau and Deccan traps of India, Columbia and Snake Rivers Plateau of North America, Kimberlay Plateau of Australia and Parana and Patagonian Plateaus of South America were also formed by the solidification of molten lava which had escaped from the earth's interior to its surface at different geological times. The evidences clearly show that the surface of our earth never remained the same as it is today and neither it will be the same in future.

Classification of Earth Movements

The earth movements are classified on various basis. On the basis of time taken by such movements, they are divided into: (a) slow movement and (b) sudden movement:

(a) Slow Movement: The movement which bring about changes on the Earth's crust very gradually or slowly taking hundreds or thousands of years and which cover a period much longer than a human life span are called slow movements. These movements act on the earth's crust either vertically or horizontally. Acting vertically, they cause uplift or

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subsidence of a part of the crust. The raised sea-beaches along the Kathiawar coast of India which contain the shells of marine life clearly point out that this coast was once below the sea level.

Similar raised beaches are found in Orissa, Andhra Pradesh, and Tamil Nadu along the eastern coast of India as well. These beaches have been. uplifted to a height ranging between 15 to 30 metres above the mean sea level. On the other hand there are numerous examples of submergence. Such as the presence of peat and lignite beds found below the sea-level in Sunderban Delta, the submerged forest in Tirunelveli in Tamil Nadu and the submerged forest on the east coast of Bombay Island.

(b) Sudden Movements: Contrary to the slow movements, there are certain movements which bring about abrupt changes in the crust. The examples of such movements are volcanic eruptions and earthquakes. The changes brought about by these two events are so sudden that the courses of rivers undergo a change, and the lava flow result.in the formation of mountains, uplands and plateaus in a matter of days. Landslides occur in mountainous regions due to these movements.

Vertical and Horizontal Movements

The slow movements can further be divided into vertical and horizontal movements on the basis of the uplift or subsidence of a part of the Earth's surface:

(a) Vertical movements: Vertical movements originate from the centre of the earth and affect its surface. Consequently large scale uplift or subsidence of a part of the earth's surface takes place. These movements are slow and wide spread and do not bring changes in the horizontal rock strata. These movements are mainly associated with the formations of continents and plateaus, hence these are also known as continent building or plateau building movements. Besides, these movements are also called epeirogenetic movements. 'Epeiros' in Greek language means 'continent ' in the previous lesson on rocks, you have studied that sedimentary rocks are deposited and formed in the oceans and seas. The presence of these sedimentary rocks is wide-spread in continents. This clearly shows that these were uplifted or raised to form continents.

Contrary to the above, there are countless evidences of submerged buildings, river-valleys and cities due to subsidence into the sea. Some of such examples include the submerged ancient buildings in Mediterranean in its Crete Island and the ancient city of Dwaraka in Saurashtra, India. These changes clearly point out the downward movement of the Earth's surface.

(b) Horizontal Movements: There are forces which act on the earth's crust from side to side i.e., horizontally or tangentially. Naturally, they cause a lot of disruption in the horizontal layer of strata as they do involve a good deal of compression and tension of the preexisting

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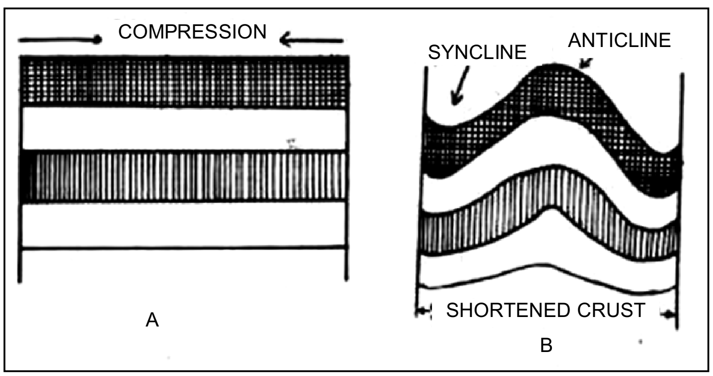
rocks since these forces act horizontally or tangentially to the earth's spherical surface. These are known as horizontal or tangential movements.

We can divide them into two types: (i) Forces of compression, and (ii) Forces of tension.

(i) Forces of compression: Involve pushing of the rock strata against a hard plane from one side or from both sides. To understand their working, let us take a piece of cloth and spread it on the table. Push the cloth with your both hands towards its centre, it will form wrinkles rising into up and down folds. Likewise rock strata also bend in the same fashion when forces of compression act on them from opposite directions. In this way, the compressional forces lead to the bending of rock layers and thus lead to the formation of fold mountains. In them the rock strata primarily of sedimentary rocks get folded, into wave like structure. This process of bending, sometimes warping and twisting of rock strata is referred to as their folding. The upfolds are called anticlines and downfold are called synclines.



When folding takes place on a gigantic scale, it represents the mountain building process. Most of the great mountain chains of the world viz, the Himalayas, the Rockies, the Andes, the Alps and others of this sort have been formed by compressional forces resulting in mountain building on a large scale. These are also called Orogenetic Movements.

(ii) Forces of tension: Are produced when these forces are working horizontally in opposite directions i.e., away from a given plane or point. Under the operation of intense tensional forces, the rock strata is broken or fractured. As a result cracks and fractures develop. The displacement of rocks upward or downward from their original position along such a fracture is termed as faulting. The line along which displacement of the fractured rock strata takes place is called the fault line. Like wise the plane along which displacement of rock strata takes place is known as fault plane.

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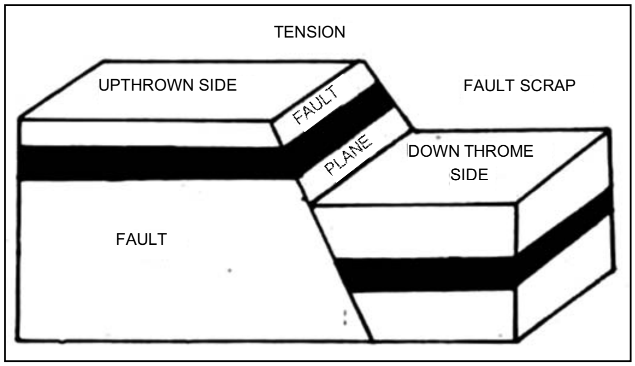
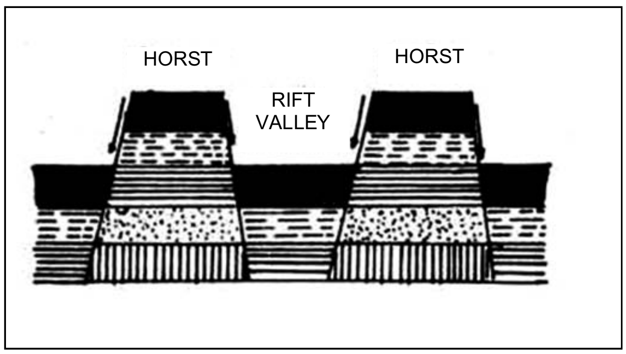


Forces of compression give rise to the operation of the forces of tension. Thus faults are closely related to the formation and occurrence of folds. It implies that folding generally leads to or is accompanied by fracturing and faulting in rock strata. Faulting results in the formation of well known relief features such as rift valleys and the block mountains. A rift valley is formed by sinking of rock strata lying between two almost parallel faults. (Figure below)



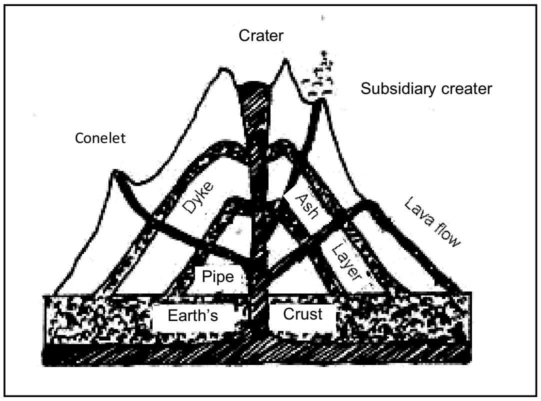
The classical examples of rift valleys in the world include the Midland Valley of Scotland, the Rhine Valley, the Valley of Nile, the Dead Sea basin and the Great Rift Valley of East Africa comprising few lakes of this region. Some geographers are of the opinion that the Narmada and Tapti valleys are also rift valleys. The coal deposits of the Damodar valley are said to be originally laid in a synclinal trough resembling a rift valley.

A rift valley is a trough with steep parallel walls along the fault lines. Such a valley is also called a graben. A rift valley may also be formed by upliftment of two blocks along the fault line. These uplifted blocks are called horsts or block mountains. The well known examples of horsts are the Vosges and the Black forest mountains on both sides of Rhine rift valley and the Plateaus of Palestine and Trans Jordan. The escarpments are the characteristic features of rift valleys and horsts. They are very steep or have highly precipitous slopes in a continuous line facing one direction. The escarpments of Western Ghats ones looking the Arabian Sea are thought to be the result of faulting. The escarpments of

Vindhyachal Mountain are also ascribed to the faulting and formation of narrow Narmada Valley.

Volcanoes

A volcano is a vent or an opening in the earth's crust through which molten rock material, rock fragments, ash, steam and other hot gases are emitted slowly or forcefully in the course of an eruption. These materials are thrown out from the hot interior of the earth to its surface. Such vents or openings occur in those parts of the earth's crust where rock strata are relatively weak.



Volcanoes are evidence of the presence of the intense heat and pressure existing within the earth. Hot molten rock materials beneath the solid outer crust is known as magma. When this magma is thrown out from the magma chamber to the earth's surface it is known as lava. The magma and the gases stored within the earth's surface keep trying to come out to the surface through a line of weakness anywhere in the crust. The tremendous force created by magma and its gases creates a hole in the crust and the lava spreads out on the surface along with ash and fragmented rock material. The process by which solid liquid and gaseous materials escape from the earth's interior to the surface of the earth is called vulcanism.

The volcanic materials accumulate around the opening or hole taking the form of a cone. The top of the cone has a funnel shaped depression which is called its crater.

Types of Volcanoes

Volcanoes are classified on the basis of the nature of vulcanism. The basis include the frequency of eruption, mode of eruption or fluidity and the manner in which volcanic material escapes to the surface of the earth. On the basis of the frequency of eruption, volcanoes are of three types:

(i) Active,

(ii) Dormant and

(iii) Extinct.

The volcanoes which erupt frequently or have erupted recently or are in action currently are called active volcanoes. Important among these include Stromboli in Mediterranean, Krakatoa in Indonesia, Mayon in Philippines, Mauna loa in Hawai Islands and Barren Island in India. The volcanoes which have not erupted in recent times are known as dormant volcano. They are as such the sleeping volcanoes. Important among these are Vesuvious of Italy, Cotopaxi in South America.

Contrary to these two, there are volcanoes which have not erupted in historical times. These are called extinct volcanoes. Mount Popa of Myanmar (Burma) and Kilimanjaro of Tanzania are important extinct volcanoes. It is not, always very simple to categorise a volcano as dormant or extinct. For example the Vesuvious and Krakatoa became suddenly active after lying dormant for hundreds of years.

When the eruption in a volcano takes place from a vent or a hole, it is called a central type of volcano. Different types of domes or conical hills are formed by this type of eruption depending on the nature of erupted materials. Majority of volcanic eruptions in the world are of this type. The other characteristic of this mode of eruption is that it is marked by violent explosion due to sudden escape of gases and molten rocks through the hole. Visuvious and Fujiyama belong to this group of volcanoes.

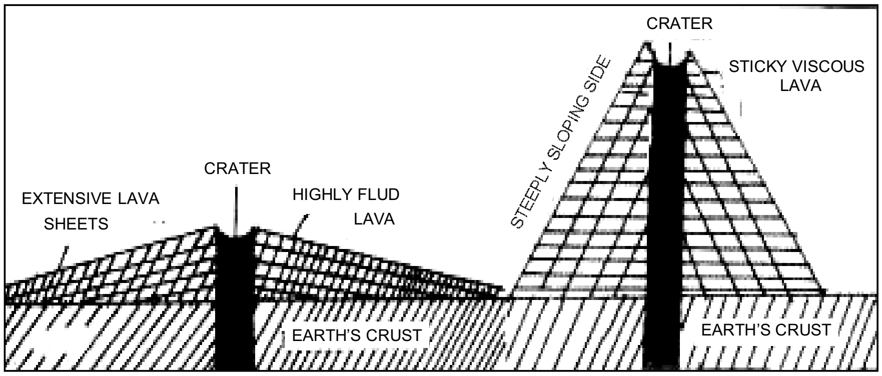
Sometimes, deep elongated cracks develop due to earthquakes or faulting. The magma starts flowing through them quietly. This mode of eruption is called fissure type of eruption. This eruption helps in the formation of thick horizontal sheets of lava or a low dome shaped volcano with broad base. It may also form what are identified as lava plateaus, and lava shields, Deccan Traps of India is one example of fissure type of eruption.

On the basis of the fluidity of lava there are two types of volcanoes:

(i) Volcanoes of basic lava and

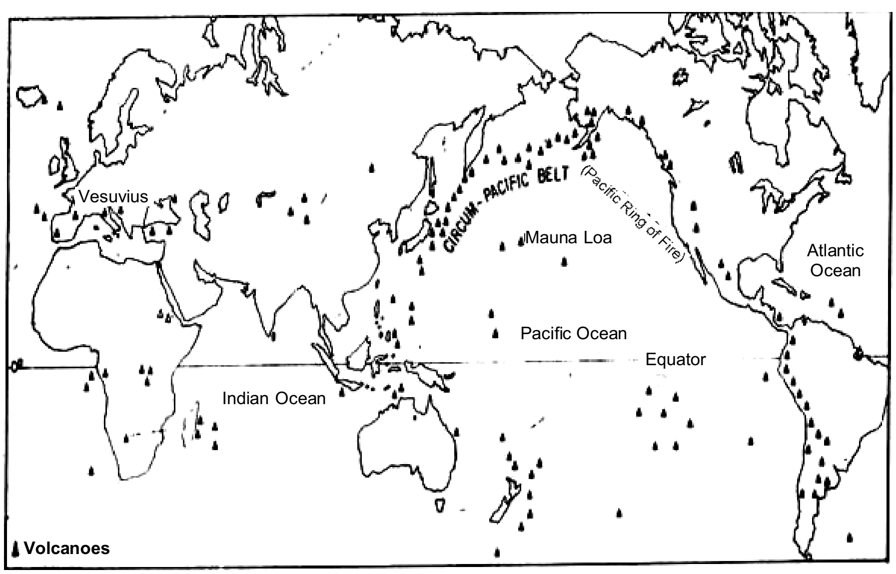
(ii) Volcanoes of acid lava.

Since the basic lava is rich in metallic minerals and has a low melting point, it has greater fluidity. In this type of eruption, lava flows far and wide quietly with greater speed and spreads out in thin sheets over a large area. Thus, it leads to the formation of shields and lava domes. The shield volcano of Hawaian Island in Pacific ocean is one of these volcanoes. Contrary to basic lava, acid lava is rich in silica and has a relatively high melting point. Therefore, it is highly viscous and solidifies quickly. Hence, the, acid lava volcanoes cause the formation of usually higher land features with steeper slopes. Acid lava cones are of steeper slopes than basic lava shields.



Distribution of Volcanoes

There are about 500 volcanoes in the world. Most of these volcanoes are found in three well defined belts, The Circum-Pacific belt, the Mid-World Mountain belt and the African Rift Valley belt. Thus, volcanoes are closely related to the regions of intense folding and faulting. They occur along coastal' mountain ranges, on islands and in the mid-oceans. Interior parts of continents are generally free from their activity. Most of the active volcanoes are found in the pacific region. About 83 active volcanoes are located in Mediterranean region (Figure below). Circum-Pacific region has the greatest concentration of volcanoes, that is why, it is called 'Pacific Ring of Fire'. This ring extends along Andes mountains of south America to Alaska and from the Aleutian Islands to Japan, Philippines, Indonesia to New Zealand. The Mid-world mountain belt occupies the second position with regard to the numbers of volcanoes. It runs from Alps in Europe to Asia Minor and crossing through Himalayan region joins the Circum-Pacific belt. The African rift valley region ranks third. Most of the volcanoes are extinct here. Mt. Cameroon is the only active volcano which is situated in Central West Africa.



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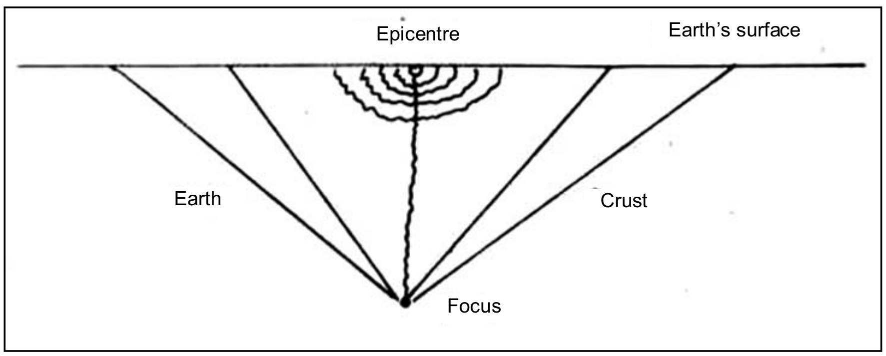
Earthquake

All the earthquakes are not of the same intensity. Some of them are very severe, others are very mild and still others are not even noticed. Major or strong earthquakes are only a few. Though our earth experiences many earthquakes everyday, however the frequency of earthquakes varies largely from place to place. The network of seismographic stations all over the world records dozens of earthquakes every day. But, occurrence of severe earthquakes is limited to a few regions. The instrument used for recording the earthquakes is known as seismograph. 'Sesamos' is a Greek word which means an earthquake.

The point within the earth's crust where an earthquake originates is called the focus. It is also referred as seismic focus. It generally lies within the depth of 60 kilometres in the earth crust. The point vertically above the focus on the earth's surface is known as epicentre. The impact of the earthquake is carried from the point of its origin by earthquake waves. These earthquake waves originating from the focus travel in all directions. But their intensity is the highest at the epicentre. That is why the maximum destruction occurs at and around the epicentre (Figure below). The intensity of vibrations decreases as one moves away from the epicentre in all directions.



Causes and Effects of Earthquakes

Folding, faulting and displacement of rock strata are the main causes of earthquakes. Some examples of this type of earthquakes are the San Francisco earthquakes of California in 1906, the Assam earthquakes of 1951, the Bihar earthquakes of 1935. The second important cause lies in the phenomenon of volcanic eruption. The violent volcanic eruptions put even the solid rocks under great stress. It causes vibrations in the earth's crust. But, these earthquakes, are limited to the areas of volcanic activity. Its important example is the earthquake which continued for six days preceding the eruption of Mauna Loa volcano of Hawaii Island in 1868.

Minor earthquakes often accompany or are the result of landslides, seepage of water causing the collapse of the rocks of cavern or underground mines and tunnel. These are least damaging earthquakes. Violent earthquakes are generally very disastrous. They may themselves cause land-slides, damming of river course and occurrence of floods, and sometimes, the depressions leading to the formation of lakes. An earthquake often forms cracks and fissures in the earth's crust.

It changes the drainage system of an area as was witnessed in Assam after its 1951 earthquake. Earthquakes also cause vertical and horizontal displacement of rock strata along fault line. They prove most catastrophic and devastating when they cause fires and seismic sea waves. Such tidal waves are called Tsunamis. These waves may wash away coastal cities. Buildings and bridges collapse causing death of the thousands of people. Lines of transport, communication and of electric transmission get disrupted. The after effect of earthquake is spread of epidemics like cholera.

Distribution of Earthquakes

The occurrence of earthquake is a phenomenon of almost every part of the world. But, there are two well-defined belts where they occur more frequently. These belts are the Circum-Pacific belt and the Mid-world mountain belt. The first belt i.e., the Circum-Pacific comprises the western coast of North and South America; Aleutian Islands and island groups along the eastern coasts of Asia such as Japan and Philippines. As it encircles the Pacific Ocean from end to end, it is named as such. The earthquakes in this belt are associated with the ring of mountains and volcanoes. It is estimated that about 68 percent of earthquakes of the world occur in this belt alone.

The second belt-extend from Alps with their extension into Mediterranean the Caucasus and the Himalayan region and continues into Indonesia. About 21, percent of total earthquakes of the world originate in this belt. Remaining 11 percent occur in the other parts of the world.

Check Your Progress

7. Valley types depend upon the __________ in which they form.
8. Large and deep holes at the base of waterfalls are called _________.

4.6 THE COURSE OF A RIVER

The way of the stream, from its starting point to its end point, is essentially called its course. It is separated into 3 sections, High, Middle and Low.

As should be obvious, the High Course starts from Mountains where the force of the stream is quite high; consequently causing solid disintegration.

The center course begins once the stream is in fields. The water stream turns into a piece increasingly slow disintegration is diminished generally and the waterway will in general silt the dissolved particles it carried with it.

The last piece of the course is Low. It is the last part where the stream completes its excursion. It ordinarily finishes in the ocean or sea.

The course of a river is the direction in which a river flows. You must remember that all rivers flow downhill. There are 3 different courses in a river: upper, middle and lower course. Upper course: usually, rivers are born in mountains.

Youth

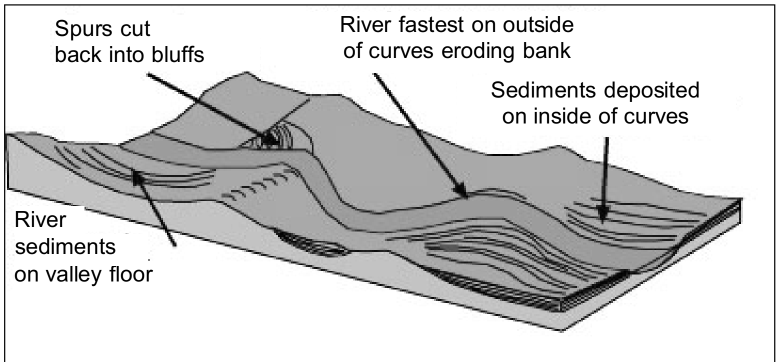
- Streams are few during this stage with poor integration and flow over original slopes showing shallow V-shaped valleys with no floodplains or with very narrow floodplains along trunk streams. Streams divides are broad and fat with marshes, swamp and lakes. Meanders if present develop over these broad upland surfaces. These meanders may eventually entrench themselves into the uplands. Waterfalls and rapids may exist where local hard rock bodies are exposed.

Mature

- During this stage streams are plenty with good integration. The valleys are still V-shaped but deep; trunk streams are broad enough to have wider floodplains within which streams may flow in meanders confined within the valley. The fat and broad inter stream areas and swamps and marshes of youth disappear and the stream divides turn sharp. Waterfalls and rapids disappear.

Old

- Smaller tributaries during old age are few with gentle gradients. Streams meander freely over vast floodplains showing natural levees, oxbow lakes, etc. Divides are broad and fat with lakes, swamps and marshes. Most of the landscape is at or slightly above sea level.



The mature river is slower. It cuts back the sides of the valley, but at the same time deposits material on the valley floor, forming a plain. The river changes course continually and winds about on the plain.

Source: geographylearners.com

Fig. 4.3: Mature River

Check Your Progress

9. In mature stage of river, the valleys are __________.
10. The two important formations of the upper course of a river are __________ and __________.

4.7 EROSIONAL LANDFORMS

NOTES

There are two significant kinds of coastal morphology: one is overwhelmed by erosionand the other by statement. They show particularly extraordinary landforms, however each type may contain a few highlights of the other. As a rule, erosional coasts are those with almost no residue, while depositional coasts are described by bountiful silt aggregation over the long haul. Both transient and geographic varieties may happen in every one of these waterfront types.

Erosional drifts regularly display high help and tough geography. They will in general happen on the main edge of lithospheric plates, the west banks of both North and South America being fantastic models. Icy movement additionally may lead to erosional coasts, as in northern New England and in the Scandinavian nations. Commonly, these coasts are overwhelmed by uncovered bedrock with steep inclines and high heights neighboring the shore. Albeit these coasts are erosional, the pace of shoreline retreat is delayed because of the opposition of bedrock to disintegration. The sort of rock and its lithification are significant variables in the pace of disintegration.

Valleys

- Valleys start as small and narrow rills; the rills will gradually develop into long and wide gullies; the gullies will further deepen, widen and lengthen to give rise to valleys.
- Depending upon dimensions and shape, many types of valleys like V-shaped valley, gorge, canyon, etc. can be recognized.
- A gorge is a deep valley with very steep to straight sides and a canyon is characterised by steep step-like side slopes and may be as deep as a gorge.
- A gorge is almost equal in width at its top as well as its bottom. In contrast, a canyon is wider at its top than at its bottom. In fact, a canyon is a variant of gorge.
- Valley types depend upon the type and structure of rocks in which they form. For example, canyons commonly form in horizontal bedded sedimentary rocks and gorges form in hard rocks.

Potholes and Plunge Pools

- Over the rocky beds of hill-streams more or less circular depressions called potholes form because of stream erosion aided by the abrasion of rock fragments.
- Once a small and shallow depression forms, pebbles and boulders get collected in those depressions and get rotated by flowing water and consequently the depressions grow in dimensions.
- A series of such depressions eventually join and the stream valley gets deepened. At the foot of waterfalls also, large potholes, quite deep and

wide, form because of the sheer impact of water and rotation of boulders.

- Such large and deep holes at the base of waterfalls are called plunge pools. These pools also help in the deepening of valleys.
- Waterfalls are also transitory like any other landform and will recede gradually and bring the floor of the valley above waterfalls to the level below.

Incised or Entrenched Meanders

- In streams that flow rapidly over steep gradients, normally erosion is concentrated on the bottom of the stream channel.
- Also, in the case of steep gradient streams, lateral erosion on the sides of the valleys is not much when compared to the streams flowing on low and gentle slopes.
- Because of active lateral erosion, streams flowing over gentle slopes develop sinuous or meandering courses.
- It is common to find meandering courses over floodplains and delta plains where stream gradients are very gentle.
- But very deep and wide meanders can also be found cut in hard rocks. Such meanders are called incised or entrenched meanders.
- Meander loops develop over original gentle surfaces in the initial stages of development of streams and the same loops get entrenched into the rocks normally due to erosion or slow, continued uplift of the land over which they start.
- They widen and deepen over time and can be found as deep gorges and canyons in hard rock areas.
- They give an indication on the status of original land surfaces over which streams have developed.

River Terraces

- River terraces are surfaces marking old valley floor or floodplain levels.
- They may be bedrock surfaces without any alluvial cover or alluvial terraces consisting of stream deposits. River terraces are basically products of erosion as they result due to vertical erosion by the stream into its own depositional floodplain.
- There can be a number of such terraces at different heights indicating former river bed levels.
- The river terraces may occur at the same elevation on either side of the rivers in which case they are called paired terraces.

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Check Your Progress

11. __________ form when the river downcuts at a less rapid pace, giving the river opportunity to erode laterally as well as vertically.
12. __________ is deep, steep-walled, V-shaped valley cut by a river through resistant rock.

4.8 DEPOSITIONAL LANDFORMS

Assuming rocks and precipices are by and large ceaselessly endured, disintegrated and moved it makes sense that this will create a great deal of material that should be kept (or set down) elsewhere along the coastline. The significant testimony landforms are sea shores, spits and bars. Affidavit happens when wave speeds moderate, or when sea flows delayed due to experiencing frictional powers, for example, the ocean bed, other counter flows and vegetation.

Beaches are spaces of sand, stones and shingle that are shaped by testimony delivered by wave measures. Sea shores are in no way, shape or form uniform and contain a gigantic assortment of silt types and measures, and have a wide range of shapes.

Tenderly inclining sea shores are framed by solid ruinous waves that discharge more material away from the sea shore that they swash up the sea shore.

Steeply slanting sea shores happen by helpful waves that swash more material up the sea shore than they discharge away, developing a lofty sea shore slope.

Alluvial Fans

- Alluvial fans are formed when streams flowing from higher levels break into foot slope plains of low gradient.
- Normally very coarse load is carried by streams flowing over mountain slopes.
- This load becomes too heavy for the streams to be carried over gentler gradients and gets dumped and spread as a broad low to high cone shaped deposit called alluvial fan.
- Usually, the streams which flow over fans are not confined to their original channels for long and shift their position across the fan forming many channels called distributaries.
- Alluvial fans in humid areas show normally low cones with gentle slope from head to toe and they appear as high cones with steep slope in arid and semi-arid climates.

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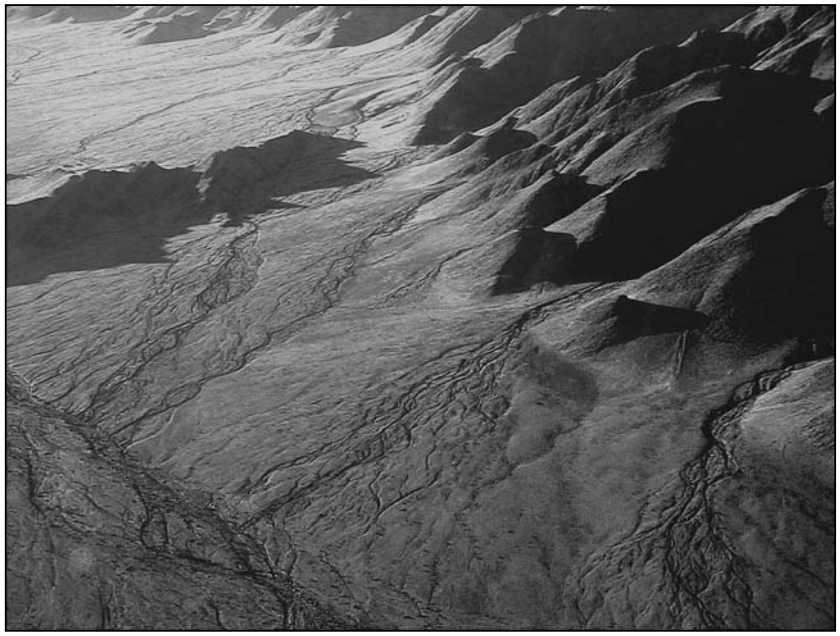
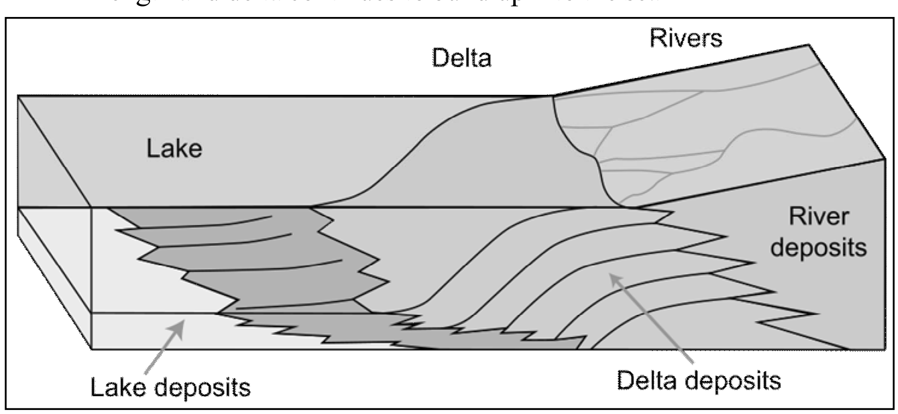


Source: commons.wikimedia.org

Fig. 4.4: Alluvial Fans

Deltas

- Deltas are like alluvial fans but develop at a different location.
- The load carried by the rivers is dumped and spread into the sea. If this load is not carried away far into the sea or distributed along the coast, it spreads and accumulates as a low cone.
- Unlike in alluvial fans, the deposits making up deltas are very well sorted with clear stratification.
- The coarsest materials settle out first and the finer fractions like silts and clays are carried out into the sea.
- As the delta grows, the river distributaries continue to increase in length and delta continues to build up into the sea



Source: commons.wikimedia.org

Fig. 4.5: Deltas

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Floodplains

- Deposition develops a floodplain just as erosion makes valleys.
- Floodplain is a major landform of river deposition. Large sized materials are deposited first when stream channel breaks into a gentle slope.
- Thus, normally, fine sized materials like sand, silt and clay are carried by relatively slow moving waters in gentler channels usually found in the plains and deposited over the bed and when the waters spill over the banks during flooding above the bed.
- A river bed made of river deposits is the active floodplain. The floodplain above the bank is inactive floodplain.
- Inactive floodplain above the banks basically contain two types of deposits — flood deposits and channel deposits.
- In plains, channels shift laterally and change their courses occasionally leaving cut-of courses which get filled up gradually.
- Such areas over flood plains built up by abandoned or cut-of channels contain coarse deposits.
- The flood deposits of spilled waters carry relatively finer materials like silt and clay.
- The flood plains in a delta are called delta plains.

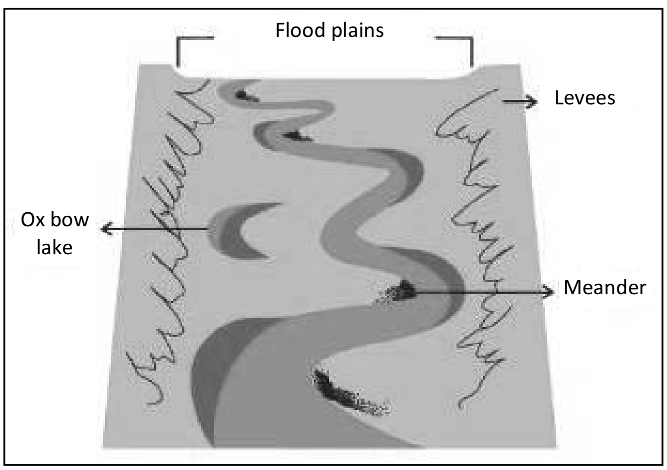

Fig. 4.6: Floodplains

Meanders

- In large flood and delta plains, rivers rarely flow in straight courses.
- Loop-like channel patterns called meanders develop over food and delta plains.
- Meander is not a landform but is only a type of channel pattern.
- This is because of: (i) propensity of water flowing over very gentle gradients to work laterally on the banks; (ii) unconsolidated nature of alluvial deposits making up the banks with many irregularities which

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can be used by water exerting pressure laterally; (iii) coriolis force acting on the fluid water defecting it like it defects the wind.

- When the gradient of the channel becomes extremely low, water flows leisurely and starts working laterally.
- Slight irregularities along the banks slowly get transformed into a small curvature in the banks; the curvature deepens due to deposition on the inside of the curve and erosion along the bank on the outside.
- If there is no deposition and no erosion or undercutting, the tendency to meander is reduced. Normally, in meanders of large rivers, there is active deposition along the concave bank and undercutting along the convex bank.
- The concave bank is known as cut-of bank which shows up as a steep scarp and the convex bank presents a long, gentle profile. As meanders grow into deep loops, the same may get cut-of due to erosion at the infection points and are left as ox-bow lakes.

Landform Made by Groundwater

- The surface water percolates well when the rocks are permeable, thinly bedded and highly jointed and cracked.
- After vertically going down to some depth, the water under the ground flows horizontally through the bedding planes, joints or through the materials themselves.
- It is this downward and horizontal movement of water which causes the rocks to erode.
- Physical or mechanical removal of materials by moving groundwater is insignificant in developing landforms. That is why; the results of the work of groundwater cannot be seen in all types of rocks. But in rocks like limestone’s or dolomites rich in calcium carbonate, the surface water as well as groundwater through the chemical process of solution and precipitation deposition develops varieties of landforms.
- Any limestone or dolomitic region showing typical landforms produced by the action of groundwater through the processes of solution and deposition is called Karst topography after the typical topography developed in limestone rocks of Karst region in the Balkans adjacent to Adriatic Sea.
- The Karst topography is also characterised by erosional and depositional landforms.

Erosional Landforms

Pools, Sinkholes, Lapies and Limestone Pavements

- Small to medium sized round to sub-rounded shallow depressions called swallow holes form on the surface of limestones through solution.

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- Sinkholes are very common in limestone/Karst areas. A sinkhole is an opening more or less circular at the top and funnel-shaped towards the bottom with sizes varying in area from a few sq. m to a hectare and with depth from a less than half a meter to thirty meters or more.
- Some of these form solely through solution action (solution sinks) and others might start as solution forms first and if the bottom of a sinkhole forms the roof of a void or cave underground, it might collapse leaving a large hole opening into a cave or a void below (collapse sinks). Quite often, sinkholes are covered up with soil mantle and appear as shallow water pools. Anybody stepping over such pools would go down like it happens in quick sands in deserts.
- The term doline is sometimes used to refer the collapse sinks. Solution sinks are more common than collapse sinks. Quite often the surface run-of simply goes down swallow and sink holes and flow as underground streams and re-emerge at a distance downstream through a cave opening.
- When sink holes and dolines join together because of slumping of materials along their margins or due to roof collapse of caves, long, narrow to wide trenches called valley sinks or Uvalas form.
- Gradually, most of the surface of the limestone is eaten away by these pits and trenches, leaving it extremely irregular with a maze of points, grooves and ridges or lapies. Especially, these ridges or lapies form due to differential solution activity along parallel to sub parallel joints. The lapie field may eventually turn into somewhat smooth limestone pavements.

Caves

- In areas where there are alternating beds of rocks (shales, sandstones, quartzites) with limestones or dolomites in between or in areas where limestones are dense, massive and occurring as thick beds, cave formation is prominent. Water percolates down either through the materials or through cracks and joints and moves horizontally along bedding planes. It is along these bedding planes that the limestone dissolves and long and narrow to wide gaps called caves result. There can be a maze of caves at different elevations depending upon the limestone beds and intervening rocks. Caves normally have an opening through which cave streams are discharged. Caves having openings at both the ends are called tunnels.

Depositional Landforms

- Many depositional landforms develop within the limestone caves. The chief chemical in limestone is calcium carbonate which is easily soluble in carbonated water (carbon dioxide absorbed rainwater). This calcium carbonate is deposited when the water carrying it in solution evaporates or loses its carbon dioxide as it trickles over rough rock surfaces.

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Stalactites, Stalagmites and Pillars

- Stalactites hang as icicles of different diameters. Normally they are broad at their bases and taper towards the free ends showing up in a variety of forms.
- Stalagmites rise up from the floor of the caves. In fact, stalagmites form due to dripping water from the surface or through the thin pipe, of the stalactite, immediately below it.
- Stalagmites may take the shape of a column, a disc, with either a smooth, rounded bulging end or a miniature crater like depression.
- The stalagmite and stalactites eventually fuse to give rise to columns and pillars of different diameters.

Landform Made by Wind

- Wind is a geomorphic agent in all terrestrial environments. It is a potent agent only in dry areas with fine-grained soils and sediments and little or no vegetation. It is limited by a protective cover of vegetation and moist soil, which helps to bind soil particles together. Winds may erode, transport, and deposit materials, and are effective agents in regions with sparse vegetation and a large supply of unconsolidated sediments. Although water is a much more powerful eroding force than wind, Aeolian processes are important in arid environments such as deserts.
- Wind can erode desert rocks in two ways:
  - **(a) Deflation:** The removal of fine, loose particles from the surface of rocks.
  - **(b) Abrasion:** Small particles being carried by the wind scrape of particles from the rock surface. It then transports the eroded material by three processes:
    - **Suspension:** Very small particles (<0.15mm) are picked up and carried by the wind.
    - **Saltation:** Small particles (0.15-0.25mm) are temporarily lifted from the ground and bounce along the surface.
    - **Surface Creep:** Larger particles (>0.25mm) are hit and pushed along the ground by particles being moved by saltation.

Erosion is removal of surface material from Earth's crust, primarily soil and rock debris, and the transportation of the eroded materials by natural agencies (such as water or wind) from the point of removal.

The broadest application of the term erosion embraces the general wearing down and molding of all landforms on Earth's surface, including the weathering of rock in its original position, the transport of weathered material, and erosion caused by wind action and fluvial, marine, and glacial processes. This broad definition is more correctly called denudation, or degradation, and includes mass-movement processes. A narrow and somewhat limiting definition of erosion excludes the transport of eroded material by natural agencies, but the exclusion of the transport phenomenon makes the distinction between erosion and weathering very vague. Erosion, therefore, includes the transportation of eroded or weathered material from the point of degradation (such as the side of a mountain or other landform) but not the deposition of material at a new site. The complementary actions of erosion and deposition or sedimentation operate through the geomorphic processes of wind, moving water, and ice to alter existing landforms and create new landforms.

Erosion will often occur after rock has been disintegrated or altered through weathering. Weathered rock material will be removed from its original site and transported away by a natural agent. With both processes often operating simultaneously, the best way to distinguish erosion from weathering is by observing the transportation of material.

Water Erosion

Moving water is the most important natural erosional agent. The wastage of the seacoast, or coastal erosion, is brought about mainly by the action of sea waves but also, in part, by the disintegration or degradation of sea cliffs by atmospheric agents such as rain, frost, and tidal scour. Sea wave erosion is accomplished primarily by hydraulic pressure, the impact of waves striking the shore, and by the abrasion (wearing, grinding, or rubbing away by friction) by sand and pebbles agitated incessantly by the water (see wave-cut platform). Wave impact and hydraulic action are usually most devastating to human-made coastal features such as breakwaters or moles. The impact and hydraulic action of storm waves are the most significant upon shores composed of highly jointed or bedded rock, which are vulnerable to quarrying, the hydraulic plucking of blocks of rock. The abrasive action of sand and pebbles washed against shorelines is probably the most significant wave erosional activity. Particles are dragged back and forth by wave action, abrading the bedrock along the coast and abrading each other, gradually wearing pebbles into sand. Wave erosion creates retrograde, or retreating, shorelines with sea cliffs, wave-cut benches at the base of the sea cliffs, and sea arches — curved or rectangularly shaped archways that result from different rates of erosion due to varied bedrock resistance. Besides the back-and-forth transportation of materials by wave action, sediments are transported by the lateral movement of waves after they wash ashore (beach drifting) or by shallow-water transport just offshore, known as longshore currents. These transportational movements lead to deposition and the formation of prograde, or advancing, shorelines, bars, spits, bayhead beaches (a bayhead beach is formed between two headlands), and barrier beaches (a barrier beach parallels the shore).

In rivers and estuaries, the erosion of banks is caused by the scouring action of the moving water, particularly in times of flood and, in the case of estuaries, also by the tidal flow on the ebb tide when river and tidewater combine in their erosive action. This scouring action of the moving water entrains (that is, draws in and transports) sediments within the river or stream load. These entrained sediments become instruments of erosion as they abrade one another in suspended transport or as they abrade other rock and soil as they are dragged along the river bottom, progressively entraining additional sediments as long as the river's volume and velocity of the stream continues to increase. As the velocity of the river decreases, the suspended sediments will be deposited, creating landforms such as broad alluvial fans, floodplains, sandbars, and river deltas. The land surface unaffected by rivers and streams is subjected to a continuous process of erosion by the action of rain, snowmelt, and frost, the resulting detritus (organic debris) and sediment being carried into the rivers and thence to the ocean.

Glacial Erosion

Glacial erosion occurs in two principal ways: through the abrasion of surface materials as the ice grinds over the ground (much of the abrasive action being attributable to the debris embedded in the ice along its base); and by the quarrying or plucking of rock from the glacier bed. The eroded material is transported until it is deposited or until the glacier melts.

Wind Erosion

In some arid and desert tracts, wind has an important effect in bringing about the erosion of rocks by driving sand, and the surface of sand dunes not held together and protected by vegetation is subject to erosion and change by the drifting of blown sand. This action erodes material by deflation—the removal of small loose particles—and by sandblasting of landforms by wind-transported material. Continued deflation of loose particles from landforms leaves behind larger particles that are more resistant to deflation. Wind action transports eroded material above or along the surface of Earth either by turbulent flow (in which particles move in all directions) or by laminar flow (in which adjacent sheets of air slip past one another). The transportation of wind-eroded material continues until the velocity of the wind can no longer sustain the size particle being transported or until the windblown particles collide with or cling to a surface feature.

Coastal Topography

Coastal landscapes are some of the most beautiful and dynamic places. **As storms, more frequent and more intense, approach the shores, the coasts are the first lines of defense for our infrastructure, resources, and wellbeing.** Beaches, sand dunes, rounded bluffs, and jagged cliffs all buffer against oceanic and atmospheric forces. Many are also eroding because of the very mechanisms they protect against. The presence of human infrastructure further means coastal landforms have little room to adapt and migrate inland.

The coastal environment of the world is made up of a wide variety of landforms manifested in a spectrum of sizes and shapes ranging from gently sloping beaches to high cliffs, yet coastal landforms are best considered in two broad categories: erosional and depositional. In fact, the overall nature of any coast may be described in terms of one or the other of these categories. It should be noted, however, that each of the two major landform types may occur on any given reach of coast.

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Factors and Forces in the Formation of Coastal Features

The landforms that develop and persist along the coast are the result of a combination of processes acting upon the sediments and rocks present in the coastal zone. The most prominent of these processes involves waves and the currents that they generate, along with tides. Other factors that significantly affect coastal morphology are climate and gravity.

Waves

The most obvious of all coastal processes is the continual motion of the waves moving toward the beach. Waves vary considerably in size over time at any given location and also vary markedly from place to place. Waves interact with the ocean bottom as they travel into shallow water; as a result, they cause sediment to become temporarily suspended and available for movement by coastal currents. The larger the wave, the deeper the water in which this process takes place and the larger the particle that can be moved. Even small waves that are only a few tens of centimetres high can pick up sand as they reach the shore. Larger waves can move cobbles and rock material as large as boulders.

Generally, small waves cause sediment usually sand to be transported toward the coast and to become deposited on the beach. Larger waves, typically during storms, are responsible for the removal of sediment from the coast and its conveyance out into relatively deep water.

Waves erode the bedrock along the coast largely by abrasion. The suspended sediment particles in waves, especially pebbles and larger rock debris, have much the same effect on a surface as sandpaper does. Waves have considerable force and so may break up bedrock simply by impact.

Longshore Currents

Waves usually approach the coast at some acute angle rather than exactly parallel to it. Because of this, the waves are bent (or refracted) as they enter shallow water, which in turn generates a current along the shore and parallel to it. Such a current is called a longshore current, and it extends from the shoreline out through the zone of breaking waves. The speed of the current is related to the size of the waves and to their angle of approach. Under rather quiescent conditions, longshore currents move only about 10-30 centimetres per second; however, under stormy conditions they may exceed one metre per second. The combination of waves and longshore current acts to transport large quantities of sediment along the shallow zone adjacent to the shoreline.

Because longshore currents are caused by the approaching and refracting waves, they may move in either direction along the coast, depending on the direction of wave approach. This direction of approach is a result of the wind direction, which is therefore the ultimate factor in determining the direction of longshore currents and the transport of sediment along the shoreline.

Although a longshore current can entrain sediment if it moves fast enough, waves typically cause sediment to be picked up from the bottom, and the longshore current transports it along the coast. In some locations there is

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quite a large volume of net sediment transport along the coast because of a dominance of one wind direction—and therefore wave direction—over another. This volume may be on the order of 100,000 cubic metres per year. Other locations may experience more of a balance in wave approach, which causes the longshore current and sediment transport in one direction to be nearly balanced by the same process in the other direction.

Rip Currents

Another type of coastal current caused by wave activity is the rip current (incorrectly called rip tide in popular usage). As waves move toward the beach, there is some net shoreward transport of water. This leads to a slight but important upward slope of the water level (setup), so that the absolute water level at the shoreline is a few centimetres higher than it is beyond the surf zone. This situation is an unstable one, and water moves seaward through the surf zone in an effort to relieve the instability of the sloping water. The seaward movement is typically confined to narrow pathways. In most cases, rip currents are regularly spaced and flow at speeds of up to several tens of centimetres per second. They can carry sediment and often are recognized by the plume of suspended sediment moving out through the surf zone. In some localities rip currents persist for months at the same site, whereas in others they are quite ephemeral.

Tides

The rise and fall of sea level caused by astronomical conditions is regular and predictable. There is a great range in the magnitude of this daily or semi-daily change in water level. Along some coasts the tidal range is less than 0.5 metre, whereas in the Bay of Fundy in southeastern Canada the maximum tidal range is just over 16 metres. A simple but useful classification of coasts is based solely on tidal range without regard to any other variable. Three categories have been established: micro-tidal (less than two metres), meso-tidal (two to four metres), and macro-tidal (more than four metres). Micro-tidal coasts constitute the largest percentage of the world's coasts, but the other two categories also are widespread.

The role of tides in molding coastal landforms is twofold: (1) tidal currents transport large quantities of sediment and may erode bedrock, and (2) the rise and fall of the tide distributes wave energy across a shore zone by changing the depth of water and the position of the shoreline.

Tidal currents transport sediment in the same way that longshore currents do. The speeds necessary to transport the sediment (typically sand) are generated only under certain conditions—usually in inlets, at the mouths of estuaries, or any other place where there is a constriction in the coast through which tidal exchange must take place. Tidal currents on the open coast, such as along a beach or rocky coast, are not swift enough to transport sediment. The speed of tidal currents in constricted areas, however, may exceed two metres per second, especially in inlets located on a barrier island complex.

The speed of these tidal currents is dictated by the volume of water that must pass through the inlet during a given flood or ebb-tide cycle. This may be either six or 12 hours in duration, depending on whether the local situation is semidiurnal (12-hour cycle) or diurnal (24-hour cycle). The volume of water involved, called the tidal prism, is the product of the tidal range and the area of the coastal bay being served by the inlet. This means that though there may be a direct relationship between tidal range and tidal-current speed, it is also possible to have very swift tidal currents on a coast where the tidal range is low if the bay being served by the inlet is quite large. This is a very common situation along the coast of the Gulf of Mexico where the range is typically less than one metre but where there are many large coastal bays.

The rise and fall of the tide along the open coast has an indirect effect on sediment transport, even though currents capable of moving sediment are not present. As the tide comes in and then retreats along a beach or on a rocky coast, it causes the shoreline to move accordingly. This movement of the shoreline changes the zone where waves and longshore currents can do their work. Tidal range in combination with the topography of the coast is quite important in this situation. The greater the tidal range, the more effect this phenomenon has on the coast. The slope of a beach or other coastal landform also is important, however, because a steep cliff provides only a nominal change in the area over which waves and currents can do their work even in a macro-tidal environment. On the other hand, a broad, gently sloping beach or tidal flat may experience a change in the shoreline of as much as one kilometre during a tidal cycle in a macro-tidal setting. Examples of this situation occur in the Bay of Fundy and along the West German coast of the North Sea.

Other Factors and Processes

Climate is an extremely important factor in the development of coastal landforms. The elements of climate include rainfall, temperature, and wind. Rainfall is important because it provides runoff in the form of streams and also is a factor in producing and transporting sediment to the coast. This fact gives rise to a marked contrast between the volume and type of sediment carried to the coast in a tropical environment and those in a desert environment.

Temperature is important for two quite different reasons. It is a factor in the physical weathering of sediments and rocks along the coast and in the adjacent drainage basins. This is particularly significant in cold regions where the freezing of water within cracks in rocks causes the rocks to fragment and thereby yield sediment. Some temperate and arctic regions have shore ice up to several months each year. Under these conditions there is no wave impact, and the coast becomes essentially static until the ice thaws or breaks up during severe storms. Such conditions prevail for three to four months along much of the coast of the Great Lakes in North America.

Wind is important primarily because of its relationship to waves. Coasts that experience prolonged and intense winds also experience high wave-energy conditions. Seasonal patterns in both wind direction and intensity can be translated directly into wave conditions. Wind also can be a key factor in directly forming coastal landforms, particularly coastal dunes. The persistence of onshore winds throughout much of the world's coast gives rise to sand dunes in all places where enough sediment is available and where there is a place for it to accumulate.

Gravity, too, plays a major role in coastal processes. Not only is it indirectly involved in processes associated with wind and waves but it also is directly involved through downslope movement of sediment and rock as well. This role is particularly evident along shoreline cliffs where waves attack the base of the cliffs and undercut the slope, resulting in the eventual collapse of rocks into the sea or their accumulation as debris at the base of the cliffs.

Check Your Progress

13. What is Gorge?
14. Define alluvial fan?
15. What is the other term for Collapse Sink?
16. What is Karst Topography?
17. What is deflation?
18. What happens in surface crip?

4.9 CYCLE OF EROSION (DAVIS)

The geographic cycle, or cycle of erosion, is an idealized model that explains the development of comfort in landscapes. The version begins with the erosion that follows uplift of land above a base level and ends, if conditions permit, within the formation of a peneplain. Landscapes that show proof of more than one cycle of erosion are termed "polycyclical". The cycle of erosion and some of its associated concepts have, no matter their popularity, been a subject of a great deal criticism.The complete collection of adjustments or tiers via which a landmass passes from the inception of erosion on a newly uplifted or exposed floor through its dissection into mountains and valleys to the very last level whilst it is worn right down to the level of the ocean or to a few different base level. The cycle is commonly subdivided into youthful, mature, and old-age degrees. One type or many styles of erosion can be involved, and the landforms produced and destroyed depend to a massive extent on the climate, geographic situation, and geologic structure of the landmass.

The cycle of erosion through fluvial approaches (running waters or rivers) is referred to as ordinary cycle of erosion due to the truth that fluvial methods are maximum substantial (covering maximum elements of the globe) and maximum extensive geomorphic agent. Even water additionally performs essential roles in glacial, and arid areas. W.M. Davis taken into consideration humid temperate regions as the most regular case for fluvial cycle of abrasion however, this claim is arguable.

The everyday cycle of erosion starts off evolved with the upliftment of any landmass close to sea level. Because the land rises, the rivers are originated

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and their erosional work starts off evolved. The price of uplift inside the starting a ways exceeds the rate of abrasion with the result absolute remedy (absolute altitude from sea stage) and relative remedy sign up boom.

After a while upliftment of the land stops and erosion becomes greater lively. The land vicinity, technically, remains solid i.e. there may be crustal stability for lengthy time period for the duration of which there may be neither upliftment nor subsidence of land place.

There may be modern improvement of river valleys in sequential order and the whole land region gradually passes through 3 successive degrees of young people, mature and antique (senile or penultimate) and is in the long run transformed into low featureless undeniable of undulating floor.

For that reason, the penultimate cease manufactured from regular cycle of erosion is known as peneplain which is characterized by using undulating surface with residual convexo-concave low hills referred to as ‘monanocks’, ‘unakas’ and ‘mosores’.

Hence, the land region has to skip through the successive levels of its improvement proper from the upliftment of landmass to its transformation into peneplain of extraordinarily low reliefs. W.M. Davis has divided the entire period of everyday cycle of abrasion into 3 successive degrees of children (juvenile), mature (equilibrium) and antique (penultimate or senile) and every degree has been similarly divided into three sub-degrees e.g. early, center and overdue (as an instance, early teens, middle youngsters and past due youth and so on).

As a consequence, the landscapes additionally come to be young, mature and antique with the advancement of regular cycle of erosion. Like landscape development through three successive stages, the improvement of river valleys additionally passes through three successive stages in their development and the rivers grow to be young or youthful rivers, mature rivers and antique rivers.

W.M. Davis was an American geographer. He gave the cycle of erosion in 1899 based on the erosion pattern of American mountainous Valleys.

As per Davis, in the beginning, there was a flat surface and due to endogenic force sudden landmass uplifted then the process of landform development started.

During landform development, uplifted landmass undergo in sequence order changes over time from young, mature, to old stages. At the old stage, **end product development is peneplain.** The development of Peneplain will be the same under uniform climatic conditions. Landform development is in the form of “slope decline”.

Trio of Davis

- Structure of landmass means rock types such as hard rock and soft rocks and features of landmass such as fault, join, fracture, etc.
- Process means the agent of erosion and weathering involved in landmasses such as water, wind, ice, etc.

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- Davis's model is based on sequential development over time passing from Youth, Mature, and Old stages.

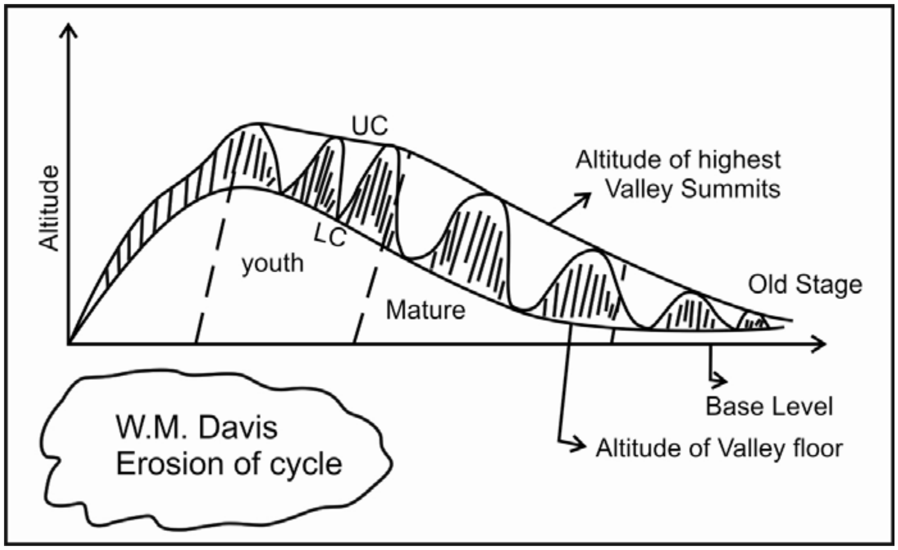

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Fig. 4.7: Davis Cycle of Erosion

The Following are the Characteristics of Stages

Young Stage

- Vertical disintegration of the valley and highest point doesn't dissolve in this stage. The hole between the culmination and valley increments. Steep slant arose at the adolescent stage.
- In this stage, steep waterway valley or "V" molded valley framed because of vertical disintegration, for instance, valleys in the Himalayan stream.

Mature Stage

- Lateral disintegration of the valley is more noteworthy than vertical disintegration at this stage.
- The Summit of the valley disintegrates more as contrast with the base disintegration of Valleys.
- Gentler slant arose.
- In this stage, the "V" molded valley gets changed over to a "U" formed valley.
- U formed valleys are found in southern Indian.

Old Stage

- Vertical disintegration halted because of valley base become base level.
- Open Valley, Meanders, and flood fields are models in this stage.
- Formation of peneplain (base level plain, no further disintegration) happens.

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Check Your Progress

19. __________, __________ and __________ are 'Trio of Davis'.
20. William M. Davis put forth the theory that landforms change through time from __________ each stage having specific characteristics.

4.10 CRITICISM OF DAVIS EROSION CYCLE

Overemphasizing the time: Davis generally disregarded the significance of structure and cycle which are significant factors of landform advancement:

- The beginning stage, abrupt upliftment, and disintegration start solely after fruition of upliftment are not commonsense.
- Davis ignored the role of testimony and enduring in landform advancement and overemphasized the disintegration factor.
- As per Davis, the erosional cycle gets finished after the old stage and peneplains arrangement, however, landform improvement is a ceaseless interaction.
- Ignored the role of environment in landform advancement.

Check Your Progress

21. Davisian model envisages __________ of landform development.
22. Davis' concept of relationship between __________ and __________ is erroneous.

4.11 PENCK'S MODEL OF THE CYCLE OF EROSION

It very well might be brought up that German researcher Walther Penck argued for the dismissal of Davisian model of geological cycle dependent on time-subordinate arrangement of landform improvement and introduced his own model of 'morphological framework' or 'morphological examination' for the clarification of scene creation.

The principal objective of Penck's model of morphological framework was to discover the method of improvement and reasons for crustal development based on exogenetic measures and morphological qualities. The reference arrangement of Penck's model is that the characteristics of landforms of a given area are identified with the structural movement of that district.

The landforms, along these lines, mirror the proportion between the power of endogenetic cycles (i.e., pace of upliftment) and the extent of uprooting of materials by exogenetic measures (the pace of disintegration and expulsion of materials).

Penck is maybe the most misconstrued geomorphologist of the world. It's anything but yet sure if he utilized the word 'cycle' in his model of landform advancement.

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Penck's views could not be known in true sense and could not be interpreted in right perspective because of:

(i) His incomplete work due to his untimely death,
(ii) His obscure composition in difficult German language,
(iii) Ill-defined terminology,
(iv) Misleading review by W.M. Davis, and
(v) Some contradictory ideas.

As per Penck landform advancement ought to be deciphered through proportions between diastrophic measures (endogenetic, or pace of inspire) and erosional measures (exogenetic, or pace of vertical cut).

Penck should have intentionally kept away from the utilization of stage idea in his model of scene improvement either to sabotage the cyclic idea of W.M. Davis or to introduce another model. As indicated by O.D. Von Engeln (1960) "Penck discovered getaway from the idea of cyclic change set apart by the stages youth, development and advanced age." In the spot of 'stage' he utilized the term entwickelung meaning accordingly improvement.

Consequently, in the spot of youth, development and old stages he utilized the terms aufsteigende entwickelung (waxing or sped up pace of improvement), gleichformige entwickelung (uniform pace of advancement) and absteigende entwickelung (wanning or decelerating pace of advancement).

Penck utilized the term primarumpf to address the trademark scene before upliftment. Primarumpf is, indeed, beginning surface or essential peneplain addressing either recently arose surface from underneath ocean level or a fastenbene or 'peneplain' kind of land surface changed over into featureless land-mass by inspire.

As per Von Engeln (1942) the "primarumpf is an essential peneplain, one which could, regardless, show shortened beds and structures, but then need never have had a more noteworthy height or a higher alleviation." All in all, primarumpf is the underlying scene with confirmations of disintegration yet with low elevation.

In opposition to the idea of W.M. Davis, 'that scene is an element of design, cycle and time (stage)', Walther Penck proposed that, 'geomorphic structures are a statement of the stage and pace of elevate corresponding to the pace of debasement.

It is expected that connection between the two components, inspire and degradation, is ceaseless. The landforms saw at some random site offer articulation to the connection between the two elements (elevate and corruption) that has been or is as a result, and not to a phase in a reformist grouping'.

The scene improvement (we may say the pattern of disintegration) starts with the upliftment of primarumpf (beginning scene with low stature and help) addressing an underlying featureless expansive land surface. As such, primarumpf is starting geomorphic unit for the start of the improvement of a wide range of landforms. Penck should have accepted changing paces of upliftment of primarumpf for the improvement of landforms.

Before all else the elevate is characterized by incredibly lethargic disturbance of long length and from there on the pace of inspire is sped up and eventually it stops subsequent to going through the intermediate periods of uniform and decelerating paces of up-heaval.

Indeed, "the most structural developments started and finished gradually, and that the basic example of such developments included a lethargic beginning elevate, an accelerated inspire, a deceleration in elevate and, at last, quiescence".

The underlying inspire starts with territorial updoming and the landform advancement goes through the accompanying three stages:

1. Aufsteigende Entwickelung

Aufsteigende entwickelung implies the period of waxing (speeding up) pace of landform development. At first, the land surface increases gradually yet after some time the pace of upliftment is sped up. Because of upliftment and resulting expansion in channel angle, stream speed and dynamic energy and obviously expansion in release (not because of elevate) the waterways keep on corrupting their valleys with accelerated pace of down-cutting (valley developing or cut) however the pace of upliftment far surpasses the pace of valley extending (say debasement of inspired landmass).

Constant dynamic downcutting and valley extending brings about the arrangement of profound and tight V formed valleys. As the pace of inspire (aufsteigende entwickelung) keeps on expanding the V formed valleys are additionally developed and honed. Since valley developing doesn't stay up with the upliftment of landmass the outright stature keeps on expanding.

As such, the heights of separation highest points just as the elevations of valley bottoms keep on expanding as the pace of upliftment far surpasses the pace of vertical disintegration yet the family member or accessible reliefs keep on expanding due to steadily expanding pace of vertical disintegration or valley extending. Accordingly, both greatest elevation (outright range from ocean level) and most extreme alleviation (relative) increment. The slants of valley sides are raised in arrangement.

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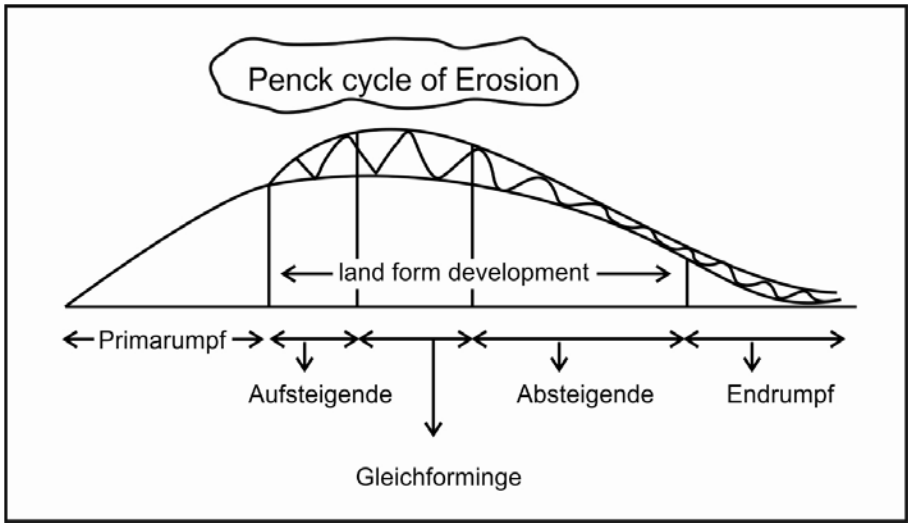

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Fig. 4.8: Graphic Presentation of Penck's Model of Landform Development

The valley side inclines are persistently steepened because of proceeded with valley extending. The range of convexity of inclines is decreased with entry of time because of equal retreat of the more extreme slant sections. With the progression of time and more sped up inspire and corruption the essential peneplain or say primarumpf is encircled by a progression of seats called as piedmont treppen. Every one of such seats creates as a piedmont level, brought in German as piedmontflache on the gradually rising edges of the dome.

2. Gleichformige Entwickelung

Gleichformige entwickelung implies uniform improvement of landforms. This stage might be partitioned into 3 subphases based on pace of inspire and corruption:

Stage (a): Is described by still sped up pace of elevate. Supreme stature actually increments on the grounds that the pace of disintegration is still not exactly the pace of upliftment.

Elevations of the two culminations of water partitions and valley floors keep on expanding however at generally lower rate than in the period of Aufsteigende entwickelung. Greatest elevation (supreme alleviation) is achieved however relative help stays consistent in light of the fact that the pace of valley extending rises to the pace of bringing down of gap highest points. The valley sides are portrayed by straight inclines.

This stage is known as the period of uniform improvement likely due to uniform pace of valley extending and bringing down of gap highest points.

Stage (b): Altitude (total help) neither increments nor diminishes for example stays consistent due to coordinating of upliftment by the bringing of gap highest point due down to denudation. It implies that upliftment actually proceeds.

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Relative alleviation likewise stays consistent on the grounds that the pace of disintegration of gap highest points matches with the pace of valley extending while both are uplifted consistently. The slants of valley sides are still straight as in stage 2a due to resemble retreat. This stage is, accordingly, portrayed by consistent total and relative reliefs and hence, uniform advancement of landforms.

Stage (c): Upliftment of the land stops totally. Total reliefs or elevations of culmination isolates begin diminishing on account of nonattendance of upliftment however proceeded with disintegration of highest points of partitions. Relative reliefs additionally stay steady in light of the fact that the pace of the bringing down of separation culminations rises to the pace of valley developing. Along these lines, this subphase is additionally portrayed by uniform improvement of scene.

3. Absteigende Entwickelung

Absteigende entwickelung implies wanning advancement of scene during which the scene is dynamically overwhelmed by the erosional cycle of sidelong disintegration and resulting valley broadening and stamped decline in the pace of valley developing through vertical downcutting.

This stage is set apart by progressive decay of landforms. Supreme alleviation (height from ocean level) diminishes strikingly on account of absolute shortfall of upliftment however kept downwasting of gap highest points. Relative alleviation additionally diminishes on the grounds that the gap culminations are persistently dissolved down and brought down in stature while downcutting of valley floor diminishes amazingly because of reduction in channel gradient and active energy. Equal retreat of valley side slants actually proceeds.

Presently the valley side incline consists of two portions. The highest fragment maintains its precarious point inspite of consistent bringing down of edge peaks. This incline is called gravity slant or boschungen. The lower fragment of the valley sides is called wash incline or haldenhang. Haldenhang, composed of bone materials of lower tendency, is framed at the foundation of the valley sides because of fast equal retreat of gravity slant or boschungen and ensuing disposal of a significant part of the raised waxing inclines.

Separation highest points are constantly brought down by the inter-section of the withdrawing boschungen of connecting valleys. Accordingly, the crossing point of boschungen and haldenhang delivers sharp knick (break in incline). Haldenhang or wash incline keeps on growing at the expense of upper gravity slants. In the high level phase of the period of absteigende entwickelung the gravity slants or boschungen are decreased to soak sided coni-cal residuals called inselbergs.

In the long run, inselbergs are additionally devoured and the entire scene is overwhelmed by a progression of inward wash slants or haldenhang. Such broad surface delivered toward the finish of absteigende entwickelung is called 'endrumpf', which might be viewed as comparable to Davis' peneplain.

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Check Your Progress

23. Penck described landform development depends on the ratio of _________.
24. Gleichformige Entwickelung is called As the phase of _________.

4.12 EVALUATION OF PENCK'S MODEL

The Penck's model of scene advancement, as brought up before all else, couldn't be effectively interpretted due to its distribution in dark German language and wrong understanding of his thoughts by English interpreters. Penck's morphological framework was seriously reprimanded in the USA similarly as the 'topographical cycle' was condemned in Germany.

Penck's ideas of equal retreat of incline and proceeded with crustal developments turned into the most delicate places of assaults by American geologists. It could be brought up that prior interpretation of Penck's work in English uncovered that Penck had faith in equal retreat of slants yet resulting English interpretations showed that Penck trusted in slant substitution wherein every upper incline unit of hillslope and valley sides was viewed as supplanted by lower slant unit of gentler slant.

It very well might be, hence, sent that a large portion of the reactions of Penck's morphological framework emerged from the broken understandings of his perspectives. A portion of the American pundits lowered down so much that they commented that "his particular ideas owed to his deficient recuperation from a head twisted endured in World War I". His idea of since quite a while ago proceeded with upliftment and structural hypotheses couldn't discover any help however his concepts of incline advancement and enduring cycles are certainly of much geomorphological importance.

Check Your Progress

25. Absteigende Entwickelung is also known as the __________.
26. Penck was criticized for his concept of __________.

4.13 DIFFERENCE BETWEEN CYCLE OF EROSION AS PROPOUNDED BY DAVIS AND PENCK

Pattern of disintegration as propounded by Davis and penck contrasted at following fronts:

1. Uplifting of landmass: For Davis it was unexpected upliftment followed by extensive stretch of crustal solidness while for penck it was slow upliftment.

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2. Davis proposed landform development as a component of construction cycle and stage (outing of Davis) while for penck landform was resultant of contest among endogenic and exogenic powers. It very well may be said that Davis restricted his thought upto exogenetic powers and nearly disregarded endogenetic powers while penck gave equivalent consideration to both the powers.
3. Davis restricted his thought upto the muggy and subhumid regions (clear from his fluvial pattern of disintegration later stretched out to different areas) while penck unique thought of pattern of disintegration was appropriate to bone-dry semiarid and tropical locales too.
4. Penck's pattern of disintegration contained the thought with respect to slant substitution while Davis didn't sponsored his hypothesis by a substantial incline improvement thought.

Applied Geomorphology

There has been an expanding acknowledgment of the reasonable utilization of geomorphic standards and the discoveries of geomorphological examination to people who are affected by and, thus, impact the surface highlights of the earth. Consistent expansion in populace has prompted tension ashore assets, augmentation of horticulture to uneven and minor terrains brought about man actuated catastrophies like soil disintegration, avalanches, sedimentation and floods. A legitimate translation of landforms illuminates the geologic history, construction, and lithology of a locale.

As geography turns out to be more particular there is developing chance that the use of geomorphology to issues of applied topography will be neglected. The part of applied geomorphology relates predominantly to the issues of dissecting and observing scene shaping cycles that may emerge from human impedance. Individuals have over the long haul attempted to tame and adjust geomorphic/natural cycles to suit their financial requirements. Geomorphology has different application over an enormous space of human action while Geomorphologist may serve all the more viably the need of society.

A portion of the utilizations of geomorphic standards have been utilized in applied geomorphology yet there are different fields where geomorphic information on territory is more significant. Soils guides somewhat are geological guides and distinction in soil arrangement essentially rest upon geographical conditions under which each segment of soil arrangement created. Soil disintegration related issue is basically an issue including acknowledgment and legitimate control of such geomorphic measures like sheet wash disintegration, gulleying, masssquandering, and stream disintegration. The point of slant is definitely not a solitary factor decided the seriousness of disintegration.

With the presentation of air photos and satellite symbolisms readiness of particular guides and deciphering them has gotten simpler and more precise. Presently a days, flying photos are being utilized for assessing landforms and

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land use for city formative plans, development projects, parkway and so on Another device for example far off detecting is important for feasible administration of normal assets like soil, timberland, crops, seas, metropolitan and town arranging and so forth At present Geographical Information Systems (GIS) innovation has been utilized alongside Remote Sensing procedures in geomorphic highlights translation. All fields talked about in this section ought to be adequate to show a comprehension of geomorphic head, other than the geomorphic history of a specific area, geomorphic highlights may contribute in applied topography to the arrangements of issues. To control the unfriendly impacts of human exercises on geomorphic structures and cycles, utilization of geomorphology can be of gigantic use.

There was an increasing recognition of the practical utility of geomorphic ideas and the findings of geomorphological research to human beings who are inspired with the aid of and, in turn, impact the surface features of the earth. continuous boom in populace has brought about strain on land assets, extension of agriculture to hilly and marginal lands led to man precipitated catastrophies like soil erosion, landslides, sedimentation and floods. A proper interpretation of landforms throws mild upon the geologic history, structure, and lithology of a place. As geology becomes more specialized there's growing opportunity that the utility of geomorphology to issues of applied geology might be neglected. The function of carried out geomorphology relates specifically to the troubles of analyzing and tracking landscape forming techniques which could get up from human interference. human beings have through the years attempted to tame and adjust geomorphic/environmental procedures to match their economic needs. Geomorphology has diverse utility over a large vicinity of human activity at the same time as Geomorphologist might also serve greater correctly the need of society.

Geomorphology and Hydrology

Water both on the floor of the earth or groundwater utilized by human is to be had from different assets like streams, lakes and rivers. The lithological zones gift unique situations of surface as well as groundwater. Hydrology of limestone terrains comprehensive knowhow of geomorphology is fundamental to recognize the hydrological problem of the limestone terrain. Limestone location yield greater water than different because of its rock formation. Availability of water in limestone location depends on the type of rock. On the basis Permeability limestone rocks may be primary or secondary. Calcareous sediments determine the formation of rock and its number one permeability at the same time as earth movements in the shape of tension and compression which includes faulting, folding, warping, and due to solution or corrosion mechanism determine the secondary permeability. Joints and fractures produced via diagenetic and diastrophic approaches formed the secondary or acquired permeability which resulted into answer. The cavities of the solution in limestone vicinity depends on whether it's been situated in the past or allow joints and bedding planes to be actively more enlarged.

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In Florida (U.S.), those answer cavities are not unusual at vast depth within the Tertiary limestones. The importance of solutional starting with multiplied permeability is important in current topography but also in karst landscape too. Geomorphology performs an crucial to acquired water in limestone area. it is able to be clean or tough to attain water from wells in a limestone terrain. There may not be issue in acquiring wells of large yields if the limestones have sufficient permeability and are capped with sandstone layer. In such case the yield of water can be low or insufficient, but challenge to contamination. Karst plains lacks filtering cowl, and any swallow holes, sinkholes, or karst valleys inside a place of clastic rocks need to solid doubt upon the purity of the water of springs. Glaciated regions and groundwater Preglacial and glacial time history, sorts of deposits and landforms decide the opportunities of massive components of groundwater potentials in glaciated regions. Yield of huge quantity of water received from Outwash plains, valley trains, and intertill gravels or buried outwash. due to clay content most of the aquifers are negative, but containing neighborhood strata of sand and gravel may additionally maintain and deliver enough water for home needs. The observe of preglacial topography and geomorphic records of the vicinity ought to discover the presence and absence of underground water.

Geomorphology and Mineral Exploration

There's a near affiliation of geological shape and minerals deposits. feature of landscapes of unique regions could imply those geological systems. Monetary geologist has no longer preferred the exploration of a few minerals in the call of knowledge of the geomorphic functions and records of a region. In search for mineral deposits, those 3 factors can also serve for Geomorphic capabilities as:

1. Some mineral have direct topographic expression for its deposits;
2. The geologic shape and topography of an area have correlation which clue the buildup of minerals;
3. Geomorphic records in reality suggests the bodily situation underneath which the minerals accrued or have been enriched of a particular area.

Surface expression of ore our bodies a number of ore our bodies have surface expression, but many do as topographic paperwork, as outcrops of ore, gossan, or residual minerals, or as such structural capabilities as faults, fractures, and breccia zones. It is not important that all ore outcrops are meditated in high quality topographic forms. The lead-zinc lode can be marked by a conspicuous ridge within the case of damaged Hill, Australia. Quartz veins could stand out prominently as they are a great deal extra proof against erosion than the unsilicified rocks, as in Chihuahua, Mexico. a few veins and mineralized areas may additionally lack conspicuous topographic expression or it is able to be meditated by way of subsidence features or depressions. Even though no generalization may be made approximately the exact form of topography necessary for the iron ore accumulation, awesome topographic expression is wanted for a selected deposit. Residual iron deposits are the results of awareness of iron due to long intervals of weathering, and as a consequence for their accumulation, old erosion and weathering surfaces are favoruable websites.

Epigenetic Minerals and Unconformities

Historical erosion surfaces are related to severa deposits of Epigenetic minerals. turbines and Eyrich (1966) emphasised the position performed by using unconformities within the localization of mineral deposits. The mineral deposits discovered from the ranging age of Precambrian to Tertiary, shown evidences of near affiliation with unconformities in districts people and Canada, such minerals are uranium, vanadium, copper, barite, fluorite, lead, nickel, and manganese. There's regular paintings of weathering and erosion at the rocks of earth's surface and this weathering work has reasonable price of rock product.

Placer Deposits

Placer deposits are combos of heavy metals with specific place, geomorphic concepts have been implemented aside from every other segment of financial geology. Geomorphic processes are the principal cause of placer concentration of minerals, determined in precise positions with extraordinary topographic expression. The deposition of placers suffering from the type of rock forming the bedrock floor. There are as many as nine forms of placer deposits. They're residual or 'seam diggings', colluvial, eolian, bajada, seaside, glacial which include the ones in cease moraines and valley trains, and buried and ancient placers. The most important among them is alluvial placers.

The opposite call of Residual placers is 'seam diggings' which are residues from the weathering of quartz stringers or veins, are commonly of partial amount, and grade down into lodes. Creep down slope is the primary cause for the manufacturing of colluvial placers and are as a consequence transitional among residual placers and alluvial placers.

Oil Exploration

Numerous oil fields had been observed due to their putting topographic expression. Those oil fields are characterized by anticlinal systems which strikingly meditated inside the topography. When regarded from aerial pics, some of the Gulf Coast salt dome structures are evident in the topography. For the scholar of geomorphology, it is reasonably appropriate running principle to suspect that regions that are topographically high can also be structurally excessive, in which possibilities of topographical inversion on the crest of a structural high may end result with weak beds.

In areas of heavy tropical wooded area, topography cannot be visible thru the intense woodland cowl, an anticlinal or domal structure may define due to the tonal variations in the vegetation. In search for oil, more subtle proof of geologic structures beneficial to grease accumulation is being made. Aerial pictures is one such method through which drainage analysis of a terrain can be shown. Drainage evaluation is useful specifically in regions where rocks have low dips and the topographic alleviation is slight. Permeability may be either number one or secondary in carbonate rocks. Wide variety of large oil yields from limestone has been obtained from rocks that have a excessive diploma of permeability produced by way of answer.

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Geomorphology and Engineering Works

Evaluation of geologic elements of one type or another regularly involve in most of the engineering initiatives, amongst all of the factors terrain traits is maximum not unusual. A detailed observe of the geomorphic history of an area may aid the proper evaluation of surfacial substances and the bedrock profile configuration.

Geomorphology and Navy Geology

Allied powers for the duration of world warfare have been slow to make the most use of geology in war. Geologist were utilized however to a constrained volume in World War I. Earlier than army government saw the desires for and opportunities of the use of geologic professionals, the war become nicely-superior. For the duration of wars the data that was beneficial changed into more geologic than geomorphic in nature. The information regarding digging trenches, mining, counter-mining, and water deliver or other material was not utilized. Topography became more crucial throughout World War II with the improvement of the blitzkrieg sort of war, due to the fact effectiveness of a blitz depends to a huge quantity upon the trafficability of the terrain. In latest years terrain appreciation or terrain evaluation have grow to be extra essential with navy.

For a terrain if geological maps fail someplace, geological fundamental can be carried out with benefit to decoding the terrain from aerial pictures. Little schooling required to apprehend features like mountains, hills, lakes, rivers, woods, plains or a few forms of swamps. it is crucial to know the sort of hill, simple, river or lake, and so on, due to the fact with the aid of knowing this it is quite possible to reconstruct the geology of that location. Aerial photographs are useful for the guidance of terrain intelligence as they provide facts on the geology of the location. Terrain had been an essential element in the Korean battle and within the combating in Vietnam region. With the improvement of atomic bomb and ballistic missiles, topography could now not play an important position in wars, however, its confine to the neighborhood regions for war purpose.

Geomorphology and Nearby Planning

Geomorphologic information may be utilized at numerous stages of making plans. Combination of topographic facts, soils, hydrology, lithology, terrain characteristics and engineering covered on terrain maps make suitable for regional making plans. applied geomorphology has distinct region in regional planning. At broadest scale it could be used as delineate regions for forest, mountain, plateau, leisure, rural and urban regions. A balanced increase of a rustic's economic system calls for a careful expertise of its herbal resources and human sources. Rural or underdeveloped terrain fulfills a selection of recreational wishes. There's a metamorphosis from a terrain maps into land-use suitability maps to increase rural and urban areas. specified facts on topography

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enlightened regional planners who may additionally then advise development initiatives excellent desirable for separate vicinity.

Geomorphology and Urbanisation

There is a separate department called urban geomorphology carried out to city development. In step with R.U. Cooke, this department of geomorphology is involved with "the study of landforms and their associated processes, substances and hazards, approaches which are useful to planning, development and control of urbanized areas where city increase is expected". Geomorphic features determine the steadiness, protection, simple needs and even its expansion. That means city or cities completely relies upon on lithological and topographical capabilities, hydrological conditions and geomorphic functions. City geomorphologist begin even earlier than city improvement through field survey, terrain classification, identity and selection of alternative web sites for settlements regardless of plain or hilly regions. Those urban geomorphologists could be concerned with effect of natural activities on the urban community and that of city improvement at the surroundings.

While geomorphological issues no longer understood by means of the planners and engineers then it leads to destruction and harm to urban settlements in exceptional environmental areas. Settling of basis material in dry or glacial region, weathering method, damages of roads and buildings through floods in many parts of the arena are not a latest phenomenon. those issues rise up because of misunderstanding of the geomorphological conditions. In growing nations attention has no longer been given to the geomorphological situations earlier than the improvement of current city centres. This ends in haphazard growth of town with squatter agreement and shanty cities with urban morphology.

Geomorphology and Coastal Zone Management

Coastal zones aren't in linear as a boundary among land and water alternatively considered as dynamic vicinity of interface of land and water. The foremost hazard to the delicate coastal quarter is its deteriorating coastal environment through coastline erosion, loss of herbal splendor, pollutants and extinction of species coastal sector control calls for an incorporated technique. The most widespread fabric is beach sand, found particularly in low latitudes. seashore sand and gravel is widely used for production industry.

Geomorphologists have made a few large contribution towards an information of coastline equilibrium in eastern Australia wherein it giant development of sand mining for heavy minerals has been performed. Some measures have been designed for coast safety consists of sea-defence structures along with seawalls, breakwaters, jetties and groynes. To shield the ocean backshore region from direct erosion cut, sea walls are designed given that these walls are impermeable they growth the backwash and produce a unfavorable wave impact. Breakwaters may be built either ordinary or parallel to the coast. It's far essential to display and quantify wave conditions, tidal currents and sediment movement in the nearshore quarter to assess how sea defenses and different man-made systems affect coastline equilibrium.

In context of coastal zone management Hails emphasizes that applied geomorphology should be concerned with quantitative and now not descriptive research with a view to acquire relevant and correct facts on: (i) natural erosion and deposition charge (ii) at what charges and quantity the sediment shipping from river catchments to the close to shore quarter; (iii) variations in sediment composition and offshore distribution; (iv) sand supply resources and shoreline equilibrium; (v) interchange rate of sand between beaches and dune systems; (vi) the effects of building sea defences; (vii) offshore sediment dispersal and the dredging effects of seabed morphology, sediment delivery and wave refraction; and (viii) evaluation of landform such as topography of the nearshore zone, shape of the continental shelf and of relict coast traces, mainly in terms of rock outcrops. Above research gives relevant baseline information needed for systematic planning process and monitoring programmes but additionally for land use scheme.

Geomorphology and Hazard Management

Dangers can be installed natural or man-brought on in which tolerable stage or surprising nature exceeds. In line with Chorley, geomorphic hazard may be described as "any change, herbal or man-made, that could have an effect on the geomorphic balance of a landform to the adversity of living matters". These hazards may rise up from immediate and sudden movements like volcanic eruptions, earthquakes, landslides, avalanches, floods, and so on. Faulting, folding, warping, uplifting, subsidence, or plants changes and hydrologic regime because of climatic change rise up from the long time factors. Regions having beyond case histories of volcanism and seismic occasions assist in making predictions of possible eruptions and earthquakes respectively. Everyday monitoring of seismic waves, dimension of temperature of craters lake, hot springs, geysers and modifications inside the configuration of volcanoes whether dormant or extinct can lessen the hazard to a point. A detailed information of topography can expect the course of lava float and its eruptions points earlier.

The behaviour of a river machine can be properly understood by way of its geomorphic know-how through its channel, morphology, float pattern, river metamorphosis and so on. It is able to help controlling excess water in river and control measures during flood season. Previous knowledge of erosion within the top catchment location and sporting sediments to its proportion might also help in apprehend the gradual upward thrust in river bed, which may result in levee breached and motive surprising floods. Earthquakes may be guy triggered or natural geomorphic hazards. particular look at of seismic waves location would assist in figuring out and mapping the zones of high to low depth to lessen the risk of human lifestyles.

Other Programs of Geomorphology

A number of the applications of geomorphic concepts have been used in applied geomorphology but there are other fields where geomorphic understanding of terrain is more crucial. Soils maps to a degree are topographic maps and distinction in soil series basically relaxation upon topographic

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conditions below which each part of soil collection advanced. Soil erosion associated trouble is largely a hassle concerning recognition and right manipulate of such geomorphic methods like sheet wash erosion, gulleying, mass-losing, and circulation erosion. The attitude of slope is not a single component decided the severity of abrasion.

With the advent of air photos and satellite tv for pc imageries training of specialized maps and decoding them has end up easier and greater accurate. Now a days, aerial photos are being used for comparing landforms and land use for metropolis developmental plans, creation tasks, motorway etc. Any other device i.e. far flung sensing is essential for sustainable management of herbal sources like soil, woodland, plants, oceans, city and town planning etc.

At present Geographical Information Systems (GIS) generation has been used along with far flung sensing techniques in geomorphic functions interpretation. All fields discussed in this unit need to be enough to expose an know-how of geomorphic principle, except the geomorphic history of a particular area, geomorphic features may make a contribution in carried out geology to the solutions of issues. To govern the damaging consequences of human sports on geomorphic paperwork and strategies, software of geomorphology may be of immense use.

Check Your Progress

27. What is Primarump?
28. How many phases are there in Gleichformige Entwickelong?

4.14 ANSWERS TO 'CHECK YOUR PROGRESS'

1. Geomorphology
2. Running water
3. Geomorphological agents
4. Deflation
5. Running water, groundwater, glaciers, wind, waves and currents, etc., can be called geomorphic agents.
6. Mass wasting, which is sometimes called mass movement or slope movement, is defined as the large movement of rock, soil and debris downward due to the force of gravity.
7. type and structure of rocks
8. plunge pools
9. V-shaped but deep
10. rapids and waterfalls
11. Entrenched meander
12. canyon

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13. A gorge is a deep channel formed by a river that has eroded the earth's crust over millions of years.
14. An alluvial fan is a triangle-shaped deposit of gravel, sand, and even smaller pieces of sediment, such as silt.
15. Doline
16. Any limestone or dolomitic region showing typical landforms produced by the action of groundwater through the processes of solution and deposition is called Karst topography.
17. Deflation is the removal of fine, loose particles from the surface of rocks.
18. In Surface Crip larger particles (>0.25mm) are hit and pushed along the ground by particles being moved by saltation.
19. structure, process and time
20. "youth" to "maturity" to "old age,"
21. 'time-dependent series'
22. upliftment and erosion
23. upliftment intensity and the rate of erosion
24. Uniform development
25. Wanning development of Landscape.
26. 'parallel retreat' of slopes and continued crustal movement.
27. Primarumpf is a primary peneplain, one which could, in either case, exhibit truncated beds and structures, and yet need never have had a greater altitude or a higher relief.
28. Three

4.15 SUMMARY

The cycles of landform development are dictated by factors like topography, environments, vegetation and base level. In Geomorphology, we study the powers causing pressure and substance activity on earth's surface through geomorphological specialists which are answerable for soil disintegration. Mass Wasting is such an interaction which causes development of rocks because of power of gravity. Rock fall, rock slide, rock torrential slide and debris flow are some such cycles. David upholds unexpected upliftment of rocks while Panck upholds continuous upliftment of rock for soil disintegration.

4.16 KEY TERMS

- **Geomorphology:** Scientific discipline concerned with the description and classification of the Earth's topographic features.
- **Channel wall:** Removal by corrosion, slumping, fall etc.

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- **Interfluve:** Divide area characterized by largely vertical subsurface water and soil movement.
- **Seepage slope:** Gently dipping portion dominated by downward percolation.
- **Convex creep slope:** Upper convex zone characterized by creep and terracette formation.
- **Fall face:** Cliff face characterized by rapid detachment of material or bedrock (weathering limited) exposure.

4.17 SELF-ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. Distinguish between Davis and Penck's view of cycle of erosion.
2. Write a note on Absteigende Entwickelung.
3. Define three stages of David's model.
4. Write a note on Mass Wasting.
5. Which are the various phases of Gleichformige Entwickelung?

Long Answer Questions

1. Discuss the concept of cycle of erosion and bring out clearly the difference between the views of Davis and Penck.
2. Discuss the limitations of the theory of Continental Drift and show how the theory of Plate Tectonics is an improvement over it.
3. Discuss the processes of mechanical and chemical weathering and show their relationship with soil formation.
4. Write the work of Geomorphic Agents.
5. Discuss Mass wasting and write its causes.

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UNIT 5 LANDFORMS AND GEOMORPHOLOGY

Structure

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5.0 INTRODUCTION

Landforms are grouped by characteristics physical attributes like rise, incline, direction, delineation, rock openness, and soil type. Net actual highlights or landforms incorporate instinctive components like embankments, hills, slopes, edges, bluffs, valleys, streams, peninsulars, volcanoes, and various other underlying and size-scaled (for example lakes versus lakes, slopes versus mountains) components including different sorts of inland and maritime waterbodies and sub-surface highlights. Mountains, slopes, levels, and fields are the four significant sorts of landforms. Minor landforms incorporate buttes, gulches, valleys, and bowls. Structural plate development under the Earth can make landforms by pushing up mountains and slopes.

5.1 OBJECTIVES

After going through this unit, you will be able to:

- What landform is and what are its types?
- The factors behind formation of different landforms.
- Subtypes of various types of landforms.
- Application of Geomorphological process.

5.2 FLUVIAL LANDFORM

Fluvial landforms are those that are created by running water, principally waterways. The term fluvial gets from the Latin word fluvius that implies stream. These are the landforms bended out (because of disintegration) or developed (because of affirmation) by running water. Fluvial cycles are related with running water forming such landforms.

Kinds of fluvial landforms are partitioned into two gatherings:

5.2.1 Erosional Landforms

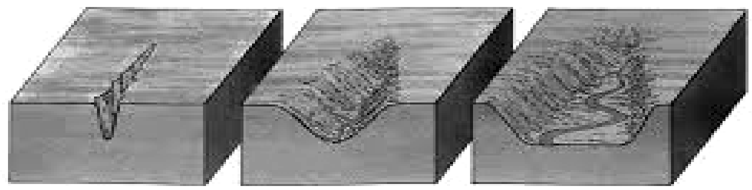
When the rocks or geomaterials are eroded by running water, the subsequent shape they turn into are Erosional landforms. For example:

1. Waterfalls,
2. River Valleys- V-shape valley, gorge, canyon etc.,
3. Terraces,
4. Meander,
5. Ox-bow lake,
6. Peneplain,
7. Gully/Rills,
8. Pot Holes.

V-Shaped Valley

Profound cutting and disintegration by fast progression of the stream cuts out a valley that looks like the English letter V. The V molded valley has a profound and limited base (or valley) floor with steep valley sides. The shape is a result of various different components at exchange. Mass development and enduring of rocks are successful in forming the valley.

How V-shaped valleys are formed?



The river uses its load to cut down into the bedrock causing vertical erosion

Loosened material is washed into the river increasing the load and therefore the ability to erode.

With time the river directs its energy into eroding the valley laterally. The whole process then repeals itself.

Fig. 5.1: V Shaped Valley

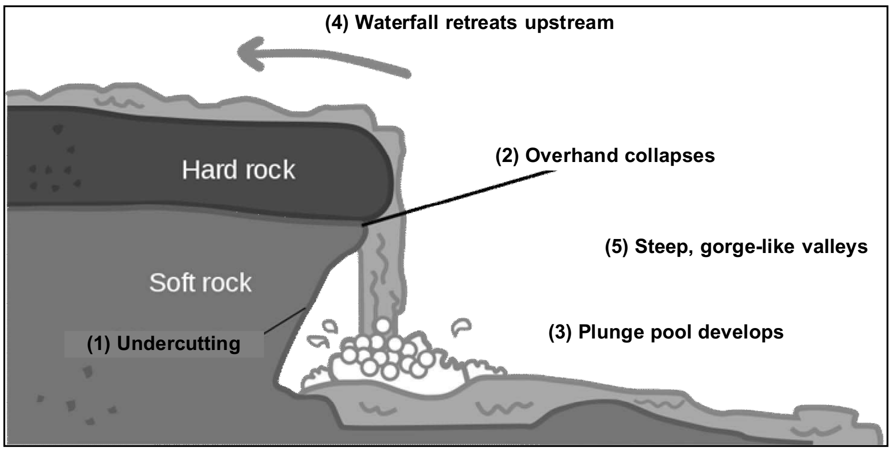
Gorge

Source: commons.wikimedia.org

Fig. 5.2: Gorge

It's anything but a tight abyss with an extremely steep sharp divider. These are regular highlights discovered all the time in rugged locales. The Himalayas are home to various canyons situated at better places in its reaches. The Kali Gandaki Gorge is perhaps the most profound canyon on the planet. River Satluj enters India through an immense crevasse close to Shipkila pass. Brahmaputra likewise travels through different crevasses and enters Indian Territory. Other than the Himalayas, the gorges have their essence across the world in the vast majority of the landmasses.

Waterfalls



Source: commons.wikimedia.org

Fig. 5.3: Formation of Waterfalls

Formation of Waterfalls Due to Structural Variation: Resistant Rock lain horizontally when a hard and safe stone overlies an exceptionally feeble stone, the last wears out rapidly and the safe stone shows profound undermining. The stream bed gets steepened at the guide giving ascent toward cascades of bigger measurement. Niagara Fall is an ideal illustration of this sort of fall where the caprock is a solid dolomite limestone of Silurian age. The tendency of the safe stone decides the nature and size of the cascade. On the off chance that the overlying hard rock dunks downstream it brings about the arrangement of rapids (a cascade of little measurement). At the point when it plunges upstream, it leads to an abrupt divider and a generally bigger cascade.

Vertical falls: Granitic interruptions (or in an upward direction masterminded hard shakes) lying vertical throughout the stream are least influenced by the disintegration when contrasted with the connecting rocks. The differential disintegration emphasizes the improvement of a lofty slant causing a high water fall. Yellowstone waterway fall is an illustration of this kind of fall, here an embankment stands abutting more fragile rocks and Yellowstone River has made a breathtaking fall when it streams over it cutting profound crevasses as it slips. Such falls don't subside upstream in contrast with the falls produce on even shakes on the grounds that there is no undermining of delicate rocks.

Fault and fracture falls: Rivers streaming over blamed stone design lead to such sort of falls. The shortcoming scarps made during blaming cause

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the water to tumble from an upward stature bringing about cascades. The Victoria Falls of river Zambezi is frequently referred to act as an illustration of this sort of fall, on the grounds that the waterway streams over a basaltic level and crosses the unmistakable breaks in the level subsequently leading to waterfalls.

Falls due to Descend from Uplifted Highlands: When a waterway streams from the elevated hard and safe rocks (like volcanic) to the plain region, it brings about cascades. Such sorts of falls are observable in the Appalachian locales where streams have fostered various falls as a result of their plunge into the Atlantic seaside plain. Different instances of waterways sliding from level to the marshes may likewise be remembered for this sort of falls. E.g. the Livingstone falls, Depict the sudden break in the progression of stream. Congo bringing about a thrilling waterfall.

Hanging valley falls: The primary glaciated valley dissolved further than their feeder valleys when they were previously involved by the glacial masses. Post glaciation the icy valleys were involved by water and as the feeders meet the profoundly disintegrated and steep mass of the fundamental frigid valleys they made cascades due to their abrupt drop into the primary valley. There are a ton of cascades present in the Scandinavian area. Yosemite falls in California lies in this classification of cascade. The stream (feeder of the fundamental waterway) shows a fall over the precipice into the Merced River Valley which was recently scoured and developed by the icy mass. This profound valley lies well beneath the valley of its feeder consequently leading to hanging valley fall.

Other than the order of waterfalls based on their method of beginning, there are a various different kinds of cascades, which are grouped based on their size, tallness and stream pace of water.

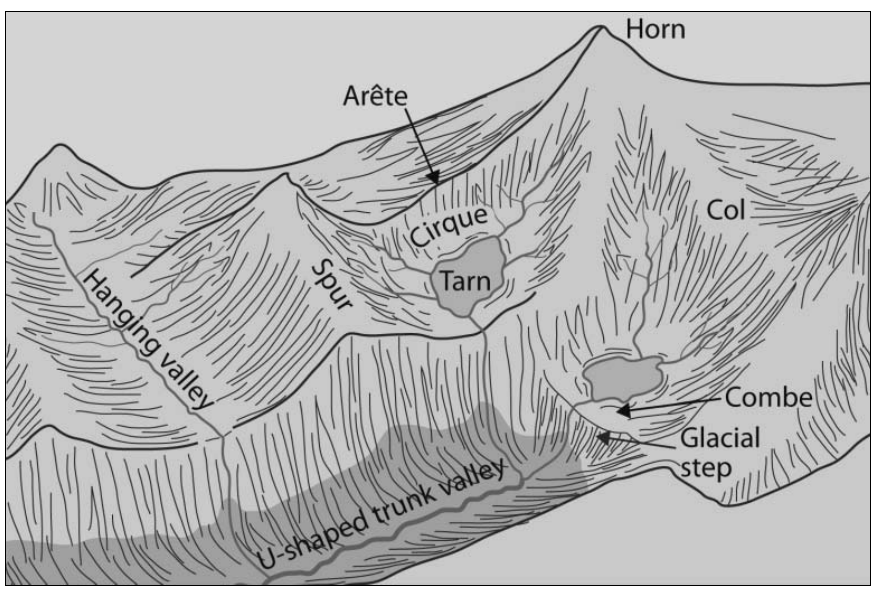

Fig. 5.4: Hanging Valley Falls

Sediment Transportation

The stream is a significant methods for transportation of residue of differing size and shape to far off lands much away from their wellspring of beginning. The dregs are shipped in different manners relying on the size of the material; their organization and volume of water.

Movement in solution: Materials like sulfate, carbonate, and chloride are broken down in water and conveyed till the finish of the stream. Streams streaming in parched and semi bone-dry districts show more material in arrangement.

Movement in suspension: Very fine particles comprising of sand, residue and mud are shipped in gigantic amounts by the streams. These particles are kept in suspension by the stream as the volume of water and its speed doesn't permit particles to settle. They are constantly kept in suspension while voyaging and in this way are conveyed for a genuinely longer distance than the bigger rock or stones which roll along the stream bed.

Development by footing: Large stones and rocks which are heavier for the stream to convey them through suspension or saltation, move by moving along the stream bed. This moving causes scraped spot on the bed and for they are in steady contact with the bed. They arise as one of the major erosive specialists of stream bed.

5.2.2 Depositional Landforms

When the geomaterials are dissolved, the residue are shipped by running water and where they are stored different depositional landforms are framed. For example:

1. Alluvial fans and cones,
2. Natural levees,
3. Delta.

These all landforms are framed through different little interaction and during various stages.

Alluvial Fans

At the point when a stream conveying substantial burden slips from a tight mountain valley onto a plain, it leaves behind its heap as a fan or a cone. This store at the foundation of a mountain happens because of unexpected drop in the speed of the stream which can't convey further a substantial burden on a plain district as it needs slope that previous gave speed to the stream empowering it to convey tremendous burden without hardly lifting a finger. The alluvial fans show a thick store at the mouth of valley and continuously slip in tallness away from it. The size of material store likewise show a progressive decay from huge to little away from the mountain front. The slant of fans differ because of variety in the size of the grains. Where there is bounty of coarse residue there is improvement of fans with more extreme inclines though fans having better dregs have gentler slants. The alluvial fans in contrast

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with cones have a more extensive spread making a circular segment (or fan) fit as a fiddle, while cones are generally less broad in their spread and have a more extreme inclination. These two terms are frequently utilized together to signify the store at the mountain front. In India one can see a fan on stream Kosi at the foundation of the Himalayas. It's anything but a huge and delicately inclining fan with a width of around 140 kilometres.

Source: Wikipedia.com

Fig. 5.5: Alluvial Fan

Movement by saltation: The particles hop and skip when up rushing water comes with a force lifting them from the bed to some distance. They can't be conveyed long as their weight is more and accordingly can't be kept in suspension. This sort of development is called saltation.

Floodplains

Floodplain is a delicately inclining level area lining the stream. It is covered with fine sediment, mud sand and so on brought somewhere near the waterway and stored in the bordering area because of its standard flooding. This ordinary flooding enhances the dirt and makes it a generally excellent prolific land appropriate for development. Waterway streaming across a floodplain may either shape wanders in its course or foster various channels because of affidavit of the residue load on its bed. It likewise brings about bank known as "Normal Levees" running along it's anything but a genuinely significant distance. Every one of the said highlights of floodplains are talked about underneath exhaustively.

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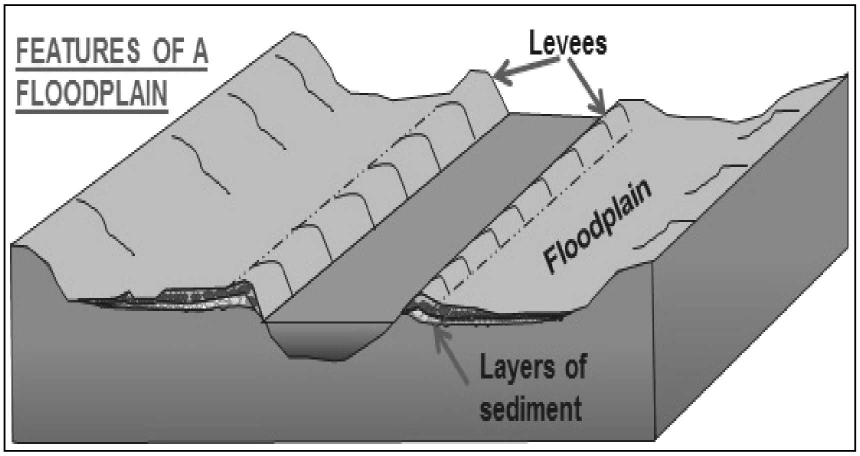
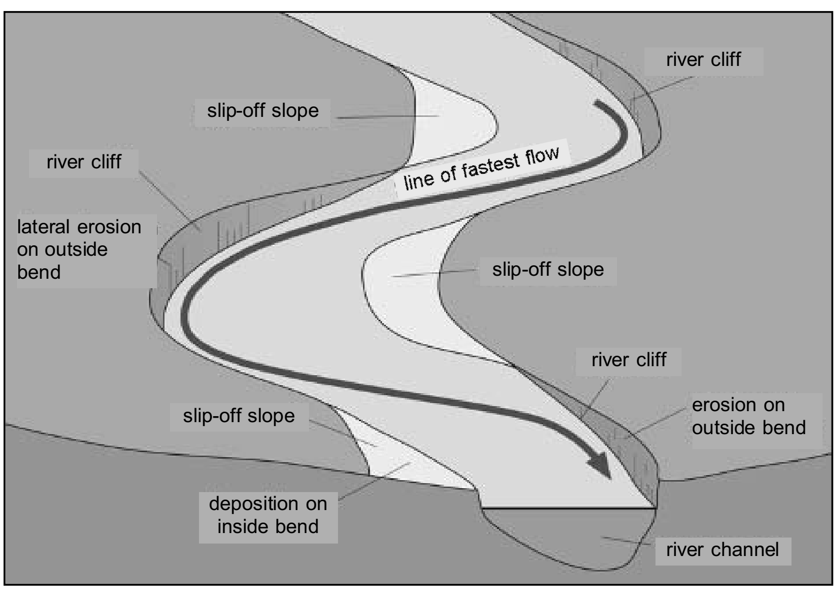


Source: The British Library

Fig. 5.6: Features of a Floodplain

1. Meanders: A stream streaming on a flat or a tenderly inclining surface rarely streams straight; it will in general take a crooked course. While streaming it makes delicate circles in its streams ordinarily alluded to as wander. There is no unanimity on the explanation prompting development of wanders. The water streaming in the stream when strike the banks causes disintegration at the site, which thusly prompts improvement of curve in the channel. The continued striking of water and resultant disintegration highlights the twist and makes it more unmistakable. This unmistakable twist appears as wander. The wander addresses the interaction of disintegration and affirmation going together on its banks. The external side of the twist shows disintegration and alluded to as removed bank while the internal side of the wander where the progression of the water is moderate brings about affidavit at the site of the twist known as point bar.



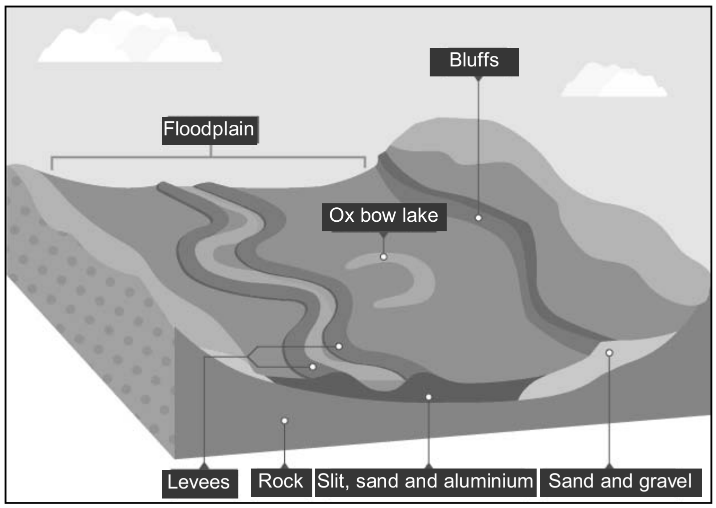
Source: The British Library

Fig. 5.7: Meander

NOTES

These two cycles going on together reason the wanders to move along the side. So wandering additionally prompts the development of floodplain. As has been said the cycle of disintegration and testimony proceeds with it will in general highlight the wander prompting arrangement of a total circle. The stream then, at that point cuts across the wander circles and takes a straighter course. The neglected wander circles structure ox-bow lakes in the flood fields.

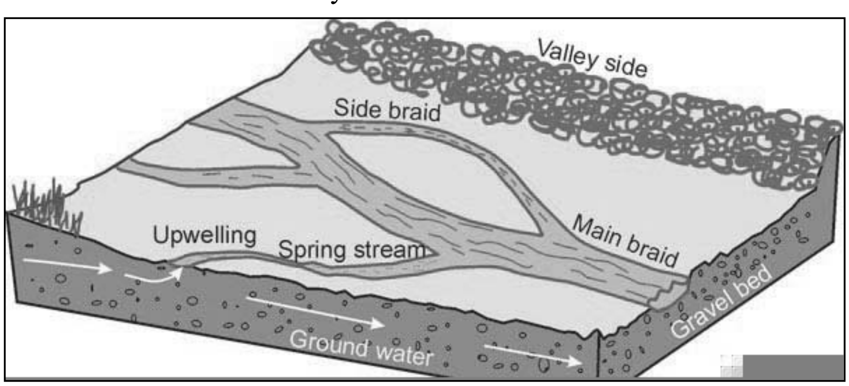
2. Natural Levees: They are banks framed on both the sides of the stream. They owe their starting point to the ordinary flooding of the stream. During floods the waterway spilling over its bank leaves behind a decent measure of material. The material because of normal event solidifies into little banks known as Natural Levees. These Levees in some cases rise high as they develop with each progressive flood.



Source: Encyclopaedia.com

Fig. 5.8: Natural Levees

3. Braided streams: The streams when get over-burden with dregs don't convey them along and leave the overabundance material on the waterway floor as shoals. These stores cause the stream to part into a few channels. The plaited stream is a typical event in the district which are moderately dry and parched and where the inventory of water isn't consistent.



Source: examias.com

Fig. 5.9: Braided Streams

Alluvial Terrace: Alluvial terraces are the locales of previous floodplains which are profoundly disintegrated by the stream because of its revival. Its cycle of development is clarified in the accompanying stages:

(a) A stream is making its valley by disintegration.

(b) The stream with decrease in its inclination will in general store its heap in bordering regions making broad floodplain.

(c) Due to fall in the base level (ocean level) or upliftment of the locale over which the river flows, restoration of stream happens. The revived stream gets effectively associated with downcutting of the floodplain bringing about advancement of porches on both the sides. New patios can likewise be made by additional disintegration on the recently settled floodplain. Accordingly, bringing down of Base Level either because of fall in ocean level or upliftment of the land surface causes the development of alluvial terraces.

Deltas

Deltas are an arcuate or fan molded element at the mouth of the stream framed by standard statement of the residue. The name owes its origin to Greek letter.

The interaction of development of delta starts with the statement of dregs when the waterway enters ocean or lake. First the waterway would shed its coarse silt which are heavier in contrast with the finer light particles. The finer particles are conveyed forward by the distributaries to some distance where they interact with the saline water, get coagulated and settle. Unmistakably delta arrangement follows a progression of steps. The longitudinal cross part of delta shows three depositional units: bottomset bed, foreset bed and topset bed.

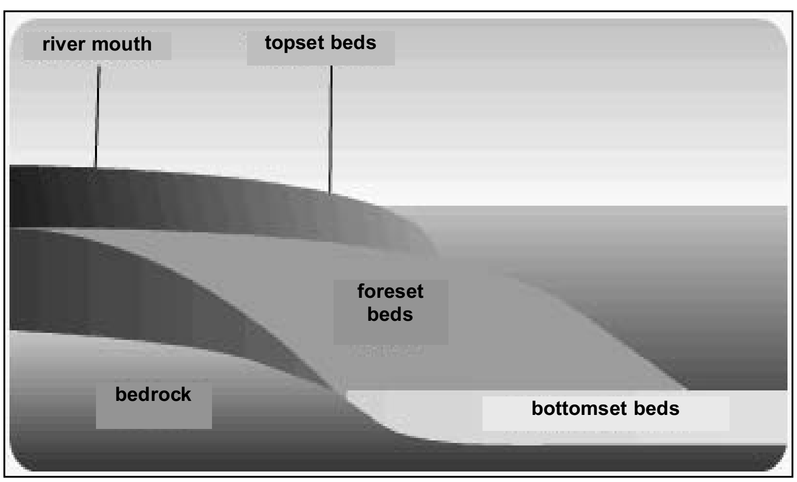


Fig. 5.10: Deltas

(a) Bottomset beds: This is a layer of fine material on the lower part of ocean or lake past the delta.

(b) Foreset beds: They are slanted beds lying between the top set beds and the bottomset beds. They are slanted in light of the fact that the dregs collect close to the delta front bringing about its sliding from the front facing slant of the delta.

NOTES

(c) Top set beds: They lie on the delta surface and as the name propose they lie on the highest point of all the previously mentioned beds.

Conditions for Delta Formation

Delta formation is an outcome of a number of factors operating together with variable rate. Delta formation takes place in those parts of the coast which are relatively protected from high tides and destructive waves. So a comparatively calm sea or lake is a precondition for delta formation. The second important factor at play is the presence of abundant load in the stream which can settle at the mouth of the river. The rate of deposition of bedload should exceed the rate of its destruction. When these two conditions appear favourable delta formation takes place. Delta is not a stable feature and is regularly modified by the waves which often redistribute the deposited material at different places along the coast. Further the fluctuations in the volume of water and the amount of load a river carries also cause modification in the shape and extent of delta. Therefore, there is no consistency in the shape and size of delta across the world, though arcuate delta is very commonly observed.

The shape of the deltas can be classified into: (a) River dominated (b) Wave dominated and (c) Tide dominated (Coleman et. al, 1986; Galloway and Hobday, 1996). Given below are few deltas which have been categorized on the basis of their shape:

(a) Arcuate Delta: These Deltas look like curve of a circle. This is the most widely recognized state of the delta found across the world. The distributaries of the primary waterway spread the heap in huge extent as they show up near the ocean and the stored material mix to give a triangle like appearance. The Nile Delta is an optimal illustration of arcuate delta. It's anything but an illustration of wave submerged delta. It has boundaries that encase a few tidal ponds. Niger delta, Ganga delta, Rhone delta, Indus delta, Po delta are for the most part instances of arcuate delta.

(b) Cuspate Delta: Cuspate delta gives a sharp tooth like appearance. It is framed on a straight shoreline where waves are in an submerging position changing routinely the kept silt by rearranging it along the shoreline. The site of the stream meeting the sea resembles a projection in the water. Tiber River structures cuspate delta at its mouth.

(c) Birdfoot Delta: The delta gets its name from the shape that looks like the hooks of bird. The delta has its feeder channels projecting into the ocean. The fine burden conveyed by the distributaries is saved along them in a direct structure making little levees. These channels seem infiltrating into the ocean in tight finger like shape. The Mississippi stream is an ideal illustration of waterway submerged delta. It's anything but a waterway of North America that structures fantastic bird foot delta when it falls in the Gulf of Mexico. This kind of delta is normally framed when an enormous waterway joins a generally shallow bay or lake.

5.2.3 Arid Landforms/Deserts

Deserts are areas with scanty precipitation, for example precipitation under 25 cm every year yet at the same time, water assumes a pivotal part in the geomorphology of the parched landforms. Nonetheless, the breeze is the submerging specialist of degree in the dry areas of the world.

Arid Landforms

Arid landforms are the described by barren wilderness, Mushroom rocks, rises, yardang, and so on These highlights are normal in a parched locale. In this article, we will examine different kinds of dry landforms, their component of arrangement and so on.

Deserts

- Deserts are areas with less precipitation concentrated to an extremely brief span. Around 20% of the topographical regions on the planet are deserts.
- There is a sure positive example to the area of the world deserts.
- Almost every one of the deserts are limited to the 15 to 30-degrees Latitude on the two sides of the equator.
- Deserts are for the most part situated in the west banks of the landmass as the Tradewinds are seaward.
- They are washed by chilly flows which produce a parching impact so dampness isn't handily consolidated into precipitation.

Type of Deserts

Crafted by wind and water in the disintegration of raised uplands, shipping the dissolved material and keeping them somewhere else has brought about five unmistakable sorts of desert scene.

Rocky Desert

- Rocky deserts are otherwise called Hamada.
- They comprise of enormous stretches of exposed rocks, cleared clear of sand and residue by the breeze.
- The uncovered rocks are altogether smoothed and cleaned.
- The area is exposed and sterile.
- **Example:** The most popular rough deserts are those of the Sahara deserts.

Stony Desert

- It is otherwise called Reg.
- Pebbles and rock structure a broad sheet of the scene of these spaces.
- Stony deserts are more far and wide than sandy deserts, in opposition to the overall thought of deserts related with sandy landforms.
- **Example:** Sturt Stony desert, Australia.

Sandy Deserts

- The regularly acknowledged thought of a desert is the sandy scene with ridges.
- Vast stretches of rises are kept by twists, in these sorts of desert.
- The wind bearing can be seen from the examples of the waves on ridges.
- **Example:** Thar desert in India is a sandy desert.

Badlands

- Badlands are parched areas where the slopes are gravely disintegrated under the activity of water because of infrequent rainstorms or stream of waterway streams.
- They are addressed by crevasses and gorges.
- **Example:** Renowned gorges of Chambal in India, gorges in South Dakota, USA and so on.

Mountain Deserts

- Mountain deserts are found on highlands such as plateaus and mountain ranges.
- Erosion has dissected the desert highlands into harsh, serrated outlines of chaotic peaks and craggy ranges.
- They have steep-sided slopes and sharp and irregular edges carved by the action of frost.
- **Example:** Tibesti Mountains in the Sahara desert.

Check Your Progress

1. What is a Gorge?
2. Define alluvial fan.

5.3 THE MECHANISM OF ARID EROSION

Arid landforms are the consequence of many joined components, one responding upon the other. Low precipitation and high pace of vanishing are the significant reasons for aridity. The desert rocks without vegetation, presented to mechanical and substance enduring cycles because of uncommon diurnal temperature changes, rot quicker and wind and the heavy rains help in eliminating the endured materials without any problem.

5.3.1 Weathering

- This is the most powerful factor of denudation in bone-dry areas.
- Weathering is characterized as the breakdown of rocks by specialists of enduring acting in situ.
- Mechanical enduring and Chemical enduring submerges in the parched landforms.

- Without plentiful water in the dry climate, the compound breakdown of rocks continues incredibly gradually. Be that as it may, the mechanical breakdown of rock continues generally rapidly in the parched environment.
- Drastic diurnal temperature changes in deserts cause pressure in the stones because of ceaseless extension and withdrawal. This pressure helps in accelerating the enduring cycle through shedding of the external stone surface.

5.3.2 Wind Action

- As an erosional specialist, the breeze is more viable in parched areas than muggy areas as in bone-dry locales, there is little dampness and vegetation to tie the free material
- The wind activity makes various fascinating erosional and depositional highlights in the deserts.
- Wind disintegration is completed in desert regions in predominantly three different ways- Deflation, Abrasion and Attrition
- **Deflation:** Deflation incorporates lifting and blowing away of residue and more modest particles from the outside of rocks.
- **Abrasion:** The sand-impacting of a stone surface by winds when they heave sand particles against them is called scraped area. The effect of such shooting brings about rock surface being damaged, cleaned and eroded.
- **Attrition:** When wind-borne particles roll against each other in a crash they wear each other away. This interaction is called weakening.

5.3.3 Water Action

- Many highlights of deserts owe their development to mass squandering and running water as sheet floods.
- Though downpour is scant in deserts, it descends heavily in a brief time frame.
- Stream directs in desert regions are wide, smooth and inconclusive and stream for a short time frame after downpours.
- The desert rocks without vegetation, presented to mechanical and synthetic enduring cycles because of extraordinary diurnal temperature changes, rot quicker
- These endured materials are effectively moved by heavy precipitation.

Check Your Progress

3. The initial stage of arid cycle of erosion is __________.
4. __________ are the characterised by badlands, Mushroom rocks, dunes, yardang, etc.

NOTES

5.4 LANDFORMS OF WIND EROSION

5.4.1 Rock Pedestal or Mushroom Rocks

- Many rock-outcrops in the deserts effectively defenseless to wind emptying and scraped area are exhausted rapidly.
- This prompts eroding of the gentler layer leaving a few remainders of safe rocks.
- Grooves and hollows are cut in the stone surface, cutting them into fabulous and abnormal looking columns called Pedestals.
- Such rock column is additionally disintegrated close to bases.
- This cycle of undermining produces mushroom with a slim tail and a wide and adjusted pear molded cap above.

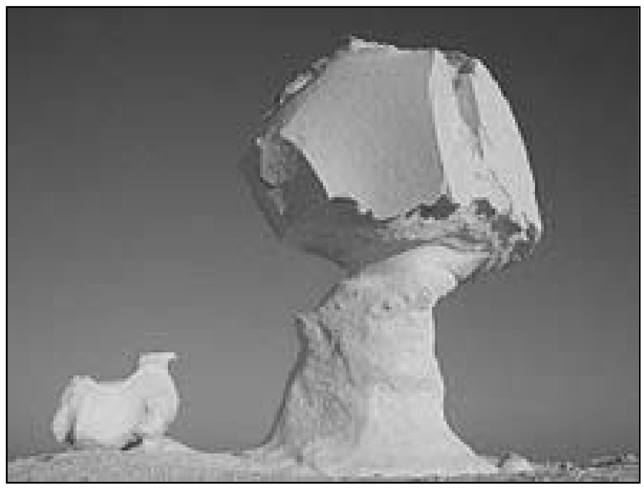


Fig. 5.11: Mushroom Rock

5.4.2 Zeugen

- These are plain masses which have a layer of delicate rocks lying underneath a surface layer of more safe rocks.
- The chiseling impacts of wind scraped area wear them into an unusual looking edge and wrinkle scene.
- Their arrangement is started by opening up of joints of surface rocks by mechanical enduring.
- Deep wrinkles are created by wind scraped area eating into the basic milder layers.
- The hard shakes then, at that point remain over the wrinkles as edges or Zeugen.
- Such plain squares of Zeugen may stand 10 to 100 feet over the indented wrinkles.
- Continuous scraped area by twist continuously brings down the Zeugen and enlarges the wrinkles.

Fig. 5.12: Zeugen

5.4.3 Yardangs

- The word yardang began in the inside deserts of central Asia where they are best evolved.
- Yardangs are a precarious sided unpredictable edge of sand lying toward the overarching wind.
- They look very like the edge and wrinkle image of Zeugen.
- They are framed by the double activity of wind scraped area by residue and sand, and emptying which is the expulsion of free material.
- Wind scraped area uncovers the groups of milder rocks into long, tight halls, isolating the lofty sided, over-balancing edges of hard shakes, called yardangs.
- They are regularly found in the Atacama desert, Chile.

Fig. 5.13: Yardangs

5.4.4 Mesas (Table) and Buttes

- Mesa is a Spanish word meaning table.
- They are level, table-like land masses with a safe even top layer and extremely steep sides.

NOTES

- The hard layer on a superficial level oppose denudation by both breeze and water, and subsequently shields the fundamental layer of rocks from being disintegrated away.
- Continuous denudation through the ages may lessen Mesas in a space so they become secluded level topped slopes called Buttes.

Fig. 5.14: Mesas

5.4.5 Inselberg

- Inselberg is a German word meaning Island-mountains.
- An inselberg is a detached remaining slope rising suddenly from a delicately slanting or basically level encompassing plain.
- They are portrayed by their precarious inclines and rather adjusted tops.
- They are regularly made out of rock or gneiss.
- They are most likely the relics of a unique level which has been predominantly disintegrated away.
- Inselbergs are normal highlights of numerous deserts and semi-parched scenes in advanced age.

Fig. 5.15: Inselberg

5.4.6 Ventifacts

- Ventifacts are rocks faceted by sand impacting.
- They are molded and cleaned by wind scraped area.
- Mechanically endured rock pieces are moved by wind in open settings to impact against the stone developments cutting aspects.
- If wind course changes, another aspect is created.
- Such rocks have trademark level aspects with sharp edges.
- Among the ventifacts, those with the three breeze faceted surfaces are known as Dreikanter.

Fig. 5.16: Ventifacts

Check Your Progress

5. __________ are rocks that have been sculpted by wind-borne particles
6. __________ arise from rocks which erode at a slower rate than that of the surrounding rocks

5.5 LANDFORMS OF WIND DEPOSITION

At the point when the speed of wind diminishes, its conveying limit additionally diminishes. Therefore, the grains of sands begin to settle down, and it prompts the arrangement of depositional landforms in a desert.

Contingent on the size of the particles, speed and heading of the breeze, distinctive depositional landforms can be found in dry and desert regions.

5.5.1 Dunes

- Dunes are slopes of sand framed by the aggregation of sand and molded by the development of winds.
- Dry hot deserts are acceptable spots for sand ridge arrangement.

NOTES

- They may be characterized as dynamic and inert rises - dynamic or live hills are continually on move and idle or fixed rises are established with vegetation.

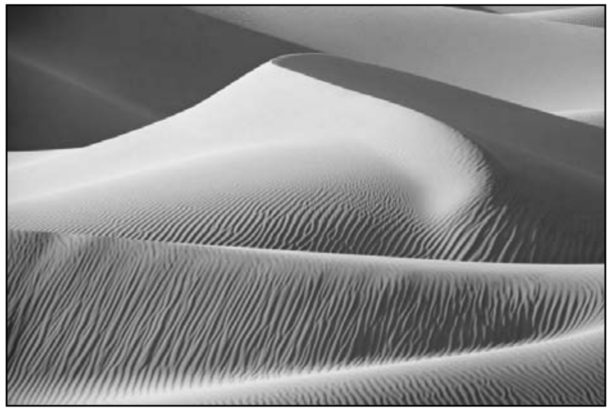
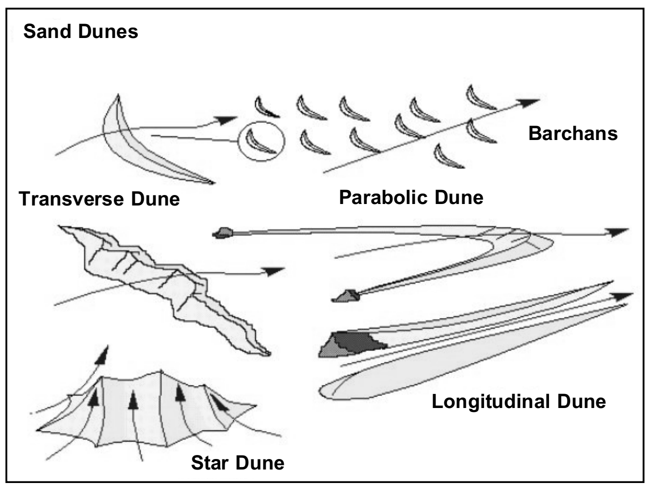


Fig. 5.17: Dunes

Types of Dunes

Due to their extraordinary differentiation fit as a fiddle, size and arrangement, they have been grouped into a few sorts of rises viz head rise, tail ridge, allegorical rise, pyramidal hill, cross over rise, longitudinal rise and so forth. Notwithstanding, there are two most normal sorts of hills - barchans and seif which are depicted as under:



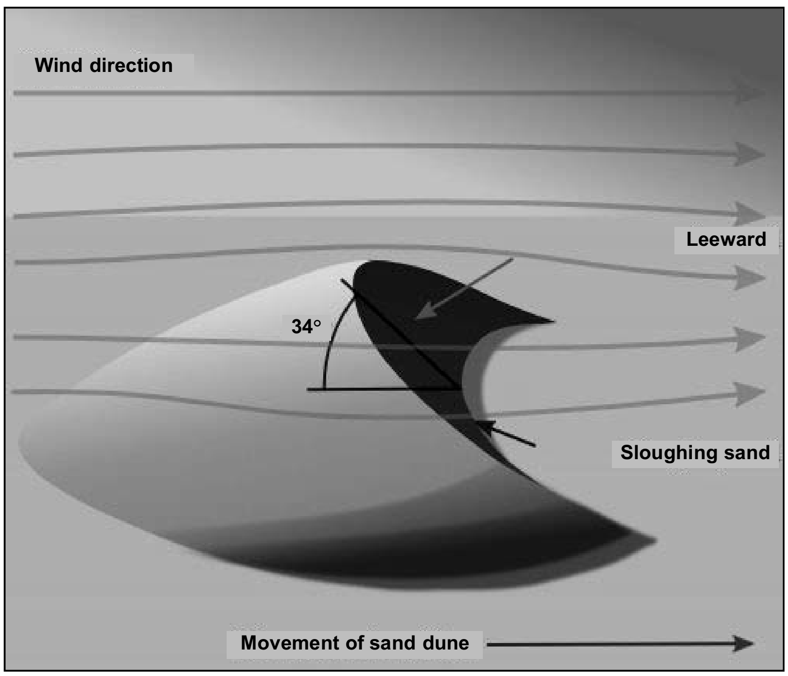
Source: The British Library

Fig. 5.18: Types of Dunes

1. Barchan

- They are moon or Crescent shaped live dunes.
- They may happen exclusively or in gatherings.
- They have their focuses or wings coordinated away from wind course i.e., downwind.
- They start forming likely by a possible collection of sand at a snag, like strands of grass or a stack of rocks.

- They happen dynamically to the breeze.
- Thus, their horns dainty out and become lower toward the breeze.
- The windward side is arched and tenderly slanting while the leeward side is curved and steep.
- The peak of sand rises and pushes ahead as more sand is amassed by the overall breeze.
- The sand is driven up the windward side and on arriving at the peak descends the leeward side so the ridge propels.
- The movement of Barchans might be a danger to abandon life as they may infringe on a desert garden cov*ering palm trees and houses.*
- They are generally predominant in the deserts of Turkestan and in the Sahara.



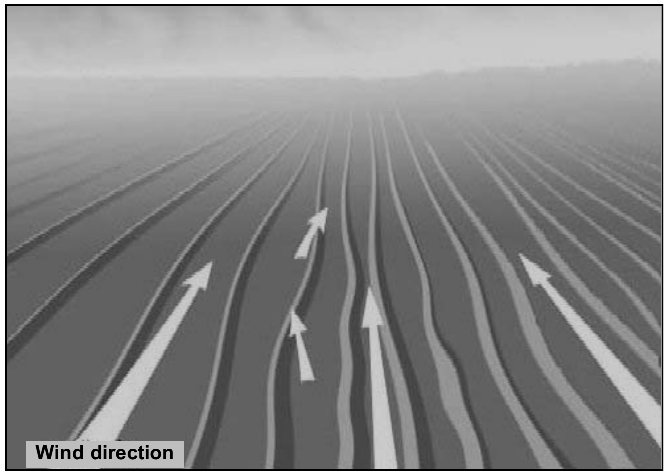
Source: commons.wikimedia.org

Fig. 5.19: Barchan

2. Seif

- Seif is an Arabic word meaning blade.
- They are long, slender edges of sand, frequently over 100 miles in length lying corresponding to the course of the overarching winds.
- Seif is like barchan with a little contrast; it has just one wing.
- Prevailing winds expands the length of the rises into tightening direct edges while periodic crosswinds will in general build their statures and width
- Extensive seif ridges can be found in Sahara desert, West Australian desert, Thar desert and so forth.

NOTES

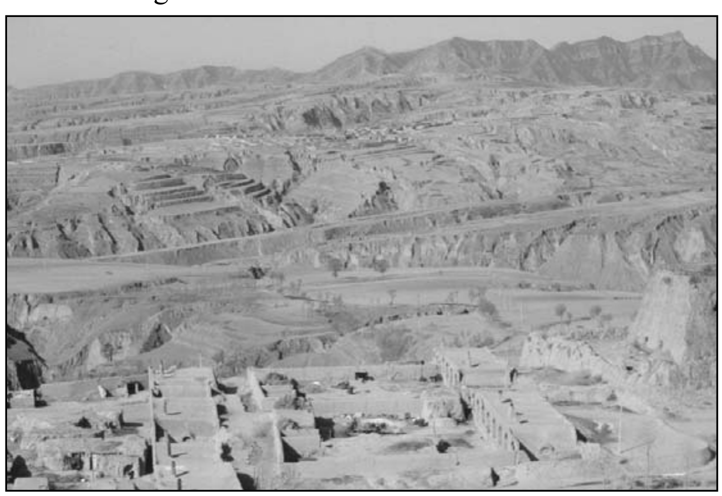


Source: study.com

Fig. 5.20: Seif

3. Loess

- The fine residue blown past as far as possible is saved on adjoining lands as loess.
- It is a yellow, friable (handily disintegrated) material which is normally extremely fruitful.
- Loess is, truth be told, fine topsoil, rich in lime, exceptionally reasonable and incredibly permeable.
- Water soaks in promptly so the surface is consistently dry,
- Streams may slice profound valleys through the thick mantle of delicate loess to create barren wilderness geology.
- The most broad stores are found in north-west China in the loess level of the Hwang-Ho bowl.



Source: commons.wikimedia.org

Fig. 5.21: Loess

NOTES

Check Your Progress

7. __________ are created when wind deposits sand on top of each other until a small mound starts to form.
8. __________ are crescent-shaped sand dunes forming in arid regions with unidirectional wind and limited sand supply.

5.6 LANDFORMS DUE TO WATER ACTION

- Desert regions have inadequate precipitation. Be that as it may, there are deserts without precipitation too.
- However, periodic and abrupt rainfalls in heavy storms may create wrecking impacts because of glimmer floods and so forth.
- Loose materials like rock, sand and fine residue are cleared down the slopes. They cut profound gorges and gorges shaping barren wilderness geography.
- There are such a lot of fine materials in the blaze floods that the stream becomes fluid mud.

1. Bajada

- The Bajada is a depositional highlight made up of alluvial material set somewhere near the irregular streams.
- Bajada is framed by the mixture of alluvial fans.
- These fan-molded stores structure from the testimony of dregs by a stream from upland district onto level land at the foundation of a mountain.
- Bajadas are basic in parched regions where a huge amount of silt is stored by streak floods.
- Bajadas regularly contain playa lakes.

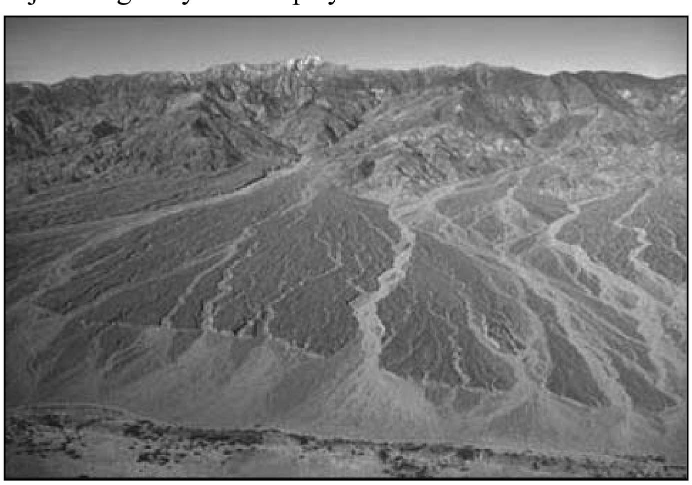


Fig. 5.22: Bajada

NOTES

2. Playa

- In parched regions waste from upland places flow into the lower sorrow, in the midst of adequate water, make shallow water body or an impermanent lake.
- Such sorts of shallow lakes are called as playas where water is held distinctly for brief span because of vanishing.
- Quite frequently the playas contain great statement of salts.
- The playa plain concealed by salts is called antacid pads.

Fig. 5.23: Playa

3. Pediments and Pediplains

- A pediment is an erosional plain formed at the foundation of the encompassing mountain scarps.
- They are delicately disposed rough floors near the mountains at their foot with or without a slight front of garbage.
- They structure through the disintegration of mountain front through a mix of parallel disintegration by streams and sheet flooding.
- Through equal retreat of inclines, the pediments broaden in reverse to the detriment of mountain front.
- Gradually, the mountain gets decreased leaving an inselberg which is a remainder of the mountain.
- That is the manner by which the high help in desert regions is decreased to low featureless fields called pediplains.

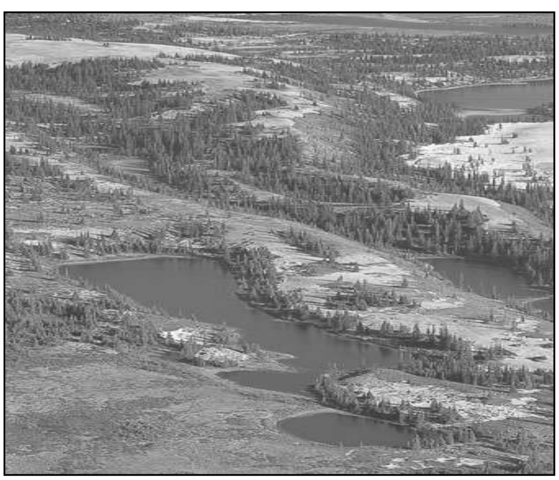
Fig. 5.24: Pediplains

Check Your Progress

9. Define weathering.
10. State types of landforms of wind erosion.

5.7 GLACIAL LANDFORM

Glacial landform, may be a result of streaming ice and meltwater. Such landforms are being created today in glaciated regions, like Greenland, Antarctica, and a significant number of the world's higher mountain ranges. Furthermore, huge extensions of present-day ice sheets have repeated over the span of Earth history. At the limit of the last ice age, which finished around 20,000 to 15,000 years prior, in excess of 30% of the Earth's territory surface was covered by ice. Subsequently, on the off chance that they have not been crushed by other scene changing cycles since that time, frigid landforms may in any case exist in locales that were once glaciated however are presently without icy masses.



Source: Digital Commons

Fig. 5.25: Glacial Landform

NOTES

Eskers, or restricted edges of rock and sand left by a withdrawing ice sheet, wind through western Nunavut, Canada, close to the Thelon River.

Periglacial highlights, which structure autonomously of icy masses, are in any case a result of the very chilly environment that favours the improvement of ice sheets, as are treated here also.

General Considerations

Prior to depicting the diverse landforms created by ice sheets and their meltwater, the icy climate and the cycles liable for the arrangement of such landforms is momentarily examined.

Check Your Progress

11. __________ are landforms created by the action of glaciers.
12. Two processes, __________ and __________, are responsible for the movement of glaciers under the influence of gravity.

5.8 TYPES OF GLACIERS

There are various kinds of ice sheets, however it is adequate here to zero in on two wide classes: mountain, or valley, icy masses and mainland glacial masses, or ice sheets, (counting ice covers).

For the most part, ice sheets are bigger than valley ice sheets. The fundamental distinction between the two classes, nonetheless, is their relationship to the hidden geography. Valley ice sheets are waterways of ice typically found in sloping areas, and their stream designs are constrained by the high help in those spaces. In map see, numerous enormous valley ice sheet frameworks, which have various feeder ice sheets that join to shape a huge "trunk icy mass," look like the foundations of a plant. Pancake-like ice sheets, then again, are consistent over broad regions and totally cover the fundamental scene underneath hundreds or thousands of meters of ice. Inside mainland ice sheets, the stream is coordinated pretty much from the middle outward.

At the outskirts, nonetheless, where ice sheets are a lot more slender, they might be constrained by any considerable help existing nearby. For this situation, their lines might be lobate on a size of a couple of kilometers, with tongue-like bulges called outlet glacial masses. Seen without anyone else, these are almost indistinct from the lower scopes of an enormous valley ice sheet framework. Therefore, a large number of the landforms delivered by valley ice sheets and mainland ice sheets are comparable or practically indistinguishable, however they frequently vary in extent. In any case, each sort of glacial mass produces trademark highlights and along these lines warrants separate conversation.

Glaciers are classifiable in 3 predominant agencies: (1) glaciers that make bigger in non-stop sheets, shifting outward in all guidelines, are referred to as ice sheets if they're the scale of Antarctica or Greenland and ice caps if they're smaller; (2) glaciers limited inside a path that directs the ice motion are known as mountain glaciers; and (three) glaciers that spread out on level floor or on the sea on the foot of glaciated regions are referred to as piedmont glaciers or ice cabinets, respectively. Glaciers in the 1/3 organization are not independent and are handled right here in phrases of their sources: ice shelves with ice sheets, piedmont glaciers with mountain glaciers. A complex of mountain glaciers burying much of a mountain range is known as an ice area.

Distribution of Glaciers

A maximum interesting aspect of recent geological time (a few 30 million years ago to the present) has been the recurrent enlargement and contraction of the arena's ice cover. These glacial fluctuations stimulated geological, climatological, and biological environments and affected the evolution and development of early humans. Almost all of Canada, the northern 0.33 of America, a lot of Europe, all of Scandinavia, and huge parts of northern Siberia had been engulfed with the aid of ice at some stage in the main glacial stages. At times during the Pleistocene Epoch (from 2.6 million to 11,700 years in the past), glacial ice included 30 percent of the world's land vicinity; at different times the ice cover may additionally have contracted to less than its present quantity. It can not be flawed, then, to kingdom that the sector is still in an ice age. Because the term glacial usually implies ice-age occasions or Pleistocene time, on this discussion "glacier" is used as an adjective whenever reference is to ice of the current.

Glacier ice today shops approximately three-fourths of all of the clean water in the international. Glacier ice covers approximately eleven percentage of the arena's land region and could motive a global sea-stage upward push of approximately ninety metres (three hundred feet) if all present ice melted. Glaciers occur in all elements of the arena and at almost all latitudes. In Ecuador, Kenya, Uganda, and Irian Jaya (New Guinea), glaciers even arise at or close to the equator, albeit at high altitudes.

Glaciers and Climate

The purpose of the fluctuation of the sector's glacier cowl is still now not absolutely understood. Periodic modifications inside the warmth received from the solar, due to fluctuations in the Earth's orbit, are known to correlate with major fluctuations of ice sheet improve and retreat on long term scales. Big ice sheets themselves, however, incorporate several "instability mechanisms" that could have contributed to the bigger adjustments in world weather. This kind of mechanisms is due to the very high albedo, or reflectivity of dry snow to sun radiation. No different fabric of good sized distribution in the world even approaches the albedo of snow. Accordingly, as an ice sheet expands, it causes an ever larger share of the sun's radiation to be meditated back into space, much less is absorbed on this planet, and the world's climate turns into cooler. Every other instability mechanism is implied with the aid of the fact that the thicker and extra sizeable an ice sheet is, the greater blizzard it'll obtain in the shape of orographic precipitation (precipitation because of the better altitude of its surface and attendant lower temperature). A third instability mechanism has been advised by way of research of the West Antarctic Ice Sheet. quantities of an ice sheet referred to as ice streams can also periodically move unexpectedly outward, perhaps due to the buildup of a thick layer of wet, deformable fabric below the ice. Although the closing causes of ice a long time are not recognised with reality, scientists agree that the arena's ice cover and climate are in a nation of delicate balance.

Only the largest ice loads without delay influence worldwide weather, however all ice sheets and glaciers reply to changes in local weather—specially modifications in air temperature or precipitation. The fluctuations of those glaciers inside the past can be inferred with the aid of capabilities they have got left on the panorama. Through studying these functions, researchers can infer earlier climatic fluctuations.

Formation and Characteristics of Glacier Ice

Transformation of Snow to Ice

Glacier ice is an mixture of irregularly shaped, interlocking single crystals that range in length from a few millimetres to numerous tens of centimetres. Many strategies are worried within the transformation of snowpacks to glacier ice, and that they proceed at a rate that relies upon on wetness and temperature. Snow crystals inside the surroundings are tiny hexagonal plates, needles, stars, or other complicated shapes. In a deposited snowpack these difficult shapes are usually volatile, and molecules tend to evaporate off the sharp (excessive curvature) factors of crystals and be condensed into hollows in the ice grains. This reasons a standard rounding of the tiny ice grains so that they in shape extra carefully together. In addition, the wind can also wreck off the factors of the tricky crystals and for this reason p.c. them extra tightly. Thus, the density of the snowpack usually increases with time from an initial low price of 50-250 kilograms per cubic metre (3-15 pounds in keeping with cubic foot).

The manner of evaporation and condensation might also hold: touching grains may additionally develop necks of ice that join them (sintering) and that develop at the expense of different parts of the ice grain, or character small grains can also rotate to suit extra tightly collectively. Those methods proceed extra unexpectedly at temperatures near the melting point and extra slowly at colder temperatures, but they all result in a internal densification of the snowpack. On the other hand, if a strong temperature gradient is present, water molecules can also migrate from grain to grain, producing an array of complex crystal shapes (called intensity hoar) of decreased density. If liquid water is present, the cost of change is regularly greater rapid because of the melting of ice from grain extremities with refreezing some place else, the compacting force of surface tension, refreezing after strain melting (law), and the freezing of water between grains.

This densification of the snow proceeds greater slowly after achieving a density of 500-600 kilograms according to cubic metre, and many of the approaches referred to above emerge as less and less powerful. Recrystallization underneath pressure caused by the burden of the overlying snow will become important, and grains trade in size and form so that you can minimize the strain on them. This modification generally method that massive or favourably oriented grains grow on the cost of others. Stresses due to glacier glide may cause further recrystallization. Those procedures thus purpose an growth within the density of the mass and inside the length of the average grain.

Whilst the density of the mixture reaches approximately 830 to 840 kilograms in line with cubic metre, the air areas among grains are sealed off, and the material becomes impermeable to fluids. The time it takes for pores to be closed off is of vital significance for extracting climate-records facts from ice cores. With time and the software of strain, the density rises in addition by the compression of air bubbles, and at remarkable depths the air is absorbed into the ice crystal lattices, and the ice becomes clean. Only not often in mountain glaciers does the density exceed 900 kilograms in line with cubic metre, however at awesome depths in ice sheets the density may additionally approach that of pure ice (917 kilograms per cubic metre at 0°C and atmospheric stress).

Snow that has survived one melting season is known as firn (or névé); its density usually is more than 500 kilograms per cubic metre in temperate areas but can be as little as 300 kilograms per cubic metre in polar areas. The permeability change at a density of approximately 840 kilograms per cubic metre marks the transition from firn to glacier ice. The transformation may additionally take only three or 4 years and much less than 10 metres of burial within the heat and moist surroundings of Washington state in North of the USA, however high on the plateau of Antarctica the equal method takes numerous thousand years and burial to depths of about a hundred and fifty metres.

A glacier may additionally accumulate mass through the refreezing of water that occurs at its base. Previously, water at the bottom of a glacier was believed to function as lubricating layer that assisted the motion of the glacier across the ground, and refrozen water occurred simplest in subglacial lakes. But, scientists have proven that refrozen water may increase the dimensions of the glacier by using adding mass to its base. Similarly, the refreezing manner tends to boost and adjust the top layers of the glacier. This lifting phenomenon has been observed in numerous Antarctic ice fields, inclusive of the substantial Dome A plateau that bureaucracy the top of the East Antarctic ice sheet.

Check Your Progress

13. __________ occur when steep valley glaciers spill into relatively flat plains, where they spread out into bulb-like lobes.
14. __________ miniature ice sheets, covering less than 50,000 square kilometers (19,305 square miles).

5.9 GLACIAL EROSION

Two cycles, inward deformity and basal sliding, are liable for the development of ice sheets affected by gravity. The temperature of icy mass is a basic condition that influences these cycles. Therefore, icy masses are grouped into two primary sorts, calm and polar, as per their temperature system. Mild glacial masses are additionally called isothermal glacial masses, since they exist at the pressing factor dissolving point (the liquefying temperature of ice at a given pressing factor) all through their mass. The ice in polar, or cold glacial masses, conversely, is beneath the pressing factor softening point. A few ice sheets have a moderate warm character. For instance, subpolar icy masses are mild in their inside parts, yet their edges are cold-based. This order is an expansive speculation, nonetheless, in light of the fact that the warm state of an ice sheet may show wide varieties in both existence.

Interior misshapening, or strain, in ice sheet ice is a reaction to shear stresses emerging from the heaviness of the (ice thickness) and the level of incline of the ice sheet surface. Inward twisting happens by development inside and between singular ice gems (moderate drag) and by fragile disappointment (break), which emerges when the mass of ice can't change its shape quickly enough by the wet blanket interaction to take up the anxieties influencing it. The general significance of these two cycles is enormously affected by the temperature of the ice. Hence, breaks because of fragile disappointment under pressure, known as chasms, are generally a lot further in polar ice than they are in mild ice.

A few different cycles of frosty disintegration are by and large included under the terms icy culling or quarrying. This cycle includes the expulsion of bigger parts of rock from the glacial mass bed. Different clarifications for this marvel have been proposed. A portion of the instruments proposed depend on differential anxieties in the stone brought about by ice being compelled to stream around bedrock deterrents. High pressure angles are especially significant, and the resultant elastic anxieties can pull the stone separated along previous joints or break frameworks. These pressing factors have been demonstrated to be adequate to break strong stone, subsequently making it accessible for expulsion by the ice streaming above it.

Different prospects incorporate the compelling separated of rock by the pressing factor of crystallization created underneath the icy mass as water got from the ice refreezes (regelation) or as a result of temperature variances in pits under the icy mass. Still another conceivable system includes water powered pressing factors of streaming water known to be available, in any event for a brief time, under virtually all calm ice sheets. It is difficult to figure out which interaction is predominant in light of the fact that admittance to the foundation of dynamic icy masses is once in a while conceivable. Regardless, agents realize that bigger parts of rock are culled from the icy mass bed and add to the quantity of grating "devices" accessible to the icy mass at its base. Different hotspots for the stone garbage in icy mass ice may incorporate rockfalls from steep inclines lining a glacial mass or unconsolidated dregs superseded as a glacial mass advances.

Check Your Progress

15. Glacial erosion includes the loosening of rock, sediment, or soil by glacial processes, and the entrainment and subsequent transportation of this material by ice or meltwater.
16. A __________ is a persistent body of dense ice that is constantly moving under its own weight.

5.10 GLACIAL DEPOSITION

Debris in the frigid environment that might be kept straight by the ice (till) or, subsequent to modifying, by meltwater streams (outwash). The subsequent stores are named frigid float.

As the ice in a valley ice sheet moves from the space of collection to that of removal, it's anything but a transport line, moving garbage situated underneath, inside, or more the icy mass toward its end or, on account of an ice sheet, around the external edge. Close to the ice sheet edge where the ice speed diminishes extraordinarily is the zone of affirmation.

As the ice liquefies away, the garbage that was initially frozen into the ice generally frames a rough and additionally sloppy cover over the glacial mass edge. This layer regularly slides off the ice as mudflows. The subsequent store is known as a stream till by certain creators. Then again, the flotsam and jetsam might be set down pretty much set up as the ice liquefies away around and underneath it. Such stores are alluded to as dissolve out till, and some of the time as removal till. By and large, the material situated between a moving icy mass and its bedrock bed is seriously sheared, packed, and "over-compacted." This kind of store is called lodgment till.

Meltwater stores, likewise called frosty outwash, are shaped in channels straightforwardly underneath the ice sheet or in lakes and streams before its edge. Rather than till, outwash is for the most part slept with or overlaid (delineated float), and the individual layers are generally very much arranged by grain size. Much of the time, rock and stones in outwash are adjusted and don't bear striations or notches on their surfaces, since these will in general wear off quickly during stream transport. The grain size of individual stores depends not just on the accessibility of various sizes of garbage yet additionally on the speed of the keeping current and the separation from the top of the stream. Bigger rocks are kept by quickly streaming rivulets and waterways near the ice sheet edge. Grain size of saved material declines with expanding distance from the ice sheet. The best portions, like mud and residue, might be saved in chilly lakes or moved right to the sea.

Check Your Progress

17. Glacial deposition is the settling of sediments left behind by a moving __________.
18. The mixture of unsorted sediment deposits carried by the glacier is called __________.

5.11 EROSIONAL LANDFORMS

Small-scale Features of Glacial Erosion

Glacial disintegration is brought about by two unique cycles: scraped spot and culling (see above). Virtually all frigidly scoured erosional landforms bear the apparatus characteristics of icy scraped spot given that they have not been taken out by ensuing enduring. Despite the fact that these imprints are not enormous enough to be called landforms, they comprise a fundamental piece of any frigid scene and hence warrant portrayal here. The kind of imprint delivered on a surface during icy disintegration relies upon the size and state of the device, the pressing factor being applied to it, and the overall hardnesses of the instrument and the substrate.

Rock Polish

The best rough accessible to an icy mass is the purported rock flour created by the consistent pounding at the foundation of the ice. Rock flour behaves like gem dealers' rouge and creates minuscule scratches, which with time smooth and clean stone surfaces, frequently to a high gloss.

Striations

These are scratches apparent to the unaided eye, going in size from parts of a millimeter to a couple of millimeters down and a couple of millimeters to centimeters long. Enormous striations created by a solitary apparatus might be a few centimeters down and wide and several meters in length.

Since the striation-cutting apparatus was hauled across the stone surface by the ice, the long pivot of a striation demonstrates the bearing of ice development in the quick area of that striation. Assurance of the territorial heading of development of previous ice sheets, be that as it may, requires estimating many striation bearings over an all-inclusive region since ice moving near the foundation of an icy mass is regularly privately avoided by bedrock obstructions. In any event, when a particularly local examination is directed, extra data is often required in low-help regions to figure out which end of the striations focuses down-ice toward the previous external edge of the glacial mass.

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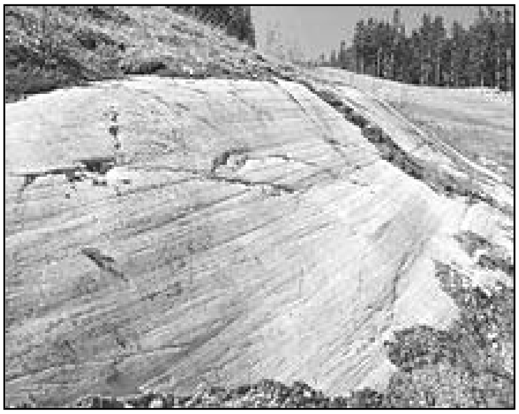

Fig. 5.26: Striation

P-forms and Glacial Grooves

These highlights, which stretch out a few to several meters long, are of dubious beginning. P-structures (P for plastically formed) are smooth-walled, direct sorrows which might be straight, bend, or some of the time barrette molded and measure several centimeters to meters in width and profundity. Their cross sections are regularly half circle to explanatory, and their dividers are generally striated corresponding to their long hub, showing that ice once streamed in them. Straight P-structures are often called icy sections, despite the fact that the term is additionally applied to enormous striations, which, dissimilar to the P-structures, were cut by a solitary device. A few scientists accept that P-structures were not cut straight by the ice but instead were dissolved by compressed mud slurries streaming underneath the icy mass.

Fig. 5.27: P Forms and Glacier Grooves

Erosional Landforms of Valley Glaciers

Large numbers of the world's higher mountain ranges—e.g., the Alps, the North and South American Cordilleras, the Himalayas, and the Southern Alps in New Zealand, just as the mountains of Norway, including those of Spitsbergen—are halfway glaciated today. During times of the Pleistocene, such ice sheets were incredibly amplified and filled a large portion of the valleys with ice, in any event, coming to a long ways past the mountain front in

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specific spots. Most picturesque snow capped scenes including sharp mountain tops, steep-sided valleys, and incalculable lakes and cascades are a result of a few times of glaciation.

Disintegration is by and large more noteworthy than affidavit in the upper scopes of a valley glacial mass, while statement surpasses disintegration nearer to the end. Likewise, erosional landforms submerge the scene in the high spaces of glaciated mountain ranges.

Cirques, Tarns, U-shaped Valleys, Aretes, and Horns

The heads of most cold valleys are involved by one or a few cirques (or corries). A cirque is an amphitheater-molded empty with the open end looking down-valley. The back is shaped by an arcuate bluff called the headwall. In an optimal cirque, the headwall is half circle in arrangement see. The present circumstance, notwithstanding, is by and large discovered distinctly in cirques cut into several levels. More normal are headwalls rakish in map see because of anomalies in tallness along their edge. The lower part of numerous cirques is a shallow bowl, which may contain a lake. This bowl and the foundation of the bordering headwall generally give indications of broad chilly scraped area and culling. Despite the fact that the specific interaction of cirque development isn't totally perceived, it appears to be that the piece of the headwall over the glacial mass retreats by ice breaking and ice wedging (see underneath Periglacial landforms). The stone trash then, at that point falls either onto the outside of the icy mass or into the randkluft or bergschrund. The two names portray the chasm between the ice at the top of the ice sheet and the cirque headwall. The stones on the outside of the icy mass are progressively covered by snow and consolidated into the ice of the ice sheet. In light of a descending speed part in the ice in the collection zone, the stones are ultimately moved to the foundation of the icy mass. By then, these stones, notwithstanding the stone garbage from the bergschrund, become the apparatuses with which the glacial mass disintegrates, striates, and cleans the foundation of the headwall and the lower part of the cirque.

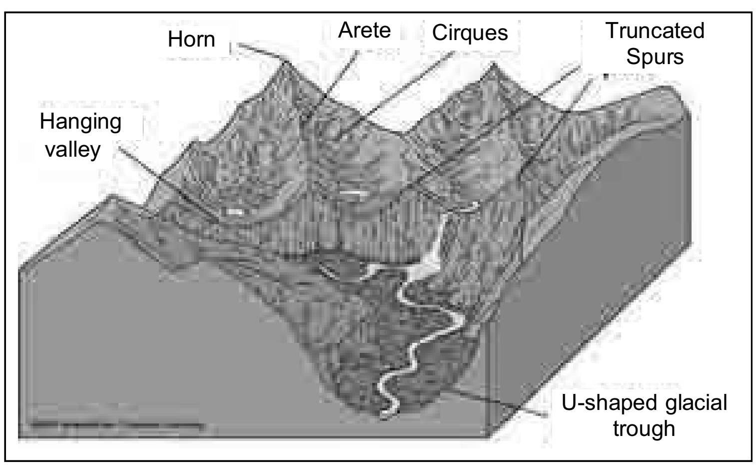

Fig. 5.28: Cirques, Tarns, U-shaped Valleys, Aretes, and Horns

During the underlying development and last retreat of a valley icy mass, the ice frequently doesn't stretch out past the cirque. Such a cirque ice sheet is most likely the fundamental driver for the development of the bowl scoured into the bedrock lower part of numerous cirques. Now and then these bowls are "over-developed" a many meters and contain lakes called pools.

Rather than the circumstance in a stream valley, all flotsam and jetsam falling or sliding off the sides and the headwalls of a glaciated valley is quickly taken out by the streaming ice. Additionally, ice sheets are for the most part in touch with a lot bigger level of a valley's cross area than comparable streams or brooks. Consequently ice sheets will in general dissolve the foundations of the valley dividers to a lot more prominent degree than do streams, while a stream disintegrates an amazingly thin line along the most minimal piece of a valley.

The incline of the adjoining valley dividers relies upon the solidness of the bedrock and the point of rest of the endured rock garbage gathering at the foundation of and on the valley dividers. Thus, streams will in general frame V-formed valleys. Ice sheets, which acquire V-molded stream valleys, reshape them radically by first eliminating all free flotsam and jetsam along the foundation of the valley dividers and afterward specially disintegrating the bedrock along the base and lower sidewalls of the valley. Thusly, glaciated valleys expect a trademark allegorical or U-formed cross profile, with generally wide and level bottoms and steep, even vertical sidewalls. By a similar cycle, ice sheets will in general restricted the bedrock splits between the upper scopes of adjoining equal valleys to rugged, blade edges known as aretes. Arêtes likewise structure between two cirques looking in inverse ways. The low spot, or seat, in the arête between two cirques is known as a col. A higher mountain frequently has at least three cirques orchestrated in a spiral example on its flanks. Headward disintegration of these cirques at last leaves just a sharp pinnacle flanked by almost vertical headwall bluffs, which are isolated by arêtes. Such icily dissolved mountains are named horns, the most generally known about which is the Matterhorn in the Swiss Alps. Hanging Valleys.

Enormous valley ice sheet frameworks comprise of various cirques and more modest valley icy masses that feed ice into a huge trunk glacial mass. As a result of its more prominent ice release, the storage compartment icy mass has more noteworthy erosive ability in its center and lower comes to than more modest feeder ice sheets that go along with it there. The fundamental valley is consequently disintegrated more quickly than the side valleys. With time, the lower part of the fundamental valley becomes lower than the rise of the feeder valleys. At the point when the ice has withdrawn, the feeder valleys are left joining the fundamental valley at heights considerably higher than its base. Feeder valleys with such inconsistent or harsh intersections are called hanging valleys. In outrageous situations where a feeder joins the fundamental valley high up in the lofty piece of the U-molded box divider, cascades may frame after deglaciation, as in Yosemite and Yellowstone public parks in the western United States.

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Paternoster Lakes

Some frigid valleys have an unpredictable, longitudinal bedrock profile, with rotating short, steep advances and more, moderately level bits. Despite the fact that endeavours have been made to clarify this component as far as some intrinsic quality of frigid stream, it appears to be more probable that differential erodibility of the basic bedrock is the genuine reason for the wonder. Subsequently the means are presumably framed by harder or less cracked bedrock, while the compliment partitions between the means are underlain by milder or more broke rocks. At times, these gentler regions have been exhumed by a glacial mass to shape shallow bedrock bowls. On the off chance that few of these bowls are involved by lakes along one frigid box in an example like globules on a string, they are called paternoster (Latin: "our dad") lakes by relationship with a line of rosary dots.

Fig. 5.29: Paternoster Lake

Roches Moutonnees

These constructions are bedrock handles or slopes that have a tenderly slanted, frigidly rubbed, and smoothed out stoss side (i.e., one that faces the heading from which the abrogating glacial mass encroached) and a lofty, frostily culled lee side. They are for the most part discovered where jointing or cracking in the bedrock permits the icy mass to cull the lee side of the snag. In arrangement see, their long tomahawks are regularly, however not generally, lined up with the overall course of ice development.

Fig. 5.30: Roche Mountonnees

Rock Drumlins

A component like roches moutonnées, rock drumlins are bedrock handles or slopes totally smoothed out, ordinarily with steep stoss sides and delicately slanting lee sides. Both roches moutonnées and rock drumlins range long from a few meters to a few kilometers and in range from several centimeters to many meter.

Fig. 5.31: Drumlins

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Erosional Landforms of Continental Glaciers

Rather than valley glacial masses, which structure only in spaces of high height and alleviation, mainland ice sheets, including the incredible ice sheets of the past, happen in high and center scopes in the two halves of the globe, covering scenes that reach from high snow capped mountains to low-lying regions with immaterial help. In this manner, the landforms delivered by mainland glacial masses are more different and inescapable. However, actually like valley ice sheets, they have a region where disintegration is the predominant interaction and a region near their edges where net testimony for the most part happens. The limit of a mainland ice sheet to disintegrate its substrate has been a subject of extreme discussion. The entirety of the spaces previously covered by ice sheets show proof of a really broad icy scouring. The normal profundity of chilly disintegration during the Pleistocene most likely didn't surpass a several meters, in any case. This is substantially less than the extending of icy valleys during mountain glaciation. One reason for the evident restricted erosional limit of mainland ice sheets in spaces of low help might be the shortage of devices accessible to them in these places. Rocks can't fall onto a mainland ice sheet in the collection zone, on the grounds that the whole scene is covered. In this way, all devices should be quarried by the glacial mass from the basic bedrock. With time, this undertaking turns out to be progressively troublesome as bedrock impediments are scraped and smoothed out. In any case, the figure for profundity of chilly disintegration during the Pleistocene referred to above is a normal worth, and locally a few many meters of bedrock were obviously eliminated by the extraordinary ice sheets. Such upgraded disintegration appears to be amassed at focuses where the ice sheets moved from hard, safe bedrock onto gentler rocks or where cold stream was channelized into outlet ice sheets.

As a mainland icy mass extends, it strips the hidden scene of the dirt and garbage amassed at the preglacial surface because of enduring. The newly uncovered more diligently bedrock is then disintegrated by scraped area and culling. During this cycle, bedrock snags are molded into smoothed out "whaleback" structures, for example, roches moutonnées and rock drumlins

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(see above). The abutting valleys are scoured into rock-stunned bowls with the apparatuses culled from the lee sides of roches moutonnées. The long tomahawks of the slopes and valleys are frequently specially arranged towards ice stream. A region completely made out of smooth whaleback structures and bowls is known as a smoothed out scene.

Streams can't dissolve profound bowls since water can't stream uphill. Icy masses, then again, can stream uphill over impediments at their base as long as there is an adequate slant on the upper ice surface pointing that specific way. Subsequently the extraordinary greater part of the countless lake bowls and little melancholies in some time ago glaciated regions must be an aftereffect of frosty disintegration. A considerable lot of these lakes, for example, the Finger Lakes in the U.S. province of New York, are adjusted corresponding to the heading of provincial ice stream. Different bowls appear to be constrained by preglacial seepage frameworks. However, different miseries follow the construction of the bedrock, having been specially scoured out of regions underlain by milder or more cracked stone.

Some of the biggest freshwater lake bowls on the planet (e.g., the Great Lakes or the Great Slave Lake and Great Bear Lake in Canada) are arranged along the edges of the Precambrian safeguard of North America. Numerous scientists accept that frigid disintegration was particularly viable at these areas on the grounds that the glacial masses could undoubtedly scrape the moderately delicate sedimentary shakes toward the south with hard, safe glasslike rocks brought from the safeguard regions that lie toward the north. Regardless, further exploration is important to decide the amount of the developing of these highlights can be attributed to frigid disintegration, rather than different cycles like structural action or preglacial stream disintegration.

Fjords are found along some precarious, high-help coast-lines where mainland icy masses earlier streamed into the ocean. They are profound, limited valleys with U-formed cross areas that regularly broaden inland for tens or many kilometers and are currently mostly suffocated by the sea. These box are normal of the Norwegian coast, however they likewise are found in Canada, Alaska, Iceland, Greenland, Antarctica, New Zealand, and southernmost Chile. The floor and steep dividers of fjords show adequate proof of icy disintegration. The long profile of numerous fjords, including rotating bowls and steps, is basically the same as that of glaciated valleys. At the mouth, fjords may arrive at extraordinary profundities, as on account of Sogn Fjord in southern Norway where the greatest water profundity surpasses 1,300 meters. At the mouth of a fjord, in any case, the floor rises steeply to make a stone edge, and water profundities decline extraordinarily.

At Sogn Fjord the water at this "edge" is just 150 meters down, and in numerous fjords the stone stage is covered by a couple of meters of water. The specific beginning of fjords is as yet an issue of discussion. While a few researchers favour a frigid beginning, others accept that a significant part of the help of fjords is an aftereffect of structural movement and that icy masses just marginally adjusted prior enormous valleys. To dissolve Sogn Fjord to its current profundity, the icy mass involving it during the limit of the Pleistocene more likely than not been 1,800 to 1,900 meters thick. Such an ice thickness may appear to be outrageous, however even now, during an interglacial period, the Skelton Glacier in Antarctica has a most extreme thickness of around 1,450 meters. This outlet glacial mass of the Antarctic ice sheet possesses a box, which in places is more than one kilometer underneath ocean level and would turn into a fjord in case of an enormous chilly retreat.

Check Your Progress

19. When waves create a notch in the base of a cliff _______ can occur.
20. Glacial grooves scratched into bedrock as the glacier moves ___________.

5.12 DEPOSITIONAL LANDFORMS

Depositional Landforms of Valley Glaciers

Moraines

As a glacial mass moves along a valley, it gets rock trash from the valley dividers and floor, shipping it in, on, or under the ice. As this material arrives at the lower portions of the ice sheet where removal is prevailing, it is concentrated along the glacial mass edges as increasingly more garbage liquefies out of the ice. On the off chance that the situation of the icy mass edge is steady for an all-encompassing measure of time, bigger collections of cold flotsam and jetsam (till; see above) will frame at the glacial mass edge. Also, a lot of material is quickly flushed through and out of the ice sheet by meltwater streams streaming under, inside, on, and close to the ice sheet. Part of this streamload is kept before the icy mass near its nose. There, it might blend in with material brought by, and liquefying out from, the ice sheet just as with material washed in from other, nonglaciated feeder valleys. Assuming the ice sheet, advances or readvances after a period of retreat, it will "demolish" all the free material before it's anything but an edge of tumultuous garbage that intently embraces the state of the icy mass nose.

Any such collection of till liquefied out straightforwardly from the ice sheet or packed into an edge by the glacial mass is a moraine. Huge valley icy masses are fit for shaping moraines a couple hundred meters high and a large number of meters wide. Direct aggregations of till framed preceding or on the lower end of the icy mass are end moraines. The moraines shaped along the valley slants close to the side edges of the icy mass are named parallel moraines. During a solitary glaciation, an ice sheet may frame numerous such moraine circular segments, yet every one of the more modest moraines, which may have been delivered during stops or short advances while the glacial mass pushed ahead to its peripheral ice position, are by and large annihilated as the icy mass continues its development. The end moraine of biggest degree shaped by the icy mass (which may not be pretty much as broad as the biggest ice advance) during a given glaciation is known as the terminal moraine of that glaciation.

Progressively more modest moraines shaped during stops or little readvances as the glacial mass retreats from the terminal moraine position are recessional moraines.

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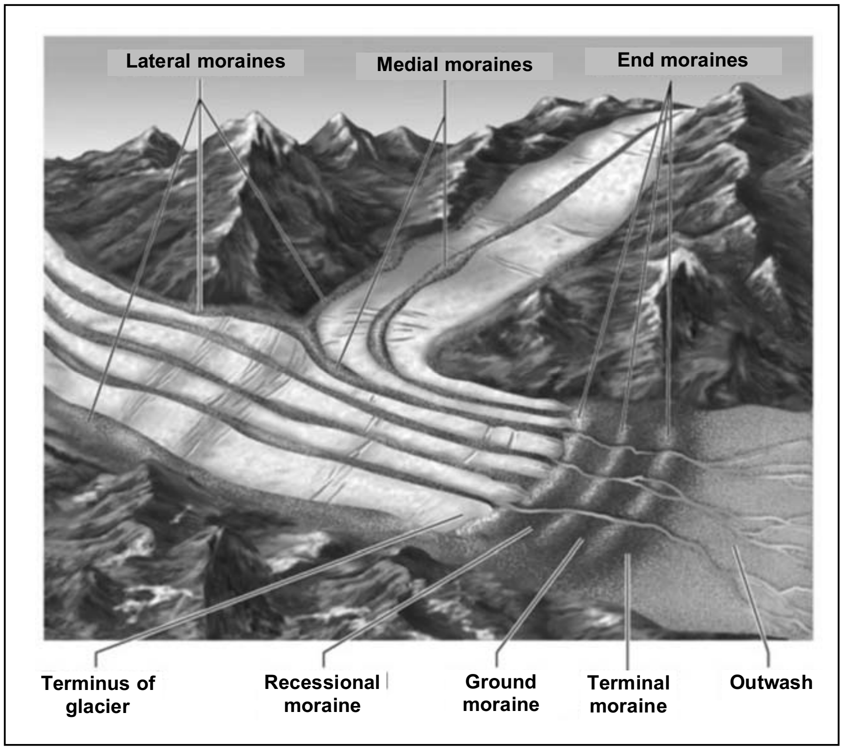

Fig. 5.32: Moraines

Flutes

What might be compared to erosional handle and tail structures (see above) are known as woodwinds. Near the lower edge, a few ice sheets gather such a lot of flotsam and jetsam underneath them that they really coast on a bed of compressed sloppy till. As basal ice streams around an articulated bedrock handle or a rock held up in the substrate, a cavity frequently shapes in the ice on the lee side of the hindrance as a result of the great consistency of the ice. Any compressed sloppy glue present under the ice sheet may then be infused into this cavity and stored as a stretch tail of till, or woodwind. The size relies primarily upon the size of the hindrance and on the accessibility of subglacial flotsam and jetsam. Woodwinds differ in range from a couple of centimeters to several meters and long from many centimeters to kilometers, despite the fact that huge woodwinds are for the most part restricted to mainland ice sheets.

Fig. 5.33: Flutes

Depositional Landforms of Continental Glaciers

A large number of the stores of mainland ice sheets are basically the same as those of valley ice sheets. Terminal, end, and recessional moraines are shaped by a similar interaction likewise with valley icy masses (see above), yet they can be a lot bigger. Morainic edges might be horizontally nonstop for many kilometers, many meters high, and a few kilometers wide. Since every moraine structures at a circumspect situation of the ice edge, plots of end moraines on a guide of appropriate scale permit the remaking of ice sheets at different stages during their retreat.

Notwithstanding straight gatherings of frigid garbage, mainland ice sheets regularly store a pretty much persistent, slim (under 10 meters) sheet of till over enormous regions, which is called ground moraine. This kind of moraine for the most part has a "hummocky" geography of low help, with substituting little till hills and discouragements. Bogs or lakes regularly involve the low-lying regions. Woodwinds (see above) are a typical element found in regions made by progress moraine.

Another depositional landform related with mainland glaciation is the drumlin, a smoothed out, stretch hill of silt. Such designs regularly happen in gatherings of tens or hundreds, which are called drumlin fields. The long hub of individual drumlins is typically adjusted corresponding to the heading of territorial ice stream. In long profile, the stoss side of a drumlin is more extreme than the lee side. A few drumlins comprise altogether of till, while others have bedrock centers hung with till. The till in numerous drumlins has been displayed to have a "texture" in which the long tomahawks of the individual shakes and sand grains are adjusted corresponding to the ice stream over the drumlin. Despite the fact that the subtleties of the cycle are not completely perceived, drumlins appear to shape subglacially near the edge of an ice sheet, frequently straightforwardly down-ice from enormous lake bowls superseded by the ice during a development. The distinction between a stone drumlin and a drumlin is that the previous is an erosional bedrock handle (see above), while the last is a depositional till highlight.

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Check Your Progress

21. State types of glaciers.
22. Define Rock Polish.

5.13 KARST LANDFORM

A karst landform is a geological feature created on the earth's surface by the drainage of water into the ground.

Fig. 5.34: Karst Landform

A sinkhole is a bowl, channel or chamber molded sorrow taking care of water underground.

A karst landform is a geographical element made on the world's surface by the waste of water into the ground. Run of the mill karst structures incorporate sinkholes, caves, regular extensions and sinking streams. They were first concentrated exhaustively in Kras, Slovenia, thus the name karst. There are 1.2 million km^2 of karst rock outcroppings in Canada, found in all land areas aside from the Canadian Shield.

A landscape that is characterized by numerous caves, sinkholes, fissures, and underground streams. Karst topography usually forms in regions of plentiful rainfall where bedrock consists of carbonate-rich rock, such as limestone, gypsum, or dolomite, that is easily dissolved.

The karsts are formed in the regions that meet the following conditions:

1. Karst topography will be found in such regions which will have a large stretch of water-soluble rocks such as limestone at the surface or sub-surface level.
2. The limestones of the karst topography are not porous.
3. The rocks found in the karsts are dense, thinly bedded and well jointed.

4. As the groundwater/surface water is the factor to form the karst topography hence, there should be a perennial source of water and a low water table to allow the formation of conspicuous features.
5. The solution or moderate to abundant rainfall to cause the solvent action of water i.e. solution of rocks.

The features of Karst Topography are listed down below:

1. **Swallow Hole in Section:** When the stream of groundwater/surface water disappears in the hole; it is called a swallow hole. It is also called 'Ponor', and 'Serbo-Coat.'
2. **Cave in Section:** Due to the erosion caused by either running water or surface water, a cavity is formed in the rock which transforms into a cave.
3. **Sink Holes:** It is one of the most common features in Karst Topography. It is a depression on the limestone/dolomitic region that ranges from a shallow saucer shape to a funnel-shaped or cylindrical pipe.
4. **Valley Sinks/Uvalas:** It is defined as a complex dosed depression with several lesser depressions within its rim.
5. **Sink Hole:** If a cave becomes large enough and the top extends close enough to the surface, the top collapses. This produces depressions called sinkholes, which are among the most characteristic features of karst topography.
6. **Karst Window:** When a number of adjoining sinkholes collapse, they form an open, broad area called a karst window.
7. **Stalactite:** A portion of the roof hangs on the roof and on evaporation of water, a small deposit of limestone is left behind contributing to the formation of a stalactite, growing downwards from the roof.
8. **Stalagmite:** The remaining portion of the drop falls to the floor. This also evaporates, leaving behind a small deposit of limestone aiding the formation of a stalagmite, thicker and flatter, rising upwards from the floor.
9. **Column:** Sometimes, stalactite and stalagmite join together to form a complete pillar known as the column.

Erosional Landforms of Karst Topography

The table below mentions the erosional landforms that characterize karst topography.

Karst Topography – Erosional Landforms

Pools	An opening at the top with water collected in the void of the surface with varying depth.
Sinkholes	Depression on the limestone/dolomitic region. A great variation is seen in sizes of sinkholes with areas from a few sq. m to a hectare and with depth from a less than half a metre to thirty metres or more.

Lapies	It is formed due to differential solution activity along parallel to sub-parallel joints. They are also called grooved, fluted and ridge-like features in an open limestone field.
Limestone Pavements	It is a smoother form of lapies.
Caves	Cave formation is prominent in areas where there are alternating beds of rocks (shales, sandstones, quartzites) with limestones or dolomites in between or in areas where limestones are dense, massive and occurring as thick beds.
Collapse Sinks	It is also referred to as 'Doline.'

source: NCERT

Depositional Landforms of Karst Topography

The table below mentions the depositional landforms that characterize karst topography.

Karst Topography – Erosional Landforms	
Stalactites	• The hanging icicles varying with diameters are called stalactites • Usually, the base is broader than the free end of the hanging stalactites
Stalagmites	• Unlike stalactites those hang from the ceiling; sta lagmites rise from the floor • It is formed due to the deposition of the dripping water of either the surface water or the stalactites • The shapes of stalagmites range from the column, a disc, with either a smooth, rounded bulging end to a miniature crater-like depression
Pillars	• The combination or fusion of stalactites and stalagmites form the pillars • The diameters of pillars vary

Suitable Conditions for Karst Formation

The karsts are formed in the regions that meet the following conditions:

1. Karst topography will be found in such regions which will have a large stretch of water-soluble rocks such as limestone at the surface or sub-surface level.
2. The limestones of the karst topography are not porous.
3. The rocks found in the karsts are dense, thinly bedded and well jointed.
4. As the groundwater/surface water is the factor to form the karst topography hence, there should be a perennial source of water and a low water table to allow the formation of conspicuous features.
5. The solution or moderate to abundant rainfall to cause the solvent action of water i.e. solution of rocks.

Erosion in Karst Region

As the rocks found in the karst regions are thinly bedded and permeable; the surface water drains underground and erodes the rocks with its horizontal and downward movement. The chemical process of solution and precipitation leads to the formation of the landforms either through erosion or deposition.

Karst topography can be a dangerous location to live because the bedrock of the area slowly erodes away. This unstable land can cause huge sinkholes and other geomorphic hazards. The development of all karst landforms requires the presence of rock which is capable of getting dissolved by water(surface and ground water). Although commonly associated with carbonate rocks (dolomite and limestone) other highly soluble rocks such as evaporites (rock salt and gypsum) can also be sculpted into karst terrain.

Fig. 5.35: Karst Cave Postojnska-Jama Formed by the Pivkariver in Slovenia

Effects on Human Life

Although there are a few ways in which Karst Topography is useful to humans aside from creating marvellous landscapes and other natural wonders, it often poses an impediment to human activities, such as farming. In Karst regions where limestone is predominant, the soils are unable to hold on to water, even being fertile and receiving abundant rainfall. Farmers in karst areas must also take into account the lack of surface water. As the water seeps through the cracks at a faster rate than in other areas, the surface is often left parched for long periods of time, deeming the ground inadequate for producing many types of crops.

Nevertheless, there are many crops that do not require a lot of water, including sweet potato, artichokes, types of squashes, watermelons, cantaloupes, and some cucumbers, as well as chickpeas, black-eyed peas, and lima beans. Other farmers utilize what they have by growing the miniature versions, such as of eggplants or the baby bell peppers. Although cattle are free to roam in the vast spaces of such topography, the pastures become depleted of grasses rather quickly through the feeding.

Water in wells, generally deemed suitable for drinking since it gets filtered through a natural porous aquifer, as well as enriched with minerals from underground sources, may be unsafe in Karst Topography settings. There, the

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water often bypasses the filtration and emerges from sinkholes in a cattle pasture, or even near garbage damps, to run contaminated directly through a cave and into the well.

Fig. 5.36: Karst of Red Lake

Red Lake is a collapse sinkhole containing a karst lake close to Imotski, Croatia. It is 530 metres deep, thus it is the largest collapse doline in Europe. Sinkholes such as these often form in karst landscapes posing great challenges to people inhabiting such areas.

The dynamic characteristic of karst topography poses more challenges to humans, in forms of sinkholes that enlarge to swallow up vehicles, cattle, machinery, and even entire buildings. Exploration of the caves becomes dangerous, as they may collapse at any given moment. Cracks in the ground, also present challenges for driving on this type of terrain, while the unstable composition of the earth makes it vulnerable to landslides.

Karst Ecosystem

Although trees are sparser here, a large variety of low-growing plants can grow in Karst ecosystems, having adopted highly developed root systems. By entering the cracks and anchoring themselves to the ground, they absorb water according to their needs.

Karst ecosystems present suitable living conditions for animals such as rabbits, foxes, reptiles and other invertebrates, bats, and wild boars that survive in all types of moderate climate and need rather a small spectrum of vegetation. Many utilize the caves, caverns and other crevices in the ground for shelter, and do not find the cracks in the ground as obstacles for their roaming needs.

Similar to regular lakes and rivers, the waters can be abundant in seaweed and fish. In Iowa, the Driftless Area National Wildlife Refuge protects *Discus macclintocki*, a species of snails having beaten the odds and survived the freezing temperatures during the Ice Age by flowing over buried Karst formations, but which are greatly diminishing in numbers today.

Description

Karst landforms are made by water sinking and flowing underground, and the subsequent substance disintegration of bedrock. Hence, the advancement of karst landforms is restricted to regions where relatively dissolvable rocks — basically limestone — exist. Roughly 8% of the world's land surface is karst landscape.

Chemical Processes

Limestone is a sort of carbonate rock — that is, a stone made up essentially of a carbonate mineral which, on account of limestone, is typically calcite or aragonite. These are the two types of calcium carbonate ($CaCO_3$). After some time, limestone might be broken down via carbonic acid (i.e., carbon dioxide disintegrated in water). Carbonic acid is framed when downpour gets CO_2 as it falls through the climate. When it hits the ground, it might get more CO_2 in the dirt, transforming into a frail carbonic acid arrangement. At the point when this arrangement saturates limestone bedrock by means of breaks and gaps, bigger openings are made. Throughout millennia, this erosive cycle makes underground waste frameworks and caverns.

Karren

The most boundless surface karst landforms are little arrangement pits, depressions and brooks, all in all called karren. Singular highlights are once in a while longer or more profound than 10 m, yet regularly they are thickly grouped and take apart bigger regions, alluded to as limestone asphalt. Limestone asphalt is especially very much evolved in Île d'Anticosti Québec, the Bruce Peninsula and Manitoulin Island, Ontario. Little fixes might be seen inside the city furthest reaches of Hamilton, Montréal and Ottawa. In metropolitan Winnipeg, around 3,500 km^2 of limestone asphalt is saved underneath chilly lake dirts and fills in as a significant modern water store. There are fabulous subarctic asphalts in the Carcajou Range west of Norman Wells, Northwest Territories. Further north, ice entrance into breaks in the bedrock is normal; the bedrock gets broken into rubble handle that are boundless on the broad carbonate rock landscapes of icy Canada.

Sinkhole

The most conspicuous karst landform is the sinkhole. This is a bowl, channel or chamber molded gloom in the earth which feeds water underground. There might be an occasional or lasting lake in the base. The length or breadth of sinkholes goes from 10 to 1,000 m. Most are framed by substance arrangement in the pipe or by breakdown of the top of a fundamental cavern. In southern Saskatchewan, breakdown arrangement pits in salt have stretched out through as much as 1,000 m of overlying insoluble rocks to create shallow sinkholes at the surface.

Sinkholes frequently happen in lines or bunches. In some karsts their recurrence surpasses 500 for every km^2, giving the territory a shell-pitted appearance. A huge number of sinkholes exist in southern Canada, from gypsum landscapes in western Newfoundland to limestones on Vancouver Island. There are some huge, fantastic models in Wood Buffalo National Park, in the Franklin Mountains, and west of Great Bear Lake where limestones and dolomites have fallen into cavities in gypsum. Some new falls happen every year, the opening showing up very quickly. These are a danger to settlement on gypsum territories in pieces of Newfoundland and Nova Scotia.

Dry Valleys and Poljes

Bigger karst landforms incorporate dry valleys and chasms, cut by past waterways that currently stream underground, and poljes, which are significant sinkholes with level floors and steep dividers. Medication Lake in Jasper National Park is a polje estimating 6 km by 1–2 km. The Maligne River channels into it and floods it's anything but a profundity of 25 m throughout the mid year liquefy season. In winter, the lake diminishes to little lake sinkholes in the polje floor. The sinking water is released 16 km northwest at somewhere in the range of 60 springs in the floor of Maligne Canyon. With a total release that may surpass 65 m^3 of water each second, these are the biggest karst springs known in Canada. Numerous different springs are known with top releases surpassing 10 m^3 each second.

Karst and Glaciation

Karst landform advancement is fairly restricted in Canada when contrasted with nations that have not gone through rehashed glaciation. Icy mass activity has disintegrated or infilled much karst. Canada's best karstland, Nahanni Karst, is found in an area of the Mackenzie Mountains, Northwest Territories, which has gotten away from glaciation for as long as a few hundred thousand years. Major karst structures have created without interference or annihilation and incorporate many sinkholes up to 150 m profound, monster arrangement grooves converging to frame a characteristic maze, a few poljes and dry ravines. Portions of the karst have arrived at an exceptionally progressed stage, showing leftover stone pinnacles and normal scaffolds, includes infrequently found in northern scopes.

A thick karstland of karren, little sinkholes and incalculable caverns has created on steep limestone plots clad in Douglas fir in northern Vancouver Island. The landforms represent some peril to ranger service rehearses, while clear-cutting may seriously harm both surface and underground karst.

Snow capped karst, including fields of karren and shaft sinkholes over the treeline that channel into profound caverns, is all around created in pieces of the Rocky Mountains and Vancouver Island. Crowsnest Pass offers excellent instances of old style snow capped karst structures: significant springs issue from dynamic water collapses the floor of the pass while parts of depleted, relict caves are dissipated at higher heights up to the mountain culminations. A portion of the advanced spring water is accepted to have gone as much as 70 km underground. The biggest icefield in the Rockies, Columbia Icefield, is for the most part depleted by sinkholes getting by in the limestone and dolostone underneath it. The waters stream in extraordinary caverns through Mount Castleguard to arise as terrific springs in the valley of Castleguard River (a headwater of the North Saskatchewan River). It is the world's pre-famous illustration of current subglacial karst.

Check Your Progress

23. Define Karren.
24. Which karst is well developed in parts of Rocky Mountain?

5.14 COASTAL LANDFORMS

Coastal landforms, any of the relief highlights present along any coast, are the consequence of a mix of cycles, dregs, and the topography of the actual coast.

The waterfront climate of the world is comprised of a wide assortment of landforms showed in a range of sizes and shapes going from tenderly inclining sea shores to high bluffs, yet beach front landforms are best viewed as in two general classifications: erosional and depositional. Truth be told, the general idea of any coast might be portrayed as far as either of these classes. It ought to be noted, notwithstanding, that every one of the two significant landform types may happen on some random reach of coast.

5.14.1 Factors and Forces in the Formation of Coastal Features

The landforms that create and persevere along the coast are the aftereffect of a mix of cycles following up on the dregs and rocks present in the waterfront zone. The most conspicuous of these cycles includes waves and the flows that they create, alongside tides. Different variables that essentially influence beach front morphology are environment and gravity.

(a) Waves

The most clear of all waterfront measures is the ceaseless movement of the waves pushing toward the sea shore. Waves change extensively in size over the long haul at some random area and furthermore shift especially from one spot to another. Waves cooperate with the sea base as they travel into shallow water; thus, they cause residue to turn out to be briefly suspended and accessible for development by waterfront flows. The bigger the wave, the more profound the water, wherein this interaction happens and the bigger the molecule that can be moved. Indeed, even little waves that are two or three many centimeters high can get sand as they arrive at the shore. Bigger waves can move cobbles and rock material as extensive as stones.

By and large, little waves cause silt—normally sand—to be moved towards the coast and to get saved on the sea shore. Bigger waves, normally during storms, are responsible for the expulsion of silt from the coast and its movement out into generally profound water.

Waves dissolve the bedrock along the coast generally by scraped spot. The suspended residue particles in waves, particularly stones and bigger stone trash, have a lot of a similar impact on a surface as sandpaper does. Waves have impressive power thus may separate bedrock basically by sway.

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(b) Longshore Currents

Waves normally approach the coast at some intense point as opposed to precisely resemble to it. Along these lines, the waves are twisted (or refracted) as they enter shallow water, which thus produces a flow along the shore and corresponding to it. A particularly current is known as a longshore current, and it stretches out from the shoreline out through the zone of breaking waves. The speed of the current is identified with the size of the waves and to their point of approach. Under rather tranquil conditions, longshore flows move just around 10–30 centimeters each second; notwithstanding, under turbulent conditions they may surpass one meter each second. The mix of waves and longshore current demonstrations to move huge amounts of residue along the shallow zone adjoining the shoreline.

Since longshore flows are brought about by the drawing closer and refracting waves, they may move one or the other way along the coast, contingent upon the course of wave approach. This heading of approach is an aftereffect of the breeze bearing, which is accordingly a definitive factor deciding the way of longshore flows and the motion of residue along the shoreline.

Although a longshore current can entrain residue on the off chance that it moves sufficiently quick, waves commonly cause dregs to be gotten from the base, and the longshore current moves it along the coast. In certain areas there is a serious enormous volume of net silt transport along the coast in view of a predominance of one breeze heading—and in this way wave bearing—over another. This volume might be on the request for 100,000 cubic meters each year. Different areas may encounter to a greater degree an equilibrium in wave approach, which causes the longshore current and residue transport one way to be almost adjusted by a similar cycle the other way.

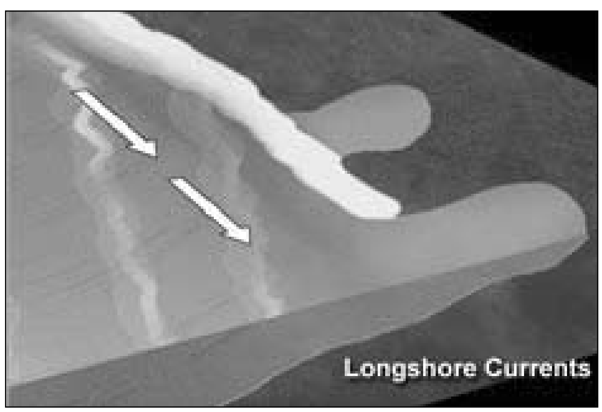

Fig. 5.37: Longshore Currents

(c) Rip Currents

Another sort of waterfront ebb and flow brought about by wave movement is the tear momentum (mistakenly called tear tide in well known usage). As waves advance toward the sea shore, there is some net shoreward movement of water. This prompts a slight however significant vertical incline of the water level (arrangement), so the total water level at the shoreline is a couple of centimeters higher than it is past the surf zone. The present circumstance is a shaky one, and water moves toward the ocean through the surf zone with an end goal to diminish the flimsiness of the inclining water. The offshore development is normally restricted to limit pathways. Much of the time, tear flows are routinely dispersed and stream at rates of up to a many centimeters each second. They can convey silt and frequently are perceived by the crest of suspended dregs moving out through the surf zone. In certain areas tear flows persists for quite a long time at a similar site, though in others they are very transient.

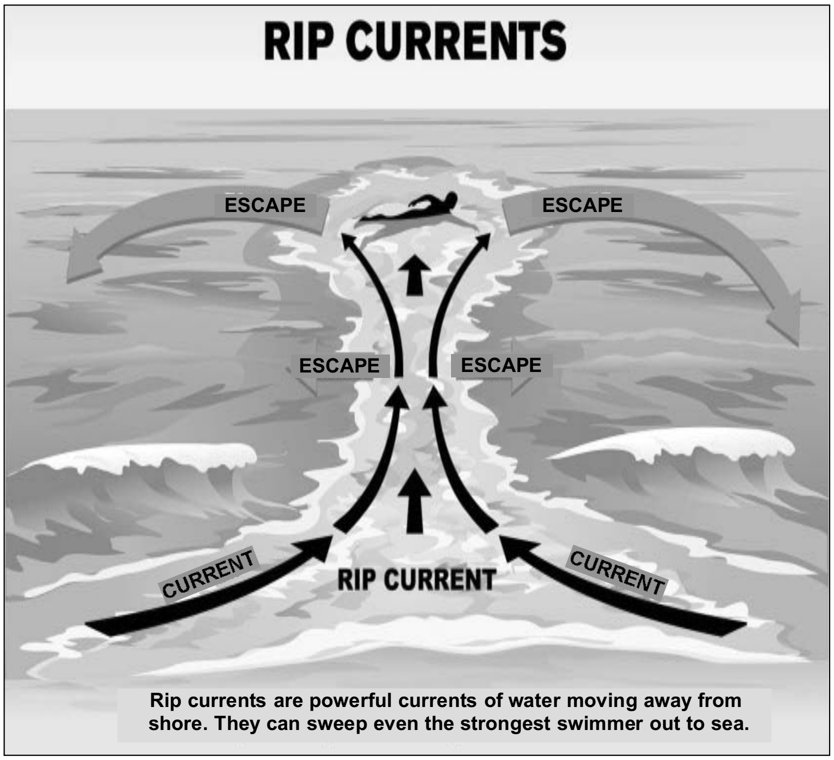

Fig. 5.38: Rip Current

(d) Tides

The ascent and fall of ocean level brought about by galactic conditions is ordinary and unsurprising. There is an extraordinary reach in the extent of this every day or semi-day by day change in water level. Along certain coasts the flowing reach is under 0.5 meter, though in the Bay of Fundy in southeastern Canada the most extreme flowing reach is a little more than 16 meters. A basic however helpful grouping of coasts depends exclusively on flowing reach regardless of some other variable. Three classifications have been set up: miniature flowing (under two meters), meso-flowing (two to four meters), and large scale flowing (multiple meters). Miniature flowing coasts comprise the biggest level of the world's coasts, yet the other two classes likewise are far and wide.

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The job of tides in trim waterfront landforms is twofold: (1) flowing flows transport huge amounts of silt and may disintegrate bedrock, and (2) the ascent and fall of the tide appropriates wave energy across a shore zone by changing the profundity of water and the situation of the shoreline.

Flowing flows transport residue similarly that longshore flows do. The paces important to ship the residue (ordinarily sand) are created uniquely under specific conditions—typically in deltas, at the mouths of estuaries, or whatever other spot where there is a tightening in the coast through which flowing trade should happen. Flowing flows on the open coast, for example, along a sea shore or rough coast, are not quick enough to ship silt. The speed of flowing flows in choked regions, nonetheless, may surpass two meters each second, particularly in bays situated on an obstruction island complex.

The speed of these flowing flows is directed by the volume of water that should go through the bay during a given flood or ebb-tide cycle. This might be either six or 12 hours in term, contingent upon whether the nearby circumstance is semidiurnal (12-hour cycle) or diurnal (24-hour cycle). The volume of water included, called the flowing crystal, is the result of the flowing reach and the space of the seaside cove being served by the delta. This implies that however there might be an immediate connection between flowing reach and flowing current speed, it is additionally conceivable to have extremely quick flowing flows on a coast where the flowing reach is low if the narrows being served by the channel is very huge. This is exceptionally regular along the bank of the Gulf of Mexico where the reach is commonly short of what one meter yet where there are numerous huge beach front inlets.

The ascent and fall of the tide along the open coast indirectly affects silt transport, despite the fact that flows fit for moving residue are absent. As the tide comes in and afterward withdraws along a sea shore or on a rough coast, it makes the shoreline move as needs be. This development of the shoreline changes the zone where waves and longshore flows can manage their job. Flowing reach in mix with the geology of the coast is very significant in the present circumstance. The more prominent the flowing reach, the more impact this marvel has on the coast. The slant of a sea shore or other seaside landform likewise is significant, in any case, on the grounds that a lofty bluff gives just an ostensible change nearby over which waves and flows can manage their job even in a full scale flowing climate. Then again, an expansive, tenderly slanting sea shore or salt marsh may encounter an adjustment of the shoreline of as much as one kilometer during a flowing cycle in a full scale flowing setting. Instances of the present circumstance happen in the Bay of Fundy and along the West German shore of the North Sea.

Check Your Progress

25. What do you mean by Rip current?
26. Which type of coast constitute the largest percentage of world's coast?

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5.15 APPLICATION OF GEOMORPHOLOGY TO HUMAN ACTIVITIES

There has been an expanding acknowledgment of the reasonable utilization of geomorphic standards and the discoveries of geomorphological examination to individuals who are impacted by also, thus, impact the surface highlights of the earth. Ceaseless expansion in populace has driven to tension ashore assets, augmentation of farming to sloping and negligible terrains brought about man actuated catastrophes like soil disintegration, avalanches, sedimentation and floods. A legitimate translation of landforms illuminates the geologic history, construction, and lithology of a district. As topography turns out to be more particular there is developing chance that the utilization of geomorphology to issues of applied topography will be ignored. The part of applied geomorphology relates fundamentally to the issues of investigating and observing landscape forming measures that may emerge from human obstruction. Individuals have over the long haul attempted to tame also, alter geomorphic/ecological cycles to suit their financial requirements. Geomorphology has assorted application over a huge space of human movement while Geomorphologist may serve all the more viably the need of society.

Early geomorphologists, natural historians, and geographers were not unaware of the power of humans as geomorphological agents . For example, in the late eighteenth and early nineteenth centuries scholars like Fabre and Surell studied the flooding, siltation, erosion and channel braiding brought about by deforestation in the Alps of Europe (Glacken, 1967). Likewise, De Saussure showed that Alpine lakes had suffered a lowering of water levels in recent times because of deforestation, and in Venezuela Von Humboldt demonstrated how Lake Valencia's level had varied with land use changes, including the cultivation of indigo. This was a theme followed up by the French rural economist, Boussingault (1845). Indeed, the appreciation by colonial scientists of the role of western-style economies in causing major landscape changes is an insufficiently recognised contribution (Grove, 1990). However, although geologists like Sir Charles Lyell recognised the effects of tree felling and land drainage activities, such actions were thought to be insignificant in comparison with the power of natural forces exercised by volcanoes, great rivers and the like (Lyell, 1835). A major change of emphasis came with Marsh's Man and Nature (1864), a clarion call for the conservation movement. He pointed with force to the multifarious and ramifying consequences of deforestation for a cascade of geomorphological processes extending from mountain slopes down to estuaries, sandbars and dunes.

An understanding of landforms may be of great use, directly or indirectly, to human beings who are influenced by and, in turn, influence the surface features of the earth which they inhabit.

If landforms are properly interpreted, they throw light upon the geologic history, structure and lithology of a region. According to D.K.C. Jones, applied geomorphology could be defined as "the application of geomorphic understanding to the analysis and solution of problems concerning land occupancy, resource exploitation, and environmental management and planning".

Indeed, all geomorphological knowledge tends to be applied, according to R.G. Craig and J.L. Craft. As each advance in knowledge provides a clear view of how the earth works, geomorphologists can make use of the knowledge for evaluating resources, development projects, locating natural hazards and mitigating the effect of natural disasters.

Geomorphic knowledge and techniques may be applied in the following areas:

(i) Studying the impact of geomorphic/environmental processes on human society and activities and dealing with problems arising out of such impact;

(ii) Investigating the changes brought about in the geomorphic/environmental processes by human activities and dealing with the problems arising out of such interaction;

(iii) Managing resources and monitoring changes in the geomorphic system to suggest suitable remedial measures for maintaining development at a sustainable level.

Two Main Lines of Application

The application of geomorphology, according to Charley, Schumn and Sugden, may be considered along two lines:

(i) Geomorphology can be an aid to resource evaluation, engineering construction and planning. In this category we may put resource inventories, environmental management, soil and land evaluation, production of maps for hydrological, erosional and stability control, geomorphic mapping, mapping for land systems and evaluating terrain, classification and retrieval of information on terrain and other matters of use to earth scientists, engineers and planners.

Applied geomorphology in this aspect can be of use in urban planning in different geomorphic environments and in preparation of natural hazard maps, morpho-agricultural regionalisation, land use planning, construction and management of roads.

(ii) Applied geomorphology is also concerned with human beings as geomorphic agents, in terms of their planned or inadvertent effects on geomorphic processes and forms.

Human beings have over time tried to tame and modify geomorphic/environmental processes to suit their economic needs. Embankments have been built to check flooding of rivers; meandering courses of rivers have been straightened and channels diverted; coastal areas have been sought to be protected against wave erosion by building walls; there have been attempts to stabilise sandy areas through plantation, and check soil erosion through afforestation. These are some examples of planned activities by human beings that have an impact on geomorphic forms and processes.

The inadvertent effects of human activities on geomorphic forms and processes are many: forests are cleared and grasslands burnt for cultivating crops or for building settlements; mining activities and water extraction cause subsidence of land; building and mining activities result in modification of terrain; excessive, unplanned deforestation causes accelerated soil erosion and increase in sediment load leading, in turn, to recurrent floods and riparian decay. Pollution has been a major inadvertent effect of human economic activity. Dams cause changes in river load and accelerated erosion. High altitude construction has modified permafrost.

There has been an increasing recognition of the practical application of geomorphic principles and the findings of geomorphological research to human beings who are influenced by and, in turn, influence the surface features of the earth. Continuous increase in population has led to pressure on land resources, extension of agriculture to hilly and marginal lands resulted in man induced catastrophes like soil erosion, landslides, sedimentation and floods. A proper interpretation of landforms throws light upon the geologic history, structure, and lithology of a region. As geology becomes more specialized there is growing possibility that the application of geomorphology to problems of applied geology will be overlooked. The role of applied geomorphology relates mainly to the problems of analyzing and monitoring landscape forming processes that may arise from human interference. Human beings have over time tried to tame and modify geomorphic/environmental processes to suit their economic needs. Geomorphology has diverse application over a large area of human activity while Geomorphologist may serve more effectively the need of society.

The substance and style of geomorphology applications in environmental management has evolved over time. Scientifically, the discipline of geomorphology has continued to add technical expertise and tools that allow its applied scientists to better tackle environmental issues. Notable in this regard has been the greater availability of predictive tools, frequently stemming from GIS-based terrain modelling, with which to evaluate alternative management scenarios, thus increasing the visibility and transparency of geomorphology centred solutions. Socially, environmental managers and the public have gradually recognized the relevance of geomorphology in environmental problem-solving, leading to greater numbers of geomorphologists interacting with public policy. In tandem with a growing public awareness that environmental conditions are important in determining human quality-of-life.

The evolution of contributions of fluvial and coastal geomorphology to environmental management in the UK is illustrative. Original engineering solutions based on dominating and controlling nature had no place for geomorphology, but a subsequent shift from ‘hard’ to ‘soft’ engineering solutions ushered in what Hooke (1999) calls the ’first phase’ of geomorphology application, based on the recognition that landforms change naturally during the lifespan of an engineering project and that projects disrupting natural geomorphic processes were frequently causing deleterious effects elsewhere. A second phase occurred once strategic geomorphological questions were asked during early project planning phases, where local geomorphological baseline information was collected and utilized to answer specific landform questions ahead of implementation, and where geomorphologists were actively involved in the project design (and ultimately its appraisal). Hooke's predicted third phase (which, a decade later, we argue is now the present) emphasizes our understanding the conditions governing geomorphological variability, instability and equilibrium, and the widespread use of enhanced modelling and remote data to predict the effects and the risks of different management scenarios.

With increasing settlement and agriculture of floodplain lands has come a need for channel 'stability', a sub-set of channelization (see Brookes, 1988) wherein the river's natural tendency for lateral migration is perceived as a hazard and forcibly resisted by structural reinforcement of river banks to prevent erosion and fix the channel planform. Planned bank protection frequently involves symptomatic and piecemeal application of rip-rap, gabion baskets, concrete walls and sheet steel piling. Likewise, erosion of the channel bed has frequently been arrested by concrete or structural grade controls which, together with bank protection, can result in a fully immobile channel. However, such schemes are invariably detrimental to in stream habitat for native aquatic species, have high failure rates, and have frequently exacerbated channel erosion problems downstream or upstream requiring additional protection measures that are also environmentally deleterious. As a consequence, there are now a suite of protective regulations in most countries that amplify the need for far more strategic applications that minimize both the environmental impact and the economic cost to taxpayers. These changes have provided numerous opportunities for geomorphology to contribute to river engineering and management.

Geomorphology and Hydrology

Water used by human beings is available from different sources—streams, lakes and rivers on the surface of the earth or groundwater. Different stratigraphic and lithological zones present different conditions of surface and groundwater.

Limestone terrains vary widely and the ability to yield water depends on the type of rock. Permeability in limestones may be primary or secondary. Primary permeability depends upon the presence of initial interconnecting voids in the calcerous sediments from which the rock was formed. Secondary (or acquired) permeability occurs because of earth movements such as faulting, folding, warping, and due to solution or corrosion mechanism.

This secondary permeability varies notably with respect to the topography of a region, being greatest beneath and adjacent to topographic lows or valleys. Much of the groundwater in karst terrain is confined to solution channels.

In early stages of karst evolution conditions are not too different from those of other types of landscapes with similar relief. But as the cycle advances, a large proportion of water is diverted to solutionally opened passageways, and surface water gets diminished. The main source of water in such regions then are karst springs. Such springs may supply water to meet moderate demands, but the quality of water may be affected by pollutants and bacteria.

The sources of the spring water should be determined in such a case of pollution. The swallow holes and sinkholes feeding water to the underground drainage systems emerging as springs may be located. This can be done by putting some colouring material, such as fluorescein, into the water entering nearby swallow holes (or sinkholes) and testing the various spring waters to find out their source. A knowledge of the structural geology of the region is of use in this context, as groundwater moves down rather than up the regional dip.

The ease with which water may be obtained in a limestone region depends on the geomorphology of the area. If the limestones have enough permeability and are capped by sandstone layer, there may be no difficulty in obtaining wells of large yields. Moreover, the water would get naturally filtered as it passes through the sandstone beds.

If, however, the limestone is dense and compact, with little mass permeability, movement of groundwater will be largely through secondary openings. In such circumstances, the yield of water may be low or, even if adequate, subject to contamination. Karst plains lack a filtering cover and sinkholes, swallow holes or karst valleys within an area of clastic rocks should cast doubt on the purity of the water from springs nearby.

Groundwater potential in glaciated regions can be determined on the basis of understanding the geomorphic history of the area, characteristics of glacial deposits and landform. Outwash plains, valley trains and intertill gravels are likely to yield large volumes of water. Most tills are poor sources of water because of the clay in them, but they contain local strata of sand and gravel which may hold and supply enough water for domestic needs.

Buried preglacial and interglacial valleys could be good sources of groundwater. Their presence (or absence) may be detected by studying the preglacial topography and geomorphic history of the area. Buried valleys are located by constructing bedrock topography maps of glaciated areas.

5.15.1 Remote Sensing

Remote sensing, which is, fundamentally founded on standards of physical science, is the science and specialty of obtaining data about an item or marvels without truly interacting with it. Geomorphology is the study of investigation of the landforms of the earth.

Distant detecting perceptions from aeronautical and space stages which are right now in activity give a succinct perspective on landscape highlights in pictures which are deciphered by topical experts to comprehend and separate data of explicit premium from the pictures. Formal preparing is needed for translation to comprehend the meaning of picture components contained in the picture notwithstanding formal instruction in the topic strength. Geomorphological planning from satellite and aeronautical pictures for instance, needs an exhaustive information regarding the matter geomorphology, i.e., how certain normal and artificial cycles lead to landforms.

Since the most satellites information are basically recorded in advanced structure without a stereoscopic inclusion, created pictures are two-dimensional. Geomorphological investigation of surface types of the earth is an immediate type of understanding from space pictures. Flying photographs with needed forward cover ordinarily give the third element of stature, which adds to the accuracy of understanding including morphometry.

5.15.2 Road Construction

Geographical highlights of a space decided the most plausible roadway course. Street designing countenances various issues by various sorts of territory that incorporates geologic construction, geomorphic history of the space, lithological and stratigraphic qualities and strength of the surficial stores. Region like karst plain required rehashed cut and fill, assuming not done, the street will be submerged after substantial downpours with surface spillover from the sinkholes.

The most major issues experienced by interstate specialists is Pumping which implies removal of water from underneath street chunks through joints and breaks. It is clear that siphoning is especially more noteworthy over cold till than over penetrable materials, for example, wind-blown sand and outwash rock. Helpless seepage in a subgrade is fundamentally answerable for siphoning. Poor and best execution of the parkway is described by silty-mud subgrades with a high water table and granular materials with a low water table separately.

5.15.3 Dam Site Selection

A blend of information concerning the geomorphology, lithology, and geologic design of territories has incredibly helped while choosing locales for dam development. As per Bryan, five primary prerequisites of good supply destinations rely upon geologic conditions:

1. Adequate size water-tight bowl;
2. A tight outlet of the bowl with an establishment that will allow conservative development of a dam;
3. To form a sufficient and safe spillway to convey abundance waters;
4. Availability of assets required for dam development (earthen dams); and
5. Assurance that extreme testimony of mud and sediment won't short the existence of supply.

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5.15.4 Location of Sand and Gravel Pits

Sand and rock have more business and mechanical uses than many designing. Assessment of geologic factors like variety in grade sizes, lithologic arrangement, level of enduring, measure of overburden, and progression of the stores are significant while choosing appropriate destinations for sand and rock pits. Floodplain, waterway patio, alluvial fan and cone, bone, wind-blown, remaining, and chilly stores of different kinds are regions where sand and rock might be found in bounty. As of late, there is an extraordinary interest of rock than sand because of diminished utilization of mortar in home development in this way information on different evaluation sizes is more significant.

5.15.5 Military Geology

Allied powers during universal conflict were delayed to utilize geography in fighting. Geologist were used however partly in World War I. Before military specialists saw the requirements for and potential outcomes of the utilization of geologic specialists, the conflict was very much progressed. During wars the data that was valuable was more geologic than geomorphic in nature. The data with respect to burrowing channels, mining, countermining, and water supply or other material was not used. Geology turned out to be more significant during World War II with the advancement of the lightning war sort of fighting, since adequacy of a rush depends generally upon the sellability of the landscape. Lately landscape appreciation or territory investigation have gotten more significant with military.

5.15.6 Regional Planning

Geomorphologic data can be used at different degrees of preparation. Mix of geological data, soils, hydrology, lithology, landscape qualities and designing remembered for territory maps make appropriate for provincial arranging. Applied geomorphology has particular spot in territorial arranging. At broadest scale it tends to be utilized as outline regions for backwoods, mountain, level, sporting, provincial and metropolitan regions. A reasonable development of a country's economy requires a cautious comprehension of its normal assets and HR. Country or immature territory satisfies an assortment of sporting requirements. There is a change from a territory maps into land-use appropriateness guides to foster provincial and metropolitan regions. Nitty gritty data on geology illuminated local organizers who may then prompt advancement projects most appropriate for isolated area.

5.15.7 Urbanisation

There is a different branch known as metropolitan geomorphology applied to metropolitan turn of events. This part of geomorphology is worried about "the investigation of landforms and their connected cycles, materials and perils, ways that are valuable to arranging, improvement and the executives of urbanized regions where metropolitan development is normal". Geomorphic highlights choose the soundness, security, essential necessities and surprisingly its development. That implies city or towns totally relies upon lithological and geographical highlights, hydrological conditions and geomorphic highlights. Metropolitan geomorphologist initiate even before metropolitan improvement through field review, landscape grouping, ID and determination of elective locales for settlements regardless of plain or sloping regions. These metropolitan geomorphologists would be worried about effect of regular occasions on the metropolitan local area and that of metropolitan advancement on the climate.

5.15.8 Hazard Management

Risks can be placed in regular or man-prompted where mediocre level or surprising nature surpasses. As per Chorley, geomorphic peril might be characterized as "any change, regular or man-made, that may influence the geomorphic security of a landform to the affliction of living things". These risks may emerge from prompt and abrupt developments like volcanic ejections, quakes, avalanches, torrential slides, floods, and so on. Blaming, collapsing, twisting, inspiring, subsidence, or vegetation changes and hydrologic system because of climatic change emerge from the drawn out factors. Regions having previous case chronicles of volcanism and seismic occasions help in making expectations of potential ejections and quakes individually. Ordinary checking of seismic waves, estimation of temperature of pits lake, underground aquifers, fountains and changes in the setup of volcanoes whether lethargic or terminated can lessen the peril somewhat. An itemized information on geography can foresee the way of magma stream and its emissions focuses ahead of time.

Check Your Progress

27. A closely related technique to GIS is __________ (RS), the non-contact recording of electromagnetic spectrum of earth/planetary surfaces
28. Those hazards that originate at or near Earth's surface and include expansive soils, soil erosion, slope failures, ground subsidence and karst, river channel changes, glaciers, and coastal erosion are called __________.

5.16 ANSWERS TO 'CHECK YOUR PROGRESS'

1. A gorge is a deep channel formed by a river that has eroded the earth's crust over millions of years.
2. An alluvial fan is a triangle-shaped deposit of gravel, sand, and even smaller pieces of sediment, such as silt.
3. mountain-grit deserts
4. Arid landforms
5. Ventifacts
6. Inselbergs
7. Sand dunes

8. Barchans
9. Weathering is to change or make something change in appearance because of the effect of the sun, air or wind.
10. Mushroom rock, Zeugen, Yardangs, Mesas, Inselberg, Ventifacts
11. Glacial landforms
12. internal deformation and basal sliding
13. Piedmont glaciers
14. Ice caps
15. Glacial erosion
16. Glacier
17. Glacier
18. Glacial till
19. undercutting
20. downstream
21. Mountain or Valley Glacier, Continental or Ice glacier
22. Rock polishing is smoothing of rock surface naturally or by human agents.
23. The surface karst landforms are small solution pits, grooves and runnels collectively called karren.
24. Alpine
25. As waves move towards the beach, there is some net shoreward transport of water called RIP current.
26. Micro Tidal
27. remote sensing
28. Geomorphic hazards

5.17 SUMMARY

After weathering, geomorphic agents operate the landforms to change. Small to medium reacts or parcels of the earth's surface are called landforms. Several landforms together are called landscape Each landform has its own shape, size and materials. Geomorphological processes are slow but significant in long run.

Every landform has a beginning, they change their shape and composition in course of time.

Due to changes in climate and vertical and horizontal movements landforms change their shape. Each landform undergo three stages called youth, mature and old stages. Geomorphology is the science of landforms. Various geomorphic agents bring the changes to the landforms such as running water, moving ice, wind glaciers, underground water, waves by erosion and deposition.

Each geomorphological agent produces its own assemblage of landforms. Most of the geomorphological processes are imperceptible. The study of the landforms reveals that the stage structure and process of landforms. They produce erosional and depositional features.

5.18 KEY TERMS

- **Alluvial fan:** A distinctly triangular, fan-shaped deposit of sediment transported by water, often referred to as alluvium.
- **Bajada:** A series of adjacent alluvial fans coalescing in a basin at the foot of a mountain range.
- **Cape:** A large headland or promontory extending into a body of water, usually a sea or ocean.
- **Strait:** A waterway separating two relatively close landmasses.
- **Esker:** A long, winding ridge of stratified sand and gravel, usually occurring in glaciated areas.

5.19 SELF-ASSESSMENT QUESTIONS AND EXERCISES

Short Answer Questions

1. State the types of fluvial landforms.
2. Write a note on deserts.
3. State the major types and subtypes of landforms.
4. What is a Barchan?
5. Write a note on dry valleys and poljes.

Long Answer Questions

1. State the application of Geomorphology to Human Activities.
2. Write an essay on Condition of formation of delta.
3. Focus on types of deserts.
4. What are the resulting landforms due to water actions?
5. Which are the factors and forces in formation of coastal features?

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